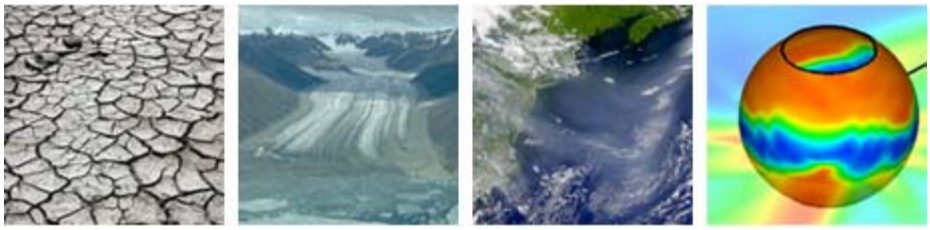
Cooperative Institute for Research in Environmental Sciences

CIRES



FY 2004 Annual Report

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EXECUTIVE SUMMARY AND RESEARCH HIGHLIGHTS

The Cooperative Institute for Research in Environmental Sciences (CIRES) is a joint institute established in 1967 between the University of Colorado and the National Oceanic and Atmospheric Administration (NOAA) to create a synergy between studies of the geosphere, biosphere, atmosphere, hydrosphere and cryosphere. The institute is comprised of more than 500 researchers, faculty, students, and staff housed on the University of Colorado campus and in the David Skaggs Research Center. Approximately half of last year's $40 million budget derives from its cooperative agreement with NOAA.

The previous year was very productive with CIRES scientists and faculty publishing over 500 scholarly papers, including nearly 400 in reviewed journals. Major activities focused on the arctic climate system as well as climate variability impacts in the Interior Western United States. Atmospheric measurements of trace gases and their implications for air quality were also a high priority last year.

Adequately summarizing the vast array of research activities across the breadth of CIRES is a challenging task. The following bullets highlight significant research accomplishments from the section titled CIRES' Scientific Themes. They are grouped by CIRES' six scientific research themes that were identified as the foci for integrated studies.

ADVANCED MODELING AND OBSERVING SYSTEMS

This theme includes the optimization of modeling and observing systems for disciplines such as atmospheric chemistry, physical atmospheric and oceanic processes, cryospheric processes, space weather, nonlinear systems applications, data centers and data management. The space domain links most research fields ranging from local, regional, and global scales. Since the emphasis here is focused upon technology advancement, this theme frequently brings together CIRES scientists of disparate backgrounds in work of cooperative interdisciplinarity that the institute was created to promote.

- Designed new instrumentation to gain a better understanding of the radiative role of atmospheric aerosol particles, currently one of the areas of greatest uncertainty in climate change predictions.
- A prototype of Geosynchronous Microwave (GEM) Sounder/Imager simulator is being developed (Polarimetric Scanning Radiometer/Sounder (PSR)). Its first deployment was during the Water Vapor Intensive Operation Period (WVIOP04) in March and April of 2004 in Barrow, Alaska.
- A mobile wind profiler for fire weather applications was designed, and a prototype was built. A new boundary-layer depth algorithm was developed for use with wind profiling radars. The plan has been to use hourly spectral data from wind profilers located in New England for NEHRTP (New England High Resolution Temperature Project) to test the fuzzy logic algorithm for the estimation of mixing depth in real time.
- Fifty observing systems were added to a geospatial information database. A webpage (http://nosa.noaa.gov) was developed to hold all the observing system description and allow for geospatial database searches to all NOAA observing systems.
- Modeling studies were conducted of upper atmosphere responses to solar, magnetospheric, and lower atmosphere forcing, and the coupling between the neighboring domains. The predicted significant solar energetic particle events versus observed event durations showed that of the 72 appropriate solar energetic particle events observed by the GOES-8 satellite, only four would be considered significantly under-estimated.
- The CIRES TLS (Tethered Lifting System) group took measurements of the lower atmosphere to establish wind flow patterns around the Pentagon to accurately model this particular region for defense purposes.

CLIMATE SYSTEM VARIABILITY

Climate variability affects virtually all natural systems and human activities. Climate directly impacts such vital areas as agriculture, water quantity and quality, and human health. Understanding, and potentially predicting, climate changes is therefore critical to the public, as well as to a broad array of decision-makers within federal and state government, industry, resources management and hazard mitigation. Indeed, basic issues include determining whether observed changes may be attributable to natural or anthropogenic forcing, and the extent to which natural and human-induced changes may be linked. Prediction problems of vital importance include estimating changes in the likelihood of extreme events, identifying risks for abrupt climate change, and the potential for major societal and ecosystem impacts.

- Substantial progress was made in assessing the differing sensitivities of the global atmospheric response to SST anomalies including confirmation the opposite sensitivity of many aspects of the global response to SSTs in the eastern Indian and western Pacific portions of the warm pool and the counter-intuitive result that warm SSTs in large areas of the tropics lead to global-mean surface cooling and drying.
- The World Data Center for Glaciology, Boulder generated an online Sea Ice index (currently 1987-present) showing recent record minima in summer Arctic ice extent available at *http://nsidc.org/news/press/20041607_seaice.html.*
- A new site was established in the Canadian arctic at Alert filling a gap in the worldwide distribution of radiation sites monitoring solar and thermal radiation.

- MM5 mesoscale model simulations of a wintertime week at the Surface Heat Flux of the Arctic Ocean (SHEBA) site over the Arctic pack ice showed the necessity of including a multi-layer snow and ice module in order to correctly simulate the near-surface temperature, the surface turbulent and radiative fluxes, and the boundary layer structure.
- Researchers constructed a website (www.ncdc.noaa.gov/paleo/abrupt) providing information and data sets describing abrupt climate changes of the past that quickly rose to fourth in Google searches for abrupt climate change.
- New approaches have been developed for quantifying stratospheric ozone migration to the upper troposphere and for understanding the interactkions between nitric acid and cirrus clouds.
- Five new carbon sampling sites were established in North America to further quantify the carbon budget.
- Development of the Weather Research and Forecasting (WRF) model continues with significant advances in data asssimilation, land surface models, air chemistry, and forecast verification techniques.

GEODYNAMICS

The goal of geodynamics is to characterize the internal processes of the planet, including the properties of the core-mantle boundary, convection within the Earth's mantle, and how that convection affects the surface of the planet. The slow changes of flow processes in Earth's deep liquid interior which drive the magnetic field are frequently described using spherical harmonic analysis of the nearly 300 years of surface magnetic observations. Relative velocities in the Earth's mantle of a few cm each year cause plates to drift across the Earth's surface, giving rise to volcanism and seismicity at their margins. Of particular interest to the geodynamics group are the processes of mountain formation, and the dynamics and evolution of surface features through their chemical and mechanical interaction with atmospheric forcing functions.

- A new real-time version of the assimilative mapping of ionospheric electrodynamics (AIME) technique was developed for specifying and predicting ionospheric electrodynamics.
- Interface Database (IDB) tools were used to create a data management system for reviewing, ingesting, integrating, and improving the quality of the significant earthquake and tsunami databases.
- Considerable success has been made this year in determining the history of earthquakes in Baluchistan, Afghanistan and the Himalaya, and in determining the geometry of India's collision with southern Tibet.
- An online geochronology and geochemistry database for igneous rocks in western North America has been established that, for the first time, will allow regional estimates of magmatic volumes to be compiled and interrogated, a significant advance in the ability to investigate changes in the sources of continental magmatism through time.
- Field studies demonstrated that, under the right conditions, fairly simple process laws predicted pendulum-like oscillations between erosion and sedimentation even in the absence of environmental change that warrants caution in reading environmental clues from the geohistorical record.

PLANETARY METABOLISM

The sustainability of the biosphere during the current period of rapid Earth system change is an issue of prime importance for the environmental sciences. The physical and chemical features of the Earth are intimately tied to organisms and the activities required for their sustenance. The health of the biosphere can usefully be considered using the concept of "planetary metabolism," which refers to the complex web of biochemical and ecological processes and their interaction with the lithosphere, atmosphere and hydrosphere. Both natural and anthropogenic disturbances drive the structure and dynamics of natural systems, and a thorough understanding of these complex processes is essential to protect the biosphere from adverse effects due to pollution, destruction of natural landscapes, and inadvertent alteration of climate.

- Used satellite maping of population centers, fires, gas flares and other light sources to produce the first global nighttime analysis of human activities spanning the ten-year time period from 1992-93 to 2003.
- Biosphere-atmosphere exchange studies revealed that a nighttime nitrate radical (NO_3) chemistry rapidly removed biogenic compounds resulting in early morning ozone formation being dominated by anthropogenic VOCs.
- Produced a generation of bacterial strains that are much more effective at degrading PCP than the wild-type strain and that could be used for biodegradation of PCP-containing waste as well as remediation of contaminated sites.
- Revealed that disturbance regime is an important aspect of regional carbon balance in the high latitudes. Established $CO^{18}O$ as a useful measure of interaction between the biosphere and hydrology.
- Revealed that fire in subalpine forest tends to "erase" the effects of previous disturbances (blowdown and logging) on soil properties and nitrogen cycling in the short term, but patterns of seedling establishment suggest successional pathways may be affected by recent disturbance history prior to wildfire.

REGIONAL PROCESSES

Many of the research endeavors within CIRES and NOAA have a regional focus because they address a particular confluence of geography, demographics, weather and climatic regimes, or scientific challenge. This confluence of factors has produced a range of research that is not only rich in its diversity but provides an essential connection between science and its constituents. These human populations range from coastal megalopolises to indigenous peoples on the Arctic Ocean, all of

which must coexist with sensitive aquatic and terrestrial ecosystems in a highly variable and evolving climate. Indeed, the impact of short-term climate variability and extremes is often regionally focused, influencing very specific populations, economies, and ecosystems. Research includes the mechanisms of atmospheric transport on climate and air quality, chemical transformation of products of biomass burning, air/sea gas transfer, and ozone pollution.

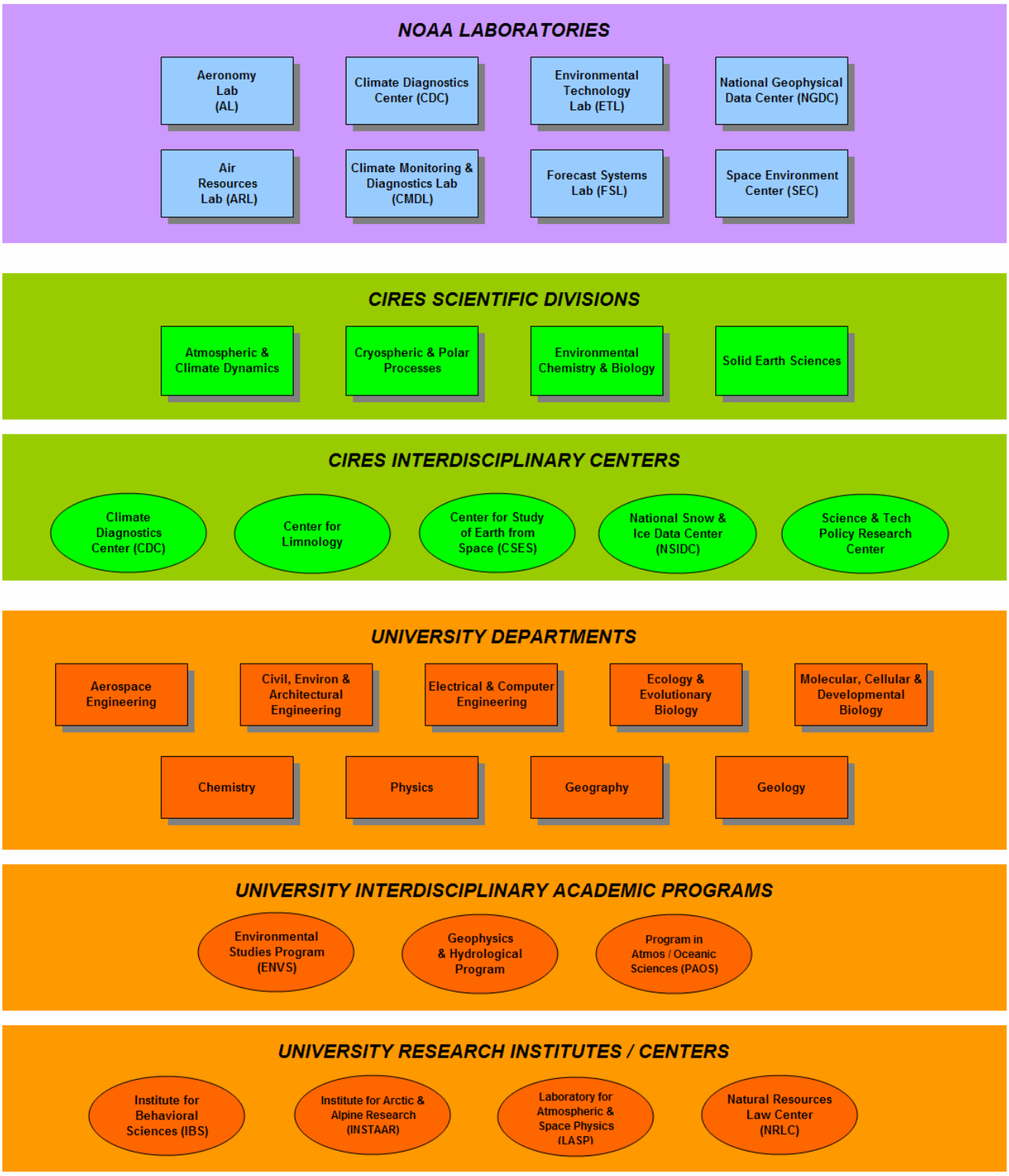
- Nighttime chemistry was discovered to be of much greater importance to air quality in New England than had been previously thought, a finding that has implications for future air quality improvement efforts in that region.
- Leaks from petrochemical facilities were found to be a major factor in causing poor air quality in Houston, resulting in Texas state air quality decisions that will save an estimated 65,000 jobs and $10B by 2010.
- Two field studies revealed that North American nitrogen oxide emissions reaching the Atlantic Ocean free troposphere are smaller than expected, thus global models calculating the photochemical formation of ozone will need to be modified.
- It was demonstrated for the first time that N_2O_5 is a major member of the reactive nitrogen (NO_y) family. This discovery means that nighttime processes are of much greater prominence than had been previously thought.
- Gas-phase and aerosol chemical characteristics of Asian emission plumes transported across the Pacific Ocean were found to be a complex mix of industrial, biomass combustion, and natural emissions where significant levels of NO_y had been removed.
- A novel technique was used to determine the chemical composition of ice nuclei capable of forming atmospheric ice clouds.The most efficient were not ubiquitous sulfate aerosols, but were instead rare mineral or fly-ash particles, some of anthropogenic origin. Aerosols rich in organic material were further shown to be inefficient ice nuclei. These results will provide valuable constraints for global climate models.
- A new procedure was used to dertermine that submicron particles in Mexico City are dominated by organic aerosols and that 60% of the organic mass is formed in the atmosphere rather than emitted directly. Results represent a quantum leap in understanding and pollution-control strategies now being designed to take these results into account.

INTEGRATING ACTIVITIES

CIRES engages in a wide range of integrating activities in research, education, and outreach that encompass each of the institute's research themes and contribute to the overall mission of the Institute, NOAA, and the University of Colorado. The primary focus is on five overlapping categories that include 1) K-16 Interdisciplinary Education and Outreach, 2) Graduate and Post-Graduate Education, 3) Scientific Assessments, 4) Interdisciplinary Research, and 5) Science and Technology Policy Research. By understanding decision-making processes, the stresses, and the constraints of this community, researchers seek to assess vulnerability to climate variability and develop hydro-climate products that enable better-informed decisions. Collaborations with colleagues in the local NOAA laboratories have resulted in the transformation of basic research into applied science.

- CIRES scientists played a leading role in major national assessments including the NOAA/RISA Western Water Assessment and the WMO/UNEP Ozone Assessment.
- Input from the Colorado Water Availability Task Force (WATF) and major intermountain west water providers guided development of climate information webpages that include climatologies, current conditions, historic relations, weather and climate forecasts, drought and flood monitoring.
- CIRES Education and Outreach established several new partnerships between CIRES researchers and local school districts.
- CIRES/CDC took a lead with government and private sector officials in supporting the Western Governors' Association's (WGA) development of the report entitled Creating a Drought Early Warning System for the 21st Century:
- The CIRES Visiting Fellows program hosted nine postdoctoral research scientists.
- A patented super-critical carbon dioxide nebulizationation technique developed in atmospheric aerosol research is being applied for pulmonary delivery of vaccines and antibiotics to prevent and cure diseases such as measles and tuberculosis.
- CIRES Center for Science and Technology Policy Research initiated a major new program focused on climate science policy research and assessment.

SCIENTIFIC CONNECTIONS FACILITATED THROUGH CIRES



CIRES IN 2003-2004

OVERVIEW

The Cooperative Institute for Research in Environmental Sciences (CIRES) is a joint institute established in 1967 between the University of Colorado and the National Oceanic and Atmospheric Administration (NOAA) to create a synergy between studies of the geosphere, biosphere, atmosphere, hydrosphere and cryosphere. CIRES is a unique bridge that provides the mission-oriented NOAA laboratories access to an academic diversity that it does not itself possess. It provides and strengthens the scientific foundation upon which NOAA's many services depend. CIRES' connections with NOAA's Office of Oceanic and Atmospheric Research (OAR) and sister joint institutes also provide an avenue for coordinated studies on a scale that could not be addressed by academic departments on their own.

Traditional disciplinary research is conducted through a broad range of academic departments and the eight local NOAA laboratories shown in the table on page 4. Interdisciplinary science is fostered through centers that cross traditional boundaries and include the *Center for the Study of Earth from Space*, the *Center for Limnology*, the *National Snow and Ice Data Center*, and the *Science and Technology Policy Research Center*. CIRES' campus affiliation provides NOAA a breadth of connections such as the Natural Resources Law Center that forms a unique component of the Western Water Assessment.

CIRES' *direction* is provided through its Council of Fellows, an active executive committee, and committees working on focused objectives (such as maintaining computing facility excellence). *Communication* is facilitated through a members' council, scientific retreats, regular town meetings, and an active outreach effort. *Career progression and excellence* are promoted through a Career Track and outstanding employee recognition program. A vibrant *academic and research environment* is fostered through a graduate research fellowship program, a visiting faculty and postdoctoral program, Innovative Research Program, an interdisciplinary lecture series, and research initiative seed funding. *Advanced research tools* are provided through an instrument design group, machine shop, glassblowing, numerical climate models, and access to various tools such as remote sensing instrumentation. Other *support* includes a computing facility, specialized software tools (such as Geographic Information System, or GIS, and statistics), auditorium, and classrooms fitted with audio-visual tools.

A NEW PROCESS FOR PLANNING AND REPORTING SCIENTIFIC RESEARCH

This is CIRES' first annual report based upon a research plan that integrates collaborative scientific objectives between CIRES, university and NOAA federal laboratory colleagues. Driven by scientific objectives, the workplan identifies goals and approaches for each of these objectives and incorporates milestones and impacts for the proposed research projects. This is shifting the process and research culture from basing activities upon funding to basing it upon the science that is expected during the coming year. It is a practical demonstration of research conducted within NOAA's recently developed matrixed approach that is providing improved collaboration on complementary efforts.

FIT WITH NOAA'S STRATEGIC VISION

CIRES has considered *NOAA's Strategic Vision* in building its research program. It is conducting activities within the four strategies of observing and monitoring, understanding and describing, assessing and predicting, plus providing knowledge in a context that enables its application by decision makers. It is addressing the NOAA cross-cutting priorities of integrated global environmental observation and data-management systems, environmental literacy and outreach, homeland security, and state-of-the-art research. Below are examples from the following plan where CIRES is contributing to all four NOAA overarching goals.

1. Protect, restore and manage use of coastal and ocean resources through ecosystem management approaches. CIRES is contributing to the second Ecosystems objective to "protect, restore, and manage species habitats listed under the Endangered Species Act" by documenting riparian habitat impacts in Rocky Mountain watersheds. CIRES is also studying forest ecosystems to understand their ability to recover from stresses including drought, wildfire and land-use changes.

2. Understand climate variability and change to enhance society's ability to plan and respond. CIRES contributions to long-term remote observations and air quality respond to "build an end-to-end system of integrated global observations of key atmospheric, oceanic, and terrestrial variables." Ensemble data assimilation of pre-radiosonde-era surface observations and tree-ring studies serve to enhance scientific understanding of past climate variations." Studies to assess predictability from deterministic as well as probabilistic perspectives will help achieve an "improved understanding to create more reliable climate predictions on all time scales."

3. Serve society's needs for weather and water information. RISA (Regional Integrated Sciences and Assessments) studies conducted within CIRES' Western Water Assessment (WWA) serve to "respond to user needs with the most recent, reliable information possi-

ble." Monitoring solar disturbances and modeling Earth's upper atmosphere promise to "improve the performance of our suite of weather and water, air quality, and space-weather prediction capabilities."

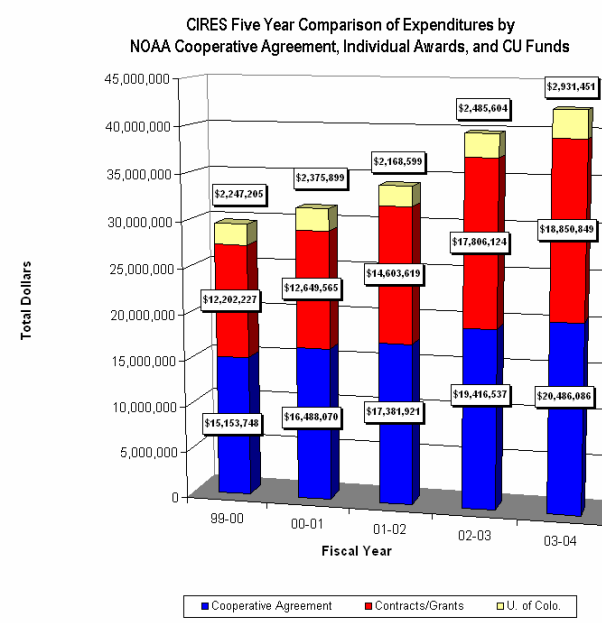
4. Support the Nation's commerce with information for safe and efficient transportation. The design and evaluation of new verification approaches and tools will provide information about the quality of aviation forecasts and their value to aviation decision makers.

SIZE AND SCOPE OF CIRES

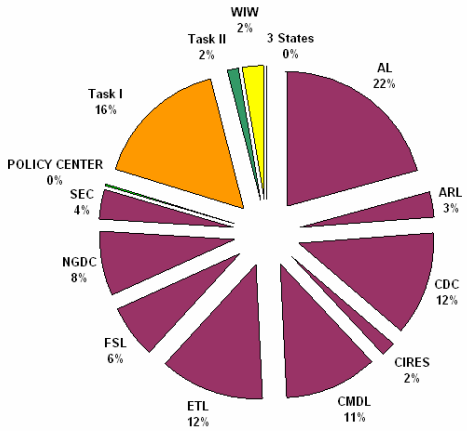
CIRES is comprised of more than 500 researchers, faculty, students, and staff housed on the University of Colorado campus and in the David Skaggs Research Center. At the end of the year, this included 24 professors, 147 research scientists, 218 research associates, 21 post-doctoral fellows, 12 visiting fellows/scientists, 54 graduate students, 11 other staff and nearly a hundred undergraduate employees.

The first two charts at right provide a summary of CIRES expenditure trends by source and NOAA laboratory. The NOAA cooperative agreement includes research and base funds, the contracts and grants bars derive from supplemental federal agency sources, and university support includes faculty salaries, indirect cost recovery, and non-research general funds.

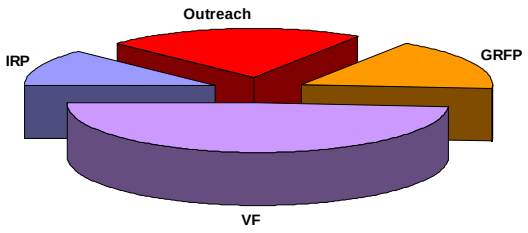
The bottom pie chart illustrates the relative funding CIRES invests in programs that create a dynamic research environment for the benefit of all its members. The Visiting Fellows (VF) program, Graduate Research Fellowship Program (GRFP), Outreach, and Innovative Research Program (IRP) are described in the following pages and together annually constitute over a million dollar investment.



2003 - 2004 NOAA COOPERATIVE AGREEMENT EXPENDITURES



Task I - 16% **Task II - 2%** **Task III - 79.9%** **WIW - 2%** **3 States - .01%**



DISTINGUISHED LECTURE SERIES

CIRES continues to promote connections with University departments and NOAA laboratories through its Distinguished Lecture Series. Scholars with global perspectives are invited in the hope of establishing enduring connections after their departures. The following is a list of scientists and academicians invited in 2003-04:

- David Sarewitz, Columbia Univ., "Science, Values, and Climate Change: Probing the Limits of Objectivity"
- Christina Ravelo, Univ. of California, Santa Cruz, "Do Tropical Conditions Determine Climate Sensitivity? Lessons from the Warm Pliocene"
- Inez Fung, Univ. of California, Berkeley, "Carbon-Climate Interactions: A Contemporary View"
- Richard B. Alley, Pennsylvania State University, "Looking Back to Our Future: Is the IPCC Optimistic on Climate Change?"
- Tanya Atwater, University of California, Santa Barbara, "A Half-Billion Years of Plate Tectonics in the Western United States, or How the West Was Made"
- Daniel Kevles, Yale University, "Patenting Life: Innovation and Controversy in the Political Economy of Patent Law"
- William F. Ruddiman, University of Virginia, "The Anthropogenic Greenhouse Era Began Thousands of Years Ago"
- Paul G. Richards, Columbia University, "Monitoring Nuclear Explosions: Why, How, and What Do We Learn?"

WORKSHOP ON ASSESSING GLOBAL GLACIER RECESSION

A three-day workshop was convened by NSIDC, with the aim of evaluating current methods of determining the worldwide recession of mountain glaciers over the last half-century or longer. Recent evidence suggests an acceleration of glacier mass loss in several key regions, and a more comprehensive evaluation of glacier changes is imperative to assess ice contributions to global sea level rise and the future of water resources from glacierized basins. The broader impacts of this workshop include bringing together experts from leading groups, as well as under-represented young and female scientists from North America and elsewhere. Twenty-four selected individuals from Australia, Canada, Chile, China, France, India, Norway, Switzerland, Russia, and the United States were funded, and the workshop was open to other interested individuals by invitation. There was a training dimension in the planned demonstration of new GIS-based mapping techniques using ASTER imagery and digital databases.

Workshop Publications:

Barry, R.G. 2003. Workshop on improving the monitoring of global glacier recession. Ice (News Bulletin of the Int. Glaciol. Soc.), No.132-133, pp. 34-35.

Barry, R.G. 2003. Assessing global glacier recession: Results of the workshop. In "Papers and Recommendations: Workshop on Assessing Global Glacier Recession." Glaciological Data Report GD32, National Snow and Ice Data Center, Boulder, CO. pp. 35-38.

Casey, A. (ed) 2003. Papers and Recommendations. Snow Watch 2002 Workshop and Workshop on Assessing Global Glacier Recession. Glaciol. Data Report #32, pp. WDC for Glaciology, NSIDC, Univ of Colorado. pp. 31-112.

WORKSHOP ON BROADENING DLESE

The Digital Library for Earth System Education (DLESE) is a community-centered resource for people interested in learning about Earth Science. The 2003 annual meeting in Boulder focused on *Broadening DLESE*. Specific goals were to develop strategies to:

- Expand the users and contributors to DLESE
- Facilitate efforts to develop earth science data/tools for educational use
- Expand DLESE's collection of earth science educational materials
- Strengthen ties between research and educational practice, evaluation and assessment

INTEGRATION OF TOWN MEETINGS AND OUTSTANDING PERFORMANCE AWARDS

In 2003 CIRES took steps to improve issues cited in the CIRES/NOAA Equities report that relate to the geographical separation of CIRES' work sites. 2003 was the first year that CIRES hosted three Town Meetings at each of the sites. Each meeting featured an Outstanding Performance Awards Ceremony, employee recognition, and a reception. The Equities Committee noted in its report that this integrated format is an important and constructive action, as the increase in attendance at the Town Meeting was
substantial.

STAFF RETREAT TO IMPROVE TEAM CULTURE

CIRES' Strategic Plan states that we will "improve and enhance the service orientation of the CIRES Administration." In the fall of 2003 CIRES Administration gathered to assess where we are, what we are doing, how we are doing it, and where we want to go in the future. The goals of the retreat were aimed at clarifying a common CIRES' Administration identity that is aligned with providing the support of CIRES' science that is equal in quality to CIRES' science itself.

SCHOLARLY PUBLICATIONS

CIRES scientists and faculty published over 500 scholarly papers during the preceding year. The following tables tabulate these by affiliation of first author, by whether or not they were peer reviewed, and compares these with the previous year total number of publications (sum of peer-reviewed and non-peer reviewed).

	CIRES Lead Author	NOAA Lead Author	Other Lead Author	Total Publications
2003 Total Publications	277	41	207	525
2003 Peer Reviewed	177	31	183	391
2003 Non-Peer Reviewed	100	10	24	134
2002 Peer Reviewed	112	60	110	282
2001 Total Publications	164	43	127	334

CIRES IN THE NEWS

SCIENCE

CIRES Fellow Roger Bilham's Earthquake Research Featured in Nature (5/24/04)
CIRES Fellow **Roger Bilham**, and colleagues at the University of Colorado at Boulder and the U.S. Geological Survey in Pasadena, California, were featured in the May 20, 2004, issue of the journal *Nature* for their work on earthquake risks associated with the New Madrid seismic zone in the Midwestern United States. The researchers identified a wider area for potential large earthquakes in the Midwest and concluded the region remains under threat.

CIRES Affiliate Henry F. Diaz Reports Results from the Manila Galleon Voyages Project (5/17/04)
An international team of researchers, including lead researcher CIRES affiliate **Henry Diaz**, CDC, discovered they could estimate weather patterns from 1590-1750, long before weather-measuring devices were widely used, by analyzing and interpreting ship logs from voyages between Manila in the Philippines and Acapulco, Mexico. For more information, visit *www.cdc.noaa.gov/spotlight.*

CIRES New England Air Quality Study Scientists Find that Nighttime Chemistry Affects Ozone Formation (4/13/04)
Lead author and CIRES scientist **Steven Brown**, along with co-authors from CIRES and NOAA's Aeronomy Laboratory, found that nighttime chemical processes remove nitrogen oxides (NO_x) from the atmosphere in the marine boundary layer off the coast of New England. These gases are one of the two basic ingredients for making ozone pollution. With less nitrogen oxide in the atmosphere, ozone production the next day will almost always be reduced in New England. These results were published on April 10 in *Geophysical Research Letters*. Read more at *EurekAlert*, a service of the American Association for the Advancement of
Science.

Study Suggests Possible New Link Between Pollution, Clouds, and Climate (3/22/04)
CIRES scientists at the Aeronomy Laboratory were among a group of researchers from NOAA, NASA, NCAR, and several universities and research institutes in the U.S. and abroad who discovered that pollutants may alter cloud formation by blocking the uptake of water vapor in the atmosphere's coldest clouds. The study appeared in the January 23 issue of *Science*. For more information, visit OAR's Hot Items
(http://hotitems.oar.noaa.gov/oaritems.php).

CLIMATE

Konrad Steffen Featured in Series of New York Times Articles (6/8/04)
CIRES Fellow **Konrad Steffen** was featured in Andrew Revkin's New York Times series of articles about Greenland, global warming, global climate change, and retreating glacial ice. In these features, Revkin reports that measurements by Steffen's group on the Petermann Glacier showed that more than 150 feet of thickness has melted in the past year. Visitors to the link will be able to view a video of Koni Steffen at his Swiss Camp. Read "*An Icy Riddle as Big as Green-land*" at the New York Times online, and view the Multimedia feature "*Revkin in Greenland*" at the same location.

CIRES Fellow Konrad Steffen Appears in the New York Times' "Postcards from the Arctic" Series (5/24/04)
New York Times' Science Reporter Andrew Revkin spent time with CIRES Fellow and Deputy Director **Konrad Steffen** in Greenland. Revkin posed questions about the balance of glacial melting with snowfall gains and suggested that answers may be found at Steffen's Swiss Camp, halfway between Greenland's summit and its shores. After working for two weeks at the floating ice tongue of the Petermann glacier, Steffen began working at his Swiss Camp.

POLICY CENTER

Science and Technology Policy Research Center Wins $2.4 Million NSF Research Grant (May 27, 2004)
CIRES' Center for Science and Technology Policy Research learned that they will receive a $2.4 million award from the National Science Foundation for a project on decision making under uncertainty. The Center was initiated within CIRES in 2001 in response to an increasing demand by public and private decision makers for "usable" scientific information.

K-12 EDUCATION AND OUTREACH

CIRES Researchers Develop Online Science Education Resources (6/15/04)
CIRES Fellow **Ted Habermann** and Researcher **Dan Kowal** at NGDC worked with science educators at a DLESE workshop in New Hampshire to develop web-based learning materials using the NESDIS GOES Image Archive. Their work will be included in the *Earth Exploration Toolbook*. DLESE, The Digital Library for Earth System Education, is an NSF-sponsored project designed to catalog earth science education resources on the web.

Ocean Interactions Outreach Program (1/28/04)
Susan Buhr and **Tamara Palmer** of the CIRES Outreach

program collaborated with **Jeff Hare** from CIRES and NOAA's Environmental Technology Laboratory to develop a ship-to-shore interactive project created in the fall of 2003 to increase ocean science education opportunities for land-locked students and educators in the Interior West and elsewhere. A pilot of successful ship-based researcher/classroom partnerships was run from October to December 2003 for eight volunteer schools across the United States. For more information, see the ETL Ocean Interactions Outreach Program site (*http://www.etl.noaa.gov/about/hotitems/2004/040128.html*) or the CIRES Ocean Interactions site (*http://cires.colorado.edu/%7Ek12/interactions/index.html*)

FELLOWS HONORED

CIRES Fellow Receives Blue Planet Award (6/24/04)

CIRES Fellow and Aeronomy Lab Senior Scientist **Susan Solomon** was awarded the prestigious Blue Planet Prize. The Blue Planet Prize, sponsored by Japan's Asahi Glass Foundation, recognizes major contributions to solving global environmental problems. Solomon received the award "[f]or her pioneering work in identifying the mechanism that produces the Antarctic ozone hole and momentous contributions towards the protection of the ozone layer."

CIRES Fellow Susan Solomon Receives Prestigious Recognition at White House (5/11/04)

Susan Solomon was one of three NOAA team members to receive a 2003 Distinguished Presidential Rank Award at a White House ceremony. The award is the most prestigious recognition given to career government senior executives and scientists. Susan was cited for her scientific contributions, particularly for her leading role in the international effort to discover the cause of the Antarctic ozone hole and her research in evaluating the environmental impacts of newly proposed substitutes for the now-banned ozone-depleting compounds. Read the full story at *http://www.noaanews.noaa.gov*.

CIRES Fellow Margaret Tolbert Elected to National Academy of Sciences (4/21/04)

CIRES Fellow **Maggie Tolbert**, Professor of Chemistry and Biochemistry, was elected to the National Academy of Sciences. Membership in the Academy is considered one of the highest honors accorded to scientists in the United States.

CIRES Fellow Receives Guggenheim Foundation Fellowship (3/9/04)

The John Simon Guggenheim Memorial Foundation selected the work of CIRES Fellow **Veronica Vaida** on "Molecular properties of organic aerosols" for a fellowship. The Radcliffe Institute selected this work for a fellowship as well. Vaida is a University of Colorado Professor of Chemistry and Biochemistry. Her research interests focus on issues of photoreactivity in the atmosphere. Her previous awards and prizes include a fellowship with the Alfred P. Sloan Foundation and the Camille and Henry Dreyfus Teacher-Scholar Award.

Susan K. Avery Serving as AMS President

CIRES Director **Susan K. Avery** assumed her duties as the 2004 President of the American Meteorological Society at the AMS 84th Annual Meeting in Seattle in early January. The AMS, founded in 1919, is the nation's leading professional society for scientists in the atmospheric and related sciences. With more than 11,000 members, the Society promotes the development and dissemination of information on atmospheric, oceanic, and hydrologic sciences through scientific journals, conferences, and public education programs across the country.

Roger G. Barry, Distinguished Professor

Recognized internationally as a top geographer and polar climatologist, CIRES Fellow **Roger Barry** was named distinguished professor by the University of Colorado Board of Regents. Barry, who directs the National Snow and Ice Data Center, joins only 19 other faculty members who currently hold the title of distinguished professor

VISITING FELLOWS PROGRAM

CIRES annually budgets approximately $500,000 to conduct a competitive visiting fellowship program that promotes collaborative research at the forefront of evolving scientific paradigms. One-year fellowships are made to Ph.D.-level scholars and university faculty planning sabbatical leave. Post-doctoral fellowships are awarded for one or two years. Selections are based in part on the likelihood of stimulating academic interactions and the degree to which both parties will benefit from the exchange of new ideas. To further this goal, priority is given to candidates with research experience at institutions outside the Boulder scientific community. The program is open to scientists from all countries, and appointments can begin at any time during the year. Visiting Fellows at CIRES last year are listed below. Further information can be found at *http://cires.colorado.edu/visfell/vf.html.*

Approximately six fellowships are offered to scientists with research interests in the areas of:

- physics, chemistry, and dynamics of the Earth system (atmosphere, biosphere, hydrosphere, lithosphere)
- global and regional environmental change
- climate system monitoring, diagnostics, and modeling
- remote sensing and *in-situ* measurement techniques for the Earth system
- interdisciplinary research themes

Following are the nine visiting fellows supported during the previous year. Details of their research and the many resulting publications and presentations can be found in the appendices.

NAME	AFFILIATION	MENTOR	PROJECT TITLE
Garizone, Carmala	Geology	Peter Molnar	Late Cenozoic climate forcing from Asian Aeolian contributions to the North Pacific.
Henderson-Sellers, Ann	NSIDC	Roger Barry	Examining the use of isotopes (stable & radioactive) as probes and tracers of environmental systems and processes.
Kollias, Pavlos	ETL	Christopher Fairall	An advanced sea-going observing system suitable for the study of marine boundary layer clouds.
Kumar, K. Krishna	CDC	Balaji Rajagopalan	Sensitivity of Indian summer monsoon rainfall and it's variability to Indo-Pacific SST patterns: Some observational and GCM studies.
Lawrence, Peter	CSES	Thomas Chase	Biosphere and surface hydrology play on weather and climate
Panayotou, Dorothea	Outreach	Susan Buhr	Watersheds in the Classroom; and A study of the effects of fire on aquatic ecosystems
Stohl, Andreas	Aeronomy	Michael Trainer	Deep vertical transport processes affecting the global concentrations of water vapor, aerosols and trace substances.
Tervahattu, Heikki	Chemistry	Veronica Vaida	Aerosol particle research
Walton, Edward	Outreach	Susan Buhr	Biogenic volatile organic compounds

CIRES' Scientific Centers

CENTER FOR THE STUDY OF EARTH FROM SPACE (CSES)

DESCRIPTION

CSES was founded in 1985 to provide a focus for the development and application of modern remote sensing techniques used in the research of all aspects of earth sciences at the University of Colorado. Although measurements from space are emphasized, aircraft and field measurements are integral to any remote sensing project. Within CSES the aim is to work on all scales of problems extending from technique development in small test sites to understanding pattern and process on a regional and global scale. Data from the available electromagnetic spectrum extending from the UV to the microwave region are used. CSES facilities were developed with generous support from the W.M. Keck Foundation and matching funds from the University. The laboratories are dedicated to both research and teaching.

ACCOMPLISHMENTS

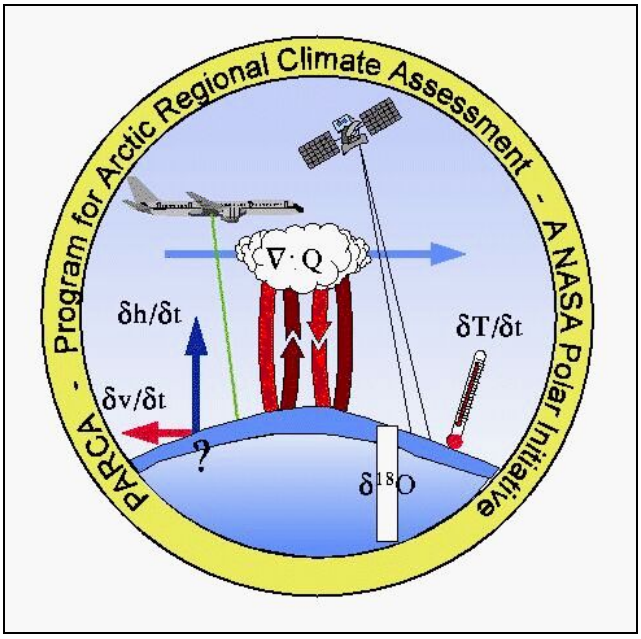
CSES is an association of five faculty members and their research groups who study and model the Earth using remote sensing and other techniques. The fields of study include landscape ecology, polar and regional climate, theoretical hydrology and surface geology.

Work during the past year on carbon sequestration in Southwestern rangelands demonstrates that dryland regions are changing mosaics of woody plant classes whose trends through time are logistically difficult to track with traditional ground-based techniques. Field work linked to remote sensing imagery offers the capability to monitor and track changes in aboveground carbon pools over large dryland regions and at frequent intervals. Our data indicate that decadal accumulations of aboveground carbon by woody plants can quickly be lost via natural disturbances and land management practices. This emphasizes the need to develop spatially explicit databases of land-use practices in drylands.

A dissertation on urbanization in the Front Range of Colorado explored the regional effects of urban development on carbon storage in this area and is serving as a basis for future work on urban ecology.

Funding through the CIRES Innovative Research Program supported the establishment of permanent plots in the Routt National Forest field site to study the long-term interactive effects of multiple disturbances to sub-alpine forest biogeochemistry and regeneration. Results show that sub-alpine forests experiencing wind disturbance retain tight biotic control on regeneration processes. However salvage logging following wind throw is a compound disturbance that disrupts recovery mechanisms, converting a biologically intact ecosystem into a modified state, in which a shift in ecosystem regime is possible.

Much time was spent in organizing a NASA/NSF field expedition called PARCA: Program in Regional Arctic Climate Assessment. This study gave new insight into the mass loss of the northern parts of the Greenland ice sheet. In summer a ship-based sea ice validation in the southern Ocean (Bellinghausen Sea) was organized to validate new aircraft and satellite sensors for ice thickness measurements.



Program for Arctic Regional Climate Assessment: A NASA Polar Initiative

Evidence of a temperature regulation mechanism at high latitudes related to sea-surface temperatures was found, which might explain the lower rate of observed arctic warming than predicted by climate models. Researchers also found a strong feedback from biosphere albedo in a simple model of the Earth's climate system. Finally, observed trends in reanalysis products were compared with previous claims of tropospheric warming causing some of the rise in tropopause height in the same data and showed that no warming existed in the data.
Data from three trenches dug into the Pierre Shale in the northern Front Range show that reflectance spectroscopy is a viable technique to detect the swell potential of smectitic soils and will provide results in seconds rather than days and at a significantly lower cost than standard methods.

IMPACT

The nature and range of responses by ecosystems to anthropogenic and natural disturbance will be indicative of the resilience of most ecosystems (including human-dominated ones) to predictable and unpredictable climate change, and may identify ecological thresholds of dramatic change. These types of studies will also aid in understanding ecosystem responses to human management regimes and may help identify systems that are more vulnerable to human activities.

The research into arctic climate regulation by sea surface temperatures, observed changes in vertical temperature structure globally, the ability of climate models to reproduce observed climate trends, and potential climate feedbacks all have strong implications for predicting future climate changes and variability.

The cost of remediation of structures, including roads, associated with swelling soil damage is approximately $2.3 billion per year, on par with flood and storm damage. Spectroscopic techniques applied in the excavation and site preparation process have the potential to reduce the need for post-construction remediation, in particular for differential heaving damage along the Front Range.

Publications and Presentations
(See appendix for full citation)

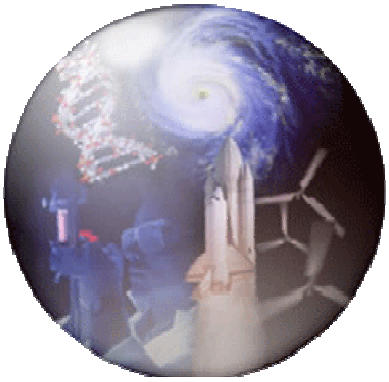
Abdalati, W., K. Steffen, and J. Box, 2003.
Ben-Dor, E., N. Goldshalager, M. Agassi, A.F.H. Goetz, O. Braun, B.C. Kindel, Y. Binaymini, D. Bonfil, 2003.
Chase, T.N., and R.G. Barry, 2003.
Chase, T.N., R.A. Pielke Sr., C. Castro, 2003.
Furey, P., and Gupta, V., 2003.
Goetz, A.F.H., B.C. Kindel, M. Ferri, Z. Qu, 2003.
Golubiewski, N., and C.A. Wessman. 2003.
Koury, J., K. Nordstrom, A. Henderson-Sellers, K. McGuffie and T. Chase, 2003.
Laxon, S., C. Dick, K. Steffen and P. Wadhams, 2003.
McAllister, M., and K. Steffen, 2003.
Mennis, J., C.A. Wessman and N. Golubieweski. 2003.
Nghiem S., and K. Steffen, 2003.
Pavlopoulos, H., and Gupta, V., 2003.
Pielke, R.A. Sr., D. Dutta S. Niyogi, T.N. Chase, and J.L. Eastman, 2003.
Pielke R.A. Jr., R. Klein, G. Maricle, T.N. Chase, 2003.
Qu, Z., B.C. Kindel, and A.F.H. Goetz, 2003.
Rumbiatis-del Rio, C. and C.A. Wessman. 2003.
Smith, L.C., Y. Sheng, R. Foster, K. Steffen, K. E. Frey, and D.E. Alsdorf, 2003.
Sivapalan, M., K. Takeuchi, S. Franks, V. Gupta, H. Karambiri, V. Lakshmi, X. Liang, J. McDonnell, E. Mendiondo, P. O'Connell, T. Oki, J. Pomeroy, D. Schertzer, S. Uhlenbrook, and E. Zehe, 2003.
Steffen, K., 2003 (*11 publications and presentations*).
Steffen, K., R.D. Huff, N. Cullen, E. Rignot, C. Stewart, and A. Jenkins, 2003
Steffen, K., N. Cullen, R. Huff, S. Starkweather, and T. Albert, 2003.
Steffen, K., N. Cullen, and R. Huff, 2003.
Thomas, R.H., W. Abdalati, E. Frederick, W.B. Krabill, S Manizade, and K. Steffen, 2003.
Tsukernik, M., T.N. Chase, M. Serreze. 2003.
Wessman, C.A., S.R. Archer, G.P. Asner, C.A. Bateson, T. Boutton, and M. McClaran. 2003.

SCIENCE AND TECHNOLOGY POLICY RESEARCH CENTER

DESCRIPTION

The Center for Science and Technology Policy Research was initiated within CIRES in the summer of 2001 as a contribution both to the CIRES goal of "promoting science in service to society" and to the University's vision of establishing research and outreach across traditional academic boundaries. The Center's vision is to serve as a resource for people, groups, or institutions that make decisions about science and technology.

The Center conducts research, education, and outreach to improve the relationship between societal needs and science and technology policy. It fulfills this mission through research, outreach, and education within the following themes: Evaluating the relationship between societal needs and science and technology policies; providing new policy alternatives for science and technology policy decision makers; and developing tools for science and technology policy decision making.



Graduate Certificate Program in Science and Technology Policy

ACCOMPLISHMENTS

During 2003-04, the first cohort of graduate students began classes under the Center's newly initiated Graduate Certificate Program in Science and Technology Policy and the Center completed a strategic planning process.

A Center scientist was awarded a three-year National Weather Service grant to develop and evaluate methods to assimilate station-based measurements of snow water equivalent into the NWS River Forecast System, and to develop and evaluate methods to produce forecasts on time scales of days through seasons.

The Center led preparation of a successful grant proposal under the National Science Foundation's Decision Making under Uncertainty program, in partnership with Arizona State University's Consortium for Science, Policy, and Outcomes. The project— Science Policy Assessment and Research on Climate (SPARC)—will commence in January 2005.

The Center became a major international collaborator on a Swedish research project, "Climate Science and Policy Beyond 2012" or "CSP 2012+," which will develop action alternatives to support international climate-change decision making with an explicit focus on the period 2012 and beyond. The Center hosted long-term collaborators from Sweden and Germany.

The Center hosted and co-sponsored 18 talks and visits at the Center or on CU campus, including nine visitors from outside the campus. The Center also hosted a public debate on current American foreign policy, including the recent preemptive invasion of Iraq by the United States.

The first annual meeting of two professional associations in the environmental philosophy community was held June 1-4, 2004 and co-organized by Center research staff. Center staff also organized a conference at Penn State University October 9-11, 2003 entitled "New Directions in Interdisciplinary Research: A Conference in Real World Experiments" as part of a collaboration between New Directions in the Earth Sciences and the Humanities and the University of Bielefeld's Real World Experiments Program.

The Western Water Assessment, which is located within the Center, completed a strategic planning process and selected 16 projects for funding. It also substantially revised its website.

PRODUCTS

Center staff produced 22 publications (10 peer-reviewed articles, 3 reports, 1 book, 6 magazine or newspaper articles, 1 book chapter, and 1 book review). Center staff and students gave 13 presentations by at academic conferences and other events. Other Center products include a newsletter, an extensive website, and workshops.

The Center started a weblog, *Prometheus*, which hosts science policy news and commentary, and provides a place for public comment and discussion.

A Center graduate student has been compiling and coordinating climate services across sectors. The resulting website, Climate Services Clearinghouse *(http://sciencepolicy.colorado.edu/climateservices/),* lists climate products from NOAA, other government agencies, academia, and the private sector.

IMPACTS

The model developed by center scientists for improving operational streamflow forecasting was transferred to the Colorado Basin River Forecast Center in December 2003.

The Center hosted twelve undergraduate students from around the country during the summer of 2003 to study the various perspectives surrounding global climate change.

A workshop in St. Petersburg, Russia in June 2004 under the New Directions in the Earth Sciences and Humanities project brought together twelve American and eighteen Russian participants under the theme "Cities and Rivers: Interdisciplinary and International Perspectives."

Center staff were quoted or referred to in 29 separate media sources including the *New York Times*, *Christian Science Monitor*, NPR, *Scientific American*, *The Economist*, Discovery Channel, *Boston Globe*, *San Francisco Chronicle*, MSNBC, as well as local newspapers.

Center staff ran a teacher training workshop on developing new ways to integrate ethics and values with science education. The workshop has resulted in the development of a number of new lesson plans, soon to be posted on the web.

Center staff taught five graduate level courses. Two students who worked with the Center graduated with MS degrees in Environmental Studies.

A graduate student completed an internship with a commercial catastrophe insurance firm and produced a report that is being used in the firm's business processes.

During the summer of 2003, the Center placed four students in policy or scientific graduate programs from around the country with reinsurance companies to increase the students' awareness of the reinsurance industry and to expose the industry to the perspectives of highly skilled students in policy and the sciences.

The Center's visiting scholar took the lead as rapporteur in preparing the summary of a workshop on national space policy. The workshop reached conclusions consonant with the policy subsequently announced by the President.

Images of climate impacts, from http://sciencepolicy.colorado.edu/climateservices

NATIONAL SNOW AND ICE DATA CENTER

DESCRIPTION

NSIDC's goal is to make fundamental contributions to cryospheric science and excel in managing data and disseminating information to advance understanding of the earth system. NSIDC serves as one of eight Distributed Active Archive Centers (DAAC's) funded by the National Aeronautics and Space Administration to archive and distribute data from NASA's past and current satellites and field measurement programs. NSIDC also supports the National Science Foundation through the Arctic System Science Data Coordination Center and the Antarctic Glaciological Data Center. Established by NOAA as a national information and referral center in support of polar and cryospheric research, NSIDC archives and distributes digital and analog snow and ice data. It also maintains information about snow cover, avalanches, glaciers, ice sheets, freshwater ice, sea ice, ground ice, permafrost, atmospheric ice, paleoglaciology, and ice cores.

ACCOMPLISHMENTS

NSIDC's core accomplishment is the growth of a catalog of data sets. Between 1 July 2003 and 30 June 2004, 91 new data sets were made available through the online catalog. These range from small data sets collected by individual investigators under NSF-supported research, to exciting new Moderate Resolution Imaging Spectroradiometer and other Earth Observing System satellite data products. More information can be found in the NSIDC Biennial Report (*http://nsidc.org/pubs/*).

NSIDC's success as a data center is due in large part to in-house scientists, who are involved in data product development and help insure responsiveness to the science community's needs. NSIDC's 13 researchers authored or contributed to 24 journal articles, three books, and numerous conference proceedings and other publications in 2003. Recent topics have been the dynamics of Antarctic ice shelves; new techniques for the remote sensing of snow and freeze/thaw cycle of soils; the role of snow in hydrologic modeling; linkages between changes in sea ice extent and weather patterns; large-scale shifts in polar climate, river and lake ice, and the distribution and characteristics of seasonally and permanently frozen ground. The research activities of NSIDC scientists are documented in the NSIDC Biennial Report (*http://nsidc.org/pubs/*).

IMPACTS

Impacts on the Science Community

In 2003, NSIDC distributed more than six thousand gigabytes of data. A diverse range of users were served, from students requesting information for school projects to media and textbook publishers requesting photographs and interviews. The majority of users (about 70%) are researchers. NSIDC's products form the basis of research into all aspects of the cryosphere, but the impact of that research may be greatest for research investigating changes. NSIDC is part of the scientific community it serves, and participates in a number of national and international projects and steering groups, including the WCRP Climate and Cryosphere (CliC) Project, Global Land Ice Measurements from Space (GLIMS), and the interagency Study of Environmental Arctic Change (SEARCH).

Societal impacts

The cryosphere bears witness to changing climate. NSIDC data products and research are assessing and monitoring these changes, most of which are having profound impacts on society. NSIDC scientists are a resource for the news media in articles explaining what is happening and why. Changes are taking place throughout the cryosphere: Permafrost extent is declining, glaciers are retreating, ice shelves on the Antarctic Peninsula are disintegrating, and arctic sea ice extent is shrinking. These changes are discussed in NSIDC outreach materials including "State of the Cryosphere" (*http://nsidc.org/sotc/*).

PRODUCTS

A significant addition to the library of publications and presentations of Center staff are the data products NSIDC has recently made available online. These are output from agency-funded programs; primarily the NASA-funded Distributed Active Archive Center, the NSF-funded Arctic System Science (ARCSS) Data Coordination Center (ADCC), Antarctic Glaciological Data Center, and Frozen Ground Data Center, and the NOAA at NSIDC program. All NSIDC data may be accessed through a user-friendly website that provides tools to permit a search for data by the name of the Principal Investigator, the project title, the measured parameter, or keywords (*http://nsidc.org/data/search.html*).

NOAA at NSIDC and the World Data Center for Glaciology, Boulder

The NOAA project at NSIDC ("NOAA@NSIDC") operates in cooperation with the NOAA NGDC to extend the NOAA National Data Center's catalogue of cryospheric data and information products, with an emphasis on *in situ* data, data rescue, and data sets from operational communities. The team also works with the International Ice Charting Working Group, and WMO Global Digital Sea Ice Data Bank at NSIDC. Our participation in these groups helps preserve ice chart data for use by researchers.

The Distributed Active Archive Center (DAAC)

The NSIDC DAAC provides access to Earth Observing System satellite data, ancillary *in situ* measurements, baseline data, model results, and algorithms relating to cryospheric and polar processes. The DAAC is an integral part of the multiagency-funded efforts at NSIDC to provide snow and ice data and information management services.

The Arctic System Science (ARCSS) Data Coordination Center (ADCC)

Since 1991, NSF has funded the ADCC at NSIDC to house data from Office of Polar Programs Arctic Systems Science-funded investigators, and to provide tools for investigators both submitting and looking for data. ADCC products have wide-ranging impacts. For example, in 2000, the ADCC in cooperation with the University of New Hampshire produced a CD-ROM titled "R-ArcticNet: A Regional Hydrographic Data Network for the Pan-Arctic Region." The distribution of over 652 copies makes this ADCC's top distributed product.

Antarctic Glaciological Data Center (AGDC)

The NSF's Office of Polar Programs (OPP) funds AGDC to archive and distribute glaciological and cryospheric-system data obtained by the U.S. Antarctic Program. Compiled data include ice velocity, firn temperature, shallow ice core measurements, geochemical composition of ice cores, snow pit data, and satellite images of ice shelves. Recent additions include tephra descriptions, Vostok gas isotope data, and ice motion data. Users can access data and documentation, citation information, locator maps, derived images, and references at *http://nsidc.org/agdc/*.

The Frozen Ground Data Center

The Frozen Ground Data Center (FGDC) (*http://nsidc.org/fgdc*), a collaborative effort between the World Data Center (WDC) for Glaciology, Boulder and the International Arctic Research Center (IARC), works internationally to collect and distribute data collected over many decades that is critical for environmental change detection and impact assessment, model validation, and engineering applications.

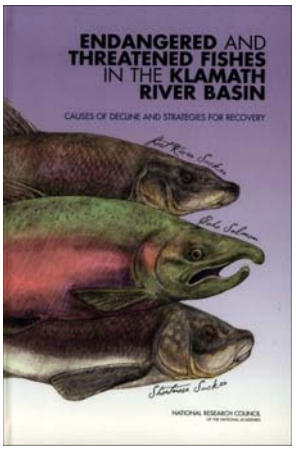
CENTER FOR LIMNOLOGY

DESCRIPTION

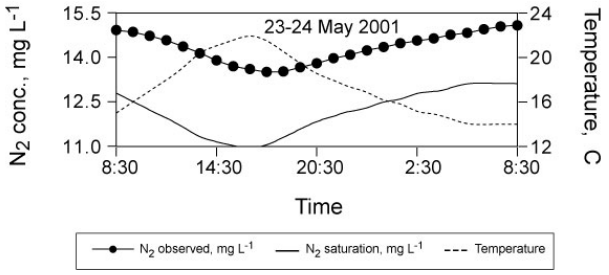
The purpose of the Center for Limnology is to promote research and teaching related to inland aquatic ecosystems, including lakes, streams, and wetlands. The Center conducts research through biogeochemical studies, which reveal processes, through studies of energy flux, which relate to foodwebs and biotic production, and studies of community and ecosystem structure, which connect organisms and their processes to physical and chemical influences in the environment. The Center has programs in tropical limnology (Venezuela and Puerto Rico) and the American West (Colorado plains and mountains). The Center conducts research on waters that are pristine or nearly so and also on waters that are strongly influenced by physical manipulation and water pollution.

ACCOMPLISHMENTS

During 2003-2004, the Center completed the editing of a volume on climate variability and water in the American West. This volume has drawn very favorable reviews because it provides a concise overview of the state of the science in the numerous disciplines that must be jointly involved in any analysis of the relationship between climate and water in the western U.S. In addition, William Lewis, Director of the Center, served as chair of the National Research Council's Com-mittee on Endangered and Threatened Fishes in the Klamath River Basin. This work, which involved the assistance of a number of staff members in the Center for Limnology, resulted in the issuance of a committee report to the National Academy of Sciences through the National Research Council. The report was widely covered in the national press and led to increased funding for environmental studies and restoration in the Klamath River basin as part of the current federal budget.



During 2004, the Center finished an extended project dealing with the lability of organic nitrogen in aquatic ecosystems. Organic nitrogen, which has been regarded as essentially unavailable to support biotic processes in ecosystems, was shown through experi-ments in the Colorado Rockies to be much more available to aquatic microbes than previously had been suspected. Thus, even when nitrate and ammonia are absent, the presence of organic nitrogen may sustain foodwebs in aquatic ecosystems. The work on this subject has been either published or sent to press.



Continuous measurements of nitrogen concentrations in the South Platte River below Denver over a 24-h interval. Consistent supersaturation with N_2 indicates denitrification; mass flux is computed from gas-exchange equations and gas concentrations.

The Center for Limnology has been engaged for the last four years in an intensive effort to improve methods for estimating denitrification in flowing waters. Denitrification is the main process by which nitrate is removed from aquatic ecosystems. The removal process involves conversion of nitrate to nitrogen gas, which then escapes to the atmosphere. This process is beneficial in that it reduces the effect of nitrogen pollution, which is a very widely distributed problem because of agricultural practices, mobilization of nitrogen oxides through the atmosphere as a byproduct of fossil fuel burning, and release of nitrate and ammonia to surface waters from municipal effluents. The process of denitrification has been difficult to study at the ecosystem scale, and cannot realistically be studied on small samples. The Center for Limnology has developed the first method for continuous measurement of denitrification in entire reaches of streams and rivers. The method is based on estimation of the rate of denitrification through the rate of escape of nitrogen gas from water to the atmosphere. The method involves measuring nitrogen gas concentrations and conducting field estimates of the escape coefficients for gas from a water body for specific concentrations of nitrogen. The method was first applied to the South Platte River, which contains high concentrations of nitrate.

The Center for Limnology has consistently contributed to tropical limnology, primarily through field studies in Venezuela and Puerto Rico. During 2003 and 2004, Center personnel finished a project on the metabolism of a Puerto Rican river. This study, which involved field measurements of photosynthesis and respiration in reaches of the Rio Mameyes, Puerto Rico, over a range of

elevations is the first comprehensive study of metabolism in tropical streams and rivers. The study showed that the undisturbed rainforest is capable of providing sufficient amounts of organic matter to streams to sustain high respiration rates throughout the year. In contrast, photosynthesis is inhibited by very strong herbivory, which is enhanced in tropical streams because of the absence of the seasonal suppression of invertebrates due to winter.

During 2003 and 2004, the Center for Limnology, through support from the Western Water Assessment, conducted statistical studies of relationships between seasonal low flows in streams and rivers and climatic conditions. In addition, the Center completed work on the oxygen carbon metabolism of the South Platte River in relation to water management and climatic variability. In the South Platte, metabolism is largely controlled by large changes in discharge. Water management has stabilized discharge as compared with the natural hydrologic regime of the river, thus changing both the total annual metabolism and the temporal pattern of metabolism.

During 2004, the Center for Limnology began working with the Colorado Department of Public Health and Environment and the U.S. EPA on the water-quality status of Cherry Creek Reservoir. This reservoir, which is the most widely used for recreation in Colorado, has presented great management problems. The state has mandated improvement of its water quality, but the residents of the watershed have been unable to devise measures that will produce improved water quality. The Center has undertaken studies that it believes will demonstrate the thresholds of effort that are required for improvement of water quality. This work not only has use in the Cherry Creek basin, but also as a model system for lakes that receive high ratios of phosphorus to nitrogen either as a result of nutrient disposal practices or as a matter of intrinsic geological factors.

During 2004, the Center finished, through one of its senior graduate students, a comprehensive study of factors affecting the distribution of the threatened cutthroat trout, which is native to Colorado. Factors limiting the distribution of this fish are related primarily to the presence of brook trout, which is introduced from the eastern United States. Studies of the mechanisms of interaction for these two species through studies of populations that were living together and separately showed that, contrary to intuition, the two species do not experience food limitation, poor body condition, or mortality in the post-juvenile stages when living together. The outcome of the interaction between these species occurs exclusively in the juvenile stages, at which time the brook trout have an advantage due to earlier spawning, which leads to larger larval brook trout.

During 2003 and 2004, the Center supported four graduate students seeking degrees, three post-doctoral associates, and a number of undergraduate students involved in independent research or honors.

IMPACT

The impact of the work of the center includes peer-reviewed publications, Congressional and public testimony on the Klamath River basin, advice to the Colorado Department of Public Health and Environment on nutrient limitations appropriate for Colorado waters, methods of maintaining water-quality standards in the South Platte basin, use of mixing-zone regulations for lakes, and improvement of water quality in Cherry Creek Reservoir

EDUCATION AND OUTREACH PROGRAM

DESCRIPTION

The CIRES Education and Outreach (EO) program provides carefully crafted science education opportunities for educators, students and scientists. Their work emphasizes scientific inquiry, links with research scientists and current research, and uses of place-based and field-based teaching methods. The impact of work increases through strategic partnerships with other geoscience organizations.

ACCOMPLISHMENTS

Opportunities for Educators

Earthworks: Earth System Science for Secondary Science Teachers

The annual CIRES Earthworks workshop was held in 2004 for 22 science teachers from 15 states. Participants designed and conducted field-based studies in aquatic sciences, fire ecology, and soils with the help of CIRES and NOAA research scientists. Interest in grant writing was high this year due to previous participants' grant writing successes; in the first half of 2004 Earthworks teachers were awarded ten grants for a total of $36K, in amounts ranging from $200 to $12K. Because new teachers are the major audience for this workshop, acquiring the ability to write grant proposals will be an advantage to them throughout their careers.

Local School District Partnerships

Through partnerships with school districts, CIRES provided expertise in science education, scientific information, and connections to CIRES research projects. In 2003-04, Outreach staff developed new curriculum and professional development designed to help the St. Vrain Valley School District (SVVSD) implement state science standards. The new curriculum uses local examples to illustrate fundamental concepts in each science, emphasizes skills in scientific inquiry, and depends upon the involvement of research scientists and graduate students. Subject areas addressed in 2003-04 included local geology, weather, and landscapes. Positive response to CIRES work within SVVSD led to a new award for work with SVVSD and six Front Range district partners in 2004-05 through the Colorado Department of Education. CIRES Outreach also spearheaded CIRES contributions to the Boulder Valley School District (BVSD), in partnership with several other university departments, the Thorne Ecological Institute, and Boulder Open Space and Mountain Parks. Through an NSF-funded K-12 award, CIRES graduate students participated in scientist-teacher partnerships in BVSD middle schools. In addition, CIRES contributed to the development of new BVSD curriculum and professional development in support of the new BVSD Sombrero Marsh Environmental Education Center.

Earthworks teachers conducting an insect study.

Opportunities for Students

National Ocean Sciences Bowl

CIRES has hosted a regional site for an academic competition, the National Ocean Sciences Bowl (NOSB), for the last six years. The Colorado competition is the only interior site and one of the largest competitions. This year, CIRES hosted 15 high schools from Colorado, Kansas and Utah. Approximately 70 scientists and community volunteers donated time and scientific expertise. The winning Colorado team, from Poudre High School, won third place in the national competition and traveled to Catalina Island, CA to snorkel and kayak, and tag fish as part of a research project,

Ocean Interactions

In partnership with CIRES/NOAA/ ETL scientists, CIRES EO developed a new project to increase ocean science education opportunities for students in the Interior West and beyond. The *Ocean Interactions* pilot was timed to coincide with a cruise to the equatorial TAO/PACS buoys on board the *Ronald H. Brown*.

CIRES EO staff developed a web presence, arranged pre-cruise visits to local classrooms, and managed ship-to-shore communications. ETL provided content for the web site, visited local classrooms and interacted with students while at sea. Eight classrooms in Colorado, California, and Pennsylvania participated. Once a week, students posed questions on a wide range of topics, ranging from "what do you do for fun on ship?" to "how did you get to do what you do?" and "we were wondering if underwater volcanoes, earthquakes and black smokers have any effect on the instruments you use in your experiments." ETL and CIRES EO will continue to develop this project during the 2004 NSF Rain in Cumulus over the Ocean (RICO) mission.

Undergraduate Course for Prospective Teachers

Outreach staff taught *GEOL 2110: Physical Science in the Earth System*, an undergraduate science course designed for prospective teachers. The course uses inquiry-based and cooperative teaching methods and emphasizes college-level content that is relevant to pre-college teachers. The course was fully subscribed and is highly recommended by the School of Education.

Opportunities for Scientists

Inquiry Workshops

Building upon previous workshops for graduate students, Outreach staff led an education workshop for research scientists during the 2003 Fall AGU meeting. The workshop explored the ways in which the scientific process may be translated to classroom inquiry, and helped scientists identify ways to use more authentic inquiry in their K-12 contributions. Attendance was standing room only, with 31 scientists in attendance and dozens more on the wait list. They are seeking funds for a series of similar workshops and will provide more workshops during the 2004 Fall AGU
meeting.

Collaboration on Scientific Research Grants

CIRES EO staff members collaborate with CIRES researchers to develop education components on scientific research grants. This year, CIRES Outreach contributed to 16 scientific research proposals in all areas of CIRES research. As a result of past contributions, current funds have been awarded to support new projects related to current research in solar science, seismology, air-sea interactions and carbon cycle.

Partnerships with other Geoscience Organizations

American Geophysical Union (AGU)

During the 2003 Fall AGU meeting, the Outreach director organized the AGU Geophysical Information For Teachers (GIFT) Workshop on the topic of abrupt climate change in the polar regions. Eleven scientists and polar educators led sessions for Bay Area teachers, who then had the opportunity to attend the meeting. See *http://cires.colorado.edu/~k12* for more information and copies of the presentations. On behalf of the AGU Atmospheric Sciences section, she will organize the 2005 Spring AGU GIFT workshop in New
Orleans.

American Society for Limnology and Oceanography (ASLO)

An Outreach research associate, also a member of the ASLO Education Committee, spearheaded the development of a new ASLO Education website. She convened the first special session focused on education during an ASLO meeting and has been asked to head the education committee for the upcoming year.

Digital Library for Earth System Education (DLESE)

CIRES EO has strong ties with the NSF-funded Digital Library for Earth System Education (*http://www.dlese.org*). The Outreach director leads a new team providing evaluation services to DLESE and the DLESE community. CIRES hosted the 2003 DLESE Annual Meeting, which was attended by more than 200 educators, agency representatives, technologists, librarians and scientists. Other current projects related to DLESE support use of geoscience data by educators and curriculum developers. Outreach recently received a new award to develop a digital climate-change collection for DLESE.

Colorado Science Education Network

In partnership with the Colorado Science Education Network, Outreach staff contributed to the science framework that will be used to develop the high-stakes Colorado Student Assessment Program (CSAP) test for science. CIRES scientists reviewed portions of the framework for scientific soundness. This work is highly significant because this test tends to drive the nature and content of instruction in classrooms.

IMPACT

Activities over the past year indicate that Outreach is reaching more people through increased partnerships. There are new partnerships with school districts, university departments, educators and geoscience organizations. Through their contributions to professional societies they are able to provide education opportunities for the wider scientific community, and through partnership with DLESE they are able to make more strategic contributions to systemic geoscience education improvements. For more information on Outreach activities, see *http://cires.colorado.edu/~k12*

GRADUATE RESEARCH FELLOWSHIP PROGRAM

CIRES has long supported a Graduate Research Fellowship program with an annual budget of around $175,000. This program is open to affiliated Ph.D. candidates to enable a greater focus upon their research project, typically in their last year. Following the 2002-2003 academic year the CIRES Council of Fellows elected to re-examine and revise the program to refocus and broaden the fellowship opportunity. No new awards were made in 2003-2004 while the program revision was underway.

In the coming year CIRES will award fellowships under the new Graduate Student Fellowship Program. The key change is greater flexibility with a focus on the early years of graduate study rather than dissertation support. The focus shifted from rewarding students in their final year to attracting the best talent in their early years.

WHAT IS A CIRES GRADUATE STUDENT FELLOWSHIP?

A CIRES Graduate Student Fellowship provides support for an outstanding current or prospective graduate student. Support can be as little as summer salary or in-state tuition, to support of one semester only, to as much as support for an out-of-state student for one year (12 months) and any support within these limits. Summer salary support can be allocated at 100% level, including to help recruit incoming students.

WHO IS ELIGIBLE?

Any graduate student advised by a CIRES Fellow or any prospective or current graduate student who might be supervised by a CIRES Fellow is eligible, except students who have already received a CIRES Graduate Student Fellowship. Fellowships can be used either to recruit prospective students and existing uncommitted students or to support advanced students in need of support. Funding for prospective students may be offered as an inducement to come to CU but then used in their second year, if a Teaching Assistantship covers their first year.

WHO NOMINATES?

Each year, each CIRES Fellow may nominate one student for a fellowship.

WHO DECIDES?

A committee of three CIRES Fellows will decide. They should be knowledgeable of the fields of study represented by the nominees, but none of them will have nominated a candidate.

SELECTION CRITERIA:

Fellowships should be restricted to Ph.D. candidates. Evaluations should be based on the promise of candidates to contribute to environmental science, on the basis of their applications to the University of Colorado and/or their accomplishments so far. Independence, passion for science, and ability to communicate should be considered. Limits should not be put on departments or general topics.

The first round of the new fellowship program will occur in 2004-05 and information on the resulting Graduate Student Fellows will be included in the CIRES Annual Report for 2004-05.

WESTERN WATER ASSESSMENT

INTRODUCTION

The Western Water Assessment (WWA) is a seven-year joint effort between CIRES and the NOAA Climate Diagnostics Center. Its mission is to identify and characterize regional vulnerabilities to climate variability and change (known generally as "assessments") and to develop information, products and processes (known generally as "products") to assist water-resource decision makers throughout the Intermountain West.

WWA is responsive to NOAA's mission, strategic goals, and cross-cutting priorities, as well as other congressional NOAA mandates including the U.S. Global Change Research Act and the Climate Change Strategic Program. WWA is funded by the NOAA Office of Global Programs as part of their Regional Integrated Sciences and Assessments ("RISA") program.

WWA is the premier integrating activity of CIRES and involves personnel from the Climate Diagnostics Center, Center for Science and Technology Policy Research, Center for Limnology, National Climatic Data Center, Natural Resources Law Center, Institute for Behavioral Studies, and the Institute for Arctic and Alpine Research.

PRODUCTS

The Climate Services Clearinghouse (*http://sciencepolicy.colorado.edu/climateservices*) is a web-based tool designed to provide for climate information seekers a one-stop portal. The heart of the site is a searchable database of meta-data (data about data) on every known climate-related website and product. Meta-data includes time scales, spatial scales, organization, and type of climate event. Over 1000 sites are currently stored in the database with more being added weekly.

Streamflow reconstructions using tree-rings allow water managers to compare known gage-based streamflows with paleo streamflows. Because most gages go back less than 100 years, these 400 to 600-year reconstructions are extremely valuable to water resource decision makers when planning new projects and evaluating the yield of current projects under paleo droughts. Researchers in 2003-04 worked to generate new streamflows in the upper Colorado River, among other locations, for use by Denver Water and other water providers. See *http://www.ncdc.noaa.gov/paleo/streamflow*.

Improved streamflow forecasts have long been a goal of water managers in the west. WWA researchers have worked closely for several years with NWS operational personnel in Salt Lake City at the Colorado Basin River Forecast Center to improve current models. In 2003-04, WWA researchers transitioned a new product to operations with substantial forecast skill over existing models.

NOAA uses a system of over 300 climate divisions in the continental U.S. for myriad research and reporting purposes. In the west, these climate divisions are typically river basins. Unfortunately, these basins have extreme topographic variability and are often inappropriate for many climate-related purposes. In 2003-04, WWA researchers created new experimental climate divisions.

NOAA's official seasonal climate predictions show limited skill in the Southwest. WWA researchers in 2003-04 issued monthly experimental temperature and precipitation outlooks for this area. These forecasts are widely read by water resource decision makers, and are featured prominently at monthly meetings of the Colorado Water Availability Task Force. See *http://www.cdc.noaa.gov/people/klaus.wolter/SWcasts*.

ASSESSMENTS

The South Platte Regional Assessment Tool is an integrated model of the South Platte basin in Colorado. The model allows investigation of the vulnerability of the South Platte to climatic and population pressures during the next 30 years. Last year the model was calibrated and verified, documentation was produced, and an experimental partnership with the Colorado Water Conservation Board was initiated to assist with state-wide water planning efforts.

WWA also completed a study of water restrictions in the Front Range during the drought of 2002. This study compared the effects of voluntary with mandatory conservation efforts by major water providers and was published in a major journal.

The relationship of water quality to climate variability is often ignored. In 2003-04 WWA researchers completed a national study of the impacts of climate variability on low flows and published in a major journal.

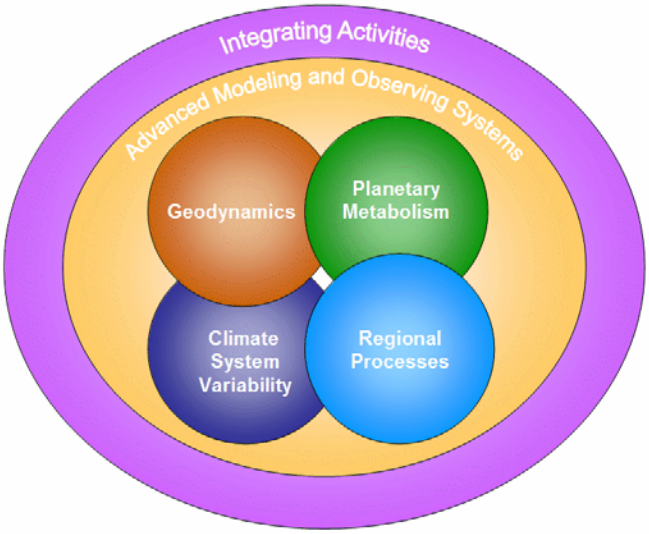
OTHER HIGHLIGHTS

WWA participates in graduate education by offering a course on climate and water. In addition, WWA funded four graduate students. WWA presents its work to decision makers in many settings across the West. WWA served an important role in assisting a Western Governors' Association effort to design a National Integrated Drought Information System.

CIRES' SCIENTIFIC THEMES

CIRES coordinates its research efforts toward specific scientific objectives through scientific themes that address questions of scientific and societal relevance in a meaningful context. This matrixed approach is decidedly more difficult than traditional organizational structures, but it represents a change in thinking that will translate into improved integration between disciplines and groups. It also allows CIRES to be more adaptive in how it responds to changing scientific priorities and national imperatives.

The current themes include *Integrating Activities, Geodynamics, Climate System Variability, Planetary Metabolism, Regional Processes,* and *Advanced Modeling and Observing Systems*. The last theme encompasses areas where CIRES has particular expertise in the development and design of techniques that can be applied to many different disciplines. These themes are intended to integrate with and complement our existing scientific divisions that include *Atmospheric & Climate Dynamics* (ACD), *Cryospheric and Polar Processes* (CPP), *Environmental Chemistry and Biology* (ECB) and *Solid Earth Sciences* (SES).



ADVANCED MODELING AND OBSERVING SYSTEMS

The development of new measurement techniques, instrumentation, and analysis methods throughout CIRES makes this one of the largest and over-arching themes, including activities in every unit. The space domain links most research fields ranging from local, regional, and global scales. It includes the optimization of modeling and observing systems for the various science disciplines, such as atmospheric chemistry processes, atmosphere and ocean physical processes, cryospheric processes, remote sensing of terrestrial applications, nonlinear systems applications, and data centers and data management. Modeling efforts deal with data assimilation applied to space weather forecasting, forecasts of the geomagnetic environment, and turbulent processes, among others. Instrumentation for more rapid and accurate real-time sampling of the atmosphere has been developed to better study the environment, and understand the complex processes affecting it. Because of its emphasis on technology rather than subject, this theme frequently brings together CIRES scientists of disparate backgrounds in work of cooperative interdisciplinarity that the institute was created to promote. Since all themes utilize measurement and modeling techniques, activities listed within this theme are those where the tools were primarily developed through CIRES-NOAA-CU partnerships or where the tools themselves are the focus of the research.

CLIMATE SYSTEM VARIABILITY

Climate variability affects virtually all natural systems and human activities. Climate directly impacts such vital areas as agriculture, water quantity and quality, ecosystems, and human health. Understanding, and potentially predicting, climate changes is therefore critical to the public, as well as to a broad array of decision-makers within federal and state government, industry, resources management and hazard mitigation. Indeed, basic issues include determining whether observed changes may be attributable to either natural or anthropogenic forcing, and the extent to which natural and human-induced changes may be linked. Prediction problems of vital importance include estimating changes in the likelihood of extreme events, and identifying risks for abrupt climate change, recognizing that the potential for major societal and ecosystem impacts is likely to be particularly significant in such cases. The major research partners in this theme include the Climate Diagnostics Center (CDC), the Aeronomy Laboratory (AL), the Climate Monitoring and Diagnostics Laboratory (CMDL), the National Snow and Ice Data Center (NSIDC) and the Program in Atmospheric and Oceanic Sciences (PAOS). Research done under this theme is especially useful to CIRES' Center for Science and Technology Policy Research, as results are often relevant to risk forecasting, management, and mitigation.

GEODYNAMICS

The goal of geodynamics is to better understand the internal processes of the planet, including the properties of the core-mantle (CM) boundary, convection within the Earth's mantle, and how that convection affects the surface of the planet. The slow changes of flow processes in Earth's deep liquid interior which drive the magnetic field are frequently described using spherical harmonic analysis of the

nearly 300 years of surface magnetic observations. The convective motion within the mantle, which is on the order of a few cm per year, causes oceans to open and close, continental plates to drift across the Earth's surface, and the Earth's crust to buckle and deform creating mountain ranges and other structural features. These convective displacements are the underlying source of earthquakes and volcanic activity. This convective process plays a fundamental role in determining the Earth's climate, through its influence on surface topography. The overriding goals of the CIRES effort in geodynamics are to 1) increase our knowledge of the fundamental processes that drive the mantle and core-mantle boundary; 2) use spherical harmonic analysis to model Earth's magnetic field; 3) use new experimental methods to detect and monitor internal motions of the mantle, the presence of layering, the movements of continents and the transfer of mass between atmosphere, continent and ocean; 4) examine the chemistry and physics of near-surface rock processes; and 5) investigate links between geophysical processes and human responses. Partners in geodynamics include the National Geophysical Data Center and National Ocean Service at NOAA and the Physics and Geological Sciences departments of the University.

PLANETARY METABOLISM

The sustainability of the biosphere during the current period of rapid changes in the Earth system is an issue of prime importance for the environmental sciences. The physical and chemical features of the Earth are intimately tied to organisms and the activities required for their sustenance. The health of the biosphere can usefully be considered using the concept of "planetary metabolism," which refers to the complex web of biochemical and ecological processes that occur within the biosphere, and the interaction of these processes with the lithosphere, atmosphere and hydrosphere. Both natural and anthropogenic disturbances drive the structure and dynamics of natural systems, and a thorough understanding of these complex processes is essential to efforts to protect the biosphere from adverse effects due to pollution, destruction of natural landscapes, and alteration of climate. This theme's overriding goals are to: 1) increase our knowledge of the fundamental processes that drive the biosphere; 2) use experimental tools to accurately measure indicators of change; 3) enhance the sophistication of prognostic models capable of forecasting the response of ecosystems and the global biosphere to future environmental changes; 4) carry out research that will develop science and technology to help restore and protect the health of the biosphere. The predominant collaborations and parallel activities include the Aeronomy Laboratory (AL), the National Geophysical Data Center (NGDC), the Molecular, Cellular and Developmental Biology (MCDB) department and the Ecology and Evolutionary Biology (EEB) department.

REGIONAL PROCESSES

Many of the research endeavors within CIRES and NOAA have a regional focus because they address a particular confluence of geography, demographics, weather and climatic regimes, or scientific challenge. This confluence of factors has produced a range of research within CIRES and NOAA that is not only rich in its diversity but provides an essential connection between science and its constituents. These constituents include human populations ranging from coastal megalopolises to communities of indigenous peoples on the margin of the Arctic Ocean, all of which must coexist with sensitive aquatic and terrestrial ecosystems in a highly variable and evolving climate. Indeed, the impact of short-term climate variability and extremes is often regionally focused, influencing very specific populations, economies, and ecosystems. CIRES scientists in the Aeronomy Laboratory (AL), the Climate Monitoring and Diagnostics Laboratory (CMDL), the Climate Diagnostic Center (CDC) and the Environmental Technology Laboratory (ETL) work on such projects as the mechanisms of atmospheric transport on climate and air quality, chemical transformation of products of biomass burning, air/sea gas transfer, and ozone pollution. This research contributes substantially to CIRES' Center for Science and Technology Policy Research and the Western Water Assessment Program. The latter is of particular value because of its broad focus which includes social scientists in the areas of economics, geography and behavioral sciences in addition to CIRES physical science experts.

INTEGRATING ACTIVITIES

CIRES engages in a wide range of integrating activities in research, education, and outreach that encompass each of the institute's research themes and contribute to the overall mission of the Institute, NOAA, and the University of Colorado. The primary focus is on five overlapping categories that include 1) K-16 Interdisciplinary Education and Outreach, 2) Graduate and Post-Graduate Education, 3) Scientific Assessments, 4) Interdisciplinary Research, and 5) Science and Technology Policy Research. For example, one team is focused on the decision-making processes of the individuals, groups, and organizations in the Interior West that have responsibility for managing, using, treating, and protecting water resources. By understanding decision-making processes, the stresses, and the constraints of this community, researchers seek to assess vulnerability to climate variability and develop hydro-climate products that enable better-informed decisions. Such scientific assessments bring together CIRES' expertise across a range of fields, including policy research and technology transfer, in collaboration with experts and end users who partner from outside the Institute. Collaborations with colleagues in the local NOAA laboratories have resulted in the transformation of basic research into applied science.

ADVANCED MODELING AND OBSERVING SYSTEMS

AL01 Instrumentation for Atmospheric Observation and Analysis

GOAL: Design and evaluate new approaches and instrumentation to make atmospheric observations of hard-to-measure species that are important players in the chemistry of the troposphere and stratosphere.

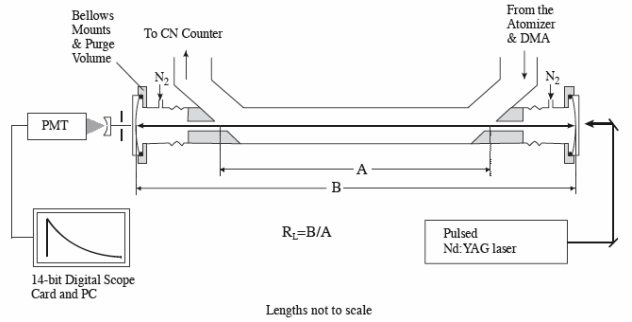
AL01.1 MILESTONE:
Design and evaluate (i) a method to accurately measure, in-situ*, the optical extinction by aerosols using the cavity ring down technique, and (ii) a particle collector to establish the chemical composition of organic aerosols.*

Methods to elucidate the role of aerosols in climate and air quality

(i) Accurate measurement of optical properties of aerosols is crucial for quantifying the influence of aerosols on climate and air quality. Extinction, the reduction in light transmission due to the presence of aerosol, is a key quantity needed for this assessment. Therefore, a Cavity Ring Down (CRD) system was designed and assembled to measure the optical extinction of aerosol and tested with well-characterized laboratory-generated aerosols. The measured extinctions agreed within 5% with those predicted by Mie light scattering theory, thereby validating the theory. It was shown that the precision of measurements of the optical extinction of aerosol in the field is determined by statistical fluctuations in the particle number density and that averaging times on the order of minutes are required to reduce statistical fluctuations to less than 5%. These measurements and calculations paved the way for building and measuring aerosol extinction in the real atmosphere and estimating the reliability of those measurements.

(ii) Organic compounds present in atmospheric aerosol have the potential to affect the radiative and microphysical properties of the aerosol with concomitant impacts on the role of the aerosol in climate forcing through direct and indirect effects. Knowledge of the organic compounds in atmospheric aerosols is needed to determine their effect on aerosol properties as well as to understand the role of aerosol surfaces in the heterogeneous chemistry of the atmosphere. The speciated measurement of aerosol organic compounds poses a significant experimental challenge due to the complexity and number of organic species and the low concentration at which individual species are present.

The effort to develop a method for determining the speciated composition of organic aerosol has followed two different paths in the past year. One technique uses aerosol collection followed by subsequent *ex situ* analysis, while the other couples collection to rapid *in situ* analysis.



Experimental layout of the Cavity Ring Down System

The first path has utilized an aerosol impactor to collect samples onto a steel plate coated with a matrix compound for analysis by MALDI (matrix-assisted laser desorption and ionization) mass spectrometry and onto quartz filter punches for solvation and analysis by electrospray ionization mass spectrometry. Exploratory atmospheric samples were taken at the Desert Research Institute's Storm Peak Laboratory in April and May 2004 and analyzed at the University of Colorado Chemistry Department mass spectrometry facility. The preliminary analyses show observable peaks across a wide range of masses. Work is ongoing to characterize the potential of the respective analysis techniques for identification and quantification of organic species from collected aerosol samples.

The second path has led to the design and construction of an aerosol impaction/thermal desorption/chemical ionization mass spectrometer. This instrument has an aerosol inlet to focus particles onto a target stage for some collection time. The stage can then be rapidly heated to vaporize the aerosol organic compounds, which are detected by proton transfer ionization and ion trap mass spectrometry. The instrument collection and analysis modules are in final assembly and the combined system will soon undergo laboratory testing and assessment for further development as a field deployable instrument.

AL01.2 MILESTONE:

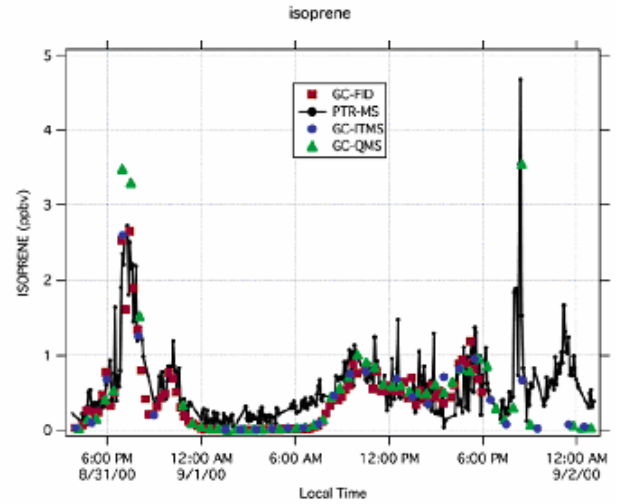
Assess the current capabilities of instrumentation to measure trace concentrations of reactive nitrogen and organic compounds in the atmosphere.

Evaluation of instrumentation to measure trace concentrations of reactive nitrogen and organic compounds in the atmosphere

Significant advances have been made in our ability to measure trace concentrations of reactive nitrogen and organic compounds in the atmosphere. These involve: (i) the evaluation and deployment of new techniques to measure atmospheric ammonia (NH_3) from an aircraft platform and (ii) the evaluation by field intercomparison of techniques to measure organic compounds.

(i) During the year, work was concluded on the development, characterization, and deployment of a chemical ionization mass spectrometry (CIMS) instrument for measuring ammonia (NH_3) from an aircraft platform. The chemical ionization mass spectrometer used to measure NH_3 was modified to improve the instrument detection limit by reducing interactions of the sampled air with inlet surfaces. This effort culminated in the integration of the instrument on the NOAA WP-3D Orion research aircraft.

Through this work, the NH_3 measurement capability that is critically important to understanding the chemical composition of the free troposphere has been greatly improved. This development will significantly increase our ability to understand the chemical processing that occurs in the atmosphere.



Representative time window of measurements of the organic compound isoprene by four different measuring techniques at La Porte during the 2000 Texas Air Quality Study. Proton-transfer mass spectrometric measurements were compared with three gas chromatographic techniques.

(ii) A key element in the understanding of atmospheric chemical composition is the ability to make unequivocal measurements of the concentrations of the compounds of interest. If these measurements are to be meaningful, it is necessary to have reliable instruments and techniques for which there are trustworthy estimates of the uncertainties in the observation. With these estimates:

1. Observations and theory can be compared meaningfully;
2. The results from separate field studies can be merged reliably;
3. Spatial gradients from separate data sets can be characterized credibly; and
4. Time series from different networks can be used to establish longer trend records.

During the past year, a field intercomparison of techniques to measure organic compounds was successfully completed. The studies were carried out to assess the current capabilities of instrumentation to measure trace concentrations of organic compounds in the atmosphere. These compounds are of great interest because they play a key role in atmospheric photochemistry. These studies have led to critical assessments of the capabilities of techniques used for the measurements of organic compounds from ground-based and airborne platforms. These developments are important contributions to efforts to develop reliable instruments that can be used to analyze and understand the atmospheric chemical transformations relevant to air
quality.

AL02 Chemical Transport Model Research

GOAL: Undertake research that contributes to the ability to forecast regional air quality and the intercontinental transport of pollution.

AL02.1 MILESTONE:

Use measurements of ozone, aerosols and their precursors made during the New England Air Quality Study (NEAQS) 2002 to evaluate the forecast capability of current chemical transport models.

Observations-based evaluation of air quality forecast models

This work involves the analysis of results from seven Eulerian-based air-quality forecast models (AQFMs) and comparisons with observations collected during the summer of 2002 New England Air Quality Study (NEAQS-2K2). The focus of the comparison is on ozone, and several other key photo-oxidants measured during July and August of 2002 at four surface sites in New Hampshire, the Harvard Forest site in central Massachusetts, and aboard the NOAA Research Vessel *Ronald H. Brown* that was deployed along the northeast U.S. coastline. The air quality forecast models are NOAA Forecast System Laboratory's MM5-CHEM model, the Baron-AMS Multiscale Air Quality Simulation Platform (MAQSIP), and the recently developed NOAA FSL WRF-CHEM model. The first two model platforms provide forecasts of meteorology and gas-phase oxidants at three horizontal grid resolutions; the coarsest (45 km and 27 km) covering much of the United States, and the finest (5 km and 3 km) covering the Northeast U.S. Comparison results are designed to test model performance with respect to different grid structures, precursor emissions estimates, physical parameterizations, and photochemical mechanisms. Standard statistical measures of variance and model bias, and species-species relationships between key photochemical species, are used in the analysis. The comparison statistics allow limited recommendations to be made concerning AQFM formulation, further observations needed to assess individual model components, and provide a statistical baseline for further AQFM development in the Northeast U.S. One important finding is that none of the three model platforms is significantly better than the other, and almost no improvement is seen with increased horizontal resolution. Model biases, however, are noticeably different between model platforms, model horizontal resolution, and distance from coastline. The comparisons between model and measured species-species relationships provide limited information on the reliability of specific model processes such as emissions and ozone production efficiencies. The models generally reproduce species-species relationships between O_3, nitrogen oxides, and CO with some dependence on model horizontal resolution. Deposition of nitric acid (HNO_3) is a strong influence on relationships involving nitrogen oxides, which limits the usefulness of model-measurement comparisons from surface sites to assess model emission inventories and photochemical mechanisms related to nitrogen oxides. The WRF-CHEM model shows noticeable improvement over the MM5-CHEM model in terms of explaining observed variance of ozone and its precursors, but biases related to the models' treatment of vertical transport within the planetary boundary layer are apparent in the WRF formalism. These findings have shown the need for upper-air data related to ozone and aerosol formation in addressing several AQFM issues, and point to specific comparisons between observations and AQFMs that upper-air data collected during the upcoming NEAQS-2004 field experiment will provide. The WRF-CHEM model predicts atmospheric aerosol mass and composition, and the comparisons with available measurements collected on-board the *Ronald H. Brown* have shown that important organic aerosol mass formation mechanisms are missing within the WRF aerosol microphysics formulation.

ARL01 Central Ultraviolet Calibration Facility

GOAL: Provide a central facility for the calibration and characterization of solar ultraviolet broadband and spectral measurement systems to improve the long-term stability and comparison of measurements across national and international networks.

ARL01.1 MILESTONE:

Calibrate and characterize broadband and filter radiometers in existing UV networks. Work with NIST and others to improve the accuracy of the standards used in absolute calibrations.

The Central UV Calibration Facility (CUCF) has organized an intercomparison of standards of irradiance between the European Joint Research Center (JRC) at Ispra, Italy and the CUCF. The UV laboratory at the JRC is the European counterpart to the CUCF. Previous impromptu intercomparisons of international standards by the CUCF have shown differences between NIST-traceable and PTB-traceable (Germany's standards lab) irradiance scale. Recently, yet-unpublished results from intercomparison campaigns held by the national labs have shown that the NIST and PTB's scales are comparing more closely. The comparison of the CUCF's secondary standards to those of the JRC is an extremely useful comparison showing how well each of the secondary laboratories is transferring their respective primary irradiance scales to the field UV monitoring instruments.

ARL01.2 MILESTONE:

Evaluate the performance of the international suite of instruments involved in the June 2003 comparison of spectral radiometers at Table Mountain, Colorado.

One paper reporting on the results of the June 2003 comparison of ultraviolet spectrometers is nearing completion. The results suggest notable improvements in agreement since the last comparison in 1997. Analysis for another paper reporting on the ultraviolet filter radiometer comparison conducted at the same time is not quite complete. The status of broadband ultraviolet radiometer calibration as conducted at the CUCF was reported at the Exeter, UK, Baseline Surface Radiation Network meeting in August 2004.

ARL02 Surface Radiation Network

GOAL: Collect long-term research-quality broadband solar and infrared radiation data at seven U.S. sites. Collect long-term, broadband ultraviolet radiation data to evaluate variations in the erythemal doses. Collect long-term, spectral filter data to measure column aerosol optical depth and cloud optical depth.

ARL02.1 MILESTONE:

Develop and evaluate automated calibration and analysis techniques for the optical depth of all aerosol channels. Investigate the retrieval of cloud optical depth. Analyze the data in the current database for trends. Provide data to the BSRN (Baseline Surface Radiation Network) archive to enable CIRES research on a wider scale.

The effects of broken clouds on satellite-based retrievals of columnar water vapor using a near-infrared radiance ratio technique were investigated. Data from the Surface Radiation Research Branch's Table Mountain surface radiation measurement site were used to show the effect of broken clouds on surface illumination. A typical difference between the retrieval using only pixels directly illuminated by the sun and pixels with mixed illumination (direct sunlight and cloud shadows) was found to be within 3%.

ETL01 Sensor and Technique Development

GOAL: Design and develop prototypical remote sensing systems for use from surface, airborne, and satellite platforms to measure critical atmospheric, surface, and oceanic parameters and address emerging observational priorities.

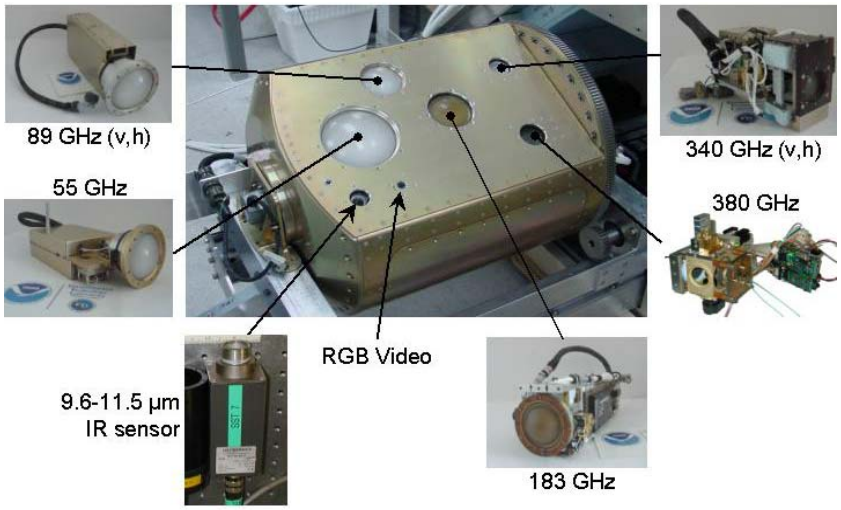
ETL01.1 MILESTONE:

Prepare the prototype Geosynchronous Microwave (GEM) Sounder/Imager simulator for FY04-FY05 high-altitude airborne missions over convective precipitation systems to verify system performance. Refine initial polarimetric radiometer calibration and validation field experiments begun during FY03 through FY04-FY08 through a regular series of field deployments.

The ETL radiometry group has been participating in soil moisture experiments since 1999. This year the Soil Moisture Experiment (SMEX04) was a part of the larger North American Monsoon Experiment (NAME). Our group installed and operated PSR/A and PSR/CXI scanheads onto the Naval Research Laboratory (NRL) P-3 aircraft. The PSR team was able to process the acquired data into the brightness temperature maps – an indication of soil moisture content – in near real time. Most recent efforts of the Radiometry group are focused on preparation for the flights over Antarctic sea ice.

A prototype of Geosynchronous Microwave (GEM) Sounder/Imager simulator is under development – the Polarimetric Scanning Radiometer/Sounder (PSR). Its first deployment was during the Water Vapor Intensive Operation Period (WVIOP04) in March and April of 2004 in Barrow, Alaska. There are a few radiometers still to include to the PSR/S and they are under development. The WVIOP04 provided a very valuable dataset for all the PSR/S radiometers and variety of atmospheric conditions. One of the first products from the WVIOP04 will be evaluation and comparison of the three levels of radiometer calibration – internal, external, and tipping calibrations. A high altitude airborne mission with the PSR/S is planned for spring
of 2005.

Figure 1. PSR/S radiometer with its five microwave and one infrared radiometers.



ETL01.2 MILESTONE:

Submit a professional paper describing the application of low frequency acoustic techniques for studying the ocean interior.

Results of research on novel acoustic techniques for remote sensing of the ocean interior and on quantifying limitations of existing techniques have been summarized in three journal papers, two of which were published and the third submitted for publication.

ETL01.3 MILESTONE:

Conduct a test with a mobile fire wind profiler at a controlled burn, modify design and operating procedures as needed, and publish results. Submit a patent application on the fuzzy logic boundary layer depth detection algorithm, and demonstrate and evaluate real-time application of the algorithm at a wind profiler site during the summer of 2003.

A primary goal has been to develop a new boundary-layer depth algorithm for use with wind profiling radars. The plan has been to use hourly spectral data from wind profilers located in New England for NEHRTP (New England High Resolution Temperature Project) to test the fuzzy logic algorithm for the estimation of mixing depth in real time during the summer of 2003. The algorithm code has been generalized to receive, as input, hourly spectral files for different types of acquisitions. The site used to test the online code has been Concord, NH, but the generalization of the code has been used to adapt it for other sites and different wind profilers as well.

A mobile wind profiler for fire weather applications was designed, and a prototype was built. The next step is to test and evaluate signal processing algorithms that will allow the profiler to obtain wind profiles in high clutter environments.

ETL01.4 MILESTONE:
Validate the X-band quantitative precipitation estimation (QPE) algorithm in the PACJET (Pacific land-falling jets experiment) domain and assess the attenuation correction technique. Use the X-band data set to investigate whether ice is present above the freezing level in situations where a radar bright band is not evident.
A radar technique was developed to use X-band radar data to identify the type of hydrometeor present above the bright band. This technique extends the applicability of the X-band radars for particle habit recognition. It was tested during the radar field projects on the West Coast.

The CIRES group within NOAA/ETL's Regional Weather and Climate Applications Division organized and conducted two field experiments that used polarimetric X-band weather research radar to observe storms and refine radar methods for estimating rainfall accumulations. The Hydrometeorological Testbed (HMT) project was conducted in northern California in the winter and the Global Precipitation Measurement (GPM) Front Range Pilot Project was conducted in Colorado in the spring and summer. Data collected with the scanning X-band radar and several other instruments, including profiling radars and raindrop disdrometers, are now being analyzed.

ETL02 Environmental Monitoring and Prediction

GOAL: Improve numerical model performance through development of new data streams that directly impact forecast ability and through focused observational campaigns supporting geophysical process studies.

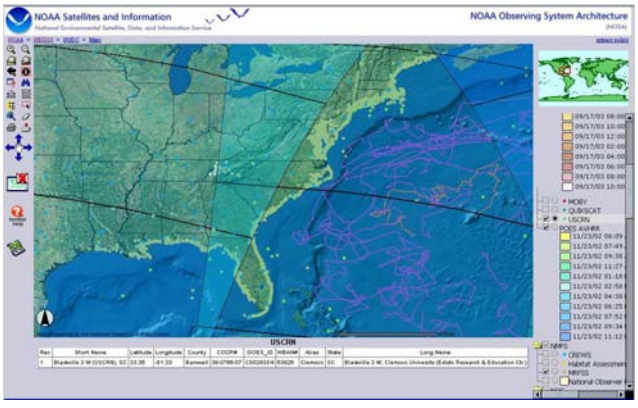
ETL02.1 MILESTONE:
Complete the first prototype of a new blended (infrared and microwave) sea surface temperature (SST) algorithm for a selected one-year period.
An optimal interpolation (OI) method for blending infrared and microwave SST products derived from AVHRR (Advanced Very High Resolution Radiometer) and TRMM TMI satellite data was developed. An air-sea flux model and ISCCP (International Satellite Cloud Climatology Project) net-solar surface flux data were used to remove diurnal fluctuations in the SST data. Validation with quality-controlled buoy data indicated a high level of accuracy for the blended SST data. Two years of daily averaged gridded SST data were constructed from the OI analysis and made available at the ETL Satellite Remote Sensing website.
ETL02.2 MILESTONE:
Develop a joint research effort with CalTrans (the California Department of Transportation) and the U.S. Department of Transportation incorporating snow-level monitoring to help improve highway maintenance associated with winter weather.
A proposal was created and presented to the California Department of Transportation (CalTrans). Unfortunately, sufficient resources were not available within CalTrans to fund the project.

The snow level product received U.S. Patent 6,615,140. NOAA's Office of Science and Technology is working on making the snow level product available to the weather forecast offices Advanced Weather Interactive Processing System (AWIPS).

NGDC01 Integration of Multiple Observation Types into a GIS framework

GOAL: Develop methods and processes for integrating multiple types of observations (gridded satellite products, *in-situ* measurements) using new Geographic Information System (GIS) data management and access tools.

NGDC01.1 MILESTONE: *Design and validate quality control on a geospatial database system for integrating gridded observations and model results with* in-situ *measurements.*
Fifty observing systems have been added to the database with geospatial information. A webpage (*http://nosa.noaa.gov*) was developed to hold all the observing system description and allow for geospatial database searches to all NOAA observing systems.



http://www.nosa.noaa.gov

The Spatial Data Import Framework, a Java framework that supports plugins for the reading and processing of spatial data, was developed. This package uses open-source tools from the Apache Jakarta project, GeoTools.org and the Java Topology suite to provide a full suite of data-processing capabilities. Tools developed using this framework were used to import geospatial data from disparate formats into an Oracle spatial database where analysis tasks can be performed efficiently. This permits easy cross-correlation between datasets that have previously been incompatible. These data-import tasks can now be performed in an entirely automated fashion where substantial manual intervention was previously required.

A monitoring system to verify that web-based map services through ArcIMS are running correctly was developed, and continues to be maintained. Response times are recorded in a database for web status pages, and automated emails are sent when errors are detected.

NGDC02 Using Metadata Standards to Facilitate Data Interoperability

GOAL: Develop methods and processes for partnering with scientists to facilitate interoperability by producing metadata for scientific observations that is compliant with national FGDC (Federal Geographic Data Committee) and international ISO (International Standards Organization) standards.

NGDC02.1 MILESTONE:
Design and implement a web interface for scientists to use, create and manage metadata for in-situ *observations.*

Many features of the NOAA Metadata Manager and Repository (NMMR) have been developed. The most important features are frameworks that have been added. The micro interface framework allows easy creation of small, specific interfaces that abstract a large metadata record. The framework for keyword thesauri allows importing keyword thesaurus. The framework to link multiple micro interfaces into a "task" allows a goal-oriented interface. The dictionary framework associates a controlled list of values with elements. Using the micro interface framework, approximately 20 micro interfaces have been created. These micro interfaces help data managers by displaying web forms that are easier to interpret than the Federal Geographic Data Committee (FGDC) standard, but are compliant metadata. Using the Jaxen project (*http://jaxen.sourceforge.net/*) as a framework, an NMMR implementation of XPath query language was created. The framework of NMMR was converted to Struts (*http://jakarta.apache.org/struts*). During this process of converting to Struts, hard-coded values were removed to create a more configurable system. This generalization has improved the flexibility of NMMR, which increases the types of users it can support.

A major refactoring of the Interface Database (IDB) web-based data access toolkit was completed. This toolset allows data managers to rapidly create online user interfaces to scientific data and is used extensively within the data center for analysis and reporting purposes.

NGDC03 End-to-end Data Management for Field Experiments and Models

GOAL: Develop prototype methods and processes for partnering with scientists to integrate modern data management and access tools into the planning and execution of field experiments as well as into the analysis and modeling of the results of those experiments.

NGDC03.1 MILESTONE:
Evaluate online mapping methods for viewing published air quality information.

1) Ingestion of existing data streams into a geospatial RDBMS.

Emission inventories pertaining to the 2000 Texas Air Quality Study (TexAQS) and EPA's 1999 National Emission's Inventory, version 2 and 3 were uploaded; data input files for their models were created based on these datasets.

2) Creation of user-defined presentations to enhance the geographic analysis of data.

Developers adhered to user requirements defined by AL scientists and created web-based interfaces (via the IDB and ArcIMS) that allowed for multiple data presentations. AL scientists are now able to obtain quick data retrievals of any specified emitted chemical species distinguished by source, time and geographical extent. Data are visualized as points or as grids based on spatial surrogates.

3) Facilitated process between NGDC GIS developers and AL scientists to add reporting tools, reference layers and a flight track data upload mechanism to assist field mission planning related to the New England Air Quality Study - Intercontinental Transport and Chemical Transformation and the ICARTT (International Consortium for Atmos-

pheric Research on Transport and Transformation) study.

This collaborative effort produced a valuable set of GIS tools for atmospheric scientists to evaluate point-source emissions such as power plants and gridded area sources such as roads and agriculture. Furthermore, the NGDC GIS team developed a custom version of the viewer for ArcGIS. Aeronomy Lab scientists on board the NOAA Ship *Ronald H. Brown,* who have limited Internet access, will be using this standalone GIS client to assist course plotting for running their experiments.

NGDC04 Multibeam Bathymetry Data Stewardship

GOAL: Contribute to a streamlined, more fully automated and web-based management and stewardship process for multibeam bathymetric data in support of seafloor research to benefit further CIRES research.

NGDC04.1 MILESTONE:

Complete a pilot development of Relational Database Management System (RDBMS) data storage and GIS-based web access to inventories, metadata, and primary data.

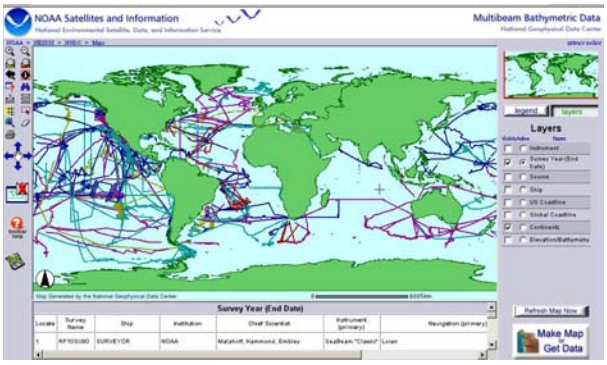
Researchers developed a database for multibeam bathymetry and produced configurable data loading scripts that serve both deep and shallow water data sets. The database has been populated with NGDC's historic as well as new multibeam bathymetric data. Some of the new data includes shallow water multibeam bathymetric data.

NGDC04.2 MILESTONE:

Web delivery of customizable, GIS-based, derivative data by means of the adaptation of acquired systems and the integration and evolution of current systems to the web environment.

An online map has been created to view multibeam tracklines and to provide access to data. Tracklines are made visible on the map as data managers enter new data, providing a means of quality control. Through an interface on the map, users may download trackline data of interest.

http://map.ngdc.noaa.gov/website/mgg/multibeam



NGDC05 Laurentian Great Lakes Geomorphology

GOAL: Map and analyze the Laurentian Great Lakes.

NGDC05.1 MILESTONE:

Completion of Lake Huron contours, integration, digital representation, and grid.

All of the Lake Huron contours have been drawn and 95% of these have been digitized. These digital contours have been integrated into the GIS map including the coastlines. Preliminary grids have been derived from the available digital contours for internal use.

NGDC05.2 MILESTONE:

Publication of a Lake Huron data CD-ROM.

NGDC has decided to present this data online instead of through a published CD-ROM. Images of the Lake Erie, Michigan, and Ontario maps can already be found online through the websites below. Also gridded data can be found for Lakes Erie and Ontario by going to these websites: *http://www.ngdc.noaa.gov/mgg/greatlakes/erie.html http://www.ngdc.noaa.gov/mgg/greatlakes/ontario.html* Lake Huron grids and map images will become available upon completion of the digitized contours.

NGDC11 Space Weather Reanalysis

GOAL: Generate a complete eleven-year space weather representation using physically consistent data-driven space weather models. The project will create a consistent, integrated historical record of the near Earth space environment by coupling observational data from space environmental monitoring system archives with data-driven, physically based numerical models.

NGDC11.1 MILESTONE:
Provide draft 2.0 of the SWR database available online and publish validation results in peer reviewed journals.

The SWR website is online and accessible through NGDC. The data now covers a full solar-cycle.

NGDC13 Space Ionospheric Observing Systems

GOAL: Research the best options for upgrading existing ionospheric monitoring systems. This effort will combine the resources of CIRES, NGDC and SEC to further current space weather capabilities.

NGDC13.1 MILESTONE:
Contribute to an implementation plan upgrading the current ionospheric monitoring system. Analyze the observational data produced by this new system in evaluating improvements on climatological outlooks.

During the period of this report, CIRES scientists in NGDC:

- Switched from Ionosonde Sounder IP-71 to DISS sounding and monitoring system.
- Upgraded the existing antenna system and designed and implemented the field site plan for future multi-antenna expansion.
- Analyzed and archived all data recorded by the station.
- Shared all data with DOD, NOAA and the private sector.
- Assisted NRL in relocating the old sounder IP-71.

SEC01 Solar Disturbances in the Geospace Environment

GOAL: Improve the prediction of traveling solar disturbances which impact the geospace environment. Such disturbances, which are associated with both coronal holes and coronal mass ejections (CME's) from the Sun, can cause substantial geomagnetic effects leading to the crippling of satellites, disruption of radio communications, and damage to electric power grids.

SEC01.1 MILESTONE:
Construct standardized sets of daily updated and full Carrington photospheric field synoptic maps using magnetograms from three different solar observatories: Mount Wilson, Wilcox, and National (on Kitt Peak) solar observatories. The synoptic maps will be assembled and warehoused and be used as input to the WSA solar-wind prediction model.

The aim of this project is to provide NOAA/SEC and the space weather forecast and research communities with routine, easy access to standardized sets of digitized synoptic maps of the solar photospheric magnetic field and other relevant solar data. The maps will be assembled and processed in a uniform way, using input from several observational sources, via implementation of a generalized algorithm developed and refined at NOAA/SEC. Although digital synoptic maps

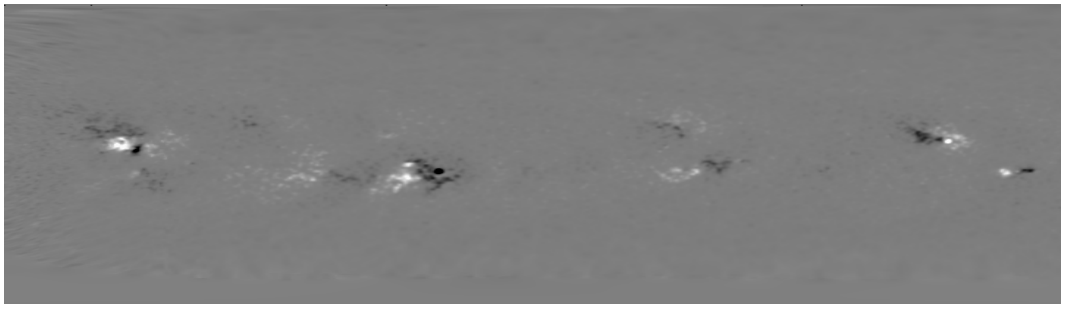


Fig. 1. Updated photospheric field synoptic map constructed by the NOAA/SEC generalized synoptic map assembly routine from individual line-of-site Mount Wilson Observatory magnetograms.

are available from a number of solar observatories, the methods and processing used to construct them differ considerably, as do their archive file formats, spatial resolutions, and physical data units. Since synoptic maps of the photospheric field distribution remain the sole quantitative observational input for coronal and solar wind models, they are key to the success of Sun-Earth modeling efforts. Thus, the ready availability of regularly updated, uniformly constructed synoptic maps (e.g., Figures 1 and 2 on these pages) from several observational sources will significantly facilitate the development of Sun-Earth propagation modeling capabilities.

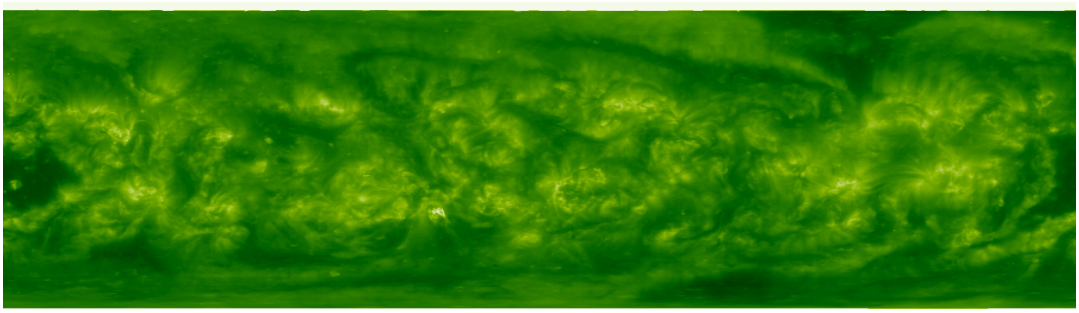


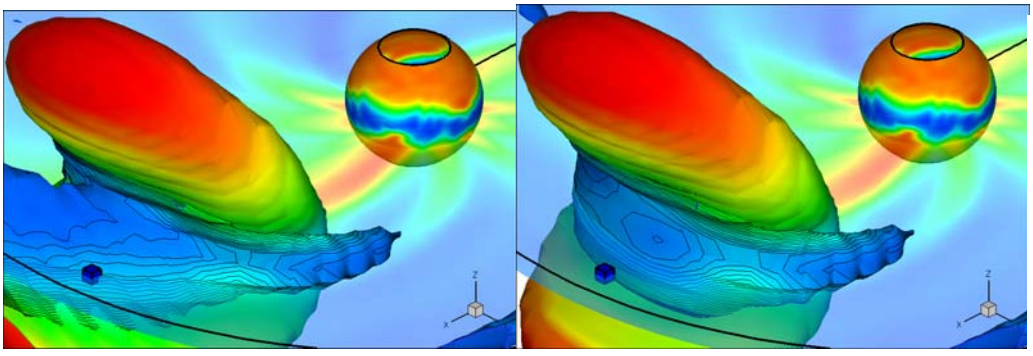
Fig. 2. SOHO/EIT λ195Å synoptic map constructed by the NOAA/SEC generalized synoptic map assembly routine from individual EUV images. Emission maps at this wavelength provide observational reference for coronal hole predictions from the WSA model.

SEC01.2 MILESTONE:

Improve our ability to predict solar wind properties at L1 by replacing the planar solar wind propagation model currently used with the more sophisticated Zeus 3-D MHD code. The main effort during the first year will focus on integrating/coupling the Zeus-3D numerical code into the WSA model. Once WSA and Zeus-3D code are fully coupled, CIRES and SEC scientists will evaluate the model's performance under a variety of initial conditions.

The geospace environment is immersed in solar wind, and its state is significantly affected by various quasi-steady and transient phenomena of solar origin. The development continues of numerical codes and their space weather applications within two large multi-institutional projects. In particular, scientists have successfully coupled the slowly evolving output of the NOAA/SEC Wang-Sheeley-Arge (WSA) coronal model with an advanced 3-D MHD interplanetary propagation model.

The figure below illustrates achievements in the simulation of real events, such as that of May 12-15, 1997. In the simulation, the ambient solar wind is derived from the coronal model, which is driven by photospheric magnetic field observations. A transient disturbance derived from geometrical and kinematical fitting of coronagraph observations is then propagated through the structured ambient flow. The plasma is compressed and forms an arc-like structure due to interaction with a fast solar wind stream. The arrival of the shock and ejecta is predicted well, but detailed analysis of the simulation shows discrepancies in the stand-off distance between the shock and ejecta and in the inclination of the shock normal. Using two different coronal models (SAIC and WSA) it is found that small-scale features (spanning ~10° of arc on the Sun) may play an important role in the manifestation of interplanetary disturbances at Earth and that their temporal evolution has to be considered.



Visualization of an interplanetary disturbance on 15 May 1997 at 00:00 UT for the ICME propagation in steady (left) and evolving (right) solar wind. The solar wind radial velocity is shown on the inner boundary at 30 solar radii, on the injected cloud, and on the translucent equatorial plane using a color scale. The injected cloud (compressed total density) is shown as an iso-surface at 6 (20) cm^{-3}. Earth position is shown by the blue box.

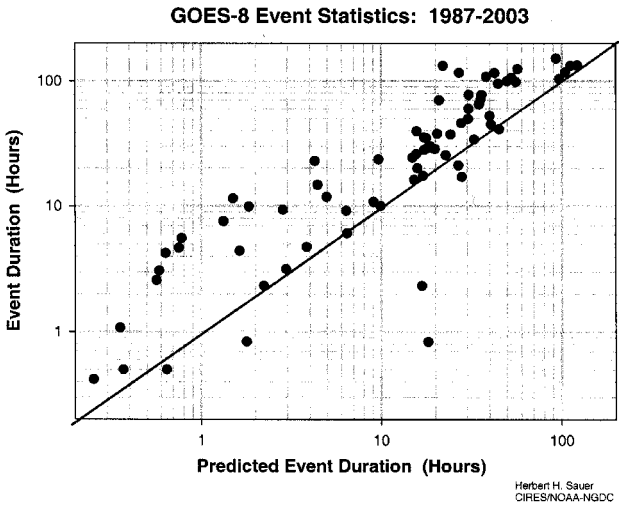
SEC02 Modeling the Upper Atmosphere

GOAL: Understand responses of the upper atmosphere to solar, magnetospheric, and lower atmosphere forcing, and the coupling between the neighboring domains. Since many of the space weather effects occur in the ionosphere and neutral upper atmosphere it is important to develop an understanding of the system to the point where accurate specification and forecasts can be achieved.

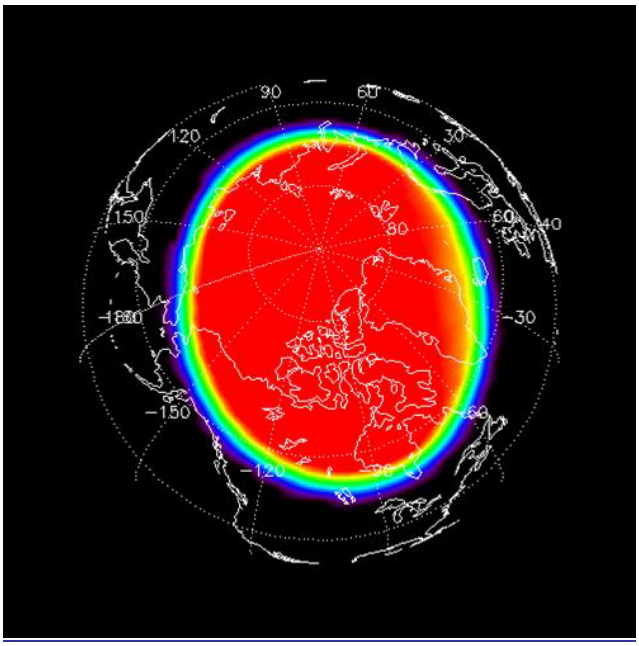
SEC02.1 MILESTONE:
Develop algorithms to quantify the impact of solar proton events on the high latitude ionosphere. In particular, determine the magnitude and geographic distribution of the level of absorption suffered by high frequency radio waves.
Specification of the propagation characteristics of radio waves through the ionosphere is of high value to the development and maintenance of reliable communication and navigation systems. Application of the near-real-time GOES energetic particle data to the timely estimate of the ionospheric absorption of HF/VHF radio waves during energetic particle events constitutes an important part of that specification. CIRES, the National Geophysical Data Center, and the Space Environment Center have cooperatively developed a system for the near-real-time estimate and display of Ionospheric HF/VHF radio-wave absorption during solar energetic particle events. Simple, one-parameter algorithms have been applied to the observed energetic proton flux as provided by the GOES series of satellites to yield estimates of the high latitude HF and VHF radio-wave absorption for both day and night respectively. The twilight response is obtained as a bi-linear function of the solar zenith angle at the observation position, and the equatorial boundary of the full absorption regions (the polar caps) are estimated from extant models of geomagnetic cut-offs and their dependence on geomagnetic activity. The approximate inverse square frequency dependence of ionospheric absorption is used to translate the results across the HF/VHF frequency range.

Calculations of the polar cap absorption of HF radio waves have been performed for eleven larger Solar Energetic Proton (SEP) events during the period from 1992 through 2002 and the results compared to observations of 30 MHz Riometers operated by the AFGL and located at Thule, Greenland. While significant discrepancies between the estimated and observed absorption using these procedures can occur, especially at low absorption levels, the estimates define well the frequency, level, and geographical extent of concern for reliable HF/VHF radio communication.

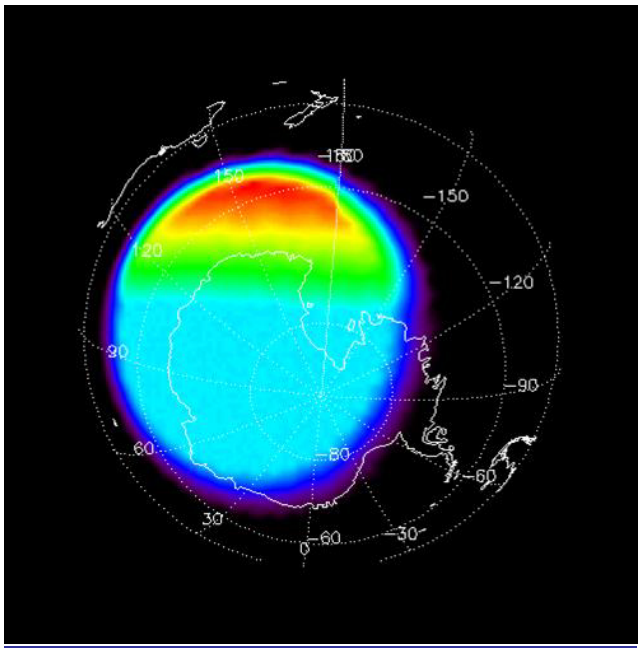
It is also desirable that some estimate of the duration of ionospherically significant solar energetic particle events be made. All comparisons with event characteristics have been found to exhibit such large deviations from the mean that they are of little operational value. However, a relationship has been developed which provides a prediction of the minimum duration of the event, given the peak event flux, with quite high reliability. A plot of the predicted versus observed event durations shown in the figure below illustrates that of



the 72 appropriate solar energetic particle events observed by the GOES-8 satellite, only four would be considered significantly under-estimated, and detailed examination of those event data characteristics illustrate their anomalous behavior. Validation results of the procedure's absorption event estimates and their minimum duration predictions confirm their value to users for whom ionospheric radio-wave propagation is important. A tentative graphical representation of the estimates is presented in the two figures on the next page. The procedure is expected to be transitioned as a test operation product in the fall of 2004.



Northern Hemisphere



Southern Hemisphere

SEC02.2 MILESTONE:

Determine the accuracy of the first version of the Global Assimilation of Ionospheric Measurements (GAIM) model. A Gauss-Markov Kalman Filter is now available to test using the CORS (Continuously Operating Reference System) network of ground-based GPS receivers. The accuracy of the model will be determined as a function of the density of ground-based sites.

One of the important problems in data assimilation is to determine the volume of data required to meet a specific accuracy requirement. A comprehensive validation is required to meet this goal, to quantify the accuracy of the method, and to determine the most efficient density of stations.

The past year has seen the emergence of at least three data assimilation models for the ionosphere. Collectively, the global assimilative ionospheric models are referred to by the acronym GAIM. One of the suite of assimilative models, US-TEC, has been validated as a function of the density of ground-based stations, which are the primary data used to drive the model. The scheme utilizes data from the Continuously Operating Reference Stations (CORS) network of ground-based, dual-frequency, GPS receivers over the CONUS to produce an estimate of the total electron content (TEC).

The model uses a Gauss-Markov Kalman Filter technique, and after solving for the GPS receiver biases, provides an estimate of the vertical TEC and the line-of-sight total electron content between any point within the CONUS and any of the GPS satellites.

In an effort to determine how many of the CORS ground-based GPS receivers are required to adequately specify the TEC, the differential TEC accuracy has been estimated for four station density scenarios. The four cases are illustrated in Figure 1 below. The 1x1° case

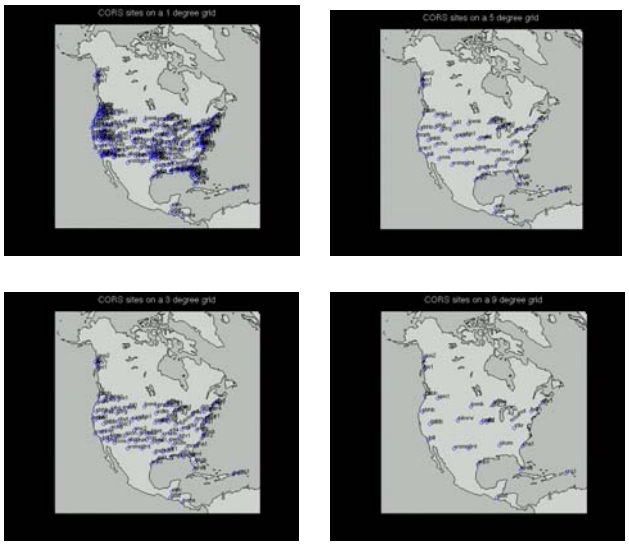


Figure 1. Illustration of the density of ground-based GPS stations for the four cases used to drive the assimilation model. The numbers of stations range from the complete set of about 160 stations to a coarse network of about 20.

corresponds to all available stations, about 200. The others are for a gradually decreasing resolution, to a very coarse network of about twenty stations, for the 9x9° case.

The differential TEC is defined as the difference in TEC between a given satellite-receiver pair separated by a given time interval. It is an excellent metric because the observable is accurate to a fraction of a TEC unit (1016 m^{-3}). U.S.-TEC maps are sampled along the particular satellite-receiver path at longer and longer time separations, and compared with the observations. The figure below shows that the root-mean-square (RMS) accuracy of the differential TEC improves by about a factor of 2 with an increasing number of stations.

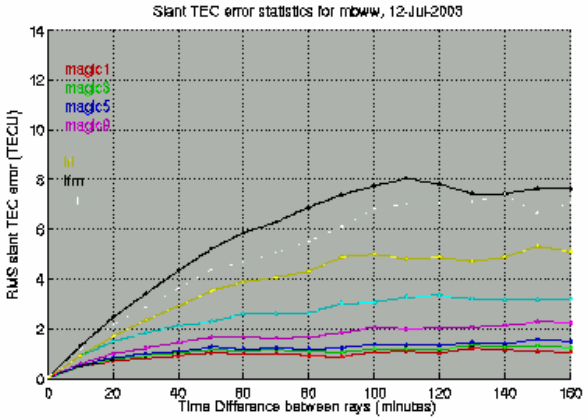


Figure 2. Illustration of the RMS accuracy of the differential TEC as a function of the time difference between the maps.

SEC02.3 MILESTONE:

Design and implement a validation procedure for the empirical storm-time ionospheric correction model (STORM). A necessary part of the procedure is to implement an on-going validation process.

Following transition as a fully supported operation product within Space Environment Center (SEC) Space Weather Operations Division, STORM has been widely used by the scientific and operational communities. Through a coordinated approach with the international community a comprehensive on-going validation has been established.

Many scholarly papers have used the STORM model in either the stand-alone mode, or embedded in the International Reference Ionosphere. This not only attests to the interest in the product but also confirms the previous validation analysis. Researchers will continue to coordinate with the international ionospheric community and monitor the performance of STORM over the coming years. The analysis will be essential in order to compare and contrast with new techniques as they are gradually introduced in the future.

SEC02.4 MILESTONE:

Identify the most important data sources required to develop and implement an ionospheric data assimilation system. Since significant resources are required to include a new data stream into an assimilation scheme, it is important to evaluate the most appropriate candidates.

Data assimilation techniques applied to the ionosphere improve the prospect for accurate specification and forecasting for space weather applications. Real-time specification and forecasts of ionospheric parameters are valuable for improved navigation and communication. CIRES, Space Environment Center (SEC), and the National Geodetic Survey (NGS) have recently developed a new ionospheric data assimilation model to characterize the total electron content over the Continental United States (CONUS). The model utilizes data from the Continuously Operating Reference Stations (CORS) network of ground-based, dual-frequency GPS receivers over the CONUS. The CORS data is being transmitted to SEC in real-time through data centers on the east coast, operated by NGS (CORS-East), and through a parallel data collection facility at the National Geophysical Data Center (NGDC), known as CORS-West. The data from both these collection points are streamed into SEC within 90 seconds of collection at the remote sites. A real-time system has been established to ingest the data into the assimilative model every 15 minutes to produce an estimate of the total electron content (TEC) in real-time. Initial validation of the model indicates that the accuracy of the slant-path TEC is between 1 and 2 TEC units (1 TEC = 1016 electrons m^{-2}), equivalent to a GPS phase delay of about 30 centimeters. In comparison, empirical ionospheric models have a typical accuracy of 5 to 10 TEC units. The model uses a Gauss-Markov Kalman Filter technique and is unique in its use of empirical ortho-normal mapping functions in the vertical direction. The model has been running continuously for over six months using real-time data from approximately sixty CORS stations. The model, after solving for the GPS receiver biases, provides an estimate of the vertical TEC and the line-of-sight total electron content between any point within the CONUS and any of the GPS satellites. The left panel of the figure on the next pages shows a typical TEC map on August 10th for the 15-minute time interval 2230 to 2245 UT, during average geomagnetic conditions. The right panel indicates the uncertainty in the model computation together with the stations used in this particular assimilation cycle. The validation indicates that the data assimilation techniques will be able to specify TEC with sufficient accuracy to be of value for improved GPS positioning. The model will be transitioned as a test operation product at SEC in the fall of 2004.

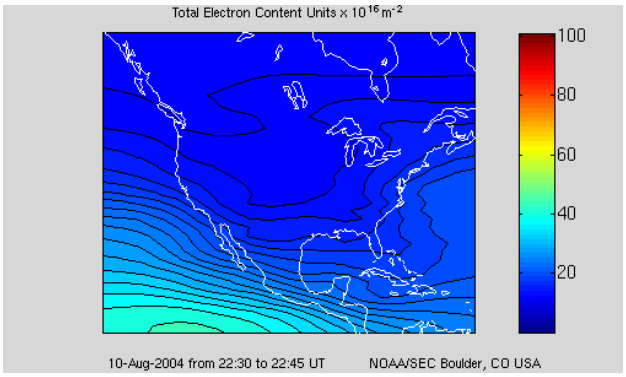


Figure 1. Real-time map of vertical total electron content on August 10th 2004 between 2230 and 2245 UT.

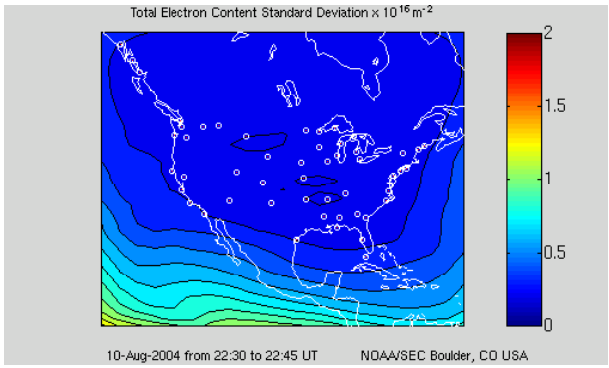


Figure 2. Real-time map of the accuracy of vertical total electron content, and the location of the GPS stations used in the assimilation cycle.

SEC03 Information Technology and Data Systems

GOAL: Determine the necessary data systems and infrastructure required for the successful implementation of empirical and physical models of the space environment, together with fast and efficient access to appropriate data sources.

SEC03.01 MILESTONE:

Determine the infrastructure needed to acquire, ingest, and store data from a variety of ground and space based systems.

SEC develops and maintains an IT infrastructure which supports the end-to-end processing of Space Weather data and products. This IT infrastructure provides the following functions:

Acquisition: Receipt and capture of raw satellite telemetry data streams.

Ingest: Transfer of raw data into SEC systems; translation of ground and space based data into a useable format (engineering units).

Processing: Secondary processing of SEC data (decoding, averaging, ratios, product generation, etc.).

Storage: Retain SEC data and products for near and long-term use (NGDS, SWDS, SELRAS).

Display: Create renderings of data and products to be used by forecasters and researchers to interpret, forecast and predict the space environment.

Dissemination: Distribute products, data and metadata to SEC customers.

Shared Services: Provide common services that support other IT Services. These include status, monitoring, software configuration management, logging, messaging, secure data access, services lookup and others.

During FY04, CIRES staff delivered components in all seven categories, providing essential research, analysis, prototyping, development, documentation and deployment of systems. Of note were the new Messaging service which provides a vehicle for applications to publish and subscribe to application notifications; the Database Bridge Server which provides a public interface to our data stores on private address space; the SAO processor which decodes and stores Ionosonde data from measuring stations around the globe; and the SXI Real Time Client Software which provides displays of real time solar images and movies. CIRES staff also deployed a Logging service which provides a central view of applications errors and warnings, and an FTP ingest and dissemination service which provides a public interface to receive and send FTP data. Since the GOES N project has dependencies on several of the above services, it was critical that they be delivered on time and be reliable and robust. Both criteria were met successfully.

SEC03.02 MILESTONE:

Design algorithms for the more rapid transition of new empirical and physical models through SEC's Rapid Prototyping Center (RPC).

The transitioning of models and new products into operations requires a multi-stage effort involving scientists, forecasters, and computer scientists. This effort includes an evaluation of model accuracy and value, documentation of the software for operational support, documentation of the model input and output modes, and forecast center training on interpretation of the model results. This effort, devoted to the transition of models and products into operations, insures that new advances effectively support customers of space weather services and that these new capabilities are efficiently maintained by the SEC staff.

During the past year the STORM model has finally completed this extensive evaluation and has been transitioned from a test product into operations fully supported by the SEC Space Weather Operations division. The final transition required the completion of training documentation, and the actual instruction of the forecast staff. The STORM model provides an estimate of the ex-

pected change in the ionosphere during periods of increased geomagnetic activity. The model estimates the departure from normal of the F-region critical frequency (foF2) every hour of the day for the current and previous day.

As the algorithms are being developed to quantify the impact of solar proton events on the high latitude ionosphere the webpage display and visualization are undergoing development and testing through the RPC. The figure below illustrates one aspect of the display which combines the information from the existing D-region absorption product from solar X-ray flares with the effect in the polar regions from solar particles. The display must accurately reflect the regions of influence of solar protons, and the magnitude of the impact. The algorithms must also be able to capture times of flare only, SPE only, and the time where the impacts are combined. Note that in the illustration the northern polar region is impacted more severely than the south. The difference reflects the seasonal dependence, where the attachment process during winter reduces the impact of the solar proton flux although the solar particle flux is the same. Algorithms are also being developed to prepare for the transition of a new product developed jointly between CIRES, Space Environment Center (SEC), and the National Geodetic Survey (NGS). The product is an ionospheric data assimilation model to characterize the total

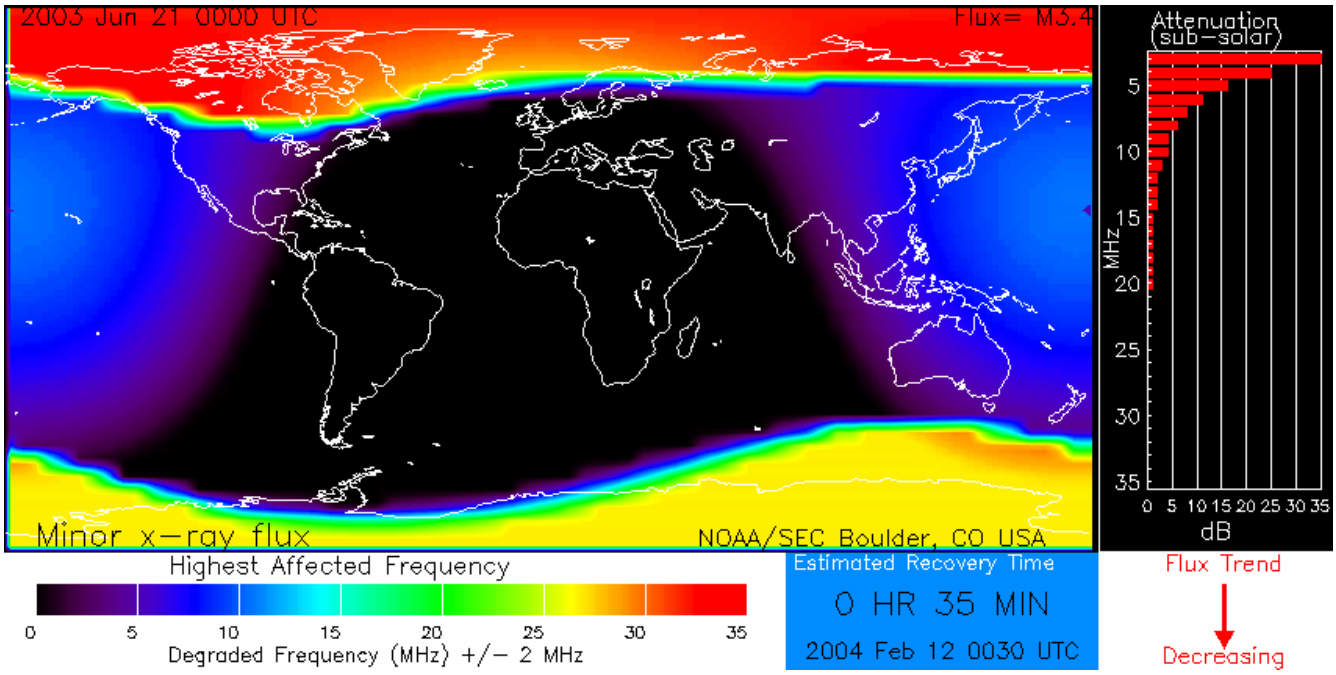


Illustration of the mid and low latitude region affected by a solar X-rays flare, and the high latitude region impacted by a solar proton event. The response shown is for June, where the sunlit northern polar regions have greater impact on radio wave absorption due to the UV wavelengths breaking the attachment bond between electrons and the molecular oxygen molecule.

electron content over the Continental United States (CONUS). The model utilizes data from the Continuously Operating Reference Stations (CORS) network of ground-based, dual-frequency, GPS receivers over the CONUS. Extensive effort has been invested to provide a reliable data feed from the CORS sites.

SEC03.03 MILESTONE:
Develop a prototype preprocessor ingest system for GOES-N space environment data to be used by CIRES scientists.

The next series of GOES satellites referred to as GOES N, O, and P (to become GOES 13, 14 and 15 after launch) are currently under development at Boeing Satellite Systems. In preparation for the launch of GOES N in December of 2004, SEC CIRES staff, in conjunction with SEC NOAA staff, have been designing and developing the computer system components needed at SEC for the ingest, processing, validation, archive, display and distribution of the GOES Space Environment Monitor (SEM) and Solar X-Ray Imager (SXI) data. These systems will provide the end-to-end IT framework needed to 1) acquire the raw satellite telemetry data and 2) to transform this data into engineering units, images and useful space weather products. The transformed data will initially be verification and checkout of Space Weather instruments onboard the GOES N Satellite. These instruments include two magnetometers, a solar X-ray sensor, an extreme ultra violet sensor, energetic particle sensors and a new solar X-ray imager.

The new GOES N GDS components include: A network data bridge which provides a gateway from the GOES N Satellite Operations Control Center (SOCC) network into

SEC's network and the GOES N GDS; an ingest preprocessor which converts raw binary data to more useable data formats; a product generation processor which creates and stores level 1 and 2 data products; and client applications for displaying and disseminating products and data.

A secondary effort associated with developing the GOES N GDS involves integration of the new hardware and software components into SEC's existing and evolving IT infrastructure. Existing IT shared services such as SEC's Logging Service, Messaging Service, Directory Service and Database Bridge Server will be utilized by the GOES N GDS software components.

The first delivery of the SEC GOES N GDS is scheduled for December 1, 2004 to coincide with the GOES N satellite launch. Subsequent GDS enhancements and products will be developed throughout 2005 in support of an early satellite activation (as early at late 2005).

ADDITIONAL RESEARCH

Daytime, Vertical ExB Drift Velocities Inferred from Ground-based Magnetometer Observations at Low Latitudes

An NSF Space Weather proposal was awarded to CIRES to investigate the relationship between equatorial magnetometer observations and the daytime vertical ExB drift velocities observed on a day-to-day basis. Previously, such a relationship had been determined qualitatively and not quantitatively. To establish the relationships between ΔH vs ExB drift velocities for the 270 days of observations, three approaches were chosen: 1.) A linear regression analysis; 2.) A multiple regression approach and; 3.) A neural network approach. The neural network method gives slightly lower RMS errors values compared with the other two methods. The relationships for all three techniques are validated using an independent set of ExB drift observations from the Jicamarca Incoherent Scatter Radar (ISR) located at Jicamarca, Peru. Magnetometer H component observations from Jicamarca (0.8°N. dip lat.) and Piura (6.8°N. dip lat.) in Peru and daytime, vertical ExB drift velocities measured by the Jicamarca Unattended Long-term Ionosphere and Atmosphere (JULIA) radar have been used to establish these relationships. Between April, 2001 and November, 2003, there were 38 days when the ISR in Peru was measuring the vertical ExB drift velocities. CIRES scientists have chosen these observations as an independent database in comparing the three approaches. Extracting the ISR ExB drift velocities between 10 and 16 LT for each of the 38 days gives 2254 samples to validate the realism of these relationships. Figures 1 and 2 below display the comparisons of the three techniques with the observed ISR drift velocities as a function of Local Time on April 17, 2002, and Sept. 25, 2003, respectively.

In each case the neural network approach gives the lowest RMS error. Over the 38 days, the average RMS error for the multiple regression method is 4.59 m/sec and for the neural network approach it is 4.21 m/sec. A paper describing these results will appear in the Space Weather Journal.

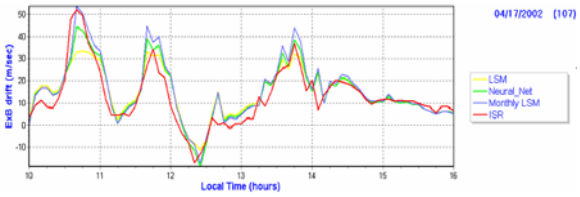


Figure 1. Comparison for April 17, 2002

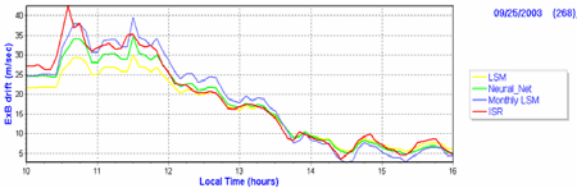


Figure 2. Comparison for Sept. 25, 2003

Collaborative Campus Research Programs

One of the strengths of and reasons for the creation of joint institutes is the symbiosis of research and academics that emerge from this partnership. While this annual report is intended to document progress on milestones identified in our integrated research workplan, it is important to recognize the breadth of complementary research being done on campus. The pages in this and the remaining five theme sections provide a snapshot of research efforts being conducted by selected CIRES Fellows.

BEN BALSLEY

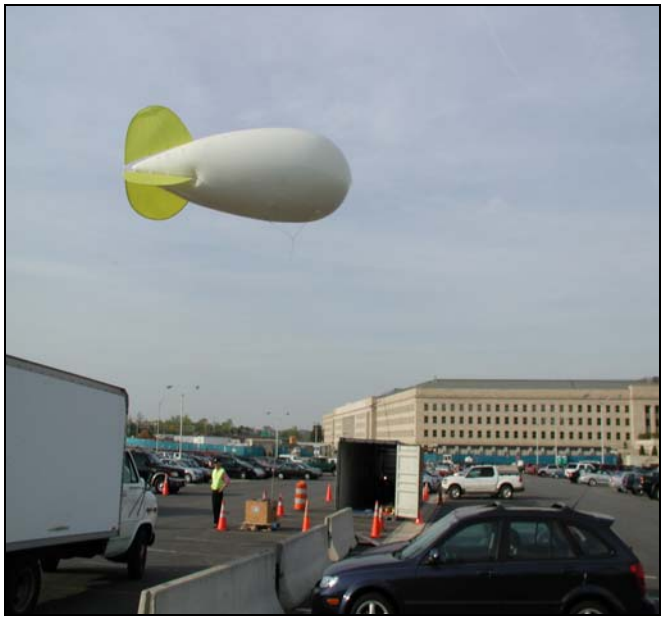
Pentagon Shield
Funding: DARPA

Project Purpose

To establish lower atmosphere characteristics around the Pentagon to accurately model this particular region for defense purposes.

Accomplishments

During April-May of 2004, the CIRES TLS (Tethered Lifting System) group was involved in measurements of the lower atmosphere from the parking lot of the Pentagon. As part of Pentagon Shield, Dr. Balsley's group made rapid high-resolution nighttime measurements of winds, temperatures, and turbulence from the surface up to 700 m (2300 feet), using the CIRES aerodynamic blimp coupled with an in-house designed sensitive instrument package suspended well below the blimp. The photo shown below illustrates the CIRES 25' blimp, the blimp storage container (low center in the photo), the measurement site, and its proximity to the Pentagon (background).



Significance

The Pentagon Shield campaign was quite significant, in that the atmospheric model incorporating the analysis of this and many other concurrent data sets will provide a greatly improved understanding of turbulence and diffusion processes in the Pentagon environs. This improved understanding will, in turn, be used to establish the best method of protecting the building from potential terrorist attacks (e.g., poison gas releases from nearby major thoroughfares upwind of the Pentagon).

From a more extensive viewpoint, however, the high-resolution measurement capability being developed at CIRES will enhance our understanding of the dynamic processes controlling the worldwide distribution of atmospheric pollutants and trace gases critical in affecting global climate.

BALAJI RAJAGOPALAN

A Feasibility Study of Estimation of Structural Systems Reliability under Hurricane Hazard
Funding Agency: NSF

The objective of the proposal was to develop an integrated framework to estimate structural system reliability under realistic hurricane hazard. The framework, for the first time, integrates the knowledge of large-scale climate, non-parametric data analysis techniques and structural failure.

Accomplishments

Dr. Rajagopalan's group developed an integrated framework for estimating structural reliability and demonstrated its utility by applying it to hurricane data on the North Carolina coast. Significant differences were found in structural reliability of a single-storied wood structure to large-scale climate. Particularly, El Niño conditions showed a marked reduction in the structural reliability. These have strong implications to infrastructure planning and management in both private and public sectors. Implementation details of the framework and results are described in *http://civil.colorado.edu/~balajir/my-papers/PMCpaper-rocf-jun09.pdf*

ANDREW MOORE

Application of the ROMS/TOMS Tangent Linear and Adjoint Models to the Littoral Ocean and Semi-enclosed Seas
Funding: Office of Naval Research

Description

Under the support of a previous grant from ONR, the PI, in collaboration with colleagues at Scripps Institute of Oceanography and Rutgers University, developed a state-of-the-art tool-box for the Regional Ocean Modeling System (ROMS) and Terrain-coordinate Modeling System (TOMS) for performing sensitivity analysis, stability analysis, data assimilation and ensemble prediction for the ocean circulation. ROMS/TOMS are complex ocean general circulation models that are available to the community at large. The purpose of the present grant is to use the ROMS/TOMS tool-box to explore the predictability of the coastal ocean circulation in various regions bordering the United States and its territories.

Accomplishments

During the last year, Dr. Moore's group refined the ROMS/TOMS tool-box by adding a series of modules that allow users to perform specific tests of their code before embarking on costly calculations. These tools provide a quick test of the efficacy of the code and allow coding errors to be identified and corrected. The ROMS/TOMS tool-box has been successfully used in three separate domains: The Southern California Bight, the entire Atlantic coast of the North America, and the Gulf of Mexico and Caribbean Sea (the so-called Intra-Americas Sea). Preliminary experiments are highlighting the influence that errors and uncertainties associated with various types of circulation features (e.g. regions characterized by confluent and diffluent flow regimes) can have on the predictability of the circulation of the regions considered. In addition, basic sensitivity calculations are revealing tantalizing information about the factors that influence flow through the Yucatan Channel and other island passages that border the Caribbean Sea.

Significance

The tool-box that they developed is unique in the ocean modeling community and is one of a kind for such a sophisticated state-of-the-art ocean general circulation. The ROMS/TOMS model is a community resource, and by developing the aforementioned tool-box they have made available to the community analysis and prediction tools comparable to those currently used in meteorology for operational weather prediction at major international centers. Armed with such tools, oceanographers can tackle many problems in coastal oceanography of relevance to fisheries, coastal zone management, search and rescue and mitigation with obvious clear benefits to society.

CLIMATE SYSTEM VARIABILITY

AL03 Chemistry, Radiative Forcing, and Climate

GOAL: (i) Observe and model the radiative forcing due to stratospheric ozone changes and tropospheric radiatively active gases. (ii) Carry out upper-troposphere airborne experiments and diagnostic analyses that characterize the dynamical and chemical processes influencing the radiative balance in the global atmosphere. (iii) Quantify the chemical and optical properties that determine the lifetimes, abundances, and trends of greenhouse gases.

AL03.1 MILESTONE:
Research new approaches, using an improved set of visible and near-infrared spectrometers, to measure atmospheric absorption by liquid water, water vapor, water ice and oxygen.

Quantifying the radiative effects of clouds

Participation in an October 2003 measurement campaign at the Department of Energy Southern Great Plains (SGP) site resulted in the collection of spectral data for several cloud coverage cases. These data will be used to compare spectrally-derived remote observations of cloud absorption with the liquid-water path estimates of the SGP microwave radiometer and atmospheric emitted radiance interferometer (AERI).

A suite of instruments, consisting of spectrometers and photodiodes, was designed, fabricated, and installed on the NOAA P-3 aircraft for participation in the 2004 New England Air Quality Study/Intercontinental Transport and Chemical Transformation (NEAQS/ ITCT) campaign (July-August 2004). The data are expected to be used in a comparison of remote and *in situ* cloud observations.

Data previously taken from the NOAA G-IV aircraft were used in an international collaborative study in 2003/2004 to test an algorithm that will allow for accurate and faster estimates of cloud attributes from down-looking spectral satellite observations.

AL03.2 MILESTONE:

Analyze vertical-pointing profiler observations collected during the 2002 Cirrus Regional Study of Tropical Anvils and Cirrus Layers - Florida Area Cirrus Experiment (CRYSTAL-FACE) field campaign, to estimate the vertical air motion and raindrop size distributions in precipitating cloud systems.

Characterization of raindrop size distributions in climate field studies

The observations collected during the CRYSTAL-FACE in July 2002 were used to estimate the vertical structure of the raindrop size distributions during several rain events. As well as surface meteorological instruments, a lidar and three vertically pointing profilers operating at three different frequencies were deployed at the same location during this experiment. The NOAA Aeronomy Laboratory provided the profiler operating at 3-GHz, the NOAA Environmental Technology Laboratory provided the Millimeter Cloud Radar (MMCR) operating at 35-GHz, the University of Miami provided the 95-GHz cloud radar, and the University of Alaska at Fairbanks operated the lidar. The different scattering properties of these instruments in rain were used to study the characteristics and the ice-particle melting processes near the melting layer during stratiform rain.

The advantage of observing precipitation events with multiple frequency radars is that the radars have different sensitivities to the different sized raindrops. The 3-GHz (S-band) radar measures an unattenuated returned power because the raindrops are small relative to the 10-cm radar wavelength and the scattering processes remain in the Rayleigh scattering regime. At 95-GHz (W-band), the radar suffers from attenuation as the raindrops are relatively large compared with the 3-mm radar wavelength. But the benefit of the W-band radar is that the ambient air motion can be estimated by analyzing the amplitude oscillations in the Doppler velocity spectrum due to Mie scattering from raindrops greater than 1.5-mm diameter. By using the air motion estimated from the W-band radar and the unattenuated returned power from the S-band radar, the raindrop size distribution can be estimated as a function of height in stratiform rain.

AL03.3 MILESTONE:

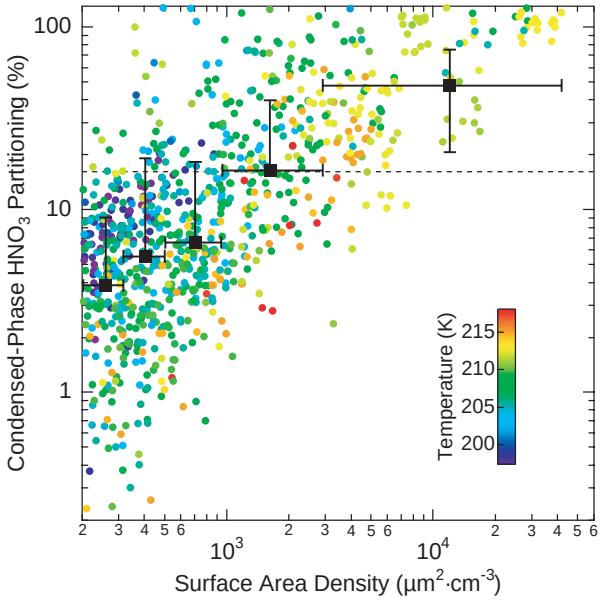
Investigate the exchange, sources, and sinks of water and ozone in the upper tropical troposphere, and understand the interactions between nitric acid and cirrus clouds.

(i) New approach for quantifying the stratospheric input to upper-tropospheric ozone

Research this past year has led to a new method for diagnosing the origins of upper-tropospheric ozone. Ozone in this region of the atmosphere affects radiative forcing and therefore is important in climate. Unlike most other greenhouse gases, upper-tropospheric ozone can come from air that is transported downward from the stratosphere, in addition to its source in the troposphere. Using measurements from CRYSTAL-FACE, researchers have developed a new technique for quantifying the stratospheric contribution to a sampled air parcel (which can range from zero to 100%). The new technique is sensitive enough to detect even small percentages of stratospheric ozone in the sampled air parcels of the upper troposphere. The approach uses hydrochloric acid (HCl) as a tracer for the stratospheric ozone. HCl has a very compact linear relation with ozone that persists throughout the upper troposphere and lower stratosphere (unlike other tracers). The relationship proved to be a very powerful way to diagnose the stratospheric component of ozone in upper tropospheric air parcels. Climate models currently have a large range in their estimates of the stratosphere-to-troposphere ozone transport, so the new method will enable some advances to be made in that arena.

(ii) Nitric acid uptake on subtropical cirrus cloud particles.

The redistribution of nitric acid (HNO_3) via uptake and sedimentation by cirrus cloud particles is considered an important term in the upper tropospheric budget of reactive nitrogen. Numerous cirrus cloud encounters by the NASA WB-57F high-altitude research aircraft during the 2002 CRYSTAL-FACE mission were accompanied by the observation of



The fraction of total nitric acid in the condensed (cirrus ice particle) phase, plotted versus cirrus-cloud particle surface-area density. Black squares represent mean values of the data grouped into quintiles. The dashed line at 16% represents the mean value of nitric acid partitioned in the condensed phase during CRYSTAL-FACE.

condensed-phase HNO_3 with the NOAA chemical ionization mass spectrometer. The instrument measures HNO_3 with two independent channels of detection connected to separate forward- and downward-facing inlets that allow a determination of the amount of HNO_3 condensed on ice particles. Subtropical cirrus clouds, as indicated by the

presence of ice particles, were observed coincident with condensed-phase HNO_3 at temperatures of 197 K–224 K and pressures of 122 hPa–224 hPa. Maximum levels of condensed-phase HNO_3 approached the gas-phase equivalent of 0.8 ppbv. Ice particle surface coverages as high as $1.4 \cdot 10^{14}$ molecules·cm^{-2} (14% of a HNO_3 monolayer) were observed. A dissociative Langmuir adsorption model, when using an empirically derived HNO_3 adsorption enthalpy of -11.0 kcal·mol^{-1}, effectively describes the observed molecular coverages to within a factor of 5. The percentage of total HNO_3 partitioned in the condensed phase ranged from near zero to 100% in the observed cirrus clouds, with a mean condensed-phase fraction of 16% (*see figure on previous page*). With volume-weighted mean particle diameters up to 700 µm and particle fall velocities up to 10 m·s^{-1}, some observed clouds have significant potential to redistribute HNO_3 in the upper
troposphere.

AL04a Tropospheric and Stratospheric Transport and Chemical Transformation

GOAL: (i) Improve theoretical capabilities to predict the natural and human influences on the stratospheric ozone layer. (ii) Characterize the photochemical reactions relating to the human-induced loss of ozone in the stratosphere. (iii) Carry out *in-situ* studies of the photochemical and dynamical processes that influence the stratospheric ozone layer.

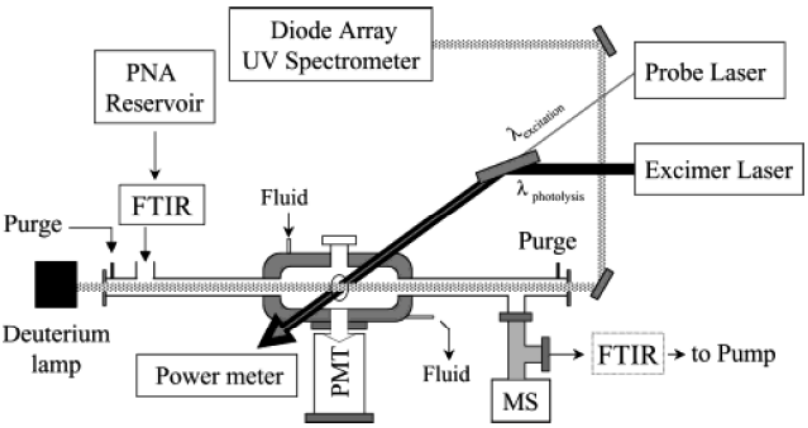
AL04a.1 MILESTONE:

Characterize the atmospheric chemistry of pernitric acid (PNA or HO_2NO_2) by obtaining laboratory data needed to calculate the rates of PNA removal by OH reaction, thermal decomposition, and photolysis.

Investigations of chemistry relevant to depletion of the ozone layer

Peroxynitric acid (HO_2NO_2, PNA) plays an important role in atmospheric chemistry as a gas-phase reservoir in both the stratosphere and troposphere for reactive nitrogen (NO and NO_2) and hydrogen (OH and HO_2) species. HO_2NO_2 is not directly emitted into the atmosphere but is formed via the association reaction of HO_2 with NO_2 ($HO_2 + NO_2 + M \leftrightarrow HO_2NO_2 + M$) thereby providing a link between the HO_x and NO_x families of reactive species. The atmospheric loss processes for HO_2NO_2 consist of: thermal decomposition, photodissociation (in the UV and visible/near IR), and reaction with the OH radical. The contribution of each of these processes to the total loss rate of HO_2NO_2 depends greatly on location and time. Laboratory work has focused on the quantification of these loss processes therein providing a more accurate understanding of the atmospheric chemistry of HO_2NO_2 and its role as a reservoir species.

In thermal decomposition experiments, an experimental approach using pulsed laser photolysis with laser-induced fluorescence detection of the OH radical was applied to measure HO_2NO_2 thermal decomposition rate coefficients. This work has reduced the uncertainty in this loss process under atmospheric conditions by a factor of two. Studies of the OH + HO_2NO_2 reaction kinetics have (1) resolved discrepancies among previously reported kinetic studies, (2) identified the products of this reaction, and (3) significantly reduced the uncertainties in this reaction at the temperatures and pressures of the upper troposphere and lower stratosphere. Studies of the UV photodissociation of HO_2NO_2 (HO_2NO_2 + light → Products) have provided the first measurements of the photolysis products in the wavelength range important in the atmosphere. In contrast to assumptions used in atmospheric-model calculations, these measurements have identified HO_2 as a major photolysis product at



Schematic of the experimental apparatus used to measure the rate coefficients for the reaction of peroxynitric acid and hydroxyl radical.

wavelengths >290 nm. It has been well established that HO_2NO_2 also photodissociates in the near-infrared (via absorption in the OH stretch overtone bands). However, there are significant discrepancies in the absorption cross-section measurements for the overtone bands. The technique of cavity ring-down spectroscopy has been applied to measure the absorption cross sections of the second and third OH stretch overtones of HO_2NO_2. This work has provided accurate cross-section data that leads to an increase in the calculated efficiency of near-infrared photolysis over that obtained in previous studies.

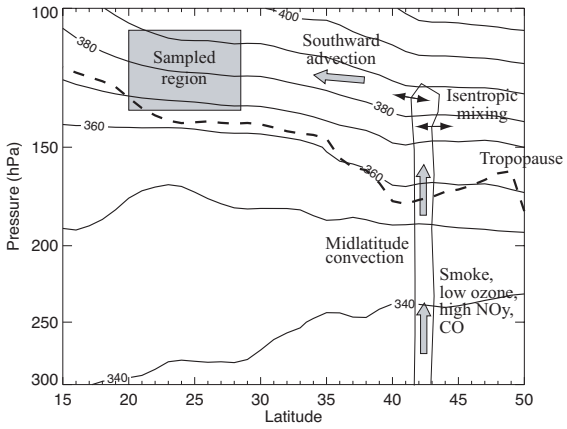
AL04a.2 MILESTONE:
Understand the interplay of dynamics and chemistry in the upper troposphere and lower stratosphere, with particular reference to the jet streams bounding the upper tropical troposphere and the polar vortex.

Characterization of dynamics and chemistry in the upper troposphere/lower stratosphere

Two studies pertinent to the above milestone were performed using data from the July 2002 NASA sponsored CRYSTAL-FACE measurement campaign. Research showed anomalous vertical profiles of ozone (>150% of normal) above the tropopause extending up to 410 K potential temperature. This ozone increase was the result of recent transport of mid- and high-latitude lower stratospheric air into the subtropics where the measurement campaign took place. This study shows the spatial and temporal extent of meridional isentropic transport into the subtropics by examining the ozone vertical profiles in combination with the NO_y:O_3 correlations as well as back trajectory calculations. The anomalous ozone profiles are also reproduced in a global chemical transport model.

A second study used trace gas and particle measurements taken during the CRYSTAL-FACE mission to examine mixing in the summer subtropical lower stratosphere. Vigorous convection in the central and eastern U.S. injected a significant amount of tropospheric air into the lower stratosphere, which was subsequently advected over the region sampled during the CRYSTAL-FACE mission (shown schematically in the figure below). Aerosols produced by biomass burning were observed over Florida during a time period with a large number of forest fires in the western U.S. and eastern Canada, providing evidence of convective injection of tropospheric air into the lower stratosphere. The circumstances of the large-scale flow pattern in the upper troposphere and lower stratosphere, vigorous summertime convection, abundant forest fires and the downstream sampling allowed a unique view of mixing in the lower stratosphere. This study calculated the fractions of midlatitude tropospheric air in the sampled lower stratosphere and mixing rates based on consistency between a number of tracer-tracer correlations. The possible impact of summertime midlatitude convection on the composition of the stratosphere as a whole is also of interest.

Schematic of the transport of tropospheric air into the sampled region of the lower stratosphere. The latitude-pressure cross section of potential temperature and tropopause height are from NCEP analysis on July 7, 2002, 06Z at a longitude of 78°E. The convection is assumed to have occurred in the midlatitudes over the continental U.S. several days before the WB-57F sampled the lower stratosphere over Key West, FL.



AL05 Climate Dynamics

GOAL: Analyze data and conduct theoretical studies to improve understanding of (i) tropical Pacific Ocean dynamical processes related to the subseasonal atmospheric variability, and (ii) atmospheric circulation, convection, and moisture and heat budgets associated with the El Niño phenomenon.

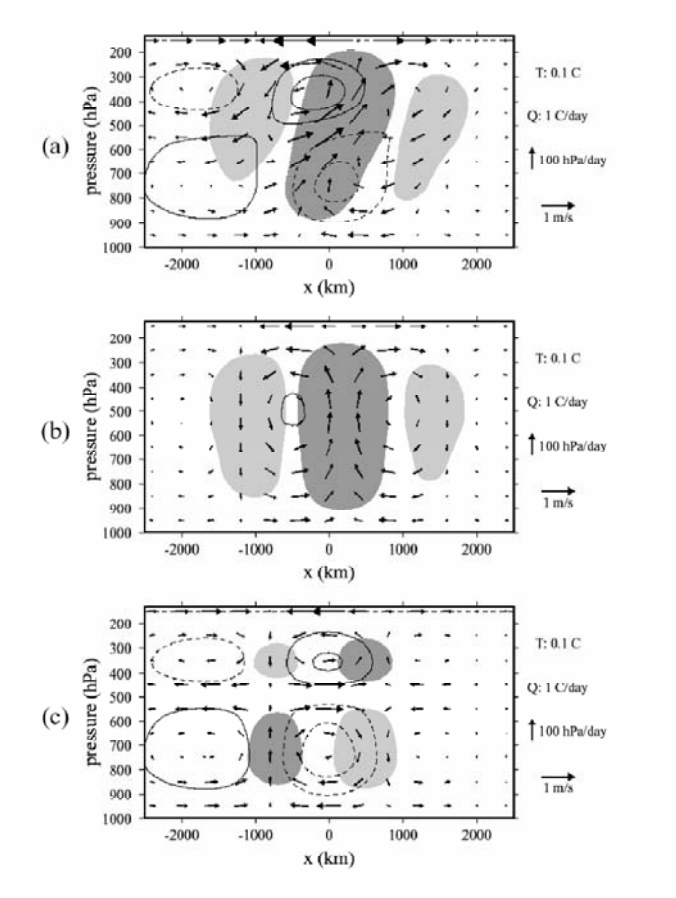
AL05.1 MILESTONE:

Determine if the wind and temperature perturbations associated with convectively-coupled tropical waves are linear responses to convective heating and cooling by simulating such responses for waves observed during the Tropical Ocean and Global Atmosphere Program's Coupled Ocean-Atmosphere Response Experiment (TOGA COARE).

Analyses of equatorial wave behavior to diagnose connections between convection and tropical circulation

Two-day equatorial waves using both observations and a linear primitive equation model were studied. Gridded objective analyses of data collected during the TOGA COARE field program were used to construct a statistical composite of a two-day wave. The composite revealed tilted wind, temperature, and heating perturbations similar to those observed in other convectively coupled equatorial waves previously observed. It was hypothesized that the bulk of the wind and temperature structure could be modeled as a linear response to the wave's heating. Two simulations of the atmospheric response to the observed heating were carried out, one for an effectively unbounded atmosphere, and the other for an atmosphere having a rigid upper boundary at 150 *hPa*. In both cases, much of the temperature and wind structure of the disturbance was reproduced (*see figure at right*). This result was especially encouraging for the latter simulation, because for that case the solution was the sum of two vertical normal modes whose dynamics were governed by shallow-water equations. In other words, the latter simulation established that a relatively simple dynamical system could capture the free tropospheric dynamics of the wave, and it supported the "two vertical mode" approximation that previously had been used in theoretical studies of equatorial waves. The two vertical mode simulation also provided for a dynamical separation of two-day waves' convective circulations. Previous studies have noted that within two-day waves, deep convection is preceded for a time by relatively shallow convection, and followed by a period of stratiform precipitation. The first vertical mode represents the heating and circulation associated with deep convection, and the second mode represents the heating and circulation associated with both shallow convection and stratiform precipitation. An analysis of the Madden-Julian Oscillation reveals that this much larger-scale disturbance is also characterized by a similar vertical structure and progression of cloud morphology. The existence of this scale invariance affords valuable insights into the coupling between convection and the tropical circulations, and provides a target for the improvement of numerical simulations of the atmosphere.

An east-west vertical cross section of the simulated two-day wave at –6 hr in the linear model. Perturbation temperature is contoured with a 0.1 K contour interval, solid (dashed) contours are positive (negative), and the zero contour is omitted. Regions with perturbation heating zones greater than 1 K day^{-1} are shaded, dark (light) for positive (negative) values. Vectors illustrate zonal and vertical winds. (a) Both modes. (b) The first (deep convective) mode. (c) The second (stratiform) mode.



AL06 Turbulent Meteorological Motions

GOAL: Understand the mechanisms and effects by which turbulence influences atmospheric chemistry, composition, radiation, and transport on all scales, from that of molecular diffusion to that of the globe, some nine orders of magnitude.

AL06.1 MILESTONE:
Examine aircraft observations of winds, temperature, ozone, and tracers to investigate the effects turbulence on atmospheric chemistry.

Investigations of meteorological effects on atmospheric chemistry

Work over the past year on exchange between the upper tropical troposphere and the lower stratosphere studied with aircraft observations illustrated that aircraft observations of water, ozone, wind, and temperature in the potential temperature range $360<\theta<420$ K were scale invariant on scales from a few hundred meters to 2700 km. It has been concluded that stratosphere-troposphere exchange occurs on all scales. It was also noted that the scale invariance of water and ozone in the upper tropical troposphere implies that the fluid mechanical energy cascade from largest to smallest scales cannot be conservative. Radiative energy is input and dissipated by water and ozone on all scales, affecting temperature and hence turbulence.

Further research, "Horizontal variability 1-2 km below the tropical tropopause," examined the variability of water and ozone in the context of aerosol mass spectra and a large suite of tracers having lifetimes ranging from 10^{-2} to 10^{3} years. It was found that local correlations dominate and that the processes contributing to the maintenance of the composition included marine convection, continental convection, *in situ* chemical production, biomass burning, downward transport from the stratosphere, and recirculation.

Another study, "Scale invariance in jet streams: ER-2 data around the lower stratospheric polar night vortex," showed that scale invariance along-jet has a different character than that across-jet. The implication is that speed shear may be a somewhat more effective mixer than direction shear. This work also illustrates the connection between scaling analysis and traditional large-scale dynamical meteorology. For example, scaling analysis of aircraft data from the southern hemisphere showed that nitrous oxide is a true passive scalar there, whereas sources and sinks are operative for ozone.

This research illustrates the usefulness of detailed chemical and meteorological observations, across many scales, in studies to diagnose the role of dynamical and chemical processes in atmospheric chemistry and climate.

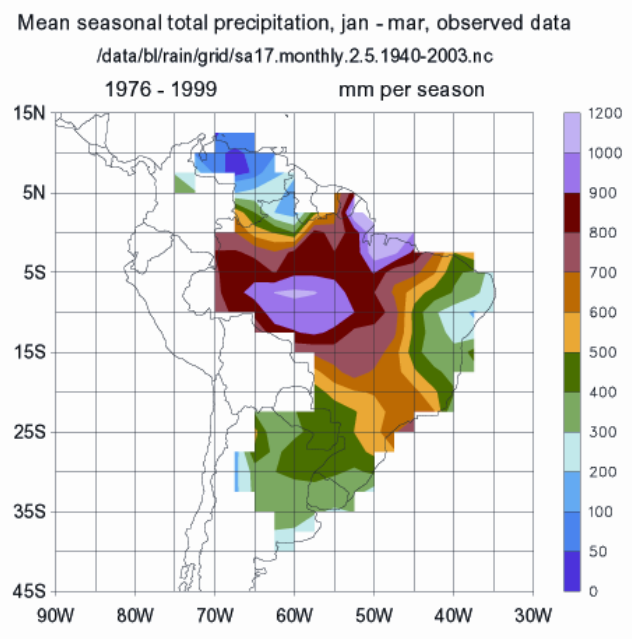
CDC01 Model Variability on Seasonal to Interannual Timeframes

GOAL: Understand how much predictability, especially outside the tropics, exists on seasonal-to-interannual timescales beyond that associated with simple, linear ENSO signals, and what additional useful predictive information can be extracted by running large nonlinear Global Climate Model (GCM) ensembles.

CDC01.1 MILESTONE:
Investigate the predictability of variation in atmospheric storm tracks on seasonal to interannual time scales.

A detailed study was completed of the predictability of extratropical stormtrack variations on seasonal to decadal scales using an empirical linear stormtrack model (STM), developed specifically for this purpose. The STM is remarkably successful at reproducing a nonlinear GCM's anomalous stormtrack response to ENSO. Using this STM, it was shown that there is substantial predictability of stormtrack variations in the Pacific sector, but not in the Atlantic sector where the prediction skill is lower than expected from signal-to-noise ratios. Our analysis clearly brings out NCAR and NCEP atmospheric GCM biases in representing short-term climate variability over the Atlantic sector.

A database of historical daily precipitation observations over South America (below) was maintained and improved. Observations were then used in various climate studies, including air-ocean interaction and model diagnosis.



CDC01.2 MILESTONE:

Determine the origins and assess the predictability of the 1998-2002 U.S. drought.

Researchers have completed a study of the causes of the 1998-2002 drought. This four-year drought, affecting the United States and large portions of southern Europe and Asia, was associated with remarkably persistent cold SST anomalies in the east tropical Pacific and remarkably warm SST anomalies in the west tropical Pacific. The cold east Pacific SSTs were clearly associated with a lingering La Niña event, whereas the warm west Pacific SSTs were possibly consistent with greenhouse gas forcing. An attribution analysis, based on both observations and GCM simulations of the last 50 years, showed that the four-year average precipitation anomaly pattern during 1998-2002 was caused primarily by the persistent La Niña forcing.

CDC01.3 MILESTONE:

Collectively implement a newly derived numerical stochastic integration scheme into meteorologically relevant numerical models and test it for accuracy.

A stochastic representation of the subgrid-scale variability of clouds has been implemented, including techniques that allow accurate calculation of radiative fluxes into the GFDL global atmospheric model AM2.

CDC01.4 MILESTONE:

Evaluate the impact of the most recent El Niño on short-term climate forecasts (6-10 days and Week Two) in real-time during the northern hemisphere winter.

CIRES scientists generated extensive sets of medium range forecasts for winter using NCEP's forecast model with and without prescribed El Niño conditions in the tropical Pacific. The differences between these sets were used to assess the impact of El Niño on individual storms over the United States. This assessment was conveyed to NCEP's Climate Prediction Center for public dissemination, and also reported and discussed at several conferences.

CDC01.5 MILESTONE:

Demonstrate and evaluate a research prototype next-generation reanalysis system for assimilation of surface-only observations in the pre-radiosonde era.

For a reconstruction of weather maps of the past 100 years (a "reanalysis"), no upper-level radiosonde wind observations are available from the early part of the record (pre-1948). However, some surface pressure observations are available. In this study, the feasibility of reanalyzing this early record using an ensemble square-root filter (EnSRF) was examined. Real surface pressure observations for 2001 were used, sub-sampled to resemble the density of observations estimated to be available in 1895, 1905, 1915 and 1935. Analysis errors were defined relative to a three-dimensional variational (3DVar) analysis performed using current observation densities. The study concluded that a northern hemisphere reanalysis of the lower and middle tropospheric circulation in the first half of the 20th century is feasible even using only surface pressure observations. The expected analysis errors of 500 hPa heights for the 1895 to 1935 observation networks would be similar to the errors of current two- to three-day forecasts.

CDC02 Understanding and Predicting Subseasonal Variations and Their Implications for Longer-Term Climate Variability

GOAL: Investigate the variability and predictability of weekly averages through modeling and diagnosis of the observed statistics and through detailed analysis of numerical forecast ensembles for Week Two.

CDC02.1 MILESTONE:
Extend analyses on the predictability of sub-seasonal variations during the northern winter season to other seasons of the year.
CIRES scientists published a detailed study of the potential and actual predictability of weekly-averaged atmospheric variations at the Week 2 and Week 3 forecast ranges using simple statistical and comprehensive NWP models. This work has been presented and discussed extensively at various venues. It has been influential in rekindling interest in Week 2 and Week 3 predictability, and has helped make Week 2 Predictability an important research theme of THORPEX, a major new international weather research program. A new NOAA/CLIVAR-Pacfic grant will help to further develop the linear inverse model of tropical variations by explicitly considering the vertical structure of the diabatic heat sources and moisture sinks and coupled interactions with the underlying SSTs.

CDC02.2 MILESTONE:
Improve understanding of atmospheric, oceanic, land surface and cryospheric processes that contribute to climate variability.
Cloud resolving model simulations of deep convection over the continents have been used to examine how cloud vertical structure depends on environmental conditions.

CDC02.3 MILESTONE:
Report on the atmospheric response to changes in arctic sea ice and on factors that influence the predictability of mid-latitude sea surface temperature anomalies.
A modeling study to assess the atmospheric response to realistic sea ice anomalies in an AGCM in winter has been completed.

CDC02.4 MILESTONE:
Implement the NCAR (National Center for Atmospheric Research) Community Climate Model and develop new coupled atmosphere-ocean models for climate analyses, prediction, and assessment research. CIRES scientists have implemented the NCAR CCSM2, a fully coupled climate model, locally on a NOAA computer. Porting the NCAR CCSM2 to the NOAA-FSL Beowulf Cluster (JET) with an implementation design that will accommodate future versions of the model was a technical achievement for the climate modeling community both within CDC and elsewhere. A by-product of this local implementation of the fully coupled climate model has been to provide CDC researchers with a capacity to run the model on JET in multiple configurations (e.g., atmosphere-only simulations, or simulations with an atmosphere coupled to a mixed layer ocean).

CDC03 Empirical and Process Studies

GOAL: Improve the understanding of basic physical processes that contribute to climate variability across a broad spectrum of scales. (i) Moist atmospheric convection, (ii) radiative transfer in clouds, and (iii) air-sea interaction are good examples of such processes.

CDC03.1 MILESTONE:
Continue the research into dynamically coupled versions of atmospheric single-column models to diagnose the interaction between different physical processes in detail to demonstrate that the dynamical coupling is essential to yield meaningful results by this approach.
Investigations continued on the viability of using atmospheric single column models (SCMs) to diagnose both observed and GCM-simulated climate variations. Two published papers address a fundamental weakness of SCMs stemming from their decoupling of adiabatic and diabatic tendencies, which often lead to explosive spurious instabilities. To correct this weakness, a simple coupling scheme that effectively stabilizes the SCM was developed. This helps maintain a realistic climate in long integrations, reduces error growth in short integrations, and reduces ensemble spread in ensemble integrations. This stable coupled SCM provides the foundation for developing more sophisticated diagnostic models, for example, by including additional stochastic forcing. This forcing can be specified in such a way as to reproduce either the observed climate variability or a GCM's climate variability at any gridpoint of interest. Such a flexible diagnostic tool has potentially wide applications. Although very new, this work has already been discussed, for instance, in the ECMWF training seminar series.

CDC04 Decadal Climate and Global Change Research

GOAL: (i) Improve our understanding of observed long-term climate variations through analysis of hierarchies of GCM experiments. (ii) Seek to offer dynamical explanations for oceanic variability and changes through observational analyses and GCM experiments. (iii) Provide attribution for regional climate changes.

CDC04.1 MILESTONE:

Publish studies of the different sensitivities of the global atmospheric response on decadal time scales to decadal changes in different parts of the world's oceans.
Considerable progress was made in assessing the differing sensitivities of the global atmospheric response to SST anomalies in different parts of the tropical oceans using the NCAR CCM3.10 AGCM. This research has confirmed and extended past results in four distinct ways:

1. The sensitivities have now been established with a different AGCM (the NCAR CCM3 instead of the NCEP MRF9) and in all seasons of the year;
2. The opposite sensitivity of many aspects of the global response to SSTs in the eastern Indian and western Pacific portions of the warm pool has been confirmed;
3. The counter-intuitive result that warm SSTs in large areas of the tropics lead to global-mean surface cooling and drying has been confirmed; and
4. The significant modification of the remote atmospheric response to localized tropical SST forcing through interactions with the underlying sea surface has been demonstrated. Four substantial journal articles describing these results are in preparation.

A recently completed study shows that much of the low-frequency variability of the Pacific Decadal Oscillation can be viewed as arising from the sum of direct ENSO forcing, re-emergence of mixed-layer anomalies, and white-noise forcing. These findings are in direct contrast to the prevailing view that ENSO plays no role in the PDO.

CDC04.2 MILESTONE:
Report the principal results of recent research to our scientific colleagues at the American Meteorological Society conference on The Interaction of the Atmosphere and Ocean.
CDC scientists organized and made prominent contributions at this conference held in Portland, Maine, on topics such as (1) the impact of ENSO on decadal variations in the North Pacific, (2) the impact of ENSO on North Pacific air-sea interactions in summer, (3) the impact of tropical Atlantic SST variations on the north Atlantic/European climate, and (4) the importance of correctly representing coupled air-sea interactions in the Indian ocean to improve the predictions of Indian monsoon rainfall. Several journal articles are expected to result from this.

CDC04.3 MILESTONE:
Complete a preliminary translation of the International Comprehensive Ocean-Atmosphere Data Set (I-COADS) Release 2.0 (1784-1997) data into a new International Maritime Meteorological Archive (IMMA).
In the June 2004 issue of "World Climate News," a publication of the World Meteorological Organization, the article "Rescuing Marine Data" describes the important work being done at CDC to rescue and compile early climatological information found in ships' log books from as early as the 1700s. The data have been incorporated in the International Comprehensive Ocean Atmosphere Data Set (ICOADS), which is maintained through a cooperative agreement between NOAA, NCAR, and several other research organizations around the world. These data can be studied to give a more comprehensive understanding of past climate.

CMDL01 Climate Forcing

GOAL: *(i) Greenhouse gases:* Conduct research to better understand the interactions of the atmosphere with the land and ocean. *(ii) Aerosols*: Characterize the means, variabilities, and trends of climate-forcing properties for different types of aerosols, and understand the factors that control these properties. *(iii) Radiation*: Research into broadband irradiance to improve benchmarks for climatic processes.

CMDL01.1 MILESTONE:
Build upon climate-related observations at observatories and cooperative sampling sites.
The HATS flasks sampling program has been under continuous operation, with weekly air samples from 13 field sites plus samples of firn air, Asian dust events, and samples collected during the TROICA-8 rail expedition in Russia. Samples are analyzed for halocarbons and other trace gases on three
instruments.

NOAA/CMDL Cooperative Air Sampling Network flask measurements were used in a Bayesian inverse modeling approach to infer monthly nitrous oxide surface emissions from 1998-2001 at the continental scale. Hourly measurements of carbon monoxide, methane, nitrous oxide, and sulfur hexafluoride were made at 30, 76, and 396 meters on the WLEF tall tower in northern Wisconsin with an automated gas chromatograph. Development began on an automated radon measurement system for use on tall towers to test atmospheric transport models, diagnose vertical turbulent transport, and calculate greenhouse gas surface emissions using boundary layer budgeting techniques.

CMDL01.2 MILESTONE:
Establish a carbon-observing network over North America.
The Carbon America network is currently under development and expansion and will incorporate up to thirty-six sites across North America by late 2008. Five new sampling sites are being added to the existing nine-site net-

work in September 2004. These regular and long-term measurements of the variation of greenhouse gasses with height will enable CMDL and other scientists to quantify the predicted North American terrestrial biosphere's net uptake of carbon dioxide (CO_2) from the atmosphere. More generally, this data will provide strong constraints for regional and global models of the carbon cycle. Quantifying the North American carbon budget and identifying the implications for the global carbon cycle are priority items outlined in the U.S. Climate Change Science Program Strategic Plan. CMDL's Carbon America program is directed specifically to this end.

CMDL01.3 MILESTONE:
Continue conducting measurements from ships and expand measurements to ocean buoys to obtain a better understanding of carbon gases and oceanic gas fluxes.
In 2002 air sampling was initiated aboard two container ships making regular voyages between Los Angeles and New Zealand. Samples are collected by the bridge officers on the *Kapitan Afanasyev* and the *Columbus Waikato* at 5-degree latitude intervals from 30°N to 30°S. The air samples are returned to CMDL for measurements of CO_2, CH_4, CO, H_2, N_2O, and SF_6. The samples are then transported to the Stable Isotope Laboratory at INSTAAR for measurements of $^{13}C/^{12}C$ and $^{18}O/^{16}O$ of CO_2. The measurements from these samples cover a large region of the Pacific Ocean where measurements at fixed sites are sparse. The measurements are used by carbon cycle modelers to help constrain global and regional estimates of the oceanic and terrestrial sources and sinks of CO_2. The air sampling has continued into 2004. In May, 2004 air sampling began on the Sealand Express, a container ship making regular voyages between
Norfolk, VA, Cape Town, South Africa, and New York, NY. The samples, collected between 30°N and 30°S, will provide measurements over large unsampled regions of the Atlantic Ocean. Sampling on all three ships is conducted in cooperation with the NOAA Voluntary Observing Ship program. VOS personnel in Long Beach and Norfolk provide essential logistical support and serve as a liaison between CMDL and the ship Captains and owners.

CMDL01.4 MILESTONE:
Add perfluorocarbons (PFC's), including CF_4 and C_2F_6, to the observing system.
Work is ongoing to build several new gas chromatographs with mass-selective detection (GC-MS) that will increase the number of trace gases measured *in situ* at the NOAA Observatories and in flask samples collected via the CMDL Air Sampling Network. Perfluorocarbons, a class of greenhouse gases targeted by the Kyoto Protocol, will be measured on these new instruments.

CMDL01.5 MILESTONE:
Maintain and improve the accuracy and representativeness of radiation data, expand the ancillary data collection, and extend the analysis of existing and newly acquired data.
Solar radiation data, and other data, that the STAR group at CMDL measures continues to be collected, archived, and distributed.

The STAR group is responsible for monitoring solar and thermal radiation in CMDL. Radiation observations are used to confirm calculations and remote estimates of surface irradiance quantities. Changes in irradiance with conditions and overtime can be considered radiative forcing which both results from and contributes to climate forcing. Members of the group are currently standardizing and checking for accuracy the calibration histories for all sensors which have been deployed in the field over the last three decades. The group recently established a monitoring site in the Canadian arctic at Alert, filling a gap in the worldwide distribution of radiation monitoring sites. Daily operations at this site are conducted by Canadian Meteorological Service. Optical depth measurements are now routinely made at all sites using narrow-band sun photometers. Meteorological measurements are made at all sites. Absolute cavity measurements for calibration purposes are made at the Erie, Colorado site as well as at the calibration facility at the David Skaggs Research Center in Boulder, Colorado. Web-based access to all data is under

continuous revision for ease of access, clarity and accuracy. Selected data sets (radiation and meteorology) are edited within a few days of the arrival of the data. Work is underway to produce objectively computer-edited optical depth data. The staffs at CMDL's baseline stations do the on-site maintenance of the instruments and data collection systems at the stations. Cooperative agreements have been established for on-site maintenance at the other sites, and they are visited by group members on at least an annual basis.

CMDL02 Ozone Depletion

GOAL: (i) *Stratospheric Ozone Measurements*: Measure ozone declines during the past two decades at northern hemispheric midlatitudes and the tropics and characterize dramatic ozone depletions over Antarctica. (ii) *Ozone-Depleting Gases*: Conduct research in the troposphere, stratosphere, oceans, polar snowpack, and terrestrial ecosystems in an effort to understand and predict the atmospheric behavior of these gases. (iii) *Stratospheric Aerosols*: Conduct experiments and measurements on aerosols to determine their impacts on solar insolation. (iv) *Stratospheric Water Vapor*: Conduct measurements to determine the change in water vapor and its coupling with aerosols.

CMDL02.1 MILESTONE:

Continue monitoring the distributions and trends of gases involved in stratospheric ozone depletion.

CIRES scientists participated in the 8th Trans-Siberian Observations into the Chemistry of the Atmosphere (TROICA-8) rail expedition in March/April 2004. Measurements will build on previous observations during 2001 that were used to estimate emissions of ozone-depleting substances in Russia.

CIRES scientists continued to monitor chlorine and bromine loadings in the stratosphere through *in situ* measurements of source gases by the balloon-borne Lightweight Airborne Chromatograph Experiment (LACE) at Fort Sumner, New Mexico, during September 2003.

CMDL02.2 MILESTONE:

Continue measurements of the oceanic and terrestrial fluxes of methyl halides and short-lived halocarbons.

In FY 2003, NOAA/CMDL scientists and current and former CIRES scientists worked in two focus areas relevant to trace gas exchange across the air-sea interface. The first of these was to continue publishing manuscripts from recent research cruises. The second was to organize and prepare for an additional expedition in the Central Pacific Ocean in 2004 in an effort to understand seasonal differences. In 2003, equipment was repaired and upgraded and arrangements made for sharing logistics and funding with co-investigators from NOAA/AOML and the University of California, Irvine. That cruise was carried out successfully in 2004. One publication appeared in Journal of Geophysical Research in early 2004 In this study, it was determined that the minimum degradation rate constants needed to maintain the observed saturation anomalies of the gases are consistent with their observed and calculated total degradation rate constants, suggesting that there is no significant production of these gases in this region. This was true even though near the Antarctic coast (south of 65°S) the saturation anomalies for both gases decreased to approximately −80%, as CFC-11 measurements showed that these extreme anomalies were associated with enhanced vertical mixing rather than with degradation in the surface waters.

CMDL02.3 MILESTONE:

Improve water vapor instrumentation and expand the measurement program.

The NOAA Climate Monitoring and Diagnostics Laboratory (CMDL) carries out vertical profile measurements of water vapor using balloon-borne, cryogenic chilled-mirror hygrometers. These are unique measurements that include the capability of making accurate measurements in both the troposphere and stratosphere. Two recent developments led by CIRES employees have produced significant improvement in the quality and operational effectiveness of water vapor profile measurements and resulted in the ability to expand the water vapor measurement program at CMDL. A redesign of the hygrometer used for a number of years by CMDL has resulted in a major reduction in the weight and power consumption of the instrument, allowing for the use of smaller balloons and integration with an ozonesonde as part of the instrument package. This version of the hygrometer is being used in Boulder where the sounding frequency has been increased from once a month to twice a month, and in New Zealand where a twice-monthly sounding program has been recently established. A CIRES scientist working with CMDL and the instrument development laboratory at the University of Colorado has developed an advanced cryogenic frost-point hygrometer (CFH). This microprocessor-controlled, miniaturized instrument has focused on accurate measurements throughout the troposphere. Continuing development of this instrument should improve its capabilities in the stratosphere. The research focus of this new hygrometer has been process studies in the upper troposphere/lower stratosphere region in the tropics. The CFH instrument is being used extensively for validation of water vapor profiles from the Advanced Infra Red Sounder (AIRS) instrument on the Aqua satellite.

CMDL02.4 MILESTONE:

Continue monitoring UV radiation and stratospheric aerosols.

Monitoring of the spectrum of ultraviolet radiation utilizing spectroradiometers provided by NIWA New Zealand (Richard McKenzie) continues at the Mauna Loa Observatory Network for the Detection of Stratospheric Change (NDSC) primary station and at Boulder, Colorado. In addition UV monitoring continues at three stations in Alaska with filter instruments. Since major volcanic eruptions produce sulfuric acid aerosols in the stratosphere, which provide enhanced surface area for heterogeneous reactions that destroy ozone, CMDL monitors the level of stratospheric aerosols utilizing NdYAG lidars at Mauna Loa Observatory and Boulder, Colorado. The stratosphere remains at a low background level which began about 1996, following the decay of aerosol from the Pinatubo eruption. This has provided an unusual opportunity to study the background aerosol, believed to be replenished by sulfurous gases entering the stratosphere, most likely in the tropics. Both annual and quasi-biennial oscillation (QBO) effects have been observed. A new lidar has been completed and will be installed at the Samoa Observatory (14S) in the near future. This will provide the first dedicated stratospheric aerosol lidar in the southern hemisphere and will be important for monitoring the progression of stratospheric aerosol following the next major volcanic eruption in the sub-tropics.

CMDL02.5 MILESTONE:

Build upon climate-related observations at observatories and cooperative sampling sites.

Dobson total ozone data from 15 Dobson stations were gathered, processed, distributed and archived.

Engineers and scientists traveled to the Canadian Forces military base in Alert, Nunavut (82.5°N, 62.3°W) to deploy the world's 38th Baseline Surface Radiation Network (BSRN) site. The Alert BSRN was established in collaboration with Environment
Canada. It is composed of a suite of upward and downward looking radiometers that are designed to comprehensively monitor changes in the Earth's radiation field that may cause climate changes. Alert is the most northern permanently inhabited location on, and is only about 800 km from, the North Pole. It is a location of a Global Atmosphere Watch (GAW) station that has been measuring atmospheric gases and chemistry since 1975. The GAW has been the long-term home of the NOAA/CMDL flask air sampling program. In March of 2004 a NOAA-supported Cloud Condensation Nuclei (CCN) counter was added to the complement of aerosol instrumentation. The GAW and BSRN measurements complement each other and will be valuable for assessing changes in the arctic climate, which has generally warmed significantly in the last decade. The Alert BSRN instruments and the CCN counter is the first installation of a NOAA Arctic Atmospheric Observatory that will eventually include cloud radar, aerosol/cloud lidar, boundary layer flux, surface aerosol, and radiometer measurements. The observatory will provide a full complement of cloud, radiation and aerosol information for monitoring, forecasting, and validation (satellite and model) activities. The Arctic Observatory is being developed in partnership with Meteorological Services Canada, the Canadian Network for Detection of Arctic Change (CANDAC) program and the U.S. Study of Environmental Arctic Change (SEARCH) Program. It is anticipated that the Arctic Observatory in Canada will be fully deployed in time for the International Polar Year in 2006.

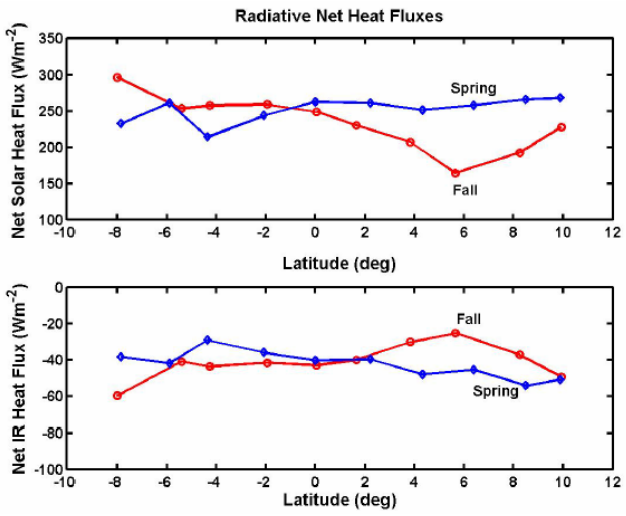
ETL03 Cloud and Aerosol Processes

GOAL: Make observations of clouds, aerosols, and water vapor over a variety of ice, land, and sea surfaces using a multi-sensor, multi-platform approach to improve retrieval techniques useful for satellite validation studies.

ETL03.1 MILESTONE:

Participate in Pan-American Climate Studies (PACS) research cruises and deploy cloud radar, radiometer, and flux systems to measure key surface marine boundary layer parameters, low cloud macrophysical, microphysical, and radiative properties.

CIRES, in partnership with NOAA-ETL, continues to participate in the yearly (fall) excursions to the Tropical Atmosphere Ocean (TAO) buoy array within the Pan-American Climate Studies (PACS) region (110°W and 95°W buoy lines) aboard the NOAA Ship *Ronald H. Brown*. Included in these deployments are the operation of the resident NOAA C-band precipitation and 915-MHz wind profiling radars, the NOAA-ETL bow-mounted turbulent and radiative flux measurement system, a NOAA-ETL Ka-band cloud radar and microwave radiometer suite, and a laser ceilometer. Along with the buoy data, the observations acquired from these excursions have provided unique air-sea climatology within this area of the equatorial eastern Pacific which is of critical importance to North American weather and climate. The analysis of the data sets has yielded rich information about the radiative forcing effects of clouds as well as provided the first systematic measurement of the air-sea turbulent flux of dimethylsulfide (DMS).



Net radiative (Incoming – Outgoing) fluxes (solar and infrared) composited over the Tropical Atmosphere Ocean Pan-American Climate Studies (TAO/PACS) cruises on the NOAA Ships Ronald H. Brown *and* Ka'imimoana*. Note the significant increase in cloudiness north of the equator in the fall (larger IR, lower solar flux) due to the presence of the intertropical convergence zone (ITCZ) over that area in that season.*

ETL03.2 MILESTONE:

Develop ground-based cloud, aerosol, radiative, and surface meteorological instruments for use in arctic observations with an emphasis on regions with strong connections to the arctic oscillation.

Scientists performed preparatory work to establish an arctic climate observation site in northern Canada as part of the interagency Study of Environmental Arctic Change (SEARCH) program. Although most instruments have not yet been deployed at the site, a conceptual design has been created to automatically monitor/diagnose the radar performance at the site. Additionally, tools have been developed to visualize and analyze radar observations, including new observations of the radar Doppler spectrum, and to combine measurements from multiple sensors (radar, lidar, radiometer, soundings) to retrieve cloud and atmosphere properties. High quality temperature and humidity sensors have been deployed at the Alert Bay, Canada SEARCH site, along with a full suite of broadband radiometers, to compute bulk fluxes, measure surface temperature, and monitor the surface radiation balance. Deployment of the radar, lidar, and GSR radiometer at the SEARCH site are expected within the next year.

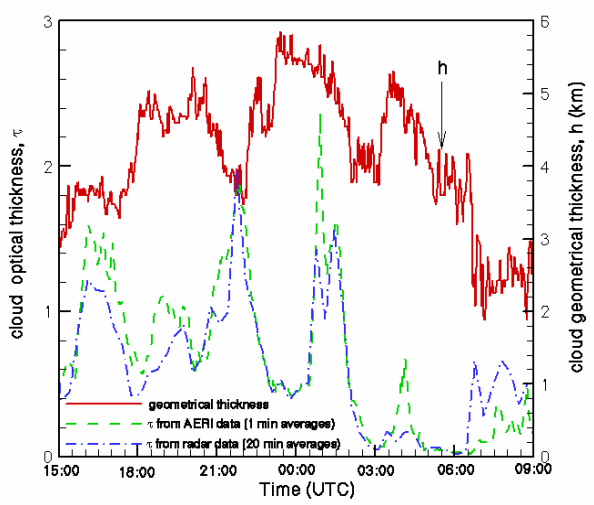
Scientists also developed the Ground-based Scanning Radiometer (GSR), a multi-frequency radiometer to measure water vapor, temperature, and clouds. This instrument was deployed at Barrow, Alaska from March 8 to April 9, 2004.

ETL03.3 MILESTONE:

Develop new algorithms for microphysical retrievals of cloud parameters (cloud water/ice content, particle/drop size distribution, and cloud optical thickness).

A number of important developments have recently been made in the field of cloud parameter retrievals. The most important ones include refinements of the Doppler radar method to retrieve vertical profiles of cloud ice water content and particle characteristic size (such as effective or median) from vertically pointing measurements of reflectivity and Doppler velocity at Ka-band. The refined version of this method now allows retrievals of the cloud optical thickness. These retrievals make use of relations between cloud particle projectional area, size and mass which were found empirically from analyses of *in situ* cloud samples. With independent retrievals of cloud mass and size from radar data, the optical thickness is then calculated with the use of these relations. Until recently only optical instruments were used to
retrieve ice cloud optical thicknesses from the ground-based instruments. While these optical retrievals are generally robust, they are limited only to

single phase clouds which are not blocked by liquid water layers and the optical thickness of which does not exceed about 3 or 4. The use of the radar-based technique overcomes these limitations providing optical thickness information on the great majority of observed ice clouds. Estimates of the retrieval uncertainties indicate that the Doppler radar-based estimates of cloud optical thickness typically have errors of about 50-70% which can generally be considered good for a non-optical instrument such as radar.



The figure at left shows a comparison between optical thickness retrievals for a single-layer ice cloud observed on April 28, 1998 during the Surface Heat Budget of the Arctic Ocean (SHEBA) field experiment. Since no liquid layers were present, optical instrument retrievals from the Atmospheric Emitted Radiance Interferometer (AERI) were also performed for comparison. The current radar sensitivity limits the radar-based retrievals to optical thicknesses of about 0.1-0.2. Another recent important advancement in the field of cloud parameter retrievals is the development of the Doppler spectral technique to independently estimate liquid and ice water content in the mixed phase clouds. It was shown that in certain circumstances, Doppler radar velocity spectra are bimodal and the radar returns from ice and liquid components can be separated. The Doppler spectral technique was applied to several mixed-phase cases observed in a recent field experiment in Florida.

ETL04 Surface Processes

GOAL: Develop and/or improve physical representations of atmosphere-surface interactions

ETL04.1 MILESTONE:

Complete the development of new stable surface-layer similarity functions valid for all ranges of stability.

Understanding and proper parameterization of sub-grid scale fluxes in the stable boundary layer (SBL) are of obvious importance for climate modeling, weather forecasting, environmental impact studies and other important applications. In the very stable boundary layer atmospheric turbulence that allows buildup of high concentration of contaminants is suppressed. In such conditions, the impact of atmospheric pollutants and potential chemical and warfare agents reach maximum. Prediction of concentrations, durations, and diffusion of such contaminants is important for environmental modeling and homeland security.

Traditionally, turbulent fluxes are derived from vertical wind speed and temperature profiles (flux-profile relationships). The importance of the flux-profile has long been recognized. Although research has been done on the SBL for at least 50 years, a unified picture or theory does not exist. Well-known predictions of the flux-profile relationships are based on the theory suggested by Monin and Obukhov in 1954. Over the past decade application of this theory to the SBL was questioned.

Measurements of the atmospheric turbulence made in the Surface Heat Budget of the Arctic Ocean Experiment (SHEBA) are used to examine the profile stability functions (the non-dimensional vertical gradients of mean wind speed and potential temperature) in the stably stratified boundary layer over the arctic pack ice. Turbulent fluxes and mean meteorological data were continuously measured at five levels on a 20-meter main tower during eleven months that cover different surface conditions and a wide range of the stability conditions. The comprehensive data set collected during SHEBA allows studying behavior of the profile stability functions in detail, including the very stable case. New parameterizations for the profile stability functions in stable conditions are proposed to describe the SHEBA data. The floe around the main SHEBA tower went from compact and totally snow covered in winter to bare ice with melt ponds and leads in the height of summer. The effect of the surface heterogeneity on the wind and temperature profiles during different polar seasons is also considered.

ETL04.2 MILESTONE:
Document the impact of ENSO on transport of moisture at the West Coast, including precipitation intensity and microphysical changes associated with orography.
A CIRES investigator was acknowledged for his contribution to a paper showing how narrow plumes of moisture referred to as atmospheric rivers are responsible for most of the meridional water vapor transport in midlatitudes. The paper was published in the July issue of Monthly Weather Review.

ETL04.3 MILESTONE:
Incorporate new ice/snow scheme into MM5 and evaluate improvements in winter and summer arctic simulations.
Simulations with the Penn State/NCAR Mesoscale Model (MM5) of a wintertime week at the Surface Heat Flux of the Arctic Ocean (SHEBA) site over the Arctic pack ice have shown the necessity of including a multi-layer snow and ice module in order to correctly simulate the near-surface temperature, the surface turbulent and radiative fluxes, and the boundary layer structure. To allow spatial variability of snow depth and ice thickness, a one-dimensional snow/ice model was first developed and tested against SHEBA data.

The snow and ice model is based on that by Semtner (1976), though both the snow and ice are represented by multiple layers rather than just the ice. The model solves the basic heat equation, and the heat flux is continuous at the snow-ice interface. The number of snow layers is variable but dependent on the snow depth and the following criteria: 1) no layer is shallower than 2 cm, 2) the top layer is 2-cm thick if at least 4 cm of snow exists, 3) the remaining snow depth is divided equally among the other layers, and 4) a maximum of five snow layers is permitted.

The performance of the 1-D code and the assessment of the importance of a spatially varying snow depth and ice thickness were tested using SHEBA data. The observed atmospheric forcing, including the observed snowfall, was used in these model tests. The surface turbulent fluxes are calculated using the COARE surface flux parameterization but using the Reynolds number formulations over snow of Andreas (1987) and the stability correction terms for stable conditions of Beljaars and Holtslag (1991).

The ice thickness evolution and the hourly surface temperature over a multi-year ice (MYI) site and a thick first-year ice (FYI) site during an 80-day wintertime test period was modeled very well, with the surface temperature correlation coefficient r2 = 0.985 and the ice thickness growth error less than 6 cm (out of 33-60 cm growth). Synthetic aperture radar (SAR) data show numerous areas of FYI that form at different times, and the digitization of these classifications have been done to produce a more realistic lower boundary. These FYI regions produce large spatial heterogeneity in ice thickness and snow cover at a given time. In mid-January near the SHEBA ice camp, five different FYI regions were present along with the MYI region (*Figure 1*). The 1-D snow/ice model was run independently on each of these FYI types and the MYI from the time they were first observed [with an assumed ice thickness (snow depth) of 5 cm (0 cm) when they were first observed].

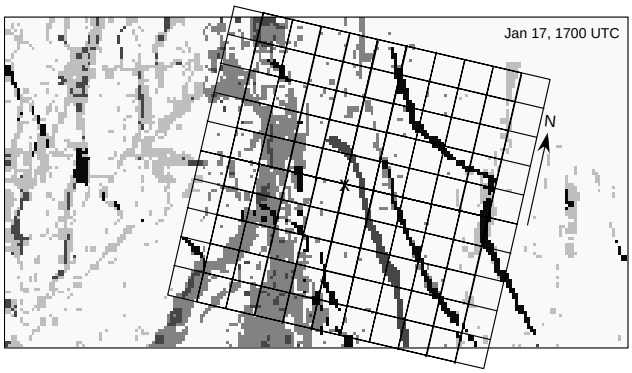


Fig. 1: Spatial distribution of FYI and MYI groups from SAR image classifications from YD17 17 UTC with the FYI regions FYI0 (light grey), FYI1(medium grey), FYI2 (dark grey), and FYI3 (black) shaded. A 100 X 110 km grid around the SHEBA ship (x) is shown. Each small grid is 10 X 10 km. The classifications have been done on 1x1 km areas

The model output shows that large spatial variability in pack ice thickness, surface temperature, and surface sensible heat flux exists on most days. For example, on YD17, 1998, (same as YD382, 1997) when four FYI groups and one MYI group were present, the ice thickness varies from 0.2 to 2.15 m, the snow thickness on these various ice types varies from 0 cm to 23 cm, the surface temperature varies from -27°C to -38°C (*Figure 2, next page*), and the sensible heat flux varies from -20°W m^{-2} over the MYI to +120°W m^{-2} over FYI3. Figure 1 above shows that FYI1, FYI2, and FYI3 occupy substantial areas in the vicinity of the SHEBA site, and AVHRR images during clear-sky periods show surface temperatures with this spatial pattern and variability magnitude. Hence, the spatial variability of snow depth and ice thickness leads to spatial differences in near-surface temperatures of about 10°C and large differences in surface fluxes.

These are large gradients and also have the potential to produce shallow mesoscale circulations over the wintertime pack ice. Both these temperature variations and any induced mesoscale circulation will impact the surface fluxes on the GCM scale (approx. 100 × 100 km^2 scale). The spatially-weighted averages of the surface

fluxes from the different FYI and MYI regions provide one estimate of the GCM-scale fluxes. To provide another estimate, the 1-D snow/ice model is now being coded into MM5 to permit the spatial variability of snow depth and ice thickness. This will allow the MM5 to produce mesoscale circulations and show the 3-D impact on the GCM-scale surface fluxes.

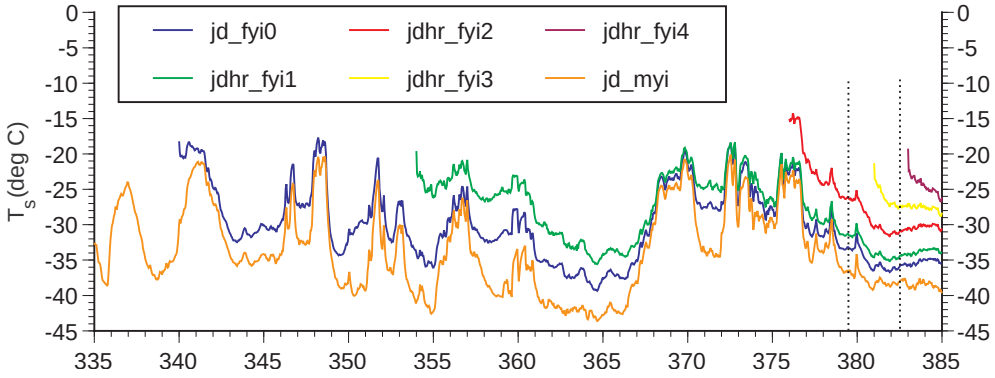


Fig. 2: Model output time series of surface temperature over the one MYI site and the 4 FYI groups near the SHEBA location. The beginning of each FYI curve shows when that FYI group formed.

FSL01 Regional Numerical Weather Prediction

GOAL: Design and evaluate new approaches for improving regional-scale numerical weather forecasts, including forecasts of severe weather events.

FSL01.1 MILESTONE:

Design and evaluate a new procedure to initialize cloud and moisture fields for regional numerical prediction models using remotely sensed data from satellites and radars, GPS integrated water vapor retrievals, and surface-based observations.

The data assimilation system for the Rapid Update Cycle (RUC) has been built around a three-dimensional variational (3DVAR) analysis. The 3DVAR performs analysis for model variables including water vapor mixing ratio as a moisture variable. An additional variational algorithm has been developed to assimilate integrated precipitable water from satellites (GOES) and ground-based GPS. The algorithm has been tested in retrospective runs and is expected to be introduced into parallel test runs at NCEP in mid-September. Cloud-top pressure information from GOES satellites (product from NESDIS) is already part of RUC hydrometeor analysis. It is used for cloud clearing and cloud building, i.e. updating cloud fields predicted by the forecast model. Visibility and ceiling data from surface-based stations are introduced into RUC hydrometeor analysis to improve cloud analysis from below. Radar reflectivity data are included in RUC hydrometeor analysis and are undergoing tests in an experimental real-time parallel run at FSL.

FSL01.2 MILESTONE:

Develop and test new versions of the WRF model for application in a rapidly updated (at least hourly) data assimilation cycle.

RUC soil/snow/vegetation model was implemented in Weather Research and Forecasting Model (WRF) as an officially supported physics option. RUC LSM was extensively tested in different configurations of the WRF model initialized from the RUC native grid output (rather than isobaric levels from ETA). WRF changes to initialize the model from RUC were performed in collaboration with scientists from NCAR and FSL. The full use of RUC-predicted variables, including all hydrometeor species, is important for reducing the spin-up in the precipitation forecast. Extra variables needed to initialize WRF land-surface models were added to the test version of the RUC output, and this change will be implemented into the operational RUC in the nearest future. The FSL version of WRF is referred to further as WRFRUC. WRFRUC using RUC LSM physics and Grell's cumulus parameterization is running in real time for TAQ (Temperature - Air Quality Program) domain with 10-km horizontal resolution, and for CONUS domain with 20-km horizontal resolution. In the course of real-time monitoring of the WRFRUC results, several problems affecting coupling of WRF to the RUC LSM were discovered and fixed. RUC models with 10- and 20-km horizontal resolution were also included into the TAQ model evaluation process. The low wind bias near the ground surface was discovered in RUC. One of the reasons for this bias was a too-high

roughness length in the areas partially covered by forests. Look-up table values of the roughness length, corresponding to the dominant vegetation class averaged for the grid box values, were replaced and implemented in the real-time RUC. This modification improved the RUC predictions of wind, temperature and moisture in the surface layer.

The work on the transition of CONUS RUC to 13-km horizontal resolution has been performed. WRF Standard Initialization (SI) package was used to provide the fixed fields for 13-km RUC (soil type, vegetation type, topography). The GRIB library capability was further increased to accommodate larger domain size in the 13-km RUC. Collaboration with GAPP (GEWEX Americas Prediction Project) community continued. Snow depth and snow cover fields from the RUC Coupled Data Assimilation System (CDAS) with radar assimilation were compared to NOHRSC snow analysis products. Improvements of RUC precipitation forecasts from the assimilation of the radar reflectivity were evaluated. Collaboration with NASA LDAS group was continued. The RUC surface grids were transferred to NASA to provide the atmospheric forcing data for the LDAS.

FSL02 Regional Air Quality Prediction

GOAL: Design and evaluate new approaches for improving air-quality prediction.

FSL02.1 MILESTONE:

Develop a forecast capability from an initial coupled atmospheric/chemistry version of the Weather Research and Forecast (WRF) model.

A fully coupled "online" Weather Research and Forecasting/Chemistry (WRF/Chem) model has been developed. In this form, the air quality version of the model is consistent, with all transport done by the meteorological model. The same vertical and horizontal coordinates are used (no horizontal or vertical interpolation), the same physics parameterization utilized for subgrid scale transport, and no interpolation in time is performed. Grid-scale advection in the mass coordinate WRF is mass and scalar conserving. This model has been running in real-time on a continuous basis (twice a day for 36-hour forecasts). Results are displayed on the WEB (*http://www-frd.fsl.noaa.gov/aq/wrf*). A more detailed description of the model can be found under *http://www.wrf-model.org/WG11/status.htm.*

FSL02.2 MILESTONE:

Evaluate coupled numerical models (WRF and Mesoscale Model version 5) with cases from the New England Air Quality Study (NEAQS) 2002 program.

WRF/Chem and MM5/Chem are fully coupled "online" air quality/weather forecast models. The chemistry package consists of dry deposition ("flux-resistance" method), biogenic emission, the chemical mechanism from RADM2, a complex Photolysis scheme, (Madronich scheme coupled with hydrometeors), and a state of the art aerosol module (MADE/SORGAM aerosol parameterization). The aerosol module was also coupled to the photolysis routine as well as the atmospheric radiation scheme to allow for feedback from the chemistry to the meteorology. These modeling systems have been rigorously evaluated with retrospective simulations using data from the 2002 New England Air Quality Study (NEAQS). In general, results were quite reasonable, but some improvements are necessary.

FSL03 Verification Techniques for the Evaluation of Aviation Weather Forecasts

GOAL: Design and evaluate new verification approaches that will provide information about the quality of aviation forecasts and their value to aviation decision makers.

FSL03.1 MILESTONE:

Design and evaluate new verification approaches for research output of the CCFP (Collaborative Convective Forecast Product). Summarize the pros and cons of the new approach in a written document.

A measure of forecast consistency (a similar series of forecasts issued at different times but valid at the same time) of the CCFP was developed. Aviation routing forecasters, many of whom are not meteorologists, may use this tool to help summarize information about the CCFP and use that information to improve air-traffic routing decisions. The results of this work illustrate in a formal way how forecast consistency can be defined and applied to a forecast like the CCFP. Further, the results suggest that care must be taken that forecasters do not assume that forecast consistency can be used to infer forecast accuracy for those cases when the forecasts are very consistent.

FSL03.2 MILESTONE:

Investigate the impact of forecast scale on the verification methodologies used to evaluate convective activity and precipitation forecasts

In order to assess the impact of forecast scale for precipitation forecasts, FSL is quantitatively documenting the

scale sensitivity in skill for four numerical model formulations run during the International H_2O Project (IHOP). The model comparisons include the operational 12-km Eta, operational 20-km RUC, experimental 10-km RUC, experimental 12-km LAPS/MM5, and experimental 12-km LAPS/WRF. Comparisons of the equitable threat score (ETS) and bias are made for each of these models, and verified against NCEP's Stage IV precipitation analysis. These results are computed on the native model grids, and on systematically coarsened grids. In the first set of experiments, both the forecast and verification fields are upscaled (two-way smoothing), allowing for the assessment of scale impacts from forecasts with significantly different energy spectra. By upscaling higher-resolution forecasts to coarser grids, scientists are able to isolate the impact of the smoothing on these skill scores. The comparison of traditional scores is complemented by spectral analyses of the forecast and verification fields. In the second set of experiments, only the forecast fields are smoothed (one-way smoothing), allowing for evaluation of the usefulness of enhanced precipitation detail, as reflected by traditional skill scores of verification. The skill-score dependence on the spectral characteristics and bias of the precipitation fields has been documented, thus illustrating the impact of scale on these scores. Preliminary results from experiments in which only the forecast fields are smoothed are also being carried out. Overall, these results support earlier research suggesting that it is difficult to show improvement in ETS for models with increasingly fine grid resolution.

NGDC14 Paleoclimatology: Understanding Decadal- to Millennial-Scale Climate Variability

GOAL: Improve our understanding of observed long-term climate variations through compilation and analysis of data from the pre-instrumental record and provide access to both data and information from the paleoclimatic record.

NGDC14.1 MILESTONE:

Develop new community-driven datasets and continue to improve existing ones. A particular focus in FY04 is the development of the new Paleofire database in collaboration with academic, NOAA and U.S. Forest Service researchers.

The new International Multiproxy Paleofire Database was developed in collaboration with an advisory board comprised of acknowledged experts in both tree-ring and sediment-based fire history research, and representing nine different institutions including NOAA and the U.S. Forest Service. Online data submission forms for the submission of paleofire data by PIs were developed. The database currently includes fire histories from 214 sites in the United States, Canada, and Mexico, and is searchable by site name, location, date, and investigator, as well as through an online mapping tool. Scientists created pages to allow PIs to easily submit paleoclimatic data to the program.

NGDC14.2 MILESTONE:

Develop and evaluate new systems for the archive and access of a wide spectrum of paleoclimatic data resulting in a multi-proxy paleoclimatic database system, with new systems for the sharing, visualization and analysis of gridded paleoclimatic data.

Scientists continue to develop and populate a database of paleoceanographic data for future use as a tool to serve data to web and ftp visitors to the Paleoceanography program.

NGDC14.3 MILESTONE:

Research new approaches for communicating climate information to K-12 and public audiences. Particular plans for FY04 include international collaborations for communicating climate change and climate variability to non-English speaking audiences and new systems for sharing visualizations of the Earth's changing climate.

Researchers constructed a website on abrupt climate change (www.ncdc.noaa.gov/paleo/abrupt). This site provides information and data sets describing abrupt climate changes of the past. Currently ranked fourth in Google searches for abrupt climate change, the site receives tens of thousands of hits per month. Researchers created an ice core exhibit at the David Skaggs Research Center that provides visitors a glimpse of thousand-year old ice, the bubbles of which contain a record of the composition of the atmosphere in the past. Staff conducted two dozen outreach sessions with local schools (K-12 and university level), including hands on activities to explore the paleoclimate record found in tree rings, participated in the National Ocean Sciences Bowl, and conducted a workshop for teachers at the Fall AGU meeting in San Francisco.

NSIDC01 Meteorological Data from Russian Arctic Stations: Completing the Historical Record

GOAL: Complete quality control on and publish Russian weather station data that are currently unavailable to western researchers. This data will fill both a temporal and spatial gap in the current record.

NSIDC01.1 MILESTONE:

Complete quality control and documentation of meteorological station data for 50 Russian stations north of 60° between 1960 and 2000 and publish the data online.
Working with colleagues at the Russian Arctic and Antarctic Research Institute, scientists at NSIDC acquire, quality control and document monthly averages of two-meter air temperature, sea-level pressure, total- and low-cloud amount, and relative humidity from 50 Russian arctic weather stations. At present, weather data from Russia available to the West are only a subset of all available Russian weather data. Publishing these data in digital form is important because *in-situ* meteorological data are necessary to understand trends in observed parameters, for developing and validating climate models, and to improve understanding of atmospheric circulation phenomena such as the Arctic Oscillation. The meteorological data from the Russian arctic, 1961-2000, are available in ASCII text format from NSIDC via FTP (*http://nsidc.org/data/g02141.html*).

NSIDC02 Observations for SEARCH: Data Integration for Arctic Reanalysis and Change Detection

GOAL*:* "Unaami," the changes in the arctic that are the subject of the Study of Environmental Arctic Change (SEARCH) program, became apparent to researchers in the context of long-term and pan-arctic observations. This work will assess what data are relevant to SEARCH reanalysis and change detection activities, collect these data from a wide variety of sources, and facilitate the SEARCH research community's access to the data. Note that this work is funded through Task III, rather than Task II.

NSIDC02.1 MILESTONE:
Identify target data sets for given geophysical parameters. Rank potential contributing data sets by importance to reanalysis and change detection teams. Assess and acquire precipitation data sets; assess frozen ground and sea-surface temperature data sets; perform any processing needed to make precipitation and frozen ground data sets ready for SEARCH. Provide progress reports to change detection and reanalysis teams.
Work to produce a set of arctic "climate indicators" that can be regularly updated and presented on the web continues. Candidate indicators include snow-melt onset, arctic soil temperatures, and changes in Normalized Deviated Vegetation Index (NDVI). Scientists have implemented an algorithm for detecting snow-melt onset in the satellite passive microwave data record and are now working on validation. Several candidate stations have been identified for soil temperature measurements and NSIDC is working to obtain regular updates to the data. Researchers have re-gridded the MODIS NDVI product to the same grid as the AVHRR Pathfinder NDVI time series and are comparing the MODIS NDVI with the AVHRR to see if the MODIS can continue the AVHRR time series.

NSIDC03 World Data Center for Glaciology, Boulder: Current Programs

GOAL: Improve our understanding of recent and unexpected changes in polar regions including lower sea-level atmospheric pressure, increased air temperature over most of the arctic, lower temperatures over eastern North America and Greenland, reduced sea ice cover, thawing permafrost and changes in precipitation patterns.

NSIDC03.1 MILESTONE:
Finalize the Sea Ice Index, an online source of monthly images of ice extent, with the median for that month overlain, images of ice concentration, and images showing trends and anomalies based on the period of record beginning in 1987, along with an archive and extensive documentation.
The extended index illustrates a larger variability and steeper downward trend of ice extent in recent years. Researchers predict a new record low for Sept 2004 based on record low May and June extent (see *http://nsidc.org/news/press/20041607_seaice.html*) and are extending the sea-ice index back in time. The current index extends from the present back to 1987. Data from the SMMR instrument, which was flown on the Nimbus-7 satellite and operated from 1978 to 1987, are being added.

NSIDC03.2 MILESTONE:
Maintain, update and improve existing research data sets (e.g. Former Soviet Union Hydrological Snow Surveys, 1966-1996; Submarine Upward Looking Sonar Ice Draft Profile Data and Statistics; and The World Glacier Inventory). Publish new data sets (e.g. Morphometric Characteristics of Ice in the Arctic Basin: Observations from the Former Soviet Union; Sea of Okhotsk Ice Concentrations from the Japan Meteorological Agency.
The former Soviet Union hydrological snow surveys are based on observations made by personnel at 1,345 sites throughout the former Soviet Union between 1966 and 1990, and at 146 of those sites between 1991 and 1996. These observations include snow depths at World Meteorological Organization (WMO) stations and snow depth and snow water equivalent measured over a nearby snow course transect. Data were acquired from the Institute of Geography, Russian Academy of Sciences Moscow, and were digitized in Russia. The Japanese Meteorology Agency (JMA) has provided NSIDC with 22 years of sea-ice chart data from shore-based radar and other observational sources as a contribution to the WMO Global Digital Sea Ice Data Bank (GDSIDB) project. These data are valuable because they are the most accurate record available of sea-ice extent and concentration in the Sea of Okhotsk. The sea-ice concentrations (JMA, 1978-2000) have been converted to a gridded format, which was compared with passive microwave (pm) data. The bimonthly JMA charts offer a truer depiction of Sea of Okhotsk sea-ice changes than do SSM/I-derived data. Meteorological data from 105 arctic and 137 Antarctic weather stations extracted from NCDC's Integrated Surface Hourly database is now available as the Historical Arctic and Antarctic Surface Observational Data Online. Variables include wind direction, wind speed, visibility, air temperature, dew-point temperature, and sea-level pressure. Temporal coverage varies by station, with the earliest record in 1913 and the latest in 2002. Graphs of meteoro-logical variables throughout the time series accompany the data.

In cooperation with OSDPD and ORA, NSIDC is archiving the archived daily output products of the OSDPD Interactive Multisensor Snow and Ice Mapping System (IMS). NSIDC now has a completed archive of IMS snow data, going back to 1966. This data record is considered critical by the climate community. NGDC and NSIDC are working with the data providers on appropriate metadata for the archive data stream that will conform to emerging NOAA CLASS standards.

In cooperation with the NWS National Operational Hydrologic Remote Sensing Center (NOHRSC), NSIDC is archiving and providing access to daily output products from the SNOw Data Assimilation System (SNODAS). The NOHRSC products available from NSIDC are gridded data sets for the continental United States at 1-km spatial resolution and 24-hour temporal resolution. These products are important for hydrological modeling. NSIDC's agreements with both data providers stipulate that NSIDC will focus on meeting the data needs of retrospective users, rather than the needs of operational customers or others in need of near-real-time data.

NSIDC03.3 MILESTONE:
Add and index approximately 400 photographs to the Glacier Photo Collection.
Compilation of the metadata for 400 photographs was completed, and approximately 200 photographs were uploaded to the NSIDC website.

NSIDC03.4 MILESTONE:
Obtain and publish snow depth, air temperature, precipitation and soil temperature data from approximately 120 stations in western China. Complete quality check and documentation and make data available online with appropriate metadata.
Data were delivered to NSIDC by visiting scientists from the Cold and Arid Regions Environment and Engineering Research Institute (CAREERI) which is also the location of the World Data Center for Glaciology - Lanzhou. Through funding provided by the NOAA ESDIM program, they provided NSIDC with the most recent updates of the Chinese snow depth, air and soil temperature data plus a limited amount of snow depth data for Tibet during the 1999 - 2003 winter season which will contribute to validating AMSR-E snow products. They assisted personnel at NSIDC in understanding the format and content of these data sets, the measurement techniques used, and associated quality control undertaken. They will assess the data for publication in the coming year.

In other work related to our goal of obtaining Tibet Plateau data, NSIDC staff attended the 4th International Symposium on the Tibetan Plateau, 4-7 August in Lhasa. NSIDC staff made presentations covering frozen ground on the Tibetan Plateau, AMSR soil moisture data, the validity of ECMWF temperature analyses and climate change over the Tibet Plateau, and climate data records available from NSIDC, respectively, and invited plenary talks on the satellite derived snow cover history of the Tibet Plateau, and railroad construction over Tibetan permafrost.

NSIDC03.5 MILESTONE:

Make research information available through the NSIDC Information Center, acquire and catalog cryospheric materials in the NSIDC library, and maintain NSIDC's analog data sets.

The NSIDC Information Center/Library serves as a resource for cryospheric information, both for researchers at NSIDC and the University of Colorado, Boulder, and for the general public. The Library acquires and catalogs both published and unpublished analog materials on snow, ice, and permafrost, and digital data such as CD-ROMs and web resources. In addition to information requests addressed by the NSIDC User Services team, library staff filled 424 information requests during CY 2003. The Library is funded in part by NOAA at NSIDC, and in part by the NASA-supported NSIDC DAAC. The Library houses over 48,000 monographs, serials, journal articles, reprints, videos, and CD-ROMs. In 2003, 707 new items were added. The Library currently receives over 75 serials and periodicals relating to the cryosphere and to remote sensing of ice and snow. All of the Library's holdings have been cataloged and can be searched during business hours on the in-house library system. The catalog is also available as part of the Arctic and Antarctic Regions Database, published on the web and on CD-ROM by the National Information Services Corporation (NISC). In addition to the Library, the Information Center also houses numerous analog data sets relating to the cryosphere. One of the largest of these data sets, the Glacier Photograph Collection, is being digitized as part of the NOAA Climate Database Modernization Project.

Collaborative Campus Research Programs

THOMAS CHASE

Tropospheric Temperature Regulation in the Arctic Winter

Description

Dr. Chase and his research group have found previously that there is an extreme lower limit to arctic winter temperatures which seems to be established by nearby sea surface temperatures. The future goals of this research are to establish a link between this mid-tropospheric temperature regulation mechanism and surface air temperatures through the tropospheric radiation balance and to further examine if such a regulation mechanism has muted the large anticipated arctic warming seen in climate change simulations due to increased CO_2.

Accomplishments:

In both model and observational studies they have found that winter arctic temperatures in the mid-troposphere have a strong minimum at about -45°C which is reached early in the winter season and never gets colder despite the lack of substantial sunshine over the next few months. Over the last year they have established in model simulations that atmospheric vertical profiles of the type observed can be created by moving cold air over warmer waters and that, once warmed, an air mass will cool upward very slowly leaving the mid-troposphere nearly at the same temperature for up to two weeks.

This warm mid-troposphere seems to have a strong connection with surface temperatures through radiative processes in the model simulations they have performed with the surface air being significantly warmer if the mid-troposphere is also warmer. They have tested this with and without the presence of clouds and the effect is quite strong.

Dr. Chase and his group have also established a similar regulative mechanism in Antarctica and are working to explain the differences in the dynamics of the two regions. Antarctica has many more instances of much colder than anticipated temperatures which appear initially to be the result of the larger ice mass and more zonal circulation in winter.

Significance:

A large part of the global warming debate revolves around the concept of arctic amplification—that warming will be seen first and will be most pronounced in this region due to ice-albedo feedbacks and related processes. An especially germane issue involves attribution of observed recent warming in the arctic to specific processes and why the observed increase is of lesser magnitude than predicted by climate model simulations. Through the temperature regulation mechanisms outlined above it is possible that a natural dampening mechanism exists which prevents rapid warming. While arctic change is certainly of scientific concern, it has also emerged as is an economic issue. For example, the timing of significant sea ice retreat under warming scenarios will bear directly on regular commercial exploitation of the northern sea route.

JOHN CASSANO

Extension of the Antarctic Mesoscale Prediction System (AMPS)
Funding: National Center for Atmospheric Research (NCAR) sub-contract from a NSF-funded project

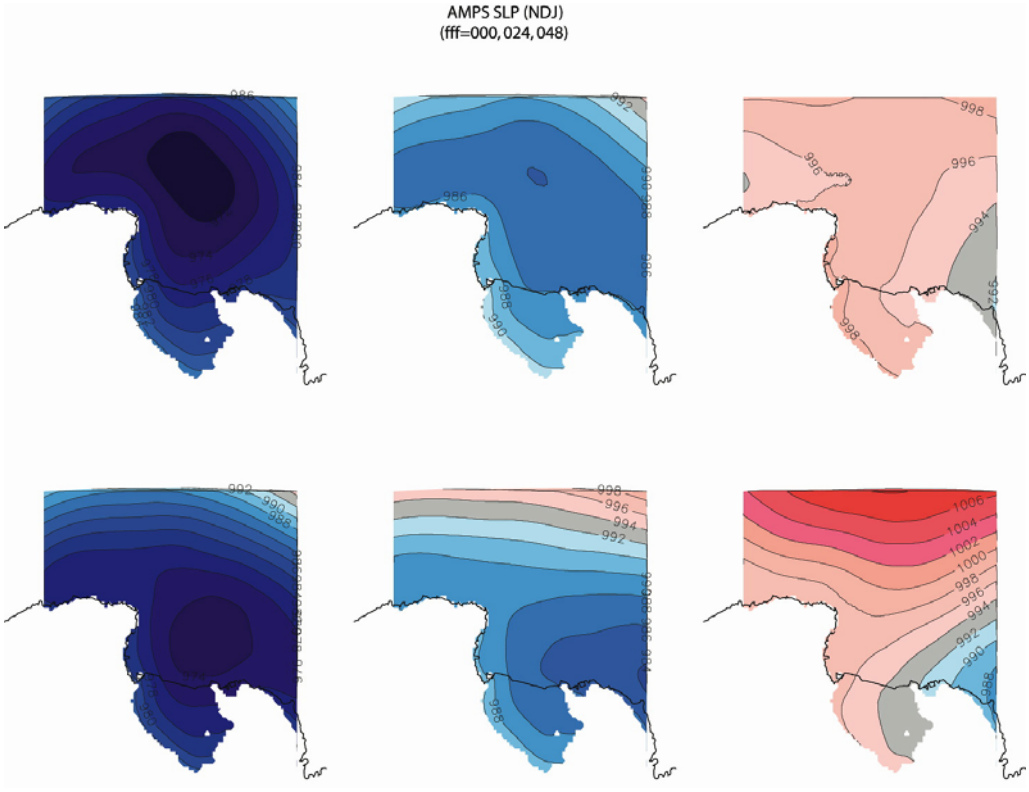
The Antarctic Mesoscale Prediction System (AMPS) project is a multi-institution collaborative research effort to merge state-of-the-science atmospheric mesoscale numerical model prediction with real-time operational weather forecasting for the Antarctic. John Cassano, as the University of Colorado Principal Investigator on this project, has been involved with model development and validation as part of this research effort.

Accomplishments

During the past year they have utilized a novel model validation technique to evaluate the performance of AMPS forecasts during the austral summer season, which coincides with the main portion of the United States Antarctic Program (USAP) field season. This model validation technique is based on an artificial neural network algorithm known as self-organizing maps (SOMs). The SOM technique has been used to objectively identify the primary synoptic weather patterns that occur in the Ross Sea sector of the Antarctic (*see figure*), allowing for model validation statistics to be calculated for each of the synoptic patterns. This approach provides useful information to the USAP operational weather forecasters, by giving them additional information about past model skill under different synoptic weather regimes, and also provides guidance to model developers regarding errors in the model formulation. This research was completed in part by an undergraduate student involved with the University of Colorado Summer Multicultural Access to Research Training program.

Significance

The AMPS forecasting system has become a critical tool to aid in real-time weather forecasting in the Antarctic since its initial implementation in January 2001. AMPS predictions are used to assist USAP meteorologists in providing weather forecasts for the daily USAP operations, including intercontinental flights between New Zealand and McMurdo Station. AMPS has also been used to provide numerical weather prediction guidance to assist weather forecasting for emergency rescue operations such as the unprecedented mid-winter air evacuation of Dr. Ronald Shemenski from the South Pole in April 2001. Ongoing model development and validation studies are a critical component of the continued success of AMPS.



The six synoptic weather patterns identified using the SOM algorithm. Color shading indicates sea-level pressure.

KONRAD STEFFEN

Assessment of Basal Melt of Petermann Gletscher in Northwestern Greenland
Funding: NSF/OPP Arctic Natural Science Program and NASA's Cryospheric Science Program

Purpose and Objectives

Petermann Gletscher is the largest and most influential outlet glacier in central northern Greenland. Located at 81°N, 60°W, it drains an area of 71,580 km^2, with a discharge of 12 cubic km of ice per year into the Arctic Ocean.

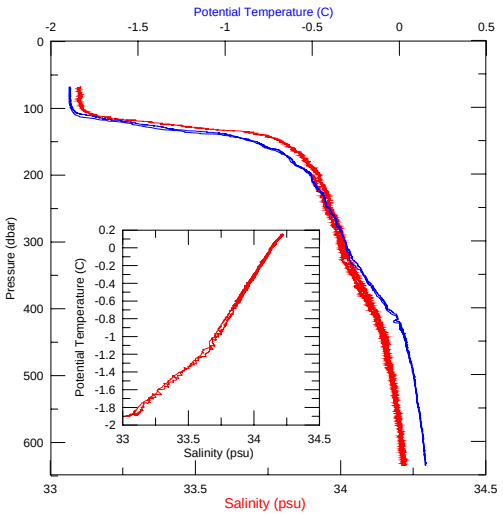
Accomplishments

Dr. Steffen and his research group finished a third field season in spring 2004 collecting *in situ* data on local climate, ice velocity, ice thickness profiles and bottom melt rates of the floating ice tongue. In addition, water properties (salinity and temperature profiles) in large, channel-like bottom cavities beneath the floating ice tongue were measured. The melt rates in these "channels" are in excess of 10 m/y and probably responsible for most of the mass loss of the Petermann Gletscher. The ocean profile measurements indicate a mixture of fresh water and Arctic Ocean water underneath the floating tongue, originating from the bottom melt. The bottom topography of the floating ice tongue has been mapped for some regions using surface-based groundpenetrating radar at 25-MHz frequency and NASA aircraft radar profiles. A new bottom topography map shows these under-ice features which run parallel to the flow direction of the ice tongue. A "worm-like" sheer feature of 50 m in height and several km in length has been studied using differential GPS readings. The mean velocity of the floating tongue ice is 1.08 km/y in that region, whereas the ice along the margin has a 30%-reduced flow speed, resulting in this strange looking sheer feature.

Significance

The mass balance of the floating ice tongue can be assessed based on *in situ* measurements, aircraft profiles, satellite data, and model approximations to determine if the northern part of the Greenland ice sheet is in balance.

This research is a collaborative effort between the University of Colorado, Boulder, the British Antarctic Survey, Cambridge, and the Jet Propulsion Laboratory, Pasadena.



Salinity and potential temperature profile underneath the floating tongue of Petermann Gletscher

Sheer feature of 50-m height due to differential ice motion

GEODYNAMICS

NGDC06	Improved Integration and Modeling of Geophysical Data

NGDC06 Improved Integration and Modeling of Geophysical Data

GOAL: Improve integration and modeling of geophysical data, further research into core-mantle processes, improve representation of magnetic fields at or near the Earth's surface, and improve understanding of past hazardous events and potential future impacts.

NGDC06.1 MILESTONE:
Apply new automated analysis and scientific review methods to the global geomagnetic database to speed ingest, identify statistical outliers, and improve integration.
A new real-time version of the assimilative mapping of ionospheric electrodynamics (AIME) technique was developed for specifying and predicting ionospheric electrodynamics. The technique uses a large number of polar data sources to produce maps of polar electrodynamics. The new AIME method uses magnetometer data from a variety of sources in different formats. Data are processed to produce plots of the polar electrodynamics, including the electric potential, currents, electron precipitation and conductance. This new version has automated algorithms for comparing observations with model predictions and identifying outlying values. This serves as the basis of machine-based quality-control for magnetometer data.

NGDC06.2 MILESTONE:
Apply new automated analysis and scientific review methods to the significant hazards database (including earthquakes and tsunamis) to speed ingest, identify statistical outliers, and improve integration.
The Interface Database (IDB) tools developed at NGDC were used to create a data management system for reviewing, ingesting, integrating, and improving the quality of the significant earthquake and tsunami databases. IDB is a java-based application that acts as middleware between science data stored in relational databases (Oracle, MySQL, Informix, etc.) and web browsers. IDB uses a series of templates to construct search interfaces, display pages, and update and insert forms. The templates interact with one another to return results in a display page based on search criteria specified in a search page. IDB content is stored in its own MySQL Relational Database Management System (RDBMS). Underlying queries are constructed from this system to extract data from database sources residing in any location and display the results on the web. The system was also used to insert and update data in the science databases.

NGDC06.3 MILESTONE:
Improved modeling of Earth's main magnetic field.
Earth's magnetic field is a vector quantity, **B**, dependent on position ***r*** and time t, and it may be expressed as the vector sum of contributions from three main sources: The main field generated in Earth's core ($\mathbf{B}_m$), the crustal field from local rocks ($\mathbf{B}_c$), and a combined disturbance field from electrical currents flowing in the upper atmosphere and magnetosphere, which also induce electrical currents in the sea and ground ($\mathbf{B}_d$), i.e.

$$\mathbf{B}(\mathbf{r}, t) = \mathbf{B}_m(\mathbf{r}, t) + \mathbf{B}_c(\mathbf{r}) + \mathbf{B}_d(\mathbf{r}, t)$$

$\mathbf{B}_m$ accounts for over 95% of the field strength at Earth's surface, and it varies slowly with time. It is this field that is represented by two new models.

The World Magnetic Model is a spherical harmonic model designed for use in air and sea navigation systems. The World Magnetic Model 2005 (WMM2005) comprises a main-field model of degree and order twelve for epoch 2005.0 and a predictive secular-variation model of degree and order 8 for the period 2005 to 2010. The second main field model is a series of spherical harmonic candidate models for the 10th generation International Geomagnetic Reference Field (IGRF), a degree and order 13 spherical harmonic model with degree and order 8 secular variation model. These models will be evaluated by the IAGA Working Group V-MOD in the fall and early winter of 2004.

The CHAMP mission has made it possible to map not only the main field from the Earth's core ($\mathbf{B}_m$), but also the field caused by magnetic minerals in the Earth's crust ($\mathbf{B}_c$). These small-scale fields are very weak at satellite altitude but can have significant amplitudes at the Earth's surface, especially near magnetite deposits and basaltic rocks. A global satellite-derived visible crustal magnetic field, downward continued to 100-km altitude, was completed in collaboration with the GeoForschungsZentrum Potsdam.

In addition to the main and crustal magnetic field work, new research into motionally induced magnetic fields in oceans is underway. Ocean flow moves conducting sea water through the Earth's magnetic field, inducing electric fields, and currents, thus generating secondary magnetic fields. These motionally induced magnetic fields have a potential for remote sensing of ocean flow variability. This is an area of developing research. New geomagnetic field models take these magnetic fields into account.

Collaborative Campus Research Programs

G. LANG FARMER

Establishing a Western North America Igneous Rock Database (NAVDAT).
Funding: NSF Petrology and Geochemistry Program.

Description

An online geochronology and geochemistry database for igneous rocks in western North America has been established (*http://navdat.geo.ku.edu/*) with collaborators at the University of Kansas, the Kansas Geological Survey, the University of North Carolina, the Carnegie Institution of Washington, and the Universidad Nacional Autónoma de México. The North American volcanic and intrusive igneous rock database (NAVDAT) is one of three global initiatives to compile and serve terrestrial igneous rocks data. All three are cooperating as the "Earthchem" project (*http://www.earthchem.org/*) and share the same basic database schema.

Accomplishments

Nearly 10,000 published and unpublished age determinations and chemical analyses from Cretaceous and younger igneous rocks from the western United States were entered into the NAVDAT database as of September, 2004. An additional 350 analyses of Mexican igneous rocks were also uploaded and an ongoing collaboration with the Geological Survey of Canada will soon allow the NAVDAT data to be combined with that from igneous rocks in western Canada. These analyses can be interrogated through a variety of search queries, and can be plotted in real time on both topographic and geologic base maps.

Significance

The NAVDAT database provides the ability for researchers to readily investigate space-time-composition patterns in igneous activity in western North America using the voluminous data set now available for both the western U.S. and Mexico. Simple space-time-composition animations of igneous activity in western North America are revealing complexities in the patterns of magmatism that can only partly be explained by the interaction of the continental lithosphere with subducting oceanic crust. NAVDAT will also allow, for the first time, regional estimates of magmatic volumes to be compiled and interrogated, a significant advance in the ability to investigate changes in the sources of continental magmatism through time.

ALEXANDER GOETZ

Moving Spectroscopic Remote Sensing Techniques for the Identification of Swelling Potential of Expansive Clays into Engineering Practice
Funding: NASA-GSFC

Description

The purpose of this project is to implement a cooperative effort with the geotechnical industry to develop a new method for rapidly testing soil samples using reflectance spectroscopy to determine their swell potential. There is a need to augment the current techniques that are time consuming and costly so that better coverage can be obtained in heterogeneous soils that are found along the Front Range and elsewhere that can cause considerable post-construction damage. This project is carried out jointly with scientists at the Colorado School of Mines, the USGS and the Colorado Geological Survey.

Accomplishments

Two trenches were opened in the lower Pierre Shale at a site north of Golden (*Figure 1*). Approximately 40,000 reflectance spectra were collected at 5-cm intervals in the trench walls. 250 soil cores were collected for analysis by standard engineering techniques for parameters such as swell potential and Atterberg limits. The samples were also analyzed by XRD techniques for mineralogy and using a new technique called PVP developed by the USGS that yields clay surface area. This technique allows separation of smectites, the cause of swelling, from all other clays. The results show that there is good correlation between reflectance in the 1800-2500-nm region and swell potential (*Figure 2*)

Significance

Swelling soils cause billions of dollars of damage in the U.S. each year, on par with floods and hurricanes. The damage causes roads to buckle, sewer, water and electrical systems to break and buildings to be made unusable. The rapid and cost-effective spectroscopic method of identification of swelling soils before construction is initiated will mitigate the possible damage and costs of remediation.

Figure 1. 2003 North Trench NW of Golden, west of CO 93. Approximately 35-m long and 5-m deep.

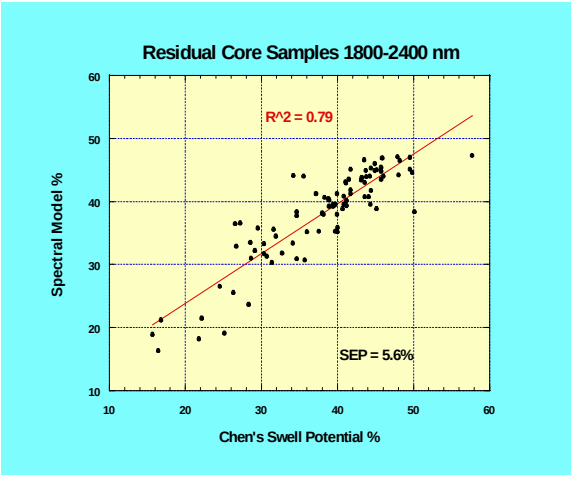


Figure 2. Partial-least-squares regression of spectral reflectance against Chen's swell potential using reflectance spectra from the same core samples used for the engineering tests.

PETER MOLNAR

Rayleigh-Taylor Instability and Mantle Dynamics Beneath Mountain Belts: An Accomplished Based Renewal
Funding: NSF

Description

One of Peter Molnar's research foci addresses processes occurring within the mantle during mountain building, and in particular gravitational instability of mantle lithosphere, the cold top boundary layer on the convecting part of the mantle. For instance, low-density crust on top of the mantle lithosphere provides buoyant resistance to a growing instability. This work, involves numerical experimentation of idealized fluids, theoretical development to find scaling laws that relate the results to simple processes, and applications relating the scaling laws to the Earth.

Accomplishments

In one study, Molnar and Gregory Houseman of Leeds University, showed how the buoyancy of a light top layer (analogous to Earth's crust) can alter flow in the underlying denser, more viscous layer (analogous to mantle lithosphere), which in turn overlies a much less viscous layer (analogous to Earth's asthenosphere). If the upper two layers are shortened horizontally, so that they thicken vertically (analogous to the process by which the Earth's crust thickens and mountain ranges are built), the unstable dense layer (mantle lithosphere) is rapidly swept into a zone downwelling flow. Intuitively one expects that the locus of this downwelling flow will underlie the locus of horizontal shortening and thickening. For various combinations of density and viscosity differences, however, the locus of downwelling develops adjacent to the region where the layers shorten horizontally. Where a crust-like layer thickens, the mantle lithosphere-like layer can thin.

In a second study, Molnar and Craig Jones of CIRES applied the scaling laws for Rayleigh-Taylor instability, some of which were developed earlier in work supported by NSF, to the volcanic and structural history of the Sierra Nevada to place bounds of the viscosity of the mantle lithosphere.

In a third study, with colleagues from Columbia University and the Université de Paris, Molnar showed how a cold, but chemically less dense, layer analogous to ancient mantle lithosphere over a warmer layer analogous to Earth's asthenosphere can undergo an oscillatory instability. As the chemically lighter layer cools and becomes denser, it can sink into the hotter layer, but as the sinking plumes warm, they become buoyant again. This group quantified the criterion for instability in terms of the two main dimensionless numbers, the Rayleigh number, which scales viscous drag and thermal diffusion, and the buoyancy number that scales density differences due to chemical and temperature differences.

Significance

The first study offers an explanation for why volcanism sometimes develops where mountain ranges are built by crustal thickening and low-temperature material is advected downward, not upward. The second provides the first known field test of laboratory-based flow laws of mantle rock and shows that they work well. The third shows how thick, chemically light, ancient lithosphere and thinner chemically less distinct younger lithosphere should both be balanced in a state near the threshold of instability.

ANNE SHEEHAN and CRAIG JONES

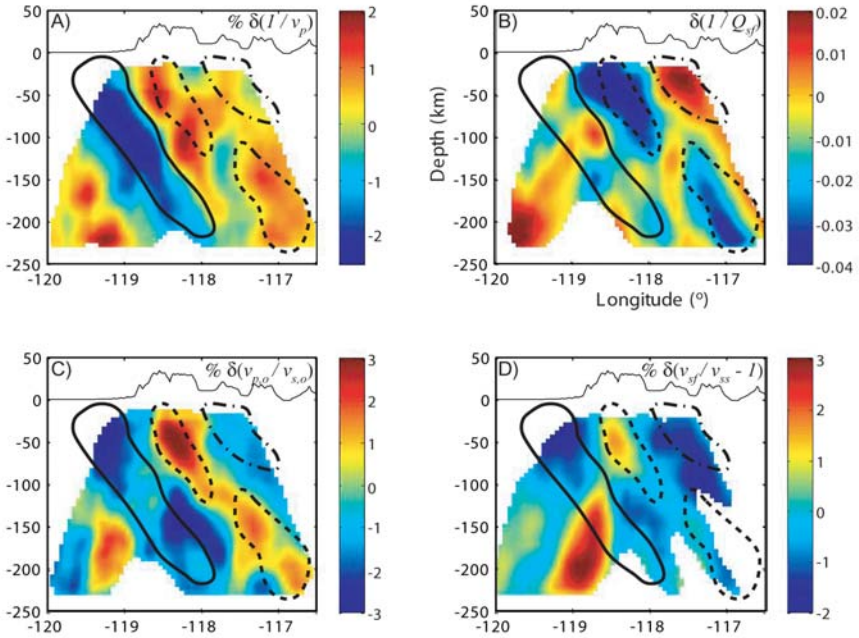
CU Geophysics Team Traces Origins and Uplift of California's Highest Mountains
Funding: NSF Geophysics Program, NSF Continental Dynamics Program

Description

The purpose of this study is to use advanced seismic imaging techniques to determine the deep structure under mountain ranges. The data used are seismic waves from distant earthquakes recorded on small portable seismometers. Advances in portable broadband seismic instrumentation over the past 15 years have resulted in the ability to make images with unprecedented resolution in regions that were before only sparsely covered. Advances in imaging techniques have accompanied the advances in data density and quality, resulting in combined field/modeling projects such as this one.

Accomplishments

Using variations in physical properties detectable using seismic waves, Profs. Sheehan and Jones have located a massive body of rock that sank into the Earth's mantle beneath the Sierra Nevada mountains some 3.5 million years ago. Undertaken with a high-tech suite of instruments designed to probe the geology to roughly 125 miles below Earth's surface, the study illustrates the mountain-building process in the southern Sierra with unprecedented detail. The measurements show how material at the bottom of the Sierran crust descended into the mantle, confirming models that suggest that the mountain range popped up as the weight on the crust dropped off. The team used 24 broadband seismometers to record scores of distant earthquakes in different wavelengths of the spectrum to create an underground image of the Sierras. Seismic travel time, attenuation, and anisotropy measurements were all combined, each providing complementary information. This is the first time such images have been processed using this full combination of techniques. The combination of measurements is similar to combining X-rays from a CAT scan with the magnetic properties of an MRI and two types of sound waves from a sonogram to separate different rock types in the crust and mantle. By combining all these techniques, the mineralogy of the anomalies can be determined, and this is the first time this study area has been imaged with this kind of clarity. The variations in mineralogy include the crust's garnet-rich rock known as eclogite and hot, mobile mantle rock called spinel peridotite. Processes of eclogite subducting into the mantle have been thought to have occurred elsewhere in the world many times, but this is the first time it has been imaged with this level of confidence.



Vertical slices of tomographic models and derived quantities, (A) percent change in P-wave slowness, (B) change in attenuation, (C) percent change in anharmonic vp/vs ratio where vs is taken from the average of the fast and slow models, and (D) shear wave anisotropy where the slow model is derived as residuals from the fast model. The solid line indicates the region of descending garnet peridotite and the dashed lines delineate the region of garnet pyroxenite. The region of low velocities and high attenuation above the garnet pyroxenite is presumably the infilling of asthenospheric spinel peridotite (dashed-dot outline). Topography is depicted with 10X vertical exaggeration.

GREG TUCKER

Modeling the Dynamics of Gully and Arroyo Development
Funding: U.S. Army Research Office

Description

Ephemeral stream channels ("arroyos") are ubiquitous in semi-arid and arid landscapes, and they bring a unique set of both scientific puzzles and environmental challenges. This project aims to understand, at a quantitative level, the dynamics of arroyo networks—why they occur, how they respond to environmental changes, and what they imply about longer-term patterns of landscape evolution.

Accomplishments

Dr. Tucker and his colleagues have deployed several different methods in an attempt to develop a better understanding of arroyos and their controls. They have discovered evidence of ancient, now filled, channels that reveal past episodes of channel incision in the Colorado piedmont. Were these episodes driven by regionally synchronous environmental changes, as appears to be the case for example in the U.S. arid southwest? To address this question, they dated the earliest channel fills using Optically Stimulated Luminescence, a technique that relies on the gradual build-up of a weak electrical charge in buried quartz grains. Different channel systems across the region show very different times of activity, casting doubt on the hypothesis of a single, regionally synchronous environmental "push." Simultaneously, they have been developing numerical models that account for key processes in arroyo formation and evolution. The modeling is aimed at answering questions such as: What are the necessary and sufficient conditions for arroyo formation? What controls the nature and timing of cut-fill cycles? Is external forcing such as climate change necessary to create alternating erosion-deposition cycles? Surprisingly, the model analysis implies that the answer to this last question is no. They find that, under the right conditions, a fairly simple set of process laws predicts pendulum-like oscillations between erosion and sedimentation even in the absence of any change of environmental conditions. Although this result does not imply that environmental triggers are never important, it does call for caution in reading environmental clues from the geohistorical record of stream network behavior.

Significance

Understanding what controls the nature and rate of earth-surface modification is a first-order problem in earth science. In particular, little is known about how, why, and to what extent climate controls the rate and pattern of landscape evolution. For example, it appears that global rates of erosion speeded up dramatically beginning in the late Pliocene. To understand why, and in particular whether, late Cenozoic climate deterioration was the culprit, they need a better quantitative understanding of what controls rates of landscape change by a variety of different processes, including stream-channel erosion and sediment transport.

Arroyos are also a source of environmental concern in semi-arid regions. Widespread channel entrenchment occurred around the end of the 19th century in the U.S. west, either as a result of grazing pressure, subtle climate change, or both. Channel entrenchment can have a range of adverse impacts, including lowering water tables, increased fine-sediment yields, and destruction of infrastructure. Design of intelligent, cost-effective reclamation strategies requires a good understanding of the processes involved. The results of this research will eventually contribute to improved land-management capabilities.

A deep and active arroyo. Two ancient infilled channels are visible in the modern channel wall, where their tan-colored fill contrasts with the dark gray shale bedrock beneath. These channels were cut between 5 and 6 thousand years ago and subsequently filled in again.

PLANETARY METABOLISM

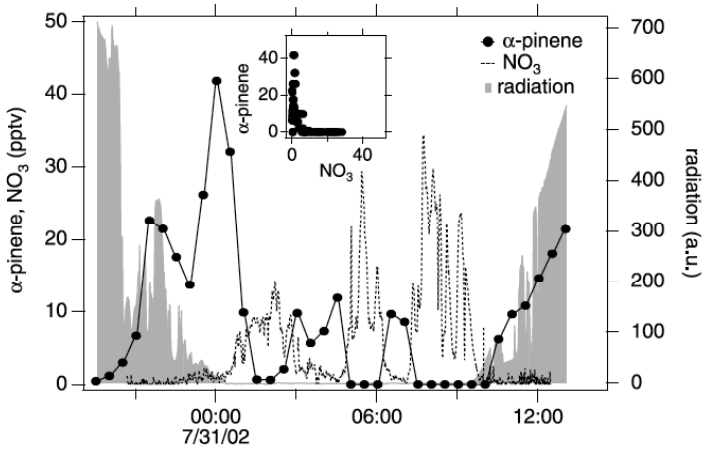
AL07 Biosphere-Atmosphere Exchange

GOAL: Gain an improved understanding of the role that the exchange of gases between the surface and the atmosphere plays in shaping regional climate and air quality.

AL07.1 MILESTONE:
Examine the role of biogenic emissions in urban air quality.

Biogenic and anthropogenic VOCs in coastal New England in summer

In many rural and urban locations in southern New England, summertime ozone levels frequently exceed the national air quality standards established by EPA. Ozone is formed in the atmosphere in the presence of sunlight through a complex sequence of reactions involving many volatile organic compounds (VOCs) from biogenic as well as anthropogenic origins. The high pollution levels come not only from the cities and industries in the region, but are also transported from the Midwest and the urbanized U.S. east coast, making this problem more regional than local. The situation is further complicated by the natural emissions from the abundant forests in New England that also contribute to the ozone and fine-particle production in the region. The air quality in New England was the focus of the NEAQS2002 campaign (New England Air Quality Study 2002). Two of the major goals of NEAQS2002 were to determine the relative role of biogenic and anthropogenic emissions to the ozone and fine particle production, and to elucidate the importance of nighttime chemistry on the oxidation of volatile organic compounds (VOCs). The biogenic emissions of isoprene and monoterpenes can be an important contribution to the local and regional VOC composition and must be considered for effective air quality control strategies in forested environments. The New England region is impacted by the emissions of biogenic VOCs from the large forested region and anthropogenic VOC emissions from the densely populated areas along the U.S. east coast. It was observed that a very efficient nighttime chemistry involving the nitrate radical (NO_3) rapidly removed the biogenic compounds from the atmosphere (*see figure*). Because the biogenic organic compounds were removed, the pool of reactive organic compounds that were available in the early morning to initiate ozone formation was dominated by the anthropogenic VOCs. The findings provide significant new insight into atmospheric chemical processes relevant to subsequent ozone formation.



Time series and anticorrelation observed for NO_3 and the volatile organic compound α-pinene on one day of the 2002 New England Air Quality Study.

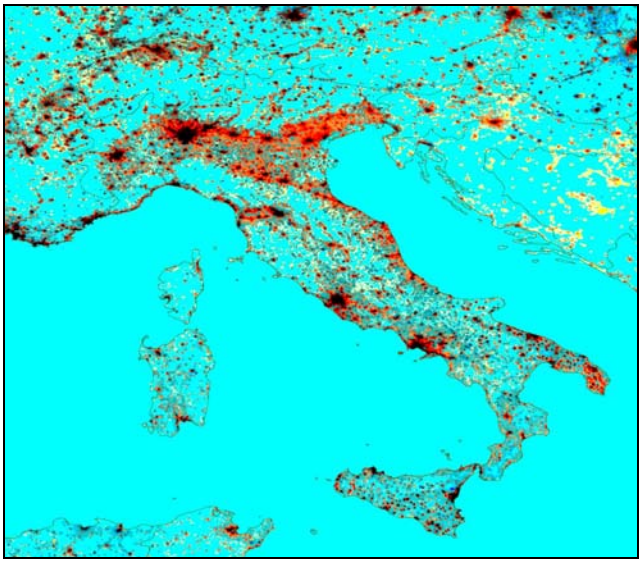
NGDC12 Anthropogenic Remote Sensing

GOAL: Provide spatial and temporal depictions of human activities based on satellite detection and mapping of population centers, fires, gas flares, and heavily lit fishing boats.

NGDC12.1 MILESTONE:
Produce the first global nighttime light change analysis spanning a ten year time period from 1992-93 to 2003.
Version 1 of the first global nighttime lights change pair was release. Seven peer-review publications with CIRES coauthors have resulted from this work. Nighttime lights change pair information and images are available at:

http://dmsp.ngdc.noaa.gov/html/download_world_change_pair.html

A one kilometer resolution impervious surface area grid of the U.S.A is available at:
http://dmsp.ngdc.noaa.gov/html/download_isa2000_2001.html.



Collaborative Campus Research Programs

SHELLEY COPLEY

Genome Shuffling Improves Degradation of the Anthropogenic Pesticide Pentachlorophenol by Sphingobium chlorophenolicum *ATCC 39723*
Funding: DOD, Army Research Office

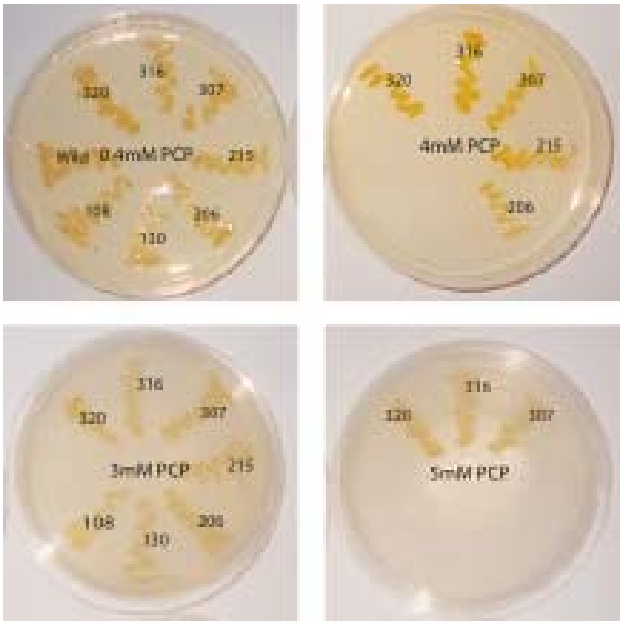
Accomplishments

Thousands of anthropogenic chemicals are released to the environment as a result of agricultural, industrial, military, and domestic activities. Biodegradation of anthropogenic compounds is often inefficient because bacteria in soil and water have had little time to evolve the metabolic pathways required to convert such compounds into readily metabolized products. Dr. Copley's group is studying the biodegradation of pentachlorophenol (PCP), an anthropogenic pesticide first introduced into the environment in 1936. Despite its toxicity and recent introduction into the environment, PCP can be completely degraded by the soil bacterium, *Sphingobium chlorophenolicum*. However, this strain is not useful for bioremediation because PCP degradation is very slow and the bacterium is able to tolerate only low levels of PCP.

Researchers in Prof. Copley's group have used genome shuffling to improve the degradation of PCP by *S. chlorophenolicum*. Genome shuffling involves generation of mutant strains that have an improved phenotype, followed by multiple rounds of protoplast fusion to allow recombination between genomes. Genome shuffling is useful for engineering of multi-trait
phenotypes that would be difficult to engineer directly because it may be impossible to anticipate all of the mutations needed to improve a complex trait while still maintaining robust growth. They have obtained several strains that degrade PCP faster and tolerate higher levels of PCP than the wild type strain. Several strains obtained after the third round of shuffling can grow on plates containing 6-8 mM PCP, while the original strain cannot grow in the presence of PCP at concentrations higher than 0.6 mM. Some of the mutants are able to completely degrade 3 mM PCP in liquid medium, whereas no degradation can be achieved by the wild type strain. Analysis of several improved strains suggests that the improved phenotypes are due to various combinations of mutations leading to enhanced growth rate, constitutive expression of the PCP degradation genes, and enhanced resistance to the toxicity of PCP and its metabolites.

Significance

This work has resulted in generation of bacterial strains that are much more effective at degrading PCP than the wild-type strain and could be used for biodegradation of PCP-containing waste as well as remediation of contaminated sites.



Growth of wild type and mutant strains of S. chlorophenolicum *on plates containing 1/4 TSB and PCP at a) 0.4 mM; b) 3 mM; c) 4 mM; and d) 5 mM. Strains 108 and 130 were obtained from the first round of genome shuffling, strains 206 and 215 from the second round, and strains 307, 316, and 320 from the third round.*

DAVID NOONE

Linking the $CO^{18}O$ Budget to Global Change Processes
Funding: NOAA Global Carbon Cycle program

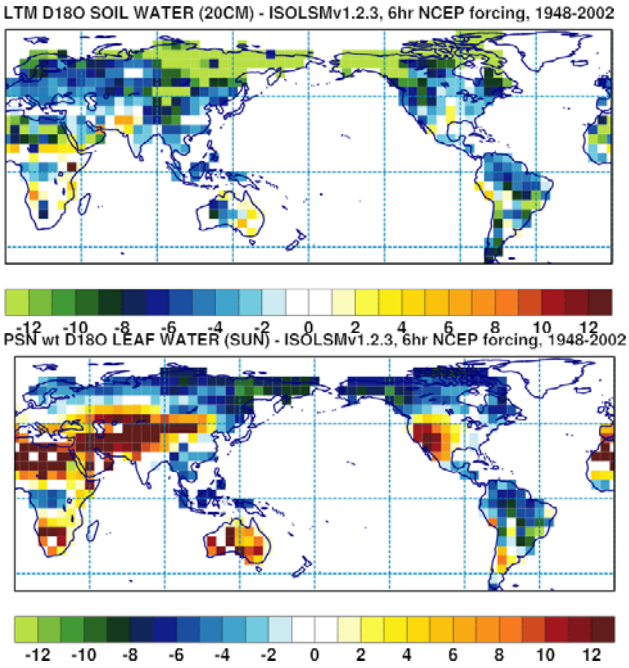
Observations of ^{18}O in atmospheric CO_2 from the global flask networks show pronounced seasonal cycles at temperate and high latitudes in the northern hemisphere. These cycles are dominated by interactions between terrestrial leaf and soil water pools and CO_2 fluxes associated with photosynthesis and respiration. Dr. Noone's group investigates terrestrial cycling of carbon using measurements and models of the $CO^{18}O$ tracer, by assessing the importance of natural and anthropogenic climate variations, changes in agricultural practices and land-cover.

Accomplishments

At high northern latitudes, interannual variation in the seasonal cycle of atmospheric $\delta^{18}O$-CO_2 exceeds that observed for $\delta^{13}C$-CO_2 or CO_2. Shifts in species composition or climate may contribute to this variability in $\delta^{18}O$-CO_2 by influencing the timing of photosynthesis and respiration and the cycling of meteoric water. To examine how stand age in the boreal forest affects the seasonal cycle of the $\delta^{18}O$-CO_2 isotopic flux, the oxygen isotopic composition of ecosystem water pools (leaf, stem, soil, water vapor, and precipitation) was measured in an 80-year-old black spruce stand, a 15-year-old trembling aspen stand, and a three-yr-old burn scar in interior Alaska. They estimated the differences in diurnal and seasonal $\delta^{18}O$-CO_2 fluxes between sites by incorporating net CO_2 eddy flux and micrometeorological measurements with oxygen isotopic signatures of ecosystem water pools and background atmospheric CO_2. A simple model was used to predict changes in the shape of the seasonal cycle of atmospheric $\delta^{18}O$-CO_2 and CO_2 at high northern latitudes that would accompany shifts in the disturbance regime. Differences between the modeled study sites indicate that fire first decreases the amplitude of CO_2 immediately following the disturbance, and then increases the amplitude of CO_2 in the fast growing intermediate stages of succession. Even though the 15-year site is a CO_2 sink with large gross fluxes, and the three-year site is a CO_2 source with much smaller gross fluxes, both had approximately the same net annual isotopic effect, enriching the atmosphere in $CO^{18}O$ relative to the 80-year-old control site, indicating the dominant role of the hydrologic cycle. A detailed model of energy and water budgets in terrestrial systems was adapted to compute the isotopic composition of water and CO_2. Global calculations of isotopic depletion in leaf water reproduced the expected enrichment with respect to soil water (*see figure*). The model was forced with meteorological data from the NCAR/NCEP Reanalysis to assess covariation between climate variability and ecosystem activity. Both the site measurements and the global simulations suggest the variability in water cycle, rather than carbon cycle, are a dominant factor in the $CO^{18}O$ composition of the atmosphere on annual and interannual time scales.

Significance

The role of species succession and disturbance in terrestrial systems has been largely overlooked when considering the impacts of climate change and feedbacks in carbon cycle. Results for the high latitudes reveal that the disturbance regime is an important aspect of regional carbon balance. This highlights also explicit linkages between the carbon cycle and the water cycle, and establishes $CO^{18}O$ as useful measure of interaction between the biosphere and hydrology.



Simulated ^{18}O in a) soil water (top) and b) leaf water (bottom) from terrestrial model forced with NCAR/NCEP reanalysis.

CAROL WESSMAN

Compound Disturbance in Managed Landscapes: Wind, Fire and Logging in the Colorado Subalpine Forest
Funding Sources: EPA, CIRES, EBIO

Scientific Impact

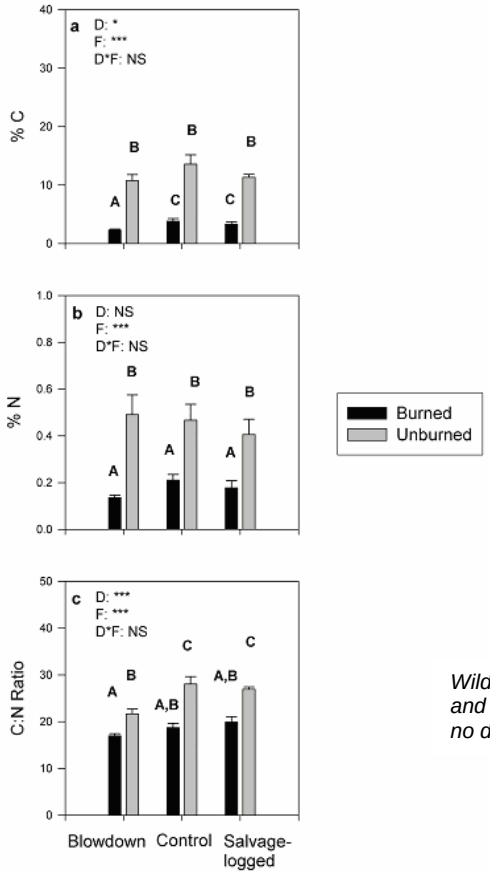
Natural disturbances of significant magnitude typically occur on 50-100+ year cycles. Increasingly, ecosystems are exposed to multiple disturbances as human land management practices fold into natural disturbance regimes, perhaps magnifying system-scale stresses. These data are the groundwork for a long-term study of the components of ecosystem resilience in subalpine forests, and the effects of pre-disturbance conditions on post-disturbance regeneration dynamics. This work will contribute to general ecological theory on the concepts of resilience thresholds in dynamic
ecosystems.

Natural disturbances in forest ecosystems such as fire and wind can restore landscape heterogeneity and structural complexity important to sustaining forest vitality and economic resources. However, if disturbances occur in rapid succession, regeneration patterns and mechanisms are much less predictable than after a single disturbance, and novel successional pathways are possible. Compound disturbances may stress forest ecosystems to the point that the resilience or ability to respond to disturbance is crippled, thus shifting successional trajectories from forest to meadow
communities.

The largest known blowdown ever recorded in the Rocky Mountain region occurred in Colorado's Routt National Forest in 1997. Two years later, the U.S. Forest Service began salvage-logging operations in selected areas. In 2002, the second largest fire during a record fire season in Colorado consumed a large portion of the area. Research seeks to understand the interactive effects of rapidly sequenced disturbances on regeneration and biogeochemical dynamics of subalpine forest ecosystems.

Research in this area of the Routt National Forest demonstrated that salvage-logging following catastrophic wind disturbance resulted in a highly modified ecosystem that was compositionally and functionally different from unlogged blowdown areas. Salvage-logging in wind-disturbed areas reduced net nitrogen mineralization rates in soil, eroded and compacted the organic soil horizon, and significantly reduced understory vegetation cover and tree seedling density. Other research has shown that regeneration may fail under these conditions, resulting in a shift from coniferous forest vegetation to subalpine grassland communities, which can preclude conifer establishment for a century or more.

Based on this research, they are establishing a longer-term study of forest resilience and regeneration in this area. Initial work in the first year following the 2002 fire study suggests that initially, the effects of a severe fire tend to "erase" the effects of previous disturbances on soil properties, and nitrogen cycling. However, with time the effects of disturbances that occurred prior to the wildfire may become more pronounced. Continued work in this study area will follow regeneration dynamics to further establish if post-fire regeneration dynamics are qualitatively or quantitatively different as a result of pre-fire disturbance histories.



Wildfire resulted in increased inorganic nitrogen availability in the top 10 cm of soil, and decreased soil carbon and nitrogen concentrations (Fig a & b), but resulted in no difference in net nitrogen mineralization rates relative to unburned areas.

REGIONAL PROCESSES

AL04b Tropospheric and Stratospheric Transport and Chemical Transformation

GOAL: Carry out modeling studies and airborne and surface measurements of chemical species in order to elucidate the processes involved in the intercontinental transport of photochemical pollution.

AL04b.1 MILESTONE:
Use field measurements made during the 2002 Intercontinental Transport and Chemical Transformation (ITCT) experiment and meteorological analysis to study the pertinent transport mechanisms of the intercontinental transport of air pollutants between Asia and western North America.

(i) Unraveling the sources, transformation and removal of gas-phase compounds and aerosols produced from Asian emissions during trans-Pacific transport

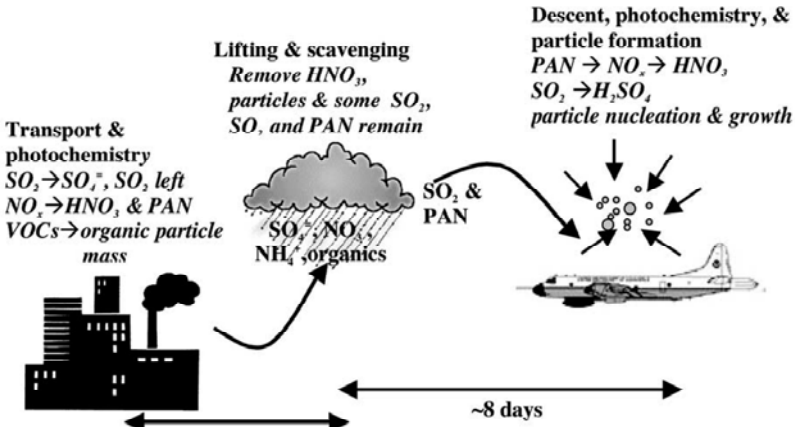
The gas-phase and aerosol chemical characteristics produced from emission plumes transported from Asia across the Pacific Ocean were measured during ITCT-2K2. The Asian emissions are found to be a complex mix of industrial, biomass combustion, and natural emissions. These findings have illuminated many aspects of these processes. For example, the NO_y observed in the remote marine free troposphere over the eastern North Pacific is associated with transport from Asia. Comparing the observed NO_y/CO ratio with those reported from Asia indicates that significant levels of NO_y had been removed.

finding that shows most NO_y removal occurs near the source. In addition, this NO_y is dominated (approximately 70%) by PAN (peroxyacetyl nitrate)-like compounds. This has important implications for the determination of photochemical production of ozone in the free troposphere and global tropospheric chemistry.

A detailed understanding of the intercontinental transport and chemical transformation of these compounds will allow improved treatment of them in global chemistry transport models. This will improve our confidence in the predictions of future climate.

(ii) Significant formation of aerosols in the remote marine free troposphere

Fast response measurements of particle size distributions, bulk sub-micron particle composition, and single particle composition were made aboard the NOAA WP-3D research aircraft in the free troposphere over the eastern Pacific Ocean. Simultaneous measurements of gas-phase tracer and photochemically reactive compounds and meteorological analysis show evidence of long-range transport of layers of aerosol particles from anthropogenic and bio-



Schematic diagram showing, from left to right, emission, oxidation, and transport of pollutants; lifting, cloud processing, and scavenging of water-soluble and particulate compounds; and descent, decomposition, photo-chemistry, oxidation, nucleation, and condensation to produce the measured layers of gas phase HNO_3 and H_2SO_4 and particulate sulfate.

These results are consistent with the

mass-burning sources in eastern Asia. It was shown that plumes of Asian emissions transported to the Pacific free troposphere are often scrubbed free of aerosols and soluble gas-phase species. However, enough SO_2 is transported to support new particle formation. Before this study it was generally believed that only pre-existing aerosols are transported. These newly formed aerosols can act as cloud condensation nuclei. Hence, their formation and transport must be understood before it is possible to accurately predict cloud fields, which are some of the major uncertainties in the current generation of global climate models.

This work points to the need to quantitatively understand the transport and chemistry of both particles, partially soluble precursor gases through cloud systems, and the formation of new particles that occurs during transport to estimate the global aerosol impacts on the radiative balance of the atmosphere. The variety of aerosol properties reported here suggests that sophisticated parameterizations regarding sources, transport, cloud processing, and gas-phase and liquid-phase chemistry involving particle precursors are required to accurately represent particle transport and evolution in chemical transport models. Such models also need to include parameterizations of particle nucleation processes and growth to realistically simulate the particle properties following long-range transport.

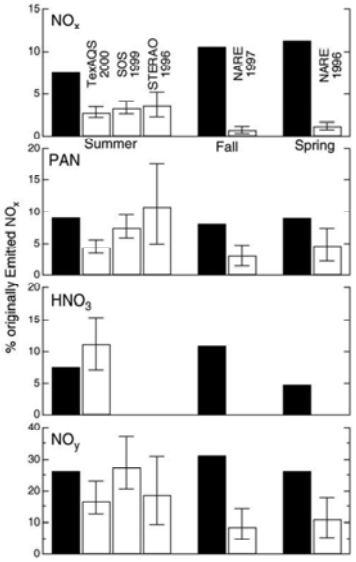
AL04b.2 MILESTONE:

Estimate the composition and quantity of reactive nitrogen compounds (NO_y) transported in polluted air masses lofted from the North American continental boundary layer.

Export of nitrogen oxides from the continental boundary layer to the free troposphere

A significant uncertainty in the determination of the sources of tropospheric ozone concerns the amount of ozone that can be produced by photochemistry in the free troposphere. It is generally accepted that the formation of ozone in the free troposphere is limited by the availability of reactive nitrogen oxides. Hence the determination of the transport of nitrogen oxides into the free troposphere is critical to the determination of the photochemical production of ozone. From the analysis of data obtained during two field studies in the early fall and in the spring over the western North Atlantic, it was found that only 9±4% of the total NO_x emitted over North America was transported to the free troposphere as any form of NO_y. This low percentage exported limits the contribution of anthropogenic NO_x emission to the photochemical formation of ozone and thus the continental contribution to the global O_3 budget.

As a result of this analysis, it has been shown that the derived export percentage is significantly lower than generally calculated by global models. Consequently understanding of the global tropospheric O_3 budget, which is based on those models, must be modified.



Summary of percent of originally emitted NO_x that is exported to the free troposphere during five field experiments. The unshaded bars with confidence limits indicate the values derived from the measurements; the shaded bars give model results for the respective season.

AL08 Regional Air Quality

GOAL: Carry out laboratory measurements, atmospheric observations, and modeling studies that characterize the chemical and meteorological processes involved in the formation of pollutant ozone and fine particles. Undertake research that contributes to the enhancement of air quality prediction and forecasting capabilities.

AL08.1 MILESTONE:

Design and evaluate a near-ultraviolet spectrograph to measure reactive sulfur and nitrogen emissions from point and regional sources.

Evaluation of emission sources important in air quality

Model calculations were used to determine requirements for a spectrograph that can measure tropospheric enhancements of both SO_2 and NO_2. A commercially available instrument was identified, purchased, and tested in the laboratory, where both gases were successfully measured. The instrument was installed on the NOAA P3 aircraft in preparation for the summer 2004 New England Air Quality Study-Intercontinental Transport and Chemical Transformation (NEAQS-ITCT) campaign.

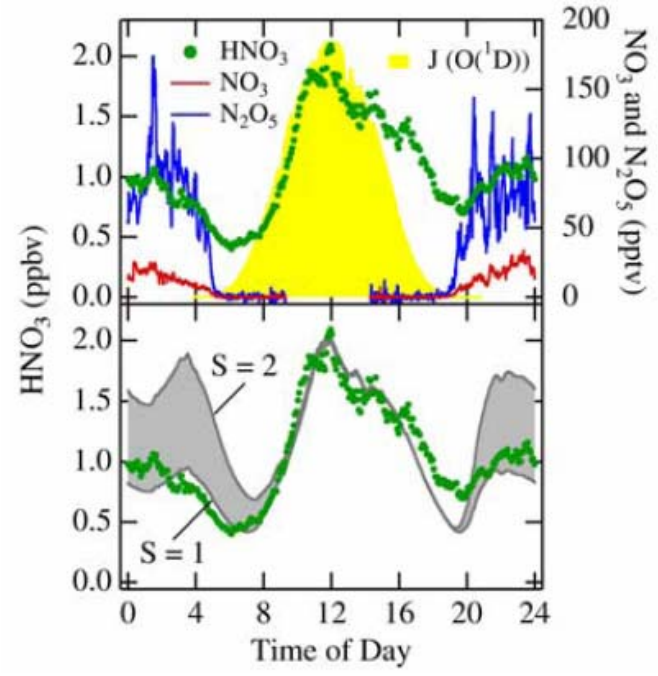
AL08.2 MILESTONE:

Measure NO_3 and N_2O_5 using cavity ring down spectroscopy and work toward elucidating the role of these species in the nighttime chemistry of the troposphere.

Unraveling the chemistry that happens at night

The reactive nitrogen ("NO_y") family exerts controlling influences on many of the atmosphere's chemical processes.

Prior to this CIRES research, key members of the NO_y family had either never been measured, or had been measured only in ways that limited the quantification of their role in the atmosphere. Those species—the nitrate radical (NO_3) and dinitrogen pentoxide (N_2O_5)—were thought to play major roles in the production of ozone pollution in the lower atmosphere, and it was speculated that an entire undiscovered realm of nighttime chemistry might exist. But the lack of measurement approaches prevented progress and perpetuated a major uncertainty in air pollution modeling. These frontier areas of atmospheric chemistry were targeted in applying the cavity ring down spectroscopic technique to atmospheric measurements of NO_3 and N_2O_5 during the 2002 campaign of the New England Air Quality Study.



Top panel shows diurnally averaged mixing ratios of NO_3 and N_2O_5 made with the cavity ring-down spectrometer, along with HNO_3 measurements made with other instrumentation, during the 2002 New England Air Quality Study. The measurements demonstrate the prominent role of NO_3 and N_2O_5 in converting NO_x to HNO_3 at night.

Through this work, the first-time demonstration has been made that N_2O_5 is a major member of the reactive nitrogen (NO_y) family. This discovery means that nighttime processes are of much greater prominence than had been previously thought. N_2O_5 nighttime removal from the atmosphere (by reactions on surfaces of particles in the air) has been shown to be an important process for reactive nitrogen removal and thus an effective "short circuit" to the chemistry that produces ozone the next day. Hence, a nighttime "control valve" for ozone generation has been identified through this research.

Related work in 2003/2004 was focused on preparing an instrument capable of making the NO_3/N_2O_5 measurements on the NOAA WP-3D research aircraft during the summer-2004 field campaign of the New England Air Quality Study/Intercontinental Transport and Chemical Transformation missions.

AL08.3 MILESTONE:
Examine the impact of automotive and industrial NO_x and VOC (volatile organic hydrocarbon) emissions on urban air quality.

Effect of petrochemical industrial emissions of VOCs and NO_x on ozone formation in Houston, Texas

Petrochemical industrial facilities can emit large amounts of highly reactive hydrocarbons and NO_x to the atmosphere. In the summertime, such co-located emissions are shown to result consistently in rapid and efficient ozone formation downwind. Airborne measurements show that hydrocarbon reactivity in plumes from petrochemical industries in the Houston metropolitan area is primarily due to routine emissions of the alkenes propene (C_3H_6) and ethene (C_2H_4). Reported emissions of these highly reactive compounds are substantially lower than emissions inferred from measurements in the plumes from these sources. Net ozone formation rates and yields in these petrochemical industrial plumes are substantially higher than rates and yields observed in urban or rural power plant plumes.

These observations suggest that reductions in reactive alkene emissions from petrochemical industrial sources are required to effectively address the most extreme ozone exceedences in the Houston metropolitan area.

AL09 Aerosol Formation, Chemical Composition, and Radiative Properties

GOAL: Carry out airborne and ground-based experiments that characterize the chemical composition of radiatively important aerosols in the upper troposphere and at the Earth's surface.

AL09.1 MILESTONE:

Elucidate steps in the formation of organic aerosols in the atmospheric oxidation of alpha-pinene via its reaction with ozone.

Evaluating factors that influence the formation of atmospheric haze

The gas phase oxidation of monoterpenes, such as α- and β-pinene (organic compounds emitted by trees), in the troposphere represents a potential source of "new" particle formation and secondary organic aerosol (growth of existing aerosol). The evaluation of this source of particles and its possible impact on the radiative budget depends on the ability to model the source under the range of conditions found in the troposphere (for example: precursor concentrations, background surface area, and temperature). Laboratory particle nucleation studies have been performed for α- and β-pinene to address these issues.

Laboratory nucleation experiments were performed in a temperature-regulated small-volume Teflon bag reactor. Particle production and growth following ozonolysis and ozone plus OH radical initiated gas-phase chemistry were measured using condensation particle counters. Experimental data demonstrating the dependence of "new" particle production on precursor concentration, the OH radical, and temperature were obtained. A two-component particle nucleation model was developed to interpret and quantify the experimental observations. The model parameters include the thermodynamics for nucleation and growth, and the reaction product yields of a single nucleating species and a single condensing species.

Using the results from this study, new particle and secondary aerosol formation in the atmosphere resulting from monoterpene oxidation was evaluated. Under favorable atmospheric conditions, monoterpene oxidation can make a significant contribution to the observed "new" particle formation in remote forests. Also, monoterpene oxidation will, under most conditions, account for a significant fraction of the observed secondary organic aerosol formation.

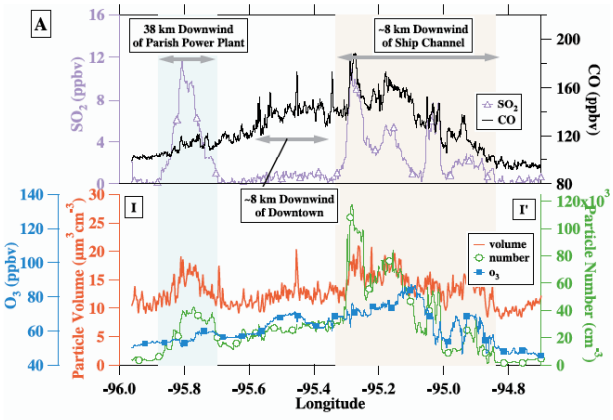
AL09.2 MILESTONE:

Investigate particle growth and composition in urban and industrial plumes.

Particle growth in urban and industrial plumes in Texas

The aim of this analysis is to investigate the sources and characteristics of aerosol particles in Houston, Texas, and the surrounding vicinity. This metropolitan region has a population of four million and contains the largest grouping of petrochemical industrial plants in the United States. Airborne measurements of particle size distributions and gas-phase particle precursors and tracer species that were made in the plumes downwind from industrial and urban sources in Houston have been analyzed. The results indicate that photochemical oxidation of sulfur dioxide regulated particle formation in all the plumes that were studied. However, the uptake of organic matter dominated particle growth in petrochemical plumes that were rich in both SO_2 and VOCs.

The studies indicate that there is rapid formation and growth of aerosols in petrochemical plumes. These particles composed of SO_2 and VOCs and their oxidation products are an important regional air quality issue that has implications for public health.



Measurements of SO_2, CO, O_3, and particle number and volume concentrations on 28 August 2000 downwind of the Parish power plant (shaded blue), the Houston urban core (unshaded), and the Houston ship channel industries (shaded peach). Substantial increases in particle volume above background are clearly associated with the power plant and industrial plumes, indicated by enhanced SO_2 mixing ratios.

AL09.3 MILESTONE:

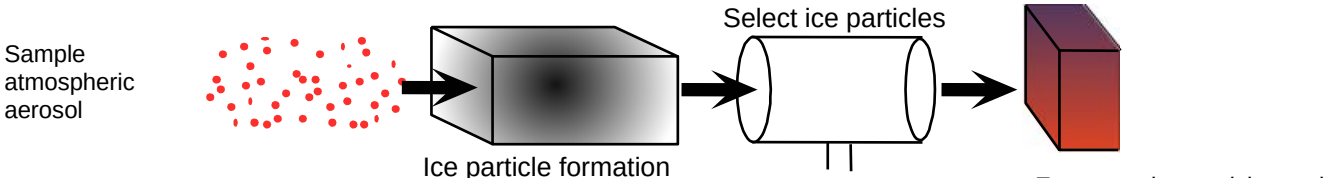
Investigate the effects of the chemical composition of individual aerosol particles on the chemistry and radiation of the atmosphere, particularly with regard to effects on cloud formation.

Identifying which atmospheric aerosol particles are effective "seeds" for cloud formation

Among the least understood but potentially important processes in atmospheric science is the relationship between small aerosol particles and ice-cloud formation. The most recent (2001) state-of-understanding climate science assessment of the Intergovernmental Panel on Climate Change (IPCC), for example, states that "The indirect radiative effect of aerosols also includes effects on ice and mixed-phase clouds, but the magnitude of any indirect effect associated with the ice phase is not known." Furthermore, the 2001 IPCC report notes that while man-made

perturbations "...may have a large … impact on forcing... it is not possible to estimate the number of anthropogenic ice nuclei at the present time."

With this as motivation, a collaboration between CIRES, the NOAA Aeronomy Laboratory, Colorado State University, and the University of Colorado, has developed a novel technique to determine the chemical composition of those aerosols, commonly termed "ice nuclei," capable of forming atmospheric ice clouds, both on a particle-by-particle basis and in real time. This technique was deployed to the Desert Research Institute's Storm Peak Laboratory in north-central Colorado during November 2003 and April and May 2004 to address the urgent need for additional and more quantitative information on the chemical composition of atmospheric ice nuclei. Among the important results shown was that the most efficient ice nuclei are not ubiquitous sulfate aerosols, but are instead rare mineral or fly-ash particles, some of anthropogenic origin (*see Figure 1*). Second, aerosols rich in organic material were shown to be inefficient ice nuclei (*see Figure 2*). These results have contributed to our understanding of the interaction of aerosol particles with clouds and will provide valuable constraints for global climate models.



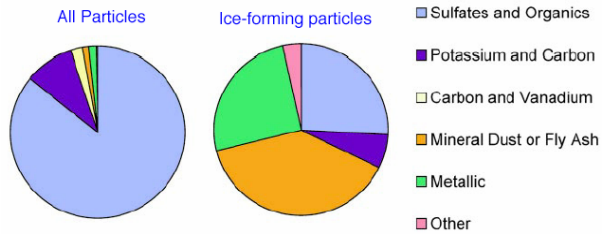


Figure 1 (above). Technique used to determine which atmospheric particles (aerosols) are effective "seeds" for cloud formation

Figure 2 (left). Results of the field experiment demonstrated that the most abundant types of atmospheric aerosols are not the ones that are most effective in forming ice clouds.

CDC05a Experimental Climate Services (including Web and Data Services)

GOAL: Couple enhanced observations and research within regions characterized by strong climate variability with analysis of past data and improved modeling. A special emphasis is on determining factors influencing the occurrence of extreme events. The need to better observe, model, and predict the regional consequences of climate change and variability on hydrological variables, on time scales ranging from days to decades, also falls within this goal.

CDC05a.1 MILESTONE:

Co-develop a shared CIRES/NOAA website dedicated to real time predictions of tropical convection associated with the Madden-Julian Oscillation where various research and operational ensemble predictions will be displayed in a uniform format to enable intercomparisons and skill evaluation.

As part of a strategy to assess current model subseasonal prediction capabilities and shortcomings, an experimental forecast and model development website has been developed that focuses on the MJO. The primary objective of the website is to deliver skillful predictions at lead times of 1-4 weeks of tropical and extratropical intraseasonal variability. In terms of directly predicting tropical variability at these lead times, it is recognized that the state of the MJO and its evolution are crucially important. In regard to extratropical forecasts, the skillful prediction of the MJO is perceived to be somewhat, or at least intermittently, important for extratropical weather forecasts during weeks 1-2. At lead times of 3 to 4 weeks, the prediction of the MJO may be helpful in foreshadowing large scale circulation changes in the extratropical flow (*http://www.cdc.noaa.gov/MJO*).

CDC05a.2 MILESTONE:

Expand the 23-year reforecast dataset from a single control run to a 15-member ensemble and develop new ex-

perimental Week Two and monthly products based on the preceding dataset.
CDC has completed development of a 23-year dataset of retrospective two-week ensemble forecasts using a reduced-resolution version of the NCEP Medium-Range Forecast (MRF) model. CDC continues to run the two-week ensemble forecasts in real time. The database of retrospective ensemble forecasts was used to demonstrate the feasibility of applying statistical corrections to the real-time ensemble forecasts, thereby improving their accuracy (see current forecasts and details at *http:/ /www.cdc.noaa.gov/~jsw/refcst*). The uncorrected ensemble forecasts had little skill at Week 2, but after statistical correction, were much more skillful than the operational Week 2 forecasts currently produced at NCEP's Climate Prediction Center (CPC). Given these results, CPC will take over the operational generation of these statistically corrected forecasts and integrate the statistical models into their operational products. CPC and CDC also plan to cooperatively work toward generating retrospective forecasts for new versions of the MRF model as they are made available.

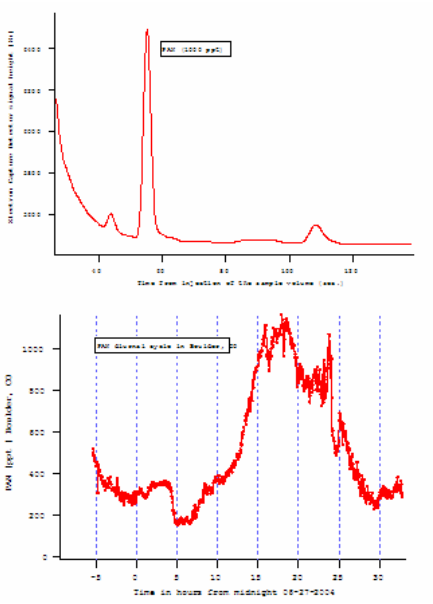
CMDL03 Air Quality

GOAL: Study intercontinental transport events to improve our understanding of their importance in affecting overall air quality and its impacts on public health.

CMDL03.1 MILESTONE:
Initiate measurements of aerosol optical depth at the West Coast Observatory.
As this was a recent campaign, data processing for distribution to the scientific community has just begun. The raw data can be viewed on the web site at *http://www.cmdl.noaa.gov/aero/net/sfc/data.html.*

CMDL03.2 MILESTONE:
Initiate measurements of hydrocarbons, Peroxyacetyl Nitrate (PAN), CO, H_2, and other species involved in air quality issues at the West Coast Observatory.
Trinidad Head, CA, was added to the network of sites collecting air samples weekly as part of the HATS flask sampling program. Samples are analyzed for selected hydrocarbons, halocarbons and other trace gases on three instruments. PAN is very unstable and requires a new approach of dynamic dilution for CMDL/CIRES scientists to calibrate their observations. This technique was a combination of past methods and was tested in Boulder this summer to obtain our first diurnal measurements.

CMDL03.3 MILESTONE:
Conduct operations with a movable aerosol sampling system
As part of the International Consortium for Atmospheric Research on Transport and Transformation (ICARTT), the NOAA CMDL Aerosol and Radiation Group conducted measurements of aerosol optical properties at Chebogue Point, Nova Scotia. The measurements included those of column optical depth at seven wavelengths and downwelling broadband diffuse and direct irradiance. *In-situ* surface measurements were performed of the aerosol scattering coefficients as a function of aerosol size, scattering wave-length and relative humidity. Researchers also measured the aerosol absorption coefficient at 550 nm, the submicron aerosol size distribution and the aerosol number concentration. They took advantage of the fog and rainy climate in Nova Scotia to measure the cloud condensation nuclei concentrations as a function of percent supersaturation. These combined measurements of aerosol optical and cloud properties will allow them to investigate the interaction between aerosols and cloud droplets and better understand indirect radiative forcing.



Measurements of PAN over the NOAA Boulder, Colorado laboratory. A chromatogram of PAN of 1000 ppt from outside air at 55 seconds after injection is shown in (a). The peak at 45 seconds is unknown, and the peak at 107 seconds is PPN. One diurnal cycle of PAN during a wet and cool period (high 60, low 50 F) in the summer of 2004 is shown in (b).

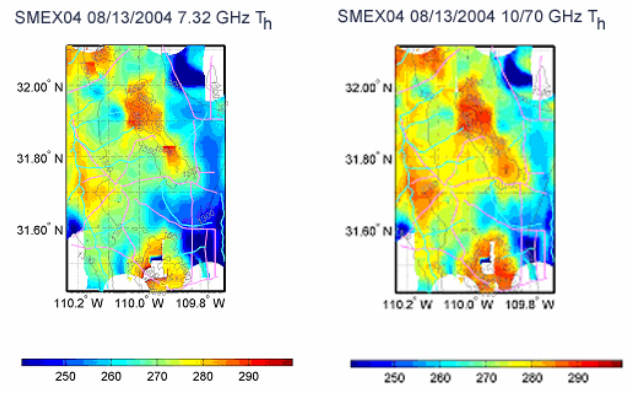
ETL05 Water Cycle

GOAL: Improve weather and climate predictions through an increased knowledge of regional and global water cycle processes.

ETL05.1 MILESTONE:

Carry out initial flights of an airborne hydrological imaging platform designed to generate high resolution maps of soil and biomass moisture in real-time using radiometric technologies.

The ETL radiometry group has been participating in soil moisture experiments since 1999. This year the Soil Moisture Experiment (SMEX04) was a part of larger North American Monsoon Experiment (NAME). This group installed and operated PSR/A and PSR/CXI scanheads onto NAVY Research Laboratory (NRL) P-3 airplane. The PSR team was able to process the acquired data into the brightness temperature maps–indication of soil moisture content– in near real time. Most recent efforts of the Radiometry group focus on preparation for the flights over Antarctic sea ice.



High resolution brightness temperature maps indicating soil moisture content observed over Southern Arizona during SMEX04/NAME experiment.

ETL06 Air-Sea Interaction

GOAL: Perform cutting-edge micrometeorological and climatological research over the open ocean aboard research vessels, sea-based towers, and buoys.

ETL06.1 MILESTONE:

Process Eastern Pacific Investigations of Climate (EPIC) and Pan-American Climate Study (PACS) data sets, provide a detailed analysis of these air-sea interaction data products, and make the final data set publicly available. Deployment on new excursions within the PACS and EPIC regions are imminent, as are cruises in the North American Monsoon Experiment (NAME) and New England Air Quality Studies (NEAQS) regions.

Since 1999, in partnership with NOAA-ETL, CIRES has continued to participate in the yearly excursions by the NOAA Ship *Ronald H. Brown* to the Tropical Atmosphere Ocean (TAO) buoys which reside within the Pan-American Climate Studies (PACS) area (110°W and 95°W buoy lines which straddle the equator). Observations of cloud forcing and surface forcing (radiative and turbulent) have been analyzed, yielding a rich climatological record of an area of the Pacific which is critically important to U.S. weather and climate. In the summer of 2004, CIRES participated in the North American Monsoon Experiment (NAME) on board the Mexican Navy Research Vessel *Altair*. Observations included turbulent fluxes of heat, moisture, and momentum; wind, temperature, and humidity profiles (from a 915-MHz wind profiler and from radiosondes); and mean meteorological measurements. The monsoon is characterized by the interaction between air, sea and land, and the information from the ship, which was stationed at the mouth of the Gulf of California, provides a critical ocean-based perspective and will be of fundamental value to modellers attempting to develop more accurate Monsoon simulations. In addition, CIRES participated in the summer 2004 New England Air Quality Experiment (NEAQS) in the Gulf of Maine on board the NOAA Ship *Ronald H. Brown*. Observational systems include the onboard wind profiler and C-band precipitation radar, a NOAA-ETL ozone lidar, the NOAA-ETL turbulent flux

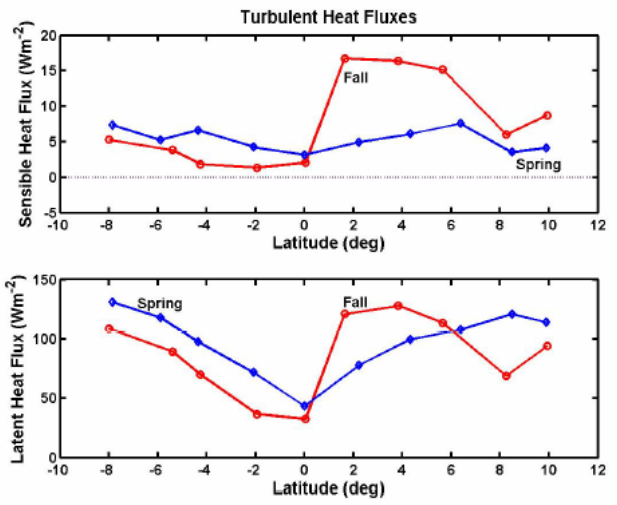


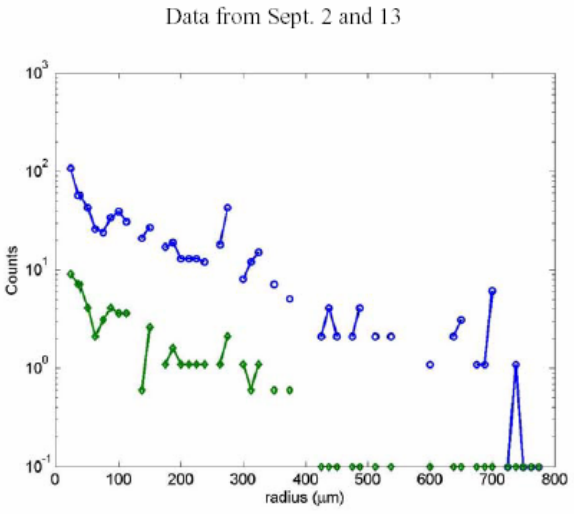
Figure 1. Turbulent heat fluxes as measured from the NOAA Ship Ronald H. Brown *(Fall) or the NOAA Ship* Ka'imimoana *during excursions to the Tropical Atmosphere Ocean (TAO) Pan-American Climate Studies (PACS) buoys on the 110°W and 95°W lines of longitude. Points are averaged at each latitude. Note the large increase in heat fluxes in the northern hemisphere fall north of the equator due to the greater air-sea temperature difference, higher winds, and change in hydrostatic stability encountered in that season.*

and radiative flux systems, and a laser ceilometer. The project is focused on obtaining measurements of boundary layer processes which are critical to air quality and pollution transport near the New England shore and within the stable air of the Gulf of Maine.

ETL06.2 MILESTONE:

Measurements of sea spray will continue near the AUTEC (Atlantic Undersea Test & Evaluation Center) range and as part of the Coupled Boundary Layers Air-Sea Transfer (CBLAST) experiment

In January and February of 2003, CIRES researchers participated in the wind-wave tunnel study under the "Spray Production and Dynamics Experiment" (SPANDEX). A total of 49 spray droplet concentrations were measured under different experimental conditions. Droplet profiles were made at three different forcing (wind stress) and three water salinities. These data verified the basic profile scaling laws used for the ETL sea spray parameterization. In August 2003, CIRES worked to incorporate the NOAA-ETL sea spray parameterization into CBLAST LES models of the marine boundary layer. In late August 2003 the NOAA-ETL droplet probe was installed on the NOAA P-3. A total of six flights were made (in hurricanes Fabian and Isabel) with a series of stepped profiles in the lower boundary layer. CIRES has taken preliminary steps in formulating a new physical model of sea spray droplet formation and initiated contact with Australian collaborators at the University of New South



Green – median counts and blue – total counts for 10 step legs on both days (0.1 means 0).

Wales for laboratory simulations of the processes. A preliminary version of the model has been given to CBLAST numerical model groups; a simplified, parameterized version has also been distributed.

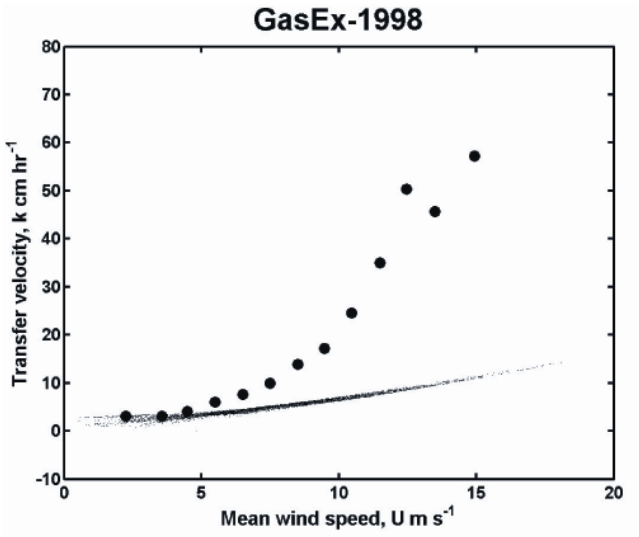
In the fall of 2003 CIRES acquired long-needed measurements of sea spray concentrations over the oceans in near hurricane force winds (25-30 m/s), and CIRES plans to have the droplet probe mounted on the NOAA P-3 for the final CBLAST deployments in the 2004 hurricane season. A wind tunnel study was conducted in the winter of 2003. If successful, CIRES can make progress on a parameterization of spray production and an evaluation of spray thermodynamic effects on hurricanes.

ETL06.3 MILESTONE:

Further quantify the air-sea transfer of gases and use a detailed physical analysis of data obtained from the GasEx surface processes experiments to evaluate and improve gas transfer parameterizations

One significant uncertainty in climate change science is the amount of sequestration of anthropogenically generated climate-relevant compounds into the worlds' oceans. Part of the difficulty in estimating the net mass exchange from the atmosphere to the sea surface is the inaccuracy of the current generation of small-scale gas transfer parameterizations. Since gas transfer occurs most efficiently at turbulent time scales (approximately one hour), it is essential that improvements be made in the modelling of this fundamental air-sea process. CIRES and NOAA-ETL collaborators have developed a micrometeorologically based air-sea gas transfer model which has foundation in the well known COARE bulk flux algorithm. After CIRES participation in the series of GasEx expeditions, an analysis of the NOAA/COARE algorithm yields discrepancies in the model output between the moderate wind and low wind regimes. Some strategies for further improvement to the parameterization include: increasing the volume of direct measurements of gas flux between the air and sea, observations of surface microbiological activity in conjunction with direct gas flux measurements, and investigations in areas where high gas fluxes will occur. In addition, CIRES scientists collaborated with the University of Hawaii to make the first direct measurements of the air-sea flux of dimethylsulfide, which is a gas of significant interest in the formation of clouds, thus affecting the radiative balance at the Earth's surface. CIRES scientists have also developed a collaboration with the University of Colorado's Institute of Arctic and Alpine Research (INSTAAR) to develop and deploy a fast-response instrument to

measure the air-sea transfer of ozone gas flux. These collaborations are also attractive, in that the range of Schmidt numbers of the observed gases will lead to further refinement of the COARE algorithm.



Transfer velocities from GasEx-2001 (large dots) along with those from the NOAA/COARE model (small dots) with NO bubble parameterization.

ETL07 Air Quality

GOAL: Gather and analyze atmospheric observations to characterize meteorological processes that contribute to high-pollution episodes. Compare these measurements with air quality forecasting model predictions to assess and improve research model performance.

ETL07.1 MILESTONE:
Document meteorological processes that contributed to high-ozone episodes in the Houston, TX, and New England areas using data from the Texas 2000 and New England 2002 air quality studies. Compare model predictions of meteorological variables and ozone concentrations with observations from these air quality studies.
The meteorological process study using a numerical weather prediction model along with observations from Texas AQS 2000 field experiment has been completed. Preliminary results from the study, based on observations and numerical model forecasts during New England 2002 air quality field experiment, have been presented in various working group meetings as well as at the 16th American Meteorological Society Symposium on Boundary Layers and Turbulence, held in Portland, Maine, 2004.

CIRES and NOAA researchers used data collected with airborne, shipborne, and ground-based lidar remote sensors during the Texas 2000 and New England 2002 air quality studies to document the impact of meteorological processes on the temporal evolution and spatial distribution of ozone and aerosol concentrations. Processes that were found to play a key role in the development of high-ozone episodes are the land-sea breeze circulation, boundary layer depth, and horizontal transport and vertical mixing processes.

ETL07.2 MILESTONE:
Develop a web-based trajectory tool that uses measurements from a regional wind profiler network.
A beta version of the wind profiler trajectory tool has been developed by CIRES and NOAA staff. The beta version was tested during the 2004 New England Air Quality Study. Based on input from scientists who used the tool during the study, improvements and modifications will be made in the near future. The tool will be used in a post-experiment analysis mode to document transport corridors that occurred during air quality episodes.

ETL08 Energy

GOAL: Improve the performance of temperature forecasts provided by operational numerical models to allow better prediction of energy loads for the power generation and distribution industry.

ETL08.1 MILESTONE:

Results from observations taken in 2002 during the New England High Resolution Temperature Program (NEHRTP) will be published in 2004 to show how improper treatment of aerosols in the ETA model leads to substantial errors in surface radiation and contributes to excess surface heating and boundary-layers that are too deep.

CIRES investigators contributed to a paper submitted to Monthly Weather Review in December 2003. The paper has been accepted in final form and will be published later in 2004. The results in the paper indicate substantial (approaching 100 W m^{-2}) errors in the average biases between modeled and observed solar irradiance associated with polluted air masses with aerosol optical depths greater than 0.1.

ETL08.2 MILESTONE:

The boundary-layer supersite will include a vertically pointing S-band radar for cloud mapping as well as spectrally-resolved radiation measurements including aerosol optical depth.

CIRES investigators led the design of a boundary-layer supersite at Plymouth, MA for the 2004 New England High Resolution Temperature Program. Measurements from the supersite will be used by NOAA and CIRES investigators to evaluate physical parameterizations of the boundary layer used in operational and research weather forecast models. The site includes a 20-m tower installed in a forest to measure the surface energy budget over the dominant land-use type in the region. An additional focus of the project is to provide detailed measurements of clouds and their impact on the surface radiation budget. Instruments devoted to this topic include a vertically pointing S-band profiler for determining the vertical extent of clouds, a dual-channel microwave radiometer for measuring integrated water vapor and liquid, and a suite of specialized radiation sensors for measuring four-stream radiation (shortwave and longwave), spectrally resolved solar radiation, and aerosol optical depth.

ETL08.3 MILESTONE:

CIRES investigators will contribute results from NEHRTP and other air-quality studies to a report to be published by North Carolina State University for EPA that summarizes policy-relevant research findings in air-quality science.

CIRES investigators updated a section of the Southern Oxidants Studies State of the Science Report (SOS-3). The section summarizes recent findings from SOS studies that pertain to atmospheric dynamics and mixing on urban and regional scales.

Collaborative Campus Research Programs

JOSE-LUIS JIMENEZ

Analysis of Submicron Aerosol Size and Composition in Mexico City during the MCMA-2003 Field Campaign
Funding: NSF Atmospheric Chemistry

Purpose of the project

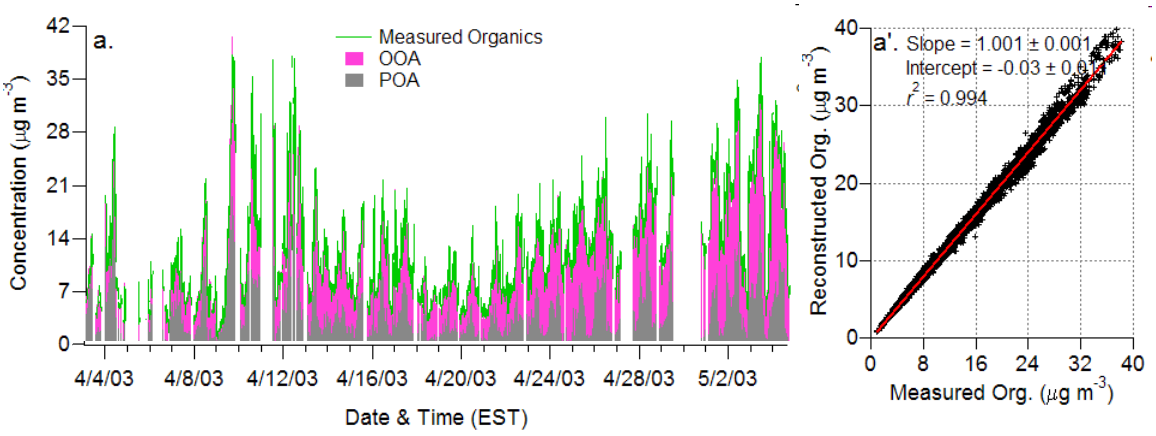
Air pollution due to fine particles is a very serious problem in Mexico City, but the sources of the particles are not well understood. Dr. Jimenez' group participated in a large international field campaign in which many advanced atmospheric chemistry instruments were deployed in Mexico for the first time. They deployed an Aerodyne Aerosol Mass Spectrometer (AMS) and a nano-Scanning Mobility Particle Sizer (nano-SMPS) to Mexico City from March 29 to May 5, 2003, to quantify the number and mass concentrations, size distributions, and chemical composition of the particles.

Accomplishments

In the last year the group has focused on the analysis of the data collected during the field campaign with our instrumentation (~17 Gbytes) as well as data collected by other researchers. The most important finding is that submicron particles are dominated by organic aerosols (~2/3 of the particle mass). They have also been able to estimate the fraction of the organic aerosol which is directly emitted by combustion sources vs. formed in the atmosphere by photochemical reactions using a new procedure developed by the group. The result is that about 60% of the organic particle mass is formed in the atmosphere, rather than emitted directly. In addition only those two components are needed to explain almost all the variability in the organic aerosol mass, as illustrated in the figure below.

Significance

Results represent a quantum leap in the understanding and characterization of submicron particles in Mexico City. They have presented these results to Mexican policy makers, who were quite surprised by the large fraction of photooxidation products in the fine particles. Particle pollution-control strategies now being designed in Mexico will take into account these results. In addition, the scientific community is extremely interested in the primary/secondary organic quantification procedure, which has led to an invitation to the PI to present two talks at the 2004 AGU meeting and one at the 2005 Atmospheric Chemistry Gordon Conference.



STEVEN NEREM

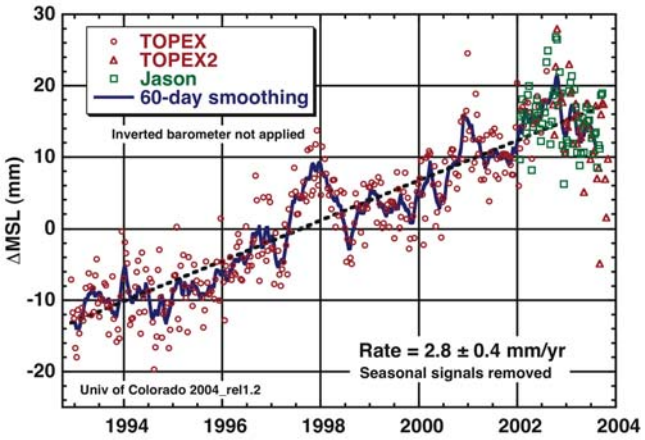
An Investigation of Very Low Frequency Sea Level Change Using Satellite Altimeter Data
Funding Agency: NASA Ocean Surface Topography Science

Description

The purpose of this investigation is to monitor long-term changes in sea level using satellite altimeter measurements from available missions such as TOPEX and Jason, calibrated via comparisons with tide gauge data.

Accomplishments

Recent accomplishments include the calibration and validation of Jason altimeter data, which was launched in December 2001. A website has been set up to publicly distribute these results: *http://sealevel.colorado.edu*. In addition, a review paper on sea level change was recently published in *Reviews of Geophysics*.



Variations in global mean sea level are of special interest, because they are often used as a barometer for climate change. The figure at right shows the most recent estimates of global mean sea level change computed from TOPEX and Jason altimeter from 1992 to the present. The TOPEX and Jason instruments have been calibrated via comparisons to a global set of tide gauge measurements. The observed rate of global mean sea-level change over the last decade is 2.8 mm/year. The error in this estimate is conservatively estimated at 0.4 mm/year, which is dominated by errors in the instrument calibration via the tide gauge measurements. The rate is significantly larger than historical estimates of sea level change (~1.8 mm/year), however it is still too early to determine if this represents an acceleration of sea-level rise due to climate change, or if this simply reflects a decadal variation in sea level that is unrelated to climate change.

Significance

The monitoring of long-term sea level change using satellite altimeter is important for a variety of reasons: 1) global climate models predict rising sea levels in response to increasing greenhouse gases, and thus these measurements can serve to corroborate the climate models; 2) Near real-time monitoring can allow the detection of relatively rapid changes in sea level that might be associated with the melting of mountain glaciers and/or the melting of ice in Greenland and Antarctica; and 3) Monitoring the geographic patterns of sea level change can help identify the cause(s) of the change, and more importantly if those cause(s) are natural or anthropogenic.

INTEGRATING ACTIVITIES

AL10 Scientific Assessments for Decision Makers

GOAL: Plan, lead, prepare, and disseminate assessments for the decision making communities associated with ozone-layer depletion, greenhouse warming, and regional air quality.

AL10.1 MILESTONE:

Assess current capabilities to measure the atmospheric concentration of the harmful substances contained in aerosols.

Knowledge of fine-particle properties and sources are needed to evaluate and manage a wide variety of air quality concerns. These include the concentrations and physical and chemical properties of particles that affect human health, atmospheric visibility, acid deposition and climate change. To undertake credible air quality management, a full understanding of the composition and distribution of particulate matter in the atmosphere and its effects on health and the environment is required. This places rigorous demands on the measurement techniques and the systems that apply them.

To provide this information, a chapter was written as part of the NARSTO Assessment of the Atmospheric Science on Particulate Matter. The chapter briefly describes the types of measurement techniques available, how the information obtained through measurements is applied, and discusses the confidence that can be placed in the data's accuracy and precision.

CDC05b Experimental Climate Services (including Web and Data Services)

GOAL: Couple enhanced observations and research within regions characterized by strong climate variability with analysis of past data and improved modeling. A special emphasis is on determining factors influencing the occurrence of extreme events. The need to better observe, model, and predict the regional consequences of climate change and variability on hydrological variables, on time scales ranging from days to decades, also falls within this goal.

CDC05b.1 MILESTONE:

Apply the results of stakeholder interactions and two-way discussions with water managers and decision-makers to improve our joint climate webpage interface.

CDC used feedback from the Colorado Water Availability Task Force (WATF) and major water providers in the intermountain west to guide development of web-based climate information and products. A monthly updated webpage for the southwestern U.S. (found at *http://www.cdc.noaa.gov/~kew/SWcasts/*) now provides access to experimental regional climate outlooks and serves as a portal for relevant climate products and services within NOAA and other agencies. A webpage was also developed to provide access to selected western states climate resources (*http://www.cdc.noaa.gov/ClimateInfo/*) such as climatologies, current conditions, historic relations, weather and climate forecasts, drought and flood monitoring.

CDC05b.2 MILESTONE:

Co-develop a pilot, rapid-response project in partnership with federal, state and local agencies to improve public services in responding to evolving, high impact climate events, such as the 2002 drought in the western U.S.

CDC took a lead coordinating efforts to work with federal, state, and local government officials and the private sector to support the Western Governors' Association's (WGA) development of the report entitled Creating a Drought Early Warning System for the 21st Century: The National Integrated Drought Information System (NIDIS; available online at *http://www.Westgov.org/wga publicat/nidis.pdf*) The NIDIS document serves as a roadmap and requirements document for the creation, operating, and management of an effective national drought system focused on user needs, observations and data requirements; existing and needed tools; research and science; information dissemination and feedback; and recommendations to implement the NIDIS. The

WGA approved the NIDIS report at their annual meeting in June 2004; NOAA is currently determining the most effective way to act on the recommendation in the report to establish a NIDIS Implementation Team within existing resources.

NGDC07 Educational Standards and Web Access to Scientific Information

GOAL: Facilitate integration of data collected by CIRES and NOAA scientists into the National Science Digital Library (NSDL) system for their research activities by creating compliant metadata for those datasets.

NGDC07.1 MILESTONE:
Work with the DLESE and THREDDS projects to provide real-time catalogs of gridded data products created by NOAA and CIRES scientists.
A data provider/developer attended a DLESE Data Services Workshop to respond to educator and user needs in defining and creating a web data access tool that delivers a meaningful representation of data. Another goal was to bring back ideas about new developments with THREDDS (Themmatic Realtime Environmental Data Distribution System) and other data access tools to compare and contrast current data discovery mechanisms available at NGDC.

An inventory process of NGDC data holdings commenced to determine which datasets are actively being managed and utilized. Based on results, DLESE records will be reviewed and assessed to determine what NGDC datasets are candidates for the online library and evaluate if current records need updating in the DLESE system.

NGDC08 Regional Ecosystems Assessment Data

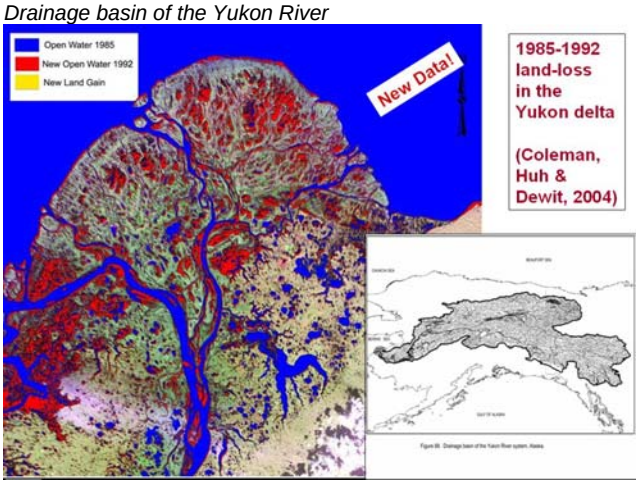
GOAL: Evaluate data and informatics needs to support integrated regional ecosystem assessments and improve the empirical basis for ecosystem assessment and communication to policy and decision makers.

NGDC08.1 MILESTONE:
Assess informatics needs for regional ecosystem assessment and build a partnership for related developments and program support.
During FY03-04, READ (Regional Ecosystems Assessment Data) aligned with programs at the international and national level. There are: (1) Coastal GTOS, where READ developed recommendations for coastal observing and model-based mapping, including a pilot study and data support initiative for global deltas research (soon to be released as part of the C-GTOS Implementation Plan); and (2) the NOAA PRIDE initiative, which supports the NOAA Pacific Islands Climate Assessment and RISA. The READ team contributed to the PRIDE report to Congress is building partnerships in the Western Pacific/Asia region to extend deltas initiatives to issues crossing with coral reef and island socio-ecology. The project team was expanded when funding was acquired in May, 2004 for work that will be completed in May, 2005. READ sponsored a series of organizational meetings in three states to discuss joint interests and develop plans with UNFAO, Coastal GTOS, UNEP/DEWA, NOAA White Water to Blue Water, and the NOAA PRIDE initiative. A plan was adopted recommending two workshops, planned for Fall and Spring of 2005, to support READ's assessment of needs and capacities, and to plan follow-up activities.

Madagascar delta

NGDC08.2 MILESTONE:
Design and demonstrate innovative data and information support capabilities for regional integrated science and assessments.
Data have been acquired and processing, website development, and research support activities began shortly after receipt of project funding in early summer, 2004. Data acquired include: 13 Gb of data were acquired from a three-year NASA study of 42 deltas around the world. 6 Tb of global Landsat data acquired for two years (1990 and 2000) that will extend the NASA study a decade. 30 years of geological research on four deltas in India. Discussions are in progress to acquire or link to distributed sources of additional data for other deltas around the world, including arctic, Mekong, Nile, South Africa, and Colorado deltas. The project will also collaborate with ongoing activities at Louisiana State University and NOAA regarding the Gulf of Mexico and the Mississippi Delta. Preliminary methods have been developed for preparing Landsat, night lights, elevation, and other data to enhance the deltas database and extend its research support potential. Also methods development is underway for spectral mixture analysis and model-based mapping of ecosystem services as "functional clusters."

Drainage basin of the Yukon River



NGDC09 GIS and Environmental Modeling

GOAL: Advance collaborative research and development of environmental modeling and mapping by improving integration of geographic information systems (GIS), prototyping second-generation informatics tools and technologies, and refining integrated assessment frameworks and protocols for application in sound decision making.

NGDC09.1 MILESTONE:
Assess the feasibility of funding and mounting a fifth GIS/EM conference in 2004/5, identify core planning group scientists and Australian on-site collaborator, initiate website for GIS/EM Secretariat and GIS/EM5, and initiate editorial action on Land Use Modeling and Biodiversity Modeling publications
Discussions with NASA, USGS, NOAA, Argonne National Labs, and NSF tied this activity to planning for Biodiversity and Ecosystem Informatics (BDEI)-III, the third in a series of national priority setting workshops aimed at defining bioinformatics needs. As a result of these discussions, BDEI-III may be held in the Boulder area, with links to GIS/EM5. A preliminary BioInformatics Secretariat was established at CIRES. Planning for GIS/EM5 began with discussions of linking it with informatics research and applications in the NOAA-CIRES Regional Ecosystem Assessment Data project, focusing on integrated assessment in the Pacific Islands and Asia region.

NGDC10 Data Mining of Environmental Archives

GOAL: Create tools that allow the mining of vast environmental archives for the purpose of knowledge extraction, data quality control and trend detection.

NGDC10.1 MILESTONE:
Build version 5.0 of the Environmental Scenario Generator and publish the ESG framework in the Data Science Journal.
Version 5.0 was deployed at the AFCCC and is used in operational support of the U.S.A.F.

Collaborative Campus Research Programs

ROBERT SIEVERS

New Inhalable Aerosol Vaccines and Antibiotics
Funding: Colorado Tobacco Fund, Aktiv-Dry L.L.C, Creare, U.S. Centers for Disease Control and Prevention

Many children are dying from infectious diseases in the war zones and populous countries of Asia and Africa. Every day more than 2000 children die from measles, a disease that should be preventable with more stable and effective vaccines not requiring refrigeration. Prof. Sievers and his group are using techniques that they developed in their studies of atmospheric aerosols to develop new, more effective aerosols of vaccines and antibiotics that can be delivered to the pulmonary tract to prevent and cure diseases such as measles and tuberculosis. Administration of measles vaccine aerosols to pulmonary mucosa requires stabilization in glassy sugar matrices and micronization of microparticles, which will hopefully be more effective than subcutaneous intramuscular injections. Similarly, antibiotics useful in treating TB and anthrax have been micronized and the nanoparticles and microparticles characterized for possible needle-free pulmonary delivery.

Use of mixing crosses with three pumps and three fluids allows supercritical carbon dioxide-assisted nebulization and desolvation of composite microparticles containing materials not mutually soluble in the same solvents. This makes it possible to make and coat composite nanoparticles and microparticles with novel compositions not heretofore attainable. Three U.S. patents have been awarded to Prof. Sievers and his colleagues for their work on stabilizing and manufacturing medical aerosols. The U.S. Centers for Disease Control and Prevention has collaborated with him to confirm that live-virus measles vaccine maintains activity throughout aerosolization and drying, using the CU-developed process. Prof. Sievers hopes to conduct preclinical and Phase I human trials of an aerosol measles mucosal vaccine, if funded, in Asia, as part of the “Grand Challenges in Global Health Program.”

MARGARET TOLBERT

Laboratory Studies of Early Earth Hazes
Funding: NASA Exobiology

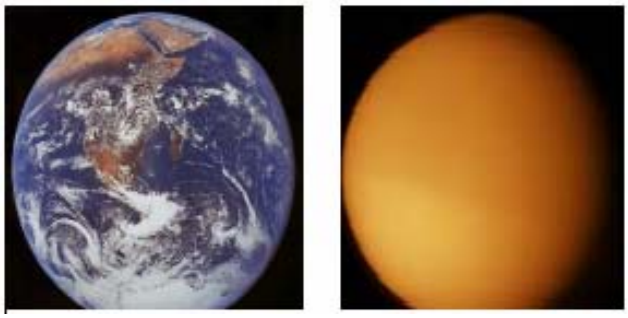
In this project, Prof. Tolbert's group performs novel laboratory experiments to probe the particles that might have been present in the atmosphere at the earliest times in Earth's history. They hope to unravel how those particles might have impacted the climate of early Earth and how they might have influenced the development of life on Earth.

Accomplishments

The warmth of early Earth despite the faint young sun suggests that the primitive atmosphere contained powerful greenhouse gases that allowed for surface temperatures above the freezing point of water. Since the early 1980's it has been thought that Mars was a good model for this early atmosphere, with an atmosphere containing large quantities of the greenhouse gas CO_2. However, geologic evidence does not support high enough CO_2 levels to explain the early warmth of the Earth. More recently, suggestions have been made that the atmosphere may be more like that of Titan, a moon of Saturn. Titan's atmosphere is rich in the greenhouse gas methane (CH_4), and photochemistry high in Titan's atmosphere causes the CH_4 to undergo reactions to form organic polymer particles. These particles have a red-brown color, giving Titan the orange hue observed in photographs. Model calculations suggest that atmospheres containing modest amounts of CH_4 and CO_2 could indeed raise the temperature of early Earth above the freezing point of water. However, there has been essentially no laboratory work to determine if haze particles would form in such an atmosphere, and if so, how they would influence the climate. In the last year, they have begun experiments to characterize particles forming in $CO_2/CH_4/N_2$ atmospheres. They expose gas mixtures to energy sources simulating the sun (an ultraviolet lamp) or lightning (electrical discharge). They then analyze the resulting particles using a novel aerosol mass spectrometer. They find that indeed, haze particles are able to form in early Earth atmospheres, with C/O ratios as low as 0.6. This is much lower than predicted by theoretical models and indicates haze production might have been more prevalent on early Earth than originally believed. Further, they find that as the C/O ratio decreases, the organic particles produced are more oxidized and contain biologically labile compounds. After life arose, the haze may thus have provided food for early biota. Ongoing studies are probing haze formation in the pre-biotic Earth.

Significance

This work helps to understand both the environment in which life arose, and the elements that may have acted to stabilize the Earth's climate over geologic time. While CH_4 may have helped warm the early Earth, the haze produced may have acted to cool the Earth in addition to supplying a rich organic soup to the world's oceans.



Did early Earth resemble present day Earth (left), or perhaps Titan (right)?

Appendices

COMMITTEES

COUNCIL OF FELLOWS

CIRES Council of Fellows is comprised of individuals with an outstanding record of achievement and ability in diverse areas of environmental sciences. They are primarily university faculty, senior research scientists or government scientists who form the core leadership of the institute. Their responsibilities are to: (1) provide leadership at all levels in environmental science, (2) maintain an active scientific research/education program, (3) support the CIRES infrastructure through indirect cost recovery and in-kind contributions, (4) participate in CIRES management, and (5) contribute interdisciplinary expertise and participate in collaborative work. As a group, they personify the concept of collaboration that is the founding principle of the NOAA Joint Institutes Program. Ex-officio individuals include representatives of the Members' Council and CIRES administration

Susan K. Avery
Ben B. Balsley
Roger G. Barry
Roger Bilham
John Cassano
Thomas N. Chase
Shelley D. Copley
Randall M. Dole
David Fahey
Christopher W. Fairall
G. Lang Farmer
Fred C. Fehsenfeld
Graham Feingold
Timothy J. Fuller-Rowell
Alexander F.H. Goetz
Vijay K. Gupta
Ray E. Habermann
R. Michael Hardesty
José-Luis Jiménez
Craig Jones
William M. Lewis, Jr
Peter H. Molnar
Russell K. Monson
Andrew M. Moore
William D. Neff
Steven Nerem
David Noone
Roger Pielke, Jr.
Balaji Rajagopalan
George C. Reid
Douglas S. Robertson
Anne F. Sheehan
Robert E. Sievers
Susan Solomon
Konrad Steffen
Margaret A. Tolbert
Greg Tucker
Veronica Vaida
John M. Wahr
Carol A. Wessman

Affiliates: Ray Fall, Henry Diaz, Pieter Tans

EXECUTIVE COMMITTEE

The Executive Committee assists and advises the director in matters regarding day-to-day management of the institute and makes important decisions and policies affecting CIRES. Members of the Executive Committee include the Associate Directors of the four administrative units for CIRES, two Fellows elected at-large for a two-year term, renewable for one term, and two voting members that are the Members' Council representatives. Staff representatives are ex-officio members of the committee.

Director	Christopher Fairall (9/05)	Carol Wessman (9/04)
Associate Directors	Tim Fuller-Rowell (9/04)	Gerd Hübler (CMC rep)
CIRES Staff (Ex-officio)	Anne Sheehan (9/05)	Donna Scott (CMC rep)

THEME LEADERS

Theme Leaders are Fellows or Senior Scientists who take the leadership role to develop science activities in each of the CIRES Research Theme areas. These science activities help to define new projects, encourage interdisciplinary dialog, and further refine strategic planning. Theme leaders are also responsible for helping to coordinate the science within their themes for reviews and annual reports.

Advanced Modeling & Observing Systems
Konrad Steffen, Michael Hardesty

Climate System Variability
Andrew Moore, Roger Barry

Geodynamics
Roger Bilham

Planetary Metabolism
Shelley Copley, Carol Wessman

Regional Processes
William Neff, Fred Fehsenfeld

Integrating Activities
Roger Pielke, Jr.

MEMBERS' COUNCIL

The Members' Council was created in 1997 to act as an information and policy conduit between CIRES' leadership and the Institute's Members (Associate Scientists, Research Scientists, and Administrative Associates). (See Members' Council Webpage at *http://cires.colorado.edu/members*)

Gabrielle Accatino
Eduardo Araujo
Lucia Harrop
David Costa
Gerd Hübler, *Representative to Fellows/Exec*
David Longenecker
Julie McKie
Theodore Scambos
Donna Scott, *Reresentativep to Fellows/Exec*
Robert Schafer
Christoph Senff
Kelly Stroker

ADMINISTRATION

The Associate Directors are the leaders of CIRES four administrative, divisional units, in which every scientist is represented. These units are aligned with disciplinary expertise. Their responsibilities include dealing with personnel and supervisory issues, financial oversight and spending policies for indirect cost recovery return within their units, and representing the scientific interest of their units to the Executive Committee and Council of Fellows. The director appoints the associate directors for an indefinite term. The Associate Directors for Administration and Science work in central administration focusing efforts in those two branches of activity.

Director: Susan K. Avery
Deputy Director: Konrad Steffen
Associate Directors:
Fred C. Fehsenfeld (Env. Chemistry and Biology)
Roger Bilham (Solid Earth Sciences)
Konrad Steffen (Cryospheric and Polar Processes)
R. Michael Hardesty (Atmos. and Climate Dynamics)

Associate Director for Administration: Jon Rush
Associate Director for Science: Paul Sperry
Acting Director(s) as needed:
Paul Sperry
thereafter: Konrad Steffen
Ben Balsley
William Lewis
Margaret Tolbert
Alexander Goetz

CAREER TRACK COMMITTEE

This committee is charged with consideration of all nominations for promotion within the CIRES career tracks of Research Scientist, Associate Scientist and Administrative Associate. Nominations are made once yearly, and the committee's recommendations are forwarded to the director for consideration and action. *Point of contact: Karen Dempsey.* Additional information on career tracks may be found on CIRES Human Resources site.

COMPUTING ADVISORY COMMITTEE

The purpose of the CIRES Computer Advisory Committee (CAC) is to provide expert counsel and recommendations on technical issues, user support, resource allocations and the establishment of computing policies. That advice is available to anyone in CIRES; however, the primary CAC advisees are the Director and Council of Fellows and the CIRES Computing Facility (CCF) Manager. CIRES staff or the CCF manager, through CAC members, or via a web suggestion page to the CAC chairperson for committee consideration, submits questions, issues and recommendations. CAC also serves as the last resort mediator of disputes between users and the CCF. The CAC membership includes people with diverse expertise that is required to understand and contribute to the CIRES computing decision-making process as well as representing the user groups that are supported by the CIRES Computing Facility. The Director of CIRES appoints the Chair of the committee as well as one other Fellow. Additional members are nominated and selected by the CAC. All members serve a three-year term.

R.E. Habermann, Chair
Thomas Chase
Julia Collins
Ted DeMaria
Rod Frehlich
Kenneth Knowles
Leanne Lestak
Mark Lohaus
Robert Schafer
ex officio:
Graham Mountain
Paul Sperry

DISTINGUISHED LECTURESHIP SERIES

This lecture series is designed to bring outstanding scientists and innovative thinkers who have given serious consideration to environmental and earth system science issues. Coordinators are given the task of putting together this program and hosting the scientists' visit.

Peter Molnar, Chair
Randall Dole
Pieter Tans

EXTERNAL AWARDS COMMITTEE

This group identifies and prepares nominations of CIRES employees for awards offered by the university, professional societies, Federal agencies, national academies, and other organizations.

William Lewis, Chair Alexander F.H. Goetz Carl Kisslinger George Reid

FELLOWS APPOINTMENT COMMITTEE

All CIRES Fellows are subject to periodic review. First-term Fellows are reviewed after two years, and continuing-term Fellows generally every five years thereafter. This committee considers the package of reappointment submitted by the Fellow, which includes a cover letter outlining reasons for continuing as a Fellow and a curriculum vita. The committee prepares its recommendations that are submitted to the full Council of Fellows for consideration and final vote. This committee is also charged with considering the identification and nomination packages of possible new Fellows within the community of scientists at the University of Colorado and NOAA. Nominations for new Fellows are considered once yearly. *Point of Contact: Lang Farmer*

GRADUATE RESEARCH FELLOWSHIP COMMITTEE

Approximately five graduate research fellowships are awarded each year through a CIRES competition. This group serves as the review and selection committee for these fellowships.

Paul Sperry, Chair Jose Jimenez Craig Jones Susan Avery, ex officio

INNOVATIVE RESEARCH PROGRAM

This program is designed to stimulate a creative research environment within CIRES and encourage synergy between disciplines and research colleagues. The intent is to provide an uncomplicated mechanism for supporting small research efforts that can quickly provide concept viability.

Paul Sperry, Chair
Thomas Schlatter

SPACE COMMITTEE

A continuing problem for CIRES is the limited office and laboratory space for employees. This committee provides advice on the best use and distribution of existing space, provides ideas on improvement of space through renovation, and develops options for the planning of future space.

Margaret Tolbert, Chair William Lewis Robert Sievers Ex-Officio: Robert Schubert

VISITING FELLOWS COMMITTEE

This committee is responsible for the review of all applications for CIRES Visiting Fellowships. In the process of this review, the committee makes the decision regarding those best qualified for a fellowship in any given year, and submits that slate to the Fellows Council for final discussion and selection. *Point of Contact: Roger Pielke, Jr.*

INNOVATIVE RESEARCH PROGRAM

The Innovative Research Program (IRP) is designed to stimulate a creative research environment within CIRES and encourage synergy between disciplines and research colleagues. The intent is to provide an uncomplicated mechanism for supporting small research efforts that can quickly provide concept viability or rule out further consideration. The program encourages novel, unconventional or fundamental research that might otherwise be difficult to fund. Funded projects are inventive, sometimes opportunistic, and do not necessarily have an immediate practical application or guarantee of success. This program supports pilot or exploratory studies where results can be quickly acquired. Activities are not tightly restricted and can range from instrument development, lab testing, and field observations to model advancement.

CIRES-wide competitions are conducted each year to foster an innovative research environment where risk-taking is allowed and even encouraged. Winners are selected by an interdisciplinary team and results are presented the next year at a poster reception. The following pages provide summaries of the topics below.

2003-2004 IRP PROJECTS:

Compound Disturbance in Managed Landscapes: Wind, Fire and Logging in the Colorado Subalpine Forest
Cristina Rumbaitis-del Rio, Carol Wessman

Web-based Geospatial Data for Aeronomy Lab Field Missions
Dan Kowal, John Cartwright and Greg Frost

Can Directional Seismic Noise be used to Hindcast Ocean Waves?
Vera Schulte-Pelkum, Andy Moore, John Wahr, Paul Earle

Does Petrochemical Ethylene Enhance the Release of Reactive VOCs by Urban Vegetation?
Joost de Gouw and Ray Fall

Using $^{14}CO_2$ to Measure the Fossil Fuel Combustion Component of Atmospheric CO_2
John Miller & Pieter Tans (CMDL) with Scott Lehman (INSTAAR)

Compound Disturbance in Managed Landscapes: Wind, Fire and Logging in the Colorado Subalpine Forest

Cristina Rumbaitis-del Rio, Carol Wessman

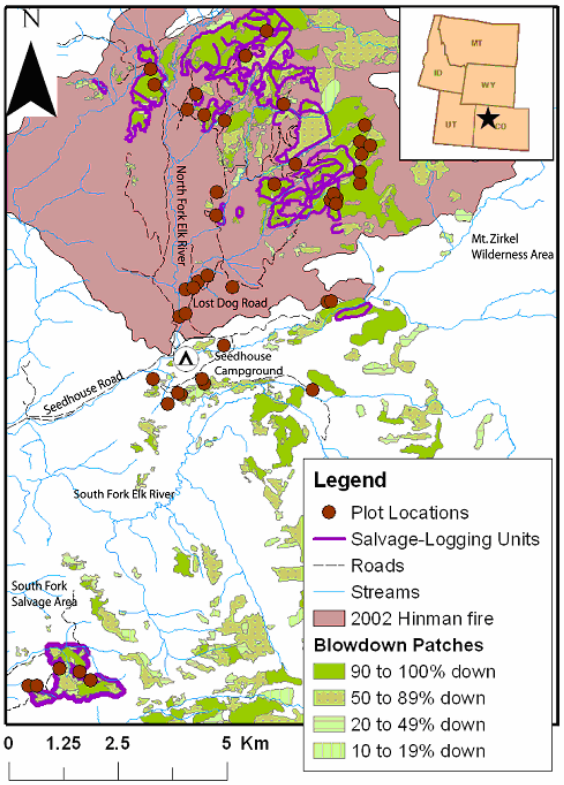
Natural disturbances of significant magnitude typically occur on 50-100+ year cycles. Increasingly, ecosystems are exposed to multiple disturbances as human land management practices fold into natural disturbance regimes, perhaps magnifying system-scale stresses. These data are the groundwork for a long-term study of the components of ecosystem resilience in subalpine forests, and the effects of pre-disturbance conditions on post-disturbance regeneration dynamics. This work will contribute to general ecological theory on the concepts of resilience thresholds in dynamic
ecosystems.

Natural disturbances in forest ecosystems such as fire and wind can restore landscape heterogeneity and structural complexity important to sustaining forest vitality and economic resources. However, if disturbances occur in rapid succession, regeneration patterns and mechanisms are much less predictable than after a single disturbance, and novel successional pathways are possible. Compound disturbances may stress forest ecosystems to the point that the resilience or ability to respond to disturbance is crippled, thus shifting successional trajectories from forest to meadow
communities.

The largest known blowdown ever recorded in the Rocky Mountain region occurred in Colorado's Routt National Forest in 1997. Two years later, the U.S. Forest Service began salvage-logging operations in selected areas. In 2002, the second largest fire during a record fire season in Colorado consumed a large portion of the area. This research seeks to understand the interactive effects of rapidly sequenced disturbances on regeneration and biogeochemical dynamics of subalpine forest ecosystems.

Research by a CIRES graduate student in this area of the Routt demonstrated that salvage-logging following catastrophic wind disturbance resulted in a highly modified ecosystem that was compositionally and functionally different from unlogged blowdown areas. Salvage-logging in wind-disturbed areas reduced net nitrogen mineralization rates in soil, eroded and compacted the organic soil horizon, and significantly reduced understory vegetation cover and tree seedling density. Other research has shown that regeneration may fail under these conditions, resulting in a shift from coniferous forest vegetation to subalpine grassland communities, which can preclude conifer establishment for a century or more.

Based on research in 2003-04 funded by the CIRES IRP program, they are establishing a longer-term study of forest resilience and regeneration in this area. Initial work in the first year following the 2002 fire study suggests that initially, the effects of a severe fire tend to "erase" the effects of previous disturbances on soil properties, and nitrogen cycling. However, with time, the effects of disturbances that occurred prior to the wildfire may become more pronounced. Continued work in this study area will follow regeneration dynamics to further establish if post-fire regeneration dynamics are qualitatively or quantitatively different as a result of pre-fire disturbance histories.



Map of the expanded study area in northwestern Colorado. Inset shows location of study area in the Rocky Mountain region. Data layers provided by the U.S. Forest Service, Rabbit Ears Ranger District, Steamboat Springs, CO.

Web-based Geospatial Data for Aeronomy Lab Field Missions

Dan Kowal, John Cartwright and Greg Frost

Project Goals

This cross-disciplinary collaboration between two NOAA Boulder organizations, the National Geophysical Data Center (NGDC) and the Aeronomy Laboratory (AL), combines the initiatives defined in the research theme of *Advanced Modeling and Observing Systems*. Two primary goals of this collaboration include:

- NGDC goes beyond its defined mission of data stewardship to a new role of supporting the entire AL observation process including mission planning, data collection, data sharing, analysis, presentation and publication.
- The partnership provides AL with a more efficient means to contribute research on air quality and convey its results to national and international scientific community.

Project Objectives

Use a Geographic Information System (GIS) to integrate and present emission inventory data consisting of different structures and formats:

- Point sources such as power plants and factories.
- Area sources like cities and agriculture.
- Mobile sources like motor vehicles and ships.
- Biogenic emissions from vegetation and soil processes.

Visualize emissions of gaseous compounds and particulates in a geographic context.

Create analysis tools for field mission planning and post-mission data analysis:

- Include a variety of geographic and science data layers for comparisons and reference.
- Offer a venue for interpreting atmospheric observations compared with emission inventories.

Project Outcomes - Impact

The Emissions Mapviewer:
http://map.ngdc.noaa.gov/website/al/emissions

Emission Inventory Analysis and Mission Planning

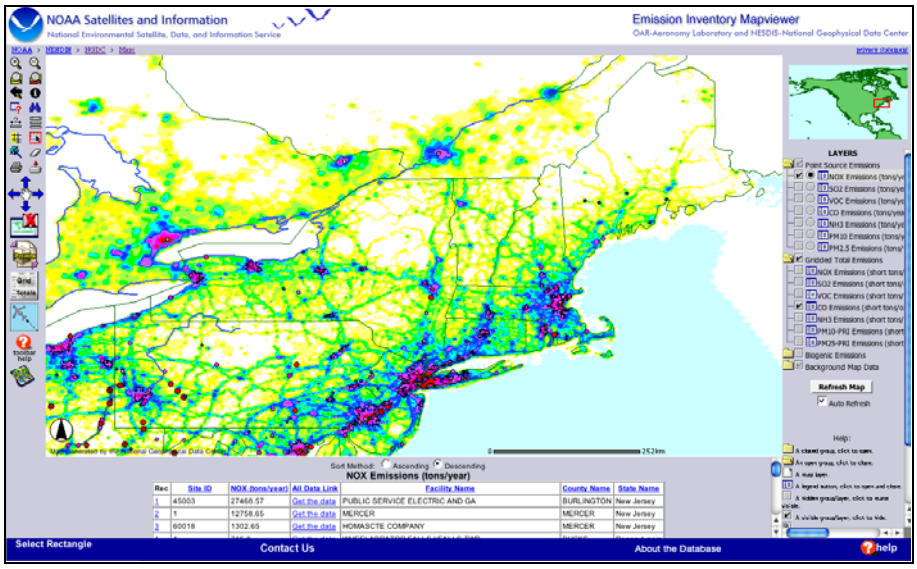
- NGDC established a flexible framework for AL to use in current and future field missions.
- A process for updating emission data and adding additional reference layers is now in place. This GIS application allows AL to validate and correct the locations of point sources, visualize and evaluate inventories in a user-friendly manner, and easily extract emissions for specific sources and over regions of interest. The display of anthropogenic and biogenic emissions along with a suite of reporting and planning tools (Grid Totals Report, Point Data Extract and Flight Track Upload) assisted AL in flight planning during its summer 2004 field program, NEAQS-ITCT (New England Air Quality Study - Intercontinental Transport and Chemical Transformation).

Value-added Products in Support of NEAQS-ITCT

- NGDC prepared a desktop GIS version of the mapviewer for the NOAA ship *Ronald H. Brown*.
- NGDC created an access mechanism for AL to retrieve data from its Fire Detection Archive. AL scientists generated animations of projected plumes of CO (Carbon Monoxide) transported across the U.S. to Europe based on the fire data (last 24 hours) from the archive.
- A WIST (Web Image Slide Tray) tool was created for ETL as a proof-of-concept to compare station meteorological data.

Future Directions

- Incorporate real-time displays of ambient observations and integrate trajectory (pollution plume) models into the mapviewer.
- Increase collaboration with AL and apply above advancements into the mapviewer by participating in the Texas Air Quality Study in 2006



Emission Inventory Mapviewer

Can Directional Seismic Noise be used to Hindcast Ocean Waves?

Vera Schulte-Pelkum (CIRES/Geology), Andy Moore (CIRES/PAOS), John Wahr (CIRES/Physics), Paul Earle (U.S. Geological Survey)

Overview

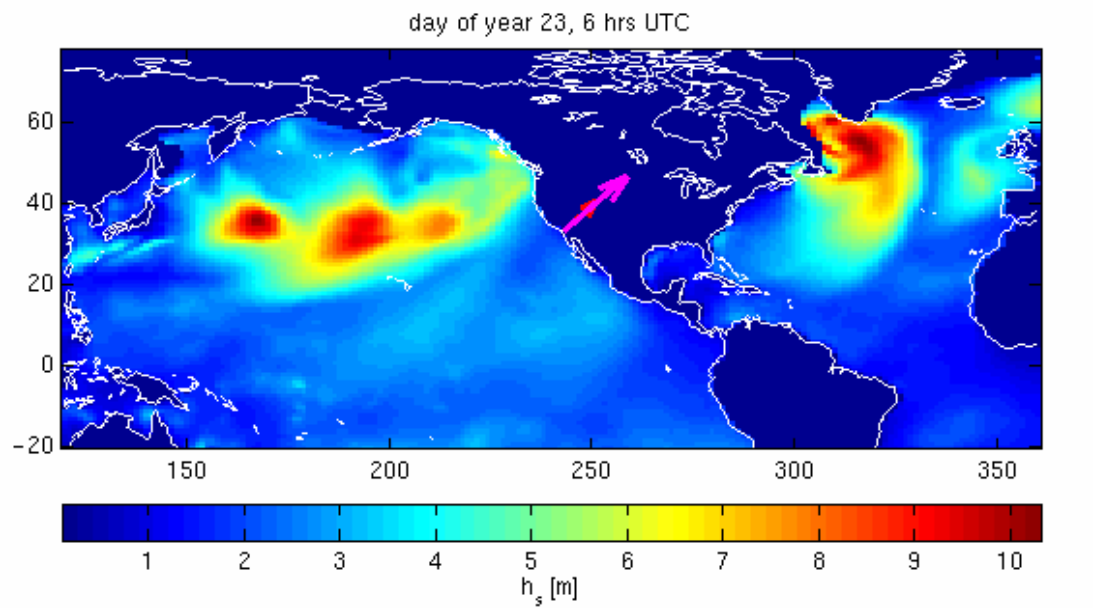
When ocean waves hit coasts, they generate seismic energy that travels in the Earth's crust far into the interior of continents. Seismic stations on land register this continuous 'hum' at frequencies between 5 to 25 seconds. Traditionally considered noise by earthquake seismologists, these so-called 'ocean microseisms' attracted interest in meteorology in the 1950s, before satellite data became available as a better way to track offshore storms. The interest was revived recently in the context of global climate change, when several groups realized that seismic records predate buoy wave height records by many decades, opening the possibility to hindcast wave heights in order to investigate whether the oceans have become stormier in the last century. While attempts to use seismic noise as a proxy for historical wave climate have been made, the methods were restricted to analysis of noise amplitude, with no control over where the ocean microseism was generated. Researchers developed two methods to calculate the direction as well as the amplitude of ocean-generated seismic noise – one requiring a seismic array, the other a single three-component station.

Findings

They analyzed continuous data at stations in the western U.S. from 1997 to 2004. Coupling from ocean wave to seismic energy predominantly occurs when swell interacts with its reflection off a coastline. Previous wave hindcasting studies assumed that this process occurs along the entire coast near a seismic station on land, so that noise conditions at the station reflect an average of regional wave heights. In contrast, these results show that a few discrete spots along the coast generate most of the seismic energy, and that the magnitude of coupling depends on the storm tracks. Large swells generated seismic noise that propagates across the continent; they found several north Atlantic storms dominating noise conditions at an array in southern California every year.

Impact

Findings indicate that directional analysis is important to avoid biases in historical wave climate analysis, and should influence future wave hindcasting studies. This method is now applied in real-time monitoring for several seismic arrays, including the future EarthScope USArray. While earthquakes occur only sporadically in most areas, the ocean microseisms are a continuously available signal, and can be used to check calibration and polarity of seismic stations at any time. Real-time noise directions and wave maps will be accessible on websites at the Scripps Institution of Oceanography starting late this year. They were also invited to participate in an attempt funded at JPL to use ocean microseism as a continuous signal for the analysis of Earth structure in regions where earthquakes are scarce.



Noise directions at a seismic array in southern California (red and pink arrows), pointing to a source (along the great circle path) in Labrador, where a large storm swell is hitting the coast. Color contours in the oceans and the color scale on the bottom show significant wave height (the height of the tallest 1/3rd of waves) from an ocean wave model provided by NOAA.

Does Petrochemical Ethylene Enhance the Release of Reactive VOCs by Urban Vegetation?

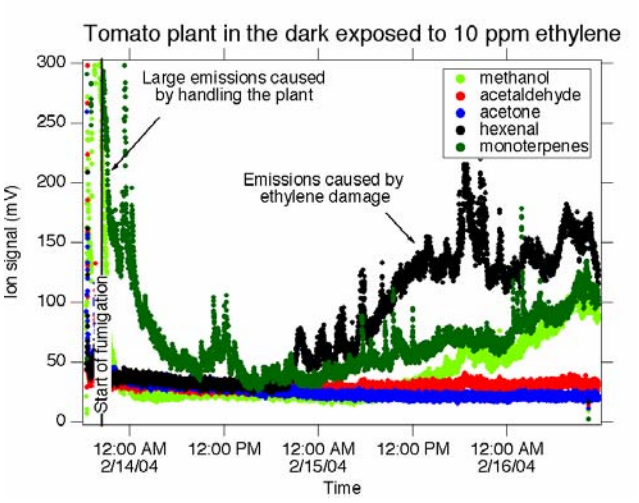
Joost de Gouw and Ray Fall

Statement of the problem and research plan

Most plants form small amounts of the volatile hormone ethylene (CH_2=CH_2), which plays a key role in controlling plant growth and development, and the ripening of fruit. However, the exposure of plants to enhanced ethylene, as occurs in the vicinity of petrochemical plants, may result in damage, such as defoliation, inhibition of growth and reduced flower and fruit production. It is well known that the Earth's vegetation is an important source of reactive volatile organic compounds (VOCs) to the atmosphere, and these VOCs can play a significant role in the formation of ozone and aerosol in polluted air. This problem is all the more opportune because of the surprising abundance of ethylene downwind of petrochemical plants in the Houston area and ethylene's significance for regional ozone pollution, as discovered by NOAA Aeronomy Laboratory scientists during the 2000 Texas Air Quality Study.

Questions arising from these observations are:

1. When green plants are exposed to and damaged by anthropogenic ethylene, do they release reactive VOCs that may contribute to air pollution episodes?
2. Does the tissue damage reduce rather than increase the emissions of reactive VOCs?
3. Are there "signature" VOCs that indicate plant exposure to ethylene?



The research plan was to expose various green plants to enhanced levels of ethylene in a Teflon flux chamber and measure the VOCs released by the plant as a function of time with a new on-line method, Proton-transfer Ion-Trap Mass Spectrometry (PIT-MS). In addition, a novel instrumental aspect of the proposed work is that they attempted to measure the levels of ethylene in air by real-time by photo-acoustic spectroscopy (PAS). The experiments were done in collaboration with an expert in detecting ethylene and other trace gases by PAS at the University of Nijmegen in the Netherlands.

Results

Of all plants species studied here (tomato, potato, bell pepper and carnation) only tomato plants emitted significant VOCs when damaged by ethylene. The tomato variety studied in detail (Ace 55) exhibited wilting when exposed to an ethylene-generating defoliant, and in the dark when exposed to 10 ppm ethylene produced strong signals for several VOCs: methanol, hexenals, and monoterpenes (*see figure below*). Experiments with tomato plants showed markedly different behavior in light and dark conditions, and in each case 10 ppm ethylene killed the plants over the course of the experiments. The other plants tested did suffer massive damage from the ethylene exposure, but did not alter their VOC emissions. Ethylene in ambient air (Boulder) was measured by both PAS and GC-FID. The two methods showed very good agreement, even at ethylene levels below 2 ppbv.

Conclusions

- Some ethylene-sensitive plants release reactive VOCs, hexenals and monoterpenes when exposed to ethylene, dependent on light or dark.
- These VOCs may be a "signature" of ethylene exposure in urban areas.
- PAS is a valid method for real-time measurements of ethylene in ambient air.

Using $^{14}CO_2$ to Measure the Fossil Fuel Combustion Component of Atmospheric CO_2

John Miller & Pieter Tans (CMDL) with Scott Lehman (INSTAAR)

One of the largest components of the contemporary carbon cycle is the 7 billion tons of C that enters the atmosphere as a result of fossil fuel combustion. While this flux is known to within 10% at global and annual scales, from economic inventories, fluxes at regional and smaller temporal scales are not well characterized. To determine the fossil flux at smaller scales, like those of interest in the North American Carbon Program (NACP), it would be beneficial to measure the fossil fuel contribution directly. Currently measured tracers like SF_6 and CO can be used, but these methods may suffer from a variety of biases, especially on small scales. Alternatively, since fossil fuel CO_2 has zero ^{14}C content, in contrast to all other reservoirs, $^{14}CO_2$ measurements are an extremely robust tracer for fossil fuel CO_2. The following table summarizes the extent of the biases and uncertainty in using CO and SF_6 to interpret observed atmospheric CO_2 gradients, relative to the use of $^{14}CO_2$. Preliminary results indicate that the CO and SF_6 tracer methods consistently underestimate the fossil-fuel component of the CO_2 gradient. In examples, which are from wintertime, the fossil fuel component explains most or all of the gradient. The one case in which there is an overestimate probably results from more complex air mixing than assumed in the calculation. These results do not bode well for the use of CO and SF_6 as tracers for fossil-fuel CO_2. Not only are the back-calculated CO and SF_6 emission ratios outside the bounds that inventories would predict, but they show significant variations**.**

Method	Harvard Forest 11th Feb, 2004	Harvard Forest 23rd Mar, 2004	Sugarloaf-Niwot 7th Jan, 2004	Boulder-Niwot 7th Jan, 2004	Niwot Ridge 20th Jan, 2004	Niwot Ridge 2nd Mar, 2004
CO_2 increase	4.3±0.4	4.9±0.4	13.3±0.4	82.9±0.4	9.0±0.4	5.1±0.4
^{14}C δ_{bio}=135‰	4.3±1.2	4.5±1.2	16.5±1.2	75.8±1.2	9.0±1.2	4.0±1.2
^{14}C no biological flux	4.3±1.1	4.4±1.1	16.6±1.1	75.7±1.2	9.0±1.1	3.9±1.1
CO R_{CO}=10	3.6±0.3	3.7±0.3	14.4±0.3		6.8±0.3	4.8±0.3
CO R_{CO}=20	1.8±0.2	1.8±0.2	7.2±0.2		3.4±0.2	2.4±0.2
SF_6 R_{SF6}=0.083	1.0±0.7	2.1±0.7	2.0±0.7	7.47±0.7	2.4±0.7	1.6±0.7
Calculated indirect tracer ratios using ^{14}C derived F_f						
R_{CO}	8.40	8.28	8.70		7.58	12.03
R_{SF6}	0.019	0.039	0.010	0.008	0.022	0.033

The table above shows the observed CO_2 gradient in the first row, followed by the fossil fuel component of the gradient as calculated by $^{14}CO_2$ (two methods), CO (two methods) and SF_6. The units are all ppm of CO_2, except for the last two rows which are emissions ratios of ppb/ppm and ppt/ppm, respectively. The $^{14}CO_2$ calculations, highlighted in yellow, are unbiased, in contrast to the other methods of calculation. In the last two rows, the inferred CO and SF_6 emission ratios are shown for each gradient, calculated using the 'true' fossil-fuel component as derived from $^{14}CO_2$ data. The first four columns show vertical gradients and the last two show the differences between upslope events and typical background values

VISITING FELLOWS PROGRAM

The following pages present summaries of CIRES' visiting fellows who were completing their work at the time of this report. Details of this program were covered earlier in this report.

CARMALA N. GARZIONE

Ph.D. University of Arizona
SPONSOR: Peter Molnar
TITLE: Late Cenozoic climate forcing from Asian aeolian contributions to the North Pacific
THEME: Geodynamics

Dr. Garzione spent the past year working with CIRES and the Geological Sciences department during a junior faculty leave from the University of Rochester. Over that year, while working with Peter Molnar, she broadened her perspective, and enjoyed a productive year of research.

This fellowship enabled Dr. Garzione to spend two and a half months doing fieldwork in Bolivia and China (two trips to Bolivia and one exploratory trip to China). Five papers were written for submission to referee journals and conference proceedings. Based on the preliminary data resulting from the China field trip, a large multidisciplinary proposal will be submitted to the NSF-Continental Dynamics program in November 2004. In addition, Drs. Molnar and Garzione are working together on a new project, based on her Bolivia research, that will likely result in an additional paper within the next year.

Articles:

Garzione, C.N., Dettman, D.L., and Horton, B.K., 2004, Carbonate oxygen isotope paleoaltimetry: Evaluating the effect of diagenesis on estimates of paleoelevation in Tibetan plateau basins: *Palaeogeography, Palaeoclimatology, Palaeoecology*, in press.

Libarkin, J.C., and Garzione, C.N., Uncertainty approximations in carbonate oxygen isotope paleoaltimetry: *Journal of Geophysical Research–Earth Surface*, in review.

Garzione, C.N. and Ikari, M., Loess as a dominant source of fine-grained sediment to the Linxia basin in NE Tibet over the past 29 Ma from Nd isotopes: *Chemical Geology*, in preparation.

Abstracts:

Garzione, C.N., 2004, INVITED: The effect of altitude on the isotopic composition of paleosols: Examples from southern Tibet and the Bolivian Altiplano: GSA Abstracts with Programs, in press.

Garzione, C.N., and Libarkin, J.C., 2004, Oxygen isotope evidence for rapid late Miocene uplift of the Bolivian Altiplano: GSA Abstracts with Programs, in press.

Proposal:

Continental Dynamics: Upward and Outward: Tibetan Plateau Growth and Climate Consequences, $2,234,506 (P.I., Molnar, P., co-P.I.s Burbank, D., Clark, M., Farley, K., Garzione, C., Kirby, E., Roe, G., and Zhang, P.)

ANN HENDERSON-SELLERS

Ph.D. University of Leicester, UK
SPONSOR: Roger Barry
TITLE: Examining the use of isotopes (stable and radioactive) as probes and tracers of environmental systems and processes
THEME: Climate Systems Variability, Advanced Observing and Modeling Systems and Regional Processes

Dr. Henderson-Sellers spent a six-month visiting fellowship at CIRES during the latter half of 2003. She proposed to examine the use of isotopes (stable & radioactive) as probes and tracers of environmental systems and processes. Specifically:

- to undertake novel investigations of isotopes as sensitive tracers of land-atmosphere exchanges (probably in tropical basins and/or semi-frozen soil-vegetation systems) jointly with CIRES staff and, if possible and appropriate, their graduate students; and
- to establish and test the use of isotopes as evaluation tools for earth system model simulations (of continental processes) and thereby create and nurture an ongoing relationship between CIRES and ANSTO (the Australian Nuclear Science & Technology Organisation).

The research planned and undertaken on stable water isotopes was well received and will add real value to model simulations and their validation in the context of applications to global and regional models of climate and its variations.

Dr. Henderson-Sellers' strongly interdisciplinary research project is integrative across three CIRES Research Themes, namely: Climate Systems Variability, Advanced Observing and Modeling Systems and Regional Processes. Specifically, she contributed to novel isotopic-based insight into investigations of the role of the continental hydrological cycle in:

- self-regulation of the global climate as portrayed in a hierarchy of models;
- sustainability of large basin dynamics (including extreme rain and stream flow events); and
- model-based inference algorithms.

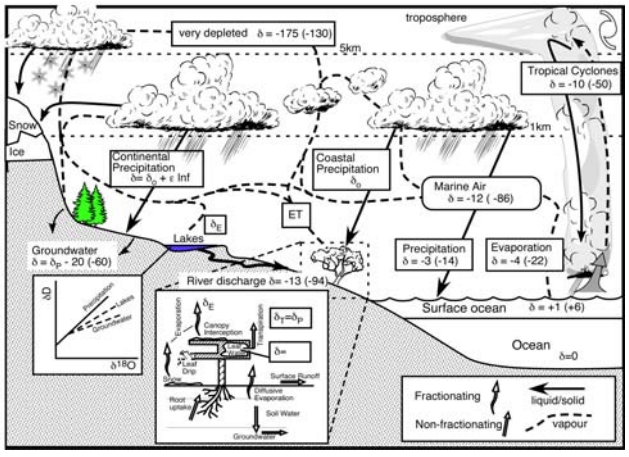
Schematic of the global hydrological cycle showing approximate depletions in $\delta^{18}O$ (and δD in parentheses). Depletions increase as altitude and distance from the ocean increase and as temperature decreases. Inputs of heavy isotopes come from continental non-fractionating processes (e.g. transpiration and evaporation of canopy-intercepted water)

Specific collaborations were conducted with Dr. R. Barry (cryosphere and isotopes), Dr. T. Chase (and jointly with K. Nordstrom, EMIC simulations and isotopic validation), Dr. R. Pielke, Jr. (climate and energy policy), Dr. James White (isotopes and environment) and Dr. T. Zhang (freeze/thaw cycles in soil parameterization. She has also been able to pursue her interest in greenhouse policy-related issues being studied in Geography and Science Policy Center seminars.

This fellowship was planned to exploit stable water isotope data in novel ways to establish objective validation of and/or improvement in existing models, ultimately reducing uncertainty in future predictions. The innovative isotopic analysis begun during this fellowship has the demonstrated potential to reveal impacts of future land-use and climate change on the hydro-climate of the Amazon, the Lena, the Murray Darling and elsewhere.

Presentations, Papers and Meetings:

12 Talks given
14 Papers published, in press, or submitted
7 Presentations at various venues
3 Meetings attended:
NCAR Community Climate System Model Isotopes Meeting, Breckenridge, 22-26 June, 2003
GLASS: GEWEX Land Atmosphere System Study, Tucson, 25-27 August, 2003
AGU Annual Meeting, San Francisco, December, 2003



PAVLOS KOLLIAS

Ph.D. University of Miami
SPONSOR: Chris Fairall
TITLE: An advanced sea-going observing system suitable for the study of marine boundary layer clouds
THEME: Regional Processes and Advanced Modeling and Observing Systems

During his CIRES visiting fellowship, Dr. Kollias collaborated with scientists from the Clouds, Radiation, and Surface Processes Division of the NOAA Environmental Technology Lab. Marine boundary layer clouds, and marine stratocumulus in particular, strongly influence global climate because their high albedo (compared with the ocean background) give rise to large deficits in absorbed solar radiative flux at the top of the atmosphere, while their low altitude prevents significant compensation in thermal
emission.

During the fellowship, Dr. Kollias examined observations from past field experiments (e.g., East Pacific Investigation of Climate, EPIC 2001). Data revealed that the Doppler measurements from the ship-borne cloud radar were contaminated by the ship motion and thus were of little or no use. In addition, the data processing was slow; the velocity Nyquist boundaries imposed on the operational characteristics of the cloud radar were very narrow; pulse compression, a technique that is often used to enhance the sensitivity of radars without losing range resolution, was generating artifacts near the cloud boundaries; and finally strong radar signal return from drizzling boundary layer clouds were saturating the radar receiver, thus introducing errors in the Doppler moments.

These findings suggested the need for substantial changes in the operational strategy of the cloud radar. These changes are now possible due to a recent upgrade of the signal processing hardware. Furthermore, in order to alleviate some of the pulse compression artifacts and maintain high sensitivity in the boundary layer, NOAA/ETL proceeded with the decision to develop a new cloud radar operating at 94-GHz, a higher frequency that offers higher sensitivity without the use of pulse compression.

Dr. Kollias' fellowship resulted in joint proposals with the Univ. of Miami. The proposals are based on the deployment of the Univ. of Miami 94-GHz Doppler radar and NOAA/ETL instruments such as microwave radiometers and ceilometers in an effort to evaluate the potential of this new instrument synergy for the study of boundary layer clouds over ocean.

Furthermore, an innovated scanner/stabilizer that would provide ship-motion compensation will be developed in the fall of 2004 as a result of the NOAA/ETL and Univ. of Miami partnership and will be deployed during the Rain In Cumuli over Ocean (RICO) experiment (January 2005). Finally, graduate students from the Univ. of Miami will participate in two fall cruises on the NOAA ship *Ronald H. Brown* with another UM cloud radar and scientist from NOAA/ETL. The aforementioned activities will lead to the development of state-of-the art radar for ship-borne observations with high sensitivity, excellent sampling capability and ship-motion compensation.

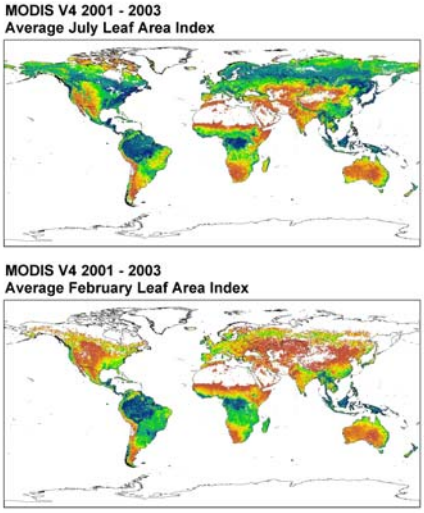
During the fall of 2003, Dr. Kollias participated with the ETL group on the annual cruise for the recovery and replacement of the WHOI buoy at the southeastern Pacific. During the cruise, they collected detailed observations of the marine boundary layer, clouds and surface fluxes. The results from the cruise were reported in a forthcoming GRL article. During the cruise the MBL structure was characterized by a strong capping inversion, periods with well mixed conditions and marine stratus, clear-sky periods and periods with moderate vertical gradients of potential temperature and mixing ratio that overlap with periods of small cloud fractional coverage, decoupled layers and low cloud-base shallow cumuli clouds. The lifting condensation level (LCL) showed strong variability consistent with the variability of the MBL. Clouds with thickness of more that 250 m had drizzle below the cloud base, especially during nighttime. Large periods of clear skies were observed at the WORS buoy location, especially just after the solar flux maximum. The aerosol size distribution measurements generally exhibited a bimodal structure. However, abrupt changes in the aerosol size distribution were also recorded, corresponding either with the presence of drizzle (and a depletion of the accumulation mode) or the presence of clear skies (and an increase in the Aitken mode). The stratocumulus observed during the five-day station at the buoy location revealed a far more complex picture from the one captured during the EPIC cruise to this same location in 2001.

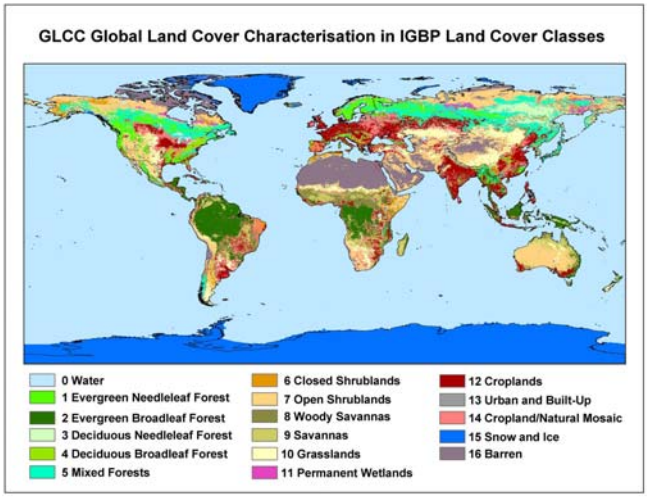
PETER LAWRENCE

Ph.D. University of Queensland
SPONSOR: Tom Chase
TITLE: Biosphere and surface hydrology play on weather and climate
THEME: Advanced Modeling and Observing Systems/Climate System Variability

The main focus of Dr. Lawrence's research as a visiting fellow at CIRES has been investigating the role of the land surface in the climate system and the impacts that human modification of the land surface may have on regional and global climate. The major achievement over the last seven months has been the representing of current day land surface conditions in the Community Land Model (CLM 3.0) of the Community Climate System Model (CCSM 3.0) from recent satellite observation. This work was presented at the NCAR CCSM annual meeting in July as well as at the MODIS vegetation workshop in August.

The motivation for this work arises from *Tian et al.* (2004) and *Oleson et al.* (2003) who have recently identified significant differences between the current land-surface parameters of the CLM, and Moderate Resolution Imaging Spectroradiometer (MODIS) satellite mapping of Leaf Area Index (LAI), Fraction of Photosynthetically Active Radiation (FPAR), and land-surface albedo. To assess how these differences in land-surface representation have impacted the climate modeled in the CLM and the CCSM, he has developed new land surface parameters at a fine scale (0.05 degree) from land surface data derived from NOAA Pathfinder Advanced Very High Resolution Radiometer (AVHRR) and MODIS satellite data to perform climate sensitivity experiments in CCSM 3.0 with the two sets of parameters.





The sensitivity experiments are currently being analyzed to assess how the new land surface representation impacts the climate of the CCSM as a framework for performing future land cover change experiments.

DOROTHEA PANAYOTOU *(Research and Education Fellow)*

Ph.D. University of California, Davis
SPONSOR: Susan Buhr, CIRES K-12 Outreach Program
TITLE: Watersheds in the classroom, and a study of the effects of fire on aquatic ecosystems
THEME: Integrating Activities

During her time as a Research and Education Visiting Fellow at CIRES, Dr. Panayotou conducted two projects:

1) An education project for middle and high school science teachers; and
2) A scientific study of the effects of fire on aquatic ecosystems

Her year-long project in Education and Outreach at CIRES had one main purpose: To help teachers effectively teach about place-based watershed education in their classrooms. She created a website titled, "Watersheds in the Classroom." Her main project goal was to create a web-based "how-to guide" for teachers to implement water science topics such as limnology, watershed science, stream ecology, aquatic insect biology, and earth science, into K-12 classrooms. This resource lessens barriers for K-12 teachers, by providing content knowledge, local resources and data, and ties to field methods. The website focused on place-based education, in addition to providing general scientific content on important concepts in the water resources field. The website was reviewed by both teachers and scientists. It can be seen at *http://cires.colorado.edu/~k12/watershed/home.htm*.

The specific objectives for the project include:

1) Provide teacher training in limnology;
2) Create a website for teachers that provides instructional resource materials; and
3) Support Earthworks teachers in using this website and incorporating limnology activities into classrooms.

Dr. Panayotou attended three conferences during which she publicized her CIRES work and promoted the Research and Education Fellowship (REF) opportunity. In April, she attended the Colorado Foundation for Water Education's First Annual 2004 Water Educators' Conference. She presented the website and made several contacts with individuals from various governmental agencies and non-profit organizations who were interested in publicizing and/or using the website. A talk was also given at the North American Benthological Society meeting in Vancouver, British Columbia in June 2004. The talk titled, "CIRES Outreach Program: Providing Opportunities for Scientists' Success in K-12 Education," included:

- An overview of CIRES Outreach and Education program
- An explanation of the Research and Education Fellowship, and
- A presentation of the website, "Watersheds in the Classroom"

Dr. Panayotou's scientific research project was conducted under the mentorship of Dr. William M. Lewis, Jr. and the CU Center for Limnology. Increased fires in the state of Colorado and nationally have prompted a concern over the environmental consequences of fires on stream water quality and its biota. After the Overland Fire in Jamestown, Colorado, she arranged to collaborate with Sheila Murphy, from the United States Geological Society (USGS) on a study to improve understanding of this wildfire on stream ecosystem health. The Overland Fire burned approximately 4000 acres in Boulder County, Colorado in October 2003, including portions of the Saint Vrain Creek Watershed and the Lefthand Watershed. These watersheds supply drinking water to the City of Longmont and the Lefthand Water District. Sites were selected on the South Saint Vrain Creek and Lefthand Creek for monthly monitoring. Fire severity mapping by the U.S. Forest Service indicated that much of Central Gulch, located in the South Saint Vrain Creek Watershed, and Spruce Gulch, located in the Lefthand Creek Watershed, was moderately or severely burned. Therefore, these ephemeral streams were selected for study. Beginning in February, monthly samples were collected from Central Gulch, Spruce Gulch, South Saint Vrain Creek upstream and downstream of Central Gulch, and Lefthand Creek upstream and downstream of Spruce Gulch. Chemical parameters were measured in the field that included discharge, water temperature, pH, dissolved oxygen, and specific conductivity. Macroinvertebrate samples were collected and are being identified and evaluated for relative abundance, species richness, and diversity. Analysis is underway with the final results to be presented to the local community and published in a peer-reviewed scientific journal.

ANDREAS STOHL

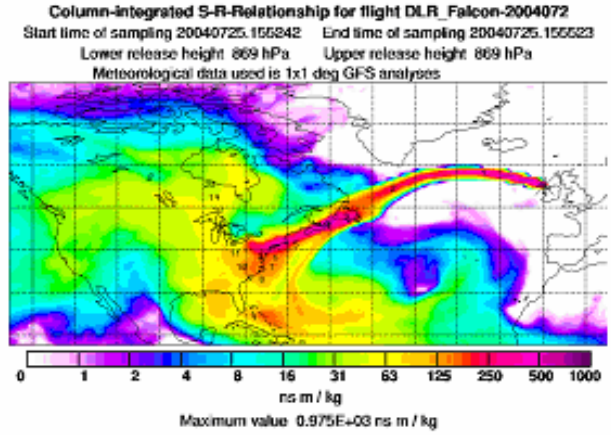
Ph.D. University of Vienna, Austria
SPONSOR: Michael Trainer
TITLE: Deep vertical transport processes affecting the global concentrations of water vapor, aerosols and trace substances
THEME: Climate System Variability

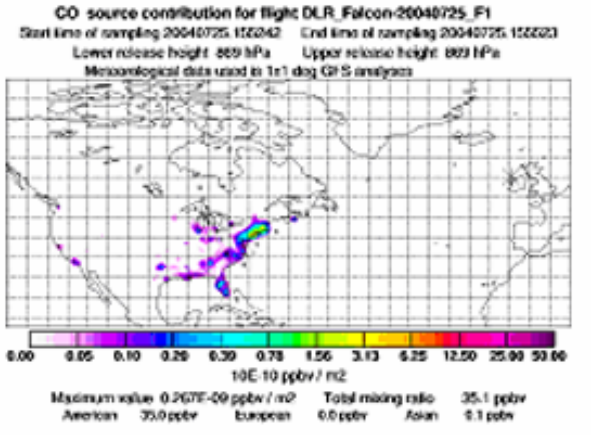
During the period of his visiting fellowship at CIRES, Dr. Stohl proposed to study the effect of (vertical) transport processes on the distribution of trace gases (both air pollutants and water vapor) and aerosols in the atmosphere. Particular objectives were:

- The identification of the sources of water falling as precipitation over a particular area,
- The development of a forecast system to predict the transport in the atmosphere of anthropogenic emissions, to be used during the ICARTT field campaign (1 July – 15 August 2004) for the planning of research flights, and
- The identification of deep transport into the stratosphere of aerosols originating from boreal forest fires.

During the ICARTT (International Consortium for Atmospheric Research on Transport and Transformation) campaign, aircraft from several agencies were deployed at the North American east coast, from the Azores in the middle of the Atlantic, and over Europe, to study the transport of North American pollution over the Atlantic and towards Europe. Furthermore, the NOAA P3 also studied regional air quality in New England. To plan the flights, a forecast system capable of predicting where pollution plumes are located was further developed and was used extensively for the NOAA flight planning.

One of the major aims of the ICARTT campaign was to coordinate aircraft such that they sampled the same air parcels both over North America (i.e., upwind) and downwind over the Atlantic and Europe in a Lagrangian sense. Before the campaign, no forecast system was available to predict the best opportunities for such an experiment and plan these flights and, therefore, a new method has been developed. The method played a central role in coordinating the flight plans for the North American (NASA DC-8 and NOAA P-3) and European (U.K. Bae-146 and German DLR Falcon) aircraft. Several Lagrangian cases were predicted during the campaign. It is too early to say how successful these experiments really were, but one case is particularly noteworthy: The NOAA P-3 sampled the New York City plume for a period of three days in its own Lagrangian experiment (i.e., each day further downwind), and the German Falcon successfully sampled the same plume just west of Ireland. The figures below show a post-mission analysis of where the air sampled by the Falcon originated from (left figure, showing that the air was transported from the North American east coast), and the source contribution distribution of carbon monoxide (right figure, showing that the New York area was indeed the major source of carbon monoxide for the sampled plume). More information on our transport analyses for ICARTT can be found at: *http://niwot.al.noaa.gov:8088/icartt_analysis.*





HEIKKI TERVAHATTU

Ph.D. University of Oulu, Finland
SPONSOR: Veronica Vaida
TITLE: Organic coatings on aerosol particles
THEME: Planetary Metabolism

The environment of CIRES enabled Dr. Tervahattu to make scientific progress in fields related to the research of atmospheric aerosols and their surface chemistry. He wrote or completed earlier works for ten referee journal papers, seven of which have been published or are in press. Two other referee journal papers are currently under preparation. Four conference proceeding abstracts have been published as well as four technical reports. Also based on his progress, one proposal has been submitted to the Helsinki University Environmental Research Center to continue the scientific collaboration between CIRES, CU's Department of Chemistry and Biochemistry and NOAA. One proposal between the same partners to NSF is under preparation.

Publications:

Biswas, S.K., S.A. Tarafdar, A. Islam, M. Khaliquzzaman, H. Tervahattu, K. Kupiainen, Impact of unleaded gasoline introduction on the concentration of lead in Dhaka air, *Journal of Air & Waste Management Association*, **53**, 1355-1362, 2003.

Donaldson, D. J., H. Tervahattu, A.F. Tuck, V. Vaida, Organic aerosols and the origin of life: An hypothesis, *Origin of Life and Evolution of the Biosphere*, **34**, doi:10.1023/B:ORIG.0000009828.40846.b3., 2004.

Kupiainen, K., H. Tervahattu, The effect of traction sanding on urban suspended particles in Finland, *Environmental Monitoring and Assessment*, **93**, 287-300, 2004.

Kupiainen, K.J., H. Tervahattu, M. Räisänen, T. Mäkelä, M. Aurela, R. Hillamo, The size distribution and composition of abrasion components in road dust, Submitted to *Environmental Science & Technology*, in press, 2004.

Niemi, J., H. Tervahattu, H. Vehkamäki, M. Kulmala, T. Koskentalo, M. Sillanpää, Characterization and source identification of a fine particle episode in Finland, *Atmospheric Environment*, in press, 2004.

Tervahattu, H., K. Kupiainen, M. Räisänen, T. Mäkelä, R. Hillamo, Generation of urban road dust from sanding and pavement aggregates, *Journal of Hazardous Materials*, in press, 2004.

Tervahattu, H., Hongisto, M., Aarnio, P., Kupiainen, K., Sillanpää, M., Composition and origins of aerosol during a high PM10 episode in Finland. *Boreal Environment Research*, in press, 2004.

Räisänen, M., K. Kupiainen, H. Tervahattu, The effect of mineralogy, texture and mechanical properties of anti-skid and asphalt aggregates on urban dust II., *Bulletin of Engineering Geology and the Environment*, submitted, 2004.

Tervahattu, H., J. Juhanoja, V. Vaida, A. F. Tuck, J. Niemi, K. Kupiainen, M. Kulmala, H. Vehkamäki, Fatty acid coatings on continental sulfate aerosol particles, *Journal of Geophysical Research–Atmospheres*, submitted, 2004.

Niemi, J., H. Tervahattu, A. Virkkula, R. Hillamo, K. Teinilä, I. K. Koponen, M. Kulmala, Continental impact of marine boundary layer aerosol on Atlantic Ocean between Europe and Antarctica, *Atmospheric Research*, submitted, 2004.

EDWARD WALTON *(Research and Education Fellow)*

Ph.D.	University of Maryland
SPONSOR:	Susan Buhr, CIRES Outreach
TITLE:	Biogenic Volatile Organic Compounds
THEME:	Planetary Metabolism

The environment at CIRES enabled Dr. Walton to gain scientific insights, background and experience in fields of environmental science that will be particularly useful in his future work.

Dr. Walton's project for this fellowship experience was to develop, and take back to Cal Poly, a research program on "Volatile Organic Compounds from Plants." This includes how VOCs affect the atmosphere and atmospheric conditions. This project is both a science research project and a science education project because a major component of the program is the involvement of pre-service teachers in the "doing of science." The intention is to have pre-service teachers work with science majors to collect samples and generate questions and organize and analyze data. This project has the potential to get students interested and involved in biological sciences, the biochemistry of plants, ecology, atmospheric chemistry, organic synthesis, analytical chemistry, and other research areas.

The involvement of students has already begun. One undergraduate chemistry student participated in research under CU's "SMART" Program for ten weeks during the summer of 2003. The student's work enabled her to have a poster presentation accepted for the Society for the Advancement of Chicanos and Native Americans in Science (SACNASZ) National Conference. A second senior chemistry major was brought to Boulder for four weeks to work on this project.

Presentations:

- "Effective Science Writing Exercises," a workshop for the annual DLESE meeting in August 2003.
- "Plants: A Look at Biogenic Volatile Organic Compounds" (CSU Chico Department of Biological Sciences Seminar Series).
- "Touching the Future, American Chemical Society Area Meeting for Northern California."

Activities Related to the Fellowship and Environmental Science Education:

- Participated in Workshop for "Creating Exemplary Professional Development Experiences for Educators."
- Participated in Center for Workshop in the Chemical Sciences. Environmental Chemistry, June 1-6 in Atlanta GA.
- Participated in NOVA LDC, Houston, TX.
- Participated in "POGIL, Process Oriented Guided Inquiry Learning… Science Teaching in Chemistry," Riverside CA, UC Riverside.

In Support of Bridges Between CIRES and the University of Colorado

- Dept of Education seminar attendance for input on selection of Science Education faculty.
- Science fair judge and CIRES representative. Boulder Valley School District and Community Montessori
- CU faculty development programs on "Preparation and Delivering Classroom Presentations."
- Faculty teaching excellence program participant presentation
- Participated in the CU Campus Diversity Summit

GRADUATE STUDENT RESEARCH: Graduates of 2003-2004

The Graduate Research Fellowship program was redefined as previously discussed, so the following represent summaries of the research accomplished by CIRES-affiliated seniors graduating this year.

NICOLAS CULLEN, Ph.D

Advisor: Konrad Steffen, Geography
Dissertation: Characteristics of the Atmospheric Boundary Layer at Summit, Greenland
Funding: NSF Office of Polar Programs

To determine impacts of snow photochemistry upon the composition of surface snow and its overlying atmosphere, field measurements were made during two summers at Summit, Greenland. A detailed understanding of the processes involved in air-snow interactions is necessary for the development of reliable models of present and past atmospheric chemistry. This dissertation works towards that goal by utilizing data from the atmospheric boundary layer at Summit in pursuit of the following objectives: (1) to demonstrate that intermittent turbulence can be characterized using existing instrumentation; (2) to parameterize scalar transfers in the near-surface layer; and (3) to describe the annual energy budget and its impact on atmospheric conditions.

ELIZABETH K. FRINAK, Ph.D.

Advisor: Margaret A. Tolbert, Chemistry and Biochemistry
Dissertation: Laboratory Studies of Surfaces Representative of Mineral Dust in the Troposphere
Funding: National Science Foundation

Mineral dust can be lofted into the Earth's atmosphere and transported on a global scale. While in the atmosphere, these particles may be exposed to varying conditions of relative humidity and may serve as reactive surfaces for trace gases such as nitric acid. Thus the dust particles age as they are transported, and may change from relatively inert particles to particles of higher toxicity. Additionally, the initial dry particles may have little impact on atmospheric chemistry or climate, while the aged particles could promote heterogeneous chemistry or be better able to nucleate cloud droplets. This dissertation examines the aging process for two components of mineral dust aerosol. Specifically, laboratory studies were performed on the mineral gamma-iron oxide and on the clay sodium-montmorillonite.

The laboratory studies used a high vacuum chamber equipped with transmission Fourier transform infrared spectroscopy to probe the dust samples and mass spectrometry to simultaneously probe the gaseous species such as water and nitric acid. Prior to these studies, there was a disagreement of three orders of magnitude in the literature about the rate at which nitric acid was taken up by clay surfaces. To improve upon the past work, initial efforts focused on measuring the specific surface area of the dust samples *in situ*. This measurement eliminated an assumption about the specific surface area and resolved the existing controversy in the literature.

Experiments showed little uptake of nitric acid on mineral aerosol surfaces at low relative humidity. For example, at 0% relative humidity, studies suggest that the lifetime of nitric acid in the troposphere is 65 days due to heterogeneous loss on iron oxide. This lifetime is too long to represent a significant loss mechanism. However, the uptake can change dramatically as water vapor increases. For example, at 44% relative humidity, work suggests that the lifetime of nitric acid is only two days with respect to heterogeneous loss to sodium-montmorillonite. This timescale is short enough to be of significance in the troposphere. The strong dependence on relative humidity is likely due to increased water in the clay. In fact, it was found that at 50% relative humidity, the clay contains 10% water by mass. The results determined in this work suggest mineral dust as a potentially significant reactive surface in the troposphere. The magnitude of the impact is dependent on factors such as the composition of the dust and the relative humidity.

NANCY GOLUBIEWSKI, Ph.D.

Advisor: Carol Wessman, Ecology and Evolutionary Biology
Dissertation: Carbon in Conurbations: Afforestation and Carbon Storage as Consequences of Urban Sprawl in Colorado's Front Range
Funding: NSF, CU IGERT program, EEB, CIRES

In the arid western United States, urbanization transforms landscapes from sparsely vegetated grasslands with tree-lined riparian corridors into matrices of asphalt, concrete, turf grass, and multi-strata wooded stands. This research sought to understand the consequences of urbanization upon carbon pools in the Front Range of Colorado, a metropolitan area undergoing expansive urban transformation. Vegetative and soil carbon, as well as biomass and other soil physical/chemical properties, were measured throughout the Denver-Boulder metropolitan area in 2000 and 2001. Anthropogenic activities leave clear signatures on all three carbon compartment measured. The comparison of carbon storage in the vegetated spaces of urban areas to that in grasslands and agricultural fields reveals a marked increase as well as a proportional shift in storage from belowground to aboveground. Lawn grass produces more biomass and stores more carbon than local prairie or agricultural fields. Introduced woody vegetation comprises a substantial carbon pool in urban greenspaces and repre-

sents a wholly new ecosystem feature. Established greenspaces harbor larger carbon pools than native grasslands on a per area
basis.

Rather than map the urban land-cover types, high spectral resolution images from NASA's Airborne Visible/Infrared Spectrometer were used to determine the distribution of built surfaces, grass, trees, soil and water in Boulder. Carbon values measured in the field were then applied to the classified imagery, as well as to land-use/land-cover categories from a USGS analysis of historical aerial photography (1930s-1990s). A carbon hotspot exists in the urbanized areas where well-established urban vegetation occupies residential neighborhoods, urban greenspaces, and city streets. Other hotspots exist along riparian corridors and on vegetated foothills. Between 1930 and 1990, developed land almost quintupled in area in the Front Range of Colorado. During the same time period, estimates of the carbon pool trajectory range from -3% to +18%. The true direction, given the local context, is surmised to be neutral or positive.

ALLISON GRIMSDELL, Ph.D.

Advisor: Wayne Angevine, Aeronomy Lab and Susan Avery, Dept. of Electrical Engineering

Dissertation: The Afternoon Transition of the Continental Convective Boundary Layer

Funding: NSF and NOAA

This research was aimed at improving understanding of the behavior of the lower atmosphere over land in the afternoon. As the incoming energy from the sun decreases, a transition takes place in which the strength and vertical extent of turbulent mixing also decreases, eventually leading to the much less turbulent situation at night. The thesis characterized the afternoon transition using measurements from radar wind profilers, and reproduced the major characteristics with a one-dimensional numerical model. The key findings were that the transition is gradual in height and time, begins several hours before sunset, and can be modeled with relatively straightforward techniques.

JESSICA LANG, M.S.

Advisor: Roger Pielke, Jr., Environmental Studies

Thesis: Connecting Science and Policy: Lessons Learned from 32 Science-Policy Assessments

Funding: NOAA OGP RISA and CIRES

This thesis focused on evaluating 32 assessments of various areas of science aimed at providing useful information to decision makers. The thesis characterized how different assessments were organized, who participated, how information was summarized and communicated, and evaluations of the assessments utility for decision makers. The thesis then applied the lessons learned from its review to the NOAA RISA Western Water Assessment and recommended strategies for how the Western Water Assessment might improve its role at the interface of science and decision makers.

MOLLY McALLISTER, M.S.

Advisor: Konrad Steffen, Geography

Thesis: Cyclone Occurrence in the Arctic 1963-2002: Impacts on Greenland Ice Sheet Melt Cycles 1979-2002

Funding: NASA Cryospheric Sciences

Does a relationship exist between cyclone frequencies in the North Atlantic and the dominant index of the North Atlantic Oscillation (NAO)? Do cyclones influence melt area on the Greenland ice sheet? This thesis work has explored these two questions through the analysis of NCEP/NCAR sea level pressure data spanning the period 1963-2002, passive microwave melt data spanning the period 1979-2002, and the derived NAO index for the respective time periods and focusing on the months April-October. Through correlation analysis and case studies it has been determined that the NAO is directly related to cyclone frequency but not as strongly to melt area. Melt area on the Greenland ice sheet is affected greatly by cyclones that originate in the lower latitudes and are accompanied by strong temperature gradients.

ANDREW G. SLATER, Ph.D.

Advisor: Konrad Steffen, Geography

Dissertation: Snow fractional cover in land surface schemes

Funding: NSF

Land surface scheme forcing data sets are constructed using observations from the Seward Peninsula in Alaska using non-parametric statistical techniques to full the gaps in precipitation. Extensive validation of NCAR and Land Surface (LS) models were undertaken using a variety of independent data such as turbulent

fluxes. The models performed consistently compared to previous studies. Several weaknesses regarding parameter assignment in summer albedo, snow density and the lack of organic soil layers were identified. Using synthetic data generated from observations, a spatially implicit comparison between the models and remotely sensed products was made. The models cannot emulate the observed variability of the regions, even that within vegetation classes. Part of this stems from the uniform view of vegetation as well as the ever-problematic snow albedo parameterization.

SANDY STARKWEATHER, PhD

Advisor: Konrad Steffen, Geography

Dissertation: Cloud Properties and Their Impacts on the Surface Energy Balance: Measurements and Validation at Summit, Greenland

Funding: NASA Cryospheric SciencesAutomated cloud observations began at Summit Camp in May 2001 and continued through July 2002. A whole-sky imager captures a digital sky image, quantifying the cloud cover each minute (daylight hours only), and a ceilometer sounds the atmosphere with a laser pulse, monitoring cloud base height every 15 seconds. These high frequency measurements, together with an accurate surface radiation data set, constitute a unique surface-based data set for Greenland. The data set directly provides the means to quantify high frequency cloud sky fraction and height and to quantify the effects of clouds on the surface radiation balance—both previously unquantified over the high plateau of Greenland. Using this data set, this research has addressed the following questions: What are the diurnal and seasonal cycles of cloud sky fraction and cloud height? What is the sign and magnitude of the cloud radiative effect at Summit, Greenland? How does this effect vary with cloud height, cloud optical depth, time of year and time of day? How frequent are radiation fogs and diamond dust precipitation? What is their radiative signature? What accounts for bi-modal cloud height distribution observed at Summit and in other high altitude, high latitude environments? What is frequency of cyclonic activity?

JOSEPH A. VILLA, Ph.D.

Advisor Robert Sievers, Chemistry and Biochemistry

Thesis: Generation and Characterization of Fine and Stable Powders Suitable for Pulmonary Drug Delivery Using CO_2-Assisted Nebulization with a Bubble Dryer® (CAN-BD)

Funding: CIRES, NIH Leadership Training Grant. Other support came from the Colorado Tobacco Research Fund and from Aktiv-Dry L.L.C.

Fine particles of atmospheric and medical aerosols such as organic acids, vaccines, surfactants, proteins, sugars, enzymes, antibiotics, and other drugs, can be rapidly made by a new patented drying process, known as CO_2-Assisted Nebulization with a Bubble-Dryer® (CAN-BD). The primary advantages of this process are that it facilitates drying of microbubbles and microdroplets at lower temperatures (25-60°C) than those used in traditional spray drying processes. The CAN-BD process did not cause detectable damage to the proteins studied. With the optimum combination of sugars, such as sucrose and trehalose, with the protein, full enzymatic activity of the protein after redissolution of the microparticles and nanoparticles was observed.

EDOUARD VON HERBERSTIEN, M.S.

Advisor: Roger Pielke, Jr., Environmental Studies

Thesis: Hurricane Risk Pricing, Catastrophe Models, and Data Quality: Why it Matters and What Should be Done about it?

Funding: ICAT Managers, Boulder CO

This thesis focused on the role of catastrophe models in the decision-making processes of insurance and reinsurance companies. Specifically, it focused on the value of accurate empirical data, e.g., on structure type, construction, and location for setting insurance and reinsurance rates. This information is important because the collection of such data can be costly and catastrophe models are now so sophisticated that accurate collection of all data possible as inputs is cost prohibitive. This thesis developed and applied a methodology for determining what data would be significant to collect as measured by its impact on catastrophe model output.

CHARLIE WILSON, Ph.D.

Advisor: Craig Jones, Geological Sciences
Dissertation: Constraining Lithospheric Deformation Mechanisms with Teleseismic Conversions
Funding: Department of the Navy (Geothermal Programs Office) and NSF.

This dissertation project was directed at understanding processes in the crust that were observable using arrays of closely spaced seismometers. Dr. Wilson developed several techniques that are becoming more widely used in analyzing such data. He found in the Coso Geothermal Field in California that a large, probably partially molten, body lay some 5 km below the geothermal field, and that it does not extend far in any direction outside the field. This is probably where magma resides under this volcanic area. He also showed that there is not an equivalent body in the lower crust, which is important in understanding the chemical evolution of these volcanic rocks. In New Zealand, Dr. Wilson helped run a network of seismometers across the northern end of the Alpine Fault, which separates the Australian and Pacific plates. Although a discrete fault at the surface, he showed that the deformation is more diffuse in the lower crust and that the surface fault does not cut the base of the crust. Instead, rocks are pervasively deformed in the lower crust and deformation is spread out over a wider zone. This has important implications for our understanding of the way that the lower crust deforms.

MATTHEW E. WISE, Ph.D.

Advisor: Margaret A. Tolbert, Department of Chemistry and Biochemistry
Dissertation: Laboratory Studies of Sulfate Aerosols at Upper Tropospheric and Lower Stratospheric Temperatures and Compositions
Funding: Department of Energy

Atmospheric aerosols can affect the Earth's radiation balance directly by scattering and absorbing solar radiation and indirectly by modifying cloud properties. In addition, aerosols can act to catalyze atmospheric reactions that would otherwise occur only slowly in the gas phase. The phase and water content of the aerosols are two of the most important parameters that determine how the particles impact atmospheric chemistry and climate. The phase and growth behavior of model inorganic aerosols is well established. However, recent work indicates that essentially all real atmospheric aerosols are complex mixtures of many components. This dissertation examines the growth and phase change behavior of sulfate aerosols internally mixed with other components. The first chapter of the dissertation focuses on the deliquescence and growth of ammonium sulfate/organic aerosols representative of one of the most common types of tropospheric particulate. For the systems studied, it was found that soluble organics in the particles contributed to water uptake. In addition, the soluble organic material lowered the deliquescence relative humidity compared to pure ammonium sulfate, implying that the aerosols would be found in a liquid state over a broader range of atmospheric conditions. Together, these studies suggest that soluble organics enhance the reactivity and cloud forming ability of inorganic aerosols. The second chapter of the thesis focused on the ability of internally mixed ammonium sulfate/organic aerosols to serve as nucleation centers for cirrus clouds. Here, it was found that the freezing temperature of each system was identical, for a given water activity of the solution, even though the solutions contained varying fractions of inorganic and organic components. Thus the soluble organics studied do not impede ice formation, in contrast to an earlier prediction. The final chapter of the thesis focused on stratospheric sulfate aerosols. Recent field studies have shown that these aerosols contain metals characteristic of meteorites. These metals, whether present as soluble ions or insoluble mineral inclusions, have an unknown effect on the formation of polar stratospheric clouds. Here he measured the solubility of metals in sulfuric acid and showed that dissolved metal ions enhanced freezing. This finding may provide a mechanism for the formation of polar stratospheric clouds and provide clues to predicting future cloud abundances and their impact on stratospheric ozone.

STUDENT DIVERSITY PROGRAMS

SIGNIFICANT OPPORTUNITIES IN ATMOSPHERIC RESEARCH AND SCIENCE (SOARS) PROGRAM

SOARS is a model learning community and mentoring program for promoting racial and gender equity in the atmospheric and related sciences. Created by and administered through the National Center for Atmospheric Research, CIRES has formed a partnership with this program to participate in this highly regarded program while providing NCAR with a wider range of disciplines in which to place students. It is a multi-summer, four-year undergraduate and graduate program for students majoring in an atmospheric science or a related field such as biology, chemistry, computer science, earth science, engineering, environmental science, mathematics, meteorology, oceanography, physics, or social science. Program information can be found at *http://www.ucar.edu/soars/*.

NAME	AFFIL	MENTOR	PROJECT TITLE
Melissa A. Burt	CIRES	Leslie Hartten Amy Stevemer	Reflectivity Gradients in the Lower Troposphere Over the Tropical Pacific: A Climatology Based on Wind Profiler Data
Carlos Medina, Jr.	CIRES/ ARL	John Augustine Brian Mapes	Improving the Method of Extracting Aerosol Optical Depth Information from Multi Spectral Solar Data
Casey Thornbrough	CIRES/ PAOS	Amanda Lynch Elizabeth Cassano Nancy Dawson	Contributing to the Prediction of Coastal Flooding: Simulating Wave Heights and Directions along the Coast of Barrow, Alaska

UNDERGRADUATE RESEARCH OPPORTUNITIES PROGRAM (UROP)

UROP was designed to create research partnerships between faculty and undergraduate students. Research in this context is interpreted as any scholarly or creative activity ranging from traditional scientific experimentation to the creation of new artistic works. UROP awards stipends and/or expense allowances to students who undertake an investigative or creative project in collaboration with a faculty member. Although projects are normally designed around some aspect of the faculty sponsor's research, they may also develop from original ideas of the student, which are endorsed by a faculty sponsor. Whether the context is scholarly or artistic, UROP projects call for significant input on the part of the faculty sponsor. Program information can be found at *http://www.colorado.edu/Research/UROP/*.

NAME	AFFIL	MENTOR	PROJECT TITLE
Noble, Andrea	Limnology	Lewis, William	Food Resources Used by Native and Non-native Trouts.
Sackett, Loren	EEB	Wessman, Carol	The Effects of Wildfire, Wind and Salvage-logging Disturbance on Soil Nutrient Cycles
Sanderson, John	EEB	Wessman, Carol	The Effects of Urbanization on Forest Health as Assessed by Remote Sensing Techniques

SUMMER MULTICULTURAL ACCESS TO RESEARCH TRAINING (SMART)

CU Boulder offers 10-week summer research internships through the SMART program. The internships provide hands-on experience in research and an introduction to graduate education at a leading university. Twenty to 25 undergraduates from institutions nationwide take part in this challenging and informative program each summer. SMART interns conduct research projects in science, math, and engineering fields under the guidance of a faculty mentor and see firsthand graduate student life at a major institution. Interns also interact in the social environment of a large university and in a community of underrepresented peers. Program information can be found at *http://www.colorado.edu/graduateschool/SMART/SMARTWebsite*.

NAME	AFFIL	MENTOR	PROJECT TITLE
Mariela Salas	CIRES	Anne Sheehan	Magnetostratigraphy of the Etchegoin Group, central San Joaquin Basin, CA

PERSONNEL DEMOGRAPHICS

			Supported by NOAA Funding			
All CIRES		*Category*		*B.S.*	*M.S.*	*Ph.D.*
144		Research Scientist	108			108
12		Visiting Scientist	8			8
21		Postdoctoral Fellow (included within the Research Scientist category)	0			0
199		Associate Scientists	121	76	45	
24		Administrative	22	17	5	
63		Undergraduate Students	26			
55		Graduate Students	19			
		Received less than 50% NOAA support	47	20	6	21
518		**Total**	351	113	56	137

Count by OAR Lab	
AL	68
ARL	10
CDC	37
CMDL	40
ETL	35
FSL	15
SEC	11
NESDIS/NGDC	28
Total	244

Obtained NOAA employment within the last year	1

(format per NOAA/OAR-OSS guidance)

ACRONYMS

3DVAR	3 Dimensional Variational Analysis
ACD	Atmospheric and Climate Dynamics
ADCC	Arctic Data Coordination Center
AERI	Atmospheric Emitted Radiance Interferometer
AFGL	Air Force Geophysics Laboratory
AGCM	Atmospheric Global Circulation Model
AGU	American Geophysical Union
AIRS	Advanced Infra Red Sounder
AL	Aeronomy Laboratory
AMS	Aerosol Mass Spectrometer
AMIE	Assimilative Mapping of Ionospheric Electrodynamics
AMOS	Advanced Modeling and Observing Systems (CIRES scientific theme)
AMPS	Antarctic Mesoscale Prediction System
AOML	Atlantic Oceanographic and Meteorological Laboratory
AQFM	Air Quality Forecast Model
ARCSS	Arctic System Science
ARCSyM	Arctic Region Climate System Model
ARL	Air Resources Laboratory
ASLO	American Society for Limnology and Oceanography
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
AUTEC	Atlantic Undersea Test and Evaluation Center
AVHRR	Advanced Very High Resolution Radiometer
AWI	Alfred Wegener Institute for Polar and Marine Research
AWIPS	Advanced Weather Interactive Processing System
BP	Before Present
BSRN	Baseline Surface Radiation Network
BVSD	Boulder Valley School District
CAC	Computing Advisory Committee
CANDAC	Canadian Network for Detection of Arctic Change
CAREERI	Cold and Arid Regions Environment and Engineering Research Institute
CBLAST	Coupled Boundary Layers Air-Sea Transfer
CCFP	Collaborative Convective Forecast Product
CCM	Community Climate Model
CCN	Cloud Condensation Nuclei
CDAS	Coupled Data Assimilation System
CDC	Climate Diagnostics Center
CFC	Chlorofluorocarbon
CFH	Cryogenic Frost-point Hygrometer
CH_3Br	Methyl Bromide
CH_3Cl	Methyl Chloride
CIMS	Chemical Ionization Mass Spectrometry
CIRES	Cooperative Institute for Research in Environmental Sciences
Cl_2O	Dichlorine Oxide
CliC	Climate and Cryosphere
CLIMAS	Climate Assessment Project for the Southwest
CLIVAR	CLImate VARiability and Predictability Program
CM	Core-Mantle
CMDL	Climate Monitoring and Diagnostics Laboratory
CME	Coronal Mass Ejection
CO	Carbon Monoxide
CO_2	Carbon Dioxide
COARE	Coupled Ocean-Atmosphere Response Experiment
CONUS	Continental United States
CORS	Continuously Operating Reference System
CRD	Cavity Ring Down spectroscopy

CSAP	Colorado Student Assessment Program
CSES	Center for the Study of Earth from Space
CPP	Cryospheric and Polar Processes
CRYSTAL-FACE	Cirrus Regional Study of Tropical Anvils and Cirrus Layers – Florida Area Cirrus Experiment
CSP 2012+	Climate Science and Policy Beyond 2012
CSTPR	Center for Science and Technology Policy Research
CSV	Climate System Variability (CIRES scientific theme)
CTI	California Technological Institute
CU	University of Colorado
CUCF	Central UV Calibration Center
DAAC	Distributed Active Archive Center
DIAL	Differential Absorption of Light
DLESE	Digital Library for Earth System Education
DMS	Dimethyl-Sulfide
DOD	Department of Defense
DOE	Department of Energy
DSRC	David Skaggs Research Center
ECB	Environmental Chemistry and Biology
ECMWF	European Center for Medium Range Weather Forecasting
ECUV	European reference Center for Ultraviolet radiation measurements
EEB	Ecology and Evolutionary Biology
EIT	Extreme Ultraviolet Imaging Telescope
EM5	Environmental Model 5
ENSO	El Niño/Southern Oscillation
EO	Education and Outreach
EPA	Environmental Protection Agency
EPIC	Eastern Pacific Investigations of Climate
ESA	Endangered Species Act
ESS	Earth Systems Science
ETA	NCEP model
ETL	Environmental Technology Laboratory
ETS	Equitable Threat Score
EUV	Extreme Ultraviolet
FGDC	Federal Geographic Data Committee
FGDC	Frozen Ground Data Center
FLEXPART	Lagrangian particle dispersion model
FSL	Forecast Systems Laboratory
FTE	Full Time Equivalent
FTP	File Transfer Protocol
FYI	First Year Ice
GAIM	Global Assimilation of Ionospheric Measurements
GAPP	GEWEX Americas Prediction Project
GasEx	Gas Exchange Experiment
GAW	Global Atmosphere Watch
GCM	Global Circulation Model
GCMS	Gas Chromatographs with Mass-Selective
GDP	Gross Domestic Product
GDSIDB	Global Digital Sea Ice Data Bank
GEM	Geosynchronous Microwave sounder/imager
GEO	Geodynamics (CIRES scientific theme)
GFDL	Geophysical Fluid Dynamics Laboratory
GFS	NCEP model
GIFT	Geophysical Information For Teachers
GIS	Geographic Information System
GLIMS	Global Land Ice Measurements from Space
GOES	Geostationary Operational Environmental Satellite
GPM	Global Precipitation Measurement

H_2	Hydrogen
HATS	Halocarbons and other Atmospheric Trace Species group
HCl	Hydrochloric Acid
HFC	Hydrofluorocarbons
HF/VHF	High Frequency/Very High Frequency
HMT	Hydrometeorological Testbed
HNO_3	Nitric Acid
HOCl	Hypochlorous Acid
I-COADS	International Comprehensive Ocean-Atmosphere Data Set
IA	Integrating Activities (CIRES scientific theme)
IARC	International Arctic Research Center
ICARTT	Int'l Consortium for Atmospheric Research on Transport and Transformation
IDB	Interface Database
IHOP	International H_20 Project
IMMA	International Maritime Meteorological Archive
IMS	Ice Mapping System
INSTAAR	Institute of Arctic and Alpine Research
IPCC	Intergovernmental Panel on Climate Change
IRP	Innovative Research Program
ISCCP	International Satellite Cloud Climatology Project
ISO	International Standards Organization
ITCT	Intercontinental Transport and Chemical Transformation
ITCZ	Intertropical Convergence Zone
JMA	Japanese Meteorology Agency
JPL	Jet Propulsion Laboratory
JRC	Joint Research Center
KWAJEX	Kwajalein Experiment
LACE	Lightweight Airborne Chromatograph Experiment
LAI	Leaf Area Index
LASP	Laboratory for Atmospheric and Space Physics
MALDI	Matrix-Assisted Laser Desorption and Ionization
MAQSIP	Multiscale Air Quality Simulation Platform
MCDB	Molecular Cellular and Developmental Biology
MHD	Magnetohydrodynamic
MJO	Madden-Julian Oscillation
MM5	Mesoscale Model 5
MMCR	Millimeter Cloud Radar
MODIS	Moderate Resolution Imaging Spectroradiometer
MRF	Median-Range Forecast
MYI	Multi-Year Ice
N_2O_5	Dinitrogen Pentoxide
NACP	North American Carbon Program
NAME	North American Monsoon Experiment
NAO	North Atlantic Oscillation
NARSTO	North American Research Strategy for Tropospheric Ozone
NASA	National Aeronautics and Space Administration
NBB	Non-Bright-Band
NCAR	National Center for Atmospheric Research
NCEP	National Centers for Environmental Prediction
NDSC	Network for the Detection of Stratospheric Change
NDVI	Normalized Deviated Vegetation Index
NEAQS	New England Air Quality Study
NEHRTP	New England High Resolution Temperature Project
NESDIS	National Environmental Satellite, Data, and Information Service
NetCDF	Network Common Data Form
NGDC	National Geophysical Data Center
NGS	National Geodetic Survey

NIDIS	National Integrated Drought Information System
NIST	National Institute of Standards and Technology
NIWA	National Institute of Water and Atmospheric Research
NMMR	NOAA Metadata Manager and Repository
NO_2	Nitrogen Dioxide
NO_3	Nitrate ion
NOAA	National Oceanic and Atmospheric Administration
NOHRSC	National Operational Hydrologic Remote Sensing Center
NOSB	National Ocean Sciences Bowl
NPOES	NOAA Polar orbiting Operational Environmental Satellite
NRL	Naval Research Laboratory
NRLC	Natural Resources Law Center
NSDL	National Science Digital Library
NSF	National Science Foundation
NSIDC	National Snow and Ice Data Center
NWP	Numerical Weather Prediction
NWS	National Weather Service
O_3	Ozone
OAR	Oceanic and Atmospheric Research
ODP	Ozone Depletion Potentials
OGP	Office of Global Programs
OI	Optimal Interpolation
OMI/AURA	ESS spacecraft
OPP	Office of Polar Programs
OSDPD	Office of Satellite Data Processing and Distribution
ORA	Office of Research Applications
PACJET	Pacific Landfalling Jets
PACS	Pan-American Climate Study
PAN	Peroxyacetyl Nitrate
PARCA	Program in Regional Arctic Climate Assessment
PAOS	Program in Atmospheric and Oceanic Sciences
PBL	Planetary Boundary Layer
PCP	Pentachlorophenol
PDO	Pacific Decadal Oscillation
PFC	Perfluorocarbons
PM	Planetary Metabolism (CIRES scientific theme)
PITS-MS	Proton Transfer Ion Track Mass Spectrometry
PSR	Polarimetric Scanning Radiometer/Sounder
PTB	Physikalisch-Technische Bundesanstalt
QBO	Quasi-Biennial Oscillation
QPE	Quantitative Precipitation Estimates
QPF	Quantitative Precipitation Forecasts
R/V	Research Vessel
RDBMS	Relational Database Management System
READ	Regional Ecosystems Assessment Data
RICO	Rain In Cumulus Over the Ocean
RISA	Regional Integrated Sciences and Assessments
RMS	Root-Main-Square
ROMS/TOMS	Regional Ocean Modeling System/Terrain-Coordinate Modeling System
RP	Regional Processes (CIRES scientific theme)
RPC	Rapid Prototyping Center
RTVS	Real-Time Verification System
RUC	Rapid Update Cycle
SAIC	Science Applications International Corporation
SAO	Semi-Annual Oscillation
SBL	Stable Boundary Layer
SCIGN	Southern California Integrated GPS Network

SCM	Single Column Models
SEARCH	Study of Environmental Arctic Change
SEC	Space Environment Center
SEM	Space Environment Monitor
SEP	Solar Energetic Proton
SES	Solid Earth Sciences
SGP	Department of Energy Southern Great Plains
SHEBA	Surface Heat Budget of the Arctic Ocean
SMEX04	Soil Moisture Experiment
SO_2	Sulfur Dioxide
SOM	Self-Organizing Maps
SPANDEX	Spray Production and Dynamic Experiment
SPARC	Science Policy Assessment and Research on Climate
SRRB	Solar Radiation Research Branch
SST	Sea Surface Temperature
STAR	Solar and Thermal Atmospheric Radiation
STM	Stormtrack Model
STORM	Storm-Time Empirical Ionospheric Correction Model
SURFRAD	Surface Radiation
SVVSD	Saint Vrain Valley School District
SWDS	Space Weather Data Stores
SWR	Space Weather Reanalysis
SXI	Solar X-ray Imager
TAO	Tropical Atmosphere Ocean
TEC	Total Electron Count
TexAQS	Texas Air Quality Study
THREDDS	Themmatic Realtime Environmental Data Distribution System
TLS	Tethered Lifting System
TOGA-COARE	Tropical Ocean & Global Atmosphere Program's Coupled Ocean-Atmosphere Response Experiment
TOPEX	Ocean Topography Experiment
TRMM	Tropical Rainfall Measurement Mission
TROICA	Trans-Siberian Observations of the Chemistry of the Atmosphere
UCAR	University Corporation for Atmospheric Research
UNOLS	University-National Oceanographic Laboratory System
U.S.A.F	United States Air Force
USAP	United States Antarctic Program
USC	University of Southern California
USGS	United States Geological Survey
UV	Ultraviolet
VOC	Volatile Organic Carbon
VOS	Voluntary Observing Ship
WATF	Water Availability Task Force
WCRP	World Climate Research Program
WGA	Western Governors' Association
WDC	World Data Center
WMO	World Meteorological Organization
WRF	Weather Research and Forecasting
WSA	Wang-Sheeley-Arge
WSR-88D	Weather Surveillance Radar 88 Doppler
WVIOP04	Water Vapor Intensive Operation Period 2004
WW2BW	White Water to Blue Water
WWA	Western Water Assessment
WWW	World Wide Web
WX	Weather
X-POL	Cross-Polar
XRS	X-Ray Sensor

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Woert, M. V., C. Zou, W. Meier, P. Hovey, and M. Chase (2003). 24-hour forecast verification of the operational "Polar Ice Prediction System." *Ice in the Environment: Proceedings of the Int'l Assoc. for Hydraulic Engineering and Research 16th Int'l Symposium on Ice*, **2**:445-452.

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Zhang, T., R. G. Barry, K. Knowles, F. Ling, and R. L. Armstrong (2003). Distribution of seasonally and perennially frozen ground in the Northern Hemisphere. *Proceedings 8th International Conference on Permafrost*, **2**:1289-1294.

HONORS AND AWARDS

Aikin Kenneth
- Group Achievement Award from NASA for the Cirrus Regional Study of Tropical Anvils and Cirrus Layers - Florida Area Cirrus Experiment (CRYSTAL-FACE) Science Team.

Balagi, Rajagopalan
- Young Researcher Award from the Department of Civil, Environmental and Architectural Engineering.

Bilham, Roger
- 2003-04 IRIS/SSA Distinguished Lecturer.

Brown, Steven
- CIRES Outstanding Performance Award.

Casey, Amy
- Merit Award from the Society of Technical Communications for the Megadunes web site.

Ennis, Christine
- Received an honorary OAR Outstanding Scientific Publication Award (group award), for the 1998 international WMO/UNEP scientific assessment on the ozone layer.

Gottas, Daniel
- NOAA/ETL 2003 Outstanding Performance Award for designing, developing, and maintaining intricate instrumentation operations and data acquisition software and a website for real-time data access.
- NOAA 2003 Bronze Medal awarded to the PACJET Research and Development Team for the development of a snow-level algorithm for boundary-layer wind profilers which will improve national winter weather forecasts.

Gupta, Vijay
- Memorial lecturer, Indian Society for Hydraulics Annual Conference, Pune, India.

Hare, Jeffrey
- NOAA Office of Oceanic and Atmospheric Research Outstanding Scientific Paper for 2002 (awarded Jan 2003): "Parameterization and Micrometeorological Measurements of Air-Sea Gas Transfer" by Fairall, Hare, Edson, and McGillis.
- NOAA ETL Award for Outstanding Performance (Feb 2003): "For major contributions in the development and execution of measurements of air-sea fluxes from NOAA ships."

Husler, Michael
- Solar X-ray Imager Program Champion Medallion awarded for excellence in database and web programming.

Jimenez, José
- Excellence in Reviewing Award from the ACS Journal Environmental Science and Technology.
- NASA Group Achievement Award for the CRYSTAL-FACE Field Mission.

Marquis, Melinda
- Goddard Space Flight Center/NASA Group Achievement Award; ADEOS-II NASA Ground Network Project Team, Outstanding Teamwork.
- Goddard Space Flight Center/NASA Group Achievement Award; Aqua Mission Team, Aug. 27, 2003.

Matrosov, Sergey
- Department of Commerce Gold Medal for development of a new remote sensing system to identify hazardous in-flight icing conditions in cloud.

McColl, Harry
- CIRES Outstanding Technical Service 2003 award.

Moore Fred
- NASA Group Achievement Award to CRYSTAL-FACE Science Team. NASA Group Achievement Award to SOLVE Science Team.
- CMDL/NOAA Annual Meeting Best Poster.
- CIRES Members' Council Award of Excellence.
- NASA Group Achievement Award to POLARIS Project Team.

Reid, George
- Outstanding Paper Award by NOAA and CIRES.

Scott, James
- CDC/CIRES employee award for "sustained excellence in scientific support which has helped advance research" at CDC and the broader scientific community.

Scott, Michon
- Seventh Annual Webby Awards People's Voice and Webby Award Winner for Education.

Sievers, Robert
- Robert Stearns Award, University of Colorado Alumni Association.

Smith, Catherine
- CDC WAC award for work on a report for Congress on the May 2003 tornado outbreak.

Tolbert, Margaret
- NASA Group Achievement Award, Crystal-Face Science Team.

Troisi, Vincent
- NASA/GSFC Group Achievement Award for the ADEOS-II NASA Ground Network Project Team in recognition for Outstanding Teamwork.

Wahr, John,
- Faculty Fellowship.
- Recipient of the Vening Meinesz Medal of the European Geosciences Union
- 2003 Editor's Citation for Excellence in Refereeing from the American Geophysical Union.

White, Allen
- CIRES Outstanding Performance Award.
- NOAA/OAR Bronze Medal Award for the development of a snow-level algorithm for improving winter weather forecasts.

Wolter, Klaus
- CDC Outreach Award 2003.

PROFESSIONAL SERVICE

Akmaev, Rashid:

- Member IAGA Working Group II-F "Long-term Trends in the Mesosphere, Thermosphere and Ionosphere."
- Convenor, Session "Space Climate Change." Space Weather Week, Boulder, CO, May 19–22, 2003.
- Convenor, Session "Global Change across the Mesopause," Annual NSF CEDAR Workshop, Longmont, Colorado, June 15–20, 2003.
- Convenor, Session "Global Change in the Upper Atmosphere and Ionosphere," AGU/CGU Joint Assembly, Montreal, Canada, May 17–21, 2004.
- Reviewer for Advances in Space Research, Annales Geophysicae. Geophysical Research Letters, Journal of Atmospheric and Solar-Terrestrial Physics, Journal of Geophysical Research.

Arbetter, Todd:

- Chaired poster session at Spring 2004 AGU meeting.
- Reviewer for Journal of Physical Oceanography.

Armstrong, Richard:

- Convenor, IUGG/IAHS, JSH01, The Remote Sensing of the Cryosphere, Sapporo, Japan, 3-11 July, 2003.
- Member, WCRP-ACSYS-CliC Data Management and Information Panel.
- Member, Remote Sensing Working Group, GEWEX Asian Monsoon Experiment (GAME).
- International Commission on Snow and Ice (ICSI).
- Representative to International Association of Hydrological Sciences (IAHS).
- Chairman, ICSI Snow and Climate Working Group.
- Member, IAHS/ICSI Panel to review World Glacier Monitoring Service.
- Reviewer for unspecified journals and proposals.

Avery, Susan:

- National Research Council, Committee for the NOAA/NESDIS Transition from Research to Operations (CONNTRO).
- American Meteorological Society, Commissioner, Education and Human Resources.
- American Geophysical Union, Nominations Committee.
- University of Arizona Science and Technology Center, Tucson, Science Policy Board, Arizona.
- American Meteorological Society, President-Elect.
- International Union of Radio Science (URSI) Representative to SCOSTEP.
- National Science Foundation, Upper Atmosphere Facilities Review Team, Chair.
- University of Oklahoma, College of Geosciences Review, Chair.

Barry, Roger:

- Co-Chair, Standing Committee for Data, Information and Communications (SCDIC), International Permafrost Association.
- Chair, two sessions of the SCDIC at the International Permafrost Conference, July 2003, in Zurich.
- Co-Vice Chair, Scientific Steering Group (SSG) for the Arctic Climate System/Cryosphere and Climate (CliC) project.
- Member, World Meteorological Organization, Joint IOC/WMO Technical Commission for Oceanography and Marine Meteorology.
- Co-Chair, Steering Group for the Global Digital Sea Ice Data Bank (GDSIDB).
- Member NASA Review Panel: EOS Instrument Team Leader proposals. NASA HQ, Washington, DC.
- Member, National Research Council (BASC) Committee on Climate Data Records from Operational Satellites.
- Member, Arctic CHAMP Scientific Steering Committee, Member.

Bergman, John:

- Reviewer for CLIVAR PACS, JGR, GRL.

Bilham, Roger:
- IRIS/SSA Distinguished lectureship (Seismological Society of America).
- Presented an invited global seismic risk talk to a group of reinsurance companies in Bermuda.
- Associate Director of CIRES.
- Reviewer of about 20 journal articles for JGR, SSA, Current Science, EPSL and Geology.

Brock Charles:
- Reviewer for Aerosol Science and Technology and Journal of Geophysical Research, NASA and NOAA proposals.

Brown, Steven:
- Reviewer for Journal of Physical Chemistry, Journal of Geophysical Research - Atmospheres, Atmospheric Environment and grant proposals for NSF and NASA.

Buhr, Susan:
- Reviewer for Journal of Geoscience Education
- Member of AGU Committee on Education Human Resources
- Chair, AGU Atmospheric Section Education Committee
- Reviewer of proposals for NASA REASON and NSD Geosciences

Cassano, John:
- Reviewer for Journal of Climate, Geophysical Research Letters, and Journal of Glaciology.
- Reviewer of grant proposal for U.S. Civilian Research & Development Foundation.
- Member of AMS Polar Meteorology and Oceanography committee.
- Member of NSF ARCSS FWI Precipitation Working Group.
- Member of Ross Island Meteorology Experiment (RIME) science plan committee.
- Session chair at AMS Polar Meteorology and Oceanography Conference.

Chase, Thomas:
- Proposal Referee for NASA, National Science Foundation
- Reviewer for Journal of Climate; J. Meteorology and Atmospheric Physics; Climate Dynamics.

Chilson, Phillip:
- Co-chairman, Permanent Working Group for Mesosphere Stratosphere Troposphere radars: System Calibrations and Definitions.
- Member, Mesosphere Stratosphere Troposphere Radar Steering Committee.
- Reviewer for Radio Science, Annales Geophysicae, Journal of Atmospheric and Oceanic Technology.

Codrescu, Mihail:
- Reviewer for JGR, GRL, Adv. Space Res., JASTP, and Annales Geophysicae, NSF and NASA proposals.

Compo, Gilbert:
- Reviewer for J. Clim., Hydrol. Sci. Jour., *The Hadley Circulation: Past, Present, and Future* (H.F. Diaz and R. Bradley eds.).
- Co-convenor, Working Group on surface pressure, Atmosphere Observation Panel for Climate, WCRP/Global Climate Observing System.

Cooper, Owen:
- Reviewer for JGR-Atmospheres, Atmospheric Environment, Atmospheric Chemistry and Physics, proposals for NASA and NSF.

Copley, Shelley:
- Councilor, Biological Division, American Chemical Society
- Co-Vice Chair, Gordon Research Conference on Enzyme, Coenzymes, and Metabolic Pathways, Meriden, New Hampshire, 2003.
- Associate, American Chemical Society Committee on Environmental Improvement.

De Gouw, Joost:
- Reviewer for Journal of Geophysical Research, Journal of Environmental Management, Atmospheric Chemistry and Physics Discussions, Atmospheric Chemistry and Physics, International Journal of Mass Spectrometry, Biotechnology Progress, Chemical Reviews, Atmospheric Environment.

Farmer, Lang:

- Member-IMAGES (International Marine Past Global Changes) Working Group on Ice Sheet/Ocean interactions.
- Contributed updated "datasheet" on igneous rock classifications to the American Geologic Institute (for their "AGI Data Sheets" series).
- Associate Editor and Reviewer of numerous manuscripts for GSA Bulletin and Lithos.
- Reviewer of NSF grant applications.
- Organizer, Second annual Workshop for North American Volcanic Rock database (NAVDAT), Boulder, CO.

Fetterer, Florence:

- Reviewer for International Journal of Remote Sensing.

Frehlich, Rod:

- Member of NASA's Coherent Lidar Technology Advisory Team
- Member of NASA's Advisory Team for Data Requirements for Global Measurements of Winds.

Frauenfeld, Oliver:

- Reviewer for Hydrological Processes, Journal of Atmospheric Sciences, Climate Research; U.S. Civilian Research and Development Foundation's Cooperative Grants Program, National Science Foundation Grant Program.

Frost, Gregory:

- Reviewer for Journal of Geophysical Research.

Fuller-Rowell, Tim:

- Reviewer for unspecified scientific journals and proposals.
- Member of JASTP Editorial Board.
- Member of COSPAR Panel for Space Weather Advances in Space Research, Editor for Space Weather edition.
- Member of IRI Working Group.
- Member of Program Committee for the 2005 Ionospheric Effect Symposium.
- Serve on NASA LWS Geospace Mission Definition Team.
- Co-organizer of CEDAR GIFT.
- Member, AGU Student Awards Committee.
- Member of Program Committee for the 2005 International Symposium for Equatorial Aeronomy.
- Member of International Heliophysical Year (IHY) Workshop Planning Committee.
- Member of the Program Committee for an AGU Chapman Conference on Corotating Solar Wind Streams and Recurrent Geomagnetic Activity.

Gangopadhyay, Subhrendu:

- Reviewer for ASCE, Journal of Hydrologic Engineering, Journal of Geophysical Research – Atmospheres.

Gentsch, Karen:

- Informix International Users Group of Colorado, Board Member, Webmaster.

Godin, Oleg:

- Reviewer for Journal of Fluid Mechanics, Journal of the Acoustical Society of America, Journal of Computational Acoustics, IEEE Journal of Oceanic Engineering, Chaos, Proceedings of the Royal Society (London), and Waves in Random Media.
- Member of the Scientific Committee of the Sixth International Conference on Theoretical and Computational Acoustics (Honolulu, Hawaii, 2003).
- Member of the Technical Committee on Acoustical Oceanography of the Acoustical Society of America.

Granier, Claire:

- Co-chair of the GEIA (Global Exchanges and Interactions Activity) of IGBP (International Geosphere-Biosphere Program).
- Member, SPARC (Stratospheric Processes and their Role in Climate) Project Scientific Steering Group.

Gross, Susanna:

- Reviewer for NSF proposal and journal papers.

Gupta, Vijay:

- Served as CU representative on the NSF-funded Consortium of Universities for Advancement of Hydrologic Sciences, Inc. (CUAHSI).

Hamill, Thomas:
- Member of ensemble forecast working group for WRF, the "Weather Research and Forecast model."
- Organizational committee for First Hydrologic Prediction Experiment (HEPEX)

Hare, Jeffrey:
- Member of the Air-Sea Exchange Committee within the American Geophysical Union Atmospheric Science Section.

Hartten, Leslie:
- Member of the AMS Board on Women and Minorities.

Hübler, Gerhard:
- Reviewer for Journal Geophysical Research.
- ICARTT 2004 Coordination and Planning workshop.

Hurst, Dale:
- Reviewer for Journal of Geophysical Research – Atmospheres, Environmental Science and Technology.

Jackson, Darren:
- Reviewer for Journal of Geophysical Research - Atmospheres, Geophysical Research Letters, and Journal of Climate.

Janches, Diego:
- Guest Editor for Atmospheric Chemistry and Physics Journal for the Special Issue "Meteors in the Atmosphere" (Arecibo Workshop 2003).
- Guest Editor, Journal of Atmospheric and Solar Terrestrial Physics special issue for Meteor and the Mesopause.
- Convenor of the Session Meteors and the Upper Atmosphere at CEDAR, June 2004, Santa Fe, NM.
- Local Organizing Committee of the Polar Aeronomy Summer School, Arecibo Observatory, Puerto Rico, 2004.
- Convenor of Radar Meteors at the Annual URSI meeting, January 2005, Boulder CO.

Jimenez, José:
- Convenor of the Heterogeneous Chemistry Special Symposium at the 2003 Annual Conference of the American Association for Aerosol Research.
- Chair (after Oct. 2003) and Co-Chair (before Oct. 2003) of the Aerosol Chemistry Working Group of the American Association for Aerosol Research (AAAR).
- Co-Organizer of the Fourth Aerodyne Aerosol Mass Spectrometer (AMS) Users Meeting, Caltech, Pasadena, California.
- Invited Panelist to the NSF Workshop "Emerging Issues in Nanoaerosol Science and Technology."
- Coordinator of the Aerosol Measurements Working Group for the Mexico City Metropolitan Area (MCMA-2003) Field Study.
- Member of the External Review Panel for Air Pollution and Combustion Research at the Spanish National Laboratory for Energy and Environmental Research (CIEMAT).
- CU representative in the organizing committee for the NCAR Aerosol Program (NAP).

Johnston, Paul:
- Reviewer for Radio Science.

Jones, Craig:
- Member, Steering/Organizational Committee for proposed EarthScope workshop on Thermal Processes, research aims and scientific return within the EarthScope initiative.
- Geological Society of America: Member, committee to define a new electronic journal for the Society. J.D. Walker, Univ. Kansas, Committee Chair.

Jones, R. Michael:
- Reviewer, book proposal, "Internal Gravity Waves" by B. R. Sutherland for Cambridge University Press.

Laursen, Sandra:

- Executive committee member, ChemLinks Coalition.
- Member of the National Visiting Committee for the Texas Collaborative for Excellence in Teacher Preparation (TxCETP).
- External evaluator for an ongoing NSF-DUE CCLI grant, "Enhancement of the Undergraduate Physical Chemistry Laboratory."
- Member of the workshop planning group and workshop leader for a three-year collaborative effort to disseminate the results of several major NSF chemistry initiatives, "Multi-Initiative Dissemination: Strategies to Promote Active Learning in Chemistry Courses."
- Member of the writing team for "Doing Science: The Process of Scientific Inquiry," National Institutes of Health and National Institute of General Medical Sciences.

Lestak Leanne:

- Developed a CU Geospatial user group with Bill Manley and Barbara Buttenfield. Membership is from CU Boulder, Denver, Colorado Springs, NOAA and NCAR.

Lewis, William:

- Board member, Council of Aquatic Scientists.
- Advisor, State of Colorado Department of Public Health.
- President, Rocky Mountain Hydrologic Research Center, Ft. Collins, CO.
- Advisory Panel, Max Planck Institute for Limnology.
- Past President, American Society of Limnology and Oceanography.
- Chair, National Academy/National Research Council, Committee on Endangered and Threatened Fishes in the Klamath River Basin.
- Editorial Board, Limnology and Oceanography Methods Journal Peer Review Panel.
- Swiss Federal Institute for Environmental Science and Technology (EAWAG).

Lin, Jialin:

- Reviewer for Journal of the Atmospheric Sciences, Monthly Weather Review, Quarterly Journal of the Royal Meteorological Society, and Journal of the Meteorological Society of Japan.

Machol, Janet:

- Reviewer for Applied Optics, SBIR proposals for DOE.

Meier, Walter:

- Reviewer for Journal of Atmospheric and Oceanic Technology, IEEE Transactions on Geoscience and Remote Sensing, Journal of Geophysical Research, Oceans.

Miller, John:

- Reviews for Global Biogeochemical Cycles, Tellus, Rapid Communications in Mass Spectrometry, Geophysical Research Letters, and proposal review for NSF.
- Organized special session at 2003 Fall AGU, "Isotopic Constraints on Global Budgets of Atmospheric Gases."

Minter, Clifton:

- Secretary for the Boulder, Colorado Chapter of Sigma Xi, Scientific Research Society

Molnar, Peter:

- Waldo Smith Medal Committee, American Geophysical Union.
- Co-organizer, Workshop of Ocean Gateways and Climate Change, Lamont-Doherty Earth Observatory, Columbia University.
- Co-organizer, Workshop of Drilling of Indian Ocean Fans, University of Colorado.
- Organizing committee, Qinghai Workshop: "Scientific Drilling at Qinghai Lake on the northeastern Tibetan Plateau: High-resolution paleoenvironmental records of eastern Asia and their significance for global change," Xining, Qinghai Province, China.

Monson, Russell:

- Member, Research Advisory Committee, Columbia University Biosphere 2 Center, Oracle, Arizona.
- President, Physiological Ecology Section, Ecological Society of America.

Moore, Andrew:

- Member of the organizing committee of a NSF/ONR sponsored workshop on "Ocean Data Assimilation," Williamsburg, VA.

Moore, Fred:

- Reviewer for journals in the atmospheric sciences and in the atomic and elementary particle sciences.

Muschinski, Andreas:

- Reviewer for Radio Science, Annales Geophysicae, Applied Optics, Journal of the Atmospheric Sciences, and NSF proposals.

Neale, Richard:
- Reviewer for Monthly Weather Review, Quarterly Journal of the Royal Met. Society and the Journal of Geophysical Research.

Nerem, Steven:
- Member and Secretary, Geodesy Section Executive Committee, American Geophysical Union.

Newman, Matthew:
- Reviewer for unspecified journals, NSF proposal.

Nowak, John:
- Reviewer for NASA proposal.

Odstrcil, Dusan:
- Reviewer for J. Geophys. Research.
- Reviewer of project proposals and participation at the NASA panel.

Painter, Thomas:
- Reviewer for Hydrological Processes, Photogrammetric Engineering and Remote Sensing, Computers & Geosciences.
- Webmaster for the Western Snow Conference.
- Intensive Study Area Leader.
- Team Leader, NASA/NWS Cold Land Processes Experiment, Rocky Mountains, Colorado.

Parsons, Mark:
- Member of the International Permafrost Association Standing Committee on Data, Information, and Communication.

Peckham, Steven:
- Reviewer for AMS journals.

Peng, Shiling:
- Reviewer for Climate Dynamics, J. Climate, Geophys. Res. Lett.

Persson, Ola:
- Reviewer for unspecified journals.
- Member of scientific steering committee for Coastal Oceans Processes.
- Member of AMS Coastal Environment Committee.

Pielke Jr., Roger:
- Member, Science Steering Committee, World Weather Research Programme.
- Member, National Academy of Sciences, Board on Ocean Sciences Committee on Abrupt Climate Change.
- Member, Expert Social Science Review Panel, National Oceanic and Atmospheric Administration Science Advisory Board.
- Adjunct Scientist, University of Illinois, Illinois State Water Survey.
- Academic Advisory Board, Columbia University, Center for Science, Policy and Outcomes.
- Faculty Associate, Columbia University, Center for Science, Policy and Outcomes.
- Advisory Panel, Program on Societal Dimensions of Engineering, Science and Technology, National Science Foundation.
- Member, Advisory Committee, Pacific ENSO Applications Center

Pincus, Robert:
- Reviewer for Journal of Climate, Journal of Geophysical Research, Quarterly Journal of the Royal Meteorological Society, Journal of Applied Meteorology, NASA, ALW (the Dutch NSF) proposals.

Rajagopalan, Balaji:
- Reviewer for papers for Journals of Climate, Water Resources Research, Geophysical Review Letters, Hydrologic Engineering, American Water Resources Association, NSF, NOAA, Hydrometeorology, Monthly Weather Review, Emerging Infectious Diseases. Reviewer for a chapter for a monograph of "American Geophysical Union."

Reid, George:
- Reviewer for unspecified journals.

Rye, Barry:
- Editor, Applied Optics (Optical Society of America).
- Reviewer for Applied Optics, Journal of Atmospheric and Oceanic Technology, and phase 1/phase 2 SBIR proposals (Dept. of Energy).

Saunders, James:
- Reviewer for USDA Water and Watersheds proposals.

Scambos, Ted:
- Scientific Editor for Journal of Glaciology Chairman of the McMurdo Area User's Committee.

Schafer, Robert:
- Reviewer for Reviews of Geophysics.

Scharfen, Gregory:
- Member, SCAR/COMNAP Joint Committee on Antarctic Data Management.
- Member, MODIS Snow and Ice Products Ad Hoc Advisory Group.

Schein, Michael:
- Engineering support to NASA during the Colombia accident investigation.

Schulte-Pelkum, Vera:
- Reviewer for proposals for NSF EAR program.

Scott, Michon:
- Earth Sciences volunteer for the Denver Museum of Nature & Science, including contributions to the Ancient Denver Web site at *http://www.dmns.org/ad/*.

Serreze, Mark:
- Reviewer of unspecified manuscripts and proposals.

Sheehan, Anne:
- Member, Colorado Earthquake Hazards Mitigation Council.
- Committee Member, Incorporated Institutions for Seismology (IRIS) Program for Array Seismic Studies of the Continental Lithosphere (PASSCAL) Standing Committee.
- Advanced National Seismic System (ANSS), Intermountain West Regional Working Group member, State of Colorado representative.
- Member, USGS National Earthquake Hazards Reduction Program (NEHRP), Proposal review panel.

Shin, Sang-Ik:
- Reviewer for J. of Geophys. Res.-Atmospheres, *The Hadley Circulation: Past, Present, and Future* (H.F. Diaz and R. Bradley eds.).

Shinoda, Toshiaki:
- Reviewer for Dynamics of the Atmosphere and Ocean, J. of Atmospheric Science, AGU, NASA proposals.

Slater, Andrew:
- Reviewer for Annals of Glaciology, Journal of Hydrometeorology, Climate Dynamics.

Smirnova, Tatiana:
- Reviewer for Journal of Geophysical Research, Journal of Hydrometeorology, Weather and Forecasting

Smith, Catherine:
- Reviewer, DOE data viewer proposal.

Smith, Lesley:
- Member of the Education Committee, American Society for Limnology and Oceanography.
- Outreach Activities section for the new American Society for Limnology and Oceanography website.
- Chaired a special session on education outreach at the Winter ASLO meeting entitled, Leave No Scientist Behind: How to Get Scientists in the K-12 Classroom.

Solomon Amy:
- Member, AMS Atmospheric and Oceanic Fluid Dynamics Committee

Sperry, Paul:
- Chair of the Science Committee for the Council on World Affairs

Steffen, Konrad:
- Member, Publication committee, International Glaciological Society,
- Member, NASA Algorithm Theoretical Review Panel for sea ice and oceans.
- Member, RADARSAT Geophysical Processor System Team (NASA/RGPS).
- Review Committee Member, NASA ICES at Science System Operation Readiness
- Member, NSF-OPP Steering committee for long-term monitoring site – Summit Greenland.

- Member, WMO/WCRP Arctic Climate Systems Scientific Steering committee
- Chair, WMO/WCRP ACSYS Observations Products Panel committee.
- Member, WMO/WCRP Remote Sensing committee.
- Member, NSF/NASA/NOAA SEARCH Scientific Steering committee.
- Associate Editor, Zeitschrift fuer Gletscherkunde und Glazialgeologie.

Stohl, Andreas:

- Editor for Atmos. Chem. Phys.
- Associate editor for J. Geophys. Res.-Atmospheres.

Stroeve Julienne:

- Member, AMSR-E Sea Ice Team.
- Member of the AATSR LST Validation Team to validate the snow surface temperature.
- Reviewer for IEEE Transactions on Geoscience and Remote Sensing, Journal of Climate, Journal of Geophysical Research, Journal of Glaciology, proposals for the NCAR and Los Alamos sea ice models and for NRA-03 NPP.

Sun, Dezheng:

- Reviewer for J. Climate, J. Atmos. Sci., and Geophys. Res. Lett. Proposal reviewers for NOAA PACS, NSF Climate Dynamics Program, and the NOAA Pacific Program.

Sura, Philip:

- Reviewer for Journal of the Atmospheric Sciences, Journal of Physical Oceanography, and Geophysical Research Letters.

Talukdar, Ranajit:

- Reviewer for J. Phys. Chem., J. Geophys. Res. and Chemical Review.
- Reviewer, PhD thesis submitted to Weizmann Institute of Science.

Tervahattu, Heikki:

- Reviewer "Estimating the Frequency Distributions of PM2.5, PM10 and its Relative Metallic Elements from Restricted Data in Temple," Journal of the Air & Waste Management Association, "SVEVESTØVPRODUKSJON OG VEGDEKKER - VEGDEKKER OG HELSE," SINTEF report (in Norwegian), Norway's Road Administration.

Thornberry, Troy:

- Reviewer for J. Geophys. Res.-Atmos.

Tolbert, Margaret:

- Department of Chemistry and Biochemistry: General Chemistry Coordination, Atmospheric Chemistry committee, Executive Committee
- Member, Diversity Panel, Faculty Club Forum
- Associate Editor, Atmospheric Environment

Tyus, Harold:

- Invited speaker at the annual meeting of the Desert Fishes Council.
- Reviewer for Toxicology and Environmental Safety, Southwestern Naturalist, and Western North American Naturalist.
- Co-chairman of the Environmental Concerns Committee of the Western Division of the American Fisheries Society.
- Contributor, Recovery Management Plan for the Big River Fishes of the Lower Colorado River, produced by the U.S. Fish and Wildlife Service and cooperators.

Voemel, Holger:

- Reviewer of unspecified manuscripts and proposals.

Wahr, John:

- Advisory Editor for Physics of the Earth and Planetary Interiors.
- Member of the IERS Special Bureau for Loading.
- U.S. Representative to the IAG Earth Tides Commission.
- Member of IAG/IAPSO working group on "The geodetic effects of non-tidal ocean processes."
- Member of GRACE Science Team.
- Member of IAG Special Study Group on "Gravity field missions calibration and validation."
- Co-Convener of session: "Ocean, atmosphere,water cycle, solid earth interactions: global scale" at the Spring Meeting of the American Geophysical Union + European Geophysical Society, Nice, France, April 7-11.
- Co-convener of session: "Interdisciplinary earth science from improved gravity field modeling," at the General Assembly of the International Union for Geodesy and Geophysics, Sapporo, Japan, June 30 - July 11.

- Chair, CIRES Director's Reappointment Committee (CIRES)
- Evaluation Panel, spring semester (Physics Department)
- Arts and Sciences Advising Committee (Physics Department)
- Member of Beverly Sears Graduate Student Grant Selection Committee (CU Graduate School)
- Physics representative to the Geophysics PhD Program (Graduate School).
- Reviewer for Science, Earth and Planetary Science Letters, Physics of the Earth and Planetary Interiors, Geophysical Research Letters, Journal of Geophysical Research, NASA, NSF, Journal of Geodesy, Proceeedings of the National Academy of Sciences, Global and Planetary Change, Geophysical Journal International, Annals of Glaciology, Tectonophysics

Warneke, Carsten:

- Reviewer for Journal of Geophysical Research, Atmospheric Environment, Journal of Air and Waste Management.

Wessman, Carol:

- Reviewer for Geophysical Research, Ecology, Ecological Applications, U.S. Department of Agriculture, National Science Foundation, BioScience, NASA.

Westwater, Edgeworth:

- Associate Editor, Radio Science.
- Reviewer for J. Appl. Meteor., Radio Sci., J. Atmos. Ocean. Tech., TGARSS, ETL papers.
- Co-editor of the Special Issue of Radio Science that resulted from the Specialist Meeting on Microwave Remote Sensing '2001.
- Co-organizer of session for IGARSS'04 Reviewed 8 abstracts from Microrad '04.

White, Allen:

- Member of NOAA/NWS Science and Technology Infusion Planning (STIP) Team for Winter Weather Services.

Williams, Christopher:

- Reviewer for Journal Geophysical Research - Atmospheres, Journal of Atmospheric and Oceanic Technology, and Radio Science.

Wolter, Klaus:

- MEI webpage (*http://www.cdc.noaa.gov/~kew/MEI/*) on tropical Pacific ENSO conditions.
- Monthly updated climate forecast webpage for the Interior Southwest (*http://www.cdc.noaa.gov/~kew/SWcasts*).
- Colorado Water Availability Task Force.
- Reviewer for J. Climate, Bull. AMS, Water Resources Research, and NOAA/OGP (Proposals).

Zhang, Tingjun:

- Editoral Board of the Journal of Glaciology and Geocryology, and Cold Regions Science and Technology.
- NASA Cold Land Surface Processes Working Group.
- Scientific director of the Institute of Plateau Meteorology (IPM), China Meteorological Administration (CMA), Chengdu, China.

Zuidema, Paquita:

- Reviewer for unspecified professional journals, NASA and NSF proposals.