National Snow and Ice Data Center/ World Data Center for Glaciology, Boulder

Annual Report For 1999

NSIDC, CIRES, University of Colorado, Boulder
March 2000

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NATIONAL SNOW AND ICE DATA CENTER/ WORLD DATA CENTER-A FOR GLACIOLOGY

ANNUAL REPORT FOR 1999

INTRODUCTION

The National Snow and Ice Data Center (NSIDC) is an information and referral center supporting polar and cryospheric research. We distribute data and maintain information about snow cover, avalanches, glaciers, ice sheets, freshwater ice, sea ice, ground ice, permafrost, atmospheric ice, paleoglaciology, and ice cores. We also publish reports and a quarterly newsletter and maintain a collection of monographs, technical reports, and journals.

NSIDC and the co-located World Data Center for Glaciology is part of the University of Colorado Cooperative Institute for Research in Environmental Sciences (CIRES), and is affiliated with the National Oceanic and Atmospheric Administration (NOAA) National Geophysical Data Center (NGDC) through a cooperative agreement. The WDC for Glaciology in the United States has been in existence since 1957, in Boulder since 1976, and affiliated with the University of Colorado Cooperative Institute for Research in Environmental Sciences since 1981.

This report summarizes the data management activities of NSIDC and related research of its scientific staff during calendar year 1999 and a few items not included in the FY 1997-1998 report that relate to activities in the last 2 –3 months of 1998.

R. G. Barry,
Director
NSIDC/WDC for
Glaciology, Boulder

HIGHLIGHTS

National Research Council Review of NSIDC DAAC Published

The NRC Review of the NSIDC and other DAACs was published in late 1998 (National Research Council, 1998). Comments on NSIDC were based on a 2-day site visit in March 1998.The review panel for the NSIDC DAAC was chaired by J.-Bernard Minster. The report finds that important factors that have helped the NSIDC DAAC implement its mission are: (1) a strong vision of serving its scientific community, and (2) its colocation with the NSIDC and WDC for Glaciology. The close relation with CIRES was also noted. The Panel considered that the current relationship with the National Geophysical Data Center seemed pro forma. They suggested NGDC could use its links to NSIDC to play a stronger role in the Earth Observing System mission. It was recommended that the NSIDC DAAC should sponsor joint activities with the ASF DAAC and should sponsor a visiting scientist program.

National Research Council. 1998. *Review of NASA's Distributed Active Archive Centers*. National Acdemy Press, Washington, DC, 233 pp.

SHEBA Reconnaissance Imagery

Reconnaissance imagery of sea ice released: In August 1999, Vice President Gore announced the declassification of reconnaissance images of the SHEBA site in the Arctic Ocean. The imagery was released at the request of the National Science Foundation (NSF). NSF is the primary sponsor of the SHEBA experiment, in which a Canadian icebreaker was frozen in pack ice for over a year. The high resolution of the imagery will allow investigators to characterize surface conditions and their impact on the net radiation balance. http://arcss.colorado.edu/Projects/ShebaRecon/.

ULS Submarine Data on Ice Drafts

Submarine Upward Looking Sonar Ice Draft Profile Data and Statistics: With this data set, NSIDC has established itself as the primary public source for declassified and unclassified data from both U.S. Navy and Royal Navy submarines. The U.S. Army's Cold Regions Research and Engineering Laboratory submitted the first cruise data to NSIDC. Contributions from Scott Polar Research Institute, University of Cambridge, and the Polar Science Center, University of Washington, followed in 1999. The archive now contains data from eight cruises and we expect it to continue growing. Data set development and management have been funded under the NOAA NESDIS Environmental Services and Data Information Management (ESDIM) program. Trends in the ice thickness distribution are postulated as a result of global warming. However, little is known about the regional and seasonal variability of ice thickness distributions. The importance of this data set is borne out by recent research on reductions in sea ice volume (e.g. Rothrock, Yu, and Maykut, "Thinning of the Arctic Sea-Ice Cover", GRL 26(23), 1999).

EOS Ground System Testing

NSIDC staff participated in the EOS Ground System (EGS) 10 Test 16-17 November 1999. The EGS 10 was developed in cooperation with Averstar , Incorporated and was designed to verify the functionality and operational aspects of the EOSDIS Core System (ECS) installed at NSIDC. Averstar is under contract with the NASA/GSFC ESDIS Project Office to perform an independent verification and validation of the EGS. The EGS 10 test was conducted at each of the ECS DAAC sites as part of the overall testing program in support of the Terra Mission.

The objectives of the EGS 10 test were to verify the following services:

- ingest and archival of MODIS and NISE products
- user services including user registration, account managment, and order tracking
- subscription services
- inventory query, browse, and data ordering
- automated staging of data for ftp access
- distribution of data on 8mm media

Anomalies due to minor problems with performance and functionality of the ECS were observed by both DAAC and Averstar staff during the EGS 10 test. Liens were documented; trouble tickets and non-conformance reports (NCRs) were filed with the ECS development organization.

Overall, the test was a success and demonstrated that the ECS Maintenance and Operations staff at NSIDC are able to support daily operations of the ECS in order to meet the objectives of the Terra Mission.

NEW PRODUCTS

Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I Passive Microwave Data

Efforts supporting the polar stereographic-grid SSM/I products included implementation of "near real-time" (typically, 3-day delay or less) SSM/I-grid brightness temperatures and sea ice products; obtaining and archiving improved Electrically Scanning Microwave Radiometer (ESMR) gridded brightness temperatures; and distribution of a new set of Bootstrap algorithm-derived sea ice concentrations. Ongoing data sets continue to be updated, including revisions to our data set summaries that provide users with a quick overview of variations in global sea ice cover. We also are continuing our efforts to document sources of biases and error in the sea ice time series, including summarizing differences between satellites, and effects of atmospheric conditions, snowcover, and sensor viewing angle.

Polar Pathfinder Data Sampler

NSIDC published a Polar Pathfinder Data Sampler CD-ROM. This CD includes data from the SSMI, AVHRR, and TOVS Polar Pathfinder data sets. Unique to this CD-ROM is the PCUBE data set, which contains data from these sensors, all gridded to 100km grid cells, and placed in HDF format. Further information on the Polar Pathfinder projects is available on page 12.

NSIDC Special Report on Ice Motion

A "Summary of Ice-Motion Mapping Using Passive Microwave Data" by J. Maslanik and six outside collaborators was published as a web document (http://www-nsidc.colorado.edu/nasa/guide/ssmi/ssmi_tech_note.pdf).

WEB DEVELOPMENT

During the year, the following improvements and additions were made to the website: site overhaul aimed at eventual site redesign and restructuring was initiated, including web development procedures together with a project aimed at automation of the online catalog.

Implemented web maintenance functions, including regular link checking, retroactive validation of all site HTML, and validation of new HTML content.

Completed topical or "theme" pages for:

"Polar Ice Sheet DEMs and Topographic Data at NSIDC"
http://www-nsidc.colorado.edu/dems/

"All About Glaciers"
http://www-nsidc.colorado.edu/glaciers/

Initiated topical or "theme" pages for:

"Antarctic Ice Shelves and Icebergs"
http://www-nsidc.colorado.edu/iceshelves/

"All About EASE-Grid"
http://www-nsidc.colorado.edu/NASA/GUIDE/EASE/ease_maps_info.HTML

"State of the Cryosphere"
http://www-nsidc.colorado.edu/NASA/SOTC/

Completed "project/program" pages for:

Moderate Resolution Imaging Spectroradiometer (MODIS)
http://www-nsidc.colorado.edu/modis/

Initiated "project/program" pagesfor:

Radarsat Antarctic Mapping Project (RAMP)
http://www-nsidc.colorado.edu/ramp/

Antarctic Glaciological Data Center (AGDC)
http://www-nsidc.colorado.edu/NSF/AGDC/

Geoscience Laser Altimetry System (GLAS)
http://www-nsidc.colorado.edu/glas/

Revamped "project/program" pages for:

the NOAA/NASA the Polar Pathfinders at NSIDC
http://www-nsidc.colorado.edu/NASA/POLAR_PATHFINDERS/

News releases made via the Web:

U.S. National reconnaissance imagery of the SHEBA site
http://www-nsidc.colorado.edu/sheba_ntm/

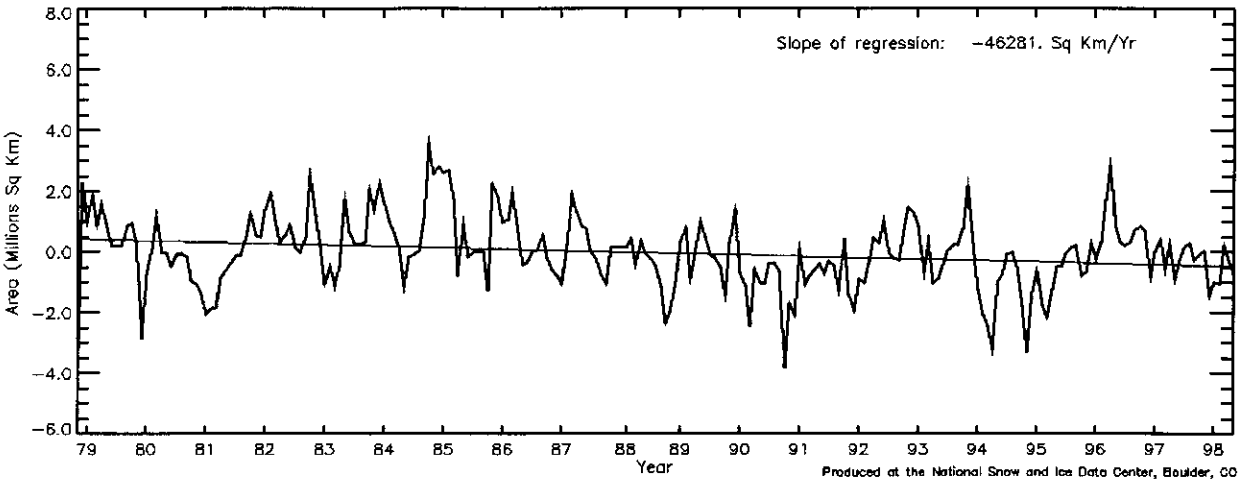
Movement of iceberg B-10A into Antarctic ship lanes
http://www-nsidc.colorado.edu/iceshelves/b10/

The World Data Center for Glaciology, Boulder has a new web page (http://www-nsidc.colorado.edu/NOAA/wdc-a.html) describing our activities, data sets, and history.

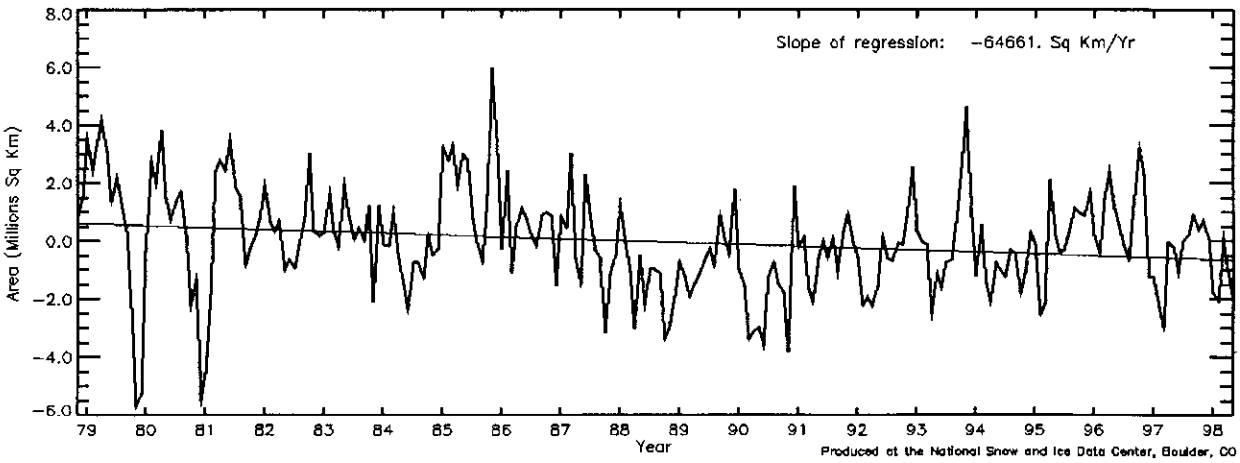
State of the Cryosphere: A new web page at NSIDC

http://www-nsidc.colorado.edu/NASA/SOTC/

This new web page is intended to provide a broad audience, both scientific and general, with a current and succinct overview of the response of various components of the cryosphere to climate change. It is now generally accepted that global mean temperatures have been increasing over the past several decades. Our initial focus in the "State of the Cryosphere" is to determine how features such as seasonal snow cover, sea ice, mountain glaciers, and the related topic, sea level, have responded to this warming. The fluctuations of these three parameters over the past several decades, derived from both satellite remote sensing and measurements on the ground, are presented in time series plots. Future enhancements of this web page will include coverage of additional cryospheric features such as ice sheets, ice shelves and permafrost. The time series and associated products represented at this site will be updated as new data and information become available at NSIDC.



Visible-derived (NOAA) snow-covered area (x 10^6 km^2) departures from monthly means for the Northern Hemisphere, 1979-1998.



Passive microwave-derived (SMMR and SSM/I) snow-covered area (x 10^6 km^2) departures from monthly means for the Northern Hemisphere, 1979-1998.

CURRENT PROGRAMS

U.S. Antarctic Data Coordination Center

The National Science Foundation (NSF) funds the U.S. Antarctic Data Coordination Center (USADCC) at NSIDC to assist investigators in the development of data descriptions, for data they have collected as a result of their Antarctic research funded by the Office of Polar Programs (OPP). The data documentation is sent by NSIDC to the Antarctic Master Directory (AMD). This is in direct support of the NSF Guidelines and Award Conditions for Scientific Data, issued December 1998.

U.S. Antarctic data descriptions. As of November 1999, there are 1739 Antarctic related entries describing data sets collected as a result of U.S. funded Antarctic research. This is an increase of more than 936 since January 1999

Improved U.S. Antarctic Data Coordination Center (USADCC) web site. The USADCC website provides an overview of the project and promotes U.S. Antarctic metadata collection. It also links to GCMD metadata registration tools, provide links to NSF, describes the data policy and other Antarctic sites. The page is at http://www-nsidc.colorado.edu/NSF/NADCC/.

The AMD host has been transferred from the International Center for Antarctic Information and Research (ICAIR) in Christchurch, New Zealand to NASA's Global Change Master Directory (GCMD), the U.S. coordinating node of the Committee on Earth Observation (CEOS)/International Directory Network (IDN).

The June 1999 Joint Committee on Antarctic Data Management (JCADM) meeting was held in conjunction with the Arctic Data Directory Council, which is involved with a comparable Arctic effort, the International Arctic Environment Data Directory (IAEDD). JCADM and ADD will attempt to coordinate their efforts so that, ultimately, the user community is presented with a consistent system across both poles, as part of the CEOS/Intenational Directory Network (IDN).

The U. S. Antarctic Glaciological Data Center

Beginning in 1999, NSF funded NSIDC to operate the U.S. Antarctic Glaciological Data Center (AGDC). The AGDC provides data management for the U.S. Antarctic Glaciological Program and related cryospheric science investigations. The AGDC is tasked with the development and implementation of a web-based archival and distribution capability for well documented physical and geochemical data derived from ice cores, ice surface elevations, ice thickness, and bedrock topography, snow accumulation data and 10-meter temperatures, ice velocity measurements from remote sensing imagery and field survey
data.

During the first year of operation, a data management template, together with the web-based archive and distribution capability, have been developed. The AGDC has been implemented with a few key data sets which are representative of investigators and data that we will be targeting over the course of the project. Our approach is to build and demonstrate the capability first and then to more data sets from the community to it over time. A limited the amount of data is currently available from the AGDC. The establishment of our data ingest procedures, continued evolution of our web distribution approach, along with our proactive interactions with the Antarctic glaciological community, will increase data set holdings at the AGDC during 2000.

The AGDC web site and its current holdings are accessible at:
http://www-nsidc.colorado.edu/NSF/AGDC/

ARCSS Data Coordination Center

The ARCSS Data Coordination Center (ADCC) at NSIDC completed its second year of an extended grant to provide ARCSS data and information to the scientific community well into the 21st century. The ADCC is the permanent archive and access point for all data and information collected by investigators in the ARCSS Program, as well as requested data by ARCSS investigators. We continue to be a catalyst for ARCSS integration through data and information management. We have continued to improve our system of data availability and submission. We also continue to work with all components of the ARCSS Program to constantly improve our scheme for data management and accessibility.

We have been actively participating in the establishment of data transfer procedures with the UCAR office for the SHEBA Phase II data collected last year. We are preparing for the large influx of data to our facility, which will happen in the early part of 2000.

We have been asked to provide the long-term archive for the SCICEX program. It is funded out of the Natural Sciences Program within NSF. This large data grouping from U.S. Navy Submarines, spanning back to 1993, will be a significant addition to the extensive collection of data and information already in-house. Data sets have already started to arrive and have been made available. We anticipate a high data volume from the project. We continually work with the appropriate people, including the Arctic Submarine Lab, to define the kinds of data and data products which we will distribute from SCICEX.

The ADCC is also experimenting with new ways to access data from our archives. We have been working with Amanda Lynch at University of Colorado to develop a completely automated system for data requests through our web site for her model output data from the regional Arctic climate model ARCSyM. We are hoping that this will help us streamline data requests and acquisitions for large data sets/groupings.

We have streamlined and improved our internal procedures for processing data through our facility. It provides a more complete data and information set to the scientific community and assists the investigators when they submit their findings to the archives.

Rudy Dichtl was appointed as manager of this project in December 1999; Chris McNeave continues as the ARCSS Data Coordinator, and is responsible for data ingest, system enhancements, CD-ROM development, and design and maintenance of the ARCSS Home Page. Tracy Thrasher is our User Services Representative from NSIDC and responsible for user requests, and Robin Welsh is our technical writer.

As we continue to improve not only our data accessibility through the WWW, but also the distribution of data on CD-ROMs and other media, we each a more diverse group of and in which we expose them to data and information from the interdisciplinary ARCSS investigators. We continue to average well over 600 megabytes of data and information downloaded per month, and have now reached over 45 countries. These data

sets are mostly in-situ and small data groupings rather than the large, multi-sensor collections which are typically distributed from NSIDC.

We continue to provide support for data previously collected under ARCSS from non-current projects (GISP2, LAII/FLUX, etc.). We consider this an extremely important element of the legacy of the ARCSS program that cannot be lost.

Polar Pathfinders

SMMR and SSM/I Pathfinders

The NOAA/NASA Pathfinder Program was initiated in 1993 to facilitate the application of currently archived satellite remote sensing data for global change research. The primary goals of the program were to assure that these data and associated products were 1) scientifically validated and of research quality, 2) placed in a readily accessible working data archive, and 3) were available long-term at a minimal cost. It was also noted that Pathfinder principal investigators should maintain close contact with users in order to provide products of the highest quality. Ultimately it would be the level of acceptance and use of these products by the research community that would determine the success of the work. With regard to the NSIDC SMMR and SSM/I Level 3 Pathfinder, we feel that these specific goals have been successfully achieved. For example, the development of the satellite swath to earth grid interpolation scheme used for the Level 3 SSM/I brightness temperature products was developed in close collaboration with key members of the remote sensing science community and the current data set is being routinely distributed to more than 150 researchers through various media including CD-ROM, 8mm tape, ftp and the EOS Information Management System (IMS).

The availability of a standard gridding scheme is a fundamental requirement for systematic time series studies and the direct digital comparison of different remote sensing algorithms, as well as the validation of algorithms, through comparison with surface measurements and other ancillary data sets which have been processed into a common grid. To this end, NSIDC developed the Equal Area Scalable Earth Grid (EASE-Grid). The NOAA/NASA Pathfinder Program Level 3 EASE-Grid passive microwave brightness temperatures were the first remote sensing products to benefit from EASE-Grid. The complete time series includes both the SMMR(Scanning Multichannel Microwave Radiometer) data (1978-1987) and the SSM/I (Special Sensor Microwave Imager, 1987 to 1999), providing a 22 year time series of satellite passive microwave data in a common format (Armstrong and Brodzik, 1997). The EASE-Grid is available in two equal area projections, full global cylindrical and azimuthal for full Northern or Southern Hemispheres (Armstrong and Brodzik, 1995).

For the SSM/I Pathfinder brightness temperatures, the interpolation scheme used to translate from swath data to the earth grid is considered optimal. It is based on weighting coefficients derived from the actual instrument antenna pattern. While the particular method used to interpolate from swath data to the fixed earth grid is unique to each

sensor and application, the common EASE-Grid format (the equal-area projections combined with an infinite number of possible grid definitions) provides a versatile framework. EASE-Grid data users are finding that visualization, intercomparison and analysis operations are greatly simplified. Finally, it should be noted that while the NSIDC EASE-Grid SMMR and SSM/I Pathfinder project has been included in the category of "Polar Pathfinders", it is, in fact, global in coverage and the primary product, earth gridded brightness temperatures, is designed to support not only the study of snow and ice but many other aspects of earth system science.

In addition to the passive microwave data, the EASE-Grid is also being used for other products developed for the NASA Polar Pathfinder Program such as AVHRR and TOVS, as well as the following environmental data sets being distributed by NSIDC: Northern Hemisphere Weekly Combined Snow Cover and Sea Ice Extent ; Arctic and Antarctic Research Institute (AARI) 10-Day Arctic Ocean Sea Ice Observations; Arctic Water Vapor Characteristics from Rawinsondes; IGBP Global Land Cover Classification; GLOBE land elevation data set; Circumpolar Active-layer Permafrost System (CAPS) map; CRREL Global Seasonal Snow Classification; and the NSIDC Near Real-Time Ice and Snow Extent (NISE) product. The EASE-Grid will also be used for snow and ice products derived from EOS MODIS and for the land products from AMSR-E which include snow extent and water equivalent, surface soil moisture and temperature.

Status of Level 3 SMMR and SSM/I Pathfinder Data Processing and Distribution

The basic approach which was undertaken with the Level 3 SMMR Pathfinder data was that it should be as compatible with the SSM/I Level 3 data as possible. To this end the grids are identical, the selection of overlapping orbits is identical, and the resampling (interpolation) function is similar, but cannot be identical. This is due to the fact that the antenna pattern information required for the Backus-Gilbert interpolation scheme applied to the SSM/I data is not available for the relocated samples in the SMMR Pathfinder data stream. One ascending and one descending SMMR file per day (when data are available) are produced by selecting those passes which are closest to noon and midnight in high latitude locations where there is more than one ascending or descending pass per day (as is done with the SSM/I). These data are gridded to the 25 km EASE-Grid. We completed the assessment of several interpolation techniques in direct collaboration with E. Njoku (JPL) and A. Chang (GSFC) and they agreed with our assessment that inverse distance squared was the best of the techniques tested. A full detailed report on the EASE-Grid SMMR processing technique can be found in Intercomparison of Resampling Methods for SMMR Pathfinder in EASE-Grid Format at http://www-nsidc.colorado.edu/ PROJECTS/SMMRPF/report/index.html

Processing of the Pathfinder EASE-Grid SMMR TB time series (1978-1987) has been completed. However several minor problems were detected during the QC following the processing, most of which have been addressed via comments in the documentation. One problem, occasional mislocated orbits, required re-processing of about 1.5 years of data. This task was completed in November of 1999. Prior to the general distribution of the final data set, a prototype version has been distributed to

several key remote-sensing scientists. The final testing of this data set (beta version) will be accomplished through actual application of the brightness temperature data by these scientists in their respective research activities.

The processing of SSM/I brightness temperatures into the EASE-Grid has been completed through mid-1999. In our original 1995 Pathfinder proposal we stated that we would be processing 1998 data in 1998 which required that we catch up on the nearly ten year back-log of orbital data. Because of the numerically intensive processing requirements associated with the interpolation scheme, this was a rather ambitious goal. It was only achieved through the application of innovative computer coding techniques and processing methodologies. Thanks to an energetic, creative and ambitious team, and thanks to effective collaboration and temporary sharing of certain NSIDC DAAC hardware, we have accomplished this goal and are now processing 1999 data. For the first time since initial launch in 1987, gridded data with full global coverage are available to users in near real-time from NSIDC. We will continue to process SSM/I orbital data into the EASE-Grid at least until there is sufficient overlap with the NASA EOS AMSR-E instrument to assure adequate cross-calibration.

AVHRR Polar Pathfinders

We continue to process the AVHRR Polar Pathfinder data, generating grids of calibrated, geolocated channel data and derived products covering both poles to about latitude 50° at 1.25 and 5 km grids over the period 1981 _ 1999. This project, which is part of the NOAA/NASA Pathfinder effort, is providing consistently geolocated, calibrated, and gridded channel radiance data, cloud masks, derived clear-sky skin temperature and albedo, and ice motion. Several corrections to both the temperature and albedo algorithms were implemented this year. We have begun to develop tools for data distribution and manipulation, and have made the data available to users to a limited extent. These gridded data sets are presently being transferred to NSIDC for archiving and distribution in early 2000. A variety of sample images and documentation for these data were provided to NSIDC for use in the production of The Polar Pathfinder Data Sampler CD-ROM. The data sets will become more broadly available in the first half of 2000. We have begun to explore the application of the data to problems in polar science. One of the first, most promising avenues of application has been in the determination of snow cover, and mapping of springtime snowpack retreat. Further potential applications are in the mapping of lake ice cover (both freeze-up and breakup date mapping) and in monitoring fast ice formation and extent.

NOAA Activities at NSIDC

NSIDC is affiliated with the NOAA National Geophysical Data Center and owes its designation as a national data center to NOAA: in 1982, NOAA's data service (now the National Environmental Data and Information Management Service) designated the cryospheric data management activities in Boulder a National Snow and Ice Data Center. NOAA funds the WDC for Glaciology, Boulder (co-located with NSIDC) as well as some data rescue activities at NSIDC.

The NOAA Scientific Advisory Board visited CIRES on 19 October to review NOAA sponsored work. NSIDC's work was represented in a variety of posters viewed by the SAB members.

NSIDC has established a NOAA data set team to develop new NOAA data sets and to maintain the 35 existing NOAA data sets in NSIDC's catalogue. The team includes a member from each of NSIDC's functional groups.

Work began on a new National Ice Center (NIC)-supported effort to assess the utility, limitations, and potential enhancements of EOS Moderate Resolution Imaging Spectroradiometer (MODIS) sea ice products for NIC's operational applications. MODIS Airborne Simulator data obtained by the NASA ER-2 have been processed using the MODIS standard algorithm approach to assess the effects of spatial resolution on the accuracy of estimates of lead fraction within the ice pack.

Arctic Atlas

U.S.- Russian Arctic Meteorology and Climate Atlas Workshops: A U.S.- Russian Arctic Meteorology and Climate Atlas is under development at NSIDC. The Atlas development team, which includes scientists from the Arctic and Antarctic Research Institute in St. Petersburg, has met in St. Petersburg and Boulder to review progress. The Atlas will contain previously unavailable Russian synoptic meteorology data, and gridded fields of monthly means for six parameters. The Atlas, which will be released in April 2000, is part of a set of four Arctic Atlases conceived by the U.S.- Russian Joint Commission Environmental Working Group's Subgroup on Arctic Climatology. NOAA has provided major funding for the Atlas.

Historical Soviet Daily Snow Depth.

NSIDC's Historical Soviet Daily Snow Depth (HSDSD) CD-ROM product has been updated with an additional 10 years of data. The data set now spans from 1881 (for the earliest operational stations) through 1995. These data are based upon observations made by personnel at 284 World Meteorological Organization (WMO) stations throughout the Russia and the former Soviet Union. Updating the data set provided an opportunity to improve the product with an HTML interface and Java tool for data browsing and extraction. Data were provided to NSIDC by the State Hydrometeorological Service in Obninsk, Russia, through the Bilateral US-USSR Working Group VIII data exchange agreement. The development of the data product was funded through the NOAA NESDIS ESDIM program.

NSIDC Distributed Active Archive Center (DAAC)

The primary goal of NSIDC DAAC is to serve communities identified by the Mission to Planet Earth Strategic Enterprise Plan 1996-2002, March 1996 by providing easy and reliable access to EOS satellite data, ancillary in situ measurements and any necessary

baseline data, model results, and relevant algorithms relating to cryospheric and polar processes. These activities will evolve from the existing practices at NSIDC DAAC to permit a smooth implementation of the EOSDIS Version 0 and transition to Version 2 of the EOS Core System (ECS) and beyond.

A highlight for the DAAC was the launch of the TERRA satellite on December 18, 1999. NSIDC anticipates ingest, archival and distribution of snow and sea ice products from the MODIS sensor by spring 2000. The DAAC also successfully completed the Operation Readiness Review of the EOSDIS science operations (see page7).

Spatial Search, Order, and Subset of data covering the Polar Regions (PSQ)

NSIDC is developing a Java-based application that will be used by the research community to search for and to order data archived and distributed by the non-ECS component of the NSIDC DAAC. The application will enable the researcher to perform queries for data and, optionally, request a subset of the of those data products which satisfied the search criteria. At a minimum, the user will be able to specify a subset based upon the following metadata attributes: spatial range, temporal range, and the geophysical or physical parameters contained in the data collection. Initially, the application will be applied to orbital data, specifically SSM/I swath and AVHRR imagery. However, the application is being designed to support other data types such as gridded products and station data.

Evaluate and Document ECS Application Programming Interfaces

The EOSDIS Core System (ECS) Application Programming Interfaces (APIs) were developed for the purpose of developing extended services to the ECS. The requirement for ECS to document APIs to the SDPS was removed, which means there would be insufficient information needed to integrate enhancements to the core set of system services.

NSIDC plans to develop a service that makes use of the APIs in order to evaluate and document the utility of the APIs. The developers of ECS do not plan to provide spatial subsets of granules archived in the ECS but not stored in HDF-EOS format; our goal is to use the ECS APIs to develop a custom service that can provide a spatial subset of data granules stored in a format other than HDF-EOS.

Mission Coordination

NSIDC DAAC staff participated in multiple mission coordination tasks. These efforts develop the essential collaborations with instrument teams, science groups, and other data providers through face-to-face meetings. Major activities involving R.L. Armstrong, J.A. Maslanik, A.W. Nolin, T.A. Scambos, V. J. Troisi, and G.R. Scharfen included:

- Attended Advanced Microwave Scanning Radiometer (AMSR) Science Team Meetings (Troisi). AMSR planning continues for the scheduled launches of ADEOSII and AQUA in the coming eighteen months.

- Attended meetings of the Geoscience Laser Altimeter Sensor (GLAS) Instrument Team. Planning for ICESat and GLAS continue with NSIDC providing archival and distribution of GLAS products.

- Installation of the ECS system at NSIDC to support MODIS operations, and testing the transfer, archive and distribution of the MODIS snow and ice test products have proceeded on schedule. Following the launch of the Terra spacecraft on December 18, 1999, the routine production of MODIS products is expected to begin during Spring 2000. The MODIS snow and ice products will be available from NSIDC in three formats: level 2 swath format, level 3 grids (equatorial sinusoidal grid for snow and EASE polar grid for sea ice; snow to be available in the polar grid as resources permit) and in a 1/4 degree Climate Modelers Grid. The sea ice products will include ice extent, determined by the reflectance method, and ice surface temperature. There will also be an 8-day composite to minimize the effect of clouds.

- NSIDC participated in the development of the Global Land Ice Monitoring from Space (GLIMS) project, designed to monitor the world's glaciers primarily using data from the EOS ASTER (Advanced Spaceborne Thermal Emission and reflection Radiometer) to be flown on the AM-1 satellite. GLIMS is a collaborative effort between the USGS Flagstaff Center, EOS ASTER Instrument Science Team, EROS Data Center (EDC), NSIDC, and a group of internationally distributed glaciologists at regional centers of expertise. NSIDC will provide the information management system for GLIMS consisting of a global inventory of land ice, including measurements (over time) of glacier length, area, boundaries, topography, snowline elevation, and surface velocity vectors, derived primarily from remote sensing data. The regional centers will derive the inventory information from the remote sensing data (archived at EDC) and provide this to NSIDC for archive and distribution. In this past year, NSIDC participated in the planning for this activity by developing a proposal for federal agency consideration, meeting with NASA, NSF and USGS potential agency sponsors, and participating in the first international meeting of GLIMS collaborators (Workshop on Satellite Measurements and Monitoring of Glaciers and Ice Sheets), held in conjunction with the International Glaciological Society meeting in Zurich, Switzerland, August 1999

Data Sets

Numerous data sets were ingested, archived, and published.

- Distributed operational NISE data to MISR, MODIS, and Tropical Rainfall Measuring Mission (TRMM) Instrument Teams
- Archived and distributed "Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I Passive Microwave Data" (10/78 - 12/96)

- Designed, produced, and promoted the "Polar Pathfinder Sampler: Combined AVHRR, SMMR-SSM/I, and TOVS Time Series and Full-Resolution Samples"
- Developed and distributed "Near Real Time DMSP-F13 SSM/I Daily and Monthly Polar Gridded Sea Ice Concentrations"
- Documented, reproduced, and distributed the improved and updated "Historical Soviet Daily Snow Depth, Version 2"
- Acquired AVHRR data from HRPT sites.
- Generated AVHRR Polar Pathfinder Data Products
- Completed the generation and archive of the Nimbus-7 SMMR Pathfinder Daily Global EASE-Grid Brightness Temperatures (10/78-8/87), distributing beta versions upon request.

Published data sets:

- SSM/I F13 EASE-grid brightness temperature data CD-ROMS (NH 12/3/91 to 10/22/93)
- SSM/I F13 Polar Stereographic gridded brightness temperature data CD-ROMS through 3/31/99 and on ftp through 6/30/99.
- SSM/I F13 Polar Stereographic gridded sea ice concentrations through 6/30/99
- Greenland and Antarctic Digital Elevation Maps (DEMs) and associated web page guiding users to appropriate elevation data (http://www-nsidc.colorado.edu/dems/).
- Near Real-Time DMSP SSM/I Daily Polar Gridded Brightness Temperatures and Sea Ice Concentrations
- Nimbus-5 ESMR Polar Gridded Brightness Temperatures, Revision 1
- All About Glaciers (http://www-nsidc.colorado.edu/glaciers/)
- TOVS Pathfinder Path-P Daily Arctic Gridded Atmospheric Parameters" (7/79 - 12/96)

Near Real-Time Ice and Snow Extent (NISE)

The Near Real-Time SSM/I EASE-Grid Daily Global Ice Concentration and Snow Extent product (Near Real-Time Ice and Snow Extent, NISE) is generated using multifrequency, multipolarization passive microwave data from the Defense Meteorological Satellite Program (DMSP) Special Sensor Microwave/Imager (SSM/I). Data from the DMSP F13 SSM/I are used to create a global map of sea ice concentrations and snow extent. Data for the NISE product are provided in two 25-km azimuthal, equal-area projections (the NSIDC Southern Hemisphere, low (25-km) resolution (SL) and Northern Hemisphere, low (25-km) resolution (NL) EASE-Grids and are updated on a daily basis.

The sea ice coverage currently includes all Arctic and Antarctic sea ice areas poleward of 35° latitude. The snow extent product is global. Wet snow and dry snow extents will be mapped separately, using two different algorithms. The NISE product is created in near real time, i.e., within approximately two to four days of the satellite overpass.

This product now has a user base of over 100 individuals and provides critical snow data to several NASA EOS instrument teams. This year, we worked to have the data ingested into NASA's EOSDIS Core System (ECS), thereby increasing product accessibility. This daily product, derived from satellite passive microwave data, was developed to support the needs of several NASA/EOS instrument teams. This product represents the first time that global daily maps of sea ice concentrations and snow cover (both wet snow and dry snow) have been made available from NSIDC.

Funding for the production of this data set was provided by the National Snow and Ice Data Center (NSIDC) Distributed Active Archive Center (DAAC). The data set is currently available via ftp to investigators and instrument team members associated with the NASA Earth Observing System (EOS) and through the EOS Data Gateway (EDG).

NSIDC Website Development

NSIDC DAAC staff participated in the site overhaul (see Web Development section above) which is aimed at eventual site redesign and restructuring, including web development procedures.

Liaison with the Modeling Community

We continue coordination of DAAC outreach to the modeling community, interacting with them to establish a DAAC "point of reference"; advising the DAAC on data-related needs of the modeling community; and identifying appropriate data sets resulting from modeling esearch to the DAAC. The goal is to improve our service to the modeling community. As a result of numerous informal and formal discussions with modelers as well as empirical researchers, we have identified a number of data set needs that can be met by the DAAC. Papers addressing aspects of NSIDC programs directed towards modellers were presented at the Birmingham IUGG meeting in July (Barry et al., 1999) and at the International Glaciological Society Meeting in August. Some of these are products, and some are new user-capabilities. New products include gridded data sets of cryospheric variables. New capabilities generally address the issues of data format and projection. For some of these products, we have had preliminary discussions with Canadian colleagues with whom there is potential for collaboration. We have tentatively identified short, medium, and long-term goals. Short-term goals include data sets for which immediate needs in the research community are apparent, and which NSIDC can provide with relatively small additional cost. Detailed cost-evaluation is currently underway for these, and they will be presented to the Data Set Review Board in early 2000.

OUTREACH AND EDUCATION

NSIDC coordinates two ESDIS-funded outreach projects for the NASA Distributed Active Archive Centers, the DAAC Yearbook and the Electronic Publishing Project.

The DAAC Yearbook, Distributed Active Archive Centers: Supporting Earth Observing Science, is an annual publication that has been produced at NSIDC since 1995, and consists of feature articles highlighting research conducted with DAAC data, tools and data management processes developed at the DAACs, and new data products. It has grown to a circulation of approximately 13,000, and is distributed to the EOS Investigators Working Group (IWG), the Science Data Panel and other science groups, to Congress and various data centers. The aim of the publication is to educate science and general audiences about the resources provided at the DAACs.

The Electronic Publishing project (EP) is an expansion of the Yearbook to the World Wide Web, and serves as an umbrella site to coordinate and unite the considerable investment in online information services maintained by each DAAC. The EP has been in development at NSIDC through 1999, and will debut approximately Feb.1, 2000. The site offers information on the "who, what, and why" of the DAACs, along with data advertising and educational outreach material and links.

DAAC Outreach Coordination Workshop

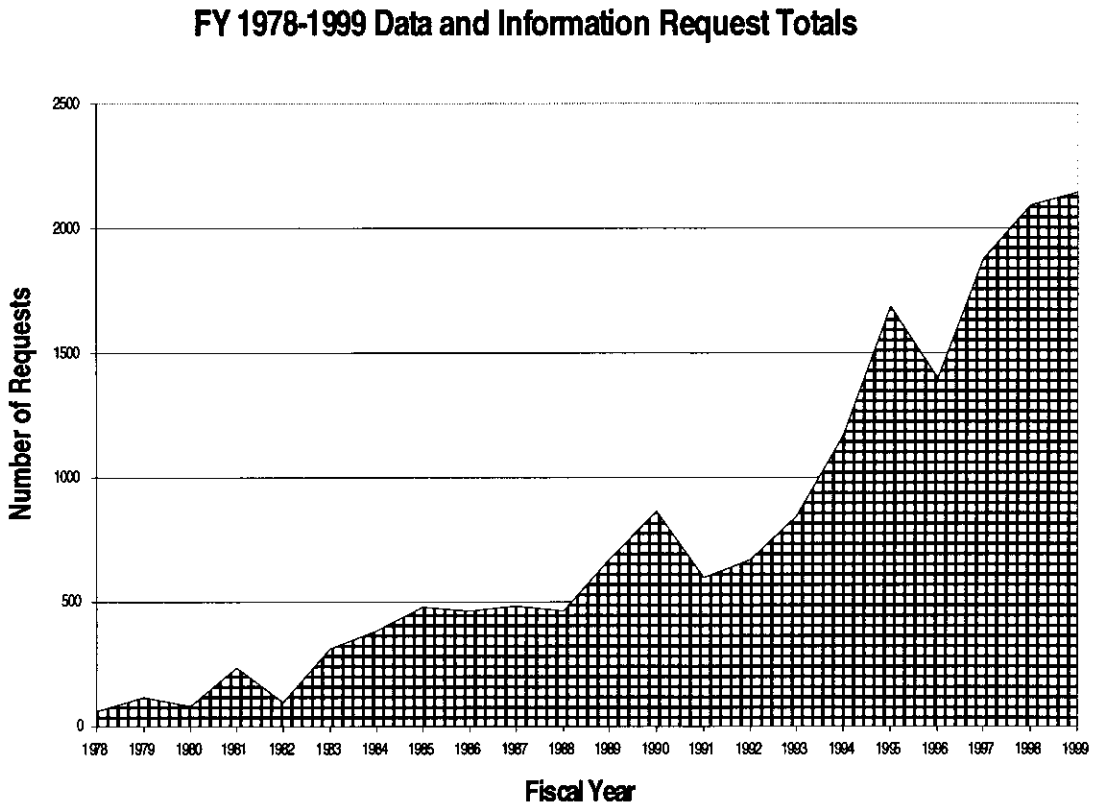
NSIDC hosted an outreach workshop on behalf of the User Services Working Group (USWG) on April 28-30, 1999. These workshop ideas originated from the EOSDIS DAAC USWG and was billed as a "Cross-DAAC" outreach workshop because one of the original objectives was to develop an outreach plan that coordinated the efforts at each of the DAACs. It was expanded to include the elements of the Earth Science Enterprise (ESE) that the DAACs interact with on a regular basis to allow for leveraging among groups with similar outreach goals. The format of the workshop was an initial element of information sharing followed by presentations and small group discussions. The presentations included current outreach efforts, identification of target audiences and goal development. This was followed by a series of speakers alternating with discussion/brainstorming groups on the topic of developing messages for each target audience. A cross-DAAC outreach plan resulted from the workshop. Since its publication in June 1999, this plan has served to organize and direct cross-DAAC outreach activities and planning.

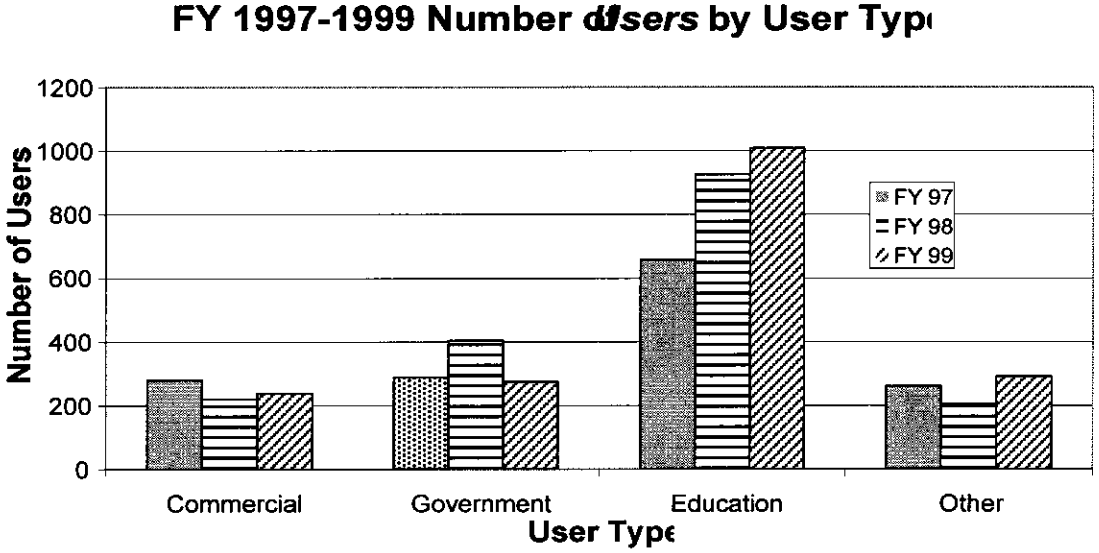
USER SERVICES

The User Services Staff is responsible for providing responses to user inquiries for the NSIDC, WDC, NSIDC DAAC, ARCSS Data Coordination Center, and Antarctic Data Coordination Center. User types and inquiries span a diverse range and include users from the commercial, government and educational sectors. Examples of inquiries received include students requesting information for school projects and reports, media and text book publishers requesting photographs and interviews, and science researchers requiring information about data holdings, processing, formats, and science algorithms.

Other activities that User Services Staff participated in include activities relating to product design and enhancement, representation on NSIDC Product Teams, and Data Center outreach activities.

Product Teams that User Services participated in this year include SSM/I Brightness Temperature and Sea Ice Concentrations, SSM/I Near-Real Time Sea Ice and Snow





Extent, SSM/I Near Real-time Brightness Temperature and Sea Ice Concentrations, AVHRR Polar 1km Data Set, AVHRR Polar Pathfinder Data Sets, TOVS Polar Pathfinder Data Set, Greenland and Antarctic Altimetry, Antarctic Ice Velocity, Historical Soviet Daily Snow Depth Data Set, All About Glaciers, Joint US-Russian Arctic Meteorology and Sea Ice Atlases, Submarine Draft data, SHEBA NTM imagery, and the MODIS data sets.

NSIDC User Services provided staffing support for the EOSDIS USWG exhibit booth at two conferences during the past year and staffed the NSIDC exhibit booth at the AGU Fall Meeting, December 13-16, 1999 in San Francisco, California. In addition User Services presented a poster at the EOSDIS Investigator Working Group meeting describing the EOSDIS DAACs products and services, and presented four posters highlighting NSIDC products and services in sessions at the AGU Fall Meeting. User Services also contributed to a poster that was presented at the IUGG conference.

Use and Request Statistics

Requests for Fiscal Year 1999 reached an all time high for the fourth consecutive year with a total of 2142 new requests received, representing a 2.25% increase over the previous year. In addition the data center supported 350 existing subscription requests in FY 1999. Educational and Research users represented 56% of the users served by the data center, with the remainder being evenly split between the categories of Government, Commercial and General Public. NSIDC distributed 4,964 CD-ROMs containing data to users with 77% of the CD-ROMs being distributed to new users and subscribers of the EASE-Grid and DMSP SSM/I Polar Brightness Temperature data sets. The primary data sets that resulted in new requests in Fiscal Year 1999 include: Greenland Summit Ice Cores, Into the Arctic: Information and Educational Activities for Studying Climate, Polar Pathfinder Sampler, Circumpolar Active-layer Permafrost System, and the Near Real-Time SSM/I EASE-Grid Daily Global Ice Concentration and Snow Extent products.

NATIONAL/INTERNATIONAL COLLABORATION

World Climate Research Programme Climate and Cryosphere (CLIC) Initiative

The World Climate Research Programme (WCRP) established a Task Group on Climate and the Cryosphere (CLIC) in 1998. CLIC will address all areas of cryosphere - climate interaction and the use of cryospheric indicators of climate change. The Task Group co-Chairs are R.G. Barry, NSIDC and Ian Allison, CRC, Hobart, Australia. The group developed a plan for coordination of CLIC in conjunction with the Arctic Climate System (ACSYS) project through 2003, and thereafter independently. A joint ACSYS/CLIC Project Office has been designated at the Norwegian Polar Institute in Tromso. The final CLIC Science and Coordination Plan was reviewed by the ACSYS Science Steering Group in November 1999 and will be presented by R.G. Barry to the WCRP/Joint Scientific Committee meeting in Tokyo in March 2000. Consideration has

been given to linking CLIC to other international and national activities under SCAR, SCOR, IGBP, IASC and IUGG bodies.

The structure and main components of the CLIC Science Plan are as follows:

- Improve understanding of the physical processes and feedbacks through which the cryosphere interacts with the climate system.

- Improve the representation of cryospheric processes in models so as to reduce uncertainties in simulations of climate and climate change

- Assess and quantify the impacts of past and future climate variability and change on components of the cryosphere, and their consequences for the energy and water budgets, frozen grouns condiitons, and sea level change

- Enhance the observation and monitoring of the cryosphere in support of process studies, model evalution, and change detection.

The Science Plan addresses:
Interactions between: the atmosphere, snow and land; land ice and sea level; and sea ice, oceans, and the atmosphere; as well as cryosphere-climate interactions on a global scale and cryospheric indicators of climate change. It also discusses cross-cutting issues of the observational framework (in situ and remote sensing observations), modelling strategy, and infrastructure for CLIC data management.

The Coordination Plan outlines the infrastructure for CLIC in the context of global change research and options for cooperation and coordination with other cryosphere-related programs and activities.

Visits to China WDCs and Institutes

Dr. R.G. Barry, Director, National Snow and Ice Data Center (NSIDC)/World Data Center (WDC) for Glaciology, Boulder spent two weeks in China in May and June 1999 at the invitation of the WDC for Space Sciences and the Institute of Atmospheric Physics (IAP) of the Chinese Academy of Sciences (CAS), Beijing, and the Lanzhou Institute of Glaciology and Geocryology (LIGG) and WDC for Glaciology and Georyology, Lanzhou. He reported on the activities of NSIDC at the newly reorganized Center for Integrated Survey of Natural Resources (CISNAR) which includes the WDC for Renewable Resources and Environment, Beijing, and the Center for Earth Science Data and Information (CESDIN). CISNAR also serves as the National Data Center on Tibet. A Letter of Intent for collaboration in research and data management relating to cryospheric and related data in China and Tibet was signed by Drs. Barry and Liu.

Presentations on NSIDC were also made at the LIGG/WDC for Glaciology and Geocryology, Lanzhou, and at the Polar Research Institute in Shanghai.

NSIDC's Dr. Tingjun Zhang also visited the WDC for Glaciology and Geocryology, Lanzhou, in June 1999. Zhang visited the China National Meteorological Bureau in Beijing to learn about surface snow measurements across China. Snow depth has been measured at several hundred weather stations across China since the mid-1950s.

Terrestrial Observation Panel for Climate

The 5th Session of the Terrestrial Observation Panel for Climate (TOPC) Scientific Steering Group (SSG) met at the University of Birmingham, 27-39 July 1999. SSG Member R.G. Barry reported on the status of the planned Global Terrestrial Network for Glaciers (GTNet-G). This activity led by the World Glacier Monitoring Service, Zurich, was accepted as a TOPC Demonstration Project. The group also discussed plans for a corresponding GTNet for Permafrost (GTNet-P). TOPC is sponsored by the Global Climate Observing System and the Global Terrestrial Observing System.

Global Digital Sea Ice Data Bank

The World Meteorological Organization Commission on Marine Meteorology established a Global Digital Sea Ice Data Bank (GDSIDB) of sea ice chart information from the operational ice forecasting centers of participating nations. The Data Bank resides at NSIDC and at the Arctic and Antarctic Research Institute (AARI), St. Petersburg, Russia. Under this project the rescue, analysis and distribution by NSIDC of Arctic chart data held at AARI has been carried out, and data from other participating nations has been archived in a standard format. The last meeting of the GDSIDB Steering Committee took place at NSIDC in August, 1998, and included representation from the participating nations of Russia, the U.S., Canada, Japan, Argentina, and Baltic states.

New Ice Chart Working Group

The data products of operational ice forecasting centers constitute the longest running and in many cases the most accurate record of the sea ice cover. However ice chart data are not often produced with an eye to constructing a scientific data set. NSIDC is working to change this through participation in a new working group. In October 1999, Florence Fetterer attended the First International Ice Charting Working Group (IICWG) meeting at the Danish Meteorological Institute (DMI), Copenhagen, Denmark. This conference was sponsored by the Navy/NOAA/Coast Guard National Ice Center (NIC) and DMI. The conference provides a forum for focused discussion of all facets of sea ice chart production and distribution, including data set development. Participants included representatives from operational ice services in the United States, Denmark, Canada, Russia, Finland, Iceland, Sweden, Japan, and Germany.

RESEARCH

NSIDC/WDC-A for Glaciology contributes actively to the basic and applied research of the Cryospheric and Polar Processes Division in CIRES. Much of this research also underpins the data management activities of the Center since the scientific staff carry out specific tasks for the NASA and NOAA or NSF related data management contracts and grants.

A summary of current projects, listed by principal investigator, follows.

Richard L. Armstrong

Global Snow Cover Mapping

Passive microwave data offer an alternative method to visible band remote sensing to monitor variations in snow cover on the global scale, avoiding the problems of fluctuating surface albedo, cloud cover and darkness. During the past year we continued with a project which evaluates the accuracy of existing passive microwave snow cover algorithms to map both snow covered area and snow water equivalent. The current validation project involves the comparison of several different passive microwave algorithms which include representative examples of both mid- and high-frequency channels, vertical and horizontal polarizations and polarization difference approaches.

Evaluation of snow extent derived from passive microwave data was undertaken through comparison with the NOAA Northern Hemisphere snow charts. Results of this study have clearly indicated those time periods and geographic regions where the two techniques (optical and microwave) agree and where they tend to consistently disagree (Armstrong and Brodzik, 1998). For example, during the early winter season the passive microwave algorithms generally underestimate the snow extent. The undermeasure in this case is due to the fact that thin snow cover does not provide a scattering signal of sufficient strength to be detected by the 37 GHz channel typically used in the algorithms. We demonstrated in this study how the inclusion of the 85 GHz channel, with the associated enhanced scattering response, improves the accuracy of mapping shallow snow. The current passive microwave techniques also tend to undermeasure snow extent in the presence of wet snow. In such cases we utilize a technique to improve the identification of wet snow which is based on a modified version of the Walker-Goodison wet snow algorithm.

Validation of snow water equivalent derived from passive microwave data is undertaken using an in situ data set from the "Former Soviet Union Hydrological Surveys" (FSUHS) which is archived at NSIDC. These data are available during both the SMMR and the SSM/I periods from more than 1,300 station transects. They represent a unique and invaluable source for algorithm validation as they include not only snow water equivalent values but additional information pertaining to snow structure including density and number and thickness of melt-freeze crusts, extent of snow cover within the surrounding terrain, as well as forest type and percent of forest cover from a 50 km diameter area surrounding the station. The transects are typically 1.0 to 2.0 km in length

with measurements every 100 to 200 m and are representative of both open and forested locations. These linear transect data allow the unique opportunity to statistically evaluate the response of an algorithm to a spatial pattern that lies between a single point measurement typical of most in situ networks and the area integration represented by the satellite foot-print. To create a best case validation data set, we focus on a regional subset where station density is the greatest (approximately one or more stations per 100 km grid cell), where topographic variability and forest cover are minimal and the snow cover is sub-freezing.

Results indicate a general tendency for the algorithms tested thus far to underestimate SWE and that the underestimate increases significantly as the forest cover density begins to exceed 30 to 40 percent. Because of the detailed land cover data available for this region, we are able to develop and apply algorithm corrections as a function of fractional forest cover. For applications in regions where such detailed forest density data are not available we will apply results from the comparison between the IGBP Global Land Cover Classification and an index of vegetation density provided by the 37 GHz polarization difference based on work by B. Choudhury (personal communication). A 1978-2000 global snow extent and water equivalent monthly climatology will be constructed based on the results of this algorithm comparison study. This product will most likely involve the application of a blend of the capabilities of the various algorithms in order to achieve optimal performance according to season, (snow structure type) and geographic location (land surface type). As partial validation for this climatology, we will compare the results with the FSUHS data described above as well as with the multi-year snow cover data set being produced by the NASA Earth Science Information Partners (ESIP) project _Evolution of Snow Pack in the Southwestern United States:Spatial and Temporal Variability from a Remote-Sensed and In Situ Data Set (J. Simpson, U. of California, San Diego).

Roger G. Barry

Circumpolar Frozen Ground Conditions and Modeling Scenarios of Future Conditions (NSF)

R. G. Barry and T. Zhang are collaborating with David Gilichinsky of the Institute for Physiochemical and Biological Problems of Soil Science RAS, Pushchino, on this NSF project, which is part of a broader analysis and modeling study undertaken in conjunction with Dr. Fritz Nelson (University of Delaware) and Dr. Oleg Anismov (State Hydrologic Institute, St. Petersburg). During the past year, we have accomplished the following:

Data Collection and Transfer: Soil temperatures at various depths from about 140 Russian Meteorological Stations had been digitized from the published books by Dr. Gilichinsky's staff and tranferred to the National Snow and Ice Data Center, University of Colorado at Boulder. Some soil temperature records begin in the 1900s but most of them were started during the 1930s or 1950s. The data sets also include soil freezing depth, timing and duration of frozen soils at various depths. This data set will be used for

further analysis and climate model validation. The data will be released through NSIDC, following quality control and documentation, under the US-Russia Agreement on Cooperation in the Field of Protection of the Environment and Natural Resources, Working Group VIII on Data Exchange protocol.

A case study of long-term trends in soil temperatures: A paper titled "An amplified signal of climatic change in soil temperatures during the last century at Irkutsk, Russia" is in press. It is known that temperature changes at the Earth's surface propagate slowly downward into the ground and modify the ambient ground thermal regime. However, causes of soil temperature changes in the upper few meters are not well documented. A major obstacle to understanding the linkage between the soil thermal regime and climatic change has been the lack of long-term observations of soil temperatures and related climatic variables. Such records are now becoming available for the territory of the former Soviet Union as noted above. We use records from Irkutsk, Russia to demonstrate how the soil temperature responded to climatic changes over the last century. Both air temperature and precipitation at Irkutsk increased from the late 1890s to the 1990s. Changes in air temperature mainly occurred in winter, while changes in precipitation happened mainly during summer. There is an anti-correlation between mean annual air temperture and annual total precipitation, i.e. more (less) precipitation during cold (warm) years. There were no significant trend of changes in the first day of snow on the ground in autumn, but snow steadily disappeared earlier in spring, resulting in a reduction of the snow cover duration. A grass-covered soil experiences seasonal freezing for more than nine months each year and the long-term average maximum depth of seasonally frozen soils was about 177 cm with a range from 91 cm to 260 cm. The relatively lower soil temperatures observed at shallow depths appears to represent the so-called "thermal offset" found in seasonally frozen soils. Changes in mean annual air temperature and soil temperature at 40 cm depth were about the same magnitude (2.0 degree Celsius to 2.5 degree Celsius) over the common period of record, but the patterns of change were substantially different. Mean annual air temperature increased slightly until the 1960s, while mean annual soil temperature increased steadily throughout the entire period. It is evident that changes in air temperature alone cannot explain the changes in soil temperatures at this station. Soil temperature actually decreased during summer months by up to 4 degree Celsius, while air temperature increased slightly. This cooling in the soil may be explained by changes in rainfall and hence soil moisture during summer due to the effect of a soil moisture feedback mechanism. While air temperature increased about 4 degree Celsius to 6 degree Celsius during winter, soil temperature increased by up to 9 degree Celsius. An increase in snowfall during early winter (October and November) and early snowmelt in spring may play a major role in the increase of soil temperatures through the effects of insulation and albedo change. Due to its relatively higher thermal conductivity compared with unfrozen soils, seasonally frozen ground may enhance the soil cooling, especially in autumn and winter when thermal gradient is negative.

Characteristics of permafrost and ground ice distribution in the Northern Hemisphere: The recently published digital version of the International Permafrost Association (IPA) circumarctic map of permafrost and ground ice conditions, together

with ancillary data sets of the global land cover characteristics data base and the Global Land One-kilometer Base Elevation (GLOBE) data base, are used to investigate the permafrost and ground ice distribution in the Northern Hemisphere. Our study indicates that permafrost underlies approximately 22.79 million squared kilometer or 23.71% of the exposed land area in the Northern Hemisphere. Permafrost extent ranges from 26 deg. N in the Himalayas to 84 deg. N in northern Greenland. Approximately 70% of the permafrost is distributed between 45 deg. N and 67 deg. N. Generally, permafrost with high ice content (>20% by volume) and relatively thick overburden cover (>5-10 m) is distributed at high latitudes, accounting for approximately 8.57% of the total permafrost area or 2.02% of the exposed land surface in the Northern Hemisphere. Permafrost with low ice content (<10% by volume with either thick or thin overburden cover) is mainly distributed in mountainous regions and high plateaus, accounting for approximately 66.53% of the total, or 15.78% of the exposed land surface. Approximately 62% of the permafrost is distributed below 500 m a.s.l. and 78% below 1000 m a.s.l. Permafrost occurring above 3000 m a.s.l. accounts for about 10% of the Northern Hemisphere total permafrost. Based on the IPA circum-arctic map of permafrost and ground ice conditions, the estimated ground ice volume in the Northern Hemisphere ranges from 5.63 to 15.12 X 10^3 km^3, corresponding to about 2 - 4 cm sea level equivalent. For a more realistic ground ice content assumption, the ground ice volume varies from 11.37 to 36.55 X 103 km3, which corresponds to 3 - 10 cm sea level equivalent. A paper by Zhang, Barry, Knowles, Brown and Heginbottom is in press in *Polar Geography.*

Traditional Knowledge of Climate and Climate Change (NSF)

In a new departure for CPP climate research, Roger Barry and doctoral candidate in Geography, Shari Fox, received funding from NSF Arctic Social Sciences program for a 3-year study of "Inuit knowledge of climate and climate change in the eastern Canadian Arctic". In summmer 2000, Shari will visit several Inuit communities to expand her previous work on oral histories and conduct interviews.

Florence M. Fetterer

Sea Ice Melt Pond Statistics from Reconnaissance Imagery

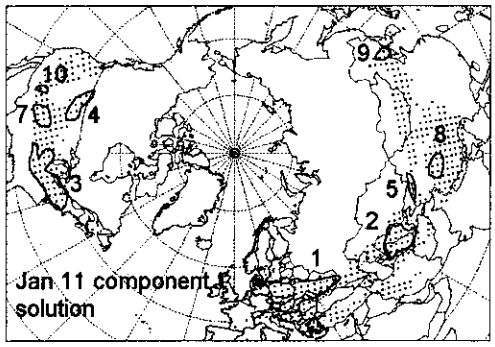
This project had its origins as the Arctic Summer Melt Study of the Medea Environmental Intelligence and Applications Program. In 1993, 1994, and 1995, satellite imagery collections in the Beaufort Sea during summer demonstrated the feasibility of using reconnaissance data to monitor the formation of melt water ponds on summer sea ice (Fetterer and Untersteiner, JGR 103(C11) 1998; Fetterer and Untersteiner, IGARSS Proceedings, IEEE 97CH36174, 1998). The extent of melt water ponds is a strong determinant of the albedo of summer sea ice, because ponds are much darker than the surrounding snow and ice. Ponds are a singularly important factor influencing the surface energy budget of the Arctic in summer. However, little is known about the timing and extent of melt pond formation because of the logistical difficulties of working in the Arctic in summer. Civilian systems do not resolve ponds, and the prevalence of

clouds in the arctic summer makes airborne surveys difficult. Collections were made during the SHEBA experiment, and with the backing of NSF the reconnaissance imagery was publicly released (see Highlights). Work continues in partnership with the USGS Rocky Mountain Mapping Center in Lakewood, CO, on analyzing the 1998 imagery, and with USGS Advanced Systems Center in Reston, VA, on continuing collections of imagery.

Allan H. Frei

Evaluation of Snow Simulations in the Second Phase of the Atmospheric Model Intercomparison Project (AMIP-II)

This NSF-funded project involves evaluation of General Circulation Model (GCM) simulations of regional-to-hemispheric scale snow cover. Here, we are examining results from GCM simulations run under the auspices of the second phase of the Atmospheric Model Intercomparison Project (AMIP2). AMIP2 is a cooperative undertaking by an international consortium of climate modeling groups designed to aid model evaluation. Allan is a member of the diagnostic subproject charged with evaluating simulations of snow extent. Although to date, only limited AMIP2 output has been made available, work has already begun evaluating snow simulations of five GCMs. Jim Miller, a graduate student in the Department of Geography, is working on this grant.



Regional variability of Northern Hemisphere snow extent for January, 1972-1994. Active areas, which include grid points that are snow-covered 10-90% of the time, are shown with dots. These active areas indicate the regions over which snow cover is variable: lands to the north of active areas are generally snow covered, and lands to the south are generally snow-free. Coherent regions, shown with bold lines, indicate areas over which interannual fluctuations in snow extents are highly correlated. Fluctuations over these regions explain most of the variability of continental to hemispheric scale snow extent. From Frei & Robinson, 1999.

Investigation of methods to estimate potential impacts of climate change on water resources in mountainous areas (NASA Land Surface Hydrology Program)

We are examining statistical downscaling techniques and synoptic analyses to be used in conjunction with water balance and hydrological models for estimating precipitation, and subsequently runoff, over two case study regions: the Upper Colorado River Basin and the Catskill Mountains. Through this project, Allan is participating in the Western Water Initiative, an interdisciplinary effort at the University of Colorado to examine a variety of water issues in the west. During this past year a water balance model has been developed, and an investigation of scale issues for downscaling is underway.

Examination of historical fluctuations in snow mass over Northern Hemisphere grassland regions (NASA Land Surface Hydrology Program)

Historical fluctuations in snow-mass are based on a combination of station-based and remotely-sensed (visible and passive microwave) observations with results of a snow pack model. In addition, this project includes evaluations of GCM simulations of snow mass over grassland regions.

James A. Maslanik

Sea Ice - Atmosphere Interactions

Combinations of sea ice data sets, ice model output, and satellite-derived products were used to investigate the interannual and regional variability of Arctic sea ice cover. These analyses documented record reductions in sea ice extent in the Beaufort and Chukchi seas during 1998, and linked these decreases to atmospheric circulation patterns and the effects of thin ice persisting through the preceding winter. Analyses of similar record reductions in 1990 were carried out using a fully-coupled regional climate model. This work suggested that such large regional changes are sensitive to relatively subtle variations in weather and climate, and that the decreases in ice cover are augmented by a positive feedback between ice dynamics and thermodynamics.

Variations in Surface Temperature within the Ice Pack Interactions

As part of the Surface Heat and Energy Budget of the Arctic Ocean (SHEBA) effort, aircraft data collected by the NCAR C-130 and AVHRR imagery from the Pathfinder project are being used to map the variability in skin temperature over the ice pack during summer. Results indicate that contrary to the standard view that surface temperatures remain close to the freezing point due to ongoing melt, skin temperatures within open-water leads during mid summer can exceed the freezing point by as much as 3 degrees C. These aircraft and satellite observations are consistent with other SHEBA field observations, and have potentially important implications for the modeling of pack ice conditions.

Investigations of Global Position System (GPS) Data as a Remote Sensing Tool

Recent work at NASA, the University of Colorado and elsewhere has shown that it is possible to record the reflection from the earth's surface of L-band signals transmitted by GPS satellites. This capability has been explored to date primarily for mapping ocean waves and windspeed. As a first test of the potential for recording useful GPS reflectance signals over sea ice, reflectance data were obtained using a sensing system installed in a small aircraft at Barrow, Alaska. Data recorded over the pack ice near Barrow show a variability in the strength of the reflected signal, with variations positively correlated with a near-coincident RADARSAT satellite image. Work is underway to obtain additional

data for further testing of the utility of the small, low-cost GPS reflectance systems for cryospheric remote sensing purposes.

Anne Nolin

Validation Studies and Sensitivity Analyses for Retrievals of Snow Albedo for EOS AM-1 Instruments (NASA)

During the past year substantial progress was made in analyzing a previously uncalibrated, but important, data set from the PARABOLA-III hemispherical scanning radiometer that was acquired during our March 1998 field campaign at Mono Lake, California. This data set allowed comparison and validation of a model that has been developed to retrieve snow albedo from single angle reflectance measurements. The validated model simulations were provided to Dr. Andrew Klein (Texas A&M) and Dr. Crystal Schaaf (Boston University) for their use in developing snow albedo estimates from MODIS.

As part of our growing interactions with the MISR science team, I contributed the snow hydrology/snow BRDF section to a jointly authored BAMS paper (see list of references). I also contributed to an article in The Earth Observer on progress in validation efforts for snow and ice products from MODIS. In addition, I wrote the snow BRDF modeling section of a joint paper that has been accepted to Remote Sensing Reviews (January, 2000). Science results were presented at the Annual AAG meeting in March 1999 and at The Second International Workshop on Multiangle Measurements and Modeling, Ispra, Italy in September, 1999. I also attended the regularly scheduled science team meetings for MODIS and MISR during the calendar year.

Multispectral Mapping of the Martian Polar Ice Caps (NASA)

During the startup phase of this new project we acquired, processed, calibrated and analyzed Mars Orbiter Camera (MOC) and Mars Orbiter Laser Altimeter (MOLA) data. Image analysis included performing spectral mixture analysis to map fractional ice and dust concentrations for a test region. Preliminary results were presented at the 5th International Conference on Mars, Pasadena CA in July, 1999 There were a number of outreach activities involving media public relations (newspaper and radio) including

- press release (written by Annette Varani)
- 3 newspaper interviews
- 2 radio interviews

Assessment of Variations in the Snow Accumulation Rate in Northern Greenland (NSF)

Final efforts on this now-finished project included performing sensitivity tests on a sublimation model that was used to compute sublimation from Humboldt Glacier and Tunu North study sites. It was estimated that approximately 25% of the total mass added to the sites is lost by sublimation.

Comparisons of delta-O18 and delta-D isotope data and chemistry data from Humboldt (with Jim White, Institute of Arctic Alpine Research) appear to indicate that the isotope record suffers from missing years of data in low accumulation zones and that other climate records (such as dust and chemistry) would be more useful for climate interpretations. Wavelet analysis of the chemistry records indicate the presence of an NAO signal. These results were described in a final report.

Southwest Regional Earth Science Applications Center (NASA-RESAC)

During the latter part of 1999 we moved forward with the assessment of snow covered area (SCA) data derived from satellite remote sensing and incorporating these data into the USGS hydrologic model (PRMS). As part of a collaboration on several related grants, we hired a Professional Research Assistant, Andrew Barrett, who with Dr. Clark, is incorporating the SCA data into they USGS Precipitation Runoff Modeling System (PRMS). In related work, progress was made in assessing the spatial distributions of estimated snow cover as functions of land cover class, slope/aspect, elevation, and AVHRR view angle. In addition, SCA product generation guidelines for University of Arizona were written.

Investigating Downscaling Techniques and Evaluating Climate Models for Use in Estimating Regional Water Resources in Mountainous Regions (NASA -- Allan Frei, PI)

As part of the second year activities of this project computer simulations were performed to assess the sensitivity of surface-atmosphere fluxes to climate model parameterizations of snow albedo. These analyses showed that springtime energy fluxes and snowmelt rates are extremely sensitive to snow albedo parameterization. Results were presented at a meeting in Les Diablerets, Switzerland (Workshop on Remote Sensing and Climate Simulations: Synergies and Limitations) and were compiled into a book chapter contributed to "Advances in Global Change Research", currently in review.

Local, Regional, and Remote Effects of Northern Hemisphere Snow Cover on Western US Climate and Water Resources (NSF)

The above-mentioned activities also directly relate to the objectives of this project. In addition, we hired Eileen McKim as a graduate research assistant; she will begin in January, 2000.

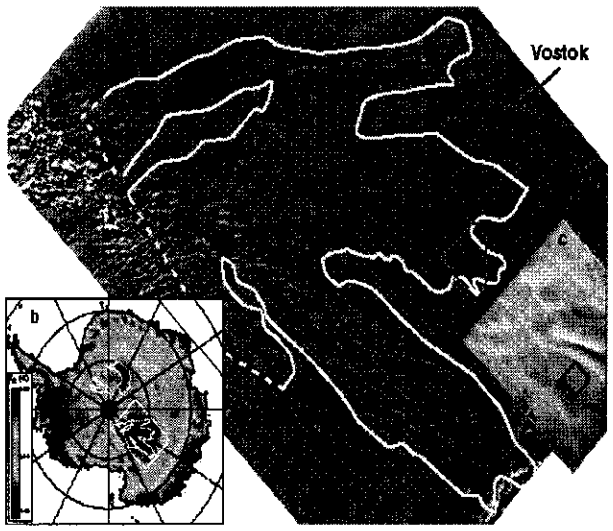
CIRES Western Water Assessment

This is a new effort, still under development, with funding from NOAA. As part of this effort, I participated in a climate and water resources workshop, assisted with proposals and workplans for both a 9-month and a 2-year effort, and also helped develop a preliminary data management plan.

Ted Scambos

Antarctic Plateau Snow Megadunes

A huge portion of the East Antarctic Plateau, approximately 500,000 km2, is covered by unique surface ripple formations. These were recognized from Landsat images in the 1980's by Charles Swithinbank, who termed the features Megadunes, but only the advent of recent imagery by AVHRR and Radarsat allowed a complete mapping of their extent. By applying a whole host of remote sensing techniques, in conjunction with Dr. Mark Fahnestock, we were able to characterize these features and to consider mechanisms for their origin. The megadunes, as measured by SAR interferometry and AVHRR-based photoclinometry, are broad-wavelength (2_5km), low-amplitude (2_5m) ripple features oriented transverse to the regional wind direction. Crests within the dunefields may be traced for up to 100 km. The features are slightly asymmetric, with steeper, shorter, upwind faces. Passive microwave emissions from the snowpack in megadune areas indicate anomalously low brightness temperatures; among several possible causes, the most likely is extremely coarse grain size (up to a few cm) causing a greater scattering of upwelling radiation. A simple grain-size measurement technique derived from comparing the reflectance of the snow in two channels of AVHRR indicates that surface grains are finer on the upwind faces and coarser on the back slopes of the ripples. A comparison of modern images with data from defense intelligence satellites acquired in the early 1960s indicates the dunes are stationary and have a fixed pattern over several decades. Limited field measurements, performed in the 1950s and 1960s by traverse parties (unaware of their exact position within the dune fields because of their subtlety) indicate that megadune fields occur in areas of very low (near-zero) accumulation and have extremely coarse recrystallized grains (up to 2cm) comprising much of the firn. Climate in the dunefield areas is almost completely



Composite image summarizing current research work on Antarctic megadunes. A. AVHRR image of the largest dunefield, located between Vostok and McMurdo Stations in East Antarctica. White outline indicates field extent, dashed where indeterminate. B. Color-coded map of mean annual brightness temperatures for 37H channel of the SSM/I sensor. The white outlines mark the extent of all identified dunefields in the Antarctic. These correlate very closely with areas of substantially reduced brightness temperature. Scattering of upwelling microwave emission due to very coarse grain size may anomalously reduce the BT in the dune areas. C. ERS-1 SAR image of a portion of the megadunes in East Antarctica. The small inset identifies an area of detailed study of topography and grain size using AVHRR and SAR in combination.

dominated by gravity flow, i.e., katabatic winds. On the basis of morphology and the characteristics of the surface grains and firn, we believe it is unlikely that the megadunes were formed by normal aeolian transport of snow grains. The current working hypothesis for their formation is based on vapor transport by standing waves in the katabatic wind inversion layer.

Innovations in the use of AVHRR imagery for polar ice sheet study

Two new techniques for applying AVHRR data to the polar ice sheets have been developed and demonstrated: data cumulation and photoclinometry. Data cumulation combines the data from several AVHRR scenes of the same area to generate an image with enhanced spatial and radiometric resolution. Photoclinometry is applied in a new approach, which uses existing low-resolution DEM information to calibrate the imagery and generate a higher-resolution elevation model. Both techniques are now described in recent papers submitted by Ted Scambos in collaboration with Geir Kvaran (a Geography graduate student) and Mark Fahnestock. Several areas have already been imaged by preliminary versions of the data cumulation technique: Siple Dome; Ice Stream C; an ice stream in northeastern Greenland, and the major ice shelves of Antarctica. Photoclinometry from AVHRR has been successfully applied at Siple Dome, Roosevelt Island, and Greenland.

Radarsat Antarctic Mapping Project

The first continent-wide radar image mosaic of Antarctica is now available from NSIDC, produced by Ohio State and Vexcel Corporation from Canada_s Radarsat satellite. The Radarsat Antarctic Mapping Project (RAMP) mosaic is a seamless, precisely geolocated image map at 125 meters resolution. Accompanying the image is a DEM compiled from all available elevation information at 200-meter resolution. Together the two data sets reveal surface features in unprecedented clarity and allow researchers to examine the entire surface of the ice sheet in context. Several unknown or under-appreciated features were revealed by the new mosaic: the system of ice streams reaching above the Slessor and Recovery Glaciers in the East Antarctic; the extent and orientation of flowstripes on the continent; the extent of the megadune features discussed above; and the variability of the surface reflectance in the Radarsat channel.

Greg Scharfen

Global Lightning

NSIDC completed its participation in the Analysis of the U.S. Air Force Defense Meteorological Satellite Program Imagery for Global Lightning for NASA Marshall Space Flight Center. By visually analyzing thousands of images, and then developing an automated system to automatically process digital data, this project resulted in the creation of a global nighttime database of lightning occurrence from 1994-98. This database provides a unique source of information concerning the spatial and temporal

distribution of global lightning. It is being applied to studies of climate, hydrological cycles and the global electric circuit, and has been used in conjunction with the analysis of data from NASA's Lightning Imaging Sensor.

NASA also contributed to the development of the Digital DMSP Archive through this project by supporting NSIDC's involvement in the development of a digital archive capability for the suite of DMSP data. Now under the auspices of NGDC, the DMSP archive supports broad access to the DMSP data stream by a diverse user community. Some examples of research using the DMSP data stream include: biomass fire detection , snow cover and sea ice extent, synoptic cloud climatologies, internal gravity wave detection, vapor trail climatologies, light pollution studies, tabular ice berg monitoring, polynya monitoring, meteorological case studies, environmental disaster case studies, aurora monitoring, and volcano monitoring.

M.P. Clark and M.C. Serreze

Western U.S. Climate and Snowpack Water Resources (NSF Hydrologic Sciences Program, the NASA RESAC Program, and the NOAA Program for Regional Assessments)

This project involves basic and applied research in western U.S. climate and snowpack water resources. Basic research has examined climatological characteristics of the western U.S. snowpack using the high elevation SNOpack TELemetry (SNOTEL) network (over 600 stations). Seasonal cycles of snow water equivalent (SWE), precipitation (PRE) and temperature for various regions were examined along the fraction of annual precipitation falling as snow. Also examined were interannual variations in SWE, and relationships with PRE and the SWE/PRE ratio. Recent work focuses on the influence of extreme accumulation and mass loss events in shaping the seasonal snowpack. The largest accumulation event typically accounts for between 11% and 22% of total annual accumulation, with the largest contributions in the Arizona/New Mexico region. These large events significantly impact interannual variations in seasonal accumulation.

Applied research has focused on the development of operational methods predict runoff. On intra-seasonal timescales of one to two weeks, the use of raw output from global-scale forecast models in basin-scale hydrologic models could provide skillful predictions of streamflow in continental regions of the western U.S. These methods improve upon the current practice of using historical data as analogs for potential future states. Methods are being refined to address scale discontinuities between global-scale atmospheric models and a basin-scale hydrologic model. Plans are to conduct real-time streamflow forecasts for selected river basins in Colorado.

Other studies have examined effects of low frequency climate variations on modulating the evolution of the seasonal snowpack. The influence of El Niño and La Niña events on snow mass in many areas of the western U.S. is found to change

significantly through the accumulation season. Combining knowledge of the seasonality of the ENSO signal through the accumulation season with knowledge of the snow mass accumulated in mid-winter can improved seasonal hydrologic outlooks.

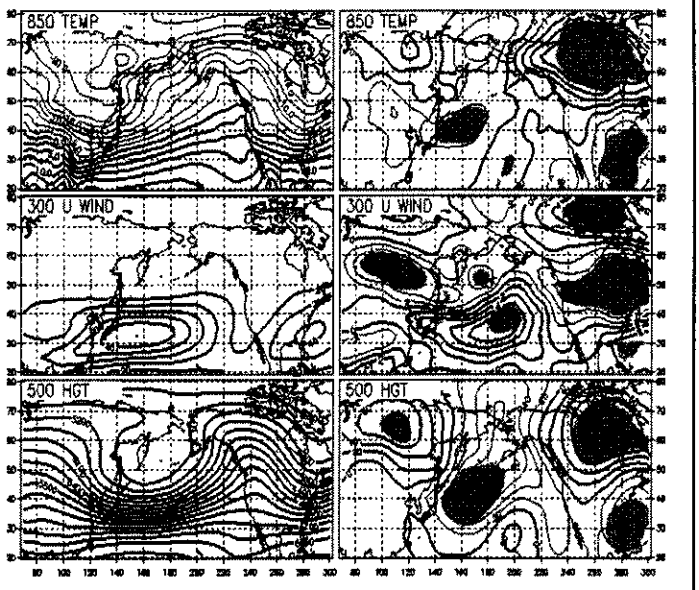
The Role of Snow Cover in the Climate System (NSF Atmospheric Dynamics Program)

These work addresses linkages between low-frequency variations in atmospheric circulation and continental-scale snow cover distributions. Recent efforts have focused on how changes in snow extent and snow mass influence circulation. Variations in snow extent over east Asia are found to be strongly related to atmospheric variability over the North Pacific Ocean and North America. While suggestive of a snow cover forcing, this needs to be further examined from sensitivity experiments with an Atmospheric General Circulation Model.

Experiments are planned to assess the role of seasonal snowpack variations in the western U.S. on the development of the summertime North American monsoon. The basic philosophy behind this work that the energy required to melt positive anomalies in snow mass and evaporate subsequent higher levels of soil moisture can delay in the seasonal warming of the landmass. This modulates the land-ocean temperature contrasts, and thus the monsoonal circulation.

Arctic Environmental Change (NSF Arctic System Science Program)

Observational evidence of environmental change in northern high latitudes was synthesized. Pronounced winter and spring warming over both continents since about 1970 is partly compensated by cooling over the northern North Atlantic. Warming is also evident over the central Arctic Ocean. There is a downward tendency in sea ice extent, dominated by reductions along the Eurasian coast, attended by warming and increased areal extent of the Arctic Ocean's Atlantic layer. Negative snow cover anomalies have dominated over both continents since the late 1980s and terrestrial precipitation has increased since 1900. Small



Composites of 850 hPa air temperature (°C), 300 hPa zonal wind (m s-1), and 500 hPa geopotential height (m) for days when anomalies in East Asian snow extent are greater than 500,000 km2 in January-February. The total fields are displayed on the left and the anomalies are displayed on the right. Areas locally significant at 95% are shaded. Generally opposing patterns are found for negative east Asian snow cover anomalies.

Arctic glaciers have exhibited generally negative mass balances. While permafrost has warmed in Alaska and Russia, it has cooled in eastern Canada. There is evidence of increased plant growth, attended by greater shrub abundance and northward migration of the tree line. Evidence also suggests that the tundra has changed from a net sink to a net source of atmospheric carbon dioxide.

Taken together, these results paint a reasonably coherent picture of change, but their interpretation as signals of enhanced greenhouse warming is open to debate. Many of the environmental records are either short, are of uncertain quality, or provide limited spatial coverage. Furthermore, roughly half of the pronounced recent rise in Northern Hemisphere temperatures reflects changes in atmospheric circulation. These include generally positive phases of the North Atlantic and Arctic Oscillations and extratropical responses to the El-Niño Southern Oscillation. The recent high-latitude warming is also no larger than the interdecadal temperature range during this century. On the other hand, not all of the recent warming is explained by circulation and the general patterns of change broadly agree with model predictions. An anthropogenic effect is also suggested from interpretation of the paleoclimate record, which indicates that the 20th century Arctic is the warmest of the past 400 years. Model studies also indicate that the recent circulation changes have themselves been partly driven by anthropogenic forcing.

Validation of Atmospheric "Reanalyses" (NSF Arctic System Science Program)

Several studies have made use of "reanalysis" fields from the National Centers for Environmental Prediction/National Center for Atmospheric Research (NCEP/NCAR) and European Center for Medium Range Weather Forecasts (ERA). The objective behind reanalysis is to compile temporally-consistent global fields of analyzed and forecast fields using "frozen" data assimilation and forecast systems, eliminating pseudo-climate signals introduced by changes in model physics. Serreze serves as chair of the World Climate Research Programme Arctic Climate System Study (WCRP/ACSYS) Working Group of Polar Products from Reanalyses. This working group is tasked with assessing the performance of renalyses in polar regions and to work with the numerical weather prediction centers to improved the representation of polar processes in future reanalysis efforts.

Precipitation forecasts over the period 1979-1988 were compared to an improved monthly precipitation climatology for the Arctic. This validation climatology was developed by blending the Legates and Willmott gridded product with measurements from Russian "North Pole" drifting stations and gauge-corrected station data for Eurasia and Canada.

Both reanalysis models capture the major spatial features of annual mean precipitation and general aspects of the seasonal cycle but with some notable errors. Both underestimate precipitation over the Atlantic side of the Arctic. NCEP overestimates annual totals over land areas and to a somewhat lesser extent over the central Arctic Ocean. Except for the North Atlantic/Scandinavia sector, the NCEP model also depicts the seasonal precipitation maximum consistently one month early in July.

Overall, the ERA predictions are better. Both models perform best during winter and worst during summer.

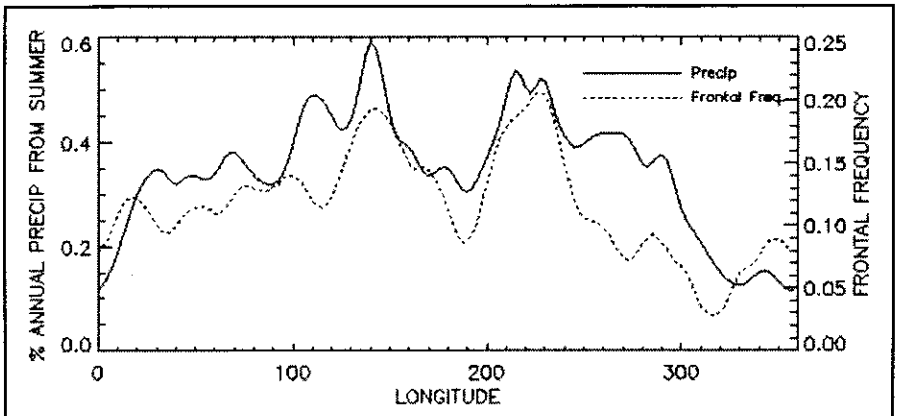
The most significant problem with the NCEP model is a severe over-simulation of summer precipitation over land areas, due to excessive convective precipitation. Further investigation for July reveals that both the NCEP analyses and 12-hour forecasts are too wet below about 850 mb and have more negative low-level temperature gradients as compared to available rawinsonde profiles. This suggests that low-level observations are not being effectively incorporated in the analyses. Given this finding, the high humidities are consistent with excessive surface evaporation rates. This problem may in turn relate to soil moisture, which NCEP updates by the modeled precipitation. If soil moisture is too high, this would favor excessive evaporation and high low-level humidities, fostering excessive precipitation, in turn keeping soil moisture and evaporation rates high. The NCEP downwelling shortwave fluxes are also much too high, contributing to excessive evaporation and possibly influencing the low-level temperature gradients. By comparison, soil moisture in the ERA model is adjusted using the difference between the model first guess and analysis value (the analysis increment) of low-level humidity, which prevents model drift. The ERA downwelling shortwave fluxes are also closer to observations. These attributes are consistent with the superior ERA precipitation forecasts in summer and suggest avenues for improving the performance of the NCEP model.

A related study examined reanalysis depictions of precipitation minus evaporation (P-E) over the Arctic based on both the forecast fields of P and E and from the flux convergence method, using the analyzed wind and moisture fields. Based on the forecasts, the ERA model captures the major spatial features of mean annual P-E as they are known. By contrast, the NCEP forecast fields contain a spurious wave pattern in both P and E. The forecast fields of annual P-E from both models are also much lower (about 60%) than values obtained from the vapor flux convergence. However, both P and E in the NCEP reanalysis are themselves too high in summer over land, indicative of an overly vigorous hydrologic cycle. The annual flux of moisture across 70oN (i.e., the meridional moisture flux) from both models was compared against results based on rawinsonde data. Annual-average fluxes from both models are significantly higher than the rawinsonde estimates during summer, with much better agreement during winter. This problem appears to lie with the rawinsonde network being insufficiently dense to capture the major moisture transport "pathways" into the Arctic. Put differently, it seems that the models provide better estimates of P-E from the flux convergence approach than can be obtained using only rawinsonde data. P-E averaged for the region north of 70oN from the ERA and NCEP flux convergences are very similar, with a value of 188 +/- 6 mm per year, compared with the rawinsonde-derived estimate of 163 mm per year.

The Summertime Arctic Front (NSF Arctic Systems Science Program)

Calculations of a thermal front parameter (TFP) using NCEP/NCAR data over the period 1979-1998 reveals a band high of high frontal frequencies to develop during summer over central to eastern Eurasia from about 60-70°N. A similar feature is found

over Alaska. Although best expressed in summer, the latter is exhibited year-round and represents the northern end of a belt of high frontal frequencies extending south. At certain longitudes, these high-latitude features can be distinguished from the polar frontal zone and collectively resemble the separate summertime Arctic frontal zone discussed by Reed and Kunkel forty years ago. The existence of a separate high-latitude baroclinic zone during summer is further evident in cross sections of mean temperature and the zonal wind, the latter showing distinct jet-like features in the upper troposphere. Clear associations are found between the regions of frontal activity, cyclogenesis and summer precipitation. Cyclones generated in association with the Eurasian frontal zone often track into the central Arctic Ocean, where they may impact the sea ice circulation. The Eurasian and Alaskan frontal zones exhibit fairly low interannual variability, and no trends are noted.



Frontal frequency for summer and the percentage of annual precipitation falling during summer averaged from62.5°N to 67.5°N by longitude. Results show a positive relationship between summer precipitation and frontal frequency.

Development of the Eurasian frontal zone is consistent with a seasonal change in circulation shifting baroclinicity to the north, setting up a zonal orientation of the isotherms. Over both Eurasia and Alaska, baroclinicity is enhanced by differential heating between the Arctic Ocean and snow-free land. Frontal activity is also most pronounced where significant orography lies near and parallel to the coast, which may help to focus the baroclinicity. While at least two studies have argued that the summer Arctic frontal zone may be in part determined by discontinuities in energy exchange along the tundra/boreal forest boundary, a vegetation forcing is not required in the present conceptual model.

NSF Arctic Climate System Study

Serreze collaborated with several scientists to compile a new gridded temperature climatology for the Alaska region using improved interpolation techniques. Serreze also assisted in a study of projected future changes in tundra carbon storage by applying the Terrestrial Ecosystem Model (TEM) to the pan-Arctic and the Kuparuk river basin.

Julienne Stroeve

AVHRR Derived Albedo of Greenland

Complete analysis of the AVHRR Polar Pathfinder (APP)-derived surface albedo over Greenland has been performed for 2 years (1997 and 1998). Comparisons with ground-based measurements show a negative bias in the APP-derived surface albedos on the order of 10%. Correlations between the two measurements are good in the ablation region and poor in the dry snow region. Oscillations in the APP-derived surface albedo correspond to the 10-day repeat cycle of the satellite, suggesting that some angular dependence remains in the satellite derived surface albedo.

Tingjun Zhang

Snow Cover Effects on Ground Thermal Regime

Using data from Russian meteorological stations and other information, a paper titled "Influence of seasonal snow cover on ground thermal regime" has been prepared. Historical variations of soil temperature at various depths at individual stations have been studied on monthly and annually bases using both spectrum and wavelet analyses. Long-term trends and periodicities of soil temperatures have been investigated at individual stations and compared from region to region. Possible factors which cause soil temperature changes during the past few decades, will also be investigated. Such factors include air temperature, precipitation, soil moisture, snowfall and seasonal snow cover.

Atmosphere - Active Layer Permafrost Modeling

This is a continued collaborative study with Knut Stamnes (Geophysical Institute, University of Alaska Fairbanks). Studies show that the energy available to melt snow at high latitudes is almost exclusively provided by radiation. The solar energy determines the period of possible snowmelt, while downwelling welling atmospheric longwave radiation modifies the onset of snowmelt. Atmospheric thickness (the vertical distance between the 500 mb and 1000 mb pressure surfaces), is directly related to the mean temperature and water vapor path of an atmospheric layer and thus has a direct influence on the downwelling longwave radiation and snowmelt. A comprehensive radiative transfer model was applied to calculate the downwelling longwave radiation to the snow surface over the period of snowmelt using radiosonde data obtained at Barrow and McGrath, Alaska. The results indicate that the atmopheric thickness has a positive impact on downwelling longwave radiation, which ranges from about 130 Wm-2 for an atmospheric thickness of 4850 m to about 280 Wm-2 for an atmospheric thickness of 5450 m. This study demonstrates that atmospheric water vapor path has a greater impact on atmospheric downwelling longwave radiation to the snow surface than the mean atmospheric temperature. Attempts were made to investigate the relationship between the atmospheric thickness and the snowmelt onset in the Arctic and Subarctic. Measurements indicate that for the period from 1980 through 1991, an atmospheric thickness of 5250 m at Barrow and 5200 m at McGrath in Alaska was sufficient to trigger

the onset of snow melt. The difference in the threshold values of the atmospheric thickness may be due to differences in the atmospheric structure and different contributions of other energy sources such as sensible and latent heat to melt snow. This study also demonstrates that snow cover disappears earlier during warm and wet (higher atmospheric temperature and precipitable water path, and greater atmospheric thickness) springs and later during cold and dry (lower atmospheric temperature and precipitable water content, smaller atmospheric thickness) springs. Atmospheric precipitable water path has a greater impact on snowmelt than the mean atmospheric temperature. Since atmospheric temperature is closely coupled to the atmospheric water vapor path in the Arctic and Subarctic (i.e., generally, higher atmospheric temperature is correlated with higher atmospheric water vapor content), the atmospheric thickness may be used as a reliable indicator of snowmelt in the Arctic and Subarctic.

Thaw Lake Study on the North Slope of Alaska

This is a continued collaborative study with Martin O. Jeffries (Geophysical Institute, University of Alaska Fairbanks). During the past year, we have accomplished the following:

Thaw lakes comprise over 20% of the total area of the Alaskan North Slope region, and up to about 40% in the coastal plain areas. This value may increase due to expansion of the extant thaw lakes and creation of new lakes under global warming scenarios that predict that impacts and changes would be greater in the Arctic than elsewhere. A physically based, two-dimensional, non-steady, finite element heat transfer model with phase change is used to investigate the heat and mass transfer between the atmosphere and permafrost, through the intervening seasonal snow cover, lake ice and lake water. The model is partly validated using available field measurements. Both field measurements and simulated results indicate that thaw lake system is a significant heat source to the atmosphere during the long cold season (8 to 9 months) in the Alaskan Arctic Coastal Plains. The heat source from thaw lake system may partly explain the relatively moderate winter climatic conditions along the Arctic Coastal Plains compared to more continental winter climate in the southerly regions. The simulated long-term (1948-1997) mean maximum lake ice thickness was 1.91+/- 0.21 m with a range from 1.33 m (1962) to 2.47 m (1976). Variations in the seasonal snow cover played a much greater role than air temperature in controlling ice thickness variability during the 50-year simulation period. Continued variability in maximum lake ice thickness combined with potential climate change could affect the area of lake ice that freezes completely to the bottom of thaw lakes each winter, resulting in changes in water storage and availability, permafrost thermal regime and talik (thaw bulb) dynamics beneath thaw lakes, and methane efflux and energy fluxes to the atmosphere. The simulated results also illustrate that talik (thaw bulk) forms when thaw lakes do not freeze to the bottom by the end of winter. The rate of permafrost thawing varies from a few centimeters during early stage of thaw lake development to a few millimeter after a few thousand years. Maximum talik thickness (distance from the lake bottom to the permafrost surface) could vary from 30 to 50 m for a 3000 to 5000 year old thaw lake which does not freeze to the bottom each winter. Talik development under thaw lakes has a significant impact on landforms due to

thaw settlement, slope and coastal stability, and permafrost degradation. Thawing of permafrost under thaw lakes could release carbon (such as gas hydrates) trapped in permafrost to the atmosphere, providing a positive feedback to the climatic system. Talik also provides an environment for microbial decomposition of organic sediments under anaerobic conditions, which could be a significant methane source to the atmosphere. This study concludes that a comprehensive investigation is required in order to better understand the role of the thaw lake system in tundra environments in the Arctic and Subarctic.

Stochastic Variability of Seasonal Freezing and Thawing at Local, regional, and Hemispheric Scales Under Modern and Predicted Climate

This is a new project funded by NSF starting August 1, 1999. T. Zhang and R. G. Barry are collaborating with David Gilichinsky of the Institute for Soil Scince, RAS, in Pushchino. This project is well under way currently. We will continue to receive soil temperature data from Russia for about 100 meteorological stations. We will also collect other data sets such as air temperature, precipitation, snow cover, soil type, digital elevation data, vegetation, soil moisture, etc. to support related work of Dr. Fritz Nelson (University of Delaware) and Dr. Oleg Anisimov (State Hydrologic Institute, St. Petersburg) on these projects.

Application of Satellite SAR Imagery in Mapping the Active Layer of Arctic Permafrost

This is a new project supported by NASA started on June 1, 1999. T. Zhang is collaborating with Shusun Li of the Geophysical Institute, University of Alaska Fairbanks.

Freezing and thawing processes of soils have a significant impact on energy and water transfer between the atmosphere and the land surface, surface hydrology, and agriculture because of the substantial differece in thermal and hydrological properties between frozen and thawed soils. The timing, duration, areal extent, and depth of surface soil freezing and thawing are important parameters for regional climatic and hydrologic studies, and changes in these parameters are important climatic indicators. The conventional point measurement of surface soil freezing and thawing provide information for process studies in local area. It is impractical to conduct large- or regional-scale investigation of surface soil freezing and thawing by using the point measurement method. In this study, onset of surface soil freezing in permafrost region and frozen soil extent in seasonally frozen soil regions were investigated using the Special Sensor Microwave/Imager (SSM/I) data. The algorithm of the freezing indicator has been developed by Zuerndofer and England (1992) using (i) a negative spectral gradient between Tb(37V) and Tb(19V), (ii) a cutoff Tb(37V). Limited validation was undertaken using field measurements in northern Plains of the United States. Preliminary results indicate that frozen soil extent is generally in good agreement with the zero deg. Celius isotherm of air temperature. The boundary of the frozen soil extent moved southward as the cold air was invading from north in northern Plains during the early winter. The

results also show that frozen soil extent was greater in the morning (about 6:00 a.m. local time) than in the afternoon (6:00 p.m. local time). Snow cover extent is also included for comparison.

STAFF

New employees

Doug Young	October 12, 1998	Systems Administrator
Beth Sigren	November 4, 1998	Associate Scientist
Mike Chhor	February 1, 1999	Operations Technician
Derek van Westrum	February 1, 1999	Scientific Programmer
Linda Green	May 17, 1999	HR Employment Specialist
Tom Priestley	June 14, 1999	Systems Administrator
Michon Scott	July 19, 1999	Web Designer
Andrew Barrett	October 1, 1999	Associate Scientist
John Pyle	October 1, 1999	WWW Administrator
Bruce Raup	October 1, 1999	Scientific Research Assistant
Teresa Mullins	October 1, 1999	Information Center Supervisor
Marianne Primett	November 1, 1999	Operations Technician
Bradley McLean	December 1, 1999	User Services Representative
Rudy Dichtl	December 6, 1999	ARCSS Manager

Promotions

Renea Ericson	September 1, 1998	Operations Supervisor
Ted Scambos	April 1, 1999	Research Scientist III
Spencer Shiotani	August 1, 1999	Software Engineer
Annette Varani	August 1, 1999	Outreach Coordinator
Ann Bessenbacher	September 1, 1999	Senior Operations Technician
Cindy Brekke Bauer	November 11, 1999	Office Manager

Departures

Jennifer Bohlander	Associate Scientist
Matt Cross	ARCSS Data Manager
Chris Haggerty	Scientific Programmer
Graham Mountain	Senior Systems Administrator
Karen Robinson	Database Administrator
Karen DeClerk	HR Employment Specialist (moved to CIRES)

Visitors

Dr. Mark Fahnestock, Goddard Space Flight Center, September 1998 – May 1999, (T. Scambos)

Dr. Hugh Kieffer, USGS, Flagstaff, 3 February 1999. (R. G. Barry, G. Scharfen)

Dr. Michael Lents, Science Applications Interaction Corporation, 8-9 December 1999. (F. Fetterer)

Dr. Martin Miles, University of Bergen, Norway, 20-30 December 1999. (R. G. Barry)

Polar DAAC User Working Group Members, 27-29 September 1999

Dr. Vladimir Radionov, Arctic and Antarctic Research Institute, St. Petersburg, Russia, 15-19 March; 6-9 December 1999. (F. Fetterer)

Professor Kumo Rikiishi, Department of Earth Science, Hirosaki University, Japan, 8 March 1999. (R. G. Barry)

Dr. Sergey Sokratov, Visiting Fellow, CIRES, from 15 November 1999

Dr. Pavel Svyashchennikov, Arctic and Antarctic Research Institute, St. Petersburg, Russia, 15-19 March; 6-9 December 1999. (F. Fetterer)

Dr. Marina Timofeeva, Kent State University, 27 October 1999. (M. P. Clark)

Professor Norbert Untersteiner, University of Washington, Seattle, 8-9 December 1999. (F. Fetterer)

Cryospheric And Polar Process Division Seminars

10 September 1999. Dr. Roger G. Barry, NSIDC, Dr. Konrad Steffen, CIRES, Dr. Mark Serreze, CIRES. ACSYS/CLIC and TOPC Activities

12 February 1999. Dr. John Behrendt, INSTAAR, Americans in Antarctica from the International Geophysical Year (1957) to the Environmental Protocol

26 February 1999. Dr. Valerie Sloan, CPP, Rock Glaciers in the Yukon

2 April 1999. Dr. John Wahr, CIRES, Gravity Recovery and Climate Experiment (Grace)

12 March 1999. Dr. Eric Hudier, Universite Trois-Rivieres, Quebec, Canada. Leads and Ridges in Sea Ice from Radarsat

Dr. Roger G. Barry, NSIDC, ACSYS/CLIC and TOPC Activities, 10 September 1999

24 September 1999. Dr. Thorsten Markus, NASA/GCFC-UMBC JCET, A Revision of the NASA Team Sea Ice Algorithm

22 October 1999. Dr. Joey Comiso, NASA/GCFC, Passive Microwave Bootstrap Algorithm

5 November 1999. Dr. Waleed Abdalati, NASA/GCFC, Altimetry and Arctic Ice Mass Balance

5 November 1999. Sheldon Drobot, University of Nebraska, Lincoln, Mapping Arctic Melt / Freeze from Passive Microwave Data

12 November 1999. Anthony Arendt, University of Alberta, Approach to Modeling the Mass Balance of High Arctic Glaciers

COMMITTEE REPRESENTATION

Earth Science Enterprise Study Team for Data and Information System and Services – R. L. Weaver

GCOS/GTOS Terrestrial Observations Panel on Climate – R. G. Barry

International Commision on Snow and Ice (ICSI) Snow and Climate Working Group – R. L. Armstrong, Chairman

International Permafrost Association (IPA) Standing Committee on Data Information and Communications – R. G. Barry, Co-Chair

International Satellite Land Surface Cliamtology Project (ISLSCP) Science Panel – G. Scharfen

NASA MISR Project Team – A. W. Nolin

NASA Science Information Services (SIS) Study Team, Lead Customer Group – R. L. Armstrong

SCAR/COMNAP Joint Committee on Antarctic Data Management – G. Scharfen, R. Bauer

WCRP-Arctic Climate System Data Management and Information Panel – R. L. Armstrong

WCRP-ACSYS Scientific Steering Group – R. G. Barry

WCRP Task Group on Climate and Cryosphere (CLIC) – R. G. Barry, Co-Chair

WMO Commission on Maritime Meteorology Steering Group for the Global Digital Sea Ice Data Bank – R. G. Barry, Co-Chair

MEETINGS ATTENDED

ACSYS, Second Meeting of the ACSYS Data Management and Information Panel (DMIP), held in conjunction with the Numerical Modeling Panel and the Observational Products Panel, Koblenz , Germany, 28 June - 1 July, 1999, (R. L. Armstrong)

ARCUS 11th Annual Meeting, Washington DC, 20-23 March 1999 (T. J. Zhang)

American Geophysical Union (AGU) Fall Meeting, San Francisco, CA, 13-17 December 1999 (R. L. Armstrong, G. Scharfen, A. W. Nolin, R. G. Barry, C. Brekke Bauer, J. Stroeve, R. Hauser, A. Varani, T. J. Zhang, T. Scambos)

American Meteorological Society (AMS) Annual Meeting, Dallas Texas, 11-15 January 1999 (R. L. Armstrong, M. J. Brodzik, G. Scharfen, T. Zhang)

American Society of Information Scientists Annual Meeting, Washington DC, 31 October – 4 November 1999. (Mark Parsons)

Association American Geographers, 95th Annual Meeting, Honolulu, HI, 22-26 March, 1999 (R.G. Barry, M.P. Clark, A. Frei, A.W. Nolin, M.C. Serreze)

ASTER Science Team Meeting, Solvang, CA, December 15-18, 1999. (B. Raup, J. Stroeve)

CLIMAR '99, WMO Workshop on Advances in Marine Climatology, Vancouver, Canada 8-15 September 1999 (F. Fetterer)

Committee on Earth Observation Satellites International Directory Network Task Team meeting, 14-15 September 1999, Charlottesville, VA (G. Scharfen)

Environmental Working Group Arctic Meteorology and Climate Atlas Workshop, Boulder Colorado, 15 - 18 March and 6-10 December 1999 (R. G. Barry, F.Fetterer and the NSIDC EWG team)

Environmental Working Group Arctic Meteorology and Climate Atlas Workshop, Arctic and Antarctic Research Institute, At. Petersburg, Russia 7-9 June 1999 (F. Fetterer, D. van Westrum, R. Welsh)

GISS Workshop on Climate Change of the Last Fifty Years, New York, NY, 21-23 November 1999 (R. L. Armstrong)

GLAS Science Team Meetings, Goddard Space Flight Center, Greenbelt MD, 6–8 January 1999, 26-31 October (T.A. Scambos); Madison, WI, 12-14 April 1999 (A. W. Nolin, T. A. Scambos, R. Welsh)

Global Climate Observing System, Terrestrial Observations Panel for Climate (GCOS/TOPC), Birmingham, UK, 27-30 August 1999 (R.G. Barry)

Ice Core Working Group Meeting, 19 March 1999, Denver CO (G. Scharfen, R. Bauer)

International Arctic Research Center, Proposal review panel, 18-25 October 1999. (T. Zhang)

International Glaciological Society, Symposium on the Verification of Cryospheric Models, Zuerich, Switzerland, 16-20 August, 1999 (R.L. Armstrong, R.G. Barry, M. Parsons, G. Scharfen, T. Zhang)

International Satellite Land Surface Climatology Project (ISLSCP) II Kickoff meeting, Greenbelt, MD, 27-29 October 1999, (G. Scharfen)

International Symposium on the Verification of Cryospheric Models (International Glaciological Society), 16-19 August 1999, Zurich, Switzerland (G. Scharfen, M. Parsons. R. Barry)

International Trans-Antarctic Expedition (ITASE) meeting, 17 March 1999, Denver, CO (G. Scharfen, R. Bauer)

International Union of Geophysics and Geodetics, XXII General Assembly, Birmingham, UK, July 1999 (R. G. Barry, R. L. Armstrong, M. Clark, M. Cross, T. Scambos, R. S. Weaver)

International Workshop on Remote Sensing and Climate Simulations: Synergies and Limitations, Les Diablerets, Switzerland, 20-24 September 1999 (A. W. Nolin)

Joint AMSR Science Team Meeting, (joint with AMSR-E and ADEOS-II AMSR) Oklahoma City, OK, July 6-7, 1999, (R. L. Armstrong)

Midwest Glaciology Meeting – convened and hosted by NSIDC and INSTAAR, Boulder, CO, 15-16 March 1999, (T.A. Scambos, A. W. Nolin, J. Bohlander, B. Raup)

MISR ScienceTeam Meeting, 15-17 December 1999 (J. Stroeve, A. W. Nolin)

MODIS Land Group Science Data Support Team meeting, 30-31 March 1999, Greenbelt, MD (G. Scharfen)

MODIS PI Processing Meeting, Greenbelt, MD, 13 July 1999 (G. Scharfen)

MODIS Science Team and MODIS Land Group meetings, 4-6 May 1999 (A. W. Nolin); 16-18 November 1999, Columbia, MD (G. Scharfen, A. W. Nolin)

NASA DAAC Scientists Meeting, Goddard Institute for Space Science, (GISS), New York, NY, 30 August – 2 September 1999 (R. L. Armstrong)

NASA Earth Science Information Partners (ESIP) 9-10 December 1999,(M. Holm, R. Weaver, T. Thrasher Hybl)

NASA EOS Investigator's Working Group (IWG) meeting, 15-17 June 1999, Vail, CO (R. G. Barry, R. Hauser, A. W. Nolin, G. Scharfen, J. Stroeve, R. Weaver, M. Marquis, A. Varani)

NASA EOSDIS DAAC Managers Meetings (R.L. Weaver, T. Thrasher Hybl, V. Troisi, M. Holm)

NASA EOSDIS User Services Working Group Meeting, SEDAC, New York, NY, 19-21 October 1999 (T. Thrasher Hybl, D. Starr)

NASA Headquarters, NASA GSFC, NOAA Satellite Applications Branch, University of Maryland, Washington D.C. area, 17-19 May 1999. Professional collaborative visits with 12 individual research scientists at these locations (R. L. Armstrong)

NASA Land Surface Hydrology Program Meeting, Washington DC, 2-4 November 1999 (A. Frei, T. Zhang)

NASA Data and Information Systems and Services Core Study Team Meetings, April, October 1998 [NEWDISS] (R.L. Weaver)

National Snow Science Workshop, Snow and Avalanche Study Establishment (SASE), Manali, India 29-30 October 1999 (R. L. Armstrong)

NOAA Climate Diagnostics and Prediction Workshop, Tucson, AZ, November 1999, (M. Clark)

NSF Arctic System Science (ARCSS) Committee Meeting, Virginia Beach, VA, 24-25 October 1999 (C. K. McNeave, M. C. Serreze)

NSF Arctic System Science (ARCSS) Ocean- Atmosphere-Ice Interaction (OAII) Investigators Meeting, Virginia Beach, VA, 20-22 October 1999. (C. McNeave, M. C. Serreze)

Polar DAAC User Working Group meeting, Boulder CO, 27-29 September 1999 (R. G. Barry, M. Holm, M. Parsons, G. Scharfen, R. L. Weaver)

RAMP Science Group Meeting, Byrd Polar Research Center, Columbus, OH, 8-10 June, 1999 (T.A. Scambos)

Russian Academy of Sciences, Council on Earth Cryology, Conference on Monitoring of Cryosphere, Pushchino, Russia, 20-23 April, 1999. (R.G. Barry).

SCAR COMNAP Joint Committee on Antarctic Data Management, Ottawa, Canada, 7-10 June 1999, (G. Scharfen, R. Bauer)

Science Working Group for the AM-1 Platform, Boulder, CO, 2-3 February 1999, (G. Scharfen, R. Weaver)

Second International Workshop on Multiangle Measurements and Modeling, Ispra, Italy, 15-17 September 1999 (A. W. Nolin)

Sixth Annual Western Antarctic Ice Sheet Initiative (WAIS) workshop, Sterling, VA, 16-18 September 1999, (G. Scharfen, T. Scambos)

Third International Scientific Conference on the Global Energy and Water Cycle, Jointly with the Fourth Conference on the GEWEX Asian Monsoon Experiment (GAME), Beijing, China, 16-19June 1999 (R. Armstrong, T, Zhang)

U.S. Arctic Research Commission, Boulder, CO, 7 July 1999 (R. G. Barry, G. Scharfen)

WCRP Arctic Climate System (ACSYS) Scientific Steering Group, Louvain-la Neuve, Belgium, 15-19 November, 1999. (R.G. Barry, M.C. Serreze)

WCRP Climate and Cryosphere (CLIC) Task Group Meeting, Grenoble, France, 10-13 August, 1999, (R.G. Barry, meeting chair)

West Antarctic Ice Sheet Initiative Meeting (WAIS), Sterling, VA, 16-19 September 1999 (T.A. Scambos, G. Scharfen)

PUBLICATIONS
(NSIDC staff indicated in bold print)

Armstrong, R.L. 1999. A Brief History of Regional to Global Scale Satellite Remote Sensing of Snow and Related Activities at NSIDC, National Snow Science Workshop, October 29 – 30, 1999, *Snow and Avalanche Study Establishment (SASE)*, Manali, India, pp. 373-379.

Armstrong, R.L. 1999. Satellite Remote Sensing of Global Snow Cover – A Brief History, *International Union of Geodesy and Geophysics, (IUGG) 22nd General Assembly*, 26-30 July 1999, Birmingham, England; B.123.

Armstrong, R.L. and **Brodzik, M.J.** 1999. A twenty year record of global snow cover fluctuations derived from passive microwave remote sensing data, *Proceedings 5th Conference on Polar Meteorology and Oceanography*, Amer. Met. Soc., Dallas, TX:113-117.

Armstrong, R.L. and **Brodzik, M.J.,** 1999. A Twenty Year Record of Northern Hemisphere Snow Fluctuations Derived from Passive Microwave Satellite Data, *GEWEX Third International Scientific Conference on the Global Energy and Water Cycle*, 16-19 June, 1999, Beijing, China. Preprint Volume Supplement pp. 17-18.

Barry, R.G. 1999. Microclimate; Precipitation. In: D.E. Alexander and R.W. Fairbridge, (eds.) *Encyclopedia of Environmental Science*, Kluwer Academic Publ., Dordrecht, p.408; p.493-94.

Barry, R.G. 1999. Review: Into the Second Century of World Glacier Monitoring: Prospects and Strategies. W. Haeberli, M. Hoelzle and S. Suter, (eds.), UNESCO, 1998, 227 pp. *Bull. Amer. Met. Soc.*, 80(9): 1922-23.

Barry, R.G. 1999. Review: Views from the Alps: Regional Perspectives on Climate Change, P. Cebon et al., MIT Press 1998, 515 pp. *Annals Assoc, Amer. Geogr.*, 89: 779-800.

Barry, R.G., Armstrong, R.L., Maslanik, J.A. and **Scambos, T.A.** 1999. Cryospheric research and data products from the National Snow and Ice Data Center, *Arctic Research of the United States*, Vol. 12: 64-69.

Barry, R.G., and Chorley, R.J. 1999. *Atmósfera, Tiempo y Clima.* (7th edn), Ediciones Omega, Barcelona, 441 pp.

Barry, R.G., Melnikov, E.S., Clark, M.J., Alekseev, V.R., Minkin, M.A.,Krenke, A.N. and Khromova, T.E. 1999. State-of-the-art and advancement of data bases on snow cover, ice phenomena and permafrost. Abstracts, International Conference on Monitoring of Cryosphere, Russian Academy of Sciences, Consolidated Scientific Council on Earth Cryology, Pushchino, pp. 28-30.

Barry, R.G.1999. Review: The Surface Climate of Canada. W.G. Bailey, T.R. Oke and W.R. Rouse, eds. McGill-Queen's University Press, 1997, 369 pp. *Int. J. Climatol.*, 19: 457.

Barry, R.G., Weaver, R.L.S, Cross, M. and **Scharfen, G.,** 1999. Advances in cryospheric data management. *International Union of Geodesy and Geophysics, (IUGG), 22nd General Assembly*, 26-30 July 1999, Birmingham, England, p.B85.

Barry, R.G., Zhang, T., Gilichinsky, D., Sorokovikov,V. and Bykhovets, S. 1999. Soil temperature variation and its relation to climatic conditions. Abstract: International Conference on Monitoring of Cryosphere, Russian Academy of Sciences, Consolidated Scientific Council on Earth Cryology, Pushchino, pp. 89-90.

Brown, J., Haeberli, W., **Barry, R.,** Nelson, F. and Burgess, M. 1999. International monitoring network and its management. Abstract: International Conference on Monitoring of Cryosphere, Russian Academy of Sciences, Consolidated Scientific Council on Earth Cryology, Pushchino, pp. 23-24.

Clark, M.P. and **Serreze, M.C.** 1999. Snowfall responses over the U.S.A. to phase and amplitude variations in the tropospheric wavetrain. In: *Interactions Between the Cryosphere, Climate, and Greenhouse Gases*, M. Tranter, R. Armstrong, E. Brun. G. Jones, M. Sharp, and M. Williams, (eds.). *IAHS Publ.* No. 256, pp. 45-54.

Clark, M.P. and **Serreze, M.C.,** 1999. Snowfall responses over the U.S.A to phase and amplitude variations in the tropospheric wavetrain. *International Union of Geodesy and Geophysics, (IUGG) 22nd General Assembly*, 26-30 July 1999, Birmingham, England; p.B.306.

Clark, M.P., Serreze, M.C., and Robinson, D.A. 1999 Atmospheric controls on Eurasian snow extent. *International Journal of Climatology*, 19, 27-40.

Cross, M.D. and **McNeave, C.K.**, 1999. The ARCSS Data coordination Center (ADCC) at the National Snow and Ice Data Center (NSIDC), USA. *International Union of Geodesy and Geophysics, (IUGG) 22nd General Assembly*, 19-24 July 1999, Birmingham, England; p.A.286.

Diner, D., Asner, G., Davies, R., Knyazikhin, Y., Muller, J-P., **Nolin, A.**, Pinty, B., Schaaf, C., **Stroeve, J.**, 1999. New directions in Earth observing: Scientific applications of multi-angle remote sensing, *Bull. Amer. Met. Soc.*, 80; 2209-2228.

Frei, A. H., and Robinson, D. A. 1999. Northern Hemisphere Snow Extent: Regional Variability 1972-1994. *International Journal of Climatology*, Vol. 19, No. 14, p. 1535-1560.

Frei, A. H., Robinson, D. A., and Hughes, M. G. 1999. North American Snow Extent: 1900-1994. *International Journal of Climatology*, Vol. 19, No. 14, p. 1517-1534.

Hall, D. K., Li, S., **Nolin, A. W.** and Shi, J. C., 1999. Pre-launch validation activities for the MOIS snow and sea ice algorithms, *The Earth Observer*, 11,31-35.

Maslanik, J., Agnew, T., Drinkwater, M., Emery, W., Fowler, C., Viwok, R., and Liu, A. 1998. Summary of Ice Motion Mapping using Passive Microwave Data. NSIDC Special Publication. 8, 25pp. (NSIDC Web document).

Maslanik, J.A., Lynch, A., and Fowler, C. 1999. Assessing 2-D and coupled-model simulations of sea ice anomalies using remotely-sensed Polar Pathfinder products. *Proceedings 5th. Conf. on Polar Met and Oceanogr*, Amer. Met. Soc., Dallas, TX, 476-479.

Maslanik, J.A., Serreze, M.C., and Agnew, T. 1999. On the record reduction in western Arctic sea-ice cover in 1998. *Geophys. Res. Lett.* 26, 13 , 1905-1908.

Maslanik, J.A., Stone, R., Pinto, J., Wendell, J., and Fowler, C. 1999. Mobile-platform observations of surface energy budget parameters at the SHEBA site. *Am. Met. Soc., 5th. Conf. on Polar Met and Oceanogr.*, Dallas, TX, 128-131.

Meier, W.M., and **Maslanik, J.A.** 1999. Assimilation of observed ice motions into a sea ice thickness distribution model. *Proceedings 5th. Conf. on Polar Met and Oceanogr.*, Amer. Met. Soc., Dallas, TX, 486-489.

Nolin, A. W. 1998. Mapping the Martian polar caps: Applications of terrestrial optical remote sensing methods, *J. Geophys. Res.*, 103, 25851-25864.

Pinto, J.O., Curry, J.A., **Maslanik, J.A.,** Fairall, C.W., and Stone, R.S. 1999. Horizontal variability in surface radiative fluxes surrounding SHEBA from airborne and ground-based sensors. *Proceedings 5th. Conf. on Polar Met and Oceanogr.* Amer. Met. Soc., Dallas, TX, 319-320.

Pinto, J.O., **Maslanik, J.A.,** Guest, P.S., Stone, R.S., Andreas, E.L., Fairall, C.W., and Persson, P.O.G. 1999. Surface energy budget and atmospheric effects of a freezing lead at SHEBA. *Proceedings 5th. Conf. on Polar Met and Oceanogr.* Amer. Met. Soc., Dallas, TX, 397-400.

Pulwarty, R. S., **Barry, R. G.,** Hurst, C. M., Sellinger, K. and Mogollon, L.F. 1998. Precipitation in the Venezuelan Andes in the context of regional climate. *Met. Atmos. Phys.*, 67:217-238.

Scambos, T.A. and Haran, A., 1999 The AVHRR Polar Pathfinder 1-25 km data set: Hydrologic and polar climate application. *International Union of Geodesy and*

Geophysics, (IUGG) 22nd General Assembly, 19-24 July 1999, Birmingham, England; p.A.286.

Scambos, T. A., Nereson, N. A., Fahnestock, M. A., 1999. Detailed Topography of Siple Dome and Roosevelt Island, West Antarctic. *Annals of Glaciology*, 27, pp. 61-67.

Scambos, T. A., Kvaran, G., Fahnestock, M. A., 1999. Improving AVHRR resolution through data cumulation for mapping polar ice sheets. *Remote Sensing of Environment* 69, 66-

Scharfen, G.R. and Bauer, R.J. 1999 Antarctic Data Management Support at the National Snow and Ice Data Center. *Western Antarctic Ice Sheet Initiative Sixth Annual Workshop Agenda and Abstracts*, September 16-18, Sterling, VA.

Scharfen, G.R. and Bauer, R.J. 1999 United States Participation in the Antarctic Master Directory, A Cooperating Node of the Global Change Master Directory. *Proceedings: 15th International Conference on Interactive Information and Processing Systems (IIPS) for Meteorology, Oceanography, and Hydrology*, Amer. Met. Soc., January 1-15, 1999, Dallas, TX, p377-399.

Schweiger, A., Fowler, C., Key, J., **Maslanik, J.,** Francis, J., **Armstrong, R., Brodzik, M.J., Scambos, T., Haran, T.,** Ortmeyer, M., **Khalsa, S.,** Rothrock, D. and **Weaver, R.,** 1999. P-Cube: a multisensor data set for polar climate research, *Proceedings 5th Conference on Polar Meteorology and Oceanography*, Amer. Met. Soc., Dallas, TX:136-141.

Serreze, M., Clark, M., Armstrong, R.L., McGinnis, D. and Pulwarty, R. 1999. Characteristics of the Western U.S. Snowpack from SNOTEL Data, *Water Resources Res.* 35:2145-2160.

Serreze, M.C. and **Hurst, C.M.** 2000: Representation of mean Arctic precipitation from NCEP/NCAR and ERA reanalysis. *Journal of Climate*, 13, 182-201.

Serreze, M.C., Clark, M.P, Armstrong, R.L., McGinnis, D.A. and Pulwarty, R.L. 1999 Characteristics of the Western U.S. snowpack from snowpack telemetry (SNOTEL) data. *Water Resources Research*,35, 2145-2160.

Tschudi, M. A., Curry, J.A., and **Maslanik, J.A.** 1999. Airborne observations of surface features during SHEBA. *Proceedings 5th. Conf. on Polar Met and Oceanogr.* Amer. Met. Soc., Dallas, TX, 162-165.

Tschudi, M. A., Curry, J.A., and **Maslanik, J.A.** 1999. Melt pond and open water fraction during the Arctic summer derived from airborne video observations. *4th. Int. Airborne Remote Sensing Conf., 21st. Canadian Symposium on Remote Sensing,* Ottawa, Ontario, Canada, 21-24 June 1999, V. I, pp. I-716 – I-722.

Weaver, R.L.S., 1999. New directions in NASA Earth Science Enterprise Data Management. *International Union of Geodesy and Geophysics, (IUGG) 22nd General Assembly,* 26-30 July 1999, Birmingham, England; p. B.82.

Weaver, RL.S., Cheshire, L., Hauser, R., Meshek, M., Marquis, M., Varani, A., and **Singh Khalsa, S.J.,** 1999. Polar Pathfinder Data Sampler: New data formats for integrated products. *International Union of Geodesy and Geophysics, (IUGG) 22nd General Assembly*, 26-30 July 1999, Birmingham, England; p.B.88.

Zhang, T. 1998. Climate and permafrost conditions in northern Alaska, USA, The Earth Geocryosphere, *The Russian Academy of Sciences, Siberian Branch*, 2 (1); 19-27, (In Russian with English abstract).

Zhang, T. 1999. Book Review: "General Geocryology'" by E. D. Yershov; P. J. Williams (Ed.). *Journal of Hydrology,* 219, 94-99.

Zhang, T. and **Armstrong, R. L.** 1999. Passive microwave remote sensing of frozen soils. *Proceedings of the Third International Scientific Conference on the Global Energy and Water Cycle*, 16-19 June, 1999, Beijing, China, Preprint Volume, Supplementary Collection, p. 19-21.

Zhang, T., Armstrong, R. L., and **Smith, J.,** 1999. Passive microwave remote sensing of frozen soils. *International Union of Geodesy and Geophysics, (IUGG) 22nd General Assembly,* 26-30 July 1999, Birmingham, England; p.B.124.

Zhang, T., Armstrong, R. L. and **Smith, J.** 1999. Detecting seasonally frozen soils over snow-free land surface using satellite passive microwave remote sensing data. *Proceedings 5th Conference on Polar Meteorological and Oceanography*, Amer. Met. Soc., Dallas, Texas, p.355-357.

Zhang, T., Barry, R.G., Knowles, K., Heginbottom, J.A., and Brown. J. 1999. Statistics and characteristics of permafrost and ground ice distribution in the Northern Hemisphere. *Polar Geog.,* 23: 147-169.

ACRONYMS

AARI	Arctic and Antarctic Research Institute (St. Petersburg)
ACSYS	Arctic Climate System (WCRP)
ADCC	ARCCS Data Coordination Center
ADD	Arctic Data Directory
AGDC	Antarctic Glaciological Data Center
AGU	American Geophysical Union
AMD	Antarctic Master Directory
AMIP-II	Atmospheric Model Intercomparison Project – II
API	Application Programming Interface
ARCSS	Arctic System Science
ARCSyM	Arctic Regional Climate System Model
AVHRR	Advanced Very High Resolution Radiometer
CAPS	Circumpolar Active Layer and Permafrost System
CD	Compact Disk
CEOS	Committee on Earth Observation
CIRES	Cooperative Institute for Research in Environmental Science
CLIC	Climate and Cryosphere (WCRP)
CRREL	US Army Cold Regions Research Engineering Laboratory
DAAC	Distributive Active Archive Center
DEM	Digital Elevation Map
DMSP	Defense Meteorological Satellite Program
EASE-Grid	Equal Area Scalable Earth Grid
ECS	EOSDIS Core System
ESDIM	Earth System Data and Information Management
GCMD	Global Change Master Directory
GCOS/GTOS	Global Climate Observing system/ Global Terrestrial Observing System
GLAS	Geoscience Laser Altimeter System
GIS	Geographic Information System
GPS	Global Position System
GSFC	Goddard Space Flight Center
HSDSD	Historical Soviet Daily Snow Depth
HTML	Hyper Text Markup Language
IAEDD	International Arctic Environmental Data Direction
ICAIR	International Center for Antarctic Information and Research
IDN	International Directory Network
IGBP	International Geosphere Biosphere Program
IMS	Information Management System
JCADM	Joint Committee on Antarctic Data Management
JPL	Jet Propulsion Laboratory
LAII	Land Atmosphere Ice Interactions (ARCSS)
LIGG	Lanzhou Institute of Glaciology and Geocryology
MODIS	Moderate Resolution Imaging Spectrometer
NASA	National Aeronautic and Space Administration

NESDIS	National environmental Satellite Data and Information Service
NGDC	National Geophysical Data Center
NIC	National Ice Center
NISE	NSIDC Near Real-Time Ice and Snow Extent
NOAA	National Oceanic and Atmospheric Administration
NSF	National Science Foundation
NSIDC	National Snow and Ice Data Center
OPP	Office of Polar Programs
QC	Quality Control
RAMP	Radarsat Antarctic Mapping Project
RESAC	Regional Earth Science Applications Center
SCICEX	Scientific Ice Expedition
SHEBA	Surface Heat and Energy Budget of the Arctic Ocean
SMMR	Scanning Multichannel Microwave Radiometer
SSM/I	Special Sensor Microwave Imager
TB	Brightness Temperature
TOVS	Tiros Operational Vertical Sounds
UCAR	University Corporation for Atmospheric Research
ULS	Upward Looking Sonar
USADCC	U.S. Antarctic Data Coordination Center
WDC	World Data Center
WMO	World Meteorological Society
WWW	World Wide Web