National Snow and Ice Data Center

World Data Center for Glaciology, Boulder

Cryospheric Science | Data Management

Annual Report 2000

http://nsidc.org/

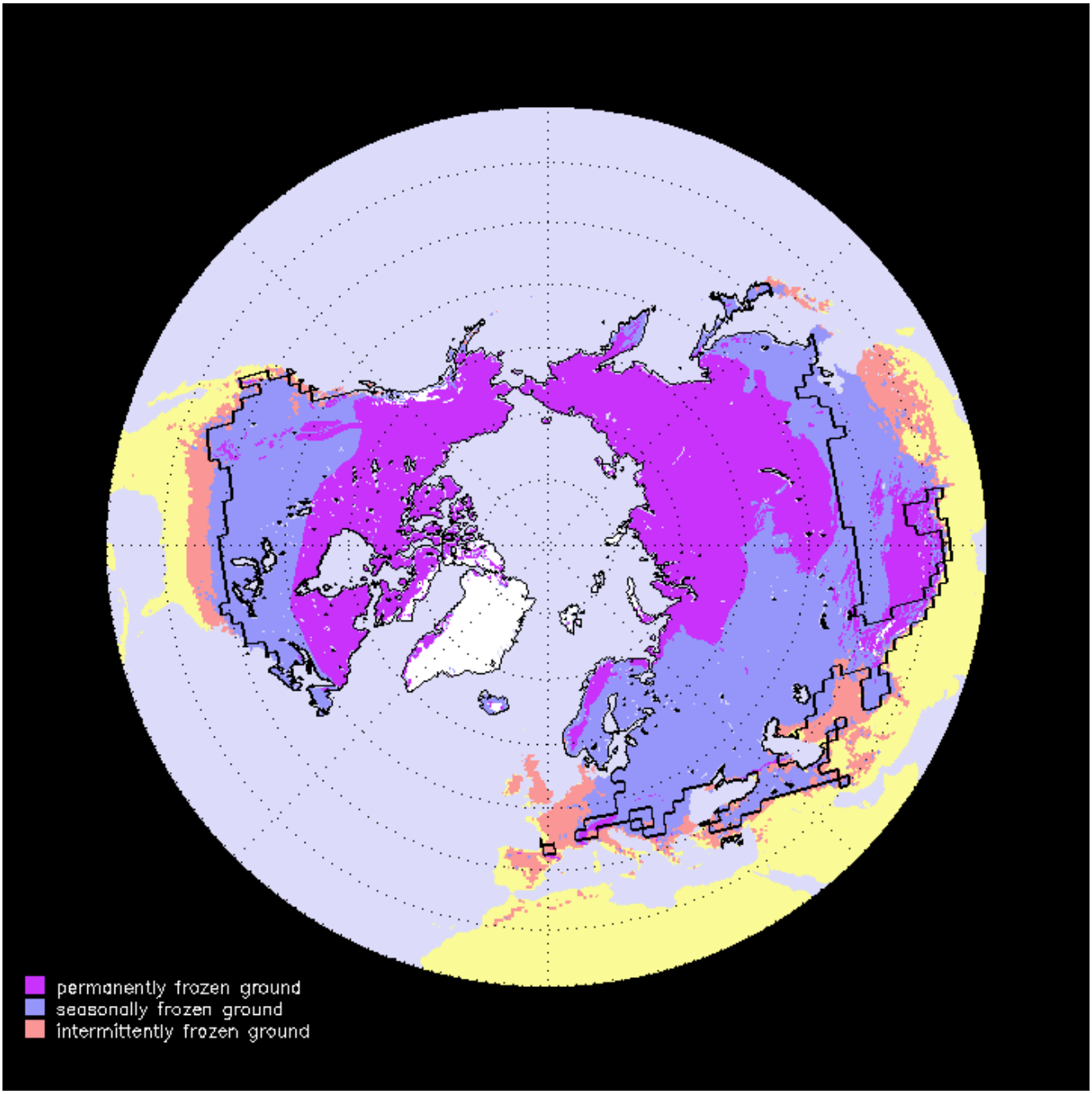

Figure 1.

Distribution of permafrost and average maximum extent of seasonally and intermittently frozen ground in the Northern Hemisphere. Seasonally and intermittently frozen ground are defined according to where the soil is frozen for more or less than two weeks each year, respectively. The solid line indicates the average maximum extent of the seasonal snow cover. Permafrost area occupies about 22.79 million km-squared or 23.9% of the exposed land surface (Zhang et al., 1999). On average, the maximum extent of the seasonally frozen ground is about 55 million km-squared or 55% of the total land area, while the maximum snow cover extent is about 47 million km-squared or about 47% of the total land surface in the Northern Hemisphere. Soil freeze/thaw status under snow cover is uncertain depending upon the timing, duration, thickness, and physical and thermal properties of snow. Investigation of ground freeze/thaw status is underway using a combined approach of numerical modeling and remote sensing techniques.

For more information, see Tingjun Zhang's research, beginning on page 36.

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NATIONAL SNOW AND ICE DATA CENTER
WORLD DATA CENTER FOR GLACIOLOGY, BOULDER

ANNUAL REPORT FOR 2000

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 2000 and a few items not included in the FY 1998-1999 report that relate to activities in the last 2 -3 months of 1999.

R. G. Barry,
Director
NSIDC/WDC for
Glaciology, Boulder
February 2001

HIGHLIGHTS

The EWG Arctic Climatology Project Arctic Meteorology and Climate Atlas

A new data product may aid investigations of arctic climate change and interannual climate variability. The Arctic Meteorology and Climate Atlas is a compilation on CD-ROM that adds newly available data to the historical record of synoptic observations in the Arctic, and presents fields of meteorological parameters in a common gridded format for ease of use by climate researchers. The Atlas contains mean monthly data from Russian coastal and island stations for the period of record until 1990. For completeness, western coastal station data are given as well. A reissued version of synoptic data from all Russian "North Pole" drifting stations, previously unavailable Russian synoptic data from ice patrol ships and from Drifting Automatic Radiometeorological Stations, and collected historical western data including observations from the Fram and Maud expeditions and from U.S. drifting stations (T-3, Alpha, Charlie, AIDJEX, and ARLIS) are contained on the CD-ROM in a common format and can be browsed with a plotting tool. Gridded fields of monthly means for two-meter air temperature, sea level pressure, precipitation, cloud, snow, and global solar radiation were constructed using existing and new data sources. For most parameters, fields are available beginning in the 1950s. Images of the gridded data can be browsed using the HTML interface. In addition to data, the Atlas contains English translations of monographs by Russian investigators on clouds and solar radiation, a glossary of meteorological terms in English and Russian, a "Primer" section with educational material for the general public, an article on Inuit climate knowledge, and a monograph on weather hazards in the Russian Arctic translated from Russian. A section titled "A Look Back" highlights the history of meteorological observations in the Arctic, with a photo gallery and new documentation of the Russian "North Pole" drifting station program.

The Atlas was developed by a joint U.S. - Russian team at the Arctic and Antarctic Research Institute, St. Petersburg, the University of Washington, Seattle, and NSIDC, under funding from the National Oceanic and Atmospheric Administration and the Environmental Working Group (EWG) Arctic Climatology Project. The NSIDC team developed the Atlas to serve as an outreach product as well as a data source for research, with attention to graphic design, navigation, and non-technical writing. The Atlas won an Award of Merit in the Rocky Mountain Chapter of the Society for Technical Communication's Online Competition.

MODIS data release

The MODIS snow cover products are now available, with observations beginning September 13, 2000 (note: the current lag between time of observation and availability of products is approximately three to four weeks). The sea ice products are currently scheduled to become available in April 2001. Reprocessing and release of earlier data is tentatively scheduled for Fall 2001

The National Snow and Ice Data Center (NSIDC) archives and distributes snow and sea ice products derived from the Moderate Resolution Imaging Spectroradiometer (MODIS). MODIS has been collecting data on board the NASA Earth Observation System (EOS) Terra satellite since shortly after its launch on 18 December 1999.

MODIS provides global coverage every one to two days in 36 spectral bands. Spatial resolution of the MODIS data varies by band from 250 m -1000 m. Calibrated, geolocated radiance data from individual bands, and a series of geophysical products from land, ocean and atmosphere disciplines are available from NASA's Distributed Active Archive Centers (DAACs). The NSIDC DAAC archives the MODIS snow and ice products which consist of global snow extent at 500 m resolution, and global sea ice extent (determined by ice surface reflectance and ice surface temperature methods) at 1000 m resolution. Snow and ice products are available in level 2 (orbital swath) and level 3 (gridded) formats. The level 3 snow product is mapped to an integerized sinusoidal grid. The level 3 sea ice products are mapped to the Equal-Area Scalable Earth-Grid (EASE-Grid) polar projection. In the future, as resources permit, both the level 3 snow cover and sea ice products will be mapped to the integerized sinusoidal grid, EASE-Grid, and a coarse resolution climate modeling grid. A snow albedo product will be available sometime in late 2001. All level 3 products are available in daily and eight-day composites. Data are archived in Hierarchical Data Format-Earth Observing System (HDF-EOS) format.

It is important to note that the current MODIS data products are preliminary. Performance of the instrument and the science processing algorithms is still being investigated. The quality of these products may not be optimal. Users are advised to use caution applying these products to science applications and are advised to examine the Science Quality Flag and Science Quality Flag Explanation metadata accompanying and stored in these products.

ECS System Moved to Operational Status

The advent of distribution of MODIS snow and ice products from the NSIDC also signifies that the EOS Core System (ECS) was also declared operational. This milestone came about after the successful completion of the Terra Mission Operational Readiness Review in November 1999.

Y2K-a non-event

We are happy to report that NSIDC did not encounter any Y2K problems.

DAAC Data Sets

MODIS

The ECS system at NSIDC was used to support MODIS operations, including the transfer, archive and distribution of the MODIS snow and products. The routine distribution of the MODIS snow products began during October 2000. Eventually all of 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 a snow and sea ice albedo product (resources permitting) and an 8-day composite to minimize the effect of clouds. For more information see: http://nsidc.org/NASA/MODIS/.

GLAS
The Geoscience Laser Altimetry System (GLAS) is the sole instrument being developed to fly on the Ice, Cloud, and land Elevation Satellite (ICESat). The GLAS operates in the 532nm and 1064nm wavelengths. The main objective of the GLAS mission is to provide accurate, high resolution data that will contribute to our understanding of ice-sheet mass balance investigations in the polar regions. The projected launch date for the GLAS instrument on the ICESat satellite is December 2001.

NSIDC will archive Level 0 data from the launch date, as well as the Level 1, 2 and higher level data products as they become available. The initial data stream will be around 20 GB per day. The data center will distribute 15 data products.

NSIDC is continuing its preparations for launch of ICESat. Participating in science team meetings develops essential collaborations with instrument teams, science groups, and other data providers through face-to-face meetings.

Below is a list of activities NSIDC has completed over the last year.

- NSIDC formed a GLAS product team, which meets regularly to share information and resolve issues related to our preparation for receiving, archiving and distributing GLAS data.
- NSIDC installed and checked out Release 5B of the ECS, which contains functionality needed to support the ICESat mission.
- NSIDC performed System Confidence Tests.
- NSIDC began drafting metadata documents (called DIFs), which will be submitted to the Global Change Master Directory (GCMD), and drafting user guides for all GLAS products.
- NSIDC has nearly completed an Interface Control Document with the ICESat SIPS.
- NSIDC completed a user survey of potential GLAS data users, which yielded information about data format and subsetting preferences.
- NSIDC participated in defining GLA16, a compilation data product that includes both altimetric and atmospheric data.
- NSIDC participated in modifying a mechanism for geolocating GLAS data; this system is called the Nominal Orbital Spatial Extent (NOSE).
- NSIDC maintains a public web site for GLAS at http://nsidc.org/NASA/GLAS/index.html.

NSIDC maintains the above-mentioned web site in part to provide information on the changing status and progress of the ICESat mission, particularly as it relates to data products.

AMSR
The Advanced Microwave Scanning Radiometer (AMSR) is a passive microwave instrument, with frequencies of 6.9, 10.7, 18.7, 23.8, 36.5 and 89 GHz, that will fly aboard the Advanced Earth Observing Satellite-II (ADEOS-II), scheduled for launch by the National Space Agency of Japan (NASDA) in November, 2001. AMSR will measure geophysical parameters, primarily those related to water, for the investigation of global water and energy circulation.

The AMSR-Earth Observing System (AMSR-E) is a mission instrument modeled on the AMSR (described above). AMSR-E is scheduled to launch on NASA's Earth Observing System (EOS) Aqua Satellite no earlier than July 12, 2001. The Aqua mission provides a multi-disciplinary study of the Earth's atmospheric, oceanic, cryospheric, and land processes and their relationship to global change.

The National Snow and Ice Data Center (NSIDC) will archive and distribute all AMSR-E products, including Level 0 data from NASA/GSFC EDOS; Level 1A data produced by NASDA/Earth Observation Center (EOC) in Japan; and Level 2 and 3 data produced by the AMSR Science Computing Facility (SCF).

NSIDC is continuing its preparations for launch of Aqua and ADEOS-II. Participating in science team and ground system meetings helps to develop essential collaborations with instrument teams, science groups, and other data providers through face-to-face meetings. Participation in testing activities with other facilities involved in receiving and managing AMSR and AMSR-E data has provided opportunities for learning and correcting imperfect systems.

Below is a list of activities NSIDC has completed over the last year. Note that below the term "AMSR" often includes AMSR-E, as well.

- NSIDC formed an AMSR product team, which meets regularly to share information and resolve issues related to our preparation for receiving, archiving and distributing AMSR data.
- NSIDC installed and checked out Release 5B of the ECS, which contains functionality needed to support the Aqua mission.
- NSIDC performed System Confidence Tests and participated in a Mission Operations Science System (MOSS) test, which simulates "day in the life" activities using the ECS at NSIDC for both Terra and Aqua missions.
- NSIDC began drafting metadata documents (called DIFs), which will be submitted to the Global Change Master Directory (GCMD), and will soon begin drafting user guides for all AMSR products.
- NSIDC completed an Interface Control Document with the AMSR SIPS. Further, NSIDC completed an Operations Agreement with AMSR SIPS, PO.DAAC, and EDOS. NSIDC is working on Operations Agreements with NASDA (for exchange of L0 data and software package for creating the L1A data.)
- NSIDC participated in modifying a mechanism for geolocating AMSR data; this system is called the Nominal Orbital Spatial Extent (NOSE).
- NSIDC established a public web site for AMSR at http://nsidc.org/NASA/AMSR/index.html.

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.

AVHRR Polar Pathfinder Data

Over the last year the AVHRR Polar Pathfinder data sets have been documented and placed online, culminating a six year effort of data gathering, algorithm development, download and distribution software development, test product production. The objective was to use the AVHRR sensor data acquired by NSIDC and other organizations to generate grids of calibrated, geolocated channel data and derived products covering both poles at 1.25 and 5 km grid spacing. The AVHRR Pathfinder has met these goals, and provides twice-daily albedo, temperature, and other products over the period 1981 - 1999.

Several corrections to both the temperature and albedo algorithms were implemented this year, in response to a round of validation studies testing the AVHRR Pathfinder algorithms against in situ data. We have begun to develop tools for data distribution and manipulation, and have made the data available to users. We have also begun to explore the application of the data to problems in polar science. One of the first, most promising applications has been the determination of snow cover, and mapping of springtime snowpack retreat. The data are also being used to assess summertime melt season and mean January temperature for ice shelves surrounding the Antarctic, in response to the recognition of the importance of melting and melt ponds to shelf stability (see above). 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.

NSIDC intends to acquire additional AVHRR raw data in support of the AVHRR Pathfinder through FY2001, to insure adequate overlap in coverage with MODIS data now being acquired by Terra. Additionally we are evaluating MODIS processing routines and derived products for comparison with the AVHRR products.

Data Sets Released

- Published TOVS Pathfinder Path-P Daily and Monthly Arctic Gridded Atmospheric Grids
- Began ongoing production and distribution of Near Real Time DMSP-F13 SSM/I Daily Polar Gridded Brightness Temperatures
- Published enhanced quality version of Nimbus -5 ESMR Polar Gridded Brightness Temperatures
- Published Nimbus-7 SMMR Pathfinder Daily EASE-Grid Brightness Temperatures
- Produced global 1 degree gridded monthly snow cover data for January 1971 to September 1995.
- Produced EASE grid versions of International Permafrost Association permafrost and ground ice map at 1.25, 12.5 and 25 km resolutions.
- Published Historical Soviet Daily Snow Depth Version 2 in conjunction with NOAA. Version 2 includes 10 more years of data and improved quality control.
- Published Bootstrap Sea Ice concentrations for NIMBUS-7 SMMR and DMSP SSM/I and a later update through 1999
- Published Radarsat Antarctic Mapping Project Digital Elevation Model
- Published Antarctic 5-km Digital Elevation Model from ERS-1 Altimetry
- Published Adjusted Monthly Precipitation, Snowfall and Rainfall for Canada (1874-1990)
- Published SSM/I F13 EASE-grid brightness temperature data CD-ROMs (NH 10/22/93 to 12/16/98; Global 5/3/95 to 9/27/95)
- Published SSM/I F13 Polar Stereographic gridded brightness temperature data CD-ROMs (through 12/31/99)
- Inserted Near-real-time Ice and Snow Extent (NISE) data in ECS for distribution to MODIS instrument team
- Began routine ingest and archive of MODIS snow and ice products.
- Provided early user services for MODIS instrument team approved uses of the MODIS snow and ice products

Tools

Grid-o-matic

After extensive testing and comparisons with the old system running in parallel, all processing of SSM/I brightness temperatures and sea ice concentrations in the polar stereographic grids, starting with the 1 January 2000 data, was successfully transferred to the Grid-o-matic system.

Graphical Interface for Subsetting, Mapping, and Ordering (GISMO)

GISMO v2.0 was released to the public in June of 2000. The GISMO is a Java based web interface that allows users to search for NSIDC's Polar Pathfinder gridded data sets by collection, parameter (channel), and temporal range. Additionally users can specify an area of interest and the back end processing system will spatially subset the data to reduce the total volume of data delivered.

User feedback during the second half of 2000 is driving development of GISMO v2.1 during 2001. Planned improvements include: zoom functionality for the maps, ability to search on annual and daily periods, and additional output format options.

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

PSQ v1.0b was made available to the public for beta testing in November of 2000. The PSQ is a Java based web interface that currently works with SSM/I swath data and AVHRR scene data. The PSQ allows users to search those data sets by parameter, temporal range, and spatial coverage. The main focus of the PSQ project was to prototype a system that searches orbit data spatially by using orbit parameters, but the design is flexible enough support other spatial types in future. The back end processing system for the PSQ subsets the requested data and maps the results to the users requested grid.

Moving the PSQ from beta to alpha during 2001 is contingent on continued funding of the project. Plans for 2001 include: implementation of an area comparison algorithm for searches on scene data, user documentation, software documentation, user services and operations groups training with the system, and integration of GISMO v2.1 upgrades as appropriate.

Systems

ECS system

Development of the operation ECS at NSIDC continues. This past year we went through two major upgrades and numerous minor patches. The system continues to improve slowly. System stability and system throughput are improving.

System enhancements to support the AQUA and ICESat satellites continues. We have made good progress in preparation for launch of these two important satellites in 2001.

Non ECS Systems

NSIDC completed migration of all V0 data to a new DLT-based robotic tape archive. This system replaces the obsolete optical disk juke box, which has been in operation since 1992

Another welcome addition to the NSIDC V0 operations was a Rimage CD-R production system. This CD-R writing system allows us to mass produce CD copies in an unattended mode.

ESIP Federation
The Earth Science Information Partners (ESIP) Federation consists of about 30 NASA funded grantees trying to work together to provide data and information services for the environmental sciences. Ron Weaver, Vince Troisi and Michelle Holm participated in Federation working groups and the committee of the Whole. NSIDC staff attended meetings in Houston (February 2000) and Greenbelt (July, 2000).

NewDISS
Ron Weaver, NSIDC DAAC Manager completed his service on the New Data Information System and Services (NewDISS) working group. The NewDISS draft report was presented to NASA HQ and is currently being reviewed by NASA. It is anticipated that a NewDISS transition team will be named in 2001. This team will start the detailed planning for movement of current EOS data sets and services into the NewDISS model.

Long Term Archive:
Discussions on the proposed Long Term Archive of EOS data (LTA) were held several times and at multiple venues during the year. In September 1999 a draft implementation plan for all EOS data held at NSIDC, as well as three other DAACs, this report is now being reviewed by NASA. In November 1999 NSIDC produced a draft LTA 'in place' plan in case the NOAA-NASA LTA schedule cannot be met.

NEW PRODUCTS

New or Substantially Updated Data Sets for 2000

Adjusted Monthly Precipitation, Snowfall and Rainfall for Canada (1874-1990)

This data set contains mean monthly rainfall, snowfall and precipitation (the sum of rainfall and snowfall) values from 6692 stations in Canada. The NOAA National Climatic Data Center (NCDC) bought the original data from the Canadian Atmospheric Environment Service (AES) in the early 1990s and adjusted the measurements to account for inconsistencies and changes in instrumentation over the period of record. NCDC distributes the data set TD-9816 *Canadian Monthly Precipitation* (Groisman 1998), which contains both the original and adjusted data. NSIDC has been authorized to release the adjusted data only.

The earliest records are from 1874, and the latest records are from 1990, although stations may have different starting and ending dates. Efforts were made to minimize the effects of instrument changes and other biases that complicate analyses of Canadian precipitation (Goodison and Louie 1986; Groisman and Easterling 1994; Metcalfe et al. 1997). The data are in ASCII fixed text format and are available via ftp.

Antarctic 5-km Digital Elevation Model from ERS-1 Altimetry

This data set provides a digital elevation model (DEM) for Antarctica to 81.5 degrees South latitude, at a resolution of 5 km. Approximately twenty million data points were used to generate this data set. Data points were derived from ERS-1 radar altimetry during the geodetic phase from March 1994 to May 1995. The improved density in coverage and resolution, compared with past satellite altimetry missions, provides better detection of topographic detail such as surface undulations, ice streams, grounding zones, and interstream ridges. DEM data are in a polar stereographic projection with the origin at the south pole, and are referenced to the OSU91A geoid.

The ERS-1 satellite radar altimeter measurements are highly useful for determining precise ice sheet elevations in Antarctica. The orthometric heights derived from the ERS-1 data contribute to a more accurate and complete mapping of the Antarctic Ice Sheets than previously possible, and therefore to ongoing studies of ice mass balance studies in Antarctica.

The DEM is provided as a single ASCII text file, accessible by ftp. Data access is unrestricted, but we recommend that users register with us. Registered users automatically receive e-mail notification of product updates and changes to processing.

Arctic Ocean Snow and Meteorological Data from Drifting Stations

During 1950-1991 the USSR maintained two, and sometimes three, drifting ice stations in the Arctic Ocean. In addition to supporting scientific studies, these manned ice camps operated as synoptic meteo-

rological stations reporting position, surface weather, atmospheric soundings, solar radiation, and snow conditions. Data from these drifting stations are daily averages, or 3-hourly measured values; spatial resolution is dependent on the movement of the drifting ice floes on which the stations were located. The data are presented on one CD-ROM in many small ASCII files totaling 73 Mbytes. Fortran formats are listed in the documentation for each file type. Some files are comma-delimited tables. Documentation files are ASCII (text) files; PostScript versions of two data reports (see references below) are included on the CD-ROM, with .GIF files containing figures.

Though these data were regularly transmitted over the GTS (Global Telecommunication System of the World Meteorological Organization) and archived at various institutions, the primary source for this data compilation is the original meteorological log books, presently archived at the Arctic and Antarctic Research Institute (AARI), St. Petersburg, Russia. As a continuation and expansion of cooperative agreements between AARI and the Polar Science Center (PSC) at the University of Washington in Seattle, AARI digitized, organized, and quality checked the data, PSC further organized and quality checked the data, linearly interpolated the position data where necessary to fill gaps in the sporadic observations during the early years, and processed all observations into the daily averaged "combined" data file. NSIDC organized the files and documentation for CD-ROM production, and is distributing the CD-ROM.

AVHRR Polar Pathfinder Twice-daily 1.25-km EASE-Grid Composites

The AVHRR Polar Pathfinder Twice-Daily 1.25 km EASE-Grid Composites are a collection of products for both poles, consisting of twice-daily gridded and calibrated satellite channel data and derived parameters. Data include five Advanced Very High Resolution Radiometer (AVHRR) channels, clear sky surface broadband albedo and skin temperature, solar zenith angle, satellite elevation angle, sun-satellite relative azimuth angle, surface type mask, cloud mask, orbit mask, time of acquisition, and ice motion vectors. Data are composited onto two grids per day based on common local solar times and scan angle. Reduced-resolution data (25 km) derived from the 1.25 km data are available to assist users in selecting these data. AVHRR local area coverage (LAC) and High Resolution Picture Transmission (HRPT) level 1b data are used to generate the Polar Pathfinder products at grid spacings of 1.25 km. AVHRR Polar Pathfinder data extend poleward from 48.4 degrees north and 53.2 degrees south latitudes, from August 1993 through December 1998 for the Northern Hemisphere, and from April 1992 through January 1996 for the Southern Hemisphere. Data are in 1-byte and 2-byte integer grid format. Ice motion vectors are in ASCII text format. Data are available on 8-mm tape or by ftp.

AVHRR Polar Pathfinder Twice-Daily 5 km EASE-Grid Composites

The AVHRR Polar Pathfinder Twice-Daily 5 km EASE-Grid Composites are a collection of products for both poles, consisting of twice-daily gridded and calibrated satellite channel data and derived parameters. Data include five Advanced Very High Resolution Radiometer (AVHRR) channels, clear sky surface broadband albedo and skin temperature, solar zenith angle, satellite elevation angle, sun-satellite relative azimuth angle, surface type mask, cloud mask, and Universal Coordinated Time (UTC) of acquisition. Data are composited onto two grids per day based on common local solar times and scan angle. Reduced-resolution data (25 km) derived from the 5 km data are available to assist users in selecting these data. AVHRR global area coverage (GAC) data are used to generate the Polar Pathfinder products at grid spacings of 5 km. AVHRR Polar Pathfinder data extend poleward from 48.4 degrees north and 53.2 degrees

south latitudes, from July 1981 through August 1998. Data are in 1-byte and 2-byte integer grid format and are available on 8mm tape or by ftp.

Bootstrap Sea Ice concentrations for NIMBUS-7 SMMR and DMSP SSM/I

A sea ice concentration data set derived from the Nimbus-7 Scanning Multichannel Microwave Radiometer (SMMR) and the Defense Meteorological Satellite Program's (DMSP) DMSP-F8, -F11 and -F13, Special Sensor Microwave/Imager (SSM/I) has been generated using the Bootstrap Algorithm with revised sets of tie-points. The revised tie-points have been found to provide a more temporally consistent data set than the standard Bootstrap data (see the DMSP SSM/I Daily and Monthly Polar Gridded Sea Ice Concentrations), with better agreement between sea ice concentration distribution, extent and area during periods of sensor overlap. In the revision, tie-points are adjusted each day to better account for daily emissivity and temperature fluctuations. False ice concentrations in the open ocean, away from the ice pack, and at land/ocean boundaries have been largely removed from the data set. Daily and monthly data, spanning 26 October 1978 through 31 December 1999, are available for both polar regions. Data are gridded onto the SSM/I polar stereographic grid (25 x 25 km) and provided in two-byte integer format.

Chukchi Sea Hydrographic (CTD) Data from the R.V. Alpha Helix Cruise, September 1996

In an international collaborative effort, Japanese, Russian, and U.S. scientists collected hydrographic CTD (conductivity, temperature, depth) samples in the Chukchi Sea north of the Bering Strait during the R.V. Alpha Helix cruise between 31 August and 27 September 1996. The CTD data were converted from the format used by the Institute for Marine Studies, University of Alaska Fairbanks, to standard Seabird format.

The data collection contains values for water depth, pressure, temperature, potential temperature, conductivity, salinity, sigma-t, sigma-theta, fluorescence, transmissometer output, oxygen probe O2 concentrations, geopotential anomaly, dynamic height, specific volume anomaly, and buoyancy.

Estonian Mean Snow Depth and Duration (1891-1994)

This data set contains the number of days of snow cover in days per year, and three 10-day snow depth means per month in centimeters from stations across Estonia from 1891 through 1994. Some stations for some years have two data entries, one for a protected collection area, and one for an exposed collection area. Jaak Jaagus of the University of Tartu in Estonia contributed these data to the National Snow and Ice Data Center. Data are available via ftp.

Global Lake and River Ice Phenology Database

The Global Lake and River Ice Phenology Database contains freeze and breakup dates and other ice cover descriptive data for 748 lakes and rivers. Of the 429 water bodies that have records longer than 19 years, 287 are in North America and 141 are in Eurasia; 170 have records longer than 50 years; and 28 longer than 100 years. A few have data prior to 1845. These data, from water bodies distributed throughout the Northern Hemisphere, allow analysis of broad spatial patterns as well as long-term temporal patterns. A paper analyzing the data was published in *Nature* by Magnuson *et al*. (2000).

The data set was prepared by the North Temperate Lakes Long-Term Ecological Research program at the Center for Limnology at the University of Wisconsin-Madison from data submitted by participants in the Lake Ice Analysis Group (LIAG). LIAG is an international ad hoc group of scientists who participated in a 1996 workshop sponsored by the Center of Limnology, University of Wisconsin-Madison and the National Science Foundation Division of Environmental Biology (Long-Term Studies Program). The group would be happy to receive additional data on these lakes or rivers or others around the world for inclusion in the database.

NSIDC has developed a Web-based user interface to the database that allows users to search the database and retrieve data by the available parameters. The interface will also include a link to more general information about the lakes and rivers in the database. The output can be directed to a Web browser, a gzipped file, or a tab-separated ASCII text file.

Note: The term "phenology" in the data set title refers to the seasonal phenomenon of the freezing and thawing of lake and river ice.

Land-Cover Map of the North Slope of Alaska

This Arc/Info map provides a spatially-explicit representation of the nature and distribution of land-cover and tundra types on the North Slope of Alaska. This was done to support the extrapolation of ecosystem models developed in the Kuparuk River basin to the North Slope Region.

Large Area Estimates of Carbon Fluxes of Arctic Landscapes

Net CO2, evapotranspiration, and energy exchange were measured during the 1994-95 growing seasons (June-August) in moist-acidic (Happy Valley: 69°09′N, 148°51′W), moist non-acidic (24-Mile: 69°56′N, 148°49′W) and wet-sedge tundra ecosystems (U-Pad: 70°17′N, 148°53′W) located on the North Slope of Alaska.

MODIS/Terra Snow Cover

Snow cover products from the Moderate Resolution Imaging Spectroradiometer (MODIS) include level 2 swath data and level 3 gridded daily and eight-day composites, at 500 m resolution. Level 3 products consist of tiles of data, approximately 1200 km by 1200 km in area, gridded in an integerized sinusoidal map projection. A snow mapping algorithm, based on the Normalized Difference Snow Index (NDSI) and other criteria tests, is used to process MODIS data.

Latitude and longitude geolocation fields are at 5 km resolution, while all other fields are at 500 m resolution. Snow cover data are in HDF-EOS format, and are available by ftp.

Radarsat Antarctic Mapping Project Digital Elevation Model

The high-resolution Radarsat Antarctic Mapping Project (RAMP) Digital Elevation Model (DEM) combines topographic data from a variety of sources to provide topographically consistent coverage of all of Antarctica. The RAMP DEM represents a substantial improvement in horizontal resolution and vertical accuracy over previous digital elevation models, particularly in mountainous and coastal regions.

A primary data source was ERS-1 satellite radar altimeter data from April 1994 to March 1995. Other data include airborne radar data, detailed cartographic data from the Antarctic Digital Database, and large-scale topographic maps from the U.S. Geological Survey (USGS) and the Australian Antarctic Division. These data were collected from the 1940s to present, with most collected during the 1980s and 1990s. Data for the 1 km and 400 m DEMs are provided in ARC/INFO GIS, binary, and ASCII formats. Data for the 200 m DEM are in ARC/INFO format only.

Russian River Ice Thickness and Duration

This data set consists of river ice thickness measurements, and beginning and ending dates for river freeze-up events from 50 stations in northern Russia. The data set includes values from 1917 through 1992, however the record length varies for each station. The longest station record covers the period 1917 through 1988 (the station table shows the beginning and end years for measurements at each station). Data were obtained through the U.S.-Russia Working Group VIII of the U.S.-Russia Bilateral Agreement on the Protection of Environmental and Natural Resources. The National Oceanic and Atmospheric Administration (NOAA) Environmental Services Data and Information Management program through the NOAA National Geophysical Data Center funded data set development. Data are in comma-delimited ASCII format. An analysis of trends in freeze-up/break-up events has recently been published by L. Smith in *Physical Geography*, 2000.

SCICEX Hydrographic Data, 1993

During the SCICEX 1993 cruise, the USS Pargo sampled hydrographic data while surfaced. The data collected were conductivity, temperature and depth (CTD), using a Sea-Bird CTD, expendable CTD probes, and a Sea-Bird Seacat. Twenty surface CTD casts and 34 expendable drops were recorded, while a CTD mounted on the sail logged a sample every 12 minutes. These data were archived in December 1996 and are in ASCII text format.

Soil Temperatures for Happy Valley and Barrow, Alaska, 1994-1999

This data set contains soil temperatures collected from late summer 1994 to late summer 1999 at the Happy Valley (site c) and Barrow (site d), Alaska. A Grant Instruments Squirrel 1204 data logger was utilized which provided sequential, hourly temperature measurements with a precision of 0.015 C at the ice point. The logging system has a lower limit of -22C, which was reached on several occasions in winter. Rows represent hourly measurements, using an integer time index beginning with zero (0).

West Greenland Glacier Inventory

The inventory includes 5,297 Glaciers from West Greenland between 59 to 71 degrees latitude N and 43 to 53 degrees longitude W. The glacier data basin division is based on a simplified version of the World Glacier Monitoring Service (WGMS) system. Data are based on 1:250000 maps, Landsat imagery, and aerial photos that were taken between 1948 and 1985.

WEB DEVELOPMENT

In terms of web development, NSIDC made both "front end" content and functionality changes as well as "back end" process oriented improvements this year. We changed our domain name to http://nsidc.org/, a shortened version of our previous domain name. We also hired and integrated a Web Server Administrator into our web development team. The Web Server Administrator maintains the integrity of our web server environment and provides support to the NSIDC web architects, writers, programmers, User Services staff, Operations staff, and various projects.

Web sites that we released this year include:

Radarsat Antarctic Mapping Project (RAMP)
http://nsidc.org/ramp/

Graphical Interface for Subsetting, Mapping, and Ordering (GISMO)
http://nsidc.org/gismo/

Polar Spatial Query (a data search, order, and sub-setting tool)
http://nsidc.org/psq/

We also implemented a web page that points to all of our various projects (http://nsidc.org/projects.html), including five new project oriented web sites:

Advanced Microwave Scanning Radiometer (AMSR)
http://nsidc.org/amsr/

Environmental Working Group (EWG)
http://nsidc.org/ewg/

Geoscience Laser Altimetry System (GLAS)
http://nsidc.org/glas/

International Ice Charting Working Group
http://nsidc.org/NOAA/IICWG/

Paleoenvironmental Arctic Sciences
http://arcss.colorado.edu/Projects/parcs.html

Web sites that we revamped this year include:

All About EASE-Grid
http://nsidc.org/ease/

Antarctic Glaciological Data Center (AGDC)
http://nsidc.org/agdc/

Antarctic Ice Shelves and Icebergs
http://nsidc.org/iceshelves/

Of particular note as new content this year is the *Sea Ice Products at NSIDC* site that we are developing. This site is intended to serve our sea ice data users by summarizing basic characteristics of our various sea ice products, highlighting significant product differences, clarifying their strengths and weaknesses. This site will also refer users to sea ice data sources outside NSIDC.

We also continued our web site overhaul, which includes both content organization and navigation improvements, as well as web development process improvements. Specifically, we developed a demonstration site to be used for internal and external reviews. We also drafted more formal web publishing procedures with the intention of enabling consistent web publishing by additional NSIDC staff. We also continued to automate our online catalog and make news releases made via the Web.

State of the Cryosphere: Continued Development of a new web page at NSIDC

http://nsidc.org/NASA/SOTC/

This web page provides an overview of snow and ice conditions as indicators of climate change. It is now generally accepted that global mean temperatures have been increasing over the past several decades. The intent is then to provide a broad audience, both scientific and general, with current and succinct information on the response of various components of the cryosphere to this climate change. Currently this web page focuses on seasonal snow cover, sea ice, mountain glaciers, and the related topic, sea level. The fluctuations of these parameters over the past several decades, derived from both satellite remote sensing and measurements on the ground, are presented in time series plots. During 2000 the web site was enhanced to include an overview of current permafrost conditions, recent news of changes in the Cryosphere based on research within and outside NSIDC and updates of the various time series examples. Future enhancements of this web page will include coverage of additional cryospheric features such as ice sheets and ice shelves.

CURRENT PROGRAMS

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 several data rescue and management projects at NSIDC. Florence Fetterer is NSIDC's NOAA liaison.

In 2000, the NSIDC NOAA data team published the following data sets:

- Arctic Climatology Project - EWG Arctic Meteorology and Climate Atlas (see Highlights)
- Estonian Mean Snow Depth and Duration,1891-1994
- Global Lake and River Ice Phenology Database
- Russian River Ice Thickness and Duration
- SHEBA Reconnaissance Imagery (with the ARCSS Data Coordination Center)
- West Greenland Glacier Inventory

In addition, data from two cruises were added to the Submarine Upward Looking Sonar Ice Draft Profile Data and Statistics data set, and the entire record of Great Lakes charts were made available on-line.

The release of the Global Lake and River Ice Phenology Database, a data collection prepared by the Center for Limnology at the University of Wisconsin-Madison, garnered considerable publicity. Research based on analysis of the data set published in *Science* showed that lakes and rivers around the world are freezing an average of nearly nine days later in winter and thawing almost ten days earlier in spring than they did 100 years ago. The analysis of lake and river freeze and thaw trends was led by John J. Magnuson at the Center for Limnology, with 13 co-authors from the International Lake Ice Analysis Group, including NSIDC director Roger G. Barry.

The Submarine Upward Looking Sonar Ice Draft Profile Data and Statistics data set is significant because it contains the most extensive publicly available record of sea ice draft. On September 6-8, NSIDC hosted a Submarine Sonar Data Providers Workshop. Participants from the Arctic Submarine Laboratory, Scott Polar Research Institute, Lamont-Doherty, and the UW Applied Physics Laboratory worked on issues surrounding ice draft data processing. NGDC co-hosted the meeting, and brought downward looking sonar (sounding) data into discussion. Participants have a common goal: to release all draft and sounding data that meets U.S. and U.K. navy declassification guidelines, after processing these data in a consistent way. The sea ice draft data set will continue to grow as analogue data are digitized at UW and added to the collection.

Other NOAA activities at NSIDC included participating in the NOAA Arctic Research Office Arctic Climate Impact Assessment Scoping Meeting, contributing to NOAA/SEARCH program planning activities, representing the WDC for Glaciology, Boulder at the All WDC Conference, planning with NGDC for an EOS data Long Term Archive prototype, and hosting a visit from hydrometeorological institutes in four Central Asian republics at the request of NOAA's International and Interagency Affairs Office.

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.

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. To this end, NSIDC developed the Equal Area Scalable Earth Grid (EASE-Grid); see http://nsidc.org/NASA/GUIDE/EASE. 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 2001), providing a 23 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.

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.

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

Processing of the Pathfinder EASE-Grid SMMR TB Level 3 time series (1978-1987) has been completed. The source data for this gridded product is the Nimbus-7 SMMR Pathfinder brightness temperature data set (Njoku et al. 1997). Prior to the general distribution of the final data set, a prototype version was distributed to several key remote-sensing scientists. The final testing of this data set was accomplished through actual application of the brightness temperature data by these scientists in their respective research activities. This NSIDC Level 3 product is available on 8mm tape or CD-ROM.

The processing of SSM/I brightness temperatures into the EASE-Grid has been completed through mid-2000. In order to accomplish this it was first necessary to process the ten-plus year back-log of orbital data. Because of the numerically intensive processing requirements associated with the interpola-

tion scheme, this was a rather ambitious undertaking. It was only achieved through the application of innovative computer coding techniques and processing methodologies. Thanks to an energetic, creative and ambitious programming and production team, and thanks to effective collaboration and temporary sharing of certain NSIDC DAAC hardware, we have accomplished this goal and are now processing 2000 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 and SSMIS 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.

The Information Center/Library

The Information Center/Library at the NSIDC/WDC serves as a resource to cryospheric information, both for researchers at the NSIDC and the University of Colorado, Boulder, as well as for the general public. The Library acquires and catalogs both published and unpublished analog materials on snow, ice and permafrost, as well as digital data such as CD-ROMs and web resources. Library staff filled over 600 information requests during 2000.

The library houses over 44,000 monographs, serials, journal articles, reprints, videos, and CD-ROMs, all of which have been cataloged and which can be searched on our in-house library system. Over 1200 new items were added in 2000. We currently receive over 75 serials and periodicals relating to the cryosphere and to remote sensing of ice and snow.

The Library system currently used is DB/TextWorks by INMAGIC. Library holdings can be searched in-house M-F from 8-5. The database is also available as part of the Arctic and Antarctic Regions Database put out on CD-ROM and the web by NISC (National Information Services Corporation).

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 (metadata) 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 activity is in direct support of the NSF Guidelines and Award Conditions for Scientific Data, issued in December 1998.

The USADCC is building support within the research community and the NSF OPP through coordinated outreach to funded investigators via tailored letters explaining the OPP data policy and PI responsibilities regarding data descriptions for Antarctic scientific data. We expect that this approach will lead to improved participation in the AMD effort.

The USADCC Web site 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://nsidc.org/NSF/USADCC/.

Beginning in 2000, SCAR and COMNAP are providing funding for the continued development and operation of the AMD at the GCMD. The GCMD is the U.S. coordinating node of the Committee on Earth Observation (CEOS)/International Directory Network (IDN).

The U. S. Antarctic Glaciological Data Center

NSIDC is funded by the NSF OPP Antarctic Glaciology Program 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 past year we have made significant progress in the following areas: individual contacts with the Glaciology Program PIs concerning the status of data resulting from their grants, and its potential inclusion in the AGDC, the creation of a password-protected Web site for PIs funded by US ITASE to use for the exchange of data during their post-field data exchange period, the development of a joint AGDC-NOAA NGDC/WDC-A for Paleoclimatology Ice Core Gateway on the web (providing a single-point-of-access to ice core data housed at the multiple data centers), intended for use by scientists from multiple disciplines (see: http://www.ngdc.noaa.gov/paleo/icgate.html), improved web pages at the AGDC (see: http://nsidc.org/NSF/AGDC/), and continued outreach at several key scientific venues.

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. The 1999/2000 Yearbook has 13 articles describing projects based on DAAC data. 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 debuted February 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.

NSIDC USER SERVICES AND USER STATISTICS

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 textbook publishers requesting photographs and interviews, and science researchers requiring information about data holdings, processing, formats, and science algorithms.

User Services Staff also participate in activities related to product design and enhancement, representation on NSIDC Product Teams, Data Center outreach activities, submission of articles to our quarterly newsletter, attend sessions and present posters at scientific conferences, and staff the NSIDC exhibit booth. NSIDC User Services Staff attended the Fall 2000 American Geophysical Union Meeting and presented two posters as well staffing the NSIDC exhibit booth. The exhibit booth this resulted in almost 100 new requests, with over 60% of those requests being from users who had never interacted with NSIDC previously.

NSIDC User Statistics

NSIDC statistics reporting indicates a 19% increase in new requests received during Fiscal Year 2000 (see Figure 2). The increase is attributed to NSIDC Library activity and the reasons for the increase are twofold. The previous year's library requests were under reported due to staffing issues, and in Fiscal Year 2000 the library undertook significant outreach activities to the NSIDC staff therefore increasing overall use of the library's services, including support of inquiries through User Services from users external to NSIDC.

The types of users that typically make requests of NSIDC have been consistent over the last four years (see Figure 3). The largest category is the Research and Education category, which includes universities, K-12, and research institutions such as NASA and NOAA. It is important to note educational institutions that utilize NSIDC's data and services are primarily from Universities. Users from the K-12 community represent approximately 30% of our educational users overall.

NSIDC also categorizes the types of transactions, or exchanges of data or information to users in support of their requests. Six percent of transactions result in a referral, 10% result in library services, 42% result in providing the user with information about our products and services, 36% result in the delivery of a data product, and 6% of transactions result in NSIDC providing support for one of our data products.

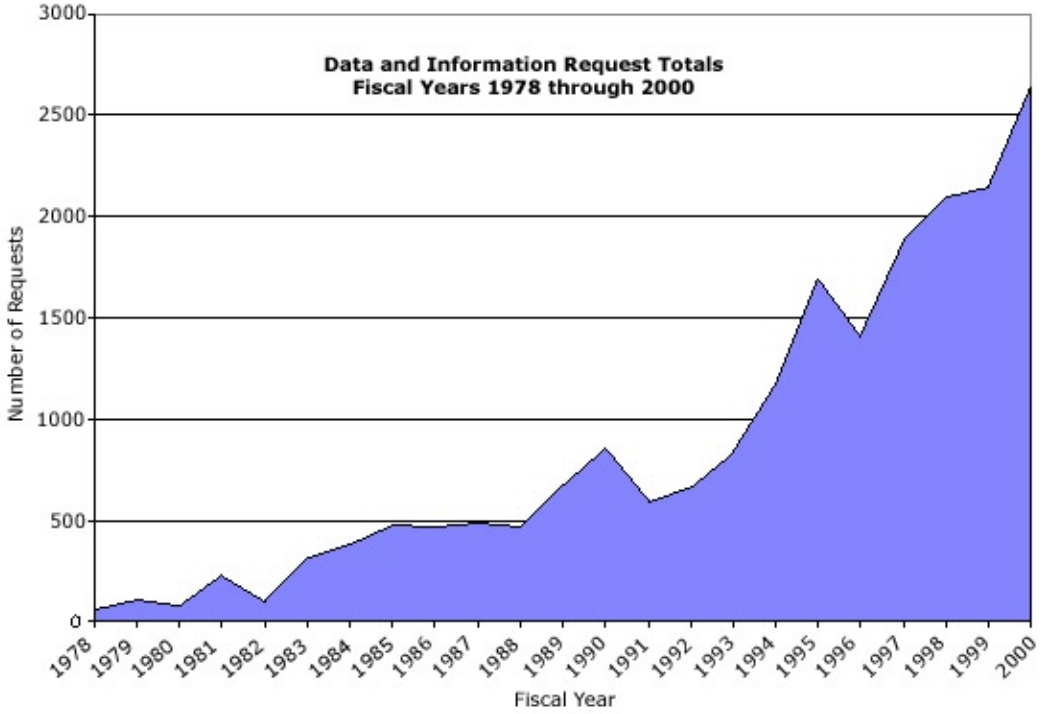

Figure 2. Number of new requests received during each fiscal year for 1978 through 2000.

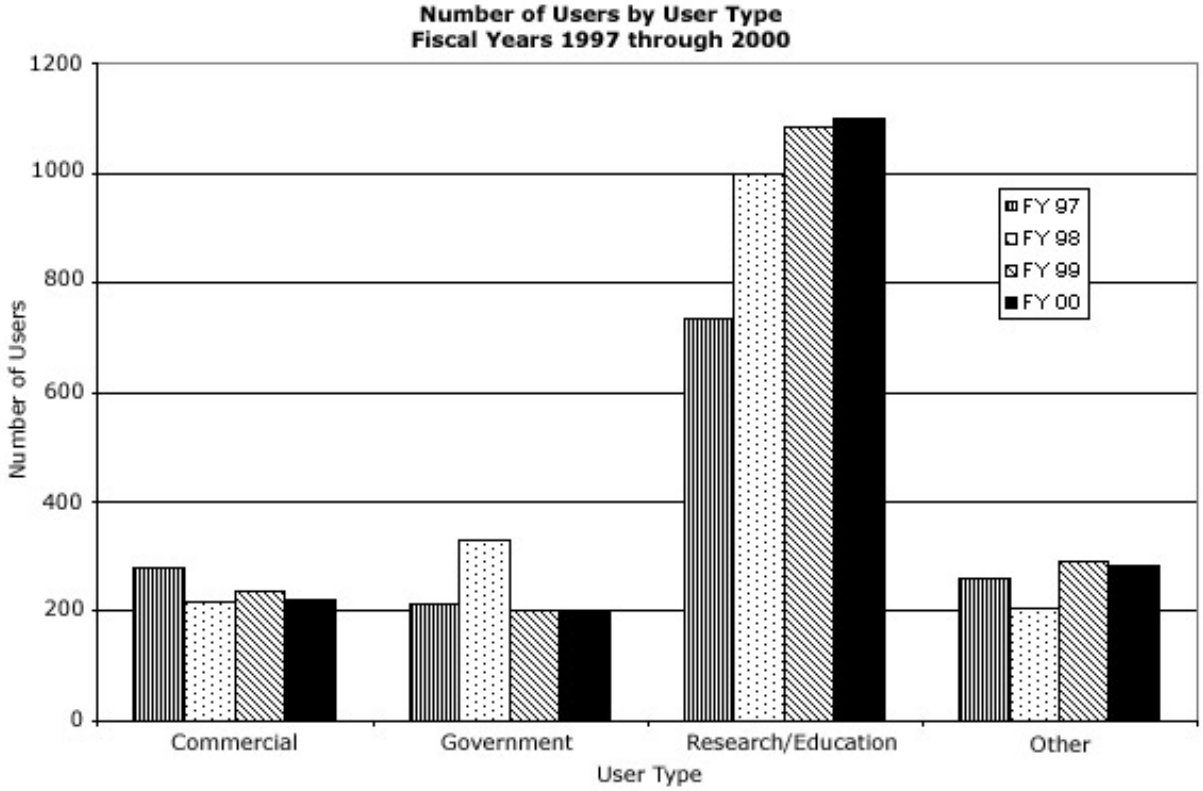

Figure 3. Number of new requests received in Fiscal Years 1997 through 2000 categorized by user type.

NATIONAL / INTERNATIONAL COLLABORATION

The WCRP Climate and Cryosphere (CliC) initiative

The following report was written by R. G. Barry, Director of NSIDC; I. Allison, Antarctic CRC, University of Tasmania, Hobart, Australia and H. Cattle, Meteorological Office, Bracknell, UK.

The World Climate Research Programme (WCRP) Joint Scientific Committee (JSC) established a Task Group under the Arctic Climate System (ACSYS) project in 1998 to develop a Science and Co-ordination Plan for a global program in Climate and the Cryosphere (CliC). The plan outlines research and coordination initiatives required to integrate fully studies of the impact and response of the cryosphere, and the use of cryospheric indicators for climate change detection, within the WCRP. It draws on an expert meeting on Cryospheric Processes and Climate in Cambridge, UK (February 1997), two meetings of the CliC Task Group, and scientist input. The plan was approved by the JSC at its XXI session in Tokyo in March 2000.

The cryosphere is an integral part of the global climate system with important linkages and feedbacks generated through its influence on surface energy and moisture fluxes, precipitation, hydrology, and atmospheric and oceanic circulation. Snow and ice are key components of climate model response to global change, and serve as important indicators of change in the climate system. However, many aspects of the cryosphere have not been fully covered within WCRP. There are notable gaps in present studies of cryospheric elements and in appropriate treatment of cryospheric processes in climate models.

In the CliC Science Plan key interactions are treated under the following headings:

- interactions between the atmosphere, snow and land
- interactions between land ice and sea level
- interactions between sea ice, oceans, and the atmosphere, and
- cryospheric interactions with the atmosphere and the ocean on a global scale.

Also considered are cryospheric indicators of climate variability and change.

Specific issues for terrestrial snow and ice include interactions and feedbacks in the current climate and its variability; in land surface processes; and in the hydrological cycle. Issues such as changes in mountain snow and glacier cover and their impacts on the hydrological cycle and water resources, that are of interest to the mountain research community, will be addressed. A further concern is how do changes of the seasonal thaw depth alter the land-atmosphere interaction, and what will be the response and feedback of permafrost to changes in the climate system?

The primary issue regarding the role of the cryosphere in sea level change is the past, present and future contribution of land ice. It is essential to measure and explain the current state of balance of glaciers, ice caps and ice sheets, and to resolve the large uncertainties in the mass budgets of the Greenland and Antarctic ice sheets.

The details and consequences of the role of sea ice in the global climate system are still poorly known. We need better knowledge of the time-varying distributions of the physical characteristics of sea ice in both hemispheres, and the dominant processes of ice formation, modification, decay and transport which determine ice thickness distribution. Improved coupled models are required to predict changes in sea ice cover under global warming.

Key issues on the global scale are understanding the direct interactions between the cryosphere and atmosphere, parameterizing correctly the processes involved in models, and providing improved data sets for these studies. Ice-albedo feedback, associated polar sensitivity to climate change, and their global implications, require detailed analysis and modeling. Improved interactive modeling of the atmosphere and the cryosphere is required in respect of the surface energy budget and surface hydrology, including freshwater runoff and its impacts on the global ocean thermohaline circulation.

The cryosphere is an integrator of processes within the climate system and a strong indicator of change. Cryospheric indicators are particularly valuable where conventional observations are sparse. It is of great importance to continue existing time series of sea ice and snow cover extent, as well as observations of glacier geometry and mass balance and frozen ground conditions, to monitor current change.

The scientific strategy for CliC is similar in each of the areas of interaction: a combination of measurement, observation, monitoring and analysis, field process studies and modeling over a range of time and space scales. A CliC modeling strategy must address improved model parameterization of the direct interactions between all components of the cryosphere, the atmosphere, and the ocean. This is required at regional to global scales, with a hierarchy of models. It is also essential to provide the improved data sets needed for validation of models and parameterization schemes via in situ and remote sensing observations. CliC data requirements will necessitate the continuation of many ACSYS data activities and their expansion to Antarctic and other cryospheric data needs.

The cryosphere is of interest to many diverse scientific organizations. CliC will develop an implementation plan that is complementary to other initiatives and draws on the expertise of other WCRP and WMO program components and, among others, relevant IGBP, SCAR, SCOR, IASC and ICSU projects.

The CliC Science and Co-ordination Plan, Version 1, may be obtained at:
http://www.npolar.no/acsys/CLIC/clic1.pdf

Further information will be disseminated through the new International ACSYS/CliC Project Office (IACPO) in Tromso, Norway, as CliC plans develop over the next several years.

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. Roger Barry chaired the annual meeting of the GDSIDB, which took place at the Canadian Ice Service in Ottawa, April 30 - May 1. Representatives from nine countries attended the meeting. Progress in the development of the GDSIDB at NSIDC and the Arctic and Antarctic Research Institute in St. Petersburg, Russia, was reviewed and plans for future data acquisitions from member countries were discussed. Of major concern is the need for a new GDSIDB archive format. Only one country continues to submit data in Sea Ice Grid (SIGRID) format. The GDSIDB will work with the International Ice Charting Working Group Ad Hoc Format Committee to develop a new, vector archive format that should help to increase GDSIDB participation by member countries. More information can be found in the Final Report of the Steering Group for the WMO Project Global Digital Sea Ice Data Bank, JCOMM Meeting Report No. 5, World Meteorological Organization.

RESEARCH

Richard L. Armstrong

Global Snow Cover Mapping

Through funding provided by the NOAA/NASA Pathfinder Program, a consistently processed, thoroughly quality-controlled 23-year time series of global gridded satellite passive microwave data has been produced. This data set was produced by processing the SMMR (Scanning Multichannel Microwave Radiometer) data for the period 1978 to 1987 and SSM/I (Special Sensor Microwave Imager) data for 1987 to 2000 to a common format called the Equal Area Scalable Earth-Grid (EASE-Grid). These EASE-Grid brightness temperatures provide the standard input to a wide range of algorithms currently in use, and being developed, to derive various land, ocean and atmosphere parameters.

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.

For the validation of snow covered area, we use the EASE-Grid version of the NOAA Northern Hemisphere weekly snow charts. The original NOAA charts were derived from the manual interpretation of AVHRR (Advanced Very High-Resolution Radiometer), GOES (Geostationary Operational Environmental Satellite) and other visible satellite data. With regard to snow water equivalent (SWE) we also focus on larger more comprehensive validation data sets which can be expected to provide a full range of snow/climate conditions rather than on smaller data sets which may only represent a "snapshot" in time and space. The primary data set used in the current phase of the SWE validation is the "Former Soviet Union Hydrological Surveys" (FSUHS). These data are available during both the SMMR and SSM/I periods (through 1990) and comprise the average of measurements along transects of 1.0 to 2.0 km in length with measurements every 100 to 200 m.

Digital image comparison techniques are being applied to a multi-year, time series analysis of several different algorithms (Armstrong and Brodzik, 2000). The ultimate goal of this study is to determine if the differences between the algorithm output and the validation data are random or systematic. In the case of systematic differences, the patterns are being correlated with the specific effects of land cover type, atmospheric conditions and snow structure. Because we compare algorithm output with continuous records of station data we will be able to identify any seasonal or inter-annual patterns in the accuracy of the algorithms.

For the 22-year period during which both passive microwave and visible data are available results show a consistent pattern of inter-annual variability and both data types indicate maximum extents consistently exceeding 40 million square kilometers. During this same period the trend in mean annual snow extent derived from both visible and microwave satellite data indicates a decrease of approximately 0.2 percent per year. When the monthly climatologies produced by the two data sources are compared, results clearly indicate those time periods and geographic regions where the two techniques agree and where they tend to consistently disagree. During shallow snow conditions of the early winter season (October through

December) the passive microwave algorithms generally indicate less snow covered area than is indicated by the visible data. The microwave algorithms tested thus far are often unable to detect the presence of snow. However, preliminary results indicate that the inclusion of the 85 GHz channel, with the associated enhanced scattering response, improves the accuracy of mapping shallow snow. As the snowpack continues to build during the months of January through March, agreement between the two data sets improves.

For snow water equivalent validation we are currently working with a topographically consistent subset of the FSUHS data was selected for the validation study area. This subset (45-60° north latitude, 25-45° east longitude) has the highest station density (approximately one transect per 100 km grid cell) and is primarily composed of non-complex terrain (grassland steppe) with maximum elevation differences of less than 500 m. Results indicate a general tendency for the algorithms tested thus far to underestimate SWE. Unlike snow extent, differences between the validation data and the microwave algorithms appear to be generally consistent throughout the winter season. Underestimates of SWE increase significantly as the forest cover density begins to exceed 30 to 40 percent. Because of the detailed land cover data available for this validation study area, we apply algorithm adjustments as a function of fractional forest cover. Future work will continue the comprehensive multi-year comparison of at least six different algorithms with the FSUHS data as well as other surface station measurements. This work is supported by NASA Research Grants NAG5-4906 and NAG5-6636.

Evaluation of the Onset of Snowmelt on the Greenland and Antarctic Ice Sheets using Passive Microwave Data.

The areal extent of snowmelt on the Greenland and Antarctic ice sheets is a specific response to prevailing energy balance conditions. Any detectable trend over time of the extent and duration of melt would provide a direct indication of polar climate variability and change. Using the twenty year record of SMMR and SSM/I brightness temperatures we apply a test algorithm which generates a time series of the occurrence of snow melt on the ice sheets. Over this relatively short period of time no significant trend is detected although, using a different statistic, Abdalati and Steffen (1997) did note a 4.4% increase in melt area during the years 1978 to 1991. The methodology and specific algorithms are being enhanced and validated in order to continue the analysis of this time series.

NASA-EOS Instrument Team Activities

Richard Armstrong serves as lead interface between NSIDC and the science and instrument teams for specific missions such as NASDA ADEOS-II AMSR and the NASA AMSR-E as well as the link to all appropriate NASA EOS IDS teams and the ECS Science Office. A discipline-specific scientific presence within these teams assures effective interaction and collaboration which in turn establishes the mission data coordinator as the informed link between the various aspects of the NASA EOS and NASDA program and the eventual data user, regardless of their individual needs or academic background. Direct interaction with the AMSR-E instrument team is by way of funding provided by NASA-EOS to assist in the development and validation of a passive microwave snow cover algorithm. Attend meetings of the NASDA AMSR Science Team and collaborate in the validation of NASDA land surface algorithms.

Jim Maslanik

During the past year, data related activities included overseeing the SSM/I-grid sea ice products, contributing to the development of value-added products from passive microwave data, and delivery and continued validation of AVHRR Polar Pathfinder products. Research tasks include contributions to several ongoing and newly funded NSF- and NASA-sponsored projects targeting the investigation of ice-atmosphere-ocean interactions in the Arctic. Specific research areas underway include investigating the predictability of sea ice conditions in the Alaskan North Slope area (NSF), assembly and analysis of gridded data sets to support Phase 3 of NSF's Surface Heat Budget of the Arctic (SHEBA) effort, integration of remotely-sensed data with modeling of sea ice leads to improve parameterizations of lead processes in climate models (NASA), deployment and testing of an unpiloted aerial vehicle for data collection in the Arctic (NSF), development of an second-generation sea ice algorithm for MODIS data (Navy/NOAA National Ice Center), and completion of a one-year study to investigate the potential of near real-time microwave data products for applications-oriented users in the North Slope area (Alaska SAR Facility and NASA).

Anne Nolin

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

In the past year, Anne Nolin was approved as a member of the MISR science team. Recent work has focussed on developing cryospheric applications of MISR data including mapping of snow albedo, ice sheet facies, sea ice, and ice sheet surface features (ice streams, megadunes). A research note covering the use of MISR data for sea ice typing was submitted to the Canadian Journal of Remote Sensing in December. Progress was made on the validation of snow albedo from MISR and MODIS including a new set measurements from the Greenland ice sheet. Preliminary results of MISR applications in snow hydrology were presented at the AGU Fall Meeting.

Multispectral Mapping of the Martian Polar Ice Caps (NASA)

During the second year of this 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. Results indicate that at least two ice types with detectable spectral differences exist in regions of the North Polar Cap. Whether or not these are water and CO2 ice cannot be determined with the spectral bands used here. The compositional differences detected here may be the result of differing dust types/concentrations mixed in with the ice. Grain size variations may also be responsible for the differences. This is certainly a viable hypothesis for the ice types mapped in the small crater. The frost streaks seen in a small crater with mixed ice types may be large-grained ice or may simply be very thin frost. Continued investigation into spectral differences will shed more light on compositional variability over the Martian ice caps. Ongoing and future efforts include combining TES Lambert albedo and MOLA topographic data to provide contextual information for these unmixing results.

Southwest Regional Earth Science Applications Center (NASA-RESAC)

Joint work with Andy Barrett is performing an assessment of snow covered area (SCA) data derived from satellite remote sensing and incorporating these data into the USGS hydrologic model (PRMS). Substantial progress was made to integrate satellite-derived snow cover into PRMS and for this work, two sub-basins in the Gunnison River Basin are being examined. In related work, data from the MODIS

snow cover product was acquired over the Gunnison river. Preliminary analysis indicates that the higher resolution binary classification may be sufficient for hydrologic modeling rather than having to produce the more time-consuming snow fraction product from AVHRR.

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 third year activities of this project, we performed a comparison of GCM-derived snow cover with observed snow cover from SMMR and SSM/I. Climatologies of snow covered area, date of snow disappearance, and snow fraction in a model grid cell were used as assessment criteria. Of the four models whose snow cover output have been assessed so far, the NCAR CCM3 model has the best fit to the observations. However, all the models examined to date have significantly less snow cover in the spring months than is demonstrated by the observations.

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

Graduate student Eileen McKim began working with us in January 2000. We have started examining the relationships between land surface and atmospheric circulation patterns as they contribute to the North American Monsoon System. In work with Sue Marshall (University of North Carolina, Charlotte), we performed a series of climate model experiments aimed at understanding the predictability of snow cover based on a specified initial state. Results from these experiments show that the initial snow cover plays a much more important role in determining the regional climate than does the initial state of the atmosphere. These results also indicate that the snow cover forcing on the local climate will can persist for several weeks and attests to the strength of the snow cover albedo/temperature feedback on the regional climate.

Advancing Glaciological Applications of Remote Sensing with EO-1

This is a new effort, still under development, with funding from NAA. As part of this effort, scheme for determining surface snow grain size from an imaging spectrometer was refined. After the successful launch of this satellite in December 2000, we expect to receive sample data in early 2001.

Ted Scambos

Ice Shelves and Icebergs in Antarctica

In the last year I and my colleagues (Mark Fahnestock of University of Maryland and Christina Hulbe of NASA Goddard) completed an important study of the recent history of the Larsen and Wilkins ice shelf, and proposed a detailed model for ice shelf breakup based on the effect of melt ponds on crevasse propagation within the shelf. We made extensive use of NSIDC's archive of satellite images of the ice shelves in both tracking the shelf breakup history and determining the root causes of disintegration. Melting to the point of ponding on the surface appears to be an important precursor to ice shelf breakups. With the advent of ponding, any crack formed on the surface fills to the brim with meltwater. Modeling of shelf behavior and of ice crack propagation shows that, if brim full, crevasses as shallow as 5 to 15 meters will rapidly propagate through the shelf, weakening it and eventually leading to breakup.

The implication is that any shelf area that reaches a mean January temperature of ~0C is susceptible to rapid disintegration. This places several important ice shelves, such as the Fimbul and Ross, much closer to their climatic limit than was earlier estimated. Further, some of these shelves lie in front of major glacier systems draining the Antarctic, and in part acting as a braking system for them. If these larger

shelves should undergo a warming of 2 to 4 degrees C, (as has occurred in the Antarctic Peninsula over the last 50 years), the ice shelves may rapidly retreat, causing an increase in outflow of ice from Antarctica and an increase in the rate of sea level rise.

Photoclinometry

Photoclinometry is applied to the refinement of DEMs over ice sheets 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. Over the last year, the technique was used to generate the most accurate DEM of Greenland to date, adding considerable detail at ~1km horizontal scale and ~1.5 meter vertical accuracy to the best current DEM, provided by KMS of Denmark. New details revealed in the topography include sub-ice drainage features, possible sub-ice volcanic edifices, and a better representation of the undulations on the flanks of the ice sheet.

Greg Scharfen

G. Scharfen, V. Troisi and R. Barry received funding from NASA for "Global Land Ice Measurements from Space" (GLIMS) NAG5-9722. The GLIMS project is designed to monitor the world's glaciers primarily using data from the EOS ASTER (Advanced Spaceborne Thermal Emission and reflection Radiometer), flown on the Terra 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 is funded to develop 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. This system has now been designed and comments are being received from the GLIMS data base working group for prior to its coding. 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.

M.C. Serreze and M.P. Clark

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

Research has focused on three major topics: 1) assessing spatio-temporal variability in the western U.S. snowpack and its links with atmospheric circulation; 2) developing methods to provide improved predictions of runoff; 3) assessing potential snow-cover feedbacks on western U.S. climate variability, particularly as they relate to the southwest summer monsoon.

Daily snow water equivalent (SWE) records from the SNOTEL archive were used to assess spatio-temporal characteristics of large snowfall events over the montane western U.S. The largest mean annual (leading) events are found in the Pacific Northwest and Sierra Nevada. The mean leading event lasting up to 72 hours typically accounts for 10-23% of the water equivalent of annual snowfall, with the largest contribution in the Arizona/New Mexico sector. For most of the West, snowfall events in the top quartile of station distributions are most common during mid-winter, but those for the Rocky Mountain states and Utah are more common during late winter or spring. Colorado also shows a secondary peak in large events during November. Large mid-winter snowfall events in the marine sectors, Idaho and

Arizona/New Mexico are spatially coherent in that when observed at one station, they tend to occur at surrounding stations. Large events are less spatially coherent for drier inland regions. When annual snowfall is anomalously positive, there tends to be an increase in the number of snow days as well as a shift in the distributions towards the larger event sizes. Opposite relationships are observed for negative annual snowfall anomalies. These finding are in accord with recent studies using lower elevation data demonstrating that the probability of extreme precipitation events is altered during El-Nino or La-Nina conditions.

A related study focused on the seasonal evolution of snowfall and stream flow anomalies associated with El-Nino and La-Nina conditions. The motivation for this project was to improve runoff forecasts made in mid-winter at the time that water managers are developing their reservoir operating plans. Our work demonstrated that in many river basins in the western United States, the associations between ENSO and annual runoff and between ENSO and snow water equivalent at the time of peak accumulation (e.g., April 1) were already present in the January 1 snowpack. In these basins, ENSO information did not add any value to traditional runoff forecasts that are based on snowpack information alone. However, in some basins (in particular, the Lower Colorado and coastal basins in the Columbia River basin) the seasonal variations in ENSO-snowpack associations were strong, and knowledge of seasonal changes in these ENSO signals did result in significant improvements in seasonal forecasts of runoff.

To assess the possibilities with using Numerical Weather Prediction (NWP) model output in hydrologic forecasting applications, the 40+ year archive of 8-day atmospheric forecasts completed as part of phase one of NCEP Reanalysis were used to assess the ability of a state-of-the-art to predict precipitation and temperature. Specifically, output from the NCEP NWP model was compared with historical station data of precipitation and temperature at over 11,000 lower elevation stations in the Nationwide NOAA cooperative network and at 625 high elevation SNOTEL stations in the western United States for the period 1958-1996 (1980-1996 for SNOTEL). Results showed the NCEP forecasts of both and precipitation and temperature were plagued by significant systematic biases in most months. These biases were not constant throughout the forecast cycle. Furthermore, the ability of the NCEP model to capture day-to-day variations in precipitation was poor, particularly during summer months. However, the NCEP temperature forecasts were surprisingly accurate, and exhibited significant skill over large areas of the country at lead times of greater than 5 days. This suggests that, if the systematic model biases can be removed, NWP output may be useful in forecasting runoff in snow melt dominated river basins.

We also assessed if it were possible to improve upon the raw NCEP output through the use of Model Output Statistics. To this end, we used a multiple linear regression (MLR) model to develop empirical relationships between outputs from the NCEP NWP model (e.g., 500 hPa height, total column precipitable water) and station observations of temperature and precipitation. The MLR model was used to predict daily variations in temperature and precipitation at the 11,000 co-op stations nationwide. Results showed that the MLR predictions of temperature were significantly better than the raw NCEP output, particularly in the interior western United States. MLR predictions of precipitation were comparable to the raw NCEP output, although some improvements were evident in summer months. These results are currently being prepared for publication.

In terms of predicting short-term variations in runoff, 38 years (1958-1996) of 8-day forecasted precipitation and maximum and minimum temperature from phase one of the National Center for Environmental Prediction (NCEP) Reanalysis (horizontal grid spacing of ~210km) were used as input to a distributed hydrologic model, to forecast streamflow in the Animas River basin. The Animas is a small (1820 km^2) mountainous (2000-4000m) river basin located in southwestern Colorado, United States. To assess the

benefits of atmospheric forecasts in hydrologic models, the U.S. Geological Survey's Precipitation Runoff Modeling System (PRMS) was forced with three sets of precipitation and maximum and minimum temperature: (1) station data; (2) climatological values; and (3) NCEP 8-day forecasts with the systematic biases removed. PRMS output forced with station data were used as "truth" to focus attention on the hydrologic effects of errors in the atmospheric forecasts. The climatological values can be considered similar to the mean value from an extend-streamflow prediction procedure and provide a baseline for measuring the accuracy of hydrologic forecasts when forcing PRMS with the NCEP 8-day forecasts.

Using climatology, some accuracy in runoff forecasts was achieved at the beginning of the forecast cycle. This can be attributed to the lag time in PRMS and stresses the importance of accurately specifying initial conditions. Significant accuracy was present in the NCEP maximum temperature forecasts in spring and autumn and in the NCEP minimum temperature forecasts during winter. The reliable maximum temperature predictions translated into reliable estimates of snow melt and runoff with forecast errors much lower than those generated using the climatology. Accuracy of the NCEP precipitation forecasts was poor. Useful forecasts using NCEP output most likely occur because the Animas River basin is dominated by snow melt (which is influenced by variations in temperature), and may not hold in other river basins where the surface hydrology is predominately influenced by rainfall. These results are currently being prepared for publication.

In terms of predicting short-term variations in runoff, 38 years (1958-1996) of 8 day forecasted precipitation and maximum and minimum temperature from phase one of the National Center for Environmental Prediction (NCEP) Reanalysis were used as input to a distributed hydrologic model set up over the Animas River basin. To assess the benefits of atmospheric forecasts in hydrologic models, the U.S. Geological Survey's Precipitation Runoff Modeling System (PRMS) was forced with three sets of precipitation and maximum and minimum temperature: (1) station data; (2) climatological values; and (3) NCEP 8 day forecasts with the systematic biases removed. PRMS output forced with station data were used as "truth" to focus attention on the hydrologic effects of errors in the atmospheric forecasts. Using the climatology forecasts, some accuracy in runoff forecasts was achieved at the beginning of the forecast cycle. This can be attributed to the lag time in PRMS and stresses the importance of accurately specifying initial conditions (particularly snow mass and extent) over the basin. However, significant improvements were evident in the NCEP-based runoff forecasts, particularly during spring when runoff in the Animas basin is highest and most variable. Improvements in forecast accuracy are derived from reliable springtime forecasts of maximum temperature (not shown) which translated into credible estimates of snow melt and runoff. The accuracy of the NCEP precipitation forecasts over the Animas basin were poor. Useful forecasts using NCEP output most likely occur because the Animas River basin is dominated by snow melt (which is influenced by variations in temperature), and may not hold in other river basins where the surface hydrology is predominately influenced by rainfall.

As a contribution to assessing snow cover feedbacks, a paper was published addressing a possible role of snow cover anomalies over eastern Eurasia in forcing downstream amplification of the Pacific North American (PNA) or PNA-type wavetrain, hence with potential impacts on western U.S. climate. Recent work has also focused on the possible effects of variations in snow mass over the North American continent in modulating variations in the North American monsoon system. We have assembled high resolution precipitation data sets for the United States and Mexico, and identified the sub-continental differences in the development of the North American monsoon system. We are currently assessing the effects of variations in snow mass in influencing monsoon development and intensity.

Arctic Climate and Hydro-climatology (NSF Arctic System Science (ARCSS), NASA IDS)

As discussed in the 1999 annual report, NCEP reanalysis data were used to assess the characteristics of the Arctic frontal zone and its influence on patterns of high-latitude cyclogenesis and precipitation. This required the development of an automated frontal analysis scheme. A paper reporting on results is in press. A thrust of this study was to re-examine earlier concepts that the position of the summer frontal zone is at least in part determined by discontinuities in energy exchange along the boundary between the tundra and boreal forest. Our work demonstrates that the more important factors are heating contrasts between the snow-free land and Arctic Ocean, and the effects of orography. A modeling framework was developed to clarify the relative importance of these mechanisms in comparison to vegetation forcing.

Assessing potential vegetation/climate relationships such as they may relate to the Arctic frontal zone and better representing surface processes in models represent major goals of a long-term NSF ARCSS effort titled "Transitions: A Study of the Spatial and Temporal Transitions of Climate and Ecosystems in the Circumpolar Arctic". This is a collaborative effort with A. Lynch (CIRES) and researchers at several different Universities. Under this grant, Serreze participated in field work (2000) near Council, AK (Seward Peninsula). Serreze was tasked with operation of the NCAR Integrated Sounding System (ISS). A major thrust of this effort was to examine differences in boundary-layer conditions between forest and tundra. It was found that during solar noon, sensible heating contrasts between forest and tundra are on the order of 50 W m^{-2}. This is considered sufficient to generate a frontal zone. However, when averaged over a day, differences are only 5-10 W m^{-2}. This argues further for a limited role of vegetation contrasts of development of the Arctic fronal zone. A paper reporting on results has been submitted.

A comprehensive paper synthesizing observational evidence of environmental change in northern high latitudes over the past several decades, also outlined in the 1999 annual report, was recently published in the journal *Climatic Change*. This paper generated considerable media interest.

Several new efforts are addressing the hydro-climatology of the Arctic. The first project, funded through NSF/ARCSS, focuses on providing a better understanding of the hydro-climatology of the major Eurasian Arctic watersheds (the Ob, Yenisei and Lena) using NCEP reanalysis fields (e.g., vapor flux convergence) and other data sources (e.g., observed precipitation). The second effort, also funded through NSF/ARCSS, seeks to develop the capability for operational monitoring of components of the Arctic hydrologic budget through combining reanalysis fields, observed records of precipitation, temperature and snow cover with output from hydrologic models. An important component of this effort is to provide timely updates of precipitation using techniques of circulation downscaling. The third effort, funded under the NASA IDS program, will enhance operational modeling of the Arctic hydrologic budget through incorporation of EOS-data streams.

Julienne Stroeve

Assessment of Greenland Outlet Glacier Albedo Variability

Since the beginning of PARCA in 1995, there has been significant improvement in mass balance estimates of the Greenland ice sheet. Results from this program reveal that at elevations above 2000m, the ice sheet is essentially in balance (within 1 cm/yr), but rapid thinning is occuring in the coastal areas. Thinning rates of more than 1m/yr are common along many of the outlet glaciers (e.g. Kangerdlugssuaq, Storstrommen). It is currently unclear however, how much of the thinning is a result of recent increases in temperatures, or increased glacier velocities and associated creep rates. With an increasingly warmer climate, it is expected that there will be a continued increase in both the area and intensity of summer melting.

Given the importance of the Greenland ice sheet to global sea level and the sensitivity of the ice sheet melt to albedo, funding from NASA was recently given to map the variability of the surface albedo, and consequently, the absorbed solar energy over time at a few outlet glaciers on the ice sheet. The purpose of the work is to improve our understanding of the rapid thinning presently happening on many of these glaciers. In mapping the albedo variability at some key glacier areas, it will be possible to examine the potential implications the albedo variability will have on the energy balance and degree-day factors commonly used to estimate ablation. For this study, the surface albedo record from the AVHRR Polar Pathfinder Data Set will be used. The glaciers to be studied are the following: Kangerdlugssuaq, Storstrommen, Peterman Glacier, Jakobshavn Glacier.

Assessment of Greenland Albedo Variability from the AVHRR Polar Pathfinder Data Set

Following recent intercomparison work between in situ and AVHRR Polar Pathfinder (APP) surface albedo at several automatic weather stations around the Greenland ice sheet (Stroeve et al., 2001), the complete albedo time-series from the APP product was analyzed and results are being published in JGR. Analysis of the APP albedo record from 1981 and 1998 show anomalously low albedo during 1995 and 1998 over most of the ice sheet as compared with the other years. The low albedo encountered during these years suggests that the ice sheet experienced considerable melt in 1995 and 1998, particularly near the western margin of the ice sheet. Conversely, anomalously high albedos were found in 1992 as a result of colder temperatures, and hence less melt following the eruption of Mt Pinatubo. The relationship between the annual North Atlantic Oscillation (NAO) index and the mean summer albedo from all the stations reveal a positive correlation of 0.44, and a positive correlation of 0.55 for the southern part of the ice sheet. Therefore, variations in the mean summer albedo over Greenland can in part be explained by variations in the NAO such that during periods of intensification of the normal mode of the NAO the mean summer albedo is above normal. Trend analysis reveals an overall downward trend in surface

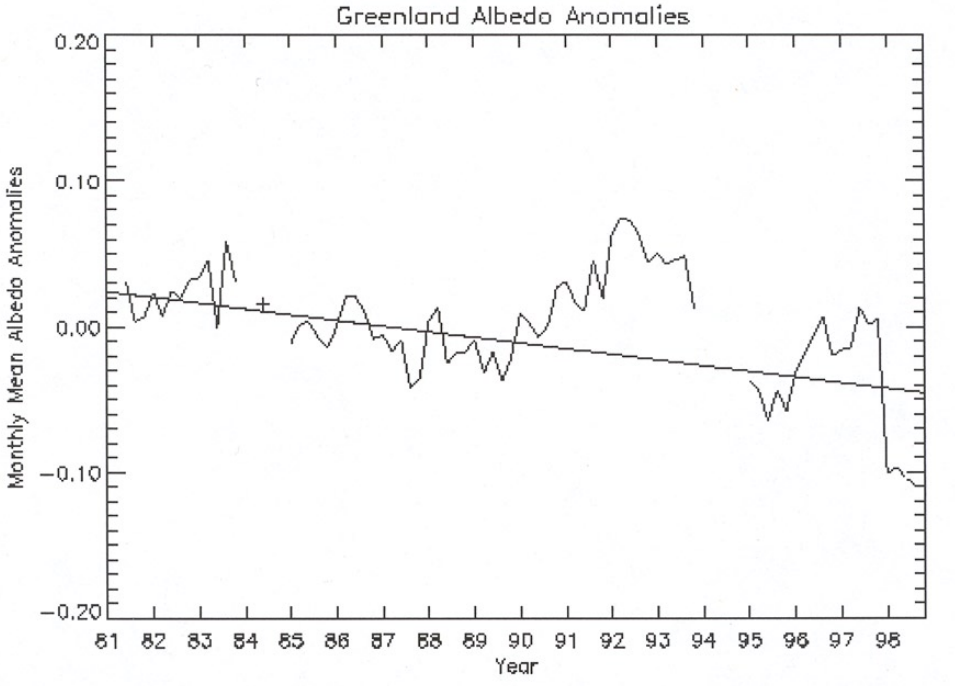

Figure 4. Time series of monthly albedo anomalies over Greenland for May-September, July 1981 to August 1998.

albedo from 1981 to 1998. However, the trend was found not to be statistically significant, but rather influenced by the low albedo in recent years. However, it is encouraging that the downward trend is in agreement with recent trends in melt and precipitation.

Evaluation and Error Assessment of Operational Passive Microwave Sea-Ice Algorithms

Records of sea ice cover derived from passive microwave data span more than 20 years, and will continue to be supplied in the future from DMSP SSM/I and EOS-PM AMSR. Time-series of ice concentrations using two commonly used algorithms, the NASA Team and Bootstrap algorithms are presently available from the National Snow and Ice Data Center DAAC. While each of these algorithms seeks to provide a consistent record of sea ice concentrations, they differ in terms of the specific approaches used, and thus exhibit different sensitivities to error sources. As a result, particular algorithms may be better suited for some applications than others, and may be more or less sensitive to secondary factors affecting retrievals of ice conditions. Given the importance of the relatively long-term passive microwave record for climate studies it is important to quantify the potential magnitudes of errors and variations in the sea ice record from the different sea ice algorithms.

Previous studies have documented relative large differences in ice concentrations between the NASA Team and Bootstrap sea ice. Although both algorithms have been widely validated, primarily through comparison with other satellite data, the causes for the observed differences remained mostly hypothetical. To improve our understanding of the observed differences between the different sea ice algorithms we have evaluated the sensitivity of the passive microwave brightness temperatures and corresponding ice concentrations from the NASA Team and Bootstrap sea ice algorithms to variations in surface conditions, atmospheric conditions and sensor incidence angle. To perform the sensitivity study, we used a combined sea ice model and atmospheric radiative transfer model called MWMOD. The sea ice model is based on the many-layer strong fluctuation theory. The modeling approach allows tests of algorithm sensitivities to a full range of ice and atmospheric conditions.

Results from the sensitivity tests show that for thin, bare ice the most important parameters determining the passive microwave signature are the ice density, air pocket size, ice thickness (up to about 0.3 m) and the salinity of the ice. For thicker ice types with snow cover, the most important parameters are the free-water content of the snow, air pocket size, snow density, snow thickness, and snow grain size. In terms of atmospheric effects on the passive microwave brightness temperatures, the most critical parameter is the cloud liquid water content. These sensitivities of the brightness temperatures with changes in atmospheric and surface conditions have different impacts on the resulting sea ice concentrations derived from the NASA Team and the Bootstrap sea ice models. In general, the NASA Team algorithm is more sensitive than the Bootstrap sea ice algorithm to changing environmental conditions. Since both sea ice algorithms are dependent upon changes in the surface and the atmosphere, caution is needed when examining trends in sea ice since long-term changes in the amount of snow cover or atmospheric water vapor for example, could manifest into artificial changes in sea ice cover.

Validation Studies and Sensitivity Analysis for Retrievals of Snow Albedo for EOS AM-1 Instruments

During the past year, J. Stroeve traveled to Greenland to obtain in situ data needed to help validate surface albedo retrievals from MODIS, MISR and AVHRR. The purpose of the field work was to validate the clear sky snow spectral albedo for MODIS and MISR, validate the narrow-to-broadband albedo conversion for MODIS and MISR, and evaluate sensitivity of albedo retrievals to atmospheric conditions. Data collected include: surface broadband albedo (0.25 - 3.0 microns) at 5 minute intervals; hemispheric and nadir view spectral albedo measurements (0.35 and 2.5 microns, in steps of 1 nm) made

at hourly intervals and during MISR overpass times; sun photometer measurements to characterize the aerosol optical depth and column water vapor and ozone amounts (at 10 minute calibration intervals and hourly during normal operation). Additional information on snow grain size and snow density were collected. Problems were encountered with the use of the spectrometer in the cold Arctic conditions both at the ETH/CU camp and at the Summit of the ice sheet that limit the use of these measurements for validation purposes. Another attempt at collecting these data will be made during February 2000 in Steamboat Springs, Colorado.

Snow albedo retrieval from MODIS and MISR data has begun. Initial results with MISR data over Greenland show that at solar zenith angles below 70 degrees, the angular model of Dr. Nolin works reasonably well. Unfortunately, no coincident ground based data over Greenland has been yet available to validate the surface albedo retrieval. Further work is needed to validate the MISR surface albedo retrievals.

Improved Surface Heat Flux and Salt Fluxes at Polar Latitudes through the Assimilation of Satellite Measurements

The purpose of this project is to provide Dr. Markus at the University of Maryland daily ice motion fields in the 25km SSM/I grid from available motion vectors. The motion vectors (u- and v-components) are currently tabulated with their respective lat/lon information. These vectors have been gridded and missing pixels interpolated. SSM/I ice extents were used to exclude cases where erroneous vectors are derived over the ice-free ocean. A second objective is to investigate the utilization of these fields together with fields of ice growth and ice concentration estimates in order to derive estimates of ice thickness. Initial work derived total ice production rates using the ice growth fields with the ice concentration. On subsequent analysis of the data, it was decided to input these fields together with the ice motion fields into the sea ice model of Dr. Maslanik. This is a data assimilation ice model that allows the final values used to be a combination of the supplied and model-calculated values instead of using 100% of the supplied value (motion, growth rate, etc.). The advantage of this method includes avoiding large inconsistencies in the results, minimizing numerical problems, and allows the process to take advantage of the strengths of the model as well as the data. The sea ice model is still underdevelopment by Dr. Maslanik, and will be used to derive ice thickness values in the near future.

Tingjun Zhang

Stochastic Variability of Seasonal Freezing and Thawing at Local, Regional, and Hemispheric Scales Under Modern and Predicted Climate
(R.G. Barry and D.A. Gilichinsky, Inst. of Basic Biology, RAS, Pushchino)

Under this international collaboration we 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 the related project work of Fritz Nelson (University of Delaware) and Oleg Anisimov (State Hydrologic Institute, St. Petersburg).

The areal extent in the northern hemisphere (see Figure 1 on the inside of the front cover) of seasonally frozen ground, snow cover, and permafrost has been determined using the NSIDC EASE-grid format. Seasonally and intermittently frozen ground are defined according to where the soil is frozen for more or less than two weeks each year, respectively. The solid line indicates the average maximum extent of the

seasonal snow cover. Soil freeze/thaw status under snow cover is uncertain depending upon the timing, duration, thickness, and physical and thermal properties of snow. Investigation of ground freeze/thaw status is underway using a combined approach of numerical modeling and remote sensing technique. The snow cover extent is based on the NSIDC EASE-Grid version of the NOAA- NESDIS weekly Northern Hemisphere snow charts. The distribution of permafrost and ground ice is based on the digital circum-arctic map of permafrost and ground ice conditions by the International Permafrost Association, re-gridded to the EASE-Grid format. About 22.79 million km-squared or 23.9% of the exposed land surface in the Northern Hemisphere is underlain by permafrost. On average, the maximum snow cover extent is about 47 million km squared or about 47% of the total land surface. The maximum seasonal frozen soil extent, determined as the 0 deg. C isotherm of mean January air temperature, is about 55 million km squared or 55% of the total land surface. Ground-based measurements indicate that soils at 5 cm depth experience freezing for at least two to three weeks when the mean monthly air temperature is at or near 0 degrees C. Soils at 5 cm depth experience freeze/thaw cycles even though the mean monthly air temperature is as high as 10 degrees C. The extent of seasonally frozen ground with freeze/thaw cycle greater than two weeks is determined using the 0 degrees C isotherm of the mean monthly air temperature obtained from surface air temperature climatology. The zone of mean monthly air temperature between 0 degrees C and 10 degrees C shown to indicate a potential freeze/thaw cycle of less than two weeks duration. In general, the freeze/thaw boundary is slightly further south than the snow cover extent in the North America and Europe while the snow cover extent retreats further north in Asia due to the strong impact of the monsoon climatic regime. Temporally, the freeze/thaw boundary is further south than the snow cover extent in autumn. During the period of spring snowmelt, the northward retreat of the snow cover extent lags behind the 0 degrees C isotherm of the mean monthly air temperature. Inter-annual and inter-decadal variations of the seasonally frozen ground and snow cover extent are discussed on regional and hemispheric scales.

Application of Satellite SAR Imagery in Mapping the Active Layer of Arctic Permafrost
(T. Zhang and S. Li, University of Alaska Fairbanks)

This project will map the active layer using SAR data in the Arctic and Subarctic, information on the timing of snow cover is required. For this purpose, we have used the AVHRR data to determine the surface snow-free period.

Spatial and temporal variations in surface albedo and the timing of snowmelt in northern Alaska has been investigated using ground-based measurements and 1.25 km Advanced Very High Resolution Radiometer (AVHRR) Polar Pathfinder Data set. Temporal variations in surface albedo was determined using a data set from nine tower sites with multiple years of data. Five distinct periods in surface albedo change can be distinguished: winter dry snow; pre-melting snow; melting snow; post-melting wet soil; and summer dry soil. These periods appear to be related to snow characteristics and surface soil moisture conditions in the region. Surface albedo could vary from >80% for winter dry snow surface to <10% for a post-melting wet soil surface, with the average value of about 20% for a relatively dry soil surface during summer. Surface albedo obtained from the ground-based measurements was used against values obtained from the AVHRR data under clear sky conditions. The results indicate that, overall, the AVHRR data can detect main patterns of seasonal surface albedo changes over the Arctic tundra. However, AVHRR data slightly overestimate dry snow surface albedo before snowmelt onset and underestimate the dry soil surface albedo during mid-summer. Both the ground based measurements and AVHRR data indicate that the most dramatic changes in surface albedo take place when snow melts in spring. Snow melting period is usually within one to two weeks at a given location but the timing of the snow melt period changes significantly from year to year. Spatially, snowmelt starts from the interior of the North Slope and expands gradually northwards to the Arctic Coast and southwards to the foothills

of the Brooks Range. The last day of snow on ground ranges from early May in the interior to mid-June along the coastal areas and to mid-July over the Brooks Range in 1995. These results are basically consistent with available ground-based measurements at the National Weather Service stations.

Changes in surface albedo and inter-annual variations in timing of the snow-melt period have a substantial impact on surface energy balance, thus on plant growth, thawing of the active layer, and on ecosystem as a whole. This study indicates that detailed field measurements and observations are needed for further validation of the algorithms used for investigating spatial and temporal variations in surface albedo and snowmelt in northern Alaska and the Arctic as a whole.

Thaw Lake Studies
(Martin O. Jeffries, Geophysical Institute, University of Alaska Fairbanks)

Thaw lakes occupy over 20% of the total area of the Alaskan North Slope region, and up to about 40% in the coastal plains. This value may increase due to expansion of the thaw lakes and creation of new lakes under global warming scenarios that predict that changes and impacts 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 with a 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 (bulk thaw) 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.

Investigation of the Seasonal Freeze/Thaw Cycles of Soils in the GCIP Region
(T. Zhang and R.L. Armstrong)

This newly funded NOAA project started in September, 2000. The goal is to map near-surface freeze/thaw cycle of soils using satellite passive microwave remote sensing data. Preliminary work has investigated the timing, duration, and areal extent of the near-surface soil freeze/thaw status were investigated using passive microwave satellite remote sensing data for the 1997/98 winter over the contiguous

United Sates. A frozen soil algorithm was validated using soil temperature data at 0 cm and 5 cm depths from more than 20 sites over the study area. Results indicated that a negative spectral gradient and a cut-off 37-GHz vertical polarized brightness temperature of 258.2K can be used to determine near-surface soil freeze/thaw status with confidence. The microwave freeze/thaw boundary generally agree with -5.0 derees C isotherm of air temperature although frozen soils occurred sporadically between 0 C and -5.0 degrees C isotherms. The maximum frozen soil area over snow-free land surface was about 3.75 million squared kilometer or about 37% of the total study area during the 1997/98 winter. The near-surface soils often froze before snow covered the land surface, but soil freeze/thaw status under snow cover cannot be detected using this microwave technique. The onset of soil freeze mainly occurred in October and November, while the last days of soil freeze occurred in March and April, resulting in the duration of soil freezing varying from five to seven months over the majority of the study areas. The number of days of surface soil freezing varied from several days to longer than five months.

Circumpolar Frozen Ground Conditions and Modeling Scenarios of Future Conditions (R.G. Barry, T. Zhang and D. Gilichinsky)

This collaborate study is part of a modeling study undertaken by Fritz Nelson (University of Delaware) and Oleg Anismov (State Hydrologic Institute, St. Petersburg). By the end of 2000, soil temperatures from the ground surface to 320 cm depth for about 140 Russian Meteorological Stations had been digitized from the published books and the digital data had been transferred to NSIDC. The monthly mean soil temperature data date back to the 1900s but most of them are from the 1930s and 1950s. The data sets also include soil freezing depth, timing and duration of frozen soils at various depths. A CD-ROM containing these soil temperature data will be released in spring 2001.

Using data described above and others, our study demonstrates that when changes in soil temperature are used as evidence of climatic warming, caution is required because changes in soil temperature are a combined product of changes in air temperature and precipitation, especially snowfall and snow cover on ground. Present findings of the surface warming of permafrost at high latitudes and ground warming at a certain depth below the ground surface elsewhere in the world could be fortuitous and may be misleading since air temperature alone cannot account for such a ground warming. It is safe to state that ground warming is evidence of climatic change (including both changes in air temperature, precipitation, and other climatic variables) rather than a simple increase in air temperature. A related paper addressing long-term changes at Irkutsk is in press in *Climate Change*.

STAFF

New employees

Rick Pitre	March 1, 2000	SSI&T Engineer
Fiona Lo	March 1, 2000	Associate Scientist II
Nick Suszczyk	March 21, 2000	Systems Administrator
Tom Elliot	April 1, 2000	Operations Technician
Laurie Schmidt	April 17, 2000	Science Writer III
Heidi Schumacher	May 30, 2000	Operations Technician
Nancy Auerbach	June 12, 2000	GIS Development Asst.
Alejandro Machado	October 9, 2000	User Services Rep
Feng Ling	December 20, 2000	Research Scientist

Promotions

Melinda Marquis	March 1, 2000	IceSat/GLAS Data Mgt Tm Ld
I-Pin Wang	April 1, 2000	Database Administrator, ASII
Ann Bessenbacher	April 1, 2000	Operations Supervisor
Laura Cheshire	April 1, 2000	Associate Scientist II
Martyn Clark	April 1, 2000	Research Scientist II
Allan Frei	April 1, 2000	Research Scientist II
Anne Nolin	April 1, 2000	Research Scientist III
Jason Wolfe	April 24, 2000	Science Writer I
Robin Welsh	May 1, 2000	Writer II
Tom Priestley:	June 1, 2000	Sr. Unix Systems Administrator
Marianne Primett:	June 1, 2000	Sr. Operations Technician
Tingjun Zhang	June 1, 2000	EOS Science Data Coordinator

Departures

Rachel Hauser	February 11, 2000	Scientific Writer
Renea Ericson	February 18, 2000	Operations Supervisor
Beth Sigren	March 6, 2000	Associate Scientist
Virginia Duffy	August 3, 2000	User Services Rep
Spencer Shiotani	August 18, 2000	Software Engineer
Mike Chhor	October 23, 2000	Operations Technician
Derek van Westrum	November 30, 2000	Scientific Programmer
John Pyle	December 12, 2000	Web Administrator

VISITORS

Dr. Jonathan Bamber, University of Bristol, England, visiting scientist, 10 July 2000 - 6 October 2000.

Dr. Olga Solomina, Institute of Geography, Russian Academy of Sciences, Moscow, Fulbright Fellow, 15 August 2000 - 30 March 2001.

Dr. Sergei Sokratov, CIRES Visiting Fellow, 15 November 1999 - 15 February 2001.

Dr. Andreas Kaab, visiting scientist on GLIMS database system, 28 November 2000 - 6 December 2000.

Dr. Daniel Bedford, Middlebury College, visiting scientist, 15 September 2000 - May 2000.

CRYOSPHERIC AND POLAR PROCESSES DIVISION SEMINARS

Friday, September 1
Dr. Jonathan Bamber
Geographical Sciences, University of Bristol
"A new (?) interpretation of ice sheet dynamics and implications for response times to climate forcing"

Friday, November 10
Dr. Susan Solomon
NOAA
"The Coldest March of Robert Falcon Scott"

Friday, November 17
Dr. Ola Persson
CIRES/NOAA/ETL
"Measurements of the Surface Energy Budget on Multi-year Ice at SHEBA"

Friday, 21 January
Dr. Martin Miles
Department of Geography, University of Bergen, Norway
"Time Scales of Arctic Sea Ice and Climate Variability"

Wednesday, 16 February
Dr. David Robinson
Rutgers University, New Brunswick
"Snow cover and climate change detection."

Friday, 18 February
Andrew Slater
CIRES
"Representation of Snow in Land Surface Schemes".

Friday, 3 March
Prof. Dr. Ute C. Herzfeld
Geomathematik, Universitaet Trier, Germany
"Geostatistical methods for mapping snow and ice surfaces at centimeter to continental scale"

Friday, 17 March
Dr. Lauren Hay
Hydrologist, USGS
"Hydrological Responses to Dynamically and Statistically Downscaled GCM Output"

Friday, 28 April
Dr. Marika Holland
Postdoctoral, Advance studies program, NCAR
“Modelling Studies of Arctic Sea Ice”

Friday, 12 May
Mark Dyurgerov
Research Scientist at INSTAAR
“Present Day Glacier Regime and Perspective for Forecast”

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 Commission on Snow and Ice (ICSI) Snow and Climate Working Group - R. L. Armstrong, Chairman

International Ice Charting Working Group - F. Fetterer

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

International Satellite Land Surface Climatology 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

U.S. Canada-Joint Ice Working Group - F. Fetterer

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

WCRP-Arctic Climate System/Climate and Cryosphere Scientific Steering Group - R. G. Barry, Co-chair

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/Clic Scientific Steering Group, First Session, Kiel, Germany, October 2000, (R.G. Barry, Co-Vice Chair)

All World Data Center Conference, National Climatic Data Center, Asheville, NC, 6-8 November 2000, (F. Fetterer)

American Geophysical Union (AGU) Fall Meeting, San Francisco, CA, December 2000, (R. Barry, F. Fetterer, A. W. Nolin, T. Scambos, G. Scharfen, J. C. Stroeve, R. Weaver, T-J. Zhang)

Arctic Climate Impact Assessment Scoping Workshop, U.S. Dept. of Commerce, Washington, DC, 28 Feb.-1 Mar 2000, (F. Fetterer)

CRYSYS, Winnepeg, Canada, 4-7 March 2000, (R. Dichtl and G. Scharfen)

Global Surveyor Workshop, June 2000, (A. W. Nolin)

Hydrology 2000, Santa Fe, 2-7 April 2000, NM (A. Armstrong, A. Barrett, G.Scharfen, A. Varani)

Ice Core Working Group Meeting, Denver CO, 7-8 June 2000 (R. Bauer)

IGARSS 2000, Honolulu HI, 24-28 July 2000 (R. Armstrong, T. T. Hybl, S. J. S. Khalsa, T. Scambos, G. Scharfen, A. Varani, T. Zhang)

International Trans-Antarctic Expedition (ITASE) meeting, Arlington VA, 28-29 February 2000 (G. Scharfen, R. Bauer)

International Union of Geophysics, Geodetics General Assembly, Birmingham, UK, July 1999, (R. Weaver)

Mapping and Archiving Sea Ice Data: The Expanding Role of Radar, Government Conference Centre, Ottawa, Canada, 2-4 May 2000, (F. Fetterer)

MISR Meeting, location, 11-13 December 2000, (J. Stroeve)

MODIS Science Team and MODIS Land Group meetings, Columbia, MD, 7-8 June2000 (G. Scharfen, S.J.S. Khalsa, B. McLean)

NOAA Arctic Strategy Meeting, David Skaggs Research Center, Boulder, CO, 15 November 2000.

Polar DAAC User Working Group (PoDAG), National Ice Center, Washington D.C., 25-27 September 2000 (R. Weaver, J. Stroeve, M. Parsons, M. Holm)

SCAR COMNAP Joint Committee on Antarctic Data Management, Tokyo, Japan, 10-14 June 2000, (G. Scharfen, R. Bauer)

Second Annual International Ice Charting Working Group (IICWG) Meeting, Icelandic Meteorological Office, Reykjavik, 3-5 October 2000 (F. Fetter)

Seventh Annual Western Antarctic Ice Sheet Initiative (WAIS) workshop, Sterling, VA, 16-18 September 2000, (T. Scambos, R. Bauer)

Steering Group for the WMO Project Global Digital Sea Ice Data Bank (GDSIDB), Canadian Ice Service/ Environment Canada, 30 April - 1 May 2000, (F. Fetterer)

Submarine Sonar Data Providers Workshop, National Snow and Ice Data Center (NSIDC), CIRES, University of Colorado, Boulder, on 6-8 September 2000 (F. Fetterer)

WMO Global Digital Sea Ice Data Bank Working Group, Seventh Session, Ottawa, 2000, (R.G. Barry Co-Chair, F. Fetterer)

PUBLICATIONS

Armstrong, R. L. and **M. J. Brodzik**. 2000. Validation of passive microwave snow algorithms, In: Remote Sensing and Hydrology 2000, *IAHS Pub. No. 267*, eds. M. Owe, K. Brubaker, J. Ritchie and A. Rango, in press.

Barrett, A. P., **A. W. Nolin**, **M. P. Clark**, G. H. Leavesley, and R. L. Viger. 2000. A comparison of satellite derived and modeled snow covered area for a mountain drainage basin. In: Remote sensing and Hydrology 2000, *IAHS Publ*., eds. M. Owe and K. Brubaker, in press.

Barrett, A., **A. W. Nolin**, and **M. P. Clark**. 2000. A comparison of satellite- and model-derived snow covered area of a mountain watershed. *IAHS Publ.* no. 267, in press.

Barry , R. G. 2000. Data on the geographical distribution of sea ice. In F. Tanis and V. Smolianitsky (eds). *Atlas Climatology Project Environmental Working Group. Joint U.S.-Russian Atlas of Arctic Sea Ice.* NSIDC, Boulder, CO. CD-ROM.

Barry, R. G. and **M. C. Serreze**. 2000. Atmospheric components of the Arctic ocean freshwater balance and their interannual variability. In E.L. Lewis et al. (eds.) *The Freshwater Budget of the Arctic Ocean*. Kluwer Academic Publ.: 45-56.

Barry, R. G., **T. Zhang,** and D. Gilichinsky. 2000. Cycling of soil temperatures in the Russian Arctic. *Abstracts. Rhythms of Natural Processes in the Earth Cryosphere.* Pushchino. Consolidated Scientific Council on Earth Cryology, Russian Academy of Sciences, 220.

Barry, R. G. and A. Seimon, A. 2000. Research for Mountain Area Development: Climate fluctuations in the mountains of the Americas and their significance. *Ambio* 29(7): 364-370.

Barry, R. G., I. Allison, and H. Cattle. 2000. The WCRP Climate and Cryosphere (CliC) Initiative. *Abstracts. Rhythms of Natural Processes in the Earth Cryosphere*, Pushchino., Russia. Consolidated Scientific Council on Earth Cryology, Russian Academy of Sciences, 201-202.

Bauer, R. J., **T. A. Scambos**, **G. R. Scharfen**, C. M. Eakin, and D. M. Anderson. 2000. The Ice Core Data Gateway: ice core data access via the World Wide Web. *Eos* 81(48): F403.

Bauer, R., **T. Scambos**, and **G. Scharfen**. 2000. U. S. Antarctic Glaciological Program Data Management. *EOS* 81(19): S22.

Clark, M. P. and **M. C. Serreze**. 2000. Effects of variations in East Asian snow cover on modulating atmospheric circulation over the North Pacific Ocean. *J. Climate* 13: 3700-3710.

Clark, M. P. and L. E. Hay. 2000. Use of atmospheric forecasts in hydrologic models. Part One: Errors in output from the NCEP Atmospheric forecast model. *Proceedings of the AWRA Spring Specialty Conference on Water Resources in Extreme Environments*, 215-220.

Cullather, R.I., D.H. Bromwich and **M.C. Serreze**. 2000. The atmospheric hydrologic cycle in the Arctic basin from reanalyses Part I. Comparison with observations and precious studies. *J. Climate* 13: 923-937.

Dick, C. A. L., I. Allison, B. Goodison, and **R. G. Barry.** 2000. Climate and Cryosphere (CliC): The World Climate Research Programme initiative for investigation of the role of the cryosphere in global climate. *EOS Suppl.* 81(48): F416-417.

Eakin, C. M., D. M. Anderson, **R. J. Bauer**, **G. R. Scharfen**, and **T. A. Scambos**. 2000. New Ice Core Data Gateway. *Eos* 81(48): F598.

Fahnestock, M. A., **T. A. Scambos**, R. A. Bindschadler, and G. Kvaran. 2000. A millennium of variable ice flow recorded on the Ross Ice Shelf, Antarctica. *Journal of Glaciology* 46 (155): 652-664.

Fahnestock, M. A., **T. A. Scambos**, C. A. Shuman, R. J. Arthern, D. P. Winebrenner, and R. Kwok. 2000. Snow 'mega-dune' fields on the East Antarctic plateau: extreme atmosphere-ice interaction. *Geophysical Research Letters* 27(22): 3719-3722.

Fetterer, F. 2000. An Overview of Sea Ice Data Sets at NSIDC. Proceedings of a Workshop onMapping and Archiving of Sea Ice Data - The Expanding Role of Radar, Ottawa,Canada, 2-4 May. *World Meteorological Organization JCOMM Technical Report No. 7*: 225-230.

Fleming, M. D., F. S. Chapin III, W. Cramer, G. L. Hufford, and **M. C. Serreze**. 2000. Geographic patterns of Alaskan climate interpolated from a sparse station record. *Global Change Biology*, 6: 49-58.

Gilichinsky, D. A., S. S. Bykhovets, V. A. Sorikov, D. G. Federov-Davydov, **R. G. Barry**, **T.-J. Zhang**, M. K. Gavrilova, and O. I. Alexander. 2000. Use of the data of hydrometeorological survey for century history of soil temperature trends in the seasonally frozen and permafrost areas of Russia. *Kriosfer i Zemli* 4(3): 59-60. (in Russian).

Haeberli, W., J. Cihlar, and **R. G. Barry**. 2000. Glacier monitoring within the Global Climate Observing System. *Annals Glaciol.* 31: 241-246.

Hall, Dorothy K., George A. Riggs, Vincent V. Salomonson, **Greg R. Scharfen**. 2000. Early Results from the Moderate Resolution Imaging Spectroradiometer (MODIS) Global Snow and Ice Cover Products. *Proceedings of the International Geoscience and Remote Sensing Symposium (IGARSS 2000).*

Haran, T., and **T. A. Scambos**. 2000. A new image-enhanced DEM of the Greenland Ice Sheet. *Eos* 81(48): F439.

Hay, L. E. and **M. P Clark**. 2000. Use of atmospheric forecasts in hydrologic models. Part Two: Case Study. *Proceedings of the AWRA Spring Specialty Conference on Water Resources in Extreme Environments*, 221-226.

Hulbe, T., and **T. A. Scambos**. 2000. A reassessment of the climatic stability limit of ice shelves and implications for the northeastern Ross Ice Shelf. *Eos* 81(48): F391.

Holm, M., **B. McLean**, **F. Fetterer**, **G. Scharfen**. 2000. River and Lake Ice Data Sets Available from the National Snow and Ice Data Center. *EOS* 81(48): F429.

Jacobel, R. W., **T. A. Scambos**, N. A. Nereson, and C. F. Raymond. 2000. Changes in the margin of ice stream C, Antarctica. *Journal of Glaciology* 46(152): 102-110.

Kahl, J. D., N. A. Zaitseva, V. Khattatov, R. C. Schnell, D. M. Bacon, J. Bacon, V. Radionov and **M. C. Serreze**. 1999. Radiosonde observations from the former Soviet Union "North Pole" series of drifting ice stations, 1954-90. *Bull. Amer. Meteor. Soc.* 80: 2019-2026.

Kargel, J., H. Kieffer, **R. Barry**, M. Bishop, D. Mackinnon, **B. Raup**, J. Shroder, **G. Sharfen**, **V. Troisi**. 2000. Worldwide Glacier Observations Planned by ASTER. *EOS* 81(19): S143.

Kargel, J.S., H. H. Kieffer, **R. Barry**, M. Bishop, D. MacKinnon, K. Mullins, **B. Raup**, **G. Scharfen**, J. Schroder, and R. Wessels. 2000. Initial glacier images from ASTER and test analysis for GLIMS. *EOS* 81(48): F548.

Kieffer, H., J. Kargel, **R. G. Barry**, and 39 others. 2000. New eyes in the sky measure glaciers and ice sheets. *EOS* 81(24): 265, 270-71.

Lazzara, M. A., K. C. Jezek, **T. A. Scambos**, D. R. MacAyeal, C. J. van der Veen. 1999. On the recent calving of icebergs from the Ross Ice Shelf. *Polar Geography* 23(3): 201-212.

Liang, S., **J. Stroeve**, I. Grant, A. Strahler and J. Duvel. 2000. Angular corrections to satellite data for estimating Earth radiation budget. *Remote Sensing Reviews* 18: 103-136.

Liu Feng-jing, Sun Jun-ying, **Tingjun Zhang**, and Cheng Gou-dong. 2000. Characteristics of surface radiative fluxes and cloud-radiative forcing with a focus on the Arctic. *Journal of Glaciology and Geocryology* 22: 384-390.

Magnuson, J. D., and 18 others/inc. **R. G. Barry**. 2000. Historical trends in lake and river ice cover in the Northern Hemisphere. *Science*, 289(5485): 1743-46.

Maslanik, J. A., A. H. Lynch, **M. C. Serreze** and W. Wu, 2000. A case study of regional climate anomalies in the Arctic: Performance requirements for a coupled model. *J. Climate* 13: 383-401.

McLean, B., **M. Holm**, **G. Scharfen**, **S. Khalsa**, **T. Hybl**. 2000. Remote Sensing Data Sets for Monitoring Snow Extent. *EOS* 81(48): F397.

McGuire, A. D., J. S. Clein-Curley, J. M. Melillo, D. W. Kicklighter, R. A. Meier, C. J. Vorosmarty and **M. C. Serreze**, 2000. Modeling carbon responses of tundra ecosystems to historical and projected climate: Sensitivity of the pan-Arctic carbon storage to temporal and spatial variation in climate. *Global Change Biology* 6: 141-159.

Nolin, A. W., **J. C. Stroeve**, **F. Fetterer**, and **T. Scambos**. 2000. Applications of Multiangle Imaging Spectro-Radiometer (MISR) data for snow and ice mappings: case studies. *Eos* 81(48): F549.

Nolin, A. W. and J. Dozier. 2000. A hyperspectral method for remotely sensing the grain size of snow, *Remote Sens. Environ*. 74: 207-216.

Nolin, A. W. and S. Liang. 2000. Progress in bidirectional reflectance modeling and applications for surface particulate media: Snow and soils. In: S. Liang and A.H. Strahler (Eds.) *Land Surface Bidirectional Reflectance Distribution Function (BRDF): Recent Advances and Future Prospects, Remote Sensing Reviews*, 18, 307-342.

Scambos, T. A., C. Hulbe, M. A. Fahnestock, and J. A. Bohlander. 2000. The link between climate warming and ice shelf breakups in the Antarctica Peninsula. *Journal of Glaciology* 54(154): 516-530.

Scambos, T., K. Jezek, H-Y. Sohn, and M. Fahnestock. 2000. New surface features of the Antarctic ice sheet from radar and visible-NIR mapping. *Proceedings of the International Geoscience and Remote Sensing Symposium (IGARSS 2000)*.

Scharfen, Greg R., Dorothy K. Hall, **Siri Jodha Singh Khalsa**, **Jason D. Wolfe**, **Melinda C. Marquis**, George A. Riggs, **Brad McLean.** 2000. Accessing the MODIS Snow and Ice Products at the NSIDC DAAC. *Proceedings of the International Geoscience and Remote Sensing Symposium (IGARSS 2000)*.

Scharfen, G., **R. Bauer**, **T. Scambos**. 2000. Ice Core Data Management at the Antarctic Glaciological Data Center, bibl. *Agenda and Abstracts of The West Antarctic Ice Sheet Initiative Seventh Annual Workshop*, Sterling, VA, September 2000, Conference Proceedings.

Scharfen, G. , **R. Bauer.** 2000. Meeting the NSF Office of Polar Programs Data Policy Requirements, Support for Principal Investigators from the U. S Antarctic Data Coordination Center. *EOS* 81(48): F440.

Serreze, M. C. and **Barry, R. G.** 2000. Atmospheric components of the Arctic ocean hydrologic budget assessed from rawinsonde data. In E.L. Lewis, et al. (eds.) *The Freshwater Budget of the Arctic Ocean*, Kluwer Academic Publ.: 151-61.

Serreze, M. C., J. E. Walsh, F. S. Chapin III, T. Osterkamp, M. Dyurgerov, V. Romanovsky, W. C. Oechel, J. Morison, **T. Zhang**, and **R. G. Barry**. 2000. Observational evidence of recent change in the northern high latitude environment. *Climatic Change* 46: 159-207

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

Sokratov, S. and **R. G. Barry.** 2000. Variations of the thermal insulating properties of snow cover during the winter season. *EOS Suppl*. 81(48): F446.

Solomina, O. N., **R. G. Barry**, and M. A. Bodnya, 2000. Retreat of Tien Shan glaciers (Kirgiz Republic) since the Little Ice Age estimated by remote sensing, lichenometric and historical data. *EOS Suppl.* 81(48): F403.

Tait, A. B., D. K. Hall, D.K. and **R. L. Armstrong.** 2000. Utilizing Multiple Datasets for Snow-Cover Mapping. *Remote Sensing of Environment* Vol. 72 (1):111.

Weaver, R. L. S., K. Steffen, J. Heinrichs, **J. A. Maslanik**, G. M. Flato. 2000. Data assimilation in sea-ice monitoring. *Annals of Glaciology* 31: 327-332.

Wilby, R. L., L. E. Hay, W. J. Gutowski (Jr.), R. W. Arritt, E. S. Takle, Z. Pan, G. H. Leavesley, and **M. P. Clark**. 2000. Hydrologic responses to dynamically and statistically downscaled General Circulation Model output. *Geophysical Research Letters* 27: 1199-1202.

Wolfe, J., **V. Troisi**, **R. Swick**. 2000. The Pathfinder GISMO: A Web-based Interface for Accessing Polar Pathfinder Data. *Proceedings of the Sixth International Conference, Remote Sensing for Marine and Coastal Environments*. II: 209-213.

Wolfe, J., **T. Thrasher Hybl**, **T. Scambos**. 2000. Polar ice sheet DEMs and topographic data available from the National Snow and Ice Data Center. *Proceedings of the International Geoscience and Remote Sensing Symposium (IGARSS) 2000 Proceedings* 2: 506-508.

Zhang, T. 2000. Frozen ground: soil moisture in solid state in cold regions/cold seasons. *GEWEX/BAHC International Workshop on Soil Moisture Monitoring, Analysis and Prediction for Hydrometeorological and Hydroclimatological Applications*. University of Oklahoma, Norman, Oklahoma, USA, 16-18 May 2000.

Zhang, T., M.O. Jeffries. 2000. Modeling interdecadal variations of lake-ice thickness and sensitivity to climatic change in northernmost Alaska. *Annals Glaciol.* 31: 339-347.

Zhang, T. and **R. G. Barry**. 2000. Promises and problems of inferring the climatic change signals from geothermal gradients. *The 30th Arctic Workshop, March 16-18, 2000, Institute of Arctic and Alpine Research*, University of Colorado.

Zhang, T., **T. Haran**, and **T. Scambos**. 2000. Spatial and temporal variations of surface albedo and snowmelt in northern Alaska using AVHRR Polar Pathfinder datasets. *Proceedings of the International Geoscience and Remote Sensing Symposium (IGARSS 2000)*.

ACRONYMS

AARI	Arctic and Antarctic Research Institute (St. Petersburg)
ACSYS	Arctic Climate System (WCRP)
ADCC	ARCCS Data Coordination Center
ADD	Arctic Data Directory
ADEOS-II	Advanced Earth Observing Satellite-II
AGDC	Antarctic Glaciological Data Center
AGU	American Geophysical Union
AMD	Antarctic Master Directory
AMIP-II	Atmospheric Model Intercomparison Project II
AMSR	Advanced Microwave Scanning Radiometer
AMSR-E	Advanced Microwave Scanning Radiometer - Earth Observing System
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
ESDIS	Earth System Data and Information Service
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
ICESat	Ice, Cloud, and land Elevation Satellite
JCADM	Joint Committee on Antarctic Data Management
JPL	Jet Propulsion Laboratory
LAII	Land Atmosphere Ice Interactions (ARCSS)
LIGG	Lanzhou Institute of Glaciology and Geocryology

MISR	Multi-angle Imaging SpectroRadiometer
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
NOSE	Nominal Orbital Spatial Extent
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
SSMIS	Special Sensor Microwave Imager Sounder
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