IP42A MC: Hall D Thursday 1330h

Monitoring an Evolving Cryosphere: The 25th Anniversary of the National Snow and Ice Data Center IV *(joint with A, H, OS, GC)*

Presiding: **J Stroeve,** CIRES/NSIDC; **R Armstrong,** CIRES/NSIDC

IP42A-0684 1330h POSTER

Arctic Ocean Snow Melt Onset Dates Derived from Passive Microwave, a New Data Set

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Physically, the timing of snow melt onset is important because surface energy absorption increases rapidly at snow melt onset, owning to variations in surface albedo. The change in surface albedo greatly influences the surface energy budget. Therefore, monitoring the energy budget over a period of time is useful for detecting climate change, validating climate models and accurately modeling surface conditions. Snow melt onset is defined as the point in time when the liquid water appears in the snow pack and changes the crystalline structure within the pack. Microwave emission changes rapidly when liquid water appears in the snow pack, allowing passive microwave remote sensing to be used to monitor melt onset. Passive microwave satellite data from the Scanning Multichannel Microwave Radiometer (SMMR) and the Special Sensor Microwave/Imager (SSM/I) are indispensable for this task because they represent an all-season, all-weather, diurnally consistent, and reasonably continuous data set for more than 20 years in length (1979-1998). The microwave data time series is created from a blended brightness temperature record generated from different satellite platforms through linear regression analysis to ensure consistency in the data set. The melt onset date is calculated by monitoring the difference between the 18 (SMMR) or 19 (SSM/I) GHz horizontal brightness temperatures and 37 GHz horizontal brightness temperatures. Results indicate both regional and annual variations exist in the melt onset dates. The melt onset dates are generated annually and will be available vis CD-ROM from the National Snow and Ice Data Center (NSIDC). This new data set provides a valuable addition to researchers for seasonal-to-interannual and long term climate studies and it is hoped that others will find the data set useful

IP42A-0685 1330h POSTER

On the relationship between atmospheric circulation and the Cosmonaut Sea polynya

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The Cosmonaut Sea of Antarctica contains an annually recurring polynya characterized by a succession of open and closed phases generally occurring between July and October (i.e., the austral winter months). In its open phase, reduced sea ice concentration of 30-40% ice cover is evident relative to the 80-90% cover in the surrounding pack ice. The Cosmonaut Sea has been theorized to be a "sensible heat polynya" in which oceanic upwelling is responsible for formation and maintainance. However, recent modeling work by Bailey (2000) shows that, once a threshold oceanic heat flux is prescribed, the opening and closing of the polynya (i.e., ice divergence) is correlated with low level atmospheric divergence. In this study, we explore this hypothesis using satellite-derived observations of sea ice cover and ice motion (derived from SSM/I), surface temperature (from AVHRR), and ECMWF reanalysis fields (sea level pressure, geopotential, and wind motion). These data are analyzed to identify relationships between atmospheric and ice/ocean surface characteristics in the Cosmonaut Sea region. In particular, a survey of the frequency and strength of the passage of low pressure systems over the region and their relation to the polynya's existence is also investigated.

IP42A-0686 1330h POSTER

Where has the ice Gone? Rapid Thinning of Arctic sea ice in the Western Arctic Ocean

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Examination of springtime ice drafts obtained from submarine profiles in a narrow band of the western Arctic Ocean from offshore Alaska to 89 N indicates that the mean ice draft decreased 1.5 m between the mid-1980s and early 1990s. No similar trend was evident in ice drafts located near the North Pole. The 1980s drafts were composed largely of ice exceeding 3.5 m, while the early 1990s drafts contained more ice in thinner categories. The differences in drafts between the two periods appear to be related largely to ice dynamics effects associated with the presence and strength of the Beaufort Gyre, which weakened considerably in the early 1990s. The strength of the Arctic anticyclone which dominates the Beaufort Gyre ice circulation and influences the ice thickness is reflected in the indices of the Arctic Oscillation and North Atlantic Oscillation.

IP42A-0687 1330h POSTER

Processing of Ice Draft Measurements From Submarine Upward Looking Sonar

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In the last several years the US Navy has agreed to release data on ice draft taken using submarine-mounted upward looking sonar. This data spans more than 40 years, from 1957 to present, and represents a significant resource for climate researchers. Currently, the data are being processed by the Navy's Arctic Submarine Lab, the Applied Physics Lab at the University of Washington and the Cold Regions Research and Engineering Lab. After processing, data are sent to the National Snow and Ice Data Center, where they are permanently archived and made available on-line.

Potential users of the data should be aware of several issues, i) processing methods, ii) data release requirements, iii) temporal and spatial coverage of the data, and iv) statistical products and potential uses of the data. The data are in two distinct forms, digital and paper record. Each form presents unique processing issues. Additionally, certain aspects of the original data are classified and particular steps are necessary to produce publicly releasable products. The data covers much of the Arctic basin and all seasons over 40+ years but the spatial and temporal coverage is not uniform. Finally, derived statistics can be used for research such as climate simulations, studies of long term changes in ice thickness, ice pack dynamics and thermodynamics.

IP42A-0688 1330h POSTER

A Practical Method for Long-Range Forecasting of Sea Ice Conditions in the Beaufort Sea

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An alarming feature noted in many climate models is the rapid and pronounced loss of Arctic sea ice due to poleward amplification of warming. Within the Beaufort Sea, changes in summer ice conditions are a particular concern because they affect the subsistence lifestyle of Alaskan North Slope residents (by altering wildlife habitats) and the fossil fuel industry (through altering the duration of the summer shipping season). An objective prediction of summer ice conditions months in advance therefore could assist residents and industries along the Alaskan North Slope react to potential changes in ice conditions. Utilizing monthly averaged low-frequency atmospheric teleconnection indices and multiyear sea ice concentrations, a statistical forecasting system is developed to predict ice severity monthly in the Beaufort Sea, from October of the preceding year through to June of the prediction year. Variations in the October predictors explain 68% of the variability in ice severity of the next year, and the proportion of variance explained increases to 93% using June predictors. Generally, light (heavy) ice years are related to reduced (increased) total ice extent and multiyear ice concentrations, and low frequency teleconnection patterns that increase (decrease) offshore wind flow. Temperature variations exert little influence over ice conditions.

IP42A-0689 1330h POSTER

Near-Real Time Microwave Sea Ice Products for Operational Sea Ice Analysis

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The U.S. National Ice Center (NIC) provides operational ice analyses for all ice-covered regions. These analyses are created from available high and low resolution imagery (including AVHRR, OLS, and Radarsat), reconnaissance data, ice forecasts, and climatology. Recently, the NIC has transitioned from weekly analyses to bi-weekly analyses for the Arctic and Antarctic.

Daily operational SSM/I ice concentration products supplement these bi-weekly analyses. The product in the Arctic is from the NIC Hybrid Algorithm, a combination of the NASA Team algorithm, the NASA Team Thin Ice algorithm, and the Cal/Val algorithm. The Antarctic product employs the enhanced NASA Team (NT2) algorithm. In addition to these two operational algorithms, a variety of experimental products are posted daily on the NIC Science Web Page (http://www.natice.noaa.gov/science/). These include several other SSM/I concentration products (e.g., original NASA Team, Bootstrap, Cal/Val), a QuikScat ice coverage product, and sea ice concentration forecasts (from 1 to 5 days). Additional products are also planned, including an ice motion product and an SSM/I 85-GHz channel ice extent product.

The goal of these experimental products is to provide improved operational ice analyses more efficiently. Here we present examples of the NIC products as well as the latest results from ongoing evaluation studies. These products are consistent with and complementary to the NSIDC sea ice products, but the focus is on the NIC mission of operational support.

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IP42A-0690 1330h POSTER

Post-processing of Bi-directional Reflectance Distribution Function Measurements of Summer Sea ice in the Southern Ocean

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Surface spectral Bi-directional reflectance distribution function (BRDF) is a fundamental surface property in radiation interaction with the atmosphere-earth surface system. However, spectral BRDF values directly measured in the field even under clear skies are often not BRDF in true sense. They are actually directional spectral reflectance measurements under given surface and sky conditions. Several factors can cause substantial departure of the direct measurements from the true BRDF values. Measurements made through scanning through the surface at various viewing zenith and azimuth angles on a tripod are impacted by errors caused by spatial variation of surface reflectance because the sensor does not view the same portion of the surface during the scanning. The measurement can be also biased if the actual spectral reflectance (or albedo) values of a reference Lambertian panel differ from their nominal values due to tarnish of the panel. Finally, strong diffuse sky radiation in the UV, violet and blue

wavelength makes the beam assumption in the BRDF measurement a poor approximation.

To reduce the errors caused by those factors, post-processing is conducted for the summer sea ice BRDF measured during our Southern Ocean cruises in 2000 and 2001. The post-processing includes three steps: smoothing raw data, calibrating spectral albedo of the reference panel, and removing the impact of diffuse radiation. Smoothing directional spectral reflectance by averaging measurements made at adjacent viewing zenith and azimuth angles can help reduce the error caused by surface heterogeneity. Based on the relationship between directional spectral reflectance and spectral albedo, the smoothed directional spectral reflectance values are integrated over the hemisphere and the results are compared with surface spectral albedo measurements. Because the spectral albedo values were derived independently from upward and downward spectral irradiance directly measured from a same flux sensor, they are not influenced by the possible errors of the spectral albedo values of the reference panel. As a matter of fact, the actual spectral albedo values of the reference panel are calibrated by comparison of the hemispherical integrals of the directional spectral reflectance values of the surface with the flux-derived spectral albedo values. The resulting spectral albedo values of the reference panel are used for further calibration of the directional spectral reflectance of the sea ice surface. Finally, the clear sky downward spectral irradiance measurements made without and with shading to the flux sensor are used to separate direct and diffuse spectral irradiance from the total spectral irradiance. The resulting proportions of diffuse radiation are combined with directional spectral reflectance measurements made under overcast conditions to remove the impact of diffuse radiation on BRDF. The resulting BRDF patterns are compared with direct measurements.

IP42A-0691 1330h POSTER

Spatial and temporal variability of Arctic summer sea-ice albedo and its dependence on meltwater hydraulics

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Next to ice extent and thickness, the area-averaged albedo of the summer sea-ice cover is a key parameter in determining the large-scale heat exchange over the Arctic Ocean. Various remote sensing applications have yielded a substantial data base for the former two parameters, not least due to the efforts of the National Snow and Ice Data Center (NSIDC) over the past 25 years. In contrast, the spatial and temporal variability of Arctic summer sea-ice albedo is much less well described. Despite its importance (incl. for ice-albedo feedback processes), few if any large-scale sea-ice and global circulation models actually predict summer ice based on the underlying physical processes. Most models employ simple parameterization schemes instead. Remote sensing of surface ice albedo also faces substantial challenges, some of which still need to be addressed in more detail.

Here, we report on albedo measurements completed over first- and multi-year sea ice in the summers of 1998, 2000 and 2001 in the North American at the SHEBA drifting ice camp and in fast ice near Barrow, Alaska. As has been established in a number of studies, spatial and temporal variability in summer sea-ice albedo is mostly determined by the areal extent of meltwater ponding at the ice surface. Given the importance of this process, a comprehensive ice hydrological program (meltwater distribution, surface topography, meltwater flow and discharge, ice permeability) has been carried out in conjunction with the optical measurements. Measurements demonstrate that Arctic summer sea-ice albedo is critically dependent on the hydrology of surface melt ponds, as controlled by meltwater production rate, ice permeability and topography. Both, remarkable short-term variability (a reduction of albedo by 43% within two days) as well as the seasonal evolution of the pond fraction and hence area-averaged albedo are forced by changes in pond water level on the order of a few centimeters. While some of these forcing functions may be difficult or impossible to represent in large-scale models, simulations with a simple hydrological model capture the essential features and variability in pond fractions and depth, identifying a promising alternative path towards predicting rather than prescribing ice albedo in numerical simulations. This work also underscores the importance of interannual variability in ice albedo for the large-scale energy exchange over the Arctic Ocean.

IP42A-0692 1330h POSTER

The Seasonal Evolution of Albedo in a Snow-ice-land-ocean Environment

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As part of a program studying arctic coastal processes, we investigated the ice-albedo feedback in a land-ice-ocean regime near Barrow Alaska. For the past two years from April through June, spectral and wavelength-integrated albedos were measured along 200-m survey lines. These lines were installed at four sites and included sea ice, lagoon ice, fresh ice, and tundra. Initially all sites were completely snow-covered and the albedo was high (0.8-0.9) and spatially uniform. As the melt season progressed, albedos decreased at all sites. The decrease was greatest and most rapid at the tundra site, where the albedo dropped from 0.8 to 0.15 in only two weeks. The spectral signature also changed as the wavelength of maximum albedo at the tundra site shifted from 500 nm for snow to 1100 nm for tundra. As the snow cover melted on undeformed first year ice, there was rapid and extensive ponding resulting in a decrease of the spatially averaged, wavelength-integrated albedo from 0.6 to 0.2 in only five days. Extensive pond drainage and below freezing temperatures caused the albedo to rebound briefly to 0.55 before resuming a steady decrease. Comparision of these results to data collected in the Central Arctic indicated that albedos of fast ice in the coastal regime decreased more rapidly than pack ice albedos.

IP42A-0693 1330h POSTER

Revisiting the fast-ice regimes of the Chukchi and Beaufort Seas 25 years on

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The landfast ice environment of Arctic Alaska extends from the shoreline to the inshore boundary of the shear zone where it interacts with the drifting pack ice. Processes within the landfast ice zone are important for both scientific and engineering considerations since it serves as habitat for some marine mammals and birds, and is the site of current and planned activities related to the exploration and production of hydrocarbons. In addition, ice interaction in the shear zone is a boundary condition for pack ice motion and deformation which is important for dynamic and thermodynamic models of ice growth, decay and deformation that are used in climatology studies. Finally, since the characteristics of the landfast ice depend primarily on the local climatic and oceanographic conditions, it is potentially useful for monitoring the effects of climate change.

Barry et al. (1979) used imagery from the ERTS-1 satellite system from 1973 to 1976 along with meteorologic data to describe the ice cycle of the landfast ice on the Arctic coast of Alaska and its implications for offshore development. Shapiro and Metzner (1989) and Shapiro and Barnes (1991) described the annual cycle and physical characteristics of the landfast ice in the Barrow, Alaska area for the years 1974-80, primarily from surface observations and data from a shore-based radar system. These two studies, along with other data availble from NSIDC provide a baseline for comparison with our studies in progress.

Here, we use data from AVHRR and ground-truth for 1998-2001 in the vicinity of Barrow, Alaska for comparison with the earlier studies. In general, the fast ice in these three years formed later than was the case in the earlier studies, but was similar in terms of break up, mean ice-thickness and fast ice extent. However, it is the less general, episodic events which may be indicative of regime changes and can also impact economic and subsistence activities in the Arctic. For example, the 2000-2001 ice season was characterised by mid-winter ice break-outs which repeatedly opened a lead at the beach near Barrow. In June 2001, the ice was pushed on-shore over a length of at least 20 km. Based on aerial photography, ground observations and side-looking radar we examine the extent and variability of the shove as well as large scaling forcing. This study highlights the importance of processes that impact communities at a local scale but are forced by regional or hemispheric atmosphere-ice-ocean dynamics.

Barry R. G., R. E. Moritz, and J. C. Rogers (1979) The fast ice regimes of the Beaufort and Chukchi Sea coasts, Alaska. Cold Reg. Sci. Technol., 1, 129-152.

Shapiro L. H., and P. W. Barnes (1991) Correlation of nearshore ice movement with seabed ice gouges near Barrow, Alaska. J. Geophys. Res., 96, 16979-16989.

Shapiro L. H., R. C. Metzner (1989) Nearshore ice conditions from radar data, Point Barrow, Alaska. Rep. UAG-R312, 46 pp., Geophys. Inst., UAF, Fairbanks, Alaska.

IP42A-0694 1330h POSTER

Sea Ice Stress and Deformation During the SHEBA Field Experiment

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The focus of the Surface Heat Budget of the Arctic Ocean (SHEBA) project is on thermodynamic processes that govern the heat exchange between the atmosphere, sea ice cover, and ocean. A key element in this complex interaction is the thickness distribution of the ice cover, which can very widely in both space and time. Thermodynamic processes are an important component in determining the thickness distribution, since they control the growth and ablation of the ice cover. Equally important, however, is the role played by sea ice dynamics. Sea ice dynamics result in the formation of leads and ridges, which thin and thicken the ice cover, respectively. Because of its recognized importance in defining the thickness distribution of the sea ice cover, and, hence, the atmosphere-ice-ocean heat exchange system, measurements associated with sea ice dynamics were made during the SHEBA field experiment. These measurements included the internal ice stress and ice deformation. The internal ice stress was determined from instrumentation frozen directly into the ice cover. The ice deformation was determined by the Radarsat Geophysical Processor System, which tracks points on the ice in radar backscatter images. The objective of this presentation is to quantitatively consider the relationship between the measurements of ice deformation and internal ice stress. Specifically, we will consider the temporal correlations and the impact of the spatial resolution of the deformation parameters on this relationship. Ultimately, we intend to use the results of this work in the development and evaluation of high-resolution sea ice dynamics models.

IP42A-0695 1330h POSTER

U. S. National/Naval Ice Center Digital Sea Ice Data and Climatology

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Weekly sea ice charts produced by the National Ice Center (NIC) from 1972 through 1994 have recently been released to the public in support of environmental research. These charts were originally intended as navigation aids for vessels operating in Northern Hemisphere sea ice-infested waters. However, it was recognized early on that these data represent a unique resource for Arctic researchers, adding significantly to sea ice data sets compiled by Walsh (1978) and others. Ice concentration records commonly derived from satellite passive microwave data are similar to the NIC data set in terms of resolution, extent and period of record, but these microwave data may suffer from systematic biases related to the imaging process and algorithms used to infer ice concentration from raw data. Although the NIC digital sea ice data set has its own limitations, its starting point precedes that of the passive microwave record and avoids some of its inherent biases. This paper describes the spatial and thematic characteristics of the NIC historical data set, as well as the digital and analog data and analysis methods used to create the data set. This study also briefly investigates long-term change in Arctic ice cover. The NIC data set reveals that sea ice concentration patterns in the Atlantic and Pacific sectors of the Arctic vary in response to changes in the North Atlantic Oscillation. This result is consistent with the findings of other researchers, who used other data sets.

These data have been permanently archived and are now available from the National Snow and Ice Data Center (NSIDC) in Boulder Colorado.

IP42A-0696 1330h POSTER

The effect of rheology on simulated sea ice drift and deformation

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Observations of ice motion and deformation archived at the Snow and Ice Data center provide a unique data set to examine the effects of nonlinear sea ice models on sea ice drift and deformation. This investigation focuses on the effects of different nonlinear rheologies on simulated ice drift and to a lesser degree on ice deformation. For this purpose a hierarchy of simulations with four different nonlinear rheologies are performed over the time period 1979-85 and compared to daily observed buoy drift. The four yield curves used are elliptical, sine lens, cavitating fluid and a mohr coulomb rheology. In the first three rheologies a normal flow rule is used whereas in the Mohr Coulomb case a non normal flow rule is used with the shear stress dependent on compressive stress. Overall the results indicate that the amount of allowable shear stress within a given rheology exerts significant control on simulated ice drift, with realistic ice drift requiring a moderate amount of shear stress. In the case of an elliptical rheology, it is found that a fixed pressure term results in excessive ice stoppage. This feature is substantially ameliorated by making the pressure term deformation dependent; a feature which also causes the rheology to be fully energy dissipative for all strain rates. In all rheologies with moderate shear stress, the simulated ice drift correlates extremely well with geostrophic wind, a fact that appears to arise from the high negative correlation of the large ice interaction force with the wind. For daily unsmoothed buoy and wind data the observed ice drift is found to correlate better with simulated values than with the geostrophic wind. In the case of deformation, all the models with some type of nonlinear rheology show a predominantly diverging strain field in the central Arctic, in general agreement with observations, whereas free drift estimates show a dominantly converging flow. Differences between simulated drift and observations from moderate shear strength models were statistically small, except in the Fram strait region where the mohr coulomb rheology with pressure dependent shear stress was found to yield higher ice speeds and less ice stoppage in somewhat better agreement with observations.

IP42A-0697 1330h POSTER

Investigating the SAR ice deformation product in validation of sea ice rheology models

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The use of highly nonlinear ice rheologies is becoming popular for sea ice models in climate simulations and ice forecasting systems. Inter-comparison projects have shown the viscous–plastic rheology with elliptical yield curve [Hibler 1979] reproduces buoy drift velocities well in comparison with rheologies that neglect shear viscosity or viscosity non-linearity [Kreyscher et al. 2000]. This paper addresses the issue of whether the yield criterion shape is an important consideration in simulations of Arctic sea ice. It is investigated whether the Synthetic Aperture Radar ice deformation product [Kwok et al. 1990] provides sufficient information to differentiate between yield criteria.

Direct comparisons are made between ice motion from two rheological models, with elliptical and sine lens yield curves. Fine resolution (5 km) simulations of the Arctic ocean over 6 days are compared to time coincident SAR data. Localised increase in shear strain rate in the SAR deformation product indicates cracks in the observed ice. The ability of the two isotropic rheologies in reproducing oriented cracks is investigated. SAR ice motion is averaged on to the model grid and compared to modelled ice motion. Fine resolution models are also compared to the lagrangian SAR ice motion. This allows evaluation of model performance at capturing large scale mean ice motion and smaller scale ice deformation events.

IP42A-0698 1330h POSTER

The State of the Cryosphere - Response to Global Warming

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Global mean temperatures have risen over the past 100 years by about 0.6 C. Over half of this increase has occurred in the last 25 years. There is variability in temperatures from year to year, and also from decade to decade superimposed on the longer upward trend. The range of natural variability in global temperature appears to be about plus or minus 0.2 C, so that it is only after the late 1970s that global mean temperatures emerge from the noise of natural variability. In some regions, extreme warming has been detected. Locations in Alaska and northern Eurasia, for example, have warmed by nearly 6.0 C in the winter months over the past 30 years. The cryosphere, or regions where water is found in solid form, are among the most sensitive to temperature change. Average temperatures in snow and ice-covered areas typically remain below 0 C much of the year. Unlike other substances found on Earth, ice and snow exist relatively close to their melting point and frequently change phase from solid to liquid and back again. Consequently, consistent and prolonged warming trends should result in observable changes to the Earth's cryosphere. Water changing from solid to liquid and back often results in dramatic visual changes across the landscape as various snow and ice masses shrink or grow. In this phase of our ongoing study of the state of the cryosphere we investigate, snow cover, glaciers, sea ice, and the related parameter sea level. Various forms of remote sensing allow the monitoring of snow and ice surfaces at varying spatial scales over the most recent 25 to 35 years. Results presented here include long-term monitoring of snow cover and sea ice as well as changes in area and mass of mountain glaciers. In all cases, regardless of parameter or measurement method, the amount of snow and ice has been decreasing over the past several decades. We also introduce the topic of permafrost. However, because reliable data on hemispheric-scale permafrost extent have only recently become available, examples presented provide only a snapshot of current permafrost conditions rather than time series data. Future work will involve similar investigations for ice sheets and ice shelves.

IP42A-0699 1330h POSTER

CRYSYS: Monitoring and Modelling the Cryospheric System in Canada

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CRYSYS (Cryosphere System in Canada) is a national collaborative research effort to improve the ability to observe, monitor and model the cryosphere, and its processes and feedbacks in the climate system. The project is a Canadian contribution to NASA's Earth Observing System and will contribute to WCRP's new initiative on Climate and Cryosphere (CliC). Better observation, monitoring and modelling is essential to understand cryosphere/climate interactions and cold climate processes. The paper provides examples of key developments from the CRYSYS investigation over the past 5 years that contribute to these objectives. These include: the merging of in-situ and satellite information on snow cover to document 20th Century snow cover variability over North America; the development of new approaches for mapping snow water equivalent (SWE) from passive and active microwave data for various landcover regions of Canada, including the boreal forest, and the use of the derived information in studying climate/cryosphere interactions and in application to flood forecasting and drought monitoring; the application of Radarsat SAR and passive microwave data for studying change in sea ice (e.g motion, regional extent) and lake ice (e.g freeze-up/break/up); the investigation of atmospheric circulation anomaly patterns associated with glacier mass balance conditions in the Canadian Arctic and Cordillera regions; development and validation of an improved 1-D thermodynamic sea ice and lake ice model; and, the integration of cryospheric information through the CRYSYS "State of the Canadian Cryosphere" web site to allow the scientific community and the public to have access to current information on the cryosphere in Canada. CRYSYS is one of the first national efforts to study the cryosphere as an entity within the climate system and to assess whether it is an effective indicator of climate change.

URL: http://www.crysys.ca

IP42A-0700 1330h POSTER

Quasi-Biennial and Quasi-Decadal Variations in Snow Accumulation over Northern Eurasia and Their Connections to the Atlantic and Pacific Oceans

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The study of 60 years of winter snow depth records reveals quasi-biennial variations of about 2.5 years and

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quasi-decadal variations of about 11.8 years and about 8 and 14 years. The quasi-biennial snow depth variation over the region east of the Caspian Sea and west of China is associated with sea surface temperatures over the northern North Pacific and tropical western Atlantic extending into the Gulf of Mexico. The associated atmospheric circulation pattern of Eurasia-I and the Pacific/North American pattern determines the surface air temperature conditions and thus snow depth at the biennial time scale. The quasi-decadal snow variation over central European Russia and western central Siberia is associated with a well-known SST anomaly pattern over the Atlantic, having opposite SST variations in alternating latitudinal belts, and SSTs over the tropical Pacific Ocean. The associated atmosheric North Atlantic Oscillation and the circulation anomaly over central Siberia affect both surface air temperature and precipitation and thus snow depth anomaly at a quasi-decadal time scale.

IP42A-0701 1330h POSTER

Initiation of Snow Melt on the North Slope of Alaska as Observed with Spaceborne Passive Microwave Data

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The initiation of snow cover melt is a significant event of the Arctic annual cycle marking the return of air temperatures from sub-freezing to near and above 0 °C. Snowmelt initiation occurs at the very beginning of the melt season shortly after maximum daily air temperatures begin to rise above 0°C and the first free water appears in the snowpack. Spatial and temporal patterns of snow melt initiation provide useful information regarding local and regional climate characteristics. We have developed a snow melt initiation (SMI) algorithm based on the diurnal difference of brightness temperatures (TBDD) observed in the SSM/I 19-GHz, horizontally-polarized channel. The NOAA/NASA Pathfinder Program Special Sensor Microwave/Imager (SSM/I) Level 3 Equal Area Scalable Earth-Grid (EASE-Grid) Brightness Temperatures (Northern Hemisphere projection) dataset, which is produced by the National Snow and Ice Data Center, was used in the analysis.

The SMI algorithm uses a dynamic threshold technique applied to the EASE-Grid brightness temperatures and was applied to the North Slope area of Alaska to evaluate spatial and temporal patterns of snow melt initiation. By using a dynamic threshold approach, geographic effects on snowpack characteristics that influence brightness temperatures can be minimized (eg. grain size and internal layers) ; thus allowing for comparison of melt initiation days over large areas. The spatial patterns evident in the melt initiation days calculated by this method show excellent correspondence with National Centers for Environmental Prediction/National Center for Atmospheric Research (NCEP/NCAR) meteorological reanalysis data. Observed variations in TBDD values between climatologic zones are consistent with diurnal differences in mesoscale seasonal air temperature patterns.

IP42A-0702 1330h POSTER

Distribution of Frozen Ground in the Northern Hemisphere

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Freeze/thaw cycles influence the thermal and hydralic characteristics of the soil, which have a significant impact on the surface energy and moisture balance, hence on the climate system. Frozen soils increase the soil heat flux significantly due to the increase in thermal conductivity. Freezing of soil moisture reduces the hydraulic conductivity of the soil leading to either more runoff due to decreased infiltration, or higher soil moisture content due to restricted drainage. Existence of a thin frozen layer essentially decouples the moisture exchange between the atmosphere and the deeper unfrozen soils. Hence, information on seasonal freeze/thaw cycles (timing, duration, and the number of days), areal extent and depth of seasonal freezing and thawing is crucial for investigating land surface processes in cold seasons/cold regions. Here, we investigate the seasonal freeze/thaw cycles of the soils in the Northern Hemisphere using ground-based measurements, remote sensing, and numerical modeling. Ground-based measurements indicate that soils at 5 cm depth experience freezing for at least 2 to 3 weeks when the mean monthly air temperature was at or near $0^{\circ}C$. The extent of seasonally frozen ground with freeze/thaw cycles greater than two weeks is determined using the $0^{\circ}C$ isotherm of the mean monthly air temperature. Using passive microwave satellite remote sensing data, daily freeze/thaw boundary in the Northern Hemisphere is detected and generally in good agreement with $-5^{\circ}C$ isotherm of air temperature. The onset of surface soil freezing starts in September or October at high latitude/altitude regions and in December or even January over middle latitude lowlands. The last day of surface soil freezing ranges from February or March in middle latitude regions to May or June at high latitude/altitude regions. These results show that the duration of surface soil freezing varies from a few weeks to several months. The number of days that surface soil actually experiences freeze/thaw cycles varies from a few days to more than five months. Generally, surface soil experiences freezing before snow covers the surface. However, modeling results indicate that the frozen soil may be thawed quickly after a consistent snow cover is established over the freezing surface, especially in the mid-latitudes. For 1988-1999, more than 50% of the land surface in the Northern Hemisphere is either snow covered or experiences freeze/thaw cycles as detected from the passive microwave remote sensing data and 55% as detected from the mean monthly air temperature. The long-term trends of snow cover and frozen ground extent and their relationship with climatic conditions are also discussed.

IP42A-0703 1330h POSTER

STAR-Light: Enabling a new vision for land surface hydrology in the Arctic

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STAR-Light, a 1.4 GHz radiometer for use on light aircraft, is an enabling instrument for monitoring thickness and water content of the active layer throughout the circumpolar Arctic. Our underlying vision is that the active layer can be modeled with a Soil-Vegetation-Atmosphere Transfer (SVAT) model that is forced by available data on weather and downwelling radiance. Through near-daily assimilation of satellite observations of microwave brightness at a frequency that is sensitive to liquid water in the upper few centimeters of soil, these SVAT models will maintain reliable spatial fields of the thickness and water content of the active layer.

Key for this vision are accurate SVAT models for Arctic terrains, an airborne radiometer for the extensive field observations necessary to calibrate these models, and a satellite radiometer to provide near-daily observations. SVAT/Radiobrightness models for Arctic tundra are in the early stages of development. The hydrology community has converged upon 1.4 GHz brightness as the most effective observation for sensing soil moisture, and the European Space Agency is completing a preliminary study of a 1.4 GHz Soil Moisture Ocean Salinity (SMOS) satellite mission for later this decade. STAR-Light is an NSF-funded, airborne instrument for SVAT model calibration in the Arctic beginning in 2004.

We will describe our progress with the STAR-Light development, and describe how others can participate in this research.

IP42A-0704 1330h POSTER

Numerical Simulation of Thermal Regime of Permafrost and Talik Formation Under Shallow Thaw Lakes in the Arctic and Subarctic

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Thaw lake is one of the dominating landscape features in the Arctic and Sub-arctic. The extent of its role in arctic climatic and hydrologic systems has not fully been investigated. This study is aimed to assess the long-term impacts of shallow thaw lakes in the Arctic and Sub-arctic on the temperature field of permafrost and talik formation. A two-dimensional, physically based finite element model of heat transfer with phase change under cylindrical coordinate system is developed to simulate the potential influence of shallow thaw lakes on the thermal regime of permafrost. Initially, it is assumed that permafrost thickness is 600 m with mean annual temperature at the permafrost surface of -9.0 $^{\circ}C$. A thaw lake is developed with a diameter of 800 m and lake water depths of 1.3 m, 2.0 m, 2.5 m, and 3.0 m. The long-term mean annual temperature at the lake bottom varies from -2.0 $^{\circ}C$ to 4.0 $^{\circ}C$ with an increment of 1.0 $^{\circ}C$, depending on lake water depth and lake ice thickness. Preliminary simulated results indicate that after 4000 years of initiation of a shallow thaw lake over permafrost, talik thickness ranges from 27 m, 43 m, 60 m, to 77 m with mean lake bottom temperatures of 1.0 $^{\circ}C$, 2.0 $^{\circ}C$, 3.0 $^{\circ}C$ and 4.0 $^{\circ}C$, respectively. Talik cannot form under thaw lakes with mean lake bottom temperature is at or below 0.0 $^{\circ}C$, but permafrost temperature increases significantly. The rates of talik formation and permafrost temperature increase with time. Variation of mean lake bottom temperature, which is a product of changes in air temperature, snow thickness and properties, lake ice thickness, and lake water depth, has a significant influence on talik formation and permafrost thermal regime under thaw lakes.

IP42A-0705 1330h POSTER

Permafrost Warming, Thawing and Impacts

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Global circulation models predict a warming of 2 to 5 °C For the next century in response to increases in greenhouse gas concentrations in the atmosphere. Permafrost in Northern Alaska warmed 2 to 4 °C over the last century and there was a concurrent warming of discontinuous permafrost at this time. Modeling indicates that continuous permafrost at Barrow generally cooled from 1950 until the latter 1970s and has generally warmed since then. Observations of permafrost temperatures north of the Brooks Range since 1983 indicate that the active layer and permafrost warmed about 2 to 3 °C at West Dock and Deadhorse from the mid-1980s to the present. There is widespread warming and thawing of discontinuous permafrost and extensive areas of thermokarst terrain are now being created as a result of climatic change. Estimates of the magnitude of the warming at the discontinuous permafrost surface are 1/2 to 1 1/2 °C. Warming rates near the permafrost surface were 0.05 to 0.2 °C yr-1. In warm discontinuous permafrost, thermal offset allows mean annual temperatures at the permafrost surface to remain below 0 °C while ground surface temperatures are positive, up to 2 1/2 °C. Thawing permafrost and thermokarst have been observed at several sites in Interior Alaska. Thawing rates at the permafrost table at two sites were about 0.1 m yr-1. Modeling at a site in discontinuous permafrost shows that the observed warming is part of a warming trend that began in the late 1960s and changes in snow cover. Thermokarst drastically modifies and remolds the ground surface. This process can severely change or disrupt ecosystems, human activities, infrastructure, and the fluxes of energy, moisture and gases across the ground surface-air interface.

IP42A-0706 1330h POSTER

Seasonal Transitions in High Latitudes : The Role of Land Surface Feedbacks

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An observational study has been initiated to examine the effects of land-surface processes on the seasonal transition from the cold season to warm season precipitation regime in the Ob River basin, Eurasian Arctic. Specifically, extreme anomalies in snow extent and mass during spring are examined in association with changes in convective available potential energy (CAPE), summertime precipitation, and the amount of precipitation recycled from local sources. The relative strengths of the positive and negative feedbacks associated with snow cover and surface hydrology is highlighted. The positive feedback, which involves a greater snow extent leading to higher albedo and a cooler land surface should result in a reduction of CAPE and convective precipitation, where as the negative feedback of greater snow mass leads to higher available soil moisture thus allowing for more local evaporation and precipitation. The hydrologic cycle in this region has implications for many processes ranging from the timing of the Asian monsoon to having impacts upon the extent of arctic sea ice.

IP42A-0707 1330h POSTER

An Evaluation of MODIS Snow Cover and Sea Ice Extent Products at the NSIDC DAAC

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With the launch of the MODIS instrument on NASA's Earth Observing System (EOS) Terra satellite a new era of cryospheric monitoring from space began. For the first time daily, global maps of snow cover and sea ice extent are being produced in a fully automated fashion from space-borne measurements in optical wavelengths.

The capabilities and limitations of the MODIS instrument for measuring snow cover and sea ice extent will be highlighted in several case studies in which the MODIS products are compared with other available operational analyses based on both optical and passive microwave measurements. The 1-km resolution MODIS sea ice product, as determined from both solar reflective and terrestrial emissive bands, will be compared to sea ice concentration based on passive microwave measurements. The 500-m MODIS snow cover product will be compared both to analyses based exclusively on passive microwave as well as to NOAA operational analyses based on multiple satellite sensors.

URL: http://nsidc.org/modis

IP42A-0708 1330h POSTER

NSIDC at the Millenium

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Over the past 25 years the National Snow and Ice Data Center (NSIDC) has played a pro-active role in cryospheric data management. Three themes illustrate the advances that have been made.

(1) Delivery of integrated data products: we have developed standalone, packaged integrative products, frequently published on CD-ROMs or on the Internet. Examples include: the first global assembly of data and information on frozen ground and permafrost; passive microwave gridded timeseries products from the ESMR, SMMR, SSMI sensors; collaborative development and distribution of the Environmental Atlases for arctic meteorology, oceanography, and sea ice. The Arctic System Science Data Coordination Center (ADCC), at NSIDC, archives and distributes via our website. These data sets are based on research under the Land Atmosphere Ice Interactions (LAII), Ocean Atmosphere Ice Interactions (OAII), including the Surface Heat Budget of the Arctic (SHEBA) program, and related reconnaissance satellite imagery; Paleoenvironmental Arctic Science (PARCS) data. R-ArcticNet: a Regional Hydrographic Data Network for the Pan-Arctic Region is available on CD-ROM. Data Sets to be added include the Rapid Integrated Monitoring System (RIMS), a collection of hydro-meteorological data for river systems that discharge into the Arctic Ocean.

(2) Leadership in data set archival and dissemination through active collaboration with scientific societies and organizations, Currently active affiliations include the International Permafrost Association, the World Glacier Monitoring Service for glacier inventory data, CONMAP SCAR for the US National Antarctic Data Center for Antarctic metadata, the Joint WMO-IOC Commission for Oceanography and Maritime Meteorology (JCOMM) for the Global Sea Ice Data Bank and the International Antarctic Buoy Program (IABP), as well as, for NSF in the form of the Arctic System Science Data Coordination Center, and the Antarctic Glaciological Data Center, as well as NOAA, and NASA.

(3) Delivery of large volume satellite data: In particular the NSIDC DAAC has begun delivery of snow and ice products derived from MODIS data on the TERRA satellite, and will deliver passive microwave data from the AMSR instrument on the upcoming AQUA satellite, and laser topography data from the ICESat. We expect an increasing emphasis on multi-sensor products and multi-disciplinary data sets.

IP42A-0709 1330h POSTER

The Advanced Microwave Scanning Radiometer-Earth Observing System Data Products from the Aqua Mission

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The Advanced Microwave Scanning Radiometer-Earth Observing System (AMSR-E) is scheduled to launch on NASA's Aqua Satellite in early 2002. The Aqua mission is an important part of the NASA Earth Science Enterprise (ESE). The Aqua mission provides a multi-disciplinary study of the Earth's atmospheric, oceanic, cryospheric, and land processes and their relationship to global change. With six instruments aboard, the Aqua Satellite will travel in a polar, sun-synchronous orbit.

The AMSR-E will measure passive microwave radiation, allowing for derivation of many geophysical parameters, including cloud properties, radiative energy flux, precipitation, land surface wetness, sea surface temperatures, sea ice, snow cover, and sea surface wind fields.

The AMSR-E has much greater spatial resolution than previous passive microwave radiometers: approximately double the spatial resolution of the Scanning Multichannel Microwave Radiometer (SMMR) and the Special Sensor Microwave/Imager (SSM/I). Further, the AMSR-E combines in one sensor all the channels that SMMR and SSM/I had individually. The AMSR-E has the following frequencies (in GHz): 6.9, 10.7, 18.7, 23.8, 36.5, and 89.

The level 1A data product will contain chronological antenna temperature count data. The level 2A data product will contain spatially-resampled brightness temperatures (in global swath format) at resolutions of 56, 38, 21, 12 and 5.4 km. Level 2B data will include ocean, soil moisture, and rain products. Level 3 data will include gridded ocean, soil moisture, and rain products; gridded snow water equivalent products; gridded brightness temperatures; and gridded sea ice concentration and snow depth products.

The National Space Agency of Japan (NASDA) will process level 0 data to level 1A data. The AMSR-E Science Investigator-led Processing System (SIPS) will process the level 1A data product to level 2 and 3 data products. The National Snow and Ice Data Center (NSIDC) will archive and distribute all AMSR-E products, including Levels 0, 1A, 2, and 3 data.

This presentation describes the AMSR-E data products and compares the AMSR-E sensor specifications with those of SMMR and SSM/I.

URL: http://nsidc.org

IP51A MC: Hall D Friday 0830h

Monitoring, Measuring, and Modeling Snow and Cold Land Processes *(joint with A, H)*

Presiding: **A Winstral,** USDA-ARS**; D Kline,** National Weather Service

IP51A-0709 0830h POSTER

Sublimation From the Forest Canopy at Different Elevations in the Fraser Experimental Forest, Fraser, CO

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Sublimation may return between 20 to 40% of annual snowfall to the atmosphere from dense conifer canopies in mid-latitude, continental climates. The local energy balance controls sublimation of snow intercepted by the forest canopy. The canopy energy balance is controlled by local climate, synoptic meteorological conditions and physical properties of both the canopy and forested slope. We quantified differences in snow sublimation from a canopy at different elevations as a function of net radiation, temperature, humidity and wind speed. Four trees (two live and two artificial) were suspended from load cells attached to towers located at two different elevations in Fraser Experimental Forest in central Colorado, U.S.A. The elevations of the lower and upper sites were 2,920 and 3,230 m a.s.l., respectively. Two anemometers were installed at each site to measure wind speed and direction at the height of the suspended trees and above the surrounding canopy. All other meteorological parameters were measured at the height of the suspended trees. Sublimation rates were monitored from January 1 to May 1, 2001. Analysis of 21 storms showed that maximum sublimation rates were similar between the sites, but the sublimation rates at the lower site showed a more rapid decline with time following the storm's cessation. Sustained higher sublimation rates at the upper site indicate that a greater total volume of water was sublimated from the trees when integrated over the sublimation period following each storm and, therefore, over the entire season.

IP51A-0710 0830h POSTER

Multi-Year Assessment of Seasonal Freeze-Thaw Dynamics in Boreal Landscapes With Spaceborne Ku-Band Scatterometers

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