CAVM divides the Arctic into five bioclimate subzones, A thru E (Subzone A is the coldest and Subzone E is the warmest), based on a combination of summer temperature and vegetation. Fifteen vegetation types are mapped based on the dominant plant growth forms. More detailed, plant-community-level, information is contained in the database used to construct the map. The reverse side of the vegetation map has a false-color infrared image constructed from Advanced Very-High Resolution (AVHRR) satellite-derived raster data, and maps of bioclimate subzones, elevation, landscape types, lake cover, substrate chemistry, floristic provinces, the maximum normalized difference vegetation index (NDVI), and aboveground phytomass. The vegetation map was analyzed by vegetation type and biomass for each county, bioclimate subzone, and floristic province. Biomass distribution was analyzed by means of a correlation between aboveground phytomass and the normalized difference vegetation index (NDVI), a remote-sensing index of surface greenness. Biomass on zonal surfaces roughly doubles within each successively warmer subzone, from about 50 g m-2 in Subzone A to 800 g m2- in Subzone E. But the pattern of vegetation increase is highly variable, and depends on a number of other factors. The most important appears to be the glacial history of the landscape. Areas that were glaciated during the late-Pleistocene, such as Canada, Svalbard, and Greenland, do not show such strong increases in NDVI with temperature as do areas that were not glaciated. Abundant lakes and rocky surfaces limit the greenness of these recently glaciated surfaces. The highest NDVI and phytomass are found in non-glaciated regions of Alaska and Russia. Soil acidity also affects NDVI patterns. In Subzone D, where the NDVI/ soil acidity relationship has been studied most closely, NDVI is lower on nonacidic surfaces. This has been attributed to fewer shrubs and higher proportion of graminoids (more standing dead sedge leaves) in nonacidic areas. This trend is probably caused by generally drier soils, with less production, on limestone-derived soils. The trend is less clear in Subzone E because of fewer nonacidic surfaces, and the abundance of glacial lakes with low NDVI on the acidic shield areas of Canada. Time series analysis of trends in NDVI in Subzones C, D, and E in Alaska have shown a 17% increase in the NDVI over the 21-year record. The increases have been greatest in moist nonacidic tundra. Future analyses of the circumpolar database will be directed at examining which geographic regions and vegetation types have shown the strongest increases, and how these are correlated with temperature changes.

URL: http://www.geobotany.uaf.edu/cavm/draft0306/index.html

C11E-06 1135h

Mapping Active-Layer Thickness in an Urbanized Environment: The Barrow Urban Heat Island Study

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Local and global changes in the Arctic climate may have profound impacts on hydrology, soil stability, and infrastructure, such as roads, buildings, and water, gas, or oil pipelines. These changes will be manifested in large part through permafrost, which can influence virtually all physical, chemical, and biological processes occurring in the soil. The "Barrow Urban Heat Island Study" (BUHIS) is an ongoing project in northern Alaska that examines the effects of urbanization on air and soil temperatures in and around Barrow. At 4600 residents, Barrow is the largest native settlement in the circumarctic region and the northernmost urban area in the United States. Initiated in summer 2001, BUHIS is recording temperature and thaw depth at more than 60 locations throughout the village, the developing suburbs, and surrounding undisturbed tundra. This paper describes one part of study examining the active layer and anthropogenic influences on its thickness. Summer air and soil temperature data, together with digital vegetation and soil maps, are used as input to a modified Stefan solution to map depth of thaw over an area of 100 square kilometers that includes both the village of Barrow and the surrounding tundra. Maps representing end-of-summer conditions for 2001 provide the first spatial/temporal representation of active-layer variability within an urbanized area. Increasing urban development in Arctic regions is causing information about changes accompanying industrial development and urbanization to become more vital, particularly given the possibility of a warming climate.

C11E-07 1150h

Slope Relaxation in Thaw Lake Terrain, NW Alaska.

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Thaw-induced subsidence of the ground surface, localized in thaw lake basins, generates topographic relief of 1 to 20 m in regions of ice-rich permafrost. After lakes drain, basin relief is modified by gravity-driven slope processes and by re-inflation of the lake floor by peat accumulation and refreezing. Unlike slopes in temperate regions, where transport laws and rates have been estimated from measurements (eg., linear diffusion of topography and diffusion time constants), rates of slope relaxation over 10 - 10^4 y have not been measured in permafrost terrain. To investigate rates of permafrost slope relaxation, we conducted differential GPS surveys (resolution $\approx$ 1 cm) and constructed digital elevation models of bounding slopes for four lake basins ranging in age from modern (an actively expanding lake) to 10^4 y, located in ice-rich aeolian Pleistocene silt on the Seward Peninsula, NW Alaska. Timing of lake drainage, marking the onset of slope relaxation, is constrained by radiocarbon ages of basal terrestrial peat samples collected from permafrost cores and stratigraphic exposures. The resulting chronosequence of slopes, each developed in similar materials and from a similar initial state, is then used to investigate time evolution of hillslopes in permafrost. Preliminary results indicate that 1) Total thaw basin relief ranges from 10–18 m; 2) Before and immediately following lake drainage, slopes display irregular, slump-dominated profiles with angle 35–60°; 3) After lake drainage, mid slopes evolve toward smooth cross- sectional and along-slope profiles consistent with diffusive transport; 4) Upper slopes exhibit gentle diffusive profiles near divides, but are marked by laterally-discontinuous steep 1–2 m high ramparts where merging into mid slope, which persist in the oldest basins. 5) Lower slopes are marked by sharp breaks where toes meet reinflating flat basin floors. Comparisons between measured slopes and transport model predictions are consistent with the view that permafrost slopes are characterized by a mixture of linear diffusive and nonlinear transport processes (eg., solifluction) that can maintain relief over long time periods.

C11E-08 1205h

CEON: A Circum-Arctic Environmental Observatories Network

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The concept of a terrestrial Circum-arctic Environmental Observatories Network (CEON) was introduced at Arctic Science Summit Week (ASSW) in 2000 at a meeting of the Forum of Arctic Research Operators (FARO: www.faro-arctic.org). CEON is conditioned by the need for increased international integration of research effort and the loss and/or danger of loss of continuous northern high latitude environmental observations. FARO has endorsed the CEON concept advocating that CEON be developed to promote environmental measurements and dissemination of these to Arctic researchers whilst encompassing and building on the strengths of existing arctic stations and environmental observatory networks. Since 2000, the CEON concept has increasingly received enthusiastic support from a variety of existing networks, disciplinary collaborations and research stations as well as endorsement from the the International Arctic Science Committee (IASC) (www.iasc.no). At ASSW 2002, a working group was formed to scope and develop the concept of CEON. Since then, presentations of the CEON concept have been made at meetings of various networks, research collaborations and polar research boards in Europe, Russia and the United States in order to make contact and collect feedback from potential CEON stakeholder and user groups. Presentations have focused on the necessity for the CEON initiative to meet and promote the needs of the participating research community, science administrators, policy makers, industry, education and indigenous communities. In doing so, it has been stressed that CEON should be seen as a network that facilitates and encourages environmental monitoring, which provides linkages between disciplines and existing networks and connectivity spanning regional to circumarctic and global scales. Following CEON presentations audiences have been asked to introduce their own bias in the development of CEON by providing feedback to the following question: "What would you do if you had the opportunity to conduct standardized long term, integrated measurements across all research stations and networks in the Arctic?" It is hoped that this approach will facilitate the development and scope of CEON based on the experience, needs and future directions envisaged by a broad range of potential CEON stakeholder and user groups. The CEON initiative should not be seen as duplicating prior or ongoing research effort, but an international partnership that aims at forming a logistic and research framework within which ongoing and future research can be oriented to cumulatively form and facilitate long-term research endeavors in the Arctic. Based on recent scoping and development activities and the convention of the first planning meeting in October 2003, this presentation recapitulates the enthusiastic support for the initiation of CEON and outlines a conceptual roadmap for its inception. This road map will include the formation of an interim multidisciplinary and international steering committee, an international workshop and a science implementation strategy. We invite your thoughts and ideas to facilitate the development of the CEON initiative.

URL: http://www.cevl.msu.edu/ael/projects/ceon.html

C12A MCC: Level 2 Monday 1330h

General Cryosphere Posters *(joint with ED)*

Presiding: **M W Williams,** University of Colorado

C12A-0860 1330h POSTER

Can we Trust Measurements of Turbulence on top of the Greenland Ice Sheet?

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The most important challenge to providing new insights into the workings of the atmosphere on the top of the Greenland ice sheet is to demonstrate that its weak and intermittent turbulence can be adequately characterized using existing instrumentation. To tackle this problem, very high temporal resolution measurements of turbulence at two heights near the surface were collected at Summit, Greenland over several field seasons. Two independent tests of stationarity on 1080 30-minute runs revealed that approximately 40% of observations are nonstationary. Nonstationary runs are characterized by periods with significant turbulent fluxes separated be extended inactive periods with little or no flux, with most of the flux during a run realized in small fractions (<25%) of the total time. However, spectral analyses of stationary runs show that velocity and temperature data, when non-dimensionalized with appropriate scaling parameters, reduce to a set of universal curves that are functions of z/L. To capture 99% of the turbulent heat flux in stable conditions sampling rates do not need to exceed 15 Hz, which is far less than the sampling frequency of 50 Hz used in this investigation. This is important as it shows that standard fast-response sensors close to the surface (2m) can capture the different scales of turbulent motion in this environment. For these measurements to be useful in other applications, such as establishing flux-profile relationships or energy budgets, the issue of stationarity must be addressed otherwise results may differ from those expected.

C12A-0861 1330h POSTER

Cyclone Occurrence in the Arctic: Coupling With Teleconnections and the Impacts on Ice Sheet Melt Cycles

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Evidence assembled over the past several decades shows the Arctic system as in the midst of significant environmental change. This includes pronounced warming over most land areas, reductions in sea ice extent, alterations in precipitation, melt-water discharge and sea ice circulation, and warming and increased aerial extent of the Arctic Ocean's Atlantic section [Serreze et al., 2000; SEARCH SSC, 2001]. The accepted paradigm is that these changes are related to the general dominance of the positive phase of the Arctic Oscillation (AO) in recent decades [Thompson and Wallace, 1998; 2000]. While the AO/NAO (North Atlantic Oscillation) has proven to be a valuable integrating framework, many aspects of climatic variability and change are fundamentally driven by events at synoptic space and time scales, in particular, by the individual or aggregate effect of extratropical cyclones. The polar basin is considered a transit area or a sink for cyclones that develop elsewhere [Putnins, 1970]. In the Northern Hemisphere, warming and cooling trends are associated, respectively, with increases and decreases in cyclone occurrence [McCabe et al., 2001]. As presented by McCabe et al. [2001], differences in extratropical cyclone frequency and strength have a direct influence on surface climate through effects on cloud cover, winds, and precipitation frequency, duration, and magnitude. Melt cycles and precipitation over the terrestrial Arctic drainage are predominantly determined by the frequency and strength of cyclones [Mote, 1998a, 1998b; Serreze et al., 2002]. Cyclone activity also has pronounced effects on the circulation and concentration of sea ice cover with attendant feedbacks. This paper uses NCEP global sea-level pressure data over the past forty years and passive microwave data of the Greenland ice sheet over the past twelve years to address the importance of cyclone processes in the moderation of melt cycles on the Greenland ice sheet. The relationship between the intensity of these processes and differences in the general synoptic environment associated with the positive and negative phases of the AO/NAO will also be addressed.

C12A-0862 1330h POSTER

Arctic National Wildlife Refuge (ANWR): The Challenge of Current and Future Concerns

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Historically, when one thinks of ANWR the immediate concern has always been the effect of development related to hydrocarbon extraction and its potential impact on the environment. Hydrocarbon extraction is always a possibility and remains before Congress today, but is this type of development the greatest threat to this region? Twenty-five years ago the beauty and hidden resources of Alaska were barely touched, but with the discovery of oil at Prudhoe Bay this quickly changed. Suddenly this once inaccessible region known as the Arctic Coastal Plain became a desirable place to visit. Today, as the Prudhoe Bay oil fields production begins to slow one can visualize an even greater impact that could affect this fragile ecosystem. The landscape is being altered in many ways; not only due to economic development, but also due to global climate change. However, a potentially even larger impact is seldom mentioned and that impact is the consequence of more individuals traveling into the region. The Dalton Highway (the road between Fairbanks and Prudhoe Bay) was opened to all traffic in 1995. Since then the number of people traveling to the North Slope of Alaska via the road has increased significantly. This includes but is not limited to potential entrepreneurs, researchers, tourists as well as the oil field workers. The anthropogenic impact humans may have in this region along with the resultant commercialization will have a lasting influence on ANWR and the surrounding region will be impacted in ways that have not yet been considered. Who will decide who is or is not permitted to visit ANWR? Who will determine what impacts will be allowed? Will the opportunity to visit this unique region be for tour groups or just occasional hikers? Will researchers be allowed access and who will monitor their inevitable footprint? Will the native people increase stress on the environment more as their use of modern methods of hunting and travel increases? All of these factors need to be considered as a comprehensive strategy for the future is developed for ANWR and the entire Arctic Coastal Plain region.

C12A-0863 1330h POSTER

Results of an Iridium-Based Data Communication System Providing Internet Access to Polar Expeditions

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The Polar Radar for Ice Sheet Measurements (PRISM) Project at the University of Kansas has developed and field-tested a versatile communications system for use by researchers in high-latitude Polar Regions. The PRISM project is developing advanced intelligent remote sensing technology that involves radar systems, an autonomous rover, and communications systems to measure detailed ice sheet characteristics, and to determine bed conditions (frozen or wet) below active ice sheets in both Greenland and Antarctica. We also have a very strong public outreach and educational program aimed at K-12 educators and students that requires data, voice and video feeds from Polar field locations in near real time. Hence, PRISM requires a robust communications system for use in the field between a base camp and the mobile remote sensing system, and from the field back to the University of Kansas and onto the Internet. The communication system that has been developed is truly mobile and is relatively inexpensive. We initially considered various satellite services during the design phase of this project. The two feasible options for high-latitude locations were Iridium, with its low-bit-rate service (2.4 Kb/s), and Inmarsat/Intelsat with broadband service. We selected the Iridium option for testing and development because it provided coverage in both Antarctica and Greenland. To achieve higher capacity communications, the multilink point-to-point protocol (MLPPP) implemented in Linux was tuned to operate efficiently over the Iridium satellite system. This mechanism combines multiple channels to obtain a seamless data connection with a capacity equal to the sum of the individual link rates. We used four Iridium modems to obtain an aggregate capacity of about 9.6 Kb/s. Standard Internet protocols (TCP/IP) were then used to provide end-to-end connectivity. The communications system field experiments were conducted at the NorthGRIP ice core drilling camp in Greenland (75° 06' N, 42° 20' W) from June 23-July 17, 2003. We measured the reliability, throughput and general performance of this system over periods of up to 24 hours. This included delay, loss, throughput, call drops/up-time, relative signal strengths, connection time and number of connection retries. The system was also successfully tested while moving across the ice sheet at speeds of up to 30 km/h. We were successful in uploading and downloading large files (.2MB to 7.2MB) to the Internet. In combination with a modified Wi-Fi deployment, wireless Internet access was also provided to the entire NorthGRIP camp for a few days. The field experiments have shown that standard Internet protocols combined with MLPPP and Iridium modems can provide Internet access for polar expeditions at useful data rates. The 4-modem configuration we tested was observed to be $>$90 % efficient, e.g., a 2.5 MB video file was transferred in 35 min. at 9.524 Kb/s. The system had an average up-time of over 90 % and thus is stable and suitable for autonomous operation. Mobile performance results were very similar to that of stationary systems. While the end-to-end network architecture developed to provide Internet access worked well, the system round trip time is significant ($\sim$ 1.8 seconds), which can impair real time interactions.

C12A-0864 1330h POSTER

A Model of Experimental Static Grain Growth in Polycrystalline Fine-grained Ice Ih

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A key to understanding the dynamic behavior of ice, both in planetary and terrestrial conditions, is a fundamental comprehension of flow mechanisms. The course of deformation in ice gives rise to dynamic recrystallization and other processes, leading to changing grain sizes, which is predicted to reach steady state over geologic time periods. Deformation and flow of polycrystalline ice crystals in ice sheets and glaciers depends strongly on crystal size and temperature. In order to help understand grain-size effects on flow, we performed laboratory experiments on fine-grained, polycrystalline ice Ih samples to investigate the effect of temperature on the rate of grain growth in statically annealed ice. Temperature was varied from 220-240K. Ice samples were placed inside the bath for 1-75 hours to examine the effect of time and temperature on grain growth, grain-size distribution, and grain orientation. Low-temperature scanning electron microscopy (SEM) was used to measure grain size and growth. Grain size distribution histograms are compiled to examine the rate at which the small grains shrink and the large grains grow. To extract information about the microphysics of grain growth, analysis criteria focus on a variety of physical properties, such as size, grain boundary curvature, and physical interaction of grains with neighbors. While it is known that some grains grow at the expense of others, it remains uncertain what properties control this action. A model based on experimental data extracted from SEM images is developed to determine laws for grain growth and shrinkage. The importance of energy changes among grains, and whether crystal energy is a significant criterion for grain growth and ultimately in which grains grow and which shrink during static growth, is suggested. The results are significant in establishing grain growth rates under ambient conditions and temperatures applicable to natural ice settings, such as in glaciers and ice sheets.

C12A-0865 1330h POSTER

Using Kernel Methods to Detect Clouds, Snow, Ice and other Geophysical Processes.

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The detection of clouds within a satellite image is essential for accurately retrieving many surface geophysical parameters from optical and thermal imagery. Even a small percentage of cloud cover within a radiometer pixel can adversely affect the determination of surface variables such as albedo and temperature. Unfortunately, cloud detection over and snow- and ice-covered surfaces remains difficult due to the small spectral contrast in the visible and thermal infrared between clouds and snow/ice. This study examines the use of kernel methods to distinguish between snow and clouds over the Greenland ice sheet using MODIS imagery. Besides being able to classify clouds, the method is also able to pick up regions of different snow types (i.e. grain size variations) over the Greenland ice sheet. Thus, the results presented here lend credibility to the idea that a kernel- based method could reveal geophysical processes and discriminate bewteen such processes. Here we present the results for several images acquired during the melt season in 2002.

C12A-0866 1330h POSTER

Arctic Sea Ice in 2003: A Year after the 2002 Record Minimum

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Among the more apparent changes in the Arctic during the recent decades,sea ice extent isarguably one parameter whose variability and trends are firmly established. Several independent analysis have led to the consensus that the annual sea ice extent in the Northern Hemisphere decreased 3% per decade from the late 1970s to the late 1990s. Seasonal and monthly analysis have found the negative trends to be greatest in summer as exemplified by the last year's record low summer ice miminum in September 2002. Although early summer 2003 did not appear to be unusual in terms of ice extent,the ice extent for August 2003 is near the August value in 2002 and the ice pack appears very diffuse with many ice floes appearing thin and flooded, suggesting substantial melt and/or the presence of relatively thin ice at the end of spring. Thus, although ice extent is slightly greater than was the case in August 2002, there is the potential for the pack to decay further if southerly winds prevail. Neither the 2002 nor 2003 sea ice anomaly appear to be strongly linked positive phase of the Arctic Oscillation(AO) during the preceding winter which in the current view preconditions the

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ice cover to extensive summer decay. Interestingly, the AO during the winter of 2002/03 was strongly negative. This leads to the suggestion that in order to explain such large negative ice anomalies during negative AO years, it may be necessary to invoke more regional atmospheric forcings, especially in summer, oceanic conditions or factors internal to the ice cover. Similar to 2002, low pressure over the Canadian Basin in July appears to have promoted ice divergence and temperatures over much of the western Arctic were above normal from January through June 2003. Furthermore, it is reasonable to expect that a general decrease in ice thickness accompanying warming would manifest itself as greater sensitivity of the ice pack to wind forcings and albedo feedbacks. The decrease in the amount of multiyear ice and attendant changes in the ice thickness distribution could in turn pre-condition the arctic sea ice cover to further reductions in the subsequent summer(s). There may not even need to be a positive anomaly in the summer temperature to reach another low ice year.

C12A-0867 1330h INVITED POSTER

Stable Isotopes in Ice: Tracers of the Global Environment

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Significant advances in geophysical sciences most often follow from development of new abilities to measure Earth's properties. One major development of the past half century has been the measurement of stable isotopic composition of precipitation and its variations on vast spatial and temporal scales, the latter especially in Arctic and Antarctic glacial ice. The venerable tradition of research in this subject emanates directly from work of Dansgaard, Craig, and Epstein. Here I discuss how isotopic variations induced by atmospheric distillation offer a compelling example of a geophysical phenomenon arising from microphysical properties, but one that is dependent on the global-scale environment. I discuss how the geography of precipitation isotopes is explicable by treating the problem as an advective diffusive reaction system. Three of the most important results of environmental geophysics have emerged from analyses exploiting (in part) the record of this system in polar ice: the strong but quixotic coupling of climate and biogeochemistry on multi-millennial time scales; the high but plausible (and contentious) values for global climate sensitivity to radiative forcings; and the documentation of past very rapid climate changes. Looking forward, I also discuss the major unresolved issues lurking behind this facade of success, including poor understanding of the controls on deuterium excess at low temperatures, and inability to quantify many non-temperature effects on isotope time series (many of which were clearly discussed by Dansgaard nearly forty years ago).

C12A-0868 1330h POSTER

Attenuation Of Microwave Signals In Snow-Covered Boreal Forest

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The presence of snow cover on the ground modifies significantly the interactions between the surface and the atmosphere. In the actual context of possible climate warming it is critical to monitor snow cover properties at different scales, including its extent, water equivalent and depth. The knowledge of these properties is of great interest not only to climate issues, global and regional water cycle hydrology, but also to agriculture management and hydroelectricity production in northern latitudes. Traditionally, snowpack physical properties are determined from snow coring, at more or less dispersed sampling points. However, the significant spatial heterogeneity of landscapes coupled to the high temporal variability of snow cover make traditional methods less effective, particularly for large and inaccessible areas. In the last decades several algorithms using remote sensing data were developed to estimate snow extent, depth and water equivalent. The determination of snow water equivalent in open areas such as Canadian Prairies, by remote sensing means is becoming more and more operational. However, in forested regions, such as boreal forests, the development of efficient algorithms remains challenging. Among other problems encountered, forest canopy transmissivity of the microwave signal emanating from the underlying snow layers is not well known in the literature. In this study, ground-based measurements using 19 and 37 GHz passive microwave radiometers were conducted in order to estimate forest transmissivity. The experiment was held in February 2003 in the former BOREAS southern study area in Saskatchewan (Central Canada). Various forest types, conditions and densities were considered. For each site two sets of microwave measurements were taken: the downwelling brightness temperature through the canopy cover and the sky brightness temperature. The canopy physical temperature was also measured. These measurements were used to estimate the transmission factor for each site. The results obtained show that depending on the forest type and structure, canopy transmittance can be as low as 15% to 20% especially in dense black spruce and old jack pine forest. Highest values (up to 90%) appear in less dense deciduous and sparsely distributed young forests.

C12A-0869 1330h POSTER

Ice Crystals Inside the Bell

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A recent universal construction of bivariate Gaussian distributions, leading to unforeseen kaleidoscopic decompositions of circular bells in terms of a host of elegant patterns having arbitrary n-fold symmetries, is reviewed. It is shown, via a variety of examples, that such patterns, revealed by iterating simple affine mappings yielding space-filling fractal interpolating functions in three dimensions, encompass the common 6-fold geometric structure encountered in natural ice crystals. It is illustrated how both stellar and sectored crystals may be grown in the "fullness of dimension" via a variety of iteration schemes, leading to the conclusion that such sets are mathematical designs concealed inside the bell.

C12A-0870 1330h POSTER

Radarsat Geophysical Processor System: Data Products, Formats, and Visualization

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Radarsat Geophysical Processor System (RGPS) is designed to generate products that provide estimates of sea ice motion, deformation and sea ice thickness. The system uses Radarsat-1 ScanSAR Wide B (SWB) imagery acquired over the last six years over the entire Arctic Ocean. At the beginning of each winter season a regular grid with a default spacing of 10 km is initialized that defines the freeze up ice condition. With changing ice condition this regular grid distorts in shape and location. The distorted Langrangian grid is stored as an RGPS data product that reflects the ice condition at a particular time. In the past, RGPS products have been used to study processes operating at the scale of the entire Arctic Ocean. We are looking into the use of the RGPS data in a more refined grid, so that the product could also be used for studying smaller regions of interest. We have converted the specific binary format of the RGPS product to the more popular ARC/INFO polygon coverage format used by a wider research community. Finally, we have developed a visualization tool that will allow the user to drape the RGPS product containing ice attribute information over the corresponding synthetic aperture radar images and view a series of images showing change in ice condition over time.

C12A-0871 1330h POSTER

Field Spectrometry, Sub-Pixel Resolution of Satellite Imagery, and Archeological Potential of the Cryosphere

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During the 2003 summer field season, a preliminary investigation was conducted with remote sensing to evaluate and determine the archeological potential of glaciers and permanent snowfields in the Wrangell Mountains, southeastern Alaska. In recent years, archeologists have realized that the cryosphere is far from barren of human contact. Rather the cryosphere provides the ideal means to preserve organic cultural material trapped within ice and snow. This preservation gives a unique glimpse of artifacts such as projectile points, wooden shafts, sinew lashing, and other materials that would have otherwise degraded hundreds or thousands of years ago. Through the use of remote sensing, we aim to narrow the enormous search area down to the most probable locations. From observations made at current sites, it is known that archeological artifacts are usually accompanied by windblown plant detritus, accumulated mammal feces, fur, and amorphous organic material melting out of the ice. We measured with a field spectrometer the hyperspectral reflectance of organic material found in situ on the ice in the vicinity of artifacts. Measurements were also made for surrounding land cover classes. By integrating the spectra with Landsat imagery we are able to create custom spectral libraries and an accurate supervised land cover classification. Since the organic material at many sites is not extensive enough to fill an entire pixel, we use sub-pixel resolution techniques to separate organic debris, inorganic debris, snow and ice. The resulting fractional amount of organic material in each pixel, and its spatial relationships with surrounding land cover features, enable an improved quantified model of archeological site potential for snow and ice.

C12A-0872 1330h POSTER

Interannual Variability of Eurasian Snow Cover in Spring and its Possible Link With Atmospheric Circulation

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We investigate the interannual variability of Eurasian spring snow cover extent (SCE) during 1973-1998, especially focused on the relationship between the recent decreasing trend and the year-to-year variation. Two major patterns are detected by applying EOF analysis to the interannual component of the snow cover duration at each grid point derived from the NOAA satellite measurement data set. Recent Eurasian SCE change, mainly characterized by an abrupt decrease after the end of 1980's, is identified as the first component of EOF analysis (representing 18.3% of the total variance), which is located over the eastern part of the continent and has an apparent persistency from February to August. This pattern is the representative of spring-to-summer snow cover variability over the whole Eurasia. On the other hand, another dominant mode is found over the western Russia (50-65N,40-80E) as the second component (8.6%), which has a fluctuation of about 4-6-year cycle without a significant linear trend. The regression analysis shows that in April there is a close relationship between the variation of this mode and air temperature and geopotential height fields over western Russia from surface up to stratosphere, which indicates that this mode is strongly controlled by the atmospheric circulation in spring. Furthermore, the results of the atmospheric heat budget analysis over the western Russia shows that adiabatic compression in relation to its vertical motion plays an important role for heating the atmosphere and the decision of the timing of snow cover disappearance over western Russia, while horizontal advection is always working as a heating sense independently of the interannual variation of snow cover disappearance. Diabatic processes merely affect the fluctuation of the atmospheric heating. Many numerical studies have shown the influence of the continental scale variability of land surface processes induced by snow cover on the following climate variation, and some diagnostic studies pointed out that western Russia (including central Asia) is a key region. But the results of this work suggest that another scenario to explain the mechanism of these relationships is needed as for that over western Russia.

C12A-0873 1330h POSTER

Recent climate trends, Glacier Bay, Alaska

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Glaciers and ice caps respond to changes in regional climate at decadal scales and can thus serve as indicators of regional climate change. Many of the tidewater and terrestrial glaciers in Glacier Bay, Alaska have been in a state of rapid retreat since the late 1700s, with highly disparate rates of recession occurring in the western versus eastern arms, yet the combination of environmental and glaciological factors that must exist to catalyze these rapid changes is not clearly understood. The Cold Regions Research and Engineering Laboratory (CRREL) initiated the first systematic analyses of weather and precipitation patterns across Glacier Bay National Park in 2000 by establishing 26 meteorological stations with the long-term objective of better understanding regional and global factors, that control terrestrial and marine physical systems. Initial temperature and precipitation trends show rapid seasonal and annual shifts. This is consistent with apparent paleotrends in climate and glacier advance and recession over the last 9K years, as well as the historical record that indicate the area is climatically sensitive. Comparisons of summer and winter precipitation totals show a precipitation gradient increasing northward from the lower bay to the head of Muir Inlet (east arm), and decreasing northwestward in the West Arm. Monthly averages of air temperatures span about 3.5 C between the warmest and coldest sites near sea level. Winter temperatures averaged more than 1 C colder in the West Arm than the East. We also found large gradients of increasing rainfall from north to south in the east arm, from north to south in the Western arm. Average temperatures in October decreased westward in the northern half of the Park and were milder at sites within the larger southern Bay. Continuing a long-term climate-monitoring program in Glacier Bay will assist with quantifying climate trends in the context of glacial movement, helping to determine the overall sensitivity of the regional glacial system to regional climate signals.

C12A-0874 1330h POSTER

Long-term Studies of Tidewater and Terrestrial Dynamics, Glacier Hydrology, and Holocene and Historic Climate Activity; Glacier Bay, Southeast Alaska

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Understanding tidewater and terrestrial glacier processes is critical when determining the impacts that contemporary climate and anthropogenic influences play in long-term glacier response. This understanding can only be acquired through a myriad of long-term glaciological and environmental measurements aimed to quantify glacial system response. The primary focus of our long-term investigations in Glacier Bay, Southeast Alaska is to better understand regional and global factors, such as climate, hydrology, oceanography and geophysical processes that control terrestrial and marine based physical systems. Our recent climatic investigations include analyzing modern climate trends at 26 locations across Glacier Bay and measuring the isotopic composition (oxygen and hydrogen) of precipitation, surface water, and glacier ice to assess regional hydrologic trends. Stable isotopes from samples of glacier ice, precipitation, and meteoric waters, have provided a regional assessment of the hydrologic cycle and weather patterns, allowing us to examine how current climate affects glacier activity and mass balance, and to assess the effect of precipitation on subglacial processes. Concurrently, the Park's longer-term Holocene glacial history and paleoclimate are being investigated using dendrochronological and radiocarbon dating of in-situ stumps, logs and soils. We have precisely located samples of 100 interstadial stumps believed to be overridden as ice moved down-fjord during glacial periods, as well as over 100 paleo-wood samples found in adjacent moraine, outwash, and lacustrine sediment deposits. Conventional radiocarbon dating by Accelerated Mass Spectrometry (AMS) has provided an estimate of ice-marginal positions throughout the Holocene. Using these data, we are also attempting to develop a tree-ring chronology of the last 9,000 years. If we succeed, this would be a unique dendrochronological record for a subarctic region in North America.

C12A-0875 1330h POSTER

Spatial Variation of Ionic and Isotopic Records From Snow Pits and Shallow Ice Cores in Central and Southeast Asia

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The alpine glaciated regions of the Belukha massif on the Altai, the massif of Pobeda-Khan Tengry in central Tien Shan, and the Bomi massif in Southeast Tibet were studied during annual summer field sessions since 1998. Analysis of soluble ion concentrations and äO18 signals in snow pits and shallow ice cores from glacier accumulation areas occurred to provide spatial coverage of documenting the climate change for the vast Asian continent, to identify the physical links controlling the glacio-chemical climate signals and to determine the appropriative deep ice core drilling sites. The geochemical records from central Asian sites show elevated levels of major ions corresponding to their terrestrial origin, continental location and greater influx of both primary and secondary aerosols compared to the Southeast Asia. Seasonal variability in the ice core obtained from the three glacier massifs was detected in the soluble ion concentrations of the vertical profiles throughout the firn pits and shallow ice cores to depths of 20 m. representing the time series for the past five years. äO18 analysis from the Asian sites shows pronounced peaks and are interpreted to represent annual accumulation layers. The signal variation is well-preserved at all locations and associates with seasonal changes in precipitation, air temperatures and sources of moisture. Analysis of the ä18O signals from the 14 m core obtained at southeast Tibet shows the considerable variability with the range of $14.19^{o}/_{oo}$, and mean value of $-16.19^{o}/_{oo}$. These isotope and geochemistry records will aid in understanding inter-hemispheric dynamics and global teleconnection of climate, and can provide information important to the forecasting of global climate change linking regional responses with broad atmospheric circulation patterns from the North Atlantic to Pacific and Indian Oceans. In addition, these snow/firn records can be directly associated with the internal circulation system in Central Asia. The developed research proved the feasibility and benefit of a deep ice coring from the Altai glaciers. Since that, the 175 m. deep core was obtained in the Belukha Plateau during the summer of 2003 to expand the high-resolution climatic records in Central Asia.

C12A-0876 1330h POSTER

A Reanalyis of the Contribution of Meteoric Ice, Flooding and Snow Ice Formation to the Mass Balance of Antarctic Sea Ice

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Sea ice core data from five autumn to early spring cruises in the Ross, Amundsen, and Bellingshausen Seas from 1993 to 1998 are reanalyzed to determine the role of meteoric ice, flooding and snow ice formation in the mass balance of Antarctic Sea Ice. Previous analysis of crystal texture and oxygen isotope data have determined that 15% to 38% of the total ice thickness has a meteoric ice component. This suggests a substantial component of the sea ice mass balance in the Southern Ocean during the growth season is due to flooding and snow ice formation. We show that although determining the meteoric component is relatively straightforward, attributing a mechanism of formation to this ice is more difficult. A number of post-genetic changes can occur that may significantly alter the isotopic signature of the ice, making definitive attribution of genesis difficult. Here, the oxygen isotope and crystal structure data is reanalyzed, and using a variety of models of ice growth and compositional evolution, we suggest that the true contribution of flooding and refreezing to the mass balance may be significantly lower, at 6% to 18% of the total ice thickness. However, we show that such estimates are highly dependent on the thermophysical behavior of the vertical exchange of brine in the ice, about which little is known quantitatively. The uncertainty in these estimates suggest that our understanding of the mass balance of Antarctic sea ice and its snow cover remains incomplete and awaits a better understanding of the ice permeability evolution and other small scale sea ice processes. Lastly, recent evidence from flooding experiments on Arctic sea ice is presented that demonstrate the importance of the vertical exchange of brine in determining the compositional properties of the ice.

C12B MCC: 3004 Monday 1340h

Fracture Processes in Glacier Ice II

(joint with OS)

Presiding: **H A Fricker,** Scripps Institution of Oceanography**; C Hulbe,** Portland State University

C12B-01 1340h INVITED

What lies beneath? The question of sub-surface crevasses

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The process of fracture is a major control on the form of the Antarctic ice sheet, both through the process of iceberg calving and through the isolation of streaming flow by the formation of crevassed shear margins. Furthermore, the presence of crevasses is a valuable diagnostic of stress within the ice sheet. Their persistent visibility after burial provides our primary tool for mapping changes in ice stream activity. However, the processes of fracture initiation and growth are poorly understood. Hitherto it has been a fundamental assumption that crevasses always initiate at the surface and propagate to some limiting depth. We revisit the linear elastic fracture mechanics (LEFM) description of the initiation and critical-growth of near-surface crevasses to examine this assumption. We assume growth of an isolated crevasse from a small "starter crack", driven by tensile stress resulting from glacial deformation and opposed by weight-induced lithostatic stress. The LEFM approach allows us to estimate the minimum length of "starter crack" required for growth to occur. In this formulation the dynamic tensile stress varies substantially with depth, such that the tensile strain rate remains constant. We show that under these conditions crevasse initiation may be from centimetre-scale starter cracks located either at the surface or at depths of 10-30 m. At present, the formulation of a reliable predictive model is limited by an incomplete knowledge of the mechanical properties of firn and a lack of material evidence to support the existence of "starter cracks". Ground penetrating radar data acquired on Rutford Ice Stream, Antarctica show crevasses at depths of several metres beneath the ice surface that do not appear to have been bridged in the normal way, and which must have been formed either at depth, or at the surface in areas where no surface crevassing is currently visible. The theoretical treatment together with apparent observations of sub-surface crevassing calls for a reinvestigation of the processes of fracture to re-establish the validity of assuming that the depth of a crevasse is a reliable indication of its age.

C12B-02 1400h INVITED

Borehole Observations of Cracks in a Polythermal Glacier

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