C31A-04 0845h

ICESAT/GLAS Reveals Ice Sheet Surface Features at Ice Stream Shear Margins in West Antarctica.

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The shear margins surrounding ice streams are marked by grooves and ridges in the ice surface. These scars remain after ice streams become inactive, recording the structure of the ice streams, and allowing investigations of the history of the ice stream system. The positions of the scars are readily found in satellite imagery of WAIS, but the character of the surface undulations is more difficult to determine. NASA's GLAS (Geoscience Laser Altimeter System) mission has produced several thousand kilometers of high-resolution elevation profiles over the West Antarctic ice streams. These profiles reveal the shape of the margin scars at high vertical and horizontal resoultion. Here I examine the marginal features of both active and passive ice streams, and track their evolution from the inland tributary region to the Ross Ice Shelf. I find the horizontal position of the marginal features using AVHRR (Advanced High Resolution Radiometer) and SAR (Synthetic Aperture Radar) imagery, and determine their vertical structure from GLAS data. Three main factors contribute to the formation of marginal features: The change in basal drag at the edge of the ice stream produces a break in the surface slope. The high strain rate associated with fast flow in the margin produces an effective softening of the ice, leading to flattening of the surface. Changes in the elevation and width of the ice stream produce slope breaks at the outside of the margin where slow-moving ice cannot rapidly respond to changing boundary conditions. I present the results of finite element modeling demonstrating the surface characteristics associated with these three processes and relate them to the features seen in the ice sheet.

C31A-05 0900h

Atmospheric and Surface Reflectance Measurements by the Geoscience Laser Altimeter System

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The Geoscience Laser Altimeter System launched in early 2003 is the first satellite instrument in space to globally observe the distribution of clouds and aerosol through laser remote sensing. The instrument is a basic backscatter lidar that operates at two wavelengths, 532 and 1064 nm. The mission data products for atmospheric observations include the calibrated, observed, attenuated backscatter cross section for cloud and aerosol; height detection for multiple cloud layers; planetary boundary layer height; cirrus and aerosol optical depth and the height distribution of aerosol and cloud scattering cross section profiles. The data will enhance knowledge in several areas of atmospheric science: the distribution, transport and influence of atmospheric aerosol, significantly more accurate measurements of the coverage and height of cirrus and other clouds, polar cloud climatology and radiation influence, the dynamics planetary boundary layer and others. An overview and summary of initial results are presented. Initial results from the first months of operation show the detailed height structure of clouds and aerosol on a global basis as expected. The 532 nm channel was expected to be the more sensitive and primary channel for aerosol measurements, but extensive aerosol loading in many regions are observed by the 1064 nm channel. Sensitivities are down to a few times 10-6 1/(m-sr), much better than originally expected. The 532 channel adds an order of magnitude addition sensitivity. Initial comparisons to aerosol models have been done. Similarly for global cloud cover, good results are obtained just from the 1064 nm signal and from both channels, a measurement of multiple layers and cloud overlap has been made. Antarctica observations show high levels of total cloud cover including unique low-level cirrus and blowing snow. Data products have been generated for cloud, aerosol and PBL presence and heights in addition to the basic scattering cross section profiles. The received reflected energy of the laser pulse from the surface has applications to characterize atmospheric parameters. The surface pulse reflectance is a function of the atmospheric transmission and the surface properties. The calibration of the surface reflectance and atmospheric transmission retrievals has been analyzed through surface based intercomparison measurements. Pulse reflectance over oceans has been related to wind speed with results that are in agreement with predicted values. Multiple scattering of photons is an important factor for the effective atmospheric transmission, especially for transmissive clouds, and analysis of surface signals provide a test of model generated corrections. Stretching of pulses due to cloud and aerosol scatting is also an important factor for the accuracy of the surface altimetry and the clearing and correction of scattering errors has been initially evaluated.

URL: http://virl.gsfc.nasa.gov

C31A-06 0915h

ICESat Observations of Forest Canopy Height

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The Ice, Cloud and Land Elevation Satellite (ICESat), a component of the NASA Earth Observing System, was launched into orbit on January 12th, 2003. The ICESat mission acquires globally distributed profiles with the Gesoscience Laser Altimeter System (GLAS), providing observations of ice sheet elevation, cloud and aerosol heights, land topography and vegetation characteristics. Vegetation height is a key indicator of the amount of above-ground carbon stored in forests, which is an essential component in the cycling of carbon dioxide between the Earth's atmosphere and land surface. Vegetation height is also a useful indicator of forest age and habitat quality. Traditional orbital remote sensing methods are not well suited to measure vegetation height. The laser altimeter waveforms recorded by the GLAS instrument provide a global means to sample the height of vegetation along the ICESat profiles. In forested areas where the ground is flat or gently sloping, we observe that the waveforms record the laser pulse reflected from vegetation and, slightly later in time, the reflection from the ground. The time difference between these two echoes yields a direct measurement of maximum canopy height. As anticipated, in areas of steep terrain, the vegetation and ground returns become mixed together in the waveforms, making the analysis more difficult and requiring independent information on ground slope at the laser footprint location. We illustrate waveform retrieval of canopy height for low slope settings for several forest ecosystems, and validate the GLAS height retrievals for Pacific Northwest forest stands using a technique that matches observed and simulated waveforms where extensive high-resolution airborne laser mapping of ground topography and vegetation height is available.

C31A-07 0930h

Sea Ice Elevation From ICESat/GLAS Laser Altimetry

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Arctic sea ice is currently in a state of change. Such changes in sea ice thickness and extent can be used to assess polar climate variability. Observational records suggest that over the past few decades a substantial decline in sea ice extent together with rapid thinning have occurred. Continuous monitoring of sea ice thickness has however proved to be a more difficult task than measuring ice extent and no data sets cover the entire Arctic. Recent research shows that radar altimetry from the ERS satellites can successfully be used to measure sea ice freeboard, from which ice thickness can be estimated. However the exploitation of this data is limited to some extent due to the large radar footprint (10km), and limited latitudinal coverage (to 81.5°). In addition all satellite altimeter estimates suffer inaccuracies due to uncertainties in snow loading on sea ice. The Geoscience Laser Altimeter System (GLAS) extends satellite altimetric coverage of sea ice to 86° latitude for the first time. In addition, the much smaller laser footprint (70m) provides improved resolution of sea ice and ocean topography. On the other hand, laser altimetry data is more susceptible to atmospheric effects such as cloud cover and forward scattering of laser pulses. Using data from the first month of operations, we examine the feasibility of deriving sea ice elevation from GLAS altimetry data. We investigate the influence of instrument errors and environmental effects (e.g. pulse broadening from clouds) on the accuracy of GLAS elevation measurements. We compare GLAS elevations over sea ice to a state-of-the-art Arctic geoid model and to a mean sea surface derived from ERS radar altimetry data. We analyse the characteristics of laser waveforms and compare these with available *in situ* data. Finally, we compare GLAS sea ice elevations with sea ice freeboards and thickness derived from ERS data. By combining these two datasets, the potential exists to obtain estimates of snow loading and hence more precise estimates of sea ice thickness.

C31B MCC: Level 1 Wednesday 0830h

Advances in Glacier Geophysics II Posters *(joint with G, H, OS, PP)*

Presiding: **B Kulessa,** Queen's University of Belfast**; T Murray,** University of Leeds

C31B-0394 0830h POSTER

Estimating the Depth and Shape of Lake Vostok's Water Cavity from Aerogravity Data

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The water circulation within Lake Vostok provides a viable mechanism for transporting mass and energy through the lake, enhancing the potential for the support of biota. The circulation pattern depends primarily on the geometry of the lake bathymetry. Water in shallow regions will warm more from the geothermal heat flux than in deeper parts, resulting in subtle lateral changes of water density. This temperature-induced change in water density is the primary driving force for the horizontal circulation within the lake. To date, only a few seismic soundings have provided estimates of the water depth of Lake Vostok. To determine the depth and shape of the water cavity over the entire lake we use gravity data acquired along a grid of flight lines traversing the region. The free-air gravity anomaly field reflects density variations related to both major geological and topographic structures and changes in the water depth of the lake. The gravity contribution from the deeper geological structures can be removed from the free-air anomaly by low-pass filtering of the data. The subglacial topography outside the lake and the geometry of the overlying ice sheet are well constrained from ice-penetrating radar measurements. The unknown parameter that dominates the filtered gravity anomaly is the relief of the bedrock-water interface. Assuming a constant density contrast across this boundary, the gravity data can be inverted for the bathymetry of the lake. The results show that Lake Vostok consists of two sub-basins, a northern and southern. The southern sub-basin is much deeper and approximately double the spatial area of the smaller northern sub-basin. The two sub-basins are separated by a saddle with very shallow water depths. The separation of Lake Vostok in two distinct sub-basins has important ramifications for the water circulation within the lake. The lake volume estimated from the inversion of gravity data is 5200 cubic km, three times bigger than previously thought. The melting and freezing pattern observed from ice-penetrating radar data is intimately linked to the bathymetric structure of the lake. Over the northern basin, basal melting is dominating while over the southern basin, basal freezing dominates the lake/ice interaction. For a fresh-water scenario, basal meltwater in the northern basin would sink to the bottom. For this reason the water exchange between the two basins is probably very limited and raises the possibility that the two separate basins have

different chemical and maybe biological compositions. Sediments released by basal meting are likely to accumulate in the northern basin while pre-glacial sediments are more likely to be found in the southern, deeper basin.

C31B-0395 0830h POSTER

Helicopter electromagnetic and glaciers: example from Mt. Adams, Washington.

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Helicopter Electromagnetic (HEM) surveys over Mt. Adams and Mt. Baker were conducted in May of 2002. The objective of the surveys was to delineate the areas of alterations under glacial cover in order to estimate the hazards associated with the weaker, clay zones. The altered, water saturated zones are electrically very conductive in comparison with unaltered rocks and glaciers (ice). Finding altered zones under glaciers with current HEM methods is relatively straightforward. In this paper we examine a more difficult task of measuring ice thickness with HEM techniques. We are evaluating the conditions that data have to satisfy in order to distinguish between electrically resistive unaltered rocks and glaciers. An example of inversion results from the HEM survey over Mt. Adams is provided.

C31B-0396 0830h POSTER

Glacial Till Detection Experiments With Transient Electromagnetic Methods

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Transient Electromagnetic (TEM) investigations have been carried out on Fireweed Rock Glacier in Wrangell-St. Elias National Park, Alaska and the East Fork Toklat Glacier in Denali National Park, Alaska. TEM methods were effective in determining the geometry of the rock glacier but were more limited in resolution on the ice glacier. A conductive layer beneath the rock glacier was identified, and its distribution is consistent with a till-like layer. A similar layer was not detected beneath the glacier; the lack of this conductive layer limits the resolution of glacial depth. These experiments and forward modeling indicate that TEM methods may provide a means for detecting a sufficiently thick and conductive till layer beneath glaciers and rock glaciers.

C31B-0397 0830h POSTER

Time-lapse monitoring of subglacial drainage conditions using borehole electrical surveying

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Subglacial electrical surveying has so far been poorly documented, although existing case studies at warm-based glaciers are encouraging. The particular advantage of such methods over other common techniques is their ability to produce multi-dimensional images especially of subglacial hydrological phenomena. This supports interpolation between measurements in single boreholes, which is otherwise often insufficient or error-prone in characterising such typically highly heterogeneous conditions. We present electrical resistivity data recorded at the base of four boreholes drilled through Haut Glacier d'Arolla, Valais, Switzerland. The resistivity data, acquired repetitively every hour over two diurnal hydrological cycles in the late melt season, were inverted in 3-D. The resulting repeat images reflect time-lapse resistivity changes in the subglacial sediment layer, and were correlated with water resistivity data recorded between the boreholes using a modified version of Archie's law. The correlation matrices reflect preferential subglacial water flow in the eastern part of the study area, and more distributed flow in the western part. Application of the modified law allows estimation of the true intrinsic formation factor by plotting the apparent formation factor (bulk sediment resistivity divided by water resistivity) against water resistivity. Use of Archie's law and the Kozeny-Carman equation then allows estimation of the porosity and hydraulic conductivity of the subglacial sediments, respectively. These results complement earlier findings from electrical self-potential modelling, which are briefly reviewed. We conclude that subglacial electrical surveying has the capacity to support interpolation of single-borehole hydrological data across the glacier bed.

C31B-0398 0830h POSTER

Post-surge distribution of warm-ice at Bakaninbreen, Svalbard from ground-penetrating radar

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Bakaninbreen, a 17-km long glacier in southern Svalbard, underwent a prolonged surge during 1985–95. The surge front, ~50 m high, propagated progressively downstream, and by 1995 had halted ~1.7 km from the glacier margin. Ground-penetrating radar (GPR) surveys located just downstream of the front suggested that ice and bed were at temperatures below the pressure melting point; surveys located just upstream of the surge front showed warm ice at the bed (at the pressure melting point), and zones of scattering at the sides of the glacier interpreted as warm ice in shear zones. These results have been used to suggest that the surge involved a thermally regulated soft bed mechanism, with the rate of propagation of the front controlled by friction at the margins and the rate of warming of the bed. However, the interpretation at Bakaninbreen was based on GPR and seismic surveys located within 1 km of the surge front. GPR surveys further upstream were conducted to identify spatial variation in the structure and thickness of the scattering zones; to image any marginal shear zones; to attempt to differentiate between water and sediment inclusions as causes for the scattering; and to assess the water content of any warm ice. Twenty-seven 100 MHz crossglacier common offset (CO) radar lines were collected, typically 1 km in length, as well as shorter multi-frequency and multi-polarisation CO and common midpoint (CMP) surveys. The distribution of scattering does not simply reflect shear margins at the sides of the glacier, nor is it confined to the areas of thickest ice. Two unexpected attributes of the regions are: (i) their distribution changes markedly over relatively short distances up and downstream (~200 m); (ii) some are isolated both from the glacier bed and the surface. The CMP surveys show the water content of the ice would be ~3-4% dependent on the inclusion model used. Warm ice could result from (1) strain heating during fast flow; (2) water "injection" from basal or surface crevasses; or (3) changes in the melting point with depth. Sediment can be added to the ice from the glacier bed or from surface sources. We assess which of these best explains the distribution of scattering within the glacier.

C31B-0399 0830h POSTER

Basal Water Flow, Melt and Accumulation in the Dome C "Lake District", Antarctica, Using Airborne Radar Profiling of Bed Echo Character and Internal Layering.

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Using airborne radar we infer the presence of subglacial water by three physical conditions: A high amplitude basal reflector, a local minimum on a potentiometric surface obtained by adding bed elevation to the thickness of the overlying ice cover times its density, and a deformation of internal layers consistent with melt at the base of the ice sheet. The coefficient of reflection at the base is calculated by solving the radar equation and correcting for temperature dependant dielectric loss. The temperature profiles used to obtain this correction are highly sensitive to two poorly constrained parameters: accumulation history and geothermal flux. Improved estimates for accumulation, and melt rate can be obtained by obtaining a best fit of these parameters as well as shear layer thickness to Fahnestock's modification of the Dansgaard-Johnsen equation relating age and depth. Five internal layers of ages ranging between 53 ka and 291 ka have been traced through 5000 line km of UTIG airborne radar profiles, and then fit to this age versus depth equation to obtain shear layer thickness, accumulation and melt rate. The accumulation figure obtained by this fit is then used to calculate a one dimensional temperature profile to correct our basal reflection coefficients. The reflector corresponding to Lake Concordia is well defined and consistent with a potentiomeric low. While melting occurs over the lake, the area of heaviest melt is centered on the Southeast shore of the lake, not in the center of this body. The maximum melt rate here is on the order of 6 mm/yr. A valley extends southward of Lake Concordia which contains moderately bright reflectors consistent with saturated sediment. Our one dimensional temperature profiles are also consistent with the ice being at the pressure melting point in this area. At the southern part of this valley, 40-50 km from lake Concordia we see refection coefficients on the order of those associated with water. However since these reflections are up potential from the lake an additional source of melt is required to sustain their existence. The necessary melt occurs directly along an escarpment located 5 km to the west of our strong echoes. This escarpment forms a boundary between strong bed echoes and weak bed echoes and also represents an abrupt increase in relative shear layer thickness. Given the combination of strong bed echoes, a downward sloping potentiometric gradient between these upper lakes and Lake Concordia and the likelihood that warm ice is present throughout the valley, it is likely that a significant subglacial water system forms a hydraulic connection between these systems.

URL: http://www.ig.utexas.edu/people/students/sasha/index.htm

C31B-0400 0830h POSTER

Estimating the ground-penetrating radar velocity distribution in temperate glaciers using common-offset migration velocity analysis

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Most ground-penetrating radar (GPR) surveys are acquired with a constant transmitter-receiver offset and often, little processing is employed in generating the final image. This can provide useful information and is valuable as a rapid reconnaissance tool, but does not take full advantage of the information that can be carried by the radar signal. One of the most valuable material properties that can be extracted from GPR data is electromagnetic (EM) propagation velocity. In cases where there are scattering events distributed throughout a GPR profile, it is possible to compute an accurate velocity distribution from common-offset data using common-offset migration velocity analysis. Migration can be thought of as a focusing operation that attempts to move all scattered energy back to its point of origin. The net effect is that diffractions are collapsed and dipping reflectors are moved to their correct spatial position. Migration is strongly dependent on the accuracy of the velocity field. We can use this dependence and the large number of "point-like" scatterers present in temperate glaciers to our advantage. By applying a series of constant velocity migrations with a range of velocities then picking the velocity at a given depth/horizontal position that yields the most "focused" image, we can estimate a laterally and vertically continuous velocity distribution. We simply choose the velocity distribution that collapses all diffractions. In a field study on Bench Glacier, Chugach Mountains, Alaska, we applied this technique and found significant lateral and vertical velocity heterogeneity which we attribute to primarily to variations in water content. Although simple conceptually, the method requires careful application due to a number of potential problems and pitfalls including out-of-plane reflections in 2D data, pegleg multiples, and precision limited by the distribution of scatterers. In spite of these limitations, with careful application the method can provide a first order estimate of the radar velocity distribution.

C31B-0401 0830h POSTER

New Methods for Enhancing Subglacial Morphology From Airborne Radar Sounding With Implications for Uplift History and Glaciation Between the Transantarctic Mountain Front and the South Pole, Antarctica

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The Transantarctic Mountains (TAM) form the high boundary between the subsided and extended crust in the Ross Sea Embayment known as the West Antarctic Rift System (WARS) and the East Antarctic craton. The objectives of this study are to characterize the subglacial bedrock morphology of the southern TAM between the Scott and Reedy Glaciers from Ice Stream A to the South Pole along 150° W and to define the geomorphology and structural geology along the southern TAM front through analysis of airborne ice-penetrating radar data. Seismic migration processing methods were applied to approximately 15,000 line km of incoherently detected and differentiated radar sounding records to correct the observed slope of the bed surface and preserve true' angular relationships for detailed morphological and structural analyses. Subsequently, the ice and bedrock surfaces were picked along each line and combined with the known geology, compiled from various sources, for geomorphologic and structural interpretation. The southern TAM have a southward tilted fault - block structure and are bounded by normal faults on both the north and south sides of the massif. Faults are oriented primarily subparallel to the TAM (nw-se) and to WARS rift fabric in the Interior Ross Embayment. Faults oriented obliquely to the TAM break the area of maximum uplift into three nnw-sse trending blocks. Four distinct morphological provinces are identified along the length of the survey based on bed surface elevation analysis. These include: 1) a polar basin and plateau region with low relief features and thick (∼3km) ice cover; 2) an area of alpine glaciation with well-preserved U-shaped valleys that show a glaciation network that flowed opposite (southward) of contemporary glaciers; 3) the TAM massif, the 30-50 km wide region of maximum uplift, includes three subglacial fault blocks and the subaerial part of the TAM; and 4) the TAM front, a normal fault zone that forms the northern terminus of the range. This fault zone down - drops the TAM from >3000 m to sea level over ∼50 km and facilitates the development of valley glaciers and Ice Stream A.

C31B-0402 0830h POSTER

Aerogeophysical evidence for complex subglacial geology below the Rutford drainage basin,WestAntarctica

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A significant part of the West Antarctic Ice Sheet appears to be imposed upon a complex and still largely unknown continental rift system, perhaps featuring sedimentary basins, thin crust and high heat flow. Subglacial geology has been postulated to strongly modulate the dynamics and stability of the ice sheet itself. Specifically, recent aerogeophysics collected over central West Antarctica at edge of the Whitmore Mountains crustal block show that narrow subglacial rift basins with thick sedimentary infill may control the onsets and lateral margins of ice streams. The British Antarctic Survey flew an aerogeophysical survey during the 2001-02 field season: the main aim was to investigate what factors control the location and dynamics of the onset region of the Rutford Ice stream. Airborne radar, aerogravity and aeromagnetic data were simultaneously collected over the drainage basin of the Rutford Ice Stream. The new bedrock elevation grid for the area shows that the Rutford Ice Stream is constrained by a deep bedrock trough with a N-S to NE-SW trend. The onset region appears however to lie within an E-W bedrock trough at the edge of the Ellsworth Mountains crustal block. Bouguer gravity maps do not reveal typical signatures for a coincident deep rift basin at this location. However, a sharp NE-SW trending gradient, likely separating crustal blocks with contrasting crustal thickness is revealed. Aeromagnetic data image NE-SW trends north of the Rutford Ice Stream. In the onset region, these trends appear to be truncated by a NNW-SSE trend, lying on strike with the Ellsworth Mountains. Hence, the new aerogeophysical data suggests greater complexity in the subglacial geology and structure of an onset region of an ice stream compared to previous investigations.

C31B-0403 0830h POSTER

Insights Into the Drainage Characteristics of Pleistocene Ice Sheets in NW Europe Using 3D Seismic Reflection Data.

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We use commercial 3D seismic reflection data to image spectacular, cross-cutting, anastomosing valley systems formed by subglacial meltwater drainage in the Pleistocene of the North Sea, at 58degN 1degE. Although the seismic data were collected to image deeper structures, the high resolution and quality of the data have allowed us to identify meltwater drainage systems formed at the base of different NW European Pleistocene icesheets in the top 400 ms of the data. The data volume comprises stacked, deconvolved and time migrated data, in 12.5 x 12.5 m bins sampled at 4 ms. The frequency bandwidth is 5-80 Hz (at the 20 dB point), giving a vertical resolution of 8 m and lateral resolution of 12.5 m. Within the 12.5 by 8 km study area, four phases of cross-cutting valley incision can be identified. Individual valleys, which are 30-155m deep and 250-1200m wide, have the irregular longitudinal profile characteristic of meltwater incision under ice sheets. The first three phases are orientated N-S, whilst the youngest, fourth phase valleys and orientated E-W. The fourth phase valleys are also narrower and shallower than the older valleys. We speculate that the successive episodes of valley formation document a history of advance and retreat of an ice-sheet, probably during the Elsterian glaciation of northwest Europe. Detailed mapping of the valley morphology and the geometry of the infill has shown that the valleys were incised by a number of meltwater flow episodes, which were variable energy, probably high velocity and episodic. As a result the valleys were dynamic and long-lived, and they existed as depressions for long periods of time under the ice sheet. When the ice sheet retreated, they were filled with proglacial sediments. From our limited study area it appears that the first of these advances had a N-S orientated drainage network and generated a greater volume of subglacial meltwater than the second, whose drainage network was orientated in a more E-W direction and was characterised by lower velocity and volume meltwater flow events.

C31B-0404 0830h POSTER

An Autonomous Multi-sensor Subglacial Probe: Preliminary Results

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Understanding subglacial behaviour is vital to our understanding of glacier dynamics and the relationship between climate change and glacier response. Over the last 10 years dramatic advances have been made by examining subglacial behaviour by in situ wired' instruments. This talk describes a new way of examining the subglacial environment by the insertation of autonomous multi-sensor subglacial probes. These are wire free' and send data back to the surface by radio transmission. Compared to wired-in probes they behave more like clasts within the subglacial environment. The preliminary findings from the first field season at Briksdalsbreen, Norway will be reported, with data from GPR, ice drilling, till samples and probe insertation.

C31B-0405 0830h POSTER

Probing Thermal Diffusivity and Microwave Extinction on Ice Sheet Surfaces Using Surface and Brightness Temperature Time Series

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Time series of Antarctic surface temperature and 37 GHz, vertically polarized brightness temperature can be simply related by convolution and a single, characteristic time scale. The time scale is given by a ratio of thermal diffusivity and extinction length in near-surface firn (Winebrenner, Steig and Schneider, submitted to Ann. Glac., 2003). Here we investigate spatial and temporal variability in the characteristic time scale using Automated Weather Station data and satellite observations, at several locations in West Antarctica, and at times from late 1979 to the present. Observations at Byrd Station, for example, show no evidence of temporal variability during the period 1981-1987. The bounds on observed variability, together with physical modeling, can be used to bound variations in thermal diffusivity and microwave extinction length (which is, in this instance dominated by absorption) in both space and time. Those bounds allow us to place quantitative constrains on the interpretation of microwave brightness temperature data in terms of surface temperature. That interpretation in turn informs analysis of Antarctic climate variability, providing a calibration data set for statistical climate reconstruction from weather station data and from ice core observations acquired by the US-ITASE program.

C31B-0406 0830h POSTER

The effect of particles on dynamic recrystallization of granular ice during creep

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This work presents experimental observations of the influence of dispersed particles on the creep behavior and dynamic recrystallization of granular freshwater ice. The particles were present both within the grains and in the grain boundaries. The mechanical behavior of granular ice with particle contents of 0 wt.%, 0.5 wt.%, 1.0 wt.% and 4.0 wt.% was investigated under reversed direct-stress and creep loading conditions. Samples were made from laboratory-prepared freshwater ice with silt-sized particles and tested at −12° C . Results show that creep rates of specimens with particles are higher than particle-free ice. Studies of the microstructural evolution showed that dynamic recrystallization occurs for both the particle-laden ice and particle-free ice, but that the particles enhance the recrystallization. Recrystallization nucleates along the grain boundaries in the early stage of creep straining for all specimens, but particle-laden ice shows a higher nucleation rate because the particles at the grain boundaries apparently cause an increase in strain energy during deformation. Microstructural observations also show that particles inside the grains both inhibit grain boundary migration, and act as nucleation centers for the new grains when the strain energy is high enough. The grain size

of the particle-laden ice is much smaller than that of particle-free ice after a given amount of creep straining. This research was supported by NSF Office of Polar Programs, Arctic Natural Sciences Program (OPP 011737), Dr. Jane Dionne, Program Manager.

C31B-0407 0830h POSTER

A Snow Accumulation Map of Part of Greenland Derived From InSAR Correlation Observations

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We present here an improved method for estimating snow accumulation rates in the Earth's polar ice sheets from remote sensing observations. Microwave methods have often been used to extrapolate point accumulation rates to obtain continent-wide maps. Because ice is semi-transparent to microwave radiation, observations of the ice sheets reveal composition and structure of the top 10's of meters of firn when interpreted using electromagnetic scattering models. These in turn constrain estimates of ice accumulation rates, critical for determining the mass balance of the ice sheets. Typical approaches use radar reflectivity or emissivity measurements to obtain snow grain sizes, which are then related to accumulation rate. But reflectivity and emissivity depend not only on grain size, but also on the thickness of annual layers in the top few meters of firn. A radar image may appear bright because grain size is large, implying slow accumulation, or because the annual layers are thick, implying high accumulation. Using InSAR measurements of both reflectivity and correlation permits solution for both the layer thickness and the grain size at depth, hence the ambiguity in the brightness measurements is avoided. We developed an interferometric ice scattering model to relate ice grain size and layer thickness to accumulation. We propose a buried layer model based on the incoherent addition of echoes from hoar layer interfaces, in which the scattering from a single layer is found by small-perturbation methods. Because the model also depends on the total thickness of the layered region, we assumed a constant 6 m thickness for the layered region in Greenland's dry snow zone. Penetration depth estimates, also derived from InSAR, in this area are typically 20 m or more, so that much of the observed echo is from depths below the layers-scattering from individual grains is also significant in this region. The interferometric model describes the ERS amplitude and correlation data simultaneously and consistently, with variations in hoar layer spacing of 11-26 cm and grain radius of 0.6-2 mm providing the needed structural fluctuations for the observed range of cross-section and correlation. In situ accumulation measurements varies from about 15-25cm w.e./yr in our test area. Comparison of our model inversion results with in situ core measurements show that the spatially-varying trend in accumulation rates over our study area is consistent between both data sets, which is not the case in many published maps derived from radar reflectivity or radiometer data alone. Interestingly, straight contouring of the Greenland-wide ice core data disagrees in this region also as the data are very sparse. Because the remote sensing InSAR method using both correlation and reflectivity data provides closer agreement to the truth measurements inferred from the cores, it is likely that a full continent accumulation map would be more accurate also.

C31C MCC: Level 1 Wednesday 0830h

Ice-Ocean Interactions and the Cryosphere I Posters *(joint with OS, GC)*

Presiding: **K Grosfeld,** University of Bremen**; D M Holland,** Courant Institute of Mathematical Sciences, New York University

C31C-0408 0830h POSTER

Ice Shelf Front Readjustment in Response to Inflow Perturbations: Towards a new Model of Ice Shelf Disintegration

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The Ross Ice Shelf has in its recent past seen a significant reduction of ice influx. The stoppage of Ice Stream C, about 150 years ago, reduced inflow of ice by 20-30 km^3/yr. Adding to this trend is the current slowdown of Whillans Ice Stream, which has averaged 5 m/yr^2 over the last 23 years. The loss of annual ice influx may become as high as 50-60 km^3/yr should Whillans Ice Stream come to a complete stop as predicted by numerical models. This influx reduction constitute a major perturbation that could trigger a critical rearrangement of the ice shelf. The collapse of smaller West Antarctic ice shelves has shown that floating ice fronts can retreat rapidly. We have developed a new numerical ice shelf model that includes a mobile ice shelf front, which can adjusts to changes in ice thickness and velocity field. The dynamic ice front condition allows us to investigate the dynamics of collapsing ice shelves. Initial model results based on simplified ice shelf geometry showed that both location and curvature of the floating ice front change in response to inflow perturbations. We intend to use our model to predict future changes in the Ross Ice Shelf due to decreasing discharge from the Ross Ice Streams. Retreat of the Ross Ice Shelf front could expose up to 400,000 km^2 of new polar sea surface area. Such exposure may change the regional sea ice conditions and maybe even cause rearrangement of the thermohaline ocean circulation.

URL: http://es.ucsc.edu/~poul

C31C-0409 0830h POSTER

Sea Ice Drift and Transports in the South Pacific: Model Results and Observations

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The first comprehensive study of sea ice drift, transports and formation rates in the southeastern Pacific sector of the Southern Ocean on time scales ranging from daily to interannual variability is presented. Sea ice drift in the Amundsen Sea and its forcing and variability is analysed using data from three buoys deployed on the ice in March 2000 and results of the coupled ice-ocean model BRIOS (Bremerhaven Ice Ocean Simulations). Three drift regimes are identified with wind as the main driving force and weak oceanic influence. A first sea ice budget is presented for the Amundsen Sea with meridional and zonal transports of almost equal magnitude and weak import from the Bellingshausen Sea. Transport magnitude and variability at the western boundary towards the Ross Sea depend strongly on the interplay between zonal easterlies and westerlies and meridional winds, which leads to accumulation of sea ice in or export from the southern Amundsen Sea. The latter strongly affects sea ice conditions in the eastern Ross Sea, while western Ross Sea ice is formed locally. An enhanced northward export of from the western part of the Ross Sea induces a large import of Amundsen Sea ice into its eastern part, because the export allows the Amundsen Sea ice to move further westward. The existence of two independent sea ice regimes in the Ross Sea with exceptionally high formation rates in the western part correlates positively with a zonal salinity gradient in the water column along the Ross Ice Shelf edge and possibly reduces the need for subsurface upwelling onto the western continental shelf.

C31C-0410 0830h POSTER

About the Freshwater Contribution of the Eastern Weddell Ice Shelves to Water Mass Formation in the Weddell Sea

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The interface between the Antarctic Ice Sheet and the Southern Ocean corresponds to the bases of floating ice shelves which constitute about one half of Antarctica's coast line. Heat and mass fluxes across this interface, associated with melting and freezing processes, directly affect the ice shelf glacial system. Furthermore, modifications of dense water masses due to melting and freezing at the ice shelf base is directly linked to the formation of deep waters at the continental shelf break. Hence, the export of Ice Shelf Water (ISW) from the extensive ice shelf cavities, especially in the Weddell- and Ross Seas, represents an important component for the ventilation of the world ocean abyss. However, the smaller ice shelf regions in the Weddell Sea, the Larsen and the Eastern Weddell Ice Shelves (EWIS) represent important contributors to this process. Their role in this discussion is up to now possibly underestimated. In this study we concentrate on the eastern Weddell Sea sector as an important inflow region for the subsequent following upstream regions, the Filchner Ronne Ice Shelf and the Larsen Ice Shelf. Applying a three dimensional ocean model with as realistic as possible bathymetry and ice thickness data based on the BEDMAP data set, we simulated the flow regime in this region and calculate the freshwater flux, formed at the base of the ice shelf. Our analysis will lead to sensitivity studies for the influence of increased ocean temperatures, possibly caused by global warming and different ice shelf–ocean boundary conditions, affecting the melting and freezing rates. EWIS is of special interest, as it is separated from the coastal current by a narrow continental shelf margin and partly overlaps the deep sea. Hence, direct interaction of the coastal current with the ice shelf is expected to lead to high melting rates.

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C31C-0411 0830h POSTER

Can the recent thinning and acceleration of Pine Island Glacier, West Antarctica be explained by changes in its ice shelf?

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There is a wealth of evidence implying that Pine Island Glacier, West Antarctica (PIG) is presently undergoing rapid change. Much of this evidence is associated with PIG's ice shelf and ice plain. This includes a retreat of the grounding line by 5 km from 1992 to 1994; a contemporaneous acceleration of flow in the same area by 18%; as well as various calving and crevassing events over the last 30 years. One of the most intriguing observations is of widespread thinning over PIG's full extent up to 150 km upstream of the grounding line at rates of approximately 0.5 m/yr. If this thinning has been caused by the ice shelf/plain changes then it implies a far closer linkage between grounded and floating ice than previously thought possible. We investigate this possibility by using a three-dimensional, numerical model of ice flow. The model incorporates the temporal changes in ice thickness generated by changes in ice flow. We investigate coupling between PIG and its ice shelf in a series of perturbation experiments in which the shelf is thinned and shortened, and the grounding of the ice plain is reduced. Results imply a two-stage process in which initial changes in the shelf have an immediate, mechanical effect up to 50 km inland from the grounding line. These changes are sufficient to initiate a kinematic wave of thinning, steepening ice that propagates rapidly (approximately 5 km/yr) upstream and affects the entire ice stream after approximately 20 years. The propagation mechanism of this wave is the increase in gravitation driving stress consequent on local steepening of the ice surface, which feeds directly into the force balance determining the velocity of the ice stream.

C31C-0412 0830h POSTER

Submarine Melting at Temperate Tidewater Glacier Termini: How Significant is it?

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