the earth's surface must be used. This paper uses co-located measurements of cloud and aerosol backscatter obtained from a well calibrated airborne lidar system to obtain the lidar calibration constant for the 1064 nm channel of the Geophysics Laser Altimeter System (GLAS). In January, 2003 GLAS was launched into a near polar orbit aboard the Ice, Cloud and land Elevation Satellite (ICESat). In addition to a high resolution altimetry channel, GLAS contains both 1064 and 532 nm backscatter lidar channels. After a month long engineering checkout phase, the first laser (GLAS has 3 lasers) was turned on and GLAS began obtaining atmospheric and surface returns at 1064 nm. The 532 nm channel was not activated at this time due to engineering concerns. In this paper we describe the methodology used to calibrate the GLAS 1064 lidar channel using validation measurements acquired by the Cloud Physics Lidar (CPL) during the THORpex (THe Observing-system Research and predictability experiment) campaign in February-March 2003. The CPL is a compact and versatile 3 wavelength (1064, 532 and 355 nm) lidar system that flies on the NASA ER-2 aircraft and serves as the primary validation instrument for the GLAS atmospheric measurements. On three days during THORpex, the ER-2 was flown directly underneath the GLAS track for 20 to 30 minutes as GLAS flew overhead at roughly the mid point of the ER-2 flight leg. The GLAS under flights were performed in regions that contained varying cloud types with one day obtaining mainly marine boundary layer aerosol. The talk will present a short overview of the GLAS instrument, the derivation of the GLAS theoretical calibration based on the system parameters, and the use of the CPL data to obtain the GLAS 1064 nm calibration.

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

C31D-06 1135h

Surface Topography and Ice-Sheet Dynamics Over the Vostok Subglacial Lake, Antarctica

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Surface topography in the region of the Vostok subglacial lake, Antarctica, from the previous analysis of radio-echo sounding and satellite radar-altimeter data indicated a trough (2-8 m) along the western margins and a rise (5-7 m) along the eastern margins. The elevation data obtained from Ice, Cloud, and Land Elevation Satellite (ICESat) show the troughs and rises in more detail, such as a deeper trough (18 m) in the western margin. These troughs and rises have been assumed to be caused by ice dynamics as the ice flows from grounded to floating and to re-grounded status, and associated buoyancy effect. We use a newly developed time-dependent 3-D thermo-mechanical higher-order numerical model to simulate the ice flow across Vostok subglacial lake. By comparing the surface topography generated from the model with the ICESat measurements, the ice-sheet behavior is investigated to explain in more detail the cause of the troughs and rises.

C31D-07 1150h

ICESat Observations of Southern Alaska Glaciers

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In late February and March, 2003, the Ice, Cloud, and land Elevation Satellite (ICESat) measured ice and land elevations along profiles across southern Alaska. During this initial data acquisition stage ICESat observations were made on 8-day repeat tracks to enable calibration and validation of the ICESat data products. Each profile consists of a series of single point values derived from centroid elevations of an ≈70 m diameter laser footprint. The points are separated by ≈172 m along track. Data sets of 8-day observations (an ascending and descending ground track) crossed the Bering and Malaspina Glacier. Following its 1993–1995 surge, the Bering Glacier has undergone major terminus retreat as well as ice thinning in the ablation zone. During the later part of the 20th century, parts of the Bering Glacier's piedmont lobe thinned ≥ 5 m/yr, while that of the Malaspina thinned by about 1 m/yr. The multiple observation profiles across the Bering and Malaspina piedmont lobes obtained in February/March are being geolocated on Landsat-7 images and the elevation profiles will be used for a number of scientific objectives. Based on our simulations of ICESat performance over the varied ice surface of the Jakobshavn Glacier of Greenland [*Mitchell et al.*, 2003], we expect to measure annual, and possibly seasonal, ice elevations changes on the large southern Alaskan glaciers. Using elevation data obtained from a second laser, we plan to estimate ice elevation changes on the Bering Glacier between March and October 2003.

C31D-08 1205h

A Test of Ocean Mesoscale Monitoring With ICESat Altimetry

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The ocean mesoscale is under sampled even with the four operational microwave altimeters currently on orbit. Laser altimetry from ICESat could potentially provide a substantial amount of ocean topography measurements that would improve ocean mesoscale sampling if we understand the performance of the laser measurement system over the ocean and process the data in a manner consistent with microwave altimeter mesoscale mapping products. To test this capability, we compare along track ICESat sea level anomaly in the Gulf of Mexico to mesoscale sea surface height anomaly maps derived from Jason-1, TOPEX/POSEIDON, Geosat Follow-on and Envisat microwave altimetry. The anomalous topographic signals associated with Loop Current fronts and eddies are clearly seen in the 40 Hz ICESat data, which are verified by coincident microwave altimetry and radiometric images of sea surface temperature and ocean color. The remaining high frequency, fine spatial scale differences between the laser and microwave measurements can be mitigated by a variety of filtering techniques to reduce the noise in the laser measurements; however, systematic and non-random errors need further investigation before more accurate mesoscale altimetry maps can be produced by blending laser and microwave altimetry.

C32A MCC: Level 1 Wednesday 1330h

NASA's Ice, Cloud, and Land Elevation Satellite (ICESat) Mission: Scientific and Technological Achievements III Posters *(joint with A, B, G, H, OS)*

Presiding: **H J Zwally,** NASA Goddard Space Flight Center**; B E Schutz,** Center for Space Research, University of Texas at Austin**; C A Shuman,** NASA Goddard Space Flight Center

C32A-0417 1330h POSTER

Glaciology From ICESat - West Antarctic Divide

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On January 12, 2003, NASA launched the Ice, Cloud, and land Elevation Satellite (ICESat) which is carrying the Geoscience Laser Altimeter System (GLAS). Orbiting at nearly 17,000 miles per hour (6 km/sec), ICESat/GLAS is providing data with unprecedented accuracy on the globe's third dimension, elevation. ICESat is the latest in a series of NASA's robotic Earth-orbiting spacecraft designed to study the environment of our home planet and how it may be changing. The main mission of ICESat is to measure the surface elevation of the large ice sheets covering Antarctica and Greenland. While several years of measurements are needed to determine mass balance changes, ICESat is already revealing details of ice sheet surface features from deep in the interior out to the surrounding sea ice. This presentation is based on 14 descending tracks from cycles 1-6 from ICESat's first mission phase (GLAS Laser 1 of 3) that occurred February 20 to March 29, 2003. Although the data are not yet fully calibrated, the Release 11 product utilized here is quite mature. Data from ICESat's second mission phase (Laser 2 of 3) is not included here. Using a technique that matches elevation data to gain and energy values enables rapid initial quality assessments. These assessments show that a substantial number of these West Antarctic elevation profiles are partially or substantially impacted by meteorological phenomena (clouds or blowing snow). This presentation will: 1) define the West Antarctic ice sheet's divide location and elevation; 2) illustrate the overall topography of a portion of West Antarctica; 3) demonstrate repeat track elevation analysis and composite track development; 4) discuss factors influencing selection of profiles for analysis; and 5) show other specific features of interest observed within the area.

C32A-0418 1330h POSTER

Accumulation-Driven and Long-Term Elevation Change on the Southern Greenland Ice Sheet

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Understanding the past and current mass balance of the Greenland Ice Sheet (GIS) is critical to predicting changes in sea level. Repeat altimetry surveys of ice sheet elevation change (dH/dt) from 1978 to 1988 and 1993/94 to 1998/99 suggest that the higher elevation parts (above 2000 m) of the southern ice sheet are in overall mass balance, with some regions observed to be thickening (gaining) and others thinning (losing). While there was general agreement in the observed spatial patterns between the two time periods, with thickening to the west of the ice sheet divide and thinning to the east in southern Greenland, significant differences in dH/dt were found. Ice sheet elevation change includes both long-term and short-term components and the short-term components likely mask repeat altimetry measurements primarily intended to monitor the long-term behavior of the ice sheet. Long-term changes in ice sheet elevation are caused by isostatic rebound and ice sheet dynamics. Short-term changes are driven by spatia

C32A-0419 1330h POSTER

Glaciological Field Measurements in West Antarctica in Support of ICESat Laser Altimetry

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We have been conducting several ground-based glaciological activities on the West Antarctic Ice Sheet to assist in the calibration/validation of ICESat laser altimeter data and to interpret elevation change results. In December 2002, just prior to the launch of ICESat, we conducted detailed geodetic mapping at two sites (100 km^2 and 25 km^2) to characterize the shape of the ice sheet surface. The ground measurements will be compared with 8-day repeat satellite data to assist in the evaluation of laser ranging accuracy. We

have also deployed sensors to monitor short-term fluctuations in the rate of firn compaction and snow accumulation, so that surface processes causing transient elevation changes can be better understood.

C32A-0420 1330h POSTER

Ice Sheet Surface Topography of Greenland and Antarctic from ICESat Altimetry

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Data from the Geoscience Laser Altimeter System (GLAS) on the Ice Cloud and land Elevation Satellite (ICESat) are used to calculate detailed topographic maps of Greenland and Antarctica. ICESat was launched on January 12th, 2003 and placed in an 8-day repeat orbit for calibration and validation activities. The initial dataset contained data from laser activation on February 20th to March 29th. In September of 2003, the spacecraft will collect data over another 8-day repeat cycle and then be maneuvered into a 91-day repeat orbit, which will provide denser groundtrack spacing in the lower latitude regions. The 94(inclination of ICESat allows for precision mapping of areas of the ice sheets where little detailed topography existed. Polar stereographic grids of Greenland and Antarctica at 5km resolution are created using a gridding procedure developed in support of previous altimetry missions. The resultant grids are compared with the 5km radar altimetry grids showing improved coverage in the higher latitudes and steeper terrain regions. The resulting Greenland gridded elevations are also compared with the data from the NASA Airborne Topographic Mapper (ATM). Slope vector plots calculated from the grids show ice sheet flow directions and are used to delineate ice sheet drainage basin boundaries. Sample maps with smaller spatial resolutions are created for some of the high-latitude areas with denser coverage to demonstrate the ultimate high-resolution capability of laser altimetry.

C32A-0421 1330h POSTER

ICESat/GLAS measurement of Ice sheet surface slope and roughness

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Surface slope and roughness are important features of ice sheets that are affected by bedrock topography, ice flow, ice thickness, and wind. Return-pulse waveforms from ICESat/GLAS provide surface elevations and information on surface slope and roughness. Surface slope and roughness within the laser footprint both affect the spread of return waveform, so information on surface slope and roughness can be derived by comparing the transmitted and return pulse waveforms. The shape of the transmitted waveform is nearly Gaussian. For typical ice sheet surfaces, the return pulse shape is also very close to Gaussian. By fitting Gaussian functions to the transmitted and return pulse waveforms and calculating the increase in width of the return pulse, surface roughness can be calculated if the surface slope is known, or vice versa. The ICESat/GLAS 1064 nm laser footprint diameter is about 70 meters and the footprint separation is about 170 meters. The small-scale surface roughness derived from the pulse shape is mostly due to wind-driven surface sastrugi. Over the larger ice sheet slopes, the pulse shape is dominated mainly by the surface slope. Information on the larger-scale (larger than 170 m) surface slope and surface undulations is also derived from successive along-track ICESat/GLAS elevations. The ICESat orbit covers Antarctica to 86°S and all of the Greenland ice sheet. Spatial distributions of surface roughness and slopes over the ice sheets for the period of ICESat operation are described. Effects of partial detector/amplifier saturation on the return pulse shape and the calculated roughness and slopes are also discussed.

C32A-0422 1330h POSTER

An Application of Spatial Interpolation Techniques to Derive Surface Characteristics and Height Changes in the Ice Sheets Using ICESat Data

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Using ICESat 8-day repeat tracks from both Laser-1 and potentially Laser-2 over Antarctica, we compare and contrast spatial interpolation techniques at cross-over locations. Our goal is to investigate an interpolator that would use both elevation statistics and local characteristics such as slopes and curvatures as a-priori information. The improvement of the interpolated surface heights and characteristic estimates using additional along-track/across-track data will be investigated. Preliminary analyses show kriging produces different results from simple linear interpolation for certain surface types. We are currently analyzing and binning 15000+ cross-overs based on surface types, slope-residual RMS, and time-difference. With additional calibrations to reduce systematic errors, we anticipate our results will provide both spatial characteristics and time rate of change in elevation in the ice sheets.

C32A-0423 1330h POSTER

Data Products from the Ice, Cloud, and Land Elevation Satellite (ICESat) Geoscience Laser Altimeter System (GLAS) at the National Snow and Ice Data Center (NSIDC) Distributed Active Archive Center (DAAC)

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The Geoscience Laser Altimeter System (GLAS) is the sole instrument on the Ice, Cloud, and land Elevation Satellite (ICESat), launched in 12 January 2003. The main objective of the ICESat mission is to measure ice sheet elevations and changes in elevation through time. Secondary objectives include measurement of cloud and aerosol height profiles, land elevation and vegetation cover, and sea ice thickness. This poster provides an overview of each of the GLAS data products that will be available from the National Snow and Ice Data Center (NSIDC) Distributed Active Archive Center (DAAC). It will include brief summaries of each product, sample images and a description of the processing steps that generate higher-level products from the lower level products. We will also provide information on how users can access GLAS data products from NSIDC. For more information about GLAS data products available from NSIDC, see: http://nsidc.org/data/icesat.

URL: http://nsidc.org/data/icesat

C32A-0424 1330h POSTER

ICESat/GLAS Standard Data Products

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The Ice, Cloud and Land Elevation Satellite (ICESat) mission will measure changes in elevation of the Greenland and Antarctic ice sheets as part of NASA?s Earth Observing System (EOS) of satellites. The Geoscience Laser Altimeter System (GLAS) on ICESat has a 1064 nm laser channel for surface altimetry and dense cloud heights and a 532 nm lidar channel for the vertical distribution of clouds and aerosols. The GLAS standard data products (SDP) are produced by the ICESat Science Investigator-led Processing System (I-SIPS) located at the Goddard Space Flight Facility. The National Snow and Ice Data Center (NSIDC) will distribute the SDPs to the general user community. There are sixteen defined SDPs related to measurement of elevations, cloud heights, vertical structure of clouds and aerosols, vegetation canopy heights; and measurements of sea ice roughness, sea ice thickness, ocean surface elevations, and surface reflectivity. The level 1 and 2 SDPs contain time ordered data stored in 15 separate products in binary integer format in direct access records. There is one defined level 3 HDF_EOS formatted product. The SDP granules vary from a quarter orbit to 14 orbits each. Examples of the main parameters for each product will be presented. Specific details of each product can be obtained from NSIDC or /glas.wff.nasa.gov under data products.

URL: http://glas.wff.nasa.gov

C32A-0425 1330h POSTER

Performance of the GLAS Onboard Surface Detection Algorithm

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The Geoscience Laser Altimeter System (GLAS) determines the range from the satellite to the Earth's surface from the time of flight of the instrument's 1064 nm laser pulses, which are generated at a rate of 40 Hz. The time of flight is defined as the difference between the laser transmit time and the time of return of the surface echo. The detector output is digitized with a 1 ns sampling interval, starting before the laser fires and ending well after any possible surface return, for a total of 5.4 million points. Because there is not enough downlink bandwidth for the entire waveform, the algorithm must extract both the transmit and surface echo waveforms from the 5.4 million digitized points, and pass these waveforms on to be included in the science data packets. The surface echo is not always easily discernible, especially when the beam passes through clouds. To detect the surface echo the algorithm uses the following techniques: (1) The search for the surface echo is limited to a few kilometers of the digitized waveform through the use of an onboard Digital Elevation Model. (2) The detection thresholds are adjusted to maximize the probability of signal detection while maintaining a fixed false alarm rate. (3) The signal-to-noise ratio is maximized for surface echoes of varying pulsewidths by passing the waveform through six matched digital filters. (4) A modified maximum likelihood detection process is used to determine which of the filter outputs is most likely to contain the surface echo. (5) The detector post-amplifier gain is adjusted to maintain the surface echo waveforms within the optimal dynamic range of the digitizer. Results from orbit show the algorithm to be effective at finding the surface echoes. A few features of the algorithm, however, require post-launch modification. One is that cloud cover tends to cause the algorithm to raise the gain, which then causes saturation of surface echoes from clear regions immediately following the clouds. Details of the algorithm, along with specific examples and recent modifications, will be presented.

C32A-0426 1330h POSTER

ICESat Instrument Support Facility

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The Ice, Cloud and Land Elevation Satellite (ICESat) mission main instrument is Geoscience Laser Altimeter System (GLAS). The interface between the ICESat Mission Operation Center (I-MOC) and the GLAS Science and Instrument teams is the ICESat Instrument Support Facility (ISF). The ISF monitors the

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GLAS performance and provides specific GLAS command request to I-MOC. Standard displays are available in realtime during passes to monitor GLAS status and near realtime post-pass to provide more detailed analysis. GLAS has several redundant units that can be switched based on its performance. The ISF coordinates with the I-MOC the switching of any components based on the GLAS instrument team recommendations. The ISF supports requests from the GLAS science team for special Targets of Opportunities (TOO) to collect data at specific locations. The interfaces, data flow and design of the ISF will be described.

C32A-0427 1330h POSTER

Science Computing Facility for ICESat/GLAS Data

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The Science Computing Facility (SCF) for ICESat/GLAS data consists of a data base management system for temporal and geographic subsetting of GLAS products, autonomous tools for electronic distribution to geographically-distributed remote sites, and a data analysis and visualization package. The SCF also maintains a website that conveys instrument state and GLAS product information, displays browse products of all GLAS products produced to date, and hosts a bulletin board for communicating product and tool problems. The 15 GLAS science and engineering data products produced daily by the ICESat Science Investigator-led Processing System (I-SIPS) are distributed electronically by the SCF to GLAS Science Team members and their associates at nine remote sites, as requested. Interactive Graphical User Interfaces easily enable the remote users to subscribe to customized data sets from the standard products by defining the product, temporal spans, and geographic regions. As data are received from the I-SIPS, the individual subscriptions are automatically filled and the customized data sets are electronically transferred to the remote users. Normally, receipt of these data sets at the remote sites occurs within hours of the I-SIPS processing. Subsetting is accomplished using a Data Management System (DMS) that quickly determines if data for a subscription are present in the newly received product and then allows fast, direct, efficient access to each second of data that falls within the subscription's temporal and geographic span, instead of reading through the files sequentially. The distribution is accomplished via secure-shell communications, a MYSql database, a series of Perl and Tcl scripts, and a collection of IDL and Fortran 90 software.

C32A-0428 1330h POSTER

ICESat Science Investigator led Processing System (I-SIPS)

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The ICESat Science Investigator-led Processing System (I-SIPS) generates the GLAS standard data products. It consists of two main parts the Scheduling and Data Management System (SDMS) and the Geoscience Laser Altimeter System (GLAS) Science Algorithm Software. The system has been operational since the successful launch of ICESat. It ingests data from the GLAS instrument, generates GLAS data products, and distributes them to the GLAS Science Computing Facility (SCF), the Instrument Support Facility (ISF) and the National Snow and Ice Data Center (NSIDC) ECS DAAC. The SDMS is the Planning, Scheduling and Data Management System that runs the GLAS Science Algorithm Software (GSAS). GSAS is based on the Algorithm Theoretical Basis Documents provided by the Science Team and is developed independently of SDMS. The SDMS provides the processing environment to plan jobs based on existing data, control job flow, data distribution, and archiving. The SDMS design is based on a mission-independent architecture that imposes few constraints on the science code thereby facilitating I-SIPS integration. I-SIPS currently works in an autonomous manner to ingest GLAS instrument data, distribute this data to the ISF, run the science processing algorithms to produce the GLAS standard products, reprocess data when new versions of science algorithms are released, and distributes the products to the SCF, ISF, and NSIDC. I-SIPS has a proven performance record, delivering the data to the SCF within hours after the initial instrument activation. The I-SIPS design philosophy gives this system a high potential for reuse in other science missions.

C32A-0429 1330h POSTER

The ICESat/GLAS Data Visualizer

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The ICESat Science Computing Facility (SCF) team has developed a software package for visualizing Geoscience Laser Altimeter System (GLAS) Level 1 and Level 2 surface altimetry, atmospheric lidar, and engineering data products. Rapid geographic and temporal sub-setting is performed with the GLAS SCF Data Management System. Along-track time-series plots show related parameters from multiple products and may be zoomed to the temporal resolution of the data. Available altimetry parameters include elevations and surface properties; atmospheric and tidal corrections; waveform and fit characteristics; and instrument orientation. Among the lidar parameters are along-track backscatter images with cloud and aerosol layers; atmospheric optical properties; and returned, transmitted, and background energies. Multiple time series may be displayed simultaneously, allowing investigation of interrelationships among parameters. Difference windows permit direct comparison of curves within a plot set. Individual returned waveforms, fitted-waveform models, laser-beam intensity images, and lidar-backscatter profiles can be displayed for any selected point in a time series. The ground track and location of the selected data are displayed on a zoomable map or DEM. Users have control over displayed curves and plot properties. PostScript files can be produced from all plots, and parameters may be dumped to ASCII files. The data visualizer is written in Interactive Data Language (IDL) in a highly modular fashion making extensive use of reusable components, object classes, and object-widget techniques. The visualizer will be made available through the NSIDC along with the GLAS data products in a form that can access data files without the sub-setting capabilities of the Data Management System. The presentation will describe the visualizer design, demonstrate its capabilities, and discuss aspects of its underlying architecture.

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

C32A-0430 1330h POSTER

ICESat Precision Orbit Determination

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Following the successful launch of the Ice, Cloud and land Elevation Satellite (ICESat) on January 13, 2003, 00:45 UTC, the GPS receiver on ICESat was turned on successfully on Jan. 17, 2003. High quality GPS data were collected since then to support Precision Orbit Determination (POD) activities. ICESat carries Geoscience Laser Altimeter System (GLAS) to measure ice-sheet topography and associated temporal changes, as well as cloud and atmospheric properties. To accomplish the ICESat science objectives, the position of the GLAS instrument in space should be determined with an accuracy of 5 cm and 20 cm in radial and horizontal components, respectively. This knowledge is acquired by the POD activities using the data collected by the GPS receiver on ICESat and the ground-based satellite laser ranging (SLR) data. It has been shown from pre-launch POD studies that the gravity model error is the dominant source of ICESat orbit errors. The predicted radial orbit errors at the ICESat orbit (600 km altitude) based on pre-launch gravity models, such as TEG-4 and EGM-96, are 7-15 cm. Performance of these gravity models and the recent gravity models from GRACE on ICESat POD were evaluated. The radial orbit accuracy is approaching 1-2 cm level with the GRACE gravity model. This paper also summarizes POD activities at Center for Space Research (CSR), which is responsible to generate ICESat POD products.

C32A-0431 1330h POSTER

ICESat Waveform Ground Processing Algorithm

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The shape of the ICESat laser-altimeter waveforms represents the interaction of the laser pulse with the surface-height distribution of the Earth's surface, which may be complex due to multiple reflecting surfaces of varying shapes within the laser footprint. Therefore, the ICESat waveforms are processed on the ground to determine the location on the waveform that represents the surface elevation and to derive characteristics of the variable surface height distributions. The transmitted pulse has a Gaussian shape and the return pulse from single-reflecting surfaces is also usually Gaussian in shape. The observed Gaussian shape of the returns confirms the assumption that the surface within the laser footprint can be modeled as a combination of a smooth-sloping surface and a rough surface with a random distribution of heights. Derived parameters include: mean surface elevations, pulse amplitude, pulse width, and the signal to noise ratio. The mean surface elevation is represented by the location of the center of the Gaussian fit. The combined effect of surface slope and surface roughness is calculated from the spreading of the pulse width. Multiple Gaussian functions are used to model waveforms resulting from multi-layer surfaces such as vegetated land or the edge of icebergs. Although the centroid of the waveform is sometimes used to represent a mean surface, the centroid is strongly influenced by asymmetry in the tails of the waveform and/or the limits over which the centroid is calculated. Over multi-layer surfaces, it is more useful to identify the individual layers and their associated mean elevations, which is done by multiple Gaussian fitting. Distortion of the waveform shape by non-surface characteristics, such as atmospheric forward scattering and detector/amplifier saturation, causes the centroid of the waveform to misrepresent the actual mean surface. These effects can be diminished by fitting a Gaussian to the return, and using the centroid of the Gaussian to determine the mean surface elevation. We present algorithms that use single or double Gaussians to fit the return waveform and show how the mean elevation and surface characteristics are calculated from the functional fit. The initial estimates and covariance matrix are set to optimize the fit to the leading edge of the return waveform corresponding to the largest Gaussian peak. Over ice surfaces, two Gaussian peaks are allowed to account for the extended tail of the returns that have high forward scattering components, or two distinct surfaces in the footprint. Over land, up to six Gaussian peaks are allowed. The algorithm was fine tuned using the first 36 days of data, which included returns over the ice regions with high detector/amplifier saturation and strong atmospheric forward scattering.

C32A-0432 1330h POSTER

Geoscience Laser Altimeter System - Characteristics and Performance of the Altimeter Receiver

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The Geoscience Laser Altimeter System (GLAS) on board ICESat spacecraft measures the surface height (altimetry) via the time of flight of its 1064 nm laser pulse. The GLAS laser transmitter produces 6 ns wide pulses with 70 mJ energy at 1064 nm at a 40 Hz rate. The altimeter receiver consists of a telescope, aft optics, a silicon avalanche photodiode, and electronic amplifiers. The transmitted and echo pulse waveforms are digitized at 1 GHz rate. The laser pulse time of flight is determined on the ground from the two digitized pulse waveforms and their positions in the full digital waveform record (about 5.4 ms long) by computing the pulse centroids or by curve fitting. The GLAS receiver algorithms in on board software selects the two waveform segments containing the transmitted and the echo pulses and sends them to ground. The probability of echo pulse detection and the accuracy of time of flight measurement depend on the received signal level, the background light within the receiver field of view, the inherent detector and amplifier noise, the quantization of the digitizer, and some times by cloud obscurations. A receiver model has been developed to calculate the probability of detection and accuracy of the altimeter measurements with these noise sources. From pre-launch testing, the minimum detectable echo pulse energy for 90% detection probability was about 0.1 fJ/pulse onto the detector. Such a receiver sensitivity allows GLAS to measure the surface height through clouds with optical density less than 2. The echo pulse energy required to achieve 10cm ranging accuracy was found to be about 3 times higher than the minimum detectable signal level. The smallest single shot range measurement error, which was determined by ranging to a fixed target with strong echo pulses and no background light, was 2 to 3cm. The maximum linear response echo pulse energy was 10 fJ/pulse for the strongest echo signals, assuming a Lambertian scattering snow surface, clear sky atmosphere transmission, and no pulse width spreading due to surface slopes. Results from the initial 38 days of GLAS operation on-orbit with Laser 1 showed the echo pulse energies varied, as expected, over a wide dynamic range due to the variability of atmosphere transmission and Earth surface characteristics. The receiver was able to reliably detect the ground surface echoes and measure time of flight under such dynamic conditions, except when there were dense clouds. When over Antarctica, the echo pulse energies were several times stronger than predicted. This suggests that the 1064 nm backscattering from the snow pack and ice-sheet surfaces are not completely Lambertian but is somewhat peaked at opposition. With Laser 1, the peak amplitude of the echo pulses from flat icesheets under clear sky conditions exceeded the linear response range of the receiver, causing some pulse waveform distortion due to saturation. We have characterized the effects of receiver saturation on the time of flight, pulse width, and pulse energy measurements for flat surfaces by testing a flight spare detector in the lab with simulated echo pulses. A data processing algorithm that minimizes the errors due to saturation for these measurements are described.

C32A-0433 1330h POSTER

Laser Pointing Determination System for the Geoscience Laser Altimeter

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The primary mission of the Geoscience Laser Altimeter System (GLAS), launched on the Ice, Cloud and land Elevation satellite (ICESat) January 12th, 2003, is to measure changes in the topography, and mass balance of the polar ice caps over 3 to 5 years. The altimetry measurement includes firing the laser at the surface at 40 Hz, collecting and timing the surface return. The time of flight is calculated to determine the elevation of the surface at each laser spot. The error of the measurement includes the accuracy of the dual frequency GPS solution for spacecraft position, timing uncertainty in the ranging measurement, and pointing knowledge of the laser with respect to inertial coordinates with an accuracy of 1.5 arcseconds (1 sigma) for every laser shot fired at 40 Hz. Therefore, a highly accurate means to determine the attitude with respect to inertial space for the laser beam was developed. This is the first time that a spaceborne laser altimeter system directly measures the pointing uncertainty of the laser beam resulting in a highly accurate altimetry measurement. The paper discusses the Stellar Reference System (SRS), which is comprised of two star trackers, one having a narrow field of view for increased accuracy, a hemispherical resonant gyro (HRG) and angle preserving beam steering optics. The paper summarizes the Stellar Reference System (SRS) design, error budget, and its pre-launch and on-orbit measurement performance.

C32A-0434 1330h POSTER

Preliminary Examination of Pulse Shapes From GLAS Ocean Returns

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We have examined GLAS data collected over the Pacific ocean during the commission phase of the ICESat mission, in an area where sea state is well documented. The data used for this preliminary analysis were acquired during two passes along track 95, on March 18 and 26 of 2003, along the stretch offshore southern California. These dates were chosen for their lack of cloud cover; large (4.0 m) and small (0.7 m) significant wave heights, respectively; and the presence of waves emanating from single distant Pacific storms. Cloud cover may be investigated using MODIS images (http://acdisx.gsfc.nasa.gov/data/dataset/MODIS/), while models of significant wave heights and wave vectors for offshore California are archived by the Coastal Data Information Program (http://cdip.ucsd.edu/cdip_htmls/models.shtml). We find that the shape of deep-ocean GLAS pulse returns is diagnostic of the state of the ocean surface. A calm surface produces near-Gaussian, single-peaked shot returns. In contrast, a rough surface produces blurred shot returns which often feature multiple peaks; these peaks are typically separated by total path lengths on the order of one meter. Gaussian curves fit to rough-water returns are therefore less reliable and lead to greater measurement error; outliers in the ocean surface elevation product are mostly the result of poorly fit low-energy shot returns. Additionally, beat patterns and aliasing artifacts may arise from the sampling of deep-ocean wave trains by GLAS footprints separated by 140m. The apparent wavelength of such patterns depends not only on the wave frequency, but also on the angle between the ICESat ground track and the azimuth of the wave crests. We present a preliminary analysis of such patterns which appears to be consistent with a simple geometrical model.

C32A-0435 1330h POSTER

GLAS Measurements of the Global Oceans

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Although not designed for ocean measurement, two-thirds of the GLAS elevation measurements occur over the global oceans, including important near-coastal and high-latitude regions. We present a summary of ocean data quality, the support given to GLAS calibration/validation by ocean comparisons, and several oceanographic results. While the high resolution (40 Hz) and small footprint (70 m) of the laser contrast sharply with radar altimetry (1 Hz and 5 km), preliminary studies indicate that measurements comparable to radar can be obtained by the GLAS laser for both sea surface height and Significant Wave Height (SWH). The laser altimetry measurements are compared to data from Jason-1 and Topex/Poseidon via dual-satellite crossovers and to a MSS model. These comparisons have helped to verify and improve instrument bias determination (Release 9) and tide model application (Release 11) in early versions of the data, and have revealed significant signals in the altimeter bias estimate, including day/night differences, a yaw-mode bias jump, and unexplained periodic equatorial anomalies on the order of 1 meter. Significant results from new comparisons will be presented, using the latest laser data and current release version (Release 12).

C32A-0436 1330h POSTER

Polar Cloud Studies from the Geoscience Laser Altimeter System

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The Geoscience Laser Altimeter System (GLAS), launched on board the Ice, Cloud and Land Elevation Satellite in January 2003 provides space-borne laser observations of atmospheric layers. In the polar regions, satellite observations of clouds and snow surfaces appear similar at both infrared and visible wavelengths. The GLAS laser profiling permits unambiguous detection of clouds over snow and ice surfaces, and allows accurate climatologies of clouds in the high latitudes to be compiled. These observations also allow the analysis of the validity of passive observations of polar cloud retrievals for the first time. Data from the Moderate Resolution Imaging Spectrometer aboard the Aqua satellite is examined along with GLAS observations of cloud layers. In more than three-quarters of the cases, MODIS scene identification from spectral radiances agrees with GLAS. These studies illustrate the capabilities of active remote sensing to validate and assess passive measurements, and also to complement them in studies of atmospheric layers. Polar clouds are also an important factor for the accuracy of the altitude measurements of ice sheet elevation change. Multiple scattering through even the thinest clouds introduces an effective pulse spreading and altitude bias. Pulse spreading up to 10 of meters is observed in data. The GLAS mission was designed so that cloud clearing and corrections would permit centimeter accuracies for surface elevation change. The adequacy the cloud detection and clearing for surface measurements is under analysis and initial results are presented.

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C32A-0437 1330h POSTER

Evaluation of GLAS Cloud and Aerosol Data Products

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NASA launched the Geoscience Laser Altimeter System (GLAS) onboard the ICESat spacecraft on January 12, 2003. The atmospheric lidar subsystem of GLAS has the capability to detect, discriminate, and vertically locate multiple layers of clouds and aerosols up to 40 km above the earth's surface. The results of these operations are a component of the standard data products that make up the GLAS data product archive. The layer detection procedures are a necessary step in the effort to find atmospheric layer optical properties from GLAS data. For the first time using and active optical instrument, GLAS makes these products available to the atmospheric research community on a world-wide basis over an extended period of time. In this paper, we evaluate the effectiveness of the layer detection algorithms and associated products from intercomparison studies. The studies are designed to address the following issues regarding GLAS layer detection: 1) what is the sensitivity of the layer detection; 2) what is the accuracy of the top and bottom boundaries; 3) how much does multiple scattering influence the accuracy of layer boundary estimates: 4) how accurate is the cloud/aerosol layer discrimination technique; 5) what are the frequencies of false positives and false negatives; 6) how well do layer detection results from the 1064nm channel compare with results from the 532 nm channel; 7) how do results from nighttime observations compare with those from daytime observations; 8) how well does GLAS atmospheric layer detection compare to other satellite-based detection, such as from MODIS. We also present in this paper early results of cloud layer climatological studies that show frequency of occurrence of

various cloud types and altitudes at various locations. These studies demonstrate the advantage of lidar's capability to unambiguously discern multiple cloud layers.

C32A-0438 1330h POSTER

Calibration of Satellite Laser Altimetry Over Precisely Mapped Terrain

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Early in 2003, NASA's GLAS laser altimeter aboard ICESat started measuring surface elevations at all latitudes up to 86 degrees latitude, with the prime objective of measuring rates of ice-surface elevation change in Greenland and Antarctica to an accuracy of a few cm/yr. Validation of these measurements and calibration of measurement biases includes comparison of GLAS measurements with detailed topographic maps of narrow stripes (200-300 m wide) of terrain surveyed by NASA's Airborne Topographic Mapper (ATM) - a scanning laser altimeter. Because these segments include a range of surface slopes, it is possible to check overall GLAS-derived elevations at the 10-cm level and to infer pointing to less than an arc second. Validation sites are in Greenland, western US, and Antarctica, including arid regions free from snow cover and vegetation which can be used to check data consistency throughout the ICESat mission and for cross calibration with follow-on missions. The ATM survey data is sufficiently dense to allow calculation of GLAS return waveforms which are then compared to the observed waveforms with differences used to estimate range bias, pointing errors, and timing errors. These comparisons can be made for surfaces with slopes of 15 deg or more to which ranges have a high sensitivity to pointing errors. Here, we present overall comparisons between GLAS and ATM, showing the level of agreement between GLAS and recent ATM surveys of ice surfaces, along with our estimates of instrument biases based on ATM/GLAS comparisons along individual orbit tracks.

C32A-0439 1330h POSTER

Calibration and Validation Tools for the ICESat Mission: Waveform Matching.

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The ICESat laser altimeter mission provides measurements of elevation data around the globe, cloud and aerosol heights, as well as land topography and vegetation characteristics. For the calibration and validation phase of the mission, we have developed a waveform-matching tool with the purpose of discriminating between geolocation solutions, assessing spacecraft pointing to off-nadir targets, validating laser altimeter beam quality parameters such as pulse width, footprint diameter and circularity, and validating footprint derived parameters including mean elevation, slope, roughness and vegetation height. The Geoscience Laser Altimeter System (GLAS) aboard ICESat digitizes the backscattered laser energy (i.e., waveform). Observed GLAS waveforms are compared to synthetic waveforms produced from high resolution Digital Elevation Models (1-5 m grid spacing) using a simplified, noise free, model of the intrument's characteristics, including pulse width and far-field energy pattern, and receiver FOV transmission and impulse response. The grid-based waveform simulations are used to reproduce the instrument's interaction with the topographic surface at the footprint location. Optimal matches are determined by minimizing the observed-to-simulated waveform residuals using an iterative spatial search. Correlation between within footprint surface height distribution as recorded in the observed and simulated waveforms is computed while shifting the location of the footprint within the DEM until the optimal location is determined. For the simulation we utilize high-resolution, airborne laser altimeter data from which 1.8 m bare-earth and canopy-top grids are derived for the Puget Lowland area in Washington State. Complex waveforms created by vegetation cover and building edges enhance precision in the validation of geolocation solutions, spacecraft pointing, and waveform-derived parameters for highest, centroid and lowest within-footprint elevations.

C32A-0440 1330h POSTER

Glaciology From ICESat - East Antarctic Megadunes

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Beginning on February 20, 2003, NASA's Ice, Cloud, and land Elevation Satellite (ICESat) began collecting high-precision elevation data across Antarctica. Using the first of its three lasers, this satellite altimetry mission has rapidly provided an extensive data set of ice sheet elevations as well as meteorological phenomena. This presentation will focus on the elevation profiles from four ascending and four descending tracks taken from the first 6 cycles of ICESat data. As part of an NSF-sponsored field project in a portion of East Antarctica's megadunes, these elevation profiles were used to support and refine our ground-based observations. The eight ICESat tracks that intersect over our field site have been quality controlled to remove the effects of clouds and/or blowing snow and then processed to yield precise repeat track and crossover elevations. Although not yet fully calibrated, ICESat's elevation measurements are sufficiently precise to illustrate the several-meter amplitude and several-kilometer wavelength of these extensive ice sheet features. Additional aspects of this valuable new glaciological data set will also be presented.

URL: http://nsidc.org/antarctica/megadunes/

C32A-0441 1330h POSTER

Validation of satellite altimeter range measurements over salar de Uyuni, Bolivia

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The salar de Uyuni in the Bolivian altiplano covers approximately 9600 km^2, and is the largest dry salt lake in the world. This vast, flat stable surface is ideal for estimation of the range bias on altimeter instruments such as GLAS on board ICESat (launched 12th January 2003), RA-2 on board ENVISAT (launched March 1st 2002) and the ERS-2 radar altimeter (RA, launched 1995), and to compare the measurements from these altimeters. Here we describe a kinematic GPS survey of the salar de Uyuni that was carried out in August/September 2002 and was designed to calibrate GLAS and RA-2. The eastern part of the salar was surveyed with 8 grids 22.5 km x 13.5 km at 2.25 km spacing, and with 2 grids which straddled one ascending and one descending ERS-2/ENVISAT orbit across this part of the salar, one 44.5 x 9 km, the other 18 x 13.5 km. Comparison of GPS heights from one GPS grid to the next and crossover analysis at intersections suggests that RMS accuracy of the GPS measurement is around 2 cm. We retracked the altimeter waveforms by fitting the system point target response to retrieve the altimeter surface elevation. We fitted a gaussian-smoothed surface to the GPS heights collected around the ERS-2/ENVISAT grids and interpolated these surfaces to the locations of altimeter footprints to obtain an estimate of the range bias for each instruments (GLAS, RA-2 and the ERS-2 RA). We also compare our results with data from one cycle of TOPEX data, which was collected during an orbit manoeuvre phase in September 2002. Ground tracks from this cycle serendipitously crossed our survey area at the same time we were on the ground.

C32A-0442 1330h POSTER

Deriving Sea-Ice Freeboard Height Distributions and Estimates of Ice Thickness From ICESat/GLAS Laser Altimetry

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The state of a sea ice pack is well described by distributions of sea thicknesses obtained over spatial scales such as 50 km by 50 km. Information that can be derived from thickness distributions includes the mean sea-ice thickness and the ratio of thicker multi-year ice to thinner ice types. Thickness distributions as a function of time also provide information on the time variability of these parameters and ice growth and decay rates. However, large-scale spatial and temporal measurement of ice thickness distributions has been an elusive goal. The total ice thickness consists of the draft, which is the ice portion below sea level, and the freeboard, which is the ice portion above sea level (defined here to include the snow cover). The total ice thickness can be derived from measurements of the freeboard height using estimates of the snow cover thickness and estimates of the snow and ice densities. This paper describes work to derive freeboard height distributions from measurements of surface elevations over sea ice by the laser altimeter on ICESat. ICESat measures the mean surface elevation over footprints 70 m in diameter spaced at 170 m along track. The along track accuracy of the elevations over surfaces with low slope is in the range of 5 to 10 cm after editing of data with pulse saturation effects and strong atmospheric forward scattering. Estimates of the freeboard height distribution are derived by calculating 50 km running means of the measured elevations, plotting the distributions of the deviations of the elevations from the centered mean for 50 km segments, fitting the distributions with a Gaussian curve, and taking the 10% point of the Gaussian fit as the open water/sea level. The mean freeboard height is then calculated from the distributions with respect to the estimate of sea level. The mean sea ice thickness is calculated from mean freeboard using snow cover climatology. The methodology assumes the existence of some open water or very thin sea ice in each segment and other approximations about the shape of the thickness distributions. Several variations of the method such as changing the averaging length and multi-track averaging in grid cells are described. Preliminary maps of sea ice thickness show some reasonable agreement with known sea ice thicknesses.

C32A-0443 1330h POSTER

Analysis of Ice Elevations along ICESat Repeat Tracks over Law Dome ice cap, East Antarctica

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The Law Dome ice cap adjoining the main East Antarctic ice sheet in Wilkes Land between longitudes 110 aE and 116 aE is about 200 km in diameter with a maximum surface elevation of 1389 m. Satellite radar altimetry results (ERS1-2) and ice flow modeling by using annual layer data derived from the deep ice cores show that the ice cap is currently close to steady state. Law Dome is characterized by a complete range of ice formation zones with extraordinarily large accumulation gradient from west to east from negative values in the ablation zone to about 4 m a-1 net accumulation in the dry snow zone. As an analogue of the main Antarctic ice sheet, Law Dome is an ideal location to examine ICESat capabilities and data quality and to perform detailed studies of seasonal and interannual changes in surface elevations. So far, data from the three 8-day repeat cycles crossing over the ice cap in February-March, 2003 are analyzed. The average separation between the repeat tracks and a reference track varies from 354 to 930 m. To inter-compare the elevations from the three profiles, the elevations are corrected for the cross-track slope estimated from the three profiles to obtain the respective elevations along the reference track. Comparisons of the derived elevations for different cycles show the high accuracy of the ICESat data with standard deviation of 30 cm for the entire crossing range and 6 cm for the lower slope region near the summit. The preliminary data also reveal systematic changes in surface roughness, with higher values at low elevations due to melting and wind erosion features, and minimum values near the summit that well agree with ground observations.

C32A-0444 1330h POSTER

ICESat Calibration-Validation and Mass Balance Studies in Antarctica

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To map mass balance changes of major drainage basins over a relatively short period, ICESat is designed to measure surface elevation changes with an accuracy of 1.5 cm/year for spatial averages of measurements over areas of 100 km^2. To achieve this accuracy different post-launch calibration-validation (CV) approaches are used to identify and to remove the nongeophysical artifacts from the data products. As part of the CV effort detailed surface topography was mapped by NASA's Airborne Topographic Mapper (ATM) scanning laser over sites in Greenland, western US and the Dry Valleys in Antarctica. Ice sheet surface elevations mapped by airborne laser altimetry surveys also serve as baselines for the ICESat mission. Here we present results from two different projects in the Antarctica. Detailed surface topography, derived from ATM data, is used to verify the ICESat products over the Dry Valleys. Surface elevations, mapped by the University of Texas airborne system (former Support Office of Airborne Geophysics), serves as baselines to map changes over the West Antarctic Ice Sheet ice streams. ATM surveys were conducted over the Dry Valleys in December 2001 in collaboration with NSF and USGS. In addition to survey candidate calibration/validation sites for the ICESat mission, the campaign was going to support NSF projects and to provide data to evaluate the potential of the use of laser altimetry in the Antarctica. The survey resulted blanket coverage over several sites. We have developed a procedure using robust estimation techniques to remove the outlier observations and to interpolate the data into regular grids (DEMs). The ICESat elevation and waveform products were verified by comparing them with the DEMs and with simulated waveforms. Surface reflectivity, necessary for the waveform simulation, was derived from satellite imagery. The stable terrain of the site makes it ideal for serving as benchmark surface throughout the ICESat mission. Precise repeat laser altimetry surveys were conducted with the SOAR system in 1997/98 and 1999/2000 over portions of the Whillans ice stream and ice streams C and E, West Antarctica. It is well known that these ice streams are undergoing substantial changes in length, width, thickness and speed at decadal and shorter changes. We determined elevation changes during the last 5 years by comparing elevations measured by ICESat over the 8-day repeat orbits with the results of the SOAR surveys. We plan to use the 91-day repeat ICESat data to investigate the details of the surface change pattern.

C32B MCC: 3010 Wednesday 1340h

International Polar Year 2007-2008 I

(joint with A, B, G, H, OS, PP, S, ED, GC)

Presiding: **C Elfring,** Polar Research Board, The National Academies**; S Drobot,** Polar Research Board, The National Academies

C32B-01 1340h

A New Phase of Exploration and Understanding: Planning for The International Polar Year - 2007/2008

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Planning is underway to hold an International Polar Year in 2007-2008. IPY 2007-2008 stands to be a significant research opportunity to further our understanding of polar regions and polar processes. The International Polar Year has the potential to capture the public's imagination and convey the crucial role that the polar regions play in global systems. IPY 2007-2008 is envisioned to be an intense, international campaign of coordinated polar observations and analysis, which will be bipolar in focus, multidisciplinary in scope, and truly international in participation. The vision is for many nations to work together to gain holistic insights into planetary processes, targeted at exploring and increasing our understanding of the poles and their roles in the global system. The concept of an International Polar Year 2007 - 2008 has been endorsed and advanced by a broad range of global and polar research groups. Earlier this year, the International Council for Science (ICSU) formed an International Polar Year Planning Group (IPY-PG) which met for the first time at the end of July. The Planning Group discussed ways to create an open process that encourages broad input from the international community. The Planning Group began to describe the desired goals of IPY 2007-2008, which should address compelling science issues through multi-national programs, enable scientific programs which would not otherwise occur, attract and develop the next generation of polar scientists, and engage the public. The Planning Group has identified three overarching themes that we hope can serve as the foundation for IPY 2007-2008: Exploring the Earth's Icy Domains, Decoding the Role of the Poles in Global Change Understanding Polar Processes. The Planning Group envisions focused research activities under each of these major themes. For example, a program to explore the sub-ice environment of East Antarctica would fit under the theme Exploring the Earth's Icy Domains, a program of Integrated Polar Observing Networks including environmental instrumentation would fit under Decoding the Role of the Poles in Global Change, and a collaborative effort to study the stability of the cryosphere would fit under Understanding Polar Processes.

C

C32B-02 1355h

A Rising Tide for Polar Science: Efforts of the U.S. National Committee for the International Polar Year

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The polar regions, fascinating yet distant and cold places, hold the keys to our changing world. While the upcoming IPY is the 50th anniversary of the International Geophysical Year and the 125th anniversary of the first International Polar Year, it also falls at a crucial time in rapid changes in environmental and social systems that may affect all peoples of the Earth. Further warming of the Arctic, changing ecosystems and opening pathways for ocean travel, impact not only the people there but also the shipping, economics, and strategic considerations of distant nations. Yet potential further warming of the Arctic may be understood by clues in the Antarctic ice. How are the polar regions changing, and how swiftly may those changes affect the entire Earth? This is but one question emerging from community discussions of the science of the upcoming IPY. Our emerging ability to investigate previously unexplored areas is increasing our understanding of the wide world we live in, through interdisciplinary studies and tools for connections. Autonomous vehicles, genomics, and remote sensing technologies are just a few of the emerging areas that may provide new tools for investigating previously inaccessible realms. At the same time, tools such as the internet are making the world smaller, enabling instant communications between the peoples of the world. Joint international investigations enhance our ability to understand one another as well as our ability to understand our world and our universe. Rapid communications and international involvement can revolutionize the way we educate young scientists and our future leaders in a complex and changing world. Involving and educating people - young scientists, college students, school children, and the public - will be included as hallmarks of the IPY. The people are here. New tools are emerging. The ideas, or scientific goals, of the IPY are being crafted jointly through broad involvement of the scientific community, through meetings, conversations, and web-based discussions. This presentation will describe the process that the U.S. National committee has employed to nurture the evolution of the IPY, and will describe the new report that is being prepared based on this process.

C32B-03 1410h INVITED

NSF and IPY 2007-2008

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International research organizations including the International Arctic Science Council, the Arctic Ocean Sciences Board, the Scientific Committee on Antarctic Research, the World Meteorological Organization and the International Council for Science have announced