PARCA 2014
Tuesday, January 28
8:30 AM - 5:00 PM
GSFC Building 33, Room H114

08:30 **Welcome: Logistics**
Thorsten Markus, NASA Goddard Space Flight Center

08:40 **View from Headquarters**
Thomas Wagner, NASA Headquarters

09:10 **Radiostratigraphy of the Greenland Ice Sheet**
Joe MacGregor, University of Texas at Austin

We have recently completed the first comprehensive radiostratigraphy of the Greenland Ice Sheet, compiled from two decades of NASA- and NSF-funded airborne radar-sounding surveys performed by The University of Kansas. This radiostratigraphy reveals a wealth of new information regarding the ice sheet's history and internal structure, including Holocene-averaged accumulation rate, basal melt rate and balance velocity. Disrupted stratigraphy due to anomalous basal processes is often located at the onset of fast flow. This radiostratigraphy is a new constraint on the dynamics of this ice sheet and could prove critical to the validation and improvement of models of its past, present and future flow.

09:30 **An Improved CryoSat-2 Sea Ice Freeboard and Thickness Retrieval Algorithm**
Nathan Kurtz, NASA Goddard Space Flight Center

We demonstrate a new physical model which is capable of simulating CryoSat-2 waveforms over Arctic sea ice. The new model can also be fit to CryoSat-2 waveforms allowing for the retrieval of surface elevation and thus sea ice freeboard and thickness. The new CryoSat-2 sea ice freeboard and thickness retrievals are found to closely agree with independent data from Operation IceBridge, allowing the satellite laser and radar altimetry records to be reconciled through the usage of consistent physical assumptions in the retrieval algorithms. A time series of available CryoSat-2 sea ice thickness maps will be shown which demonstrate changes in the current Arctic sea ice regime.

09:50 **Status of Submeter Imagery Collection, Processing and Delivery**
Paul Morin, University of Minnesota

The past year has seen large advances in the use and availability of commercial imagery to the US government funded science community. In the Arctic, we are now collecting between 700,000 to 2 million km2 of 0.5 m resolution imagery per week with almost all of it collected as in-track, single pass stereo. PGC now has web services and web applications for browsing orthorectified and mosaic sub-meter imagery for all of Alaska and Greenland. PGC plans to fill in the rest of the Arctic in coming year. The wider community has also made strides in the processing and distribution of 2 to 4 m posting digital elevation models. These DEMs can be distributed without the copyright restrictions that limit the distribution of the raw and orthorectified imagery. In this talk we will also discuss raw imagery distribution and the 2014 Arctic collection strategy.

10:05 **An Update from the SUrface Mass balance and snow on sea ice working groUP (SUMup)**
Lora Koenig, NASA Goddard Space Flight Center

The Surface Mass Balance and Snow on Sea Ice Working Group (SUMup) is leading NASA's effort to improve spatial and temporal estimates of surface mass balance on ice sheets and snow accumulation on sea ice. SUMup was convened at the direction of the NASA Cryospheric Sciences Program to assess current satellite algorithms, regional models, and measurements to recommend future directions for improving calculations of surface mass balance over the ice sheets and snow accumulation on sea ice. Improving our measurement and modeling of surface processes such as accumulation, redistribution of snow and melt are required to accurately determine future changes in both land ice and sea ice.

10:15 **BREAK**

10:30 **KEYNOTE:**
Cat-Herding - Developing Community Resources for Seismological Research
David Simpson, President, Incorporated Research Institutions for Seismology

11:00 **PSTG Coordinated SAR Data Collection in Polar Regions: An Update**
Bernd Scheuchl, University of California Irvine

The Polar Space Task Group (PSTG) is succeeding the IPY coordinating body of international space agencies, the Space Task Group (STG). The PSTG SAR Coordination Working Group was created to address the issue of SAR data acquisitions of the cryosphere in response to user requirements from the science community. Based on science requirements input from the ice sheet community in 2012 and 2013, a coordinated effort was undertaken to cllect spaceborne interferometric SAR data over the Greenland and Antarctic ice sheets in 2013. The 2013 RADARSAT-1 data acquisition effort in Greenland was the final science campaign of th emission which ended in late March 2013. An update on the status of the data, access for NASA-funded scientists, and ongoing PSTG efforts to collect SAR data in Greenland (and Antarctica) will be provided.

11:15 Assimilation of Surface Altimetry Data on 79 North Glacier Using Automatic Differentiation and ISSM
Eric Larour, Jet Propulsion Laboratory

Extensive surface altimetry data has been collected on polar ice sheets over the past decades, following missions such as Envisat and IceSat. This data record will further increase in size with the new CryoSat mission, the ongoing Operation IceBridge mission and the soon to launch ICESat-2 mission. In order to make the best use of these datasets, ice flow models need to improve on the way they ingest surface altimetry to infer: 1) parameterizations of poorly known physical processes such as basal friction; 2) boundary conditions such as Surface Mass Balance (SMB). Ad-hoc sensitivity studies and adjoint-based inversions have so far been the way ice sheet models have attempted to resolve the impact of 1) on their results. As for boundary conditions or the lack thereof, most studies assume that they are a fixed quantity, which, though prone to large errors from the measurement itself, is not varied according to the simulated results.

Here, we propose a method based on automatic differentiation to improve boundary conditions at the base and surface of the ice sheet during a short-term transient run for which surface altimetry observations are available. The method relies on minimizing a cost-function, the best fit between modeled surface evolution and surface altimetry observations, using gradients that are computed for each time step from automatic differentiation of the ISSM (Ice Sheet System Model) code. The approach relies on overloaded operators using the ADOLC (Automatic Differentiation by OverLoading in C++) package. It is applied to the 79 North Glacier, Greenland, for a short term transient spanning a couple of decades before the start of the retreat of the Zachariae Isstrom outlet glacier. Our results show adjustments required on the basal friction and the SMB of the whole basin to best fit surface altimetry observations, along with sensitivities each one of these parameters has on the overall cost function. Our approach presents a pathway towards assimilating multiple datasets in transient ice flow models of Greenland and Antarctica, which will become increasingly important as the amount of available observations becomes too large to assess on a case by case basis.

11:30 Challenges Faced by Ice Sheet Projections: Lessons from the SeaRISE Effort and the Upcoming SeaRISE-2 Project
Sophie Nowicki, NASA Goddard Space Flight Center

Projecting the future evolution of the Greenland and Antarctic ice sheets is a problem of enormous societal importance, as ice sheet influence our future sea levels. This crucial issue is however a non trivial task, as demonstrated by the Sea level Response to Ice Sheet Evolution (SeaRISE) effort: prescribing simple external forcings to a group of ice sheet models results in a spread in responses. Understanding the source of the diversity in the model results is therefore crucial in order to reduce the uncertainty in the projection. Just as in any future climate simulation, the analysis presented here demonstrates that the model spread in the SeaRISE effort is due to a number of factors. First is the problem of obtaining an initial configuration for the projection. The two commonly used methods, interglacial spin-up or data assimilation, have both advantages and drawbacks, and will affect the determination of fields that cannot be measured (such as basal slipperiness). Second is the uncertainty in actual observations, which includes but is not limited to surface mass balance, basal topography, ice thickness, and surface velocities. An additional issue with these observations is that they can be transient quantities which are not measured at the same time, but ice sheet models require them to be simultaneous. Third is the uncertainty in the models' physics and discretization, which is limited by our understanding (or lack of understanding) of crucial processes that often occur at subgrid scale relative to the resolution used by continental ice sheet models, and thus require parameterization. Grounding line migration and sliding laws are such an example. Fourth is the determination of the future forcing scenarios and their implementation as the external forcing. Unfortunately, as demonstrated in this analysis, all ice sheet models face these limitations to some degree, so that it is extremely difficult to identify a set of models and projections that should be trusted in preference to others. One model might be more suitable for assessing the impact of a warmer atmosphere because of its initialization procedure, but its deficiencies in capturing grounding line migration, for example, might make its projections for oceanic forcing unreliable. More work is thus required to evaluate individual ice sheet models' skills in projection, and to reduce the uncertainties in ice sheet projections.

11:50 LUNCH

01:00 The Greenland Firn Aquifer: Observations from OIB, In Situ Measurements, and Future Plans
Rick Forster, University of Utah

Improving our understanding of the complex Greenland hydrologic system is necessary for assessing change across the Greenland Ice Sheet and its contribution to sea level rise. A new component of the Greenland hydrologic system, a Firn Aquifer, was recently discovered in April 2011. The Greenland aquifer represents a large storage of liquid water within the Greenland Ice Sheet with an area of 70 ± 10 x 103 km2 simulated by the RACMO2/GR regional climate model which closely follows Operation IceBridge radar-derived mapping (Forster et al., 2013). Repeated OIB flight lines indicate the shape of the undulations in the upper boundary of the aquifer is stable but there may be subtle changes in extent. In April 2013, our team drilled through the aquifer for the first time to gain an understanding of firn structure constraining it, to estimate the water volume within the aquifer, and to measure the temperatures and densities. Our team will return to the drill site in April 2014 to make additional measurements.

01:15 **Spatial Distribution of Ice Sheet Meltwater Export and Retention in Southwest Greenland from In Situ Observations**

Asa Rennermalm, Rutgers University

To accurately determine the Greenland ice sheet contribution to raising global sea levels, a better understanding of how much surface meltwater is exported and how much is retained is needed. It is possible to calculate catchment meltwater retention from land-terminating outlet glaciers with an input/output method. Here, this method is used to determine meltwater export and retention within the large Watson River catchment in Southwest Greenland using runoff calculated with a surface energy balance model relying on input data from three on-ice automatic weather stations, and river discharge datasets from two nested ice sheet catchments (60 - 9750 km2) for 2008 - 2012. By using data from two nested basins of different sizes, an understanding of spatial distribution of melt water export and retention can be obtained. This analysis shows that melt water export from near the ice margin is roughly constant from year to year, while melt water export from the interior exhibit considerable variability. Melt water retention is substantial and includes firn percolation, supra glacial lake storages, as well as englacial and subglacial storage. This study is the first time Greenland ice sheet melt water export and retention's spatial distribution has been quantified with in situ data.

01:30 **Supraglacial River Networks Dominate Surface Meltwater Drainage of the Greenland Ice Sheet**

Larry Smith, University of California Los Angeles

The runoff of water melted from the surface of the Greenland ice sheet is a critical contributor to global sea level rise and primary source of heat and water delivery to the bed, yet remains one the least understood surface water hydrologic systems on Earth. We present synoptic observations of GrIS supraglacial meltwater drainage organization, storage, and discharge, as obtained from in situ hydraulic measurements and simultaneous high-resolution WorldView-2 satellite images covering ~5,500 km2 of southwestern Greenland. In July 2012 we collected water column depth and spectral reflectance and depths in supraglacial rivers and lakes from an unmanned surface vessel (USV), surface flow velocities from autonomous drifting GPS beacons and Doppler radar, cross-sectional river velocity and turbulence structure from Acoustic Doppler Current Profiler (ADCP) surveys, and hydraulic measurements of river flow width, depth, velocity and roughness coefficient. Calibration of 32 simultaneously acquired WorldView-2 scenes with these field data enabled detailed mapping of supraglacial rivers, moulins, and lakes, their total liquid water storages, and instantenous meltwater discharges moving through the supraglacial drainage system. Results reveal that the supraglacial drainage system is highly efficient, with rapid evacuation of meltwater off the ice surface via extensive, well-organized supraglacial river networks, little to no water retention on the surface, and close convergence with SMB losses estimated by a regional climate model.

01:45 **High Resolution Modeling of Cryo-Hydrologic Warming and its Parameterization in Ice Sheet Models**

Hari Rajaram, University of Colorado at Boulder

There is widespread evidence for a rise in the Equilibrium Line Altitude (ELA) in many areas of the Greenland Ice Sheet. In a recent study, West Greenland was found to have experienced a 200m increase in the ELA since 1990, which corresponds to a 3.9% increase in area experiencing melt annually. In the wet snow and ablation zones, water storage capacity in the firn is limited and much of the melt water will enter the englacial hydrologic system via moulins, crevasses and surface fractures. Of this englacial water, a fraction may persist in the Cryo-Hydrologic System (CHS) long enough to refreeze, releasing latent heat and warming the background ice, i.e. cryo-hydrologic warming (CHW). We modeled the small-scale thermodynamics of warming for several "end-member" scenarios that capture a range of plausible CHS geometries and spacing. In particular, we considered crevasses and deeper water bodies subject to one-time water filling, and crevasses that are filled annually and drain via a diffuse drainage system where some liquid water is retained. We found that CHW from shallow crevasses is largely driven by one-dimensional horizontal conduction and that the warming is limited by the depth of crevasse penetration. Deep but not fully penetrating englacial water bodies can significantly warm the lower layer of the ice sheet where the increase in the Flow Law Parameter has the greatest impact on velocity and velocity gradient. The horizontal velocity gradient also caused stretching of deep englacial water bodies, which can increase persistence of liquid water at depth. Finally, drainage of crevasses through fracture networks was found to be an efficient mechanism to transport liquid water to depth. The small cross-sectional area, large surface area, and heterogeneity of the fractures provided the fastest and most efficient release of latent heat into the background ice. Based on the modeling results, we propose some simple mathematical parameterizations that may be used to represent CHW in large-scale ice sheet models.

02:00 **Ongoing Studies of Ice-Ocean Interactions in Greenland**

Eric Rignot, Jet Propulsion Laboratory

Since 2008, we have collected bathymetry and CTD along west Greenland north of Jakobshavn Isbrae to study ice-ocean interactions and their impacts on ice dynamics. We will report on the results of the 2013 campaign in Torssukataq, Umanak and Upernavik systems, including some of the glacier face mappings performed with multibeam sounders, the current level of seafloor mapping achieved in Umanaq fjord combining data from different teams, and results from CTD casts illustrating how Atlantic warm water penetrate into glacial fjords. We will discuss the science results and plans for future surveys.

02:15 Connecting Subglacial Hydrology to Sediment Plumes and Submarine Melt
Timothy Batholomaus, University of Texas at Austin

The upstream subglacial hydrologic network dictates how and where meltwater emerges at a glacier's terminus. Recent models of submarine melt indicate that water emerging in a well-distributed sheet results in more melting at the terminus than water emerging in a single conduit. Thus, the up-glacier flow path of water can have a significant impact on mass loss at a glacier's terminus. At a tidewater glacier in central western Greenland, we model water flow along gradients in hydropotential to identify locations where subglacial water is predicted to emerge at the glacier terminus. We find that the three predicted outlets coincide with observed cavities at the base of the glacier terminus. A seasonal sediment plume frequently recurs at one of the predicted outlets. In ongoing work, we will compare the location of this sediment plume with areas where the terminus retreats seasonally, in an effort to identify the controls on the glacier's terminus position.

02:30 Using a Coupled Observational and Modeling Approach to Investigate Buoyant Plume Structure in Two Adjacent West Greenland Outlet Glacial Fjords
David Sutherland, University of Oregon

The dynamics controlling the coupling between fjord circulation and glacier movement and mass loss are poorly understood. Here, we use oceanographic data collected in summer 2013 from two west Greenland fjords, Rink Isbrae and Kangerdlugssup Sermerssua, to constrain the spatial and temporal variability observed in fjord circulation and begin to compare the different fjord/glacier systems. We quantify the structure and transport observed in the plume from the glacier face to the fjord mouth. Repeat transects allow an unprecedented look at the temporal variability in plume structure close to the glacier terminus. Finally, we compare the results from a 3D numerical model of the fjord to the observations in order to isolate the role of tides and wind forcing. We find the fjord circulation is a complex, 3D process that depends on local bathymetry and offshore density fluctuations, in addition to the freshwater buoyancy forcing.

02:45 Bathymetric Control of Tidewater Glacier Mass Loss in Northwest Greenland
David Porter, Columbia University

The geometry of glacial fjords may play a large role in determining the stability of outlet glaciers. Sloping seafloors will feedback on a moving grounding line and shallow sills and deep continental shelf troughs will allow greater interaction with the surrounding ocean water. New estimates of fjord bathymetries in Greenland, using airborne gravimetry measurements from Operation IceBridge flights, are compared to several important characteristics of their outlet glaciers and ocean waters. We investigate the importance of glacier parameters such as surface velocity and elevation changes on recent changes in glacier behavior. Are faster flowing glaciers found in fjords with deep sills and a greater exchange with continental shelf water? These broad correlations are a starting point in an effort to investigate the role of bed geometry in the variability of observed recent changes in some of Greenland's largest outlet glaciers.

03:00 Capturing the Seasonal Evolution of Greenland Hydrology and Ice-Ocean Processes with Icepod
Robin Bell, Columbia University

Icepod is an ice/ocean imaging system installed on New York Air National Guard LC-130s that provides capability to make seasonal synoptic measurements of the ice-ocean system with tremendous spatial coverage. The Icepod system currently includes a scanning laser, a visual camera, an infrared camera, a shallow ice radar and a deep ice radar. These instruments provide observations on the surface elevation of the ice sheet, the freeboard of floating ice, the surface temperature of the ice and ocean, estimates of the ice surface velocity and constraints on the supra and sub-glacial hydrology. Icepod can be deployed multiple times through the melt season to capture the complete cycle, resolving the variability of the process in time and space. Integrated into routine NYANG operations, Icepod can provide estimates of the surface mass balance, constraints on the glacial hydrology and insights into the fjord stratification.

03:15 BREAK

03:30 Observational data from the Programme for Monitoring of the Greenland Ice Sheet (PROMICE)
Andreas Ahlstrom, Geological Survey of Denmark and Greenland

Climate change in the Arctic has resulted in accelerated mass loss from the Greenland Ice Sheet. The shortage of observations on the Greenland ice sheet infers large uncertainties in estimates of the ice mass loss and in predicting the contribution to sea level rise. For this reason the Programme for Monitoring of the Greenland Ice Sheet (PROMICE) was established in 2007. The aim of the programme is to quantify the mass loss of the Greenland ice sheet and track changes in the extent of the glaciers, ice caps and ice sheet margin.

Within PROMICE data sets from several activities are collected. These include: A network of currently 19 automatic weather stations on the margin of the Greenland ice sheet measuring ice ablation and snow fall as well as meteorological parameters. Airborne surveys, yielding surface elevation and ice depth along the entire margin of the Greenland ice sheet. Mapping of all Greenland ice masses, based on the highest detail aero-photogrammetric maps produced from mid-80's aerial photographs.

Real-time data from the PROMICE automatic weather station network is shown in at the PROMICE web site www.promice.org and the data is freely available for download. Data from the airborne surveys and mapping activities will also become freely available.

Data from PROMICE also contribute to the website www.polarportal.org which is a new Danish web site for providing updated information on the arctic cryosphere to the public.

03:45 **An Improved Mass Budget for the Greenland Ice Sheet**
Ian Howat, Ohio State University

Extensive ice thickness surveys by NASA's Operation IceBridge enable over a decade of ice discharge measurements at high precision for the majority of Greenland's marine-terminating outlet glaciers. Despite widespread acceleration, only 15 glaciers accounted for 80% of the 730 ± 26 Gt of ice lost due to acceleration since 2000, and four accounted for ~50%. Among the top sources of loss are several glaciers that have received little scientific attention. Our results will help guide more effective data collection and modeling for constraining current and future ice sheet mass changes.

04:00 **Acceleration of Ice Sheet Mass Losses from GRACE, Altimetry, Surface Mass Balance and Ice Flux: Trends, Significance and Uncertainties**
Isabella Velicogna, University of California Irvine

We analyze spatial trends in ice sheet mass loss in Greenland to determine areas where the mass loss is significantly increasing with time versus areas where the acceleration is not significant and areas where the ice sheet is gaining mass with time using GRACE gravity solutions. This analysis is done both at the island level and at the regional level. We compare the GRACE regional ice mass changes with independent observations, e.g. trends of ice volume from altimetry, changes in surface mass balance from regional atmospheric climate models and from changes in ice flux from interferometric SAR and ice thickness. We identify the key processes that control changes in mass loss at the regional scale from the GRACE data.

04:15 **Greenland Ice Sheet Changes from Satellite Altimetry, GRACE and SAR Interferometry**
Rene Forsberg, Technical University of Denmark

Satellite data provide a unique and continued time series of the changes of the Greenland ice sheet since 1991. The recently started ESA Greenland Ice Sheet Climate Change Initiative project (http://www.esa-icesheets-cci.org) aims to provide a continued time series of elevation and calving front location changes, as well as Greenland-wide ice velocity data from InSAR data. Some initial results from the project are presented, along with a novel integrated mass-balance estimation based on simultaneous inversion of GRACE data and satellite altimetry changes. The integrated inversion combines the advantages of satellite altimetry in terms of spatial resolution with the monthly time-resolution of the GRACE RL-5 data, and ensures the overall consistency of the total mass loss time series, as well as the agreement between radar and laser altimetry changes (IceSat and EnviSat) when using similar repeat-track analysis methods. The combined mass change time series for Greenland since 2002 highlight the accelerating mass loss from the major outlet glaciers, as well as the northward moving increased ice margin melt.

04:30 **Evaluating MAR and ISSM Simulated Mass Balance over Greenland Using GRACE Satellite Data**
Patrick Alexander, City University of New York

The Mass Balance (MB) of the Greenland Ice Sheet (GrIS) is an important contributor to changes in global sea level, now and in the future. Both modeling and observational studies have recently revealed accelerating mass loss over Greenland, of which approximately 50% has been attributed to changes in the GrIS Surface Mass Balance (SMB), while 50% is assumed to be associated with increases in glacial discharge. Regional Climate Models (RCMs) provide detailed estimates of SMB, but their validation is limited by a lack of observational data. Studies comparing satellite-derived mass change estimates from the Gravity Recovery and Climate Experiment (GRACE) to RCM SMB estimates combined with measured ice sheet dynamical changes suggest an agreement between modeled and measured mass changes over the past decade on an ice-sheet wide scale, but do not involve a detailed analysis of their spatiotemporal variability. The combination of Ice Sheet Model (ISM) and SMB model results can provide insights for improving the prediction of future GrIS mass loss, with the evaluation of both ISMs and RCMs at higher spatial and temporal resolutions being a key aspect. In this study, we make use of a high-resolution gridded GRACE mass concentration solution to evaluate monthly simulated MB produced from a combination of results from the Ice Sheet System Model (ISSM) and the Modèle Atmosphérique Régionale (MAR) RCM. Analysis of spatiotemporal MB variability reveals a lag in the modeled seasonal cycle of mass loss, a positive MB bias along the southeast Greenland coast, and an overall positive simulated MB bias. Further analysis will lead to an improved understanding of model biases and the importance of processes not captured by either model, potentially resulting in improved mass change predictions for the GrIS.

04:45 **Comparison of Using Ice-Sheet Accumulation Rates from ERA-Interim Re-analysis and RACMO Modeling for Accumulation-Driven Mass-Change Estimates**
H. Jay Zwally, NASA Goddard Space Flight Center

Information on ice-sheet accumulation rates and surface temperatures from RACMO (Regional Atmospheric Climate Model) and various meteorological re-analyses such as ERA-Interim are now widely used in cryospheric studies for studies of surface mass balance, for driving firn-compaction models, and for separating accumulation-driven and dynamic-driven surface elevation changes. Among the available data sets, RACMO is probably the most widely used and tends to be generally viewed as the most accurate for both Greenland and Antarctica. However, our analysis of the accumulation-driven mass changes (dMa/dt) on the Antarctic ice sheet for the 1992-2001 period of ERS measurements and the 2003-2008 period of ICESat measurements of elevation changes shows large difference in values calculated from ERA-Interim and those from RACMO. For East Antarctica (EA) the dMa/dt are -11 Gt/yr and -11 Gt/yr using ERA-Interim and -6 Gt/yr and -33 Gt/yr using RACMO respectively for the two periods. For West Antarctica (WA), the dMa/dt are -17 Gt/yr and +17 Gt/yr using ERA-Interim and -9 Gt/yr and +32 Gt/yr using

RACMO for the two periods. The largest differences are for the 2003-2008 period, for which the RACMO data show a negative accumulation anomaly 3 times as large in EA and a positive anomaly 2 times as large in WA. These differences are significant because the values of dMa/dt affect the apportionment of altimetric-measured dH/dt between the accumulation-driven changes in surface mass balance and the dynamic-driven thickening or thinning. A significant conclusion from our analysis using ERA-Interim is the near-equivalence of the dynamic-driven changes (dMd/dt) between the two periods in EA indicating long-term dynamic thickening with little decadal scale change. In addition to providing better glaciological interpretation of the observed elevation changes, our use of ERA-Interim as the preferred data set is further supported by Medley et al. (2013) that showed a temporal correlation of 0.93 between OIB snow-radar measurements of accumulation in WA versus only 0.68 for RACMO.

05:30 POSTER SESSION & COCKTAIL HOUR (GSFC RECREATIONAL CENTER)

06:30 DINNER (GSFC RECREATIONAL CENTER)

POSTER SESSION
Tuesday, January 28
5:30 - 6:30 PM
GSFC Recreational Center

Remote sensing of supraglacial river discharge on the Greenland Ice Sheet
Vena Chu, University of California Los Angeles

Recently observed increases in temperature and melt extent over the Greenland ice sheet have prompted studies gauging the response of the ice sheet and outlet glaciers to increasing meltwater input. Satellite images show supraglacial rivers abundantly covering the western ablation zone throughout the melt season, transporting large volumes of meltwater into moulins and to the ice edge, yet these rivers remain poorly studied. Here we map supraglacial river discharge over western Greenland using high-resolution visible/near-infrared WorldView-2 (WV2) satellite imagery and field measurements. Water features were extracted from WV2 imagery through an automated process that uses a modified normalized difference water index threshold. A centerline vector product representing the river network was produced from the water mask and split into individual moulin drainage basins, with moulins manually identified from panchromatic WV2 imagery. Discharge was calculated along extracted river networks from derived components of width, depth, and velocity. The requirements include: 1) widths calculated along river centerlines using water masks; 2) depths retrieved using an empirical algorithm relating WV2 reflectance to water depth developed from field measurements of depth and spectral reflectance in the ice sheet ablation zone; and 3) velocities calculated using Manning's equation, roughness coefficient (n) values derived from field data, and water surface slopes calculated using the 30 m GIMP DEM. Finally, an alternate method for calculating discharge using a hydraulic geometry relationship between width and discharge derived from field measurements was applied and compared to the Manning's method of discharge retrieval.

Optimizing the MODIS ice-surface temperature (IST) climate data record of the Greenland Ice Sheet
Dorothy Hall, NASA Goddard Spaceflight Center

Ice-Surface Temperature (IST) of Greenland is needed to study temperature and melt trends and may be used in ice sheet models to calculate mass balance. Accurate ISTs are also needed to estimate radiative fluxes and to validate skin temperatures derived from models. We developed a climate-quality data record of the clear-sky surface temperature and melt of the Greenland Ice Sheet using the Moderate-Resolution Imaging Spectroradiometer (MODIS) IST algorithm (Hall et al., 2012; 2013). Daily and monthly quality-controlled MODIS ISTs of the Greenland ice sheet beginning on 1 March 2000 and continuing through 31 December 2011 are available at 6.25-km spatial resolution on a polar stereographic grid along with metadata for accuracy assessment. This dataset provides a highly-consistent and well-characterized record suitable for merging with earlier and future IST data records, for climate studies. Detailed analysis of the dataset is being conducted (e.g., see Shuman et al., submitted), to enable increased accuracy of the record. The dataset is currently being refined and updated by improving the spatial resolution of the maps to 1 km, utilizing enhanced cloud-screening techniques, and updating it (through 2014). The complete MODIS IST daily and monthly data record is downloadable as either Flat Binary or GeoTIFF files and is available online: http://modis-snow-ice.gsfc.nasa.gov/index.php?c=greenland. The enhanced dataset should be available beginning in the summer of 2014.

Greenland mass losses from GRACE using Slepian functions
Christopher Harig, Princeton University

We present an update to our Greenland mass loss estimates from GRACE, using Slepian basis functions. We continue our published results up to September 2013 for Release 5 data. The new results compare well with other observations that recent years have had record amounts of mass loss from Greenland. We will also generally discuss our method of working with GRACE Level 1b data, in the hopes of increasing the spatial sensitivity we can extract from GRACE.

Towards better simulations of ice/ocean coupling in the Amundsen Sea Sector, West Antarctica, using a coupled ocean, sea-ice, and ice-sheet model
Eric Larour, Jet Propulsion Laboratory

Currently, observations of polar ice sheets (Antarctica and Greenland) show a contribution to Sea Level Rise (SLR) of approximately 1 mm/yr, out of 3.4 mm/yr globally. This contribution is expected to increase significantly in the future, to a point where steric expansion will be overtaken by the contribution of melt-water runoff as well as calving and melting of ice shelves. It is therefore paramount to better understand the interaction between the ocean and ice-sheets, in order to better quantify the feedbacks between melting under ice shelves, ocean circulation, and ice-sheet dynamics. Here, we show recent results of coupled ice/ocean simulations in the Amundsen Sea Embayment region of Antarctica, using the Massachusetts Institute of Technology general circulation model (MITgcm) and the Ice Sheet System Model (ISSM), over a period of 20 years, coinciding with the acceleration of the Pine Island and Thwaites Glaciers. Our simulations take into account the shape of the cavities (generated by the ice-sheet model), as well as melting rates (generated by the ocean circulation model) under ice shelves in a fully two-way coupled mode. We show results on the sensitivity of ice-sheet dynamics and ocean circulation to the shape of the cavity, as well as the underlying circulation. Our approach demonstrates the influence of a fully coupled approach on the evolution of the Ocean/Ice System, and presents an efficient way of implementing such two-way coupling.

The response time of surface height change from firn compaction to the fluctuations of the accumulation rate and temperature
Jun Li, NASA Goddard Space Flight Center

The fluctuations of the accumulation rate and temperature cause the short-term changes in the surface height and the mass of polar ice sheets. In order to understand the variations in the observed surface height-time series from altimetry and derive the mass changes from the altimetry data that normally span limited years, it is necessary to know the time required for the adjustment of the surface height to the perturbations of the accumulation rate and temperature. This is of the particular importance to the knowledge of the sustained impact from the previous changes in the accumulation rate and temperature to the current surface height change. Using our numerical model of firn compaction, we have performed the sensitivity studies under the climate conditions at selected sites of the Antarctica to examine the response time of the surface height variation to the given perturbations in the accumulation rate and temperature. Our results show that the response time from the rate of the surface height change to the changes in both accumulation rate and the temperature changes, are much shorter than previously documented and typically from several years to less than 20 yrs in polar ice sheets. The rate of the short-term height change closely follows the variations in the accumulation rate from 84% in the coastal to 99% inland of the Antarctica indicating altimetry measurements can provide strong information of the accumulation rate change. The associated fluctuations of the firn density are significantly preserved in the density profiles along the depth.

Bed topography under the Greenland ice sheet based on mass conservation and OIB data
Mathieu Morlighem, University of California Irvine

Bed topography, together with ice thickness, is an essential characteristic of glaciers and ice sheets for many glaciological applications. Despite significant technical advances, it remains challenging to measure remotely. Here, we employ a mass conservation optimization approach that combines radar sounder collected by NASA's Operation IceBridge since 2009, complemented by data acquired by NASA in 2001-2008, with high-resolution ice motion data from interferometric SAR (ALOS PALSAR, RADARSAT-1 and Envisat ASAR) to reconstruct bed topography beneath the Greenland Ice sheet at an unprecedented level of detail. The results reveal overdeepening in the glacier fjords that are not apparent in current maps, and deep subglacial valleys that channelize ice flow to the coast. These features, mapped for the first time around Greenland using a combination of OIB and InSAR data, have vast implications for the modeling of the evolution of the Greenland ice sheet in a warming climate and suggest that the ice sheet will be more vulnerable to rapid retreat in the coming century than previously thought. These results also provide guidelines for future deployments.

Subpixel variability of MODIS albedo retrievals and its importance for ice sheet surface melting in southwestern Greenland's ablation zone
Samiah Moustafa, Rutgers University

On the Greenland ice sheet, albedo declined across 70% of its surface since 2000, with the greatest reduction in the lower 600 m of the southwestern ablation zone. Because albedo plays a prominent role in the ice sheet surface energy balance, its decline has resulted in near doubling of meltwater production. To characterize ice sheet albedo, Moderate Resolution Imaging Spectroradiometer (MODIS) surface albedo products are typically used. However, it is unclear how the spatial variability of albedo within a MODIS pixel influences surface melting and whether it can be considered a linear function of albedo. In this study, high spatiotemporal resolution measurements of spectral albedo and ice sheet surface ablation were collected along a ~ 1.3 km transect during June 2013 within the Akuliarusiarsuup Kuua (AK) River watershed in southwest Greenland. Spectral measurements were made at 325-1075 nm using an Analytical Spectral Devices (ASD) spectroradiometer, fitted with a Remote Cosine Receptor. In situ albedo measurements are compared with the daily MODIS albedo product (MCD43A V6) to analyze how space, time, surface heterogeneity, atmospheric conditions, and solar zenith angle geometry govern albedo at different scales. Finally, analysis of sub-pixel albedo and ablation reveal its importance on meltwater production in the lower reaches of the ice sheet margin.

Fully-automated high-resolution digital elevation model generation over glaciated regions from WorldView stereo pairs
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The monitoring of surface change in glaciated regions such as Alaska, Greenland and Antarctica is an important pursuit in climate-related Earth Science. Repeat Digital Elevation Models (DEM) created by photogrammetric surface extraction from a time-series of stereo pairs provide an efficient and low cost means for analyzing surface change over large, remote areas. Stereo-photogrammetric DEM extraction over glaciated regions is challenging due to typically low-contrast surfaces such as ice, snow, mountain shadows and steep slopes, resulting in large feature search areas and matching failures. A method for reducing the feature search area is critical for successful and efficient DEM extraction in this terrain.

The SETSM (Surface Extraction with TIN-based Search-space Minimization) algorithm is developed for overcoming these problems and performs surface extraction fully-automatically, without any user-defined or a-priori information, such as seed DEMs, using only the sensor Rational Polynomial Coefficients (RPCs) for geometric constraints. Rotation-invariant, multi-patch Normalized Cross Correlation (NCC) is used as its basic similarity measurement. SETSM constructs a TIN (Triangular Irregular Network) in the object-space domain in order to minimize the necessary search space. It employs a pyramiding strategy that uses iteratively finer resolution TIN's to minimize the search space and uses a vertical line locus to provide precise geometric constraints for reducing the search area. As a major benefit, SETSM relatively adjusts the Rational Function Model (RFM) between stereo pairs to reduce the offset between corresponding points projected by the vertical line locus caused by RPC errors, dramatically reducing the number of matching failures. In SETSM, this offset is iteratively removed with a parabolic adjustment of the NCC solution.

As a demonstration, Worldview stereo pairs for a variety of test areas in Alaska, Greenland and Antarctica are selected for creating 2m grid-spacing DEMs and validating the SETSM algorithm. Each DEM granule was mosaicked to a master grid by a simple height co-registration and split into 20 x 20 km tiles. Qualitatively, most surfaces in snow and ice-covered areas, mountain shadows and steep slopes are exactly reconstructed by SETSM. In addition, SETSM resolves edges and height of discrete features, such as icebergs, crevasses, rocks and streams at high detail. For analyzing DEM accuracy quantitatively, Operation IceBridge data is utilized for validating the height accuracy in Kangerlussuaq and Unmmannaq, Greenland. The RMSE mean and standard deviation without co-registration are 2.21 m and 1.47 m, and 1.75m and 1.82 m in rock area, respectively

Inferring hydrologic drainage of the Greenland Ice Sheet from a new high resolution meltwater outlet dataset
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Warming Arctic temperatures have accelerated mass loss of the Greenland Ice Sheet (GrIS) and increased its contribution to global sea level rise. Approximately half of GrIS mass loss occurs via meltwater runoff but the physical processes and pathways of hydrologic drainage are poorly understood. To gain improved understanding, we mapped all GrIS meltwater exit points along the ice edge using 30m resolution Landsat satellite imagery (for regions north of 78oN Latitude with poor Landsat coverage high-resolution imagery publicly available via the GoogleEarth and BingMaps mapping services was used). 1343 meltwater outlets were mapped according to 8 categories: (1) proglacial lake, (2) proglacial lake to proglacial river, (3) proglacial river to proglacial lake, (4) proglacial river, (5) marine terminating glacier with visible sediment plume, (6) marine terminating glacier with visible ice fracture, (7) marine terminating glacier, and (8) unclassified. These meltwater exit point categories are further summarized into: (A) land terminating glaciers, (B) marine terminating glaciers and (C) undefined. Next, to enhance understanding of supra-, en-, and subglacial meltwater routing these outlet points are used as known pour points to calibrate drainage basin networks for the GrIS using gridded topography datasets and the importance of bedrock topography for hydrologic modeling of the GrIS is assessed. Finally, for a sample or large proglacial rivers in southwest Greenland, the relationship between contributing watershed areas and river widths is compared.

Comparison of near-surface air temperatures and MODIS ice-surface temperatures at Summit, Greenland (2008-2013)

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We have investigated the stability of the MODerate-resolution Imaging Spectroradiometer (MODIS) infrared-derived ice-surface temperature (IST) data from Terra for use as a climate-quality data record. The availability of climate-quality air temperature data (TA) from a NOAA observatory at Greenland's Summit station has enabled this high−temporal resolution study of MODIS ISTs. During a >5 year period (July 2008 to August 2013), more than 2500 IST values were compared with ±3-minute average TA values derived from NOAA's primary 2 m temperature sensor. These data enabled an expected small offset between air and ice sheet surface temperatures to be investigated over multiple annual cycles. Our principal findings show that: 1) IST values are slightly colder than the TA values near freezing but this offset increases as temperatures decrease; and 2) there is a distinct pattern in IST-TA differences as the solar zenith angle (SoZA) varies annually. This latter result largely explains the progressive offset from the in situ data at colder temperatures but also indicates that the MODIS cloud mask is less effective approaching and during the polar night. The consistency of the results over each year in this study indicates that MODIS provides an alternative platform for deriving surface temperature data, but that the resulting IST data is most compatible with T_A data when the sky is clear and SoZA is less than ~85 degrees. The IST values should benefit from improved cloud filtering as well as an algorithm modification to account for the progressive offset from TA.

Using GRACE measurements of time variable gravity, elevation changes from ICESat, OIB and ENVISAT and surface mass balance outputs from RACMO to improve ice mass balance estimates

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The glacial isostatic adjustment (GIA) correction represents a source of uncertainty for ice sheet mass balance estimates from Gravity Recovery and Climate Experiment (GRACE) time-variable gravity measurements. We evaluate Greenland and Antarctic GIA corrections by comparing the spatial patterns of GRACE-derived ice mass trends corrected for glacial isostatic adjustment with volume changes from ICESat (Ice, Cloud, and Land Elevation Satellite) and OIB (Operation IceBridge) altimetry missions, and surface mass balance (SMB) products from the Regional Atmospheric Climate Model (RACMO). We show that using the spatial and temporal characteristics of the different contributors to the ice mass balance estimates that it is possible to evaluate different GIA corrections. In Greenland, the GRACE ice mass changes obtained using the Simpson et al. (2009) and A et al. (2013) GIA corrections show good agreement in the spatial patterns and amplitude. The GRACE estimate corrected using the Wu et al. (2010) GIA shows similar spatial patterns to the other two, but produces an average ice mass loss for the entire ice sheet that is 64--67 Gt/yr smaller. We show that the Wu et al. (2010) correction leads to a large mass increase in the Northeast that is inconsistent with independent observations.

Sea ice motion and age, and relationship to ice thickness

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Using satellite data and drifting buoys, it is possible to observe the formation, movement, and disappearance of sea ice. This history can then be used to estimate ice age, as shown by Fowler et al. (2004) and Rigor and Wallace (2004). In the Fowler et al. (2004) approach, ice movement is calculated using a cross-correlation technique applied to sequential, daily satellite images acquired by SMMR, SSM/I, and AMSR-E.   Motion vectors are then blended via optimal interpolation with International Arctic Buoy Program drifting-buoy vectors and NCEP wind fields (a recent update). Using the resulting 12.5 km x 12.5 km EASE grid vector fields for 1979 onward, ice age (in years) is then estimated by treating each grid cell that contains ice as a discrete, independent Lagrangian particle and transporting the particles at weekly time steps.   We present ice age results for recent years and compare to distributions during the early satellite record. Comparisons of ice age to ice thickness derived from IceBridge observations is also discussed.

Modeling dynamic thickening in East Antarctica as observed from ICESat

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Mass changes of the Antarctic ice sheet derived from ICESat laser altimetry show that during 2003-2008 mass gains from snow accumulation exceeded losses from ice discharge by 73 Gt yr-1 (0.20 mm yr-1 sea level depletion). Results from ERS radar altimetry give a similar net gain of 120 Gt yr-1 for 1992-2001. In East Antarctica and four West Antarctic drainage systems, most of the net mass gain is caused by persistent dynamic thickening (excess of long-term accumulation relative to ice flow) at a rate of 207 Gt yr-1, and not by contemporaneous increases in snowfall. To investigate the dynamic thickening rate, we apply a 3D ice-sheet model to Antarctic ice sheet for the sensitivity experiments with climate change. The model results indicate that the East Antarctica ice sheet has been growing due to increased snowfall after the last ice age. The modeled thickening rate near Vostok is 2.5 cm/a for the present time, which is consistent with the observations from ICESat and ERS data. Overall, the model and observations indicate a long-term mass gain for East Antarctica and the interior of West Antarctic that has been offsetting dynamic losses, which have increased in the Antarctic Peninsula and West Antarctica during the last two decades.