Pre-Meeting Wednesday, September 24, 2014

3:00 to 7:00	**Workshop check in**	
4:30 - 6:00	Open Discussion on the WAIS Science Plan	Griffin Hall
6:30	**Dinner and icebreaker**	Poster Hall & Dining Hall

Day 1 Thursday, Sept 25

7:30-8:30- Breakfast and check in (Dining Hall/then Griffin Hall)

8:30	Welcome and logistics	Helen Fricker, Ted Scambos, Jason of Camp Cedar Glen

Session 1 Marine ice sheet instability ("The Girl's a Super-Freak")

8:45	Impact of Improved Ice-Front Physics on Models of West Antarctic Ice Sheet Response to Climate Warming	Robert de Conto
9:00	Modelling the PIG+Thwaites system	Hilmar Gudmundsson
9:15	The influence of sea-level changes on ice-sheet evolution in Antarctica	Natalya Gomez
9:30	Response of the Antarctic ice sheet to ocean forcing using the POPSICLES coupled ice sheet-ocean model	Daniel Martin
9:45	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
10:00	**Discussion**	**Discussion**

10:15-10:45 Coffee

Session 2 Observations of West Antarctic Ice Sheet Change
"Times they Are A-changing"

10:45	Irreversible changes in the northern part of WAIS: a view from above and below	Eric Rignot
11:00	Cryosat: a new perspective on Antarctic ice sheet elevation changes (WAIS & Peninsula)	Andy Shepherd
11:15	Recent Changes in Ice Mass Balance of the Amundsen Sea Sector	Tyler Sutterly
11:30	Larsen-B and -C Ice Shelf Velocities Revisited	Bernd Scheuchl presented by Eric Rignot
11:45	Eighteen years of height and mass changes in West Antarctic Ice Shelves	Fernando Paolo
12:00	**Discussion**	**Discussion**

12:15-2:00 lunch and posters

Session 3 Ice-ocean interaction in Antarctica ("Surfin' USA")

2:00	Ocean Variability Contributing to Basal Melt Rate Near the Ice Front of Ross Ice Shelf, Antarctica	Laurie Padman
2:15	An Oceanic Heat Transport Pathway to the Amundsen Sea Embayment	Angelica Gilroy
2:30	Ocean-driven basal melt channels and the stability of Amundsen and Bellingshausen Sea ice shelves	Karen Alley
2:45	Modeling the spreading of glacial melt water from the Amundsen and Bellingshausen Seas	Yoshihiro Nakayama
3:00	Sensitivity of ice shelf basal melting to ocean forcing	Ben Galton-Fenzi
3:15	**Discussion**	**Discussion**

See Poster list at end of document

3:30 - 4:00 Coffee/tea break

Session 4 Grounding zones around WAIS ("I Get Around")

4:00	The nature and dynamics of the bed beneath Pine Island Glacier, Antarctica	Rob Bingham
4:15	The influence of geological fabric on grounding line dynamics in the Amundsen Sea	Kirsty Tinto
4:30	Characterizing the Location and Extent of the Thwaites Glacier Grounding Zone Using Airborne Radar Sounding	Dustin Schroeder
4:45	Tidal Flexure and Associated Seismic Activity Near the Grounding Zone of Beardmore Glacier	Paul Winberry
5:00	Satellite Observations of Ice Thickness and Deformational Properties in Antarctic Grounding Zones	Oliver Marsh
5:15	**Discussion**	**Discussion**

5:30 End of sessions for the day
6:30 Dinner

Day 2 Friday, Sept 26

7:30 Breakfast

8:30	WAIS meeting outlook for 2015	Helen Fricker, Ted Scambos
8:45	NSF Program Officers	Julie Palais, Lisa Clough, Paul Cutler
9:00	WAIS Divide Outcomes	TJ Fudge
9:20	NAS Study: 'Strategic Vision for NSF investments in Antarctic and Southern Ocean Research'	Laurie Geller NAS
9:40	**Strategic Antarctic Science discussion**	**All**

10-10:30 Coffee break

Session 5 Climate, Accumulation ('It Never Rains in California')

10:30	Variability of Accumulation Rates from ERA-Interim and RACMO and Impacts on West Antarctic Mass Balance Estimates	Jay Zwally
10:45	It's a wet, wet WAIS: observations of current and historical snow accumulation from the Amundsen Sea sector	Brooke Medley
11:00	A Rossby Wave Bridge from the Tropical Atlantic to West Antarctica	Xichen Li
11:15	Central West Antarctic Accumulation: annual resolution for the past 31 ka	TJ Fudge
11:30	Localized Sea Ice Changes in the Amundsen Sea	Sharon Stammerjohn
11:45	**Discussion**	**Discussion**

12:00-2:30 Lunch, Posters, Activities

Session 6 Rogue Waves, Rogue Water, and Rogue's Gallery ("Wish They All Could Be California Girls")

2:30	Measuring Wave-Induced Vibrations on the Ross Ice Shelf	Peter Bromirski
2:45	Predicting the Presence of a Firn Aquifer on the Antarctic Peninsula using C-Band Satellite-Borne Scatterometry	J.Z. Miller
3:00	Observations of sea ice and ice sheet interaction in Greenland and the Antarctic Peninsula	Twila Moon
3:15	Climate, Sea Ice, and Ocean Precursors to the Larsen Ice Shelf Disintegrations	Ted Scambos
3:30	**Discussion**	**Discussion**

3:45 – 4:00 Coffee Break
Session 7 Ice Divides and Traverses -- "Truckin' "

4:00	Evidence of WAIS Loss during MIS 5e: Siple Dome and more	Richard Alley
4:15	Holocene stability of the Amundsen-Ross ice divide, Central West Antarctica	Michelle Koutnik
4:30	iSTAR: UK ice sheet traverse across Pine Island Glacier drainage basin	Andy Smith
4:45	2014 over-snow traverse to the ice divide between Pine Island, Rutford and Institute Ice Stream, WAIS	Jonathan Oberreuter
5:00	Subglacial conditions and ice flow across the Weddell Sea sector of West Antarctica: synthesis from recent aerogeophysical surveys	Robert Bingham
5:15	**Discussion**	**Discussion**

5:30 End of sessions for the day
6:30 Dinner

Day 3 Saturday, Sept 27

8:30 Breakfast
Session 8 Subglacial Hydrology -- "Slip-Sliding Away"

9:00	Multiple Modes of Refreezing Meltwater beneath Ice Sheets	Robin Bell
9:15	Half-full of half-empty? Informing a model of subglacial lake drainage with observations of surface motion	Sasha Carter
9:30	A Model for Subglacial Flooding Along a Pre-existing Hydrological Network During the Rapid Drainage of Supraglacial Lakes	Surendra Adhikari

9:45	Shallow Sub-Permafrost Groundwater Systems in a Buried Fjord: Taylor Valley, Antarctica	Neil Foley
10:00	Measurements of basal change properties from repeat radar measurements	Sridhar Anandakrishnan
10:15	**Discussion**	**Discussion**

10:15-10:45 coffee break

Session 7 WISSARD project results ("Witchy Woman")

10:45	Environment and Processes of Subglacial Lake Whillans, West Antarctica	Ross Powell
11:00	Inference of grounding-zone properties from radar basal reflectivity, dielectric modeling, and basal-echo phase analysis	Knut Christianson
11:15	Interfacial stresses at the grounding line of the Whillans Ice Plain control the initial stick-slip rupture speed	Jacob Walter
11:30	Spatial Heterogeneity in Ice-bed Interactions Revealed by Variable Seismic Coupling and Basal Seismicity on the Whillans Ice Plain, West Antarctica	Grace Barcheck
11:45	Interruption of the Whillans Ice Stream stick-slip cycle by a subglacial lake discharge event	Matthew Siegfried
12:00	**Final Discussion**	**Final Discussion**

12:30 Lunch and Adjourn (can stay at Camp Cedar Glen all afternoon)

Posters

	Change in the Stick-Slip Cycle of Whillans Ice Stream, West Antarctica	Lucas Beem
	Defining models of glacial isostatic adjustment in West Antarctica and the Antarctic Peninsula	Alex Brisbourne

	(UKANET): better constraints on Earth structure and uplift	
	New high resolution views of the bed of Pine Island Glacier, West Antarctica	Davies, Bingham
	Effects of sub-glacial transport and shearing on siliceous microfossils found in sediments from the Siple Coast region of West Antarctica	Jason Coenen
	The first geothermal heat flux measurement below the West Antarctic Ice Sheet	Andrew Fisher, presented by Slawek Tulaczyk
	Seeking YOUR input for a National Academy of Sciences' study: "A Strategic Vision for Antarctic and Southern Ocean Research"	Laurie Geller
	A connectionist approach to mapping deformation in fast-moving glaciers	Ute Herzfeld
	Late Quaternary history of Hatherton Glacier, Antarctica	Trevor Hillebrand, presented by John Stone
	Bistatic radar case studies from Antarctica and Greenland	Nicholas Holschuh
	Feedbacks Between the Labrador Sea Dynamics and Freshwater Runoff in the Regional Arctic System Model	Saffia Hossainzadeh
	Advanced Ice Velocity Mapping Using Landsat 8	Marin Klinger
	Subglacial conditions as inferred from small repeating earthquakes	Brad Lipovsky
	The ARM West Antarctic Radiation Experiment (AWARE)	Dan Lubin

	Understanding Interactions Between Different Cryosphere Elements: A New WCRP CliC (Climate and Cryosphere) Targeted Activity	Rob Massom, presented by Ben Galton-Fenzi
	Ice flow over plastic beds	Brent Minchew
	Large-Ensemble modeling of past Antarctic variations in the Amundsen Sea Embayment	David Pollard
	Recent Changes of Surface Velocities at Byrd Glacier	Gang Qiao
	Measuring Changes in the Vicinity of the Seal Nunataks Ice Shelf Remnant from Imagery and Altimetry	Christopher Shuman
	Modeling the Elastic Transmission of Tidal Stresses to Great Distances Inland in Channelized Ice Streams	Jeffrey Thompson, presented by Mark Simons

A Model for Subglacial Flooding Along a Pre-existing Hydrological Network During the Rapid Drainage of Supraglacial Lakes

Surendra Adhikari (1,2) and Victor C. Tsai (1)

(1) Seismological Laboratory, California Institute of Technology
(2) Jet Propulsion Laboratory, California Institute of Technology

As presently happening on the Greenland Ice Sheet, large numbers of supraglacial lakes may form and drain rapidly in the future on the West Antartic Ice Sheet. Vertical discharge of water during such events may find a pre-existing film of water potentially within a system of linked cavities. Here, we present a theoretical model for subglacial flooding applied specifically to such circumstances. Given the short timescale of events, we treat the ice and bed as purely elastic and assume that fluid flow is fully turbulent. We evaluate the effect of initial thin film thickness, w_i, on the rate of flood propagation and along-flow profiles of field variables. We find that floods propagate much faster, particularly in early times, for larger w_i. For $w_i = 10$ and 1 cm, for example, floods travel about 68 and 50% farther than in the fully coupled ice/bed scenario after 2 hours of drainage, respectively. Irrespective of the magnitude of w_i, we also find that there exists a region of positive pressure gradient. This reversal of pressure gradient draws water in from the farfield and causes the thin film to narrow, respecting mass continuity. While the general shape of the profiles appear similar, greater conduit opening is found for larger w_i. For $w_i = 10$ and 1 cm, for example, the elastostatic conduit opening at the point of injection is about 1.39 and 1.26 times that of the fully coupled ice/bed scenario after 2 hours of drainage. The hypothesis of a pre-existing thin film of water is consistent with the spirit of contemporary state-of-the-art continuum models for subglacial hydrology. Using this framework also results in avoiding the pressure singularity, which is inherent in classical hydrofracture models applied to fully coupled ice/bed scenarios, thus opening an avenue for integrating the likes of our model within continuum hydrological models. Furthermore, we foresee that the theory presented can be used to potentially infer subglacial hydrological conditions, particularly the initial thin film thickness, given accurate observations of ice surface displacement during drainage events.

For session: Modeling of ice and polar ocean (*California Dreamin'*)

Ocean-driven basal melt channels and the stability of Amundsen and Bellingshausen Sea ice shelves

Karen Alley, Ted Scambos

National Snow and Ice Data Center, CIRES, University of Colorado Boulder

Basal melt channels carved into floating ice shelves are important both as indicators of sub-shelf oceanic conditions and for their potential direct relationship to ice shelf stability. A survey using MODIS and Landsat imagery of all Antarctic ice shelves reveals extensive basal melt channeling around the continent. The observed channels may be divided into two main categories: those that originate at the grounding line, and those that begin away from the grounding line. Past research has suggested that melt channels starting at the grounding line are driven by freshwater outflow from the ice sheet at the distal end of sub-glacial hydrologic flow. This type of channel appears in many locations around the Antarctic continent (e.g. Le Brocq et al. 2013). In contrast, channels that start away from the grounding line appear mainly in the Bellingshausen and Amundsen Sea regions. IceBridge ice-penetrating radar data show that these channels are ~1-5 km wide and are carved ~50-250 m deep into the base of the shelf. Though they approximately follow the ice flow direction, they are often highly sinuous and may cut directly across ice flow. Because they can start anywhere on the shelf, occur mainly in areas exposed to Circumpolar Deep Water (CDW) intrusions, and frequently terminate in persistent polynyas at the shelf edge, we assume that these channels are formed by melt caused by warm ocean water.

An increase in frequency of CDW intrusions has been observed along a broad area of the northern West Antarctic coastline. In some cases, such as the Pine Island Glacier, the greater presence of CDW has led to enhanced calving and retreat. However, shelves in the region that are more confined by islands and peninsulas, such as the Abbot, Dotson, Getz, and Sulzberger ice shelves, have remained relatively stable to this point despite high rates of basal melt. These are also shelves that exhibit many ocean-driven melt channels carved into their bases, visible in satellite imagery because hydrostatic adjustment over channels creates significant surface depressions. At least one of these channels is visibly growing, indicating that not all channels are in steady state. Additionally, the channels in many locations appear to preferentially form adjacent to islands and peninsulas. At one location on the Getz Ice Shelf, a large crevassed region has developed over the last decade at the tip of a peninsula surrounded by deep channels. We hypothesize that the presence of the channels has weakened the shear margins, leading to the observed fracturing. If channels become large and extensive enough along many of the islands and peninsulas buttressing a confined ice shelf, this mechanism could ultimately lead to reduced back-stress, increased calving rates, and/or break-up. As some of these shelves drain a significant portion of the West Antarctic Ice Sheet, understanding this mechanism is necessary to accurately predict future sea level rise.

Theme: Ice-ocean interaction *(Surfin' USA)*: Amundsen Sea (*West Coast Blues)*

Evidence of WAIS Loss during MIS 5e: Siple Dome and more

Richard B. Alley[1], Edward J. Brook[2], David Pollard[1], Jeffrey P. Severinghaus[3], Eric J. Steig[4], Edwin D. Waddington[4], James W.C. White[5], and Jinho Ahn[2]

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Evidence has been accumulating that a future deglaciation of the deep basins of the West Antarctic Ice Sheet (WAIS) would be a replay of earlier events, with the most recent marine deglaciation probably during Marine Isotope Stage 5e. The strongest evidence may be the height and pattern of far-field sea-level records, which together indicate a southern contribution to the 5e high-stand, of magnitude similar to the sea-level equivalent of the marine portions of WAIS (e.g., Kopp et al., 2009, *Nature*). Sedimentary records from under (Scherer et al., 1998, *Science*) or just in front of (Naish et al., 2009, *Nature*) the Ross drainage of WAIS, coupled to ice-flow modeling (Pollard and DeConto, 2009, *Nature*), indicate Pleistocene deglaciation. Excess warmth in East Antarctica during 5e and earlier deglaciations (Holden et al., 2011, *J. Quat. Sci.*), and the patterns of relatedness of bryozoans (Vaughan et al., 2011, *Geochem. Geophys. Geosys.*) and octopi (Strugnell et al., 2012, *Molecular Ecology*) around the coast, are most easily explained if WAIS deglaciated recently. The meltwater channels incised into bedrock in deep water in Pine Island Bay, and rising away from the ice sheet, have been explained as resulting from: i) deglaciation of the marine basins but with ice remaining on the highlands; ii) cooling-induced ice-shelf formation fed by the ice on the highlands, bridging the deep basins and grounding on higher seafloor beyond; iii) thickening of this ice cover in response to the greater friction from the grounding, pressurizing the water trapped in the deep basins, concurrent with ice advance into Pine Island Bay; and iv) subglacial outburst flooding forming the observed channels (Alley et al., 2006, *Geomorphology*). New data are being collected from the deep ice of the Siple Dome core. Results so far indicate deposition at significantly higher, colder elevation than the top of the modern dome (Alley and White, 2000, *WAIS Workshop abst.*), likely recording grounding of an ice shelf fed from highlands, followed by formation of the dome "trapping" ice from higher elevation in the dome. Very careful modeling of existing data, new ice cores situated to find similar signals, and rapid-access drilling to study cosmogenic isotopes in bedrock and perhaps subglacial microfossils and other indicators, offer the possibility of confirming this hypothesis. (Note: This abstract is similar to one presented at the WAIS Divide meeting just before the WAIS meeting; we hope that the results will be of interest to the full breadth of the community.)

Theme: Changes in WAIS from observations (*The Times They are a-Changin')*

Measurements of basal change properties from repeat radar measurements

Sridhar Anandakrishnan, Cameron Lewis, Prasad Gogineni, John Paden, Peter Burkett, Carl Leuschen

Dept of Geosciences and EESI, Penn State University; Dept of Electrical Engineering, U of Kansas; Center for Remote Sensing of Ice Sheets

Processes at the base of glaciers and ice sheets are important for controlling their flow speed and direction, as well as for affecting changes in those properties over time. Some of these properties are relatively stable over time and space, and some can change rapidly. For example, ice shelf basal melt is on the order of meters per year; sediment erosion and deposition varies from nil to meters per year.

Techniques for measuring these properties are many and varied. Here I report on radar methods, with emphasis on phase-sensitive high-resolution measurements of the bed. We made radar measurements over multiple sites on Whilllans Ice Stream, Kamb Ice Strea, and the Ross Ice Shelf to compare and contrast bed conditions. These measurements were repeated after a two- and four-week interval to monitor change. The radar system used was a broad band multichannel array system optimized for high spatial resolution. Bed reflection phase is compared to internal-horizon phase to estimate change in bed properties. Work was conducted (and repeated) along long traverse lines allowing for measuring spatial and temporal variations in changes in bed conditions.

Spatial Heterogeneity in Ice-bed Interactions Revealed by Variable Seismic Coupling and Basal Seismicity on the Whillans Ice Plain, West Antarctica

C Grace Barcheck[1], Susan Y Schwartz[1], Slawek Tulaczyk[1], Jacob I Walter[2], Jeremy Paul Winberry[3]

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(2) University of Texas at Austin, Austin, TX, United States,
(3) Central Washington University, Ellensburg, WA, United States

The Whillans Ice Plain (WIP) moves by stick-slip motion with periods of little to no motion followed by a brief rapid surge, or slip event. Previous work has found that sliding motion initiates in one of two regions of the WIP depending on tide height: in the middle of the ice plain during high tide (Site A), and near the grounding zone during low tide (Site B). The persistence of these two slip initiation areas suggests that these two locations have different basal conditions than the surrounding ice plain. In order to investigate spatial variability in bed properties, we combine 3 GPS and 4 passive seismic datasets collected on the WIP over 4 months between 2008-11 for a comprehensive analysis of ice dynamics and seismicity during the stick-slip cycle. Using continuous GPS (15 sec interval), we calculate seismic coupling, or the percent of total ice motion that occurs during slip events, at >40 locations. We find Site A is highly coupled (~80- 90%) and surrounded by less coupled ice (55-75%). This suggests that Site A has a stronger bed and accumulates a greater shear stress between slip events than the surrounding ice, which responds to shear stress by creeping. Visual inspection of high frequency seismic data (>1Hz) in both the time and spectral domain reveals ~10s-100s of tiny earthquakes during slip events at 11 locations near Site A. Seismicity is scarce in the surrounding areas during slip, and at all seismic sites during the inter-slip periods. Site B has lower coupling (<55%) and few basal microearthquakes. This result confirms elevated basal stress near Site A and suggests that it occurs as isolated small regions of high friction. S-P times of the microearthquakes change over weeks, suggesting different rupture patches evolve over short timescales. The pattern of GPS-derived coupling shows mesoscale variability in bed strength (~10s of km) while microseismicity with varying S-P times indicates small-scale bed variability within the initiation area (~100s of m).

I am submitting this abstract to the most closely related them of “Changes in WAIS from observations (*The Times They are a-Changin')”.*

Change in the Stick-Slip Cycle of Whillans Ice Stream, West Antarctica

Lucas H. Beem[1,], Slawek M. Tulaczyk[1], Matt A. King[3], Helen A. Fricker[4]*

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The motion of the Whillans Ice Stream has been previously documented to be changing with time. The trend of long term deceleration has been observed to be variable over inter-annual time scales with the maximum observed magnitude of declaration occurring between 2009 and 2014 at a rate of up to 10 m/yr^2. Additionally, the lower portion of the ice stream, Whillans Ice Plain, exhibits motion characterized by longer periods of slow stable sliding (6 to 24+ hours at <0.5 m/day) and rapid sliding slip events (~30 minutes at up to 20 m/day) for which the timing is tidally modulated.

Through the use of continuous GPS observations of Whillans Ice Plain ice surface displacement, we show that the stick-slip cycle is changing in two main ways, 1) the frequency of slip events is decreasing at ~30 events per year and 2) the rate of stable sliding is decreasing. The observed reduction in total ice surface displacement is partitioned equally between these two types of ice motion. Given the time since the last slip event, the magnitude of the following slip event is predictable. This slip-predictability is unchanged throughout the duration of the observations.

We compare two simple models of ice stream stick-slip motion to determine likely mechanisms for observed changing stick-slip behavior. One model, a frictional slider block model, requires a reduction in compressional stress loading rate or an increasing threshold of slip initiation to reduce the frequency of slip events. Reduction in stress loading is potentially supported by observations of slower stable sliding magnitudes and slower upstream ice velocity, which does not experience stick-slip motion. Complicating this interpretation are observations of increased compressional strain rates along ice stream flow for portions of the ice stream between 2007 and 2013. An increasing stress threshold for slip initiation is potentially precluded by consistent slip-predictability.

A second model used was a slip-predictable elastic force balance model. To match observations the model requires a temporal increase or decrease in both mean basal resistance and compressional stress loading. Alternatively, an increase in ice surface slope coupled with either,

or both, a decrease in compressional stress loading and an increase in mean basal resistance yield similar results. Pervious work suggests that mean basal resistance is increasing with time and that the spatial variability of ice surface elevation change results in increased mean surface slope along Whillans Ice Plain. These observations generally support the second possible result

Neither model is complete in its treatment of ice stream stick-slip motion. But both models suggest increased ice stream surface slope coupled with increased basal resistance is consistent with secular and spatial trends of slow down. These mechanisms are consistent with the observation of stick-slip cycle variability. These results reinforce the sensitivity of ice stream motion to internal dynamic and geometric feedbacks.

Theme: Changes in WAIS from observations (*The Times They are a-Changin')*

Multiple Modes of Refreezing Meltwater beneath Ice Sheets

Robin E. Bell[1], Fausto Ferraccioli[2], Tom Jordan[2], Kirsteen Tinto[1], Indrani Das[1], Michael Wolovick[1], Winnie Chu[1], Timothy T. Creyts[1], Nicholas Frearson[1], John D. Paden[3]

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Meltwater can influence ice flow by lubricating the base or by freezing-on new warm ice that changes ice sheet strength. In East Antarctica water in subglacial networks along the valleys of the Gamburtsev Mountains refreezes along the high ridge producing large bodies of basal ice. Basal ice units thicken along flow and deflect the overlying stratigraphy upward up to 1000m. In Antarctica, basal units are characterized by a upper reflector and often emerge from the bright, water-filled ice sheet bed. Basal freeze-on in the Dome A region must have persisted in the same locations through the last glacial-interglacial transition to produce the 60km long features. While the surface accumulation, surface slope and bed morphology vary on the north and south of Dome A, a quarter of the ice sheet base consists of ice freeze-on from the bottom. Similar structures are present within the Greenland Ice Sheet. In Antarctica, refrozen ice has been sampled over Lake Vostok and imaged downstream of Lake Vostok, over Lake Concordia, close to Dome C and on both sides of Dome A. In Greenland, both surface and basal meltwater refreeze to the bottom of the ice sheet producing distinct ice units up to 1100m thick. In Greenland it is clear the units consist of a core of refrozen water commonly surrounded by 100's of meters of heavily deformed ice. Beneath Petermann Glacier, Greenland refrozen ice units coincide with the onset of fast flow and continue downstream where they correspond to locations of rapid melting of the floating ice tongue. Refreezing can modify the temperature structure and rheology of an ice sheet influencing both deformation and discharge of ice into the global oceans. The basal freeze-on modifies the fundamental structure of ice sheets, thickening the ice column from the base. Inclusion of these basal processes is essential to produce robust predictions of future ice sheet change and to accurately predict the location of the oldest ice.

Free Falling

The nature and dynamics of the bed beneath Pine Island Glacier, Antarctica

Robert G. Bingham[1], Damon Davies[1], Edward C. King[2], Stephen L. Cornford[3], David G. Vaughan[2], Jan De Rydt[2], Andrew M. Smith[2]

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The dramatic acceleration, recession and thinning of Pine Island Glacier observed over the last 20 years represent some of today's highest-profile contemporary glaciological phenomena, and are of global concern due to their contribution to eustatic sea level. The last decade has witnessed multiple initiatives to predict the future of the catchment with numerical modelling, but the different models disagree on the likely future pace of loss and its spread inland. Progressive aerogeophysical surveys of the catchment have increasingly constrained the catchment-wide form of the bed, providing regional boundary conditions, but there has remained a dearth of information at the smaller scales that many glaciological studies have shown can, in fact, be critical in controlling ice-stream motion.

In 2013/2014, as part of the UK NERC iSTAR (ice Sheet sTAbility Research programme) traverse across PIG, we deployed the British Antarctic Survey's DEep-LOoking Radio Echo Sounder (DELORES) to alleviate this data gap. Our goal was to survey patches of the bed at high resolution to: (a) image subglacial landforms and detect presence/absence of water and/or sediments, and (b) produce detailed subglacial topographies useful for quantifying basal roughness and modelling basal drag. We present and discuss here the form of the bed imaged at six sites across the trunk and tributaries of Pine Island Glacier.

In the light of recent findings indicating that sub-ice stream landforms may be transient and subglacial erosion high, we also undertook opportunist repeat-surveys of DELORES tracks previously surveyed in 2007/08 and 2010/11 (six and three years earlier respectively). We present and discuss preliminary findings from these surveys.

Sung to the tune of: Amundsen Sea (*West Coast Blues)*

New high resolution views of the bed of Pine Island Glacier, West Antarctica

Damon Davies[1], Robert G. Bingham[1], Stephen L. Cornford[2], Edward C. King[3], David G. Vaughan[3], Alastair G.C. Graham[4], Matteo Spagnolo[5], Jan De Rydt[3], Andrew M. Smith[3]

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[5] School of Geosciences, University of Aberdeen, UK

Pine Island Glacier (PIG) in West Antarctica is currently losing ice at a rate equivalent to ~7% of current sea-level rise, and predicting its future is therefore an important scientific goal. Though the glacier has now been the focus of several modelling studies, the different models disagree on the likely future pace of loss and its spread inland. Significantly, all models depend critically on the form of the subglacial conditions used, and though the general form of the bed has been mapped from surveys over the last decade, the resolution of bed required for modelling to be improved, i.e. at the sub-km scale, has hitherto been unavailable. Addressing this dearth of detailed bed information was therefore a key objective for the 2013/14 UK iSTAR (ice Sheet sTAbility Research programme) traverse across PIG.

We deployed the British Antarctic Survey's DEep-LOoking Radio Echo Sounder (DELORES) to sound 10 x 15 km patches of the bed in six locations across PIG. Each patch was surveyed in 22 parallel transects lying 500 m apart and which were each 15 km long. Along each radar transect, the bed was sounded approximately every 5 m. The patches sample the main trunk of the ice stream, the beds of four of the main tributaries, and as a control site, an inter-tributary ridge. Here we present an image of the ice-sheet bed at each of the six sites. We show that the nature of the bed varies significantly between sites, and make some preliminary interpretations of the subglacial forms relative to those observed in palaeo-ice stream settings.

Poster drawn to the tune of: Amundsen Sea (*West Coast Blues)*

Subglacial conditions and ice flow across the Weddell Sea sector of West Antarctica: synthesis from recent aerogeophysical surveys

Robert G. Bingham[1], Neil Ross[2], Hugh F.J. Corr[3], Fausto Ferraccioli[3], Tom A. Jordan[3], Anne M. Le Brocq[4], David M. Rippin[5], Kathryn C. Rose[6], Andrew P. Wright[4], David W. Ashmore[7] and Martin J. Siegert[8]

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Institute and Möller Ice Streams (IMIS) together drain ~20% of the ice from West Antarctica, forming major contributors to the Weddell Sea Sector (WSS) of Antarctica. Before 2010, relative to the other major West Antarctic drainage basins feeding the Ross and Amundsen Seas, the WSS was rated as West Antarctica's "pole of ignorance" concerning past and present glaciological conditions and sensitivity to change. Underpinned by the hypothesis that IMIS may be underlain by deformable marine sediments analogous to the Siple Coast ice streams, and may therefore be prone to similar ice-dynamical instabilities, a comprehensive aerogeophysical survey of IMIS was undertaken in the austral summer 2010/11 under the auspices of NERC's Antarctic Funding Initiative. Herein we present a synthesis of findings from the new data.

We now know that the lower portion of IMIS is underlain by a deep basin filled with marine sediments and sloping inland, rendering much of the region vulnerable to the marine ice-sheet instability. Inland of the marine basin, the subglacial terrain is composed of mixed roughness. This reflects, in part, a significant tectonic signature of faults, structural lineaments and Jurassic intrusions likely emplaced during opening of the Weddell Sea Rift. Superimposed is a geomorphological signature testifying to the basin's experience of waxing and waning ice cover over glacial cycles. An extensive plateau inland of the deep basin was likely created under ice-free conditions during the mid-Miocene (17-15 Ma), while large channels cut into the bedrock testify to the presence of thinner, temperate ice cover which allowed supraglacial-subglacial connections during the Pliocene (5.3 – 2.6 Ma). Today the regional ice cover is thinning steadily from the Last Glacial Maximum (20 ka). Patterns of englacial layering suggest that in the less topographically constrained western and southern parts of IMIS the spatial configuration of ice has changed considerably, likely in response to thinning and increased grounding of the Bungenstock Ice Rise and a proportional increased to drainage of IMIS via Institute Ice Stream. Multiple lines of evidence show that IMIS is today underlain by a highly dynamic subglacial hydrological system which may facilitate further changes to the ice flow. Modelling suggests that of all the WSS ice streams, IMIS may be particularly susceptible to considerable change after only a projected moderate increase in ice-shelf melt at its grounding zone.

Sung to the tune of: Changes in WAIS from observations (*The Times They are a-Changin')*

Defining models of glacial isostatic adjustment in West Antarctica and the Antarctic Peninsula (UKANET): better constraints on Earth structure and uplift

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Accurate predictions for the evolution of WAIS require an understanding of the *dynamics* of present-day ice mass change. A first step towards this goal is the quantification of the *spatial distribution* of this change. Two key methods for deriving spatially-variable ice mass change are satellite gravimetry and altimetry. Crucially, both of these techniques - in particular satellite gravimetry, as carried out by the GRACE satellites - are susceptible to errors introduced by correcting for the uplift response of the solid Earth to past ice mass loss. This process, Glacial Isostatic Adjustment (GIA), is strongly dependent upon the underlying Earth structure.

In West Antarctica the gravitational signal due to GIA is of the same order of magnitude as the signal due to current ice mass change, but of the opposite sign. Separating out the contribution from these competing signals is the greatest barrier to accurately determining the distribution of present-day ice mass change in Antarctica. Current GIA models show strong disagreement across West Antarctica due to uncertainties in both ice history and Earth rheology. In particular, absolute values of mantle viscosity are poorly constrained, and most GIA models only consider vertical variations in Earth structure. By independently determining even the order of magnitude of upper mantle viscosity, significant inroads can be made into reducing the uncertainty associated with the GIA correction. The inclusion of lateral variations in Earth structure is a key step towards more realistic models. We will determine Earth structure through a new passive seismological experiment. We will deploy a network (UKANET) of 10 broadband seismometers in West Antarctica for 2 years to estimate 3D variations in Earth rheology by determining shear-wave velocity models down to depths of c. 400 km from surface wave dispersion.

In addition, 10 existing GPS sites on the Antarctic Peninsula will be maintained for the duration of the seismic deployment. Whilst this sparse network of GPS will constrain the deformation pattern on a broad scale, we expect smaller wavelength variability in deformation due to present-day ice mass change, which is localised to individual glaciers. These present-day processes can be distinguished from the long term GIA by their differing spatial pattern. We will apply InSAR to outcrops on the Antarctic Peninsula to increase the spatial sampling of the deformation field by orders of magnitude. This technique has been widely applied to tectonic and volcanic settings and has the potential to revolutionize our understanding of the spatial field of solid Earth deformation in response to rapid ice mass change in Antarctica. Because distances between rock outcrops can be large, assumptions from weather models need to be made about the spatial variability of the tropospheric radar propagation delay during interferometric processing. We will test these assumptions with a temporary GPS deployment on the Antarctic Peninsula.

Marine ice sheet instability *(Free Fallin')*

Measuring Wave-Induced Vibrations on the Ross Ice Shelf

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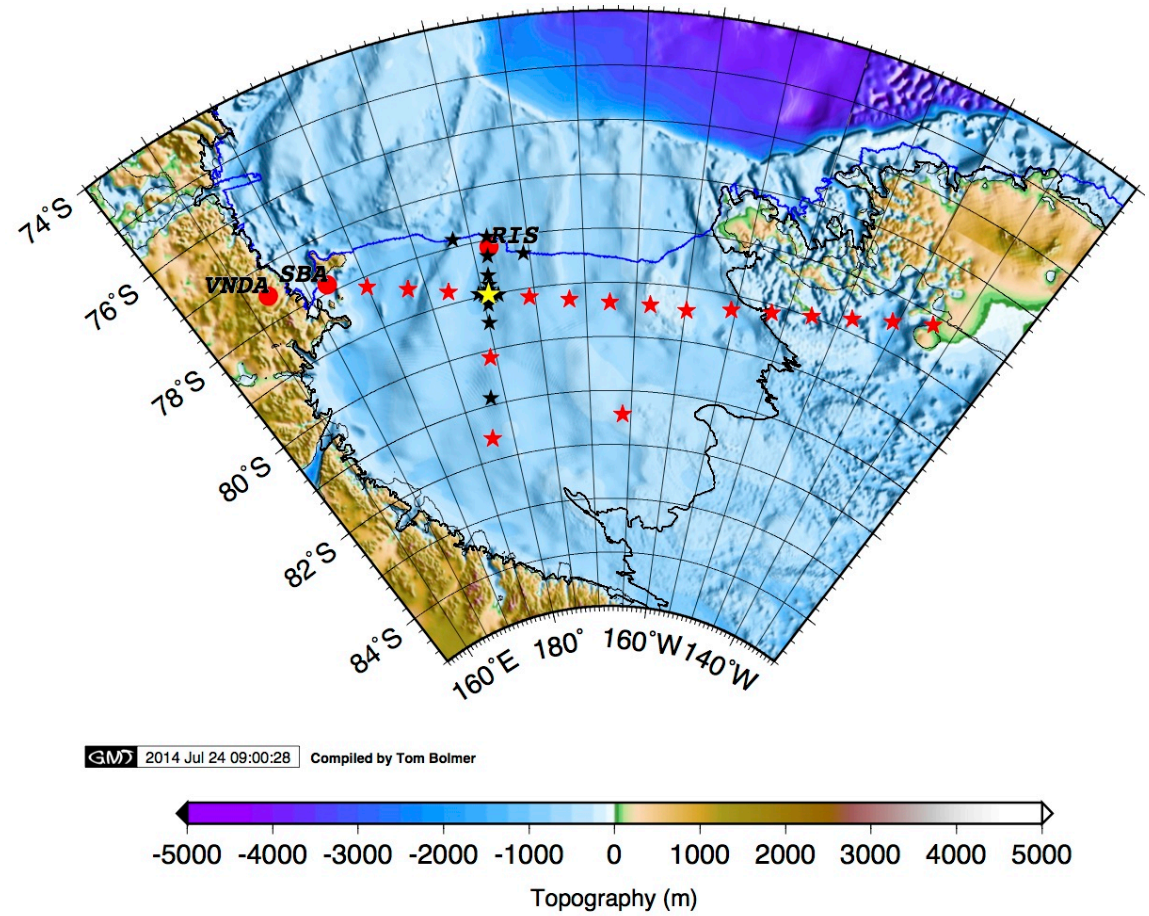
Ocean gravity waves are dynamic elements of the global ocean environment, affected by ocean warming and changes in ocean and atmospheric circulation patterns. Their evolution may thus drive changes in ice-shelf stability by both mechanical interactions, and potentially increased basal melting. The resulting weakening of the RIS will likely cause decreased buttressing of land ice and result in increased rates of ice flow to the Ross Sea, which in turn feed back on sea level rise.

Long-period oceanic infragravity (IG) waves (ca. [250, 50] s period) are generated along continental coastlines by nonlinear wave interactions of storm-forced shoreward propagating ocean swell. Seismic observations on the Ross Ice Shelf (RIS) show that free IG waves generated along the Pacific coast of North America propagate transoceanically to Antarctica, where they induce a much higher amplitude ice shelf response than ocean swell (ca. [30, 12] s period). Additionally, unlike swell, IG waves are not significantly damped by sea ice, and thus impact the ice shelf throughout the year.

Signal propagation across ice shelves depends on ice shelf and sub-shelf water cavity geometry as well as ice shelf physical properties (e.g. structure, thickness, crevasse density and orientation). The vibration response of the RIS varies with season and with the frequency and amplitude of the gravity-wave forcing. A 16 station broadband seismometer array (Dynamic Response of the Ross Ice Shelf to Wave-Induced Vibrations, DRRISWIV, I-348) across the RIS (in conjunction with the Wiens et al. earth structure 18 station array, G-089) will be deployed during November 2014 to study the response of the RIS to swell and IG wave impacts continuously for two years, measuring seasonal changes in ice shelf properties. Field observations and numerical simulations will reveal how wave–induced vibrations on ice shelves in general, and the RIS in particular, can be used (1) to infer spatial and temporal variability of ice shelf mechanical properties, (2) to infer bulk elastic properties from signal propagation characteristics, and (3) to determine whether the RIS response to IG wave forcing observed distant from the front propagates as elastic stress waves from the front or is continuously "locally" generated by IG wave energy propagating within the RIS sub-shelf water cavity. Emphasis will be placed on observation and modeling of the RIS response to IG wave forcing at periods from 75 to 300 s, as these waves constitute a potentially significant and deeply penetrating forcing mechanism contributing to rift expansion and potentially to ice shelf fragmentation.



Station location map for the 16 broadband seismic station array (black stars). Also shown are the 18 Wiens et al. RIS earth structure project (G-089) broadband stations (red stars) to be deployed jointly from a base camp located near RS04 (yellow star). Locations of permanent Global Seismic Network (GSN) seismic stations VNDA and SBA and the McAyeal et al. 2005-06 broadband station RIS are indicated by red circles.

Half-full or half-empty? Informing a model of subglacial lake drainage with observations of surface motion

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Since 2005, approximately 130 new subglacial lakes have been discovered from observations of surface uplift and subsidence; these are commonly referred to as “active lakes”. In contrast to the ~160 lakes detected by radar sounding (“RES” lakes), which are typically in mountainous terrain near the ice divide and have residence times spanning millennia, active lakes are typically located beneath fast flowing ice streams far from the divides, have short residence times, and, when surveyed with radar, do not exhibit basal reflections consistent with RES lakes. While the connection between RES lakes and ice dynamics has not been observed, discharge from active lakes has been shown on multiple occasions to temporarily accelerate the flow of ice downstream. We have developed a numerical model that can reproduce the timing and magnitude of observed subglacial lake drainage events in Antarctica based on earlier theoretical work and informed by lake-volume estimates inferred from of ice surface displacements detected by satellite radar and laser altimetry. We find that the overall pattern of filling and drainage is similar to that for ice dammed lakes in alpine regions via channels thermally eroded into the ice that then creeps shut as water pressure declines. However Antarctic lake drainage is better simulated by invoking a channel mechanically eroded into the underlying sediment. Our model predicts that maximum lubrication immediately downstream of the lake should occur when the lake nears its high stand and outflow via a distributed system dominates. The majority of outflow however, occurs via a channelized system, peaking while the lake is half-empty. The amount of lubrication available per unit outflow is sensitive to the geometry of the water system as well as the strength and composition of the surrounding sediments. We explore how this sensitivity is expressed through a variety of environments throughout lower Whillans and Mercer Ice Streams.

Inference of grounding-zone properties from radar basal reflectivity, dielectric modeling, and basal-echo phase analysis

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Properly mapping bed topography and basal conditions in ice-sheet grounding zones is crucial to understanding ice-sheet evolution. Detailed maps of bed topography are needed to properly assess the impact of bed pinning points in grounding-line retreat scenarios. Other processes, including sediment deposition, till compaction, and infiltration of seawater upstream of grounding via tidal flexure, may also have important effects on grounding-line stability. Ice-penetrating radar is the most commonly used technique to examine ice-sheet grounding zones because it supplies large amounts of useful data comparatively easily. Although mapping the bed topography is relatively straightforward, more-complete interpretations of radar data incorporating information from basal reflectivity and basal-echo phase remain challenging, especially in complex environments, where thin films of various materials (e.g., freshwater, seawater, debris-bearing ice, sediment of varying compaction state), widespread crevasses, and off-nadir reflections may affect the radar returned signal. Here we use information from basal reflectivity and bed-echo phase analysis to infer basal conditions and water column properties at the grounding zone of Whillans Ice Stream, West Antarctica. This analysis is further informed by active-source seismic data, which image grounding-zone bathymetry. Our results indicate substantial mixing in the shallow water column in a subglacial embayment where several subglacial lakes drain whereas the transition from ice overlying till to ice overlying seawater is more abrupt in nearby areas with no subglacial drainage. Thus, properly considered, radar data can yield valuable information on grounding-zone conditions, including water properties as the ice begins to float. We conclude by discussing ramifications of this study for interpretation of airborne radar data collected over other grounding zones, including those of Pine Island and Thwaites Glaciers.

Theme: Surfin' USA (both West Coast Blue and Promised Land)

Effects of sub-glacial transport and shearing on siliceous microfossils found in sediments from the Siple Coast region of West Antarctica

Jason Coenen[1], Reed Scherer[1], Sophie Warny[2], Jeremy Wei[1], Isla Castenedas[3], and the WISSARD science team

Northern Illinois University[1], Louisiana State University[2], University of Massachusetts Amherst[3]

Sub-ice sediment samples from the Siple Coast region in West Antarctica; have been collected over the past few decades. We present micropaleontological data from different sub-ice locations part of the Ice streams in the Siple Coast region. The main focus of this study is on the sediments collected from Sub-glacial Lake Whillans (SLW) in 2013. A reanalysis of the upstream portion of the sediments from the Whillans Ice Stream (WIS) was also done, which includes new analysis of the Unicorn shear margin drilled in '93.

Other areas of interest covered in this study are the up and downstream portion of the Kamb Ice Stream (KIS); and the "sticky spot" drilled in the 2000 season. Additionally sediments from the Bindschadler Ice Stream (BIS) were analyzed and are also reported. These samples were all analyzed for siliceous microfossils such as diatoms and sponge spicules. Absolute abundances of diatoms and diatom fragments were performed on sediments in different size classes to compare and contrast sub-ice environments. Sponge Spicules were analyzed for taphonomic effects indicating sub-ice process.

Overall, the Siple Coast Region samples ranged from 10^6 to 10^8 diatom fragments per gram. SLW, the downstream component of WIS contains 10^6 to 10^7 diatom fragments per gram, while upstream WIS have higher fragments per gram in some cases and higher numbers of whole diatoms found in upstream WIS than SLW. Counts on the Unicorn shear margin samples have similar numbers to SLW for diatom fragments per gram and lower whole diatom abundance was also noted. The upstream component of KIS has a higher amount of fragments per gram than SLW, while the downstream component and sticky spot yield numbers similar to SLW. The upstream portion of KIS has higher whole diatoms upstream in some cases than SLW and WIS suggesting closer proximity to source beds. While downstream KIS has similar numbers to SLW. BIS has numbers similar to upstream WIS and KIS for diatom fragments per gram. The whole diatoms are more abundant than SLW. The differences in abundance and preservation of diatoms and spicules in the upstream and downstream components of these ice streams, as well as, shear margins and lakes seems to corroborate with the subglacial shearing index of Scherer et al. (2005). Neogene aged marine diatoms dominate KIS and WIS, whereas older Paleogene marine diatoms dominate BIS. This suggests a different source for BIS or further erosion into older sediments.

The highest amount of shear is noted in the sediments from shear margins, SLW and downstream components of ice streams. Upstream portions reveal higher abundance of whole to half diatoms suggesting closer proximity to source beds and less cumulative shear strain. Quantitative analysis of siliceous microfossils preserved in these sub-ice sediments is revealing a complex glacial history. Data presented is providing a better understanding of microfossil conditions at different sub-glacial environments. This will provide further insight into modeling conditions of past and present ice sheet behavior.

- I think it could be in: *The Times They are a-Changin', California Dreamin', or Free Fallin'* . Not really sure what would be the best fit at this time.

Impact of Improved Ice-Front Physics on Simulations of Antarctic Ice Sheet Response to Climate Warming

Rob DeConto[1], David Pollard[2],

[1]University of Massachusetts, [2]Pennsylvania State University

While geologic records of past sea level high stands remain poorly constrained, Antarctica is now thought to have contributed more than 10 meters of equivalent sea-level rise during the warm Pliocene (~3 million years ago), and 4-7 m during the more recent Last InterGlacial (LIG; ~130 to 115 ka). This magnitude of Antarctic Ice Sheet retreat during these past intervals (only slightly warmer than today) has been difficult to reconcile in most ice sheet models.

Here, we use a hybrid continental ice sheet-shelf model, with new treatments of 1) the influence of surface meltwater on ice-shelf calving and 2) structural failure of large tidewater cliffs. The ice sheet-shelf model is coupled with high-resolution atmosphere and offline ocean components and used to simulate the Antarctic Ice Sheet response to conditions during the mid-Pliocene and the LIG. The addition of the new physics produces Antarctic contributions to sea-level rise of 17 meters during the warm mid-Pliocene, and 3 meters during LIG, in much better agreement with (albeit uncertain) geological sea-level indicators than our previous simulations.

When applied to long-term future simulations assuming extended RCP greenhouse gas emission scenarios and using high resolution atmosphere and ocean components, the new model physics produce a dramatic retreat of Antarctic marine-based ice over the next 500 years, beginning within a few decades in the Amundsen Sea sector of West Antarctica. In the warmest RCP scenario (RCP8.5), combined retreat of the Amundsen Sea and Siple Coast outlet glaciers results in the near-total collapse of the West Antarctic Ice Sheet (WAIS) within a few centuries, followed by substantial retreat into the deep subglacial basins (Wilkes and Aurora) underlying the East Antarctic Ice Sheet (EAIS). If valid, the new model physics implies Antarctica has the potential to contribute up to 10 m of sea level rise within the next five centuries.

For theme: Modelling of ice and polar ocean (California Dreamin')

The first geothermal heat flux measurement below the West Antarctic Ice Sheet

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Geothermal heat flux represents an important boundary condition for ice sheet dynamics and mass balance. It influences ice sheet mass balance directly, through its control of basal melting and freezing, and indirectly as a result of the dependence of ice sliding velocity on subglacial water volume and/or pressure. Until now, geothermal flux reaching the base of the Antarctic ice sheet has been inferred indirectly from geophysical and glaciological models. We measured directly the geothermal heat flux below the West Antarctic Ice Sheet (WAIS), under Subglacial Lake Whillans (SLW), as part of the Whillans Ice Stream Subglacial Access Research Drilling (WISSARD) project. The one-dimensional, conductive heat flux is the product of thermal gradient and thermal conductivity. We developed a borehole tool to determine the thermal gradient in lake sediments, after penetrating ~800 m of ice using a hot water drilling system. We used the needle-probe method to measure the thermal conductivity of sediments recovered from the bottom of the lake with a gravity-driven multi-corer. We installed also a fiberoptic Distributed Temperature Sensor (DTS) to measure englacial ice temperatures and estimate conductive heat loss from the ice base. The subglacial thermal gradient was determined during two separate deployments of the geothermal tool, which penetrated ~1.1 m into the sediments at the bottom of SLW, yielding essentially identical vertical temperature gradients: 0.21±0.07 °K/m. Fifteen sediment thermal conductivity measurements yield an average value of 1.36±0.12 W/m-K. Based on these measurements we calculate the geothermal heat flux to be 285±85 W/m^2. This value is somewhat higher than that estimated from the WAIS-Divide ice core site, 230 mW/m^2, ~800 km away, and much higher than regional estimates based on magnetics and a global seismic model, generally ≤100 mW/m^2. It is also about three times higher than the conductive heat flux into the ice estimated from repeat DTS measurements in January 2013 and 2014. Elevated geothermal flux in this area could result from thermal perturbations associated with rifting, crustal thinning, or volcanic activity. Geothermal heat input of this magnitude is likely to cause basal melt rate of a few cm/year. If this value is representative of conditions below this part of the WAIS, it might help explain the occurrence of active subglacial lakes and fast-moving ice streams.

- Marine ice sheet instability (*Free Fallin')*

Shallow Sub-Permafrost Groundwater Systems In A Buried Fjord: Taylor Valley, Antarctica

Neil Foley, Slawek Tulaczyk, Esben Auken, Jill Mikucki

UC Santa Cruz, UC Santa Cruz, U. Aarhus – Denmark, U. Tenn. Knoxville

The McMurdo Dry Valleys (MDV), Antarctica, represent a unique geologic setting where permanent lakes, ephemeral streams, and subglacial waters influence surface hydrology in a cold polar desert. Past research suggested that the MDV are underlain by several hundreds of meters of permafrost. Here, we present data collected from an Airborne EM (AEM) resistivity sensor flown over the MDV during the 2011-12 austral summer. A focus of our survey was over the Taylor Glacier where saline, iron-rich subglacial fluid releases at the glacier snout at a feature known as Blood Falls, and over Taylor Valley, where a series of isolated lakes lie between Taylor Glacier and the Ross Sea. Our data show that in Taylor Valley there are extensive areas of low resistivity, interpreted as hypersaline brines, beneath a relatively thin layer of high resistivity material, interpreted as dry- or ice-cemented permafrost. These hypersaline brines remain liquid at temperatures well below 0°C due to their salinity. They appear to be contained within the sedimentary fill deposited in Taylor Valley when it was a fjord connected to the Ross Sea. This brine system continues up valley and has a subglacial extension beneath Taylor Glacier, where it may provide the source that feeds Blood Falls. By categorizing the resistivity measurements according to surficial land cover, we are able to distinguish between ice, permafrost, lake water, and seawater based on characteristic resistivity distributions. Furthermore, this technique shows that areas of surface permafrost become increasingly conductive (brine-filled) with depth, whereas the large lakes exhibit taliks that extend through the entire thickness of the permafrost. The subsurface brines represent a large, unstudied and potentially connected hydrogeologic system, in which subsurface flows may help transfer water and nutrients between lakes in the MDV and into the Ross Sea. The widespread presence of brines beneath ice and permafrost in the MDV raises the possibility that similar systems exist across the coast of Antarctica and therefore that submarine groundwater discharge is a more significant factor than previously thought. Such a system is a potential habitat for extremophile life, similar to that already detected in the Blood Falls outflow, and may serve as a terrestrial analogue to potential extraterrestrial habits, where liquid surface waters are not expected to exist.

Theme:

- Ice-ocean interaction *(Surfin' USA)*
    - **everywhere else (*Promised Land)***

Sensitivity of ice shelf basal melting to ocean forcing

Benjamin K. Galton-Fenzi

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The Antarctic ice sheet is coupled to the ocean via ice shelves that fringe most of the coast. Changes to ice shelves can influence the flow of grounded ice into the oceans, with implications for the mass budget of the ice sheet, sea-level rise and the global thermohaline circulation. Recent observed ice shelf thinning is thought to be a result of enhanced basal melting, driven by increased ocean heat circulating beneath the ice shelves. This ocean heat supply is regulated by several factors including winds, sea ice production rates, ocean circulation, mixing, and the shape of both the bathymetry and ice shelf draft. Generally, the relative importance of each of these factors for basal melt, and their interaction with each other, is different for each ice shelf/ocean system. For each system, it is the combination of these factors that determines the sensitivity of basal melting to the available heat. Here, the sensitivity of each system is calculated using observed basal melt rates and estimates of ocean temperature, representing the heat. This approach also provides the susceptibility of each system to change. These results are then used as a robust evaluation metric for an ice-shelf/ocean model.

Theme: Ice-ocean interaction *(Surfin' USA)*

Seeking YOUR input for a National Academy of Sciences' study: "A Strategic Vision for Antarctic and Southern Ocean Research"

Laurie Geller
National Academy of Sciences, Polar Research Board

The National Research Council has been asked to articulate a strategic vision for NSF's investments in Antarctic and Southern Ocean research-- anchored by community engagement and input, and building upon the broad vision of key scientific questions identified in the 2011 NRC report "*Future Science Opportunities in the Antarctic and Southern Ocean*", and other relevant efforts such as the SCAR Horizon Scan. The goal of this study is to recommend (to NSF) priorities for compelling research that could feasibly be undertaken in the coming decade or so, and to outline practical steps forward to implement this research. Our scope stretches across topics as diverse as geology and geophysics, terrestrial and aquatic biology, glaciology and ice core studies, ocean and atmospheric sciences, astrophysics and space weather, as well as cross-cutting areas such as education, public engagement, and data management.

The study committee would like to draw widely upon ideas from experts across the Antarctic and Southern Ocean science communities. To this end, we are holding a series of outreach activities across the country, including stand-alone workshops at a number of universities and shorter sessions held at existing gatherings of relevant community groups (such as the WAIS meetings). In addition, we have established an online 'Virtual Townhall' where anyone can submit their ideas at any time: http://www.surveygizmo.com/s3/1622544/Development-of-a-Strategic-Vision-and-Implementation-Plan-for-the-U-S-Antarctic-Program-at-the-National-Science-Foundation

In this session, we will explain more about motivation and goals of the study, and about the types of input we are seeking. As time allows, we hope to have some group discussion, to get your views about what scientific activities are of greatest important to the WAIS research community.

Theme: other

An Oceanic Heat Transport Pathway to the Amundsen Sea Embayment

Angelica Gilroy, Matthew Mazloff, and Sarah Gille

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The Amundsen Sea Embayment (ASE) on the West Antarctic coastline has been identified as a region of accelerated glacial melting. A Southern Ocean State Estimate (SOSE) is analyzed over the 2005-2010 time period in the ASE region. The SOSE oceanic heat budget reveals that advection and local air-sea heat flux both contribute significantly to the heat content of the ASE waters, while the contribution of parameterized small-scale mixing is negligible. Above the permanent pycnocline the local air-sea flux dominates the heat budget and is controlled by seasonal changes in sea ice coverage. Overall, between 2005 and 2010, the model shows a net heating of the ASE in the layer above the pycnocline by 8.2×10^{19} J. Sea water below the permanent pycnocline is isolated from the influence of air-sea heat fluxes, and thus, the divergence of heat advection is the major contributor to increased oceanic heat content of these waters, with a total net heat content increase of 1.7×10^{19} J. Heat transport across the continental shelf slope in the layer below the pycnocline is strongest in the eastern sector of the embayment. Here, the oceanic transport of mass and heat is primarily geostrophic, sustained by the local wind-stress curl.

- Ice-ocean interaction *(Surfin' USA)*
    - Amundsen Sea (*West Coast Blues)*

The influence of sea-level changes on ice-sheet evolution in Antarctica

Natalya Gomez[1], David Pollard[2], Jerry Mitrovica[3], David Holland[1]

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2. *Earth and Environmental Systems Institute Pennsylvania State University*
3. *Earth and Planetary Sciences, Harvard University*

This presentation will focus on the influence of local sea-level changes and glacial isostatic adjustment on the stability and dynamics of marine ice in Antarctica. We will discuss the physics of sea level – ice sheet interactions using simplified modeling, then present the results of simulations using a more realistic, three-dimensional ice sheet-shelf model coupled to a gravitationally self-consistent global sea-level. The coupled model incorporates deformational and gravitational perturbations to a viscoelastic, rotating Earth and it captures the complex spatiotemporal geometry of post-glacial sea-level change, including at the grounding lines of marine-based ice. We apply the coupled model to simulate the evolution of the Antarctic Ice Sheet over the last 40,000 years, focusing in particular on ice distributions and sea levels from the Last Glacial Maximum to present. We also compare our model predictions to relative sea level (RSL) histories and GPS-derived present-day uplift rates at sites around the periphery of Antarctica. The results demonstrate that the sea-level feedback has a significant stabilizing influence on marine ice-sheets, acting to slow down grounding-line migration relative to ice sheet model simulations that do not include the sea-level coupling. Finally, we explore the sensitivity of the results to adopted Earth model parameters, and the implications of applying more realistic models of Earth structure on West Antarctic ice volume at the Last Glacial Maximum and the Antarctic contribution to sea-level rise over the Last Deglaciation.

We will submit this abstract to the theme "Marine ice sheet instability" (Free Fallin'), but it would also be suitable for "modeling of ice and polar ocean".

Modelling the PIG+Thwaites system

G. Hilmar Gudmundsson, Sebastian Rosier, Jan deRydt
British Antarctic Survey, UK

Victor Tsai, Caltech

We present some ongoing modeling work on PIG+Thwaites. Our primary objective is to assess if the flow regime of these two glaciers can be treated independently in forecast runs. We suggest that this may generally not be the case. Another question that we address is the sensitivity of the PIG+Thwaites system to applied ocean melting. We find that chancing the applied melt rate by no more than factor of 2 to 4, can cause anything between total WAIS collapse within a few centuries or very little change at all. Giving these findings we discuss the importance of ice+ocean coupled models and present some ongoing coupled ice+ocean modeling work currently done at BAS. We also present some recent in-situ measurements of ice flow in the vicinity of PIG grounding line. Finally we address the issue of basal control on fast flow ice streams and present some recent and ongoing modeling work done on tidally induced variations in ice-stream flow.

Marin ice sheet instability

A connectionist approach to mapping deformation in fast-moving glaciers

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Deformation is a class of highly non-linear geophysical processes from which one can infer other geophysical variables in a dynamical system. For example, in an ice-dynamic model, deformation is related to velocity, basal sliding, surface elevation changes, and the stress field at the surface as well as internal to a glacier. While many of these variables cannot be observed, deformation state can be an observable variable, because deformation in glaciers (once a viscosity threshold is exceeded) manifests itself in crevasses.

Given the amount of information that can be inferred from observing surface deformation, an automated method for classifying crevasse types in surface imagery becomes increasingly desirable. In this paper, we introduce a connectionist-geostatistical approach to mapping crevasse types and hence deformation types. The approach results in a Neural Network for crevasse classification. An aspect of interest to the glaciological community is that a new Neural Net can be derived in a semi-automated way, requiring minimal pre-sorting of imagery, and this can be carried out by non-experts in NNs.

The connectionist-geostatistical approach uses directional experimental (discrete) variograms to parameterize images into a form that the Neural Network can recognize. Recognizing that each tpe of fast glacier movement results in different crevasse types and that environmental conditions affect the appearance in imagery, we have developed a semi-automated pre-training software to adapt the Neural Net to changing conditions and surface types, as well as to different types of imagery, such as airborne videography and satellite imagery.

Applications to different types of fast-moving glaciers will be presented, including Amundsen Embayment Glaciers (Pine Island Glacier, Thwaites Glacier), Bering Glacier (Alaska) and Jakobshavn Isbrae, Greenland.

Late Quaternary history of Hatherton Glacier, Antarctica

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During Marine Isotope Stage 2 (MIS-2), grounded ice in the Ross Sea extended to a limit near Coulman Island (73.5 S). Constraints on the extent of this ice can be obtained from deposits alongside glaciers in the Transantarctic Mts. We are working to map and date deposits of Hatherton and Darwin Glaciers. In earlier work, Bockheim *et al.* (1989) mapped Hatherton Glacier deposits and assigned an LGM age to the Britannia II drift and a post-LGM age to the Britannia I drift, based on minimal soil development and a limited number of radiocarbon ages of algae from former ice-dammed marginal ponds. Recently, Storey *et al.* (2010) and Joy *et al.* (2014) dated deposits at Lake Wellman, Dubris and Bibra Valleys using cosmogenic nuclides; they inferred an MIS-5 age for Britannia-II drift, with little or no thickening of Hatherton Glacier (and Ross Sea ice) during MIS-2, and interpreted Britannia I drift as the result of a Holocene re-advance.

During the 2013-2014 season, we re-examined deposits at these same middle and upper glacier sites. Our initial mapping closely confirms the drift limits proposed by Bockheim *et al.* (1989); the two Britannia limits are distinct at Dubris Valley, but may coincide at Lake Wellman. In addition, we collected several hundred samples of cobbles for exposure dating and algae for radiocarbon analyses. Our initial exposure ages for the Britannia II limit at Dubris Valley indicate that it is older than 130 ka. We did not find any ancient algae associated with this unit, consistent with a drift age older than MIS-2. Ages from Britannia I drift limits on bedrock ridges above Dubris and Bibra Valleys are 8.5 ± 0.3 ka (n=4) on Danum Platform and 7.1 ± 0.3 ka (n=2) on the ridge west of Bibra Valley. Exposure ages from an elevation transect below the Britannia-I limit on Danum Platform show that Hatherton Glacier subsequently thinned by >150 m over ~2,000 years. This thinning continued into the late Holocene. Radiocarbon dates on algae from former ice-marginal ponds at the Britannia I limit at Lake Wellman indicate ice was near its maximum at ~9.5 kyr B.P. Dates in elevation transects at Lake Wellman and Bibra Valley suggest that retreat was underway by ~9.0 kyr B.P. and continued until at least ~4.0 kyr B.P. Collectively, these results indicate a glacial history like that of comparable sites at Reedy, Scott, and Shackleton Glaciers.

Joy *et al.* (2014) interpreted dates from Hatherton Glacier as evidence of limited Ross Sea ice during the LGM, followed by a Holocene advance. In contrast, our previous work in the southern Transantarctic Mts has shown Holocene thickening at up-glacier sites was preceded by thickening at glacier mouths ~ 19-14 ka. Planned fieldwork at Diamond Hill at the mouth of Darwin Glacier will determine whether the Darwin-Hatherton glacier system experienced a similar history.

References: Bockheim *et al.*, *Quat. Res.* 31, 229 (1989); Storey *et al.*, *Ant. Sci.* 22, 603 (2010); Joy *et al.*, *Quat. Sci. Rev.*, 83, 46 (2014). Supported by NSF award PLR-1246110.

Theme: Marine ice sheet instability (*Free Fallin')*

Bistatic radar case studies from Antarctica and Greenland

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Englacial absorption of radar waves varies as a function of ice temperature and impurity content. Direct measurements of these properties are costly and time consuming, making geophysical methods for determining characteristics of the ice increasingly attractive. We examine a set of 5 common-midpoint (CMP) surveys to determine the local attenuation profiles for Kamb Ice Stream, the Whillans Ice Plain, the Whillans Grounding Zone, and the Northeast Greenland Ice Stream (NEGIS). These surveys were conducted between 2004 and 2012, using a 3 MHz radar system with dipole antennae. The results of the CMP analyses are then compared against attenuation rates estimated using a common offset profile, and once validated, we explore the possibility of using attenuation rates to infer ice properties. A borehole derived thermal profile is used to calibrate our analysis at the Whillans Ice Plain field site. If this method proves successful, it will provide a fast, low-cost means of gathering information about the thermal and chemical structure of the ice. Precise attenuation measurements are also crucial to the interpretation of reflection amplitudes in common-offset radar surveys; however, independent measures of attenuation are rarely used to correct these data. Our work suggests a way to determine those attenuation rates, thus improving our ability to make inferences about basal and internal properties from the large scale, common-offset surveys collected in Antarctica and Greenland.

Changes in WAIS from observations (*The Times They are a-Changin')*

Feedbacks Between the Labrador Sea Dynamics and Freshwater Runoff in the Regional Arctic System Model

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The oceanic forcing of a marine terminating glacier may rapidly destabilize the inland outlet glacier. In turn, the regional ocean circulation can be affected through coastal freshwater inputs. In order to realistically model ice sheet - ocean interactions, heat and buoyancy exchanges between a sub-ice cavity or fjord and the adjacent open ocean need to be accurately simulated. These exchanges and the ocean circulation are controlled by the overall climate state, synoptic atmospheric forcings, such as mesoscale storms, and air-sea interactions. Thus, large-scale coupled earth system models (ESMs), including atmosphere, ocean, sea/land ice, and other components of the climate system are required to better understand such feedbacks.

While there are still many challenges to modeling physical processes at the ice sheet – ocean interface, especially in narrow Greenland fjords, regional climate models exist and can be used to study the ocean circulation upstream of fjords and downstream of glacial origin runoff. In this study, we evaluate the skill of the Regional Arctic System Model (RASM) in simulating the hydrography and dynamics of the Labrador Sea due to varying magnitudes of land runoff, including the local source from the Greenland Ice Sheet.

RASM is a fully coupled regional ESM, however here we use a subset of RASM, where the ocean and sea ice components (Los Alamos Sea Ice – CICE and Parallel Ocean Program – POP, respectively) are active while the atmosphere (Weather and Research Forecasting – WRF) and land (Variable Infiltration Capacity – VIC) components are replaced with realistic atmospheric data from the Common Ocean Reference Experiment version 2 (CORE2) reanalysis for 1948-2009. POP/CICE models use the same grid configured at 1/12° in the horizontal and 45 levels in the vertical direction.

We analyze RASM's sensitivity to the surface salinity conditions by comparing two simulations, one using surface salinity restoring to monthly climatology and the other with monthly mean runoff fluxes from land prescribed from CORE2. We find that the run with prescribed freshwater fluxes yields more realistic simulation, including coastal currents, a stronger boundary current, and sharper shelf-basin density gradients. In addition, the sea ice extent in the Labrador Sea follows observations more closely, and the spatial distribution and temporal evolution of mixed layer depth are more accurate in this model run compared to the run with salinity restoring. Finally, eddy generation and distribution also differs between the two simulations, which we argue plays an important role in preconditioning or inhibiting deep-water formation in the region. On the other hand, we also find warmer and more salty water penetrating the west Greenland's continental shelf region and getting advected further north in the model run with realistic runoff forcing. Thus, our study shows that freshwater runoff plays an important role in the region, acts to communicate potential feedbacks between the ocean and marine terminating glaciers, and that such feedbacks need to be accounted for in ESMs.

Theme: Ice-ocean interaction *(Surfin' USA)*: everywhere else (*Promised Land)*

Advanced Ice Velocity Mapping Using Landsat 8

Marin Klinger[1], Theodore Scambos[1], Mark Fahnestock[2], Terry Haran[1]

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Improved image-to-image cross correlation software is applied to pairs of sequential Landsat 8 satellite imagery to accurately measure ice surface velocity over ice sheets and glaciers (± 0.1 pixel displacement, 15 m pixels). The high radiometric fidelity of Landsat 8's panchromatic band (12-bit), and exceptional geolocation accuracy (typically ± 5 m) supports the generation of ice velocity fields over very short time intervals (e.g., 16-, 32-, 48-day repeat cycles of the same scene location). The high radiometry supports velocity mapping in areas with very subtle topographic detail, including un-crevassed sustrugi regions on ice dome flanks or the ice sheet interior. New Python-based software presently under development (named PyCorr) takes two sequential Landsat 8 OLI scenes (or suitably processed ETM+ or TM scenes) and matches small sub-scenes ('chips') between the images based on similarity in their gray-scale value patterns, using an image correlation algorithm. Peak fitting in the region of maximum correlation for a chip pair yields sub-pixel fits to the feature offset vector. Vector editing after the image correlation runs seeks to eliminate spurious and cloud-impacted vectors, and correct residual geolocation error. This processing is based on plausible values of ice strain rates and known areas of near-zero ice flow (rock outcrops, ice dome areas, etc.). In preliminary processing, we have examined ~800 Landsat 8 image pairs having <20% cloud cover spanning the near-coastal Antarctic ice sheet during the 2013-14 summer season.

Holocene stability of the Amundsen-Ross ice divide, Central West Antarctica

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The Amundsen-Ross ice divide near the West Antarctic Ice Sheet (WAIS) Divide ice-core site is migrating today (Conway and Rasmussen, 2009), and because internal layers observed across the divide do not exhibit arches characteristic of a stationary divide, it is likely that the divide has been migrating and/or the basal ice has been sliding over the past few thousand years. It has been shown that the interior ice in this region can respond rapidly to perturbations near the margins (e.g. Payne et al., 2004), and that changes in the flow of WAIS outlet glaciers may have major implications for draw down of interior ice. While we expect divide migration through the Holocene and we expect that flow changes near the margins can affect interior ice, we have not yet been able to answer these questions: How far has the Ross-Amundsen ice divide migrated in the Holocene, and what were the drivers of this divide migration?

We find that the Ross-Amundsen ice divide has been relatively stable over the past 8.4 ka and has most likely migrated only ±10 km from the modern position. To bound plausible scenarios of divide migration we solve a suite of inverse problems to infer unknown boundary conditions that give the best fit to the available data. In our new work we use the high-resolution WAIS Divide ice-core timescale (WAIS Divide Project Members, 2013) to date all observed internal layers, and we use an accumulation history that we infer from the ice-core data and a 1-D model in order to constrain our 2.5-D transient flow modeling. We present a synthesized Holocene history of accumulation and ice flow that is consistent with the ice-core chronology and available internal layers, and we put bounds on the timing and magnitude of Holocene variations in the flow of outlet glaciers on the Amundsen Sea coast and of the Ross Ice Streams that could have altered interior layer shapes. The Amundsen-Weddell ice divide was also relatively stable through the Holocene (Ross et al., 2011), which puts our results in a broader West Antarctic context.

Conway, H. and L.A. Rasmussen (2009). *Geophys. Res. Letters* 36, doi:10.1029/2009GL038072.
Neumann, T.A. et al. (2008). *Journal of Geophys. Res.* 113, doi:10.1029/2007JF000764.
Payne, A.J. et al. (2004). *Geophys. Res. Letters* 31, doi:10.1029/2004GL021284.
Ross et al. (2011). *Geology* 39 (10), 935-938.
WAIS Divide Project Members (2013). *Nature*, *500*, p. 440 - 444, doi: 10.1038/nature12376

Submit to session:

- Changes in WAIS from observations (*The Times They are a-Changin')*

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

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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.

This work was performed at the California Institute of Technology, Jet Propulsion Laboratory under a contract with the National Aeronautics and Space Administration (NASA) Modeling Analysis and Prediction (MAP) and Cryosphere programs.

This abstract is submitted to the Marine ice sheet instability session (*Free Fallin')*

A Rossby Wave Bridge from the Tropical Atlantic to West Antarctica

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David Holland, Edwin Gerber, Changhyun Yoo
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Antarctica has experienced a series of dramatic climate changes on regional scales in recent decades. Surface air temperature observations of the Antarctic Peninsula and West Antarctica reveal rapid warming trends. In contrast to the sea ice decline over the Arctic, Antarctic sea ice has not declined, but rather exhibiting a perplexing redistribution, with increases in the Ross Sea and decreases in the Amundsen-Bellingshausen Sea. While changes in radiative forcing from greenhouse gases and ozone have played important roles in Antarctic surface temperature change, these regional scale changes are strongly influenced by changes in the atmospheric circulation, and is linked to the tropical Ocean through tropical – polar teleconnections. In this study, we used different observational and reanalysis datasets, as well as a hierarchy of atmospheric models with different complexity, to establish a teleconnection between the Atlantic Ocean and Antarctic climate. We show that the Sea surface temperature warming related to Atlantic Multi-decadal Oscillation generates Rossby wave trains propagating to the polar region, induces a positive phase response in the Southern Annular Mode, strengthens the Amundsen Sea Low, projects onto the observed dipole-like sea-ice redistribution between the Ross and Amundsen Seas, and contributes to Peninsula warming. This teleconnection depends critically on the Rossby wave dynamics and is pronounced in all seasons except austral summer.

- Climate and accumulation (*It Never Rains in California)*

Subglacial conditions as inferred from small repeating earthquakes

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Department of Geophysics, Stanford University

The Whillans Ice Stream, West Antarctica, is notable for its regular and periodic sliding events. During these sliding events, Winberry et al. (2013) observe a low-amplitude seismic signal that is recorded on seismometers located on the ice stream. The seismic signal consists of sets of gliding spectral lines that increase and decrease with observed ice surface velocities as measured by GPS. Similar signals in the field of volcano seismology have been attributed to the occurrence of small repeating earthquakes. When such events are sufficiently closely spaced, their spectral signature appears as a fundamental frequency with overtones, with the fundamental frequency being inversely proportional to the inter-event time.

We investigate the occurrence of small repeating earthquakes using a force balance model that incorporates rate- and state-variable friction laws. Together, the earthquake inter-event time and velocity amplitude measured at seismometers constrain the mechanical conditions at the sliding interface. In particular, we use these observations to constrain basal shear stress, pore pressure and the rigidity of the seismic sliding interface. This inversion is under-determined and such parameter constraints are inherently non-unique. Nevertheless, this analysis provides an independent estimate of these quantities that may be compared to classical glaciological methods.

Modeling of ice and polar ocean (California Dreamin')

The ARM West Antarctic Radiation Experiment (AWARE)

Dan Lubin, David Bromwich, Lynn Russell, Johannes Verlinde, Andrew Vogelmann

Scripps Institution of Oceanography (SIO), Byrd Polar Research Center, SIO, Pennsylvania State University, Brookhaven National Laboratory

West Antarctica is one of the most rapidly warming regions on Earth, and this warming is closely connected with global sea level rise. Yet there has been no substantial atmospheric science or climatological fieldwork on West Antarctica since that started during the 1957 International Geophysical Year and continuing for just a few years afterward. Direct meteorological information on the WAIS has been limited to a few automatic weather stations for several decades. And yet satellite imagery and meteorological reanalysis indicate that West Antarctica is highly susceptible to advection of warm and moist maritime air and cloud cover, depending on the location and strength of low-pressure cells in the Amundsen, Ross, and Bellingshausen Seas. There is a need to quantify the role of these changing air masses on the surface energy balance, including all surface energy components and cloud radiative forcing, and to identify teleconnections with lower latitudes. Fortunately, McMurdo Station, where the most advanced cloud and aerosol instrumentation can be situated, has a meteorological relationship with the WAIS via circulation patterns in the Ross and Amundsen Seas.

The US Department of Energy Atmospheric Radiation Measurement (ARM) program West Antarctic Radiation Experiment (AWARE) will deploy an ARM Mobile Facility (AMF) to McMurdo Station, Antarctica from October 2015 until October 2016. AWARE will deploy an additional subset of ARM instruments to the West Antarctic Ice Sheet (WAIS) Divide Ice Camp for a 75-day observing period between November 2015 through January 2016. The full AMF at McMurdo will comprise the most advanced ground-based atmospheric research equipment available, including a suite of cloud radars, high spectral resolution lidar, and spectral radiometers operating at the visible through microwave wavelengths. AWARE will also send basic radiometric, surface energy balance, and upper air equipment directly to the WAIS to make the first well-calibrated climatological suite of measurements seen in this extremely remote but globally critical region in more than forty years. The suite of instruments going to the WAIS has been selected for maximum value for climate science consistent with the logistical constraints at this distant summer-only field station. AWARE has been approved for full Department of Energy support, pending NSF agreeing to support preliminary but substantial research by the AWARE Science Team.

AWARE data will be analyzed first in two areas: (1) provide quantitative information on WAIS energy balance components and cloud radiative forcing as they relate to changing air masses and warm air advection, which are ultimately related to lower latitude teleconnections, and (2) provide cloud microphysical data to evaluate and improve climate model performance in the coldest and most pristine environment on Earth. More generally, this year-long field campaign with the most advanced atmospheric science instrumentation available, the first of its kind in Antarctica, will provide a data set having lasting value for climate and geophysical science.

- Climate and accumulation (*It Never Rains in California)*

Satellite Observations of Ice Thickness and Deformational Properties in Antarctic Grounding Zones

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Remote measurement of ice thickness in the Antarctic grounding zone is the key to understanding catchment-scale ice discharge and local mass-balance, and for quantifying ice-shelf basal-melt rates in the vicinity of the grounding line. Here we use satellite altimetry and InSAR to map the surface profile of the ice and changes in this profile due to interaction with the ocean. Both the static buoyancy bending length scale and the time-dependent vertical movement of the surface due to tides provide us with information about ice stiffness, rheology and basal properties. We show how regularization can be used to control the inverse form of the Euler-Bernoulli equation for an elastic plate. By combining satellite-derived diurnal flexure patterns and a regional tide model we can infer ice stiffness and estimate grounding zone ice thickness. At the Beardmore Glacier, a 2-D thickness map produced using detailed differential flexure information from TerraSAR-X imagery agrees with radio-echo sounding measurements to within ~50 m. A more extensive comparison of surface elevations with ice-penetrating radar data highlights the spatial extent of error in the commonly used hydrostatic equilibrium assumption in this region, reaching over 100m in some areas, and the consequent potential for miscalculation of ice shelf basal melt rates close to grounding zones. This new satellite-based approach provides potential for improvement to remote grounding line ice thickness measurements where airborne surveys are not available.

Ice-ocean interaction *(Surfin' USA)* - everywhere else (*Promised Land)*

Response of the Antarctic ice sheet to ocean forcing using the POPSICLES coupled ice sheet-ocean model

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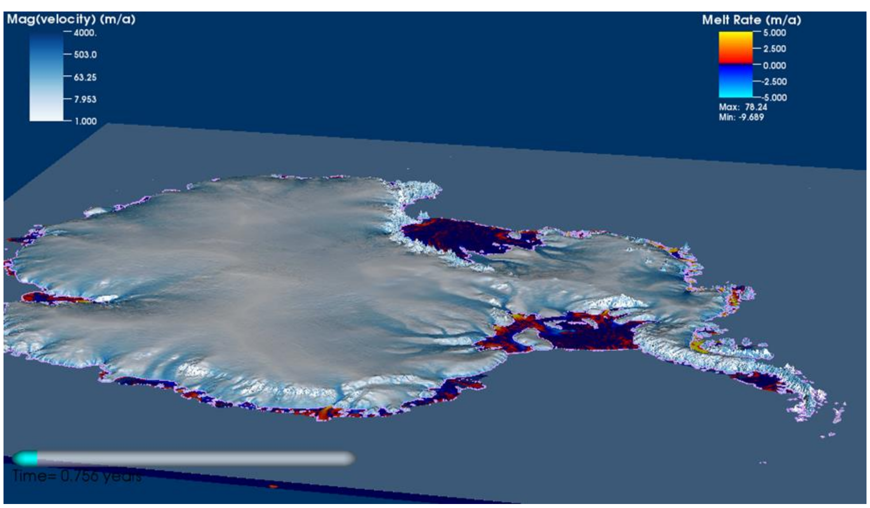
The POPSICLES model couples the POP2x ocean model, a modified version of the Parallel Ocean Program (Smith and Gent, 2002), and the BISICLES ice-sheet model (Cornford et al., 2012). Initial results from modeling the response of the continental Antarctic ice sheet to sub-shelf-melt forcing demonstrate the promise of our approach, and cover the full Antarctic Ice Sheet and the Southern Ocean. Simulations are performed at 0.1 degree (~5 km) ocean resolution and ice sheet resolution as fine as 500 m using adaptive mesh refinement. A comparison of fully-coupled and comparable standalone ice-sheet model results demonstrates the importance of two-way coupling between the ice sheet and the ocean.

BISICLES makes use of adaptive mesh refinement to fully resolve dynamically-important regions like grounding lines and employs a momentum balance similar to the vertically-integrated formulation of Schoof and Hindmarsh (2009). Results of BISICLES simulations have compared favorably to comparable simulations with a Stokes momentum balance in both idealized tests like MISMIP3D (Pattyn et al., 2013) and realistic configurations (Favier et al. 2014). POP2x includes sub-ice-shelf circulation using partial top cells (Losch, 2008) and boundary layer physics following Holland and Jenkins (1999), Jenkins (2001), and Jenkins et al. (2010). Standalone POP2x output compares well with standard ice-ocean test cases (e.g., ISOMIP; Losch, 2008) and other continental-scale simulations and melt-rate observations (Kimura et al., 2013; Rignot et al., 2013).



The figure shows the BISICLES-computed vertically-integrated ice velocity field about 1 month into a 20-year coupled Antarctic run, with the Filchner-Ronne ice shelf in the foreground. Grounding lines are shown in magenta. Subshelf melt rates are painted onto the ice shelves.

Development of POP2x and BISICLES has been supported by The Department of Energy (DOE) Office of Science under the IMPACTS and PISCEES projects and in support of the new DOE Accelerated Climate Model for Energy (ACME).

Session:
Ice-ocean interaction

Understanding Interactions Between Different Cryosphere Elements: A New WCRP CliC (Climate and Cryosphere) Targeted Activity

Rob Massom

Australian Antarctic Division and Antarctic Climate & Ecosystems Cooperative Research Centre, Hobart, Tasmania, Australia

Major change is occurring across the high-latitude cryospheres of both polar regions, yet little is known about the inter-relationships between the different component "elements" of the cryosphere - sea ice, ice sheet/glaciers, icebergs, snow and permafrost (connected by oceanic and atmospheric processes) - and how change in one element affects others. Tantalizing new/recent studies suggest that these linkages may be complex and involve subtle and previously-unconsidered feedbacks. The aim of this new initiative is to:

- encourage a more holistic approach to cryosphere-climate change/variability research that crosses boundaries, bridges the disciplines and links observations and modelling, "looking outside the box" in the process;
- foster and facilitate cross-disciplinary and –polar collaboration, discussion and coordination; and
- provide input towards improving parameterisation of more realistic coupling of key cryosphere components and processes in (future) Earth System models, coupled regional high-resolution models and ice sheet/shelf models.

This topic forms a new "targeted activity" of the WCRP CliC (Climate and Cryosphere) Project (http://www.climate-cryosphere.org/activities/targeted). As defined by CliC, a targeted activity is a focussed 3- to 5-year research activity designed to increase understanding of the relationship between climate and cryosphere.

Planned deliverables include a (first-ever) review paper highlighting the current state of knowledge (including key gaps) of cross-linkages and feedbacks between difference elements of the cryosphere, their response to climate change/variability, and how change in one element can affect other elements. Discussion is still underway as to whether this should entail a single over-arching paper or a series of separate (but interlinked) papers on more focussed/narrower topics e.g., sea ice-ice shelf interactions. Finally, a special session and workshop are planned at the IUGG (International Union of Geodesy and Geophysics) General Assembly in Prague, June 22 – July 2, 2015 (http://www.iugg2015prague.com/).

Should you wish to be involved and contribute to this exciting new initiative, please contact Rob Massom (Rob.Massom@aad.gov.au).

THEME – This poster topic cuts across all of the WAIS Workshop themes, and is meant to advertise and engender interest in a new initiative that is of broad relevance. As such, could the poster please be displayed throughout the meeting, if appropriate. I am not attending, but Ben Galton-Fenzi has offered to bring and look after the poster.

It's a wet, wet WAIS: observations of current and historical snow accumulation from the Amundsen Sea sector

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It snows a lot in the Amundsen Sea (AS) sector of West Antarctica – relatively speaking. For instance, the average annual accumulation of approximately 40 cm water equivalence (w.e.) is more than ten times the annual accumulation observed on much of the high East Antarctic plateau. Yet the sector's accumulation is dwarfed in comparison to areas closer to home: it's less than one tenth the annual accumulation on Blue Glacier in Washington State. So what's the big deal?

The sector's average annual accumulation is unimpressive - the paltry 16 inches w.e. that collects in a year was nearly matched in a 24-hour period during a rainstorm on Long Island, NY in August 2014. Its impressiveness, however, lies in its extent. An average of ~40 cm w.e. accumulates each year over an area of ~370 × 103 km2, which is equivalent to 148 Gt. As a result, sea level is reduced every year by nearly half a millimeter due to snowfall becoming trapped in the AS sector, where it begins its slow journey back out to sea. At the same time, ice that began its journey long ago is reunited with the sea – a perfect balance? While snow accumulation over the past few decades and even centuries has remained somewhat stable in the AS sector, warm ocean waters have eroded buttressing ice shelves, causing the glaciers to accelerate and thin near the margins. The losses outweigh the gains.

Here, we discuss snow accumulation from the AS sector of West Antarctica, particularly over the Pine Island and Thwaites drainage area, using a variety of observation techniques. Several firn cores provide insight into the long-term accumulation variations over the past few centuries. Mapping the internal stratigraphy of the upper ~50 m of the ice sheet from airborne radar data allows us to investigate the spatial – and even coarse temporal – variations in accumulation. More specifically, we (1) provide a general overview of the current and recent history of accumulation, (2) discuss how the spatiotemporal variations in accumulation impact the mass balance as well as the interpretation of mass change from surface elevation change, and (3) investigate the strengths and weaknesses of atmospheric models in reproducing accumulation variations in this sector. The geometry of the Pine Island-Thwaites drainage area provides an excellent moisture pathway into the interior, and any accumulation changes in this sector could be illustrative of changes impacting a much larger area of the ice sheet.

Theme: Climate and accumulation (*It Never Rains in California)*

Predicting the Presence of a Firn Aquifer on the Antarctic Peninsula using C-Band Satellite-Borne Scatterometry

J. Z. Miller[1], R. R. Forster[1], T. A. Scambos[2], D. G. Long[3]
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The recent discovery of substantial quantities (~140±20 Gt) of liquid meltwater stored within Greenland's extensive (~70,000 km^2) firn aquifer highlights evolving knowledge of melting, refreezing, and retention processes within the upper layers (<~35 m) of the percolation facies of ice sheets. Firn aquifers are hypothesized to form in regions that experience high melt rates that saturate snow and firn layers with liquid meltwater during the melt season, and high accumulation rates that thermally insulates this saturated layer during the winter season allowing it to be retained in liquid form at decreasing depths as refreezing propagates from the ice sheet surface downward. Little is known about Greenland's firn aquifer – open questions remain on its formation, spatiotemporal variability, the mechanism(s) and time scales associated with the potential transport of liquid meltwater to the base of the ice sheet, and its influence on mass and energy budgets. Observational evidence of Greenland's firn aquifer is currently limited in space and time to field (ACT-10,-11, FA-13) and airborne (IceBridge) observations.

The C-band microwave response is sensitive to near-surface liquid meltwater within Greenland's firn aquifer, as well as winter season decreases in its depth resulting from the refreezing process. When snow and firn layers are saturated with liquid meltwater, surface scattering dominates the response. Electromagnetic energy is significantly attenuated by reflection away from the scatterometer at the smooth air-saturated layer interface, and by absorption and extinction within the top few centimeters of the saturated layer. When snow and firn layers are frozen to penetration depth (<~5 m), volume scattering induced by large embedded ice structures dominates the response. Over Greenland's firn aquifer, the surface-to-volume scattering transition following surface freeze-up results in distinct microwave signatures that exponentially increase on timescales of weeks to months. This response is not observed in adjacent regions of the percolation facies where meltwater is stored in solid form. We developed a microwave signature algorithm that describes this exponential response using a simple two-layer radiative transfer model that defines decreases in firn aquifer depth using time-dependent parameters that are calibrated using thousands of airborne observations. Initial comparisons between the calibrated microwave firn aquifer model and firn aquifer simulations generated by the regional climate model RACMO2 are consistent, suggesting strong potential for spatiotemporal continuous satellite observation over the C-band scatterometer climate record.

While no observational evidence of a firn aquifer is known to exist, similar to Greenland, regions of the percolation facies of the Antarctic ice sheet experience sufficiently high melt and accumulation rates. Here we use C-band backscatter data collected by the Advanced SCATterometer (ASCAT) aboard the MetOp-A satellite and the Greenland-calibrated microwave firn aquifer model to predict the presence of a firn aquifer on the Antarctic Peninsula.

Ice flow over plastic beds

Brent Minchew[1], Mark Simons[1], Helgi Björnsson[2], Finnur Pálsson[2], Mathieu Morlighem[3], Helene Seroussi[4], Eric Larour[4], and Scott Hensley[4]

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Portions of WAIS are underlain by plastically deforming beds but the influence of basal plasticity on ice flow is not completely understood. Here we consider the dynamics of Hofsjökull, a soft-bedded ice cap in central Iceland, using surface velocity observations taken before and at different times during the melt season. Hofsjökull serves as an ideal natural experiment in which basal processes are isolated from oceanic forcings. This isolation helps to illuminate the salient mechanics of plastic-bedded glaciers. We first infer the existence of a plastically deforming bed beneath the ice cap by constraining numerical ice flow models with surface velocity measurements derived from airborne radar interferometry and inverting for the optimal basal shear stress and basal slip rate fields. Basal plasticity is evident from the independence of basal shear stress and basal slip rate. By comparing velocity fields collected at different times of year, we highlight the response of ice flow to surface melt in various outlet glaciers. We assume that ice flow accelerations are caused by variations in basal water pressure, which are driven by fluctuations in surface meltwater flux and modulated by the characteristics of the hydrological systems beneath each outlet glacier. Our data clearly show that different outlet glaciers respond in different ways to similar environmental forcing. Most outlet glaciers accelerate following the onset of melt, but the characteristics of slowdown vary significantly between different outlet glaciers. Some outlet glaciers slow completely to wintertime velocities, some slow partially, and some do not slow at all over the same time period and under roughly the same melt conditions in the early melt season. This heterogeneity in response, which can be at least partially accounted for by differential evolution of the basal hydrological systems, motivates an idealized physical model of ice flow over plastic beds. Our data and our associated model indicate that the sensitivity of ice flow to changes in basal water pressure scales as the inverse of the ice surface slope. This finding has implications for ice flow in WAIS, where surface slopes are relatively shallow, subglacial lake drainage events are known to occur, and basal hydrological systems may be linked to the ocean.

Theme: Modeling of ice and polar ocean (*California Dreamin'*)

Observations of sea ice and ice sheet interaction in Greenland and the Antarctic Peninsula

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Theoretical work and some observations, especially in Greenland, suggest that sea ice and ice mélange may play an important role in determining outlet glacier dynamics, particularly ice front position and calving. Research from both Greenland and Antarctica can inform a comprehensive understanding of the role of sea ice/mélange in influencing ice sheet flow. We examine sea ice/mélange and glacier interaction for systems at both poles. In northwest Greenland, we focus on 16 glaciers along the Melville Coast. We observe seasonal regulation of ice front position via sea ice/mélange and multiyear speedup potentially in response to sustained retreat from extended sea-ice free periods.

Since collapse of the Larsen B Ice Shelf in Antartica, the embayment areas of the former ice shelves have experienced episodes of persistent fast ice occupying the entire embayment for as much as two to three years. This fast ice interacts with the ice fronts of Crane, Hektoria, and Green Glaciers. We examine the evolution of this interface using MODIS timeseries and Landsat 7 and Landsat 8 data. We use the similarities and difference between the Greenland and Antarctic systems to shed light on the problem of ice-ocean interaction.

- Ice-ocean interaction: everywhere else (*Promised Land*)

Modeling the spreading of glacial melt water from the Amundsen and Bellingshausen Seas

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The ice shelves and glaciers of the West Antarctic Ice Sheet (WAIS) are rapidly thinning, especially in the Amundsen Sea (AS) and Bellingshausen Sea (BS). The high basal melting of these small ice shelves is caused by relatively warm Circumpolar Deep Water (CDW) that, based on observations, mainly intrudes via two submarine glacial troughs located at the eastern and central AS continental shelf break. When CDW reaches the grounding line of the fringing glaciers, strong basal melting supports a buoyant melt water plume. As the glacial melt becomes part of the AS shelf circulation, it may cause a freshening of the shelf water locally as well as remotely in the Ross Sea (RS). To test whether the observed freshening of the RS is a consequence of the enhanced basal melting of AS ice shelves, we use Finite-Element Sea-ice/ice-shelf/Ocean Model (FESOM) with a horizontal resolution of 2-10 km on the AS and BS continental shelves. The model is forced with 6-hourly atmospheric data from the National Centers for Environmental Prediction Climate Forecast System Reanalysis (NCEP-CFSR). The model results show realistic bottom temperatures and basal mass loss rates of the ice shelves in the AS and BS. Using several independent virtual passive tracers to identify pathways of the glacial melt, we find that the melt water from the ice shelves in the AS flows towards the Ross Ice Shelf front. After 10 years of simulation, about half of the melt water in the RS originates from the Getz Ice Shelf. Further, we investigate how the strength of the basal melting influences the melt water transport into the RS.

Modelling of ice and polar ocean (*California Dreamin')*

2014 over-snow traverse to the ice divide between Pine Island, Rutford and Institute Ice Stream, WAIS

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On January 2014 we completed a new scientific exploration to WAIS. During this campaign we took advantage of the logistic facilities in the region, especially at Union glacier (79º46'S/83º24'W), where the private company Antarctic Logistics and Expeditions (ALE), annually operates for their commercial operations. From this base camp, we conducted a 1200 km long radar and GPS survey to the triple ice divide between Institute Ice Stream, Rutford Ice Stream and Pine island glacier. This was done on the ground by using a brand new mobile scientific research module (caboose) that was pulled by an ALE tractor. During this survey, we also carried out mass balance measurements, snow samples collection (short ice/snow cores) and meteorological observations.
The radar systems that we used are a low-gain high-frequency (203-1019 MHz) and a high-gain low-frequency (155 MHz, 20 MHz bandwidth) antenna. This feature allowed us to detect ice-bed interface as well as snow-firn stratigrahy. A minimum of 518 m and a maximum of 3100 m of ice thickness were detected, using a mean ice density of 0.168 m/ns. The Bed Reflection Power (BRP) was also calculated by analyzing the radar along profiles. The GPS surveys allowed radar data positioning as well as surface height estimation (accuracy of +-10cm). Also, an automatic weather station (AWS) was mounted on the module to collect meteorological data (temperature, humidity, pressure and sun radiation). The main feature of the AWS is the real time data transmission to a server via iridium.
The comparison between CECs and BEDMAP2 data has revealed a difference up to 1700 m in ice thickness, especially in areas, where the bed topography is steep and where BEDMAP2 coverage is poor.
After these findings, we think that more radar ice thickness surveys are necessary to enhance model and simulation results associated with ice dynamics.
On December 2014 we will carry out a new campaign to survey in more detail the study area.

The Times They are a-Changin'

Ocean Variability Contributing to Basal Melt Rate Near the Ice Front of Ross Ice Shelf, Antarctica

Laurie Padman[1], Isabella Arzeno[2], Robert C. Beardsley[3], Richard Limeburner[3], Breck Owens[3], Scott R. Springer[4], Craig L. Stewart[5,6], and Michael J. M. Williams[5]

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Basal melting of ice shelves is an important, but poorly understood, cause of Antarctic ice sheet mass loss and freshwater production. We use data from two moorings deployed through Ross Ice Shelf, ~6 and ~16 km south of the ice front east of Ross Island, and numerical models to show how the basal melting rate near the ice front depends on sub-ice-shelf ocean variability. The moorings measured water velocity, conductivity, and temperature for ~2 months starting in late November 2010. About half of the current velocity variance was due to tides, predominantly diurnal components, with the remainder due to subtidal oscillations with periods of a few days. Subtidal variability was dominated by barotropic currents that were large until mid-December and significantly reduced afterward. Subtidal currents were correlated between moorings but uncorrelated with local winds, suggesting the presence of waves or eddies that may be associated with the abrupt change in water column thickness and strong hydrographic gradients at the ice front. Estimated melt rate was ~1.2±0.5 m/year at each site during the deployment period, consistent with measured trends in ice surface elevation from GPS time series. The models predicted similar annual-averaged melt rates with a strong annual cycle related to seasonal provision of warm water to the ice base. These results show that accurately modeling the high spatial and temporal ocean variability close to the ice-shelf front is critical to predicting time-dependent and mean values of meltwater production and ice-shelf thinning.

Session choice:

Ice-ocean interactions: everywhere else (Surfin' USA)

Eighteen years of height and mass changes in West Antarctic Ice Shelves

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Recent mass losses from the grounded Antarctic Ice Sheet have been associated with changes in its floating ice shelves, but the duration and variability of these changes is so far undocumented. Using data from three overlapping satellite radar altimetry missions (ERS-1, ERS-2 and Envisat) we construct a record, at high spatial and temporal resolution, of ice-shelf height changes for the 18-year period 1994-2012. The record reveals a complex pattern of ice-shelf height change resulting from the varying impacts of the Antarctic oceans and atmosphere on the ice sheet. We show that Antarctica-wide average ice-shelf height increased moderately up until ~2003 and then declined rapidly after ~2006. The Amundsen Sea ice shelves have experienced persistent surface lowering since the beginning of the record, with mean values ranging from ~-5 cm/year (Cosgrove) to ~-30 cm/year (Dotson). We observe more rapid lowering at the deep grounding lines than at the shallower ice shelf fronts, consistent with thermal erosion driven by warm Circumpolar Deep Water flowing under the ice shelves. On the eastern Antarctic Peninsula, the rate of thinning starts much larger at the northernmost portion and develops southwards, consistent with a response to the observed trend of atmospheric warming. Although relatively stable with average rates of -1.6 to +0.5 cm/year, the two largest ice shelves (Ross and Filchner-Ronne) show large interannual and spatial variability. Our 18-year-long dataset demonstrates that results from single satellite missions, with typical duration of a few years, are insufficient to draw conclusions about long-term response of ice shelves to changes in oceanic and atmospheric conditions.

Session: Changes in WAIS from observations (*The Times They are a-Changin')*

Large-Ensemble modeling of past Antarctic variations in the Amundsen Sea Embayment

David Pollard[1], Robert DeConto[2]

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Recent observations of thinning and retreat of the Pine Island and Thwaites Glaciers identify this sector of West Antarctica as particularly vulnerable to future climate change. To date, most future modeling of these glaciers has been validated using recent and modern observations. As an alternate approach, we apply a hybrid 3-D ice sheet-shelf model to the last deglacial retreat in this sector, making use of geologic data of ice extents from ~20,000 years BP to present.

Following recent ice-sheet studies, we use Large-Ensemble statistical techniques, performing sets of ~500 to 1000 runs with varying model parameters. The model is run for the last 20 kyrs on 5 to 20-km grids spanning West Antarctica, with lateral boundary conditions from a prior continental-scale simulation. An objective score for each run is calculated using reconstructed past grounding lines, shelf extents, and modern conditions. Runs are extended into the future (few millennia) with simple atmospheric and oceanic forcing. The goal is to produce calibrated probabilistic envelopes of model parameter ranges and future ice retreat.

Preliminary results are presented for Large Ensembles with (i) Latin HyperCube sampling in high-dimensional parameter space, and (ii) dense sampling with a lower number of parameters. One preliminary finding is that most reasonable parameter combinations produce drastic future retreat into the interior Pine Island and Thwaites basins within ~2000 years, contributing ~2 m to global sea-level rise.

For theme: Modelling of ice and polar ocean (California Dreamin')

Environment and Processes of Subglacial Lake Whillans, West Antarctica

Ross Powell[1], Tim Hodson[1], Jeremy Wei[1], Slawek Tulaczyk[2], Stefanie Brachfeld[3], Isla Castañeda[4], Rebecca Putkammer[1], Reed Scherer[1], and the WISSARD Science Team

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Subglacial Lake Whillans (SLW) lies 800m below the low gradient, Whillans Ice Plain West Antarctica, upstream from where Whillans Ice Stream goes afloat into the Ross Ice Shelf. During 2013-14 season the WISSARD project made measurements in, and collected water and sediment samples from SLW. Sediment is typical subglacial till; a homogenized, structureless diamicton. Debris from local basal ice is likely not contributed to SLW by rainout because ice is theoretically below pressure melting. So lake floor diamicton likely was transported to SLW by deformation while the ice stream was grounded at the drill site both prior to lake formation and during lake “lowstands”. Satellite altimetry has shown SLW experiences short (~7 month) discharge events, lowering the ice surface and lake water level by between 1-4m. Lake lowstands are separated by longer periods of gradual recharge, but over the period of many lowstands the ice stream is suspected to touch down and couple with the lake floor, potentially shearing new till into SLW. Subglacial hydrological diversions also may play a role in SLW history; if water is captured by another drainage basin, then the bed at SLW will also act as a till. The lack of sorted sediment (apart from a lamina of mud at the sediment-water interface) and erosional lags within sediment cores indicate water flow during discharge/recharge events has had a low current velocity with quiescent conditions in the lake. Although important volumes of water are moved during such events, water velocities are not those of classic “floods” due to low hydropotential gradients on the ice plain and wide channels. Sediment source indicators (particle composition, form and surface texture, geochemistry (XRF, XRD, ^{10}Be), fossils, biomarkers) show sediment is recycled from older Cenozoic sediments and bedrock. Biologists show δ^{18}O values of lake water likely from up-stream ice sheet melt; however, Cl and Br ion concentrations indicate a seawater source likely recycled from older marine sediments. Chemolithoautotrophs dominate an active microbial community, indicating they play a role in breakdown of subglacial particulates. The most notable variability in cores is a weak, critical porosity horizon down to ~50cm depth above more consolidated till. We interpret the weak upper horizon as a product of shear deformation and decreasing effective pressure experienced during final stages of grounding prior to a lake recharge event. The presence of this weak layer illustrates the importance of hydrology in modulating till rheology and is an example of how subglacial sediments can preserve archives of hydrologic conditions at the ice-bed interface. All results show till is being subglacially deformed and sheared from up-ice-stream into SLW and beyond. That appears to be the main sediment transport

mechanism rather than fluvial transport. We cannot yet constrain basal/englacial debris transport.

Recent Changes of Surface Velocities at Byrd Glacier

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Large glaciers are important outlets by which ice is transported from the interior Antarctica to the ocean, and changes of their surface velocities can have significant impacts on ice sheet mass balance and hence sea level. Byrd Glacier, with the largest catchment basins in Antarctic and flowing into the western part of the Ross Ice Shelf through the Trans-Antarctic Mountains, is one of the largest glaciers in East Antarctica. Here we report some new ice velocity measurements obtained at the main trunk of Byrd Glacier, using the recent acquired Landsat 8 imagery. The velocities were derived from automatic tracking of the surface feature points on sequential images using a cross-correlation algorithm. Images were first precisely co-registered to ensure the high accuracy of surface measurement. Comparison of the new ice velocity maps with earlier measurements of velocities documented by literatures indicates that since 2007, the glacier has overall undergone a deceleration-to-acceleration process. Different velocity change patterns could be viewed for the upstream, midstream and downstream regions, respectively, and the downstream part has the largest flow speed increase in 2013-2014. The cause of the changes in ice dynamics is so far not clear, but requires further study with more knowledge employed.

Irreversible changes in the northern part of the WAIS: a view from above and below.

Eric Rignot[1,2], Jeremie Mouginot[2], Mathieu Morlighem[2], Bernd Scheuchl[2].

[1]*University of California Irvine, Earth System Science*
[2]*NASA's Jet Propulsion Laboratory.*

Terry Hughes named the Amundsen Sea Embayment (ASE) sector the weak underbelly of the WAIS 40 years ago. No one believed him then because there was no observation to support it, but everyone took a note of it. This situation changed with the advent of satellite missions in the early 1990s, ship cruises in the mid 1990s, airborne deployments in the early 2000s that reveal rapid, ongoing changes in the region, with more observations to come. We now have a record of 40 year of change in flow speed and mass change, 20 years of grounding line migration, a detailed mapping of the bed topography and ice thickness which was only sketchy in the 1970s (and still included major artifacts as recently as 6 months ago), information about the sea floor topography in front of the glacier and beneath ice shelves, and a better understanding of local ocean conditions, wind forcing and sensitivity of the glaciers to oceanic perturbations. The time scales of projection of collapse of this sector from numerical ice sheet models remain highly uncertain, anywhere from 100 to 900 yr. We will review these observations, what lead us to conclude that this sector is undergoing irreversible retreat, how this relates to the big picture of climate change in Antarctica, and what this means for the coming decades. We will highlight key observational and numerical modeling elements that are still missing from this picture to help reduce uncertainties in time scale of projection and the implications of what we have learned in northern WAIS for other sectors.

Changes in WAIS from observations (*The Times They are a-Changin').*

Climate, Sea Ice, and Ocean Precursors to the Larsen Ice Shelf Disintegrations

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Ice shelf/ice tongue disintegrations and break-ups have a major impact on glacier mass balance, and nowhere has this been more evident than in the northern sections of the Larsen Ice Shelf in the Antarctic Peninsula. Ice flux in this region surged 2- to 6-fold after ice shelf disintegration events in 1995 and 2002, and glacier imbalance has remained roughly double the balance ice loss rate (Scambos et al., 2014). The disintegration events are driven by a group of processes based on the presence of extensive surface melt lakes and hydrofracture. However, precursor changes in the ice shelves beginning more than a decade before the disintegration events have been identified in satellite imagery, beginning around 1990. Prior to this time, available satellite data suggests steady-state evolution of the ice shelf areas. The onset of non-steady structural changes appears to coincide with reduced sea ice extent in the northwestern Weddell Sea. This is linked to climate changes based on increased frequency of Chinook / foen events due to changing Southern Annular Mode trends. An examination of satellite imagery spanning 1963 to the present of the Larsen A and B ice shelves, and of the remnant Scar Inlet Ice Shelf of the former Larsen B shelf, shows that shear margins and suture zone features were essentially unchanged through 1986. Following that time, but well prior to the break-up events or significant ice shelf front retreat, ice shelf shear zones show significant evolution including increased and expanded areas of rifting, concentration of shear, and ice flow speed increases. These early changes, occurring prior to shelf area loss, suggest either increased ocean-driven basal melt or effects of increased meltwater are the cause of early shelf weakening that led to disintegration. The reduced sea-ice extent in the 1990s in the region suggests that wind traction on the ocean surface may have influenced sub-shelf ocean circulation.

Either of these foci would be appropriate:

- Changes in WAIS from observations (*The Times They are a-Changin')*
- Ice-ocean interaction *(Surfin' USA)* everywhere else (*Promised Land)*

Larsen-B and -C Ice Shelf Velocities Revisited

Bernd Scheuchl[1], Jeremie Mouginot[1], and Eric Rignot[1,2]

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[2] Jet Propulsion Laboratory

The Antarctic Peninsula has undergone significant changes over the last two decades. This includes the 1995 collapse of the Larsen-A ice shelf, the 2002 collapse of the Larsen-B ice shelf, and a large iceberg breaking off of Larsen-B remnant ice shelf in 2006. We present a series of ice velocity maps of the Larsen-B (remnant) and -C ice shelves and their tributaries spanning from 1997 to 2013. Velocity Measurements are based on spaceborne SAR data from RADARSAT-1 and -2, ALOS PALSAR, ENVISAT ASAR, TerraSAR-X and TanDEM-X. Our analysis shows that the adjustment period following the Larsen-B collapse continues to this date. The surface velocity of the Larsen B remnant ice shelf continues to increase following the 2002 collapse. The speed at the ice front has more than doubled compared to 2000. Its major tributaries, Flask and Leppard Glacier, also show an increase in velocity over that period. Crane glacier, with no more buttressing from a shelf, saw its speed triple between 2000 and 2006. Since then the speed receded to about twice of what it was before the collapse of the shelf. The Larsen-C ice shelf is well bounded by a number of ice rises and islands and appears relatively stable in terms of surface velocity over the last 13 years.
Our velocity maps will be made available to the science community as Earth Science Data Records (ESDR) as part of a NASA funded MEaSUREs project.
Spaceborne SAR data were made available for this project courtesy of the Polar Space Task Group.

Theme: Changes in WAIS from observations (*The Times They are a-Changin')*

Characterizing the Location and Extent of the Thwaites Glacier Grounding Zone Using Airborne Radar Sounding

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The impact of warm ocean water on ice sheet retreat and stability is a one of the primary drivers and sources of uncertainty for the rate of global sea level rise. One critical but challenging observation required to understand and model this impact is the location and extent of grounding ice sheet zones. However, existing surface topography based techniques do not directly detect the location where ocean water reaches (or breaches) grounded ice at the bed, which is a significantly factor in ice sheet stability.

Airborne radar sounding is the primary geophysical tool for directly observing the basal properties of ice sheets at the catchment scale. However, uncertainty in englacial attenuation from unknown ice temperature and chemistry can lead to erroneous interpretation of subglacial conditions from bed echo strengths alone (especially in the complicated scattering environment near grounding zones). Recently developed analysis techniques for radar sounding data have overcome this challenge by taking advantage of information in the spatial pattern of radar returns and subglacial water routing. We have developed a similar approach based on the modeled spatial pattern of echo strengths to address the problem of improved grounding zone detection and characterization.

The spatial signal of the transition from an ice-bed interface to an ice-ocean interface is an ~10 dB increase in bed echo strength. However, rapidly changing attenuation (due to variations in temperature and scattering) near the grounding zone prevents the unambiguous interpretation of this signal in typical echo strength profiles and violates the assumptions of existing empirical attenuation correction techniques. We present techniques that treat bed echoes as continuous signals to take advantage of along-profile ice thickness, propagation distance, and echo strength variations to constrain the spatial pattern of attenuation. In this framework, the grounding zone transition can be detected and characterized as a deviation from the spatial pattern of englacial attenuation. We present the application of this technique to a gridded airborne radar sounding survey of the Thwaites Glacier catchment to constrain the location and extent of the grounding zone and compare this characterization with the surface expression of the transition from grounded to floating ice.

Ice-ocean interaction (Surfin' USA): Amundsen Sea (*West Coast Blues)*

CryoSat-2: A new perspective on Antarctica

Andrew Shepherd[1], Thomas Armitage[2], Kate Briggs[3], Thomas Flament[4], Anna Elizabeth Hogg[3], Malcolm McMillan[1], Alan Muir[2], Andrew Ridout[2], Aud Sundal[4], Rachel Tilling[2] and Duncan Wingham[2]

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CryoSat-2 is ESA's first satellite mission dedicated to measuring changes in the polar land ice and sea ice cover.

Following its launch in April 2010, we have examined the performance of the instrument over the continental ice sheets of Antarctica and Greenland, the Artic Ocean, and, for the purposes of calibration, over the oceans. We have confirmed the engineering performance at system level of the interferometer demonstrating that it measures across-track surface slopes with a precision of 25 micro-radians and an accuracy of 10 micro-radians, greatly exceeding the pre-launch specifications (100 micro-radians). Over the polar ice sheets, we have examined the performance of the range estimation, and determined the range precision to be 19 cm RMS at 20 Hz. We have examined the retrieval of the phase information over the ice sheets, and found the phase estimates to be robust and little affected by the uncertain ice sheet topography. Based on the calibration of the interferometer, the contribution of the across track slope error is, at 0.4 mm, negligible. Over marine sea ice, we have verified the discrimination of sea ice and ocean lead returns using contemporaneous SAR imagery from ENVISAT, and we have estimated the precision of individual (20 Hz) measurements to be 2 cm. In summary, the CryoSat system performance meets or exceeds its specification over the continental and marine ice sheets.

This presentation summarises the mission performance and presents a series of example case studies where CryoSat-2 data have been applied to study changes in Antarctica. We show that in just 4 years the mission has been able to detect changes in the ice sheet mass with an accuracy comparable to that of the past 20 years of conventional satellite altimetry, that important changes have occurred in West Antarctica and at the Antarctic Peninsula, and we show that the mission has been able to detect changes in rugged, glaciated terrain, that were beyond the capability of past altimeter missions. Finally, we demonstrate the mission performance in full, swath-interferometric mode, which is capable of detecting elevation and elevation change with extremely fine and dense spatial resolution.

Theme: Changes in WAIS from observations (*The Times They are a-Changin'*)

Measuring Changes in the Vicinity of the Seal Nunataks Ice Shelf Remnant from Imagery and Altimetry

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Abstract
Acquisition and analysis of a combination of repeated imagery and ICESat laser altimetry has enabled the ongoing losses from the northern Larsen B ice shelf remnant to be assessed. The remnant, the Seal Nunataks ice shelf (SNIS), has four ICESat tracks that cross it as well as adjacent tracks that cross Robertson Island (RI) and the margin of the Antarctic Peninsula. The available altimetry data from ICESat (2003-2009) shows that elevation losses increase from west to east across the SNIS. Ice elevation losses suggest mean ice shelf thinning rates of up to 1.7 m a^{-1} and reveal processes continuing to impact the shelf remnant. The derived mean ice shelf thickness losses are dependent on firn compaction and inferred density values but along with the average elevation losses measured for RI's grounded ice suggest the magnitude of local ice losses. Asymmetric changes across RI indicate that strongly sloping terrain can influence ice loss depending on slope aspect sufficiently to impact overall mass balance estimates. Imagery analysis using Landsat 7 and ASTER images acquired during 2001-2013 shows that ice area losses continued on the shelf remnant after the Larsen A break up in early 1995 and the Larsen B collapse in early 2002. The largest losses (~340 km^2) occurred on the north side of the remnant in late 2004 into 2005 [Shuman et al., 2011] with small losses along the remaining margins. Despite a slight regional cooling in recent years and more persistent sea ice in the area, the SNIS is still retreating past its pinning points. In contrast to SNIS, RI has experienced minor ice area losses that are consistent with most of it being grounded and is less directly impacted by ocean interactions compared to the shelf remnant. Together, these data sets provide additional insights about ongoing ice losses in the Larsen A/B area.

- Ice-ocean interaction *(Surfin' USA)*
    - everywhere else (*Promised Land)*

Interruption of the Whillans Ice Stream stick-slip cycle by a subglacial lake discharge event

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Understanding the mechanisms that control ice velocity in Antarctica is intrinsically important for predicting future ice sheet mass balance and therefore sea level rise. While the significance of water at the ice-bed interface to ice velocity changes has long been known, there have only been two observations of the extensive dynamic hydrological system beneath Antarctica considerably altering ice dynamics. Unique tidally-paced stick-slip motion, which is sensitive to small changes in stress regime, combined with an extensive active subglacial hydrological system make the confluence of lower Whillans Ice Stream (WIS) and Mercer Ice Stream (MIS), West Antarctica, an ideal location to investigate the relationship between subglacial water and ice dynamics. Here we used data from a four-year, semi-continuous GPS experiment on WIS and MIS to observe a subglacial lake discharge event cascade from Subglacial Lake Mercer (SLM) to Lake 7 (L7), and the subsequent effect of these two floods on both the basal environment and regional ice flow. In addition to a basin-dependent acceleration, we observed a significant interruption to the timing of the slip-stick cycle during the initial discharge event from SLM. Furthermore, during both the SLM and the L7 event, we discovered two slip-event types that do not appear elsewhere during the experiment. These changes to the stick-slip regime suggest a rapidly evolving subglacial hydraulic system which can fundamentally alter both the slip and inter-slip velocities. These results demonstrate the complexity of the subglacial system and the difficulties of accurate long-term monitoring of ice dynamics.

Session:

- Ice-ocean interaction *(Surfin' USA)*
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iSTAR: UK ice sheet traverse across Pine Island Glacier drainage basin

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iSTAR is a UK NERC-funded programme of ice sheet research in West Antarctica. Its emphasis is in the Amundsen Sea and on Pine Island Glacier and it aims to improve our understanding of key ice sheet and ocean processes and enable incorporation of this into models. To achieve these, the iSTAR Programme is studying the whole system, from the ocean, through the ice shelf, up the glacier and into the catchment basin.

The ocean and the ice parts of iSTAR are equally important, but here I will concentrate on one aspect of the latter, the first iSTAR oversnow traverse on Pine Island Glacier. This was carried out in 2013/14 and is noteworthy as a new logistics capability and method of supporting fieldwork in Antarctica, for the UK. I will present more of the practical side of the activity, rather than details of the science achieved, which will be for the individual science projects to report on.

The iSTAR Traverse comprised a 900 km tractor-train journey across the Pine Island Glacier drainage basin. From the inland ice divide it followed the main glacier trunk as far downstream as crevassing allowed, then visited a number of tributaries and inter-tributary ridges, finally ending up almost overlooking the ice shelf and the Amundsen Sea coast. Glaciological and geophysical measurements were carried out along the traverse route and at 22 specific sites. These included deep-radar sounding of the glacier bed, shallow-radar sounding of the snow and firn, high resolution density measurements in the upper ~10 m of the glacier, and the installation of GPS stations measuring the ice movement. This work was achieved by scientists from BAS and the universities of Edinburgh, Bristol, Leeds and Reading.

Key to the operation of the traverse was the major infrastructure, deployed over the previous two years, including two *Pisten Bully* tractors, a living caboose and bulk fuel in large bladders mounted on plastic sledges.

It is worth emphasising that the amount of science completed, and the geographical area covered, would have taken many years to complete with traditional UK field operations. On the second iSTAR Traverse (2014/15) we will reverse the route, repeat some measurements, recover the GPS stations, drill ice cores and acquire seismic data. The 2013/14 iSTAR Traverse was highly successful and demonstrated a mode of operation that opens up many more possibilities for UK and collaborative research in Antarctica.

Theme: Changes in WAIS from observations (*The Times They are a-Changin')*

Recent Changes in Ice Mass Balance of the Amundsen Sea Sector

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The glaciers flowing into the Amundsen Sea of West Antarctica were identified in the Ice Sheet Mass Balance Inter-comparison Exercise (IMBIE) as the dominant contributor to current Antarctic mass loss, and were recently determined by multiple investigators to be undergoing a possible marine ice sheet instability. Here, we investigate the regional ice sheet mass balance using a series of satellite and airborne data combined with model outputs from the Regional Atmospheric and Climate Model (RACMO). Our datasets include laser altimetry data from the ICESat-1 satellite mission and Operation IceBridge aerial campaigns, satellite radar altimetry data from the Envisat mission, time-variable gravity data from the GRACE mission, surface mass balance outputs from RACMO-2, ice velocity from a combination of international synthetic aperture radar satellites and ice thickness from Operation IceBridge airborne radio echo sounding. We present a record of ice mass balance for the Amundsen Sea Sector, which is in agreement in magnitude and temporal oscillations between the analyzed techniques. We find that the mass balance of the region has shifted into a state of much higher annual loss over our entire 1992-2013 observation period, with marked shifts over the last decade. We find that over 1992-2013, the ASE has contributed 4.5 mm in total to global sea level rise. Overall, our results demonstrate the synergy of multiple analysis techniques for examining Antarctic Ice Sheet mass balance at the regional scale.

Changes in WAIS from observations (*The Times They are a-Changin')*

Modeling the Elastic Transmission of Tidal Stresses to Great Distances Inland in Channelized Ice Streams

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Geodetic surveys suggest that ocean tides can modulate the motion of Antarctic ice streams, even at stations many tens of kilometers inland from the grounding line. These surveys suggest that ocean tidal stresses can perturb ice stream motion at distances about an order of magnitude farther inland than tidal flexure of the ice stream alone. Recent models exploring the role of tidal perturbations in basal shear stress are primarily one- or two-dimensional, with the impact of the ice stream margins either ignored or parameterized. Here, we use two- and three-dimensional finite element modeling to investigate transmission of tidal stresses in ice streams and the impact of considering more realistic, three-dimensional ice stream geometries. Using Rutford Ice Stream as a real-world comparison, we demonstrate that the assumption that elastic tidal stresses in ice streams propagate large distances inland fails for channelized glaciers due to an intrinsic, exponential decay in the stress caused by resistance at the ice stream margins. This behavior is independent of basal conditions beneath the ice stream and cannot be fit to observations using either elastic or nonlinear viscoelastic rheologies without nearly complete decoupling of the ice stream from its lateral margins. Our results suggest that a mechanism external to the ice stream is necessary to explain the tidal modulation of stresses far upstream of the grounding line for narrow ice streams. We propose a hydrologic model based on time-dependent variability in till strength to explain transmission of tidal stresses inland of the grounding line. This conceptual model reproduces observations from Rutford Ice Stream.

Submitting to: Ice-ocean interaction *(Surfin' USA)* / everywhere else (*Promised Land)*

The influence of geological fabric on grounding line dynamics in the Amundsen Sea

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Aerogeophysical surveys reveal a strong fabric in both the morphology and geology of the sea floor of the Amundsen Sea embayment. The shape and geological character of the ice bed and sea floor exert control on glacier behavior in a variety of ways. Troughs across the continental shelf, carved by past glacial advances, define the access routes for warm water towards the grounding line. Smaller scale features can affect both water mixing and ice dynamics near the grounding line and play a complex role in ice sheet stability. The geological character of the bed under grounded ice can also influence ice dynamics through basal friction and changes in geothermal heat flux.

Operation IceBridge has flown aerogravity surveys in West Antarctica since 2009, with the goal of mapping the bathymetry of the sea floor under floating ice, and understanding the geological setting of the ice sheet where ice is grounded. At the same time, the IceBridge instrument suite has monitored the thickness and surface elevation of the ice and reveals the grounding line changes in the region. We combine these observations from the Amundsen Sea, and identify morphological trends in both the bathymetry and geological fabric in the grounding zone region. We show that in spite of strong erosion, some geological features maintain a bathymetric expression that exerts strong control on the behavior of the grounding line. The resulting fabric is marked by ridges and troughs that define present day bed slopes and the pinning points that have stabilized the grounding line in the past.

Previous surveys have investigated trends in both offshore magnetic data (Gohl et al, 2013) and onshore gravity data (Diehl, 2008). Here we compare these trends with those from the present day grounding zone and demonstrate that even after significant erosion, the geological framework of the Amundsen Sea plays a persistent role in ice sheet stability.

Abstract submitted to: Ice-ocean interaction *(Surfin' USA)* - Amundsen Sea (*West Coast Blues)*

Interfacial stresses at the grounding line of the Whillans Ice Plain control the initial stick-slip rupture speed

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Each day, as many as two slip events occur beneath the Whillans Ice Plain over a region ~100 km long (Bindschadler et al., 2003; Wiens et al., 2008; Winberry et al., 2009; 2011; Walter et al., 2011). Recent studies have established that the rupture velocity varies systematically with loading over the tidal cycle and therefore cannot be controlled solely by the material properties (Wiens et al., 2008). Total slip, recurrence time and nucleation location also covary with rupture velocity and the tidal cycle (Winberry et al., 2009; Walter et al., 2011; Winberry et al., 2011). Typically individual rupture fronts initiate at two distinct nucleation regions that vary with the tide (Winberry et al., 2009; Pratt et al., 2014); events that begin at low tide nucleate closer to the grounding line than those that begin at high tide. Surprisingly, the low tide events rupture almost an order of magnitude fast initially (first ~100 s) within ~40-50 km of nucleation (~1,000 m/s) compared to high tide events (~400 m/s), even though typically the low tide events occur with significantly less time elapsed between events. Further, events occurring during high tide have an average rupture speed (when averaged across the Ice Plain) that is faster than low tide events, the low tide events tend to have significantly higher initial rupture speeds.

We attribute this behavior to local stress configurations that are spatially and temporally heterogeneous and utilize laboratory measurements of stick-slip sliding on plastic blocks to mimic the WIP behavior. Basal interfacial stresses are known to control rupture speed in numerous laboratory analogue experiments. We hypothesize a similar control on the WIP behavior and show that laboratory experiments can explain most of the rupture speed behavior. We propose a mechanism where the nucleation of faster initial rupture near the low-tide initiation point can be explained by locally high shear to normal stress ratios (τ/σ) caused by flexure near the grounding line. This is an effect caused not by lowering of the ice column, but by the flexural forebulge created in the upwards direction further inland from the Ross Sea during low tide. A momentary reduction in normal stress (upwards ice motion) would cause a temporary increase in the interfacial stress (τ/σ), which is possibly an instability, and may be the cause of the high initial rupture speeds observed near the grounding line during the low tide events. The central conclusion of this study is that the observed systematic variations in rupture velocities are governed by the applied stresses and may provide insight into grounding line stability.

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Tidal Flexure and Associated Seismic Activity Near the Grounding Zone of Beardmore Glacier

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Near grounding zones, glacier behavior is significantly influenced by interactions with floating ice shelves. Thus, insights into the mechanical behavior and stability of ice shelves are required to understand the flow of ice sheets. We conducted a multi-faceted geophysical survey near the grounding zone of the Beardmore glacier in December 2013 to provide in situ constraints on physical processes relevant to understanding the interactions between floating and grounded ice. As observed in previous studies of the region, our GPS results record significant tidal flexure of the ice shelf as well as tidal modulation of flow speeds. Associated with this tidal deformation, we observe 100's of icequakes per day associated with the brittle deformation in the upper portion of the ice shelf. Seismicity rates peak during the rapid rising and falling of the tides, with only minimal seismicity near the daily low and high tides, when strain rates are minimal. The location of seismic events is concentrated near ridges in the surface topography that separate large melt channels we observed at the base of the ice shelf in our radar traverses. Thus, it appears that the melt induced structure of the ice shelf and tidal flexure regulate the plastic deformation in the upper portion of the ice shelf. These results highlight the interaction between tides, ocean processes, and the stability of ice shelves near grounding zones.

- everywhere else (*Promised Land)*

Variability of Accumulation Rates from ERA-Interim and RACMO and Impacts on West Antarctic Mass Balance Estimates

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Time-series of ice-sheet accumulation rates, A(t), such as those provided by ERA-Interim re-analysis and RACMO regional climate modeling, are very important for studies of current changes in mass balance. In addition to providing essential information on the temporal variability of the surface mass input, time series of A(t) along with observed temperatures, Ts(t), provide important information for modeling of surface elevation changes caused by changes in the rate of firn compaction driven by accumulation and temperature variations. Firn-compaction elevation changes, which do not involve changes in mass, provide significant corrections to the surface elevation changes, dH/dt, observed by satellite altimetry. For studies of current ice-sheet mass changes, the accuracy of the temporal variability of $\delta A(t) = A(t) - A_{mean}$ is more important than the accuracy of the mean, A_{mean}. Results from comparison of the temporal variability (1980 to 2009) of accumulation from snow radar measurements in West Antarctic with accumulation from four meteorological data sets showed a much higher temporal correlation of 0.93 for ERA-interim than the 0.68 for RACMO (Medley et al., 2013). We compare the accumulation driven mass changes, dM_a/dt, derived from the two data sets in West Antarctica for two periods: the 1992-2001 period of ERS1&2 radar-altimeter measurements, and the 2003-2008 period of ICESat laser-altimeter measurements. For 1992-2001, a pattern of reduced dM_a/dt in the WA drainage systems (DS) near the base of the Antarctic Peninsula is similar for both data sets, as is the near zero dM_a/dt for the principal Siple Coast ice streams. The principal differences in 1992-2001 are the larger dM_a/dt in the coastal DS of Marie Byrd Land and in the interior Mercer ice stream using RACMO. For 2003-2008, a pattern of increased dM_a/dt in the WA drainage systems (DS) near the base of the Antarctic Peninsula in both data sets is much stronger using RACMO, although the near zero dM_a/dt for the principal Siple Coast ice streams is again the same for both. The principal differences in 2003-2008 are the increased dM_a/dt in the coastal DS of Marie Byrd Land and the interior Mercer ice stream using RACMO versus decreased dM_a/dt in both those DS using ERA-Interim. Since RACMO uses the ERA-interim reanalysis data, the differences between the two data sets presumably lie in the regional climate modeling included in RACMO. For 1992-2001, the net dM_a/dt from the anomalies is -17 Gt/yr in West Antarctic using ERA-Interim and -9 Gt/yr using RACMO. For 2003-2008, the net dM_a/dt is +17 Gt/yr using ERA-Interim and +32 Gt/yr using RACMO. In addition to the snow radar comparison, other aspects of the temporal variability in the two data sets indicate that ERA-interim provides a better representation of the temporal accumulation anomalies than RACMO.