FRISP 2018

PROGRAM (Abstracts below)

Monday 3rd

19h00: Arrival in Aussois.

20h00: Dinner.

Tuesday 4th

7h30 – 8h30: Breakfast.

8h30 – 8h40: Introduction.

8h40 – 10h20: 5 presentations. **Weddell/FRIS, 1st part – *chair: Elin Darelius***

- Svenja Ryan.
- Markus Janout.
- Tore Hattermann.
- Camille Akhoudas.
- Kaitlin Naughten.

10h20 – 10h40: Tea or coffee Break.

10h40 – 12h20: 5 presentations. **Weddell/FRIS, 2nd part – *chair: Ute Hausmann***

- Kjersti Daae.
- Keith Nicholls.
- Ole Zeising.
- Lukrecia Stulic.
- Martin Wearing.

12h30 – 14h00: Lunch.

14h00 – 15h40: 5 presentations. **Greenland – *chair: Jean-Baptiste Sallée***

- Jérémie Mouginot.
- Irena Vankova.
- Fiama Straneo.
- Julia Christmann.
- Donald Slater.

16h00 – 18h00: Posters.

19h00: Dinner.

Wednesday 5th

7h30 – 8h30: Breakfast.

8h30 – 10h10: 5 presentations. **Processes and parameterizations – *chair: Xylar Asay-Davis***

- Lionel Favier.
- Adrian Jenkins.
- Catherine Vreugdenhil.
- Lucie Vignes.
- Stephen Warren.

10h10 – 10h40: Tea or coffee break.

10h40 – 12h00: 4 presentations. **Ross – *chair: Yoshihiro Nakayama***

- Craig Stevens.
- Alena Malyarenko.
- Carolyn Branecky Begeman.
- Justin Lawrence.

12h10 – 14h00: Lunch.

14h00 – 16h00: 6 presentations. **Amundsen – *chair: Nicolas Jourdain***

- Karen Assmann.
- Tae-Wan Kim.
- Yoshihiro Nakayama.
- Paul Holland.
- Alessandro Silvano.
- Won Sang Lee.

16h00 – 18h00: Posters.

19h00: Dinner (Fondue).

Thursday 6th

7h30 – 8h30: Breakfast.

8h30 – 9h50: 4 presentations. **Antarctic ice sheet/Southern Ocean – *chair: Lionel Favier***

- Ole Richter.
- Xylar Asay-Davis.
- Bertie Miles.
- William Lipscomb.

9h50 – 10h20: Tea or coffee Break.

10h20 – 11h20: 3 presentations **East Antarctica – *chair: Jérémie Mouginot***

- Minowa Masahiro.
- Chad Greene.
- Jamin Stevens Greenbaum.

11h30 – 12h00: Lunch (take-away).

12h00: bus departure to Geneva airport.

POSTERS (Abstracts below)

- Leo Middleton
- Ralph Timmermann
- Nadine Steiger
- Masahiro Minowa
- Alistair Everett
- Peter Davis
- David Bett
- Elin Darelius
- Marion Donat-Magnin
- Gunter Leguy
- Ute Hausmann
- Emilia Kyung Jin
- Alice Barthel
- Lianne Harrison
- Christopher Bull
- Jamin Stevens Greenbaum
- Taewook Park
- Ozgur Gurses
- Salar Karam

ABSTRACTS

Akhoudas Camille

LOCEAN Paris - camille.akhoudas@locean-ipsl.upmc.fr

The freshwater cycle of the Southern Ocean: A stable water isotopes approach.

C. Akhoudas[1], G. Reverdin[1], G. Aloisi[1], JB. Sallée[1], M. Benetti[2]; (1) LOCEAN - Sorbonne Universités - UPMC/CNRS/IRD/MNHN - Paris, France; (2) Institute of Earth Sciences - University of Iceland - Reykjavik, Iceland.

The freshwater cycle of the Southern Ocean is pivotal for Earth's climate, but it is still poorly observed and understood. Indeed, the large freshwater fluxes directly control ocean circulation, the geography of sea-ice, the melt of the ice-caps, with global and major consequences for global climate and sea-level rise. In particular, the relatively warm circumpolar deep water entering in contact with ice-shelves, and the dense water formed as a result through ocean-ice interactions is essential for establishing global ocean circulation. In this study, we aim at shedding light at ocean circulation and how it interacts with ice-shelves. As part of the WAPITI project cruise, we acquired in Jan-Mar 2017 a new set of oxygen and deuterium isotope. We will present preliminary results from this exciting set of observations and present longer-term plans for freshwater cycle, ocean-ice interaction, and ocean circulation analysis of the region.

Asay-Davis Xylar

Los Alamos National Laboratory - xylar@lanl.gov

The newly released U.S. Department of Energy's Energy Exascale Earth System Model (E3SM) is an ideal tool for studying the relationship between smaller-scale regional phenomena and the global climate. Each E3SM component is capable of regional refinement within a global domain. E3SM also includes the ability to simulate ocean circulation in ice shelf cavities, and dynamic ice sheet-ocean interactions are under development. These new capabilities are critical for projecting Antarctica's potential future contributions to global sea level, one of three main scientific foci of the E3SM project. Here we compare global E3SM simulations with and without ice-shelf cavities under various conditions. We show that ice shelves improve the vertical distribution of temperature and salinity in the region around Antarctica, but also that their inclusion has far-reaching consequences in the model. By comparing simulations with prescribed atmospheric and land forcing at two mesh resolutions, ~30 km and ~10 km near Antarctica, we show that biases in both melt rates and the temperature field on the Antarctic continental shelf are reduced at higher resolution. We also explore the influence of ice-shelf cavities in a pre-industrial control simulation with fully coupled atmosphere, land, sea-ice and ocean components.

Assmann Karen

University of Gothenburg - karen.assmann@marine.gu.se

The West Antarctic Ice Sheet has been losing mass at an increasing rate over recent decades. The presence of warm ocean water at the ice-ocean interface has been identified as an important contributor to this mass loss. In the Amundsen Sea, research efforts have mainly focused on Pine Island and Thwaites Ice Shelves due to their extremely high melt rates and retreating grounding lines. Getz Ice Shelf, located further west, has received less attention because of its lower melt rate and smaller drainage basin. However, its large size makes it the largest source of ice shelf melt in Antarctica. Model studies have shown that this melt water reaches the Ross Sea continental shelf and is a major contributor to the freshening observed over past decades. It may thus impact Antarctic Bottom Water formation. The Getz Ice shelf extends along the Amundsen Sea coast between 115° and 135° W and has a complex configuration with multiple openings. We present new observations from three moorings between 2016-18 in the warm inflow to the western Getz Ice Shelf cavity between Siple and Dean Island. Two of the moorings were deployed on the Siple Island slope 16 km from the ice shelf front at

depths of 600 and 700 m. The third mooring was located about 800m from the ice shelf edge at a depth of 600m. All three moorings show a persistent flow of modified Circumpolar Deep Water. There are regular events where essentially unmodified Circumpolar Deep Water with temperatures exceeding 1.5°C reaches the ice shelf cavity. The mean current within the warm bottom layer is between 0.15-0.20 m/s implying an advection time scale of 8 days for the 110km from the shelf break to the ice shelf edge. We relate the sub-annual variability from the moorings to historical CTD stations and use atmospheric data to investigate possible driving mechanisms for the sub-annual and inter-annual variability.

Barthel Alice

Los Alamos National Lab - abarthel@lanl.gov

Quantifying multi-model uncertainty in Antarctic basal melt rate.

Global sea level rise (SLR) of several meters is thought to be possible within a century or two, and has serious implications for coastal protection into the future. The largest uncertainty in global SLR is the contribution from melting Antarctic land ice. This uncertainty is due to the fact that state-of-the-art climate models 1) cannot explicitly represent the small-scale processes occurring in the shallow shelf seas around Antarctica and in the ice-shelf cavities where melt is occurring, 2) differ in their projected ocean and atmospheric conditions. We present a study aiming to quantify the multi-model uncertainty in future Antarctic basal melt rate. A regional circum-Antarctic ocean model (with 5km horizontal resolution) with static ice-shelf cavities is used to relate large-scale atmospheric and ocean conditions to melt occurring underneath ice shelves. A suite of such simulations, each driven by distinct boundary conditions derived from a given state-of-the-art (CMIP5) climate model, will inform on the impact of climate model biases on Antarctic melt rate. By providing a better representation of ocean processes, and relying on a range of climate forcings (rather than a single CMIP5 model), this study will contribute to quantifying uncertainties in SLR and pave the way for better projections to inform strategic adaptation decisions.

Branecky Begeman Carolyn

Los Alamos National Laboratory - carolyn.begeman@gmail.com

Ocean-driven melting of ice shelves is a primary mechanism for ice loss from Antarctica. However, due to the difficulty in accessing the sub-ice-shelf ocean cavity, the relationship between ice-shelf melting and ocean conditions is poorly understood, particularly near the grounding zone, where the ice transitions from grounded to floating. We present the first borehole oceanographic observations from the grounding zone of the Ross Ice Shelf, Antarctica's largest ice shelf by area. Contrary to predictions that tidal currents near grounding zones mix the water column, we found that Ross Ice Shelf waters were vertically stratified. Current velocities at mid-depth in the ocean cavity did not change significantly over measurement periods at two different parts of the tidal cycle. The observed stratification resulted in low melt rates near this portion of the grounding zone, inferred from phase-sensitive radar observations. These melt rates were generally <10 cm yr-1, which is lower than average for the Ross Ice Shelf (~20 cm yr-1). Melt rates may be higher at portions of the grounding zone that experience higher subglacial discharge or stronger tidal mixing. Stratification in the cavity at the borehole site was prone to double-diffusive convection as a result of ice-shelf melting. Since double-diffusive convection influences vertical heat and salt fluxes differently than shear-driven turbulence, this process may affect ice-shelf melting and merits further consideration in ocean models of sub-ice-shelf circulation.

Bett David

British Antarctic Survey - davbet33@bas.ac.uk

The Amundsen Sea has some of the highest thinning rates of ice shelves in Antarctica, due to increased ocean melting. This increased input of freshwater into the region could affect the currents and mixing, due to density being strongly dictated by salinity in the polar regions. However first a clear understanding of the sources and sinks of freshwater in the region is lacking, which is needed before the effect of this excess freshwater can be understood. Therefore here we present the preliminary results and methods of investigating the distribution and effect of freshwater from different sources in the Amundsen Sea, using passive tracers in both idealised and realistic regional MITgcm models. The vertical distribution of ice shelf meltwater is investigated in an idealised model and is found to be dependent on the Circumpolar Deep Water layer thickness. Meanwhile the local freshwater feedback of ice shelf meltwater on melt rates is found to be small for the oceanographic ranges seen in the Amundsen Sea.

Bull Christopher

British Antarctic Survey - chbull@bas.ac.uk

The role of atmospheric variability on modulating melt rates in the Filchner Ice Shelf System.

The Filchner Ice Shelf System located at the southern boundary of the Weddell sea is the largest body of floating ice in the world, it is fed by four ice streams which have a combined discharge of over 100 Gtons yr-1 or approximately 19% of the Antarctic continent. In the future the FISS system then, has the potential to be a major component of Antarctica's contribution to sea level rise. Work by Hellmer et al. (2012; 2017) suggests that the intrusion of warm circumpolar deep water could lead to dramatic, irreversible changes for the ice shelf system in the future, first-order questions remain however, as to the present day factors influencing FISS' melt rates on inter-annual timescales. Recent in-situ moorings and a seismic survey (e.g. (Rosier et al., 2018)) by the British Antarctic Survey offer an unprecedented opportunity to improve and evaluate numerical simulations of the region. Here, using eddy-permitting NEMO ocean model simulations, we focus on understanding the large-scale ocean and atmospheric circulation patterns that influence melt rates over the re-analysis period. Additional simulations highlight the importance of model settings and ice shelf cavity geometry to melt rates in the Filchner Ice Shelf system. The eddy-permitting results presented shed light on the historical context of the BAS S03/S05 in-situ mooring observations.

Christmann Julia

Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, Bremerhaven, Germany - julia.christmann@awi.de

Modeling and observation of the deformation response of 79°N Glacier, Greenland.

Julia Christmann[1,2], Ole Zeising[1], Daniel Steinhage[1], Niklas Neckel[1], Tobias Binder[1], Veit Helm[1], Ralf Mueller[2], Dietmar Gross[3] and Angelika Humbert[1,4]; (1) Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, Bremer- haven, Germany (2) TU Kaiserslautern, Kaiserslautern, Germany (3) TU Darmstadt, Darmstadt, Germany (4) University Bremen, Bremen, Germany

In Greenland only a few floating ice tongues still exist, including one of the outlet glaciers of the North East Greenland Ice Stream, the 79°N Glacier. The backpressure of these floating ice shelves is important for the contribution of the grounded ice streams to sea level rise. In the project Greenland Ice Sheet Ocean Interaction (GROCE) a team of glaciologists, oceanographers, and atmospheric scientists combine measurements and model studies of these different research fields to investigate the dynamics at 79°N Glacier. We present a glaciological study, focusing on the response of the 79°N Glacier to tidal forcing by means of observations and viscoelastic modeling. GPS measurements for this glacier show vertical displacements of the floating ice tongue due to tides. In the hinge zone, i.e. the transition between the grounded and floating ice, the tidal forcing leads to bending of the ice and a movement of the grounding line. However, other stations that are located at the fully grounded part of the ice further upstream the grounding line observe horizontal displacements caused by tidal forces in a distance of more than 35km to the grounding line. In order to simulate these measured displacements a viscoelastic material model is required. In a purely viscous material model the tidal dependency of the horizontal displacements cannot be realized. Geometries are obtained by airborne radar measurements and form the data basis for the finite element simulations using a viscoelastic Maxwell material model with a nonlinear Glen-type viscosity. This material model combines the typical short-term elastic behavior of ice with the long-term viscous response. Nonlinearities of basal sliding and viscous deformation result in an asymmetry of the ice outflow across the grounding line and are also included in the model. We present preliminary modeling results using the vertical displacement from the observations as forcing and a geometry obtained by using AWI's new ultrawideband radar.

Daae Kjersti

Geophysical Institute, University of Bergen - kjersti.daae@uib.no

Variability and mixing of the Filchner overflow plume descending the continental slope, Weddell Sea.

A large fraction of Antarctic Bottom Water is produced in the Weddell Sea, through mixing between the cold and dense shelf water masses and the warm and saline off-shelf water. We present observations of the dense Filchner overflow plume from one mooring at the Filchner sill and two moorings located downstream, at the continental slope. The plume variability over the continental slope at monthly time scale is related to upstream conditions at the Filchner sill, with high correlation in density. Revised volume transport (per unit width) calculations across the Filchner sill indicate 50% higher values in 2010 compared to the earlier estimates available from 1985. Over the continental slope, the plume thickness fluctuates strongly between less than 25 m and more than 250 m. Observations of elevated temperature variance and high Froude numbers at the plume interface imply high mixing rates and entrainment of ambient water masses. The mixing events typically coincide with shear spikes across the plume. The shear spikes appear quasi-periodically, when counter-rotating oscillations with periods of 24 and 72 hours align. The clockwise 24-hour oscillation is related to diurnal, barotropic tidal currents and topographic vorticity waves, whereas the counterclockwise 72-hour oscillation is related to vortex stretching or topographic vorticity waves.

Darelius Elin

Geophysical Institute - elin@gfi.uib.no

The Ice Shelf Water (ISW) found in the Filchner Trough (FT), located in the southern Weddell Sea, Antarctica, is climatically important; it descends into the deep Weddell Sea contributing to bottom water formation and it blocks warm off shelf waters from accessing the Filchner Ice Shelf cavity. Yet, the circulation of ISW within the FT and the processes determining its exchange across the ice shelf front is to a large degree unknown. Here, up to four-year-long mooring records from the ice shelf front are presented. They show that the coldest (theta = -2.3°C) ISW, which originates from the Ronne Trough in the west, exits the cavity across the western part of the ice shelf front during late Austral summer and early autumn. The super-cooled ISW escaping the cavity flows northward with a velocity of about 0.03 m/s. During the rest of the year, the flow at the western site is eastward, parallel to the ice shelf front, and the temperatures are slightly higher (theta = -2.0°C). The eastern records show a more persistent outflow of ISW.

Davis Peter

British Antarctic Survey - petvis@bas.ac.uk

Antarctic ice shelves restrain the flow of grounded ice into the ocean, and thus are an important control on Antarctica's contribution to global sea level rise. Ice shelves interact with the ocean beneath them, and the transfer of heat through the ice shelf-ocean boundary layer is critical in setting the basal melt rate and the sub-ice shelf circulation. The physics of this boundary layer is poorly understood however, and its inadequate representation in numerical models is hampering our ability to predict the future evolution of Antarctic ice shelves and global sea-level rise. Using a hot-water drilled access hole, two turbulence instrument clusters were deployed beneath the southern Larsen C Ice Shelf in December 2011. Both instruments returned a year-long time series of observations, providing a unique opportunity to explore the turbulent processes at two depths within the ice-ocean boundary layer. Our results show that the scaling between turbulent kinetic energy (TKE) dissipation and mean flow speed varies with distance from the ice shelf base, and different terms are important in the balance between TKE production and dissipation. Ultimately the aim of these observational efforts is to better constrain our parameterisations of the boundary layer in large-scale numerical models, allowing more accurate simulations of ice shelves to be made under the warming climate.

Donat-Magnin Marion

IGE/UGA/CNRS - Marion.Donat-magnin@univ-grenoble-alpes.fr

Over the last three to four decades accelerated thinning of Amundsen Sea ice shelves is responsible for coastal glaciers accelerations, ice flux increases and sea level rise. Nowadays, the Amundsen glaciers are the largest contributors to sea level rise in Antarctica. Ice-shelf thinning takes place from below and above through oceanic melt and surface melt. In the Amundsen sector, which is a warm summer region, the surface processes can lead to the disintegration of West Antarctic ice shelves through the hydrofracturing mechanism (i.e surface melt draining into crevasses). This has been already observed in the Peninsula for the Larsen's ice shelves disintegrations. There is a need of considering hydrofracturing mechanism into ice-sheet models as it can lead to a large increase in sea level rise. To assess present sea level changes with the lack of multi-year observation we therefore need numerical ice-sheet models with surface mass balance (SMB) and surface melt estimations. Here, we focus on surface processes and we provide SMB for 1979-2017 using a regional atmospheric model, MAR, at 25 and 10km resolution. This relatively high resolution permits to look at surface melt events and therefore to better understand what drives hydrofracturing, including climate modes of variability such as ENSO. We also evaluate the drivers of interannual variability in SMB.

Everett Alistair

Norwegian Polar Institute - alistair.everett@npolar.no

The impact of terminus morphology on plume dynamics.

Plumes of subglacial discharge are known to enhance submarine melt rates at marine-terminating glaciers. Plume models allow a valuable insight into the volume and spatial distribution of melt rates driven by the plume. However, many assumptions must be made in these models necessitated by a lack of field data, the complexity of the problem and limitations of the models used. One of the major assumptions, often made in both simple and complex models, is that the glacier terminus is a flat, vertical plane. However, sideways sonar scans of the submarine portion of marine-terminating glaciers in Greenland and Svalbard have revealed complex morphology, particularly around outlets of subglacial discharge. We present the first results from a high-resolution plume model run in a domain generated from sideways sonar scans of Kronebreen, Svalbard. The plume model uses Fluidity, a finite-element fluid dynamics code, which is run on a three-dimensional, fully unstructured mesh allowing the model to accurately reproduce complex domains. Fluidity is also capable of online evolution of the mesh, opening up exciting possibilities for future studies using a time-evolving ice front. We compare the results using a realistic terminus morphology to the same model run on a flat, vertical terminus, as well as to a simplified model based upon plume theory. These results allow us to better understand the implications of this widely used assumption.

Favier Lionel

IGE/CNRS/Univ. Grenoble Alpes - lionel.favier@univ-grenoble-alpes.fr

Inter-comparison of sub-shelf melt parameterizations and coupled simulations in a MISOMIP-like framework.

Sub-shelf melting is the main driver of ice-shelf thinning in West Antarctica, potentially affecting the stability of the upstream ice sheet. Standalone ice-sheet models account for sub-shelf melting through parameterized relationships of various complexity. The simplest are depth dependent without accounting for any physics, some of intermediate complexity are based on linear or quadratic thermal forcing, and the most complex relationships also account for the transformation of the ocean properties along the ice shelf draft (Lazeroms et al., 2017 and Reese et al., 2017). These parameterizations are all based on various level of assumptions, but their use is required for long simulations and large ensembles for which ice-ocean coupled models are too computationally expensive. Evaluating these parameterizations is difficult because the level of details in the melt patterns that is needed to constrain an ice sheet model is not well understood. Therefore, we compare several melt parameterizations applied to Elmer/Ice simulations with four different ocean warming scenarios. These simulations are compared to an ensemble of NEMO-Elmer/Ice coupled simulations (with varying grids or physics) under the same warming scenarios. These simulations are built upon the MISOMIP protocol (Asay-Davis et al. 2016), and the differences are quantified in terms of volume above flotation, i.e. contribution to sea level rise.

Greenbaum Jamin Stevens (Oral presentation)

University of Texas Institute for Geophysics - jamin@utexas.edu

Ocean-driven thinning of Denman Glacier and the Shackleton Ice Shelf, East Antarctica Denman (DEN) Glacier is one of the primary outlets of East Antarctica's Aurora Subglacial Basin (ASB) which contains at least 3.5 meters of eustatic sea level potential in ice grounded below sea level. DEN drains through the Shackleton Ice Shelf, the seventh largest and the most northern ice shelf in Antarctica outside the

Antarctica Peninsula. The ice surface elevation in the DEN grounding zone has been lowering steadily since the beginning of the satellite altimetry record and recent work indicates that the grounding line is retreating faster than any other glacier in East Antarctica. The nature of those observations indicates ocean-driven thinning; however, the sub-ice shelf bathymetry and nearby ocean state have not been known well enough to confirm that hypothesis. Here we present a new sub-ice shelf bathymetry compilation derived by airborne gravity inversion using a geological model constrained by seafloor depth estimates. Depth constraints were derived from airborne-deployed bathythermograph sensors and depth to basement solutions from airborne magnetics data. The new bathymetry reveals at least one seafloor trough deep enough to allow warm Modified Circumpolar Deep Water, which has been observed by Autonomous Pinniped Bathythermographs (tagged seals) near this location, to reach the grounding line. Finally, we use ice core data acquired nearby to confirm that atmospheric temperatures have not been high enough since at least 1931 to explain the thinning observed in the DEN grounding zone. These results confirm that the western outlet of the ASB, via Denman Glacier, is vulnerable to ocean-driven retreat also known to be responsible for rapid thinning of Totten Glacier and several glaciers in West Antarctica.

Greenbaum Jamin Stevens (Poster)

University of Texas Institute for Geophysics - jamin@utexas.edu

Airborne-deployed ocean sensors for constraining the bathymetry and ocean state on the Antarctic continental shelf.

The Antarctic continental shelf is one of the least observed regions on Earth. Shipborne bathymetric and oceanographic sampling along the Antarctic coastline are complicated by icebergs and multiyear sea ice which restrict marine expeditions to irregular temporal sampling of accessible areas. As a result, numerical ocean circulation models struggle to produce reliable estimates of the ocean state south of the continental shelf break. Recognizing the need for improved bathymetric and oceanographic sampling to constrain ocean circulation models, the International Collaborative Exploration of the Cryosphere through Airborne Profiling (ICECAP) consortium deploys Airborne eXpendable Conductivity, Temperature, Depth (AXCTD) and Airborne eXpendable Bathy-Thermograph (AXBT) ocean sensors in areas critical for understanding heat delivery to coastal glaciers. Here we present an overview of the ICECAP airborne oceanographic system design, concept of operations, and results from the last two Antarctic field expeditions where AXBT and AXCTD profiles were acquired near the Totten, Shackleton, and Moscow University Ice Shelves in East Antarctica. Eighteen AXBT profiles were deployed in 2016/2017 for bathymetric sampling; fifteen AXCTD and twenty-three AXBT profiles were deployed in 2017/2018 for oceanographic and bathymetric sampling. In both seasons, deployments were concentrated along the calving fronts and inner continental shelf region near the three primary ice shelf targets. Of the fifty-six total instrument deployments, four profiles resulted in no data. The profiles indicate deep, warm, Modified Circumpolar Deep Water (MCDW) east of Totten Glacier in the Dalton Polynya, where it had been observed in previous years but at different depths; MCDW was also observed northwest of Totten Glacier, in an area where no ocean measurements had been made previously. We identify typical seafloor impact signals by deploying AXBT sensors where the seafloor had previously been mapped with multibeam echo sounding and find that the depth estimated by the AXBT descent rate calculation differed from the known depth by less than 30 meters. This level of uncertainty makes AXBT-derived seafloor estimates useful constraints on airborne gravity-derived seafloor bathymetry inversions where there are geological transitions that cause large level shifts in gravity data. We also include an overview of the ICECAP airborne survey plans for the 2018/2019 field season.

Greene Chad

University of Texas at Austin - chad@chadagreene.com

Dynamics of Totten Ice Shelf detected by satellite images and laser altimetry Totten Ice Shelf couples a variable ocean to 3.5 m of sea level potential held in East Antarctica's Aurora Subglacial Basin. The floating ice shelf readily responds to intermittent intrusions of modified circumpolar deep water along the Sabrina Coast continental shelf, but its grounded tributaries have shown nearly monotonic mass loss and surface drawdown in recent decades. Understanding Totten Glacier's mass balance and sensitivity to environmental forcing requires high-resolution mapping of the ice shelf geometry, its pinning points, and the magnitude and distribution of annual basal melt. We use airborne and satellite data collected from 2003 to 2018 to characterize the surface elevation, ice thickness, firn air content, ice velocity, and the bathymetry of Totten Ice Shelf. We compare our measurements to previous estimates ice shelf mass balance and assess potential sensitivities of the ice shelf.

Gurses Ozgur

Alfred Wegener Institute - ozgur.gurses@awi.de

Modelling the ocean circulation underneath the Filchner-Ronne ice shelf: What is the role of vertical discretization?

Ozgur Gurses, Svenja Ryan, Qiang Wang, Ralph Timmermann, Christian Rodehacke, Madlene Pfeiffer, Tido Semmler.

Warm waters intruding underneath the Filchner-Ronne ice shelf might destabilize the Antarctic ice sheet. This could have long-term implications for global sea level rise. Modelling this process is thus highly important for understanding future climate changes. The Finite Element Sea-ice Ocean Model (FESOM) is a multi-resolution model that allows to refine the mesh in regions of interest, while keeping the rest of the world oceans relatively coarse. It is coupled to an ice-shelf model. In the current setup, FESOM employs a hybrid sigma/z layer in the vertical. In this study we investigate the benefits of using z-layers in the vertical. The advantage of a discretization with z-layers is its higher numerical efficiency, as a larger time step can be used. We focus our analysis on processes underneath the Ronne-Filchner ice shelf. The z-level configuration leads to improvements in circulation, e.g. along the rim of Berkner Island, and bottom temperatures, e.g. in Filchner Trough.

Harrison Lianne

British Antarctic Survey/University of East Anglia - liahar11@bas.ac.uk

Modelling ocean circulation beneath Larsen C Ice Shelf.

The calving of a trillion tonne iceberg from Larsen C Ice Shelf (LCIS) in July, 2017 has led to concern about whether the ice shelf is heading for collapse; the reduction in buttressing that would result from a partial or total collapse could affect global sea level rise on decadal time scales. Satellite radar altimetry measurements have shown that the surface of LCIS lowered between 1992 and 2011. It has been suggested that oceanic basal melting caused the ice to thin, resulting in the observed lowering. To determine the extent to which ocean melting has driven ice loss, a numerical model is currently being developed to simulate ocean conditions in this region. The model has a new 1 km bathymetry created from a composite of BEDMAP2 data and 111 seismic soundings, taken on the surface of the ice shelf, which indicate the presence of a trough running into Mobiloil Inlet from the calving front. An analysis of the melt water flux from two initial temperature sensitivity tests, using a non-tidal version of the model, is presented here to ascertain the magnitude of melting and freezing and where the greatest flux takes place. Future experiments, to be conducted once tides have been incorporated into the model, will also be discussed.

Hattermann Tore

AWI / Akvaplan-niva - tore.hattermann@awi.de

Circulation and melting beneath Filchner-Ronne Ice Shelf.

T. Hattermann and the Filchner-Ronne Ice Shelf group.

Recent observations from moorings, cruises, ground based radar and remote sensing suggest the presence of two circulation modes that control basal melting beneath the Filchner-Ronne Ice Shelf. The first mode spans the entire cavity and is driven by the densest High Salinity Shelf Water that originates on the western part of the continental shelf. In this "Ronne Mode", melting is concentrated at the deep grounding lines and the northeastern part of the ice shelf is affected by the outflow of cold Ice Shelf Water that only induces weak melting near ice front. In the second mode, High Salinity Shelf Water of local origin enters the cavity in the east and separates the circulation into multiple regional cells. In this "Berkner Mode", intrusions of warmer water near the ice base enhance melting at the ice front and the presence of dense water in the Filchner Trough is limiting the eastern outflow of Ronne-type ice shelf water. The apparent interannual variability is partially explained by the regional pattern of the surface heat loss in front of the ice shelf, while the transient response of the shelf and cavity circulation is also likely contributing to the modal interplay. In particular the role of locally formed High Salinity

Shelf Water inside the Filchner Trough will need attention in future work, both for the cavity circulation and the exchange across the shelf break.

Hausmann Ute

LOCEAN, IPSL, Sorbonne University - uhausc@gmail.com

Realistic high-resolution model simulations of the southwestern Weddell Gyre are prepared using a state-of-the art z-coordinate ocean plus sea ice model (NEMO, LIM version 3). One of the novelties of the proposed setup consists in the explicit resolution of the sub-iceshelf seas adjacent to the Weddell shelves, including the cavity between the Filchner-Ronne iceshelf (FRIS), modelling the melt at the iceshelf bases, the oceanic processes accounting for it, as well as its impact on the ocean circulation in the cavities and beyond. The configuration is designed to explore the mechanisms of communication between the open Weddell Gyre and the sub-iceshelf seas, and notably, the role played therein by the circulation, stratification and water mass (trans-)formations on the Weddell shelves. Simulations are spun up from a 1/4° Nemo simulation, and carried out at an isotropic horizontal resolution of 1/12° longitude, which ranges from about 4.5 km at the northern boundary of the gyres, varies between 4 to 2 km over the gyre's shelves, and reaches less than 2 km in the FRIS cavity.

Holland Paul

British Antarctic Survey - p.holland@bas.ac.uk

Something interesting about surface stresses on the Amundsen Sea...

Janout Markus

Alfred-Wegener-Institute - markus.janout@awi.de

The Filchner-Ronne Ice Shelf edge revisited.

Janout, M., H. Hellmer, M. Schroeder, S. Ryan, A. Wisotzki, and S. Osterhus.

After the last complete occupation in 1995, favorable wind and sea-ice conditions in February 2018 allowed for a densely-spaced hydrographic survey along the entire 600km-long Filchner-Ronne Ice Shelf edge as part of Polarstern cruise PS111. Here, we show the 2018-distribution of temperature, salinity, and oxygen jointly with geostrophic and LADCP-derived ocean velocities and compare these parameters with historical measurements to investigate whether any changes might have occurred on the southern Weddell Sea continental shelf during the past 23 years. We present details regarding the distribution of High Salinity Shelf Water and Ice Shelf Water in Ronne and Filchner Troughs and discuss their implications for the sub-ice shelf circulation.

Jenkins Adrian

British Antarctic Survey - ajen@bas.ac.uk

A simple diagnostic model of the circulation beneath an ice shelf

----

Jin Emilia Kyung

Korea Polar Research Institute (KOPRI) - jin@kopri.re.kr

Utilization of filed observations to improve the reliability of ice sheet model.

Emilia Kyung Jin, In-Woo Park, Choon-Ki Lee, and Won Sang Lee.

The impact of high-resolution bed geometry data through airborne radar on the performance of ice sheet model is investigated targeting the Drygalski Ice Tongue and David Glacier, East Antarctica. The 2-dimensional (2-D) shallow shelf approximation model (MacAyeal, 1989), which is implemented in the Ice Sheet System model (ISSM) (Larour et al., 2012) is used. Sensitivity experiments are conducted to verify the significant differences induced by changes in model. A series of projected simulations are compared to explore the role of improved geometry to the grounding line migration, surface mass balance and sea level contribution based on various forcing scenarios including atmospheric forcing, floating ice melting rate, and ice front position.

Karam Salar

University of Gothenburg - salarkaram111@hotmail.com

The importance of predicting future sea level rise has led to more attention towards the West Antarctic Ice Sheet. Glaciers draining the ice sheet into the Amundsen Sea are thinning and accelerating due to melting of its floating ice shelves, presumably caused by basal melt due to inflow of relatively warm Circumpolar Deep Water. While knowledge of the circulation of Circumpolar Deep Water has increased recently, measurements of oceanographic conditions from sub-ice shelf cavities are scarce. In order to understand the coupled system it is necessary to measure both the ice and the ocean side of the coupled system. Here results from Autonomous phase-sensitive Radio Echo Sounder (ApRES) are discussed. ApRES are capable of collecting time series of both basal melt rate and the vertical strain rate in the ice. Four ApRES devices were deployed on the Getz Ice Shelf in 2016. Results show that thinning of the ice shelf is about 1.5-2 metres per year, and oscillates at the tidal frequency. A fortnightly signal in thinning rates can also be detected at two of the sites. Whether these oscillations are caused by external forces of oceanic origin or by the bending of the ice shelf will be discussed.

Kim Tae-Wan

Korea Polar Research Institute - twkim@kopri.re.kr

Seasonal variability of ocean circulation near the Dotson Ice Shelf The rapid thinning of ice shelves in West Antarctica has recently been established from remote satellite observations, especially in the Southeast Pacific where relatively warm deep water intrudes onto the continental shelf1,2. The heat that seawater supplies to ice shelves causes basal melting and transports the meltwater seaward. Lying south of the productive Amundsen Sea Polynya, the ~5800 km2 Dotson Ice Shelf has a high melt rate due to southward ocean heat transport along the Dotson-Getz Trough. To investigate the existence and effects of seasonal variability on the Dotson mass loss we deployed three bottom-moored instrument arrays near the ice shelf, obtaining vertical profiles of temperature, salinity, current speed and direction during 2014 and 2015. Deep water inflow velocities are highest near bottom along the eastern slope of the trough, and spread northward higher above its western slope after being freshened by ice shelf meltwater. The rate of warm water intrusion into the sub-Dotson cavity reached a maximum during summer, 60 % larger than a minimum during autumn and winter, and depended mainly on variability of the ocean wind stress curl. Meltwater outflows were strongest during autumn and weakest in spring, with velocities influenced by a zonal density gradient caused by the seasonal variability of its meltwater fraction, and melt export lagging heat import by 145 days. The thickness of warm deep water above the eastern slope changed from one year to the next resulting from variable Ekman upwelling along the trough. Southeasterlies wind on the eastern boundary of the polynya also differed between summers because of a shift in the meridional location of the Amundsen Sea Low.

Lawrence Justin

Georgia Institute of Technology - jlawrence@gatech.edu

HROV Icefin: Antarctic sub-ice oceanography

J. D. Lawrence[1], B. E. Schmidt[1] (PI), M. R. Meister[1], D. Dichek[1], C. Ramey[1], B. Hurwitz[1], J. J. Lutz[1], J. P. Lawrence[1], A. Spears[1], A. Mullen[1], J. B. Glass[1], A. Stockton[1], N. Speller[1], D. Block[1], M. Philleo[1], L. Kassabian[1], J. S. Bowman[2]; (1) Georgia Institute of Technology, (2) Scripps Institution of Oceanography

Icefin is a 3.5 m long, 24 cm diameter hybrid remote or autonomous underwater vehicle (HROV) developed for sub-ice observations in Dr. Britney Schmidt's Planetary Habitability and Technology Lab at Georgia Tech (US). First deployed beneath McMurdo Ice Shelf (MIS) in 2014, Icefin can conduct basal ice, water column, or benthic surveys through ≥ 35 cm boreholes with a modular oceanographic sensor payload including CTD, DO, fDOM, turbidity, pH/ORP, ADCP, 2D forward sonar, altimetry, sidescan, and HD or 4K imaging. With live data via fiber optic tether, remote or autonomous survey ability, and 5 km range, Icefin provides a novel platform for better understanding ocean circulation, ice mass balance, and ecosystem diversity in sub-ice environments.

Now, through the NASA PSTAR-funded RISE UP program (Ross Ice Shelf and Europa Underwater Probe), Icefin is under continued advancement and in 2017 completed the first of three more Antarctic deployments. RISEUP aims to autonomously characterize habitability and under-ice environments on broad spatial scales via robotic platforms, providing insight into largely unmapped regions. In addition to HROV-based observations, complementary water column profiling under RISE UP includes CTD casts, nutrients, cell counts, and 16/18s amplicon surveys. Here, we present results from the first field season of RISE UP beneath McMurdo Ice Shelf, sea ice, and Erebus Glacier Tongue where we observed macrofauna, bathymetry, ice shelf water, supercooling, and platelet ice formations.

Future work includes collaborations with the Antarctica New Zealand Ross Ice Shelf Programme (2019/20, PI Christina Hulbe) at Ross Ice Shelf Grounding Zone, and the International Thwaites Glacier Collaboration with MELT (2019/20, PIs Keith Nicholls, David Holland). Icefin also serves as a sensor development and test platform- microfluidic cell counting, holographic microscopy, and onboard ice/sediment/water sampling modules are currently in design and assembly phases.

Lee Won Sang

Korea Polar Research Institute - wonsang@kopri.re.kr

Land-Ice/Ocean Network Exploration with Semiautonomous Systems applied to the Thwaites Glacier (LIONESS-TG).

Won Sang Lee, Choon-Ki Lee, Yongcheol Park, Sukyoung Yun, Christopher Zappa, Craig Stevens, Don Blankenship, Alex Forrest, Robert Dziak, Mechita Schmidt-Aursch, Christine Dow, Jinseok Kim, Jiyeon Lee, Seung-Tae Yoon, Ho Il Yoon, and Yeadong Kim.

The Polar Regions have been experiencing dramatic changes particularly including glacier retreating, ice thinning, and declining in sea ice extent. Ice shelves in Antarctica are of critical importance because they have a buttressing effect on the ice sheet behind the shelf. Losing stability by thinning or disappearance leads to an acceleration of the grounded ice upstream which causes sea level rise ultimately. The Cryosphere is a complex form of interactions between the Lithosphere, the Hydrosphere, and the Atmosphere, which requires intensive cross-disciplinary works for a complete understanding. In an attempt to address scientific questions related to rapid changes in Antarctica, Korea Polar Research Institute has initiated an international collaboration called 'Land-Ice/Ocean Network Exploration with Semiautonomous Systems (LIONESS)' in the Western Ross Sea (WRS) in 2015. In this presentation, we show current research activities of the LIONESS-WRS and future plans for the LIONESS-TG that will be launched in 2019 and continue until 2025.

Leguy Gunter

Climate and Global Dynamics Laboratory, NCAR - gunterl@ucar.edu

Marine ice sheet sensitivity to grounding line and ice shelf basal melt representations.

G. R. Leguy[1] and W. H. Lipscomb[1], (1) Climate and Global Dynamics Laboratory, National Center for Atmospheric Research, Boulder, CO, USA.

Theoretical studies suggest that using a sub-grid scale parameterization of the grounding line in marine ice sheet experiments improves the numerical accuracy of ice flow representation and relaxes the requirement on horizontal grid resolution. In previous work we have shown that a resolution of ~1 km (and in some cases ~2 km) remains sufficient to accurately simulate grounding line-dynamics. When simulating ocean warming scenarios, the model accuracy also depends on the numerical treatment of the ice shelf basal melt. Here we present results from a marine ice sheet sensitivity study using the MISMIP+ experimental framework and a developmental version of the Community Ice Sheet Model (CISM) to investigate the model sensitivity to grounding line and ice shelf basal melt parameterizations. To this end we will compare results for 2 different basal sliding laws and several basal melt rates. We will ultimately use the LARMIP experimental setup to show preliminary results on how grid resolution impacts the estimation of sea level evolution as a function of basal melt rate and melt rate parameterization in 5 different Antarctic regions: the Amundsen sea, the East Antarctic Ice Sheet, the Antarctic peninsula, the Ross region, and the Weddell sea region.

Lipscomb William

National Center for Atmospheric Research - lipscomb@ucar.edu

Sensitivity of an Antarctic ice sheet model to ice shelf melting and buttressing.

William Lipscomb and Gunter Leguy, Climate and Global Dynamics Laboratory, National Center for Atmospheric Research.

Theory and observations suggest that marine-based sectors of the Antarctic ice sheet could retreat rapidly under ocean warming and increased melting beneath ice shelves. Numerical models of marine ice sheets vary in sensitivity, depending on grid resolution and physics parameterizations. Here we present results from a study of Antarctic ice sheet sensitivity following the initMIP-Antarctica and Antarctic Buttressing MIP (ABUMIP) experimental protocols using a developmental version of the Community Ice Sheet Model (CISM). We first spin up the model, aiming to match observed Antarctic ice thickness, velocity, and grounding-line locations as closely as possible given model physics, grid resolution, and forcing. We relax toward the observed thickness by inverting for basal friction parameters (for grounded ice) and basal mass balance (for floating ice shelves). The spun-up model is then forced for several centuries by applying basal melt rate anomalies under ice shelves or by removing all shelves. We will discuss how grid resolution and physical assumptions affect the results.

Malyarenko Alena

University of Otago & NIWA, New Zealand - alena.malyarenko@niwa.co.nz

Recent observations in the north-western corner of the RIS demonstrate basal melt rates higher than previously observed, with high seasonal variability, connected to surface water inflow into the cavity. Existing mechanisms for cross-ice shelf flow in the frontal region are found to be insufficient to explain the observed water masses. We therefore propose a new mechanism by which ice wall melting, previously identified in summer surface water next to the RIS (AASWG), promotes formation of a freshwater wedge immediately adjacent to the ice wall. This allows isopycnals to curve downwards, forming a conduit by which the surface waters of the SW Ross Sea are directly connected with the cavity, and inflow by tides and eddies is enhanced. In support of the new mechanism, we present observations from the RIS cavity demonstrating inflow of unmodified AASW to 230 mbsl within the cavity. In addition, seal-borne observations from the SW Ross Sea reveal the existence of a freshwater wedge that thins with distance from the ice shelf front.

Miles Bertie

Durham University - a.w.j.miles@durham.ac.uk

Seasonal monitoring of Antarctic ice shelf velocity.

The 6/12 day repeat cycle of the Sentinel-1a/b satellites has provided unprecedented coverage of the Antarctica Ice Sheet enabling the investigation of previously undocumented processes. Using offset tracking on pairs of Sentinel 1a/b SAR images we present velocity dataset at a temporal resolution of every 6-12 days, which covers most fast flowing (>300 m yr) Antarctic outlet glaciers and ice shelves over the past 18 months. Analysis of this large dataset reveals contrasting behaviour. Some outlet glaciers show evidence of a seasonal cycle in velocity which we link to sea-ice buttressing (e.g. Totten, Moscow University, Rayner), whereas others show little change in their behaviour throughout the observational period (e.g. Cook, David). We are also able to analyse the immediate dynamic response in velocity to recent calving events (e.g. Pine Island). The mechanisms driving rapid changes in outlet glacier velocity may ultimately play an important role in their future stability.

Masahiro Minowa (Oral Presentation)

Instituto de Ciencias Fisicas y Matematicas, Universidad Austral de Chile –

minowa.masahiro@gmail.com

Water Properties and Circulation Underneath a Floating Tongue of Langhovde Glacier, East Antarctica.

Basal melting of ice shelves and glacier floating tongues is an important ice sheet ablation process of the Antarctic ice sheet. Acceleration in the melt rate is considered as the driver of recent ice mass loss in Antarctica. It is thus important to study water properties and circulations underneath Antarctic ice shelves and floating tongues. Despite the importance and interests, in-situ subshelf data are sparse because measurements are difficult under several hundred-meter-thick ice. To better understand subshelf environments of an Antarctic outlet glacier, we performed how-water drilling and subshelf measurements at Langhovde Glacier in East Antarctica. We drilled through the floating part of the glacier at four locations in 0.5-2.5 km from the ice front. Sea floor under the drilled region deepens downglacier from 380 to 510 m below sea level, whereas ice thickness decreases from 412 to 234 m. The boreholes were utilized to lower down a CTD (conductivity, temperature and depth) profiler, current meter, video camera, and water samplers into the subshelf ocean. Two boreholes were instrumented with mooring systems for long-term measurements of temperature, salinity, current and pressure. Potential temperature of the seawater near the ice sole was between -1.4 and -1.1°C, which was ~0.8°C warmer than freezing temperature. Temperature slightly increased towards the ocean floor at all the drilling sites. Salinity was around 34.30 psu with a spatial variability in the vertical columns within 0.05 psu. Water flowed upglacier, except for the layer directly below the ice shelf where water moved towards the ocean. The mean basal melt rate was calculated as 1.4 m/yr by solving the heat and salt flux balance equations at ice-ocean boundary. The melt rates were greater near the grounding line. Mooring measurements over four weeks showed short-term (day to weeks) variations in temperature (0.2°C) and salinity (0.1 psu). Subshelf water was sampled at several depths for oxygen isotope measurement. In the presentation, we report the results of the borehole measurements and discuss implications for basal melting and subshelf environments of Antarctic outlet glaciers.

Minowa Masahiro (Poster)

Institute of Low Temperature Science - minowa.masahiro@gmail.com

Tidally controlled ice dynamics observed at the floating tongue of Langhovde Glacier, East Antarctica.

The Antarctic ice sheet is fringed by ice shelves and glacier floating tongues, which play crucial roles in the mass change of the ice sheet. Understanding the motion of the floating ice is important because it controls the rate of ice transport from the interior to the marginal regions. Previous studies have shown that ocean tides have a substantial influence on horizontal and vertical ice motion. Nevertheless, the amplitudes and phases of the variations are different among glaciers, indicating complex mechanisms linking the tidal forcing and the tidally controlled ice motion. To investigate the tidally controlled ice motion of a glacier floating tongue, we observed ice speed and icequakes near the front of Langhovde Glacier in East Antarctica for several weeks in January 2018. We installed four GPS stations on the ~3-km long floating tongue at 0.3-2.5 km from the ice front. A seismic array formed of three seismometers was installed at 0.5 km from the ice front. Diurnal and semi-diurnal variations in the ice speed were observed at all the GPS stations. At the lowermost GPS, for instance, the maximum speed reached 250% of the ground level. The maximum ice speed was measured during falling tide, implying contribution of elastic deformation to the horizontal ice motion. Occurrence rates of icequakes also showed diurnal and semi-diurnal variations. We observed a greater number of icequakes during the rising tide and the highest ice speed, presumably due to vertical bending and horizontal stretching. In the presentation, we report details of these measurements and discuss possible mechanisms driving the observed dynamics of the glacier floating tongue.

Middleton Leo

University of Cambridge/British Antarctic Survey - lm758@cam.ac.uk

In 2012 a drilling mission led by Keith Nicholls of the British Antarctic Survey installed in situ monitoring equipment beneath three ice shelves in West Antarctica. The aim of these instruments was to obtain the first long term measurements of the turbulent boundary layer beneath ice shelves. The current parameterisation of the Ice Ocean Boundary Layer (ISOBL) is based upon fairly primitive physics, and is in need of updating if we are to accurately forecast the effect of ocean warming on ice shelf melt rates. The data from this mission was intended to help us better characterise the ISOBL, and provide some much needed data to guide our modelling efforts. Whilst deploying CTD casts through the borehole on the George VI Ice Shelf, the team noticed a signature of staircasing in the profiles. This was the first time this behaviour had been observed beneath ice shelves and became the topic of a paper by Kimura et al. in 2015, who argued that these were in fact double-diffusive staircases, and presented some analysis of the CTD data. The work presented in this poster is the first analysis done of the in situ velocity and temperature data collected on the aforementioned mission. It poses some key questions about this under-ice regime in which double diffusion may play a role, and it contains a discussion of the energy budget which gives some insight into the underlying dynamics. The larger work in which this sits is concerned with constructing some fine resolution (DNS and LES) models of the under-ice environment. The poster will also contain a discussion of these small scale models and the way in which they are being guided by this data. Including also some preliminary work on a model that aims to accurately simulate the observed melt rates beneath George VI.

Mouginot Jeremie

IGE/CNRS/Univ. Grenoble Alpes - jeremie.mouginot@univ-grenoble-alpes.fr

In the northern sectors of Greenland, that hold more than 2.7 m of sea level equivalent, ice drains through ice shelves similarly to Antarctica. Zachariae Isstrøm, in northeast Greenland, is retreating and accelerating, most probably because of enhanced melting at its ice-shelf bottom followed by its break-up. Nioghalvfjerdsfjorden, its neighbor, is also showing signs of thinning close to its grounding line, as is Petermann Gletscher, located 800_km more to the west. Here, we investigate dynamic and geometrical changes of all current and former ice shelves located along the northern coast of Greenland, namely Humboldt Gletscher, Steensby Gletscher, Ryder Gletscher, Ostenfeld Gletscher, Marie Sophie Gletscher, Academy Gletscher and Hagen Bræ. Using satellite and airborne-based remote-sensing sensors, we reconstruct the time series of speed, grounding-line position, submarine melt, ice thickness and surface elevation changes since the 80s. We will provide an update of the glacier ice discharges and will discuss any large-scale pattern of enhanced melting of the northern Greenlandic ice shelves . We will conclude with the possibility of actual or future destabilization -or lack thereof- of the glaciers in this sector of Greenland.

Nakayama Yoshihiro

NASA Jet Propulsion Laboratory - yoshihiro.nakayama@jpl.nasa.gov

Pathway of Circumpolar Deep Water into Pine Island and Thwaites ice shelf cavities and to their grounding lines.

Yoshihiro Nakayama[1], Georgy Manucharayan[2], Patrice Kelin[1,3], Hector G. Torres[1], Michael Schodlok[4], Eric Rignot[1,5], Pierre Dutrieux[6], Dimitris Menemenlis[1]; (1) Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA,_ (2) California Institute of Technology, Pasadena, CA, USA (3) Laboratoire de Physique des Oceans, IFREMER_CNRS_IRD_UBO, Plouzane, France, (4) JIFRESSE, University of California Los Angeles, CA, USA (5) Earth System Science, University of California Irvine, CA, USA (6) Lamont-Doherty Earth Observatory Ocean and Climate Physics, NY, USA.

Melting of Pine Island and Thwaites ice shelves is caused by Circumpolar Deep Water (CDW) intruding onto the Amundsen Sea continental shelves via submarine glacial troughs located at the continental shelf break. Despite existing works on on-shelf CDW transports with horizontal grid resolutions of ~1-2 km or coarser, it has been difficult to fully resolve sub-ice shelf environments with steep changes in both bathymetry and ice shelf shapes. In this study, we use a regional Amundsen Sea configuration of the Massachusetts Institute of Technology general circulation model (MITgcm) with horizontal and vertical grid spacings of 200 and 10 m, respectively. We calculate time-mean and time-evolving fields of velocity and investigate the mechanisms of how CDW is transported into the ice shelf cavities and to their grounding lines. We find a prominent submesoscale variability in the ice cavity, with scales of motion O(1-5km) and Rossby numbers O(1). Preliminary analysis shows that these submesoscales are formed due to instabilities associated with the positive potential vorticity patches located in the sub ice-shelf mixed layer, particularly near strong topographic features. Our results emphasize the importance of submesoscales processes for sub-ice shelf circulation and thus transport of warm CDW to the grounding lines and ice shelf bases.

Naughten Kaitlin

British Antarctic Survey - kaight@bas.ac.uk

Processes beneath the Filchner-Ronne Ice Shelf (FRIS) are of particular interest to the ice-shelf/ocean community, due to the extensive size of the FRIS catchment, the increasing number of observations within the cavity, and the importance of the surrounding Weddell Sea for the ventilation of the deep ocean. Here we present a new model configuration designed to study the FRIS cavity, using the MITgcm ocean model coupled to the Úa ice sheet model on a regional Weddell Sea domain. Ocean-only simulations, with static ice shelves, will be assessed with respect to their water mass properties, sub-ice shelf circulation, and FRIS melt rates. The first results from fully coupled simulations, with an evolving ice shelf draft, will also be presented. This will include a description of the coupling framework and a discussion of ongoing challenges in ice-sheet/ocean coupling.

Nicholls Keith

British Antarctic Survey - kwni@bas.ac.uk

Sub-mesoscale variability beneath Ronne Ice Shelf, Antarctica.

Keith Nicholls[1], Emma White[2] and Svein Østerhus[3]; (1) British Antarctic Survey, High Cross, Madingley Road, Cambridge CB3 0ET, U.K. (2) University of Southampton, University Road, Southampton SO17 1BJ, U.K. (3) Uni Research Climate, Jahnebakken 5, 5007 Bergen, Norway.

Measurements of oceanographic conditions beneath ice shelves initially focussed on determining the mean circulation within the cavity. The availability of longer time series has more recently allowed the study of seasonal and interannual variability. The all-important fluxes of heat and salt across the ice-ocean boundary layer are now also beginning to be studied using turbulence-resolving instrumentation. To date, the influence of mesoscale and sub-mesoscale oceanographic structures beneath ice shelves has largely been ignored. Here we present observations of such features beneath Ronne Ice Shelf at Site 5, located around 17 km from the west coast of southern Berkner Island. The multi-year datasets consist of measurements from moored current, temperature and conductivity sensors, and radar-based observations of basal meltrates (ApRES). The features are around 5 to 10 km in radius, and are associated with temperature anomalies of about 0.2 degrees C, which is the close to the maximum range in temperatures observed at the site. We discuss the likely nature of the structures, and, assuming them to be eddies, we discuss their probably source, their impact on the basal meltrate, and whether they are particular to the Site 5 region or if they are likely to have a broader relevance within the cavity.

Park Taewook

Korea Polar Research Institute - twpark@kopri.re.kr

Comparisons of Circumpolar Deep Water variability in the Amundsen Sea between simulations and observations.

Taewook Park, Tae-Wan Kim, Kyoung-Ho Cho, SangHoon Lee Korea Polar Research Institute, Incheon 406-840, South Korea Yoshihiro Nakayama, Dimitris Menemenlis Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, USA Pierre Dutrieux Lamont-Doherty Earth Observatory, Columbia University, Palisades, NY, USA.

Outlet glaciers of the Amundsen Sea Embayment (ASE), West Antarctica, have thinned over recent decades. Circumpolar Deep Water (CDW) originated from Antarctic Circumpolar Current is responsible for the thinning due to basal melting beneath ice shelves in the ASE. Observations based on mooring stations as well as hydrography survey during the past decade have revealed that CDW intrusion into the ASE shows year-to-year variations. In this preliminary study on cross-shelf and on-shelf processes, we validate a simulation (2001-2016) of a high-resolution MITgcm ocean model that allows ice shelf-ocean interaction, by comparing with observation data including the latest Araon expedition. Also, we find that zonal wind at the shelf edge can contribute to CDW intrusion from analysis of Mercator-Ocean re-analysis data (1993-2015), thereby delivering more heat into the ASE; however, oceanic responses to local forcing could be underestimated because the horizontal resolution is not fine enough to resolve key bathymetric features and does not have ice shelf-ocean interaction in the cavity.

Prakash Abhay

Stockholm University - abhay.prakash@natgeo.su.se

Where ice sheets meet the ocean through their outlet glaciers, calving of icebergs and disintegration of floating glacier tongues is often observed. Invisible but equally important is submarine melt, below the waterline. Induced by warm waters, melt-undercutting destabilizes glacier fronts and causes a retreat of the grounding line (GL), demarcating the position at the seafloor where grounded glacier ice becomes afloat. A cavity develops, in which ocean water circulates under the glacier tongue, and the geometry of which both depends on and determines submarine melt and calving. Calving and submarine melt at ocean terminating glaciers is likely to become the largest single contributor to sea

level rise over the next century [1,2,3,4,5,6]; it accounts directly for most of the mass loss from the Antarctic ice sheet, and indirectly (through so-called dynamical thinning) for at least half of the increase in mass loss from the Greenland Ice Sheet over the last two decades [7,6]. In the Arctic, the annual specific mass loss due to calving alone is largest from the Svalbard Archipelago [8]. In this project, we investigate the recent and ongoing ocean-induced changes in calving glacier margins in the wider context of the dynamical behavior of the inland ice masses feeding calving glaciers, and to promote data supported simulation-verification-validation. We aim to develop a multiscale model suitable for short, medium and long timescales for glacier calving, submarine melt, and dynamical thinning, driven by novel, glacier proximal datasets comprising of e.g. timeseries of ocean temperatures, and to provide estimates for associated glacier mass loss in 2100 AD. Furthermore, we analyse how uncertainty, inherently associated with forcing and input data to numerical models, propagates to simulation results, and to quantify uncertainty for these results on short, medium and long time scales.

References: 1) DeConto, R., Pollard, D., 2016. Contribution of Antarctic to past and future sea-level rise. Nature 531, 591-597. 2) IPCC, 2013. www.ipcc.ch 3) Luckmann, A., et al, 2015. Calving rates at tidewater glaciers vary strongly with ocean temperature. Nat Comm 6:8566. 4) Moore, J. et al, 2013. Semiempirical and process based global sea level projections. Rev Geophys 51, 484-522. 5) Rignot, E. et al., 2010. Rapid submarine melting of the calving faces of West Greenland glaciers. Nat. Geosci 3, 187-191. 6) Truffer, M, Motyka, R.J, 2016. Where glaciers meet water: Subaqueous melt and its relevance to glaciers in various settings. Rev Geophys, 54, doi:10.1002/2015RG000494. 7) Liu Y., et al, 2015. Ocean driven thinning enhances iceberg calving and retreat of Antarctic ice shelves. PNAS 112(11), 3263-3268. 8) Blaszczyk, M. et al, 2009. Tidewater glaciers of Svalbard: Recent changes and estimates of calving fluxes. Polish Polar Res 30(2), 85-142.

Richter Ole

Institute for Marine and Antarctic Studies - ole.richter@utas.edu.au

Models of ocean-ice shelf interaction around Antarctica are essential to improve predictions of the Antarctic contribution to sea level rise. Here we present a new circum-Antarctic ocean-ice shelf model, which is based on the Regional Ocean Modeling System that includes a thermodynamic representation of ice shelves. The model is forced by prescribed surface fluxes and tides and features an eddy resolving horizontal resolution. Tidal forcing uses a novel approach, that is applying the solution of a global 2D tidal model to the baroclinic pressure gradient at the surface. This way we overcome previous shortcomings of 3D tides on a circumpolar domain. Preliminary results show that the model compares well against tide gauge records for M2 and O1 and observed basal melt rates. The model framework presented here applies, for the first time, tidal forcing at an eddy-resolving resolution on a circum-Antarctic domain and provides a new tool for investigations into tidal melting of Antarctic ice shelves.

Ryan Svenja

Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research - svenja.ryan@awi.de

The Filchner Ronne Ice Shelf (FRIS), located in the southern Weddell Sea, plays a key role in the formation of Weddell Sea Deep and Bottom Water, which are precursors of world ocean's AABW. At present, a large continental shelf covered with cold and dense water protects FRIS from intense melting. Model studies, however, have suggested the potential for enhanced flow of Modified Warm Deep Water (MWDW) toward and under FRIS via the Filchner Trough, causing a substantial increase in basal melt rates by the end of this century. Mooring time series recorded from 2014 to 2016 at 76°S reveal a distinct seasonal cycle in hydrography along the eastern flank of the Filchner Trough. A southward flow of MWDW persists from summer through to autumn, connected to a seasonal shoaling of the Antarctic Slope Front (ASF). In winter, a weakly stratified water column with temperatures being at the surface freezing point, suggests the occurrence of deep convection. The mooring time series was now extended to 2018 and preliminary results are presented. While the general pattern of the described seasonal cycle is reaffirmed, a very strong warm inflow with temperatures above -1°C is observed in 2017, where bottom temperatures above -1.5°C persist throughout the whole winter. This event might be comparable to the warm inflow event observed in 2013 where MWDW was found in the vicinity of the Filchner Ice Shelf front in autumn. Measurements from a LoTUS buoy in 2017 show bottom temperatures above -1.4°C at 77°S in Mai.

Silvano Alessandro

University of Tasmania - Alessandro.Silvano@utas.edu.au

Freshening by glacial meltwater enhances melting of ice shelves and reduces formation of Antarctic Bottom Water

Strong heat loss and brine release during sea ice formation in coastal polynyas act to cool and salinify waters on the Antarctic continental shelf. Polynya activity thus both limits the ocean heat flux to the Antarctic Ice Sheet and promotes formation of Dense Shelf Water (DSW), the precursor to Antarctic Bottom Water. However, despite the presence of strong polynyas, DSW is not formed on the Sabrina Coast in East Antarctica and in the Amundsen Sea in West Antarctica. Using a simple ocean model driven by observed forcing, we show that freshwater input from basal melt of ice shelves partially offsets the salt flux by sea ice formation in polynyas found in both regions, preventing full-depth convection and formation of DSW. In the absence of deep convection, warm water that reaches the continental shelf in the bottom layer does not lose much heat to the atmosphere and is thus available to drive the rapid basal melt observed at the Totten Ice Shelf on the Sabrina Coast and at the Dotson and Getz ice shelves in the Amundsen Sea. Our results suggest that increased glacial meltwater input in a warming climate will both reduce Antarctic Bottom Water formation and trigger increased mass loss from the Antarctic Ice Sheet, with consequences for the global overturning circulation and sea level rise.

Slater Donald

Scripps Institution of Oceanography - daslater@ucsd.edu

Parameterizing total mass loss by submarine melting at tidewater glaciers.

Submarine melting of ice in contact with the ocean at the calving fronts of tidewater glaciers is thought to be a key link in the climate system, coupling the atmosphere and ocean to the dynamics of the Greenland Ice Sheet. With increasing interest in coupling ice and climate models, necessarily at coarse resolution, simple parameterizations for submarine melting are highly desirable. Process studies have revealed essentially four modes of submarine melting: (i) rapid, focused melting within vigorous plumes driven by the drainage of subglacial runoff from focused channels beneath the glacier, (ii) widespread melting within weaker plumes driven by diffuse drainage of subglacial runoff from beneath the glacier, (iii) melting outside of plumes driven by fjord-scale secondary circulations, and (iv) weak melting driven by spontaneous convection in the absence of subglacial runoff. Current parameterizations for submarine melting are based exclusively on the first mode. While this mode likely drives the most rapid melting, plumes are localized features typically occupying a small fraction of the calving front and thus assuming current parameterizations apply over the full calving front may grossly overestimate total mass loss by submarine melting. Equally, neglecting melting outside of plumes may grossly underestimate total mass loss. Here we motivate simple parameterizations for melting under each of the above modes, and validate these parameterizations with a suite of idealized numerical simulations. Given knowledge of the magnitude of subglacial runoff, deep fjord water temperature, calving front geometry, and some knowledge of the subglacial drainage system, the result is an estimate of total mass loss by submarine melting. We provide an example application to two contrasting glaciers in Greenland.

Steiger Nadine

Geophysical Institute, University of Bergen - nadine.steiger@uib.no

How does warm water intrude into ice shelf cavities? A laboratory and modeling study.

Many ice shelves fringing the Antarctic ice sheet are threatened by relatively warm water that intrudes into ice shelf cavities and melts the ice from below at an increasing rate. Warm circumpolar deep water originates from the deep Southern Ocean and flows along the continental shelf break. Its transport onto continental shelves and underneath ice shelves is prohibited by large steps in ocean thickness at the continental shelf break and at ice shelf fronts. Glacially carved troughs cross-cutting continental shelves allow for on-shelf transport of that warm water. Reaching the ice shelf front, this topographically steered current is prevented from entering ice shelf cavities due to conservation of potential vorticity. It is not clear to what extent barotropic currents can continue below the ice shelf, and if they are blocked whether a baroclinic flow can instead penetrate into the cavity. We use a 13m-diameter rotating platform and the MIT general circulation model to study how much and under which conditions a current is blocked by an ice shelf front. Both methods use an idealized setup with a v-shaped channel sloping down from the water source towards an ice shelf front. The cubic ice shelf does not interact thermodynamically with the water to solely focus on dynamic processes. The laboratory experiments and the numerical model results agree largely and show that a barotropic current is deflected as it hits the ice shelf front. However, the current can partly enter the cavity once it reaches into deeper water depths at the center of the channel. A baroclinic current enters the cavity undisturbed.

Craig Stevens

NIWA/Uni Auckland - craig.stevens@niwa.co.nz

Observations of the thermohaline structure of the central Ross Ice Shelf ocean cavity.

Craig Stevens[1,2], Christina Hulbe[3], Gavin Dunbar[4], Mike Brewer[1], Natalie Robinson[1] and Stefan Jendersie[1]. (1) NIWA, New Zealand; (2) Univ. Auckland; (3) Univ. Otago; (4) Victoria Univ. at Wellington.

Here we report on a new hydrographic dataset from beneath the Ross Ice Shelf Cavity from the Aotearoa New Zealand Ross Ice Shelf Programme HWD2 borehole melted in the central region of the shelf in December 2017. While broadly comparable to the only previous data in the region, J9 in 1977, there are some unique features to these new profiles and associated velocity timeseries. Data come from CTD profiles over a ten-day period, moored CTD and current meters, shear microstructure and visual imagery. The mooring data are telemetered and so recent results will be shown. There are clear basal and benthic boundary layers separated by a highly interleaved region. In addition, there is evidence of ephemeral re-freezing on the shelf under-side, as well as regions within the interleaving that approach in situ freezing temperature. These data will be contextualized with concurrent oceanic data and numerical simulations (ROMS) of the cavity circulation captured as part of a Ross Sea modelling exercise.

Straneo Fiamma

Scripps Institution of Oceanography UCSD - fstraneo@ucsd.edu

Propagation of oceanic anomalies to the margins of Helheim Glacier, SE Greenland.

Fiamma Straneo, Donald Slater, James Holte (SIO - UCSD) and Leigh Stearns (KU).

The speed up (slow down) and terminus retreat (advance) of Greenland's marine terminating glaciers has been linked with variations in submarine melting at the glacier terminus as a result of oceanic or atmospheric variability. Yet reconstructions of changes in oceanic forcing have been challenging to obtain because they require a knowledge of the ocean properties at the glaciers' margins which are difficult to obtain and, at best, based on summer records over a handful of years. Here we use a relatively long record of fjord and continental shelf properties, derived from moorings from summer 2009 to 2017, in combination with meteorological station data and a plume model, to show how variations in oceanic forcing at Helheim's margins are linked to large scale oceanic and atmospheric changes in the North Atlantic. Using the relation derived for this recent decade, and available historical oceanic and atmospheric data, we then reconstruct the oceanic forcing for Helheim from the 1950s to present day and discuss to what extent it can capture the observed and reconstructured variability of Helheim.

Stulic Lukrecia

Alfred Wegener Institut - lstulic@awi.de

Sea ice production in the southern Weddell Sea: role of atmospheric forcing and fast ice.

Lukrecia Stulic[1], Ralph Timmermann[1], Torsten Kanzow[1], Stephan Paul[1], Rolf Zentek[2], and Gunther Heinemann[2]; (1) Alfred Wegener Institute, Climate Sciences, Bremerhaven, Germany, (2) University of Trier, Trier, Germany.

In the southern Weddell Sea coastal polynyas, enhanced ice production leads to the formation of dense shelf water that drives thermohaline circulation and influences the circulation beneath the Filchner-

Ronne Ice Shelf. We use the Finite Element Sea ice-ice shelf-Ocean Model (FESOM) to investigate sea ice production and High Salinity Shelf Water (HSSW) formation in the southern Weddell Sea coastal polynyas for the period 2002-2014. The model forced with ERA-Interim reanalysis data reproduces well the locations and high freezing rates in the major coastal polynyas when compared to MODIS retrievals with the largest contributions from the Ronne and Brunt Ice Shelf polynyas. Using output from the regional atmospheric model COSMO-CLM as a forcing data set reduces polynya ice production, mostly over the eastern shelves due to weaker offshore winds. An additional experiment is conducted to represent polynyas formed on the lee side of grounded icebergs. MODIS data is used to obtain reliable information about existence, location, and extent of the fast-ice bridge formed between the Filchner-Ronne Ice Shelf (FRIS) and a chain of grounded icebergs. Position and shape of the fast-ice bridge affect interannual variability of polynya sea ice production, increase sea ice production westward of the ice bridge and suppress it eastward of it, leading to a more realistic polynya representation. It is found that high-resolution atmospheric forcing and treatment of grounded icebergs are crucial to realistically reproduce ice production in the region. Consequences for the HSSW production and basal melt of FRIS will be discussed.

Timmermann Ralph

AWI - Ralph.Timmermann@awi.de

Ice sheet-ocean coupling with FESOM: Technology, caveats and perspectives.

The Regional Antarctic and Global Ocean (RAnGO) model has been developed to study the interaction between the Southern Ocean and the Antarctic ice sheet. The coupled model is based on a global implementation of the Finite Element Sea-ice Ocean Model (FESOM) with a mesh refinement in the Antarctic marginal seas and in the sub-ice shelf cavities. The cryosphere is represented by a regional setup of the ice flow model RIMBAY comprising the Filchner-Ronne Ice Shelf and the grounded ice in its catchment basin up to the ice divides. Coupling is achieved by providing melt rates from FESOM's ice-shelf component to the base of the RIMBAY ice shelf. RIMBAY returns ice thickness and the position of the grounding line. To adjust the FESOM domain to varying cavity geometries, we use a pre-computed mesh that comprises the present-day ocean plus areas that may potentially become ungrounded. For each coupling step, the coupler determines the area covered by ocean and removes grid nodes that are covered by grounded ice. Changes in water column thickness are easily handled by the terrain-following vertical coordinate system in the sub-ice cavity. RAnGO simulations with a 20th-century climate forcing yield realistic basal melt rates and a quasi-stable grounding-line position close to the presently observed state. In a warm-water-inflow scenario reaching to the end of the 22nd century, the model suggests an ice shelf thinning by almost 300 m at the inflow of Support Force Glacier, and a gradually retreating grounding line at this and several other ice streams. The potentially negative feedback from ice-shelf thinning through a rising in-situ freezing temperature is more than outweighed by the the increasing water column thickness and the steepening of the ice base slope in the deepest parts of the cavity. Compared to a control simulation with fixed ice-shelf geometry, the coupled model thus yields a slightly stronger increase of ice-shelf basal melt rates. Compared to the first operational version of RAnGO, the computational burden associated with dynamic grid modification has been reduced by 90% now. However, several details of the numeric implementation still call for refinement. While the terrain-following vertical coordinate in the ocean model yields an elegant framework for a smooth representation of sub-ice shelf cavities, the requirement of a minimum water column thickness even in shallow grounding zones and a spurious lateral (not isopycnal) ocean diffusivity call for attention. Sensitivity studies with varying minimum water column thicknesses for the Filcher Ronne Ice Shelf cavity indicate that the area-mean basal melt rate is largely insensitive to a spuriously increased water column thickness. However, the local distribution of melt rates near the grounding line may vary substantially, with the potential to exaggerate grounding line sensitivity in the case of an artificially deepened water column. Ongoing work is exploring the potential use of z-coordinates or largely arbitrary vertical coordinate systems in coupled models.

Vankova Irena

New York University - iv356@nyu.edu

Vertical structure of diurnal englacial hydrology cycle at Helheim Glacier, East Greenland.

The interior dynamics of Helheim Glacier were monitored using an autonomous phase-sensitive radio-echo sounder (ApRES) during two consecutive summers. The return signals from all observational sites exhibited strong non-tidal, depth-dependent diurnal variations. We show that these variations in the glacier interior can be explained by an englacial diurnal meltwater cycle: a data interpretation that assumes constant ice-column composition through time leads to dynamical inconsistencies with concurrent observations from GPS and terrestrial radar. The observed diurnal meltwater cycle is spatially-variable, both between different sites and in the vertical, consistent with the existence of a dense and complex englacial hydrologic network. Future applications of this observational technique could reveal long-term meltwater behavior inside glaciers and ice sheets, leading to an improved understanding of the spatio-temporal evolution of the basal boundary conditions needed to simulate them realistically.

Vignes Lucie

LOCEAN - lucie.vignes@locean-ipsl.upmc.fr

Warm water circulation toward Antarctic ice shelves: an experimental approach.

The observed thinning of many ice shelves surrounding Antarctica is linked to ocean heat fluxes, but the dynamics governing the flow of warm waters towards the ice shelf ice shelves are poorly known. A set of experiments has been realized in order to understand the factors controlling the heat flux circulation. The heat reservoir is located off the continental shelf and must past a topographical barrier : the continental shelf break. An idealized topography of the Weddell Sea continental shelf, shelf break and the Filchner Depression was built within the 13m large rotating tank Coriolis at LEGI (Grenoble). Barotropic and baroclinic flows were injected onto the slope using a pumped source. Different parameters were varied during the experiments in order to understand which were the ones to control the circulation.

Vreugdenhil Catherine

University of Cambridge - cv329@cam.ac.uk

Large-eddy simulations of turbulence in the ocean boundary layer below ice shelves.

The melting of ice shelves around Antarctica and Greenland has implications for ocean circulation and sea-level rise. Turbulence and mixing in the boundary layer below ice shelves stand to effect ocean driven melting, however knowledge of these processes is incomplete. Here, we use large-eddy numerical simulations to resolve all but the smallest scales of turbulence in an idealised ocean domain. The domain is bounded from above by the ice shelf base under melting conditions that lead to a vertical stratification in both temperature and salinity. The simulations solve the Boussinesq and non-hydrostatic equations of motion, together with a state-of-the-art subgrid-scale model. Far-field ocean currents and modest slopes away from the horizontal are included to examine how such dynamical processes can impact the stratified turbulence in the boundary layer and hence ice shelf melt rates. Conditions are chosen similar to those at Antarctic sites to compare with observations and allow exploration of future scenarios.

Warren Stephen

University of Washington - sgw@uw.edu

Rethinking green icebergs Ice crystals form in supercooled seawater beneath several Antarctic ice shelves.

As they float up to the ice-shelf base they scavenge particles from the water and incorporate them into the growing basal ice. On the Amery Ice Shelf the resulting marine-ice layer is ~100 m thick; it differs from sea ice in that it is clear, desalinated, and bubble-free. Many of the icebergs produced by the Amery are therefore composite icebergs; the upper part is meteoric glacial ice from snowfall and the lower part is frozen seawater (marine ice). When the icebergs capsize, the marine ice is exposed to view. Icebergs of marine ice vary in color from dark blue to green, depending on the nature and abundance of foreign constituents in the seawater that became trapped in the ice as it grew. A red or yellow material (i.e., one that absorbs blue light), in combination with the blue of ice, can shift the wavelength of minimum absorption to green. Previously, dissolved organic carbon (DOC) had been proposed to be responsible for the green color (Warren et al., 1993). Subsequent measurements of low DOC values in green icebergs, together with the recent finding of large concentrations of iron in core samples of marine ice from the Amery Ice Shelf (Herraiz-Borreguero et al., 2016), suggest that the color of green icebergs is caused more by iron-oxide minerals than by DOC (Warren et al., 2018). The iron-oxide minerals would have been components of "glacial flour" produced by erosion of bedrock at the base of the ice sheet and delivered to the sub-ice-shelf water. Radiative-transfer modeling, using optical constants of goethite (FeOOH), show that the measured iron concentrations can indeed shift the color of ice from blue to green. Upon transport offshore and melting, green icebergs can fertilise surface waters with iron. If it can be demonstrated that (a) the DOC content of marine ice is routinely too small to significantly affect the reflectance spectrum of icebergs, and (b) there is a consistent mineralogy for the iron in the particles, then a remote-sensing method might be developed to assay the iron content of icebergs using reflectance spectroscopy from an instrument deployed on a drone or an airplane.

References:
Herraiz-Borreguero, L., D. Lannuzel, P. van der Merwe, A. Treverrow, and J.B. Pedro, 2016: Large flux of iron from the Amery Ice Shelf marine ice to Prydz Bay, East Antarctica, J. Geophys. Res. Oceans, 121, 6009-6020, doi:10.1002/2016JC011687.
Warren, S.G., C.S. Roesler, V.I. Morgan, R.E. Brandt, I.D. Goodwin, and I. Allison, 1993: Green icebergs formed by freezing of organic-rich seawater to the base of Antarctic ice shelves. J. Geophys. Res. (Oceans), 98, 6921-6928 and 18309.
Warren, S.G., C.S. Roesler, R.E. Brandt, and M. Curran, 2018: Green icebergs revisited. In preparation for J. Geophys. Res. (Oceans).

Wearing Martin

Lamont-Doherty Earth Observatory, Columbia University, New York, USA - mgw2133@columbia.edu

The Re-grounding of the Henry Ice Rise Inferred from Ice-Penetrating Radar.

Martin Wearing and Jonathan Kingslake.

Lamont-Doherty Earth Observatory, Columbia University, New York, USA.

We present ground-based ice-penetrating radar data from the Henry Ice Rise (HIR) in the Ronne Ice Shelf, West Antarctica that indicates re-grounding during the Holocene. Relic crevasses and melt synclines are observed upstream of the present-day grounding line. We conclude that these features formed during a previous flow configuration, from which the grounding line has since advanced to its current position. We hypothesize that initial grounding of the floating ice shelf occurred over a bathymetric high, triggered by GIA uplift. This formed an ice rumple that migrated upstream off the high point. The present-day ice rise then evolved from lower bathymetry, with the history of advance preserved in disturbed isochrones and relic basal crevasses that were grounded with the advance. Using a simple ice-flow model we date the burial of features within HIR. Taking into account uncertainty in accumulation, firn density, radar-derived depth, ice-thickening history, initial crevasse height, and GIA uplift, we estimate a burial time of 4 ± 2 kyr before present for the oldest relic crevasses, indicating that the ice rise formed at approximately this time. According to previously published ice-sheet modelling results, this re-grounding may have increased the buttressing generated by the Ronne Ice Shelf and led to thickening and advance of the main ice-sheet. By dating the formation and constraining the details of ice-rise formation, these new results can provide useful constraints on both large-scale ice-sheet models and models of ice-rumples and ice-rise formation.

Zeising Ole

Alfred-Wegener-Institut Helmholtz-Zentrum fur Polar- und Meeresforschung - olezeising@gmail.com

Is basal melting indeed enhanced in melt channels?

Ole Zeising[1], Daniel Steinhage[1], Keith Nicholls[3], Hugh Corr[3], Craig Stewart[4] and Angelika Humbert[1,2]; (1) Alfred Wegener Institute, Helmholtz-Centre for Polar and Marine Research, Bremerhaven, Germany (2) University Bremen, Bremen, Germany (3) British Antarctic Survey, Natural Environment Research Council, Cambridge, UK (4) Scott Polar Research Institute, University of Cambridge, Cambridge, UK.

Enhanced basal melting on ice shelves can reduce the buttressing effect to the feeding glacier. A major question is whether basal melting is concentrated in channel-like structures at the ice base and if this dominates the basal melt distribution. Here, we present the distribution of basal melt rates from Filchner Ice Shelf, Antarctica along the flow line of Support Force Glacier (SFG). In this study, the basal melt rates are based on phase-sensitive radar measurements during a field campaign in 2015/16 and

2016/17 and were estimated by subtracting the measured vertical strain rate from the observed thinning of the ice shelf. Highest basal melt rates > 2 m/a were found in the vicinity of a melt channel near the grounding line of the SFG. Measurements from inside the channel reveal a reducing basal melt rate, from 1.5 m/a near the grounding line, to gentle freezing 45 km further downstream. Basal melt rates of between 0 m/a and 1 m/a were measured in the central flow line of the SFG. The distribution, as well as the magnitude of the basal melt rates presented in this study, match results derived from satellite data. Data from an autonomous radar station show season-independent basal melting and demonstrates a tidal dependency.
