International Research Training Group
"Processes and impacts of climate change in the North Atlantic Ocean and the Canadian Arctic"

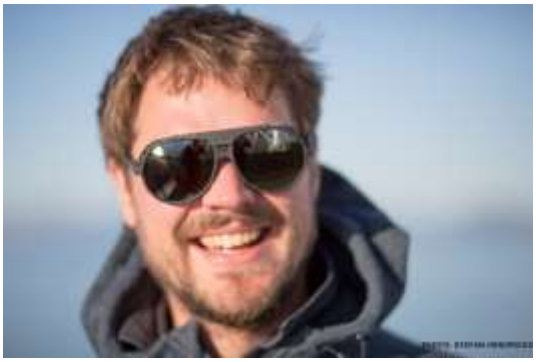
VII. Annual Meeting

26 – 30 October 2020

MARUM, University of Bremen

VII. Annual Meeting of ArcTrain

Invited Speakers



Benjamin Rabe (AWI, Bremerhaven)

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MOSAiC: a year in the Arctic ice and ocean

Benjamin Rabe is a physical oceanographer who graduated with a PhD at the University of Southampton / National Oceanography Centre in 2004 working on laboratory experiments of exchange flows through ocean straits. He then proceeded to GEOMAR in Kiel to work on the upper thermohaline circulation in the Tropical Atlantic using output from model simulations and observations by ARGO profiling floats. After this brief tropical interlude, he joined the Alfred Wegener Institute in Bremerhaven to study Arctic upper ocean processes from 2006, where he is now looking at large scale freshwater variability and biochemical/physical processes. He has been co-coordinating the distribution of autonomous buoy observations and the work of team OCEAN within the Multidisciplinary drifting Observatory for the Study of Arctic Climate (MOSAiC) project. The project aims to understand medium to small scale processes of ocean-ice-atmosphere interaction.

Georgi Laukert (GEOMAR, Kiel)

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Isotopic tracers of ocean circulation and biogeochemical processes in the Arctic Ocean

Georgi Laukert is a postdoctoral researcher at GEOMAR focusing on the distribution, behavior and biogeochemical cycling of nutrients and trace elements in the Arctic Ocean by applying various novel and well-established isotope tracers. He obtained his B.Sc. and M.Sc. degrees at the University of Freiburg in 2008 and 2011, respectively, and completed his doctorate with distinction at the University of Kiel in 2017. Outside academia he worked as an exploration geochemist for a Colombian exploration and mining company in 2011 and 2012. He is involved in GEOTRACES, is a member of the EuroMarine early career network OYSTER and Council Member of APECS.

Lourdenie Jean (Montreal)

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L'environnement c'est intersectionnel!

Intersectional feminist, speaker and community worker, Lourdenie is a passionate for social sciences who loves to marry her interest for arts and social justice. Currently, she is investing most of her time on her initiative L'environnement, c'est intersectionnel (The environment is intersectional). It is an educational platform to widen our take on the climate crisis whilst making punctual projects to dismantle our ways of consuming.

Martin Jakobsson (Stockholm University)

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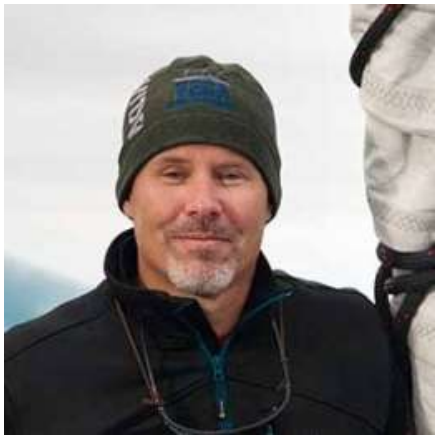
Arctic glacial history



After completing his PhD in Stockholm and his first postdoc at the University of New Hampshire, Martin returned to Stockholm in 2004, where he is now Professor of Marine Geology and Geophysics and head oft he Department of Geosciences. He is member and 1:st Vice President the Royal Swedish Academy of Sciences. Martin spent more than one year onboard ocean research vessels and acted been Co-Chief Scientist on eight international ocean expeditions. His research focusses on the Arctic Ocean glacial history, the West Antarctic Ice Sheet, submarine glacial landforms and geophysical seafloor mapping using acoustic methods. In his talk, he will discuss the progres over the last decades concerning our knowledge of the Northern Hemisphere ice-sheets prior to the Last Glacial Maximum (LGM). Since traces of the older glaciations are scarce, erased during subsequent ice advances, the uncertainties of pre-LGM ice sheets' extents and behaviours remain high. However, a recent synthesis of numerical modelling results and other information reveals interesting patterns throughout the Quaternary. An intriguing component of the Arctic Ocean glacial history is the existence of km-thick large floating ice shelves, which during, at least one previous glacial period, i.e. Marine Isotope Stage 6 (ca 140 ka), may have extended virtually across the entire Arctic Ocean.

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Abstracts of poster presentations

Tiffany Audet, Université du Québec à Montréal

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Recent evolution of hypoxia along the Laurentian Channel from biogenic content of sediment

Dissolved oxygen concentration in the deep waters of the Estuary and Gulf of St. Lawrence has declined dramatically over the past century. This decline lead to hypoxia in the Lower St. Lawrence Estuary. We assume that this hypoxia is the result of several factors; natural or anthropogenic, including a modification of the ocean circulation in the northwestern North Atlantic, the warming of deep waters, and eutrophication. Recent changes in hypoxia are non-linear and could correspond to quasi-cyclical variability. Thus, it is relevant to reconstruct the variations of deep waters oxygenation over long periods of time exceeding short instrumental series. In this context, the study aims to develop an index of the severity of hypoxia from micropaleontological tracers, mostly benthic foraminifera. This study focuses on four sediment cores collected along the Laurentian Channel that cover the recent period characterized by an increase in hypoxia. Preliminary results illustrate a decrease in taxonomic diversity with the severity of hypoxia. In sediments of the Laurentian Channel, affected by hypoxia, the results indicate the dominance of low oxygenation conditions tolerant taxa, *Brizalina subaenariensis* and *Eubuliminella exilis*, during the last decade.

Niraula Bimochan, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Bremerhaven

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Sea ice edge forecast using probabilistic damped anomaly persistence

Recent advancement in dynamical sea-ice models have enabled weather agencies to forecast sea-ice conditions at sub-seasonal to seasonal timescales. In previous studies using the S2S dataset, the ice-edge output of various forecasting centers was compared against reference forecasts to assess the predictive skill of the models. However, the simplest types of reference forecasts – persistence of the initial state and climatology – do not exploit the observations optimally and thus lead to artificially high forecast skill. For spatial objects such as the ice-edge location, the development of damped-persistence forecasts that combine persistence and climatology in a meaningful way poses a challenge. With this motivation, we have developed a probabilistic reference forecast method based purely on ice-edge observations that combines the climatologically derived probability of ice presence with initial anomalies of the ice edge. We have tested and optimized the method based on minimization of the Spatial Probability Score (SPS), and compared it to the output from other models in the S2S dataset. Besides SPS we also applied the Modified Hausdorff Distance (MHD) as verification metric to make sure that the results are robust to the choice of the metric. We find that the resulting reference forecasts provide a challenging benchmark to assess the added value of dynamical forecast systems.

Charles Brunette, McGill University, Montreal

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Improving sea ice motion tracking: a new parameterization for the free drift of sea ice

Tracking the motion of sea ice in a Lagrangian framework can be used to produce skillful seasonal forecasts of sea ice at the pan-Arctic scale (Williams et al. 2016) and at the regional scale (Brunette et al. 2019). Several applications of Lagrangian ice tracking require spatially and temporally complete ice motion datasets. Free drift estimates are important for complementing drifting-buoy and satellite-derived ice motion estimates, especially in the summer when less satellite drift vectors are available (e.g.: Polar Pathfinder, Tschudi et al. 2019). However, current free drift estimates are poorly-constrained and present a low speed bias compared to buoy drifts. To improve the quality of ice motion estimates in the summer, we propose to compile a new free drift sea ice motion dataset, based on surface winds from ERA5 and calibrated on drifting buoys from the International Arctic Buoy Program. We include dependencies of free drift velocity on sea ice concentration and thickness, which will improve the representation of temporal and spatial variability of sea ice in a free drift regime. We present work on the parameterization of an ice state dependent wind-ice transfer coefficient and wind-ice turning angle, and estimates of the near surface oceanic currents that are necessary to constrain ice motion.

Shettima Bukar, University of Bremen

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Elucidating the internal structure of Heinrich-event layers, south-eastern Grand Banks slope, Newfoundland

The North Atlantic Ocean (NAO) is one of the key drivers of global climate change and an important region for palaeoclimate studies. During the last (as well as previous) glacial period, huge armadas of icebergs mainly from Laurentide ice-sheet have been discharged periodically into the NAO through the Hudson Strait. Subsequently, these icebergs were influenced by ocean currents and eventually depositing their entrained sediments (IRD) as they thaw. Compositionally, it is established that Heinrich event layers consist of varied and discrete rock fragments originating from different parental sources. However, the Heinrich layers found at South-eastern Grand Banks are not only made up of discrete rock fragments but rather the beds displayed some internal architecture. In that, enhanced signals of rock magnetic proxies are observed at the top and bottom of each event layer. The hypothesis is that specific detrital rock types were deposited more than others at a given during the course of evolution of each individual bed. Hence, the intended aim is to investigate the depositional sequence of various IRD fragments and inferring their potential provenances using physical rock/mineral characterization and petrography. Thus, determining the region of greater ice-sheet calving during each episode.

Brian Crow, University of Bremen

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An Initial Look at MIS-11 from a High-Resolution Modelling Perspective

In order to better understand how the Greenland ice sheet will respond to periods of significantly warmer temperatures now and in the near future, past warm interglacial periods may offer some insights. The Community Earth System Model has been used to simulate portions of the Marine Isotope Stage (MIS)-11 and MIS-5 periods, which mark the last time the planet was notably warmer than the modern Holocene. During these periods, paleorecords suggest significant retreat of the Greenland ice sheet. We therefore examine the differences in climate conditions during these periods, with a particular focus on the North Atlantic sector and, for this presentation, the MIS-11 period. It is clear that patterns of temperature, precipitation, and the meridional overturning circulation are all substantially different during the peak warmth of MIS-11. These conditions will be used to constrain ice sheet simulations in future work.

Marine Decupere, McGill University, Montreal

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Impact of ocean heat transport on Arctic sea ice extent : the effect of varying horizontal resolution in a climate model suite

Climate model projections of Arctic sea ice extent (SIE) underestimate the observed rate of decline in the minimum sea ice extent. A recent study links future rapid sea ice extent declines with ocean heat transport (OHT) anomalies through the Barents Sea Opening and the Bering Strait, when the SIE is extending over the continental shelves. Moreover, several studies show that high resolution ocean models tend to produce higher Atlantic OHT into the Barents Sea Opening than their coarser resolution counterparts. Since ocean currents are tightly constrained by topography in the Arctic basin, we expect ocean models of different resolutions to show different patterns of sea ice retreat. To investigate the impact of refining horizontal resolution on OHT and subsequent sea ice retreat in the Arctic, we use a hierarchy of global climate models that only differ by their horizontal resolution in the ocean (0.1°, 0.25°, and 1°) and that are run under a pre-industrial and a 1% per year CO2 increase forcing until a doubling of CO2. We find that the rate of decline of the minimum SIE in the medium and high resolution models are in agreement with satellite observations, while that of the low resolution model is much smaller. At all gates, the medium resolution model presents the highest OHT of the model suite in response to the climate change forcing. The link between magnitude and variability in OHT through various gates of the Arctic and the decline in sea ice extent is currently being investigated.

Jade Falardeau, Université du Québec à Montréal

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Ostracod and benthic foraminifer assemblages in the rapdidly changing nearshore areas of northern Yukon

On Arctic shelves, benthic foraminifers in surface sediment have shown to be good indicators of various bottom water conditions, like salinity and temperature, as well as carbon flux based on their assemblages and the geochemistry of their tests. Similarly, in the shallow benthic life of the Arctic Ocean, ostracods are also abundant and diverse and their assemblages relate to specific water mass conditions. In this context, micropaleontological records in sediment archives prove to be a useful tool to shed a light on the impacts of recent anthropogenic forcing on the rapidly changing Arctic Ocean coasts and shelves. As a dynamic environment, sediment records of Arctic shelves are however rare and sparse. Here, we suggest two high-resolution sediment records analysed for their content in ostracods and benthic foraminifers, as well as other microfossils, in a unique depression off northern Yukon, the Herschel Basin. The assemblages will be compared with in situ (mostly winds and erosion rates) and reanalysed data, to improve our knowledge on their ecological affiliation. Based on preliminary results, the records present an important shift at 2000 CE which could be linked to increased coastal erosion, a change in dominant winds and potentially increased food supply. Additional statistical tests and environmental data collection are underway in order to test this hypothesis. This study will not only offer unprecedented micropaleontogical records for the Canadian Beaufort Sea shelf, but should be able to illustrate the impacts of climate change on the habitat of nearshore area marine resources important for local arctic communities.

Marilena Geng, Memorial University of Newfoundland

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Efficient selection of parameter vectors for fully coupled ice-climate modelling of glacial cycles

While the Last Glacial Maximum (LGM) configuration of ice sheets and climate has had much attention, much less is known about glacial cycles further in the past. Geological evidence suggests that the Eurasian ice sheet was overall larger and reached further east during LGM than it did during the Penultimate Glacial Maximum (PGM, e.g. Svendsen et al, 2004). To improve understanding of the penultimate glacial cycle, we are carrying out an order 400 member ensemble of fully coupled ice/climate transient simulations. The simulations are performed with the LCice coupled model (Bahadory and Tarasov, 2018) that incorporates the Glacial Systems Model and Loveclim. Previous experience with modeling last glacial inception (Bahadory et al, Cryosphere discussion), indicates that random parameter selection will tend to give model simulations that fail to be within uncertainty bounds for inferred sea-level. To improve the density of acceptable simulations as well as coverage of the potential glacial phase space, we have added more ensemble parameters (to a total of 19 LOVECLIM parameters) and redesigned the parameter selection algorithm.

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Holocene changes in meltwater discharge and ice sheet dynamics traced by radiogenic isotopes on marine sediments from western Baffin Bay

The reconstruction of past ice sheet variability and their driving mechanism are crucial to understand present ice stream retreats and to improve future simulations. Baffin Bay is a key area to study past ice sheet dynamics because it was surrounded by three large ice sheets during the Late Quaternary: the Laurentide Ice Sheet (LIS), the Innuitian Ice Sheet (IIS) and the Greenland Ice Sheet (GIS). The LIS covered large parts of North America and its retreat led to changes in continental meltwater discharge, which is preserved in marine sediment from western Baffin Bay. To provide insights into Holocene LIS dynamics and climate change, we investigate the radiogenic isotope composition and mineralogical assemblage of two marine sediment cores from the Clyde inlet (GeoB22346-3, GeoB22357-3), a fjord on northeastern Baffin Island. Sr-Nd-Pb isotope ratios from continental detritus and the bulk mineral assemblage can infer the provenance and allows the reconstruction of spatial and temporal variations of meltwater discharge and material transport from the Baffin Island into Baffin Bay. The position of the of the two sediment cores (fjord and inner to mid shelf) provides the opportunity to observe the traceability of a radiogenic isotope signal from a proximal to more distal area of sediment deposition. First results from GeoB22346-3 (fjord) show strong variations in the radiogenic isotope composition in all systems over the past ~9 kyrs and support the hypothesis of rather changing ice sheet dynamics than a constant retreat over the last deglaciation.

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Evolution of sea-surface conditions and primary productivity during the last 2000 years of climatic variability in northern Baffin Bay

The current Arctic warming has resulted in a rapid decline in the thickness and extent of sea ice, with increased freshwater export out of the Arctic. The North Water (NOW) polynya (area of open water conditions in a region characterized by high sea-ice concentrations) in northern Baffin Bay, is influenced by the export of this freshwater through Nares Strait and the Canadian Arctic Archipelago. The formation and maintenance of the NOW polynya rely on both physical (e.g., Nares Strait ice bridges and northerly winds) and oceanic (e.g., upwelling of relatively warm water masses) conditions. However, due to the Arctic warming these formation factors, including the Nares Strait ice bridges, have become more variable in recent years. This project aims at understanding how changes in the Arctic cryospheric outflow has impacted biological and physical parameters in northern Baffin Bay and the NOW polynya in the past. To reach this objective, I will be conducting a high-resolution (multi-decadal), long-term (ca. 2000 years), multi-proxy study on marine sediment cores collected from the western side of the NOW polynya and northern Baffin Bay. Emphasis will be put on understanding changes to the sea-surface conditions, primary production, and nutrient utilization through a combination of biogenic proxies (dinoflagellate cysts, diatoms, and foraminifera) and geochemical analyses (TOC, $\delta^{13}C$, and $\delta^{15}N$). This project will provide key information on the response of the NOW to changes in the freshwater outflow and place recent changes in context with the system's natural variability.

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Sea ice mass balance, vertical ocean heat flux & surface ocean stratification in the Community Earth System Model - Large Ensemble

The presence of freshwater at the surface of the Arctic Ocean leads to strong stratification which traps heat. This amount of heat at the surface drives the mass of sea ice. Here, the Community Earth System Model - Large Ensemble is used to study the temperature and salinity profiles in the Canada Basin. The focus is on change at a monthly scale. First, the sources of heat are calculated by closing a flux budget at ice and ocean surface. Then, a 1D model is built to disentangle the vertical transport from diffusion and from advection through Ekman pumping from the Beaufort Gyre.

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Numerical modeling on landfast ice in Arctic region

Sea ice is regarded as a significant indicator of climate change in the Arctic Ocean. Landfast ice is sea ice that is immobile or almost immobile in coastal regions of the Arctic and peripheral seas, decreasing the transfer of heat, moisture, and momentum. As an extension of the land for travel and hunting, landfast ice also influences the construction of ice roads and arctic shipping routes in the summertime. The formation and maintenance of landfast ice are not well simulated by current sea ice models. We apply different resolution configurations with the MIT General Circulation Model (MITgcm) sea ice package to study the distribution and energy dissipation of landfast ice. The high-resolution model better represents landfast ice with VP rheology, potentially because of the increased shear strength. However, increasing spatial resolution leads to a decrease in the dissipation in shearing. We also find the simple parameterization of coast side drag can help simulate fast ice, especially in the Kara Sea.

Jan-Hendrik Malles, University of Bremen

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Modeling glacier-ocean interactions in the Canadian Arctic

Glaciers in the Canadian Arctic store the greatest amount of glacier ice outside of Greenland and Antarctica and could thus add a large amount of freshwater to the oceans under the influence of anthropogenic warming. As 36 % of the total glaciated area in this region drains into marine-terminating glaciers, their interaction with the ocean, and potential feedback mechanisms involved, are a key to understanding the processes controlling mass changes in this region. Modeling glacier-ocean interactions requires the glacier and ocean model respectively to be able to work with the output of each other. The two main processes concerning frontal ablation of marine-terminating glaciers are calving and submarine melt. Until now, the standard version of the Open Global Glacier Model (OGGM) only contains a parameterization for glacier front calving, but not for submarine melt. Since the latter is directly connected to ocean processes, it is necessary to enable OGGM to work with ocean data variables for the computation of submarine melt estimates in order to supply the ocean model (NEMO) with a realistic freshwater flux input. For this purpose, I formulated a submarine melt parameterization using output data of the ocean model, i.e. the variables temperature, salinity, and speed, for implementation into OGGM. This makes it possible to study the sensitivity of marine-terminating glaciers to the variables and parameters involved, and to explore potential feedbacks in the coupled system.

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Impacts of ocean-ice interactions on the Holocene sedimentary system in northern Baffin Bay

Several AMS radiocarbon dates, geophysical and geochemical data have been obtained on two high-resolution sediment cores GeoB22336-4 and GeoB22315-2, respectively retrieved from the edge of Lancaster Sound and Nares Strait in northernmost Baffin Bay, to better understand the mutual impacts of shrinking ice sheets and changing paleoceanography on sedimentation in the bay during the Holocene. Here we aim to access sediment input from the Arctic region by comparing the aforementioned cores with the hypothesis that a global climate rather than regional forcing controls sediment input through both pathways, resulting in similar depositional records. Preliminary age models constructed generally reveal that both cores enclosed stratigraphic records from the last deglaciation to Holocene. Major changes in sedimentological and physical characteristics, magnetic properties, and XRF-derived elemental compositions reflect rapid shifts in paleoenvironmental and paleoceanographic conditions broadly fitting pre-Holocene and Holocene subdivisions. Our multiproxy record indicates a relatively highly unstable and cold deglacial to early Holocene conditions dominated by glaciomarine, ice-rafted, melt-water plume, and mass-wasting deposits, associated with the rapid retreat of surrounding ice sheets. Post-glacial sedimentation is marked by the dominance of bioturbated hemipelagic and suspension deposits during middle to late Holocene. However, the gradual increase in the delivery of coarse-grained materials in late Holocene is probably linked to neoglacial readvance. Collectively, both cores from the Lancaster Sound and Nares Strait show largely similar lithofacies evolution through time suggesting strong feedbacks of climate, ice sheet dynamics, and oceanography on sedimentation to the bay during the Holocene.

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Breaking The Ice: Fracture angles in sea ice simulations with viscous-plastic rheologies

The arctic sea ice cover plays an essential role in the earth's climate system. The sea ice-covered area is drastically impacted by the current anthropogenic climate change, making accurate sea ice predictions necessary for precise climate scenarios, as well as for navigation. Most heat transfer between the arctic ocean and the arctic atmosphere happens through deformation lines called Linear Kinematic Features (LKFs). Using idealized compression experiments, we investigated the creation of LKFs in sea ice models and their intersection angles. High-resolution sea ice models have been shown to create larger angles than observed. We use a rheology to model sea ice dynamics as a viscous-plastic (VP) medium. Our results show that the rheology's definition influences the fracture angles, especially that the most commonly used rheology cannot model the acute angles below 30º observed in the arctic sea ice. However, we show that modifying the rheology formulation can change this behavior and allow smaller angles. With theories adapted from material sciences, we show that the rheologies' details accurately predict the fracture angles for different strength and deformation parametrizations. This better understanding of the behavior of VP sea ice models will allow building sea ice rheologies for high-resolution simulations with more accurate LKFs.

Linda Thielke, University of Bremen

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Temporal evolution of Arctic sea ice surface temperature and thin ice types from airborne thermal infrared imaging during the winter 2019/2020 MOSAiC expedition

During the MOSAiC expedition thermal infrared imaging from a helicopter is used to measure the brightness temperature of sea ice and ocean water surfaces. Thin ice and open water areas dominate the heat exchange between the ocean and atmosphere during wintertime. This influences the Arctic Climate and becomes even more important in the currently changing Arctic. The sea ice gets thinner, moves faster, and breaks up easier. Observations with high accuracy of parameters like thin ice area or lead fraction are needed for a better understanding. In our study, a thermal infrared camera is flown on a helicopter flights. The measured surface temperature is evaluated up to a regional scale. Two helicopter survey types were conducted: (i) a series of detailed survey flights of the MOSAiC floe and central observatory and (ii) repeated regional flights within the distributed network of autonomous buoys around the ship. We can resolve the surface in a georeferenced map with 1 m grid resolution where several hundred images are combined. Based on the temperature distribution we can conduct a surface classification for thin ice and open water. This allows us to investigate the spatial and temporal variability of the thin ice areas. This knowledge will be used to compare and evaluate the thin ice or lead coverage as well as the ice surface temperature with satellite products. Based on these results, a new understanding of the variability of the ocean to atmosphere heat flux in the Arctic can be developed.

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Carbonate fluxes and calcification depth of planktonic foraminifera in the Fram Strait

The flux of calcite shells of planktonic foraminifera from the surface ocean to the seafloor is a significant component of the marine carbon cycle, especially in the Arctic, where calcite production by coccolithophore algae is low. To predict how the foraminifera-derived calcite flux in the Arctic will behave in response to the ongoing global change, my project will generate new data from plankton tows, sediment traps and marine sediments, allowing me to better constrain the calcification process and parametrize the flux as a function of key environmental parameters.

The first aim of the project is to determine the depth at which planktonic foraminifera calcify. To this end, I am using samples of planktonic foraminifera from plankton tows taken at different locations in the Fram Strait in July 2015. Using vertical profiles of abundances of living specimens and dead shells, as well as shell sizes, shell weights and measurements of stable isotopes, the depth of calcification could be identified. Sizes and weights already indicate that calcification is not restricted by depth. Furthermore, the abundance of empty shells could be used to determine the total foraminifera carbonate flux and the relative contribution of the different resident species to the total flux could be assessed. In the western Fram Strait, plankton tow data shows an average calcite flux by the dominant species, *N. pachyderma*, of about 670 µg m^{-2} d^{-1} .

Sandrine Trotechaud, McGill University, Montreal

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A seasonally ice-free Arctic: uncertainties associated with natural variability

We know that for the last decades, the sea ice has been melting. An ice-free Arctic has an impact on climate (ice is like a mirror reflecting solar radiation and keeping the earth cool). Knowing when it will happen is therefore important. Of the 40 ensemble-members of the CESM-LE, two follow an observed trend in the minimum sea ice extent with drastically different future evolution of the sea ice extent, one where the sea ice undergoes a considerable recovery whereas the other decreases until reaching the ice-free state. My objective is to explain how different simulations (equally realistic) can have such different behavior in their trajectory to an ice-free arctic. In more practical terms, I study the mechanisms for rapid declines in the minimum sea ice extent and explain why, in the context of CO_2 forcing, would the sea ice undergoe a recovery.

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The trouble maker - sea ice deformation during MOSAiC

Sea ice deformation creates areas of open water that enable heat and gas exchange, ridges that act as habitat for biota and obstacles for winds and ocean currents, and is crucial in maintaining a thick ice cover. Understanding the interplay of forcing, ice pack properties, and sea ice deformation remains challenging. We addressed this gap in the context of the Multidisciplinary drifting Observatory for the Study of Arctic Climate (MOSAiC) expedition, and aimed to analyze how ice dynamics, i.e. drift and deformation, change with season, ice thickness, concentration and distance to the ice edge. We derived deformation with a temporal and spatial resolution of nearly one day and 1.4 km from high-resolution satellite imagery along the drift track of the MOSAiC floe. We combined this data set with meteorological and deformation observations from the MOSAiC floe and found that the MOSAiC deformation time series exhibits low deformation in winter, far (> 1000 km) away from the ice edge and high deformation rates in summer, close (< 300 km) to the ice edge. The spring and summer months were dominated by divergence increasing the lead fraction in the area. Compared to the surroundings, the deformation on the 5 km scale close to the MOSAiC floe was representative for the deformation in the wider (50 km) region.

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An Eulerian Iceberg Module for the MITgcm

The Greenland Ice Sheet's (GIS) mass loss is indicated to increase every year. The mass loss happens through continental runoff and calving icebergs. The latter are transporting a huge amount of freshwater over long distances far off the coast but release it in rather small areas. In models without icebergs the discharge of the GIS is often modeled as a uniformly distributed freshwater input over the North Atlantic region. But icebergs do not release freshwater in that homogeneous way and therefore the effect of locally distributed freshwater is to be determined in this project. We want to know if icebergs may indeed enter the deep water formation areas and affect the Atlantic Meridional Overturning Circulation through melting and freshwater release.
Regarding these questions a new iceberg module for the general circulation model MITgcm is being developed which can be used for future and paleo simulations. The new iceberg module differs from modules in most other models as these consider single icebergs and calculate their trajectories in a Lagrangian approach. Here we will use an Eulerian approach which treats icebergs not as individual particles but considers a concentration of icebergs per grid cell. The module will be validated with data from observations and afterwards simulations for the future will be done. The future simulations will be based on the RCP scenarios used in the IPCC reports.

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The AMOC at 47°N in Observations and a High Resolution Ocean Model

The Atlantic Meridional Overturning Circulation (AMOC) is the main driver of northward oceanic volume and heat transport in the Atlantic. Since the early 2000s, hydrographic sections across the Atlantic at 47°N and continuous current measurements from moored instruments at specific locations are available. From these observations AMOC components can be estimated. However, the spatial resolution of current measurements is coarse and shipbased hydrographic sections are mostly done only once a year. Also, the observational timeseries still remain too short to allow conclusions about decadal trends in the variability of individual AMOC components. Due to its definition via the streamfunction the exact calculation of the AMOC requires knowledge of the full velocity field. Thus, today our knowledge about the role of the AMOC in the global climate system is mainly based on model simulations. Comparing these model simulations against observations remains an important task to understand the past changes in the AMOC and possibly predict the future of the AMOC and adapt to changes. We present first results of a model observations comparison in the subpolar North Atlantic between observations at 47°N and the high resolution ocean model VIKING20X. This model has a 1/20° nest in the North Atlantic embedded in a global 1/4° model. It covers the years from 1980 to 2018 and thus has a large overlap with the observational period. This comparison will help estimating the past development of the AMOC strength in the subpolar North Atlantic from observations.

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Exchange of water mass properties between the Greenland shelf and the surrounding subpolar North Atlantic

The Labrador and Irminger Seas are affected by the northward transport of warm and saline waters. In addition, an accelerated loss of mass from Greenland's ice sheet together with melting sea ice contributes to a release and propagation of cold and fresh water along the Greenland shelf. The great amounts of heat and freshwater are both impacting the local water mass formation by changing the buoyancy in the water column. To analyze the exchange between the Greenland shelf and the subpolar North Atlantic, we use a large-scale hydrographic data set from ARMOR3D, as well as 41 ship sections. We identified a salinity anomaly in the eastern Labrador Sea at the Greenland shelf in a depth of about 200 meters throughout a period between 1993 and 2018. Moreover, these anomalies could not be identified upstream in the Irminger Sea. This led to the hypothesis that the Irminger Sea might not be the only source for saline waters in the Labrador Sea. Moreover, saline signals from elsewhere may lead to a local increase of salinity especially in late summer and winter were the anomalies show its strongest signal. To find the origin of these salinity anomalies is important to understand the local current structure and the exchange between the Greenland shelf and the surrounding subpolar North Atlantic. Understanding these processes may strengthen the knowledge of possible impacts on the deep convection in such regions.

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Deglacial carbon source from the high latitude lands

It is a consensus that the deglacial changes in ocean carbon storage and circulation play a role in regulating atmospheric CO_2. Despite the carbon sources from the ocean, there is emerging evidence suggesting that the rapid deglacial CO_2 rises are attributed to large quantities of pre-aged carbon release from the high latitude lands/permafrost. Here, we apply a radiocarbon approach on terrestrial compounds and bulk organic carbon on Core ARA04C/37 from the southern Beaufort Sea. Based on the high-resolution radiocarbon record, a major source of ancient carbon was supplied to the ocean during the last deglaciation and the early Holocene, by frequent high sediment flux events. The processes of coastal erosion and flood transport played an important role in ancient carbon remobilization.

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Late Quternary Changes in Sea Ice Cover, Meltwater Discharge and Primary Productivity in Eastern Labrador Sea

Understanding the processes that control the natural variability of sea ice can help us to increase the reliability of climate change predictions in future. This study gives a new insight into changes in sea ice cover and meltwater discharge and their impact on primary productivity and deep water formation in the eastern Labrador Sea based on biomarker records.

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Mathematical Modeling for Iceberg Calving

Calving is the process of blocks of ice detaching from an ice shelf of grounded calving cliff. Here, we focus on calving that occurs through the propagation of fractures through a floating ice shelf on sufficiently short time scales to allow ice rheology to be treated as elastic. We revisit the linear elastic fracture mechanics models of Weertman and van der Veen, which consider the propagation of cracks into slabs of ice, driven by an applied extensional stress and by water pressure inside the crack, due to sea water and surface melt entering the cracks. We extend their work by considering the interaction between multiple cracks and developing a method that allows us to compute crack propagation in arbitrary domain geometries. We show that the simple case of two aligned cracks, one extending from the ice surface and the other from the base, can be considered as a two-dimensional dynamical system. We are able to show that viable steady crack configurations (where the ice shelf is crevassed without calving) correspond to stable fixed points of that dynamical systems. Calving corresponds to the annihilation of steady states under a parameter change. That can either take the form a bifurcation that happens at specific combinations of forcing parameters, and leads to the abrupt, dynamic propagation of the crack across the remaining unbroken thickness of ice. Alternatively, calving can occur because the two crack tips gradually meet as forcing parameters change. We derive different forms of calving laws, depending on whether crack propagation to full calving is initiated from a previously un-cracked floating slab of ice, or from a previously cracked configuration. For the former, we show that calving laws take the form of a functional relationship between a water storage parameter, extensional stress, ice thickness and fracture toughness. For the latter, we obtain an history-dependent relationship in the form of a steady crack evolution problem that bears abstract similarity with plasticity models. We also discuss how these could be implemented in ice

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The millennial-scale climatic variability in the North Atlantic Ocean over the last 43 000 years: the role of the subpolar gyre dynamics

For a long time, because of a much more larger amplitude of variation during the last glacial period, and especially during the marine isotope stage 3 (MIS 3, 60 – 30 ka), the millennial-scale climatic variabilities of the present interglacial (MIS 1, 11,7 ka - present) and the MIS 3 have been mainly studied separately as if they were two distinct phenomena. However, recent studies conducted independently on these two periods in the North-east Atlantic sector, along with preliminary comparisons with records located in the Norwegian Sea, have highlighted strong similarities between the variation modes of the oceanographic and atmospheric circulation of the two periods in the North Atlantic sector. These observations arise the possibility that the mechanisms and/or forcings triggering these two millennial-scale climatic variabilities might be the same. Following this hypothesis, we will investigate the continuity of this variability during the last 43 000 years and focus on three phenomena that seem to play a key role in it: the East Greenland Current (EGC) and the Subpolar Gyre (SPG) dynamics, and an atmospheric phenomenon that resembles the modes of variability of the North Atlantic Oscillation (NAO).