Sensitivity of simulated high-latitude ocean biogeochemistry to model resolution and forcing

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The high-latitude oceans are expected to experience more intense climate change and ocean acidification as well as larger changes in primary production and air-sea CO_2 fluxes. Yet those potential future changes have only been assessed with coarse-resolution ocean models, typically within an Earth System Modeling (ESM) framework. Small-scale features and processes have not been explicitly accounted for, even though they may be critical to high-latitude ocean circulation patterns and variability, which affect ocean biogeochemistry. Ocean models are also forced with different atmospheric reanalysis data products or coupled within different ESMs, which may be just as important as model resolution. Here our aim is to assess how simulated ocean biogeochemistry in the high latitudes, particularly in the Arctic and Southern Ocean, is sensitive to model resolution and forcing. Thus we have made sensitivity tests with the OPA ocean general circulation model coupled to the sea-ice model LIM3 and the PISCES biogeochemical model (NEMO system). Four hindcast simulations were made over 1958–2009, i.e., at two resolutions (2° and 1/4°) and with two forcings (reanalysis data products CORE2 and DFS5.2). The global configurations ORCA2 and ORCA025 were used to avoid artifacts associated with lateral boundary conditions of regional models. Atmospheric CO_2 was fixed at 287 ppm, the preindustrial level. Results were compared among simulations and to observations. Analysis has focused on the mean state (2000-2009 average) as well as the seasonal amplitude and phase; it is currently being extended to study simulated interannual variability. Generally it was found that results are insensitive to model resolution and forcing in the low latitudes but there were larger differences in the high latitudes. Although modeled temperature and salinity agree well between models and compared to observations at the global scale. biogeochemical variables agree less and were more affected by the change in resolution than by the change in atmospheric forcing. For example, in the Arctic Ocean, enhancing model resolution reduced average surface Chl-*a* by 27% and increased average ΔpCO_2 by 3%; conversely, in the Southern Ocean refining resolution increased Chl-*a* by 7% and reduced ΔpCO_2 by 8%. Changing the forcing from CORE2 to DFS5.2 reduced ΔpCO_2 in the Arctic and Southern Oceans by 5% and 12%, respectively but increased Chl-*a* by 3% in the Arctic Ocean and by 13% in the Southern Ocean. In contrast, the mean state for surface pH is essentially unaffected by changes in forcing and resolution. Enhancing model resolution also affects the seasonal amplitude, reducing that of Chl-*a* by 21% in the Arctic Ocean and by 25% in the Southern Ocean and increasing that of ΔpCO_2 by 30% in the Arctic Ocean. Changing the forcing from CORE2 to DFS5.2 increased the seasonal amplitude of Chl-*a* by 8% in the Arctic and 20% in the Southern Ocean. The change in forcing from CORE2 to DFS5.2 reduced the mean amplitude of ΔpCO_2 by 8% in the Arctic Ocean and increased it by 12% in the Southern Ocean. Generally, these differences between models in terms of their mean states and seasonal amplitudes are smaller than corresponding model-data differences. The ongoing analysis will determine if models differ more in terms of their simulated interannual variability.

Poster preference

Argo floats in the European Artic Ocean and Nordic Seas: avoiding sea ice and detecting climate change

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Aiming to extend the Argo mission to higher latitudes and partially-ice covered areas, the European contribution to the Argo program (Euro-ARGO RI) has targeted the European Artic Ocean and the Nordic Seas (Greenland, Iceland, and Norwegian seas) for a regional enhancement of the float array. The region is crucial for the understanding of the global ocean circulation and climate change as hotspot for water mass formation and exchange corridor for Atlantic and Polar waters. Moreover, it is largely influenced by the neighboring ice sheet and local sea ice dynamics. In this work, we focus on the two main challenges for the operation of Argo floats in the region: sea-ice avoidance and delayed mode data quality control.

Argo floats may be damaged when encountering sea ice during ascend or while parking at the surface. Therefore, floats are equipped with an Ice Sensing Algorithm (ISA), that uses data collected by the float during ascend (temperature), to determine the presence of sea ice above. Ice detection triggers the interruption of the ascending trajectory, avoiding collision and increasing the floats lifetime. The local tuning of the ISA parameters and its performance in the Barents Sea and the East Greenland Current are discussed.

Data collected by Argo floats undergo strict a Delayed Mode Quality Control (DMQC) procedure to ensure its scientific quality. The correction of salinity errors due to drifts in the conductivity sensors is of particular importance. The correction method, described in Wong et al. (2003), uses historical hydrographic data to estimate a background climatological salinity for the profile position using objective mapping. Therefore, the use of an up-to-date high quality CTD Reference Database is necessary for an appropriate DMQC. This is of special importance for the Nordic Seas, since warming and salinification trends in the last three decades have been reported for the upper 2000 m (Latarius and Quadfasel, 2010; Lauvset et al., 2018). We document the procedures for data acquisition, homogenization and quality assurance of a comprehensive CTD Reference Database for the Nordic Seas.

Oral preference

Wind-waves and currents across the ice edge: exploring mechanical effects and feedbacks with models and remote sensing

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A quantitative monitoring of wind-generated wave penetration in the sea ice is now possible with synthetic aperture radars (Ardhuin et al. Remote Sens. Env. 2018, Stopa et al. PNAS 2018). This new data set is providing a deluge of data complementary to the few previous in situ measurements, that is completely changing our understanding of ice impact on ocean waves. In particular, the paradigm of wave scattering by floes or ice thickness variations, which may have been representative of a thick ice Arctic in the 1980s, is now replaced by measurements of wave dissipation with little evidence of scattering. This dissipation is not yet understood but is presumably related to fast cycling of stresses in the ice and, in the presence of pancakes, dissipation in a dual phase solid-liquid system. The new data also clearly shows that wave attenuation can be very strong, releasing a large momentum flux that can be larger than the wind stress over a wide band in the marginal ice zone. That momentum flux is also very heterogeneous, probably due to heterogeneous ice properties, including ice thickness, possibly associated to feedback mechanisms between ice and waves (e.g. Sutherland and Dumont JPO 2018). So far most of the wave-in-ice data available from Sentinel 1 comes from the the Southern Ocean, thanks to the routine acquisition in high resolution IW and wave modes. A few images in the Arctic have allowed to evaluate and adjust parameterizations in wave models (Ardhuin et al. JGR 2018). New data from the SWIM instrument on CFOSAT, launched in October 2018, are bringing measurements of waves in ice in particular in the low incidence beams. These data are presented and discussed. We look forward to the proposed SKIM mission that would measure ice drift, surface current and waves with a Doppler radar. Based on numerical simulations, we expect to observe complex interactions between the near-ice jets, the wave field impinging on the ice, and the momentum flux to the ice layer near the edge, with possible hotspots of ice break-up.

Multi-altimeter combination for the retrieval of sea surface height in the ice-covered Southern Ocean

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A new high-resolution Sea Level Anomaly (SLA) product is being constructed over the Southern Ocean. This product uses multiple satellite altimetry missions (both LRM and SAR) to map SLA data on an equal-area grid, including the ice-covered areas of the ocean.

Along-track waveforms are classified using a neural algorithm, allowing the selection of open ocean and lead echoes only. A dedicated retracking algorithm is then used to estimate geophysical parameters. Geophysical corrections and editing allow to derive valid SLA measurements. These measurements are mapped on an EASE-2 grid using an objective analysis method derived from current CMEMS processing, with updated mapping parameters over the area.

As a first processing prototype, 3 months of SLA daily maps have been computed over one winter combining SARAL/AltiKa, Cryosat-2, Jason-3 and Sentinel-3A data. These preliminary results suggest that we can map ocean features with unprecedented resolution for the region. Comparisons between these maps, the current CMEMS product, GLORYS12 model and previous regional studies are shown. A sensitivity study showing the influence of the choice of mapping parameters is also included.

Oral preference

Predicting DMS(P) production in a high carbon dioxide world. Does algal carbon-utilization provide an answer?

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Climate change is considered a global threat to humankind in our current understanding. A region showing some of the largest measurable changes in surface-ocean temperature is the West Antarctic Peninsula (WAP). Increasing winter temperature of about 6 °C since 1951 has led to a 41 % decrease in mean sea ice cover over the past 50 years. The increasing levels of CO_2 result in a lower oceanic pH. It is uncertain how the ecosystem, especially the productive phytoplankton community of the Southern Ocean, will react to these major factors: sea ice retreat and ocean acidification. Here I will present an outline of the experiments that are planned to investigate how the rising levels of CO_2 and the retreat of sea ice will impact the phytoplankton communities in the Southern Ocean. Especially, the physiological mechanisms underlying the sulfur and the carbon cycle will be studied in detail. The focus will be on the production of the algal metabolite DMSP (dimethylsulfoniopropionate) and its potential coupling to algal carbon uptake mechanisms and subsequently the production of the climate active gas DMS (dimethylsulfide). The study involves both controlled laboratory studies and field experiments at the WAP considering environmental factors as temperature, salinity, pH and light. DMSP-production will be tracked using stable isotope addition experiments and analyzed by Proton-transfer-reaction mass spectrometry (PTR-MS) combined with Cavity Ring down spectroscopy to measure isotope ratios of total particulate organic carbon (POC). The carbon uptake mechanism will be studied using an isotopic disequilibrium technique. We hypothesize that the mechanisms that regulate DMSP production are related to the carbon-uptake mechanism of the algae involved. We hope to get an insight into how the algal sulfur and carbon cycles are linked and how CO_2 and DMS concentrations will develop in the ocean and ultimately in the atmosphere under changing climate conditions.

Poster preference

Deriving water levels in the Arctic region from SAR altimetry

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The impact of Arctic sea ice decline on future global tidal and storm surge extreme water levels is unknown. Regional studies have shown that the impact can be substantial causing increased erosion and posing higher risks to fragile Arctic ecosystems in low-lying areas. Because Arctic tides and surges influence North Sea water levels, the consequences of sea ice decline will also be noticed in the Dutch coastal waters. To quantify this impact, we need an accurate Arctic total water level (TWL) model rather than to rely on existing Arctic/global ocean tide models and storm surge models. Only for a TWL model we can complement the sparsely available number of tide gauge records in the Arctic waters by satellite radar altimeter data, which are required to calibrate the model for the large uncertainties in bathymetry and other model parameters. For the Arctic region it is essential to make direct use of TWLs, as a decomposition of the observed water level in its tidal and non-tidal constituents is not possible based on harmonic analysis.

In the ongoing FAST4Nl project, we aim to develop an Arctic TWL model as an extension of the Global Tide and Surge Model (GTSM). This model will be calibrated using SAR altimeter derived water levels provided by the CryoSat-2 and Sentinel-3 satellites. An advantage of using SAR altimeters is their high along-track resolution (300 m), that enables to derive water levels from leads in the sea ice. This is necessary to obtain a sufficiently large data set for calibration of the ice covered areas. For this purpose we have developed a multi-criteria classification scheme that distinguishes between radar echoes from sea ice leads and those from other surfaces, based on their typical waveform shapes. In addition, we implemented a method to the derive water levels. This allowed us to make a preliminary comparison of the SAR altimeter derived water levels with the output of the GTSM model to assess its performance for the Arctic seas.

Advancing methodology for sub-zero temperature application of DGT technique on sea ice samples for two-dimensional imaging of biogenic metals

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Sympagic (ice-associated) communities colonize the brine-filled spaces and are exposed to major biogeochemical and physical changes during its incorporation into the ice: temperature fluctuations, salinity, dissolved oxygen, light, pH, the surrounding organic matrix, and nutrients. A key adaptive response is the formation of biofilms, which play a major role in macro- and micro-nutrient storage, transformation and mobilization. Considerable enrichment of Fe and other trace metals has been recorded in sea ice, supposedly being adsorbed onto organic matter.

Current methods for collecting pristine ice samples mostly involve melting an ice core, erasing any spatial information and discrimination between solid, liquid and gaseous phases. As a result, sea ice analytical methods have an insufficient spatial resolution to detect or describe microbial processes at submillimetre scale (in biofilms or micro-environments within the brine network), yet there is currently no alternative option for these experiments.

Based on Diffusive Gradients in Thin-films technique (DGT) for imaging 2-dimensional distribution of total labile metal concentrations in soil/sediment by laser ablation ICP-MS, we have advanced a DGT procedure for sea ice application. During the optimization process, we considered atypical conditions for DGT application at sub-zero temperatures; hydrogel freezing, slow diffusion, high brine salinity. We defined diffusive coefficients at water freezing temperatures and assured contact with hydrogel and thus diffusion. Using Peltier element to precisely control the temperature of immediate sea ice environment, slow equilibration to *in situ* temperature of -1.8°C successfully maintained the brine liquid, the ice did not melt, and the hydrogel did not freeze. This was critical for the diffusion to occur, and importantly, allowed degassing from the sea ice. Without gradual equilibration, gases from sea ice were trapped between hydrogel and ice, separating the two and preventing diffusion.

Our result are the first two-dimensional images of biogenic metal micronutrients in the sea ice, revealing a clear spatially diverse signal. Fe, Zn and Mn were associated with organic matter-rich micro-locations where the sympagic communities were clearly visible. The new procedure had immense potential to advance our understanding of the sea ice biogeochemistry. It could provide missing empirical evidence to connect hypothesized reductive conditions in biofilm, bioligand interaction with trace element and OM growth/remineralization on a fine spatial scale, thus increasing our understanding of processes occurring in polar oceans and its feedback on the ongoing global change.

Evolution of an Arctic melt-water front

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The ice-ocean-atmosphere system near the ice edge and in marginal ice zones in the Arctic is governed by a complex set of dynamics which control fluxes of heat and buoyancy in the upper ocean. These dynamics are further complicated by the high degree of heterogeneity near the ice edge. In particular, strong fronts may occur near the ice edge between the warmer waters of the ice-free regions and the cold, fresh waters near and under the ice. This study presents observations from the upper 25 m of the water column collected during the fall season of 2014 in the Beaufort Sea with an underway CTD system and simultaneous measurements of atmospheric forcing. The observations show a well-defined density front located along the ice edge. Multiple cross-front sections show that the front evolved over a 2-day timeframe, and SAR images bookending this period show that the ice edge itself underwent concurrent evolution. Prior to the survey, the ice edge is compact and well defined while after the survey it is diffuse and filamented with coherent vortical structures. This transformation is indicative of the development an active ocean eddy field. Over the course of hours, increasing wind stress caused the front to steepen and imparted potential energy into the system. Following cessation of the wind, the frontal adjustment appears to conform to previous numerical studies of ice-edge submesoscale dynamics, which would include the development of the mixed-layer eddies observed in the SAR images.

Poster preference

Observing and understanding change in the Southern Ocean – building systems for future science

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The Southern Ocean is disproportionately important in the functioning of Earth's climatic, biogeochemical, and ecological systems, so recent changes observed in the Southern Ocean are cause for global concern. Enhanced understanding and improvements in predictive skill are needed, both of which require sustained observations. Yet, despite recent significant investment in Southern Ocean data collection, major gaps remain. Given the finite resources available for observing the Southern Ocean, it is clear that new initiatives need to be based on quantified estimates of requirements, taking multiple objectives into account and delivering to multiple end-user groups. Importantly, international integration of activity will avoid duplication, maximise benefits, and enable the long-term maintenance of a fully coherent system.

The Southern Ocean Observing System (SOOS) has established networks for regional coordination to deliver an integrated, circumpolar system, and research-community groups that drive development of observing system capabilities. End-user engagement and participation is key; SOOS is developing data systems that enhance the quality, discoverability and accessibility of Southern Ocean data and data products. These SOOS networks and data systems will be used by resource and conservation managers, climate prediction agencies, operational managers, and scientific communities. The sustainability of SOOS relies on its ability to engage these user groups, meet their evolving needs, and to demonstrate the value of sustained ocean observations to those working within and beyond the Southern Ocean. This presentation will describe these advancements and our community-building efforts to enhance this flow of vital ocean knowledge.

Oral preference

We believe this presentation will fit well in Ocean Observing sessions.

Closing the global ocean carbon loop through ventilation of Indo-Pacific Deep Water in the Southern Ocean

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Deepwater ventilation in the Southern Ocean has long been thought to importantly regulate the global oceanic carbon cycle, yet it has not been proved directly by in-situ measurements. Combining ship-based measurements with the annual air-sea carbon flux estimated from biogeochemical floats deployed over a broad region in the Southern Ocean, we show that ventilation of the Indo-Pacific Deep Water (IPDW) plays the dominant control to the Southern Ocean carbon cycle. Specifically, vertical potential PCO_2($pPCO_2$) maxima in the ocean interior is tightly linked to the IPDW, the upwelling of which establishes the subsurface $pPCO_2$reservoir in the Southern Ocean high latitude. The availability of high $pPCO_2$waters at shallow depths enables the vertical $pPCO_2$supply and leads to significant degassing fluxes surround the Polar Front. This underexplored mechanistic link between the Southern Ocean CO2 release and the ventilation of IPDW improves our understanding of the Sothern Ocean's role in regulating atmospheric CO_2 from interannual to longer timescales.

Impact of an abrupt Arctic sea ice reduction on high and mid-latitude climate

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In the past decades, anthropogenic global warming combined with natural variability has been driving the loss of Arctic sea ice, which is projected to disappear in summer in the second half of the 21st century. The current sea ice melting is accompanied by a significant Arctic warming, which induces several climatic responses not limited to the high latitudes. These responses include changes in storm tracks, modification of the jet stream patterns as well as a stimulation of the planetary waves. The frequency, intensity and persistence of extreme weather events, including droughts, heat waves and cold spells, might be influenced by the melting of sea ice via these climate changes. The objective of this study is to determine the short-term changes in the high and mid-latitude climate due to a sudden loss of Arctic sea ice. These changes are analysed using different climate models that participate to the EU Horizon 2020 PRIMAVERA project. First, we find that the rapid loss of Arctic sea ice in summer causes intense Arctic warming, which is accompanied by an increase in precipitation in this region in autumn. Second, significant cooling in eastern Eurasia is modelled in autumn and winter. This is directly related to the anticyclonic anomalies over the Barents and Kara seas following the abrupt reduction of Arctic sea ice which can induce a weakening of stratospheric polar vortex. These climatic responses are likely to be expected in the coming years with a sudden Arctic sea ice loss, but further modeling studies are needed in order to improve our understanding of Arctic sea ice loss impacts on the climate.

Poster preference

Estimation of Antarctic sea ice primary production inferred from biomass accumulation

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Antarctic sea ice is one of the largest ecosystems on Earth, with an extent varying between a maximum of $19x10^6$ km^2 in late winter and a minimum of $3x10^6$ km^2 in late summer, most of which consists of annual pack ice. Direct measurements of primary production in Antarctic sea ice, using either oxygen-based or tracer incubation methods, remain scare. Thus, to estimate large-scale Antarctic sea ice primary productivity, two approaches have been used. First, sea ice biogeochemical models suggest that Antarctic pack ice contributes to a small but significant fraction (10 to 28%) of the primary production in the ice-covered area of the Southern Ocean. Second, accumulation of organic matter being trapped within sea ice during the growth season is likely to be representative of the net community production. More than 20 years ago, Legendre et al. (1992) used the few available observations to infer Antarctic sea ice primary productivity. We believe that it is time to revisit this estimation by accounting from a much larger compilation of data (historical to present). Here, we present the first results using an updated dataset of historical ice cores sampled between 1989 and 2017. These allow us to provide an updated estimation of the sea ice primary production based on in-situ data, and its contribution to the SIZ and Southern Ocean. A comparison between pack and fast ice will be also briefly discussed.

No preference

Strong Southern Ocean summer winds induce ice loss the following winter through anomalous heat storage in the seasonal ice zone

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Stronger summertime westerly winds lead to anomalously cold sea surface temperature in the following weeks and months. Here we present a mechanism by which these winds can also cause anomalously warm wintertime sea surface temperatures and a reduction in the maximum wintertime sea ice extent. Strong summertime winds lead to enhanced vertical mixing, which draws heat downwards from the warmer surface waters. At the same time, anomalous atmospheric heat fluxes act to damp the cold sea surface temperature anomalies, drawing additional heat into the ocean. As the mixed layer deepens during the autumn months, the subsurface heat anomalies are brought back to the surface, leading to anomalously warm sea surface temperatures and reduced sea ice extents. Using a combination of observations and models we assess this mechanism in a zonally averaged context, and speculate about its importance regionally.

Oral preference

Past and future dispersal of Antarctica species: a Lagrangian modeling tool

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During environmental changes in Antarctic ecosystems, biota faces three possible outcomes: adaptation, migration or extinction. Successful migration depends on dispersal behaviour which allows individuals to move from natal to reproductive sites or between different reproductive sites. Dispersal can be an essential key in the ability of marine Antarctic biota to find refugia and therefore to survive environmental changes as the ongoing ones. The scientific knowledge over dispersal abilities and therefore also on past and current survival strategies is crucial to predict biota responses to climate changes.

To this end, the Lagrangian particle module of the regional hydrodynamic model COHERENS has been implemented over the Southern Ocean with an horizontal resolution of ~8 km. Adaptation were made to study the dispersion of several Antarctica species such as the fish *Trematomus eulepidotus* and the *Chionodraco rastrospinosus* and the bivalve *Lanternula elliptica* during their larval pelagic stages. This modelling tool helps understand how dispersal of selected species is influenced by ocean circulation, biological traits and habitat preferences. The tool allows to assess the connectivity of populations in the considered geographic area and to estimate the influence of dispersal on species survival during changing environmental conditions (i.e. warming of the ocean, earlier spawning).

Poster Preference

Impact of the recent oceanic anomalies around the Greenland ice sheet on its surface mass balance.

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Since the end of the 1990s, we have observed a significant acceleration of the melt of the Greenland ice sheet which has been becoming the largest contributor of the recent observed sea level rise. However, this acceleration of melt increase has being stopped from a few years, notably because of the collapse of sea ice extent around Greenland in winter. The abnormal presence of open water this last winters around Greenland has enhanced evaporation and allowed to storms (including tropical cyclones) to go more northward by discharging huge snowfall accumulation along the east coast, compensating the melt in summer. The impact of these recent oceanic anomalies in the neighbourhood of the Greenland ice sheet are studied here with the help of the regional climate model MAR (developed at Uliège) forced by the ERA-Interim reanalysis and future scenarios from CMIP5 and CMIP6 data base.

Meridional Overturning Circulation: insights from nitrate isotopes and perspectives for past oceanic circulation

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The sinking of organic matter into the deep ocean is balanced by the return of nutrient-rich deep water to the surface ocean. In its first conception, the upper branch of the meridional circulation was thought to be driven by the addition and extraction of buoyancy at the surface and vertical mixing in the ocean interior, allowing a diffuse upwelling of deep water into the pycnocline. However, the required level of mixing was not supported by observations, and wind-driven upwelling in the Southern Ocean was proposed as an alternative mechanism. The "overturning ratio", the fraction of the water supplied to the pycnocline by wind-driven upwelling, is now widely believed to be high, but this has not been thoroughly tested with observations. The nitrate isotopes are investigated here as a new data constraint on the overturning ratio. The two sources of water supplying the pycnocline (southern vs. deep) are distinct in their nitrate isotope ratios: partial assimilation in the Southern Ocean surfaces raises the $\delta^{15}N$ and $\delta^{18}O$ of nitrate that is subsequently subducted into the pycnocline. Pycnocline nitrate $\delta^{15}N$ is not strongly altered by low-latitude export production and remineralization because of complete nitrate consumption at the surface. Accordingly, a high overturning ratio predicts a high nitrate $\delta^{15}N$ in the pycnocline. Here, we compare large-scale observations of nitrate isotopes with the output of a box model. By minimizing the misfit between the model output and observations, we estimate that the overturning ratio is ~ 0.75, with ~ 65% of the nitrate and phosphate supplied to the low latitude pycnocline originating from the Southern Ocean. Thus, we confirm previous suggestions that the wind-driven upwelling in the Southern Ocean supplies most of the nutrients required to sustain low-latitude export production and represents the main connection between the deep and surface ocean. Taken in consideration than the pycnocline feed in nitrogen most of the low-latitude export production, it also allows a teleconnections between sedimentary $\delta^{15}N$ records at global scale.

Sea ice thickness records from altimetry over Antarctica

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The main difficulties to retrieve sea ice thickness (SIT) in the southern ocean come from the lack of in-situ observation and knowledge related to sea ice. For instance, whereas polar expeditions and in-situ observations over the Arctic have enabled to construct snow depth climatologies (e.g the Warren climatology), there are no equivalent data available over Antarctica. By consequence, except for a few studies such as Zwally et al, 2008 or Kurtz et al, 2012, based on ICESat data, sea ice thickness estimations over Antarctica nearly remain nonexistent and no valid sea ice volume estimations have yet been drawn (SI-CCI-2015 report). The objective of this presentation is to review our recent developments leading towards sea ice thickness estimations over Antarctica.

First, we detail the methodology used to derive sea ice freeboard from altimetric power echo measurements and we present a 2002-2017 Envisat/Cryosat-2 sea ice radar freeboard time serie. The continuity between these 2 satellites is ensured by a re-calibration of the Envisat Low Resolution Mode (LRM) on the Cryosat Synthetic Aperture radar (SAR) mode we describe in this presentation. Thereafter, the computation of sea ice thickness from sea ice freeboard require snow depth fields. Recently, the ESA CryoSeaNICE project demonstrated that snow depth is one of the most important obstacle to compute sea ice thickness. Meanwhile, Guerreiro et al, 2016, has showed the ability to retrieve snow depth from CryoSat-2 Ku and Saral/AltiKa Ka radar frequencies. Based on this approach, we present in this second part the first bi-frequency altimetric snow depth product over Antarctica computed from the Cryosat-2 Pseudo-LRM ESA product. The relevancy of the solution will be assessed by comparison with ICESat and Operation Ice Bridge (OIB) laser measurements. From these results, a 2013-2018 sea ice thickness time serie will be presented and assessed. Finally, we briefly explain how these sea ice products will be used to better understand recent sea ice variations and to derive sea ice volume estimations.

Data assimilation of sea surface temperature reconstructions from marine sediments in the North Atlantic over the past two millennia

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The assimilation of paleo-sea surface temperature (SST) reconstructions from proxies into climate models allows combining those two complementary sources of information to better estimate past climate variability. Up until now, its application has been limited due to the mismatch in model-data variance and the spatio-temporal heterogeneity of SST proxy signals. This study aims at combining SST reconstructions from several proxy types with climate model results across the North Atlantic and North Atlantic-Arctic regions via data assimilation experiments over the last two millennia, a key period for understanding past climate variability. SST reconstructions used are from: 1) the Ocean2k SST synthesis database, 2) a dataset solely composed of dinoflagellate cysts, and 3) an Arctic proxy database. Marine proxies include dinoflagellate cysts, foraminifera, diatoms and alkenones, and are grouped according to their seasonality and ocean depth signal prior to the assimilation applications. In order to resolve the mismatch in variances between proxies and models, we present a model-data scaling experiment based on satellite observations and on the change in variance with timescale. Assimilating scaled time series leads to robust results at the local and regional scales. The best results are obtained with the summer SST reconstructions from the dinoflagellate cysts database. Nonetheless, the assimilation with scaled variances also works technically when combining proxies carrying contrasting seasonal and ocean depth signals. Regional reconstructions are then compared to higher-resolution terrestrial archives, and potential and limitations of the scaling procedure and the choice of proxies are discussed.

Oral preference

Numerical study of the Arctic Rivers water pathways and water mass transformation in the Arctic Ocean

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1 ICMMG

Continental runoff is one of the major sources for the Arctic freshwater budget. It is generally known that it influences water column stratification and maintain Arctic halocline that isolates sea ice and the cold and fresh upper layer from the warmer, saltier Atlantic Waters of the Arctic Ocean. Increasing river discharge observed in recent years, suggest that this will have impact on the Arctic water mass transformation. Nevertheless, few details are known regarding the rivers freshwater export into the Central Arctic Basin.

The river water pathways over vast shelf seas and residence time are closely linked to atmospheric variability. In this study, we used model simulations forced by atmospheric reanalysis data, to investigate changing freshwater pathways in the Arctic Ocean and the water mass transformation due to variability of the atmospheric dynamics and increasing of the largest Arctic rivers runoff.

Poster preference

Sensitivity of the Upper Ocean Heat Content in a WAP Fjord

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In the Western Antarctic Peninsula (WAP), fjords make up most of the interface between the ocean and the cryosphere and they are hotspots of biological productivity and biodiversity. Changes in the upper ocean (<50m) heat content, H_f, of a fjord could directly affect primary productivity and melting of icebergs and glacial fronts. In the context of a warming Antarctic, we aim to identify the current key drivers and potential future contributors to H_f in a modeling study of a WAP fjord, Andvord Bay. We built a high-resolution numerical model (350 m) of the region using the Regional Ocean Model System (ROMS). The model is forced by tides and by atmospheric forcing from the Regional Atmospheric Climate Model. Initial conditions and oceanic boundary conditions are based on observed temperature, salinity, and currents. Key drivers of the fjord's upper ocean heat content were determined using adjoint sensitivity analysis. Results exhibit that in context of the atmospheric forcing the fjord is most sensitive to changes in the wind (both along the fjord as well as along the shore). Another important driver is water masses originating from the North with influences from the Weddell Sea. Despite the protected location of the fjord, results show that external warming trends will similarly affect the fjord's upper ocean heat content. In our presentation, we will further discuss the following climate change scenario: How will the fjord's upper ocean heat content be affected by an atmospheric warming of 1K and an increased input of meltwater?

Oral preference

Impacts of tides on ocean-ice interactions in East Antarctica

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The current generation of global climate models exhibits large biases in the Southern Ocean. While key processes governing heat and freshwater exchanges – such as polynyas or ocean ice shelf interactions – take place in coastal Antarctica, the resolution of global models is too coarse to adequately represent them. Parameterizations are used to simulate their effect, but they rely on sparse observations and might be too crude to catch the complexity of air-sea-ice interactions. Knowing whether or not small-scale processes are relevant for the study of the Antarctic climate and if current parameterizations are adequate to represent them is yet unclear. Here, we propose to evaluate the sensitivity of air-sea-ice interactions to the representation of small-scale processes, at hourly to seasonal time scales. To do so, we developed a very high-resolution model of the ocean and sea ice off Adélie Land, East Antarctica. We focus on the particular role of tides and ocean-ice shelf interactions. A series of sensitivity experiments is performed in which tidal forcing and under ice shelf cavities are removed. In the presence of tides, the seasonal sea ice growth is lowered. This is particularly the case for shallow regions of the coastal seas, where tidal velocities amplitude and associated mixing are large. While ice shelfves also experience stronger basal melt in the presence of tides, the response is highly variable from one glacier to the other. This spatial variability is due to the fact that tides also deeply modify ocean circulation on the continental shelf, resulting in changes in pathways connecting warm water and ice shelf cavities. While our results are specific to the particular case of Adélie Land, we argue that both tides and ice shelf cavities influence ocean-ice interactions in coastal Antarctica, and that high resolution is recquired to represent the broad spectrum of their effects.

Oral preference

Geospatial Assessments Of Climate Change Impacts On Marine Pollutants And Coastal Degradation Along The Gulf-Of-Guinea

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Climate change environmental degradation had affected the world's natural resources, ecosystem services, socio-economy values and societies to a large extent. However, considerable differences in the range and intensity of these impacts between regions provide insight into cumulative threats to marine biodiversity. Human-induced risks along the coastal zone have lead to coastal degradation from marine pollutants, anthropogenic activities such as untreated discharges of municipal, industrial liquid and solid waste, depletion of marine species, and loss of marine habitat. The research adopted remote sensing techniques with data capabilities from ground-based meteorological station (NIMET), Landsat OLI, and Sentinel-2A satellite imageries, for monitoring the environmental impacts of marine pollutants and wastewater discharge along the Gulf-of-Guinea. The high-precision ALOS DSM and TANDEM-X satellite data were used to model the coastal terrain and the slope. The satellite data were processed using a web-based GIS tool known as Coastal Environmental Risk Index (CERI) was used to estimate the level of environmental damage and coastal degradation over the study area. Further geostatistical analysis were performed using the cellular automata and Support Vector Machines (SVM) methods. The results of the research suggested adaptation and protection measures through integrated management of land-ocean interaction in the coastal zone, enhancement of integrated global observation system, and coastal ecosystem-based management. Lastly, adequate information tools should be made available to policy makers and environmentalists to identify the most severe and pressing risks, and to assess and implement the most effective prevention and adaptation measures in reducing pollution of the seas.

Oral preference

Sea level extremes in the coastal zone of the Barents and Kara Sea in the present and future climate

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Proper quantification of extreme water levels, their return periods and particularly the possible long-term trends in these quantities is crucial to establish appropriate mitigation and adaptation strategies for possible flooding, coastal erosion, agricultural soil contamination and changes in habitat for fish and plants in countries with extensive low-lying nearshore areas. The Barents and Kara Seas experienced a significant loss of the sea ice in recent decades, which can lead to more severe extremes in water levels, wave climate and accelerate coastal erosion. There is also increasing evidence of temperature extremes in the Northern hemisphere affected by the changes in the Barents Sea sea ice. We perform stationary and non-stationary modelling of location, scale and shape parameters of a generalized extreme value (GEV) distribution based on the block maximum method and block maxima. The goal is to identify changes in the sea level extremes and investigate the possible reasons behind it. The analysis is performed for MPIOM global ocean model with the focus on North Atlantic and the Arctic Ocean and EHBARSEM regional climate model of the Barents and Kara seas. The model runs are split into two sections, namely modern climate 1933 – 2005 for MPIOM and 1966 – 2005 for EHBARSEM and the future climate 2060 - 2099. The modern climate data were validated with 30 years of Teriberka station in-situ 1-hour resolution data and yearly average data from other stations along the Barents and Kara Seas. The extreme value distributions retrieved from Teriberka measurements showed very good correspondence with the extremes from MPIOM and worse correspondence with EHBARSEM modern climate data. The parameters of generalized extreme value distribution showed a significant trend over the studied period and strong spatial variation along the coast. We discuss the relation between the increase in sea level extremes and other climatic factors, such as sea ice extent and temperature.

Oral preference

The Antarctic Circumpolar Current modeling study based on Argo data

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The most prominent feature of the Southern Ocean is the Antarctic Circumpolar Current (ACC), the largest ocean current with a mean transport reaching 170 Sverdrups (1 Sv = million m**3/s). Due to the lack of Sothern Ocean oceanographic data and sustained observations, there is no consensus yet about the amount of water is transported by the current. Accurate estimates of the ACC transport are very important in understanding the Southern Ocean impact for the climate change.

The development of a global array of free-drifting profiling floats in the beginning of the 21st century (known as the international Argo Program) provides oceanographic community with the unique opportunity to continuously monitor the Southern Ocean and the ACC transport. Starting from 2005, measurements with the Argo floats have been performed over the majority of the World Ocean: today up to 4000 active floats autonomously profile the upper 2000-m of the ocean with a 10-day interval. The Argo-based model for Investigation of the Global Ocean (AMIGO), designed at the Shirshov Institute of Oceanology, consists of a block for variational interpolation to a regular grid of irregularly distributed Argo data and a block for model hydrodynamic adjustment of variationally interpolated fields. Such a technique makes it possible to obtain from irregularly located Argo measurements a complete set of oceanographic characteristics: temperature, salinity, density and current velocity [Lebedev, 2016].

In the present study we analyze the AMIGO simulations results covering a period from 2005 to 2018. The mass, heat, and salt transports over several regions of the Antarctic Circumpolar Current were calculated; seasonal and interannual variability of the transports was studied. The study was supported by the Russian Foundation for Basic Research (project 19-05-00878a).

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Poster preference

Environmental drivers of sea stars feeding ecology in the Southern Ocean

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The Antarctic continent and the surrounding Southern Ocean undergo strong and contrasted impacts of climate change. In the Western Antarctic Peninsula, sea ice cover and ice season duration are decreasing, presumably in relation with increased air and water temperature and northwesterly winds originating from the also warming subtropical Pacific. In contrast, despite increased air and deep water temperatures, sea ice cover and ice season duration are increasing in other Antarctic regions. This is possibly linked with ocean stratification due to freshwater inputs from the melting continental ice. These changes are likely to impact marine communities and food webs of the Southern Ocean.

Sea stars (Echinoderms: Asteroidea) are an important group of the Southern Ocean benthos. Compared to other organisms, they seem to have relatively high physiological tolerance to warming. However, they could be indirectly affected by climate change, notably through quantitative and qualitative modifications of food availability.

In this context, the aim of this study was to infer the trophic diversity of sea stars of the Southern Ocean to assess their potential trophic plasticity regarding food web changes. Thanks to collaborative networking and valorization of museum samples, Sea stars samples taken in summer in various regions around the Antarctic continent with different types of environment (Antarctic or Subantarctic, deep-sea or coastal, presence of sea ice or not) were obtained. Stable isotopes ratios of C (denoted δ13C) and N (denoted δ15N) were then analysed in the tegument of sea stars in order to investigate their trophic ecology. Isotopic niches metrics were also computed to assess differences of trophic diversity between regions.

Variability in stable isotope ratios and isotopic niche metrics revealed strong differences in sea star feeding ecology between and within locations, possibly in relation with differences in environmental conditions, notably sea ice coverage and dynamics. For example, on the continental shelf of Antarctic South Shetland Islands, small isotopic niches could indicate that sea stars exploit a food web based on a common basal food source and exhibit a "trophic continuum". In this context, absence of sea ice before and during the sampling period could have limited the number of available food sources. By contrast, on the continental shelf of the Antarctic Marguerite Bay or in the Subantarctic South Georgia Island, sea stars had large isotopic niches that suggest that they could exploit one or several food webs based on more than one food source, and exhibited strong trophic segregation. In Marguerite Bay, this could be linked with progressive sea ice melting, which allows export of both sea ice materials and blooming phytoplankton to the benthic compartment. In South Georgia, on the other hand, oligotrophic conditions and thus reduced availability of phytoplankton are more likely to explain this pattern. Ultimately, this project helps us understanding which ecological processes determine how an ecologically important animal group copes with environmental modifications linked to climate change.

This research was funded by the Belgian Federal Science Policy Office (BELSPO) in the framework of the vERSO and RECTO project (rectoversoprojects.be).

Tracing upstream pathways of anomalies driving Eastern Arctic and Barents Sea atlantification

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Satellite observations show that the sea ice extent in the Eurasian Arctic has receded northwards such that the much of the northern Barents Sea is ice-free even in winter. Recent work by Barton et al., 2018 demonstrates that this sea ice retreat coincides with a warming and increasing salinity trend - an 'atlantification' - of the Barents Sea seawater below. This atlantification has increased the temperature gradient across the northern Barents Sea Polar Front such that the extra heat south of the Polar Front acts to inhibit sea ice formation and limited import from the north since 2005. This atlantification signal can be traced back to warming of the the Atlantic Water (AW) flowing into the Barents Sea. Indeed, the warming of the northwards-flowing AW has also been shown to be impacting ocean stratification and sea ice extent in the Eurasian Arctic Ocean north of Fram Strait (Polyakov et.al, 2017). Thus, medium-term forecasting of the ocean stratification and sea ice of the eastern Arctic Ocean and Barents Sea may be improved by better upstream monitoring of anomalies propagating along the AW pathways through the sub-polar seas.

The AW propagating from the subpolar North Atlantic is a key feature of Barents Sea circulation. This AW flow is vertically coherent at the Barents Sea opening and along its path as it propagates across much of the south and central Barents Sea. We demonstrate that this characteristic of Barents Sea hydrography renders SST a reliable indicator of heat content, which in turn sets the thermostatic height. A comparison between thermosteric height inferred from in situ data and combined satellite observations of sea surface height and eustatic height shows considerable promise in being able to monitor Barents Sea heat content variability from space and highlight changes in seasonality observed in the last decade and a half. We explore the potential of extending this analysis upstream along the AW pathway through the sub-polar seas.

No preference

Dynamics of the Beaufort Gyre from satellite observations and a high resolution model.

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Variability of Arctic freshwater export to the North Atlantic has the potential to affect the global thermohaline circulation and hence our climate. Within the Arctic Basin, most of the freshwater is stored within the Beaufort Gyre in the Canadian Basin, which acts to modulate the freshwater export. In recent decades, sea surface height (SSH) and freshwater content within the gyre have increased as a consequence of gyre spin-up and extension. Results from highly idealized process models have revealed that the main dynamical balance of the Beaufort Gyre is between Ekman pumping (resulting from wind forcing modulated by the sea ice conditions) and eddy salt fluxes arising from baroclinic instability that tend to arrest the steepening of the isohalines through lateral salt fluxes.

First, we use a satellite altimetry dataset that provides SSH in ice-covered regions to provide a detailed description of the spatial and temporal characteristics (e.g. extent, shape, intensity and location) of the surface expression of the gyre over 2003-14. These observations suggest that, in response to intensified and displaced wind forcing, the gyre has strongly spun up after 2007 and started to expand over shallow bathymetry in the Chukchi Plateau.

Second, we use results from simulations with a realistic ocean-sea ice model run at 4km resolution, in order to quantify the variations of the mesoscale activity in the Beaufort Gyre in response to the spin up of the gyre. When compared against satellite observations, the model is successful at reproducing the observed behavior of the gyre. The simulations allow us to elucidate the behavior of the gyre and associated mesoscale eddies in presence of bathymetry on its southern boundary.

Oral preference

Assessment of the capacity of Halicarcinus planatus larva to reach the South Shetland Islands through passive dispersal.

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In the last 50 years, the anthropogenic activity and atmospheric temperature in the West Antarctic Peninsula have increased constantly, and consequently have facilitated the establishment of exotic species. Different populations of alien plant and insect species have been already recorded in the terrestrial Antarctic (*e.g. Poa annua*, *Juncus bufonius* and *Eretmoptera murphyi*). In contrast, no alien marine species have been reported until now in Antarctic seawater, with the exception of a single ovigerous female of *Halicarcinus planatus* found in the shallow waters of Deception Island in 2010 and reported in the scientific literature in 2015. *Halicarcinus planatus* is a small brachyuran crab living in shallow habitats, distributed in the southern South-America and in Sub-Antarctic islands (*i.e. Prince Edward and Marion Islands, Crozet and Kerguelen Islands, Falkland Islands and New Zealand*). In the Sub-Antarctic islands, *H. planatus* is usually the unique crab species present in the shallow ecosystems. This species is able to live in cold Sub-Antarctic water mainly because of its capacity to down-regulate Magnesium concentration ($[Mg^{2+}]$) in the hemolymph below seawater concentration. Because of these physiological characteristics, together with a high potential of dispersal through a 45 to 60 days larva, *H. planatus* has been historically considered as a potential invasor of Antarctic shallow ecosystems.

Here, the ability of *H. planatus* larvae to be transported by water current from Sub-Antarctic to Antarctic is evaluated through the Lagrangian particles approach and model-estimated ocean circulation. Model parameters were defined by the species characteristics (*i.e. behavior, habitat preference and reproductive strategy*) and ecophysiology lab experiments. The survival rates of *H. planatus* were measured for extreme temperatures (between -1.8 and 5°C for adults and at 1, 2 and 5°C for larvae) and for salinity between 4 and 32 PSU (for only adults). Results showed that *H. planatus* could survive at temperature above 1°C and salinity above 18 PSU. So that, larvae could reach Antarctic waters during summer, when temperatures are above 0°C.

A possible larvae transport is from Diego Ramirez Island; it's the last island from South America that in addition is located very near of polar front and where *H. planatus* can be found.

Financial support: FONDECYT 1161358, Centro Fondap-IDEAL 15150003, INACH DG_14_17, FONDECYT 1160877, PIA CONICYT ACT172065. The collaborative Belgian BRAIN project: Refugia and ecosystem tolerance in the Southern Ocean (RECTO).

Poster preference

Influence of the initial ocean state on the predictability of the Antarctic sea ice at the seasonal timescale: a study with NEMO3.6-LIM3

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The Southern Hemisphere sea ice extent experienced an overall positive trend over the last 30 years. However, after a record high in 2014, the sea ice extent in 2017 fell down to its lowest value since the beginning of satellite measurements in 1979. Due to the unprecedented melting rate in December 2018, the Antarctic sea ice extent headed for a new record summer minimum in 2019 before stabilizing. Those rapid sea ice fluctuations exemplify the high seasonal and year-to-year variability of Antarctic sea ice.

The reasons of those recent changes are still the subject of active research. Predicting those anomalies several months in advance is of prime importance for multiple activities, including the organization of scientific field campaigns. Besides, exploring the sources of Antarctic sea ice predictability at sub-seasonal-to-interannual timescales certainly helps refine our understanding of the Southern Ocean variability and the way the Southern Ocean interacts with sea ice.

Although there is evidence that recent changes in Antarctic sea ice have been triggered by the atmospheric forcing, the Southern Ocean has been pointed out as a source of predictability of the sea ice cover. In this study, we explore the influence over one year of a biased initial ocean state on the sea ice predictability. In this respect, a control simulation covering the period 1980–2016 was performed using the ocean-sea ice model NEMO3.6-LIM3. The model was driven by atmospheric fields derived from the JRA-55 reanalysis. For one specific control year, the perturbation of the initial ocean state was achieved by simply selecting the 36 other control ocean states simulated over the period 1980-2016 by the model at the same time. Repeating this procedure for the 37 years of the control simulation, i.e. for the 37 different atmospheric forcing years, led us to create 37 x 37 simulations. We demonstrate how unsatisfactory it could be to attempt to produce the best possible sea ice forecasts from an uncertain ocean state, even if the atmospheric conditions were perfectly known, which is never the case in reality.

Baroclinic instability in an ice covered ocean

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We argue that the development of baroclinic eddies in the Arctic is strongly influenced by the seasonality in ice cover: during summer, eddies are free to develop starting from a baroclinically unstable flow. During winter, eddy kinetic energy is dissipated against the ice cover. We discuss the consequences of seasonal damping of baroclinic eddies on the equilibration of the Beaufort Gyre (BG). The dissipation mechanism we identify may explain why the interior of the BG is relatively quiescent, despite the availability of much potential energy.

Oral preference

Plume modeling beneath the glacial tongue of the 79° North Glacier

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Accurately estimating basal melting below ice shelves is of interest because of their vital impact on ice sheets as a component of Earth's climate. As a subproject of GROCE (Greenland Ice Sheet Ocean Interaction), we aim to understand the hydrodynamic processes, which are responsible for basal melts rates beneath the glacial tongue of the 79°N glacier. We developed and used a horizontal two dimensional numerical plume model of meltwater. The plume model predicts the dynamics and physical properties of subglacial meltwater discharge underneath the ice shelf that are modified by basal melting and turbulent entertainment of ambient seawater. Neglecting the seasonal variability, our very first estimation of the basal melt rate shows approximately the right order of magnitude in comparison to the observational measurement with melt rates exceeding 50 m/yr near the grounding line and pronounced magnitude on the sides. Furthermore, we have conducted several modeling experiments in order to determine the sensitivity of basal melting rate to small scale, complex, dynamic features in ice topography, different scenarios describing the subglacial discharge etc.

Poster preference

Polar ocean amplification and shift of seasonal extremes in ocean acidity during the 21st century

ORR J.[1] AND KWIATKOWSKI L.[2]

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Unlike extreme marine warming events, future extremes in ocean acidification may be more cyclic and occur on both shorter and longer time scales (diurnal and seasonal) because that variability is altered along with the annual-mean trend as ocean chemistry responds dramatically to increasing atmospheric CO2 (reducing surface-ocean buffer capacity). The amplitude of the seasonal cycle of surface-ocean free acidity [H+] is projected to increase by 81 ± 16% on average over the global ocean during the 21st century under the RCP8.5 scenario based on our recent comparison of nine CMIP5 Earth System Models; conversely, there are only minor changes in their seasonal cycles of sea surface temperature and salinity. Here we will focus on the polar oceans where that seasonal amplification is projected to be larger. The annual cycles of other ocean acidification variables are also altered but exhibit smaller changes in amplitude. For instance, the annual cycle of surface-ocean pH is attenuated by 16 ± 7%, a counter-intuitive result when compared with the change in amplitude in free acidity, which is larger and of opposite sign. This contrast exists because a change in pH actually represents a relative change in [H+], i.e., ΔpH is proportional to Δ[H+] / [H+], and the increase in the numerator (the seasonal amplitude of [H+]) is less than the increase in the denominator (the annual mean [H+]). The projected enhancement of the seasonal amplitude of ocean acidity may well exacerbate future impacts on marine organisms, relative to the case of considering no change in seasonality. At higher latitudes, marine organisms would be exposed to relatively higher acidity in the winter and lower acidity in summer; in the lower latitudes, it would be the opposite. This CMIP5 analysis is now being extended to the latest generation of Earth System Models, as the CMIP6 model output becomes available. Our analysis further assesses shifts in seasonal phasing and decomposes uncertainties into internal variability, model uncertainty, and scenario uncertainty, applied for the first time to projected changes in the seasonal cycle, not changes in the annual mean.

Oral preference

Investigating the unprecedented 2016 sea ice extent minimum with an eddy-permitting Southern Ocean configuration

PELLETIER C.[1], GOOSSE H.[1] AND KLEIN F.[1]

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The Southern Ocean (SO) sea ice extent reached an unprecedented and unanticipated minimum in the spring of 2016. The maximum extent in this year also occurs much earlier in the season than on average. A large part of this event's causes can be attributed to changes in the Antarctic atmosphere, reverberating on the SO through air-sea fluxes. However, the ocean thermal content also needs to be taken into account for enhancing future predictions of such extreme sea ice events. Here we investigate this aspect using several simulations obtained from a new NEMO-LIM eddy-permitting (1/4°) and ice shelf cavities including Southern Ocean configuration, developed within the framework of the Belgian PARAMOUR project. A particular focus will be given to the vertical heat fluxes in the ocean and how the conditions in summer and fall have an impact on the ocean and sea ice state at the winter maximum of the ice extent.

Oral preference

I am not available on Friday, May 10th.

Sensitivity of Ocean Biogeochemistry to the Iron Supply from The Antarctic Ice Sheet explored with a Biogeochemical Model

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2 LOCEAN/IRD

3 ENS

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Iron (Fe) delivery by the Antarctic Ice Sheet (AIS) through ice shelf and iceberg melting enhances primary productivity in the largely iron-limited Southern Ocean (SO). To explore this fertilization capacity, we implemented a simple representation of the AIS iron source in the global ocean biogeochemical model NEMO-PISCES. We evaluated the response of Fe, surface chlorophyll, primary production and carbon export to the magnitude and hypothesized vertical distributions of the AIS Fe fluxes. We will show that (i) surface Fe and chlorophyll concentrations are increased up to 25% and 12%, respectively, over the whole SO, (ii) the AIS Fe delivery is found to have a relatively modest impact on SO primary production and C export but significant in the Atlantic sector and along the coast of Antarctica, (iii) the response of surface Fe and chlorophyll is maximum downstream of the tip of the Antarctic Peninsula and along the East Antarctic coasts, (iv) icebergs are predicted to have a much larger impact on Fe, surface chlorophyll and primary productivity than ice shelves in the SO, (v) the iceberg Fe delivery below the mixed layer may, depending on its assumed vertical distribution, fuel a non-negligible subsurface reservoir of Fe, and (vi) the Fe supply is effective all year round and seasonal variations in iceberg melting have regional impacts which are almost negligible for annual-mean primary productivity and C export at the scale of the SO.

Oral preference

Hg dynamics in Arctic top predators: insights from a captive experiment on hooded seals Cystophora cristata.

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Arctic predators like true seals have been experiencing a strong increase in Hg levels in their tissues in the last 150 years. This is in contrast with other terrestrial animals or other parts of the world. Dietary Hg accumulates and biomagnifies in marine food webs in its most toxic form, monomethylmercury (MMHg). Hg seven stables isotopes (^{196}Hg, ^{198}Hg, ^{199}Hg, ^{200}Hg, ^{201}Hg, ^{202}Hg and ^{204}Hg) undergo both mass-dependent and mass-independent fractionation (MDF and MIF, respectively) as a result of abiotic and biotic reactions occurring in the environment and within the organism. For this reason, they are a promising tool for tracing Hg cycling in the natural environment. The interpretation of Hg isotopic data remain however a challenge, especially when taking into account species such as Arctic true seals, which have highly complex life styles and metabolism. In 2012, six pups of hooded seals *Cystophora cristata* were captured on the ice edge of the Greenland Sea and kept in captivity for 2 years. During this period, they were fed on a constant diet made of Norwegian herring *Clupea harengus* and vitamin complements. This allowed us to study Hg kinetic in an Arctic top predator without the influence of age, distribution and diet specialization. The main objective was to select the tissue in which the information about Hg pathways would be conserved, leading to the optimal tracing of Hg sources along the food web. Total Hg (THg) concentrations were determined on a Milestone direct mercury analyzer, while MeHg and IHg concentrations were determined by isotope dilution-gas chromatography-inductively coupled plasma-mass spectrometer (ID-GC-ICP-MS) following microwave-assisted extraction and aqueous phase derivatization. Mercury isotopic composition analysis was performed using cold vapor generation (CVG) with multicollector-inductively coupled plasma-mass spectrometer (MC-ICP-MS, Nu Instruments). The analysis was conducted in seal muscle, liver, hair, and kidney, plus muscle of herring. Hg speciation changed significantly among tissues. Hair and muscle were predominantly enriched in MMHg (range: 84 to 98% and 74 to 95%, respectively) relative to liver and kidney (range: 7 to 38% and 4 to 27% respectively) that tend to mainly accumulate iHg. δ^{202}Hg values were positively related with levels of MMHg ($p > 0.0001$, $R^2 = 0.531$). With higher values found in hair, followed by muscle, liver and kidney. Δ^{199}Hg and Δ^{201} values were not influenced by Hg species composition in tissues, as well as slope values of Δ^{199}Hg/Δ^{201}Hg. When calculating the isotopic trophic enrichment between herring and hooded seals' tissues, a significant ^{202}Hg enrichment resulted between seal hair and kidney and herring ($p = 0.011$ and $p < 0.001$), indicating important MDF between the ingested prey and these tissues. Instead, a significant MIF (Δ^{199}Hg and Δ^{201} values) was observed only between seals' kidney and herring ($p = 0.0003$). Our results show that: (1) Hg isotopic composition reflects Hg molecular speciation; (2) as a result of isotopic incorporation during tissue turnover, hair and kidney present a strong trophic MDF; and (3) with the exception of kidney, MIF signal is conserved in all tissues during assimilation of prey items. Based on these observations, we believe that muscle is the optimal monitoring tissue for tracing of Hg sources since both the MDF and MIF signals are conserved from prey to predator. The important MDF observed in hair instead, make this tissue the best option for the analysis of Hg biomagnification along food webs.

Oral preference

Assessment of the future trends in atmospheric forcing and associated tendencies in Arctic ice and ocean

PLATOV G.[1] AND GOLUBEVA E.[1]

[1] *ICMMG*

EOF decomposition of atmospheric forcing including sea level pressure, temperature and wind velocity at 10 m showed the presence of trends in the time series of the expansion coefficients for four dominating modes. By eliminating these trends it is possible to reveal the role of each mode in the formation of climate changes both in the entire Arctic Ocean and in its seas using results of coupled ice-ocean simulation. EOF found on CORE-2 reanalysis were used to decompose the atmospheric forcing resulting from a number of CMIP-5 project models to identify common trends in XXI century. Numerical results of these models show a similar dynamics in the development of the Arctic climatic system in the coming decades according to CMIP scenarios, however, a number of differences in the forecast of the development of the situation in individual Arctic seas are also revealed.

Oral preference

Statistical predictability of Arctic sea ice volume anomalies: identifying predictors and optimal sampling locations

PONSONI L.[1], MASSONNET F.[1], DOCQUIER D.[1] AND FICHEFET T.[1]

[1]*Université catholique de Louvain, Georges Lemaître Centre for Earth and Climate Research*

In this work, we have studied the statistical predictability of Arctic sea ice volume (SIV) anomalies. First, in terms of identifying best predictors and, second, aiming at spotting optimal sampling locations. To do so, we made use of 6 model outputs, from 3 different models, with 2 different horizontal grid resolution each. The main open questions which drive this research are: (i) What is the predictability skill of different pan-Arctic predictors, such as SIV itself, Sea Ice Area, Sea Ice Thickness, Sea Ice Concentration, Sea Ice Drift, Ocean Heat Transport and Sea Surface Temperature, for predicting pan-Arctic Sea Ice Volume anomalies? (ii) How does model resolution impact the statistical predictability of Sea Ice Volume anomalies (iii) What are the best in situ locations where predictor variables should be sampled in order to optimize the statistical predictability of SIV anomalies? An empirical statistical model, based on the ideas of correlation maps between predictand and predictors, and set up in a Monte Carlo scheme, was built to answer those questions. Preliminary results from the 6 different models outputs suggest that Sea Ice Thickness, Sea Ice Concentration, and Sea Surface Temperature are the best predictors, in that order. Apparently, model resolution does not have large impact on the skill of the statistical prediction and 3 optimal placed locations are enough to explain more than 70% of the SIV variance, though the both the predictability skill and the optimal locations are model dependent.

Oral preference

Is the Antarctic sea ice variability linked to the Antarctic Circumpolar Current (ACC) variability?

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[2] *Universidade Federal do Rio Grande, Oceanographic Institute*

The Antartic Circumpolar Current (ACC) is a geostrophic flow that surrounds the Antarctic continent and its associate sea ice sheet. It moves from west to east, in a clockwise pattern of circulation. It acts as an important climate and environmental barrier by isolating the cold waters around Antarctic from the relative warmer waters in the southern Atlantic, Pacific and Indian Oceans. Due to large-scale meanders, the ACC velocity front (region of maximum geostrophic velocity) is not spatially steady, what allows the ACC to approach and move away from Antarctic from time to time. In this work, we aim at understanding whether the variability of the Antarctic sea ice extent is somehow linked to the variability of the ACC velocity front, both in terms of location and intensity. To do so, we first explore geostrophic velocity and sea ice concentration data from satellites along few different longitudinal transects around the Antarctic continent, in order to track both the sea ice extent (the isoline of 15% of sea ice concentration) and the ACC velocity front. In the second step, the variability (seasonal cycle, interannual variability and long-term trend) of these two climate players are compared. Based on these results, we will be able to draw preliminary conclusions on whether or not the sea ice extent variability is somehow coupled to the ACC velocity front variability.

Poster preference

Satellite radar altimetry for polar regions: ocean and cryosphere observations

PRANDI P.[1], GUILLOT A.[2], AUBLANC J.[3], DAGUZE J.-A.[3], DEKEYNE G.[3], DIBARBOURE G.[2], FLEURY S.[4], GARNIER F.[4], POISSON J.-C.[3], PICOT N.[2] AND PIRAS F.[3]

1 Collecte Localisation Satellites

2 CNES

3 CLS

4 CNRS/LEGOS

Satellite radar altimetry was designed to observe the global open ocean, yet it provides a unique view of polar regions. For several years, CNES has supported the use of radar altimeter data for the monitoring of polar environment. We present a synthesis of the activities performed in the current Alti-Glacio project funded by CNES.

- Sea surface height retrieval in the ice covered Arctic & Antarctic Oceans, using a multi-altimeter combination approach. This processing is based on a dedicated classification and retracking of echoes from sea-ice leads. The processing developed here paves the way for future operational CMEMS products,
- Sea-ice freeboard estimation, with a focus on quantifiying the sensitivity to different processing strategies. Small differences at processing level may lead to large effects on the freeboard estimation, and freeboard products are often calibrated with respect to in-situ data. Here we investigate the impact of the waveform classification, retracking threshold and interpolation scheme,
- Antarctic DEM estimation from SARAL/AltiKa, CryoSat-2 and Sentinel-3A/3B data. This updated version extends previous work by integrating CryoSat-2 SARIn data in the marginal regions of Antarctica as well as Sentinel-3B measurements.

No preference

Mixing at intermediate depths in a changing Arctic Ocean

RIPPETH T.[1], LINCOLN B.[1], VLASENKO V.[2], GREEN M.[1], STASHCHUK N.[2], SCANNELL B.[1], LENN Y.-D.[1] AND BACON S.[3]

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[2] *Plymouth University*

[3] *National Oceanography Centre*

The wind and the tides are recognized as major sources of kinetic energy which support turbulent mixing in the global oceans. The prime mechanism for the transfer of wind energy to turbulent mixing is the generation and decay of inertial oscillations, whilst the transfer of tidal energy to turbulent mixing is geographically limited and is a result of the interaction between topography and stratified tidal flow. The tidal flow of stratified water over sloping topography leads to the generation of a lee wave. Across much of the global oceans this lee wave then forms a freely propagating internal tide with the same period as the forcing tide. However, much of the Arctic is poleward of the critical latitude (where the period of the principal tidal constituent exceeds the local inertial period), and so the action of the Coriolis force precludes the development of a freely propagating linear internal tide. Consequently, it has been widely speculated that mixing will increase under retreating sea ice, in response to increased transfer of momentum from the atmosphere to the ocean. Here we present microstructure and other measurements made in open water in the Canada Basin, during the unprecedented summer cyclone of 2012, which show that although there is increased mixing in the upper ocean in response to open water, the influence of the wind does not extend to the intermediate depths of the intruding warm Atlantic water. We will also present measurements from a region of sloping topography which, despite being poleward of the critical latitude, hosts significant conversion of tidal energy. We will combine the measurements with a high-resolution non-linear modelling study to demonstrate the key role of unsteady tidally generated lee waves and super-critical flow in the transfer of energy from the barotropic tide to internal waves in these high latitude regions. The results suggest that the tide supports significant levels of turbulent mixing in the Arctic Ocean, but that the pathway of energy from the tide to turbulence is different to that found equatorward of the critical latitude. This process is not currently parameterised in global ocean and climate models.

Oral preference

Unravelling the evolutionary processes that shaped the diversity of the amphipod genus Eusirus in the Southern Ocean

SALABAO L.[1,2], FRÉDÉRICH B.[1], LEPOINT G.[1], VERHEYE M.[1], SCHÖN I.[3]

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[3] *Royal Belgian Institute of Natural Sciences, OD Nature, Belgium*

Various evolutionary processes greatly influenced by the geological and climatic history shaped the diversity of the current Antarctic marine fauna. In the past, these Antarctic species have survived different glacial cycles through dispersal to refugia, and/or adaptations to novel abiotic and biotic conditions. With the increasing temperatures in the polar regions, marine fauna is currently faced with three possible outcomes: adaptation, migration or extinction. Based on how these organisms were able to survive environmental changes in the past will allow us to predict their future response. In this study, amphipods of the genus Eusirus are as model organisms as knowledge on their ecology and biogeography is still very limited. The evolutionary history of Eusirus amphipods is phylogenetically reconstructed through time with molecular data. DNA sequence data are obtained by sequencing the complete mitochondrial genomes, using a combination of skimming sequencing and long-range PCRs amplicons of different Eusirus species. Mitochondrial data will be complemented with additional sequence data from nuclear genes. Time-calibrated phylogenies will be used as basis for plotting ecological and trophic data generated by stable isotope analyses as well as morphological information. By combining data from time-calibrated phylogenies as well as from ecology and morphology, we aim to understand the evolutionary processes that led to the current diversity of Eusirus amphipods.

Poster preference

Physics of Interannual Variability and Trend of the Bering Strait Throughflow Gleaned from Satellite Altimeters

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Beginning with the TOPEX/Poseidon altimetry mission in 1992, along-track satellite sea surface height (SSH) estimates have been taken every 6-7 km at 10-day intervals at a cluster of satellite tracks across the Bering Strait at 66^{o}N where the satellite tracks turn. Using SSH, year-to-year August/September/October (ASO) geostrophic estimates of the Bering Strait throughflow beginning 1993 agree well with the in situ estimates, and both are highly correlated with the estimated in situ annual transport. Energy flux calculations using the SSH support the recent hypothesis of Peralta-Ferriz and Woodgate (2017) that the Bering Sea throughflow is mainly driven by zonal winds on the East Siberian Sea. Wind-forced shelf wave dynamics explains physically why this should be so and, along with this, explains the dynamical origin of the "pressure head" at the northern "end" of Bering Strait. Interannual variability is large, making it difficult to discern a significant transport trend. However, likely increased melting of coastal fast ice along the northern Russian coast will increase the access of alongshore westward wind stress to open water along that coast. This will likely result in the increased flux of northward volume, heat and nutrients through the Bering Strait and will likely accelerate physical and ecological change there.

Oral preference

What is APECS Belgium?

SAVAGLIA V.1, BRODE-ROGER D.2, CHRISTIANSEN H.2, DE MAEYER L.3, DURIEU B.1, GAN Y.M.4, GOSSART A.2, HEINDLER F.M.2, HIRST C.5, JACQUES C.6, JOSSART Q.6, MAES S.2 AND PINSEEL E.7

1Université de Liège, Belgium

2 KU Leuven, Belgium

3 Universiteit Gent, Belgium

4 Royal Belgian Institute for Natural Sciences, Belgium

5 Université catholique de Louvain, Belgium

6 Université libre de Bruxelles, Belgium

7 Universiteit Gent, Belgium

The Association of Polar Early Career Scientists (APECS) is an international and interdisciplinary organization for undergraduate and graduate students, postdoctoral researchers, early faculty members, educators and peoples with interests in Polar Regions and the wider cryosphere. Its main goals are communication, education, outreach, and assistance to early career scientists. The APECS leadership team is comprised of early career researchers that are interested in and committed to furthering the activities and the future directions of the organization. Project initiation and management, web-based or in-person events are carried out by a number of member-initiated working groups and committees made up of both members and mentors.

APECS Belgium, the Belgian National Committee of APECS, was founded in 2011 and has organized and participated in many events and activities since; for example: Conference Symposia, a Science Fair, School visits, Workshops, Documentary Screenings, popular Science event and much more. APECS Belgium encourages polar research at the national level by promoting research projects and institutes in the Belgian territory and sharing the fascination of the Poles with other researchers and the public.

Every early career scientist based in Belgium with an interest in the Polar Regions is highly encouraged to join us! We also invite peoples with links to polar education and research to become a part of APECS Belgium. For more information, visit our website: www.apecsbelgium.wordpress.com.

No preference

Refugia and ecosystem tolerance in the Southern Ocean – the RECTO project

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[5] *University of Liege, MARE Centre, Laboratory of Oceanology*

[6] *Vrije Universiteit Brussels (VUB), Marine Biology*

[7] *Ghent University, Marine Biology Research Group*

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Confronted with fast-paced environmental changes, biota in Antarctic ecosystems are strongly challenged and face three possible outcomes: adaptation, migration or extinction. Past glaciation periods have already forced marine zoobenthos of the Southern Ocean (SO) into refugia, followed by recolonization when the ice retreated. The collaborative Belgian BRAIN project RECTO, "Refugia and ecosystem tolerance in the Southern Ocean", will strive at understanding how such past events have driven diversification and adaptation in different animal groups and how these can be applied as proxies to understand the contemporary situation and predict future scenarios.

With molecular approaches, RECTO will reconstruct population histories and spatio-temporal features of Pleistocene refugia. The RECTO target taxa include birds, fish, sea stars, bivalves, amphipods, and ostracods. For all RECTO target taxa, the following molecular data will be obtained: (1) mitochondrial COI barcodes, (2) ddRAD data, and (3) mitochondrial genomes. In fish and amphipods, RECTO will also study in a novel phylogenetic framework how morphological diversification and trophic adaptability (estimated by stable isotope data) are interacting with each other and whether ecotypes of selected species have faster modes of evolution.

Geographic models on future species and trait distributions based on physiological and energy limits and present and future climate data will be refined and integrated with an Individual-Based Model for the SO. Using the latter model, larval dispersal of selected RECTO model groups (e.g. fish & bivalves) is simulated and compared to genetic patterns. Finally, scenarios of future dispersal abilities and possible habitat shifts of the RECTO target groups will be developed to infer how the RECTO target species will respond to future climate change.

Oral preference

If there will be a session on RECTO, this talk would give an overview on the project.

Biogeochemical modeling of the West Antarctic Peninsula

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[2] *University of Virginia*

Over the past several decades, the West Antarctic Peninsula (WAP) has undergone physical and ecological changes at a rapid pace, with warming surface ocean and a sharp decrease in the duration of the sea ice season. The impact of these changes in the ocean chemistry and ecosystem are not fully understood and have been investigated by the Palmer-LTER since 1991. Given the data acquisition constraints imposed by weather conditions in this region, an ocean circulation, sea ice and biogeochemistry model was implemented to help fill the gaps in the dataset. The results with the present best case from the suite of sensitivity experiments indicate that the model is able to represent the seasonal and interannual variations observed in the circulation, water mass distribution and sea ice observed in the WAP, and has identified gaps in the observations that could guide improvement of the simulation of the regional biogeochemistry. Comparison of model results with data from the Palmer-LTER project suggests that the large spatial and temporal variability observed in the phytoplankton bloom in the WAP is influenced by variability in the glacial sources of dissolved iron. Seasonal progression of the phytoplankton bloom is well represented in the model, and values of vertically integrated net primary production (NPP) are largely consistent with observations. Although a bias towards lower surface dissolved inorganic carbon (DIC) and alkalinity was identified in the model results, interannual variability was similar to the observed in the Palmer-LTER cruise data.

Oral preference

Coupling of ocean model NEMO to regional climate model MAR over the arctic Ocean

SIEVERS I. AND FETTWEIS X.

University of Liège - Laboratoire de Climatologie

The Arctic is currently undergoing rapid changes with major effect on the global climate system. Since the Arctic is a ruff environment which is hard to sample with observations, modelling is often chosen to understand the different processes and interactions at play. Most regional modelling efforts however focus on only one component of the arctic climate system at a time (ocean, atmosphere, ice sheet...) and therefore, neglect that many climate components are linked to each other.

To fully understand all the interactions involved in the Arctic climate system we will present first results of a coupling of an atmosphere-ocean regional climate model with an integrated sea ice model set up over the arctic Ocean in the framework of the Belgian PARAMOUR project. The models used are the regional climate model MAR (developed at Uliège), which is especially designed to model the Polar regions, and the ocean model NEMO with the integrated ice model LIM at a resolution of 1/4°. By coupling these high resolved models we aim to get a better insight into the small scale interactions between atmosphere, ocean as well as the Greenland Ice Sheet Surface Mass Balance, and with this insight contribute to a better understanding of the arctic climate system.

Poster preference

The effects of atmospheric uncertainties on two melt pond schemes in global climate models

STERLIN J.[1], FICHEFET T.[1] AND MASSONNET F.[1]

1 UCLouvain

In order to predict future changes in the polar regions, the ice-albedo feedback must be adequately represented in the climate models. The albedo in the Louvain-la-Neuve Sea Ice Model is calculated as the weighted sum of the bare ice, snow covered, and open ocean surfaces. The albedos of the ice and snow are functions of their thicknesses and of the surface temperature. During the melt season in the Arctic, melt water collects in the depressions of the ice field. The albedo of the ponds is lower because of the melt water, absorbing more solar radiation. For this reason, melt ponds are hot-spots for the ice-albedo feedback. However, melt ponds are generally poorly accounted for in climate models, by tuning the albedo to include a constant bare puddled ice offset.

There is two main approaches to represent the melt ponds in Global Climate Models. The first approach is empiric and relies on observations to determine the available water capacity of the ponds from the sea ice state. Then, a fraction of the surface melt water accumulates is the ponds. The second makes use of the Ice Thickness Distribution to infer the surface topography of the sea ice and distribute the melt water among the ice categories.

Although the role of melt ponds has been extensively studied, less is known on the response of the ponds to atmospheric uncertainties. Insights can be gained from using different reanalyses of the atmospheric surface state to force the ocean and ice components. Because of a lack of observations in remote areas, reanalyses still suffer from biases notably in the polar regions. The choice of a reanalysis has a strong influence on the representation of the sea ice state of the Antarctic. We expect similar deviations in the Northern Hemisphere. To evaluate the effect of the melt pond schemes on the sea ice when subject to uncertainties in the atmospheric state, we have run the empiric and topographic schemes forced with JRA-55, DFS 5.2, and NCEP/NCAR atmospheric reanalyses. From the simulations, We expect to see the degree of difference between the pond schemes and the influence of the forcing onto their climatic response. We will be able to assess the importance of the melt ponds for the climate and check the consistency of the parameterizations. This will allow us to formulate a recommendation on the use of melt ponds in climate models.

Poster preference

Remote sensing and in situ observations of wave attenuation dynamics in diverse marginal ice zones.

SUTHERLAND P.[1], DUMONT D.[2] AND BARAST L.[1]

[1] *LOPS – IFREMER*

[2] *ISMER - UQAR*

Summer sea ice extent in the Arctic Ocean has been decreasing since the beginning of the satellite record. This ice reduction is resulting in the development of a "seasonal sea" in which open ocean processes, notably surface waves, are present. Waves are known to break up ice over large areas, and affect ice formation, upper ocean turbulence, and mixing. For these reasons, the emerging presence of waves in the Arctic has the potential to provide many conflicting feedback mechanisms. In order to include the effects of these feedbacks in simulations of Arctic weather and climate, a good understanding of wave propagation in ice is necessary. Wave attenuation is generally divided into two categories: scattering and dissipation. The relative importance of these mechanisms depends strongly on ice conditions, particularly ice thickness, floe size, and floe morphology. Further, while the scattering mechanism has been relatively well studied, there is no clear consensus on the dominant dissipative mechanisms and their mathematical formulation.

In this presentation, the conditions under which scattering and dissipation are significant will be explored with measurements from a series of field experiments. At large scales, using data from two Arctic airborne campaigns, various theoretical attenuation descriptions are tested against observed wave spectral evolution. This includes comparing the modelled and predicted attenuation rates, the frequency dependence of attenuation, and the spectral spreading. At smaller scales, in a "natural laboratory" on the St. Lawrence Estuary, measurements of turbulent kinetic energy dissipation and under-ice currents were taken in conjunction with collocated buoy and unmanned aerial vehicle measurements of the wave spectra. This allows preliminary estimation of the quantity of wave energy that is transferred to the upper ocean, and the calculation of an energy budget in which the effects of scattering, under-ice dissipation, and in-ice dissipation are isolated. Due to the parameter space of the experiments, and the concurrent measurements of ice characteristics, it is possible to begin to determine which ice conditions support which types of attenuation. The implications of this work, and plans for future efforts to address these questions, will be discussed.

Oral preference

The microbial Antarctic Resource System: integrating discoverability and preservation of environmental annotated microbial -omics data.

SWEETLOVE M.[1], GAN Y.M.[1], MURRAY A.[2], VAN DE PUTTE A.[1]

[1] *Royal Belgian Institute of Natural Sciences*

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Microbial organisms, including Archaea, Bacteria and unicellular Eukaryota, collectively dominate the Earth in terms of bio- and functional diversity. Their study, often constrained by technology, has strongly benefited from the recent advancements in high throughput DNA sequencing techniques. The vast amounts of microbial data generated in the wake of these developments, however, remains severely underrepresented on open access biodiversity data repositories (e.g. GBIF). Moreover, when sequencing data has been made publicly available, is often poorly annotated with metadata and environmental variables, making it difficult to find or query. Therefore, the microbial Antarctic Resource System (mARS) aims to fill this lacuna by documenting and geo-referencing (Antarctic) microbial datasets, and linking the sequence data on INSDC repositories with associated environmental measurements. This way, mARS helps to preserve data, connect researchers to the existing wealth of molecular information, and allow these datasets to be more effectively mined. Given the general complexity of microbial ecological datasets, mARS needs to operate between different data archiving standards, such as MIxS, which is oriented towards DNA sequence data, and the biodiversity based DarwinCore standard. Integrating microbial data with these existing systems, as well as connecting with communities behind them has been a major challenge in the continued development of mARS.

Oral preference

The Census of Antarctic Marine Life, and its legacy 10 years on

VAN DE PUTTE A.[1], ALL EDITORS[2], WADLEY V.[3], STODDART M.[3], GAN Y.M.[1] AND SWEETLOVE M.[1]

[1] *RBINS*

[2] *Biogeographic Atlas of the Southern Ocean*

[3] *AAD*

The Census of Antarctic Marine Life (CAML 2005-2010) was a component of the Census of Marine Life (2000-2010) that brought together a community of Southern Ocean researchers and helped them exchange expertise and coordinate at various levels. The International Polar Year was a pivotal component of CAML, and included 18 major research voyages to Antarctica and the Southern Ocean This formed a new benchmark for the assessment of Southern Ocean biodiversity. While previously thought to be low in species diversity, the Southern Ocean has an unexpected richness of life.

At the end of five years of extensive biodiversity exploration and assessment by CAML, a new initiative, the multi-authored "CAML Biogeographic Atlas of the Southern Ocean", was established under the aegis of the Scientific Committee on Antarctic Research (SCAR) to provide an up-to-date synthesis of Antarctic and sub-Antarctic biogeographic knowledge. In an unprecedented international collaboration 147 scientists from 91 institutions across 22 countries (Australia, Belgium, Brazil, Canada, Chile, Denmark, France, Germany, Ireland, Italy, Japan, the Netherlands, New Zealand, Norway, Poland, Portugal, Russia, South Africa, Spain, Switzerland, the UK and the USA) combined their expertise and knowledge and published the Atlas in 2014.

Data gathered during CAML was preserved in the Scientific Committee on Antarctic Research Marine Biodiversity Information Network (SCAR-MarBIN), which is now part of the Antarctic Biodiversity Portal (biodiversity.aq). These data are freely and openly available.

The knowledge and data gathered as a result of CAML will continue to help inform conservation policy, including the debate over whether or not to establish marine protected areas in the open ocean. Sophisticated environmental models coupled with existing species distribution data provide a valuable outlook on the possible future distribution of key species as they adapt to climate change.

No preference

Ocean-sea ice-atmosphere gas exchanges in the early stages of ice formation: insight from the PIPERS cruise

VAN DER LINDEN F.[1,2], CARNAT G.[2], SAPART C.[2], DE JONG J.[2], KOTOVITCH M.[1,2], STAMMERJOHN S.[3], ACKLEY S.[4], TISON J.-L.[2] AND DELILLE B.[1]

[1] *Université de Liège*

[2] *Université Libre de Bruxelles*

[3] *University of Colorado*

[4] *University of Texas at San Antonio*

In polar oceans, the CO_2 cycle is influenced by the presence of sea ice. Studies highlighted the complex role of sea ice in CO_2 exchanges and reported CO_2 fluxes over sea ice, in spring and summer, yet few studies have examined the winter CO_2 exchanges above sea ice in Antarctica – a prerequisite to budget air-ice CO_2 fluxes over the year. We present insights of the dynamics of potent greenhouse gases (CO_2, CH_4 and N_2O) during early sea ice growth in the Ross Sea from April to June 2017 in the frame of the PIPERS project. It was a unique opportunity to capture temporal and spatial evolution of pack ice biogeochemistry during the first stages of sea ice formation. Multiple sea ice types were sampled (frazil, unconsolidated and consolidated pancakes, first-year ice) in contrasted areas (marginal ice zones, polynyas, and the central Ross Sea pack ice). The comparison of CO_2 fluxes over consolidated and unconsolidated ice shows that 1) sea ice acts as a source of CO_2 for the atmosphere during early winter 2) largest fluxes occur at the earliest sea ice growth stages (i.e. frazil ice, unconsolidated grey ice, pancake ice). Large fluxes are due to ongoing active rejection of impurities, high porosity of highly saline and young ice, and the absence of snow. Overall, snow appears to restrict CO_2 fluxes. In some cases, fluxes over snow appears to be nil or even opposite to fluxes over bare ice. Therefore, while snow is often view as a transient buffer for air-ice gases fluxes, the role of snow appears to be more complicated. The new measurements of CO_2 fluxes over young ice carried out during PIPERS potentially allow to complete a budget of CO_2 fluxes over Antarctic pack ice.

Poster preference

Community structure and photoacclimation in Antarctic ice-algal assemblages

VAN LEEUWE M.[1], FENTON M.[2] AND ANNETT A.[2], DAVIS E.[2] AND STEFELS J.[1]

1 University of Groningen

2 British Antarctic Survey

Microalgal composition and production was studied in sea ice in Ryder Bay, West-Antarctic Peninsula. This area isthe fastest warming oceanic region on earth; between 1979-2007 a 41% decline relative to the mean was recorded. The impact on biogeochemical cycles is poorly described. Development of microalgal sea-ice communities was studied from winter to summer during three years. Over the course of spring, modest surface communities developed with a Haptophyte pigment signature. Major biomass increases were recorded in the bottom layers and reached a maximum concentration of more than 700 µg Chl-a l^{-1}in December 2014. Early in the season, a mixed algal community inhabited the bottom layer. From November onwards, diatoms dominated the bottom community, with *Nitzschia, Fragillariopsis and Berkeley sp.*as the main species. The maximum electron transfer rate (Pmax) and the light affinity as determined by PAM-fluorescence were highest in spring. Light saturation towards summer was reflected in an increasing contribution of the light protective pigment-pool diato- plus diadinoxanthin. This times series provides unique patterns of community structure and photoacclimation in Antarctic landfast ice-algal communities.

Poster preference

Reconstructing NCP from O2 and Ar concentrations in winter sea ice of the Ross Sea (Antarctica)

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Measuring the net community production (NCP) – which is the balance between O_2 production by primary producers and the respiration of the entire community – in sea ice is very challenging due to its heterogeneous nature (mixture of pure ice, brines, gas bubbles and salts). Different techniques are currently used to determine NCP: either by direct (i.e. ^{14}C incubation) or indirect (ice-water O_2 interface eddy correlation, gas analyses) measurements. These techniques are still in the process of inter-calibration in sea ice (SCOR ECVice).

NCP measurements are scarce in sea ice, peculiarly in the winter. Here we present a reconstruction of the NCP levels by measuring the concentrations of O_2 and Ar at high resolution using gas chromatography in sea ice cores collected during the PIPERS (Polynyas, Ice Production and seasonal Evolution in the Ross Sea) field project. This project is one of the rare that took place in the Ross Sea during the austral winter. It aims to document the physical and biogeochemical properties of pack ice and to study the dynamics of the polynyas of the Ross Sea and of Terra Nova Bay. Polynyas are open water areas of strong sea ice production under sustained coastal katabatic winds originating on the ice sheet.

Two main conclusions can be drawn from this study: it has been possible to dissociate the biotic and abiotic controls on O_2 concentrations in sea ice and therefore to reconstruct the levels of Net Community Production during this winter period. The discrimination of abiotic and biotic controls is based on the use of O_2/Ar ratios because dioxygen concentration is modified by physical processes (temperature and salinity changes, brine convection) and by biological activity (photosynthesis and respiration) whereas Ar is only influenced by physical processes. A dominance of the physical processes was highlighted in most of the stations considered, with a contrast between the stations of polynya where no trace of biological activity could be identified, whereas a non-negligible biological activity could be observed in the centre of the Ross Sea.

To reconstruct the levels of NCP, a multidisciplinary approach was used because of the spatial and temporal variability of the cores sampled during the mission. Estimates of the age of the cores (and thus of the period of biological activity) required the use of satellite data and of a thermodynamic model. The concentrations measured in the ice made it possible to calculate the deviation from the saturation ratio ($\Delta(O_2/Ar)$), the equilibrium O_2-concentration in the brines and eventually, the O_2-concentration due to biological activity. From the time evolution of the latter, the NCP allowed us to determine the general regime (auto- or heterotrophic) in place. These NCP values are compared to the literature for the winter period and the good correspondence confers reliability to our results.

What is the impact of brines conditions on the biogenic DMSP and DMSO production? A cell culture approach

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Sea ice is an extreme environment known to host microbial communities which produce dimethylsulfoniopropionate (DMSP) and dimethylsulfoxyde (DMSO), two biogenic precursors of the climate cooling gas dimethylsulfide (DMS). Despite decades of research, drivers and pathways of the sea ice DMS cycle remain largely unknown. This study quantifies for the first time the production of the metabolites DMSP and DMSO by the diatom *Fragilariopsis cylindrus* and the prymnesiophyceae *Phaeocystis antarctica* under changes of temperature and salinity typically encountered in the sea ice brine habitat. Salinity 75 and salinity 100 experiments suggest an osmolyte function of both dimethyled sulfur compounds in the diatom cell. A stronger salinity shift to 150 induces an osmotic shock and ultimately cell death. Decreases of temperature combined with increases of salinity reveal similar trends and suggest that the cryoprotectant function of DMSP and DMSO is not relevant in our cultures. Through this study, we improve our knowledge and the modelling capabilities of the sea ice DMS cycle.

On the meridional shift of the zone of maximum winds in the Southern Ocean

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Zone of the meridional maximum of the kinetic energy of the currents is in the northern part of the Antarctic Circumpolar Current (ACC) band encircling the Antarctic continent from west to east. This maximum corresponds to the highest intensity of the process of energy transfer from the atmosphere to the ocean. The meridional shift of this maximum for the period of 1993–2015 is investigated on the basis of satellite altimetry data of the absolute dynamic topography (ADT) of the French agency CLS (http://www.aviso.altimetry.fr) with a resolution of ¼ ° × ¼ ° in the whole circumpolar circle. In particular, the specific kinetic energy calculated from the ADT data was averaged for each year over the latitudes in the band covering the ACC zone. Then a linearized change in energy over 23 years was calculated for each latitude, as well as an average energy over 23 years depending on the latitude. Further, the meridional gradient of average kinetic energy was calculated. Linear regression coefficients were also determined for the relationship between the linearized change in kinetic energy and this gradient. The coefficient of proportionality in such a linear regression corresponds to the average meridional shift over the band of latitudes, and the free term corresponds to the average energy change. The calculations showed a shift of the zone of maximum kinetic energy, and consequently the band of maximum westerly winds, by 58 ± 17 km to the north. At the same time a general increase in energy of about 10% is observed. Present work was supported by grant 16-17-10149 of Russian Science Foundation.

Oral preference

Emerging ecological patterns of Arctic sea-ice decline

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The Arctic sea-ice decline is among the most emblematic manifestations of climate change and is occurring before we understand its ecological consequences. At the base of a food web, any trophic or phenological change to primary producers has the potential of cascading effects along trophic levels through what is known as “bottom up” effect. In the Arctic Ocean, the marine food web is particularly short. Owing to the large stress that the Arctic food web is subjected to by the ongoing warming, major cascading effects derived from changes at the bases can be expected. In this talk, I will review current knowledge and deliver a set of predictions for key biogeochemical and ecological variables representative of the ice-covered Arctic Ocean. In particular, I will give an overview of:

- The changing Arctic icescape, including e.g., sea ice extent and thickness, snow depth, melt ponds and leads;
- The drivers of biological changes for Arctic marine algae such as light, habitat and nutrients;
- The different pulses of Arctic marine primary production, from sympagic to under-ice to open-water blooms;
- The patterns of trophic and phenological changes using sea-ice algae as a case study.

Impact of riverine carbon and nutrient fluxes on the Arctic Ocean biogeochemistry

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The Arctic Ocean is more than any other ocean influenced by riverine delivery of carbon and nutrients. Moreover, this riverine delivery of carbon and nutrients is projected to experience profound changes during the 21st century. Here we quantify the impact of Arctic riverine delivery on marine primary production, air-sea CO_2 fluxes, and ocean acidification with the eddy resolving ocean circulation-biogeochemical model NEMO-PISCES. Therefore we developed a monthly riverine forcing set for all Arctic riverine delivery of carbon and nutrients based on observed river delivery from the six largest Arctic rivers. We find that riverine delivery of nutrients sustain 13-19% of basinwide Arctic Ocean net primary production (NPP) and up to 100% locally. This riverine sustained NPP reduces surface ocean dissolved inorganic carbon and thus increases the aragonite saturation state locally by up to 50%, a significant attenuation of coastal ocean acidification. In addition to nutrient fluxes, the riverine carbon fluxes reduce the Arctic Ocean air-to-sea CO_2 flux by 17% and turn the Laptev Sea from a sink of atmospheric carbon into a source. To quantify the effect of future changes, we performed idealized sensitivity tests with increasing riverine delivery by 1% per year. When riverine dissolved organic carbon fluxes are doubled, the Kara Sea, the East-Siberian Sea, and the Beaufort Sea also become sources of carbon to the atmosphere. Moreover, doubling of riverine nutrients leads to an increase in basinwide NPP by 11% and by up to 100% locally.

Oral preference

Study of landfast ice over the Totten Ice-Shelf with a NEMO-LIM local configuration

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The Totten ice shelf drains over 570 000 km² of East Antarctica. Most of the ice sheet that drains through the Totten ice-shelf is from Aurora Subglacial Basin and is marine based making the region potentially vulnerable to rapid ice sheet colapse.

Understanding how the changes in ocean circulation and properties are causing increased basal melt of Antarctic ice shelves is crucial for predicting future sea level rise. In the context of the PARAMOUR project, we built a NEMO-LIM local configuration over the Totten ice shelf area in East Antarctica, to study the variability and predictability of the ice-ocean-atmosphere system. In the future we wish to coupled our model with an ice-sheet model and an atmospheric model.

Current sea ice models are unable to represent very crudely the formation, maintenance and decay of coastal landfast ice. Landfast ice is sea ice that is fastened to the coastline, to the sea floor along shoals or to grounded icebergs. We applied several parameterization for modeling landfast ice over the Totten ice shelf area.

Poster preference

The Antarctic Biodiversity Portal, an online ecosystem for linking, Integrating and Disseminating Antarctic Biodiversity Information

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The Antarctic Biodiversity portal (www.biodiversity.aq) is a gateway to a wide variety of Antarctic biodiversity Information and tools. Launched in 2015 as SCAR-MarBIN and the register of Antarctic Marine Species (RAMS) the system has grown in scope from purely marine to also include terrestrial information.

Biodiversity.aq is a SCAR product, currently supported as one of the Belgian contribution to the European Lifewatch-ERIC (European Research Infrastructure Consortium). *The goal of lifewatch is to provide access to: Distributed observatories/sensor networks; Interoperable databases, existing (data-)networks, using accepted standards; High Performance Computing (HPC) and Grid power, including the use of the start-of-art of the so-called Cloud and Big Data paradigms technologies; Software and tools for visualization, analysis and modeling*."

Here we provide an overview of the most recent advances in the biodiversity. aq online ecosystem, a number of use cases as well as an overview of future directions. Some of the most notable components are:

The Register of Antarctic Species (www.marinespecies.org/RAS) provides an authoritative and comprehensive list of names of marine and terrestrial species in Antarctica and the Southern Ocean. It serves as a reference guide for users to interpret taxonomic literature, as valid names and other names in use are both provided.

IPT.biodiversity.aq allows disseminating Antarctic biodiversity data into global initiatives such as the Ocean Biogeographic Information System (OBIS) as Ant-OBIS (formerly also known as SCAR-MArBIN) and the Global Biodiversity Information Facility (GBIF) as AntaBIF. Data that can be made available includes metadata, Species checklists, species occurrence data and more recently event based data. Data from these international portals can be accessed through data.biodiversity.aq.

Biodiversity.aq, provides a strong and tested platform for sharing integrating, discovering and analysing Antarctic biodiversity information originating from a variety of sources into a distributed system.

No preference