10/26/15

A

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Source-sink driven planetary flows in a polar basin

Analytical and numerical methods are used to study linear, steady-state, source-sink driven barotropic planetary flows in a circular polar basin on the sphere. Analytical solutions are obtained in a basin with no topography and in a basin with a uniform step shelf. The leading order dynamical balance is geostrophic except near the boundary of the basin and the shelf edge, where linear frictional boundary layer become significant. In the absence of topography the inflow deflects eastward (in the North Hemisphere) upon entering the basin and bifurcates into a branch that flows anticyclonically adjacent the boundary wall to the outflow and a branch that flows cyclonically. With the addition of a step shelf the circulation inflow again bifurcates into two branches. The anticyclonic branch once again forms a boundary current confined to the shelf that exits directly through the outflow open boundary. On the other hand, the majority of the cyclonic branch is confined to the shelf and exits through the out flow boundary, while the remaining cyclonic branch traverses the deep basin before exiting the domain. In general, the deep basin has a weak flow and is in this sense dynamically isolated from the shelf. Numerical experiments conducted using the NEMO ocean model confirm these analytical results. We will also report as a series of numerical experiments using the NEMO ocean model to study structure of source –sink driven barotropic flow in a circular polar basin with a step shelf and a simple representation of the Lomonsov ridge.

A

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Future navigability of Arctic sea routes:
High-resolution projections of the Arctic Ocean and Sea Ice decline

Aksenov et al.

The rapid Arctic summer sea ice reduction in the last decade has led to debates in the maritime industries whether one could expect an increase in cargo transportation in the region. Shipping data shows a reduction in average sailing times, attributed to easing sea ice conditions along the Siberian coast. However, the economic risk of exploiting the Arctic routes is substantial. It lies in the uncertainty of the length of the navigation season, and in changes in sea ice and ocean, and requires robust environmental predictions. Here a detailed high-resolution future projection of ocean and sea ice forced with the RCP8.5 IPCC emission scenario is used to examine navigability of the Arctic sea routes. In summer, opening of large areas of the Arctic Ocean previously covered by pack ice to the wind and surface waves leads to the Arctic pack ice cover evolving into the Marginal Ice Zone (MIZ). The new emerging state of the Arctic Ocean features large areas of ice-free ocean, fragmented and thinner sea ice, stronger winds, ocean currents and waves. It presents new challenges for resources mining and transportation in the Arctic and for forecasting.

A

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Dynamics of Arctic Pacific Water

Aksenov et al.

Pacific Water (PW) enters the Arctic Ocean through Bering Strait and brings heat, fresh water and nutrients from the northern Bering Sea. The circulation of PW in the central Arctic Ocean is only partially understood due to the lack of observations. We simulate PW pathways by tracking it with a passive tracer, released in Bering Strait and analyze changes in the PW through the Arctic Ocean due to changes in the wind. A hypothesis relating Ekman pumping, changes in vertical shear of oceanic relative vorticity and PW pathways is suggested.

A

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A Study of the Impact of Snow Cover on the Navy's Arctic Cap Nowcast/Forecast System

The U.S. Navy's Arctic Cap Nowcast/Forecast System (ACNFS) is a coupled ice-ocean modeling system consisting of the Community Ice CodE (CICE) and the HYbrid Coordinate Ocean Model (HYCOM). The coupled system is forced with the Navy Global Environmental Model (NAVGEM) and assimilates observations of satellite-derived sea surface temperature, in situ data, ocean profiles, ice concentration and ice edge data through the Navy Coupled Ocean Data Assimilation System (NCODA). ACNFS has been running operationally at the Naval Oceanographic Office since 2013 to provide 7-day forecasts of ice thickness, concentration, ice drift, and lead opening rates to the National Ice Center. ACNFS uses monthly varying precipitation from the Global Precipitation Climatology Project to determine monthly-varying snowfall rates which are applied in the CICE model. In this study we compare snow depths from the ACNFS against data from NASA IceBridge during 2012-2015. In separate model runs, daily precipitation fields from NAVGEM are used to provide snowfall for the CICE component in ACNFS. Comparisons of the climatological versus NAVGEM-derived snowfall and the impact on the resulting ice thickness are presented.

A

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Sea level in the Arctic Ocean from satellite radar altimetry

Sea surface height (SSH) is poorly observed in the Arctic due to limitations of conventional observation techniques. We present the first monthly estimates of Arctic Ocean SSH from satellite radar altimetry and combine this with GRACE ocean mass to estimate steric height. SSH estimates from altimetry agree well with tide gauges and estimates of geopotential height from Ice-Tethered Profilers. The large seasonal cycle of Arctic SSH (amplitude ~4cm) is dominated by seasonal freshwater fluxes and peaks in October-November. Overall, the annual mean steric height in our study region increases between 2003-2012 before falling to ca. 2003 levels between 2012-2014. The total secular change in SSH between 2003-2014 in our study region is then dominated by a net increase in ocean mass. The well-documented doming of SSH in the Beaufort Sea dominates non-seasonal SSH variability and is revealed by Empirical Orthogonal Function analysis to be concurrent with SSH reductions in the Siberian Arctic. Ocean storage flux estimates from altimetry agree well with high-resolution modelled results, demonstrating the potential for altimetry to elucidate the Arctic hydrological cycle. We also examine changes in Arctic Ocean geostrophic circulation and compare this with sea ice drift and atmospheric circulation. There is an increase in ocean geostrophic circulation around the Beaufort Gyre in late 2007, a year that saw large reductions in multiyear sea ice coverage in the Canadian Arctic as well as strong wintertime atmospheric forcing.

A

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Oceanographic changes in the Arctic Ocean since the 1990s

In the last two decades, significant changes have occurred in the Arctic Ocean. The ice cover of Arctic seas, which was gradually decreasing from the beginning of the 20th century has began to shrink rapidly in the 1990s and in the 21st century. Water salinity has reduced significantly in the surface water layers. The temperature of Atlantic waters in the Arctic basin started to increase. At the end of the 1990s, stabilization of Atlantic water transport to the Arctic Basin was observed, but starting from 2004, the temperature of Atlantic waters in the Eurasian sub-basin increased even more and reached values that had not been observed here previously. In 2007, extreme summer processes in the Arctic that followed this increase and anomalous state of the ice cover and upper layer of the ocean that were formed by the beginning of autumn put forward a pressing problem to evaluate the variation in the thermohaline structure of the Arctic Ocean as a whole.

Analysis of the data of observations demonstrated the following. In the summer of 2007, extremely high temperatures were observed in the upper layer of the American–Asian sub-basin, and high positive anomalies were formed, which reached +3°C. The area occupied by waters with temperatures greater than –1°C was almost two times greater than the climatic one. In the central part of the Eurasian subbasin, the water temperature in the surface layer was close to the climatic value. Anomalies were within –0.5 to +0.5°C. However, in the northern parts of the Barents and Kara seas, the temperature of the upper layer was greater than the climatic mean value with anomalies up to +2°C; in the eastern part of the Laptev Sea, positive anomalies were within +2 to +5°C in the layer of 5–10 m.
Like many other manifestations of climate change, sea level rise is already a problem in the arctic regions. The current rate of sea level rise in the Arctic Ocean estimated based on nine tide gauge stations for 1950–2014 is 2,08 ± 0,34 mm/yr. With continuing arctic warming and sea ice decline it is expected that sea level will continue rising and storms with storm surges will be stronger and more frequent and coastal communities now struggling with erosion will see shoreline retreat accelerate. On the other hand, the Arctic Ocean has a strong interannual and decadal scale natural variability and s.

A

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Wind-forced Propagation of Ocean Waves into the Periphery of the Pack Ice in the Southern Beaufort Sea

Asplin et al.,

A seasonally ice-free Arctic Ocean may become a reality sooner than originally thought, and this possibility therefore emphasizes the need for better understanding of Arctic storm interactions with the ocean and subsequent implications for the sea ice cover. Synoptic-scale atmospheric circulation patterns drive wind forcing of both the ocean and sea ice cover through transfer of momentum, creating ocean waves and inducing sea ice drift. Large ocean waves may intrude into the pack ice, causing flexural swell and fracture within the ice cover, thereby affecting dynamic and thermodynamic processes in the sea ice cover. The climatology of ocean waves in summer and fall were analyzed using available mooring data sets equipped with upward looking sonar (ULS) instruments located along and across the continental shelf of the Canadian Beaufort Sea from 2009 – 2011. The ULS data provided the wave movements of the sea ice as non-directional wave spectra and parameters, combined with ice drafts and ice velocities in varying types and concentrations of sea ice cover. Large wave propagation events within sea ice cover are identified from the ULS data record and documented in terms of surface wind forcing, ice cover characteristics, and available fetch. Wave modeling studies using satellite imagery and surface wind fields were conducted to determine the spatial distribution of the largest waves within the pack ice, and estimate the deterioration of the ice cover following wave propagation events.

A

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No presentation

B

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A changing Beaufort ice pack: replacement of multiyear sea ice, changes in the open water season duration and an ice free Beaufort Sea in September 2012

During the record September 2012 sea ice minimum the Beaufort Sea became ice free for the first time during the observational record. Increased dynamic activity during late winter enabled increased open water and seasonal ice coverage that contributed to negative sea ice anomalies and positive solar absorption anomalies which drove rapid bottom melt and sea ice loss. As had happened in the Beaufort Sea during previous years of exceptionally low September sea ice extent, anomalous solar absorption developed during May, increased during June, peaked during July and persisted into October. However in situ observations reveal that only 78% of the energy required for bottom melt during 2012 was available from solar absorption. We show that the 2012 sea ice minimum in the Beaufort Sea was the result of anomalously large solar absorption that was compounded by an arctic cyclone and other sources of heat such as solar transmission, oceanic upwelling and riverine inputs, but was ultimately made possible through years of preconditioning towards a younger, thinner ice pack. Significant negative trends in sea ice concentration between 1979 and 2012 from June to October, coupled with a tendency towards earlier sea ice reductions have fostered a significant positive trend of 12.9 MJ m-2 year-1 in cumulative solar absorption, sufficient to melt an additional 4.3 cm m-2 year-1. Overall through preconditioning towards a younger, thinner ice pack the Beaufort Sea has become increasingly susceptible to increased sea ice loss that may render the Beaufort Sea ice free more frequently in coming years.

B

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An examination of double-diffusive processes in a mesoscale eddy in the Arctic Ocean

Yana Bebieva and Mary-Louise Timmermans, Yale University

Temperature and salinity measurements of an Atlantic Water mesoscale eddy in the Arctic Ocean's Canada Basin are analyzed to understand the effects of velocity shear on a range of double-diffusive processes. Double-diffusive structures in and around the eddy are examined through the transition from low shear (outside the eddy and within its solid body core) to high geostrophic shear zones at the eddy flanks. The presence or absence of a double-diffusive staircase structure (in regions where the vertical gradients in temperature and salinity are double-diffusively unstable) can be predicted by a Richardson number criterion, with low Richardson numbers (high shear) coinciding with the absence of a well-formed staircase. A double-diffusive staircase is not observed at the eddy flanks, where Â shear-driven turbulent mixing dominates; a Thorpe scale analysis is used to estimate turbulent diffusivities in these regions. Double-diffusive and turbulent heat, salt and buoyancy fluxes from the eddy are computed, and used to place bounds on the timescale for eddy decay. Estimated lateral variations in vertical fluxes across the eddy allow for speculation that double diffusion speeds up the eddy decay, having important implications to the transfer of Atlantic Water heat in the Arctic Ocean.

B

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Surface ocean properties in MITgcm Arctic regional model

Surface physical processes in the Arctic ocean are a key component in understanding air-sea fluxes at high latitudes, considering the scarcity of data on sea-ice covered areas, continuous monitoring of these phenomena require a numerical model which can offer a realistic sea ice mechanics, filling the data gaps in our representation of forces that drive gas exchange. In this study, we used the regional Arctic configuration of the Massachusetts Institute of Technology general circulation model (MITgcm). The MITgcm includes a sea ice dynamic and thermodynamic sub model, which permits the investigation of heat, salt and freshwater fluxes and their impact on the surface ocean. To capture near surface phenomena we implemented a high resolution vertical grid spacing of 2m from 0 to 50 m water depth. Below 50 m, the steps increase to a maximum stepsize of of 650 meters at 4900 meters. After comparison with other cases this setup is used to study density structure and mixed layer depth. Sea ice cover, drift trajectory, water velocity, and mixed-layer depth are all evaluated by comparing model output to data collected from ice-tethered profilers, bottom-mounted moorings. We observe that the seasonal trend in mixed-layer depth and sea ice drift are reasonably well captured by the model physics. However, the instantaneous surface velocity showed very poor correlation with moored velocity and velocity data from ITP-V profilers. In many instances, model and data were inversely correlated reflecting problems with the model correctly capturing Ekman flow in the surface layer. We discuss how peculiarities in the model's treatment of ice-water exchange and the ice-water interface may lead to some of these spurious results.

B

Withdrawn

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Reproducing sea-ice deformation distributions with viscous-plastic sea-ice models

Amélie Bouchat and Bruno Tremblay, McGill University

High resolution sea-ice dynamic models offer the potential to discriminate between sea-ice rheologies based on their ability to reproduce the satellite-derived deformation fields. Recent studies have shown that sea-ice viscous-plastic (VP) models do not reproduce the observed statistical properties of the strain rate distributions of the RADARSAT Geophysical Processor System (RGPS) deformation fields [1][2]. We use the elliptical VP rheology and we compute the probability density functions (PDFs) for simulated strain rate invariants (divergence and maximum shear stress) and compare against the deformations obtained with the 3-day gridded products from RGPS. We find that the large shear deformations are well reproduced by the elliptical VP model and the deformations do not follow a Gaussian distribution as reported in Girard et al. [1][2]. On the other hand, we do find an overestimation of the shear in the range of mid-magnitude deformations in all of our VP simulations tested with different spatial resolutions and numerical parameters. Runs with no internal stress (free-drift) or with constant viscosity coefficients (Newtonian fluid) also show this overestimation. We trace back this discrepancy to the elliptical yield curve aspect ratio (e = 2) having too little shear strength, hence not resisting enough the inherent shear in the wind forcing associated with synoptic weather systems. Experiments where we simply increase the shear resistance of the ice by modifying the ellipse ratio confirm the need for a rheology with an increased shear strength.

[1] Girard et al. (2009), Evaluation of high-resolution sea ice models [...], Journal of Geophysical Research, 114
[2] Girard et al. (2011), A new modeling framework for sea-ice mechanics [...], Annals of Glaciology, 57, 123-132

B

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Temperature evolution of the upper Arctic Ocean mixed layer prior to the onset of freeze-up

As the Arctic is increasingly being used for economic purposes (resource extraction, shipping, etc), the ability to understand and forecast the date of ice growth is more important than ever for human and environmental safety. This study examines the cooling processes in the summer mixed layer of the upper ocean between the increasingly warm late-summer Arctic Ocean and the onset of ice growth. In situ measurements of upper ocean temperatures from UpTempO buoys and a number of CTD profiles in the Beaufort and Chukchi regions indicate that as expected, most of the heat in the upper ocean is lost to the atmosphere at the surface. However, a not-insubstantial amount of heat gets trapped below the summer mixed layer in temperature features similar to the Near Surface Temperate Maximum, but seemingly created through sudden decreases in mixing depth associated with passing storms. This heat will, on erosion of the summer halocline, slow the growth of sea ice likely resulting in thinner ice cover.

C

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Unusual Surface Conditions in Summer, 2015

Authors: James A. Carton, Gennady A. Chepurin, Michael Steele, Sirpa Hakkinen, and Jinlun Zhang

In summer 2013 the Barents Sea underwent a remarkable warming, with SSTs approaching 3C above normal by August. Our examination of the causes identified a combination of anomalous surface warming resulting from southerly wind anomalies and reduced cloud cover acting on water that likely began the summer with temperatures well above normal. Early this summer 2015, we are already experiencing even more severe rises in SST. Remarkably the early season warming this summer is occurring on both sides of the Arctic -- in the Barents as well as in the Bering/Chukchi Seas. In the Barents Sea anomalous warm air advection associated with a northward displacement of the Icelandic low pressure system again is playing an important role. We intend to follow the meteorological and oceanographic developments this summer and provide FAMOS with a summary/review, comparing and contrasting the conditions in the eastern and western Arctic, and putting this summer in the context of recent warmings such as the summer 2013.

C

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Preliminary analysis of a Biogeochemical model (BLING) copuled to the physical ocean sea ice model (NEMO-LIM2)

We will present a preliminary analysis of a NEMO-BLING modelling simulation using the ANHA4 (Arctic and Northern Hemisphere Atlantic) configuration. We will look at the evolution of dissolve inorganic phosphate, iron and oxygen, and dissolve organic phosphate in the Labrador Sea and Baffin Bay. We will determine oxygen and carbon fluxes (atmosphere-mixed layer-deep ocean) to examine the role of the Labrador Sea in the ventilation and carbon sequestration in the subsurface ocean.

C

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On the Flow of Atlantic Water and Temperature Anomalies in the Nordic Seas Towards the Arctic Ocean

The climatic conditions over the Arctic Ocean are strongly influenced by the inflow of warm Atlantic water conveyed by the Norwegian Atlantic Slope Current (NwASC). Based on sea surface height (SSH) data from altimetry, we develop a simple dynamical measure of the NwASC transport to diagnose its spatio-temporal variability. This supports a dynamical division of the NwASC into two flow regimes; the Svinøy Branch (SvB) in the southern Norwegian Sea, and the Fram Strait Branch (FSB) west of Spitsbergen. The SvB transport is well correlated with the SSH and atmospheric variability within the Nordic Seas, factors that also affect the inflow to the Barents Sea. In contrast, the FSB is influenced by regional atmospheric conditions around Svalbard and northern Barents Sea. Using a composite analysis, we further relate anomalous strong SvB flow events to temperature fluctuations along the core of Atlantic water. A warm composite anomaly is found to propagate northwards, with a tendency to amplify enroute, after these events. A roughly 12-months delayed temperature signal is identified in the FSB. However, also in the Lofoten Basin interior a delayed temperature signal is found, which appears to originate from the NwASC. This study suggests that hydrographic anomalies both upstream from the North Atlantic, and locally generated in the Norwegian Sea, are important for the oceanic heat and salt transport that eventually enters into the Arctic.

C

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Atlantic Water variability in the global Simple Ocean Data Assimilation (SODA) project

Warm salty Atlantic Water is the main source water for the Arctic Ocean and thus plays an important role in the mass and heat budget of the Arctic. We use global Simple Ocean Data Assimilation (SODA) to explore interannual to decadal variability (years 1980-2014) of Atlantic Water properties in the Nordic Seas area and the Arctic basin. The analysis shows a combination of long time positive temperature trend and two multi-year warm events, where temperature anomalies at 100m depth exceed 0.5^{O}C, and two cold events. Warm events are accompanied by elevated salinities consistent with previous observations and related to enhanced ocean transport of Atlantic Water into the Arctic. Cold events are associated with reduced salinities. The transport of Atlantic Water and the role of advection in warming of Arctic basin are discussed. The SODA's currents were compared with independent current meter data. We also compare total volume and heat advective transports and those for the Atlantic Water fraction through Fram Strait and Barents Sea Opening.

C

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Poster: Internal waves and mixing in the Marginal Ice Zone

from Ice-Tethered Profilers with Velocity

The dynamics of near-inertial motions and internal waves are investigated in the Beaufort Sea using observations from Ice-Tethered Profilers with Velocity. Three systems separated by 100 km profiled the upper 250 m every 3 hours while drifting with the overlying ice cover and transiting the Canada Basin from March to September as part of the Office of Naval Research Marginal Ice Zone Program. Near-inertial motions and the internal-wave field varied on intermittent to seasonal timescales as wind and ice speed changed, the ice cover broke apart, and the mixed layer shoaled. Near-inertial motions were largest at intermediate ice concentrations, and were affected by the shallow summer mixed layer depths. Dominant vertical wavelengths in velocity shear were largest under full ice cover, suggesting that the smaller ice floes at intermediate ice concentrations generate internal waves with smaller vertical and horizontal scales. Richardson number decreased due to increased velocity shear from internal wave packets, eddies, and shear near the winter mixed layer base. Variability in energy content, timing, and other properties of near-inertial motions varied between the three systems due to differences in location, ice cover, and wind/ice speed. Observed changes in water mass properties also show how vertical mixing modified the mixed layer and Pacific Water layers. The ability to simultaneously observe currents, temperature, and salinity in the upper Arctic Ocean at timescales sufficient to investigate internal-waves improves our understanding of the links between ice cover, internal waves, and vertical mixing.

C

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No presentation

D

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A Surface Fresh Layer in the Seasonal Ice Zone

Seasonal Ice Zone Reconnaissance Surveys (SIZRS) of the Beaufort Sea aboard U.S. Coast Guard Arctic Domain Awareness flights were made monthly from June to October, 2012 to 2014. The seasonal ice zone (SIZ), where ice melts and reforms annually, encompasses the marginal ice zone (MIZ). Thus SIZRS tracks interannual MIZ conditions, providing a regional context for smaller-scale MIZ processes.

Observations with Air eXpendable CTDs (AXCTDs) reveal the seasonal formation of a 20m-deep fresh layer relative to the ice edge. While this layer extends under the ice edge as the melt season progresses, its presence is independent of year and absolute latitude north. To test a formation mechanism for this lens, a 1-D Price-Weller-Pinkel (PWP) model adapted for ice-covered seas simulates mixing processes in the top 100m of the ocean. Surface forcing fluxes are taken from the Marginal Ice Zone Modeling and Assimilation System (MIZMAS). PWP output supports local formation of the layer exclusively by ice melt. This layer may have implications for the behavior of freshwater in the Beaufort Gyre as the local SIZ grows and persists.

D

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Evaluation of climate model skill in representing upper Arctic Ocean hydrography for its potential effect on sea ice.

The satellite derived rate of sea ice cover decline in the Arctic for the past decades is faster than those simulated by the latest suite of models participating in the Coupled Model Intercomparison Project (CMIP5), which is likely due to under-represented or missing high-latitude processes and feedbacks. We hypothesize that a critical source of energy in the Arctic Ocean, heat content accumulating below the surface mixed layer and above the Atlantic layer, has been increasing in magnitude and area, especially over the western Arctic marginal ice zone, and it may be contributing to the recent decline in the ice cover. Global and regional climate models must account for this heat content to more realistically simulate the altered regime of Arctic climate and its heat budget. We evaluate against observations results from the Regional Arctic System Model (RASM), including several model configurations, as well as output from other climate models to identify improvements needed to better represent upper Arctic Ocean hydrography and its impact on the sea ice cover.

D

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Tropical forcing of the recent rapid Arctic warming in northeastern Canada and Greenland

Rapid Arctic warming and sea ice reduction in the Arctic Ocean are widely attributed to anthropogenic climate change1-3. The Arctic warming exceeds the global average warming due to feedbacks that include sea ice reduction4,5 and other dynamical and radiative feedbacks6-13. We show that the most prominent annual mean surface and tropospheric warming in the Arctic since 1979 has occurred in northeastern Canada and Greenland. In this region, much of the year-to-year temperature variability is associated with the leading mode of large-scale circulation variability in the North Atlantic, the North Atlantic Oscillation (NAO)14,15. We show that the recent warming in this region is strongly associated with a negative trend in the NAO, which is a response to anomalous Rossby wave-train activity originating in the tropical Pacific. Atmospheric model experiments forced by prescribed tropical sea surface temperatures simulate the observed circulation changes and associated tropospheric and surface warming over northeastern Canada and Greenland. Experiments from the Coupled Model Intercomparison Project Phase 5 (CMIP5)16 models with prescribed anthropogenic forcing show no similar NAO-related circulation changes or associated tropospheric warming. This suggests that a substantial portion of recent warming in the northeastern Canada and Greenland sector of the Arctic arises from unforced natural variability.

D

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Arctic Ocean Internal Waves - Connecting Wind, Sea Ice, and Mixing

The changing internal wave field in the Arctic Ocean is quantified for the last decade, and predictions are made for the associated impact on mixing. Using data from drifting Ice-Tethered Profilers, connections between internal wave energy and sea-ice properties are examined. Since 2005, sea-ice area and thickness in the Arctic have been in rapid decline, and the average speed of sea ice moving in response to wind forcing has risen by about 50%. Near-inertial waves, the most energetic internal waves in the Arctic, have increased in amplitude by about 15% over the last decade in the Canada Basin. Surface generated near-inertial waves transport wind energy into the ocean interior, and cause mixing if they break. The fraction of large-amplitude, energetic near-inertial waves predicted to become unstable and cause mixing has more than doubled for depths above the Atlantic Water temperature maximum, and now account for more than 10% of the wave field. This increase in energy in the internal wave field has implications for vertical fluxes of heat and nutrients, and reflects the ongoing transition from predominantly multiyear to first-year sea ice in the Western Arctic Ocean.

D

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Sea Ice Matters: Science Communication through the SEARCH Sea Ice Action Team

The Study of Environmental Arctic Change (SEARCH) aims to develop scientific knowledge to help society understand and respond to the rapidly changing Arctic. In September 2015, the SEARCH Sea Ice Action Team (SIAT), with a primary focus on science communication, developed a strategy for mobilizing the research community to organize, synthesize, and disseminate scientific knowledge for a broad range of Arctic sea ice stakeholders. Key elements are to (1) support and promote SEARCH and the SIAT as a trusted and timely source of information about Arctic sea ice and impacts of its loss, (2) develop sustained and sophisticated dialogues between the research community and decision-makers, and (3) co-communicate the importance and state-of-the-art of Arctic research using a range of voices beyond those of scientists. The core product of the strategy will be a website to comprehensively communicate why and how sea ice matters. This website will provide tiered access to sea ice information, organized across a series of high-level topics via a hierarchical, pyramid structure based on increasing levels of scientific complexity. This resource will depend on collaboratively developed, peer-reviewed, and concisely edited scientific content, which will serve to coordinate the scientific community, disseminate important findings to broad audiences, and provide a take-away “go-to” resource for decision-makers and the media. In addition, Sea Ice Matters will facilitate and host guest perspectives from across both the science and stakeholders communities and provide timely scientific information on emerging high-interest topics, such as notable weather events or recent high-profile science publications. Evaluating the project through targeted outreach and user feedback represents a strategic focus for the Team. Most importantly, this science communication endeavor will require organizing interests and complementary efforts within SEARCH and across related organizations and broader science communities.

D

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The ice associated-ecosystem studied during the Norwegian Young Sea Ice cruise (N-ICE2015) in the Arctic Ocean: preliminary results

Pedro Duarte, Anette Wold, Haakon Hop, Hanna Kauko, Lasse Mork Olsen, Mar Fernández-Méndez and Philipp Assmy

During the 6-month ice drift cruise N-ICE2015, an international team of interdisciplinary scientists studied the thinning sea ice cover from January to June 2015 in the Nansen Basin of the Arctic Ocean, in order to improve our understanding of the energy budget of the Arctic Ocean, the sea ice mass balance and the seasonal dynamics of the ice-associated ecosystem under the new ice regime. The main goal of the biological oceanography work was to quantify feedbacks between seasonal ice dynamics and ecosystem processes, with emphasis on the physical forcing of the spring "wake up" of the ice-associated ecosystem. Through experiments and in-situ incubations important biological rates were obtained to facilitate ecosystem modelling. Ice and seawater chemical properties were sampled along with phytoplankton, ice algae and zooplankton abundance and ice fauna presence. Photosynthetic quantum yields, primary production, community and zooplankton respiration and grazing rates were measured to get insight into the autotrophy/heterotrophy relationship over the winter-spring transition. Sediment traps were deployed to measure biogenic fluxes from the ice. The main strengths of this study are its interdisciplinarity and the geographic and temporal context. This research was conducted in an area where there is a lack of data on many of the variables and processes studied, especially during the winter season. The main emphasis of this talk/poster is on ice algal and phytoplankton bloom dynamics and their relationship with the timing of seasonal vertical migration of zooplankton towards the upper part of the water column below drifting sea ice.

D

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Pathways and fate of Greenland freshwater in the sub-Arctic seas: Results from numerical experiments

The objective of this study is to investigate the role of Greenland freshwater fluxes in the North Atlantic sub-Arctic Seas. Recent studies demonstrate accelerating Greenland melting rate and associated with it increasing freshwater fluxes to the surrounding seas over the last decade. It is hypothesized that the Greenland freshwater can impact open-ocean deep convection processes in the Labrador, Nordic, and Irminger seas. The study is motivated by the following questions: What are the pathways of Greenland freshwater in the sub-Arctic seas? What is the time scale of freshwater propagation in the sub-Arctic seas? What are the mechanisms of freshwater penetration in the convection regions? To address these questions numerical experiments with several models have been performed. The experiments are integrated for 14 years with passive tracers continuously released at the river runoff locations along the Greenland coast. Results from these experiments are presented.

D

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Greenland freshwater pathways in the sub-Arctic seas:
Results from model experiments with a passive tracer

Accelerating since the early 1990s, the Greenland Ice sheet mass loss exerts a significant impact on thermohaline processes in the sub-Arctic seas. Surplus Greenland freshwater, the amount of which becomes comparable to the freshwater volume fluxed into the region during the Great Salinity Anomaly events, can spread and accumulate in the sub-Arctic seas influencing convective processes there. Curiously, hydrographic observations in the Labrador Sea and the Nordic Seas, where the Greenland freshening signal might be expected to propagate, do not show a persistent freshening in the upper ocean during last two decades. This raises the question of where the surplus Greenland freshwater has propagated. In order to investigate the fate and pathways of Greenland freshwater in the sub-Arctic seas and to determine how and at what rate Greenland freshwater propagates into the convective regions, several numerical experiments using a passive tracer to track propagation of Greenland freshwater have been conducted as a part of the Forum for Arctic Ocean Modeling and Observational Synthesis effort. The models show that the Greenland freshwater does propagate and accumulate in the sub-Arctic seas, although there is disagreement among the models on the amount and rate of tracer propagation into the convective regions.

D

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Dynamic ice embedding in coupled NEMO-CICE

Better resolved upper ocean and use of the log-layer approach to derive the drag coefficient between water and ice both lead to larger drag. In effect, this raises numerical stability issues which requires using smaller time-steps. To circumvent the problem, we have successfully tested an implicit approach to the treatment of the drag seen by the ocean, but at the loss of the conservation of momentum between the ice and the ocean. To remedy the conservation issue, we are now testing an IMplicit-EXplicit (IMEX) coupling approach between CICE and NEMO. Results will be discussed.

E

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Physical Control of Distributions of a Key Arctic Copepod in the Northeast Chukchi Sea

The copepod Calanus glacialis is one of the most important zooplankton taxa in the Arctic shelf seas where it serves as a key grazer, predator, and food source. Its summer distribution and abundance have direct effects on much of the food web, from blooming phytoplankton to migrating bowhead whales. The Chukchi Sea represents a highly advective regime dominated by a barotropicly driven northward flow modulated by wind driven currents that reach the bottom boundary layer of this shallow environment. In addition, a general northward gradient of decreasing temperature and food concentration leads to geographically divergent copepod growth and development rates. The physics of this system establish the connection potential between specific regions. Unless biological factors are uniform and ideal the true connections will be an uneven subset of this physically derived connection potential. In August 2012 and 2013, C. glacialis distributions were observed over Hanna Shoal in the northeast Chukchi Sea. Here we used the Finite Volume Community Ocean Model i-State Configuration Model to advect these distributions forward and back in time to determine the source and sink regions of the transient Hanna Shoal C. glacialis population. We found that Hanna Shoal supplies diapause competent C. glacialis to both the Beaufort Slope and the Chukchi Cap, mainly receives juveniles from the broad slope between Hanna Shoal and Herald Canyon and receives second year adults from as far as the Anadyr Gulf and as close as the broad slope between Hanna Shoal and Herald Canyon. These connection potentials were not sensitive to precise times and locations of release, but were quite sensitive to depth of release. Deeper particles often traveled further than shallow particles due to strong vertical shear in the shallow Chukchi. The 2013 sink region was shifted west relative to the 2012 region and the 2013 adult source region was shifted north relative to the 2012 region.

E

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Initial value problem for superficial salinity fields and their impact on the AMOC on decadal timescales

The Atlantic Meridional Overturning Circulation (AMOC) is one of the principal regulators of the climate in the North Atlantic on decadal to multi-decadal time scales. For these time scales, two factors limit the good skills of AMOC predictions: lack of initialization accuracy (initial value problem) and poor skills to represent the processes involved in its evolution (forced boundary condition problem). This work aims first to look at the impacts of initial errors on the variability and predictability of the AMOC, particularly on the implication of erroneous initialization of surface salinity. Secondly to understand the effects of salinity anomalies such as the Great Salinity Anomalies into the North Atlantic circulation.

In this study we look at the possible effects of a superficial perturbation on the salinity field with a 2-dimensional Gaussian distribution centred in the East coast of Greenland. Perturbations vary in intensity (maxima with a positive or negative values, respectively saline perturbation or freshwater perturbation) and amplitude (extension of the perturbation). Besides these two parameters, different boundary conditions have been used to represent the effects of these salinity perturbations in a more realistic settings. The perturbation induce a Rossby-Like feature that propagates the anomaly remaining trapped in the coast of Newfoundland, its impacts on the AMOC vary up to 0.14 Sv per psu of the distribution´s maximum. Qualitatively, the processes triggered by the perturbation depend on the sign on the perturbation rather its extension. Current work is focused on investigating the mechanisms behind this propagation and to understand the importance of different shapes and intensities of GSA-type perturbations.

Work with Florian Sévellec (Ocean and Earth Sciences, National Oceanography Centre, University of Southampton, UK) and Bablu Sinha (National Oceanography Center, Southampton, UK)

F

Daniel Feltham
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A New Parameterisation of Frazil and Grease Ice Formation in a Climate Sea Ice Model

Harold Heorton, Daniel Feltham*, Alexander Wilchinsky, Centre for Polar Observation and Modelling, Department of Meteorology, University of Reading, UK

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Leads are cracks in sea ice that often form because of deformation. During winter months, leads expose the ocean to the cold atmosphere, resulting in supercooling and the formation of frazil ice crystals within the mixed layer. Here the authors investigate the role of frazil ice formation in leads on the mass balance of the sea ice pack through the incorporation of a new module into the Los Alamos sea ice model (CICE). The frazil ice module considers an initial cooling of leads followed by a steady-state formation of uniformly distributed single size frazil ice crystals that precipitate to the ocean surface as grease ice. The grease ice is pushed against one of the lead edges by wind and water drag that the authors represent through a variable collection thickness for new sea ice. Simulations of the sea ice cover in the Arctic and Antarctic are performed and compared to a model that treats leads the same as the open ocean. The processes of ice formation in the new module slow down the refreezing of leads, resulting in a longer period of frazil ice production. The fraction of frazil-derived sea ice increases from 10% to 50%, corresponding better to observations. The new module has higher ice formation rates in areas of high ice concentration and thus has a greater impact within multiyear ice than it does in the marginal seas. The thickness of sea ice in the central Arctic increases by over 0.5 m, whereas within the Antarctic it remains unchanged.

F

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High resolution ice modeling and future sea ice modeling needs

TBD

F

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Early ice retreat and ocean warming may shift copepod biogeographic boundary in the Arctic Ocean

Early ice retreat and ocean warming is changing various facets of the Arctic marine ecosystem, one of which is the biogeographic distribution of the organisms. This study aimed to gain insights into how and why ongoing changes in the Arctic Ocean may induce biogeographic boundary shifts of Calanus glacialis, a representative endemic copepod species. To that end, an individual-based model was offline coupled to a fully validated ice-ocean-ecosystem model to simulate temperature- and food-dependent life history development of C. glacialis. Model runs were conducted in two comparative years, a relatively cold and normal ice year (2001) and a well-known warm year with early ice retreat (2007). We focused our analyses on four critical factors in copepod development: spawning time, temperature, food availability, and growth season length. Model results reproduced the observed biogeographic distributions that C. glacialis is a typical shelf and slope species and cannot colonize the vast majority of Central Arctic basins. Early spawning maximized C. glacialis fitness to the narrow growth season and could expand its biogeographic boundary. Those failed C. glacialis individuals all had short growth season lengths of less than 100 days, which resulted from either a late spawning time (due to late food appearance) or an early diapause initiation (due to early food depletion). In the Chukchi and East Siberian Seas where severe warming and loss of sea ice occurred in summer 2007, early ice retreat and elevated sea surface temperature (about 2°C higher than 2001) created favorable conditions for C. glacialis development and caused a remarkably poleward expansion. Diapause success of C. glacialis in the Atlantic and Pacific Arctic sectors, based on these two years, appeared to be controlled by different mechanisms: food-limiting in the Barents Sea and temperature-limiting in the Chukchi Sea.

F

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Microstructure observations of upward turbulent heat fluxes in the Beaufort Gyre

Recent years have seen dramatic reduction of summer Arctic sea ice coverage, particularly in the Western Arctic. Due to this reduction of sea ice, large areas of the Beaufort Sea are now exposed to direct wind forcing during the summer and autumn months. Understanding potentially increased turbulent heat and salt fluxes in this new regime is crucial for accurate climate prediction.

On a 28-day cruise in September 2015 that included direct microstructure measurements, high-resolution lateral tows and a turbulence-measuring profiling mooring, we conducted multiple process studies in the Beaufort Sea aimed at observationally constraining heat and salt fluxes in the upper ocean, and at developing an understanding of the dynamics that set ocean stratification in the Canada Basin. Preliminary results, including observations of shallow turbulent heat fluxes on par with atmospheric heat fluxes and the possible influence of the warming Atlantic and Pacific layers, will be presented.

F

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Changes in Arctic fresh water export: a new proxy from 50 years of hydrographic surveys in the Labrador Sea

Cristian Florindo-López, N. Penny Holliday, Sheldon Bacon, Yevgeny Aksenov, and Eugene Colbourne

The Arctic Ocean is the most rapidly changing environment in the globe. One of the observed changes is a significant increase in the freshwater storage at the region. It is believed that a large and rapid export of this freshwater into the North Atlantic could potentially affect high-latitude dense water formation, the overturning circulation and climate. However, Arctic freshwater fluxes to the Labrador Sea are poorly known and observational time series are not available beyond the last decade. We present a new insight in Labrador shelf dynamics, which allows us to connect locally-observed property variability to net Arctic freshwater exports west of Greenland. By combining the high-resolution (1/12 degree) NEMO model and hydrographic observations at the Labrador Shelf, we describe two major components of the shelf circulation. On the one hand the Labrador Current fills the shelf with Arctic originated waters. On the other hand, the Hudson Strait Outflow generates a very distinctive inshore buoyancy-driven flow. This newly described current is geographically and dynamically independent of the Labrador Current, and we are able to separate it from the waters of Arctic origin which flow further offshore. We apply this methodology to a Labrador hydrographic time series of over 50 years in length, allowing us to generate a proxy that we can use to assess the variability of Arctic freshwater export west of Greenland for over 50 years. We show that on decadal timescales, periods of decreased freshwater export on the Labrador Shelf coincide with periods of increased Arctic freshwater content.

F

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The simulations of the Lena River estuary dynamics

The Lena River is one of the largest rivers in the Arctic and has the largest delta. Given the large territory of the Lena Delta, the direct measurements are by far insufficient, calling for a modeling approach. However, most of the models, which include the Laptev Sea shelf zone, do not resolve the Lena Delta and as a consequence lose information about Lena river stream changes using input data with insufficient quality. In the current work we present the hydrodynamics model for the Lena Delta region and full baroclinic model for the Laptev Sea shelf area. The available hydrological information in the Lena Delta was collected, analyzed and used for the model verification. The developed hydrodynamics model provides the first necessary step for the further modeling efforts in the area. It also gives an input for the larger scale models resolving hydrodynamics of more than twenty main Lena River freshwater channels with switched-on wetting/drying option. Additionally the Lena Plume dynamics in the Lena Delta region of the Laptev Sea are explored by us in simulations performed with the FVCOM (Finite Volume Coastal Ocean Model). The impact of winds and tides on the Lena plume propagation is analysed based on simulations for the summer season of 2008 and also on idealized experiments. For that period, the simulated distributions of temperature and salinity agree well with the observations, including the thickness and border position of the buoyant plume. The model simulates the most energetic semi-diurnal and diurnal tidal constituents. The amplitudes and phases of the tidal components at the open boundary were derived from AOTIM5 and TPXO7.1 with corrections. These corrections noticeably improve the agreement of the modelled tidal maps with available tide gauge data.

G

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Impact of atmospheric forcing and river discharge on the variability in the East Siberian Arctic shelf hydrography

East Siberian sector of the Arctic shelf (ESAS), including the Laptev Sea and the East - Siberian Sea, is the region where climatic changes of recent decades are the most pronounced. Recently it was reported about increasing coastal erosion rates and extensive methane venting in the eastern Siberian shelf. Climatology of bottom hydrography demonstrates warming that extends offshore from the 30–50 m depth contour. The 1920–2009 time series of summer mean bottom layer temperature analyzed for the inner shelf and coastal zone of the Laptev and East Siberian seas demonstrate a large warming from 1984 to 2009.

This study discusses the ESAS variability obtained from the numerical results based on the Arctic Ocean model developed in ICMMG SB RAS, forced by 1948-2013 atmospheric reanalysis. The ESAS is controlled by regional atmospheric circulation, Siberian river discharge, ice formation/melting, and water exchange with the Arctic Ocean. Based on the numerical simulation we tried to explore possible reasons for the increase in bottom layer temperature known from observations. Among them were considered: a) atmosphere warming; b) Laptev sea on-shelf inflow of warm and saline waters of Atlantic Layer of the Arctic Ocean c) the redistribution of water masses over shelf zone caused by the change in atmospheric circulation regimes and leading to a weakening of density stratification; d) temperature anomalies caused by thermal river flux. We analyze the effect of raising the bottom layer temperature of coastal region on the enhancement of the underwater permafrost degradation.

H

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No presentation

H

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Estimating the sea-ice compressive strength in the Canadian Arctic Archipelago

We estimate the sea-ice strength in the Canadian Arctic Archipelago (CAA) by calculating the air drag force and identifying the time when ice drifts and ceases. When ice drifts, the maximum compressive stresses caused by air drag force are larger than the sea-ice compressive strength. When ice is immobile, the maximum compressive stresses caused by air drag force are smaller than the sea-ice compressive strength. We use the floe velocity data, obtained in the CAA from 2010 Fall to 2011 Summer, to identify the time when ice drifts and is landfast (immobile). We focus on the data before and after the landfast onset (January 18), and before and after the landfast break-up (June 22). The reforecast wind data from the Canadian Meteorological Center's global deterministic forecast system shows that before and after the landfast onset, the maximum northerly and southerly winds were approximately 7 m/s. This results in a sea-ice strength estimate of 43.9 - 22.0 kN/m for a 0.85-m thick ice in mid-winter. Similarly, the maximum northerly and southerly winds before and after the landfast sea ice break up were approximately 6 m/s. This gives a sea-ice strength estimate of 19.7 - 9.9 kN/m for a 1.39-m thick ice in summer. This decrease in sea-ice strength from winter to summer accords with the measurements by Johnston [2006] and is probably due to an increase in brine volume with ice temperature.

H

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Regional Arctic Sea Ice Forecasting in Support of the U.S. Coast Guard Operations

The Naval Research Laboratory (NRL) is supporting the U.S. Coast Guard Research Development Center (RDC) as part of the Regional Arctic Prediction component of the Earth System Prediction Capability (ESPC) program through a demonstration project during the summer and autumn of 2015. Specifically, a modeling system composed of a mesoscale atmospheric model (COAMPS), regional sea ice model (CICE), and regional wave model (WW3) are loosely coupled to provide real-time 72-hr forecasts of environmental conditions for the Beaufort/Chukchi Seas. The modeling components assimilate atmosphere, ocean and ice observations available from satellite and in situ sources. Model forecasts graphics are shared on a common web page with selected graphical products available via ftp for bandwidth limited users. This demonstration serves as a precursor to a fully coupled atmosphere-ocean-wave-ice modeling system under development. National Ice Center (NIC) analysts will use these additional model data products (CICE and COAMPS) along with other model and observational data to produce the predicted 72-hour position of the ice edge.

H

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The impact of Anisotropy in the Force Balance of the Arctic Sea-Ice cover in a numerical model

Harold Heorton, Daniel Feltham, David Schroeder

The Arctic sea ice cover is continually cracking and deforming. Observations show the cracks have directional alignment and are thus anisotropic. An anisotropic rheology of sea ice, relating sea ice stresses to its deformation rate and state of anisotropy, has been previously developed and incorporated into a numerical sea ice model in order to represent the observed deformations. Here we present further investigations into the impact of the new rheology upon the force balance and compare it to an existing isotopic, viscous-plastic rheology. The anisotropic rheology has been further developed to represent thermodynamic healing of cracked sea ice.

In this study we analyse the link between the emergent and observable properties of the sea ice cover; the ice concentration, thickness and strain state, with the sea ice stress and force balance. The confinement of internal ice stress in the numerical model is examined and compared to laboratory observations of sea ice deformation. The impact of increasing model resolution upon the sea ice deformation is also investigated.

H

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Pathways of Petermann glacier's meltwaters, Greenland

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[3] University of Delaware

Radar and satellite observations suggest that the floating ice shelf of Petermann glacier, north Greenland, loses up to 80% of its mass through basal melting, caused by the intrusion of warm Atlantic water into the fjord and under the ice shelf. The fate of Petermann's glacial meltwater is still largely unknown. It is investigated here, using hydrographic observations collected during a research cruise onboard I/B Oden in August 2015. Two layers are found: one at 200 m (i.e. terminus depth) mostly on the eastern side of the fjord where a calving event occurred this summer, and one around 500 m depth (i.e. the grounding line) on the western side. At the sill, approximately 3 mSv of freshwater leave the fjord around 150 m on the eastern side. On the western side, a more complex circulation occurs as waters intrude in. Outside of the fjord in Hall Basin, only one layer is found, around 300 m, but its oxygen content and T-S properties suggests it is a mixture between Petermann's meltwater, meltwater from the neighbouring glaciers, surface run-off and sea ice. As Atlantic water warms up, it is key to monitor Greenland melting glaciers to properly assess sea level rise.

H

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Ice-tethered platforms in the central Arctic: a contribution by the FRAM project (2015-2019)

Authors: M. Hoppmann, M. Nicolaus, B. Rabe, F. Wenzhöfer

Although the Arctic Ocean has been studied extensively during recent decades, observational data are still relatively sparse due to its remoteness and harsh environmental conditions. One important tool to fill this gap has become more and more feasible during the last years: autonomous, ice-tethered measurement platforms, which are able to record data throughout the winter, and cover a larger area than manned expeditions.

Over the following five years, the FRAM (FRontiers in Arctic marine Monitoring) infrastructure project aims to establish a network of autonomous, ice-tethered platforms (buoys) in the central Arctic Ocean. Types of buoys range from snow depth and ice mass balance buoys for monitoring ice growth and snow accumulation, over radiation and weather stations for energy budget estimations, to ice-tethered profilers to monitor upper ocean properties. The first wave of 32 buoys was deployed in September 2015 from onboard RV Polarstern.

Data from these buoys is expected to play a crucial role in understanding the linkages between the atmosphere, sea ice and upper ocean in the Arctic. Integration of bio-optical and biogeochemical sensors on established platforms will enhance our understanding of physico-biological processes, and enable us to derive reliable models of the physical, biological and biogeochemical states of the future Arctic Ocean.

H

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Link between multidecadal freshwater anomalies in the AO and SPNA

A significant increase in liquid freshwater content has been observed in the Arctic Ocean over the last 20 years, whereas the Arctic sea ice volume shrank significantly. In contrast, the North Atlantic became more saline in recent years. Both regions are of great importance for the global ocean circulation and climate, and salinity changes may have a profound impact on the global climate.
We found that for the period between 1992 and 2013, the liquid freshwater content of the subpolar North Atlantic, calculated from objectively mapped in-situ salinity measurements, and the total freshwater content of the Arctic Ocean, i.e. the liquid freshwater content and freshwater stored in sea ice, are significantly negative correlated (r=-0.77). Moreover, the amount of the anomalies are of the same size. Furthermore, the time series hint at multi-decadal oscillations. The highest negative correlation with the total freshwater content of the Arctic Ocean can be found in the Irminger and Labrador Seas, while we observed a positive correlation east of the Mid-Atlantic Ridge at the path of the North Atlantic Current, which is the source of Atlantic Water entering the Arctic Ocean through the Nordic Seas.

We suggest a redistribution of freshwater as a response to frequent changes in atmospheric pressure patterns. Under certain conditions the freshwater is re-routed and kept in the Arctic Ocean, while it is released under other conditions. We conclude that decadal scale changes of the freshwater content in the North Atlantic, particularly those in the deep water formation sites like the Labrador Sea, are originating in the Arctic Ocean.

H

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High-resolution modeling of Arctic baroclinic tides

Authors: S. Howard, L. Padman, A. Nguyen, I. Polyakov and A. Pnyushkov

Tidal currents in the Arctic Ocean contribute to ocean mixing, affecting large-scale hydrographic distributions, and periodic divergence of sea ice with consequences for the annual cycle of ice production and decay. Sparse measurements indicate that the baroclinic component of the tide can be important in some regions, especially along the major pathways of Atlantic Water entering and within the eastern Arctic. We investigate the energetics of baroclinic tides using two high-resolution (dx=2 km) models: one idealized with simplified (initially laterally homogeneous) hydrography and the other fully forced with realistic ocean state and an active sea-ice component.

In both models, hot spots for baroclinic tide generation are in Fram Strait, and along the eastern Arctic continental slope at three locations: one in the Barents Sea and two areas in the Laptev Sea. In the idealized model, the M2 baroclinic energy is trapped on the slope but the S2 baroclinic tide propagates north; these differences relate to the relative critical latitudes for these two components. When a rigid frictional surface is added to the idealized model to represent ice that is not in free drift, the baroclinic tidal energy flux is significantly reduced relative to the free-drift case. The realistic model produces a much more complex pattern of baroclinic energy flux through effects related to spatial variability of stratification and changes in background vorticity influencing the location of critical latitudes for M2 and S2. We also use the realistic model to investigate the interaction of baroclinic tides with sea ice, including the likely role of these interactions on the seasonal cycle of ice concentration.

I

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High-resolution Arctic ocean-ice model

Not sure if can attend

J

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Quantifying Rates of Biological Production to Better Understand the Carbon Cycle in the Canada Basin

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Profound changes are occurring in the Arctic Ocean as climate warms. Most dramatically perhaps, the summer sea ice extent has decreased significantly over the last decades with 2012 being the year of lowest sea ice extent. Additionally, the water temperature is warming and the freshwater content and terreginous input are increasing. How is the carbon cycle changing concurrent with these environmental changes? Biological productivity is one of the main drivers of the carbon cycle in the ocean since photosynthesis consumes CO2 and respiration releases it. Net community production (NCP) reflects the total amount of CO2 drawn down by the ocean's biological pump. Gross primary production (GPP) is a measure of the photosynthetic flux and thus represents the total amount of CO2 removed by photosynthesis. Gas tracers – namely O2/Ar ratios and triple oxygen isotopes – can be used to quantify in situ rates of net community production and gross primary production. Here we present rates of NCP and GPP from the Beaufort Gyre region of the Canada Basin in late summer and early fall for four years between 2011 and 2014. We examine the relationship of these biological productivity rates to environmental variables such as ice cover, location, mixed layer depth, season, etc. In particular, the very low ice cover in 2012 likely leads to higher rates of GPP in 2012 and may also be affecting the 2013 GPP because of the lack of multi-year ice cover. In spite of large differences in GPP between the years, the rates of NCP are more similar, suggesting a very coupled autotrophic/heterotrophic network so that even when photosynthesis increases, there is little change in carbon export. If this finding is substantiated in other seasons and other regions of the Arctic, it has profound implications - that the changing climate may not change the net carbon balance or CO2 fluxes in and out of the Arctic Ocean even though it might change local production.

J

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No presentation

J

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Ecosystem model intercomparison of under-ice and total primary production in the Arctic Ocean

Previous studies have found increasing primary production (PP) in response to declining sea ice cover in the Arctic Ocean. In this study, under-ice PP (where ice concentration is greater than 15%) in the Arctic Ocean was assessed based on the consensus of three coupled ice-ocean-ecosystem models (two global and one regional) participating in the Forum for Arctic Modeling and Observational Synthesis project (FAMOS). All models showed good agreement with under-ice measurements of surface Chlorophyll and vertically integrated PP rate during the main under-ice production period from mid-May to September. The modeled 30-year (1980-2009) mean sea ice concentration compared well with remote sensing data. The under-ice PP was higher in the Arctic shelf seas than in the Arctic Basin, but the ratios of under-ice PP over total PP resembled that of the annual mean sea ice concentration with higher ratios in higher ice concentration regions. The decreases in sea ice from 1980 to 2009 were significantly related to the increases of total PP and the under-ice PP/total PP ratio for most of the Arctic, but insignificantly related to under-ice PP, especially in marginal ice zones. The total PP within the Arctic Circle increased at an annual rate of between 3.2 and 8.0 Tg C/year from 1980 to 2009. The increase of total PP was much stronger than the changes of the under-ice PP, and therefore the ratios decreased during the last 30 years for all models. The total PP increase was mainly due to PP increase in open water, which included increases in both open water area and PP rate per unit area. All models suggested that, on a pan-Arctic scale, the fraction of under-ice PP declined with declining sea ice cover in the last three decades, and the Arctic Ocean might have transitioned to support more pelagic ecosystem.

J

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The Year of Polar Prediction (YOPP)

The Year of Polar Prediction (YOPP) is one of the key elements of the Polar Prediction Project. YOPP is scheduled to take place from mid-2017 to mid-2019. It aims at enabling significant improvement in environmental prediction capabilities for the polar regions and beyond, by coordinating a period of intensive observing, modelling, verification, user-engagement and education activities. In this presentation an overview of the present planning will be given that serves as a basis for a discussion how the FAMOS community can engage in YOPP.

J

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Inertial Oscillations in Sea Ice

Inertial oscillations, this circular motion caused by the Coriolis force and triggered by the wind, are observed in sea ice drift. They follow a period of about half a day, and are particularly visible during the summer and early fall, when the cohesion of the ice is weak. With the last decades changes suffered by the Arctic, sea ice drift speeds and inertial oscillations frequency have been noticed to increase. It is, therefore, of great importance to understand how inertial oscillations work, in order to provide good predictions of sea ice extent. Yet, how the energy is transfered from the wind to the ice, and how the ice interacts with the ocean underneath still has to be studied.

K

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No presentation

K

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Detection of melt ponds on sea ice in the Chukchi Sea in summer season using TerraSAR-X dual-polarization data

Miae Kim, Hyangsun Han, Jungho Im, Sungmun Sim

As a prevalent phenomenon in the Arctic winter season, melt ponds have a significant influence on climate change by absorbing incoming solar radiation and changing the melting rate of sea ice. Detection of melt ponds can help us better understand the interaction between sea ice and climate. In this study, melt pond classification models were developed using the TerraSAR-X dual-polarization data and two machine learning methods including decision trees (DT) and random forest (RF). Reference data of melt ponds, sea ice, and open water were extracted from the airborne SAR images with spatial resolution of 0.6 m through visual interpretation. A total of 8 polarimetric parameters such as HH and VV backscattering coefficients, co-polarization ratio, co-polarization phase difference, co-polarization correlation coefficient, alpha angle, entropy, and anisotropy from the TerraSAR-X dual-polarization data were used as input variables in the models. Due to the similarity of the polarimetric signature between melt ponds and open water, two spatial texture metrics such as average and standard deviation of the polarimetric parameters were also used as input variables. The use of the texture features in the DT and RF models showed better performances for detection of melt ponds. The HH and VV backscattering coefficients and their average were considered as the most contributing variables to the classification in both models. Furthermore, the comparison of melt pond fraction and sea ice concentration for the RF-derived melt pond and reference maps showed a root mean square deviation of 2.4% and 7.0%, respectively. This result indicates that high-resolution dual-polarization SAR data can be utilized for the accurate monitoring of melt pond fraction at a local scale.

K

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No presentation

K

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Hot-spots of internal solitary waves in the Arctic seas observed from space

Internal waves are very important for dynamics and thermodynamics of the Arctic Ocean. Mixing processes associated with internal waves impact sea-ice formation and biological systems, propagation of acoustic signals and under-water navigation. Recent in situ observations indicate enhanced IW-related vertical mixing over rough topography enabling the diffusion of heat from Atlantic water to the Arctic Ocean. Yet, the locations of enhanced IW activity and mixing still remain unclear. Moreover, in the vicinity of the critical latitude (74.5° N) and beyond tidally generated internal waves have properties similar to unsteady lee waves with short spatial and temporal scales and propagate in the form of packets of internal solitary waves (ISW), as those usually observed from space by Synthetic Aperture Radars.

In this work taking the advantage of high resolution space-borne SAR we present a first account on the ISW activity in the seasonally ice-free Arctic seas including the Norwegian Sea, the Greenland Sea, the Barents Sea, the Kara Sea, the Laptev Sea, the East-Siberian Sea and the Chukchi Sea. We consider about 3000 Envisat ASAR images taken in June-October 2007-2011 and show that most frequently ISWs are found over the steepest continental slope regions. Detailed maps of ISWs kinematic properties and observational frequency helped to identify main hot-spots of ISW activity in the ice-free Arctic seas. We also point out the regions where large-scale nonlinear IW packets with wavelengths of 2-5 km and crest lengths >200 km are observed. For the first time SAR observations compared with historical ship measurements and modeling results uniquely uncover the complex picture of ISW field in the seasonally ice-free Arctic seas.

The work is supported by RFBR, research projects No. 14-05-31423 mol_a and 15-05-04639 A.

K

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No presentation

K

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Tidal effect on the sea-ice volume in the Arctic Ocean

We investigate the effect of tide on the sea-ice volume in the Arctic Ocean using an ice-coupled Ocean General Circulation Model (OGCM). The OGCM used in this study is the Regional Ocean Modeling System (ROMS) version 3.4, which is a three dimensional, s-coordinate, primitive equation ocean model with a free surface. The model covers the Arctic Ocean with the adjacent seas including Norwegian Sea, Greenland Sea and Hudson bay. We used an orthogonal curvilinear coordinates of 23 to 30 km grid resolution. A total of 50 s-coordinate levels are adopted along the vertical direction with enhanced resolution near the surface. Along open boundaries, we set four major tidal forcing (M2, S2, K1, O1) retrived from TPXO8-atlas.

To initialize the model, the model was spun up for 10 years with climatological monthly mean atmospheric fields. After spinning up model, we conducted a hindcast simulation from January 1, 1980 to the end of 2008 with and without tidal forcing. The last 6 years averaged values are used for the analysis.

L

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Balanced co-limitation sets Arctic Ocean biological carbon fixation: present and coming century

Biological carbon fixation is one of the central features of global biogeochemical cycles, retrieved from space over much of the global ocean. However, Arctic phytoplankton exhibit substantial growth under ice, in photosynthetically competent subsurface chlorophyll maxima and in optically complex waters, hindering accurate assessments of phytoplankton distributions or governing mechanisms, exacerbated by shipboard undersampling. Rapidly retreating sea ice is expected to influence future carbon fixation by perturbing nutrient and light fields, but poor understanding of present production distributions and governing mechanisms makes projected changes highly uncertain.

Here we use a model combined with a synthesis of recently compiled datasets to demonstrate that phytoplankton respond to environmental variability by balancing opposing nitrate and light co-limitation, explaining contemporary Arctic production magnitudes and distributions. A consequence is that in our simulation robust projections of reducing surface nitrate with ice-retreat correspond to deepening of co-located production maxima, mitigating light-induced production increases to 10% in an ice-free Arctic, increasing to 30% by end century.

L

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No presentation

L

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Estimating Arctic sea ice thickness in melting season using microwave satellite sensors

Arctic sea ice thickness and volume in the melting season (i.e., May to September) directly influence determining sea ice thickness and volume in the following winter and spring seasons. However, estimating sea ice thickness on pan-Arctic in the melting season is still challenging. While various satellite sensors have observed Arctic sea ice thickness during the spring and winter seasons (i.e., October to April) over the entire Arctic Ocean, it is hard to retrieve sea ice thickness during the melting season using satellite data because melt ponds on sea ice surface interrupt with measuring signals from the sea ice. In this study, Arctic sea ice thickness in the melting season was retrieved using microwave satellite data such as CryoSat-2, Advanced Microwave Scanning Radiometer 2 (AMSR-2), and Soil Moisture and Ocean Salinity (SMOS). The retrieved sea ice thickness was validated with drifting buoy data.

L

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Sensitivity of an ice-ocean coupled model to COREv2 atmospheric forcing over the Arctic Ocean

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Atmospheric dynamic/thermodynamic forcing is an external driver for underlying ice and ocean variability in an ice-ocean coupled model. In this study, we examine the sensitivity of an ice-ocean coupled component set (compset) of the NCAR CESM v1.2.1 to different Coordinated Ocean-ice Reference Experiments version 2 (COREv2) atmospheric forcing data. In a control run, the model is forced with the normal year forcing from COREv2, which is the default setup of the G_Normal_Year_Forcing (G_NYF) compset. In G_NYF, the atmospheric forcing includes many years of the pre-satellite era. Thus, it may not represent the recent climate during which Arctic sea ice has been rapidly declined. To test the model response to the recent climate forcing, the climatological mean of interannually varying COREv2 forcing for the period from 1984 to 2009 is prescribed for the same model in the G_IAFmean experiment. Both G_NYF and G_IAFmean are integrated for 100 years enough to reach an equilibrium state for the sea ice.

The annual cycle of the Arctic sea ice extent (SIE) in G_NYF reasonably follows that from the SMMR and SSM/I satellite records, while the nearly ice-free Arctic is obtained during late summer in G_IAFmean due to the rapid ice disappearance during July. The sea ice volume is underestimated all-year-round ice, compared with PIOMAS, for the two simulations. The underestimation largely comes from the lower simulated ice thickness than expected. It is noted that the G_IAFmean simulation of Arctic sea ice has larger discrepancy with the recent Arctic state than the G_NYF simulation despite we applied the recent climate forcing in the experiment.

The excessive incoming total energy flux to sea ice seemed to play a critical role in leading to the ice-free Arctic in G_IAFmean. The dramatic acceleration of the retreat of SIE during July in G_IAFmean is natural because most of the accumulated energy is effectively used to melt the sea ice. In G_IAFmean, the ice surface becomes bare without snow earlier in July, so the melting goes faster over the ice top than that in G_NYF. Moreover, it seems that relatively less energy consumed to melt the snow in G_IAFmean because snow volume also underestimated. The increase of net shortwave radiative flux during early summer in G_IAFmean seems to make such differences in summer SIE between the two simulations, reflecting the importance of enhanced ice-albedo feedback in accelerating sea ice melting.

Acknowledgement

This study was supported by the “Investigation of Climate Change Mechanism by Observation and Simulation of Polar Climate for the Past and Present (Grant no. PE15010)” of the Korea Polar Research Institute.

L

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An assessment of net primary productivity estimates using coupled physical-biogeochemical models in the Arctic Ocean

Younjoo J. Lee, Patricia A. Matrai, Marjorie A. M. Friedrichs, Vincent S. Saba, and the Modeling Teams.

Net primary production (NPP) is the major source of energy for the Arctic Ocean (AO) ecosystem. Hence, reproducing current patterns of NPP is essential to understand the physical and biogeochemical controls in the present and the future AO. The Primary Productivity Algorithm Round Robin (PPARR) activity provides a framework such that the skills and sensitivities of NPP estimated by coupled global/regional climate models can be assessed in the AO. We present here the first phase results from 18 global/regional climate models that estimate marine NPP with respect to a unique pan-Arctic data set (1959-2011) that includes in situ NPP as well as nutrients. Model results showed a distribution similar to the in situ data distribution, except for the low and high values of integrated NPP. Average model skills were determined by variability and mean difference between model estimates and observations, using root-mean square difference (RMSD). Model performance of integrated NPP exhibited little difference as a function of sea ice condition (ice-free vs. ice-covered) and region (shallow vs. deep), but it varied significantly as function of seasons. For example, model integrated NPP was negatively biased in the beginning of production season (April-June) compared to mid-summer (July and August) and had the highest variability in late summer and early fall (September-October). In general, models underestimated mean NPP while mean nitrate concentration was overestimated. The model performance was similar at all depths within the top 100 m, both in NPP and nitrate. Models performed better in reproducing nitrate than NPP in terms of unbiased RMSD and correlation coefficient. Continual feedback, modification and improvement of the participating models and the resulting increase in model skill are the primary goal of the PPARR-5 AO exercise.

L

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Ecosystem and biogeochemical modeling and observations:
Present and future needs to advance the state-of-knowledge

TBD

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Combining isotropic tensile strength and a parameterization for grounded ridges for modeling landfast ice

We have recently developed a basal stress parameterization representing the effect of grounded ridges on the sea ice cover. This parameterization has been coded in the CICEv4.0 model. Numerical simulations using a pan-Arctic 0.25° NEMO-CICE configuration demonstrates that, overall, the parameterization really improves the simulation of landfast ice when compared to a simulation done with the standard model (no basal stress). However, in some regions where landfast ice is observed in deep water (e.g. the Kara Sea and parts of the Laptev Sea), the model underestimates the area of the landfast ice cover. This indicates that another mechanism is at play for maintaining the landfast ice cover. We have therefore also added isotropic tensile strength to the sea ice rheology. We will show preliminary results of simulations combining tensile strength and the parameterization for grounded ridges.

Jean-François Lemieux, Frédéric Dupont, Philippe Blain, François Roy and Gregory Smith

L

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Sea Ice Variability in the Bering Sea: Cause and Impact

Sea ice in the Bering Sea is sensitive to climatic forcing, and imposes a large impact on the marine ecosystem there. Interestingly, the winter sea ice in the Bering Sea has been expanding in the most recent years, while the summer Arctic sea ice has been shrinking rapidly especially in the western Arctic Ocean. This talk will address the cause and impact of sea ice variability in the Bering Sea.

First, I study thermodynamic and dynamic processes driving sea ice variability in the Bering Sea on the seasonal and interannual timescales, using an eddying global ocean/sea ice model (0.1 degree POP-CICE). This study confirms and quantifies conveyor belt hypothesis for winter Bering sea ice growth/melt and transport, and reveals the S-shaped asymmetric ice edge due to the warm ocean current. Furthermore, this study finds that specified surface air temperature explains high model skill in simulating sea ice variability, and thermodynamic processes dominate the interannual ice variability on the large scale via air-ice sensible heat flux, while dynamic processes are important locally near ice margins with ocean and land.

Second, I study oceanic response to recent changes in atmospheric and sea ice forcing in the Bering Sea, using a regional coupled ocean/sea ice model (BESTMAS) in combination with in-situ and satellite observations. Recently, the Bering Sea experienced a warm period (2001-2005) and a cold period (2007-2010). Large differences in ocean velocity, sea surface height, sea surface salinity, and sea surface temperature exist between these two periods. Most recently, 2012 is an extremely cold year for the Bering Sea, while 2014 and 2015 are very warm years for the Bering Sea. The ocean conditions for 2012-2015 are still under investigation.

L

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No presentation

L

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Arctic sea ice thickness loss determined using subsurface, aircraft, and satellite observations

Sea ice thickness is a fundamental climate state variable that provides an integrated measure of changes in the high-latitude energy balance. However, observations of mean ice thickness have been sparse in time and space, making the construction of observation-based time series difficult. Moreover, different groups use a variety of methods and processing procedures to measure ice thickness, and each observational source likely has different and poorly characterized measurement and sampling errors. Observational sources used in this study include upward-looking sonars mounted on submarines or moorings, electromagnetic sensors on helicopters or aircraft, and lidar or radar altimeters on airplanes or satellites. We will discuss these different sources of ice thickness data and the Unified Sea Ice Thickness Climate Data Record data set. Web then use a curve-fitting approach to determine the large-scale spatial and temporal variability of the ice thickness as well as the mean differences between the observation systems, using over 3000 estimates of the ice thickness. The trend in annual mean ice thickness over the Arctic Basin is -0.58 ± 0.07 m/decade over the period 2000–2012. Applying our method to the period 1975–2012 for the central Arctic Basin where we have sufficient data (the SCICEX box), we find that the annual mean ice thickness has decreased from 3.59m in 1975 to 1.25m in 2012, a 65% reduction.

L

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No presentation

L

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What drives the variability of the Atlantic Water circulation in the Arctic Ocean?

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The Atlantic Water (AW) layer in the Arctic Basin is isolated from the atmosphere by the overlaying surface layer; yet observations of the AW pan-Arctic boundary current have revealed that the velocities in this layer exhibit significant variations on all timescales.

Here, analysis of a global ocean/sea ice model hindcast, complemented by experiments performed with an idealized process model, are used to investigate what controls the variability of AW circulation, with a focus on the role of wind forcing. The AW circulation carries the imprint of wind variations, both remotely over the Nordic and Barents seas where they force variability on the AW inflow to the Arctic Basin, and locally over the Arctic Basin through the forcing of the wind-driven Beaufort gyre, which modulates and transfers the wind variability to the AW layer. Our results further suggest that understanding variability in the large amount of heat contained within the AW layer requires a better understanding of the circulation within both AW and surface layers.

L

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Numerical Investigations of the Hydrographic Observations of Chukchi Sea Shelf Using ROMS Model Integrations

Summer-fall hydrographic observations from the northeastern Chukchi Sea frequently indicate 1) the intrapycnocline intrusions of warm, moderately salty summer waters derived from the Bering Sea, and 2) the dense bottom water induced circulation around Hanna Shoal caused by the interaction between trapped winter water and the warm Bering Sea inflow. A 3-D hydrodynamic model ROMS (Rutgers Ocean Modeling System) is used to investigate the dynamics and structure of these two characteristic hydrographic observations of Chukchi Sea. The intrusions derived from Bering Sea Water are 10-20 m thick and appears as distinct blobs or horizontal plumes. They occur within the shallow (~20 m depth) pycnocline that separates cold, dilute, surface meltwater from near-freezing, salty, winter-formed waters along the bottom. A simple numerical model suggests that the intrusions result from instability of the front that separates meltwater from the Bering Sea Water and generates meanders and eddies, which propagate warm Bering Sea Waters into the pycnocline. These lateral eddy heat fluxes could play a major role in ablation along the ice edge throughout summer and delaying the onset of ice formation in fall. Another characteristic hydrographic observation is the baroclinic circulation around Hanna Shoal. A dome of dense bottom water is found around the Shoal, which is formed when cold winter water trapped in topographic depressions of Hanna Shoal after the onset of summer stratification. The numerical model suggests that the dense bottom waters induce significant baroclinic circulations, which lead to the warm Bering Sea Waters turning southward along the east side of Hanna Shoal and eventually entering the head of Barrow Canyon. The baroclinic circulations resulting from dense bottom water may have significant effects on the movement and distribution of sea ice along Hanna Shoal.

M

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Understanding and Modeling a turbulent Arctic Ocean

We review the likely role of the ubiquitous geostrophic eddy field in the general circulation of the Arctic Ocean drawing on ideas from 'Residual-mean' theory which attributes 'eddy-induced' circulation the same status as the 'Eulerian-mean'. The Beaufort Gyre is presented as a system in which the Residual and Eulerian circulation are likely very different, leading to descriptions of the kind being developed by, for example, Mike Spall and Georgy Manucharyan at WHOI.

If the distinction between Eulerian and Residual circulation is widespread in the Arctic, this has far-reaching implications for understanding its circulation and biogeochemistry and how we observe, think-about and model the system. Parallels are drawn with analogous developments in our understanding and modeling of the Antarctic Circumpolar Current of the Southern Ocean. Finally, implications for calibrating and evaluating low, high and very-high resolution models of the Arctic Ocean are discussed.

M

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New satellite-derived observational sea ice concentration and extent products for modeling

Two new sea ice concentration/extent data products are now available for use by modelers. The first is a sea ice concentration climate data record produced by NSIDC and NOAA based on NASA algorithms. It is a consistent, long-term, quality-controlled data product from passive microwave sensors spanning 1979 to present with full metadata and data quality information. It ameliorates summer concentration biases via a simple combination of two concentration algorithms and a surface melt flag. Intersensor calibration and thorough quality control insures a consistent multi-decadal product for investigating long term climate trends and variability. The second product is an ice concentration/edge product that combines retrievals from relatively high resolution (10 km) passive microwave data with a daily manually analyzed high resolution (4 km) operational field produced by the National Ice Center. The manual product captures low concentration features that are often missed by passive microwave sensors and provides a more detailed ice edge, while the passive microwave retrieval provides concentration estimates in high concentration (>70%) regimes. This product is being assimilated in the Navy's ArcticCap model for operational sea ice forecasts produced by NRL. The combined product has been found to substantially improve the ice edge forecast over the previously used lower resolution passive microwave source. However, the use of manually analyzed daily ice edge does not yield concentration variability at low concentrations.

M

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From winter to summer: oceanographic observations collected during the Norwegian Young sea ICE cruise (N-ICE2015)

Meyer, Amelie[1], Arild Sundfjord[1], Lars H. Smedsrud[2] and Paul A. Dodd[1]

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Understanding the heat fluxes between the ocean and the sea ice in the Arctic is of fundamental importance to understanding the new first year sea ice regime and consequences for regional and global ocean circulation. Here we present preliminary results from the Norwegian Young sea Ice cruise (N-ICE2015) that took place between January and June 2015 in the Arctic Ocean north of Svalbard.
In January 2015, the Norwegian research vessel Lance was frozen into the ice at 83o.3N 21.5oE. A camp was established on an ice floe and data capturing oceanographic, atmospheric, sea ice, snow and biological characteristics and development were collected. Over the next six months, the Lance was relocated north several times, to re-build new science camps far from the ice edge, as the ice floe drifted south and became too unstable to work on.

The oceanography package collected turbulence measurements to estimate heat, salt and momentum fluxes in the ice-ocean boundary layer and between the sub-surface Atlantic Water layer and the ice-ocean boundary layer. Water tracer data was collected to map water mass properties, describe freshwater sources, and the distribution of the Atlantic Water inflow.

With such a data set spanning over the winter months, the spring transition and early summer, we will quantify the impact of the upward Atlantic Water heat fluxes on the sea ice energy budget and relate forcing mechanisms to the Arctic stratification and circulation regime.

M

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Analysis on the response of an Arctic ice-ocean coupled model to two different atmospheric reanalysis datasets

Authors: MU Longjiang, ZHAO Jinping

The downward radiative fluxes, wind speed, near surface temperature, precipitation, humidity got from Climate Forecast System Reanalysis (CFSR) and the Japanese 25-year Reanalysis Project (JRA25) are compared in this article. We find that most significant biases between the two datasets are precipitation, downward fluxes for both shortwave and longwave radiation. Driving by these two datasets, model results forced by CFSR shows big differences on sea ice, Atlantic water and thermohaline structure in Canada basin compared to in situ observations, with the simulated geostrophic current on isopycnal surface 20% higher than that forced by JRA25and a larger volume fluxes than that derived from SODA data. Sensitivity experiment forced by downward radiative fluxes from CFSR, which have been evaluated to be close to observed values, demonstrates comparable results to observational results. The cloud data plays a key role in modeling sea ice while freshwater flux brought by precipitation can change the heat transport of Atlantic inflow prominently and carry a further effect on sea ice in the Arctic. The overestimated precipitation in CFSR is the major for large biases of volume flux through Fram Strait, geostropic current on isopycnal surface and thermohaline structure in central Arctic. Although reanalysis wind have different resolution for the two datasets, our results indicates that it carries an ignorable effect on modeling sea ice and thermohaline structure on basin scale.

M

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Shelf-Basin exchange in the Labrador Sea and Baffin Bay

Myers P., X. Hu, A. Holdsworth, C. Pennelly, L. Gillard and J. Marson

This presentation looks at questions of exchange between the continental shelf and the basin interiors of the Labrador Sea and Baffin Bay. Most of the work is based on numerical modelling using an pan-Arctic regional configuration of the NEMO model run at one-quarter and one-twelfth degree. Some historical data is also used to complement the model analysis. Locations and processes associated with freshwater exchange from both the Labrador Current and West Greenland Current are considered. Impacts of enhanced Greenland melt on the West Greenland Current are also examined. Finally, through the use of a passive tracer proportional to Greenland mass loss, the ways that this tracer is transferred into the deeper layers of Baffin Bay and the Labrador Sea are also examined. Co-authors are Xianmin Hu, Amber Holdsworth, Clark Pennelly, Laura Gillard and Juliana Marson.

N

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Spatial variability and seasonality of light transmission through Arctic sea ice

Changes in the Arctic sea ice result in a thinner and younger ice cover with changing physical properties and strong impacts on the energy budget. In addition to long-term trends, the physical properties of sea ice and its snow cover underlay a strong seasonal and spatial variability that impact observations and conclusions. Here, I present results from recent studies to observe the sea ice energy budget on different time and length scales. These studies include advances in methodological aspects of operating spectral radiation measurements on remotely operated vehicles (ROV) and on autonomous stations, but also time series from manned observations are shown. The measurements over and under sea ice reveal changes in the optical properties of sea ice and their implications for the energy and mass budget. A strong link to the onset of algae blooms and melt pond processes may be derived from the radiation measurements. Combing measurements from different platforms with large-scale observations allows deriving key processes over large regions and during different seasons.

O

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Sea ice dynamics determined from coastal radar image sequences in the Baltic Sea

We have studied sea ice dynamics in the coastal region of northern Baltic Sea from the sequences of coastal radar images. Data was collected during winter 2011, and it covers the whole ice seasons from the formation of the ice cover to the break up. Analyses are based on tracking algorithm and ice floe trajectories are calculated using images taken on average every 2 minute. The total area of coastal radar images is 40*40 km. This unique data set allows the determination of sea ice dynamics and deformation in very small scale, both in time and space, and also shows the seasonality of the phenomenon. From the coastal radar data, we determine the ice drift at different distances from the shore, and thereby the offshore gradient of ice velocity can be calculated. Ice drift is compared to wind, which is the main forcing in the Baltic Sea ice dynamics. The ice response to wind differs largely depending on the wind direction, distance to shore and prevailing ice conditions.

P

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Estimates of water mass transformation rate in subpolar North Atlantic using different atmospheric forcing data.

J.-P. Paquin, Y. Lu

This study compares the surface-forced water mass transformation (WMT) in the subpolar North Atlantic diagnosed using three different atmospheric datasets: the NCEP coupled reanalysis (CFSR), the Canadian Meteorological Center Global Deterministic Prediction System Reforecast (CGRF) and the ECMWF Reanalysis (ERA-Interim). The analysis is performed using solely the atmospheric variables generally used to force ocean models, with common sea surface temperature and salinity data, to estimate the potential sensitivity of ocean models to the differences in the forcing data. We use daily averages from 2m-air temperature and humidity, winds, precipitations, short- and long-wave radiation from each atmospheric dataset. Daily turbulent heat fluxes are then calculated using the COARE3.0 algorithm (Fairall et al. 2003) using common daily SST and SSS data either from a combination of OSTIA-GLORYS2v3 or the World Ocean Atlas 2013. The WMT is then diagnosed over the North Atlantic with a focus on the Labrador, Irminger and Nordic Seas.

Results show that the density distribution of the WMT is mostly sensitive to the choice of the reference SST and SSS data. The WMT for each atmospheric dataset shows coherent time variability but some systematic differences in magnitude can be identified, especially over the Irminger and Nordic Seas. For densities higher than 27.2 kg m-3, the WMT rates estimated using different forcing are generally consistent, but differences are noted in terms of contributions from different terms. The results suggest that notable differences are expected among model solutions of the subpolar North Atlantic using different atmospheric forcing data.

P

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No presentation

P

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Observations of thermohaline sound speed structure in the Beaufort Sea in the summer of 2015

Observations of temperature and salinity were made by ship CTD casts and a mooring in the central Beaufort Sea between July 15 and August 15 2015, as part of the Canada Basin Acoustic Propagation Experiment (CANAPE) pilot study. This talk will present an analysis of the observed temperature, salinity, and sound speed structure in terms of the fresh upper layer, the Pacific layers, the Arctic halocline, and the Atlantic layer. The talk will focus on identifying the spatial and temporal variability of the thermohaline and sound speed structures associated with eddies, internal waves, and diffusive layering (stair cases).

P

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No presentation

P

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Decadal variations of the Arctic water temperature and salinity

Zhenxia Long and Will Perrie

In this study, we investigate the decadal variability of water temperature and salinity in the central Arctic Ocean, performing simulations for 1948 to 2009 with the ocean model, NEMO (Nucleus for European Modelling of the Ocean). NEMO is implemented in the Arctic Ocean, forced by GLORYS water temperature, salinity, current as well as CORE II surface fields. Outflows from the 13 largest rivers along the Arctic coast are implemented in the boundary conditions for the Arctic domain. The Neptune effect is applied to provide a representation of the cyclonic rim currents along the central Arctic basin. We show that compared to PHC data, NEMO can reliably reproduce the upper layer water temperature and salinity, suggesting a warm layer at intermediate depths and a salinity minimum in the Beaufort Sea. In addition, the model simulations exhibit significant decadal variations in the water temperature associated with the Atlantic water layer (AWL) and water salinity in the Beaufort Sea. In addition, there is an increase in the fresh water content in the Beaufort Sea and the water temperature at the intermediate layers after the 1990s. On average, the fresh water from the Siberian coast is transported into the eastern Arctic along the transpolar drift and into the Beaufort Sea through the coastal current; however, its pathway is shifting westward during the last decades of the simulation. Further analyses suggest that the decadal variations in the water temperature and salinity are associated with the variability of polar vortex. For example, the eastward shift of polar vortex enhances the Beaufort High in the western Arctic, which accelerates the accumulation of fresh water in Canada Basin along with the increased ice melting.

P

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Wave-ice interactions in the Marginal Ice Zone

Will Perrie (BIO), Mike Meylan (Newcastle), Hui Shen (BIO) Yongcun Hu (BIO), Bash Toulany (BIO)

WAVEWATCHIII (WW3) ocean wave is the 3rd generation operational state-of-the-art forecast model for NOAA and many operational marine forecast offices, internationally. In this study, WW3 is adapted for wave scattering in the marginal ice zone (MIZ) following earlier development by Masson and LeBlond (1989, JFM), Perrie and Hu (1996, JPO) and Meylan and Masson (2006), and correcting errors in earlier formulations. Presently, no practical methodology has been developed to directly incorporate a reliable wave attenuation scattering model for the MIZ, into a model like WW3. As part of a recent ONR initiative, Squire et al. (2014) developed a phase resolved scattering model which is capable of simulating hundreds of elastic ice floes. However, the latter model cannot be incorporated into WW3 directly. By comparison, the theory of how to include scattering into ocean wave models was developed by Masson and LeBlond (1989), Meylan et al. (1997), and Meylan and Masson (2006) ; but Perrie and Hu (1996) were able to make such an implementation in an earlier 2nd generation wave model. One limitation on their methodology is that they used rigid floes, whereas ice floe flexure can be expected to be a dominant factor in some situations in the MIZ, for large floes, (Meylan and Squire, 1994; 1996). However, Perrie and Hu (1996) were able to predict many of the features observed in measurements such as the roll over effect and the strong dependence of wave scattering on wave period. Moreover, the change from rigid to flexural ice floes is quite feasible in this formulation. We update and optimize this model approach for wave-ice attenuation and scattering, with implementation in WW3. The resulting model system is validated with in situ and satellite remotely sensed MIZ data, collected during recent field experiments. These include some of: (b) a storm in the Greenland Sea in February 2012, (b) ice motion data from the MIZ off Antarctica, collected by Kohout et al. (2014, Nature) to estimate ocean wave attenuation, (c) an ONR Sea State experiment in the Beaufort Sea during October 2015.

P

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Characterizing Arctic sea ice surface topography using high-resolution IceBridge data

Here we present a detailed analysis of Arctic sea ice topography, using high resolution, three-dimensional surface elevation data from the NASA Operation IceBridge Airborne Topographic Mapper (ATM).

Surface features in the sea ice cover (from ice deformation and snow redistribution) are detected using a novel feature-picking algorithm. We derive information regarding the height, orientation and spacing of `unique' surface features from 2009-2014 across first-year and multiyear ice regimes within the Beaufort/Chukchi and Central Arctic regions.

The sea ice topography exhibits strong spatial variability, including increased surface feature height and volume within the multi-year ice regimes. The ice topography also shows a strong coastal dependency, with the feature height increasing as a function of proximity to the nearest coastline, especially north of Greenland and the Canadian Archipelago. The interannual variability in feature height and volume, especially north of Greenland, alludes to the importance of ice deformation variability in the sea ice mass balance.

A strong correlation between surface feature height and sea ice thickness (from the IceBridge sea ice product) demonstrates the potential for skillful (and quick) estimates of ice thickness based on surface measurements alone.

P

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Large scale material properties of land-fast ice

A linear elastic model is developed to simulate the internal stresses induced by the wind on the land-fast ice, modelled as a 2D elastic plate. To estimate the large scale material properties of the ice, observed break up events are used to infer the tensile and shear strength of the ice from the modelled stresses. Using brightness temperature imagery from MODIS (Moderate Resolution Imaging Spectroradiometer) on the Terra and Aqua satellites, multiple break up events (usually happening in the ice bridges formations of the South-eastern Laptev Sea) are shown to produce ice floes of a characteristic scale. This scale is indicative of the strength of the ice relative to the wind forcing. The position of the flaw lead before, during and after these events, along with the characteristic scale of the resulting ice floes, are used to extrapolate from the model the stress states that corresponds to these observations. The results from a collection of events will then used to investigated the relationship between the ice thickness and the ice strength, the timing of the land-fast ice stabilisation, the formation of ice bridges and the seasonal break up.

P

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Mesoscale eddies in the Eurasian Basin of the Arctic Ocean: a view from observations

Mesoscale eddies are an important component in Arctic Ocean dynamics and can play a role in vertical redistribution of ocean heat from the intermediate layer of warm Atlantic Water (AW). We utilized extensive collection of mooring data collected by Nansen and Amundsen Observational System (NABOS) at the continental slope of the Laptev Sea in 2007-11 to document properties of Arctic mesoscale eddies in this region of the Eurasian Basin (EB). Implementation of the rotational wavelet for eddy identification has revealed that ~20% of the mooring record is occupied by mesoscale eddies, whose vertical scales can be large, often >600 m. Based on similarity between temperature/salinity profiles measured inside eddies and modern climatology for the 2000s, we found two distinct sources of eddy formation in the EB; one in the vicinity of Fram Strait and the other at the continental slope of the Severnaya Zemlya Archipelago. Both sources of eddies are on the route of AW propagation along the EB margins, so that the Arctic Circumpolar Boundary Current (ACBC) can carry these eddies along the continental slope.

The average temperature anomaly inside Fram Strait eddies in the layer above the AW temperature core (i.e., above 350 m depth level) was ~0.1º C with the strongest temperature anomaly in this layer exceeding 0.5ºC. These temperature anomalies suggest ~1% surplus of total heat transport compared with the mean heat transport by the ACBC at the mooring site. In contrast to Fram Strait eddies, Severnaya Zemlya eddies carry anomalously cold and fresh water, and likely contribute to ventilation of the AW core. In addition, we found increased vertical shears of the horizontal velocities inside eddies that result in enhanced mixing. Our estimates made using the Pacanowski and Philander (1981) relationship suggest that, on average, vertical diffusivity coefficients inside eddies are four times larger than those in the surrounding waters.

P

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Arctic circulations regimes changes in the 21 st century

Andrey Proshutinsky, Dmitry Dukhovskoy' Mary-Louise Timmermans,
Richard Krishfield, Jonathan Bamber

Between 1948 and 1996, mean annual environmental parameters in the Arctic experienced a well pronounced decadal variability with two basic circulation patterns: cyclonic and anticyclonic alternating at 5 to 7 year intervals. During cyclonic regimes (CCRs), low sea level atmospheric pressure (SLP) dominated over the Arctic Ocean driving sea ice and the upper ocean counterclockwise; the Arctic atmosphere was relatively warm and humid and freshwater flux from the Arctic Ocean toward the subarctic seas was intensified. By contrast, during anticylonic circulation regimes (ACCRs), high SLP dominated driving sea ice and the upper ocean clockwise. Meanwhile, the atmosphere was cold and dry and the freshwater flux from the Arctic to the subarctic seas was reduced. Since 1997, however, the Arctic system has been under the influence of an anticyclonic circulation regime (17 years) with a set of environmental parameters that are atypical for this regime. We discuss a hypothesis explaining the causes and mechanisms regulating the intensity and duration of arctic circulation regimes, and speculate how changes in freshwater fluxes from the Arctic Ocean and Greenland impact environmental conditions and interrupt their decadal variability. We speculate that continuation of Greenland melting will support longer duration ACCRs will result in Arctic cooling accompanied by increased ice extent and thickness -- similar to conditions observed in the 1970s. Enhanced upper ocean stratification in the sub-arctic seas will inhibit heat exchange between the ocean and atmosphere and subsequently – transport of heat by cyclones to the Arctic. This would have broad-reaching climate implications by limiting the advection of heat from the mid-latitudes and is therefore a negative feedback on Arctic amplification under global warming.

R

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Arctic Cyclones and Sea Ice in HadGEM3

Alexander Todd and Jamie Rae

Several recent observational studies have suggested a link between cyclones entering the Arctic in summer, and September minimum ice area and extent. Here, we investigate whether such links are found in output from the fully-coupled model HadGEM3. We find that, while large-scale mean-sea-level pressure has an impact on the sea ice dynamics, and on export through the Fram Strait, the correlations between cyclone characteristics and summer ice loss, seen in observations, are not reproduced by HadGEM3. We then investigate the reasons for the lack of agreement with observations by various means, including analysing the impacts of individual cyclones in hindcasts produced with the seasonal forecasting system GloSea5. In doing so, we aim to gain some understanding of the model enhancements most likely to improve the response of the Arctic sea ice to cyclones.

R

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Impact of North Atlantic waters on the Arctic Sea-Ice in the CCSM version 3 and 4

The Community Climate System Model (CCSM) version 3 and 4 depicts different sea-ice scenarios in the future [Holland et al., 2006; Jahn et al., 2011]. The CCSM3 predicts rapid sea-ice decline while the CCSM4 shows slow and steady loss of sea-ice. The temperature-density profile over the Arctic Ocean of the CCSM4 is too warm and too saline at depth. Some studies are showing that the ocean plays an important role on the melting [McPhee et al., 2005, 2003; Perovich et al., 1989; Maykut and McPhee, 1995; Perovich and Elder , 2002] while others are proving the opposite [McPhee and Untersteiner , 1982; Timmermans et al., 2008; Rainville and Winsor , 2008; Lique et al., 2013]. Even if the impact of the North Atlantic waters on the sea-ice is still not well understood, a possible explanation to the sea-ice discrepancies between model versions could be from disparities in the heat fluxes at each gates of the Arctic Ocean and its interaction with the surface.

R

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Sea ice observations: Present and future needs to advance the state-of-knowledge

The aim of this presentation is to set the stage for discussions to identify present and future sea ice observational needs, to improve the ability to monitor changes in the characteristics of the Arctic sea ice cover and better understand the processes governing these changes. The first part of the talk will be an overview of current observational techniques, including instruments deployed on satellite, airborne, submarine and in situ platforms. With this as background, an initial summary of shortfalls in the observational arsenal will be made to stimulate discussion in the breakout sessions. Special attention will be paid to observational needs generated by high resolution modeling and process study requirements and upcoming opportunities to conduct observational studies.

R

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Forum for Arctic Modeling & Observational Synthesis, 2015
Toward the floe scale: High resolution coupled modeling of sea ice

Andrew Roberts[1*], Elizabeth Hunke[2], Wieslaw Maslowski[1]

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The first sea ice models to comprehensively simulate both the thermodynamics and dynamics of the pack were developed in the 1970s. These models represented sea ice using horizontal grid resolutions typically ranging from 100km to 200km, used daily model timesteps, and were often coupled to idealized mixed ocean layers and thin atmospheric boundaries. Such models formed the basis for more sophisticated coupled ice-ocean models developed during the 1980s, which in turn precipitated fully coupled climate models that incorporated detailed physics of sea ice growth, drift, deformation and melt during the 1990s. Since then, we have seen the growing sophistication of fully coupled sea ice models, and current generation codes incorporate explicit ice, snow and melt pond morphologies, brine drainage, as well as isotropic or anisotropic sea ice mechanics with form drag. Yet, the standard configuration of many prominent fully coupled sea ice models remains at a horizontal resolution of 100km, and are sometimes coupled to at least one component no more frequently than on daily timesteps.

Some of the most important spatial and temporal processes affecting sea ice and its feedbacks to the ocean and atmosphere cannot be represented without coupling the pack to atmospheric models that resolve mesoscale features of storms, to ocean models that represent eddy kinetic energy on scales approaching the Rossby radius, and temporal scales resolving several kinds of high-frequency waves in the ice-ocean boundary layer. In this presentation we demonstrate the importance of high resolution fully coupled modeling of the Arctic using the sophisticated sea ice component in the Regional Arctic System Model with a standard configuration of 9km, and using a resolution of 2.4km. We discuss the limitations and challenges of approaching the floe scale in fully coupled models, laying open research questions emerging in this field.

S

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S

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Monthly Isopycnal & Mixed-layer Ocean Climatology (MIMOC)

MIMOC is a trio of global monthly ocean property maps from 80°S to 90°N at 0.5° lateral resolution, all available for download. Products include mixed layer and select interior ocean isopycnal maps. These maps are combined into a third set of maps on 81 standard pressure levels from the surface (0 dbar) to 1950 dbar (approximately 1925 m). The maps are based mostly on Argo CTD data, supplemented by shipboard and Ice-Tethered Profiler CTD data. The maps mostly reflect the modern ocean state, although they relax back to historic data from as early as the 1970s when no recent data are available for a region or season.
A new version V2.5 for the Arctic region will be presented to address previous issues in shallow data sparse areas.

S

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Arctic primary production in a multi-resolution model

The acceleration of the Arctic sea-ice decline observed over the past decade has consequences for the mixed layer light availability and nutrient concentration, and thus for the marine productivity in the area. One way to study the pan-Arctic impact of declining sea-ice on biological production is by using coupled Ocean General Circulation Biogeochemical Models (OGCBMs). Currently, these models agree on the present day productivity, but due to tight bio-physical coupling in the Arctic Ocean, differences in the ocean components mean that they differ in what is controlling the production; light or nutrient availability. This highlights the importance of using ocean models that have been optimized for the Arctic Ocean.

Here, we present first results of Arctic biogeochemistry from the Finite Element Sea-ice Ocean Model coupled to the biogeochemical model REcoM2. In this set-up, the resolution of the Arctic Ocean varies from 10 to 70 km. The spatial distribution of net primary production (NPP) agrees well with previous estimates, as does the mean annual NPP of 663 Tg C/yr for Arctic Ocean north of 65N. We observe a 10% increase in NPP from 1998 to 2008, due to increasing light availability. While the model's production is dominated by diatom growth in the area, the increase in NPP is characterized by an increase in nanophytoplankton growth, indicative of increased nutrient limitation towards the end of the period.

Future work includes a run with an eddy-permitting 4.5 km pan-Arctic resolution, in which we will evaluate how a better description of the nutrient supply affects the NPP.

S

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Extreme acidification in the East Siberian Arctic Shelf: where modeling is required

Igor Semiletov[1,2,3*] , Natalia Shakhov[1,2]and the international Siberian Shelf Studies Team

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Ocean acidification (OA) is a direct, fast, and strong effect of anthropogenic carbon dioxide (CO_2), which is challenging marine ecosystems and carbon cycling[1-3]. Accumulation of CO_2 in ocean surface waters has led to an average pH decrease of 0.1 since the Industrial Revolution, and is bound to make the ocean twice as acidic by the end of this century[4]. The Arctic Ocean is particularly sensitive and exhibits the highest levels of OA (lowest pH) because more CO_2 can dissolve in cold water[4-6]. We here use decadal data to show that extreme and extensive OA in the East Siberian Arctic Shelf (ESAS) is caused not by direct uptake of atmospheric CO_2 but rather by naturally-driven processes: carbon mobilization from thawing coastal permafrost/coastal ice complexes, and freshening due to growing Arctic river runoff and ice melt, which transport carbon along with freshwater to the ESAS. These processes compose a unique acidifying phenomenon that causes persistent, and potentially increasing, aragonite under-saturation of the entire water column. Extreme aragonite under-saturation in the western near-shore ESAS is associated with >80% depression of the total calcifying benthic biomass. Massive OA on the ESAS, the largest sea shelf system of the World Ocean, illustrates the complexity of the Earth system interacting with increasing anthropogenic pressure. Modeling is required to evaluate: 1) OA contribution of fresh water (melt vs riverine), and oxidation of organic carbon (terrestrial vs marine); 2) off-shelf export of the ESAS acidified water.

S

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No presentation

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Subsea permafrost and gas hydrates release conditions (as referred from investigations of the East Siberian Arctic Shelf).

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Igor P. Semiletov, University of Alaska Fairbanks, Fairbanks, AK, United States; Tomsk Polytechnic University, Tomsk, Russia

Methane is a powerful greenhouse gas. A huge amount of methane is frozen in methane hydrates, which are found in ocean sediments and permafrost. Most methane hydrates are stored in continental shelf deposits, where >95% of sedimentary organic carbon is preserved. As the East Siberian Arctic Shelf (ESAS) alone composes ~8% of the world's continental shelf, spatial fraction of hydrates preserved there could be at least 7.5% of the global inventory of hydrates. Considering that thickness of sedimentary drape in the ESAS 2-3 times greater than continental shelf average, this fraction could be significantly larger. Gas hydrates can be stable over a wide range of pressures and temperatures; conditions that determine stability of Arctic marine hydrates are very specific and physics of these hydrates is poorly known. Since Arctic hydrates are permafrost-controlled, they destabilize when sub-sea permafrost thaws. Current warming in the Arctic is already causing sub-sea permafrost to thaw. Thawed permafrost fails to reliably seal off the hydrate deposits, leading to extensive methane release into the shallow water of the ESAS. When hydrates destabilize, methane within sediments increases tremendously in volume and releases to the water column as large conglomerations of bubbles called flares. Such flares occur over extensive seep fields, observed, for example, in the ESAS. High pressure that results from hydrate decomposition can lead to methane bursts or non-gradual releases. Based on isotopic signature of methane releasing from the ESAS, we suggest involvement of both biogenic and thermogenic sources. Methane emissions in the ESAS currently vary within 3-5 orders of magnitude; higher rates correspond to areas where permafrost is degraded most. Further progress of these releases will be determined by progress in subsea permafrost degradation that will depend on environmental dynamics, including hydrological conditions.

S

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Methane release from the East Siberian Arctic Shelf: Issues addressed and questions raised.

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Specific feature of the Arctic Ocean is that it is surrounded by permafrost and that its shelf – the largest shelf in the world – is underlain by subsea permafrost. Due to long existed gap in observational knowledge and lack of understanding of key processes, subsea permafrost has never been considered in regards to its interaction with other key processes ongoing either in the Arctic Ocean (AO) or in the Arctic as a whole or in the global climate system. As frozen grounds in the Arctic preserve significant fraction of planetary organic carbon and pre-formed methane, certain fraction of which is stored as hydrates, destabilization of this storage and its involvement to the modern biogeochemical cycle might cause climatic consequences to our planet. Comprehensive data sets collected in the ESAS during the last two decades, which include hydrological, biogeochemical, geophysical, geo-electrical, microbiological, and isotopic methods, followed by modeling efforts on current state of subsea permafrost allowed to spill some light on the processes driving methane emissions in the ESAS. Unlike gradual release when ancient carbon in thawed on-land permafrost is mobilized, methane releases from the East Siberian Arctic Shelf (ESAS) largely stems from seabed deposits. Current state of subsea permafrost serves as major methane emission determinant; rates vary by 3-5 orders of magnitude over the ESAS. Future of these emissions will depend on dynamics of the number of factors, controlling/accelerating emissions: growing rates of permafrost degradation, increasing river runoff, spread of dissolved methane via currents, longer emissions period due to extended periods of open water, decreasing sea ice extent and growing areas of flaw polynyas and breaks in the ice, deeper water mixing caused by stronger winds and growing wave heights, etc. To assess contribution of all these factors, serious modeling effort is required.

S

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Consequences of Future Increased Arctic Runoff on Ocean Stratification, Circulation, and Ice Cover

The Arctic Ocean is the most freshwater dominated of the world oceans, and in the future we expect it to be even more so as the global hydrological cycle accelerates, increasing the high latitude precipitation and runoff . The effects of positive high latitude freshwater perturbations on the large scale is a slowdown of the oceanic circulation. At the same time idealized modelling suggests enhanced cyclonic circulation in the Arctic Ocean as a response to positive freshwater perturbations. With the broad range of scales and processes involved the overall effect of increasing runoff on the ocean circulation and stratication requires an understanding of both the local processes and the broader linkages between the Arctic and surrounding oceans.

Here we increase the Arctic river runoff in a coupled ice-ocean general circulation model and show contrasting responses in the polar and sub-polar latitudes. In our simulations the Arctic Ocean responds with a spin-up of the cyclonic circulation and with a warmer halocline and Atlantic layer. In the sub-polar gyre region we simulate colder and fresher water column with weaker barotropic circulation. In contrast to the estuarine circulation theory the volume exchange between the Arctic and the surrounding oceans does not increase. While these results are robust in our model system we call for model and observational synthesis to further narrow down the sensitivity of the climate system to high latitude freshwater perturbations.

S

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Incorporating small-scale heterogeneities into a high-resolution sea ice model

These heterogeneities at the rheological scale (several kms or less) create preferential failure pathways along which the deformation is concentrated. The deformation behavior of the Arctic ice pack has been shown to lack coherence at smaller length scales [Hutchings et al., 2011]. This suggests that rheologies could be improved by incorporating a parameterization of the observed heterogeneities. We use a discrete element method (DEM) sea ice model that is capable of explicitly describing the heterogeneities and discontinuities in the ice pack and using remote sensing to derive realistically shaped inclusions, such as melt ponds, to examine the scale dependence of the deformation behavior at a high spatial resolution.

S

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Eddies in the Arctic Ocean: Sources and Dynamics

Eddies have now been observed throughout the basins of the Arctic Ocean. Water mass properties indicate that they originate from many source regions and likely play an important role in regional heat and salt balances and in the maintenance of the Arctic halocline. A review of historical and recent observations, and the dynamics of eddy formations based on numerical and theoretical approaches, will be presented. Finally, the importance of these eddies for the large-scale dynamics and thermodynamics of the Arctic basins, and their representation in climate models, will be discussed.

S

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The Bering Sea

In the far north, off the west coast of Alaska, lies the Bering Sea - the world's third-largest semi-enclosed sea. In early winter, the combination of geology, latitude, winds and ocean currents results in a rapid ice advance (approximately 1200 km in 2-3 months). In the spring, warming and a change in the wind direction result in ice retreat. Thus, during summer the Bering Sea is ice-free. Retreating ice, longer daylight hours, and nutrient-rich ocean waters result in high marine productivity vital to both sea life and people. This high-latitude sea is among the most productive in the world, supplying almost half the U. S. catch of fish and shellfish and approximately 70% of the subsistence harvest for those living in its coastal communities. Approximately 80% of the seabird population in the U. S. and 25 species of marine mammals visit or live in these cold waters each year. The extent of ice and the timing of its retreat play a powerful role in structuring this ecosystem – from physics to primary production to species distributions. Climate scientists predict a major reduction in ice cover in future decades. To understand the Bering Sea ecosystem, we spend more than months each year at sea collecting information on ocean temperature, currents, plankton, and fish. Data collected over the last several decades show marked changes in this ecosystem – a reduction in sea ice, a warming ocean, a decrease in zooplankton abundance, and changes in fish populations. Year-around, long-term moorings provide information for the 4-6 months each year when ship operations are not possible, and new technology, such as wave gliders and Saildrones, are expanding our ability to sample this ecosystem.

S

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No presentation

S

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Loitering of the Retreating Sea Ice Edge in the Arctic Seas

Each year, the arctic sea ice edge retreats from its winter maximum extent through the Seasonal Ice Zone (SIZ) to it summer minimum extent. On some days, this retreat happens at a rapid pace, while on other days, some parts of the pan-arctic ice edge hardly move for periods of days up to 1-1.5 weeks. We term this behavior "ice edge loitering," and identify areas that are more prone to loitering than others. Generally, about 20-25% of the SIZ area experiences loitering, most often only one time at any one location during the retreat season, but sometimes two or more times. The main mechanism controlling loitering is an interaction between surface winds and warm sea surface temperatures in areas from which the ice has already retreated. When retreat happens early enough to allow atmospheric warming of this open water, winds that force ice floes into this water cause melting. Thus while individual ice floes are moving, the ice edge as a whole appears to loiter. The time scale of loitering is then naturally tied to the synoptic time scale of wind forcing. Perhaps surprisingly, the area of loitering in the arctic seas has not changed over the past 25 years, even as the SIZ area has grown. This is because rapid ice retreat happens most commonly late in the summer, when atmospheric warming of open water is weak. We speculate that loitering may have profound effects on both physical and biological conditions at the ice edge during the retreat season.

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No presentation

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Looking back at Sea Ice Outlook Predictions

The modern satellite passive microwave record provides consistent estimates of Arctic sea ice extent since late 1970s. These data document downward linear trends in Arctic sea ice extent for all months, but with the largest trend for September. It is expected that Arctic sea ice extent will continue to decline, the eventual outcome being an essentially seasonally-ice Arctic Ocean. As the Arctic loses its summer sea ice cover, the region becomes more accessible to marine transport, tourism and extraction of energy resources. While the growing economic and strategic importance of the Arctic demonstrates a need to reduce the large uncertainty as to when ice-free conditions will be realized, arguably a more important need is to improve seasonal forecasts of ice conditions, for even in an ice-diminished Arctic, there will be large variability in conditions from year to year.

There are several notable aspects of the September trend that bear upon seasonal forecasting. First, the downward trend is steepening, which is linked to the ice cover becoming younger and thinner. Second, while major excursions in September ice extent from the trend line are strongly driven by variations in atmospheric circulation, large departures (exceeding 0.5x106 km2) seldom persist more than a few years, manifesting a strong negative (stabilizing) feedback in the sea ice system associated with ocean heat loss during autumn and winter. Thus, in the absence of strong summer atmospheric forcing, one may expect September extent to fall somewhere near the trend line. Indeed, contributions to the SEARCH Sea Ice Outlook (SIO) from 2008 to 2015 show that forecasts for September extent do not perform as well during years when there are large departures in extent from one year to the next. Thus, while studies show that better initialization of initial conditions can lead to more skillful forecasts, there remains an inherent limit to seasonal predictability due to the chaotic nature of atmospheric variability. This is further highlighted through evaluations of predictive skill of freeze-up in the Chukchi Sea.

S

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Study on the melt pond fraction of Arctic using CICE model

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During melt season, melt pond is significant phenomena on the sea ice surface. The albedo of melt ponds is greater than open water but less than sea ice. The accuracy of melt pond fraction simulation is important to understand the heat budget of the atmosphere-ice-ocean system.

Melt water sources from melting snow, ice and liquid precipitation, the liquid precipitation is an order of magnitude smaller than melting snow and melting ice. In CICE 5.0+ model, three melt pond parameterization schemes have different processes on the melt pond's generation, melt water distribution and frozen. In numerical simulation based on CICE model, the simulation results of 'topo' scheme, when use the freezing conditions as that of 'cesm' scheme, have tendency of more matching MODIS retrieval results data than the other two schemes in the aspect of the inter-annual variability of spatial averaged melt pond fractions of Arctic, melt ponds coverage extent, the length of maximum melt season and its amplitude of interannual variation. Snow infiltration effect is introduced in 'topo' scheme in our study which leads to a more reasonable spatial evolution of melt pond. But in the current simulation, the melt pond coverage extent as well as the melt pond fraction snow infiltration is too small on the multiyear ice. The loss of melt water volume is also analyzed. The portion of the available melt water draining immediately into the ocean as well as the portion of melt water's permeability through sea ice are calculated in this study.

T

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Time-Varying Arctic Surface Currents from Cryosat-2

Sam Thomas, Andy Ridout

The Arctic Ocean is known to be a region of significance in global climate, and has been observed to undergo drastic changes in recent decades. As research continues to understand the Arctic and the interaction of atmosphere, ice & ocean, a key area of study is ocean circulation – the investigation of which has traditionally been hampered by the region's harsh and ice-covered nature. However with the advent of polar altimetry and the development of lead retracking, we may draw back the veil of sea ice and study the ocean beneath.

Sea ice retracking techniques developed at UCL allow us to find leads in the floe and acquire sea surface height (SSH) measurements across the Arctic. In combination with the geoid we calculate dynamic topography and associated geostrophic surface currents.

We demonstrate the quality of surface current data made possible by Cryosat-2, with its major improvements in coverage and resolution over previous altimeters. We show the variations in currents in the high Arctic seen on both yearly and monthly timescales, and discuss the benefits & drawbacks of employing different processing techniques and source data. We discuss the applications of surface current products, and look to how suck data may be improved further.

T

Zhongxiang Tian
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Sea ice Observation and Forecast in Polar Region

In recent years, the environment of polar regions has undergone significant changes, and the role of polar prediction became more and more important. I am working on sea ice prediction and field observation.

Firstly, I had been to Antarctic Zhongshan station for a winter campaign, from October 2012 to December 2013. My major work there was daily weather forecasting and sea ice observation. I measured sea ice thickness by drilling hole, and deployed two sets of Ice Mass Balance (IMB) within 5km from Zhongshan station. Electromagnetic (EM) measurement of sea ice is an efficient, fast and high-precision method. So I used an electromagnetic induction device - EM31 to measure sea ice & snow thickness. In addition, I set up a CNR4 and a TriOs to measure the spectral incident and reflected solar radiation above the sea ice surface.

Secondly, I also had been to Arctic with Chinese XueLong icebreaker from July to September, 2014. During this cruise, I was onboard as a sea ice forecaster who is responsible for the onboard sea ice service. Besides this, I used an EM31 and an ice auger to measure sea ice and snow thickness at 7 short-term ice stations and 1 long-term ice station. I also deployed two sets of IMB, both are still working well now. I am also responsible for the IMB data processing and analysis .

In addition, I used sea ice concentration data derived from satellite to analyze sea ice condition and sea ice variability in recent years. Now, combined with SAR image, Modis image, and weather condition, I am able to distinguish iceberg from ice floes, and predict sea ice condition in Antarctic and Arctic, especially during Chinese Antarctic/Arctic Research Expedition. Additionally, I use MITgcm ice-ocean model to do sea ice numerical prediction. Running this numerical forecast is our daily operational work. Further, I am taking efforts on tuning the new Arctic 4km forecasting system. The data obtained from the in-situ sea ice observation will help us to improve the model performance.

T

Zhongxiang Tian
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Sea ice Observation and Forecast in Polar Region

I am working on and also very interested in the sea ice prediction and field observation.

I had been to Antarctic Zhongshan station for a winter campaign, from October 2012 to December 2013. My major work there was daily weather forecasting and sea ice observation. I measured sea ice thickness by drilling hole, and deployed two sets of Ice Mass Balance (IMB) within 5km from Zhongshan station. Electromagnetic (EM) measurement of sea ice is an efficient, fast and high-precision method. So I used an electromagnetic induction device - EM31 to measure sea ice & snow thickness. In addition, I set up a CNR4 and a TriOs to measure the spectral incident and reflected solar radiation above the sea ice surface.

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Near Real Time estimates of Arctic sea ice thickness from CryoSat-2

Since October 2010, data from the European Space Agency (ESA) CryoSat-2 (CS-2) satellite has provided the means to produce sea ice thickness maps across the entire Arctic Ocean basin. These large-scale observations of Arctic sea ice thickness are required to determine trends, compare hemispheres and aid predictive models of future global climate change. However, the final ESA data product is not available until ~30 days after the satellite acquisition, and as such the use of the data for near real time (NRT), operational purposes, has not been possible.

At University College London (UCL) we are now able to produce the first and only NRT estimates of Arctic sea ice thickness, with a lag of only 2 days, using NRT data restricted to those given special access by ESA. We hope that this original dataset will allow operational users to access NRT estimates of Arctic-wide sea ice thickness, and will be a great help to industries such as transport, tourism, and the scientific community. This presentation will summarise the NRT product and its differences with the final product, and analyse its reliability and data coverage in particular regions of interest (e.g. the northwest passage, Beaufort Sea etc…)

T

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Arctic Ocean observations: results and future needs

This talk will highlight new understanding of the Arctic Ocean based on the past decade of intensive observations. The state of the Arctic Ocean and processes on a range of temporal and spatial scales will be outlined, from basin-wide freshwater and heat content evolution and distribution, to measurements of the smallest scales of relevance to ocean mixing. Recent advances in Arctic Ocean observing capability will be discussed, with implications to future Arctic observing networks. The aim of the talk is to set a framework to guide discussion between the observational and numerical modeling communities, and weigh the expectations and needs of both.

T

John Toole
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An Investigation into Arctic Sea-Ice Dynamics and Energetics

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VIT University, Vellore, Tamil Nadu, India
John M. Toole and Sylvia T. Cole
Woods Hole Oceanographic Institution, Woods Hole, Massachusetts, USA

Sparse observational data impede understanding of the Arctic Ocean and the sea ice that drifts upon it. Quantifying the exchanges across the air-ice-ocean boundary layer and their representation in models are central research problems today. Focusing on the sea ice component of this system, we analyze data from 5 Ice-Tethered Profilers with Velocity (ITPV) systems deployed in support of the 2013-2015 Marginal Ice Zone program. Ice motion is examined in the time and frequency domains and characterized using the momentum and kinetic energy balance equations. Wind velocity data were obtained from Autonomous Weather Stations augmented by reanalysis data. The ITPVs directly measured the ocean velocity relative to the ice, while the ice velocities were derived from hourly GPS fixes by the ITPV surface buoys. The latter two data streams were combined to estimate absolute ocean velocity. The ITPV data also support direct covariance estimates of the turbulent vertical momentum flux about the ice-ocean interface. Spectral and coherence analyses of the ice, ocean and wind velocity data document significant coupling at subinertial frequency, with the characteristic offset of the velocity vector to the right between the wind and ice velocities and between the ice and ocean velocities. During summer months, rotary spectra of the ice and ocean velocities show clockwise peaks in energy density at the inertial frequency with high coherence and near zero phase. Wind spectra in contrast are red with no discernible peaks at any frequency. Analysis of individual terms in the sea ice momentum and kinetic energy balance equations reveals that the wind stress and the ocean drag on the ice constitute the dominant first order balance for major segments of the records. This analysis will help evaluate and guide models used to predict and characterize sea ice motion.

T

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Regional forecast of minimum sea ice extent: a Lagrangian approach

In this contribution we extend the pan-Arctic analysis presented in Williams et al. (2015) and produce a regional forecast of sea-ice conditions for each of the Arctic peripheral seas including the Beaufort, Chukchi, East Siberian, Laptev and Kara seas. The model builds on the idea that it is the mean large scale sea ice circulation the previous winter that determines how retreated the following summer minimum sea ice extent will be and in particular the mid to late winter coastal sea-ice divergence. When ice divergence occurs late in the winter, new ice forms but it does not have the time to grow to thickness such that it will survive the following summer melt. In order to produce a regional forecast, we use a Lagrangian sea-ice model to backtrack an imaginary line defining the boundary of a given sea starting from the beginning of the melt season in May until the mid winter in January. Results show that the position of the ice edge in each of the peripheral seas of the Arctic is well correlated with the previous winter divergence. The maximum correlation is obtained when the synthetic ice edge is backtracked from May to February. Note that, unlike the previous pan-Arctic study of Williams and colleagues in which the net ice divergence could be correlated with the winter mean Arctic Oscillation index, the regional analysis requires sea ice drifts in order to the winter mean ice divergence along the coast. This begs for real-time production of satellite-derived sea-ice velocity vectors in order to develop an observation based regional forecasting. It is also interesting to note that the use simulated drift from a coupled ice-ocean model (e.g. PIOMAS) cannot replace observed sea ice drift because of biases in the sea ice thickness that leads to biases in the sea ice drift vector feeding the Lagrangian model.

U

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The impact of an ITD parameterisation on the quality of model results

The ice thickness distribution (ITD) parameterisation aims to account for sea-ice of different thickness inside of a single grid cell and to account for sub-grid cell processes which alter the sea-ice thickness (e.g. ridging, rafting). By now ITDs and ridging schemes are widely used by the community; however, it is difficult to assess the gain in model quality through those parameterisations. Since neither the overall state of Arctic sea ice nor the specifics of the processes that are to be reproduced are very well known, an evaluation has been difficult so far. We want to investigate the impact of an often used ITD parameterisation on the quality of obtained model results. For this a cost function measures the misfit of model output to different satellite products for sea ice concentration, thickness and drift. In a Green's function approach this cost function is used to estimate sets of optimal parameters for different model configurations, investigating the role of parameter tuning in this context. Further we will be able to make conclusions about the overall utility of the ITDs and the formulations currently used.

V

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Seasonal cycle of mesoscale instability of the West Spitsbergen Current

The West Spitsbergen Current (WSC) is a topographically steered boundary current that transports warm Atlantic Water northwards in Fram Strait. In Fram Strait the WSC splits with about half of the transport entering the Arctic Ocean and the rest recirculating to be exported southward in the East Greenland Current. The WSC has previously been shown to temporarily exhibit baroclinic and barotropic instabilities triggering eddy formation. The recirculation of the WSC is closely linked to the eddies stemming from the WSC. Here we investigate 16 years of current and temperature/salinity measurements from moorings in the WSC at 78°50'N to establish the seasonal cycle of the stability of the WSC. In winter, the WSC is a strong vertically sheared current advecting weakly stratified water. The baroclinic e-folding growth rate is about 3 days in winter indicating that the current has the ability to rapidly grow unstable and form eddies. In summer the WSC is weaker with weaker shear and higher stratification. It therefore is significantly less unstable. This corresponds well with observations of the eddy kinetic energy (EKE) in Fram Strait which has a peak in the WSC in January/February when the boundary current is most unstable. The eddies are then advected westward with the recirculation and the EKE peak is observed 1-2 months later in the central Fram Strait. In late summer the EKE in the WSC and the central Fram Strait is three times smaller than in winter. This seasonality results from the stronger atmospheric forcing over the Nordic Seas in winter with both increased wind stress curl and increased atmospheric heat loss compared to summer.

W

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Subsurface warm water layer in the western Arctic Chukchi Abyssal Plain

Oceanic heat transport is a possible important factor for recent sea ice decline, especially in the western Arctic Ocean. It has been indicated that the vertical hydrographic profile in the Canada Basin was characterized by three temperature maxima. The near-surface temperature maximum was the shallowest one arising from summertime solar heat absorption and subsequent autumn Ekman downwelling. The subsurface temperature maximum reflected the intrusion of the Pacific summer water. The deeper maximum was located in the Atlantic layer. Significant parts of the upper ocean heat would eventually affect sea ice freezing/melting. However, the spatial and temporal variability of these warm layers still remains uncertainties.

JAMSTEC field campaign conducted the bottom-tethered year-long mooring with sediment trap measurements in the Chukchi Abyssal Plain (Station CAP: 75.21°N, 172.55°W, 447 m) around the Chukchi Borderland. The time series of temperature at 95 m of Station CAP showed a rapid warming event (from -1.6 to -0.8°C) for December 2012 to March 2013. During this period, the high sea level pressure (i.e., anti-cyclones) covering the Canadian Basin induced strong easterly wind near the mooring station, where the sinking flux of lithogenic materials remarkably increased at the sediment trap depth (270 m). These situations suggest that the lateral advection of warm shelf-origin water is a key factor for the subsurface warming in the CAP region.

To address the winter ocean circulation fields, the pan-Arctic sea ice-ocean modeling was also conducted in this study. The horizontal grid size was approximately 5 km to resolve mesoscale eddies and narrow jets. In the interannual experiments, the strong easterly wind produced a westward shelf-break jet along the northern edge of Chukchi shelf in winter of 2012–2013. The warm eddies generated north of the Barrow Canyon were still located east of the Northwind Ridge. Therefore, the subsurface warming event observed at Station CAP would have been attributed to shelf-break jet streams rather than eddy-induced transports. Comparison with other years will also be reported.

W

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Melt pond evolution on drifting Arctic sea ice

The seasonal evolution of melt ponds has been well-documented on multiyear and landfast first-year sea ice, but is critically lacking on drifting, first-year sea ice, which is becoming increasingly prevalent in the Arctic Basin. Using 1-meter resolution panchromatic satellite imagery paired with airborne and in situ data, we evaluated melt pond evolution for an entire melt season on drifting first-year and multiyear sea ice near the 2011 Applied Physics Laboratory Ice Station (APLIS) site in the Beaufort and Chukchi seas. A new algorithm was developed to classify the imagery into sea ice, thin ice, melt pond, and open water classes on two contrasting ice types: first-year and multiyear sea ice. Surprisingly, melt ponds formed ~3 weeks earlier on multiyear ice. Both ice types had comparable mean snow depths, but multiyear ice had 0 - 5-cm deep snow covering ~37% of its surveyed area, which may have facilitated earlier melt due to its relatively low surface albedo. Maximum pond fractions were 53 ± 3% and 38 ± 3% on first-year and multiyear ice, respectively. APLIS pond fractions were compared with those from the Surface Heat Budget of the Arctic Ocean (SHEBA) field campaign. APLIS exhibited earlier melt and double the maximum pond fraction, which was in part due to the greater presence of thin snow and first-year ice at APLIS. These results reveal considerable differences in pond formation between ice types, and underscore the importance of snow depth distributions in the timing and progression of melt pond formation.

W

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Numerical Instability in a viscous plastic sea-ice model arising from unresolved plastic deformation

James Williams, Bruno Tremblay, Jean-Francois Lemieux

The plastic deformation wave in a viscous plastic sea-ice model travels at speeds greater than 25 m/s, as shown by Gray. It is this wave which dictates, in a CFL sense, the maximum allowable time step for a given model grid spacing. We find that typical configurations of high resolution (dx=5km) sea-ice models require a time step of less than ~100 second to resolve the plastic deformation wave. The constraint on the timestep will become more strict as models continue towards higher spatial resolution. We show that failure to correctly resolve this wave introduces first order noise into the model deformation fields and that the resulting error is exacerbated by use of the elastic-viscous-plastic integration technique. It is important that the model deformation fields be correctly resolved as they are increasingly being analyzed as a means to validate and compare different sea-ice rheologies. The underlying issue is the splitting in time of the sea-ice momentum and continuity equations, resulting in a discrepancy between the sea-ice mass and momentum at a given model time step. We propose the IMplicit-EXplicit (IMEX) method for coupling the momentum and continuity equations as a way of correctly resolving the propagation of the plastic wave while maintaining a longer time step.

W

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No presentation

Y

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Sensitivity of SMOS sea ice thickness data assimilation on atmospheric uncertainty

The sensitivity of the assimilation of sea ice thickness data on atmospheric uncertainty is examined using ensemble data assimilation experiments with the Massachusetts Institute of Technology general circulation model (MITgcm) in the Arctic Ocean during November 2011 to January 2012. The UK Met Office (UKMO) ensemble forecasts from the TIGGE (THORPEX Interactive Grand Global Ensemble) database are used as the atmospheric forcing. The assimilation system is based on a local Singular Evolutive Interpolated Kalman (LSEIK) filter. Sea ice thickness data derived from ESA's Soil Moisture and Ocean Salinity (SMOS) satellite together with Special Sensor Microwave Imager/Sounder (SSMIS) sea ice concentration data of the National Snow and Ice Data Center (NSIDC) are assimilated. The effect of representing the atmospheric uncertainty is assessed by two different assimilation experiments: The first one uses a single deterministic forcing and a forgetting factor to inflate the ensemble spread. The second experiment uses 23 members from the UKMO atmospheric ensemble prediction system. It avoids additional ensemble inflation and is hence easier to implement. As expected, the model-data misfits are substantially reduced in both systems. However, with the ensemble forcing the errors in the forecasts of sea ice concentration and thickness are more strongly reduced compared to the experiment with deterministic forcing. Furthermore, the ensemble forcing increases the stability of the data assimilation. This is because the ensemble forcing results in a larger and more realistic spread of the model state ensemble, which represents model uncertainty and produces a better forecast.

Y

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Knowledge Infrastructure at 90 Degrees North: The Sustaining Arctic Observing Networks (SAON) Initiative (poster)

Julianne Yip, McGill University

The Sustaining Arctic Observing Networks (SAON) initiative was officially established in 2012 in response to growing concerns about rapid environmental change in the Arctic. Although several studies had offered well-supported glimpses on the extent and degree of such change (SEARCH 2001), they remained disjointed and fragmentary.

To detect arctic environmental change, it was argued that research designs, funding mechanisms, and inter-organizational links had to be scaled to match the long-term and pan-arctic scales of the very phenomenon under study (NRC 2006). Subsequently, the Study of Environmental Arctic Change (SEARCH) was launched in the late 1990s, followed by the initiation of SAON during the Fourth International Polar Year (IPY) 2007-2008. Although an arctic observing network—and the data it produces—was presented as the most self-evident solution to the problem of studying arctic change (SEARCH 2001, 2003; NRC 2006), what receives less attention are the historical contingencies that made observational data an obvious choice in the last 20 years. Concern about environmental changes in the arctic had grown increasingly visible on the global stage, with the founding of the IPCC in 1988, the launch of the Arctic Environmental Protection Strategy in 1991, the publication of the Arctic Climate Impact Assessment (ACIA) Report in 2004, and the IPY in 2007-2008.

The 1990s also witnessed advances in information and communication technologies, particularly those associated with the Internet (e.g., open source software, creation of online data repositories and information retrieval tools, networking of distributed data and documents, etc.), which enhanced access to information, data, tools, and services. Other relevant technological advances for the earth sciences include the creation and deployment of embedded sensor networks, unmanned aerial vehicles, and autonomous underwater vehicles, to name a few.

Accompanying these changes, data management emerged as a new field of study that could offer tools, techniques, and conceptual frameworks to cope with the challenges of storing, sharing, and making discoverable data. While no one of the given changes singlehandedly drove the creation of SAON, collectively they comprise the context in which SAON became thinkable and actionable. Appreciating this larger context is critical to understanding assumptions that underpin the design of SAON.

Drawing on primary documents and concepts from science and technology (STS) studies, I trace the development of SAON. I adopt the STS concept of 'knowledge infrastructures' as a framework to understand SAON as a socio-technical assemblage that emerges in relation to a set of organized practices (Star and Ruhleder 1994, 1996; Edwards et al. 2013). Attention to SAON as a 'knowledge infrastructure' foregrounds scientific processes and practices, as well as shape questions about the kind of knowledge that SAON produces: What possibilities for understanding does an arctic observing network give rise to? What assumptions about knowledge production implicitly shape the design of an arctic network that privileges observational data? The findings presentedhere are provisional and would benefit from interviews, first-hand observation of SAONrelated activities, and corroboration of facts from key actors.

Z

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The Impacts of Winter Arctic Atmospheric Circulation on Following Summer Sea Ice

Minghong Zhang, William Perrie, Zhenxia Long and Shuanglin Li

We investigated the relation of September sea ice in the East Siberian Sea, to the preceding Arctic winter atmospheric circulation. Using sea ice observations and model-generated data from PIOMAS (Pan-Arctic Ice-Ocean Modeling and Assimilation System), we found that the leading winter circulation pattern, the polar vortex, accounts for over 30% of the interannual variance of the following summer sea ice concentration in the East Siberian Sea. This cross-seasonal interconnection is realized through the polar vortex modulation of the storm activity. An enhanced winter polar vortex steers more storms into the East Arctic, leading to enhanced ice advection from the East Siberian Sea and weakened sea ice thickness. Moreover, thinner sea ice with reduced surface albedo allows the East Siberian Sea to gain more shortwave radiation which in turn, enhances the melting rate. Air-sea feedback also plays a role. The associated winter Arctic Oscillation anomalies result in tripolar North Atlantic SST anomalies, which persist into the following spring and early summer, causing a negative summer NAO-like circulation response and a southward shift in the polar jet. More storms are steered to the northwest of Europe, where the resulting atmospheric perturbation propagates eastward along the subpolar jet, leading to a surface low anomaly in the Siberian Arctic. The cyclonic-driven ice motion increases the advection of ice away from the East Siberian Sea to Fram Strait and enhances transpolar drift, resulting in further reductions in sea ice.

Z

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A future climate change projection of the Arctic atmosphere using the high-resolution regional atmospheric model PWRF

Minghong Zhang, William Perrie, Zhenxia Long, and Haibo Hu

Atmospheric and oceanic components of the Arctic are transitioning to a more dynamic state, compared to earlier decades. For example, recent observed decreases in multi-year ice suggest that projections of ice-free Arctic Ocean summers by 2030–2050 may underestimate the observed rate of change. Global Climate Models (GCMs) are useful tools to understand potential climate change on the scale of ocean basins but they lack the spatial resolution to give good estimates over the shelf, especially in semi-enclosed systems like the Beaufort and Chukchi Seas. Semi-enclosed seas typically respond to local forcing (including winds, heat fluxes, precipitation and runoff) which is not represented well in GCMs, thus rendering the analysis of their output less reliable for shelf and land-bounded waters. In order to better assess ocean climate change over the Arctic, we use a dynamical regional climate downscaling system for simulate the Beaufort Sea and west Canadian Arctic. As a first step, high-resolution, regional climate change projections of atmospheric forcing over the Arctic are conducted following IPCC climate change scenario RCP8.5, downscaling the coarse-resolution global climate model HadGEM-ES2 estimates to finer scale, using the 25km Polar Weather Forecast and Research (PWRF) regional atmospheric model.

We will present a simulation of the Arctic climatology in comparison with HadGEM-ES2 and ERA-Interim Reanalysis data-sets during the historical period 1979-2005, with special focus on the intensity, frequency and tracks of Arctic storms using an advanced cyclone tracking scheme. We also discuss the historical simulation and future projection of Arctic atmospheric forcing and the associated links to changes in the Arctic Ocean.

Z

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Internal-tide Generation and Beam-like Onshore Propagation in the Vicinity of Shelfbreak Canyons

A hydrostatic numerical model with alongshore-uniform barotropic M2 boundary forcing and idealized transcritical canyon bathymetries is used to study internal-tide generation and onshore propagation. Although the canyons are symmetrical in structure, barotropic to baroclinic energy conversion rates, Cv, are typically asymmetrical within them. The resulting onshore-propagating internal waves (IW) are strongest along beams in the horizontal plane, with the stronger beam lying on the side with higher Cv. Analysis suggests that the cross-canyon asymmetrical Cv distributions are caused by multiple-scattering effects on one canyon side-slope, because the phase variation in the spatially distributed internal-tide sources, governed by variations in the orientation of the bathymetry gradient vector, allows resonant internal-tide generation. Analysis based on a semi-analytical modal IW propagation model shows that the source phase variation also results in onshore radiation beams on both canyon sides through the single-scattering effect and the relative beam strengths are controlled by the cross-canyon source amplitude variation that results from the multiple-scattering effect.

Z

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No presentation

Z

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The Improvement of Arctic Sea Ice Concentration Forecasting by Nudging Assimilation

The rapid decrease of arctic sea ice make the regular open of arctic passage possible in the near future. High level sea ice forecasting serves become more important for arctic shipping activities. Based on sea-ice coupled model MITgcm and Nudging assimilation, an operational arctic forecasting system was established in this paper. Three different kinds of Nudging assimilation schemes were used and results showed that all three Nudging schemes could achieve similar improvements in the initial sea ice concentration field. Comparison experiments with and without nudging assimilation were compared with ship-based sea ice concentration observations, and it proved that nudging assimilation could significantly improve the 24-120h sea ice concentration forecasting.

Z

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Vertical scales and dynamics of eddies in the Arctic Ocean's Canada Basin

A decade of moored measurements from the Arctic Ocean's northwestern Beaufort Gyre (collected as a component of the Beaufort Gyre Exploration Project) are analyzed to examine the range of mesoscale eddies over the water column, and the dynamical processes that set eddy vertical scales. A total of 58 eddies were identied in the moored record, all anticyclones with azimuthal velocities ranging from 10 cm/s to 43 cm/s. These are divided into three classes based on core depths. Shallow eddies (core depths around 120 m) are shown to be vertically conned by the strong stratication of the halocline; typical thicknesses are around 100 m. Deep eddies (core depths around 1200 m) are much taller (thicknesses around 1300 m) owing to the weaker stratication at depth, consistent with a previous study. Eddies centered around mid-depths all have two cores (vertically aligned and separated in depth) characterized by velocity maxima and anomalous temperature and salinity properties. One core is located at the base of halocline (around 200 m depth) and the other at the depth of the Atlantic Water layer (around 400 m depth). These double-core eddies have vertical scales between those of the shallow and deep eddies. The strongly decreasing stratication in their depth range motivates a derivation for the quasi-geostrophic adjustment of a nonuniformly stratied water column to a potential vorticity anomaly. The result aids in interpreting the dynamics and origins of the double-core eddies, providing insight into transport across a major water mass front separating Canadian and Eurasian Water.