2017 ABSTRACTS BOOK

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Aaboe, Signe: Norwegian Meteorological Institute

Improved sea ice products: concentration, drift and type

Aaboe, Signe[1]; Lavergne, Thomas[1]; Sørensen, Atle[1]; and Eastwood, Steinar[1]

[1] Norwegian Meteorological Institute

This contribution has two parts. We first give a short overview of the sea ice satellite observations newly made available from the EUMETSAT OSISAF and ESA CCI Sea Ice projects, including recent advances in mapping of sea ice concentration and motion. These products, whether in the form of near-real-time daily maps or climate data records are continuously improved to support polar prediction efforts.
In a second part, we provide more insights into current research for more accurately mapping sea ice type. Sea ice type distinguishes between the 'first-year ice' (FY), which forms during freezing and disappears during the following summer melt, and the 'multiyear ice' (MY), which is ice that has survived at least one summer period. Older sea ice is generally thicker than younger ice, and therefore the trend of decreasing MY coverage is of concern for the overall volume and stability of Arctic sea ice.
Classification of sea ice into FY and MY ice is possible with satellite data since the physical properties of the sea ice changes significantly during summer melts when salinity is rejected from the ice. This salinity decrease is strongest during the first summer melt. However, the classification algorithms regularly fall short when observations are influenced by e.g. snow and melt ponds on the ice, atmospheric disturbances like warm air intrusions over the ice cover, or the increasing about of younger MY ice which do not differ as much from FY ice as the older MY ice. These limitations call out for a re-visiting of the standard classification algorithms.
We present here an alternative ice type algorithm for the Northern Hemisphere based on the linear dependency of sea ice to passive microwave frequency and polarization variations. In the context of an ESA sea ice CCI option on Sea Ice Age various channel combinations in the algorithm are examined and validated against independent data sources representing knowledge of ice age. The outcome is a more robust and automatic ice type classification. By utilizing the 19 and 37 GHz channels also opens up the possibility of generating a consistent climate data record of sea ice type covering the long passive microwave period back to 1978.

Ahlert, Abigail: University of Colorado Boulder, USA

Definitions Matter: Arctic Sea Ice Melt and Freeze Onset

Ahlert, Abigail[1]; Jahn, Alexandra[1]

[1] University of Colorado Boulder

Climate models in CMIP3 and CMIP5 show a large spread in their simulated Arctic sea ice cover, with large mean biases of sea ice cover in many models. One contributing factor could be that simulated melt season lengths are too short or too long. However, there are multiple possible physical definitions for sea ice melt and freeze onset in climate models, and none of them exactly correspond to the brightness temperature-based melt and freeze onset definitions used for satellite retrievals. This makes the comparison of climate model output to satellite data challenging, as different definitions can bracket the satellite derived melt season dates. To assess the influence of various melt and freeze onset definitions, we compare data from the Community Earth System Model Large Ensemble (available for 1920-2100) to passive microwave-derived melt onset/freeze-up dates (available for 1979-2014). Melt onset definitions for the Large Ensemble are derived from thermodynamic volume tendency, surface temperature and snowmelt, while freeze onset definitions are derived from thermodynamic volume tendency, surface temperature, frazil ice growth, and congelation ice growth. By determining how the modeled melt and freeze onset vary based on different definitions within the model, we gain insight to the interannual, spatial and internal variability of melt and freeze onset dates. This allows us to better assess the level of agreement with the satellite-derived melt and freeze onset dates, and to highlight the challenges in identifying model biases through model-to-satellite comparisons. This analysis will be useful in the upcoming assessment of CMIP6 simulations for melt season biases and can inform sea ice predictability studies that make use of the spring-time melt onset for the predictability of ice advance.

Al-Janabi, Rusul: Alfred Wegener Institute, Germany

Natural Variability of Arctic Sea Ice

Al-Janbai, Rusul[1]; Jung, Thomas[1]; Goessling, Helge[1]

[1] Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research

Natural variability of Arctic sea ice has emerged as an important topic in the last years, mainly prompted by the realization that the recent dramatic decline in September sea ice extent cannot be explained as the product of anthropogenic Green House Gases (GHGs) forcing alone. Predicting future changes in the Arctic and whether or not it will continue this dramatic transformation requires better understanding of processes in the earth climate system that influence and interact with sea ice. Better understanding of physical mechanisms and interactions acting in the context of natural modes of variability will be helpful in predicting future changes in the Arctic, especially those related to the shrinking sea ice minimum. This thesis will be concerned mainly with the September sea ice extent minimum and the conditions and factors contributing to low sea ice extent events, that occur without GHGs forcing. By doing so we gain further insight into the Arctic climate system and the sea ice component of this system, which to date has a degree of uncertainty that might impact future decision making. In this thesis a number of research question have been presented, related to Arctic sea ice variability. What are the time scales of Arctic sea ice variability? What are the conditions that lead to low September sea ice extent events? How predictable is the sea ice extent minimum? And how does characteristics of the Arctic climate system effect this predictability? These are questions that are shrouded with uncertainty. To remedy the problem of the short observational record we have analysed pre-industrial CMIP5 control runs which for each model span many hundred of years. This allows us to obtain multiple realizations of the September sea ice minimum allowing for robust statistics. The pre-industrial runs being free of anthropogenic GHG forcing allows us to gain insight into interactions in the global climate system in "natural" conditions without rising CO2 levels. We start by examining the simulated sea ice conditions for 8 selected CMIP5 models and the Alfred Wegner Institute-Climate Model (AWI-CM) in order to explore the mean and variability in these models, and have found (1) that there is a still a considerable intermodel spread. By taking advantage of the long preindustrial control simulation length we conduct spectral analysis of the September sea ice extent and March sea ice volume in order to get an idea about the time scales of variability of both aforementioned climate indices. We find that (2) the main characteristics of the spectra are consistent with the general shape of climate spectra, however there is uncertainty regarding the true spectra that cannot be answered yet. Moreover, we have estimated the coherence spectra of both indices and find that there is a (3) high degree of coherency indicating common time scales of variability. Next we move on to explore the potential predictability of the September sea ice extent index based on the extent in previous months and to locate areas of the Arctic which may hold predictive information. By doing so we find that (4) there is a loss of correlation between the early melt season and the September sea ice minimum. However, after the initial loss of correlation reemergence of correlation have been detected in the freeze up season. This is consistent between the models. The persistence of sea surface temperatures created in the start of the melting season which interact with the retreating and advancing ice

edge is one explanation of the reemergence. The other could be explained by the persistence of sea thickness anomalies. We suggest that processes in the Arctic ocean mixed layer in areas of deep convection are responsible for persistence in sea surface temperatures. Based on the September extent index we define events of sea ice decline, where we later proceeded to analyze anomalies in the atmospheric, oceanic and sea ice fields accompanying these events. The large number of realizations obtained in this study allows for robust statistics Anomalies in atmospheric and oceanic fields have been detected in the winter, spring and summer before the September sea ice minimum have been calculated using composite analysis. We find that (5) atmospheric circulation patterns are responsible for the patterns of sea ice thickness and concentration anomalies that initiate a series of events which lead an enhanced sea ice albedo effect. In the summer before the occurrence of the September minimum extent a high sea level pressure area situated over the Arctic is common in all models that leads to ice convergence whereupon the ice extent is further decreased. Through the analysis of oceanic conditions in the North Atlantic we find (6) no indication of an increased ocean heat transport to the Arctic. The sea ice minimum in preindustrial control runs are a product of processes taking place in the Arctic.

Bayler, Eric: NOAA/NESDIS Center for Satellite Applications and Research (STAR), USA

Retrieving thin sea-ice thickness from SMAP data

The satellite passive microwave L-band measurements employed for soil moisture and ocean salinity retrievals can be exploited for useful measurements of thin sea-ice thickness. Active radar measurements of sea-ice freeboard, e.g. the European Space Agency's (ESA) Cryosat mission, have notable uncertainty for values less than about 1 meter; yet, understanding and observing the growth of necessarily thin new sea ice is critical for improving predictions of the closely coupled ocean-atmosphere-cryosphere system. Extending work done by others on retrieving sea-ice thickness from ESA's Soil Moisture – Ocean Salinity (SMOS) mission data, this effort applies those approaches to data from the National Aeronautics and Space Agency's (NASA) Soil Moisture Active Passive (SMAP) mission, exploring the dependencies of observables and component factors in pursuit of improved thickness retrievals.

Bell, Louisa: University of Hamburg, Germany

Towards a better understanding of seasonal sea-ice predictability in the Arctic

Bell, Louisa[1]; Notz, Dirk[2]; Bunzel, Felix[2]

[1] University of Hamburg
[2] Max Planck Institute for Meteorology, Hamburg

In this study we aim to get a better understanding of why a model can predict Arctic sea-ice area in some years, and why it fails to predict sea-ice area in other years. Therefore, we analyse the behaviour of a 10-member ensemble of 6-month hindcasts, initialised each year within 1981-2012 with a seasonal prediction system based on the Max Planck Institute Earth System Model. As previous studies suggest, there is potential for the Arctic sea ice to be predictable, but the predictive skill of current seasonal prediction systems decreases rapidly after the month of hindcast initialisation. So far, studies providing a comprehensive explanation for this decrease are still lacking. We compare time series of Arctic sea-ice area for each month individually with observations. Hindcasts started in May cannot reproduce the observed downward trend of September Arctic sea-ice area, with an increasing offset since 1997. Analysing the sea-ice thickness suggests that especially near the ice edge the sea ice is too thick in our prediction system for the time period after 1997. Hindcasts started in November show a constant negative offset towards observations for all lead months. We present a summary of our findings which aim at contributing to a better understanding of seasonal sea-ice predictability in the Arctic.

Bitz, Cecilia: University of Washington, USA

Which Observations Are Most Important for Creating an Accurate Arctic Sea Ice Reanalysis?

Zhang, Yongfei[1]; Blanchard-Wrigglesworth, Ed[1]; Anderson, Jeffrey[2], Colins, Nancy[2]; Hoar, Tim[2]; and Raeder, Kevin[2]

[1] University of Washington
[2] National Center for Atmospheric Research

Assimilating observations in sea ice models is a new and promising means of investigating Arctic sea ice. The Arctic Ocean is used for a variety of purposes and knowledge of sea ice conditions can benefit humans in many ways. However, only a few variables are well observed on a routine basis. Yet, we know certain relations prevail across variables and across time and space. We take advantage of these relations by employing a multivariate data assimilation scheme in a state-of-the-art sea ice model. We use the system to determine which observables when assimilated lead to improved characterization of the sea ice state.

Blockley, Ed: Met Office Hadley Centre, United Kingdom

Impact of initialising sea ice using CryoSat2 thickness within the Met Office's coupled seasonal prediction system.

Blockley, Ed[1]; Peterson, Drew[1]; Johns, Tim[1]

[1] Met Office Hadley Centre

Seasonal predictions at the Met Office are made using the GloSea5 coupled forecasting system which is run daily out to 210 days using the NEMO ocean and CICE sea ice models at 1/4 degree global resolution. The ocean and sea ice components of GloSea are initialised using analysis fields from the FOAM ocean-sea ice analysis and forecast system. Satellite and in-situ observations of temperature, salinity, sea level anomaly and sea ice concentration are assimilated by FOAM using the NEMOVAR 3D-Var data assimilation scheme. The Met Office are currently developing capability to assimilate sea ice freeboard and thickness observations from CryoSat-2 and SMOS sensors within the NEMOVAR 3D-Var framework. Results from an initial study to test the impact of initialising with CryoSat-derived thickness observations will be presented here with particular foci being the impact on seasonal sea ice extent predictions and the evolution of the sea ice budget within CICE.

Bresson, Hélène Marie Emilie: The University of Reading, United Kingdom

Polar lows in high-resolution atmospheric reanalyses

Bresson, Hélène M.E.[1]; Hodges, Kevin I.[1]; Shaffrey, Len C[1]; and Zappa, Giuseppe[1]

[1] The University of Reading

Polar lows are intense mesoscale cyclones that form at high latitudes during the cold season. Their size is typically around 200-600 km and their wind speeds are usually above 15 m.s-1. Their strong winds can have substantial impacts on shipping, coastal communities and offshore infrastructure such as oil and gas exploitation. Moreover, the high wind speeds and heat fluxes associated with Polar lows may have a strong impact on deep-water formation in the Nordic Seas, which can affect the Atlantic meridional overturning circulation. This interaction between the atmosphere and oceans have led to Polar lows being considered as important for the climate system. Despite their importance, there are still large uncertainties in how frequently they occur, how they are spatially distributed and how they might respond to climate change. The initial aim of the study is to investigate how Polar lows are represented in atmospheric reanalyses and to determine their temporal and spatial variability. The uncertainty between using different reanalysis products will be evaluated by comparing the latest high resolution atmospheric reanalysis datasets. Initially we compare the ERA-Interim and NCEP-CFS reanalysis for 36 extended Winter seasons (October 1979 to March 2015). We apply a tracking algorithm to 3-hourly vorticity data at 850 hPa. We then apply criteria to different variables, to discriminate Polar lows from other tracked features. The sensitivity of Polar low numbers to these criteria has been investigate, for the Northern hemisphere, the Norwegian and Barents Seas and the Sea of Japan. The seasonal and inter-annual variabilities of Polar low numbers were then studied. The mean Polar low numbers found with the reanalyses are different, possibly due to the difference in spatial resolution, but the inter-annual variability of these numbers is better represented. The large fluctuations found in the inter-annual variability of Polar low numbers led us to investigate the possible influence of the large-scale environment on Polar low occurrences. The results found re-emphasis the importance of Cold Air Outbreaks (CAO) and horizontal surface temperature gradients in the formation of Polar lows.

Bunzel, Felix: Max Planck Institute for Meteorology, Germany

RevisiSome issues in seasonal predictions of Arctic sea ice

Bunzel, Felix[1]; Notz, Dirk[1]; and Kauker, Frank[2]

[1] Max Planck Institute for Meteorology
[2] Alfred Wegener Institute, Bremerhaven

We examine the impact of small disturbances of initial Arctic sea-ice concentrations on 1 May on the September ice thickness predicted with the Max Planck Institute Earth System Model (MPI-ESM) seasonal prediction system. Initial numerical roundoff errors are transmitted to the atmosphere quickly and cause large-scale difference patterns already a few days after initialization. The feedback of growing atmospheric disturbances on the ice generates substantial large-scale difference patterns in ice thickness of regionally more than 1 meter after a few weeks. The strong sensitivity of local September Arctic ice thickness to the exact initial state of the model reflects the large uncertainty of September Arctic sea-ice predictions. Nevertheless, previous modelling studies found potential predictability of the Arctic sea-ice extent of up to a few years. We find, however, correlations between May and September Arctic sea-ice extents to be substantially larger in the model compared to observations. Thus, it may as well be that the potential predictability of the Arctic sea-ice extent is overestimated in modelling studies due to unrealistically large persistence of sea-ice anomalies. We discuss the implications of our findings for the reliability of September Arctic sea-ice predictions.

Burgard, Clara: Max Planck Institute for Meteorology, Germany

Drivers of past and future Arctic Ocean warming in CMIP5 models

Burgard, Clara[1]; Notz, Dirk[1]

[1] Max Planck Institute for Meteorology

We investigate modeled changes in the Arctic Ocean energy budget to understand if the past and future Arctic Ocean warming is primarily driven by changes in the net atmospheric surface flux or by changes in the meridional oceanic heat flux. We use data from 26 general circulation models run in the Coupled Model Intercomparison Project 5 (CMIP5), covering the period 1960 to 2099. We find that in 11 models, the Arctic Ocean warming is driven by positive anomalies in the net atmospheric surface flux, while in 11 other models it is driven by positive anomalies in the meridional oceanic heat flux. In the four remaining models, the Arctic Ocean warming is driven by positive anomalies in both energy fluxes. The different behaviors between the models are mainly driven by the different changes in the meridional oceanic heat flux. We find that the magnitude of increase in the mass transport into the Barents Sea as well as the increase in temperature at the Barents Sea Opening and the Fram Strait influence the sign of change in the meridional oceanic heat transport. Additionally, we find that changes in the meridional oceanic heat flux and changes in the net atmospheric surface flux are strongly linked together through the atmospheric turbulent heat fluxes. In summary, our results show that the multi-model ensemble mean is not representative for a consensus behavior of the models. The highest uncertainties can be found in the evolution of the meridional oceanic heat transport, which is important for decadal predictions in the Arctic as well as for the long-term evolution of the Arctic sea-ice cover.

Bushuk, Mitch: Princeton University and GFDL, USA

Skillful regional prediction of Arctic sea ice on seasonal timescales

Bushuk, Mitch[1,2]; Msadek, Rym[3]; Winton, Michael[2]; Vecchi; Gabriel A.[1]; Gudgel, Rich[2]; Rosati, Anthony[2]; and Yang, Xiaosong[2]

[1] Princeton University
[2] Geophysical Fluid Dynamics Laboratory (GFDL)
[3] CNRS/CERFACS

Recent Arctic sea ice seasonal prediction efforts and forecast skill assessments have primarily focused on pan-Arctic sea-ice extent (SIE). In this work, we move towards stakeholder-relevant spatial scales, investigating the regional forecast skill of Arctic sea ice in a coupled dynamical prediction system. The regional skill assessment is based on a suite of retrospective initialized forecasts spanning 1981-2015 made with an atmosphere-ocean-sea ice-land model. Regional prediction skill for detrended SIE is highly region and target month dependent, and generically exceeds the skill of an anomaly persistence forecast. Prediction skill is notably high for winter and spring SIE in the Barents and Labrador Seas, which is partially attributable to the prediction system's initialization and dynamical evolution of surface and subsurface ocean temperature anomalies. The prediction system also skillfully forecasts regional summer SIE in the East Siberian, Laptev, and Beaufort Seas. These regions display prediction skill barriers, in which forecast skill drops off sharply in particular initialization months (May, May, and June, respectively). Both the prediction skill and the prediction skill barriers in these regions are partially attributable to the initialization and persistence of sea-ice thickness anomalies. These results suggest that improved subsurface ocean and sea-ice thickness initial conditions represent a promising route to improved regional sea-ice predictions.

Casagrande, Fernanda: Earth System Science Centre, National Institute for Space Research, Brazil

Sea ice Study and Arctic Polar Amplification using CMIP5 models

Casagrande, Fernanda[1]; Nobre, Paulo[2]; and Buss, Ronald[3]

[1] National Institute for Space Research: Earth System Science Centre
[2] Institute for Space Research: Center for Weather Forecasting and Climate Research
[3] National Institute for Space Research: Souza Antarctic Program

Important international reports and a significant number of scientific publications have reported on the abrupt decline of the Arctic sea ice, polar amplification and its impact on the Global Climate System. In this work, we evaluate the ability of Coupled Model Intercomparison Project, Phase 5 (CMIP5), specially the Brazilian Earth System Model (BESM) to represent the Arctic sea ice changes and sensitivity to the atmospheric Carbon dioxide (CO2) forcing. We used decadal simulations (1980- 2012), future scenarios with Representative Concentration Pathway RCP 4.5 and RCP 8.5 (2006-2100) and quadrupling of the atmospheric CO2 concentration (2006-2300). We validated our results with satellite observations and reanalysis data set. BESM results for the Arctic sea ice seasonal cycle are consistent with CMIP5 models and observations. However, almost all models tend to overestimate sea ice extent (SIE) in March compared to observations. The correct evaluation of minimum record of sea ice, in terms of time, spatial and area remains a limitation in Coupled Global Climate Models (CGCM). Looking to spatial patterns, we found a systematic model error in September sea ice cover between the Beaufort Sea and East Siberia for most models. Future scenarios show a decrease in SIE as response to an increase in radiative forcing due to the increase of greenhouse gases concentration for all models. From the year 2045 onwards, all models show a dramatic shrinking in sea ice and consequent expansion of ice-free conditions at the end of the melting season. The projected future sea ice loss is explained by the combined effects of both: the amplified warming in northern hemisphere high latitudes and climate feedbacks. The quadrupling of CO2 concentration numerical experiment shows the amplified warming at high latitudes as response to CO2 forcing with strongest warming in winter (DJF) and Autumn (SON). The Polar warming is linked with changes in SIE and Sea Ice Thickness (SIT). The albedo sea ice feedback reinforces the polar warming with marked contributions from April to August.

Cavallo, Steven: University of Oklahoma, School of Meteorology, USA

Atmospheric dynamics and predictability of sea ice

Cavallo, Steven[1]; Szapiro, Nicholas[1]

[1] University of Oklahoma, School of Meteorology

Polar weather and extended-range prediction is in its infancy in comparison to midlatitude and tropical prediction, and as a consequence, key polar processes remain unidentified or not well-understood. One feature important for the formation of surface cyclones are tropopause polar vortices (TPVs). While surface cyclones may be associated with rapid sea ice loss events, lifetimes are generally limited from a few days to a week, and hence themselves can be viewed as a consequence of various environmental factors. On the other hand, TPVs are a necessary feature for the formation of surface cyclones, yet TPVs are present sometimes weeks to months before a corresponding surface cyclone. This talk will provide an overview of atmospheric dynamics over the Arctic with regard to sea ice predictability from the perspective that knowledge of TPVs may be important consideration for extended range numerical weather prediction over the Arctic. After briefly summarizing the characteristics and mechanisms that govern TPV evolution, a climatology of TPVs with respect to sea ice loss events will be discussed. Results indicate that for all sea ice loss events at time scales of less than 15 days, there is a surface cyclone and corresponding TPV in close proximity of the sea ice loss location. Furthermore, it is found that the strength of the surface cyclone is correlated with the strength of the resulting surface cyclone and hence the atmospheric forcing on sea ice during the events. Numerical modeling experiments are designed with the goal of testing sensitivities of sea ice loss events to specific TPV-related processes using the Model for Prediction Across Scales (MPAS). The MPAS is a global model and an advantageous tool for such studies due to (1) gradual mesh refinement, allowing for high horizontal resolution over the Arctic, (2) no dependence on lateral boundary conditions, and (3) the ability to fully couple the MPAS non-hydrostatic atmospheric dynamical core as part of the Community Earth System Model (CESM). Given the mesoscale-to-synoptic horizontal scale of TPVs, grid refinement over the Arctic is found to be necessary for skillful atmospheric forecasts, particularly at extended range (i.e., weeks to months). In addition to sensitivity experiments, we demonstrate that MPAS is a promising tool for subseasonal-to-seasonal coupled forecasting of sea ice and atmospheric processes during the Arctic summer.

Cheng, Wei: University of Washington, USA

Diagnostic sea ice predictability in the pan-Arctic and US Arctic regional seas

Cheng, Wei[1]; Blanchard-Wrigglesworth, Edward[1]; Bitz; Cecilia M[1]; Ladd, Carol[2]; and Stabeno, Phyllis J.[2]

[1] University of Washington
[2] NOAA/PMEL

This study assesses sea ice predictability in the pan-Arctic and US Arctic regional (Bering, Chukchi, and Beaufort) seas with a purpose of understanding regional differences from the pan-Arctic perspective, and how predictability might change under changing climate. Lagged correlation is derived using existing output from the CESM Large Ensemble (CESM-LE), Pan-Arctic Ice Ocean Modeling and Assimilation System (PIOMAS), and NOAA Coupled Forecast System Reanalysis (CFSR) models. While qualitatively similar, quantitative differences exist in Arctic ice area lagged correlation in models with or without data assimilation. On regional scales, modeled ice area lagged correlations are strongly location- and season-dependent. A robust feature in the CESM-LE is that the pan-Arctic melt-to-freeze season ice area memory intensifies whereas the freeze-to-melt season memory weakens as climate warms, but there are across-region variations in the sea ice predictability changes with changing climate.

Day, Jonny: University of Reading, United Kingdom

Towards seasonal Arctic sea route predictions

Melia, Nat[1]; Haines, Keith[1]; Hawkins, Ed[1]; and Day, Jonny[1]

[1] University of Reading

The continued decline in Arctic sea ice will likely lead to increased opportunities for shipping in the region suggesting that seasonal predictions of route openings will become ever more important. Here we present results from a series of 'perfect model' experiments to assess the seasonal predictability characteristics of the opening of Arctic sea routes. We reveal that the Arctic shipping season is becoming longer due to climate change; with later closing dates mostly responsible. We demonstrate that from predicting the opening of the open water season from January is twice as hard as predicting the closing date, despite the increased forecast lead-time. We find skilful predictions of the upcoming summer shipping season can be made as far in advance as January although typically forecasts show lower skill before a May ‘predictability barrier’. The predictive skill is state dependant with predictions for high or low ice years exhibit greater skill than medium ice years. Forecasting the fastest open water route through the Arctic is accurate to within 200 km when predicted from July, a six-fold increase in spatial accuracy compared to forecasts initialised the previous November. Finally we find that initialisation of sea ice thickness information is crucial to obtain accurate forecasts, further motivating investment into sea ice thickness observations and model development.

Day, Jonny: University of Reading, United Kingdom

Estimating the extent of Antarctic summer sea ice during the Heroic Age of Antarctic Exploration

Day, Jonny[1]; and Edinburgh, Tom[2]

[1] University of Reading
[2] University of Cambridge

In stark contrast to the sharp decline in Arctic sea ice, there has been a steady increase in ice extent around Antarctica during the last three decades, especially in the Weddell and Ross seas. In general, climate models do not to capture this trend and a lack of information about sea ice coverage in the pre-satellite period limits our ability to quantify the sensitivity of sea ice to climate change and robustly validate climate models. However, evidence of the presence and nature of sea ice was often recorded during early Antarctic exploration, though these sources have not previously been explored or exploited until now. We have analysed observations of the summer sea ice edge from the ship logbooks of explorers such as Robert Falcon Scott, Ernest Shackleton and their contemporaries during the Heroic Age of Antarctic Exploration (1897–1917), and in this study we compare these to satellite observations from the period 1989–2014, offering insight into the ice conditions of this period, from direct observations, for the first time. This comparison shows that the summer sea ice edge was between 1.0 and 1.7° further north in the Weddell Sea during this period but that ice conditions were surprisingly comparable to the present day in other sectors.

de Boer, Gijs: University of Colorado, USA

The Oliktok Point Observatory: Providing New Perspectives on the Arctic Atmosphere

de Boer, Gijs[1]; Shupe, Matthew[1]; McComiskey, Allison[2]; Creamean, Jessie[1]; Solomon, Amy[1]; Turner, David[2]; Matrosov, Sergey[1]; Williams, Christopher[1]; Maahn, Maximilian[1]; and Norgren, Matthew[1]

[1] University of Colorado
[2] NOAA

The US Department of Energy Atmospheric Radiation Measurement (ARM) program has deployed one of its mobile facilities to Oliktok Point Alaska for an extended deployment. This observatory provides measurements on key processes related to Arctic clouds, aerosols, radiation, surface energy exchange and thermodynamic state. Additionally, this observatory provides access to airspace for unmanned aerial systems and tethered balloon systems, providing new perspectives on the vertical and horizontal variability of the atmosphere, and on processes occurring over the adjacent Beaufort Sea. In this presentation, I will provide an overview of this facility, as well as ongoing research efforts being undertaken by the Oliktok Point site science team using measurements from this facility. This work includes, among other things, evaluation of modern reanalysis products and modeling tools related to prediction of sea ice along coastal Alaska.

Dirkson, Arlan: University of Victoria, School of Earth and Ocean Sciences, Canada

Improvements in probabilistic seasonal forecasts of Arctic sea ice

Dirkson, Arlan[1]; Merryfield, William[2]; and Monahan, Adam[1]

[1] University of Victoria, School of Earth and Ocean Sciences
[2] Canadian Centre for Climate Modelling and Analysis, ECCC, University of Victoria

The need for societally relevant sea ice forecast products on seasonal timescales is receiving increasing attention. Seasonal forecasts are inherently uncertain, and probabilistic forecasts that represent uncertainty can be essential for end-users who want to quantify risk and make decisions taking forecast uncertainty into account. A simple means for estimating forecast uncertainty is to produce an ensemble of dynamical forecasts which can be used to quantify the likelihood of specific "events". The Sea Ice Prediction Network currently requests sea ice probability (SIP) forecasts for its annual Sea Ice Outlook using an approach that is equivalent to counting the number of ensemble members that have local ice concentrations of at least 15%, and reporting those relative frequencies as a probability for sea ice coverage. The research presented here focuses on the development of an improved methodology for producing probabilistic forecasts of sea ice by fitting ensemble sea ice concentration (SIC) forecasts parametrically to the beta distribution on the interval [0,1], and calibrating by means of quantile mapping between the hindcast and observed distributions. The method is tested using 10-member ensemble hindcasts from the Canadian Climate Model, version 3 (CanCM3), initialized four times per year from 1981-2012. We demonstrate that probabilistic forecast skill is generally improved relative to the count-based approach using the parametric approach prior to calibrating, particularly during the summer months. Further, we establish that skill after calibrating generally exceeds that of reference forecasts consisting of either a non-stationary climatological distribution or a "persistence-adjusted" climatological distribution, particularly in the peak melt and early re-freezing months. Finally, we illustrate various ways in which sea ice probabilistic forecast information can be conveyed.

Fučkar, Neven S.: Barcelona Supercomputing Center (BSC), Earth Sciences Department, Climate Prediction Group, Spain

Decomposition of climate aspects leading to the record minimum of the northern hemisphere sea ice extent in March 2015

Fučkar, Neven S.[1]; Massonnet, Francois[1,2]; Guemas, Virginie[1]; Garcia-Serrano, Javier[1]; Bellprat, Omar[1]; Doblas-Reyes, Francisco[1]; and Acosta, Mario[1]

[1] Barcelona Supercomputing Center (BSC), Earth Sciences Department, Climate Prediction Group

[2] Georges Lemaitre Center for Earth and Climate Research, Earth and Life Institute, Universite catholique de Louvain, Louvain-la-Neuve, Belgium

The northern hemisphere (NH) sea ice extent (SIE) has reached the record low in the satellite era in March 2015. Would the 2014/15 fall–winter atmosphere yield this sea ice extreme if we reversed in time the long-term change in the ocean and sea ice state? We examine the contributing aspects of the surface atmosphere and the long-term memory of the ocean and sea ice to the March 2015 record low of the NH SIE with forced state-of-the-art ocean-sea-ice general circulation model (NEMOv3.3). First, we perform a set of retrospective control simulations initialized on 1 November from 1979 to 2014 to establish appropriate bias correction method and assess the model skill in predicting the NH March SIE. We produce ERA-Interim-forced five ensemble members initialized from the five members of the ORAS4 ocean reanalysis and the associated five-member sea ice reconstruction. A climate variable can be decomposed into the sum of the background state represented as a linear fit over the period of interest and an interannual anomaly with respect to this fit: $var(t) = [at + b] + var'(t)$. More specifically, initial conditions (IC) and surface forcing fields contain: (i) linear-fit background state of IC, (ii) interannual anomaly in IC with respect to factor (i), (iii) linear-fit background state of surface forcing fields, and (iv) interannual anomaly in surface forcing fields with respect to factor (iii). Second, we conduct two sets of sensitivity experiments with IC and surface forcing fields modified in such manner that one set examine the influence of 2014/15 fall–winter atmospheric conditions, while the other set focuses on the influence of change in linear-fit background state of the ocean and sea ice cover. Our forced experiments indicate that the most important factor driving the NH SIE to the record low monthly mean in March 2015 was surface atmospheric conditions on average contributing at least 54% to the change from the past March states to 2015. The 1 November 2014 interannual anomaly of IC, which on average contributes less than 10%, is the least important factor. A change along the 36-year linear-fit of IC, representing the accumulative impact of the climate change in the ocean and sea ice, is the second most important factor for reaching the March 2015 extreme in our experiments. Even if we keep IC and forcing factors (ii) through (iv) in the 2014–15 conditions, but translate the background state of ocean and sea ice, IC factor (i), more than three years into the past, it prevents the Arctic sea ice in our model from reaching this record low. We find that the record low NH winter sea ice maximum stemmed from a strong interannual surface anomaly in the Pacific sector, but it would not have been reached without underlying long-term climate change.

Gierisch, Andrea: Finnish Meteorological Institute (FMI), Finland

Towards sea ice forecasting in the Kara Sea: A regional setup for NEMO-LIM3

Gierisch, Andrea M. U.[1]; Hordoir, Robinson[2]; and Uotila, Petteri[1]

[1] Finnish Meteorological Institute (FMI)
[2] Swedish Meteorological and Hydrological Institute (SMHI)

The Kara Sea is covered by sea ice for a large part of the year. Nevertheless, many ships navigate this region, mostly to and from the local ports. To support ships in finding their route through the ice, short-range forecasts of the ice conditions are useful. These, however, need to have a high enough spatial resolution in order to adequately resolve shipping relevant ice features such as shore leads. Such a high-resolution sea ice forecast model is now being developed at the Finnish Meteorological Institute. We use the latest version of the ocean—sea-ice model NEMO-LIM3 and set up a regional domain for the Kara Sea with a resolution of 2 nautical miles. The model is driven by prescribed atmospheric forcing, tides, river runoff and lateral boundary conditions derived from global model output. We will present the latest model development status as well as some evaluations of its results, for example a comparison of temperature and salinity profiles and sea ice conditions with observations. In order to better meet the needs of navigators sailing in ice covered waters, we convert the simulated ice conditions into the navigability index RIO (POLARIS). This approach can support ships in finding navigable areas for their specific ice class.

Goessling, Helge: Alfred Wegener Institute, Germany

The Sea Ice Drift Forecast Experiment

Goessling, Helge[1]; Schweiger, Axel[2]; Blanchard-Wrigglesworth[2], Ed; Krumpen, Thomas[1]; and Nicolaus, Marcel[1]

[1] Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research
[2] Polar Science Center, Applied Physics Laboratory, University of Washington

We propose a Sea Ice Drift Forecast Experiment – a community effort to solicit, collect, and analyse real-time sea ice drift forecasts, based on arbitrary methods, for a number of sea-ice buoys on a regular basis. The initiative is inspired by the need to determine an optimal deployment position of the research icebreaker Polarstern when she will start her year-long drift across the Arctic in autumn 2019 (MOSAiC drift). Specifically, it's unclear whether forecast systems that account for initial conditions and provide forecasts of the evolving atmosphere, ice, and ocean system, can provide additional skill over drift forecasts made using historical sea ice velocity fields. The MOSAIC drift provides a template for assessing the capabilities to forecast sea-ice drift for a range of applications, ranging from logistics support for future field experiments to potential search and rescue operations. The examination of sea ice drift forecasts provides an integrated assessment of many aspects of the coupled atmosphere-ice-ocean system and will motivate in depth investigations into how key variables are measured, modeled, and forecast. In particular we expect coordinated drift forecasts to draw attention to the interaction between sea ice physics and boundary layer physics in both atmosphere and ocean. We expect that a systematic assessment of real drift forecasting capabilities will improve our physical understanding of sea ice and enable us to identify and resolve model shortcomings and identify limits of predictability. We suggest to start soliciting forecasts with the 2017 Sea Ice Outlook season – concurring with the YOPP launch – so that participating groups can easily add Lagrangian tracers to their models. Forecasts can be single trajectories, but preferably ensembles or spatial probability densities. A seamless approach is envisaged, with lead times ranging from days to one year. Other crucial aspects yet to be determined are the frequency at which forecasts are solicited, the output format, and how the analysis will be organised. These points shall be discussed at PPW2017.

Goessling, Helge: Alfred Wegener Institute, Germany

A probabilistic verification score for contours demonstrated with idealized ice-edge forecasts

Goessling, Helge[1]; Jung, Thomas[1]

[1] Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research

We introduce a probabilistic verification score for ensemble-based forecasts of contours: the Spatial Probability Score (SPS). Defined as the spatial integral of local (Half) Brier Scores, the SPS can be considered the spatial analog of the Continuous Ranked Probability Score (CRPS). Applying the SPS to idealized seasonal ensemble forecasts of the Arctic sea-ice edge in a global coupled climate model, we demonstrate that the SPS responds properly to ensemble size, bias, and spread. When applied to individual forecasts or ensemble means (or quantiles), the SPS is reduced to the 'volume' of mismatch, in case of the ice edge corresponding to the Integrated Ice Edge Error (IIEE).

Heil, Petra: Australian Antarctic Division and ACE CRC (Univ. Tasmania), Australia

An East Antarctic observatory for marine cryosphere and near-surface atmosphere

Knowledge of sea-ice characteristics and their evolution within the coupled climate systems are crucial to understand and numerically model the ocean-ice-atmosphere system, to monitor change in the Earth System and to support planning of research projects as well as of logistics in ice-invested waters. While in situ observations are invaluable to provide high spatial and/or temporal resolution data, local information, and ground truthing for remotely sensed data, the polar regions, especially the maritime polar regions, are poorly sampled. To overcome this a number of initiatives have been set up for the East Antarctic region. These include the bridge-based Antarctic Sea-Ice Processes & Climate [ASPeCt] observations to characterise the local sea ice around the vessel; repeat measurements of the near-coastal fast ice under the Antarctic Fast-Ice Network [AFIN], IPADS-supported sea-ice motion assessments using remotely sensed images, as well as near-surface atmospheric measurements on sea ice and the glacial ice sheet.

ASPeCt observations have been carried out intermittently for several decades. While the observations were taken by a range of vessel/investigators covering the Southern Ocean, the Australian Antarctic Division has supported ASPeCt sea-ice observations on all its continental voyages (typically 3 per season) since 2014/15. ASPeCt data from across the (scientific) community are merged into the AADC for quality control and distribution.

Similarly, AFIN data have been obtained intermittently since the 1950s at the three Australian manned bases in Antarctica, with Casey only offering very few measurements due to unsuitable ice conditions. Basic AFIN measurements are carried out at a weekly schedule include ice- and snow thickness as well as freeboard. The ice is characterized by analysis of a full-length ice cores. In addition automated instrumentation has been deployed at a number of sites, including vertical ice temperature, ice stress and tilt. Where deployed, the configuration of automated instrumentation is individual to each site. For example, David Station (eastern Prydz Bay) has seen deployments of (multiple) sea-ice mass-balance units, tiltmeters, 3-wire stress gauges and shore lead photography. Partner investigators undertake similar manual and automated observations, for example in Atka Bay, or off Zhong Shan.

The IPADS-derived sea-ice motion and fast-ice edge data are based on remotely-sensed imagery, such as aerial digital photography or high-resolution SAR or MODIS imagery. Partly overlapping time-separated images are analyzed using maximum cross-correlation methods. Such information is invaluable to provide logistical support as well as in investigation local and regional sea-ice conditions and forcing.

Lastly, the Australian Antarctic Programme also operates a number of Automatic Weather Stations [AWS]es, both on the continental ice sheet as well as on the sea ice. Most of these data contribute to the WMO's GTS, but some are only available after post-processing.

Here we will provide an overview of our near-surface cryospheric and atmospheric observatory network, including setting up and management. Examples of investigations using data from the various observation sites will be presented to demonstrate the usefulness of in situ information and to remind the wider community of the importance of long-term observing networks.

Huot, Pierre-Vincent: ELIC UCL, Belgium

Impacts of small scale processes on the coupled ocean-atmosphere-sea ice system

Huot, Pierre-Vincent[1]; Fichefet, Thierry[1]; Kittel, Christoph[2]; and Fettweis, Xavier[2]

[1] ELIC, Universite catholique de Louvain, Louvain-la-Neuve, Belgium
[2] University of Liege

Despite the crucial role of ocean-atmosphere fluxes in polar regions, studies frequently neglect the coupled aspects. Our aim in this study is to develop a regional high-resolution configuration of the NEMO-LIM3 ocean-sea ice model and to couple it to a high-resolution version of the MAR atmospheric model. This will be done in the Adelie Land region (60-70°S, 120-150°E) in east Antarctica during years 2012-2013. This coupled model will be used to assess the impact of a variety of small scale processes occurring in the atmosphere (blowing snow, cloud microphysics), ocean (waves, ocean-ice shelves interactions) and sea-ice (new rheology, mutli-column ocean mixing). Here the NEMO-LIM3 and MAR regional configurations are introduced and a first evaluation of the results obtained in standalone forced simulation is presented.

Ionita, Monica: Alfred Wegener Institute, Germany

September Arctic Sea Ice minimum prediction – a new skillful statistical approach

Ionita, Monica[1]; Grosfeld, Klaus[1]; Scholz, Patrick[1]; Treffeisen, Renate[1]; and Lohmann, Gerrit[1]

[1] Alfred Wegener Institute Helmholtz Center for Polar and Marine Research

Sea ice in both Polar Regions is an important indicator for the expression of global climate change and its polar amplification. Consequently, a broad interest exists on sea ice, its coverage, variability and long term change. Knowledge on sea ice requires high quality data on ice extent, thickness and its dynamics. However, its predictability is complex and it depends on various climate and oceanic parameters and conditions. In order to provide insights into the potential development of a monthly/seasonal signal of sea ice evolution, we developed a robust statistical model based on ocean heat content, sea surface temperature and different atmospheric variables to calculate an estimate of the September Sea ice extent (SSIE) on monthly time scale. Although previous statistical attempts at monthly/seasonal forecasts of SSIE show a relatively reduced skill, we show here that more than 92% (r = 0.96) of the September sea ice extent can be predicted at the end of May by using previous months' climate and oceanic conditions. The skill of the model increases with a decrease in the time lag used for the forecast. At the end of August, our predictions are even able to explain 99% of the SSIE. Our statistical model captures both the general trend as well as the interannual variability of the SSIE. Moreover, it is able to properly forecast the years with extreme high/low SSIE (e.g. 1996/ 2007, 2012, 2013). Besides its forecast skill for SSIE, the model could provide a valuable tool for identifying relevant regions and climate parameters that are important for the sea ice development in the Arctic and for detecting sensitive and critical regions in global coupled climate models with focus on sea ice formation.

Jahn, Alexandra: University of Colorado Boulder, USA

Predictability of Arctic sea ice under different emission scenarios

Using output from several ensembles with the Community Earth System Model (CESM), I will show how the evolution and predictability of sea ice in the Arctic changes under different greenhouse gas forcing scenarios. The scenarios used to force the CESM ensembles range from the strong emissions scenario RCP8.5 to strongly reduced emission scenarios constructed to fulfill the IPCC Paris climate conference goal of limiting global warming to 1.5° C by 2100. Given the large impact of internal variability on Arctic sea ice projections, we need ensemble simulations for all of these emission scenarios to assess whether scenario differences lead to statistically significantly different climate outcomes. I will show that while internal variability is large in all ensembles, we can detect some significant differences due to the different forcing scenarios that are outside the range of internal variability. Using the range of the different emission scenarios, this allows a new kind of assessment of the predictability of the late 21st century Arctic sea ice cover, identifying changes that are likely to occur under all assessed future forcing scenarios and changes that are strongly dependent on the future forcing scenario.

Kaleschke, Lars: Institute of Oceanography, University of Hamburg, Germany

How to make the best use of L-band satellite radiometry for sea ice prediction

Kaleschke, Lars[1]; Tian-Kunze, Xiangshan[1]; Maaß, Nina[2]; Schmitt, Amelie[2]; Miernecki, Maciej[2]; Ricker, Robert[3]; Hendricks, Stefan[3]; Haas, Christian[3]; Bertino, Laurent[4]; Xie, Jiping[4]; Tietsche, Steffen[5]; Drusch, Matthias[6]; and Richter, Friedrich[6]

[1] Institute of Oceanography, University of Hamburg
[2] University of Hamburg
[3] Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research
[4] Nansen Environmental and Remote Sensing Center (NERSC)
[5] European Centre for Medium-range Weather Forecasts (ECMWF)
[6] ESA European Space Research and Technology Centre (ESTEC)

The availability of L-band microwave (1.4 GHz) radiometry, from ESA's SMOS and NASA's SMAP missions, together with ESA's CryoSat altimeter has advanced our capabilities to estimate the sea ice thickness from space. While CryoSat was specifically designed to measure the ice thickness this was not the case for SMOS and SMAP. With the two primary aims to measure soil moisture and ocean salinity the application for sea ice was introduced as a third spin-off product. In this presentation we discuss the application of sea ice products, i.e. sea ice thickness, derived from L-band radiometry, and the uncertainties of the products. Different approaches for the use of the observational data in predictive ocean-ice models have been studied: 1) the initialization/assimilation using the sea ice thickness derived from SMOS, 2) the potential assimilation of brightness temperatures by using a radiative transfer forward model (as an observation operator) included in an ocean-ice model, 3) the usage of synergy products combining both radiometry and altimetry.

Kaminski, Thomas: The Inversion Lab, Germany

The Arctic Earth Observation Impact Assessment (A+5) Study

Kaminski, Thomas[1]; Kauker, Frank[2]; Pedersen, Leif Toudal[3]; Voßbeck, Michael[1]; Haak, Helmuth[4]; Niederdrenk, Laura[4]; and Karcher, Michael[2]

[1] The Inversion Lab
[2] Ocean Atmosphere Systems, Hamburg
[3] eolab.dk, Copenhagen
[4] Max Planck Institute for Meteorology, Hamburg

The Arctic Earth Observation Impact Assessment (A+5) study addresses the combination of Earth Observation (EO) data streams with a numerical model of the Arctic ocean sea-ice system using quantitative network design (QND) techniques. The team is constructing a highly flexible system for Arctic Mission Benefit Analysis (the ArcMBA system) that evaluates in a mathematically rigorous fashion the effect that observational constraints imposed by individual and groups of EO data products would have in an advanced data assimilation system. The assessment of the observation impact (added value) is performed in terms of the uncertainty reduction in simulated/predicted sea ice, snow, and oceanic target quantities of scientific and societal interest. A definite asset of the ArcMBA system is that it can also be used to assess the impact of hypothetical data streams, i.e. it can assist in the design of new space mission concepts or the construction of novel product types from existing missions. This project belongs to a group of projects, called ARCTIC+ projects, all funded by ESA's Support to Science Element. It is endorsed by the Polar Prediction Project, as a substantial contribution to its Year of Polar Prediction (YOPP) element. We will present the study approach and show, hopefully, a set of first results.

Keen, Ann: Met Office, United Kingdom

Drivers of Arctic sea ice decline in a coupled climate model

Keen, Ann[1]; Blockley, Ed[1]

[1] Met Office, UK

Arctic September sea ice cover has declined at a rate of 13% per decade since satellite observations began, and there is much interest in how this decline will continue in the future, both in terms of the predictability of ice cover in a given year, and in terms of the manner and timing of the transition to a seasonally ice-free Arctic. Global coupled models are arguably the best tool we have for making future projections of the Arctic sea ice, but generate a wide spread of projections of future ice decline. There are many factors potentially contributing to this spread, and it is becoming increasingly clear that as well as investigating 'integrated' quantities like ice cover and volume directly, it is also necessary to consider, compare and evaluate the underlying processes, and how they change. Here we consider the volume budget of the sea ice in the Arctic Basin in the HadGEM2-ES global coupled model (which was the UK/Met Office contribution to CMIP5), and how the seasonal cycle of budget components evolves during the 21st century under a range of difference forcing scenarios. In terms of what happens per unit surface area of the ice, the processes that change most as the climate warms are summer melting at the top surface of the ice, and basal melting due to extra heat from the warming ocean. However, due to the declining ice cover these are not the processes the contribute most to reductions in the ice volume, which is dominated by a reduction in the total amount of basal ice formation during the autumn and early winter. The choice of forcing scenario affects the rate of ice decline and the timing of change in the volume budget components, but does not have a strong impact on the balance between the individual budget components. The methodology used here should be readily applicable to other models, and in particular those with SIMIP diagnostics submitted to the CMIP6 data archive.

Kimmritz, Madlen: NERSC, Bjerknes centre for Climate Research, Norway

Assimilation of sea ice within the Norwegian Climate Prediction Model

Kimmritz, Madlen[1,2]; Counillon, Francois[1,2]; Gao, Yongqi[1]; Bethke, Ingo[2,3]; Wang, Yiguo[1,2]; and Keenlyside, Noel[2,4]

[1] Nansen Environmental and Remote Sensing Center (NERSC)
[2] Bjerknes centre for Climate Research
[3] UniResearch, Norway
[4] University of Bergen (UiB)

A method capable of constraining the sea ice of a coupled climate system in a dynamically consistent manner would have several important implications for the climate community. It would allow for: more accurate and reliable reconstruction of the climate, enhance the skill of climate prediction on seasonal-to-decadal time scale and allow testing the sensitivity of our climate to changes in sea ice. Data assimilation methods serve this purpose and make use of observations, a dynamical model and their respective error statistics to estimate a new, improved model state. Preserving the dynamical consistency with sea ice assimilation is challenging because sea ice is highly non linear, non Gaussian distributed and because it requires coupled updates – in particular of ocean and sea ice that are thermodynamically tightly connected. Flow dependent assimilation methods such as the Ensemble Kalman Filter have shown some assets for strongly coupled ocean and sea ice assimilation as they can represent the non-stationary and anisotropic covariance of sea ice and salinity that are crucial for preserving the ocean stratification. In this study, we use the Norwegian Climate Prediction Model that is based on the Norwegian Earth System model and the Ensemble Kalman Filter, in the framework of idealized perfect twin experiments (observing system simulation experiment). The assimilation provides combined updates for the isopycnal ocean model and the multicategory sea ice model (CICE4.0) of NorESM but the atmosphere is left unchanged. We quantify the benefit of flow dependent coupled covariance over prescribed cross covariances, and try to identify the assimilation state vector that performs best with a multicategory sea ice model. Our results highlight the challenges that arise due to the linear approximation of the EnKF.

Koldunov, Nikolay: MARUM, AWI, Germany

Arctic sea ice simulation in global ocean model with unstructured mesh

Koldunov, Nikolay[1,2]; Sein, Dmitry[1]; Danilov, Sergey[1]; Wang, Qiang[1]; Sidorenko, Dmitry[1]; and Jung, Thomas[1]

[1] Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research
[2] Center for Marine Environmental Sciences (MARUM)

We present assessment of the Arctic sea ice simulated by the global AWI Finite Element Sea ice Ocean Model (FESOM) in the HighResMIP type historical experiments. The FESOM model uses unstructured triangular mesh that allows flexible distribution of horizontal resolution through the model domain. This gives an opportunity to create computationally efficient global model configurations with resolution increased only in the regions of particular interest. We analyze results of global FESOM simulations calculated on the mesh with about 5 million surface nodes. The horizontal resolution was adjusted to the baroclinic Rossby radius with 4 km minimal resolution. The sea ice is simulated using elastic-viscous-plastic approach (EVP). The simulations differ by the number of subcycling time steps in the EVP solver, which are 120 and 800 steps. The latter is computationally more demanding and increases simulation wallclock time on the same amount of CPUs by about 30%. Both simulations are able to capture many long and narrow cracks typically observed in the sea ice, however number of cracks increases in the simulation with 800 subcycling time steps and their statistics become closer to the observed characteristics of the leads. Comparison to satellite observations shows that the sea ice extent is overestimated in the simulations and further tuning is required.

Kondrashov, Dmitri: University of California, Los Angeles, USA

Data-adaptive Harmonic Decomposition and Real-time Prediction of Arctic Sea Ice Extent

Decline in the Arctic sea ice extent (SIE) has profound socio-economic implications and is a focus of active scientific research. Of particular interest is prediction of SIE on subseasonal time scales, i.e. from early summer into fall, when sea ice coverage in Arctic reaches its minimum. However, subseasonal forecasting of SIE is very challenging due to the high variability of ocean and atmosphere over Arctic in summer, as well as shortness of observational data and inadequacies of the physics-based models to simulate sea-ice dynamics. The Sea Ice Outlook (SIO) by Sea Ice Prediction Network (SIPN, http://www.arcus.org/sipn) is a collaborative effort to facilitate and improve sub-seasonal prediction of September SIE by physics-based and data-driven statistical models. Data-adaptive Harmonic Decomposition (DAH) and Multilayer Stuart-Landau Models (MSLM) techniques [Chekroun and Kondrashov, 2017], have been successfully applied to the nonlinear stochastic modeling, as well as retrospective and real-time forecasting of Multisensor Analyzed Sea Ice Extent (MASIE) dataset in key four Arctic regions. In particular, DAH-MSLM predictions outperformed most statistical models and physics-based models in real-time 2016 SIO submissions. The key success factors are associated with DAH ability to disentangle complex regional dynamics of MASIE by data-adaptive harmonic spatio-temporal patterns that reduce the data-driven modeling effort to elemental MSLMs stacked per frequency with fixed and small number of model coefficients to estimate.

Kotov, Pavel: Lomonosow Moscow State University, Russia

Forecasting equations for thaw settlement calculation

Currently, thaw settlement estimation is a very important task, especially due to global warming in permafrost area. Two main approaches for settlement estimation have been specified: calculating (using only physical characteristics of soils) and experimental (field or laboratory frozen soil testing). Prediction of thawing soil settlements is focused on experimental determination of deformation characteristics (thawing and compressibility coefficients). But tests are laborious and time-consuming. At the same time, using equations, you can calculate thaw settlement inexpensively. The aim of this work was to conduct calculations thaw settlement for various regions of Western Siberia using different equations and compare with the value, obtained using deformation characteristics. Forecasting equation was chosen for each region. Calculations were performed using 10 different equations. These equations are obtained by the authors using different approaches, but all are based on the generalization of experimental data. These equations do not take into account the pressure thawing rate, cryogenic structure, but allow to calculate a preliminary assessment of thaw settlement. This is a particularly important characteristic on stage of project preparation and choice of key areas for drilling and sampling. Analysis of the equations showed that the thaw settlement depends on: density (frozen soil density, dry soil density, soil particles density), water content indicators (water content, ice content, unfrozen water content). Influence of dispersion was taken into account plastic limit or plasticity index. As a result, the applicability of different equations depending on the permafrost soil conditions were obtained. The equation proposed by the P.I. Kotov, has the smallest error in comparison with the calculation data using deformation characteristics. This equation is based on generalization of 600 compression tests thawing soils sampled in the north of Western Siberia and European part of Russia.

Li, Chunhua: National Marine Environmental Forecasting Center, China

Operational weather and sea ice forecasting service for Chinese shipping in the Arctic Northeast Passage in summer 2016

In an effort to facilitate the Chinese Arctic commercial shipping, daily operational weather, sea ice and wave forecasting services are conducted by National Marine Environmental Forecasting Center of China (NMEFC), to 6 cruises of China COSCO Shipping Corporation Limited from July to September, 2016. The Arctic summer sea ice seasonal outlook is conducted using a statistical model, the weather, sea ice and wave numerical forecasts in 1-5 days are mainly based on the Polar WRF atmospheric model and the MITgcm sea ice – ocean model outputs running at NMEFC, and the numerical forecasts from European Centre for Medium-Range Weather Forecasts (ECMWF). We also use Synthetic aperture radar (SAR) based high resolution and Moderate-resolution Imaging Spectroradiometer (MODIS) remote sensing images to observe the local sea ice conditions. Overall, accurate and effective forecasting and navigation service are provided for the Chinese commercial shipping cruises passing through the Arctic Northeast Passage in summer 2016.

Liang, Xi: Polar Environmental Research and Forecasting Division, National Marine Environmental Forecasting Center, China

Assimilating Copernicus SST Data into a pan-Arctic Ice-Ocean Coupled Model with a Local SEIK Filter

Liang, Xi[1]; Yang, Qinghua[1]; Nerger, Lars[2]; Losa, Svetlana N.[2]; Zhao, Biao[3]; Zheng, Fei[4]; Zhang, Lin[1]; and Wu, Lixin[5,6]

[1] National Marine Environmental Forecasting Center (NMEFC): Polar Environmental Research and Forecasting Division, China
[2] Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, Germany
[3] The First Institute of Oceanography, State Oceanic Administration, Qingdao, China
[4] International Center for Climate and Environment Science (ICCES), Institute of Atmospheric Physics, Chinese Academy of Sciences, China
[5] Physical Oceanography Laboratory/CIMST, Ocean University of China
[6] Qingdao National Laboratory for Marine Science and Technology, Qingdao, China

Sea surface temperature (SST) data from the Copernicus Marine Service are assimilated into a pan-Arctic ice-ocean coupled model using the ensemble-based Local Singular Evolutive Interpolated Kalman (LSEIK) filter. It is found that the SST deviation between model hindcasts and independent SST observations is reduced by the assimilation. Compared with model results without data assimilation, the deviation between the model hindcasts and independent SST observations has decreased by up to 0.2 ºC. The strongest SST improvements are located in the Greenland Sea, the Beaufort Sea and the Canadian Arctic Archipelago. The SST assimilation also changes the sea ice concentration. Improvements of the ice concentrations are found in the Canadian Arctic Archipelago, the Beaufort Sea and the central Arctic basin, while negative effects occur in the west area of the Eastern Siberian Sea and the Laptev Sea. Also sea ice thickness benefits from ensemble SST assimilation. A comparison with upward-looking sonar observations reveals that hindcasts of sea ice thickness are improved in the Beaufort Sea by assimilating reliable SST observations into light ice areas. The study illustrates the advantages of assimilating SST observations into an ice-ocean coupled model system and suggests that SST assimilation can improve sea ice thickness hindcasts regionally during the melting season.

Lieser, Jan: University of Tasmania, Australia

On the strategy of sea-ice service delivery - An Australian Antarctic perspective

Sea-ice service delivery is a crucial aspect of safe and efficient shipping operations in ice covered waters. The Australian Antarctic sea-ice service is currently a research-based effort, supported by the Australian Research Council. It consists of near real time satellite data delivery to clients and bespoke expert analysis of sea-ice conditions delivered as now-casting reports. Clients consist of the Australian Antarctic Division (RSV Aurora Australis operations) and the Australian Marine National Facility (RV Investigator operations), other national programs operating in East Antarctica (including China, France, Japan, US and New Zealand) as well as commercial fishing operators. We will present the procedures of Australian sea-ice service delivery, the user-defined needs which require tailored solutions and the requirements identified for a sustainable, long-term future of such service, which include, but are not limited to, incorporation of probabilistic short- to medium-term sea-ice forecasts and seasonal outlooks, training and pre-departure briefings of ship's crews as well as strategic funding and staffing of the service.

Liu, Jiping: University at Albany, USA

Improving Arctic Sea Ice Prediction in the NCEP Climate Forecast System by Assimilating Satellite-derived Sea Ice Concentration and Thickness

Liu, Jiping[1]; Chen, Zhiqiang[2]

[1] University at Albany
[2] Institute of Atmospheric Physics

We assimilate sea ice concentration derived from the Special Sensor Microwave Imager/Sounder (SSMIS) and sea ice thickness derived from the Soil Moisture and Ocean Salinity (SMOS) and CryoSat-2 in the NCEP climate forecast system version 2 using a recently developed localized error subspace transform ensemble kalman filter (LESTKF). Three ensemble-based hindcasts are conducted to examine impacts of the assimilation on Arctic sea ice prediction, including CTL (without any assimilation), LESTKF-1 (with initial sea ice assimilation only), and LESTKF-E5 (with every 5-day sea ice assimilation). Comparisons with the assimilated satellite products and independent sea ice thickness data sets show that assimilating sea ice concentration and thickness leads to improved predictive skill of Arctic sea ice. LESTKF-1 improves sea ice forecast initially, but the initial improvement in the ice extent (thickness) gradually diminishes after a few weeks of integration (remains steady through the integration). Large biases in both the ice extent and thickness in CTL are reduced remarkably through the hindcast in LESTKF-E5. Additional numerical experiments suggest that the hindcast with sea ice thickness assimilation remarkably reduces systematic bias in the predicted ice thickness compared to with sea ice concentration assimilation only or without any assimilation, which also benefits the prediction of the ice extent/concentration due to covariability of thickness and concentration. Thus, the corrected state of sea ice thickness would aid in the forecast procedure. Impacts of the number of ensemble member and extending the integration period to generate estimates of initial model states and uncertainties on sea ice prediction will be also discussed.

Marchi, Sylvain: Université catholique de Louvain, Belgium

Evaluating Antarctic sea ice predictability at seasonal to interannual timescales in global climate models

Marchi, Sylvain[1]; Fichefet, Thierry[1]; Goosse, Hugues[1]; Zunz, Violette[1]; Tietsche, Steffen[2]; Day, Jonny[3]; and Hawkins, Ed[3]

[1] Université catholique de Louvain, ELIC, TECLIM
[2] European Centre for Medium-Range Weather Forecasts
[3] NCAS-Climate, Department of Meteorology, University of Reading

Unlike the rapid sea ice losses reported in the Arctic, satellite observations show an overall increase in Antarctic sea ice extent over recent decades. Although many processes have already been suggested to explain this positive trend, it remains the subject of current investigations. Understanding the evolution of the Antarctic sea ice turns out to be more complicated than for the Arctic for two reasons: the lack of observations and the well-known biases of climate models in the Southern Ocean. Irrespective of those issues, another one is to determine whether the positive trend in sea ice extent would have been predictable if adequate observations and models were available some decades ago. To answer this question, we analyse the outputs of 6 global climate models (HadGEM1.2, MPI-ESM-LR, GFDL CM3, EC-Earth V2, MIROC 5.2 and ECHAM 6-FESOM) coming from the APPOSITE database. We evaluate how sensitive models are to initial conditions by performing a set of perfect ensemble experiments. The limits of the initial-value predictability are estimated thanks to the potential prognostic predictability and the anomaly correlation coefficient. The former is a measure of the uncertainty of the ensemble while the latter assesses the accuracy of the prediction. These two indicators are applied to the ice edge location and the ocean heat content. Although all the models show some skill in predicting the ice edge location for the first months of simulation all around Antarctica, the ice edge predictability is lost from November/December as the sea ice retreat. Nevertheless the predictability reemerges in 4 of the 6 models the following year (MPI-ESM-LR, GFDL CM3, MIROC 5.2 and ECHAM 6-FESOM). The reemergence occurs in April/May as the sea ice grows, but it is limited to some locations. Given its thermal inertia, we expect the ocean to retain information at depth about November/December surface conditions and then to give it back to the surface in April/May as the ocean mixed layer deepens. The depth of the mixed layer could be a key parameter in explaining the effectiveness of this process and why no reemergence of the ice edge predictability is found in EC-Earth V2 and HadGEM1.2.

Massonnet, François: Université catholique de Louvain and Barcelona Supercomputing Center, Belgium

Beyond radiative feedbacks: a process-oriented perspective on climate feedbacks in polar regions

Goosse, Hugues[1]; Kay, Jennifer E.[2,3]; Armour, Kyle C.[4]; Bodas-Salcedo, Alejandro[5]; Chepfer, Helene[6]; Docquier, David[1]; Jonko, Alexandra[7]; Kushner, Paul J.[8]; Lecomte, Olivier[1]; François Massonnet[1,9]; Hyo-Seok Park, Hyo-Seok[10]; Pithan, Felix[11]; Svensson, Gunilla[12]; and Martin Vancoppenolle, Martin[6]

[1] Earth and Life Institute, Université catholique de Louvain, Belgium
[2] Department of Atmospheric and Oceanic Sciences
[3] Cooperative Institute for Research in Environmental Science, University of Colorado
[4] School of Oceanography and Department of Atmospheric Sciences, University of Washington
[5] Met Office Hadley Centre, Exeter, UK
[6] Sorbonne Universités, UPMC Paris 6, LOCEAN-IPSL, CNRS, France
[7] Earth and Environmental Sciences Division, Los Alamos National Laboratory, USA
[8] Department of Physics, University of Toronto, Canada
[9] Earth Sciences Department, Barcelona Supercomputing Center, Barcelona, Spain
[10] Korea Institute of Geoscience and Mineral Resources, Daejeon, South Korea
[11] Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research
[12] Department of Meteorology and Bolin Center for Climate Research, Stockholm University

The concept of feedback is key in assessing whether an initial perturbation to a system is amplified or damped by mechanisms internal to the system. In climate research, fundamental insights have been gained using radiative feedbacks that quantify the impact of changes in temperature, humidity, cloud, snow and sea ice cover on the global radiative balance. In the standard formulation, radiative feedbacks are expressed linearly and normalized by global mean surface temperature change. Although successful globally, this framework has important limitations in polar regions. Due to phase changes of water and the structure of the Arctic lower troposphere, many polar feedbacks are inherently non-linear. This non-linearity means that polar feedbacks depend strongly on the mean state of the system. We propose a framework extending radiative feedback theory to objectively quantify and inter-compare the role of various processes in the climate system, and to allow for process-oriented evaluation of global climate models. The framework is based on the evaluation of a feedback factor that measures, for a system subject to a perturbation, the relative changes directly attributable to the feedback under investigation. To cover a wide range of interactions and to be adapted to polar regions, the analyses are based on observable physical variables, such as sea ice thickness or ocean temperature profiles. Strategies for handling non-linearities are also introduced. The proposed framework can be used to quantify feedbacks coupling different components, allowing a better understanding of polar climate change and variability in both observations and models.

Massonnet, François: Université catholique de Louvain and Barcelona Supercomputing Center, Belgium

Sea ice reanalyses: how useful are they and can we trust them?

Massonnet, François[1,2]; Chevallier, Matthieu[3]; Uotila, Petteri[4]; Guemas, Virginie[2,3]; Fichefet, Thierry[1]; Goosse, Hugues[1]; Fuckar, Neven[2]; and Doblas-Reyes, Francisco[2]

[1] Université catholique de Louvain, Louvain-la-Neuve, Belgium
[2] Supercomputing Center, Barcelona, Spain
[3] Centre National de Recherches Météorologiques (CNRM), Toulouse, France
[4] Finnish Meteorological Institute (FMI)

At the midpoint between climate models and observations, reanalyses are widely used by the climate community in various contexts. In polar regions where observations are sparse, they offer potential insights in understanding how the mass and energy budgets have evolved in recent decades. They can also be used as a basis for initialization of near-term predictions. In this presentation, we discuss the validity of a suite of sea ice reanalyses derived from the ORA-IP project. We compare the reanalyses to each other and to independent sea ice thickness data. We find large inter-reanalysis spread and large biases at the individual level, but find that the ORA-IP as an ensemble can be deemed useful. We also point out several major limitations in current reanalyses (in terms of model output, experimental design). Finally, we introduce a new ensemble Arctic and Antarctic sea ice reanalysis produced with an advanced data assimilation method and a state-of-the-art ocean-sea ice model. We offer additional diagnostics useful to interpret the recent Arctic sea ice changes, including changes in ice thickness distribution and the increase in ocean and sea ice energetic content. In light of the reanalysis, we also discuss the possible origin of recent Antarctic sea ice trends.

Massonnet, François: Université catholique de Louvain and Barcelona Supercomputing Center, Belgium

SIPN-South: Designing an Antarctic sea ice prediction coordinated experiment

Massonnet, François[1,2]; Reid, Phil[3];

[1] Université catholique de Louvain, Louvain-la-Neuve, Belgium
[2] Supercomputing Center, Barcelona, Spain
[3] Bureau of Meteorology, Melbourne, Australia

Since 2008, the Sea Ice Prediction Network (SIPN) collects, processes and analyzes an ever-increasing number of contributions that attempt to forecast the summer Arctic sea ice development. While the skill of such forecasts is still moderate, this suite of sea ice outlooks has represented an invaluable source of information to understand the origin of forecast errors, design new diagnostics adapted to special needs (e.g., the shipping industry) and to identify the major questions that should drive the scientific community during the next decade. Surprisingly, no such initiative exists for the Southern Ocean. In the context of the upcoming Year Of Polar Prediction (YOPP), we coordinate a seasonal sea ice prediction experiment for the austral summer 2018-2019, that is, during the Special Observing Period of YOPP in the Southern Hemisphere. This poster will be the opportunity to outline our implementation plan, exchange with experts and use this feedback to move this project forward.

Mohammadi Aragh, Mahdi: Alfred Wegener Institute, Germany

Predictability of Deformation Features in Arctic Sea Ice

Mohammadi-Aragh, Mahdi[1]; Losch, Martin[1]; Goessling, Helge[1]; Hutter, Nils[1]; and Jung, Thomas[1]

[1] Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research

Sea ice deformation localizes along Linear Kinematic Features (LKFs) that are relevant for the air/ocean/sea-ice interaction as well as for shipping and marine operations. At high resolution viscous-plastic sea ice models start to resolve LKFs. Here, we study the short-range (up to 10 days) potential predictability of LKFs in Arctic sea ice using ensemble simulations of an ocean/sea-ice model with a grid point separation of 4.5 km. We analyze the sensitivity of predictability to idealized initial perturbations, mimicking the uncertainties in sea ice analyses, and to growing uncertainty of the atmospheric forcing caused by the chaotic nature of the atmosphere. The similarity between pairs of ensemble members is quantified by Pearson correlation and Modified Hausdorff Distance (MHD). In our perfect model experiments, the potential predictability of LKFs, based on the MHD, drops below 0.6 between 3 and 4 days in winter. We find that forcing uncertainty largely determines LKF predictability on the 10-day time scale, while uncertainties in the initial state impact the potential predictability only within the first 4 days.

Nakanowatari, Takuya: National Institute of Polar Research, Japan

Evaluation of the summertime Arctic sea ice conditions in TOPAZ4

Nakanowatari, Takuya[1]; Inoue, Jun; Kazutoshi, Sato[1]; Takeshi, Sugimura[1]; Hironori, Yabuki[1]; and Otsuka, Natsuhiko[1]

[1] National Institute of Polar Research

In this study, we evaluated the operational forecast sea ice data in TOPAZ4, and its potential impact on the summertime sea ice forecast, particular in the East Siberian Sea within a week range. During 2002-2013, The climatological sea ice thickness (SIT) data in TOPAZ4 shows the seasonal variation with a maximum in May and minimum in October, which is comparable to the in-situ data, although the absolute value has a negative bias of ~50 cm. The examination of vessel speed data also supports the validity of SIT data in TOPAZ4 in and around the East Siberian Sea. These results suggest that the TOPAZ4 sea ice forecast data have a great potential for medium-range forecast of summertime sea ice in the Arctic Ocean.

Notz, Dirk: Max Planck Institute for Meteorology, Germany

When is all the sea ice gone?

The long-term evolution of Arctic summer sea ice is receiving increasing public attention, given the prospects of a complete sea-ice loss during summer before mid century. In this presentation, I will discuss the relationship between observations and models as relevant for estimating the evolution of sea ice on time scales of a few decades. In particular, I will outline why it is so difficult to identify models that most reliably simulate the future of Arctic sea ice, making a reliable estimate of the timing of a near-ice free Arctic from large-scale model simulations very hard. Based on this discussion, I will then introduce an observation-based estimate of the future evolution of Arctic sea ice that considers our physical understanding of the main processes that cause the ongoing ice loss.

Ólason, Einar Örn: NERSC, Norway

New Lagrangian sea-ice model neXtSIM as a forecast model

Olason, Einar; Bouillon, Sylvain; Rampal, Pierre[1]; and Williams, Timothy[1]

[1] Nansen Environmental and Remote Sensing Center (NERSC)

The next generation dynamic-thermodynamic sea ice model neXtSIM harnesses a new mechanical framework based on an elasto-brittle (EB) rheology to simulate sea ice drift and deformation. neXtSIM is capable of reproducing the observed drift and deformation of the ice, as well as the scale dependent nature of sea-ice deformation from the scale defined by the spatial resolution of the model (about 10 km) to the scale of the Arctic basin (about 1000 km). It is also able to reproduce the observed dispersion/diffusion properties of the Arctic sea-ice cover. As such neXtSIM is ideally suited for high resolution simulations over short time scales where drift and deformation are of main concern. We will present neXtSIM along with an overview of the most important evaluation metrics we use for the model. We will then discuss a short-term-forecast platform we are currently constructing to cover the Arctic Ocean at about 5 km resolution. The platform will consist of the neXtSIM ice model, coupled to a waves-in-ice model (neXtWIM), forced by atmospheric and oceanic forecasts. The platform will also feature data assimilation for the ice state and automatic forecast evaluation.

Olonscheck, Dirk: Max Planck Institute for Meteorology, Germany

Quantifying drivers of internal sea-ice variability using feedback locking

Olonscheck, Dirk[1]; Mauritsen, Thorsten[1]; and Notz, Dirk[1]

[1] Max Planck Institute for Meteorology

Current research highlights the importance of internal climate variability for the observed and modeled evolution of sea ice. However, the contributions of the various drivers of internal sea-ice variability are still largely unknown. We here investigate the individual role of atmospheric and oceanic drivers of sea-ice variability by in turn suppressing and imposing climate feedbacks and forcings in the Max Planck Institute Earth System Model MPI-ESM-LR. Specifically, we quantify the contribution of the water vapour feedback, the cloud feedback, the ice-albedo feedback, the surface wind forcing and the ocean heat forcing to the total sea-ice variability. Our results show an opposing response of Arctic and Antarctic sea-ice variability to the individual atmospheric feedbacks and oceanic forcings: while the variability in Arctic sea-ice area is reduced, the variability in Antarctic sea-ice area is enhanced by non-interactive feedbacks, except for the surface wind forcing that shows an opposite behaviour. We further present synergies and interactions among the locked feedbacks and discuss the physical mechanisms that explain the modelled results. Our quantification of feedbacks and forcings and our improved understanding of the mechanisms that control sea-ice variability might promote better predictions of the polar climate.

Pedersen, Leif Toudal : eolab.dk, Denmark

Recent developments in satellite data sets for model initialisation

New and improved datasets are emerging with associated uncertainties. The presentation will discuss some recent developments in the sea-ice project of ESA's Climate Change Initiative and in the EUMETSAT Ocean and Sea-Ice Satellite Application Facility (OSI-SAF).

Peterson, K. Andrew (Drew): Met Office, United Kingdom

Forecasts of March Arctic minimums and Antarctic maximums from the Met Office seasonal forecast system

Peterson, K. Andrew[1]; Blockley, Edward W.[1]

[1] Met Office UK

The Met Office has been providing forecasts of the September Arctic minimum for several years. Evidence suggests that other times of year may offer even better forecast skill, and could be equally valuable to the end user. Here we present forecasts of the March Arctic minimum and Antarctic maximum from the Met Office seasonal forecast system, GloSea5, along with an estimate of skill as deduced from the system hindcast.

Petrescu, Eugene: NOAA/NWS Alaska, USA

A review of the Alaska Sea Ice Program

The Alaska Sea Ice Program (ASIP) has made several improvements over the past two years to improve services to its customers. The customers, both mariners, and coastal communities, face a number of ice related challenges that are often complex and not captured well by the current sea ice guidance. A brief overview of the current product suite and customer base will be presented along with a few examples of current challenges. A brief overview of current Arctic Testbed and Proving Ground focus areas will also be presented.

Petty, Alek: NASA-GSFC/University of Maryland, USA

Skillful seasonal sea ice forecasts using satellite derived ice-ocean observations: Results for September Arctic sea ice and beyond

Petty, Alek[1,2]; Schroeder, David[3]; Stroeve, Julienne[4]; Markus, Thorsten[1]; Miller, Jeff[1]; Kurtz, Nathan[1]; Feltham, Daniel[3]; and Flocco, Daniella[3]

[1] NASA Goddard Space Flight Center
[2] University of Maryland
[3] University of Reading
[4] University College London

We demonstrate skillful spring forecasts of detrended September Arctic sea ice extent using passive microwave observations of sea ice concentration (SIC) and melt onset (MO), and compare these with forecasts made using a sophisticated melt pond model. The SIC forecasts show the highest skill in June-August, especially when forecasts are evaluated since 2008 (the start of the Sea Ice Outlook), while the MO forecasts show the highest skill in March-May (when evaluated since 1985). Spatial maps of detrended sea ice state anomalies and regional correlations with September Arctic sea ice highlight the physical drivers of the different forecast models. We additionally explore the skill in forecasting months other than September, the forecasting of sea ice area (as opposed to extent) and the forecasting of regional Arctic sea ice (e.g. the Beaufort Sea). We look towards forecasting Antarctic sea ice utilizing this same prediction model framework. Our desire going forward is to provide publicly available, near real-time sea ice forecasts (and uncertainties), utilizing open-source, near real-time, polar climate datasets. We hope to solicit feedback from the sea ice prediction community regarding these proposed activities.

Rosenblum, Erica: Scripps Institution of Oceanography, USA

Faster Arctic Sea Ice Retreat in CMIP5 than in CMIP3 due to Volcanoes

Rosenblum, Erica[1]; Eisenman, Ian[1]

[1] Scripps Institution of Oceanography

The downward trend in Arctic sea ice extent is one of the most dramatic signals of climate change during recent decades. Comprehensive climate models have struggled to reproduce this trend, typically simulating a slower rate of sea ice retreat than has been observed. However, this bias has been widely noted to have decreased in models participating in phase 5 of the Coupled Model Intercomparison Project (CMIP5) compared with the previous generation of models (CMIP3). Here simulations are examined from both CMIP3 and CMIP5. It is found that simulated historical sea ice trends are influenced by volcanic forcing, which was included in all of the CMIP5 models but in only about half of the CMIP3 models. The volcanic forcing causes temporary simulated cooling in the 1980s and 1990s, which contributes to raising the simulated 1979–2013 global-mean surface temperature trends to values substantially larger than observed. It is shown that this warming bias is accompanied by an enhanced rate of Arctic sea ice retreat and hence a simulated sea ice trend that is closer to the observed value, which is consistent with previous findings of an approximately linear relationship between sea ice extent and global-mean surface temperature. Both generations of climate models are found to simulate Arctic sea ice that is substantially less sensitive to global warming than has been observed. The results imply that much of the difference in Arctic sea ice trends between CMIP3 and CMIP5 occurred because of the inclusion of volcanic forcing, rather than improved sea ice physics or model resolution.

Schroeder, David: CPOM, Dep. of Meteorology, University of Reading, Berkshire

Using CryoSat-2 sea ice thickness distribution to constrain the CICE sea ice model

Schroeder, David[1]; Tsamados, Michel[2]; Feltham, Danny[1]; Tilling, Rachel[2]; and Ridout, Andy[2]

[1] CPOM, Dep. of Meteorology, University of Reading, UK
[2] CPOM, University College London, UK

What can we learn from the recent CryoSat-2 sea ice thickness measurements for sea ice modelling? Are the CryoSat-2 thickness data accurate enough to derive sub-grid scale ice thickness distribution (ITD)? For the first time the ITD is derived from the along track CryoSat-2 individual thickness measurements for 5 winter periods October to April from 2010 to 2015. The monthly mean ITD is calculated with respect to 5 CICE ice categories used in e.g. HadGEM3 simulations: (1) ice thickness $h < 60$ cm, (2) 60 cm $< h <$ 1.4 m, (3) 1.4 m $< h <$ 2.4m, (4) 2.4 m $< h <$ 3.6 m, (5) $h >$ 3.6 m. We perform stand-alone CICE simulations initialized with CryoSat-2 ITD in November 2010 to 2014 and April 2011 to 2015. Winter sea ice growth is underestimated applying the default CICE setup during all years. An increase in ice and snow conductivity can match the mean simulated ice growth with the CryoSat-2 ice growth and also improves the simulation of summer ice extent. The width of ITD is generally wider in CICE than in CryoSat-2. A reduction of ice strength and of the area participating in ice ridging can reduce the width of ITD within CICE. Impacts of these changes on longer CICE simulations are discussed.

Schwegmann, Sandra: Bundesamt für Seeschifffahrt und Hydrographie, Germany

Translating model predictions about sea ice for users on the bridge

Holforth, Jürgen[1]; Schwegmann, Sandra[1]

[1] Bundesamt für Seeschifffahrt und Hydrographie

As ships are navigating ice infested water the officers on the bridge have to make decisions for future routing. Ideally these decisions are made with help of reliable numerical sea ice predictions together with the associated uncertainties. But it is not sufficient that from scientific and modelling view all the information about model sea ice variables and their uncertainties are available, it has to be translated into the "language" the seaman are using.

For one, a variable in a sea ice model is often not the same as what a mariner understands under this name (or as defined in the WMO sea ice nomenclature). Other (WMO) sea ice variables are not realized in numerical predictions; others variable are only present in the numerical realm. So some translating has to be done, in extreme form perhaps from full model output to a single variable from something like "easy ice conditions for my particular ship" to "difficult ice conditions for my particular ship".

Similarly with uncertainties, different model variables will have different ranges and types of errors, probably mostly with a non-gaussian form. Full interpretation of such errors will take time, even for a knowledgeable sea ice scientist. On the bridge there is at maximum some minutes time for the officer to make routing decisions, so also here an intelligent compression of information is necessary.

As an operational sea ice service we believe it is within our responsibilities to make such a translating, clearly together with the scientist developing and running the models. But also the user needs have to be taken into account in the model development, an area where also better communication and collaboration between operational ice services and model developers would be very helpful.

Schweiger, Axel: University of Washington/Applied Physics Laboratory/Polar Science Center, USA

Short Term Sea Ice Forecasts

We investigate the accuracy of short term sea ice forecasts for the Arctic. Sea ice forecasts are generated for 6 hours to 9 days using the Marginal Ice Zone Modelling and Assimilation System (MIZMAS) and 6 hourly forecasts of atmospheric forcing variables from the NOAA Climate Forecast System (CFSv2). Forecast sea ice drift is compared to observations from drifting buoys and other observation platforms. Forecast buoy positions are compared with observed positions at 24 hours to 9 days from the initial forecast. Forecast Ice concentrations and ice edge positions are compared to observed passive microwave products. We also examine sea ice drift hind casts for the MIZ experiments from several other models. The initial thickness fields are compared to aircraft remote sensing data from Operation IceBridge (OIB) and CryoSat. We examine sources of errors and make suggestions for future research directions and the linkage between short term and seasonal forecasts.

Schweiger, Axel: University of Washington/Applied Physics Laboratory/Polar Science Center, USA

The Unified Ice Thickness Climate Data Record

The Unified Ice Thickness Data Climate Record (http://psc.apl.uw.edu/sea_ice_cdr/) integrates in-situ and remote sensing observations of sea ice thickness into an easy to use, single format, coordinated data set. The data set contains measurements spanning from 1948 to the present from sources ranging from moored upward looking sonar (ULS) data to satellite-derived thickness such as CryoSat. The data set provides mean monthly ice-thickness for 50 km clusters and within-cluster thickness distributions for some data sources. The data set is designed to address for sea-ice model development and validation. Other applications, such as the investigation of source dependent systematic errors, are possible. I will present an overview of the data set and sample applications of model validation and the identification of instrument biases.

Senftleben, Daniel: German Aerospace Center (DLR), Germany

Sea-Ice Predictability in the MiKlip prediction system

Senftleben, Daniel[1,2]; Eyring, Veronika[1,2]; Bunzel, Felix[3]; Müller, Wolfgang[3]; and Notz, Dirk[3]

[1] German Aerospace Center (DLR)
[2] Institute of Atmospheric Physics, Germany
[3] Max Planck Institute for Meteorology, Ocean in the Earth System

An open science topic is whether the initialization of climate model simulations with observations of the slowly varying components of the climate system results in more accurate decadal predictions compared to uninitialized (historical) simulations in the polar regions. Here, we assess the decadal hindcast skill for Arctic sea ice, surface and sea-surface temperature in the prototype MiKlip prediction system that is based on the Max Planck Institute Earth System Model (MPI-ESM) and in the MPI-ESM high resolution system. The prototype system involves a full field initialization of atmospheric and oceanic variables not including sea ice quantities, whereas the high-resolution model from MiKlip II is additionally initialized with sea ice concentration and thickness. Metrics used to assess predictability include the anomaly correlation coefficient and the root mean square error.

Stroeve, Julienne: UCL/NSIDC, United Kingdom

Preparing for the Sea Ice Outlook Season 2017

Stroeve, Julienne[1,2]; Bitz, Cecilia[3]; Hamilton, Larry[4]; Bhatt, Uma[5]; and Wiggins, Helen[5]

[1] University College London, London, UK
[2] The National Snow and Ice Data Center (NSIDC, Boulder)
[3] University of Washington
[4] University of New Hampshire
[5] University of Alaska Fairbanks

Since 2008, the Sea Ice Outlook (SIO) has invited researchers and members of the public to contribute their predictions regarding the September mean extent of Arctic sea ice. The SIO collects and publishes these contributions online in June, July and August each year. and a subsequent post-season report summarises how predictions compared with the observed September extent, aiming to provide feedback and insights for improvement. The performance of more than 500 individual predictions from the SIO's last nine years shows that prediction accuracy follows a pattern of easy and difficult years, reflecting the difference between climate and weather. Difficult years tend to be those with large positive or negative excursions from overall downward trends. In contrast to these large interannual effects, ensemble improvement from June to August occurs but is comparatively small. Among method types, predictions based on statistics and ice-ocean-atmosphere modeling perform better. Thinning ice that is sensitive to summer weather, which complicated predictions in these SIO years, may reflect our present transitional era between an historical Arctic cool enough to retain much thick, resistant multiyear ice; and a warmed future Arctic where little ice remains at summer's end. Keys to the continued success of the SIO and the growing SIPN community are the networking activities that SIPN organises, which include the open SIO reports, across-network research experiments (e.g., done through SIPN Action Teams), webinars, AGU meetings, workshops, and web and email communication – all of which are critical for advancing the complex science of Arctic sea ice prediction. High-priority recommendations for future work from the network have been incorporated into this outline of activities. Under Phase 2 of SIPN ("SIPN2") we plan to expand the network's research goals to address current needs for sea ice prediction. Key outcomes that we envision over the next 4 years include: (1) continue to lead and manage the network, including running the SIO; (2) greatly expand our network's scientific reach by providing automated analysis and visualization of full fields of year-round predictions (including retrospective predictions) at the subseasonal-to-annual range (known as the expanded SIO or "eSIO"); (3) coordinate across-network collaborative research activities; and (4) participate in network research activities ourselves using network resources and collaboration.

Sun, Nico: Citizen Scientist / Sea Ice Prediction Network, United Kingdom

Albedo-Warming Potential for Sea Ice Forecasts

The Albedo-Warming Potential is a forecasting method based on daily sea ice concentration measurements. By combining daily surface radiation calculations with sea ice concentration measurements the absorbed energy in a grid cell can be approximated. From this energy its possible to calculate sea ice loss and/or ocean warming. It is not only useful to forecast the sea ice minimum extent, but also autumn sea ice extent when warm water temporarily stops refreezing and prevents the formation of a high pressure polar cell above the Arctic. Part of my work is already included in the 2016 Post-Season report of the Sea Ice Prediction Network. Current work:
https://sites.google.com/site/cryospherecomputing/warming-potential/project-description

Tietsche, Steffen: European Centre for Medium-Range Weather Forecasts, UK

The 2016/17 record melt of Antarctic sea ice in ECMWF reanalyses and forecasts

Tietsche, Steffen[1]; Mayer, Michael[2]; and Zuo, Hao[1]

[1] European Centre for Medium-Range Weather Forecasts
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During the austral summer months 2016/2017, Antarctic sea ice melted at a pace far faster than ever observed since the onset of satellite sea ice observations in the early 1980s. This resulted in record-low values of sea ice area for each of these months, far outside the previously observed trend and variability. Here, we discuss precursors and fingerprints of this unusual event as seen in the atmosphere, ocean and sea-ice reanalyses of the European Weather Centre for Medium-Range Weather Forecasts (ECMWF), concentrating on anomalies of near-surface winds and temperatures, and the Antarctic ice-ocean-atmosphere coupled energy budget. We also discuss the ability of the ECMWF subseasonal forecasts, which include a prognostic sea ice model, to capture the observed sea ice anomaly.

Tremblay, Bruno: McGill University, Canada

Quantification of the biases and error in the Polar Pathfinder dataset: towards a new optimally interpolated sea ice drift dataset

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We have recently developed a Lagrangian Ice Tracking System (LITS) for the Arctic Ocean. LITS began with the "IceTracker" developed by Chuck Fowler at the University of Colorado. It has been used to develop a seasonal forecasting model of the Minimum Sea Ice Extent (Williams et al. 2016) and a decadal forecasting model for the pattern of retreat of sea ice in the transition to a seasonally ice-free Arctic Ocean (DeRepentigny et al., 2016). During the development of LITS, problems with the raw drift vectors used to construct the Polar Pathfinder sea ice drift dataset became apparent, including: low biases in the drift derived from the Scanning Multichannel Microwave Radiometer (SMMR) in the eighties, Special Sensor Microwave Imager (SSMI) particularly in the summer, Advanced Very High Resolution Radiometer (AVHRR, mostly in the Southern Hemisphere) and free drift estimates, when compared with buoy drift observations (taken to be essentially true). Errors are largest in the 1980's and in the summer months when few satellites see the surface and the dataset relies more heavily on the low biased free-drift estimates. While performance of the Polar Pathfinder dataset is on par with similar products (Sumata et al., 2015) and can, in the statistical sense, provide useful motion estimates, problems limit its utility to the post-1987 (post SMMR) era, and winter (when freedrift is seldom used). We recompile a new optimally interpolated Polar Pathfinder dataset correcting for the biases and using the error to properly weigh each of the raw drift products. We combine data from several sources (SMMR, SSMI, AVHRR, AMSRE, RadarSat, ERS-1 & 2, ADEOS-1, QuikSCAT, ASCAT (EUMETSAT METOP), NSIDC buoys and freedrift estimates derived from reanalysis sea level pressures) into an optimally interpolated sea ice drift dataset.

Tsamados, Michel: University College London, United Kingdom

Using Stepwise Linear Regression Based on Spatio-temporal Complex Networks to Forecast September Sea Ice Concentration

Tsamados, Michel[1]; Watson, Callum[2]; Stroeve, Julienne[3]; and Sollich, Peter[4]

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The sea ice prediction problem can be broken down into drivers that occur on different timescales, but function in an additive way to produce the eventual state of sea ice: 1) A long-term external driver that is impacting many aspects of the cryosphere 2) Annual- to sub-seasonal scale mechanistic drivers that contain some predictability, such as snow cover, spring-time humidity melt ponds, atmospheric pressure patterns, and sea surface temperatures that may in turn drive persistent atmospheric patterns. 3) Chaotic events with predictability similar to that of weather (on the order of two weeks), for example, the Great Arctic Cyclone of 2012. The focus of our proposed work is to investigate mechanisms that provide predictability on the sub-seasonal to annual time scale. Such sources of sea ice predictability emerge from spatio-temporal teleconnections between key climatological data that can be classified as land-ice, ocean-ice, atmosphere-ice, ice-ice or even as a combination between such variables. Numerous forecast methods have been put forward to predict sea ice. These range from heuristic to statistical models built on spatio-temporal correlations in the Arctic, to those based on fully coupled ocean-ice or ocean-ice-atmosphere dynamical models (e.g. GCMs). Direct use of GCMs with prognostic sea ice has been employed singly, or in an ensemble of models. Such systems provide spatial maps of predicted SIE, yet simulations by these groups leave much room for improvement. While fully coupled GCMs that realistically simulate the feedbacks among the ocean, atmosphere, and cryosphere should provide the most accurate forecast of Arctic sea ice conditions, such a model is presently not available. Until these limitations are overcome, statistical forecasts remain a powerful complement and often outperform their coupled model counterparts. Such statistical forecasts can be derived purely from observations or from a mixture of models and data assimilation. For example, at the sub-seasonal (50-day) scale, a purely statistical technique that looks at the probability of ice survival relative to its concentration at the start of the forecast period provides high consistent and competitive mean pan-Arctic September SIE and SIP. Other statistical forecast systems have applied multiple linear regression to forecast September SIE from as early as April, with predictors being SIC, sea ice thickness (SIT), temperature, downwelling longwave radiation (DLR), ocean mixed layer temperatures, melt pond area, etc. Here we present some preliminary results in order to illustrate our methodology and we focus as an example test study a forecast of the September sea ice concentration from the sea ice concentration in May and the melt onset date used as predictors. We compare our results with the observed September sea ice extent minimum of 2016.

Tsubouchi, Takamasa: Alfred Wegener Institute, Germany

Pan-Arctic oceanic volume, temperature & heat transport variabilities during 2004-2010

Tsubouchi, Takamasa[1]; von-Appen, Wilken[1]; and Schauer, Ursula[1]

[1] Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research

Entire Arctic boundary through Bering, Davis, Fram Straits and Barents Sea Opening (BSO) has been monitored since 2004. Gathering of all the data together allows for a comprehensive estimate of oceanic transports across the Arctic gateways: quasi-synoptic estimate in summer 2005 [Tsubouchi et al., 2012] and a full annual cycle in Sep. 2005 - Aug. 2006 [Tsubouchi et al., in review]. This study aims to reveal, for the first time, an inter-annual variability of oceanic and sea ice heat fluxes through the Arctic gateways. We analyze around 1,000 moored instruments across the pan-Arctic boundary during October 2004 to May 2010, with supplement of 37 repeat CTD sections in BSO and PIOMAS output. Volume and salt conserved velocity fields are obtained applying box inverse model for consecutive 68 months. The result shows that obtained volume transports are reasonable both in averaged value and it's seasonal variability in each four Arctic gateway. We quantify total boundary heat flux, as a sum of oceanic and sea ice contributions, is 180±57 TW (mean ± standard deviation for the 68 months). We find that the net oceanic heat transport has a clear seasonal cycle, with highest values of ~210 TW in October-December and lowest values of ~100 TW in April-June. We also find that annual mean oceanic heat flux (average from October to following September) changes from year to year. The highest value of ~170 TW appears during 2004-2005, and the lowest value of ~130TW appears during 2008-2009.

Wang, Keguang: Norwegian Meteorological Institute, Norway

A coupled ROMS-CICE model for the Arctic

Wang, Keguang[1]; Kristensen, Nils[1]; and Debernard, Jens[1]

[1] Norwegian Meteorological Institute

The latest Regional Ocean Modeling System (ROMS 3.7) and Los Alamos sea ice model (CICE 5.1.2) is coupled using the Model Coupling Toolkit (MCT 2.9). This coupled modeling system is employed to simulate the Arctic ocean-ice system from 1993 to 2010. The forcing field is the ECMWF ERA-Interim atmospheric reanalysis, and the initial and boundary conditions are provided by the global Forecast Ocean Assimilation Model (FOAM) reanalysis. We present the preliminary results from this simulation, and assess the simulation results against observations. A special attention is paid to the simulation of melt pond fraction.

Wang, Muyin: University of Washington, USA

Sea ice evolution in the Pacific Arctic by selected CMIP5 models: the present and the future

Wang, Muyin[1]; Yang, Qiong[1]

University of Washington

With fast declining of sea ice cover in the Arctic, the timing of sea ice break-up and freeze-up is an urgent economic, social and scientific issue. Based on daily sea ice concentration data we assess three parameters: the dates of sea ice break-up and freeze-up and the annual sea ice duration in the Pacific Arctic. The sea ice duration is shrinking, with the largest trend during the past decade (1990-2015); this declining trend will continue based on model projections. The simulation results from the coupled Atmosphere-Ocean General Circulation Models from phase 5 of the Coupled Model Intercomparison Project (CMIP5) are the major data source for this study. CMIP5 models are able to simulate all three parameters well when compared with observations. Comparisons made at eight Chukchi Sea mooring sites and the eight Distributed Biological Observatory (DBO) boxes show consistent results. The 30-year averaged trend for annual sea ice duration is projected to be -0.68 days/year to -1.2 days/year for 2015-2044. This is equivalent 20 to 36 days reduction in the annual sea ice duration. A similar magnitude of the negative trend is also found at all eight DBO boxes. The reduction in annual sea ice duration will include both earlier break-up dates and later freeze-up date. However, models project that a later freeze-up contributes more than early break-up to the overall shortening of annual sea ice duration. Around the Bering Strait future changes are the smallest, with less than 20-days change in duration during next 30 years. Upto 60 days reduction of the sea ice duration is projected for the decade of 2030-2044 in the East Siberia, the Chukchi and the Beaufort Seas.

Werner, Kirstin: Alfred Wegener Institute, Germany

Advancing Environmental Prediction Capabilities for the Polar Regions and Beyond during The Year of Polar Prediction

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Environmental changes in polar regions open up new opportunities for economic and societal operations such as vessel traffic related to scientific, fishery and tourism activities, and in the case of the Arctic also enhanced resource development. The availability of current and accurate weather and environmental information and forecasts will therefore play an increasingly important role in aiding risk reduction and safety management around the poles. The Year of Polar Prediction (YOPP) has been established by the World Meteorological Organization's World Weather Research Programme as the key activity of the ten-year Polar Prediction Project (PPP; see more on www.polarprediction.net). YOPP is an internationally coordinated initiative to significantly advance our environmental prediction capabilities for the polar regions and beyond, supporting improved weather and climate services. Scheduled to take place from mid-2017 to mid-2019, the YOPP core phase covers an extended period of intensive observing, modelling, prediction, verification, user-engagement and education activities in the Arctic and Antarctic, on a wide range of time scales from hours to seasons. The Year of Polar Prediction will entail periods of enhanced observational and modelling campaigns in both polar regions. With the purpose to close the gaps in the conventional polar observing systems in regions where the observation network is sparse, routine observations will be enhanced during Special Observing Periods for an extended period of time (several weeks) during YOPP. This will allow carrying out subsequent forecasting system experiments aimed at optimizing observing systems in the polar regions and providing insight into the impact of better polar observations on forecast skills in lower latitudes. With various activities and the involvement of a wide range of stakeholders, YOPP will contribute to the knowledge base needed to managing the opportunities and risks that come with polar climate change.

Yamagami, Akio: Center for Computational Sciences, University of Tsukuba, Japan

Medium-range predictability of an extreme Arctic cyclone in August 2016

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An extremely strong Arctic cyclone (AC) developed in August 2016. The AC exhibited a minimum sea level pressure (SLP) of 967.2 hPa and covered the entire Pacific sector of the Arctic Ocean at 0000UTC on 16 August. At this time the AC was comparable to the strong AC observed in August 2012, in terms of horizontal extent, position, and intensity as measured by SLP. Two processes contributed to the explosive development of the AC: growth due to baroclinic instability, similar to extratropical cyclones, during the early part of the development stage, and later nonlinear development via the merging of upper warm cores. The AC was maintained for more than one month through multiple mergings with cyclones both generated in the Arctic and migrating northward from lower latitudes, as a result of the high cyclone activity in summer 2016. This study also investigated the predictability of the AC using operational medium-range ensemble forecasts: CMC (Canada), ECMWF (EU), JMA (Japan), NCEP (USA), and UKMO (UK), available at the The Interactive Grand Global Ensemble (TIGGE) database. The minimum SLP of the AC at 0000UTC on 16 August was well predicted by ECMWF 6-day, NCEP and UKMO 5-day, CMC 4-day, and JMA 3-day in advance. The predictability of the minimum SLP of the AC in August 2016 was much higher than that of the AC in 2012 August. Whereas most of the members well predicted the cyclogenesis of the AC, the growth due to baroclinic instability was weaker in some members. Even if the baroclinic growth was predicted well, predicted AC did not develop when the nonlinear development via the merging was not predicted accurately. The accurate prediction of the processes in both early and later parts of the development stage was important for the accurate prediction of the development of the AC.

Yang, Qinghua: National Marine Environmental Forecasting Center, China

Simultaneous assimilation of CryoSat-2 and SMOS sea ice thickness data with a local SEIK filter into a regional ice-ocean coupled model improves overall model performance

Mu, Longjiang[1]; Yang, Qinghua[1]; Losch, Martin[2]; Losa, Svetlana N.[2]; Ricker, Robert[2]; Nerger, Lars[2]; and Jung, Thomas[2]

[1] National Marine Environmental Forecasting Center
[2] Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research

The benefit of assimilating weekly CryoSat-2 sea ice thickness data sets of the Alfred Wegener Institute together with daily SMOS sea-ice thickness data set of the University of Hamburg and daily SSMIS sea ice concentration data of the National Snow and Ice Data Center (NSIDC) in a coupled sea ice-ocean model of the Arctic Ocean is investigated. The forecasts are based on the Massachusetts Institute of Technology general circulation model (MITgcm), and the assimilation is performed by a localized Singular Evolutive Interpolated Kalman (LSEIK) filter coded in the Parallel Data Assimilation Framework (PDAF). A period of three months from November 2011 to January 2012 is selected to assess the forecast skill of the assimilation system in the cold season. By comparing with the unassimilated model, it is shown that the model-data misfits are reduced substantially in areas of both thick and thin ice. The sea ice thickness agrees significantly better with the in-situ observations in the central Arctic Ocean than the sea ice thickness obtained from assimilating only SMOS data, while the sea ice concentration forecasts show very small improvements. The forecast obtained by assimilating the SMOS and CryoSat-2 data also has lower thickness and concentration errors with respect to observations than that of directly assimilating a statistically merged SMOS and CryoSat-2 sea ice thickness product (CS2SMOS data of the Alfred Wegener Institute). The lower errors show that physical processes play a significant role in data blending.

Zampieri, Lorenzo: Alfred Wegener Institute, Germany

Verification of Seasonal and Sub-seasonal Sea Ice Forecasts

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Sea ice forecasts are becoming a demanding need since human activities in the Arctic are constantly increasing and this trend is expected to continue. Forecast system development needs to be guided by verification metrics that quantify skill in an appropriate way. Here we apply different verification metrics to real sea ice forecasts to study the behaviour of the metrics and to quantify potential predictability, focussing on the sea ice edge position and on sub-seasonal to seasonal time scales. The employed metrics are the pan-Arctic sea ice extent (SIE) and area (SIA), the Integrated Ice Edge Error (IIEE), the Spatial Probability Score (SPS), and the Modified Hausdorff Distance (MHD). While the first two metrics evaluate a single integrated quantity, the latter three assess the spatial distribution of the ice cover. Forecasts are verified against the high-resolution AMSR-E and AMSR2 89 GHz sea ice concentration products provided by the University of Bremen. Sea ice forecast products from various research institutes and operational centers are analysed, in particular those collected within the Sub-Seasonal to Seasonal Prediction Project. The forecast systems are characterized by quite different features with regard to the spatial resolution and the complexity of the forecast model, the number of ensemble members and the forecast length. The broad pool of models allows a comprehensive analysis of the metrics' behavior in different situations, highlighting strengths and weaknesses of the models and of the metrics themselves.