2019 ABSTRACTS BOOK

Year of Polar Prediction (YOPP)
Arctic Science Workshop 2019

14-16 January 2019

Finnish Meteorological Institute
Erik Palménin aukio 1, 00560 Helsinki, Finland

Content

Credits:
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Agenda

Monday, January 14th 2019		
08:00 – 09:00	***Registration***	
Welcome and Introductory session (Auditorium 'Brainstorm')		(chair: Helge Goessling)
09:00-09:10	*Welcome from FMI, IASC and PPP*	Juhani Damski (FMI Director General) Thomas Spengler Thomas Jung Timo Vihma
09:10-09:25	*Bridging Modelling and Observational Efforts during the Year of Polar Prediction*	Thomas Jung (Alfred Wegener Institute) (*presenting author*: Helge Goessling, Alfred Wegener Institute)
Invited Presentations I (Auditorium 'Brainstorm')		(chair: Manisha Ganeshan)
9:25-09:50	*Atmosphere-Ocean Single-Column Model (AOSCM) – a tool to help improve coupled models in the Arctic*	Gunilla Svensson (Stockholm University)
09:50-10:15	*Predictability Characteristics of Arctic Cyclones*	James Doyle (Naval Research Laboratory)
10:15-10:40	*Canadian Contributions to the Year of Polar Prediction: Deterministic and Ensemble Coupled Atmosphere-Ice-Ocean Forecasts*	Gregory Smith (Environment and Climate Change Canada)
10:40-11:00	***Coffee Break***	
Invited Presentations II (Auditorium 'Brainstorm')		(chair: Kirstin Werner)
11:00-11:25	*Large-scale Arctic sea ice modeling: Forging a community*	Elizabeth Hunke (Los Alamos National Laboratory)
11:25-11:50	*Co-production and use engagement in Arctic metocean forecasting: Experiences from the SALIENSEAS project*	Machiel Lamers (Wageningen University and Research)
11:50-12:15	*An overview of the Iceland Greenland Seas Project: Cold-Air Outbreaks and Air-Sea-Ice Fluxes*	Ian Renfrew (University of East Anglia)
12:15-12:40	*On forecasting sea ice trajectories using the Lagrangian sea ice model neXtSIM (cancelled)*	Pierre Rampal (Nansen Environmental and Remote Sensing Center)
12:40-13:40	***Lunch***	
Introduction to Breakout Groups (Auditorium 'Brainstorm')		(chair: Thomas Jung)
13:40-14:05	*Breakout Groups: Groups will be assigned at registration*	

Session A (Auditorium 'Brainstorm'): Coupled Atmosphere-Ocean-Sea Ice (chairs: Evelien Dekker/Claudia Hinrichs)		
14:05-14:20	*Predicting ocean waves and sea ice and the Polar Oceans*	Stefanie Rynders (National Oceanography Centre)
14:20-14:35	*Is the Arctic Losing Climatic Resilience?*	James Overland (NOAA Pacific Marine Environmental Laboratory) (*presenting author:* Kevin Wood, Joint Institute for the Study of the Atmosphere and Ocean)
14:35-14:50	*The influence of ice fragmentation on the atmospheric boundary layer processes*	Marta Wenta (University of Gdansk)
14:50-15:05	*Results of hydrometeorological studies at Research station "Ice Base "Cape Baranova" during YOPP*	Alexander Makshtas (Arctic and Antarctic Research Institute)
15:05-15:20	*Coupling scales and components: When is an interactive sea ice component required for weather forecasting?*	Clemens Spensberger (University of Bergen & Bjerknes Centre for Climate Research)
15:20-15:35	*Next Iteration of the Arctic System Reanalysis*	David Bromwich (*remotely*; Byrd Polar & Climate Research Center)
15:35-16:00	***Coffee Break***	
Session B (Auditorium 'Brainstorm'): User Engagement (chairs: Riina Haavisto/Machiel Lamers)		
16:00-16:15	*Who are the end-users of improved polar environmental forecasting services?)*	Marijn Anna Cornelia Hooghiem (Wageningen University and Research & SALIENSEAS)
16:15-16:30	*From detailed sea-ice services to end users*	Till Soya Rasmussen (Danish Meteorological Institute)
16:30-16:45	*Toward salient metocean services for the marine Arctic: exploring metservice perspectives on the user-producer interface*	Maaike Knol (University of Tromsø) (*presenting author:* Jelmer Jeuring, Umeå University)
16:45-17:00	*The contribution of the Icelandic Meteorological Office to YOPP*	Guðrún Nína Petersen (Icelandic Meteorological Office)
17:00-17:15	*INTAROS – A Project contributing to improving Arctic observing systems*	Stein Sandven (Nansen Environmental and Remote Sensing Center)
17:15-17:30	*General Discussion*	
17:30-19:00	***Posters I (Sessions A, B, E) & Icebreaker***	

Tuesday, January 15th 2019		
Session C (Auditorium 'Brainstorm'): Forecasting & Data Assimilation (chairs: Madlen Kimmritz/Yonghan Choi)		
09:00-09:15	*Impact of assimilating AIRS cloud-cleared radiances on atmospheric dynamics and boundary layer height at high latitudes*	Erica McGrath-Spangler (Universities Space Research Association/GESTAR) (*presenting author*: Manisha Ganeshan, Universities Space Research Association /GESTAR)
09:15-09:30	*On the warm bias of atmospheric reanalysis over sea-ice in Arctic winter*	Malte Müller (Norwegian Meteorological Institute)
09:30-09:45	*Dynamics of weather extremes during the YOPP Special Observations Periods*	Timo Vihma (Finnish Meteorological Institute)
09:45-10:00	*Impact of a multi-layer snow model in the ECMWF Integrated Forecasting System*	Gabriele Arduini (European Centre for Medium-Range Weather Forecasts)
10:00-10:15	*The Sea Ice Drift Forecast Experiment*	Helge Goessling (Alfred Wegener Institute)
10:15-10:30	*Predictability of extreme weather events in North*	Kent Moore (University of Toronto)
10:30-11:00	***Group Photo & Coffee Break***	
Session D (Auditorium 'Brainstorm'): Verification (chair: Barbara Casati/Jonathan Day)		
11:00-11:15	*Verification of sea-ice prediction by using distance measures*	Barbara Casati (Environment and Climate Change Canada)
11:15-11:30	*Merged Observatory Data Files at the YOPP Super Sites for Special Observing Periods: Preliminary Verification Results*	Taneil Uttal (NOAA) (*presenting author*: Leslie Hartten, University of Colorado/CIRES)
11:30-11:45	*A NWP model inter-comparison of surface weather parameters during the Year of Polar Prediction Special Observing Period 1*	Morten Køltzow (Norwegian Meteorological Institute)
11:45-12:00	*Assessing the value of the Arctic Observing System for Medium-Range NWP*	Jonathan Day (European Centre for Medium-Range Weather Forecasts)
12:00-12:15	*Evaluation of seasonal Arctic sea ice forecasts from the ECMWF SEAS5 system*	Cyril Palerme (Norwegian Meteorological Institute)
12:15-12:30	*What's in a Name? - Matching Observational Data with Model Output*	Siri Jodha Khalsa (University of Colorado)
12:30-13:30	***Lunch Break***	

PARALLEL SESSIONS (13:30–15:00)

Session E (Auditorium 'Brainstorm'): Atmosphere (chairs: Manisha Ganeshan/Carolina Viceto)

13:30-13:45	*Atmosphere-Wave Coupling in a NWP System*	Erin Thomas (Norwegian Meteorological Institute)
13:45-14:00	*Profiling at Oliktok Point to Enhance YOPP Experiments (POPEYE)*	Gijs de Boer (University of Colorado)
14:00-14:15	*Experiences from Arctic forecasting during the Arctic Ocean 2016 expedition*	Michael Tjernström (Stockholm University)
14:15-14:30	*The De-Icing Comparison Experiment (D-ICE): A well-characterized verification data set of Arctic broadband downwelling longwave and shortwave radiative fluxes for YOPP*	Christopher Cox (CIRES/NOAA)
14:30-14:45	*Polar lows in the ECMWF versus Arome Arctic models*	Matilda Hallerstig (Norwegian Meteorological Institute/ECMWF)
14:45-15:00	*Boundary layer measurements at Cape Baranov (YOPP project CATS-BL)*	Günther Heinemann (University of Trier) (*presenting author:* Alexander Makshtas, Arctic and Antarctic Research Institute)

Session F (Aura): Sea Ice and Ocean (chairs: Francesca de Santi/François Massonnet)

13:30-13:45	*Nudging the Arctic Ocean to quantify sea ice feedbacks*	Evelien Dekker (Stockholm University)
13:45-14:00	*The Arctic Heat Open Science Experiment 2018: collaboration, initial results, and data availability*	Kevin Wood (Joint Institute for the Study of the Atmosphere and Ocean)
14:00-14:15	*Recent observations of sea ice thickness change in the Arctic*	Christian Haas (Alfred Wegener Institute)
14:15-14:30	*Towards an operational snow on sea ice product*	Julienne Stroeve (University College London)
14:30-14:45	*Limited predictability of extreme decadal changes in the Arctic Ocean freshwater content*	Torben Schmith (Danish Meteorological Institute)
14:45-15:00	*Recent Achievements in Derivig Sea Ice Thickness from Satellite Observations and Transition into an Operational Service*	Robert Ricker (Alfred Wegener Institute)
15:00-15:30	**Coffee Break**	

GROUP DISCUSSIONS I (15:30–17:00)

Auditorium 'Brainstorm'	Processes I	Gunilla Svensson

Briefing Room	Processes II	Thomas Spengler
Room ‘Aura’	Predictability I	Thomas Jung
Room ‘Mare’	Predictability II	Greg Smith
Room ‘Aqua’	User Engagement	Machiel Lamers
Room ‘Terra’	Verification	Barbara Casati
17:00-18:30	***Posters II (Sessions C, D, F)***	
19:30	***No-host Conference Dinner at Ravintola Lasipalatsi*** ***Address: Mannerheimintie 22-24, 00100 Helsinki***	

Wednesday, January 16th 2019		
GROUP DISCUSSIONS II (09:00–10:30)		
Auditorium ‘Brainstorm’	Processes I	Gunilla Svensson
Briefing Room	Processes II	Thomas Spengler
Room ‘Aura’	Predictability I	Thomas Jung
Room ‘Mare’	Predictability II	Greg Smith
Room ‘Aqua’	User Engagement	Machiel Lamers
Room ‘Terra’	Verification	Barbara Casati
10:30-11:00	***Coffee Break***	
REPORT FROM GROUP DISCUSSIONS (Auditorium ‘Brainstorm’)		(chair: Thomas Jung)
11:00-11:10	Processes	Gunilla Svensson
11:10-11:20	Processes II	Thomas Spengler
11:20-11:30	Predictability I	Thomas Jung
11:30-11:40	Predictability II	Greg Smith
11:40-11:50	User Engagement	Machiel Lamers
11:50-12:00	Verification	Barbara Casati
WRAP UP AND CLOSURE (12:00–12:30) (Auditorium ‘Brainstorm’)		(chair: Thomas Jung/Thomas Spengler)
12:30-13:30	***Lunch (optional)***	

Presentations - Abstracts

Session C: Forecasting and Data Assimilation – Tuesday, January 15th 09:45-10:00

Impact of a multi-layer snow model in the ECMWF Integrated Forecasting System

Arduini, **Gabriele**[1]; Balsamo, Gianpaolo[1]; Dutra, Emanuel[2]; Day, Jonathan[1]; Sandu, Irina[1]

[1]European Centre for Medium-Range Weather Forecasts (ECMWF), United Kingdom
[2]University of Lisbon, Instituto Geofísico do Infante D. Luiz, Portugal

Due to its unique physical properties, snow has a significant impact on the distribution of water and energy fluxes at the surface/atmosphere interface. Cold processes associated with snow have implications spanning from short-range weather predictions to seasonal and climate projections. To resolve such processes on a range of time-scales from the sub-diurnal to seasonal, physically-based multi-layer snow models are required. These models enable a detailed description of internal snowpack processes. In this work, the impact of a new multi-layer snow scheme in the ECMWF Integrated Forecasting System (IFS) is evaluated with a focus on Arctic and Subarctic landmasses. Simulations with the multi-layer snow scheme and with the current single-layer snow scheme are compared. 10-day forecasts are initialized every day at 00UTC for the wintertime 2016/2017 and 2017/2018. The latter evaluation period is during the Year Of Polar Prediction (YOPP), and includes the first Special Observing Period (February 1st to March 31st, 2018). To produce equilibrated snow initial conditions for each of the forecasts, surface initial conditions are derived from long integrations using the land-surface model only. The evaluation in the northern hemisphere (poleward of 45°N) of the coupled forecasts using standard observations (synop) shows an improved representation of the snow in the multi-layer snow scheme. The root-mean-square error of snow depth decreases by 17% at day 1 (mainly because of improved initial conditions) and by 19% at day 5. The single-layer snow scheme generally overestimates snow depth compared to the observations, which is reduced using the multi-layer snow scheme. The introduction of the multi-layer snow scheme increases the amplitude of the diurnal cycle of the 2-metre temperature over snow-covered area, mainly because of the reduced thermal inertia of the surface snow layer. The impact on 2-metre temperature biases and the relationships with other sources of error, like cloud cover, are discussed. These results show the added value of increased physical complexity in the representation of snow in numerical weather prediction applications.

The Impact of Uncertainty in Arctic Ocean Precipitation on Estimates of Snow Depth and Density Over Sea Ice

Barrett, Andrew[1]; Stroeve, Julienne[2]

[1]National Snow and Ice Data Center, USA
[2]University College London, United Kingdom

Precipitation is a fundamental input for snow accumulation-melt models developed to estimate snow thickness and density for use in laser and radar altimeter retrievals of sea ice thickness. Of the current crop of reanalyses, only four products will extend through the planned operations of ICESat2 and CryoSat2: NASA's MERRA2, NOAA's CFSRv2, ECMWF's ERA5, and the Japanese JRA55. No one reanalysis is better than the others: MERRA2 and CFSRv2 have positive biases of about 50 mm based on pan-Arctic mean precipitation; JRA55 has a negative bias of 50 mm. Biases vary spatially: MERRA2 and CFSRv2 tend to have a wetter eastern Arctic than JRA55. ERA5 is still in production. A full run from 1979 to present is slated to be available by the end of 2018. Such large spread in precipitation estimates introduces uncertainty in estimates of snow cover over sea ice. In this presentation, we evaluate spread of precipitation estimates, along with other forcings, from the four covering the ICESat2 and CryoSat2 periods, and the associated uncertainty in estimates of snow depth and density for North Pole drifting stations, and SHEBA. We also explore the impact on snow cover uncertainty of bias correcting precipitation.

Session F: Sea Ice and Ocean – Poster ID: #F01

Towards a more detailed representation of sea-ice in AROME-Arctic - operational convective-scale NWP system for European Arctic by Met Norway

Batrak, Yurii[1]; Müller, Malte[1]; Landgren, Oskar[1]

[1]Norwegian Meteorological Institute, Norway

Operational numerical weather prediction (NWP) in the Arctic region is challenged by the presence of large sea-ice covered areas. Complex and highly dynamic processes of the evolution of sea-ice are difficult to correctly reproduce in NWP applications but expected to be of high importance for the quality of forecasts. AROME-Arctic is the operational forecasting system based on the HARMONIE-AROME configuration of the ALADIN-HIRLAM NWP system. AROME-Arctic is operated by Met Norway and covers the region of the Greenland and Barents Seas. Sea-ice in this system is simulated by a simplistic snow-free thermodynamic parameterization scheme with uniform prescribed ice thickness, and the ice-covered areas are defined by the ice fraction products derived from measurements made by the passive microwave satellite sensors. In the current study we assess the performance of the sea-ice parameterization in AROME-Arctic by comparison against the near real time satellite-based ice surface temperature products and test the possible effects of introducing the more detailed representation of sea-ice. Two advances in the parameterization of sea-ice are considered: kilometer-scale features in the sea-ice cover within MIZ, and the presence of non-uniform prognostic ice thickness accompanied by the snow layer on top of the sea-ice. We show that introducing the kilometer-scale features in the ice cover affects the atmospheric dynamics in the regions up to 500-1000 km away from the ice edge. Furthermore, adding the prognostic ice thickness and the snow layer to the parameterization of sea-ice cover helps to considerably improve the modelled surface temperature over the ice-covered areas.

The Met Office's YOPP-endorsed aircraft campaign: Measurements of Arctic Cloud, Snow and Sea Ice in the Marginal Ice ZonE (MACSSIMIZE)

Blockley, Ed[1]; Harlow, Chawn[1]

[1]Met Office, United Kingdom

In March 2018, during the YOPP Special Observing Period (SOP), the Met Office carried out an airborne campaign in northern Alaska and north-western Canada: Measurements of Arctic Cloud, Snow and Sea Ice in the Marginal Ice ZonE (MACSSIMIZE). The MACSSIMIZE campaign was focussed on: (1) snow emissivity measurements at IR and mm-wavelengths over collocated ground-based measurements of snow structure on sea ice and nearby land, (2) boundary layer and energy balance measurements in clear and cloudy skies, and (3) orographic flows and their leeside impacts. The goal of these measurements and modelling efforts is to improve predictability in the Arctic while focussing on assimilation of satellite sounder data into NWP systems, and evaluation and development of boundary layer and snow pack parameterisations suitable for Arctic conditions for use in coupled ocean-atmosphere NWP and climate models. Here we shall provide details of the MACSSIMIZE aircraft campaign and introduce some of the initial findings. The plans for future evaluation of the snow thermodynamic and emissivity models using the observations from MACSSIMIZE will also be presented.

Next Iteration of the Arctic System Reanalysis

Bromwich, **David**[1]; Bai, Lesheng[1]; Liu, Zhiquan[2]

[1]Byrd Polar & Climate Research Center, Ohio State University, USA
[2]National Center for Atmospheric Research, USA

To detect and diagnose rapid climate changes occurring in the Arctic, a state-of-the-art assessment and monitoring tool is imperative. The Arctic System Reanalysis is a university-led reanalysis of the Greater Arctic region (roughly poleward of 40N) using blends of the polar-optimized version of the Weather Research and Forecasting (Polar WRF) model and WRF three-dimensional variational data assimilation system. Two ASR versions have been completed, version 1 at 30 km for 2000-2012, and version 2 at 15 km for 2000-2017 at 3-h intervals. Both had very similar physics with 71 vertical levels and the lowest level at 4 m above the surface. The high-resolution topography and land surface, including weekly-updated vegetation and realistic sea-ice fraction, sea-ice thickness, and snow cover depth on sea ice, resolved fine-scale processes. Analysis revealed superior reproduction of near-surface and tropospheric variables in comparison to the global ERA-interim reanalysis. Forecast precipitation and downward radiative fluxes are where improvement in ASR is desirable. The next version of ASR is under development to improve on the performance. The horizontal resolution will be increased to 12 km for even more refined topographic forcing and the number of vertical levels to 100 with a top at 1 hPa to better assimilate satellite radiances. The atmospheric data assimilation will be enhanced to three-dimensional hybrid ensemble variation. The microphysics parameterization will be changed to the advanced 2-moment Morrison scheme and variable specified aerosol concentrations will be used better capture Arctic mixed phase clouds and improve upon the predicted radiation fluxes and precipitation amounts. The land surface model will be upgraded to the state-of-the-art Noah-MP with continuing assimilation of weekly-updated vegetation and realistic sea-ice characteristics. We anticipate making this new version (version 2.5) span 2000-2020 to extend through the MOSAiC drift across the Arctic Ocean with surface variable output every hour. This presentation will focus on the YOPP Arctic Special Observing Periods during 2018.

Opening the Review of IPCC Reports to Early Career Scientists

Casado, Mathieu[1]; Gremion, Gwenaelle[2]; **Rosenbaum, Paul**[3]; Aho, Kelsey[4]; Bradley, Alice[5]; Caccavo, Jilda Alicia[6]; Champollion, Nicolas[7]; Dahood, Adrian[8]; Fernández, Alfonso[9]; Fugmann, Gerlis[1]; Lizotte, Martine[10]; Vidal, Florian[11]

[1]Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Germany
[2]Institut des Sciences de la Mer, Université du Québec, Canada
[3]Uppsala University, Sweden
[4]University of Alaska Fairbanks, USA
[5]Williams College, USA
[6]University of Padua, Italy
[7]University of Bremen, Germany
[8]University of California Santa Cruz and Antarctic Ecosystem Research Division, USA
[9]Universidad de Concepción, Chile
[10]Université Laval, Department of Biology, Canada
[11]Paris Descartes University, France

Early Career Scientists (ECS) represent a large part of the workforce in the natural sciences. While they typically have significant academic training, they have limited experience in how the scientific community self-evaluates and communicates, and they are rarely invited to engage in the peer-review process. We argue that such engagement would be beneficial to ECS - and to the scientific community as a whole. Our research presents a group review of the first order draft of the Intergovernmental Panel on Climate Change (IPCC) "Special Report on Ocean and Cryosphere and in a Changing Climate" (SROCC) supported by 75 ECS from 22 countries on behalf of the Association of Polar Early Career Scientists (APECS) during Spring 2018. We present our working process, results and lessons learned. Data from participant surveys and a comments catalogue collectively illustrate that ECS are competent reviewers comparable to more experienced researchers. Furthermore, our study advances discussion about ECS as valuable reviewers of publications by the IPCC, other institutions and academic journals. We also note the particularly diverse expertise and geographic perspectives that APECS and its affiliates bring to the process. The IPCC has agreed to collaborate with APECS in the second order review of their SROCC starting in late 2018, so we aim to enhance our conclusions with additional data from this - and future - group review processes.

Session D: Verification – Tuesday, January 15th 11:00-11:15

Verification of sea-ice prediction by using distance measures

Casati, Barbara[1]; Lemieux, Jean-François[1]; Smith, Gregory[1]; Pestieau, Paul[2]; Cheng, Angela[3]

[1]Meteorological Research Division, Environment and Climate Change Canada, Canada
[2]Canadian Ice Service, Environment and Climate Change Canada, Canada
[3]McGill University, Montreal, Canada

Sea-ice is characterized by a coherent spatial structure, with sharp discontinuities and linear features (e.g. leads and ridges), the presence of spatial features, and a multi-scale spatial structure (e.g. agglomerates of floes of different sizes). Traditional point-by-point verification approaches do not account for this complex spatial structure and the intrinsic spatial correlation existing between nearby grid-points. This leads to issues (such as double penalties), and an overall limited diagnostic power (e.g. traditional scores are insensitive to distance errors). This work explores the use of binary image distance measures of the Hausdorff and Baddeley family for the verification of sea-ice extent and sea-ice edge. The metrics are illustrated for the Canadian Regional Ice Ocean Prediction System evaluated against the Ice Mapping System analysis. The distance measures account for the sea-ice coherent spatial structure, are sensitive to the overlapping and similarities in shape of observed and predicted sea-ice extent: they reveal to be a robust and suitable set of verification measures, complementary to the traditional categorical scores. Moreover, these measures can provide distance errors, e.g. of observed versus predicted sea-ice edge, in physical terms (i.e. km), thereby being informative and meaningful for user-relevant applications.

Session D: Verification – Poster ID: #D01

Performance of the Canadian deterministic prediction systems over the Arctic during the winter and summer YOPP Special Observing Periods

Casati, Barbara[1]; Robinson, Tom[1]; Lemay, François[1]; Milbrandt, Jason[1]; Smith, Greg[1]; Køltzow, Morten[2]; Haiden, Thomas[3]

[1]Environment and Climate Change Canada, Canada
[2]Norwegian Meteorological Institute, Canada
[3]European Centre for Medium-Range Weather Forecasts (ECMWF), United Kingdom

As contribution to the Year of Polar Prediction (YOPP), Environment and Climate Change Canada has developed the Canadian Arctic Prediction System (CAPS, 3 km horizontal grid spacing), that has been running in experimental mode since February 2018. The Meteorological Service of Canada is also running two other operational systems that cover the Arctic: the Regional Deterministic Prediction System (RDPS, 10 km grid spacing) and the Global Deterministic Prediction System (GDPS, 25 km grid spacing). The performance of these three systems over the Arctic has been monitored and routinely compared during 2018, both subjectively and with objective verification scores. This work presents the results of the surface variable objective verification for the Canadian deterministic prediction systems during YOPP, focusing in particular on the Arctic Special Observing Periods (Feb-March and July-Aug-Sept 2018). All three systems exhibit a diurnal cycle in the near-surface temperature biases. Conditional verification reveals a dependency between temperature biases and cloud cover. All three systems systematically over-predict weak winds and under-predict strong winds. CAPS outperforms RDPS and GDPS in predicting near-surface wind, however it underperforms the other two systems for mean sea level pressure. Verification of winter precipitation is performed by correcting observations from solid precipitation under-catchment. Scores for the entire North Pole region (latitudes > 60N) are dominated by the performance in the Fennoscandia region, which hosts a denser observation network. To address this, results obtained by spatially thinning the observations and by applying spatial block bootstrapping are compared. These YOPP dedicated intense verification activities identified some strengths, weaknesses and systematic behaviours of the Canadian deterministic prediction systems at high latitudes, and led to the development of better verification practices for the polar regions (and beyond).

Real-time forecasts over the Arctic region during 2017/2018 Arctic expedition of the KOPRI IBRV Araon

Choi, Yonghan[1]; Kim, Joo-Hong[1]; Kim, Baek-Min[2]; Lim, Chang-Kyu[1]; Noh, Nam-Kyu[2]; Kim, Shin-Woo[2]; Zhang, Xiangdong[3]

[1]Korea Polar Research Institute (KOPRI), South Korea
[2]Pukyong National University, South Korea
[3]University of Alaska, Fairbanks, USA

The Korea Polar Research Institute (KOPRI) has an ice-breaking research vessel (IBRV) Araon, and radiosonde observations have been taken during the Arctic cruise period of the Araon since 2015. Starting in 2017, the KOPRI performs real-time weather forecasts over the Arctic region during the Araon's Arctic cruise period (August 6 to September 16 in 2017, August 4 to September 20 in 2018) to support scientific activities of the Araon. 6-hourly radiosonde observations from the Araon are assimilated using the three-dimensional variational (3D-Var) data assimilation method in a cycling mode, and 5-day forecasts are made using the polar-optimized Weather Research and Forecasting (Polar WRF) Model on every Monday, Wednesday, and Friday. Forecasts results such as sea-level pressure, 2-m temperature, 2-m relative humidity, 10-m wind speed/direction, and precipitation are transmitted to the Araon. Effects of assimilating radiosonde observations from the Araon on weather forecasts over the Arctic region are investigated by comparing two experiments: one with the assimilation of radiosonde observations and the other without the assimilation of radiosonde observations. Verification statistics against reanalysis data (e.g., ERA-Interim from the European Centre for Medium-range Weather Forecasts) and independent observations (e.g., buoy observations from the International Arctic Buoy Programme) are calculated for the Arctic cruise periods in 2017 and 2018. Some cyclone cases over the Arctic region are also analyzed to show impacts of assimilating radiosonde observations on 5-day forecasts of those cyclones.

The De-Icing Comparison Experiment (D-ICE): A well-characterized verification data set of Arctic broadband downwelling longwave and shortwave radiative fluxes for YOPP

Cox, Christopher[1]; Morris, Sara[1]; Uttal, Taneil[1]; Long, Charles[2]

[1]Cooperative Institute for Research in Environmental Sciences (CIRES)/NOAA Physical Sciences Division, USA
[2]Cooperative Institute for Research in Environmental Sciences (CIRES)/NOAA Global Monitoring Division The D-ICE Team, USA

Radiative fluxes are amongst the core process-specific diagnostic variables that will be a focus of the planned YOPP verification activities. The downward broadband longwave and shortwave fluxes at the surface are significant and variable contributors to the surface energy budget, representing the integrated effects of radiative transfer through the atmosphere, including clouds. Despite their importance for process-oriented diagnostics, these quantities are difficult to observe reliably at high latitudes. The occurrence of ice on longwave and shortwave radiometer sensors, either by snow, rime (contact freezing) or frost (vapor deposition) is a common problem that is both difficult to prevent and difficult to identify in post-processing because the signal is not easily distinguished from variability caused by clouds. Even when data is successfully screened, the missing values cause a climatological bias in the observational record because icing occurs under particular meteorological conditions that then go unrepresented. The De-Icing Comparison Experiment (D-ICE) was a campaign carried out by NOAA and the Baseline Surface Radiation Network (BSRN) at the NOAA Baseline Atmospheric Observatory in Utqiaġvik (formerly Barrow), Alaska from August 2017 to July 2018. The purpose of D-ICE was to evaluate ventilation and heating technologies developed to mitigate radiometer icing. D-ICE consisted of 20 pyranometers and 5 pyrgeometers operating in various ventilator housings alongside additional operational radiometers that are part of NOAA's Utqiaġvik BSRN station and the U.S. Dept. of Energy (DoE) Atmospheric Radiation Measurement (ARM) Program North Slope of Alaska (NSA) broadband radiation station. The D-ICE and ARM radiometers were monitored using high-resolution security cameras capturing images of the sensors every 10-15 minutes. While not an anticipated outcome of D-ICE, analysis of the data from the 2017-2018 winter indicate that at least some pyranometers and pyrgeometers were ice-free continuously, regardless of icing conditions. Consequently, a high-quality (BSRN-traceable), well-documented and verifiably ice-free observational time series can be derived from the collective measurements. To our knowledge this is the first ever verifiably ice-free data set of broadband radiative fluxes for the Arctic. This time series is further enhanced by empirically-derived uncertainties developed from the spread of the measurement suite and observations of the biases caused by ice that are calculated from the differences between the clean and contaminated data. The data set of 1 min averages is nearly a full year in length and spans a complete Arctic cold season, including the entire first YOPP Special Observing Period (SOP) (Feb-Mar 2018). The D-ICE Team is working to complete this data set and publish it as a stand-alone, citable product that we hope will be of use to the YOPP community and others.

Impact of the Arctic sea ice on the predictability of NAO events during wintertime

Dai, Guokun[1]**;** Mu, Mu[1]

[1]Fudan University, China

Utilizing the Community Earth System Model (CESM), the impact of the Arctic sea ice on the predictability of North Atlantic Oscillation (NAO) events during wintertime is investigated. Numerical sensitivity experiments show that NAO events response to the sea ice concentration uncertainty in marginal seas mainly after 2 weeks. The most sensitive sea ice concentration uncertainty to NAO predictability is obtained by solving the corresponding conditional nonlinear optimal perturbation (CNOP) problem. Further diagnostic analysis shows that the NAO response to the sea ice concentration uncertainty is involved with turbulent flux processes, such as sensible heat, latent heat and longwave radiation processes. Moreover, the total NAO response is divided into a portion which projects onto the tropopause NAO mode (the indirect response) and a portion which is the residual from that projection (the direct response). The direct response which refers to the local adjustment close to the surface plays a leading role in the first 3 weeks. However, the role of indirect response which involved with nonlinear atmospheric dynamics becomes important after 3 weeks.

Session D: Verification – Tuesday, January 15th 11:45-12:00- Poster ID: #C03

Assessing the value of the Arctic Observing System for Medium-Range NWP

Day, Jonathan[1]; Lawrence, Heather[1]; Sandu, Irina[1]; Magnusson, Linus[1]; Farnan, Jaqueline[1]; Bromann, Niels[1]

[1]European Centre for Medium-Range Weather Forecasts (ECMWF), United Kingdom

Recent studies have suggested that Arctic teleconnections play a significant role in determining the weather of the mid-latitudes at timescales relevant for medium-range forecasting. However, the evidence for this comes from relaxation experiments (e.g. Jung et al. 2014) or from Observing System Experiments (OSEs) with reduced complexity observing systems (e.g. Sato et al. 2018), and therefore are not necessarily representative of what one might find in an operational NWP system. We present the first Arctic OSE in an operational NWP system and comprehensively assess the value of several observation types, e.g. leaving out conventional observations (radiosondes, surface pressure etc.) and different satellite data sets at high latitudes (>60°N). We also assess the value of the extra Arctic observations collected during the first Year of Polar Prediction-Special Observing Periods, YOPP-SOPs. The OSEs were performed with the ECMWF Integrated forecasting system at a global resolution of ~25 km for both summer and winter seasons.

Growing Land-Sea Temperature Contrast and the Intensification of Arctic Cyclones

Day, Jonathan[1]; Hodges, Kevin[2]

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[2]University of Reading, United Kingdom

Cyclones play an important role in the coupled dynamics of the Arctic climate system on a range of time scales. Modeling studies suggest that storminess will increase in Arctic summer due to enhanced land-sea thermal contrast along the Arctic coastline, in a region known as the Arctic Frontal Zone (AFZ). However, the climate models used in these studies are poor at reproducing the present-day Arctic summer cyclone climatology and so their projections of Arctic cyclones and related quantities, such as sea ice, may not be reliable. In this study we perform composite analysis of Arctic cyclone statistics using AFZ variability as an analog for climate change. High AFZ years are characterized both by increased cyclone frequency and dynamical intensity, compared to low years. Importantly, the size of the response in this analog suggests that General Circulation Models may underestimate the response of Arctic cyclones to climate change, given a similar change in baroclinicity.

Profiling at Oliktok Point to Enhance YOPP Experiments (POPEYE)

de Boer, Gjis[1]; Shupe, Matthew[1]; Solomon, Amy[1]; Intrieri, Janet[2]; Mei, Fan[3]; Dexheimer, Darielle[4]; Hubbe, John[3]; Bendure, Albert[4]; Goldberger, Lexie[3]; Carroll, Peter[3]; Ivey, Mark[4]; Schmid, Beat[3]

[1]University of Colorado, USA
[2]National Oceanic and Atmospheric Administration (NOAA), USA
[3]Pacific Northwest National Laboratory, USA
[4]Sandia National Laboratory, USA

The Arctic is rapidly evolving, and enhanced predictive capabilities for both weather and climate are urgently required. Therefore, the international community has formulated plans for the execution of an extended period of focused observations and modeling of the arctic environment, dubbed the Year of Polar Prediction, or YOPP. The YOPP features two special observing periods, with the first occurring in the spring of 2018 and the second during the late summer and early fall. POPEYE (Profiling at Oliktok Point to Enhance YOPP Experiments) is deploying additional ARM resources to Oliktok Point, Alaska, during the second three-month special observing period (1 July 2018 – 30 September 2018). This includes additional radiosonde launches, ARM-operated unmanned aerial systems (DataHawks), and ARM-operated tethered balloons. These instruments will conduct routine profiling activities over the course of the special observing period to obtain measurements on atmospheric thermodynamic structure, cloud and precipitation properties, and aerosol properties. These measurements will be used for a variety of purposes, including to: • conduct detailed studies of arctic cloud and aerosol processes • inform YOPP modeling efforts through real-time availability for assimilation into operational and research analysis products • evaluate and improve retrieval algorithms involving ARM remote sensors • evaluate and improve a variety of modeling tools being used to forecast arctic weather and climate • initialize and evaluate simulations associated with a potential Arctic large-eddy simulation framework similar to the ongoing ARM LASSO project. In this presentation, we provide an overview of the POPEYE campaign. Additionally, we provide perspectives on the types of conditions sampled over the 3-month period and a glimpse at initial measurements from the platforms deployed.

Modelling and Observations of Waves Attenuation in Pancake Ice

De Santi, Francesca[1]; De Carolis, Giacomo[1]; Olla, Piero[2]

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[2]Institute of Atmospheric Sciences and Climate (ISAC), National Research Council, Cagliari, Italy

Young sea ice types, namely grease-pancake ice (FPI), as well as thin ice floes mainly compose the marginal ice zone (MIZ) during the freezing period. Such types of sea ice are considered the primary source of the sea ice fringing the Antarctica continent during winter season through the process called the "pancake cycle", and are massively produced in the Arctic as a result of the sea ice extent and volume decline. The properties of such sea ice types are exceedingly difficult to measure autonomously, due to their size, transient nature, and the hostile environment where they form and grow. However, some internal properties of the ice cover, such as the ice thickness, can in principle be inferred by measuring the modifications induced by the presence of the sea ice cover on the propagation of gravity waves coming from the open ocean. Unfortunately, only a few data sets collected in situ by instrumented wave buoys over long periods exist due to the intrinsic difficulty to deploy instruments in the harsh wavy environment of polar seas. In contrast to punctual buoy deployments, which are sparse and discontinuous due to the high costs and limited accessibility of remote areas, spaceborne satellite observations of sea ice fields offer a valid alternative to provide synoptic snapshots of waves traveling through extensive ice fields. Among others, synthetic aperture radar (SAR) systems have the capability to efficiently monitor the Polar Regions as microwave radiation can image the Earth surface independent of the solar illumination and penetrate haze or cloud cover. In this regard, we have investigated the ability of different viscous layer models to describe the attenuation of gravity waves propagating in GPI covered ocean. In particular, the Keller's model (Keller, 1998), the two-layer viscous model (De Carolis & Desiderio, 2002) and the close-packing model (De Santi & Olla, 2017) have been extensively validated by using wave attenuation data collected during two different field campaigns (Weddell Sea, Antarctica, April 2000; Western Arctic Ocean, autumn 2015). For thin GPI, a good ice thickness retrieval has been obtained by considering the ice layer as the only source affecting the wave dynamics, so that the wind input can be disregarded. In addition, such viscous layer models validation has been extended by using a SAR inversion procedure, which is able to track the attenuation of incoming ocean waves inside GPI fields. In conclusion, we aim to assess to what extent the available spaceborne SAR imagery can be operated as a synoptic wave buoy in the sea ice environment in order to map GPI thickness in the MIZ of Arctic and Antarctica as well.

Nudging the Arctic Ocean to Quantify Sea Ice Feedbacks

Dekker, Evelien[1]; Bintanja, Richard[2]; Severijns, Camiel[2]

[1]Meteorological Institute Stockholm University, Sweden
[2]Royal Dutch Meteorological Institute, the Netherlands

With Arctic summer sea ice potentially disappearing halfway through this century, the surface albedo and insulating effects of Arctic sea ice will decrease considerably. The ongoing Arctic sea ice retreat also affects the strength of the Planck, lapse-rate, cloud and surface albedo feedbacks together with changes in the heat exchange between the ocean and the atmosphere, but their combined effect on climate sensitivity has not been quantified in a fully coupled model. This study presents an estimate of all Arctic sea ice related climate feedbacks combined. We use a new method to keep Arctic sea ice at its present day (PD) distribution under a changing climate in a 50 year CO2 doubling simulation, using the fully coupled global climate model (EC-Earth V2.3). We nudge the Arctic Ocean column to the (monthly-dependent) year 2000 mean temperature and minimum salinity fields on a mask representing PD sea ice cover. We are able to preserve about 95% of the PD mean March and 77% of the September PD Arctic sea ice extent by applying this method. Using simulations with and without nudging, we estimate the climate response associated with Arctic sea ice changes. We find the Arctic sea ice feedback to be between 0.28 - 0.68 Wm-2. The total sea ice feedback thus amplifies the climate response for a doubling of CO2, in line with earlier findings. Our estimate of the Arctic sea ice feedback agrees reasonably well with earlier CMIP5 global climate feedback estimates and shows that the Arctic sea ice exerts a considerable effect on the Arctic and global climate sensitivity.

Invited Talk – Monday, January 14th 09:50-10:15

Predictability Characteristics of Arctic Cyclones

Doyle, James D.[1]; Amerault, Clark[1]; Fearon, Matt[2]; Finocchio, Peter[2]

[1]Naval Research Laboratory, Monterey, USA
[2]National Research Council, Monterey, USA

Arctic cyclones that rapidly intensify are notoriously difficult to predict, particularly with regard to their attendant mesoscale boundary layer features such as near-surface jets that can have important impacts on the sea ice and ocean state. In this study, we compare and contrast initial condition sensitivity and multi-scale predictability aspects of several noteworthy high-latitude cyclones using a regional nested adjoint modeling system. One event we highlight is the "Great Arctic Cyclone of 2012" that was centered on the Arctic Ocean in early August 2012 and was the strongest summer storm in the Arctic since satellite observations began in 1979 with a peak intensity of 962 hPa. A second cyclone investigated formed in the Kara Sea north of Siberia and attained a center pressure of 966 hPa. Both cyclones appeared to have a significant impact on local changes in the sea ice extent. We also examine several other Arctic cyclones that occurred during the YOPP Arctic Special Observing Periods, particularly focusing on several active periods that featured strong cyclones in July and August 2018.

We apply the COAMPS nonhydrostatic moist adjoint system using 15-25 km horizontal resolution and some cases with a 5-km resolution nested grid. The adjoint diagnostics indicate that the intensity of severe winds and strong surface fluxes in these high-latitude storms in open ocean regions and along the ice edge are especially sensitive to narrow filaments in the moisture and temperature fields and to a lesser degree the wind fields. The mesoscale structure (e.g., low-level jets) associated with these cyclones are also sensitive at times (including seasonal dependence) to the surface flux distribution, which is linked with the ice edge location. The results of this study underscore the need for accurate moisture observations on the mesoscale in the Arctic and data assimilation systems that can adequately assimilate these observations in order to reduce the forecast uncertainties for these intense cyclones. However, given the nature of the sensitivities and the potential for rapid perturbation and error growth, the intrinsic predictability of the mesoscale structure associated with these intense Arctic cyclones appears to be limited.

Additionally, we perform diagnostics using Navy Global Environmental Model (NAVGEM) to assess the impact of the 06Z and 18Z radiosondes launched during the YOPP Arctic Special Observing Periods through comparison of the NAVGEM analyses with other operational centers such as NCEP. We also will present results assessing the impact of the 06Z and 18Z radiosonde launches on cyclones during the special observing period using the COAMPS adjoint regional modeling system.

Session F: Sea Ice and Ocean – Poster ID: #F04

Toward estimating the role of Greenland freshwater in salinity changes of the subpolar North Atlantic

Dukhovskoy, Dmitry[1]; Proshutinsky, Andrey[2]; Yashayaev, Igor[3]

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[2]Woods Hole Oceanographic Institution, USA
[3]Bedford Institute of Oceanography, Canada

The cumulative Greenland freshwater flux anomaly has acceded 5000 km3, which is half of the freshwater volume advected into the North Atlantic during the 1970s Great Salinity Anomaly. The event was well observed and recorded in terms of salinity and temperature anomalies at the observational sites in the North Atlantic as the anomaly propagated around the Subpolar Gyre. In contrast to the Great Salinity Anomaly, there is no observational evidence of salinity changes in the North Atlantic that can be directly related to the Greenland FW flux anomaly. The motivation for this study is to investigate the absence of evidence of increased Greenland FW flux. The paper presents results of the numerical experiment with a passive tracer released continuously during the simulation at freshwater sources along the Greenland coast. The location and flux rates are derived from a detailed gridded product of Greenland freshwater fluxes. Results from the model experiments are analyzed to investigate pathways, vertical spreading, and accumulation rate of Greenland freshwater in the northern North Atlantic. Predictions of salinity anomalies over the study region related to the Greenland freshwater flux anomaly are provided based on the numerical simulation and tracer budget analysis. The tracer study suggests the strongest freshening along the Greenland coast (<–0.1). In the interior regions, due to horizontal and vertical mixing the freshening signal is weaker ranging from –0.015 in the upper Labrador Sea to –0.004 in the upper central Greenland Sea. It is concluded that Greenland freshwater anomaly has small impact on salinity in the interior regions.

Session C: Forecasting and Data Assimilation – Poster ID: #C04

Assimilating ice chart observations into a high resolution coupled ocean-sea-ice model

Fritzner, Sindre Markus[1]; Graversen, Rune[1]; Wang, Keguang[2]; Christensen, Kai Håkon[2]

[1]University of Tromsø, Norway
[2]Norwegian Meteorological Institute, Norway

In this study, a coupled ocean-sea-ice model covering the area around Svalbard is used to assess the impact of assimilating high-resolution ice chart observations. The model used in the study is the state-of-the-art coupled model system consisting of the Regional Ocean Modeling System (ROMS) as the ocean component, and the Los Alamos sea-ice model (CICE) as the sea-ice component. The model has a resolution of 2.5 km. In this study, we use the time period from mid-Mars 2018 to mid-May 2018 as the period of study. The deterministic ensemble Kalman filter (DEnKF) from the EnKF-c code is used for assimilation of the observations. In this study, 10 ensemble members with an assimilation time-step of seven days were used. We compare the effect of assimilating ice charts from the Norwegian meteorological institute to a control run without assimilation. In addition, we compare the result of assimilating ice charts to an assimilation of coarse resolution EUMETSAT OSISAF observations. It is found that there are large benefits to the short term forecast when assimilating the ice charts. In addition, we show that for a high-resolution model, such as the one used in this study, it is crucial to have high-resolution observations. When assimilating the OSISAF observations, only small improvements to the short-term forecast was found.

Session E: Atmosphere – Poster ID: #E02

A regional analysis of factors affecting the Antarctic boundary layer during the Concordiasi campaign and comparison with reanalyses

Ganeshan, Manisha[1]; Yang, Yuekui[2]

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This study explores the regional variability in factors affecting the atmospheric boundary layer over continental Antarctica using high-resolution dropsonde observations from the Concordiasi campaign in the austral spring of 2010. Analyses show that although the surface-based inversion (SBI) remains the dominant feature, well-mixed boundary layers, some with convective features, are observed with an occurrence frequency of 33% and 18% in West and East Antarctica, respectively. The boundary layer mixing is dominated by mechanical instability albeit with regional flavors caused by topographically forced winds, shortwave radiation, and air mass influences. In East Antarctica, the downsloping wind regime is prevalent, and related katabatic effects are strongest over high elevation slopes where the wind-induced turbulence is the primary cause of SBI erosion and boundary layer mixing. Previous studies over Dome C have demonstrated the significance of shortwave radiation for mixed layer development during the peak of summer. While such an effect is not dominant during spring, solar forcing may contribute to turbulent mixing in high latitude regions. Well-mixed boundary layers are most frequently observed in the "moist tongue" region of West Antarctica, highlighting the importance of dynamical systems for boundary layer mixing. Additionally, we compare the stability representation in the Modern Era Retrospective analysis for Research and Applications version 2 (MERRA2), accounting for possible differences due to the coarser model vertical resolution compared to the high-resolution Concordiasi dropsondes. The impact of systematic errors in the model low-level wind field and their contribution to the stability representation is investigated, following which recommendations are made for improving related parameterized processes in the NASA Goddard Earth Observing System (GEOS, version 5) model.

Impact of assimilating AIRS cloud-cleared radiances on the representation of Polar Lows

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Polar lows are mesoscale high-latitude cyclones that form over the ice-free ocean poleward of the midlatitude jet stream during winter and spring season. Due to their rapid growth at sub-synoptic scales in regions with very few traditional observations, prediction of polar lows using conventional assimilation methods remains challenging. This study explores the sensitivity of polar lows in the Southern Ocean to the assimilation of cloud-cleared AIRS (Atmospheric Infrared Sounder) radiances in the Goddard Earth Observing System (GEOS, version 5) data assimilation and forecast system during the austral spring 2014 season using observing system experiments (OSEs). Assimilating AIRS cloud-cleared radiances (CCR) instead of the current, operational clear-sky only radiances is found to benefit the representation of convectively-driven small-scale cyclones at high latitudes at no loss of global skill. In a manner previously noted for tropical cyclones, the assimilation of CCRs creates a temperature dipole over the top of meteorologically active and strongly convective systems such as Antarctic lows, which helps improve the analyzed representation of their scale and vertical structure.

Short-range sea ice forecasting in the Barents and Kara Seas to support ship navigation

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[2]Finnish Meteorological Institute, Finland
3Swedish Meteorological and Hydrological Institute/Institute of Marine Research, Sweden

Barents and Kara Seas are located on the western part of the Northern Sea Route (NSR) and are thus important regions for shipping. With the shrinking sea ice cover, the Northern Sea Route has been open and navigable more often during the last years and also shipping to and from local ports in the Kara Sea is increasing. For such ship operations, knowledge about the ice conditions is crucial for route planning. The current state of the ice cover can be obtained from satellite images, which are very valuable for tactical navigation, but in order to estimate the future evolution of the ice state numerical models are needed. A first version of such a sea ice forecast model system for the Kara and Barents Seas has been set up at the Finnish Meteorological Institute. It consists of a regional setup of the ocean--sea-ice model NEMO-LIM3 using weather forecast data from ECMWF as surface forcing and lateral boundary forcing data from Copernicus. The resolution of about 4 km is sufficient to resolve small scale features like shore leads. The system is run automatically once a day using the scheduler ecflow. The skill of the 10-day forecasts has not yet been evaluated but we expect that the model can produce valuable information about the location of open water areas, the ice concentration and the ice thickness. Furthermore, the model output can be converted into quantities that are targeted specifically to shipping activities: The Risk Index Outcome, calculated following Polar Code's POLARIS system, provides estimates of the risk for ships navigating in the ice. Forecasts of such end-user friendly quantities can support safe navigation in the Kara Sea.

The Sea Ice Drift Forecast Experiment

Goessling, Helge F.[1]; Schweiger, Axel[2]; SIDFEX Lead Team and Contributors

[1]Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Germany
[2]University of Washington, USA

The Sea Ice Drift Forecast Experiment (SIDFEx) is a YOPP community effort to solicit, collect, and analyze sea ice drift forecasts, based on arbitrary methods, for a number of IABP sea-ice buoys on a regular basis. SIDFEx is inspired by increasing research and operational needs to forecast future positions of assets drifting in Arctic sea ice. 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. A systematic assessment of real drift forecasting capabilities is foreseen to improve our physical understanding of sea ice and to identify and resolve model shortcomings. Since the launch of SIDFEx in summer 2017, nine groups have started contributing drift forecasts to SIDFEx on a regular basis. Most groups derive their 10-days to seasonal-range forecasts by means of diagnostic tracking based on prediction drift fields of coupled or uncoupled general circulation models. Forecasts based on satellite-derived drift fields of past years serve as a proxy for a climatological reference forecast. Some groups submit ensembles of drift trajectories instead of single (deterministic) trajectories, and several groups submit their forecasts in near-real-time. A software package to search, visualise and analyse SIDFEx forecasts online and offline is under development. Ultimately, SIDFEx will supply (experimental) drift forecasts for the MOSAiC Arctic ice drift campaign which commences in autumn 2019.

Evaluation of six atmospheric reanalyses over Arctic sea ice during winter and spring

Graham, Robert M.[1]; Cohen, Lana[1]; Ritzhaupt, Nicole[2]; Segger, Benjamin[3]; Graversen, Rune G. [4]; Rinke, Annette[3]; Walden, Von P.[5]; Granskog, Mats A.[1]; Hudson, Stephen R.[1]

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[3]Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Germany
[4]University of Tromsø, Norway
[5]Washington State University, USA

This study evaluates the performance of six atmospheric reanalyses over Arctic sea ice during winter and spring. The reanalyses include ERA-Interim, ERA5, JRA-55, CFSv2, MERRA 2 and ASRv2. These reanalyses are compared with atmospheric observations from the Norwegian young sea-ICE campaign (N ICE2015). N ICE2015 consisted of a five-month ice drift in pack-ice north of Svalbard. The atmospheric observations include surface meteorology, vertical profiles from radiosondes, as well as radiative and turbulent heat fluxes. Overall, the reanalyses perform remarkably well for the winter season (January-March). Correlation coefficients (R) between the reanalyses and observations are above 0.90 for the mean sea level pressure, 2 m temperature, total column water vapour, and downward longwave flux. All reanalyses exhibit a positive 2 m temperature bias of 1–4˚C and upward net longwave bias of 3–19 W m-2. These biases are associated with poorly represented surface inversions and hence foremost with cold stable periods. Notably, these biases are not reduced in the newly released ERA5 or Arctic regional reanalysis ASRv2. JRA 55 captured the most accurate distribution of winter 2 m temperature. In spring (April-June), all reanalyses failed to simulate observed persistent elevated cloud layers. As a result, the reanalyses overestimated the downward shortwave flux by 1–82 W/m2 and underestimate the downward longwave flux by 0–41 W/m2. While optimised for the Arctic, ASRv2 did not perform better than any of the global reanalyses for these surface radiative fluxes. However, substantial improvements in these spring fluxes are identified for ERA5 over the earlier ERA-Interim.

Session F: Sea Ice and Ocean – Tuesday, January 15th 14:00-14:15

Recent observations of sea ice thickness change in the Arctic

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As the Arctic sea ice cover continues to shrink, the causes and consequences of its specific variability and change are still not well understood nor accurately predictable. Ice thickness is an important sea ice property that needs to be better observed on regional and basin scales to help untangle the various thermodynamic and dynamic processes affecting the ice, and that is required to initialize seasonal forecasts. Here we present results from airborne electromagnetic (EM) ice thickness surveys of some of the key multiyear ice regimes north of Greenland and Canada carried out during the YOPP special observing periods in 2018. These show large interannual and regional variability superimposed on a slow thinning trend. However, they also show that the region of the thickest multiyear ice had retreated to a narrow zone north of the coasts of Greenland and Canada in 2018. A special opportunity arose during a survey of a prominent refrozen polynya north of Greenland in March 2018. The polynya had only formed a month earlier and its refreezing and closing were well observed by satellite synthetic-aperture radar images. Results show strong thermodynamic growth and a mean thickness that was twice as large as the modal thickness of the one month old ice. This natural month-long deformation experiment lends itself for modeling studies of ice deformation and rheology. All data and results are available for model validation, assimilation, and sea ice forecasting.

Session E: Atmosphere – Tuesday, January 15th 14:30-14:45 – Poster ID: #E04

Polar lows in the ECMWF versus Arome Arctic models

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Polar lows are small, intense cyclones on the cold side of the polar front. They produce short-lived, but intense storms with heavy snow showers and strong, gusty winds that can cause extensive damage. Historically, they have been poorly represented in global model systems like the one operated by the ECMWF. However, after the upgrade of the HRES model to 9 km horizontal grid spacing in 2016, the model has represented some polar lows explicitly. Here we compare the performance of the ECMWF products with the Arome Arctic limited area model with 2.5 km resolution. Since the resolutions of these models are within the convective "grey zone" where convection is partly but not fully resolved, we performed sensitivity tests on ECMWF HRES with 5 km resolution and with the deep convection parametrization scheme turned off. Our analysis showed that turning off the convection scheme produced higher wind speeds while changing the resolution had a minimal effect. All ECMWF experiments gave far too low winds compared to observations. Arome Arctic was closer but did not capture the highest wind peaks correctly. These preliminary results suggest that the handling of deep convection was more important than the horizontal resolution.

Boundary layer measurements at Cape Baranov (YOPP project CATS-BL)

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[2]Arctic and Antarctic Research Institute (AARI), Russia

The goal of the project was the generation of a new data set of in-situ observations of the (ABL) in the high Arctic for the verification of regional climate models and process atmospheric boundary layer studies. We performed measurements of the ABL structure for one year (Sept. 2017-Sept. 2018) at the Russian station Cape Baranov (79°18'N, 101°48'E), which is one of the northernmost observatories in the Arctic. The measurements are part of the project CATS (Changing Arctic Transpolar System) as a joint effort of AARI and the University of Trier. ABL measurements were made using a SODAR (Sound Detection And Ranging), a RASS (Radio Acoustic Sounding System) and large-aperture boundary layer scintillometer (BLS). The SODAR yields vertical profiles of the wind speed, wind direction and the turbulence characteristics with a vertical resolution of 10m and a temporal resolution of 15-20min. The RASS extension allows for the determination of the temperature profile with the same resolution. In addition, the BLS was used to measure line-averaged sensible heat fluxes. The measurements covered the YOPP Special Observing Periods (SOPs) in the Arctic (Feb-Mar 2018 and Jul-Sep 2018). First results of the measurements are presented. The height range of the SODAR wind profiles was typically around 400m (mean data availability 50%), temperature profiles from RASS are generally available for the lower 300m. A stably-stratified ABL is typical for wintertime conditions, but only few strong low-level jets were found. A topographical channeling effect for the wind field can be seen in the lowest 100m with the highest frequency of strong winds (larger than 15 m/s).

Influence of Atmospheric and Oceanic Model Resolution on Volume and Heat Transports through Arctic Gateways in Coupled Climate Simulations

Hinrichs, Claudia[1]; Wang, Qiang[1]; Sein, Dmitry[1]; Koldunov, Nikolay[1]; Jung, Thomas[1]

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Coupled climate simulations were performed with four different combinations of atmospheric and oceanic horizontal resolutions in our mixed-resolution experiments (OCE_LR+T63, OCE_LR+T127, OCE_HR+T63, OCE_HR+T127). We investigated the effect of horizontal grid resolution on volume and heat transports through the Arctic gateways and found that the difference in ocean resolution accounts for most of the differences in simulated present-day and future volume and heat transports through the gateways - most prominently in the Atlantic sector through the Fram Strait and at the Barents Sea entrance. In Fram Strait, with the lower ocean resolution a higher increase in net outflow is predicted for the end of the 21st century than with higher ocean resolution. This is mainly driven by a predicted decrease in inflow through Fram Strait. For the Barents Sea entrance the net inflow is predicted to increase towards the end of the first century. This predicted increase is also higher with lower resolution. At the Barents Sea entrance all simulations predict a considerable increase of heat transport into the Arctic. In accordance with the predicted higher volume transport into the Barents Sea in the lower resolution ocean, the heat transport is also significantly higher with lower ocean resolution. Between low and high atmospheric resolution, the predicted end-century heat transport into the Barents Sea is higher with higher atmospheric resolution on both ocean grids.

Session E: Atmosphere – Poster ID: #E05

Monitoring and Forecasting Presence and Influence of Atmospheric Super-Cooled Liquid Water Containing Clouds in the Vertical Profile – Final Results of the Project

Hirsikko, Anne[1]; Hämäläinen, Karoliina[1]; Leskinen, Ari[1]; Ruuskanen, Annti[1]; Komppula, Mika[1]

[1]Finnish Meteorological Institute, Finland

Clouds have a significant role in the atmospheric hydrological cycle. Phase of hydrometeors determines cloud radiative, dynamical and microphysical properties. In the high latitudes mixed-phase clouds are frequently associated with long-lasting super-cooled liquid water containing layer on their top. Super-cooled liquid water layers can occur in one or more cloud layers in vertical profile of the atmosphere. Super-cooled liquid water droplets can cause icing. Icing, as phenomenon, is essentially controlled by amount of super-cooled liquid water and number size distribution of droplets. Icing is known for its significant hazard risk for aviation and transport sectors. Until recent, observational monitoring and forecasting with numerical weather prediction models of clouds causing icing have been challenging. The Finnish Meteorological Institute (FMI) has carried out a two-year research project "Observations of atmospheric icing conditions with ground-based remote-sensing techniques". The project investigated potential to use a ceilometer to monitor atmospheric icing conditions in the vertical profile. We developed a new method to identify super-cooled liquid water containing clouds from ceilometer attenuated backscatter profile observations. The method was validated against in-situ icing rate and in-cloud droplet size distribution observations. Results from method validation suggests that the ceilometer can be used as real-time monitor for super-cooled liquid water containing clouds. FMI operates an icing forecast model (based on ISO STANDARD 12494) which is fed with atmospheric parameters from operational HARMONIE model. Results of icing forecast model were evaluated with ceilometer observations in order to validate current model representation. In the conference final concluding remarks of the project's results will be discussed together with future perspective.

Session B: User Engagement and Projects – Monday, January 14th 16:00-16:15

Who are the end-users of improved polar environmental forecasting services?

Hooghiem, Marijn Anna Cornelia[1]; Lamers, Machiel[1]

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Who are the end-users of improved polar environmental forecasting services? The higher latitudes of our planet are changing rapidly. The context of these intertwined climatic, environmental, technological and socio-cultural developments are demanding reliable and accurate climate weather and ice services. The primary goal of the Polar Prediction Project (PPP) is to improve the understanding of physical phenomena within the Arctic and Antarctic in order to enable the development of improved environmental forecasting services in these regions. In other words, investments in polar observation and modelling should ultimately benefit societal end-user groups and economic sectors, through the applications of improved weather, ice and climate services. This relation cannot be taken for granted. It has been claimed that there is a typical discrepancy between what is scientifically interesting and practically relevant (Thoman et al., 2017). The extent to which this objective of saliency is reached within PPP remains unclear. This paper aims to contribute to understanding the saliency of PPP by providing an overview of the end-users reported in YOPP-endorsed projects. Currently there are over a fifty PPP endorsed projects that take place within the Arctic and Antarctic region, varying from observation & modelling research to socio-economic research and interdisciplinary projects. As part of the social science agenda within PPP there is a need for a stocktaking of the societal interests served by these projects. By undertaking a content analysis on PPP documentation and endorsed projects, and by possibly interviewing project leaders, we aim to establish an important baseline for evaluating PPP from a social science perspective in the coming years. What are key end-user groups mentioned in the project documentation (shipping, tourism, indigenous communities)? Who will benefit? Are stakeholders implicitly or explicitly mentioned as end-users? Is there mentioning of consultation of, or a co-creation process with, particular stakeholder groups? In other words how do these projects involve society in the process of improving weather and environmental prediction services in a way that they will ultimately benefit society within the Arctic, Antarctic and beyond.

Session A: Coupled Atmosphere-Ocean-Sea Ice – Poster ID: #A10

Repeat fixed-wing UAV surveys to determine controls on seasonal acceleration of Store Glacier, West Greenland

Hubbard, Alun[1]; Ryan, Johnny[2]; Box, Jason[3]; Doyle, Sam[4]

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[3]Geological Survey of Denmark and Greenland (GEUS), Denmark
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Despite progress using remote sensing to characterization of the seasonal velocity patterns of Greenland's calving outlet glaciers, the mechanisms that cause these variations remain poorly understood. Here, we determine the drivers of Store Glacier's seasonal flow patterns using a dense series of unmanned aerial vehicle surveys between May and July 2014. We find that large calving events cause abrupt short-term (6-hour) accelerations at the terminus. The frequency of large calving events increases after the break-up of the ice mélange - a rigid mixture of icebergs and sea-ice floating in front of the glacier terminus - and the events appear to be responsible for the early melt-season acceleration of Store Glacier. Later in the melt-season, terminus velocities decrease after two supraglacial lake drainage events, suggesting that the structure of the subglacial hydrological system evolves and mitigates the acceleration of ice flow caused by increased calving activity. We conclude that the interplay between calving, meltwater lubrication and subglacial drainage evolution explains the complex response of Store Glacier to seasonal oceanic and atmospheric forcing.

Invited Talk – Monday, January 14th 11:00-11:25

Large-scale Arctic sea ice modeling: Forging a community

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The CICE sea ice model is used extensively by climate and Earth system research groups, and also by operational centers for applications such as numerical weather prediction and guidance for military operations. While the research community is energetically improving the models, observationalists are busy taking measurements and operational experts are using all of it to produce predictive products via data assimilation. In the past, the sea ice research and operational communities have been somewhat distinct with little cross-pollination. Partly in response to this issue, the CICE Consortium has formed as a formal community effort to to provide a mechanism for accelerating further sea ice model development and its transfer into operational uses. This colloquium will provide a broad overview of current CICE model capabilities and uses, highlight new development activities and analysis techniques for statistically assessing model skill against diverse observations, and discuss our community engagement effort, all toward addressing society's needs in the face of the Earth's changing polar regions.

Japanese activity using RV Mirai (Part 1): Predictability studies of ice-free ocean wave height in the Arctic and tracks of tropical cyclones over the North Atlantic

Inoue, Jun[1]; Sato, Kazutoshi[2]; Yamazaki, Akira[3]; Waseda, Takuji[4]

[1]National Institute of Polar Research, Japan
[2]Kitami Institute of Technology, Japan
[3]Japan Agency for Marine-Earth Science and Technology, Japan
[4]The University of Tokyo, Japan

The Arctic research cruise using the Japanese research vessel Mirai was made over the southern Chukchi Sea in autumn 2016. Two pre-YOPP activities were made. One is wave-buoy deployments over the ice-free ocean to monitor the wave height during the pre-freezing period (Waseda et al. 2018 Sci. Rep.; Nose et al. 2018 Ocean Dyn.); the other is 6-hourly radiosonde observations to understand a remote influence on the summertime mid-latitudes atmospheric circulations, in particular, tropical cyclones (Sato et al. 2018 Sci. Rep.). Wave buoy data demonstrated two high wave events with the significant wave height of about 4.7 m during September and October associated with storms. The NOAA-WAVEWATCH III model with the 16-km resolution was forced using wind and sea ice reanalysis data (ERA-interim) and obtained general agreement with the observation. The September storm was reproduced well; however, model accuracy deteriorated in October with a negative wave height bias of around 1 m during the October storm. The analysis has found that there is a 20% reduction of in situ SLP observations in the area of interest, presumably due to fewer ships and deployment options during the sea ice advance period. Our ensemble atmospheric reanalysis showed that this led to a larger ensemble spread in the October monthly mean wind field compared to September. As for the remote atmospheric influences, during September 2016, several tropical cyclones (TCs) were found over the North Atlantic. The prediction of the intensity and track of TCs are examined by using additional Arctic radiosonde observations and an ensemble data assimilation system. Comparisons with ensemble reanalysis data revealed that large errors propagate from the data-sparse Arctic into the mid-latitudes, together with high-potential-vorticity air. Ensemble forecast experiments with different reanalysis data confirmed that additional Arctic observations sometimes improve the initial conditions of upper-level troposphere circulations. In 2018, RV Mirai will conduct the same kind of observations. The target season is not September but November. The summary of the early winter observations will be presented.

Validation of the Arome Arctic Numerical Weather Prediction Model - A Case-Based Study

Kähnert, Marvin[1]; Jonassen, Marius O.[2]; Valkonen, Teresa[3]; Buehler, Stefan A.[4]

[1]University of Bergen, Norway
[2]University Centre in Svalbard, Longyearbyen, Norway
[3]Norwegian Meteorological Institute, Norway
[4]University of Hamburg, Germany

Dedicated to the European Arctic, AROME Arctic is a newly developed, convection permitting numerical weather prediction model, operational since 2015. This study is one of the first to validate AROME Arctic based on model independent observations. For this purpose, near-surface and upper-air observations from two field campaigns conducted in central and western Spitsbergen during late winter 2014 and early spring 2016 are used. Focusing mainly on temperature and humidity, the model is shown to perform generally well for both of these datasets. Biases do exist, however, and in the near-surface data moist biases are found over land and dry biases over the sea. Furthermore, a dominant cold bias is documented over land, which is attributed to a negative bias in the net longwave radiation. Both the down-welling and up-welling longwave radiation components contribute to this bias, with the former contributing the strongest, particularly during conditions with a high fractional cloud cover. Some of the largest errors in the modelled lower-tropospheric profiles are found in connection with the passage of a synoptic front during the 2016 campaign. This is related to the misrepresentation of an elevated temperature inversion. The challenges in modelling the Arctic atmosphere documented herein could potentially be addressed by improving the representation of cloud microphysics processes and near-surface turbulent fluxes over land and sea.

Session D: Verification – Tuesday, January 15th 12:15-12:30

What's in a Name? - Matching Observational Data with Model Output

Khalsa, Siri Jodha[1]; Uttal, Taneil[2]; Casati, Barbara[3]; Day, Jonathan[4]; Svensson, Gunilla[5]

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[3]Environment and Climate Change Canada, Canada
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[5]Stockholm University, Sweden

A primary goal of the Year of Polar Prediction is to demonstrate advancements in numerical weather prediction arising from model improvements and enhanced observation efforts that YOPP is helping to coordinate. A concerted effort is underway to specify a set of core data fields that all model simulations will produce in order to facilitate model intercomparisons and verification of model data against observations. A set of "Supersites" have been identified where multi-variate, high-frequency observations are being acquired for model process evaluation. The International Arctic Systems for Observing the Atmosphere (IASOA) is coordinating the effort to define a common set of observatory outputs, to be distributed in what is being called Merged Observatory Data Files (MODFs) for YOPP. The objective is to make MODFs consistent with YOPP model output files by matching variables, time interval and averaging conventions, levels and units, as well as file format. The IPCC CMIP and SIMIP have established common names to be used by models participating in those comparisons, and these names are being proposed for YOPP common model outputs. For the in-situ data IASOA has developed a thesaurus of variable names for observatory outputs. To achieve a common understanding of data, especially in an interdisciplinary context, it is important that the names used to describe concepts and measurables have persistent, web-resolvable identifiers with definitions. The Climate and Forecast standards names (http://cfconventions.org/standard-names.html) and the geoscience standard names (http://geoscienceontology.org) are two such resources. This presentation will describe how we have attempted to harmonize the names of variables in MODFs with the YOPP common model output names, aligning them with these established semantic resources.

Session E: Atmosphere – Poster ID: #E07

Observations of Meteorological Profiles, Clouds and Radiative Fluxes Over the Arctic Ocean during SOP-NH2

Kim, Joo-Hong[1]

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In the 2018 Arctic Expedition of the Korea Polar Research Institute (KOPRI) IBRV Araon (4th August to 20th September), ship-borne meteorological observations (e.g., radiosondes, micro-pulse lidar, cloud camera, radiometer, etc.) were enhanced to fulfill our committed mission for the Year of Polar Prediction (YOPP)'s Northern Hemispheric Special Observing Period 2 (SOP-NH2). For the entire cruise period, we obtained vertical profiles of meteorological variables (temperature, humidity, pressure and horizontal winds) and clouds, sky cloud images, and surface radiative fluxes over a variety of surface and synoptic conditions. In particular, we allowed the regular 6-hourly radiosonde data on-line by broadcasting them real-time via the Global Telecommunication System (GTS). The additional real-time radiosonde vertical profiles in the high-latitude Arctic Ocean are valuable products for contributing to their impacts on operational weather forecasts in the NH Arctic and mid-latitudes. Those data have been used to assess the predictability impact by their additional assimilation to the in-house forecast system of KOPRI. The combined ship-borne observations will be applied for various studies on the characteristic variability of the vertical distribution of Arctic summer clouds and the quantification of surface radiative effects of Arctic summer clouds, which depend on synoptic patterns, inversion structures. Preliminary results will be analyzed after completion of the entire cruise and presented in the workshop.

On the impact of sea ice assimilation for seasonal predictability of the Arctic

Kimmritz, Madlen[1]; Counillon, François[1]; Wang, Yiguo[1]; Keenlyside, Noel[1]; Bethke, Ingo[1]

[1]Nansen Environmental and Remote Sensing Center, Bjerknes Center, Norway

We discuss the impact of assimilating sea ice concentration (SIC) within the Norwegian Earth system model, that combines the fully coupled Norwegian Earth system model (NorESM) with an ensemble Kalman filter data assimilation method, on the predictive skill in the Arctic. In an observing system simulation experiment (OSSE) we identify the optimal implementation of SIC assimilation in NorESM, that contains a multicategory sea ice model. Our key findings are: a) an update of SIC in each individual category largely improves SIC and sea ice thickness (SIT) without introducing a drift b) joint update of the ocean and the sea ice results in an enhanced performance of the ocean and the sea ice component. These are used in a realistic setting in combination with assimilating sea surface temperature and sub-surface hydrographic data, and compared to the version of the system without assimilation of sea ice data. We identify the impact of ocean only assimilation on the ice state and assess the added benefit of SIC assimilation on the ice state and its impact for the ocean. The seasonal prediction of sea ice extent is greatly enhanced for all sub-regions of the Arctic in the case of a jointly assimilated ocean and sea ice state. But, ocean only assimilation leads to regionally and seasonally improved forecast skill already. In our discussion we will identify regions and seasons a) in which the variability predominantly is driven by the ocean and thus already successfully constrained by assimilation of only oceanic data, and b) in which additional assimilation of sea ice data enhances the forecast skill.

Session B: User Engagement and Projects – Monday, January 14th 16:30-16:45

Toward salient metocean services for the marine Arctic: exploring metservice perspectives on the user-producer interface

Knol, Maaike[1]; **Jeuring, Jelmer[2]**; Sivle, Anders[3]

[1]University of Tromsø, Norway
[2]Umeå University, Sweden
[3]Norwegian Meteorological Institute, Norway

In the context of polar prediction, there is growing and widespread recognition that better metocean services for marine, Arctic environments can only be produced in close dialogue with the actual users of these services. This denotes an acknowledgment that knowing how users incorporate metocean information in their activities should be considered throughout the value chain. Notions like co-design, co-production and salience are often used in these contexts. However, little is known about how such concepts are operationalized in the practical context of the national meteorological services' tasks and responsibilities. Based on – among more - a series of in-depth, qualitative interviews with a diversity of personnel from the Norwegian Meteorological Institute, we describe the shifting dynamics of the relationship between metocean service providers and their maritime users operating in Arctic environments, both in their day-to-day and strategic interactions. We include a discussion of the role of technological advancements, the growing potential of user observations, and the increasing automation of meteorological practices, and how these trigger shifting relations, roles and responsibilities.

Equations for Thaw Settlement Calculation

Kotov, Pavel[1]

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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 [1]. 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 [2]. The work was supported by the Russian Foundation of Basic Research (projects no 16-35-00227).

References 1. Roman L.T. 2002. Frozen soil mechanics. Moscow, Academic publishing house "Nauka/Interperiodica", 426 p. (in Russian) 2. Forecast settlement of frozen soils after thawing / P. I.Kotov, L. T. Roman, M. N. Tsarapov // Journal of Engineering of Heilongjiang University. — 2014. — Vol. 5, no. 3. — P. 8–12.

A NWP model inter-comparison of surface weather parameters during the Year of Polar Prediction Special Observing Period 1

Køltzow, Morten[1]; Casati, Barbara[2]; Bazile, Eric[3]; Haiden, Thomas[4]; Valkonen, Teresa[1]

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[2]Environment and Climate Change Canada, Canada
[3]Meteo France, France
[4]European Centre of Medium-range Weather Forecast (ECMWF), United Kingdom

The Arctic experience rapid changes in its harsh climate and environment. An anticipated increase in ship traffic, resource exploitation, tourism and other activities call for accurate and reliable weather predictions for safe and efficient operations. Still, it is reported that Arctic weather forecasts verify worse than at lower latitudes. High resolution limited area models are one way to improve the forecast skill with the possibility of increased resolution and more targeted description of physical processes. In this study we take advantage of the modelling efforts during the Year of Polar Prediction (YOPP) Special Observing Period 1 (SOP1). A model inter-comparison of three limited area convective permitting models and the global IFS HRES model for their overlapping domain in the European Arctic is presented. The three high resolution limited area models are AROME Arctic (in daily operational use at MET Norway with 2.5 km horizontal grid spacing), the Canadian Arctic Prediction System (a Pan Arctic YOPP dedicated model system at Environment and Climate Change Canada with 3 km grid spacing) and a Meteo France set up of the AROME model (dedicated for the YOPP SOP1 with 2.5 km grid spacing). The inter-comparison domain is divided into homogeneous regions for a more stratified verification and forecasts of temperature, wind speed, precipitation, cloud cover and mean sea level pressure are compared with surface observations. Furthermore, over ocean areas, satellite-based Advanced Scatterometer wind product is used for verification. None of the model systems perform superior to the others for all parameters, regions or verification metrics. However, while some forecast challenges are similar for all model systems, there are also challenges that are unique to only some of the systems. These similarities and differences will be presented and discussed. In addition, we will touch on some aspects of how observation uncertainty and representativity influence model verification in the Arctic.

Invited Talk – Monday, January 14th 11:25-11:50

Co-production and user engagement in Arctic metocean forecasting: Experiences from the SALIENSEAS project

Lamers, Machiel[1]

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The gap between scientific observations and modelling and stakeholder needs is recognized as a barrier in the production of actionable, decision-relevant knowledge. This gap is at the core of a number of partnerships and projects to help tailor Arctic weather and sea-ice predictions to user needs. The Year of Polar Prediction (YOPP) aims to improve polar environmental monitoring and forecasting. YOPP also aims to strengthen interaction and communication between polar forecast providers and users. Meeting the challenge to ensure societal value from scientific efforts demands the application of social and interdisciplinary science to better understand the vulnerabilities and resilience of sectors and communities and the way weather and ice forecasts relate to relevant decision-making processes. Across the polar regions, these users range from small indigenous communities scattered across the circumpolar Arctic, to regional industries and governmental activities relying on public weather services or private providers for information, to multi-national commercial ventures that may fund their own extremely specialized weather or sea ice products for their own uses. It also requires improved methods of co-production and engagement with users to enhance the social and economic value of polar prediction across a spectrum of potential user communities and sector. This presentation will outline and discuss outcomes of the co-production approach followed in the SALIENSEAS project. SALIENSEAS (Enhancing the saliency of climate services for marine mobility sectors in European Arctic seas) is an international project that aims to contribute to improved services at short and longer temporal scales in the Arctic maritime mobile sector, particularly cruise tourism, shipping and fisheries. The project brings together social scientists, climate scientists, service providers and users in iterative ways. By analyzing contexts of various marine mobilities, including their sociomaterial and spatiotemporal characteristics, and the network of service users and producers, the project aims to contribute to a more enhanced understanding of user needs. Further, by simulating services use of different Arctic maritime sectors through participatory methods (e.g. scenario workshops, serious gaming) the project aims to explore effective spatiotemporal resolutions for information delivery. Finally, the project develops, tests and evaluates a range of demonstration services, based on both existing and enhanced models, for conditions and contexts identified by our collaborating end-users.

Surface heat flux studies at the "Ice Base Cape Baranova"

Laurila, Tuomas[1]; Hatakka, Juha[1]; Aurela, Mika[1]; Asmi, Eija[1]; Loskutova, Marina[2]; Kustov, Vasilii[2]; Movchan, Vadim[2]; Makshtas, Alexander[2]

[1]Finnish Meterological Institute, Climate System Research, Finland
[2]Arctic and Antarctic Research Institute, Russia

Finnish Meteorological Institute (FMI), together with Arctic and Antarctic Research Institute (AARI) of the Russian Hydrometeorological Service started continuous GHG, aerosol and meteorological observations at the Arctic observatory "Ice Base Cape Baranova".
FMI measurements started in October 2015 at "Ice Base Cape Baranova" (79°16.82'N, 101°37.05'E), which is located at the very northern part of the Bolshevik island to the north from Taimyr. Ice cover exists from October to August but ice may be present also in autumn. In this presentation, we show observations of surface heat balance components in 2018 during polar day and night and transitional periods.

ECMWF Activities Connected to Polar Prediction Project

Magnusson, Linus[1]; Sandu, Irina[1]; **Day, Jonathan J.** [1]; Bauer, Peter[1]; Fuentes, Manuel[1]; Mladek, Richard[1]; Arduini, Gabriele[1]

[1]European Centre for Medium-Range Weather Forecasts (ECMWF), United Kingdom

ECMWF is contributing in several ways to the World Meteorological Organisation's Polar Prediction Project (PPP), which aims to improve weather prediction and services for the polar regions. For example, during the Year of Polar Prediction (YOPP), ECMWF is providing an extensive global data set of coupled forecasts for the community. The data set includes model tendencies to facilitate process evaluation. As a part of EU-H2020 project APPLICATE, which supports YOPP and PPP, ECMWF is also assessing how the observation network in the Arctic helps to improve weather forecasts, developing a new snow scheme for the Integrated Forecasting System, performing targeted verification for the Arctic and developing new diagnostic tools. This poster will highlight all these different activities related to PPP, and its core activity YOPP.

Linking PEEX with Russian Arctic Observations and Datasets

Mahura, Alexander[1]; Petäjä, Tuukka[1,2]; Lappalainen, Hanna K.[1,2,3]; Oblogov, Gleb[2]; Vasiliev, Alexander[2]; Borisova, Alla[1]; Bashmakova, Iryna[1]; Altimir, Nuria[1]; Chalov, Sergej[4]; Konstantinov, Pavel[4]; Bäck, Jaana[1]; Järvi, Leena[1,5]; Ojala, Anne[1]; Pumpanen, Jukka[1]; Noe, Steffen M.[6]; Duplissy, Ella-Maria[1]; Pankratov, Fidel[7]; Shevchenko, Vladimir[8]; Varentsov, Mikhail[4]; Baklanov, Alexander[9]; Ezau, Igor[10]; Zilitinkevich, Sergej[1,2,3,4,11]; Kulmala, Markku[1,2]

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[7]Institute of Northern Environmental Problem, Kola Science Centre of the Russian Academy of Sciences, Russia
[8]P.P. Shirshov Institute of Oceanology, Russian Academy of Sciences, Russia
[9]World Meteorological Organization (WMO), Switzerland
[10]Nansen Environmental & Remote Sensing Centre (NERSC), Norway
[11]Nizhny Novgorod State University (NNSU), Department of Radiophysics, Nizhny Novgorod, Russia - Institute of Geography, Russian Academy of Sciences, Moscow, Russia - Institute of Applied Physics, Russian Academy of Sciences, Russia

Pan-Eurasian EXperiment (PEEX; www.atm.helsinki.fi/peex) initiative is an international, multi-disciplinary, multi-scale programme focused on solving interlinked global challenges influencing societies in regions of the Northern Eurasia, including Russia and China. In particular, PEEX is aimed to establish in-situ observation network covering environments from the Arctic coastal regions, tundra to boreal forests, from pristine to urban megacities. It is based on existing stations activities and establishing new stations towards a comprehensive observation network. Overview of measurement capacity of exiting stations was one of the first steps. Although more than 200 stations are presented in PEEX domain, only about 60 Russian stations have metadata information available (peexdata.atm.helsinki.fi - under request). The metadata enables to categorize stations in a systematic manner and to connect them to international observation networks as well as to standardize data formats following guidelines of WMO, GAW, etc. PEEX provides e-catalogue (as living document) introducing measurements and contact information of the Russian stations. The catalogue aim is to promote PEEX research collaboration and stations as partners of collaboration network and to give wider visibility to the stations activities. As INTAROS contribution, the updated metadata were obtained from 11 stations located within the Russian Arctic. Metadata include basic information on measurement sites, description physico-geographical conditions, instrumentation and infrastructure peculiarities; details on atmosphere and ecosystem (including soils–forest–lakes–urban–peatland–tundra) observations. Measurements at these sites represent more local conditions of immediate surrounding environment and datasets are available under request. As a "show case" of the PEEX Observational System capabilities, detailed analysis (including

inter-annual, month-to-month and diurnal cycle variabilities of meteorological and ecosystem parameters) for selected Russian station (Marre-Sale) is presented. Obtained results underline climatic and environmental changes observed in the Russian Arctic. As iCUPE contribution, datasets as products for researchers, decision- and policy makers, stakeholders and end-users will be produced and publicly available for different applications. Focusing on the Arctic region territories, the planned datasets will include novel data on anthropogenic contaminants in snow and ice cores and organic contaminants in the air-snow-water; concentrations of different chemical species and aerosols as well as their characteristics including vertical profiles; various atmosphere-hydrosphere-cryosphere-etc. related parameters in the Arctic based on ground-airborne-satellite-etc. platforms; near-real time parameters of the Arctic Research Infrastructures; others. Some datasets will focus on selected areas in northern latitudes, others - on geographical locations (measurement sites). The planned datasets are promoted through so-called "teasers" (www.atm.helsinki.fi/icupe/index.php/submitted-datasets). These also include those from the iCUPE collaborators for the Russian Arctic: atmospheric mercury measurements at Amderma station; elemental and organic carbon over the northwestern coast of the Kandalaksha Bay of the White Sea; micro-climatic features and Urban Heat Island Intensity in cities of Arctic region; and others.

Results of hydrometeorological studies at Research station "Ice Base "Cape Baranova" during YOPP

Makshtas, Alexander[1]; Kustov, Vasilii[1]; Bogorodskii, Petr[1]; Makhotina, Irina[1]; Loskutova, Marina[2]; Heinemann, Günther[2]

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[2]Dept. of Environmental Meteorology, University of Trier, Germany

Results of hydrometeorological studies at Research station "Ice Base "Cape Baranova" during YOPP Alexander Makshtas, Vasilii Kustov, Petr Bogorodskii, Irina Makhotina, Marina Loskutova Arctic and Antarctic Research Institute (AARI), 199397 St. Petersburg, Russia Günther Heinemann Dept. of Environmental Meteorology, University of Trier, 54286 Trier, Germany. The results of meteorological and radiation measurements and observations of cloudiness and state of the underlying surface (permafrost, fast ice) obtained in 2018 together with preliminary analysis of air - surface interaction processes in different seasons of the year are presented. The measurements covered the YOPP Special Observing Periods (SOPs) in the Arctic (Feb-Mar 2018 and Jul-Sep 2018).

Session E: Atmosphere – Poster ID: #E09

An Evaluation of Wind Profile Observations at the Iqaluit Supersite

Mariani, Zen[1]; Crawford, Robert[1]; **Casati, Barbara[1]**; Laroche, Stéphane[1]; Lemay, François[1]

[1]Environment and Climate Change Canada, Canada

Environment and Climate Change Canada (ECCC) commissioned two supersites to provide automated and continuous observations of altitude-resolved winds, water vapour, clouds and aerosols, visibility, radiation fluxes, and precipitation. The supersites are located in Iqaluit (64oN, 69oW) and Whitehorse (61oN, 135oW). The benefit of integrated measurement systems at these supersites are being investigated to: 1) recommend the optimal cost-effective observing system for the Canadian Arctic that can complement existing radiosonde observations, and 2) provide enhanced meteorological observations during the World Meteorological Organization's Year of Polar Prediction (YOPP). This presentation will describe the suite of instruments at the two supersites and present an evaluation of wind profile observations at Iqaluit by comparing Doppler lidar, radiosonde, and operational numerical weather prediction (NWP) model output from ECCC's Global Environmental Multiscale Model (GEM-2.5 km, GEM-10 km, and GEM-Global). Results indicate good agreement between the Doppler lidar and the radiosonde, with the lidar exhibiting an average bias of -0.48 m/s compared to the sonde and R2 > 0.81 up to 2 km a.g.l. Preliminary results comparing the Doppler lidar's wind profiles and ECCC's GEM model before and during YOPP will also be shown to illustrate the model's performance in Arctic conditions.

Using Numerical Models to Design the Future Arctic Observing Systems: Insights from the APPLICATE Project

Massonnet, François[1]; Sandu, Irina[2]; the APPLICATE WP4 Consortium

[1]Earth and Life Institute, Université Catholique de Louvain, Belgium
[2]European Centre for Medium-Range Weather Forecasts (ECMWF), United Kingdom

Our ability to monitor weather and climate variability in the Arctic is severely hampered by the lack of reliable, long-term and spatially evenly distributed conventional observations. Moreover, despite large data volumes from polar orbiting satellites, these observations are difficult to use in data assimilation because of ambiguous signal properties and because model errors in these regions are large. These shortcomings are likely to contribute to the limited predictive capacity at high latitudes. It is therefore of primary importance to address several questions: Is the current observing system fit for prediction purposes? What is the added value of the current observing systems in existing datasets, i.e. analysis and reanalysis? What are the key variables to monitor? Where and when should these measurements be done? How can these observations be fed into models for initialization? The Horizon 2020 APPLICATE project (2016-2020) aims, among others, at developing evidence-based strategies for the design of future observing Arctic systems, with the final goal to improve Arctic and lower latitude weather and climate predictions. In this work, we highlight several examples showing that Numerical Weather Prediction (NWP) and Seasonal Forecast systems, and more generally Earth System Models (ESM) can be used to inform the polar community about the optimal way to monitor the Arctic and exploit the available observational data. We present a number of case studies: (1) We determine the specific type of observations that contribute most to weather forecast skill using appropriate sensitivity and data denial experiments, (2) we determine the optimal way to deploy a finite number of moorings in order to best reconstruct sea ice volume variability, and (3) we analyze the added value of data assimilation of observed sea ice concentration and thickness for state estimation and prediction purposes. This approach supports the notion that numerical models are valuable tools to guide the development of high-latitude observing systems.

Session F: Sea Ice and Ocean – Poster ID: #F06

SIPN South: Seasonal Sea-Ice Prediction for the Southern Ocean

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The Sea Ice Prediction Network South is a YOPP-endorsed international effort that aims at assessing the skill and value of seasonal sea-ice forecasts for the Southern Ocean. The project enters its main phase and will culminate in the provision of sea-ice forecasts targeting the YOPP austral summer Special Observing Period (January-February 2019). In February 2018, a "dress rehearsal" was carried out highlighting that sea ice is more difficult to predict in certain regions than others (e.g., in the Ross Sea) and that current forecasting systems yield highly scattered results. Here, we conduct a brief evaluation of the 2018 forecasts and present the 2019 summer forecasts for the first time. Possible reasons behind forecast discrepancy will be discussed. Finally, we will present ways to map forecast agreement tailored for possible future users of this data.

Evaluate and improve the usage of Arctic Observation for weather and extended range forecasts using OSEs and OSSEs with NGGPS. Preparation for YOPP and beyond

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Arctic ice has declined during the last decade, and possibly related unprecedented abnormal midlatitude weather has been reported. There is evidence a more complete that Arctic observing system will improve tropical cyclone track forecast in midlatitude. Arctic observations require urgent research efforts for effective planning to prevent or mitigate potentially large societal and economic losses. In this project effective observation system in the Arctic region to improve Arctic and midlatitude extended-range forecasts will be investigated using Observing System Simulation Experiments (OSSE). Global and Regional OSSE, and theoretical prediction can provide complementary information about requirements for future Arctic observing systems. First, OSSE with global coverage will be conducted at relatively low resolution and resolution will then be varied to evaluate how the observation impact depends on the model resolution and various configurations. The impact of higher resolution will be investigated with regional OSSEs with advanced physics over the Arctic. Simulated experiments with idealized observations will be conducted in the initial stage. Idealized observations are designed based on distribution of planned potential observing systems without current technical limitations. The task will be accomplished by making the best use of the recently developed US operational weather forecast system including Next Generation Global Prediction System (NGGPS). The Nature Run is simulated 'truth' for the OSSE. For this project new Nature Run produced by ECMWF with reduced Arctic Ice will be used.

Impact of assimilating AIRS cloud-cleared radiances on atmospheric dynamics and boundary layer height at high latitudes

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High latitude weather forecasts, on scales ranging from mesoscale to synoptic, present difficulties due, in part, to the sparsity of conventional observations. In addition, the prevalence of extended low-level stratus cloud cover limits the use of infrared data, which are operationally assimilated only in areas unaffected by clouds. Use of cloud-cleared AIRS (Atmospheric Infrared Sounder) radiances (AIRS CCR), allows the assimilation of infrared information in cloudy regions, permitting data ingestion in regions usually undersampled. This study explores the sensitivity of planetary boundary layer height and related atmospheric dynamics to the assimilation of these data in the Goddard Earth Observing System (GEOS, version 5) data assimilation and forecast system during the boreal fall 2014 season using observing system experiments (OSEs). Examined here are comparisons between the current, operational approach of assimilating AIRS clear-sky radiances against the assimilation of CCR. Assimilation of hyperspectral infrared information from AIRS over the Arctic region slightly modifies the lower midtropospheric temperature structure, which in turn contributes to adjustments in geopotential height, affecting the baroclinic instability properties over the entire hemisphere and explaining the overall improvement in global forecast skill.

Advanced Use of Non-Conventional Observations in an Arctic Data Assimilation System

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In the Arctic region the conventional observations are very sparse, hence not enough to build an accurate high-resolution initial condition of limited-area NWP systems. By this fact the non-conventional observations play even more important role in data assimilation, but the way such data is usually employed is conservative and suboptimal. One objective of the ALERTNESS (Advanced models and weather prediction in the Arctic: Enhanced capacity from observations and polar process representations) project is an improved use of observations by taking into account the observation footprint in the observation operator. The reduced scale differences between model resolution and the footprint of satellite observations reduces the observations representativeness error, hence improving the use of observations in data assimilation resulting in better initial conditions for Arctic weather prediction. The operational variational assimilation system of AROME-Arctic is used to test this strategy and its observation operator is further developed to match "scale-selectively" the model (via background fields) and observations during the assimilation procedure. The method is tested primarily with scatterometer observations and later going to be examined with AMV (Atmospheric Motion Vectors) and radiance observations from different satellites. Preliminary results are demonstrated through data assimilation diagnostics and case studies.

Session C: Forecasting and Data Assimilation – Tuesday, January 15th 10:15-10:30

Predictability of Extreme Weather Events in North Greenland

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Given the changing nature of the Arctic climate system, there is renewed interest in the possibility that we are observing an increased frequency of extreme events. In this regard, the extreme warming event observed in North Greenland during February 2018, during the first YOPP SOP, is of interest. The event occurred just after the 2018 Sudden Stratospheric Warming and there is evidence that it was associated with the surface transient response to it. During the event, regional wind speeds and temperatures were the highest recorded during February going back to the start of observations in North Greenland during the1960s. A rare opening of a polynya over the Wandel Sea, to the north of North Greenland, was associated with the anomalously strong southerly flow. During the second YOPP SOP in August 2018, the polynya re-opened during another period of anomalously warm and windy conditions. These two events, one during the winter and the other during the summer, provide useful benchmarks to assess our current ability to forecast extreme Arctic warming events. Here we use the output from Environment and Climate Change Canada's Canadian Arctic Prediction System (CAPS) to investigate the predictability of these events including the air-sea-ice interactions associated with them.

On the warm bias of atmospheric reanalysis over sea-ice in Arctic winter

Müller, Malte[1]; Batrak, Yurii[1]

[1]Norwegian Meteorological Institute, Norway

Atmospheric reanalysis tends to have large biases for temperature, humidity and wind speed in Arctic regions, which are often larger than recent climatological trends and thus considerably limit their usage to monitor climate change and variability. In the present study we are evaluating reanalysis (ERA-Interim, ERA5, MERRA2, and JRA-55) over sea-ice covered areas and during the polar night. For the evaluation we are using atmospheric, snow, sea-ice and ocean observations from N-ICE drift in 2015. The data are from two subsequent drifts of a research vessel in between January and March 2015. Additionally, we use for a pan-Arctic assessment, a sea-ice surface temperature satellite product based on infrared data from AVHRR instruments. We find that during clear-sky conditions, when observed temperatures are often below -30 degree, the reanalysis have a warm bias of 5 to 10 K. This warm bias can be attributed to the missing representation of a snow layer on top of the sea-ice in the atmospheric models. Due to the low thermal conductivity of snow compared to sea-ice, a thin snow layer reduces the conductive heat flux much more efficiently than sea-ice, and thus, insulates the cold atmosphere from the relatively warm ocean. We can consistently show with a regional high-resolution atmospheric model (AROME Arctic) that the inclusion of a prognostic snow model on top of the sea-ice results in more than 10 K colder surface temperatures during clear-sky conditions and thus, leads to a significant reduction of the warm bias. We conclude that the snow component on the sea-ice improves the surface atmospheric energy budget in cold atmospheric conditions and thus is an important but often missing component in state-of-the-art reanalysis and forecasting systems.

Dynamic Drivers of Arctic Warm Events

Murto, Sonja[1]; Caballero, Rodrigo[1]; Svensson, Gunilla[1]

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Atmospheric blockings are defined as quasi-stationary synoptic-scale systems of high pressure that can influence different weather events. However, the mechanisms and theories for blocking formation and maintenance are yet not fully understood. Recent studies have shown that diabatic processes and thereby the northward transport of extratropical air-masses with low potential vorticity in the ascending air are important for the formation and maintenance of these blocking anticyclones(1,2). Furthermore, the Arctic sea-ice loss is shown to be related with Arctic anticyclones(3). In this study, we look closer at the dynamic drivers behind the Arctic warming by investigating the mechanism and origin of polar anticyclones, identified during 50 warm events of extreme wintertime Arctic surface temperature anomalies(4). The analysis is based on the ERAInterim-reanalysis dataset. Here, five days backward trajectories originated from anticyclones at 70 degree north a few days prior to each warm event are used to study this concept and to find general patterns concerning the identified polar anticyclones during these events. To examine and highlight the importance of the diabatic processes involved, meteorological variables, such as potential vorticity and potential temperature, along the trajectories are also interpolated and analyzed. Results of this study also show that these events are mainly characterized by double dipolar patterns of low- and high-pressure systems, one at the Atlantic sector and one mainly weaker over the Pacific sector. This study aims to improve the understanding of the preconditions needed for these Arctic warm events to occur, emphasizing the connection between extratropical cyclones and diabatic processes in the formation and maintenance of the polar anticyclones, which in turn are relevant in contributing to the Arctic warm events.

(1): Pfahl, S., Schwierz, C., Croci-Maspoli, M., Grams, C. M., & Wernli, H. (2015). Importance of latent heat release in ascending air streams for atmospheric blocking. Nature Geoscience, 8(8), 610. (2): Binder, H., Boettcher, M., Grams, C. M., Joos, H., Pfahl, S., & Wernli, H. (2017). Exceptional air mass transport and dynamical drivers of an extreme wintertime Arctic warm event. Geophysical Research Letters, 44(23). (3): Wernli, H., & Papritz, L. (2018). Role of polar anticyclones and mid-latitude cyclones for Arctic summertime sea-ice melting. Nature Geoscience, 11(2), 108. (4): Messori, G., Woods, C., & Caballero, R. (2018). On the drivers of wintertime temperature extremes in the High Arctic. Journal of Climate, 31(4), 1597-1618.

Under-Ice Upper Ocean Buoy Observation in MOSAiC Project

Na, Liu[1]; **He, Yan[1]**; Lin, Lina[1]

[1]The First Institute of Oceanography, SOA, China

In recent years, the environment of the Arctic has experienced unprecedented rapid changes, such as the rising air temperature, decreasing sea ice extent, decline and recovery of the cold halocline, increasing fresh water flux, etc. The change in the Arctic Ocean mainly occurs in the upper layer which participates in air-ice-sea interaction and has direct impact on the Arctic climate. The volume and heat flux of the Pacific inflow have increased, with variable distribution in the Arctic. Our work is focus on the changes in the upper ocean environment and their effects on Arctic stratification, heat content, circulation and sea ice evolution. We plan to deploy two buoys (one ocean profiler buoy and one fixed-layer ocean buoy) to obtain a year-round dataset of temperature, salinity, pressure and velocity and try to increase the understanding of variabilites in upper ocean under sea ice. Now one test set of ocean profiler buoy was deployed in Canadian Basin during the CHINARE 9 cruise and sending continuous data back to onshore control center in real time.

Evaluation of Critical Spatial Gaps in the Arctic Atmospheric Observations from the Point of View of Numerical Weather Prediction

Naakka, Tuomas[1]; Nygård, Tiina[1]; Vihma, Timo[1]; Pirazzini, Roberta[1]

[1]Finnish Meteorological Institute, Finland

We study the differences between ECMWF operational model data assimilation first-guess fields, analyses, and assimilated observations in the circumpolar Arctic north of 60°N during 2010-2018 (years with a large Arctic Amplification), with a particular focus on the YOPP Special Observation Periods in February-March and July-September 2018. The difference between the operational analysis and model first-guess field (the analysis increment) quantifies the impact of data assimilation, and the comparison of observations, first-guess fields and analyses yields information on the weight given for observations in the analysis. We calculate the spatial variations of the analysis increments and their relations to in-situ observations. Locations where observations contribute to large analysis increments are those where the existing observations are particularly valuable for NWP models, whereas locations with large analysis increments but no in-situ observations nearby suggest locations where new in-situ observations may be valuable. The latter aspect is further studied on the basis of YOPP observations from sites where observations are not made regularly (either never or not at all synoptic hours). Large analysis increments and weight of observations from those sites suggest critical spatial gaps in the observation network and a high priority of regular observations. We further evaluate how the differences between observations, first-guess fields, and analyses depend on (a) season, (b) synoptic-scale weather conditions, and (c) air-mass origin. In (c) we evaluate how the differences vary in specific observation sites (e.g. Ny-Ålesund and Bear Island) in cases when the air-mass is advected from regions where the observation density is high (from Europe) compared to cases when the air-mass is advected from regions where the observation density is low (from the Arctic Ocean).

Studying Sea Ice Deformation in Small Scales

Oikkonen, Annu[1]; Haapala, Jari[1]; Lensu, Mikko[1]; Karvonen, Juha[1]

[1]Finnish Meteorological Institute, Finland

Sea ice deformation has an important role in determining the total volume of sea ice and the properties of the ice pack. Also, opening of leads strongly impacts the interaction between ocean and atmosphere as well as the oceanic ecosystem. As Arctic sea ice is getting thinner and thus more mobile, the importance of sea ice deformation is likely to even increase in the future. So far, the majority of sea ice deformation studies have been based on sea ice motion detected using drifters or satellite images. With these methods, it has been possible to study sea ice deformation in the length scales down to few kilometers and time scales down to few hours or days. However, sea ice deformation is a strongly localized and intermittent process. This has motivated the development of a new method that extends the research to clearly smaller scales. With images capture by ship and coastal radars we have been able to study sea ice deformation in length scales down to 50 meters and in time scale down to 10 minutes. Here we present results from N-ICE2015 campaign which covered nearly 6-month long period in the area north of Svalbard. During the campaign, ship radar images (15 km x 15 km) were recorded with one minute interval and the study period covers variety of conditions from cold winter to summer melt and from compact pack ice to marginal ice zone. Our results show that deformation rates follow the power law with respect to both length and time scale even on these small scales, and the obtained length and time scale dependencies are in good agreement with previous studies covering clearly larger scales. With this unique data set we were able to study the impact of several factors on sea ice deformation rate, including the distance to ice edge and the wind and drift speed. We will use the same type of data and methods in the forthcoming MOSAiC campaign. That will allow us to extend these analyses to cover all the seasons and also the central Arctic.

Is the Arctic losing Climate Resilience?

Overland, James[1]; **Wood, Kevin**[2]; Walsh, John[3]

[1]NOAA - Pacific Marine Environmental Laboratory, USA
[2]JISAO - University of Washington, USA
[3]IARC - University of Alaska, USA

Unlike 20 years ago when thick ice was resistant to change, the present Arctic has lost its climatic resilience and is vulnerable to large atmospheric events that cause new extremes. From autumn 2017 through spring 2018, as in winter 2016, the Arctic was more susceptible to influences from subarctic storms. The combination of thin ice and southerly winds resulted in record warm Arctic temperatures. These events caught the public's attention with reports of temperatures warming to near the freezing point at the North Pole. Northward advection of temperature and moisture, which increases of downward long wave radiation, delayed sea ice freeze-up, resulting in an unprecedented absence of sea ice in the Bering Sea, near Svalbard and north of Greenland, thus providing a positive feedback by Arctic process. We argue that the Arctic may have passed a threshold based on multi-year evidence. Arctic annual temperatures for the last 5 years are all greater than all previous years. Arctic winter sea ice maximums for the last 4 years are all less than all previous years. Sea ice has gone through a transition from mostly thick multi-year sea ice to mostly thin (<1 m) sea ice. There are reduced sea ice concentrations during summer in the central Arctic, on the verge of a major reduction. In the summer of 2018, an atmospheric circulation anomaly led to unprecedented heat and wildfire activity in the European subarctic. Other indicators include an acceleration of the Arctic hydrologic cycle, loss of glacier and ice sheet mass, and changing ecosystems. Over the Late Quaternary (past 1.2 million years) the earth system has remained bounded between glacial and interglacial extremes. Present conditions represent the beginning of a rapid human-driven trajectory away from this glacial–interglacial limit cycle (Steffan et al. 2018). The current global atmospheric CO_2 concentration of over 400 ppm is well above the Holocene maximum and the upper limit of any interglacial. Given the persistent changes in the Arctic over the previous 5 years and the apparent trajectory of the earth climate system, the future state of the Arctic is historically new and recent data suggest that the rate of change is unknown.

Session E: Atmosphere – Poster ID: #E13

Observations at the Thule High Arctic Atmospheric Observatory during the YOPP SOPs

Pace, Giandomenico[1]; Di Iorio, Tatiana[1]; di Sarra, Alcide[1]; Meloni, Daniela[1]; Muscari, Giovanni[2]; Cacciani, Marco[3]

[1]ENEA, Laboratory for Observations and Analyses of Earth and Climate, Rome, Italy
[2]Istituto Nazionale di Geofisica e Vulcanologia, Italy
[3]University of Rome 'La Sapienza', Italy

In the frame of the OASIS-YOPP (Observations of the Arctic Stratosphere In Support of YOPP) project both tropospheric and stratospheric observations have been carried out at the Thule High Arctic Atmospheric Observatory, THAAO, during the two Arctic Special Observing Periods of 2018. THAAO is an international infrastructure located in proximity of Thule Air Base (76.5°N, 68.8°W), Greenland (http://www.thuleatmos-it.it/), operational since 1990 as part of the Network for the Detection of Atmospheric Composition Change (NDACC). Italian institutions involved in the OASIS-YOPP project (INGV, ENEA and Univ. of Rome) carried out continuous observations of integrated water vapour and liquid water path, temperature profiles, downward and upward shortwave and longwave irradiances, and zenith sky brightness temperature in the 9.6-11.5 μm band. Measurements were carried out with a microwave profiler, pyranometers, pyrgeometers, and a pyrometer; atmospheric temperature and humidity and images of the sky were also acquired. Few radiosondes were also launched during SOPs. Water vapor profiles in the 25 to 70 km altitude range, and integrated water vapor have also been measured with the VESPA-22 microwave spectrometer (water Vapour Emission Spectrometer for Polar Atmosphere) during the wintertime SOP. The temporal evolution of the measured parameters during both the winter and summer SOPs will be presented and discussed with emphasis and on the surface radiation budget and on the atmospheric thermodynamic structure of the lower troposphere; the observations allow, in particular, to investigate the evolution of the surface temperature inversion and its seasonal variation.

Session D: Verification – Tuesday, January 15th 12:00-12:15

Evaluation of seasonal Arctic sea ice forecasts from the ECMWF SEAS5 system

Palerme, Cyril[1]; Müller, Malte[1]

[1]Norwegian Meteorological Institute, Norway

There is a growing demand for seasonal sea-ice predictions by Arctic marine operators which put great expectations on the forecasting systems, calibration methods, and ability to inform on predictive skill. As part of the European climate service project SALIENSEAS, we are using the new ECMWF seasonal prediction system SEAS5, which provides 7-month probabilistic forecasts once a month. In this study, the set of re-forecasts of Arctic sea ice (covering the period 1981-2016) is evaluated with several verification methodologies such as the timing of the retreat and advance dates, and the spatial probability score (SPS) which allows to account for observational and forecast uncertainties. Overall, the SEAS5 system performs better during the advance season (from October to March) than during the retreat season (from April to September). However, there is a high spatial variability in the performance of the SEAS5 forecasts over the Arctic. This work will further help to develop seasonal sea-ice forecasts tailored to the needs of end-users, and assess the potential of the SEAS5 product for operational end-user services.

The evolution and energetics of Arctic cyclones observed during the 2014 ACSE campaign

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[2]National Oceanic and Atmospheric Administration (NOAA)/ESRL, USA

Improved understanding and prediction of Arctic cyclones is important for supporting the increasing human activity in the Arctic Basin. The frequency of strong cyclones in the Arctic is increasing, and their potential impacts on sea ice and upper ocean compound their effects well beyond direct impacts on Arctic weather. The dynamics of Arctic cyclones differs from lower-latitudes, for example, due to the due to the lack of lateral wind shear and the magnitude and juxtaposition of profiles of upper-level radiative cooling combined with mid-tropospheric latent heating, which can cause the persistence of upper-tropospheric potential vorticity anomalies and increased coupling between upper and lower-tropospheric anomalies. In addition, because of the unique aspects of the Arctic environment compared to mid-latitudes, such as cold, dry, and stable air masses, Arctic cyclone evolution and their coupling to the surface are not as well understood and modeled. As part of the Polar CORDEX pre-MOSAiC model intercomparison, simulations during the period of the Arctic Cloud Summer Experiment (ACSE) campaign (1 July - 1 Nov 2014) were run with a fully-coupled high-resolution Arctic climate system model. These simulations are used to examine processes related to cyclone structure, energetics, evolution, and interactions with the surface. Specifically, we use potential vorticity diagnostics to investigate the coupling between free-troposphere cyclones and boundary-layer and surface processes. We use these diagnostics to quantify the relative contributions of local/surface and advective/upper-troposphere energy sources on cyclone evolution. Case studies are presented with and without a preceding upper-tropospheric potential vorticity anomaly to explore the evolution of these upper-tropospheric anomalies and the impact of phasing between upper and lower tropospheric anomalies on Arctic cyclone evolution and coupling with the surface.

Session B: User Engagement and Projects – Monday, January 14th 16:45-17:00

The Contribution of the Icelandic Meteorological Office to YOPP

Petersen, Guðrún Nína[1]

[1]Icelandic Meteorological Office, Iceland

The Icelandic Meteorological Office (IMO) is responsible for weather monitoring, weather forecasting and warning for a large area in the North Atlantic. IMO monitors and forecasts weather in Iceland and over the surrounding seas, covering in total about 1,460,000 km2. The aviation monitoring and warning region much larger, extending all the way to the North Pole. IMO and the Danish Meteorological Institute (DMI) have a joint NWP domain covering the whole of Iceland and Greenland. In Greenland surface observations are sparse which makes it a challenge to both forecast and verify forecasts. It is thus clear that any improvement in the understanding of processes in the Arctic as well as any improved polar prediction are of high interest to IMO. IMO's main activity during the Special Observing Periods (SOPs) was to double the frequency of radiosonde launches from the two fixed stations in Iceland. Furthermore, IMO supported the Iceland Greenland Seas Project (IGP) by tailoring weather charts for both the maritime and the atmospheric field campaign as well as partaking in discussions about the coming weather.

Optimization of RAOB Network in Northern Asia

Pokrovsky, Oleg[1]

[1]Russian State HydroMeteorological University, Russia

Dynamic of Siberian RAOB during last 15 years is considered. Lack of sondes after 1998-th year financial crisis was evaluated. It was found a small set of stations provided the regular profile measurements twice per day during 2001-2002 and estimated its information content. Information model for Siberian RAOB based on multi-channel Shannon information measure was developed. A numerical method providing the maximization of information content for a sonde network was developed and applied to optimize a configuration of Siberian RAOB. Existing network mainly covers the interior Siberian areas. In contrast, the optimal RAOB should have a priority along Arctic and Pacific Ocean coasts. It was found that most meteorological parameters have largest variance just in these regions. These areas also perform the most important low oscillation patterns: East and West Pacific oscillations, Polar-EuroAsian oscillation and others. Latter regulate the airflow not only over Asia, but also over North Pacific and Western coast of North America. For example, when West Pacific oscillation attains negative magnitudes RAOB stations at Kamchatka and Chukotka peninsula deliver important pieces of data to predict weather over Polar Canada and California for medium terms. Optimal network has advantage in objective analysis accuracy for temperature and geopotential height fields with respect to existed network and remote sensing systems. Latter is due to considerable contamination of outgoing radiation by cloudiness. Heavy clouds occur most part of the year in these areas. H500 objective analysis accuracy providing by optimal RAOB is equal to 40-50 m, while existed network delivers only 60-70 m and NOAA remote sensing system - about 70-80 m.

A Causal Link between Atlantic Multidecadal Oscillation, Eastern Arctic Ice Extent and Changes in Atmospheric Circulation Regimes over Northern Eurasia

Pokrovsky, Oleg[1]

[1]Russian State HydroMeteorological University, Russia

We analyzed a coherence between the oscillations responded to various climate system components. The ocean is a principal climate component as it is the major heat container on the Earth. The climate swings of the Atlantic Multidecadal Oscillation (AMO) are most evident in and around the North Atlantic and take roughly 60 years to complete. The studies of paleoclimate proxies, such as tree rings and ice cores, have shown that oscillations similar to those observed instrumentally have been occurring for at least the last millennium. In the 20th century, the climate swings of the AMO have alternately camouflaged and exaggerated the greenhouse warming, and made attribution of global warming more difficult to ascertain. The data sets of the ice extents in the Russian marginal seas for 1900-1999 have been prepared in the Russian Arctic and Antarctic Research Institute. Our smoothing technique allows us to filter out the high frequency components presented in original time series and to reveal a 60-year AMO cycle in a more transparent mode. The AMO wavelet power spectrum demonstrates very strong anomaly area corresponding to a cycle of about 60 years, confirming the result based on the AMO series smoothing. Moreover, a statistical analysis showed the 60-year cycle to be a significant phenomenon at the 95% probability level. A smoothed ice extent curve for the Barents and Kara Sea September monthly data demonstrates slow multi-decadal oscillations similar to AMO, but opposite in phase. Wavelet analysis exhibits a power spectrum structure similar to those for AMO. Global warming led to an increasing of water temperatures in North Atlantic, which in turn caused a rapid degrading of ice cover in Eastern Arctic. Most dramatic reduction of ice sheet was observed in Russian margin seas: Kara, Laptev and East-Siberian during late summer and early autumn. Absence of ice sheet provides a more intensive energy exchange between air and sea surface while sea surface temperature demonstrates a significant positive trend. Appearance of new phenomenon - the atmospheric convection over ice-free sea surface led to development of low atmospheric pressure anomaly area, which spread over most part of Northern Siberia in Septembers since the beginning of current century. It is only one part of Arctic dipole phenomenon related to appearance of two atmospheric pressure field extreme value domains of opposite signs in Eastern and in Western Arctic. Extremes in anomalies of atmospheric pressure field, which spread over vast territory, prevents a normal zonal atmospheric flow across Siberia from west to east and can cause a flow of opposite direction in Eastern and Western Siberia. Inflow of warm and humid air masses from Pacific Ocean and South-East Asia is a main reason of sudden spring warming in Eastern Siberia. Catastrophic flood in Lena river basin, which was occurred in May 2001, is an example of dangerous consequence of circulation regime development related to a negative pressure anomaly. It is interesting to note that in contrast to a low anomaly the winter positive pressure anomaly can cause a rapid cooling in Eastern Europe and in Western Siberia. Thus, suggested approach permits us to develop a physical background for long-term forecasting model of potentially dangerous weather situations, which might be precedent to catastrophic floods at Siberian rivers and sudden cooling in Eastern Europe.

Empirical Statistical Models for Predicting Arctic Sea Ice Volume

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The seasonal predictability of Arctic sea ice volume, and its respective stability over time, are investigated by means of empirical statistical models. The empirical models are applied to the set of CMIP5 outputs and an ensemble of fourteen state-of-the-art reanalyses. Preliminary results show that predicting sea ice volume based on past values of this same variable is more effective for late winter (March) than late summer (September). The skill of the predictability, quantified by the coefficient of determination (R2), accounted for the preceding 12 months are on average 0.56, 0.57, 0.60, 0.66, 0.71, 0.71, 0.72, 0.76, 0.81, 0.87, 0.93, 0.98, respectively, in winter/March, compared to 0.53, 0.55, 0.57, 0.58, 0.58, 0.58, 0.59, 0.59, 0.63, 0.74, 0.90, 0.98, respectively, in summer/September. Based on these results, the skill prediction of winter/March sea ice volume is higher than 0.7 back to 8 months (July of the preceding year), while the skill of summer/September sea ice volume is higher than 0.7 only 3 months before (June of the same year). In addition, the statistical models were applied as a moving window with 30-year length, for a entire time span of ~150 years, in order to verify whether or not the sea ice volume predictability has decreased in the last decades. However, the results suggest a stable predictability over time.

Annual Blooms of a Coccolithophore E. Huxleyi: Are They Presently Consequential for Atmosphere- surface Ocean Carbon Cycles in the Arctic and Subarctic and What are Perspectives on the Future?

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A coccolithophore E. huxleyi cause less uptake of atmospheric CO2 by the ocean. A global assessment of this phenomenon has so far not been quantified. We used Ocean Colour Satellite time series data for a 19-year period (1998-2016) to quantify the CO2 partial pressure increase (ΔpCO2) within E. huxleyi blooms in the North, Norwegian, Greenland, Barents, and Bering Seas. E. huxleyi outbursts in the North Atlantic and Arctic Seas proved to occur annually, but their extent vary interannually. In the Bering Sea, during 1998-2001 there was a splash in blooming activity followed by a drastic drop. The bloom duration in the Bering Sea in 1997/98-2001 reached 10 months, in the North Atlantic seas it was ~ 1 month. The maximum particulate inorganic carbon (PIC) content in E. huxleyi blooms in all seas varied over the 19 years between ~ 15 and 70 Kt. When normalized to pCO2 in the absence of bloom, the mean and maximum ΔpCO2 values within the bloom areas varied in percent between 21.0 – 43.3 and 31.6 - 62.5, respectively. Utilizing OCO-2 spaceborne data on columnar XCO2, we also quantified changes in atmospheric columnar CO2 over E. huxleyi blooms in the target seas and documented a reversion of CO2 flux from ocean to atmosphere. Collected and presented an extensive multi-year database of a variety of internal and external factors that allegedly are capable of affecting the E. huxleyi growth rate, bloom spatial extension, localization, PIC content and increment of calcification-driven dissolved CO2 partial pressure in surface water. As the development of this database is intended to help analyses of intra- and interannual variations in the above bloom-related characteristics over a nearly two decadal time period, solely spaceborne data were employed to this end. However, even with this limitation, the overall number of factors liable to analyses proved to be extensive. As many of them, if not all, are involved in forward and feedback interrelations, multidimensional statistical tools are liable to be exploited for the analyses and prioritization of forcing factors. As such Random Forest and Gradient Boosting Classifiers. The results of the two mutually-controlling/collaborating statistical analyses are further employed as input variables for climatic modelling. Modelling results were first checked against past data, which was then followed by ongoing and forecasting climatic modelling in order to make projections of the expected spatio-temporal variations in the variables and hence, on this basis, achieve projections of dynamics of the phenomenon. 21 climatic models from CMIP5 were employed. Based on the data of the climatic reanalysis Era-Interim, the selection of model optimal sets was performed for each sea. This allowed to best represent the regional characteristics of the climate, and accommodate the variables/set of variables identified from the statistical analyses. Our results strongly indicate that factors prioritization is sea-specific, and can hardly be extended over the world's oceans.

Invited Talk – Monday, January 14th 12:15-12:40

On forecasting sea ice trajectories using the Lagrangian sea ice model neXtSIM

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We present a sensitivity analysis, and discuss the probabilistic forecast capabilities, of the novel sea ice model neXtSIM used in hindcast mode. The study pertains to the response of the model to the uncertainty on winds using probabilistic forecasts of ice trajectories. neXtSIM is a continuous Lagrangian numerical model, and uses an elasto-brittle rheology to simulate the ice response to external forces. The sensitivity analysis is based on a Monte Carlo sampling of 12 members. The response of the model to the uncertainties is evaluated in terms of simulated ice drift distances from their initial positions, and from the mean position of the ensemble, over the mid-term forecast horizon of 10 days. The simulated ice drift is decomposed into advective and diffusive parts that are characterised separately both spatially and temporally and compared to what is obtained with a free-drift model, that is, when the ice rheology does not play any role on the modelled physics of the ice. The seasonal variability of the model sensitivity is presented, and shows the role of the ice compactness and rheology in the ice drift response at both local and regional scales in the Arctic. Indeed, the ice drift simulated by neXtSIM in summer is close to the one obtained with the free-drift model, while the more compact and solid ice pack shows a significantly different mechanical and drift behaviour in winter. For the winter period analysed in this study, we also show that, in contrast to the free-drift model, neXtSIM reproduces the sea ice Lagrangian diffusion regimes as found from observed trajectories. The forecast capability of neXtSIM is also evaluated using a large set of real buoy's trajectories, and compared to the capability of the free-drift model. We found that neXtSIM performs significantly better in simulating sea ice drift, both in terms of forecast error and as a tool to assist search-and-rescue operations, although the sources of uncertainties assumed for the present experiment are not sufficient for a complete coverage of the observed IABP positions.

Intercomparison of Sea-Ice Observational datasets

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In this study we investigate possible uncertainties and differences in various sea-ice observational products, including sea-ice concentration, area and extent. We use several datasets (namely, but not limited to, National Snow & Ice Data Centre - NSIDC, Ocean and Sea Ice Satellite Application Facility - OSISAF and Met Office Hadley Centre - UKMO) and focus our analyses on both the Northern and Southern Hemispheres. The products differ by the retrieval methods that were employed as well as by their horizontal resolution (varying from about 0.1º to 0.25º). We illustrate differences and uncertainties over the historical period by applying several univariate (climatologies, trends, standard deviations) and multivariate (per-pair RMSE, correlations) statistical indices. This approach allows us to i) evaluate the ability of each of the datasets to simulate the observed climatology in regions of focus, ii) analyze similarities and contradictions in historical dataset between multiple observational datasets and iii) estimate the level of observational uncertainty and gauge its impact in climate model evaluation studies.

Regional observations simulation experiments over the Arctic during the YOPP SOP1

Randriamamplanina, Roger[1]

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In frame of the APPLICATE project the ECMWF conducted series of experiments aiming to check the impact of different observations on analyses and forecast, focusing on global scale and the Arctic. The output of these experiments is made available for us to be used as lateral boundary conditions (LBC) in our regional Arctic observations simulation experiments (OSE). This OSE, conducted in frame of the Alertness project, aims at evaluating the impact of different observations on our limited area model (LAM) analyses and forecasts. The peculiarity of this study compared to what we have done earlier is that we have sets of LBCs allowing us to check the following: 1) impact of the observations through their assimilation in LAM; 2) impact of observations on LAM through the LBCs; 3) impact of non-Arctic observations on an Arctic LAM; and 4) impact of the SOP observations on an Arctic LAM. Since the ECMWF have done series of denial experiments, to have the answer to all the four scenarios listed above, a lot of experiments needs to be done. The experiments are ongoing and, so far, we have results for some observation types with scenarios 1), 2) and 4). In these very preliminary results, on top of what we gain through the LAM data assimilation (DA), a non-negligible impact of the observations are brought to LAM through the LBCs. Also, the SOP1 observation have positive impact in our Arctic LAM analyses and forecasts. The impact is shown through verification against all available observations in our DA system, including non-conventional ones.

From Detailed Sea-Ice Services to End Users

Rasmussen, Till Soya[1]; Brandt Kreiner, Mathilde[1]; Olsen, Steffen Malskaer[1]; Jeuring, Jelmer[2]; Ribergaard, Mads Hvid[1]

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The Danish Meteorological institute (DMI) has focus on services that adds value to public and commercial stakeholders within the oceans of the Danish Kingdom that includes Danish, Greenlandic and Faroese waters. For this purpose, existing operational ocean, weather and sea-ice services are continuously developed. DMI conducts user surveys in order to improve the services and the user experience. These surveys aim at linking the gap between the research and development of the DMI system and the services requested by the user. One of the main Arctic activities at DMI is the Greenlandic ice service, which provides sea-ice information for the Greenlandic waters. Traditionally this is based on manually generated ice charts; however, DMI is investigating opportunities to integrate automated services including forecasts of the ocean and sea ice around Greenland. DMI is involved both in new developments of the model system and attempts to increase the lead time from days to seasonal forecast. This presentation will focus on the project Salienseas and the ocean and sea-ice services of the Greenlandic and Arctic waters. The task of DMI is to improve the forecast skill by adding landfast ice created by interaction with ice bergs in the description of landfast ice around Greenland. In addition, user reactions to this service and other sea-ice services will be discussed.

Invited Talk – Monday, January 14th 11:50-12:15

The Iceland Greenland Seas Project: Cold air outbreaks and air-sea-ice interactions

Renfrew, Ian[1]; Pickart, Bob[2]; Våge, Kjetil[3]; Moore, Kent[4]; Lachlan-Cope, Tom[5]; Elvidge, Andrew[1]; Weiss, Alexandra[5]; Reuder, Joachim[3]; Sodemann, Harald[6,7]; Terpstra, Annick[3]; Papritz, Lukas[3]; Petersen, Guðrún Nína[8]; Barrel, C; Zhou, Shenjie[1]; Sergeev, Denis[9]; Brooks, Ian[10]; Bracegirdle, Thomas[5]; Ladkin, Russell[5]; Pope, James[5]; Kolstad, Erik[7]; Spengler, Thomas[3]

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[8]Icelandic Meteorological Office, Iceland
[9]University of Exeter
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A coordinated meteorological and oceanographic field campaign over the Iceland and southern Greenland Seas took place in February and March 2018. The aim being to characterise the atmospheric forcing and the ocean response of coupled atmosphere-ocean processes; in particular cold-air outbreaks in the vicinity of the marginal-ice-zone and their triggering of oceanic heat loss and the generation of dense water masses. We observed the spatial structure and variability of surface flux fields in the region and the weather systems that dictate these fluxes, through the first meteorological field campaign in the Iceland Sea. This was done as part of a coupled atmosphere-ocean field campaign in winter 2018 involving a rare wintertime research cruise, airborne observations and a host of ocean and atmosphere observing systems. We made in situ observations of air-sea-ice interaction processes from several platforms. Here we will present some highlights from the meteorological component of the field campaign – illustrated by observations from some of the research aircraft cases.

MOSAiC - The Multidisciplinary drifting Observatory for the Study of Arctic Climate

Rex, Markus[1]; Shupe, Matthew[2]; Dethloff, Klaus[1]; **Sommerfeld, Anja**[1]; the International MOSAiC Team

[1]Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Germany
[2]Cooperative Institute for Research in Environmental Science, University of Colorado and NOAA-ERSL, USA

MOSAiC is an international research initiative under the umbrella of IASC, designed by an international consortium of leading polar research institutes. Rapid changes in the Arctic lead to an urgent need for reliable information about the state and evolution of the Arctic climate system. This requires more observations and improved modelling over various spatial and temporal scales, and across a wide variety of disciplines. Observations of many critical parameters have, to date, not been carried out in the central Arctic for a full annual cycle. MOSAiC will be the first year-around expedition into the central Arctic exploring the coupled climate system. During 2019 to 2020 the research vessel Polarstern will drift with the sea ice from the Siberian Sector of the Arctic across the polar cap towards the Fram Strait. The focus of MOSAiC is based on a constellation of in-situ observations of the climate processes that couple atmosphere, ocean, sea ice, biogeochemistry and ecosystem. These measurements will be supported by weather and sea ice predictions, and remote sensing operations to aid operational planning and extend the observational results in time and space. The project includes coordinated aircraft measurement campaigns and expeditions by icebreakers from MOSAiC partners. All of these observations will support the main scientific goals of MOSAiC: Enhancing the understanding of the regional and global consequences of Arctic climate change and sea ice loss, and improving weather and climate prediction.

Session F: Sea Ice and Ocean – Tuesday, January 15th 14:45-15:00

Recent achievements in deriving sea ice thickness from satellite observations and transition into an operational service

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Sea ice thickness is an essential climate variable (ECV) and crucial for the polar climate system. On basin scale, Arctic sea-ice thickness can only be retrieved by satellite observations. The European CryoSat-2 radar altimeter mission and its almost 9-year long period of operations has produced an unprecedented record of monthly sea-ice thickness information. We present CryoSat-2 results that show changes and variability of Arctic sea ice from the winter season 2010/2011until fall/winter 2018. CryoSat-2, however, was designed to observe thick perennial sea ice, while retrieving thin seasonal sea ice accurately is more challenging. We have therefore developed a method of completing and improving Arctic sea ice thickness information by merging complementary satellite retrievals. The European SMOS satellite is detect thin sea ice thickness, in a thickness range where CryoSat-2 lacks sensitivity. Merging the two observational data sets with an optimal interpolation scheme overcomes several issues of single-mission retrievals and provides a more accurate and comprehensive view on the state of Arctic sea-ice thickness at higher temporal resolution. In order to meet the requirements for operational systems of climate forecasting, we aim to transform research-oriented products into an operational service within the framework of the Copernicus Climate Change Service project (C3S) and the ESA SMOS & CryoSat-2 Sea Ice Data Product Processing and Dissemination Service (CS2SMOS-PDS). Here, we will also present on the status and future evolutions of this service, maintained at the Alfred Wegener Institute.

Session F: Sea Ice and Ocean – Poster ID: #F12

The Role of Tides in Driving Diapcynal Mixing in the Arctic Ocean

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The tides provide a major source of the kinetic energy which supports turbulent mixing in the global oceans. The prime mechanism for the transfer of tidal energy to turbulent mixing results from the interaction between topography and stratified tidal flow, leading to the generation of freely propagating internal waves at the period of the forcing tide. However, poleward of the critical latitude the action of the Coriolis force precludes the development of freely propagating linear internal tides. Here we will focus on a region of sloping topography, poleward of the critical latitude, where there is significant conversion of tidal energy and the flow is super-critical. A high resolution numerical model is used to demonstrate the key role of tidally generated lee waves and supercritical flow in the transfer of energy from the baroclinic tide to internal waves in these high latitude regions. Time series of flow and water column structure observations show internal waves with characteristics consistent with those predicted by the model, and concurrent mircrostructure measurements show significant levels of mixing associated with these internal waves. These new results identify a key Arctic Ocean mixing process which is as yet unparameterised process in ocean models.

Predicting ocean waves and sea ice and the Polar Oceans

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Abstract Sea ice retreat and opening of large, previously ice-covered areas of the Arctic Ocean, to the wind and ocean waves leads to the Arctic sea ice cover becoming more fragmented and mobile, with large regions of ice cover evolving into the Marginal Ice Zone (MIZ). We examine effects of ocean surface waves on the polar sea ice and ocean using a sea ice-ocean general circulation global model NEMO (stands for Nucleus for European Modelling of the Ocean) coupled with the ocean wave model output from model of the European Centre for Medium-Range Weather Forecasts (ECMWF). In the model the wave-ice interactions include: ice fragmentation due to break–up by waves in the vicinity of the ice edge; wave attenuation due to multiple scattering and non-elastic losses in the ice, wave advection and evolution of ice fragmentation. We analyse the impact of the waves on sea ice and the upper ocean, focusing on MIZ, where the wave impacts are the most. A combined Collisional rheology, reflecting the granular behaviour of MIZ sea ice, and Elastic-Viscous-Plastic (EVP) rheology are seamlessly implemented in the model with the effect of surface waves on ice motion is included in the turbulent kinetic energy. We found that the new rheology combined with ice fragmentation make a substantial effect on sea ice and upper ocean dynamics in the Arctic and the Southern Oceans. The study combines the model results with the observations, and highlights a need to farther theoretical understanding of sea ice fragmentation and summarise requirements for observational techniques. For this research we acknowledge the funding from the project ‘Ships and waves reaching Polar Regions (SWARP)’ supported by the European Union’s Seventh Framework Programme (FP7/2007-2013) under grant agreement No 607476 and from the Grant NE/R000654/1 ’Towards a Marginal Sea Ice Cover’ funded by the UK Natural Research Council (NERC). We also acknowledge funding from the NERC Programme “The North Atlantic Climate System Integrated Study (ACSIS)” NE/N018044/1.

INTAROS – a Project Contributing to Improving Arctic Observing Systems

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Through the H2020 INTAROS project, the goal is to develop integrated observing systems in the Arctic, including improvement of data sharing and dissemination to various user groups. INTAROS is also developing more collaboration between institutions involved in data collection in the pan-Arctic region. There are significant efforts to develop Arctic observations by many countries, organisations and projects in the Pan-Arctic region. The amount of data collected in the Arctic is growing, but the funding of these systems is to a large extent dependent on time-limited research and observation projects. These systems are therefore not sustainable and there is a high risk that many will not be maintained in the future. Some satellite Earth Observation programmes, such as Copernicus, have long-term perspectives and funding plans for 5 – 10 years, but most of the observations from in situ systems on ground and in water have no long-term funding. It is therefore essential to develop and maintain long-term in situ observing systems to monitor trends, and to detect natural variations and human impacts on climate, environment, livelihoods and societies. This requires mechanisms for long-term funding to be established. With support from INTAROS, the following in situ observing systems will be deployed in the period 2018-2020: ice-tethered platforms (by IOPAN), ice mass balance buoys (by FMI), bio-Argo floats in Baffin Bay (by CNRS Takuvik), and gliders in the Fram Strait (by CNRS LOCEAN). Also, the Ferry-box system between Tromsø and Longyearbyen will be enhanced (by NIVA). All these platforms have capacity to deliver data in near-real time. In addition, INTAROS is also supporting a number of systems providing data in delayed mode: bottom-anchored moorings, the Long-Term Ecological Research observatory as part of the Hausgarten system, and the Kongsfjorden observatory with acoustic observations (CNRS IUEM) and observations of pH and CO_2 (CNRS LOV) As a research project INTAROS can only support time-limited observations for about two years. In order to maintain observations beyond a 3 – 4year period, it is necessary to establish funding mechanisms with long-term perspectives.

Japanese activity using RV Mirai (Part 2): Model intercomparison using RV Mirai data as a part of Arctic CORDEX

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An Arctic voyage of the Japanese Research Vessel (RV) Mirai was conducted in the Chukchi Sea during September 2014 as part of the Arctic Research Collaboration for Radiosonde Observing system (ARCROSE) 2014. During these cruises, radiosonde observations were made every 3-hours at RV Mirai. AWI applies Arctic regional climate models to improve our understanding reproductions of climate process in the Arctic Ocean. These models are used for Arctic CORDEX. In this study, we compared the results of HIRHAM with observation data obtained by Mirai. Comparison between of observation data by RV Mirai and simulations by the HIRHAM revealed that vertical structures of temperature at RV Mirai in the Arctic Ocean were reproduced well in the HIRHAM. Although wind speeds had some biases when wind speeds were strong, HIRHAM captured wind speeds in the Arctic Ocean. In our presentations, we will show the results of other regional models participating in Arctic CORDEX and reanalysis data.

Session F: Sea Ice and Ocean – Tuesday, January 15th 14:30-14:45

Limited predictability of extreme decadal changes in the Arctic Ocean freshwater content

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Predictability of extreme changes in the Arctic Ocean freshwater content and the associated release into the subpolar North Atlantic up to one decade ahead is investigated using a CMIP5-type global climate model. The perfect-model setup consists of a 500 years control run, from which selected 10 yearlong segments are predicted by initialized, perturbed ensemble predictions. Initial conditions for these are selected from the control run to represent large positive or negative decadal changes in the total freshwater content in the Arctic Ocean. Two different classes of ensemble predictions are performed, one initialized with the 'observed' ocean globally, and one initialized with the model climatology in the Arctic Ocean and with the observed ocean elsewhere. Analysis reveals that the former yields superior predictions 1 year ahead as regards both liquid freshwater content and sea ice volume in the Arctic Ocean. For prediction years two and above there is no overall gain in predictability from knowing the initial state in the Arctic Ocean and damped persistence predictions perform just as well as the ensemble predictions. Areas can be identified, mainly in the proper Canadian and Eurasian basins, where knowledge of the initial conditions gives a gain in predictability of liquid freshwater content beyond year two. Total freshwater export events from the Arctic Ocean into the subpolar North Atlantic have no predictability even 1 year ahead. This is a result of the sea ice component not being predictable and LFW being on the edge of being predictable for prediction time 1 year.

MOSAiC for Unique Processed-based Assessment of YOPP Models

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The Multidisciplinary drifting Observatory for the Study of Arctic Climate (MOSAiC) expedition will drift across the Arctic ice pack from fall 2019 through fall 2020 making the most extensive set of coupled-system observations ever obtained in the central Arctic. This expedition will present a unique opportunity to evaluate numerical models in this challenging Arctic environment in a way that has not been possible in the past. MOSAiC's main focus is on the changing Arctic sea ice and the many physical, chemical, and biological processes that interact with this changing ice. Based on the drifting Polarstern icebreaker, detailed measurements will cut across the atmosphere-ice-ocean system, while a key set of parameters will also be measured in a spatial domain around the Polarstern. Continuous, high-resolution observations over a full year will offer some unique possibilities for model evaluation. First, the comprehensive nature of MOSAiC observations will allow for detailed assessment of model processes. For example, the coupled responses of all energy budget terms at the sea-ice surface to variability in atmospheric radiative forcing will be quantified in a way that can isolate model shortcomings in representing surface exchange, stable boundary layers, and related processes. Second, the spatial network of MOSAiC measurements, of quantities such as ice thermodynamic state, surface radiation, and snow depth, will enable the development of characteristic distributions of these key quantities that must ultimately be represented by models. Lastly, MOSAiC will offer these important process and spatial perspectives in all seasons. Clearly process interactions differ over the course of the annual cycle, and these differences are essential to represent when interested in the evolution of the sea-ice pack, changes in boundary layer structure, and formation of clouds, among other seasonally-varying processes. Examples of potential approaches to model assessment will be provide in this presentation. To enable these unique model evaluations as part of the YOPP verification effort, it is essential that operational models participating in YOPP produce routine output for a region surrounding the drifting MOSAiC constellation. Specific topics of focus should be on surface properties, surface energy budgets, atmospheric boundary layer structure, clouds, and precipitation.

Invited Talk – Monday, January 14th 10:15-10:40

Canadian Contributions to the Year of Polar Prediction: Deterministic and Ensemble Coupled Atmosphere-Ice-Ocean Forecasts

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The Year of Polar Prediction (YOPP) is running from mid-2017 to mid-2019 as the core phase of the ten year (2013-2022) Polar Prediction Project (PPP), an initiative of the WMO's World Weather Research Programme (WWRP), to enable a significant improvement in environmental prediction capabilities for the Polar Regions and beyond. As a Canadian contribution to YOPP, a number of deterministic and ensemble coupled environmental prediction systems have been running in real-time at the Canadian Centre for Meteorological and Environmental Prediction (CCMEP). These include high-resolution short-range pan-Arctic coupled atmosphere-ice-ocean forecasts, global coupled medium-range forecasts and monthly ensemble forecasts. The pan-Arctic coupled atmosphere-ice-ocean model has been developed to investigate the impact of coupled interactions in daily 48h forecasts produced in real-time during YOPP. The atmospheric component, the Canadian Arctic Prediction System (CAPS), runs over a regional domain with a 3 km grid spacing and has the latest innovations from the Global Environmental Multiscale (GEM) model, including a new Prediction Particle Properties (P3) microphysics scheme (clouds, precipitation). During the forecast, the atmospheric model is coupled at each time step to an ice-ocean model running over a regional 3-8 km resolution domain, covering the Arctic and North Atlantic regions, namely the Regional Ice-Ocean Prediction System (RIOPS). RIOPS uses the NEMO-CICE ice-ocean model and includes explicit tides, a landfast ice parameterization based on the effect of grounded ice ridges, and an increased resistance to tension and shear in the ice rheology (for improved representation in land-locked areas). Additionally, a 32-day ensemble ice-ocean forecasting system has been running weekly since summer 2016. The potential usefulness of this system to provide guidance for long-range forecasts produced by the Canadian Ice Service has been investigated. Results of a subjective evaluation by forecasters at CIS and interactions with users in the Marine Shipping Industry will be presented. Finally, perspectives on developing new user-relevant products (such as probability of encountering dangerous high pressure ridges) for ice services will be discussed.

Water vapour isotope observations during YOPP SOP1 and SOP2

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The stable isotopic composition of water vapour and precipitation, expressed by the quantities dD, d18O, d17O and the secondary parameters d-excess and 17O-excess, contains information about the condensation history of water vapour in the atmosphere. The complex interplay of atmospheric flow and topography in the European Arctic, and the location in the storm track, lead to precipitation arriving from a wide variety of source regions that are characterized by differing stable isotope compositions. Such differences offer the opportunity to test the water cycle in atmospheric models from observational constraints in new ways. During YOPP SOP1, water vapour isotope measurement instrumentation was deployed on the scientific vessel R/V Alliance, the research aircraft MASIN and a coastal location in Northern Iceland during the campaign of the Iceland-Greenland Seas project. With additional sampling of the snow deposited on land, a complete water cycle during continuous cold-air outbreak conditions could be sampled. During YOPP SOP2, continuous water vapour measurements were performed on board of the vessel KV Svalbard during the INTAROS cruise 2018 north of Svalbard in the Marginal Ice Zone. First results from both comprehensive sampling campaigns provide insight into the spatial gradients and synoptic variability in the stable isotope composition. In particular, analyses provide insight into evaporation conditions at the moisture sources from the secondary parameters d-excess within and outside of CAO airmasses. Initial modeling results show the importance of local topography in modifying the isotope signal during the deposition with precipitation.

Coupling Scales and Components: When is an Interactive Sea Ice Component Required for Weather Forecasting?

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Cold air outbreaks (CAOs) play a key role in air-sea interactions in high latitudes but forecasting their intensity and extend poses a major challenge. The cold, windy, and snowy conditions associated with these outbreaks regularly have a socio-economic impact, in particular when they go along with mesoscale extremes such as polar lows. Despite increasing model resolution, reliable forecasts of these events remain a challenge because of the vast range of scales and physical processes involved. On its way from the central Arctic to inhabited coast lines, an air mass translates several thousands of kilometres, while being influenced by processes over leads and over the marginal ice zone (MIZ) that act on the scales of meters. We use atmospheric column models with varying lower boundary, the dynamic sea ice model NextSIM, as well as three-dimensional mesoscale atmospheric simulations with varying resolution and complexity to identify the processes and scales required for accurate simulations of CAOs. We investigate whether leads in the central Arctic play a role on larger scales by transforming the incipient air mass forming the CAO, as well as the role of the ice distribution in the MIZ for the atmospheric flow over the open ocean. While some model studies indicate an integral constraint for total sensible and latent heat taken up by an atmospheric column moving off the sea ice, independent of the ice distribution in the MIZ, the robustness of this result for different resolutions and model complexities is unclear. We also test the resolution-dependence of mesoscale organisation of atmospheric flow with respect to inhomogeneities along the sea-ice boundary. These results will help understand the upscale growth of cloud streets and subsequent polar low development. Through the improved process understanding from the column model and the results of the sensitivity analysis for the model resolution and complexity, we will be able to identify circumstances during which sea ice modifies the atmospheric flow on the mesoscale. The latter allows us to identify situations during which an interactive sea-ice component is important to allow for the feedback of the altered mesoscale flow on the sea ice.

Grounded Sea Ice and Tensile Strength for Landfast Ice Formation and Effects on Global Climate Models

Sterlin, Jean[1]; Huot, Pierre-Vincent[1]; Chevallier, Matthieu[2]; Massonnet, François[1]; Fichefet, Thierry[1]; Raulier, Jonathan[1]

[1]Université Catholique de Louvain, Belgium
[2]Centre National de Recherches Météorologiques, France

Landfast ice is the part of sea ice fastened to the coast. As the landfast ice is immobile, it has an influence on the interactions between the ocean and the atmosphere, the fresh water budget, deep water formation and the stability of the ice cover. It equally plays a role for coastal ecosystems in the Arctic and Antarctic. Two main mechanisms for landfast ice formation are known in the Arctic. The first occurs when the ice is thick enough to ground on the sea floor. The weight of ice unbalanced by buoyancy forces leads to basal stress limiting its displacements. Over deeper waters, landfast ice can also be sustained by tensile strength. The fast ice develops as arches anchored to islands, grounded icebergs, or other points such as the shoreline. To model the landfast ice, grounding schemes have been introduced (Rousset et al., 2013; Lemieux et al., 2015) while the yield curve of sea ice has been modified to account for tensile strength (Dumont et al., 2009; Lemieux et al., 2016; Olason, 2016), showing promising results for regional modelling. However, little is known about the behaviour of the grounding schemes in global models with an ice thickness distribution and a coarser bathymetry. The effects of tensile strength on the ice dynamics have not been studied either, nor the potential impact of landfast ice on interannual to multi-decadal high latitude climate variability. In this study, we use the global ocean-sea ice model NEMO- LIM3 to test the Lemieux et al. (2016) grounding scheme and effect of isotropic tensile strength in the sea ice rheology. We evaluate the representation of fast ice and the ice dynamics. We then run a global simulation at 1 degree resolution, from 1958 to 2015. We formulate an initial assessment of the importance of landfast ice for current climate models and we suggest a set of parameters that can be used.

Session F: Sea Ice and Ocean – Tuesday, January 15th 14:15-14:30

Towards an Operational Snow on Sea Ice Product

Stroeve, Julienne[1]; Liston, Glen[2]; Buzzard, Samantha[1]; Barret, Andrew[3]; Tschudi, Mark[4]

[1]University College London, United Kingdom
[2]Colorado State University, USA
[3]National Snow and Ice Data Center, USA
[4]University of Colorado, USA

Incomplete knowledge of snow depth and density on sea ice remains one of the largest uncertainties in ice thickness retrievals from laser or radar altimetry. In this study we produce daily, pan-Arctic snow depth and density estimates using a sophisticated new snow model (SnowModel) developed specifically for sea ice applications and forced by atmospheric reanalysis. SnowModel is implemented in a Lagrangian framework, where snow accumulates on each ice parcel as it moves around the Arctic. Validation of our derived snow depth estimates is performed through comparisons of snow depths from Operation IceBridge (OIB), ice mass balance buoys (IMBs), snow buoys, magnaprobes and rulers. We perform three model simulations: one from 1980 to 2015 where we include a mean bias correction of retrieved snow depths using all available OIB data for the bias-correction, one from 2009 to 2016 where we compute a bias correction for each year using that years OIB data, and one from 2009 to 2016 where the snow density is adjusted to match OIB snow depths.

Atmospheric Soundings Measurements from the Chinese Arctic Expedition in Summer 2018

Sun, Qizhen[1]

[1]National Marine Environmental Forecasting Service, China

During YOPP Special Observing Period (SOP), eighty-four radiosondes have been launched for meteorological measurements of the Arctic atmosphere from the Chinese icebreaking research vessel Xuelong from 31 July to 4 September 2018 in the Arctic Ocean. Two radiosondes were released per day at 00 and 12 UTC as part of the YOPP-endorsed project 'Intensive Atmospheric Soundings during the Chinese National Arctic Research Expedition (CHINARE) in 2018'. In addition, three radiosondes were deployed per day from 26 August to 4 September during the expedition. The CHINARE project aims to study the vertical atmospheric profile above the Arctic Ocean by looking at meteorological parameters such as air temperature, humidity, wind speed, wind direction, or air pressure. The data will be used for assimilation experiments in numerical weather prediction models and verification of the weather forecasts for the Arctic ocean.

Invited Talk – Monday, January 14th 09:25-09:50

Atmosphere-Ocean Single-Column Model (AOSCM) – a tool to help improve coupled models in the Arctic

Svensson, Gunilla[1]

[1]Stockholm University, Sweden

The polar regions are known for their complex small-scale processes that need to be parameterised in models, such as the formation of clouds, boundary-layer mixing in ocean and atmosphere, sea ice formation/melt and the surface energy exchanges. These processes are also involved in substantial feedback mechanisms in the climate system. Numerical models, both for weather forecasts and climate applications, have been shown to have large biases in polar regions that may originate from these parameterised processes.

The Atmosphere-Ocean Single-Column Model (AOSCM) is a recently developed tool to be used to analyze and develop processes important for the surface energy budget including the coupling procedures. It is developed within the EC-Earth portal in such a way that it easily can keep up with developments in the various components and consist of NEMO-LIM and OpenIFS coupled using OASIS. It builds on the more commonly used atmosphere-only and ocean-only frameworks and extends to capture the entire system from ocean bottom, through the sea ice and snow, to the top-of-atmosphere. The new tool is presented and a summer moist-intrusion event observed during the ACSE expedition with the Swedish icebreaker Oden is used to show the versatility of the tool.

Atmosphere-Wave Coupling in a NWP System

Thomas, Erin[1]; Batrak, Yurii[1]; Carrasco, Ana[1]; Sætra, Øyvind[1]; Kristiansen, Jørn[1]

[1]Norwegian Meteorological Institute, Norway

Modeling the interactions between the ocean and atmosphere both advances our understanding of the physical mechanisms operating in rapidly changing Arctic environments and is critical to improve the predictability of extreme weather events, wave activity, and sea ice behavior. This study presents the development of a two-way coupled atmosphere-wave numerical weather prediction (NWP) system in the Arctic as well as the initial evaluation of the coupled model performance and sensitivity experiments. The HARMONIE-AROME configuration of the ALADIN-HIRLAM NWP system is coupled to the wave model WAM using the OASIS3-MCT coupling toolkit. The coupled model is configured over the AROME-Arctic domain in the Barents Sea region. The two-way coupling is structured as follows: AROME-Arctic receives sea surface properties from WAM, which influences the calculation of the surface roughness and surface fluxes. This in turn effects the near surface dynamics in the atmospheric model. The 10m wind is then passed to WAM, which updates the sea surface properties. The coupled model performance is evaluated against observations such as significant wave height based on Jason-3 and Sentinel-3A satellite altimeter data as well as Advanced Scatterometer (ASCAT) surface wind data. High impact events during the YOPP SOP1 time period are selected for sensitivity experiments. Future work will include sea ice and wave interactions within this coupled model framework.

Experiences from Arctic Forecasting during the Arctic Ocean 2016 Expedition

Tjernström, Michael[1]; Svensson, Gunilla[1]; Prytherch, John[1]; Brooks, Ian[2]

[1]Stockholm University, Sweden
[2]University of Leeds, United Kingdom

During the Arctic Ocean 2016 several projects collaborated on taking atmospheric measurements in a column from the upper ocean to the top of the troposphere with a suite of remote sensing as well as in-situ instruments during a five-week long ice drift. For the expedition forecasting we had access to column output from the ECMWF IFS, that we evaluated on-line using the measurements on board. This presentation will provide an overview of the observations and a preliminary version of the forecast evaluation.

An Assessment of Ten Ocean Reanalyses in the Polar Regions

Uotila, Petteri[1]; Goosse, Hugues[2]; Haines, Keith[3]; Chevallier, Matthieu[4]; Barthélemy, Antoine[2]; Bricaud, Clément[5]; Carton, Jim[6]; Fučkar, Neven[7]; Garric, Gilles[5]; Iovino, Doroteaciro[8]; Kauker, Frank[9]; Korhonen, Meri[10]; Lien, Vidar S.[11]; Marnela, Marika[10]; Massonnet, François[2]; Mignac, Davi[3]; Peterson, K. Andrew[12]; Rautiainen, Laura[1]; Sadikni, Remon[13]; Shi, Li[14]; Tietsche, Steffen[15]; Toyoda, Takahiro[16]; Xie, Jiping[17]; Zhang, Zhaoru[18]

[1]University of Helsinki, Finland
[2]Université Catholique de Louvain, Belgium
[3]University of Reading, United Kingdom
[4]Météo France/CNRS, France
[5]Mercator Océan, France
[6]University of Maryland, USA
[7]University of Oxford, United Kingdom
[8]Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici, Italy
[9]Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Germany
[10]Finnish Meteorological Institute, Finland
[11]Institute of Marine Research, Bergen, Norway
[12]Met Office, United Kingdom
[13]University of Hamburg, Germany
[14]Australian Bureau of Meteorology, Australia
[15]European Centre for Medium-Range Weather Forecasts (ECMWF), United Kingdom
[16]Japan Meteorological Agency, Japan
[17]Nansen Environmental and Remote Sensing Center, Norway
[18]Shanghai Jiao Tong University, China

Global and regional ocean and sea ice reanalysis products (ORAs) are increasingly used in polar research, but their quality remains to be systematically assessed. To address this, the YOPP endorsed Polar ORA Intercomparison Project (Polar ORA-IP) has been established following on from the ORA-IP project. Several aspects of ten selected ORAs in the Arctic and Antarctic were addressed by concentrating on comparing their mean states in terms of snow, sea ice, ocean transports and hydrography. Most polar diagnostics were carried out for the first time in such an extensive set of ORAs. For the multi-ORA mean state, we found that deviations from observations were typically smaller than individual ORA anomalies, often attributed to off-setting biases of individual ORAs. The ORA ensemble mean therefore appears to be a useful product and while knowing its main deficiencies and recognising its restrictions, it can be used to gain useful information on the physical state of the polar marine environment. This work is continuing with the assessments of interannual variability and trends of ORAs in the polar regions. For example, we will present ORA ensemble based estimates of decadal trends since 1990s for the Arctic Ocean stratification showing statistically significant warming and freshening in the top 300 metres.

Merged Observatory Data Files at the YOPP Super Sites for Special Observing Periods: Preliminary Verification Results

Uttal, Taneil[1]; Walden, Von[2]; Svensson, Gunilla[3]; Casati, Barbara[4]; Khalsa, Siri Jodha[5]; Konopleva, Elena[6]; Day, Jonathan[7]; Morris, Sara[5]; **Hartten, Leslie**[5,8]

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[2]Washington State University, USA
[3]Stokholm University, Sweden
[4]Environment Climate Change Canada, Canada
[5]University of Colorado, USA
[6]Science and Technology Corporation, USA
[7]European Centre for Medium-Range Weather Forecasts (ECMWF), United Kingdom
[8]Cooperative Institute for Research in Environmental Sciences (CIRES)

The International Arctic Systems for Observing the Atmosphere or “IASOA” (www.iasoa.org) is a consortium of 10 Observatories that encircle the Arctic Ocean that are supported by the National environmental monitoring and/or university institutions of each respective Arctic Nation as well as partner, non-Arctic countries. The IASOA consortium was initiated by NOAA during the International Polar Year (2007-2009) with a goal of standardizing measurement practices, filling geographical measurement “gaps”, and developing standardized data processing and quality control (QC). Although often co-located with regular weather stations that broadcast to the Global Telecommunications System (GTS), the Observatories are distinguished by the operation of suites of complex instrumentation that collect information on not only the how, but also the why of Arctic system trends and extremes. IASOA has developed a data portal for accessing a wide selection of data through a standardized metadata and harvesting procedure. https://www.esrl.noaa.gov/psd/iasoa/dataataglance This data portal presently serves as only a partial inventory, however it documents that there are hundreds of measurements producing information on scores of variables (made by as many instruments) with multiple versions of data being stored separately in a myriad of different files, formats and locations. The portal has proved to be insufficient for comprehensive and uncomplicated data access; data sets are collected by organizations with a wide range of archiving, metadata, availability and attribution practices. It is particularly daunting to assemble coordinated sets of these measurements across the network to serve such purposes such as model or satellite verification that require a consistent network product. Since IASOA Observatories have been designated as YOPP supersites, it is imperative that a solution be found to this problem. The solution proposed is to increase the access, usability and significance of the research-grade data from IASOA/YOPP Supersite network with the creation of federated data files. These federated files will be standardized, integrated, comprehensive, and inclusive and will be called Merged Observatory Data Files (MODFs). These files will be format and semantically matched internally and externally to model time step data sets being developed by YOPP modelers for the YOPP Special Observing Periods. We expect a tiered approach for model-observation comparisons starting with well-characterized variables (with low uncertainty) such as surface meteorology (2-m air temperature, pressure and humidity, 10-m wind speed and direction) and surface radiation (4-component), followed

by more stringent comparisons of the vertical structure of the atmosphere (e.g., radiosondes, cloud/aerosol profiling radars/lidars) and the full surface energy budget (including sensible and latent heat fluxes). The length of the periods of the organized data will also allow for regime-sorting to find periods when different processes dominate the bias for example strongly stable boundary layer regime or mixed-phase clouds. The ensemble of cases provide a more solid reference for model improvement work than single cases and also the possibility to learn about a selection of parameterization performance from the diversity of models participating in the YOPP exercise. Initial MODF and model comparisons will be presented as part of this presentation.

Impact of YOPP Radiosonde Soundings in NWP-Model HARMONIE-AROME in the Nordic MetCoOp Domain

Välisuo, Ilona[1]; Vihma, Timo[1]; Fortelius, Carl[1]; **Suomi, Irene**[1]; Randriamampianina, Roger[1]

[1]Finnish Meteorological Institute, Finland

The impact of additional radio soundings [from the YOPP] in a limited-area NWP system was studied in a set of data-denial experiments carried out using the HARMONIE-AROME system, nested into global forecasts from the IFS, obtained from corresponding experiments. The domain and version of HARMONIE used for this study corresponds to those used operationally by the MetCoOp coalition of the National weather services of Finland, Norway, and Sweden. In this study, the impact of additional YOPP radiosonde soundings is evaluated. During the YOPP Special Observation Periods, February – March and July - September 2018, the frequency of radiosonde soundings was increased from 2 to 4 or even 6 per day, depending on the radiosonde sounding station. The stations at which additional soundings were done, are located in the Northern Hemisphere, both inside and outside of the MetCoOp domain. The data denial experiments include three experiments. In the first experiment all available radiosonde soundings, including all additional YOPP soundings, are assimilated. This would include sounding at 00, 06, 09, 12, 15 and 18 UTC, at most. In the second experiment all additional YOPP-soundings are excluded to mimic the usual operational conditions. In the third experiment, part of the additional sounding is assimilated, such that only additional soundings at 09 and 15 UTC are rejected. All the experiments are planned together with partners from the Norwegian Meteorological Institute and ECMWF. The results of the experiments were analyzed to assess how the increased number of soundings affects the performance of the numerical weather predictions. Previous studies have shown that additional Arctic radiosonde observations improved the forecast capabilities over the Arctic Ocean. Here, focusing on the Nordic countries, we evaluate the differences between the three experiments to find out how much the assimilation of additional observations improves the analyses and short-term (12 and 24 h) forecasts. We analyze how the improvements depend on the time of the day, synoptic situation, season, and distance from the sounding stations.

Inter-comparison of Arctic Storms in Reanalysis Datasets

Vessey, Alexander[1]; Hodges, Kevin[1]; Day, Jonathan[2]; Shaffrey, Len[1]; Philp, Tom[3]

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[3]XL Catlin, United Kingdom

Arctic sea ice has reduced significantly over recent decades and is projected to reduce further over this century. Reduced Arctic sea ice will open up opportunities for the expansion of business and industrial activities into the Arctic. As a result, the exposure and risk of humans and infrastructure to extreme Arctic storms will increase. In addition, Arctic storms have also been found to travel through Northern Europe, leading to hazardous weather in heavily populated areas. Our understanding of the current risk from Arctic storms comes from analysing the past, for example by using reanalysis datasets. However, there are a number of reanalysis datasets available from different institutions that make use of different models and data assimilation systems. This can introduce uncertainty, especially in the relatively poorly observed Arctic. To quantify this uncertainty, Arctic storms have been identified and compared using data from four reanalysis datasets; ERA-Interim, JRA-55, MERRA-2 and NCEP-CFSR. The results suggest that there are substantial differences in the spatial distribution, intensity and frequency of Arctic storms in the different reanalysis datasets. For example, the largest uncertainty in the genesis density of Arctic storms was found to occur around north Greenland. ERA-Interim shows that 365 storms had genesis around north Greenland in winter months (DJF) between 1980 and 2017, though, NCEP-CFSR shows that only 265 storms had genesis over north Greenland respectively. This has an impact on the track densities calculated from each reanalysis datasets, and the largest uncertainty in track density of Arctic storms was found to occur in the North Atlantic Ocean and the Canadian Archipelago.

Session E: Atmosphere – Poster ID: #E20

An Atmospheric River Case Study during the ACLOUD Campaign at Ny-Ålesund (Svalbard)

Viceto, Carolina[1]; Mech, Mario[2]; Crewell, Susanne[2]; Rinke, Annette[3]; Rocha, Alfredo[1]; Gorodetskaya, Irina[1]

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[2]Institute for Geophysics and Meteorology, University of Cologne, Germany
[3]Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Germany

The Arctic is a region of major interest due to its high sensitivity to global warming with significant implications for both regional climate and global climate system. Significant increase in the atmospheric moisture content has been documented over the Arctic in the recent years. This is partially explained by the reduction of sea-ice cover, which enhances local evaporation. However, others argue that the predominant reason is the enhanced poleward moisture flux during the recent decades, which is expected to continuously increase in the future. This might be due to several factors or a combination of them, such as changes in the atmospheric circulation patterns, increased moisture transport intensity, and/or higher evaporation rates in the lower-latitude moisture source regions. Our study focuses on the anomalous moisture transport events confined to long, narrow and transient corridors, known as atmospheric rivers (ARs) which are expected to have a strong influence on Arctic mass and energy budget. Here we present a case study on 29-30 May 2017 with anomalous moisture transport identified as an AR reaching Ny-Ålesund (Svalbard), during the ACLOUD campaign (Arctic Cloud Observations Using airborne measurements during polar Day). We explore the temporal and spatial evolution of the AR by means of two tracking algorithms (Gorodetskaya et al., 2014; Guan and Waliser, 2015) and two reanalysis products (ECMWF's ERA-Interim, and NASA's MERRA-2). The intensity and pathways of the AR are analysed in synergy with the measurements from the AWIPEV research station in Ny-Ålesund. We analyse ground-based remote sensing measurements from Humidity and Temperature Profiler (HATPRO) and Jülich ObservatorY for Cloud Evolution (JOYCE) 94 GHz radar (JOYRAD-94), and the vertical profiles of the atmosphere by radiosondes. Further, we analyse the spatio-temporal development of the event using satellite-borne measurements by Infrared Atmospheric Sounding Interferometer (IASI) sensor and microwave sounder (AMSU-B/MHS) deployed on the MetOp (Meteorological Operational) satellite. Preliminary results show the AR that reached Ny-Ålesund extended from Western Siberia and was characterized by integrated water vapour transport greater than 200 kg m-1 s-1 intensifying significantly over the coastal regions, Kara Sea and the Arctic Ocean before reaching Svalbard. Integrated water vapour (IWV) showed large values over the Siberian Plain indicating that it could be a potential source region for anomalous moisture transport. At the same time large IWV values over the Arctic Ocean together with anomalous sea ice retreat south of Svalbard during the campaign period (Knudsen et al., 2018) indicate local evaporation as an additional moisture source. The IWV showed a peak up to 1.5 cm at Ny-Ålesund on 29-30 May 2017 with radiosonde measurements showing intense and short-lived warm and moist advection below 600 hPa.

Dynamics of Weather Extremes During the YOPP Special Observations Periods

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The YOPP Special Observations Periods in February – March and July – September 2018 were characterized by the occurrence of several extreme weather events. In February 2018, the circumpolar mean 2-m temperature north of 80N was approximately 10 K higher than the mean over 1958-2002. For a few days, the anomaly reached 20 K, and melting temperatures were observed in northeastern Greenland. The February extremes were apparently associated with occurrence of a predominant wavenumber 2 pattern of the atmospheric circulation, with a strong vortex over northeastern Canada and an extreme northwest displacement of the Aleutian Low. The displacement was also accompanied by a building up of the Pacific Ridge. These generated anomalous poleward advection of warm, moist air masses from both the Atlantic and Pacific sectors to the central Arctic. March 2018 was characterized by cold anomalies over the Kara Sea, northern Russia and large parts of Europe, and warm anomalies over the Labrador region as well as the Beaufort and Bering seas. Movement of low geopotential heights from the central Arctic into Eurasia and high heights west of Scandinavia gave the extreme "beast from the east" cold conditions over Europe. July 2018 was exceptional because of warm extremes in Fenno-Scandia and northwestern Russia. Cold anomalies occurred in Canadian Arctic archipelago. Summer conditions were, however, unexceptional over Greenland and Iceland. The synoptic conditions in summer were conducive to blocking over Scandinavia, with the UK having its joint-warmest summer on record, although the block broke down during August. We present analyses on large- and synoptic-scale conditions and processes affecting the occurrence and evolution of these extreme events. Considering the large-scale conditions, attention is paid to sea ice and SST fields, meridional air temperature, pressure and humidity gradients, geopotential height fields, the Polar front jet stream, North-Atlantic Oscillation, Pacific Decadal Oscillation, and sub-Arctic blocking. Synoptic-scale evolution of the extreme events is analyzed considering storm tracks over oceans and continents and high-pressure patterns over Greenland, Scandinavia, Urals, and Siberia. Dynamical processes are evaluated by the means of the baroclinic instability as measured by the Eady growth rate, stratosphere polar vortex and associated potential vorticity anomalies, and stratosphere-troposphere interactions, quantified on the basis of operational analyses of numerical weather prediction (NWP) models. We expect that thorough understanding of dynamics of the extreme events during YOPP SOPs will be beneficial for several YOPP studies addressing NWP model performance and the added value of the extra observations taken during the SOPs.

Session F: Sea Ice and Ocean – Poster ID: #F16

Modeling Sea Ice as a Two-Dimensional Granular Plastic: Some Preliminary Results

Wang, Keguan[1]

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We present the theoretical framework for modeling sea ice as a two-dimensional granular plastic. A dynamical model based on this framework is developed with some preliminary results from a six-day simulation of the Arctic sea ice. The model uses 10-km grid resolution. The initial sea ice conditions are from the SSMIS sea ice concentration and the combined CS2SMOS sea ice thickness. The forcing fields use the ERA-Interim reanalysis. We compare the modeled linear kinematic features with satellite observations, and analyze the scaling properties of the deformation fields.

The influence of ice fragmentation on the atmospheric boundary layer processes

Wenta, Marta[1]; Agnieszka, Herman[1]

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The response of oceanic and atmospheric boundary layer (ABL) to subgrid - scale variations of sea ice properties and fracturing has only recently attracted attention and mostly focused on the mixing occurring in the ocean. Additionally, processes taking place on the level of individual ice floes are not fully understood and therefore not taken into account in mesoscale Numerical Weather Prediction (NWP) models parameterizations. In response to growing need of improving the models performance, a series of high-resolution simulations with Weather Research and Forecasting (WRF) model is performed for different spatial sea ice distributions, ice concentrations and ambient wind speed profiles. The model parameters are set to represent Arctic winter conditions. The results indicate that the structure of ABL is highly sensitive to the spatial distribution of sea ice and open water. With identical ice concentration, considerable variability of several domain-averaged quantities like surface turbulent heat flux or ABL water vapor content for different arrangements of leads and ice floes is found. We suggest that NWP models need improvement and new parameterizations of the ABL are necessary. In order to provide a basis of such parameterizations we examine in detail the influence of sea ice spatial distribution on the turbulent heat flux. The comparison is made between the area averaged values of turbulent heat fluxes calculated for every grid cell of 100x100 m and turbulent heat fluxes determined from the domain averaged values of temperature, wind speed, exchange coefficients etc. - as in most of currently used NWP models. On the basis of acquired results we attempt to obtain coefficients indicating the influence of floe size and distribution on turbulent heat fluxes.

The Arctic Heat Open Science Experiment 2018: Collaboration, Initial Results, and Data Availability

Wood, Kevin[1]; Jayne, Steven[2]; Mordy, Calvin[1]; Ladd, Carol[3]; Schweiger, Axel[4]; Lui, Zheng[4]; Thomson, Jim[4]; Mackinnon, Jennifer[5]; Morison, James[4]

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[4]University of Washington, Applied Physics Laboratory (UW-APL), USA
[5]Scripps Institution, USA

In 2018 the Arctic Heat Open Science Experiment, in collaboration with the Innovative Technologies for Arctic Research (ITAE) program, and with projects supported by the Office of Naval Research (ONR) and NASA, carried out a combined engineering development and multidisciplinary research program in the Chukchi and Beaufort Seas using a specially-equipped NOAA Twin Otter aircraft (NOAA 56). A principal aim of the project was to monitor the seasonal evolution of oceanographic properties in the Chukchi Sea from the onset of melt to freeze-up using an extensive array of autonomous profiling floats and other expendable probes launched from ships and NOAA 56. Data from the array was used to investigate water mass modification and interactions across the continental shelf and into Canada Basin, and to support sea-ice forecasting and long-range projection of freeze-up in the Chukchi Sea. Between May and October 2018 an array of 26 near real-time autonomous profilers was deployed, with more to follow late in the season. The standard suite of weather instruments on the aircraft (flight-level data, radiometers) was augmented with a sea-surface LIDAR and thermal imaging system. Experimental deployments were carried out, such as a high-resolution atmospheric section, for example, using new types of devices. In this presentation we describe initial results obtained through this collaborative effort and provide information about open data resources that have been created.

North American Ice Service YOPP Engagement and Activities

Woods, John[1]; **Darden, Alexandra**[1]; Wesse, Scott[2]; Hicks, Michael[3]; Hebert, David[4]; Metzger, E. Joseph[4]; Tivy, Adrienne[2]; Petrescu, Gene[5]

[1]US National Ice Center, USA
[2]Canadian Ice Service, Canada
[3]International Ice Patrol, USA
[4]US Naval Research Laboratory, USA
[5]NOAA National Weather Service, USA

The North American Ice Service (NAIS) is an international partnership between the Canadian Ice Service (CIS), the International Ice Patrol (IIP), and the U.S. National Ice Center (USNIC). The mission of the NAIS is to leverage the strengths of the CIS, IIP, and USNIC to monitor and provide the highest quality, timely and accurate ice analysis, in order to meet the needs of the maritime interests of the United States and Canadian governments in support of: Safe and efficient maritime operations Weather and environmental modelling National and environmental security Research and climate understanding International treaty obligations NAIS centers have been endorsed as both operational center (Environment Climate Change Canada) and as an institutional partner through the USNIC with a goal of developing ice forecasting capabilities and products. The national centers within NAIS (CIS, USNIC, IIP) use model guidance to assist with operational support and long term sea ice and iceberg forecasting. Models currently used for ice support include: GOFS 3.1 (U.S. Navy) RTOFS (NOAA) RIOPS (ECCC) GIOPS (ECCC) NAIS Iceberg (NRC/CIS/IIP) Research and development centers (ex. NOAA Arctic Test Bed, Earth System Research Lab, U.S. Naval Research Lab, Canadian Centre for Meteorological and Environmental Prediction) are also engaged with the operational ice centers to understand requirements and transition the latest model products to operations on various time scales and resolutions. There is also a strong interest to continue iceberg modeling efforts to help meet the requirements of the IIP and CIS. The goal of this presentation will be to engage the YOPP Science Partners, update on the usage of model guidance within NAIS and YOPP activities, and explore further collaborations.

Evaluation of Thermodynamic and Dynamic Contributions to 2007 Summer Arctic Sea Ice Retreat in a Coupled Regional Climate Model

Yu, Xiaoyong[1]; Rinke, Annette[1]; Dorn, Wolfgang[1]; Spreen, Gunnar[2]; Sumata, Hiroshi[1]; Lüpkes, Christof[1]

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We evaluate the thermodynamic and dynamic contributions to the 2007 summer Arctic sea ice retreat in the coupled regional atmosphere-ocean-sea ice model HIRHAM-NAOSIM. Compared to ERA-Interim reanalysis data, the anomalous southerly wind and the transport of warm and moist air from the Pacific Ocean into the Arctic is much weaker in HIRHAM-NAOSIM. The positive surface energy budget anomaly is also much smaller in the model. Therefore, the simulated sea ice melt is underestimated. Further, HIRHAM-NAOSIM severely underestimates the Fram Strait sea ice volume export as compared to PIOMAS data. We also compare the observed and simulated relationship between near-surface wind, sea ice concentration and ice drift speed in September 2007, using 10-m wind from ERA-Interim, NSIDC sea ice concentrations, and KIMURA ice drift data. Based on observations over the Transpolar Drift Stream, the ice drift speed shows a clear linear relation with sea ice concentration (higher sea ice concentration, lower ice drift speed) when the concentration is lower than 95%. For more compact sea ice, there is not such a linear relationship. In HIRHAM-NAOSIM, most ensemble members agree on a linear relationship between sea ice concentration and drift speed when sea ice concentration is lower than 75%. However, the slope of this relation in the model is smaller than in the observations. The observed higher wind factor (ratio between ice drift speed and wind speed) for lower ice concentration is qualitatively reproduced by the model. However, the model ensemble mean wind factors are higher (lower) than in the observations when the sea ice concentration is lower (higher) than 90% for the whole Arctic. This indicates that the ice drift is more (less) responsive to wind forcing in HIRHAM-NAOSIM than in the observations. A sensitivity experiment with respect to an improved parameterization of the transfer coefficients for momentum and heat over sea ice (Lüpkes et al., 2015) shows pronounced impact on surface turbulent fluxes, sea ice drift speed and wind factor. However, deviations to the observations are still substantial and only partly lower than in the control experiment.

Prospects for subseasonal sea ice prediction at both poles

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With retreating sea ice and increasing human activities comes a growing need for reliable sea ice forecasts up to months ahead. We exploit the subseasonal-to-seasonal (S2S) prediction database and provide a thorough assessment of the skill of operational forecast systems in predicting the location of the Arctic and Antarctic sea ice edges on these time scales. We find large differences in skill between the systems, with some showing a lack of predictive skill even at short weather time scales, and the best producing skillful Arctic forecasts more than 1 1/2 months ahead. We assess the forecast skill in both hemispheres, thereby showing that prospects for subseasonal sea ice predictions are promising, especially for Arctic late summer forecasts. To fully exploit this potential, it will be imperative to reduce systematic model errors and develop advanced data assimilation capacity.

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