8th International Workshop on Sea Ice Modelling, Data Assimilation and Verification

1-3 November 2017 – Hotel Zander K, Bergen Norway

INTAROS

Updated programme and abstract book (2017-10-27)

A joint workshop between the International Ice Charting Working Group (IICWG), the World Weather Research Programme (WWRP) Polar Prediction Project (PPP), WWRP Joint Working Group on Forecast Verification Research (JWGFVR) and GODAE Oceanview (GOV)

The 8th International Ice Charting Working Group's Data Assimilation workshop is also a stakeholder engagement event of the EU Horizon 2020 INTAROS project. INTAROS will develop an integrated Arctic Observation System by extending, improving and unifying existing systems in the different regions of the Arctic. This includes the sea ice as an essential element of the Arctic climate system. The observations are intended for real-time monitoring as much as for climate change predictions.

The workshop is sponsored by EU projects INTAROS and ICE-ARC and by CliC – Climate and Cryosphere, a core project of the World Climate Research Programme (WCRP)

Location: Hotel Zander K, Zander Kaaes gate 7, 5015 Bergen, Norway

Hotel reservation:

Follow the link to book a room at preferential rate at Hotel Zander K.(deadline 1st October)
https://gc.synxis.com/rez.aspx?Hotel=72004&Chain=14718&template=ZANDERK&shell=ZK_2017&locale=en-US&arrive=10/30/2017&depart=11/4/2017&adult=1&child=0&group=IICWG-DA

Day 1, Modelling and Data Assimilation

09.00	09.30	Yang Zhang	Second Institution of Oceanography, SOA	Applications of an Unstructured Grid Surface Wave Model (FVCOM-SWAVE) to the Arctic Ocean: Effects of Ice-induced Wave Attenuation
09.30	10.00	Jonni Aleksi Lehtiranta	Finnish Meteorological Institute	Ensemble sea ice forecasting and different fast ice schemes in the Baltic Sea
10.00	10.30	Amy Solomon	University of Colorado and NOAA/ESRL	Improving sea ice forecasting in the marginal ice zone with a regional climate model
10.30	11.00	Coffee		
11.00	11.30	Till Soya Rasmussen	Danish Meteorological Institute	Developments of the Arctic operational ocean and sea ice model at DMI
11.30	12.00	Gregory Smith/Lynn Pogson	ECCC	ECCC YOPP Coupled Forecasting System
12.00	12.30	Andrea Gierisch	Finnish Meteorological Institute (FMI)	Risk assessment for ship operations in the Arctic from a sea ice model
12.30	13.30	Lunch		

13.30	14.00	Gilles Garric	Mercator Ocean	Impact of uncertainties from 7 atmospheric reanalysis surface conditions on Arctic sea ice cover
14.00	14.30	Einar Olason	NERSC	On the statistical properties of sea-ice lead fraction and heat fluxes in the Arctic
14.30	15.00	Clement Rousset	LOCEAN-CNRS	Evaluation of kilometer-scale ice-ocean simulations in the Svalbard Archipelago region
15.00	15.30	Coffee+Poster intro		
15.30	16.00	Helge Goessling	AWI	The Year of Polar Prediction and the Sea Ice Drift Forecast Experiment
16.00	16.30	Michael Mayer	ECMWF	Current sea-ice-related activities at ECMWF
16.30	17.00	Ali Aydogdu	NERSC	Probabilistic forecasts with the Lagrangian-coordinates neXtSIM model: relevance for search-and-rescue operations.
17.00	17.30	Frank Kauker	Alfred Wegener Institute	Assessment of ten ocean reanalyses in the polar regions

18:30 -> Workshop Icebreaker event and Poster Session at NERSC (Pizza + beer)

Day 2, Data assimilation and Observations

09.00	09.30	Mark Buehner	Environment and Climate Change Canada	Recent Sea Ice Data Assimilation Research at ECCC
09.30	10.00	Andrea Scott	University of Waterloo	Toward the assimilation of high-resolution sea ice observations
10.00	10.30	Giovanni Ruggiero	Mercator Ocean	Assimilation of sea-ice concentration into a multi-category sea-ice model using an Ensemble Kalman Filter
10.30	11.00	Coffee		
11.00	11.30	Sindre Markus Fritzner	University of Tromsø	The ROMS-CICE data assimilation system for sea-ice assimilation

11.30	12.00	Ed Blockley	Met Office	Impact of initialising sea ice using CryoSat2 thickness within the Met Office's coupled seasonal prediction system
12:00	12:30	Keguang Wang	Norwegian Meteorological Institute	Multi-source data merging for Arctic sea ice concentration and thickness
12.30	13.30	Lunch		
13.30	14.00	Thomas Kaminski/Frank Kauker	The Inversion Lab/OaSys	Impact of Sea Ice Thickness and Freeboard Products on Performace of Seasonal Forecasts
14.00	14.30	Madlen Kimmritz	NERSC Bergen	Optimising assimilation of sea ice concentration in a fully coupled Earth system model with a multicategory sea ice model
14.30	15.00	Charles-Emmanuel Testut/Giovanni Ruggiero	Mercator-Ocean	Recent advances in the Mercator-Ocean reanalysis system: Application to an Arctic configuration
15.00	15.30	Coffee		
15.30	16.00	Hiroshi Sumata/Frank Kauker	AWI	A simultaneous optimization of Arctic sea ice model parameters by genetic algorithm
16.00	16.30	Sean Helfrich	NOAA's Center for Satellite Applications and Research (STAR)	A Proposed Method for WMO Ice Chart Uncertainty Metrics.
16:30	17:00	Shengli Wu	National Satellite Meteorological Center of China	Sea Ice monitoring and analysis using Chinese Meteorological Satellite Satellite

Day 3, Observations and Verification

09.00	09.30	Leif Toudal Pedersen	Technical University of Denmark	Satellite observations of sea ice concentration

09.30	10.00	Björn Erlingsson	University Centre of the Westfjords, Iceland	Using RGPS derived sea ice kinematics data for measurements of internal friction
10.00	10.30	Xu, Shiming	Tsinghua University	Combined retrieval of sea ice thickness and snow depth using altimetry and passive microwave remote sensing data
10.30	11.00	Coffee		
11.00	11.30	Giacomo De Carolis	CNR-IREA	CRYORAD: a spaceborne ultrawide band microwave radiometer for sea ice thickness monitoring. A feasibility study.
11.30	12.00	Arne Melsom	Norwegian Meteorological Institute	Comprehensive validation of sea ice forecasts from a real-time operational ocean-ice model
12.00	12.30	Lorenzo Zampieri	Alfred Wegener Institute for Polar and Marine Research	Verification of Subseasonal to Seasonal sea ice Forecasts
12.30	13.30	Lunch		
13.30	14.00	Oleg M. Pokrovsky	Russian State HydroMeteorological University, St. Petersburg	Classification of Atmospheric Circulation Regimes in the North Atlantic and the Subarctic Zone of Europe and the Methodology of Seasonal Weather Prediction using a Neuro-Fuzzy Model
14.00	14.30	Lynn Pogson	Canadian Ice Service	Verification activities at the Canadian Ice Service/Environment and Climate Change Canada
14.30	15.00	Takamasa Tsubouchi	Alfred Wegener Institute for Polar and Marine Research	Observed Arctic Ocean volume and heat transports during 2004-2010
15:00	15:30	Andrew Ryan	Met Office	GODAE OceanView Global Ocean sea-ice inter-comparison
15.30	16.00	Coffee+end of WS		

Abstracts
Day 1

Applications of an Unstructured Grid Surface Wave Model (FVCOM-SWAVE) to the Arctic Ocean: Effects of Ice-induced Wave Attenuation

Yang Zhang[1,2], Guoping Gao[1], Changsheng Chen[2,1], Yu Zhang[2], Robert C.Beardsley[3], Jianhua Qi[2], William Perrie[4] , and Huichan Lin[2]
1: College of Marine Sciences Shanghai Ocean University, Shanghai, China
2: School for Marine Science and Technology University of Massachusetts-Dartmouth, New Bedford, Massachusetts, USA
3: Department of Physical Oceanography Woods Hole Oceanographic Institution, Woods Hole, Massachusetts, USA
4: Fisheries & Oceans Canada Bedford Institute of Oceanography, Dartmouth, Nova Scotia, Canada

Rapidly melting processes during the summer tend to enlarge the open water in the Arctic region.
The resulting larger fetch for surface waves allows significant wave generation and development in the region. The sea ice plays an energy dissipation role for waves propagating into the marginal ice zone (MIZ). A spherical-coordinate surface wave model was established within FVCOM to examine the influence of ice-induced wave attenuation on waves propagating into the ice in the Arctic Ocean. An advection method was introduced to solve the problems of the invalid scalar assumption at high latitudes and singularity at the North Pole. Ice-induced wave attenuations with effectively reducing numerical dissipation during the energy advection in geographic space were implemented. The wave partition and source tracking methods were added to distinguish the windsea and swell, as well as to backtrack swell waves to their sources. The model-simulated significant wave heights and peak periods were compared with available buoy and Jason-2 satellite measurements. The process-oriented model results showed that simulations of the surface waves in the Arctic region improved when ice-induced attenuation was included in the model system. An empirical method was used to statistically estimate wave-induced ice breakage when the ice concentration was less than 0.4, based on the wave-induced internal ice strain as the waves penetrated into the ice zone. The simulation results supported the 'ice retreat-wave growth' positive feedback mechanism, which was persistent on the Atlantic side and becomes more important on the Pacific side of the Arctic Ocean.

Ensemble sea ice forecasting and different fast ice schemes in the Baltic Sea

Jonni Lehtiranta, Mikko Lensu, and Jari Haapala
Finnish Meteorological Institute, Helsinki, Finland

An ensemble sea ice forecast is under development at the Finnish Meteorological Institute.
Forecasting of sea ice hazards is important for winter shipping in the Baltic Sea. In current numerical models the ice thickness distribution and drift are captured well, but compressive situations are often missing from forecast products. We have found that compression can not be predicted well in a deterministic forecast, since it can be a local and fickle phenomenon. It is also sensitive to small changes in the wind speed and direction, the prevailing ice conditions, and the model parameters. An ensemble model setup was developed in the SafeWIN project for this purpose using the HELMI multicategory ice model.
We have found that compressive situations often happen near the fast ice edge both in the model and in reality. For a long time, our forecast model has assumed a static fast ice area based on the Baltic IOW topography only. This fast ice scheme doesn't produce a realistic fast ice edge, and correspondingly, it is found to cause an unrealistic spatial distribution for compression. Worse, the compression maxima are affected, making it difficult to forecast the risk of compression in a probabilistic sense.
New reanalysis simulations have been made with an alternative fast ice parametrization, and with the fast ice zone assimilated from the daily ice chart data. This work will study the sensitivity of the forecasts to the fast ice parametrization and the possible improvements to our sea ice model. The model results will be compared to ice compression reports gathered from ships.

Improving sea ice forecasting in the marginal ice zone with a regional climate model

Amy Solomon, University of Colorado and NOAA/ESRL

In recent decades, Arctic climate has changed rapidly. The most apparent physical manifestation of this change is a decline of Arctic sea ice, which is a key indicator of global climate transitions. Sea ice has significant and immediate consequences for evolving societal and economic interests in the region, such as transportation, resource development, safety, and ecosystem

responses. Ultimately, improved sea ice forecasting must be based on improved model representation of coupled system processes that impact the sea ice thermodynamic and dynamic state. Pertinent coupled system processes that remain uncertain include surface energy fluxes, clouds, precipitation, boundary layer structure, momentum transfer and sea-ice dynamics, interactions between large-scale circulation and local processes, among others.

The NOAA-CIRES Sea Ice Forecasting (SIF) team produces daily quasi-operational 10-day forecasts of the Arctic Ocean freeze-up season (July-November) with the Regional Arctic System Model (RASM-ESRL). These forecasts are used by the NWS Alaska Sea Ice Program, Arctic Testbed, and U.S. National Ice Center for their operations.

In this presentation, we will present results from studies that assess improvements in forecast skill by using different initialization strategies, for example, using CRYOSAT2 sea ice thickness and ocean fields that assimilate all available campaign and buoy data. Results from a study to assess the impact of using a dynamical ocean model on these short time scales will also be

Developments of the Arctic operational ocean and sea ice model at the Danish Meteorological Institute

Till Rasmussen, Danish Meteorological Institute

The Danish Meteorological Institute (DMI) runs an operational coupled ocean and sea ice model (HYCOM+CICE+ESMF) based on a model system mainly developed by the Naval Research Lab. This runs in a regional configuration that covers the Arctic and the Atlantic oceans to 20 degrees south of equator and it is forced by ERA-INTERIM in hindcast mode and the operational ECMWF in forecast mode. The model system is continuously being developed with focus on new physics, improved assimilation and new data feeds for the assimilation.

This presentation will cover the current status of development, recent result and validations with observed data and other model data. In addition potential use cases will be outlined.

ECCC YOPP Coupled Forecasting System

G. Smith, F. Dupont, F. Roy, J-F Lemieux, K Chikhar, Ji Lei, Y Liu, and the CONCEPTS Team
Environment and Climate Change Canada

As part of the Year of Polar Prediction (2017-2019), Environment and Climate Change Canada (ECCC) is implementing an experimental coupled atmosphere-ice-ocean forecasting system for the Arctic. The ice- ocean component is based on the Regional Ice Ocean Prediction System and uses the NEMO-CICE model at a resolution of 3-8 km covering the Arctic and North Atlantic Oceans. ECCC's atmospheric model GEM is coupled to RIOPS using a pan-Arctic configuration at 2.5km resolution. Here we will examine the impact of coupling on forecast skill and describe a number of improvements made to the various modelling components. These include the use of an explicit landfast ice parametrization based on the effect of grounded ice ridges (Lemieux et al. 2015) and on an increased resistance to tension and shear in the ice rheology (Lemieux et al. 2016), and the use of a variable form drag parameterisation (Tsamados et al., 2014).

Risk assessment for ship operations in the Arctic from a sea ice model

Andrea Gierisch, Eero Rinne, Petteri Uotila
Finnish Meteorological Institute

With ice conditions in the Arctic becoming lighter, ship traffic is expected to increase. Sailing in ice-covered waters can entail additional risks for a ship and these risks should be evaluated during the planning of the ship operation. A recommended method for risk assessment is proposed by the Polar Code, which entered into force in 2017. This method, called POLARIS, determines risks depending on the ship's ice class and the prevailing ice conditions. However, POLARIS was developed to be applied only to ice information from ice charts or from bridge observations, but not to ice conditions simulated by sea ice models. Because navigators are also interested in modelled/forecasted ice conditions and the related risks, we show in this presentation how POLARIS can be adopted to be used on model output. We use simulated ice thickness distributions from a global NEMO-LIM 3.6 hindcast simulation and relate them to the risk calculated from Russian AARI ice charts. This relationship is then used to convert forecasted ice conditions into risk estimates.

Impact of uncertainties from 7 atmospheric reanalysis surface conditions on Arctic sea ice cover

Clément Bricaud, Giovanni Ruggiero, Olga Hernandez, Gilles Garric, Jerome Chanut
Mercator Océan, France

Previous and numerous studies have already shown that atmospheric forcing fields essentially drive the results of Arctic sea ice simulations or are at least as important as the details of the sea ice model itself. Given the relative errors found in state of the art atmospheric reanalysis in the Arctic Ocean (Lindsay, et al., 2014), we propose here to estimate error bars of the last decade Arctic sea ice cover (2007-2015) related to uncertainties errors in state-of-the-art atmospheric forcing.

To address this question, we have built an ensemble of pan-Arctic experiments driven at the surface by all the following global atmospheric reanalysis available on the 2007-2015 periods: IFS (Integrated Forecasting System from ECMWF), ERA-Interim, NCEP-R2, MERRA-2, CFSR/CFSv2, JRA-55 and CGRF. The pan-Arctic configuration uses the latest version 3.6 of the NEMO-LIM3 platform at 1⁄4° resolution. First assessments show sea ice volume is overestimated applying the default LIM3 setup. Increasing the number of categories, changing the ice thickness distribution, modifying rheology parameter, reducing the area participating in ice ridging largely improve the sea ice thickness in the Canadian Basin.

Assessment of the impact of atmospheric forcing uncertainties on the simulated sea ice extent, thickness, drift, snow depth and on the surface temperature is performed. Atmospheric sources uncertainties of FW storage and of solid and liquid FW transports through Arctic gateways are finally given.

On the statistical properties of sea-ice lead fraction and heat fluxes in the Arctic

Einar Olason, Pierre Rampal, and Sylvain Bouillon, NERSC, Norway

Heat flux through leads and polynyas is an order of magnitude larger than that through unbroken ice. In this paper, we explore some statistical properties observed in Arctic sea ice lead fraction, showing that our model (neXtSIM) reproduces well the probability density function (PDF) and the mono-fractal spatial and temporal scaling of observed lead fluxes in the Central Arctic. Given the importance of heat flux through leads we then use the model to explore the statistical properties of the modelled heat fluxes. We show that the heat fluxes have a multi-fractal scaling in the Central Arctic which we attribute to lead formation, while coastal polynyas destroy the scaling in the wider Arctic. We also demonstrate a temporal scaling of the Central Arctic heat fluxes. Finally, we show that the scaling of simulated lead fraction is preserved for different model resolutions, while further work on a sub-grid scale parameterisation of surface heterogeneity is required to preserve the scaling of heat fluxes for different model resolutions.

Evaluation of kilometer-scale ice-ocean simulations in the Svalbard Archipelago region

Clement Rousset, LOCEAN-CNRS

Traditionally sea ice models have been used at coarse resolution to represent relatively large scale processes (few tens of kilometers). The continuous increase in computing resources recently allows to effectively resolve scales of order 1-10 km but this raises the question of what can be represented at this resolution. We document this issue with very high resolution simulations (order 1 km) of the Storfjorden area in the Svalbard Archipelago, which encapsulates recurrent coastal polynyas. We focus on the relation between dense water formation and production of sea ice, and on the role of high frequency processes such as tides, which illustrates the upcoming capabilities of ice-ocean systems.

The Year of Polar Prediction and the Sea Ice Drift Forecast Experiment

Helge Goessling, AWI

The Year of Polar Prediction (YOPP; www.polarprediction.net/yopp), established by the World Meteorological Organization's World Weather Research Programme, is an international initiative to significantly advance our environmental prediction capabilities for the polar regions and beyond, on time scales from hours to a season. The YOPP Core Phase (mid-2017 to mid-2019) comprises intensive observing, modelling, prediction, verification, user-engagement and education activities in the Arctic and Antarctic. Closing gaps in the conventional polar observing systems during Special Observing Periods will allow carrying out numerical experiments aimed at diagnosing model shortcomings and optimising the future polar observing system. At this workshop I will provide an update on the YOPP achievements and planning.

I will also present one particular activity that has been initiated as part of YOPP in collaboration with other initatives and networks: The Sea Ice Drift Forecast Experiment (SIDFEx, 2017–2020; www.polarprediction.net/yopp/sidfex) is a community effort to collect and analyse Arctic sea ice drift forecasts at lead times from days to a year, based on arbitrary methods, for a number of targets such as sea-ice buoys on a regular basis. We expect that a systematic assessment of real drift forecasting capabilities will (i) improve our physical understanding of sea ice, (ii) help us identify and resolve model shortcomings, (iii) reveal the limits of sea-ice drift predictability, and (iv) generate a solid basis to provide operational support - e.g., when it comes to the planning of supply operations and the ordering of satellite imagery during the upcoming MOSAiC expedition.

Current sea-ice-related activities at ECMWF

Michael Mayer, Steffen Tietsche, Beena Balan-Sarojini, Magdalena Alonso-Balmaseda
European Centre for Medium-Range Weather Forecasts, Reading, UK

Several activities dealing with sea ice within the ongoing H2020-funded SPICES project will be presented. The main aim of that project is to provide a better estimate of sea ice initial conditions in order to improve seasonal sea ice forecasts. Forecast experiments using improved initial conditions of sea-ice fraction and thickness are currently carried out using ECMWF's seasonal forecasting system. Impact of the improved initial conditions on sea ice forecast skill is assessed by comparison to forecasts from the operational system. On the diagnostic side, an energy budget approach is employed to infer the annual cycle of Arctic sea ice mass from atmospheric and oceanic heat budgets, using satellite-based and in-situ data as well as atmospheric and oceanic reanalyses to estimate energy flux and storage terms. The inferred annual cycle of sea ice mass will provide a largely independent estimate of this important quantity.

Probabilistic forecasts with the Lagrangian-coordinates neXtSIM model: relevance for search-and-rescue operations

Matthias Rabael, Ali Aydogdu, Pierre Rampal, Alberto Carrassi, Laurent Bertino
Nansen Environmental and Remote Sensing Center, Bergen, Norway

We present a sensitivity analysis, and discuss the probabilistic forecast capabilities, of the novel sea ice model *neXtSIM*. 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 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 of 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 buoys' 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.

Assessment of ten ocean reanalyses in the polar regions

Frank Kauker (Alfred Wegener Institute, Germany), Petteri Uotila (Finnish Meteorological Institute), Doroteaciro Iovino (Centro Euro-Mediterraneo sui Cambiamenti Climatici, Italy), Neven Fučkar (Barcelona Supercomputing Centre, Spain), Li Shi (the Bureau of Meteorology, Australia), Matthieu Chevallier (Centre National de Recherches Météorologiques, Météo France/CNRS UMR3589, France), Steffen Tietsche (the European Centre for Medium-Range Weather Forecasts), Meri Korhonen (Finnish Meteorological Institute), Marika Marnela (Finnish Meteorological Institute), Vidar Lien (Institute of Marine Research, Norway), Takahiro Toyoda (Japan Meteorological Agency), K Andrew Peterson (Met Office, UK), Gilles Garric (Mercator Ocean, France), Clement Bricaud (Mercator Ocean, France), Jiping Xie (Nansen Environmental and Remote Sensing Center, Norway), Zhaoru Zhang (Shanghai Jiao Tong University, China), Antoine Barthélemy (Université catholique de Louvain, Belgium), Hugues Goosse (Université catholique de Louvain), François Massonnet (Université catholique de Louvain, Belgium and Barcelona Supercomputing Centre, Spain), Remon Sadikhi (University of Hamburg, Germany), James Carton (University of Maryland, USA), Keith Haines (University of Reading, UK), Davi Mignac Carneiro (University of Reading, UK)

Ocean reanalysis (ORA) combines observations with a hydrodynamical model, to reconstruct historical changes in the ocean. Global and regional ORA products are increasingly used in polar research, but their quality remains to be systematically assessed. To address this, the Polar ORA Intercomparison Project has been established following on from the ORA-IP project (see Balmaseda et al. 2015; and Chevallier et al. 2016 in Climate Dynamics). The Polar ORA-IP is constituted under the COST EOS initiative with plans to review reanalyses products in both the Arctic and Antarctic, and is endorsed by YOPP - the Year of Polar Prediction project. The Polar ORA-IP team consists of 22 researchers from 16 institutes and universities. The ORA-IP products with polar physics, such as sea ice, have been updated where necessary and collected in a public database. In addition to model output, several observational polar climatologies are collected and used in the assessments. Due to the extensive variety of products, this database should become a valuable resource outside the Polar ORA-IP community.

For a comprehensive evaluation of the ten ORA products (C-GLORS025v5, ECDA3, GECCO2, Glorys2v4, GloSea5-GO5, MOVE-G2i, ORAP5, SODA3.3.1, TOPAZ4 and UR025.4) in the Arctic and Southern Oceans several specific diagnostics are assessed. The Polar ORA-IP diagnostics target the following topics: hydrography and water masses; heat, salinity and freshwater content; ocean transports and surface currents; mixed layer depth; sea-ice concentration, extent, area, thickness and volume; and snow depth on sea ice. Based on these diagnostics, ORA product biases against observed data and their mutual spread are quantified, and possible reasons for discrepancies discussed.

So far, we have identified product outliers, evaluated the multi-model mean and investigated interannual variability and trends from 1993-2010. Results emphasise the importance of the atmospheric forcing, air-ocean coupling protocol and sea-ice data assimilation for the product performance. For example, products with sea-ice data assimilation produce more realistic sea-ice extent (but not necessarily a more realistic sea-ice thickness), a more realistic MIZ/pack ice area ratios, and mixed layer depth, while products with a thick snow layer on ice tend to generate a relatively shallow mixed layer. For the multi-model mean, we identified a link between deep North Atlantic mixed layer depth and oceanic convection, relatively low heat transport to the Arctic through the Fram Strait and cooler than observed Atlantic water in the Arctic. We will also present other diagnostic results which provide closely related information for those interested in enhancing model predictive skill over a range of time scales, including seasonal to decadal.

Day 2

Recent Sea Ice Data Assimilation Research at ECCC

Mark Buehner, Alain Caya, Alex Komarov, Lynn Pogson
Environment and Climate Change Canada

The regional ice and ocean prediction system (RIOPS) uses a 3DVar-based sea ice data assimilation system to produce analyses of sea ice concentration. This system assimilates several types of observations, including data from passive microwave and visible-infrared satellite sensors in addition to manually produced ice charts from the Canadian Ice Service. Recent research has focused on the assimilation of ice extent information from Radarsat-2 data and ice thickness from SMOS data. The approaches used for these two data types will be described and recent results showing the assimilation impacts will be shown.

Toward the assimilation of high-resolution sea ice observations

K. Andrea Scott, Nazanin Asadi and David Clausi Department of Systems Design Engineering University of Waterloo, Waterloo, Canada

High resolution observations of the sea ice state can show small scale features, such as leads, ice floes, and possibly ridges. Depending on the method by which the observations are acquired, they may contain spatially correlated errors. For example, observations from a synthetic aperture radar (SAR) sensor are typically obtained by considering information in the neighbourhood of an image pixel. When these observations are closely spaced, such that these neighbourhoods overlap, this dependency can lead to correlated errors. Assimilation of observations taking into account the error correlations is known to lead to improved representation of small scale details, but sometimes also generates unwanted noise. In the image processing community, a robust method to reduce im- age noise is to regularize the cost function using an l_1 norm. In this talk, the impact of using a correlated observation error covariance matrix on the representation of sharp features in sea ice analyses will be compared with that from using a mixed $l_1 - l_2$ formulation.

Assimilation of sea-ice concentration into a multi-category sea-ice model using an Ensemble Kalman Filter

Giovanni Ruggiero, C-E. Testut, C. Bricaud, J. Chanut, Olga Hernandez and Gilles Garric

The future global forecast system of Mercator Ocean, to be released in 2020, is being configured with a multi-category sea-ice model and ensemble based data assimilation method. In a multi-category sea-ice model the ice at each grid point is characterized by a finite number of sea-ice categories that are defined by classes of thickness. This means that the ice concentration in a grid point is the sum of the concentrations of each category and the sea-ice volume per unit area is the weighted mean of the ice thickness for each category where the weights are the sea-ice concentration of the corresponding category.
The most important impact on the assimilation system of using a such a multi-category model is the need to control the sea ice concentration and sea ice volume for each category, which are the prognostic variables, with observations of total concentration, which is a diagnostic variable. This means that we need somehow to find a sea-ice thickness distribution with the correct mean and the correct weights/concentrations without any information about its distribution. The big issue is that changes in the distribution of sea ice concentration will potentially change the total sea ice volume as well as the ice thermodynamics properties leading to bad short term forecast as well as non realistic long term trends.
In this work, the problem of assimilating sea ice concentration into a multi-category model is addressed by using ensemble methods along with stochastic perturbations of some model parameters. More specifically, the regional Arctic configuration CREG025 is used to create a 32 member ensemble simulation. Each member is initialized from fields issued from a deterministic simulation and then atmospheric forcing fields, ice-strength concentration parameter, ice-ocean drag and the ocean state equation are modeled by an auto-regressive process with mean (mode in the case of Gamma process) equal to the parameter used in the deterministic simulation. Then an Ensemble Kalman Filter (EnKF) is used to constrain sea-ice concentration and sea-ice volume for each category.
The ensemble of model simulations are compared against independent sea-ice concentration product and non-assimilated sea-ice thickness and sea-ice drift. Deterministic metrics such as bias and rms errors as well as probabilistic

metrics such as rank histogram and spread/error relationship are produced for each data set.

The ROMS-CICE data assimilation system for sea-ice assimilation

Sindre Fritzner[1], Rune Graversen[1], Philip Rostosky[2]
[1]Department of Physics and Technology, University of Tromsø, Norway
[2]Institute of Environmental Physics, University of Bremen, Germany

This study introduces a new data assimilation system for the coupled model system between the Regional Ocean Modeling System (ROMS) and the Los Alamos sea-ice model (CICE). The focus of this study is how the model system is effected by assimilation of various sea-ice observations. For assimilation the deterministic ensemble Kalman filter (DEnKF) from the EnKF-c code is used. The assimilation system has 20 ensemble members and a localization radius of 300km. To asses the new assimilation system, different observations have been assimilated individually. The different observations are EUMETSAT OSISAF sea-ice concentration, Cryosat thick ice thickness observations, SMOS thin ice-thickness observations and snow thickness observations.
Initial experiments show that assimilation of ice thickness and snow thickness observations have a small impact on the short term ice concentration, while assimilating Cryosat ice thickness and snow thickness observations gives a significantly improved model state. This is due to no ensemble spread of concentration in the central Arctic during the cold season, thus other observations are needed to improve the model state.
For sea-ice concentration assimilation there is a bias in the assimilation system towards the model when the concentrations are high, this is due to the fact that ice concentrations cannot exceed one. In this study, a method to improve utilization of ice concentration observations, especially during the warms season, is proposed. This new method increases the concentration ensemble spread when the ice concentrations are near maximum. The increased spread is achieved by allowing concentrations larger than one during assimilation. This is done by using the perturbed values less than one and mirroring them to values larger than one. This gives a more realistic model spread and avoids unrealistic high confidence in the model system during assimilation.

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

Ed Blockley, Met Office, UK

Seasonal predictions at the Met Office are made using the GloSea5 coupled forecasting system which is run daily out to 210 days using the NEMO ocean and CICE sea ice models at 1/4 degree global resolution. The ocean and sea ice components of GloSea are initialised using analysis fields from the FOAM ocean-sea ice analysis and forecast system. Satellite and in-situ observations of temperature, salinity, sea level anomaly and sea ice concentration are assimilated by FOAM using the NEMOVAR 3D-Var data assimilation scheme.
At present only concentration is assimilated within the FOAM sea ice analysis but the Met Office are currently developing capability to assimilate sea ice freeboard and thickness observations from CryoSat-2 and SMOS sensors within the NEMOVAR 3D-Var framework.
A scoping study has been performed to assess the impact on the evolution of sea ice seasonal forecasts of initialising with CryoSat2-derived thickness observations. Results from this study will be presented here which show the initialisation of thickness leads to improved skill for seasonal predictions of Arctic summer sea ice extent and ice-edge location.

Multi-source data merging for Arctic sea ice concentration and thickness

Keguang Wang, Caixin Wang, Thomas Lavergne, Frod Dinessen
Norwegian Meteorological Institute

With the rapid change in the Arctic sea ice, a large number of Arctic sea ice observations are emerging in recent years. To make the best use of these observations, a multi-source optimal data merging (MODM) method is developed to merge any number of different sea ice observations. Such merged data is independent on model forecast, so it is valid not only for sea ice model initialization and but also for model validation. Based on the maximum likelihood estimation theory, it is proved that any model assimilated with the merged data is equivalent to assimilating the original multi-source data. This greatly facilitates sea ice data assimilation, as the more complex and computation-demanding multi-source data assimilation can be avoided. The MODM method is applied to merge sea ice concentration (SIC) and sea ice

thickness (SIT) in the Arctic. For SIC merging, the Special Sensor Microwave Imager/Sounder (SSMIS) and Advanced Microwave Scanning Radiometer 2 (AMSR2) data are merged together with the Norwegian Ice Service ice chart. This substantially reduces the uncertainties at the ice edge and in coastal areas. For SIT merging, the daily Soil Moisture and Ocean Salinity (SMOS) data is merged with weekly merged CryoSat-2 and SMOS (CS2SMOS) data. This generates a new daily CS2SMOS SIT data with better spatial coverage for the whole Arctic.

Impact of Sea Ice Thickness and Freeboard Products on Performace of Seasonal Forecasts

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The A+5 study belongs to the STSE ARCTIC+ cluster of ESA projects and specifically contributes to the Year of Polar Prediction (YoPP). A+5 is constructing a flexible system for Arctic Mission Benefit Analysis (ArcMBA) that evaluates in a mathematically rigorous fashion the observational constraints imposed by individual and groups of EO (and in situ) data products in using the quantitative network design (QND) approach.

The assessment of the observation impact (added value) is performed in terms of the uncertainty reduction in seasonal predictions of sea ice area, sea ice and snow volume.

Response functions for observations and target quantities are computed by the sea ice-ocean model of the Max Planck Institute (MPIOM) in a global setup with focus over the Arctic.

The project started in June 2016 and has a duration of 18 months. First, preliminary assessments address CryoSat-2 sea ice thickness and sea ice freeboard products provided by AWI. The observation impact is quantified through reduction in the uncertainty for predicted sea ice conditions over three regions along the Northern Sea Route. For regional sea ice volume, observed sea ice thickness provides a more powerful constraint than sea ice freeboard, and vice-versa for regional snow volume. For regional sea ice volume, observed radar freeboard is as powerful a constraint as sea ice thickness, for regional snow volume radar freeboard is more powerful than sea ice thickness. The study further plans a systematic assessment of the impact that characteristics of a synthetic snow depth product (sampling frequency and accuracy) will have on the performance of sea ice predictions. For more information see http://arctic-plus.inversion-lab.com/

Optimising assimilation of sea ice concentration in a fully coupled Earth system model with a multicategory sea ice model

Madlen Kimmritz, NERSC

A method capable of constraining the sea ice of a coupled climate system in a dynamically consistent manner would be of crucial societal importance.

It would allow for a more accurate and reliable reconstruction of the climate and enhance the prediction skill on seasonal-to-decadal time scale.

Data assimilation (DA) methods serve this purpose by making use of observations, a dynamical model and their respective error statistics to estimate a new, improved model state. Preserving the dynamical consistency with sea ice assimilation is challenging because sea ice is highly non-linear, non-Gaussian distributed and tightly coupled with the other compartments of the Earth system- in particular thermodynamically with the ocean.

We discuss and evaluate key practical implementations of the assimilation of ice concentration tested in the framework of idealized perfect twin experiments (observing system simulation experiment). We use the Norwegian Climate Prediction Model that is based on the Norwegian Earth System model and the Ensemble Kalman Filter. The performance of the different configurations of the assimilation systems are tested by carrying 10 years reanalyses with monthly assimilation of synthetic ice concentration.

It is found that strongly coupled DA (i.e. assimilation updating both the ocean and sea ice compartment) with flow dependent covariance outperforms weakly coupled DA (i.e. assimilation updating only the sea ice compartment) for the ocean interior, and thin ice category concentration. The benefits are largest where sea ice variability is largely influenced by ocean variability.

An attempt to prescribe the cross covariance between ocean temperature and sea-ice concentration are found to diverge in our system.

Solving the analysis for the multicategory state variable greatly reduces the error for ice concentration and thickness in all categories compared to solving the analysis for the accumulated state with uniform stretching. However, the

former approach introduces a weak drift in the bias of the volume of the thickest category that is caused by the increased need of post processing of the unphysical values produced by the multicategory analysis.
Preserving the thickness in each category during the assimilation annihilates the drift without degrading the performance of the assimilation. This indicates that the cross-correlations between the ice concentration and the individual ice volumes are not beneficial to enhance the ice state, but an improved distribution of the total concentration among the thickness categories as is gained by multicategory assimilation.
Assimilation of the full water column in the ocean yields a slight reduction of error in the deep ocean compared to when only the mixed layer hydrography is updated. However, it also leads to more volatile performance and induces a slight drift in the intermediate ocean, which may be problematic for a system with model bias. The robustness of the optimal setting are demonstrated for a 20 years reanalysis and the potential impact for prediction and teleconnection is identified for the most successful strategy.
SMOS (CS2SMOS) data. This generates a new daily CS2SMOS SIT data with better spatial coverage for the whole Arctic.

Recent Advances in the Mercator-Ocean Reanalysis System: Applications to an Arctic Configuration

Testut Charles-Emmanuel[1], Bricaud Clement[1], Chanut Jerome[1], Garric Gilles[1], Ruggiero Giovanni[1] and Smith Greg[2]
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In the framework of the Copernicus EU (FP7 and Horizon 2020) funded projects, Mercator Ocean, the French operational oceanography centre, is in charge of the development and of the production of real time analysis and forecasts and reanalysis for the global ocean at the resolution of 1/12°. The operational systems are all based on the ocean (NEMO3.6) and sea ice model (LIM3) and the multivariate data assimilation system SAM2 (Système d'Assimilation Mercator V2). The assimilation method is a reduced order Kalman filter based on SEEK formulation with bias correction scheme for temperature and salinity and an Incremental Analysis Update.
The strong need of a realistic description of the mean state and variability of the rapid changing Arctic Ocean and its adjacent seas over the last decades motivated the use of the Canadian Arctic Ocean and Nordic seas configuration (CREG). This dedicated configuration at 1/4° developed by the Canadian research teams has been coupled to the multivariate data assimilation system SAM2. The objectives of this pan-Arctic platform is both to improve the sea ice assimilation method used in the Mercator Ocean and Canadian analysis and forecasting systems and to produce reanalysis over recent periods at lower numerical cost in order to prepare global higher resolution reanalysis at 1/12° . After a description of this Arctic reanalysis system, we present results on the abilities of this configuration to reproduce sea ice extent and volume interannual variability without assimilation and, secondly, the impact of assimilating sea ice data on the sea ice cover with hindcasts experiments.

A simultaneous optimization of Arctic sea ice model parameters by genetic algorithm

Hiroshi Sumata, Frank Kauker, Michael Karcher, Ruediger Gerdes
Alfred Wegener Institute, Germany

We develop a parameter optimization system for a coupled ocean-sea ice model. The system is based on a genetic algorithm. Since the sensitivities of dynamic and thermodynamic parameters of sea ice models are interrelated, the system is set up to optimize 15 model parameters simultaneously. We define a cost function which quantifies the model-observation misfits of three sea ice properties (ice concentration, ice drift and ice thickness) for the period 1990-2012 and optimize the model parameters so as to minimize the cost. We find that the system successfully reduces the cost for the three sea ice properties. On the other hand, we also find that different sets of parameters give similar costs close to the global minimum. A correlation analysis shows that the optimal parameters are interdependent and covariant. The result indicates that genetic algorithm can efficiently improve simulated sea ice properties, while additional observations of different sea ice properties are necessary to constrain the model parameters to unique values.

Assimilating Copernicus SST data into a pan-Arctic ice-ocean coupled model with a local SEIK filter **Cancelled**

Xi Liang
National Marine Environmental Forecasting Center, State Oceanic Administration, China

Sea surface temperature (SST) data from the Copernicus Marine Service are assimilated into a pan-Arctic ice-ocean coupled model using the ensemble-based Local Singular Evolutive Interpolated Kalman (LSEIK) filter. It is found

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

Remote Sensing of Sea Ice Motion : updates from the EUMETSAT OSI SAF and the ESA CCI Sea Ice projects - Cancelled

Thomas Lavergne (Norwegian Meteorological Institute, Oslo, Norway) and colleagues

Pushed by winds, ocean currents and internal stresses, sea ice is always on the move. Its motion can swiftly close or open sailing routes, and locally deform sea ice to open leads or pile ridges. It plays a role in the sea ice mass balance over entire basins. The polar conditions being so harsh against autonomous drifting equipments, Earth Observation have long been recognised as a key tool for monitoring sea ice motion at regional to global scales.

Algorithms for accurately retrieving sea ice motion vectors are regularly refined and adapted to new satellite sensors. Some operational services are providing daily global sea ice drift data to be ingested by coupled ocean and ice forecasting systems. For climate applications, GCOS states that sea ice motion is the third most important variable to be observed for the Sea Ice ECV.

In this presentation I will report about recent advances in two on-going projects. For near-real-time applications, I will review the recent upgrades to the EUMETSAT OSI SAF sea ice drift product that now works during summer months, and is shipped with maps of uncertainties. For climate applications, I will present the status of the sea ice drift work in the ESA CCI Sea Ice project.

A proposed method for WMO ice chart uncertainty metrics.

Sean R. Helfrich, NOAA Center for Satellite Applications and Research (STAR),
Penelope Wagner, Norwegian Ice Service
Antti Kangas, Finnish Meteorological Institute

Many of the International Ice Charting Working Group (IICWG) member states generate ice charts using World Meteorological Organization (WMO) Sea Ice Grid (SIGRID) – 3 format. SIGRID -3 is a vector format that allows ice analysts to encode all standardized ice information that would normally be included in ice charts. While the charts are vital for ice navigation and are among the standards applied toward IMO ice code, their inclusion into models has been limited. The lack of ice charting information in models creates a discontinuity between model guidance needed for forecasting and the ice forecaster that is generating the ice chart, thus reducing the application of the model guidance. The IICWG is working to provide a method for quantifying ice charting uncertainties. The approach is to use existing SIGRID values with only minor additional information to determine standard deviation as a measure of uncertainty. Uncertainty calculations are assigned to each polygon as part of the SIGRID and are divided into concentrations, thickness, and floe size. Calculations include factors for reliability and accuracy to differentiate between uncertainty introduced by the data sources, “smearing” of the imagery into common polygons, the imagery interpreter, and time difference. Test data is being generated to provide modelers with data to provide feedback about model performance results with the application of this new ice charting uncertainty metric.

Sea Ice monitoring and analysis using Chinese Meteorological Satellite

Shengli Wu, National Satellite Meteorological Center of China

The operational sea ice monitoring and analysis system of CMA (Chinese Meteorological Administration) has been built during the last several years. In this system, we can get the Arctic and Antarctic sea ice concentration using Chinese meteorological satellite near real time. We also build a data

base in this system to do the long time series analysis of polar sea ice coverage. The data base hold 4 different kind of sea ice coverage data, including NASA Team, NASA Team 2, BootStrap and IMS. We do the data analysis
on the different kind of dataset, and found that there are 3%-5% difference between NT\BS and IMS. For NT dataset, there are 1.24% over-estimate and 1.79% under-estimate. For BS dataset, there are 1.81% over-estimate and 3.08% under-estimate. For NT2 dataset, which using Chinese meteorological satellite data, there are 4.56% over-estimate and 1.73% under-estimate. After the bias correction of NT2 dataset, the total accuracy of NT2 dataset are similar with other 2 datasets.

Day 3

Satellite Observations of Sea Ice Concentration

Leif Toudal Pedersen (DTU) and Matilde Brandt Kreiner (DMI)

We will present pros and cons of various sea ice concentrations datasets. EUMETSAT OSISAF and ESA's Climate Change Initiative sea ice projects have made significant improvements in sea ice concentration retrievals from passive microwave data, and the Copernicus Marine Environment Monitoring Service (CMEMS) have been using ice charts for comparison with the passive microwave datasets. We will discuss advantages and disadvantages of active (radar) and passive (radiometer) based sea ice products and potential future developments.

Using RGPS derived sea ice kinematics data for measurements of internal friction

Björn Erlingsson, University Centre of the Westfjords, Iceland

The GPRS data from Lindsay and Stern Polar Science Center University of Washington, 1996-2007 has been explored with respect to information on mechanical conditions. The data reseals information on the internal friction. The data was explored to reveal how internal friction as expressed by functional relationship between the divergence and shear-rate corresponding to maximum dissipation-rate of mechanical energy. The statistical distributions parameters of measured internal friction where explored with respect to:

- divergence sign and magnitude
- ice concentration
- fraction of old ice as determined from back-scatter intensity,
- regional dependencies with respect to dominating ice types/age and
- the relation to the mechanical settings derived from atmospheric loads using ERA-Interim reanalysis data.

The curvature of LKF's reveal information on the internal shear stress and external loads. The use of Method of Characteristics for determining the internal ice stress conditions will be explained and outlined how current data resources can be applied for finding information on the shear-stress and ice compression in the context of a simple rheological model

Combined retrieval of sea ice thickness and snow depth using altimetry and passive microwave remote sensing data

Xu, Shiming, Tsinghua University

Sea ice thickness and the snow depth are important parameters or both climate studies and forecast operations. State-of-the-art retrieval methods are based on satellite altimetry or passive microwave remote sensing operations. Due to the limited knowledge of snow loading, there exists large uncertainty in the retrieved sea ice thickness and volume. On the other hand, there is limitations in retrievable snow depth using L-band passive microwave observations. We propose a new retrieval method using simultaneous L-band passive microwave remote sensing data and altimetry data. Reduced uncertainty in both snow depth and sea ice thickness are achieved. Furthermore, with no spatial correlation between the uncertainty of the retrieved sea ice thickness, the u certainty in retrieved sea ice volume can be greatly reduced. The proposed method can be applied in the basin-scale retrieval using CryoSat, ICESat and SMOS satellite remote sensing data.

CRYORAD: a spaceborne ultrawide band microwave radiometer for sea ice thickness monitoring. A feasibility study.

Francesca De Santi[1], Giovanni Macelloni[2], Marco Brogioni[2], Francesco Montomoli[2], Marion Leduc-Leballeur[2], Giacomo De Carolis[1], Lars Kaleschke[3], Joel Jhonson[4], Ken Jezek[4]

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4 ElectroScience Laboratory, The Ohio State University, Columbus, OH

A preliminary mission concept study, recently funded by the Italian Space Agency, is being carried out to develop a spaceborne, low-frequency, multi-channel microwave radiometer (0.5 – 2 GHz).

The instrument, called CRYORAD, has a primary scientific objective of monitoring the cryospheric environment with a particular focus on sea ice thickness mapping. It is designed and conceived starting from the heritage of a similar airborne instrument (called UWBRAD) which was developed within the framework of a NASA-ESTO project and that recently collected data in two flights over Greenland [1].

It is expected that the low-frequency microwaves will allow extending the performances of SMOS sea ice thickness retrievals up to approx. 3 m, well beyond the actual limit of approx 1 m [2].

A preliminary system concept in terms of space-time coverage, spatial resolution, and revisit time will be presented and discussed. In addition, temperature brightness simulations as a function of frequency and typical sea ice salinity/temperature profiles computed by the 1D thermodynamic sea-ice model with parametrized brine dynamics (SAMSIM) [3] using realistic ECMWF forcing parameters will also be presented. Such results will form the base for the selection of the microwave channels, which will be best suited for accurate sea ice thickness estimation. Some preliminary results of real data acquired over Greenland will be also presented.

Comprehensive validation of sea ice forecasts from a real-time operational ocean-ice model

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As a part of the Copernicus Marine Environment Monitoring Service (CMEMS), the TOPAZ model system provides daily updated 10-day forecasts for the ocean and sea ice in the Arctic region.

An essential element of CMEMS is the provision of product quality assessments. Hence, the TOPAZ results for sea ice are extensively monitored, with weekly updates on the model system's performance. Presently, the status is as follows

- sea ice concentration is compared with ice charts from the Norwegian Ice Service, and with the EUMETSAT OSI SAF product derived from SSMIS brightness temperature data
- sea ice drift is compared with an observational product based on SAR data from Sentinel-1, provided by the Danish Technical University
- sea ice type (first year ice vs. multi-year ice) is compared with a multi-sensor product from EUMETSAT OSI SAF
- thickness of thin ice is compared to data derived from SMOS, provided by Meereisportal/ University of Bremen

Moreover, derived quantities such as the position of the sea ice edge and the sea ice extent are also monitored. With the exception of the latter product (SMOS), all observational data are distributed by CMEMS.
The presentation will focus on (1) methods used, and challenges faced, when comparing model results for sea ice and the various observational products, and (2) the quality, and its evolution, of the CMEMS forecast product.

Verification of Subseasonal to Seasonal sea ice Forecasts

Lorenzo Zampieri, Alfred Wegener Institute for Polar and Marine Research

Sea ice forecasts are becoming a demanding need since human activities in the Arctic are constantly increasing and this trend is expected to continue. Forecast system development needs to be guided by verification metrics that quantify skill in an appropriate way.
Here we apply different verification metrics to real sea ice forecasts to study the behavior of the metrics and to quantify potential predictability, focusing on the sea ice edge position and on subseasonal to seasonal time scales. The employed metrics are the pan-Arctic sea ice extent (SIE) and area (SIA), the Integrated Ice Edge Error (IIEE), the Spatial Probability Score (SPS), and the Modified Hausdorff Distance (MHD). While the first two metrics evaluate a single integrated quantity, the latter three assess the spatial distribution of the ice cover.
Forecasts are verified against the high resolution AMSR-E and AMSR2 89 GHz sea ice concentration products provided by the University of Bremen. Sea ice forecast products from various research institutes and operational centers are analyzed, in particular those collected within the Sub- Seasonal to Seasonal Prediction Project. The analysis covers a time period of 15 years, from June 2002 to June 2017. The forecast systems are characterized by quite different features with regard to the spatial resolution and the complexity of the forecast model, the number of ensemble members and the forecast length. The broad pool of models allows a comprehensive analysis of the metrics' behavior in different situations, highlighting strengths and weaknesses of the models and of the metrics themselves.

Classification of Atmospheric Circulation Regimes in the North Atlantic and the Subarctic Zone of Europe and the Methodology of Seasonal Weather Prediction using a Neuro-Fuzzy Model

O.M. Pokrovsky
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It is known that the temperature of the surface of the waters of the North Atlantic influences the formation of weather in Europe, and the atmospheric pressure in the Icelandic region on the weather in northern Europe, including the subarctic and arctic region. In turn, the Gulf Stream forms not only the configuration of the spatial anomalies of the surface temperature field of the northern Atlantic, but also the water temperature in the Russian sector of the Arctic Ocean, which has a decisive influence on the ice cover area in the Barents and Kara
The purpose of this work is to study the regimes of atmospheric circulation in the subarctic zone of the North Atlantic and northern Eurasia. For this purpose, the Fuzzy method was used to analyze the long-term sample of two-dimensional wind fields obtained from reanalysis data. The combination of fuzzy analysis and the methodology for modeling the neural network made it possible to design a neuro-fuzzy network that provides the solution of the seasonal forecast problem of atmospheric temperatures in the subarctic zone of the North Atlantic and northern Eurasia.
The efficiency of the self-learning neuro-fuzzy network for seasonal prediction is demonstrated by compare of the results of the forecast and the actual monthly average temperature fields borrowed from reanalysis data

Verification activities at the Canadian Ice Service/Environment and Climate Change Canada

Lynn Pogson
Canadian Ice Service/Environment and Climate Change Canada.

As sea ice forecast systems mature, model verification continues to be a challenge. This presentation will show some recent and planned verification activities at the Canadian Ice Service (CIS) and Environment and Climate Change Canada (ECCC). Objective verification topics include the recent comparisons of the Global Ice Ocean Prediction System (GIOPS) with CIS MetArea bulletins, as well as new verification techniques like the binary image distance measures for

ice extent and edge verification. Subjective verification will also be discussed, particularly the Year of Polar Prediction activities and plans for CIS to evolve towards more model-guided forecast products.

Verification of sea-ice prediction by using distance measures (POSTER)

Authors: B. Casati[1], J-F. Lemieux[1], G. Smith[1], P. Pestieau[2], A. Cheng[3].
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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.

Observed Arctic Ocean volume and heat transports during 2004-2010

Takamasa Tsubouchi, Wilken-Jon von Appen, Ursula Schauer
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This study aims to reveal, for the first time, an inter-annual variability of volume and heat transports through the Arctic gateways (Davis, Fram Straits and Barents Sea Opening). We analyze around 1,000 moored instruments across the pan-Arctic boundary during October 2004 to May 2010, with supplement of 37 repeat CTD sections in BSO and PIOMAS output. Volume and salt conserved velocity fields are obtained applying box inverse model for consecutive 68 months. The result shows that obtained volume transports are reasonable both in averaged value and it's seasonal variability in each four Arctic gateway. We quantify total boundary heat flux, as a sum of oceanic and sea ice contributions, is 180±57 TW (mean ± standard deviation for the 68 months). We find that annual mean boundary heat flux (average from October to following September) changes from year to year. The highest boundary heat flux appears during 2004-2005, and lowest boundary heat flux appears during 2008-2009.

The obtained time series of the pan-Arctic boundary volume and heat fluxes provide a benchmark data set for the validation of numerical general ocean circulation models of the Arctic Ocean and estimates of air-sea surface heat and FW fluxes from atmospheric re-analyses. The long-term mean boundary heat flux of 180±57 TW is equivalent to 15.9±5.0 Wm-2 within the boundary. Among major atmospheric reanalysis datasets (NRA, ERA40, JRA25, MERRA), we find that surface heat flux from MERRA has the best agreement with the observation.

GODAE OceanView global ocean sea ice inter-comparison

Andrew Ryan, Fabrice Hernandez, Gregory C. Smith, Fraser Davidson, Charly Regnier, Jinshan Xu

The GODAE OceanView inter-comparison and validation task team (IV-TT) have been conducting a global ocean forecast verification experiment since 2010. The framework is known as "class 4", which consist of comparing model counterparts in observation space. A recent addition to the experiment (starting in 2014), are sea ice concentration estimates derived from brightness temperature measurements made by AMSR-2. Environment Canada assembles these measurements daily and make them available to participating IV-TT operational ocean forecasting systems (OOFS). Participating OOFS map their forecasts to these observations and upload them to the IV-TT servers. This procedure enables a direct comparison between operational sea ice forecasts. We will present results from participating "class 4" sea ice inter- comparison OOFS for 3 years of sea ice concentration measurements.

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