MISSION REPORT

Climate Forecasting Unit

To: CFU

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Subject: 2014 Sea Ice Prediction Workshop at NCAR, April 1-2, 2014, Boulder, Colorado, USA

The 2014 Sea Ice Prediction workshop took place at NCAR (National Center for Atmospheric Research) in Boulder, Colorado, USA, on 1st and 2nd of April. The workshop was organized under the umbrella of SIPN (Sea Ice Prediction Network) to plan the 2014 SEARCH (Study of Environmental Arctic Change) Sea Ice Outlook (SIO). SIPN is funded by NSF (National Science Foundation), ONR (Office of Naval Research), NOAA (National Oceanic and Atmospheric Administration), NASA (National Aeronautics and Space Administration) and DOE (Department of Energy) of the USA. The SEARCH SIO is a forum to compare and analyze seasonal sea ice predictions produced by academic institutions and operational centers around the globe with the primary focus on September sea ice extent (seasonal mínimum). The SEARCH SIO has received 309 contributions since its inceptions in 2008 ranging from predictions of statistical and heuristic models to results of the state-of-the-art coupled general circulation models. The key drive is to improve sea ice predictions on intraseasonal to interanual (and longer) time scales by connecting scientists, operational forecasters and stakeholders in an active network to advance sea ice research, operational products and dissemination of the results to the community and general public.

Day 1. Welcome, several science presentations and rounds of discussion

This workshop brought more than 70 researchers and communicators with common interest in the Arctic climate change and variability, and specifically the prediction of sea ice conditions and its impacts on the climate. One of the key goals is to improve two-way interaction between observational and modeling communities. Viewed all predictions together, since the beginning of SEARCH SIO in 2008, September sea ice extent in the Northern Hemisphere exhibit a bimodal pattern of outcome. Specifically, all models (from statistical to most comprehensive dynamical ones), basically either perform well when observations show conditions close to the long-term trend, or they perform poorly when the observed extent is far from the trend line reaching substantial extreme. Such bimodal pattern of success or unsuccess firstly depends on the characteristics of the year itself and reflects the limitations of current generations of models and used initial conditions that require our attention to make further progress in predictions.

Sea ice prediction at different characteristic time scales and spatial scales have different levels of success and encounter different problems:

1) weather predictions: 1hr to 20days on local to regional scales (e.g. NWP systems have many problems with producing realistic polar lows and clouds)
2) intraseasonal-to-interannual predictions: 21days to 5yrs on regional to pan-Arctic scales (a very hard problem to produce probabilistic monthly and seasonal forecast - the focus of this workshop and the 2014 SEARCH SIO)
3) decadal predictions: >5yrs on pan-Arctic scale (e.g., beside model biases a lack of long-term high quality observations is a serious obstacle).

One of the goals of Arctic climate research community is the development of integrated data sets crucial for improving the sea ice forecasting. One such good source is nsidc.org/data/sipn/ Also, predictive models can provide guidance for planning effective observational strategies. We should strive to produce useful probability based outlook, so that we predict realistic monthly means as well as monthly standard deviations, i.e., have specific uncertainty associated with each forecast.

The key themes of the workshop and plans for the 2014 SIO:

i) make a contribution to the science of sea ice prediction

ii) gather a wider community of modelers (from statistical to dynamical) and coordinate experiments for the 2014 SIO (forecasts and potential sensitivity runs with perturbed sea ice thickness IC)

iii) discuss and make recommendations for data sets for initialization and how to validate them

iv) propose new and better metrics for evaluating predictions

v) identify stakeholder needs in a more encompassing manner

Current SIO results show that there is a considerable range in the forecasts, probably due both to different IC and methods. Which brings us back to the fundamental questions on what is the predictability and how to attain it with our methods. Are some years inherently more predictable than then others? Most likely yes, because even the most successful NWP system exhibit different clases of synoptic conditions with different ranges of predictability. Equivalently in seasonal forecasting, even using one GCM, different years can show very different predictability. Hence we need to understand what makes some years more predictable than the others? We do not know yet what matters the most; method and IC.

James Overland (PMEL) summarized the key difference between the two most extreme minima in Arctic summer sea ice extent in recorded history. September 2007 minimum, which was an important event for the inception of the SEARCH SIO, was firstly due to substantially different meteorological conditions that summer. Surface pressure high system is typically located over Beaufort Sea in winter and spring, but in 2007 anomalously high pressure persisted well into summer, thus contributed to extreme melting of sea ice. While 2007 conditions are connected to a long string of anomalous synoptic systems, in summer of 2012 there was no strong weather component among processes leading to the most prominent September minimum, but it appears that such extreme was primarily due to the shift to thinner and younger ice. September 2012 minimum was not characterized just by a strong loss of total extent, but also by a

significant loss of volume (much thinner ice) and multi year ice (MYI). Such evolution of Arctic sea Ice on seasonal time scale is compatible with long-term changes that since about 2005 are characterized by significant loss of MYI (that is very hard to grow back even after few very cold winters).Jim also pointed that for seasonal predictions the central limit theorem helps after we average over three months even if synoptic conditions can be rather extreme. He points that probability based outlook is critical step.

I presented about research on the Arctic sea ice and climate being conducted at IC3 in Barcelona (funded by the Spanish government under the PICA-ICE project and European Commission under the FP7 SPECS project). IC3 sea ice reconstructions represent very valuable source of sea ice IC over a very long period (one reconstruction starts in 1958). Also, application of classification methods (specifically, the k-means cluster analysis) enables us to determine key modes of interannual variability and predictability in the Arctic sea ice and related climate fields. IC3 is in position to contributed to the SEARCH SIO a multi-member ensemble prediction of the September 2014 Arctic sea ice extent with EC-Earth2 (and hopefully EC-Earth3).

Various presentations by researchers and constructive discussion lead to the following conclusions and important questions: Persistence is a good indicator of predictability. Lag-correlation reveals re-emergence of the persistence (winter and summer). June 1st to May 1st shift in initialization show a significant drop in forecast skill. Many coupled climate models show stronger correlation and more re-emergence of persistence than observations, hence we need to address whether models are more predictable than reality (it looks like that is the case for many state-of-the-art CGCMs). One summer condition does not correlation well with the other summer (they are related almost like a white noise). Decay of anomaly correlation is very seasonally dependent – is this due to sea ice physics or climate state? Besides common correlation of integral variables (such as total sea ice area or extent) pattern correlation offers additional valuable information on regional characteristics (regional sources of predictability as well as regions of biases). Pattern correlations (how January pattern correlates with February pattern, then with March pattern, etc.) are lower than sea ice extent correlations, but they are significant.

There are missing processes, or processes that need improved representation in models, that could significantly boost predictability. Snow (less) over sea ice in spring has a strong influence on predictability of sea ice (less) in summer. Melt ponds (only recently parameterized in CGCMs) also strongly benefit predictability because models become more sensitive and better represent feedbacks (positive are sources of predictability, while negative damp anomalies and predictability). Assimilating sea ice conditions, most importantly concentration and thickness (even more critical then concentration), into the observationally-based IC is important for improvement of prediction skill. Nudging with one time scale, or even better with two time scales, is useful, but ensemble Kalman filter (more consistent transfer of useful information from sea ice concentration to sea ice thickness) offers even stronger potential for improvements in forecast skill. We should develop more ways to use limited sea ice thickness data that we have. Hindcasts (retrospective predictions) enable us to examine different factors that contribute to a good or bad forecast. For example, if we had a bad forecast for Arctic summer and we suspect that errors in surface meteorology are primarily responsible for that, we can, e.g. nudge surface winds to observations and see whether the rest of coupled system will reach more realistic state. In this context positive summer extreme of 1996 was discussed.

Day 2. Breakout sessions, science discussion and workshop conclusions

The main prediction target is the Arctic sea ice cover in September (summer minimum), firstly the sea ice extent, with method(s)/model(s) initialized on May 1st, June 1st, and July 1st. IC3 will strive to contribute ensemble prediction with EC-Earth to the 2014 SEARCH Sea Ice Outlook in the 2nd week of July. Besides this integrated key value and its uncertainty it was suggested to expand the outlook (increase resolution) from pan-Arctic to regional scale by providing also regional averages and maps of sea ice extent showing longitudinal distribution. Furthermore, many stakeholders have specific interest at local scale, so few specific points (center of the Chucki Sea, Northwest Passage, Davis Strait, etc.) were also recommended to produce, if feasible, their probabilistic sea ice forecast.

● Breakout session on model intercomparison:

The question of energy budget on seasonal and longer time scales requires full attention of our community. However, many CMIP5 models did not put in public archive all thermodynamic terms necessary to close energy budget on daily and/or monthly time scales. We should diagnose precisely Arctic imbalances and how they are related to the global climate budget. The role of energy budget is important for predictability on seasonal and longer time scales, and specific patterns of predictability.

Many models have strong biases in several critical Arctic fields. Role of surface winds is crucial (e.g., for export of sea ice through Fram Strait), but they have many problems (like being to zonal in many models) that are probably more important than clouds biases (also important for closing radiative budget in the atmosphere). For example, too few clouds leads to too much SW, that causes too warm SST (Jul-Nov model bias) which results with delayed sea ice formation in December (typical problem in NOAA CFSv2 - CFSv3 should be available probably in 2018). We also need to address problems in surface albedo as well as to strive to reproduce realistic stratospheric structure and dynamics (high-top versions of model, with a high resolution in the stratosphere, have higher predictability in several forecast systems)

The SEARCH SIO community should take advantage and make substantial contribution to the year of polar prediction (mid-2017 to mid-2019).

Interesting side point: Following the very active discussion on the recent hiatus in surface global warming and how likely it would be to occur only due to natural variability, we were discussing how probable would be to have rapid decline in Arctic sea ice observed over the same period (since 1998) only due to natural variability. This question is very much active area of research and it should be addresses with a wide spectrum of CGCM under the control conditions.

● Breakout session on metrics to validate predictions:

The SEARCH sea ice outlook needs to go beyond the NH sea ice extent. The science community and stakeholders have interest in regional and even point predictions that can be verified with modern high-quality observations. Regional scale demand more details and can have rather variable success (e.g., statistical forecast of Canadian sea ice service is very good in Baffin Bay, but not very useful in Beaufort Sea, there it “tanks” rather fast).

We also need to expand our deterministic and probabilistic set of validation tools. Using satellite-derived sea ice velocities could be a useful approach for model verification. There is crucial difference between the skill in reproducing the mean state of climate (annual mean and seasonal cycle), and prediction skill at different time scales (predicting anomaly). Unfortunately, many CGCM are barely beating persistence on regional scales (some do even worse).

Perhaps it would be productive to define specific key regions of Arctic from physical point of view (like the set of Nino indices in tropical Pacific important for ENSO dynamics). Also, we already have internationally defined marine regions of Arctic that are critical for operational centers (they are responsible for issuing forecast for specific regions), so we should also use them when we start putting out regional outlook predictions.

Taylor diagrams are valuable tools for compact presentation of model predictions. The classification methods deserve more attention of the community and IC3 is specifically making push in this area. Forecasting dates and times of certain sea ice conditions is important for validation and to many stakeholders. We can utilize many standard validation methods from meteorlogy to do validation of sea ice conditions. Let's try to predict Barnett (1980) sea ice severity index used by shipping vessels and navy.

The specific start dates and target time for the 2014 SEARCH Sea Ice Outlook are set and now the community is preparing for the production phase from May until August, and verification in September. We will predict the total sea ice extent as well as sea ice extent maps and regional averages. Besides the monthly and seasonal mean value, if possible, it is also advisable to predict higher statistical moment.

A very active area of research is how is Arctic variability and predictability changing with warming climate. Dynamics can rule on short time scales, but thermodynamics is the key on longer time scales. We need to answer why certain years are more predictable than the others. A very important element of data assimilation and initialization for sea ice prediction is proper treatment of sea ice thickness. For example, nudging can break relationship between variables and create imbalances. We need to take structure of the model into the account (not recommendable to do data assimilation with only one constrained variable).

The proposal was made at this workshop to start continuously present sessions on Arctic sea ice and climate predictons at AGU meeting in San Francisco and EGU meeting in Vienna (for which IC3 will take organizational lead along with key participation of scientists from the University of Washington in Seattle, USA). The deadline for proposing AGU session is April 16 and there is already working group dedicated to this. IC3 will initiate submitting proposal for EGU Arctic session after the publc call for session proposals is issued in mid-July this year.