August 2015 Sea Ice Outlook – AWI consortium contribution

F. Kauker [a,b], T. Kaminski [c], R. Ricker [a], L. Toudal-Pedersen[d], G. Dybkjaer[d], C. Melsheimer [e], S. Eastwood [f], H. Sumata [a], R. Giering [g], M. Karcher [a,b], R. Gerdes [a,h]

August, 2015

[a] Alfred Wegener Institute for Polar and Marine Research, Bremerhaven, Germany
[b] O.A.Sys - Ocean Atmosphere Systems, Hamburg, Germany
[c] The Inversion Lab, Hamburg, Germany
[d] Danish Meteorological Institute, Copenhagen, Denmark
[e] University of Bremen, Institute for Environmental Physics, Bremen, Germany
[f] The Norwegian Meteorological Institute, Oslo, Norway
[g] FastOpt, Hamburg, Germany
[h] Jacobs University, Bremen, Germany

1. Extent Projection

We estimate a monthly mean September sea-ice extent of 5.55 +- 0.38 million km^2. The out-of-competition estimate with assimilation of sea-ice/ocean observations is 4.76 +- 0.30 million km^2.

2. Methods/Techniques

Sea ice-ocean model ensemble run (without and with assimilation of sea-ice/ocean observations)

3. Rationale

For the present outlook the coupled ice-ocean model NAOSIM (Kauker et al., 2003) has been forced with atmospheric surface data from January 1 1948 to July 30 2015. This atmospheric forcing has been taken from the NCEP/NCAR reanalysis (Kalnay et al., 1996) from 1948 to 1979. From 1980 to 2010 the new NCEP Climate Forecast System Reanalysis (NCEP-CFSR, Saha et al. 2010) and for the period from 2011 to June 30 2015 NCEP Climate Forecast System version 2 (CFSv2) (Saha et al., 2014) has been used. All ensemble model experiments have been started from the same initial conditions on July 30 2015. In contrast to the outlook contributions of the previous years the model parameters have been adjusted. The simulated September sea-ice extent slightly overestimates the OSI SAF ice concentration product (based on the postprocessed ice concentration data from 1979 to 2009) by about 0.02 million km^2 on average. This very small bias will be subtracted from the ensemble predictions. We have used atmospheric forcing data from each of the years 2005 to 2014 for the ensemble prediction and thus obtain 10 different realizations of potential sea-ice evolution for the summer of 2015. The use of an ensemble allows to estimate probabilities of sea-ice extent minimum values in September 2015.

In an out-of-competition effort the benefit of remotely sensed ice thickness observations to constrain the model's initial state has been tested. The system was developed and validated for the years 2011 to 2014 within the project 'Arctic Climate Change, Economy, and Society (ACCESS)' funded through the Seventh Framework Programme Research and Technological Development of the European Commission (contract number 265863). It uses a variational assimilation system around NAOSIM and the Alfred Wegener Institute's CryoSat-2 ice thickness product, University of Bremen's snow depth product, and the OSI SAF ice concentration and sea-surface temperature products. Observations from March and April have been utilized. For 2011 to 2014 the skill of predictions of the summer ice cover starting in March was investigated whereby the atmospheric forcing has been assumed to be perfectly known (CFSv2 data have been employed). Direct assimilation of the four data streams resulted in slight improvements over some regions (especially in the Beaufort Sea) but reduced the over-all fit to independent observations (ice concentration in Summer). A bias correction scheme for the CryoSat-2 ice thickness which employs a spatially variable scaling factor could enhance the skill considerably (for a detailed description of the method see the project report D.1.83 at http://www.access-eu.org/en/deliverables2/wp1.html). However, because of the limited time period for which CryoSat-2 data are available the scheme could not be tested with fully independent data (the bias correction depends on CryoSat-2 data from 2011 to 2014). This test will be done here in the course of the SIO 2015.

The simulated ice extent for all 10 realizations is shown in Figure 1 for the period from July 30 until September 30 for the outlook without assimilation (a 'control') and with assimilation of sea-ice/ocean remotely sensed observations (b 'initialized').

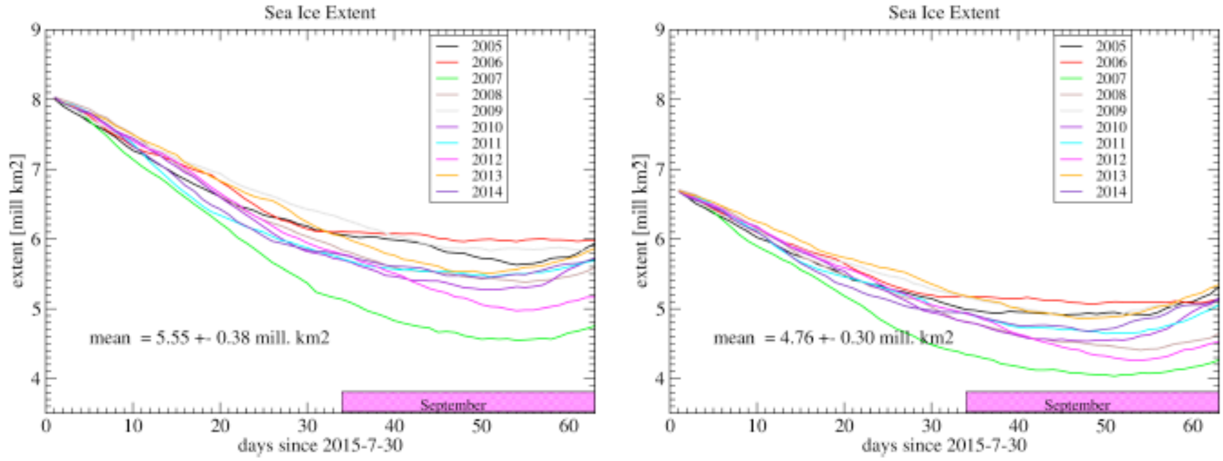
The ensemble mean of the mean September sea-ice extent of the control outlook amounts to 5.55 million km². The ensemble standard deviation is 0.38 million km^2 which serves as uncertainty estimate of the prediction. The ensemble mean of the initialized outlook is 4.76 million km² with a standard deviation 0.30 million km^2. Some remarks with respect to Figure1:

1. The forcing from the year 2007 yields sea-ice extents which on any given day are lower than for a forcing from 2012 which yields the second lowest values.
2. The main effects of the assimilation is a reduction of the ice thickness in the Beaufort Sea and an increase of the ice thickness in the eastern Eurasian Basin in March (see also ACCESS report D1.83). This leads to a reduction of the sea ice extent in September for all ensemble members although the reduction is not uniform (i.e. depends on the specific atmospheric forcing).
3. The assimilation reduces the sea-ice extent in July by more than 1 million km^2 which is the consequence of a reduction of a model bias in the Nordic Seas (not shown).
4. Compared to the July outlook the ensemble mean and the standard deviation of the ensemble without and with initialization is almost unchanged.

As stated above, the main effect of the assimilation is a reduction of the ice thickness in the Beaufort Sea in March and an increase of the ice thickness in the eastern Eurasian basin. Accordingly maps of the ensemble mean September ice concentration show a reduced ice cover in the Beaufort Sea and even stronger further upstream in the Chukchi Sea. A comparison of the ice concentration on July 30 2015 for both ensemble runs reveals that the ensemble run with initialization is much closer to the 'observed' OSI SAF ice concentration (compare Figure 2 a, c, and e). Especially the large polynia in the Laptev Sea is much better captured. Additionally shown in Figure 2 is the ice thickness on July 30 2015 for both ensemble runs (b and d). Figure 3 depicts the probability of a grid cell to have an ice concentration larger then 15% for both outlooks and the probability for a grid cell to exhibit a mean ice thickness above 0.5m in September. According to these metrics both outlooks predict an ice free North West Passage for the section along the Alaskan coastline (The model resolution is too low to give reliable estimates within the Canadian Archipelago.). Only the initialized outlook yields a large probability for an ice free North East Passage.

References:

Kalnay et al. (1996), The NCEP/NCAR 40-year reanalysis project, Bull. Amer. Meteor. Soc., 77, 437-470.
Kauker, F., R. Gerdes, M.J. Karcher, C. Koeberle and J.L. Lieser (2003), Variability of Arctic and North Atlantic sea ice: A combined analysis of model results and observations from 1978 to 2001, J. Geophys. Res. Oceans, 108 (C6).
Saha et al. (2014), The NCEP Climate Forecast System Version 2, J. of Climate, 27, 2185–2208. http://dx.doi.org/10.1175/JCLI-D-12-00823.1.
Saha et al. (2010), The NCEP Climate Forecast System Reanalysis, Bull. Amer. Meteor. Soc., 91, 1015–1057, http://dx.doi.org/10.1175/2010BAMS3001.1.



(a) (b)

Figure 1: Simulated evolution of the ice extent [million km2] when forced with atmospheric data from 2005 to 2014 until end of September. The abscissa gives the days since the initialization of the forecast on Jul 30 2015. Model-derived ice extents are averaged over day 34 to 63 (magenta box) and have been adjusted assuming a bias (see text). The left panel (a) shows the ice extent of the ctrl outlook and the right panel (b) the ice extent of the initialized outlook.

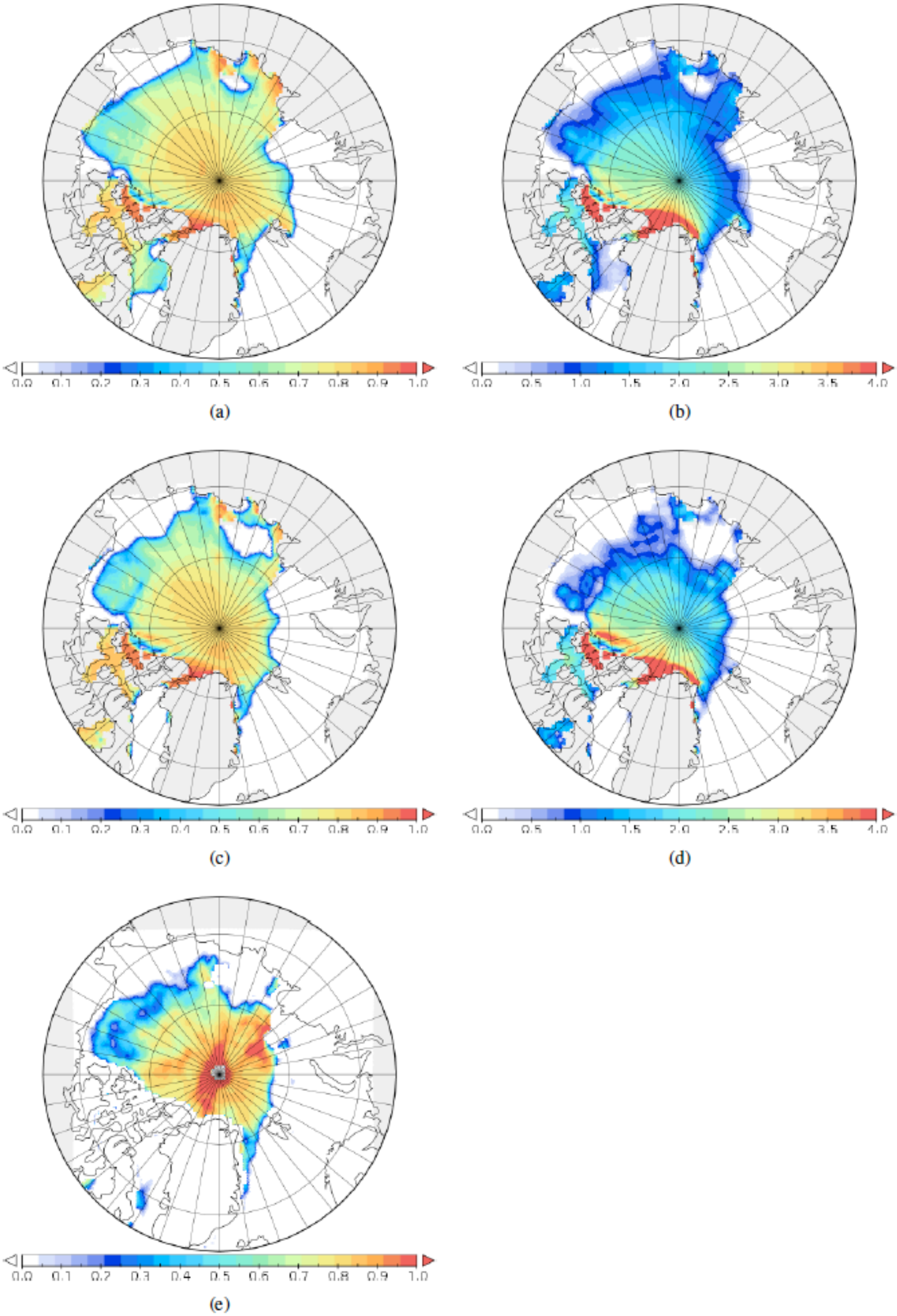


Figure 2: The modelled ice concentration [0-1] (a and c) and the ice thickness [m] (b and d) on July 30 2015 for the ensemble run without initialization (a and b) and with initialization (c and d). Additionally shown is the OSI SAF ice concentration on July 30 2015 (e).

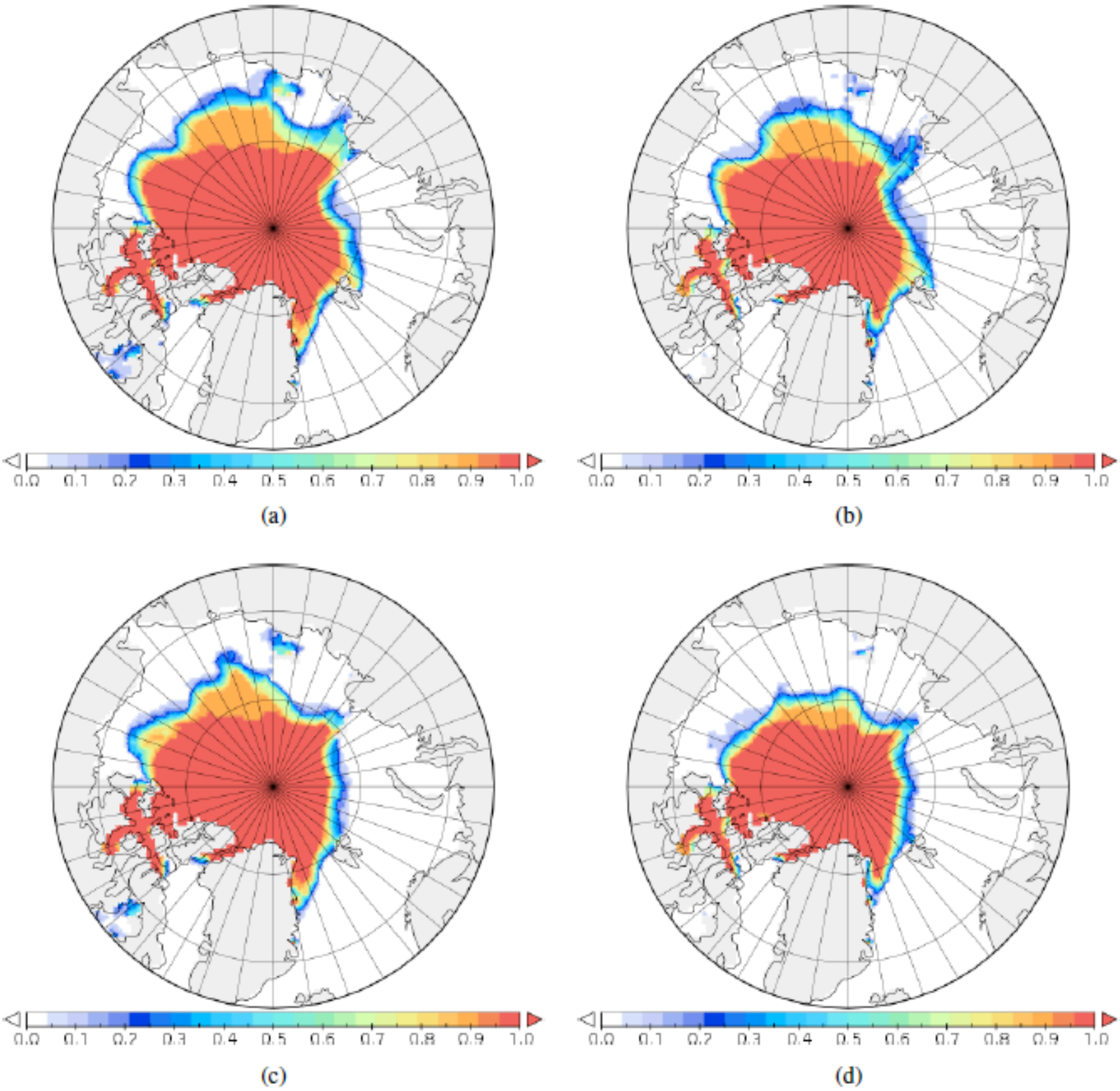


Figure 3: The probability in a grid cell to reach higher ice concentration than 15% (a) and c)) and the probability to reach higher ice thickness than 0.5m (b) and d)) in September for the ensemble run without initialization (a) and b)) and with initialization (c) and d)).