June 2016 Sea Ice Outlook – AWI consortium contribution

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June, 2016

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1. Extent Projection

We estimate a monthly mean September sea-ice extent of 4.73 +- 0.41 million km^2.

2. Methods/Techniques

Sea ice-ocean model ensemble prediction run initialised with assimilation of sea ice and ocean observations.

3. Rationale

For the present outlook the coupled ice-ocean model NAOSIM has been forced with atmospheric surface data from January 1948 to May 29th 2016. 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 from 2011 to May 29th 2016 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 May 29th 2016. The model setup has not changed with respect to the last year. We used atmospheric forcing data from each of the years 2006 to 2015 for the ensemble prediction and thus obtain 10 different realisations of potential sea ice evolution for the summer of 2016. The use of an ensemble allows to estimate probabilities of sea-ice extent predictions for September 2016.

For the 2015 edition of the SIO, in an out-of-competition effort, the benefit of remotely sensed sea ice and ocean observations to constrain the model's initial state was tested. The system was developed and validated for the years 2011 to 2014 within the project 'Arctic Climate Change, Economy, and Society (ACCESS)' within the Seventh Framework Programme Research and Technological Development of the European Commission (contract number 265863). It employed a variational assimilation system around NAOSIM to initialize the model using the Alfred Wegener Institute's CryoSat-2 ice thickness product, the University of Bremen's snow depth product, and the

OSI SAF ice concentration and sea-surface temperature products. Observations from March and April were used. 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 (Kauker et al, 2015a). Given the success of this test (Kauker et al., 2015b) we apply the approach for this year's edition of the SIO.

The simulated ice extent for all 10 realisations is shown in Figure 1 for the period from end of May until end of September for the outlook initialised with assimilation (a 'with initialisation') and (as a control experiment) without assimilation (b 'w/o initialisation').

The ensemble mean of the mean September sea-ice extent of the initialised outlook amounts to 4.73 million km². The ensemble standard deviation is 0.41 million km² which serves as uncertainty estimate of the prediction. The ensemble mean in the control experiment is 5.00 million km² with a standard deviation of 0.42 million km². Some remarks with respect to Figure 1:

1. The realisations with forcing from the years 2007 and 2012 yield the lowest mean September sea ice extents (4.05 and 4.11 million km², respectively) which exceed the observed 2012 minimum of 3.62 million km². The forcing from 2013 gives the largest September mean extent (5.29 million km²) due to unusually low melting in that year.
2. The main effects of the assimilation are a reduction of the ice thickness in the Beaufort Sea and an increase of the ice thickness in the eastern Eurasian Basin in March (Kauker et al, 2015a,b). This leads to a reduction of the sea ice extent in September for all ensemble members, although the amount of the reduction depends on the specific atmospheric forcing for the respective year.
3. The assimilation reduces the sea-ice extent in June by about 0.8 million km² which is the consequence of a reduction of a model bias in the Nordic Seas (not shown).

As stated above, the main effect of the assimilation of the bias corrected CryoSat-2 ice thickness of the four data streams in March and April 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, September ensemble mean ice concentration is reduced in the Beaufort Sea and even stronger further upstream in the Chukchi Sea. The ice cover in in the eastern Eurasian Basin on the other hand is enhanced. For the September ensemble mean ice thickness the effects are even stronger (not shown). Figure 2 shows the CryoSat-2 ice thickness for March from 2012 to 2016 (not biased corrected). The ice thickness in the Beaufort Sea in March 2016 is similar to those of the years 2012 and 2013 and considerably thinner than in 2014 and 2015. In 2016 north of the Laptev Sea the ice is thicker than in 2012 and closer to the thickness in 2013, 2014 and 2015). Figure 4 depicts the probability of a grid cell to have an ice concentration above 15% for both outlooks and the probability for a grid cell to exhibit average ice thickness (mean thickness of ice covered grid cell) above 0.5 m, respectively. The latter is a common threshold used for Arctic shipping. According to these metrics both outlooks predict an ice free North West Passage for the section along the Alaskan coastline (the coarse model resolution does not allow reliable estimates within the Canadian Archipelago) while the probability of an ice free North East Passage is about 50%.

References:

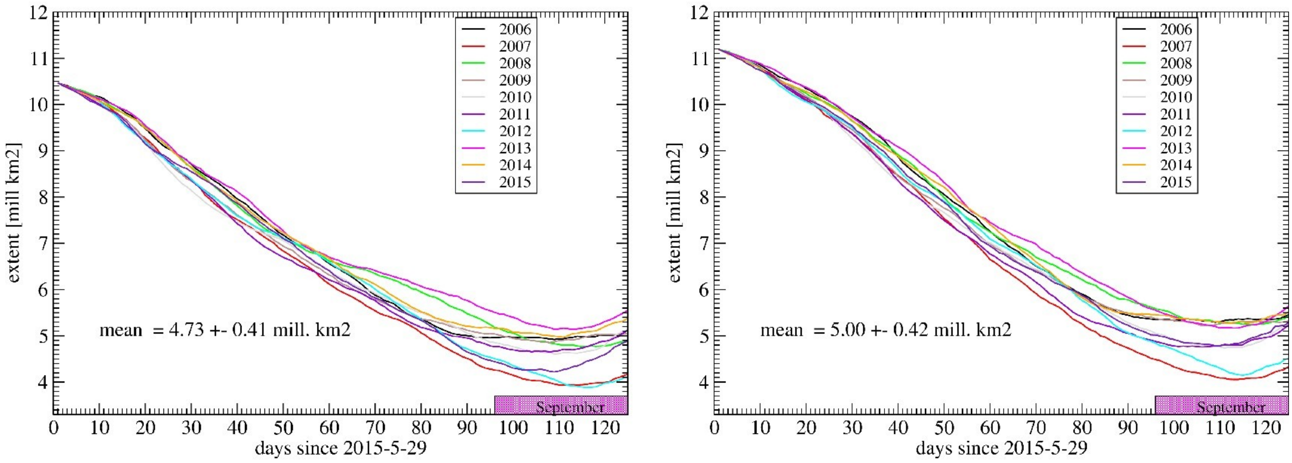
Kalnay et al. (1996), The NCEP/NCAR 40-year reanalysis project, Bull. Amer. Meteor. Soc., 77, 437-470.

Kauker et. (2015a), Seasonal sea ice predictions for the Arctic based on assimilation of remotely sensed observations. The Cryoshere Discussion, doi:10.5194/tcd-9-5521-2015.

Kauker et. (2015b), Bewertung des AWI-Konsortium Sea Ice-Outlook Beitrags für Sommer 2015 (in german), http://www.meereisportal.de/services/archiv/2015-kurzmeldungen-gesamttexte/nachlese-sio-2015.html

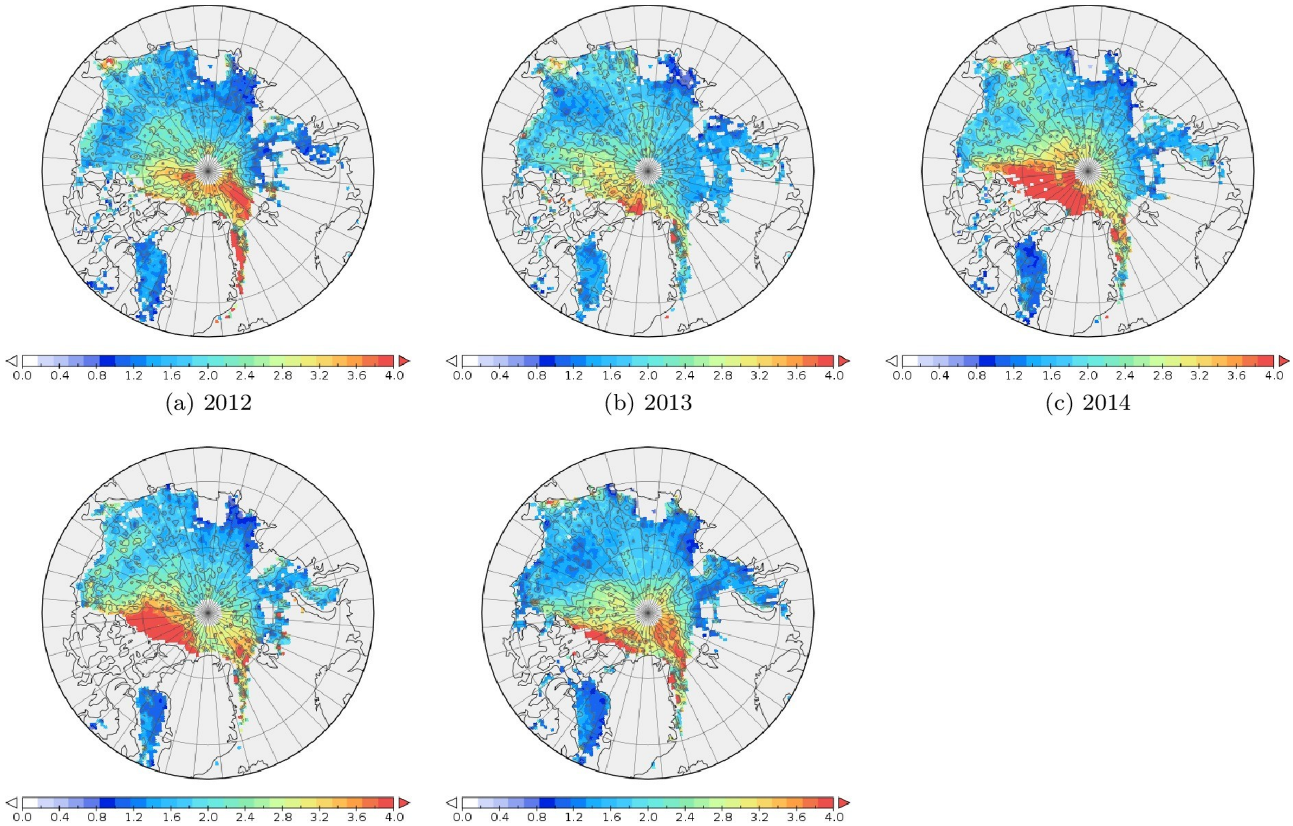
Saha et al. (2014), The NCEP Climate Forecast System Version 2, J. of Climate, 27, 2185–2208. http://dx.doi.org/10.1175/JCLI-D-12-00823.1.

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.



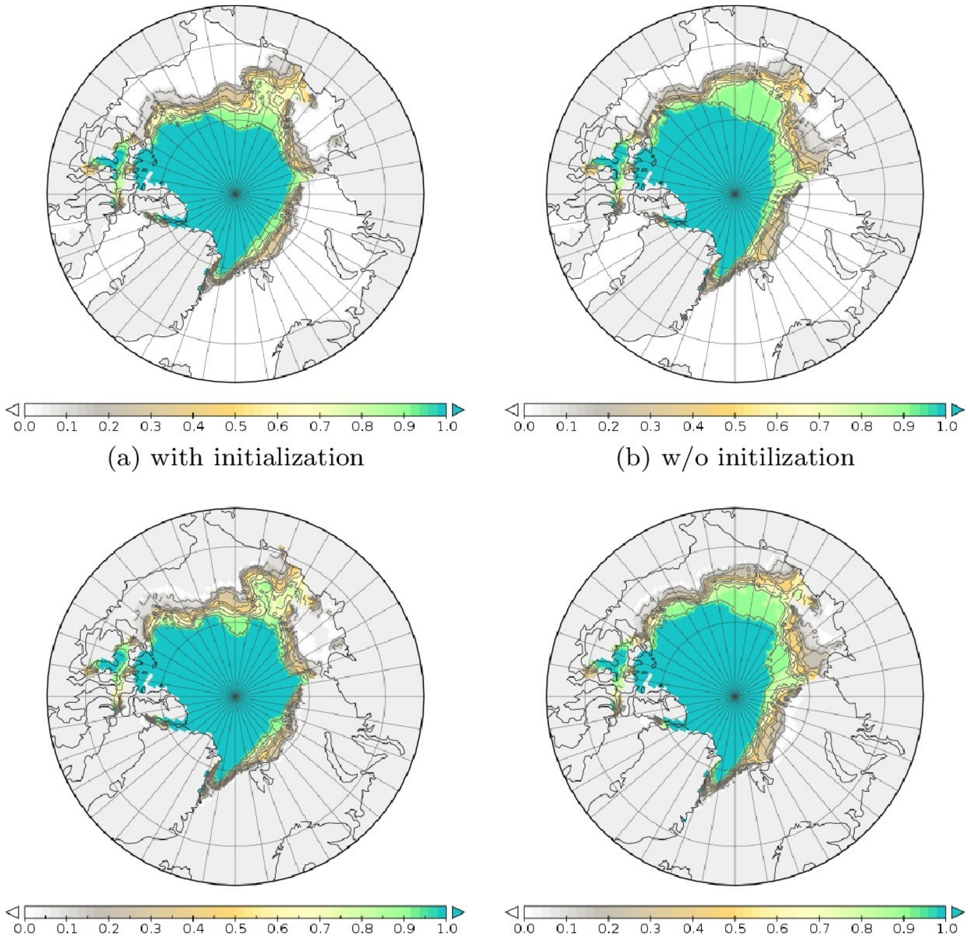
(a) with initialization (b) w/o initilization

Figure 1: Simulated evolution of the sea ice extent [million km^2] when forced with atmospheric data from 1996 to 2015 (different colours) from May 29th to end of September. The abscissa gives the number of days since initialization of the forecast. Model-derived September ice extents are averaged over day 96 to 125 (magenta box). The left hand panel (a) shows the simulated evolution from a state initialised with assimilation (in March and April) and the right panel without.



(a) 2012 (b) 2013 (c) 2014 (d) 2015 (e) 2016

Figure 2: The March CryoSat-2 ice thickness from AWI for the years 2012 to 2016.



(a) with initialization

(b) w/o initilization

(c) with initialization

(d) w/o initilization

Figure 3: The probability of an ice concentration above 15% (a and b) or an averaged ice thickness above 0.5 m (c and d) for the ensemble initialised with assimilation (a and c) and without (b and d).