July 2016 Sea Ice Outlook – AWI consortium contribution

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1. Extent Projection

We estimate a monthly mean September sea-ice extent of 4.32 +- 0.30 million km^2.

2. Methods/Techniques

Sea ice-ocean model ensemble run initialised through assimilation of sea-ice/ocean observations (CryoSat-2 ice thickness, OSI SAF sea ice concentration and SST, and University of Bremen snow depth) in March and April.

3. Rationale

For the present outlook the coupled sea ice-ocean model NAOSIM has been forced with atmospheric surface data from January 1948 to July 5th 2016. This atmospheric forcing has been taken from the NCEP/NCAR reanalysis (Kalnay et al., 1996) from 1948 to 1979, the new NCEP Climate Forecast System Reanalysis (NCEP-CFSR, Saha et al. 2010) from 1980 to 2010, and the NCEP Climate Forecast System version 2 (CFSv2) (Saha et al., 2014) from 2011 to July 5th 2016. All model runs composing the ensemble were started from the same initial conditions on July 5th 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 a probabilistic forecast of the sea-ice extent in September 2016. A variational assimilation system around NAOSIM was employed to initialise the model at March 1st using the following four observational data streams in March and April 2016: The Alfred Wegener Institute's CryoSat-2 ice thickness product (version 1.2, Hendricks et al., 2016), the University of Bremen's snow depth product, and the OSI SAF ice concentration and sea-surface temperature products.

For the years 2011 to 2014 the skill of predictions of the summer sea ice cover starting in March was investigated whereby the atmospheric forcing has been assumed to be perfectly known. 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 reapply 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 beginning of July until end of September for the outlook initialised with assimilation of sea ice/ocean observations (in March and April) (panel a 'with initialisation') and (as a control experiment) without assimilation (panel b 'w/o initialisation'). Note that no sea ice/ocean observations from May-July are assimilated, even though they might further improve the forecast.

The ensemble mean of the mean September sea-ice extent of the control outlook amounts to 4.79 million km². The ensemble standard deviation is 0.44 million km² which serves as uncertainty estimate of the prediction. The ensemble mean of the outlook that was initialised through assimilation is 4.32 million km² with a standard deviation of 0.30 million km².

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 (not shown).

Table 1 shows the skill, quantified as root mean square error (RMSD), for prediction of the September Arctic sea ice extent in the years 2012 to 2015 with and without assimilation of March and April sea ice/ocean observations for ensembles using the last 20 and 10 years of atmospheric data. The three years 2012 to 2014 are calculated in retrospect. The result of 2015 has been submitted as an out-of-competition contribution last year. Ensembles consisting of the last 10 years outperform the ensembles consisting of the last 20 years slightly, i.e. years too far back in the past degrade the skill (probably because they represent an Arctic that is too 'cold') but more importantly the assimilation of sea ice/ocean observations in March and April outperforms the predictions without assimilation ('w/o init') strongly. The June outlook's RMSD reduces by about 30% while the July and August outlook's RMSD reduces by about 50% or more. The RMSD of the July outlook with 10 ensemble members and sea ice/ocean observation assimilation amounts only to 0.32 mill. km² although only March and April sea ice/ocean observations are used.

start day	w/o init		with init	
	20 members	10 members	20 members	10 members
June 1	0.99	0.87	0.62	0.58
July 1	0.78	0.63	0.33	0.32
August 1	0.74	0.58	0.32	0.25

Table 1: The skill (root mean square error) [mill. km²] of the ensemble forecast (10 and 20 ensemble members) initialised with (with init) and without (w/o init) assimilation (reference: NSIDC mean September sea ice extent).

Next we compare the spatial pattern of the September sea ice concentration predicted for the past years with observations. Figure 2 displays the probability of an ice concentration above 15% in September for the ensemble initialised with assimilation of sea ice and ocean variables (in March and April) for 2012 to 2016 based on atmospheric forcing data up to end of June (July SIO). For the years 2012 to 2015 this July SIO already succeeded in providing a good match to the 15% ice concentration that was observed in the respective September.

References:

Hendricks et al. (2016), User Guide - AWI CryoSat-2 Sea Ice Thickness Data Product (v1.2), July 2016, http://data.meereisportal.de/data/cryosat2/doc/AWI_CryoSat2_Documentation_current

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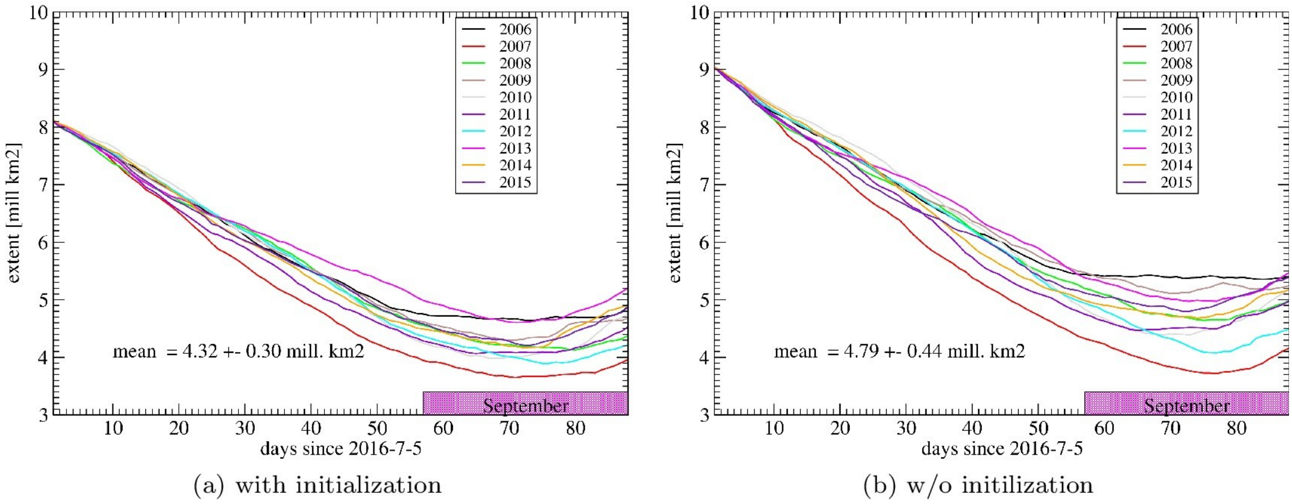
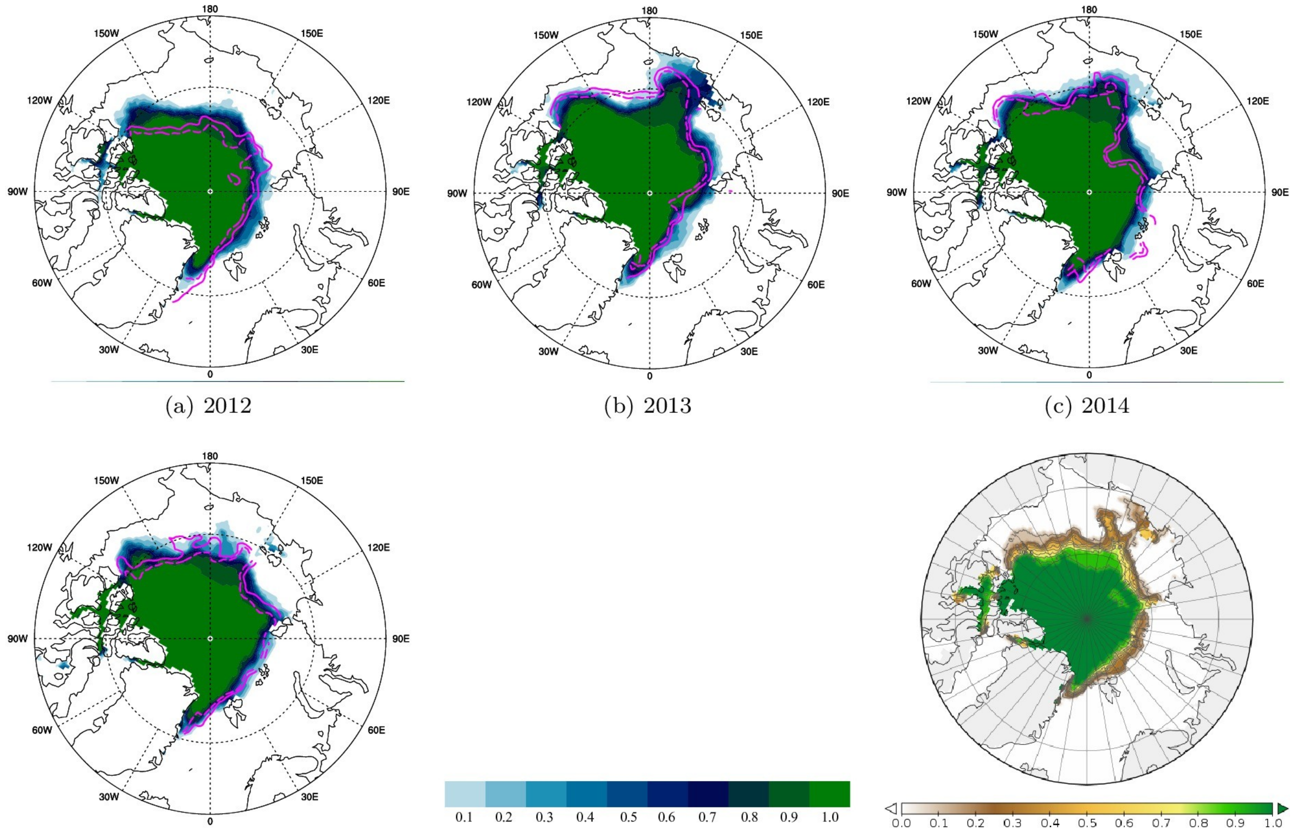


Figure 1: Simulated evolution of the sea ice extent [million km^2] when forced with atmospheric data from 1996 to 2015 (different colours) from July 5th to end of September. The abscissa gives the number of days since initialization of the forecast. Model-derived September ice extents are averaged over day 58 to 88 (magenta box). The left hand panel (a) shows the simulated evolution from a state initialised with assimilation of sea ice/ocean observations (in March and April) and the right panel without.



(a) 2012 (b) 2013 (c) 2014

(d) 2015 (e) color bar 2012-2015 (f) 2016

Figure 2: The probability of an ice concentration above 15% in September for the ensemble initialised with assimilation of sea ice and ocean variables (in March and April) for 2012 to 2016 based on atmospheric forcing data up to end of June. The three years 2012 to 2014 (panels a to c) are calculated in retrospect. The result of 2015 was submitted as an out-of-competition contribution to last year's SIO edition (panel d). This year's probability is shown in panel f. In panels a-d the magenta lines display the 15% (straight) and the 50% (dashed) isoline of the ice concentration in September provided by OSI SAF. The colour bar for the panels a to d is included in panel e.