2014 September Arctic Sea Ice Outlook

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1 Extent Projection

4.39 ± 0.50 million square kilometers

2 Methods

Our outlook uses a state-of-the-art General Circulation Model (GCM) initialized with May 2014 sea ice thickness anomalies obtained from the Pan-arctic Ice-Ocean Modeling and Assimilation System (PIOMAS). The GCM used is the National Center for Atmospheric Research (NCAR)'s Community Earth System Model version 4 (CESM1) at 1° resolution in all components.

Our strategy is to initialize the sea ice with anomalies that are approximations to actual Arctic sea ice anomalies. Because our predictions are several months in the future, we make no attempt to initialize the atmosphere with true conditions. Instead we create an ensemble of predictions from integrations that begin on May 1 with identical sea ice, ocean, and land conditions but with variable atmospheric initial conditions, which are drawn from consecutive days near May 1 of an arbitrary model year. In other words, an ensemble is created by shifting the dates of the initial conditions of the atmosphere component relative to the other components. We utilize one of 6 hindcast runs with CESM1 that have been submitted for analysis to the CMIP5 dataset for IPCC AR5. The hindcast was run with observed greenhouse gas and aerosols through the year 2005. We take 2005 as the arbitrary year, whose mean state is close enough to present to be used for seasonal prediction in 2014.

We only apply anomalies to the sea ice and we apply no anomalies to the ocean or land. Without ocean anomalies in the initial conditions, the full ocean GCM of the model is not needed, so we carry out our integrations with a slab ocean model whose ocean heat flux convergences is specified from the CESM1 hindcast for the years 1995-2005. We run the hindcast with slab ocean forward from 1 January 2005 through the end of May 2005, and then we create two ensembles. One, the 'control' ensemble, consists of 15 runs each initialized with the same unperturbed model sea ice, ocean and land conditions, but with variable initial atmospheric conditions. The second, the 'experiment' ensemble, consists of 20 runs initialized as the control ensemble, but with anomalous sea ice initial conditions based on PIOMAS.

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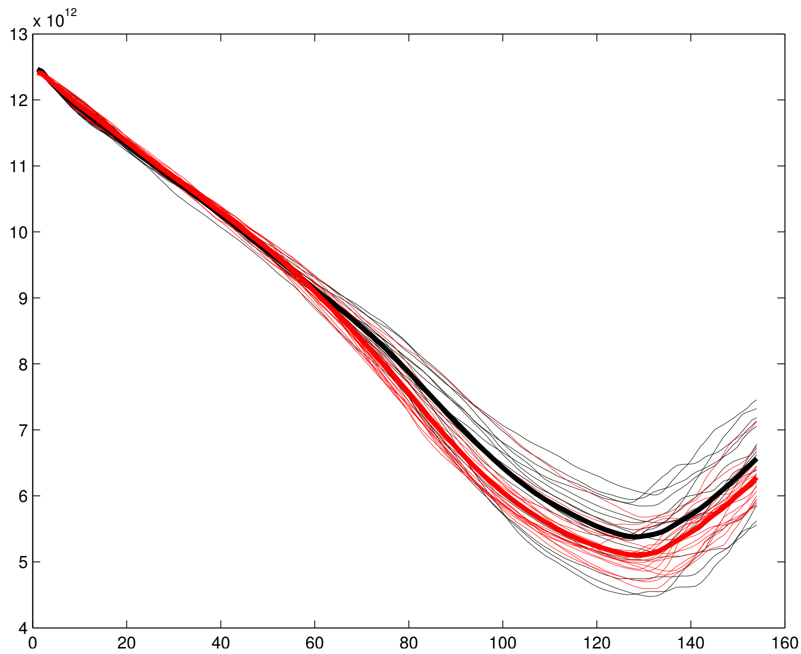

Figure 1: Daily sea ice area for the control (black) and experiment (red) ensembles. The mean for both ensembles is shown in bold.

Retrospective simulation of PIOMAS assimilate satellite ice concentration data and sea surface temperature and represent an approximation to May 2014 observations. We calculate the May monthly mean anomalies in the ice-thickness distribution (ITD) from the linear trend in PIOMAS for the period 1979-2013 and input these anomalies for 1 June sea ice conditions in the CESM1.

We run both ensembles for 5 months until October 1st, and obtain two distributions, a 'control' and an 'experiment' of September sea ice area (see figure 1).

The mean September sea ice areas in the GCM are 5.47 $\times 10^6$ km^2 and 5.74 $\times 10^6$ km^2 in the experiment and control ensembles respectively, with a standard deviation of $\sim$0.50 $\times 10^6$ km^2 - given the design of our experiment, the difference between both ensembles (0.27 $\times 10^6$ km^2) is a result solely of the differing initial conditions, i.e. the different sea ice distributions, while the spreads in each ensemble are solely due to the (unpredictable) stochastic forcing in the system, originating mainly in the atmosphere, during the May-September period. This is an estimate of uncertainty in our outlook, but is a lower bound of uncertainty, since it is the uncertainty associated with a 'perfect model' forecast in which the initial conditions, and system physics, are known perfectly.

We make a prediction for September 2014 based on the difference between the ensembles and the standard deviation of the experiment ensemble. To translate from area to extent, rather than calculate the extent directly in the GCM, we apply the ratio between the extent and area linear anomalies for September in the observational record, which is $\sim$ 1.2 (ie an extent linear anomaly is on average 20% greater in magnitude than the area linear anomaly). If we asume that the control run represents the 'linear' state, then the September forecast results

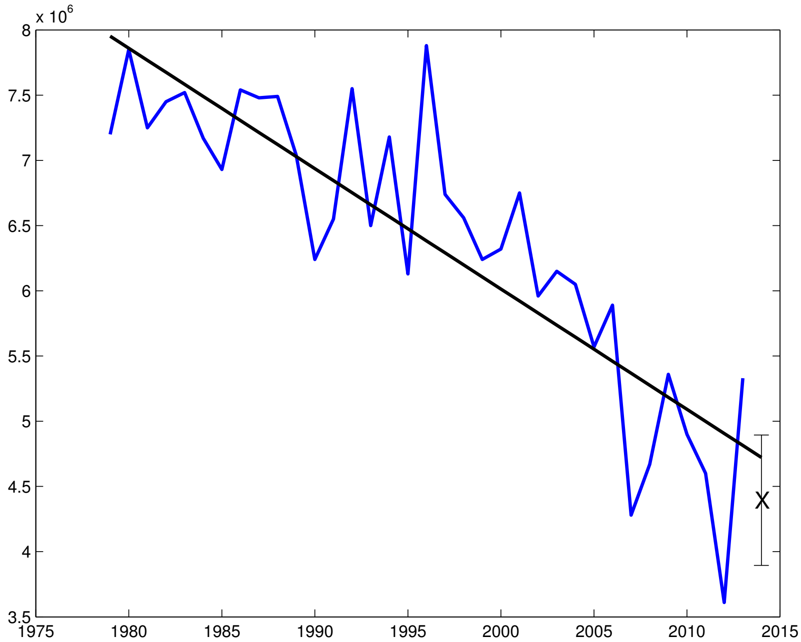

Figure 2: September sea ice extent in observations (1979-2013) together with a linear trend and 2014 forecast

from the linear value for September 2014 in observations plus the aforementioned difference, with an errorbar representing one standard deviation. Thus, our forecast for September 2014 is

$$Sep2014 = Sep2014\_linear + Ensemble\_diff \pm Ensemble\_stdev = 4.39 \times 10^6 km^2 \pm 0.50 \times 10^6 km^2, \quad (1)$$

This is visually shown in figure 2.

2.1 Regional outlook

This year we include a brief discussion on regional aspects of the outlook. Figure 3 shows the difference in September sea ice concentration between the experiment and control ensembles. Overall, there is a loss in sea ice in the experiment relative to the control, but the Atlantic-facing sea ice region (Svalbard, Franz Josef, Severnaya Zemlya) tends to have positive anomalies relative to the control ensemble (not climatology). This suggests that the greatest sea ice loss will be in East Siberia and Alaska, somewhat reminiscent of the pattern in 2007.

Since the GCM and observations have a slightly different mean state (the September GCM sea ice limit extends further south), it is not appropriate to apply GCM anomalies one-to-one to an observational climatology. Instead we derive a relationship between ice concentration in the control and experiment GCM ensembles for each longitude, and apply this relationship at each longitude to an observational climatology (which itself is a mean SIC of the last 10 years- this approximates to the expected linear trend value). The results are shown in figure 4.

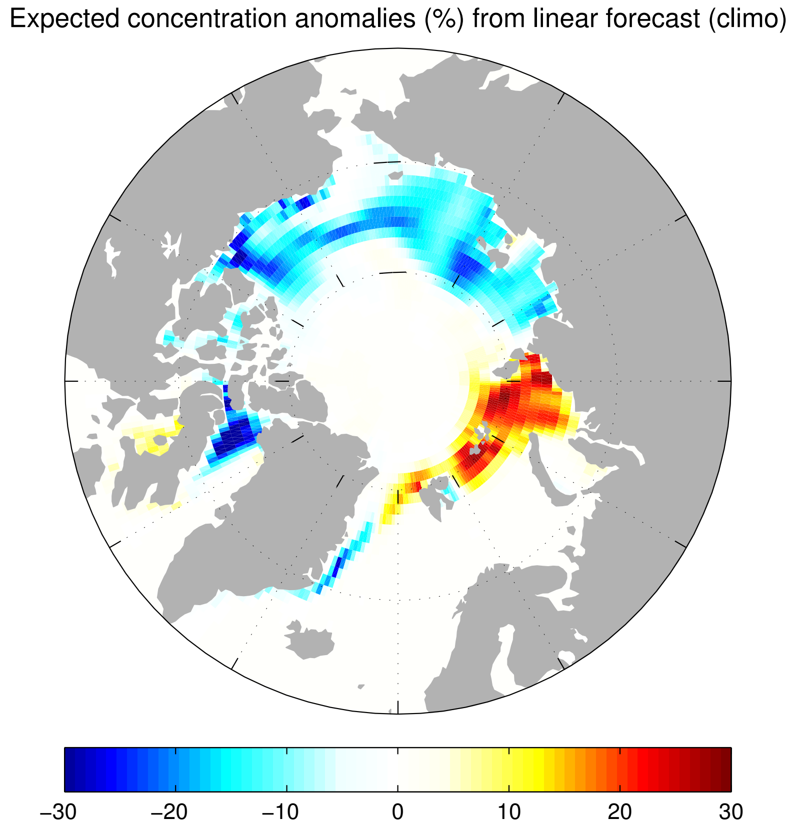

Figure 3: Difference in September sea ice concentration between the experiment and control ensembles in the GCM.

Figure 5 shows the Julian Ice-free day for the period 2003-2012 and our outlook values for 2014. We use daily sea ice concentration data from NSIDC to compute the mean. To calculate the outlook value, we apply the changes in sea ice concentration between the GCM experiment and control to the 2003-2012 observational mean obtained from NSIDC. To account for the difference in mean state between GCM and observations, we use the methodology described above. We define IFD as the first day when the SIC is below 25% in a grid cell. The changes between the outlook and the mean reflect the changes in extent described above; later IFDs in the Kara/Barents sectors, and earlier IFDs in East Sibera/Alaska.

3 Executive Summary

Our 2014 September sea ice extent forecast is 4.39 $\pm$ 0.50 million square kilometers. This is based upon a forecast using the CESM1 model initialized with sea ice anomalies obtained from the PIOMAS model for May for the period 1st May-1st October. The quoted error is obtained from the standard deviation of the ensemble distribution in September.

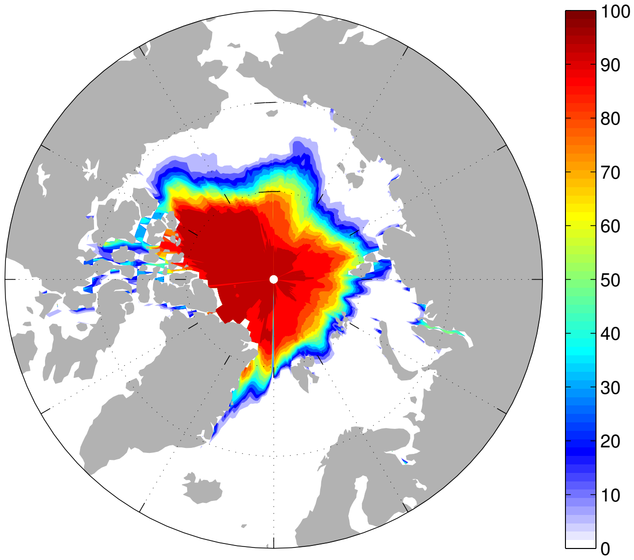

Figure 4: Sea ice concentration probability for September 2014

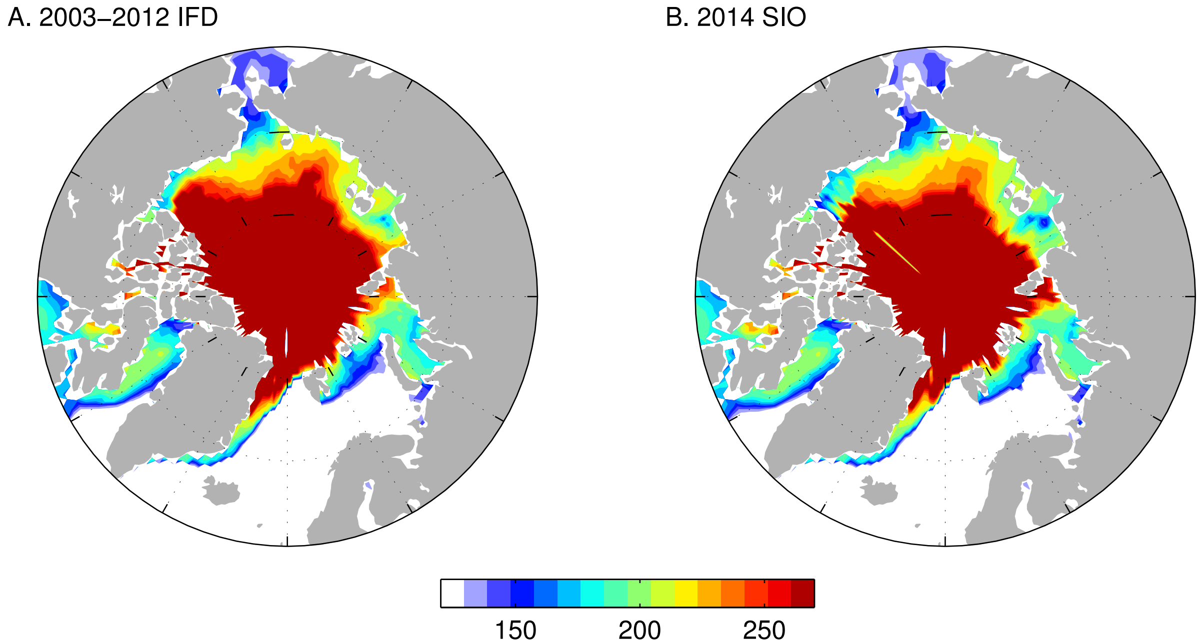

Figure 5: a) mean Ice-free day (IFD) for the period 2003-2012 and b) outlook of IFD for 2014.