Summer 2012 September Arctic Sea Ice Forecast

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Extent Projection

4.88 $\pm$ 0.55 million square kilometers

Methods

Our forecast uses a state-of-the-art General Circulation Model (GCM) initialized with spring 2012 sea ice area and volume anomalies from the Pan-arctic Ice-Ocean Modeling and Assimilation System (PIOMAS). The GCM used is the National Center for Atmospheric Research (NCAR)'s Community Climate System Model version 4 (CCSM4) [1] at 1° resolution in all components.

Our strategy is to initialize the sea ice anomalies with respect to the model mean that are good 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 June 1 with identical sea ice, ocean, and land conditions but with variable atmospheric initial conditions that are drawn from consecutive days near June 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 CCSM4 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, which is close enough to present to be used for seasonal prediction in 2011.

At this time 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 CCSM4 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 (so far) 10 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 (so far) 18 runs just like the control, but with anomalous sea ice initial conditions based on PIOMAS. We refer to the second ensemble as the forecast ensemble henceforth, though it is specifically a forecast relative to our control.

Retrospective simulation of PIOMAS assimilate satellite ice concentration data and sea surface temperature and represent a close approximation to April 2012 observations. We calculate the April 2012 anomaly in the ice-thickness distribution (ITD) as a departure the

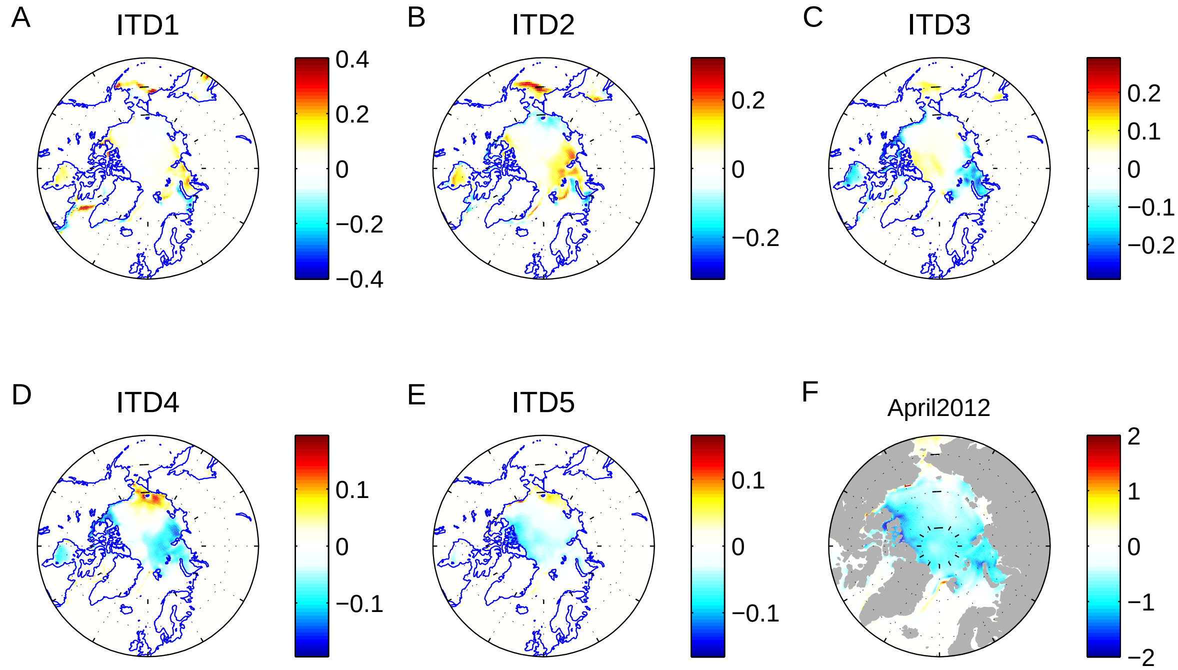

Figure 1: Ice fraction anomalies for individual ice-thickness category of the ITD for April 2012 from PIOMAS (Panels A to E for thinnest to thickest category). The mean thickness anomaly across ice-thickness categories in meters for April 2012 (Panel F). Anomalies are computed from the 1979-2011 April ice conditions in PIOMAS. The first two ice-thickness categories have mostly positive anomalies and the next three have mostly negative anomalies, which reflects a shift of thicker ice to thinner categories.

linear trend in PIOMAS (computed from 1979-2011). We then input these anomalies for 1 June sea ice conditions in the CCSM4 (see Figure 1).

We note that we only have available PIOMAS output to April 2012. In last year's Outlook, we were able to make use of output through May 2011. Given the slow variation of ice thickness anomalies, April and May total ice thickness anomalies are almost identical (r=0.97 for 32 year period 1979-2011), and hence we do not expect that beginning our integrations on June 1 with thickness anomalies derived from April is a significant source of error.

We run both ensembles for 4 months until October 1st, to produce two distributions, a control and a forecast of September sea ice area (see figure 2).

While observed April 2012 sea ice area (and extent) anomalies were actually positive compared to the linear trend (+5% anomaly), volume anomalies in PIOMAS are negative ($\sim$ -7% anomaly) and manifest in greater meltback by the end of summer in the forecast ensemble relative to the control ensemble (see Figure 2).

The mean September sea ice areas in the GCM are 5.89 $\times 10^6$ km^2 and 6.11 $\times 10^6$ km^2 in the forecast and control ensembles respectively, with a standard deviation of $\sim$0.51 $\times 10^6$ km^2. Given our experimental design, the difference between forecast ensemble mean and control ensemble means (0.22 $\times 10^6$ km^2) is due to the influence of interannual variability on initial conditions, not climate forcing. We ignore the influence of climate forcing on our prediction over the 4 month because our research has shown that it does not become

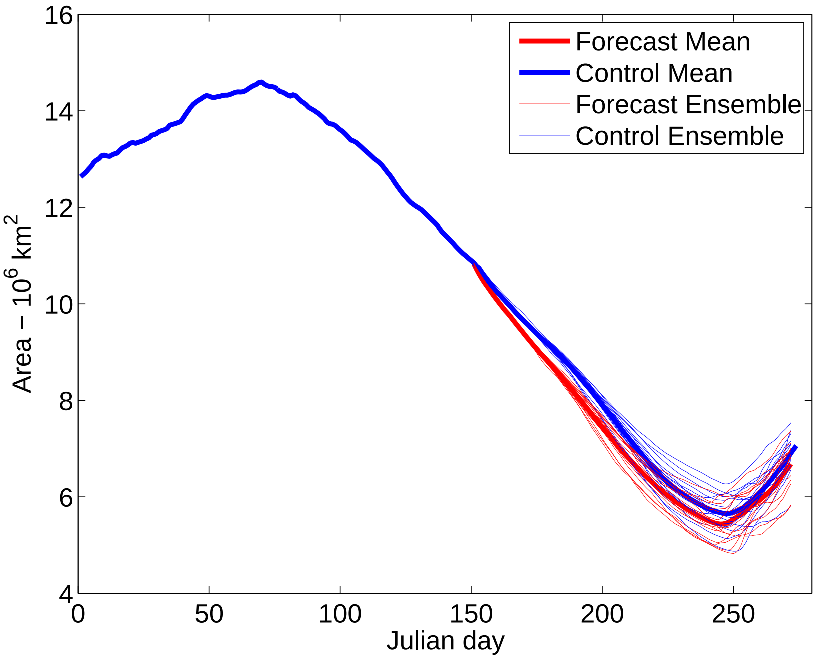

Figure 2: Daily sea ice area for the control (blue) and forecast (black) ensembles

a significant factor in sea ice area prediction in periods less than about 3 years [2]. The spread in each ensemble is solely due to the (coupled) sea ice-atmospheric forcing in the June-October period.

We make a prediction P for September 2012 based on our forecast anomaly, which is the difference in the ice area between the control and forecast ensemble means δ and the standard deviation σ of the forecast 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 ~ 1.2 (i.e. the extent linear anomaly is on average 20% greater in magnitude than the area linear anomaly). We add our forecast anomaly to the linear extrapolation of observed $\bar{O}$ September ice extent to 2012. Thus, our prediction for September 2012 is

$$P = \bar{O} + 1.2[\delta(\text{ensemble}) \pm \sigma(\text{ensemble})] = 4.88 \pm 0.52 \times 10^6 \text{km}^2,$$

This is visually shown in figure 3.

Executive Summary

Our 2012 September sea ice extent forecast is 4.88 ± 0.51 million square kilometers. This forecast is from the CCSM4 model initialized with sea ice anomalies from the PIOMAS model for April. The quoted error is the standard deviation of the ensemble distribution in September.

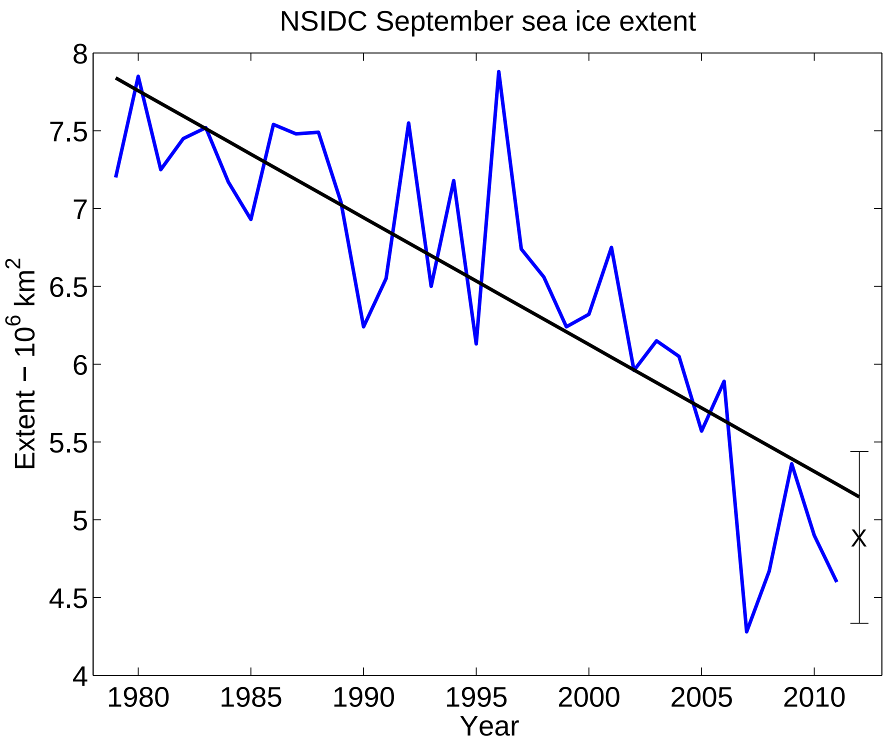

Figure 3: September sea ice extent in observations (1979-2011) together with a linear trend and 2012 forecast

References

[1] Gent, P. R., et al. (2011), The community climate system model version 4, *Journal of Climate*, *24* 4973–4991.

[2] Blanchard-Wrigglesworth, et al. (2011), Influence of initial conditions and boundary forcing on predictability in the Arctic *Geophysical Res. Lett.*, *38, L18503, doi:10.1029/2011GL048807.*