GFDL Contribution to September 2013 Sea Ice Outlook
July report (based on June data)

Rym Msadek, Gabriel Vecchi and Mike Winton
GFDL/NOAA, Princeton, NJ, USA

Note: This is an experimental projection and is not an official NOAA forecast.

1-Extent Projection

Our projection for the September monthly Arctic sea ice extent is **5.8** million square kilometers, with a **range from 5.0 to 6.2** million square kilometers (Fig.1). The standard deviation among the ensemble members is 0.3 million square kilometers. While the projected 2013 extent remains below the 1979-2007 observed average, the model predicts that September Arctic sea-ice extent will recover to a value comparable to that reached in 2006.

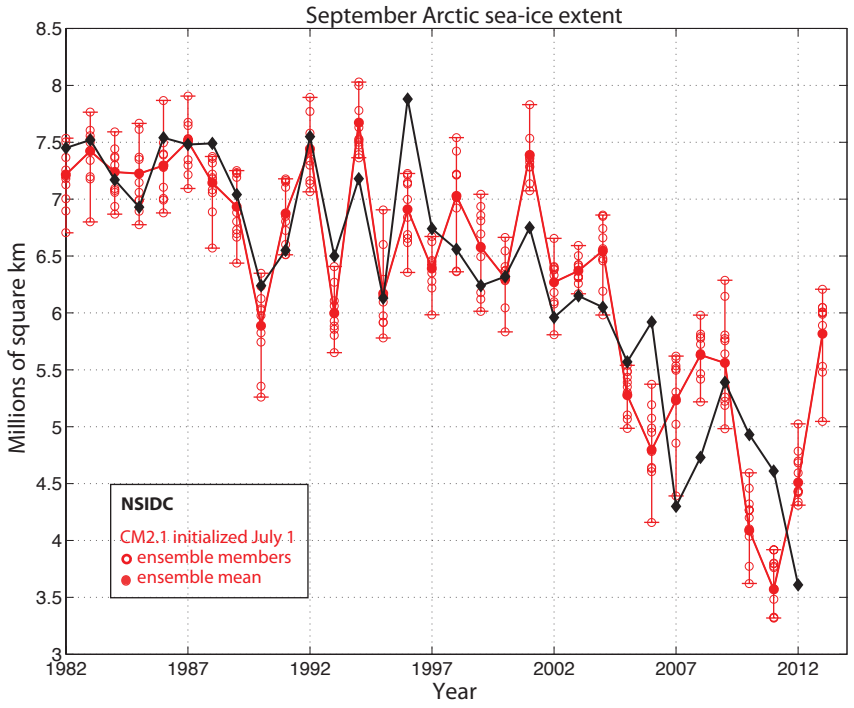

Figure 1: September Northern Hemisphere sea-ice extent for the GFDL CM2.1 predictions initialized July 1 compared to observations from NSIDC. The ensemble means and the individual ensemble members are shown. The error bars indicate the lowest and highest extents in the 10-member ensemble. The model values have been bias-corrected.

2-Methods/Techniques

Our projections are estimated from the GFDL ensemble coupled data assimilation and prediction system based on the CM2.1 global coupled ocean-atmosphere-sea ice model (Delworth et al. 2006). Both the ocean and the atmosphere are initialized

through a full-field assimilation to bring the state of the coupled model closer to observations (Zhang et al. 2007). This forecast system currently contributes to the North American Multi-Model Ensemble project and has been used to investigate the predictive skill of large-scale climate and its impacts (Yang et al. 2013, Vecchi et al. 2013, Msadek et al. 2013). Sea-ice extent is initialized through assimilation of sea-surface temperature but sea-ice concentration and thickness are not explicitly assimilated. Historical radiative forcing is used prior to 2005 and the RCP4.5 scenario for the predictions started after 2005. For the predictions initialized after 2004, the aerosols are fixed at the RCP4.5 scenario year of 2004. A 10-member ensemble is produced every year between 1982 and 2013, starting on the 1st of every month and run for one year. The ensemble members are expected to sample the atmospheric variability that may prevail each month. We focus here on the forecasts initialized 1-July, based hence on June data.

Over the period 1982-2012, the predictions initialized July 1 underestimate the September extent by 1.0 million square kilometers (a bias that increases with lead time). A bias correction is hence applied to account for differences in the mean Northern Hemisphere extent compared to observed values from NSIDC. The estimate given above corresponds to the bias corrected ensemble mean.

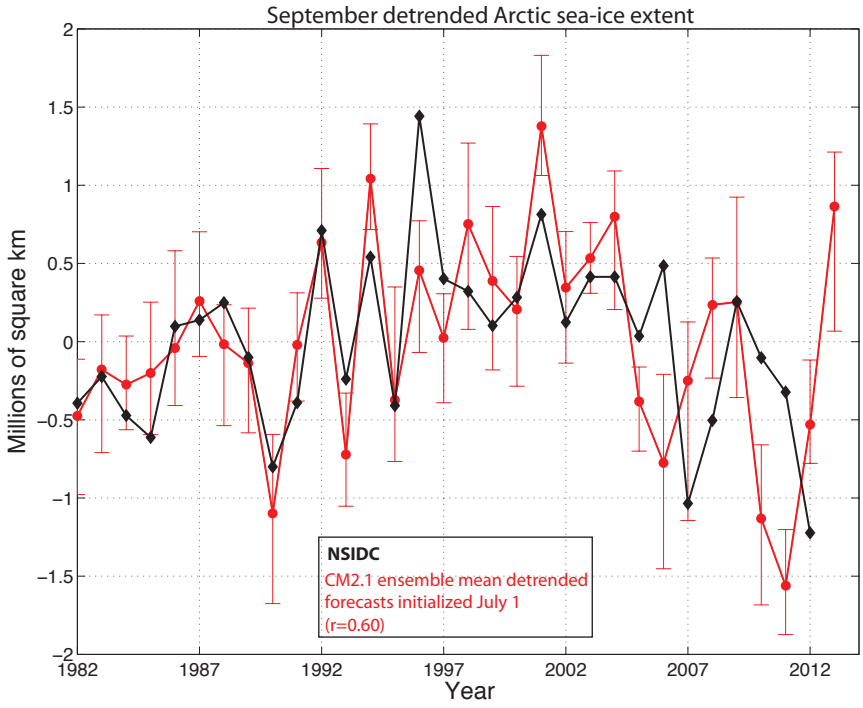

Figure 2: Comparison of detrended observations of September Arctic sea-ice and detrended CM2.1 predictions initialized July 1. The error bars indicate the lowest and highest extents in the 10-member ensemble. The model values have been bias-corrected.

3-Rationale

The GFDL CM2.1 forecast system has been proven skillful in retrospectively predicting the observed long-term downward trend of September Arctic sea ice extent anomalies as well as the deviation from the recent linear trend over the last 30 years (Fig. 1 and 2). Over the period 1982-2012, the correlation between observed September Arctic sea ice extent and the predicted extent when the model is initialized July 1 equals 0.87. The correlation is still statistically significant at 95% when data are detrended (r=0.60.) We note however a degradation of skill in predicting the year-to-year variability during the recent decade that is coincident with the rapid decline and thinning of Arctic sea-ice. While the model predicted in 2011 a minimum comparable to the observed 2012 value, it did not capture the 2007 and 2012 minima. Assimilating sea-ice thickness and concentration would likely improve future forecasts.

4-Executive Summary

Our projection for the September monthly Arctic sea ice extent is 5.8 million square kilometers, with a range from 5.0 to 6.2 million square kilometers. Our estimate is based on the GFDL CM2.1 ensemble forecast system in which both the ocean and atmosphere are initialized on July 1 using coupled data assimilation. Our projection is the bias-corrected ensemble mean, and the given range corresponds to the lowest and highest extents in the 10-member ensemble. While the projected 2013 extent remains below the 1979-2007 observed average, the model predicts that September Arctic sea-ice extent will recover to a value comparable to that reached in 2006.

5-Uncertainty of Forecast skill

The uncertainty range is estimated from the lowest and highest values in the ensemble forecast. Although relatively large, this uncertainty range only reflects variations in atmospheric summer conditions and does not account for other sources of uncertainty like errors in the initial conditions and model deficiencies that prevail despite the bias correction. The ensemble standard deviation is also given as a measure of error.

References

Delworth, T. L., et al., 2006: GFDL CM2 global coupled climate models. Part I: formulation and simulation characteristics. J. Climate, 19, 643–674.

Msadek R., T. L. Delworth, A. Rosati, W. Anderson, G. Vecchi, Y.-S. Chang, K. Dixon, R. G. Gudgel, W. Stern, A. Wittenberg, X. Yang, F. Zeng, R. Zhang, S. Zhang (2013): Predicting a decadal shift in North Atlantic climate variability using the GFDL forecast system, to be submitted

Vecchi G**.,** R. Msadek, W. Anderson, Y.-S. Chang, T. Delworth, K. Dixon, R. Gudgel, A. Rosati, B. Stern, G. Villarini, A. Wittenberg, X. Yang, F. Zeng, R. Zhang, S. Zhang (2013): Multi-year predictions of North Atlantic hurricane frequency: promise and limitations, J. Climate (in press) doi: 10.1175/JCLI-D-12-00464.1

Yang X., A. Rosati, S. Zhang, T. L. Deworth, R. G. Gudgel, R. Zhang, G. Vecchi, W. Anderson, Y.-S. Chang, T. DelSole, K. Dixon, R. Msadek**,** W. F. Stern, A. Wittenberg, F. Zheng (2013): A predictable AMO-like pattern in GFDL's fully coupled ensemble initialization and decadal forecasting system, J.

Climate, 26(2), doi:10.1175/JCLI-D-12-00231.1

Zhang, S., M. J. Harrison, A. Rosati, and A. T. Wittenberg, 2007: System design and evaluation of coupled ensemble data assimilation for global oceanic climate studies. Mon. Wea. Rev., 135 (10), doi:10.1175/MWR3466.1.