September 2010 Sea Ice Outlook
July Report

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Caveat: This is an experimental projection, not an official Met Office forecast

Extent Projection

5.5 million square kilometres.

Method (Coupled atmosphere-ice-ocean model ensemble runs)

This projection is an experimental model prediction from the Met Office Hadley Centre seasonal forecasting system (GloSea4). GloSea4 is an ensemble prediction system and became operational in September 2009 (Arribas *et al.*, 2010). It uses the same coupled model as the latest Hadley Centre coupled climate model (Hewitt *et al.*, 2010) consisting of the following model components:
  *   atmosphere = UM (Met Office Unified Model; Davies *et al.*, 2005)
  *   ocean = NEMO (Nucleus for European Modelling of the Ocean; Madec, 2008)
  *   sea ice = CICE (Los Alamos sea ice model; Hunke and Lipscomb, 2010)
  *   land surface = MOSES (Met Office Surface Exchange Scheme; Essery *et al.*, 2003).

The GloSea4 system has a real-time forecasting component, together with an accompanying set of hindcasts (or historical re-forecasts) which are used for bias correction and skill assessment. The forecasts and hindcasts differ only by their initial conditions and are typically run for 6 months. The hindcasts are currently done for the period 1989-2002.

The ocean is initialised using an ocean data assimilation scheme (Martin *et al.*, 2007) which assimilates ocean SST (in-situ and satellite) and ocean profiles (temperature and salinity). The atmosphere initial conditions are provided by the Met Office operational numerical weather predition analyses for the forecast run and from ERA-interim (ECMWF, 2009) reanalysis for the hindcast runs. Currently sea ice is initialised from a previous coupled model climatology (HadGEM1 under pre-industrial conditions). This is a major limiting factor in our ability to attempt to forecast the sea ice over a timescale of months. Work is ongoing to assimilate sea ice concentration observations into the ocean data assimilation scheme, which should become operational within the next year.

Both GloSea4 and the coupled model are under continual development. For example, work is currently being done to improve the Arctic ice thickness distribution which is not as realistic as the previous Hadley Centre climate models (HadGEM1 and HadGEM2). This is also the first time that the sea ice in the GloSea4 system has been investigated, as the focus for seasonal forecasts has generally been looking at ENSO and its teleconnections. Given these issues and the lack of realistic sea ice initial conditions, the September sea ice extent prediction is given here with low confidence as a prediction, but more as an illustration of our potential to provide such estimates in the future. It will also act as a useful benchmark for assessing the impact of future developments.

Further information on GloSea4 is available on the Met Office website:
(http://www.metoffice.gov.uk/research/modelling-systems/unified-model/climate-models/glosea4).

Hindcast Results and the Summer 2010 Forecast

September ice extent anomalies for 1989-2002 from the May hindcast ensemble are shown in figure 1. The ensemble for each year consists of 9 model runs (3 different start dates each used for 3 runs with different physics perturbations). The correlation of the ensemble mean with the observational data set HadISST (Rayner *et al*., 2003) is low (0.31) which is probably to be expected given the issues discussed above.
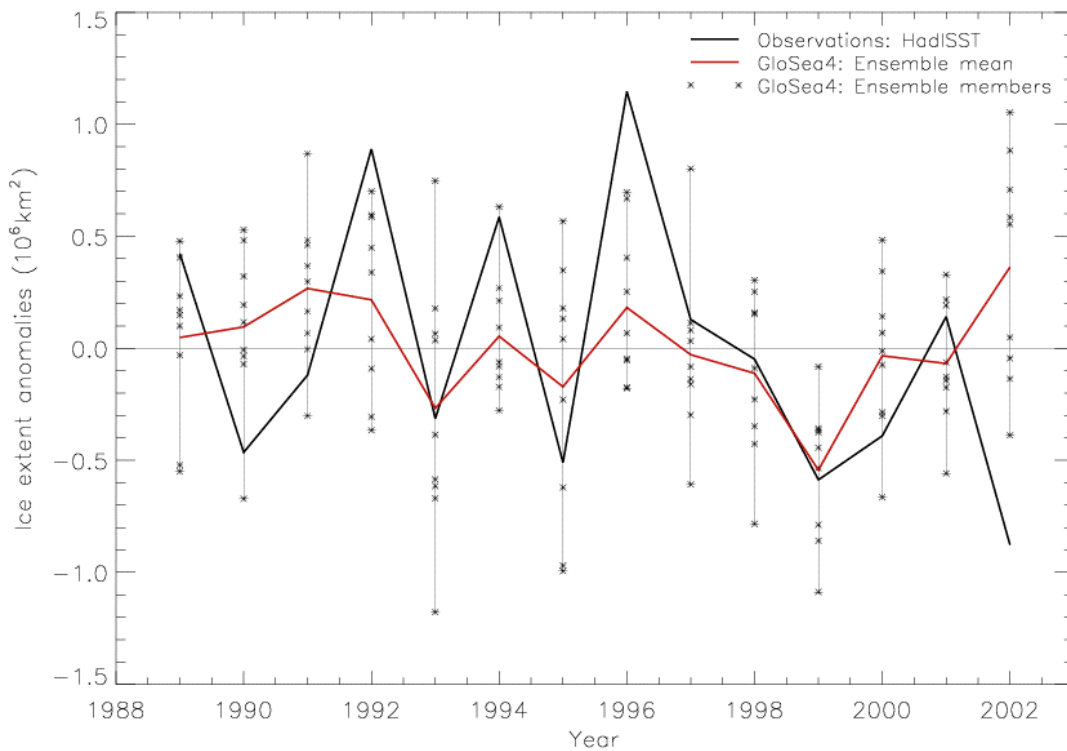
Figure 1: Arctic ice extent anomalies of the September monthly mean for the HadISST observational data set (Rayner *et al*., 2003) (red line) and the GloSea4 hindcast ensemble mean (thick black line) for 1989-2002. Observed (model) anomalies are relative to the observed (model) climatology for 1989-2002. Results from the individual ensemble members are shown by the asterisks.

The September 2010 prediction uses the ensemble mean from 42 runs (3 different start dates each used for 14 runs with different perturbed physics) starting in May. The ice extent anomalies for the different ensembles are shown in figure 2, relative to the hindcast 1989-2002 climatology. The ensemble mean anomaly is then added to the HadISST dataset 1989-2002 climatology to give a prediction for September 2010 of 5.5 million square kilometres. Despite the known model deficiencies, it is encouraging that this estimate lies in the range of the June Outlook report projections.
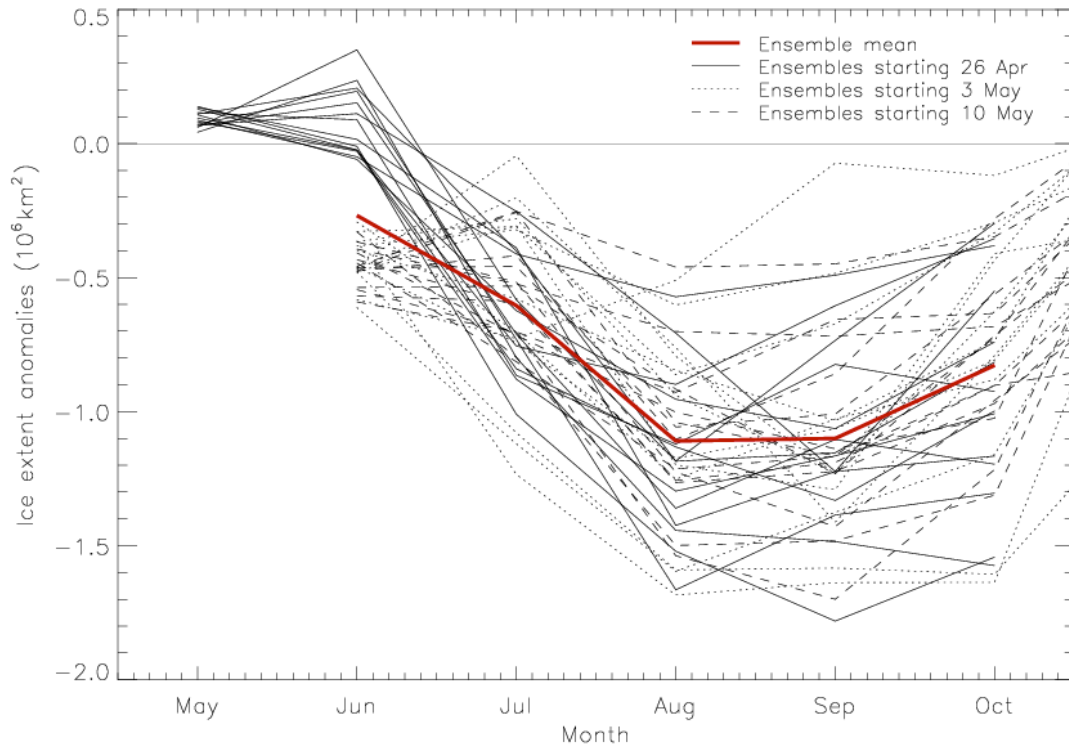
Figure 2: GloSea4 forecast for summer 2010 Arctic sea ice extent anomaly relative to the model climatology for the hindcast period 1989-2002. The ensemble mean (red line) is shown together with the 42 ensemble members (black lines).

Executive Summary

The September monthly mean sea ice extent for the Arctic is predicted to be 5.5 million square kilometres.

This experimental estimate is from the Met Office Hadley Centre seasonal forecasting system (GloSea4). GloSea4 is an ensemble prediction system that uses the same atmosphere-ice-ocean coupled model as the latest Hadley Centre climate model. Both the system and the model are under continuous development; for example the sea ice in the seasonal forecast is currently initialised with a model climatology, but this will be improved to use assimilated ice concentration observations soon. Hindcast runs indicate that there is little skill in our *current* system for predicting September ice extent. Therefore the 2010 prediction is given with low confidence, but illustrates our methods and our potential to provide improved model estimates in the future.

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