Met Office
September 2015 Pan-Arctic Sea Ice Outlook
June Report (Using May Data)

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Group: Met Office

Projection Type: Model based estimate.

September Monthly Averaged Extent Projection: $(\mathbf{4.4 \pm 0.9}) \times \mathbf{10^6}$ $\mathbf{km^2}$

Model: HadGEM3, Global Coupled Model 2.0 [Williams et al., 2015]

Ice Component: CICE [Hunke and Lipscomb, 2010], Global Sea Ice 6.0 [Rae et al., 2015]

Ocean Component: NEMO [Madec, 2008], Global Ocean 5.0 [Megann et al., 2013]

Atmospheric Component: Met Office Unified Model (UM) [Brown et al., 2012], Global Atmosphere 6.0

Land Component: JULES [Best et al., 2011], Global Land 6.0

Coupler: OASIS3 [Valcke, 2006]

Method: Ensemble coupled model seasonal forecast from the GloSea5 seasonal prediction system [MacLachlan et al., 2014], using the Global Coupled 2 (GC2) version [Williams et al., 2015] of the HadGEM3 coupled model [Hewitt et al., 2011]. Forecast compiled together from forecasts initialized between 30 March and 19 April (2 per day) from an ocean and sea ice analysis (FOAM/NEMOVAR) [Blockley et al., 2014, Peterson et al., 2015] and an atmospheric analysis (MO-NWP/4DVar) [Rawlins et al., 2007] using

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observations from the previous day. Special Sensor Microwave Imager (SSM/I) ice concentration observations from ESA OSI-SAF [OSI-SAF, 2011] were assimilated in the ocean and sea ice analysis, along with satellite and in-situ SST, subsurface temperature and salinity profiles, and sea level anomalies from altimeter data. No assimilation of ice thickness was performed. The forecast (Figure 1) has a small bias correction downward of 0.2×10^6 km^2 due to a mean over forecast of the ice extent relative to the observed NSIDC ice extent over the hindcast period 1996 to 2009 [Peterson et al., 2015].

Projection Uncertainty: $\pm 0.9 \times 10^6$ km^2 representing two standard deviations of the (42 member) ensemble spread around the ensemble mean.

Executive Summary: Using the Met Office GloSea5 seasonal forecast systems we have generated a model based mean September sea ice extent outlook of $(\mathbf{4.4 \pm 0.9}) \times \mathbf{10^6}$ km$^\mathbf{2}$. This has been generated using startdates between 30 March and 19 April to generate an ensemble of 42 members.

Additional Information: Validation and calibration of the forecast was done using a 1996-2009 historical re-forecast (hindcast) using startdates of 1/9/17 April (3 members each). Over the hindcast period, the correlation between the GloSea5 forecast and NSIDC sea ice extent observations was 0.80 which reduces to a correlation of 0.32 if the trend is removed from the time series. See figure 1 showing the time series of September sea ice predictions in the hindcast, along with the forecast for 2015. The non detrended correlation value is significantly different from 0 at the 95% confidence level. However, it is not a significantly better indicator of September sea ice extent then a simple trend analysis. After bias correcting, the hindcast has a root mean square error (rmse) of 0.5×10^6 km^2 comparable to the quoted error.

Note: The forecast has been made with an updated GC2.0 version of the coupled model (see `http://www.metoffice.gov.uk/research/climate/seasonal-to-decadal/gpc-outlooks/notice`). In particular, changes have been made to improve the modelled sea ice climatology through parameter changes to the sea ice albedo scheme.

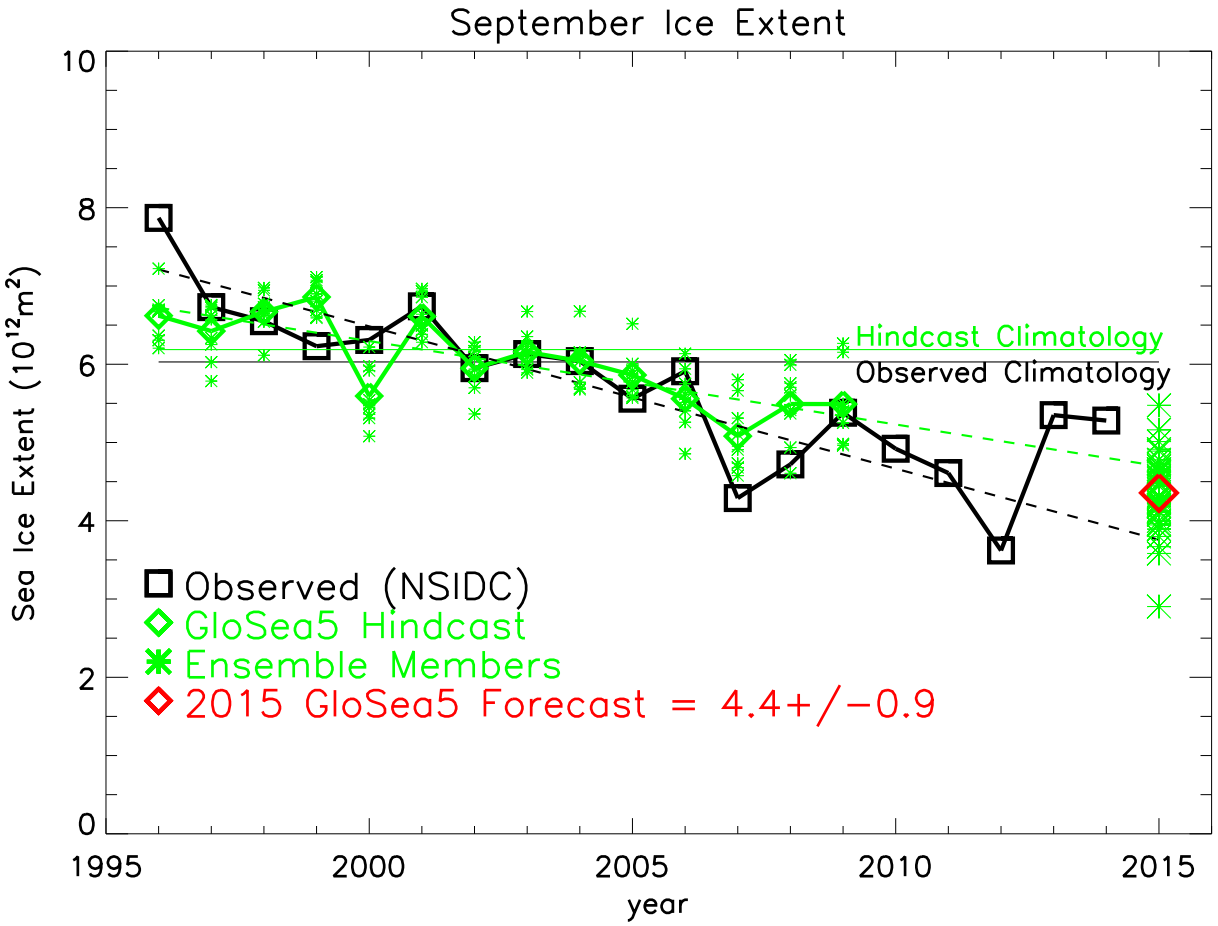

Figure 1: Time series of ensemble mean September sea ice extent from GloSea5 (green ⋄) and observations (NSIDC; black □). Individual ensemble member sea ice extents are denoted by ∗ (green). The green and black horizontal lines denote the hindcast and observed (1996-2009) climatology respectively. The forecast and hindcast values have all been adjusted downward by the amount between the two lines ($0.2 \times 10^{12}m^2$). The green and black dashed lines are the forecast and observed trends in the timeseries over the 1996-2009 hindcast period. Note: Due to the changes made to the system since our 2014 forecast, neither the previous 2013 nor 2014 forecasts from our system are representative of how the system might behave in 2015, and therefore they are not plotted in the figure.

September 2015 Monthly Mean Ice Edge

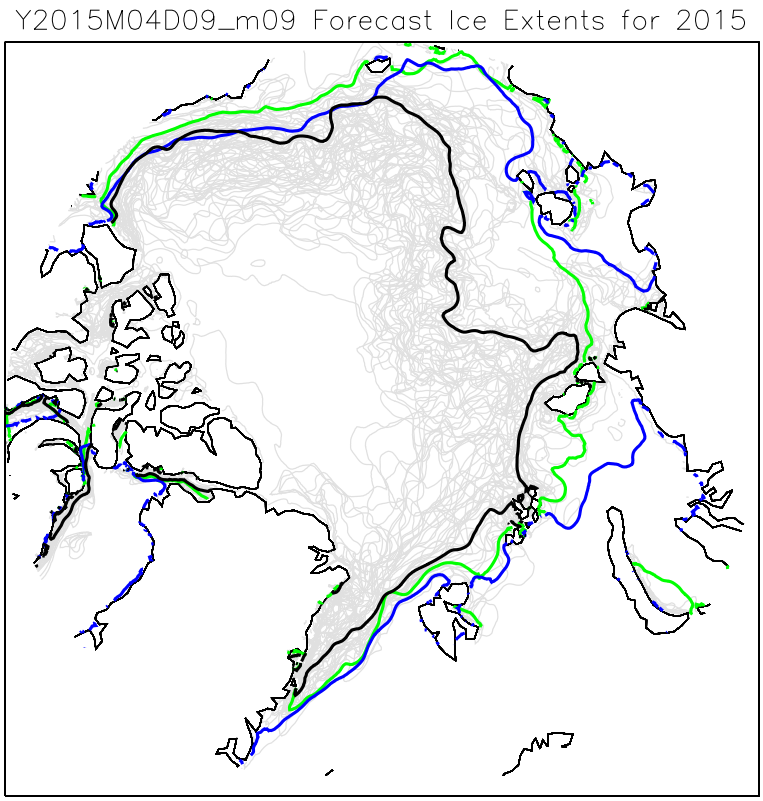

Figure 2: Plot of ice edge. Black line is the location of ice edge (ice concentration > 0.15) for the ensemble mean sea ice concentration. Individual grey lines are the ice edges for the individual ensemble members. No bias correction has been applied. The green and blue lines are the ice edges of the 1996-2009 sea ice concentration climatologies for the hindcast and observations respectively. Differences between these two climatological ice edges would indicate how and where the model climatology differs from the observed. Note: Ice extent is a non-linear quantity. The ice extent represented by the ensemble mean sea ice concentration (area inside the black curve of $5.3 \times 10^{12}\mathrm{m}^2$) is larger then the ensemble mean ice extent before bias correction ($4.5 \times 10^{12}\mathrm{m}^2$), which is the mathematical mean of the ice extent (area inside) of each of the grey ensemble member lines, upon which our forecast (before bias correction) is based.

September 2015 Probability of Ice

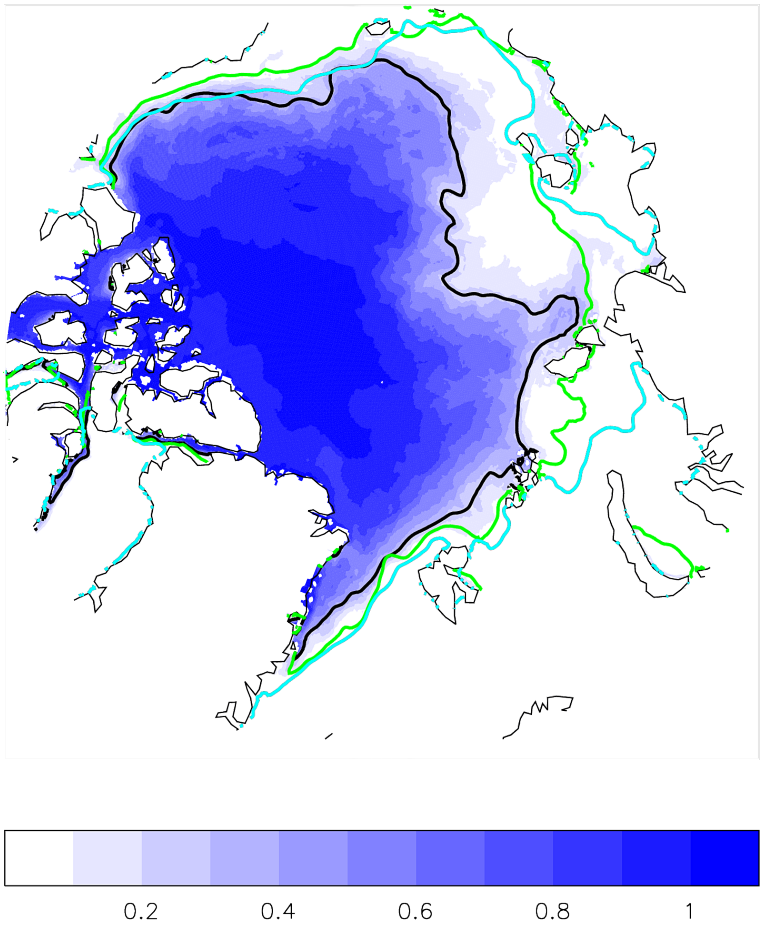

Figure 3: September 2015 monthly mean probability of ice (fraction of ensemble members with ice concentration > 0.15). Note: The numerical value of our sea ice forecast before bias correction, $4.5 \times 10^{12}\mathrm{m}^2$, will be the area integral of the ice probabilities represented by this figure. The black line is the ice edge of the ensemble mean ice concentration as in figure 2. The green and cyan lines are the ice edges of the 1996-2009 sea ice concentration climatologies for the hindcast and observations respectively.

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