

Met Office
September 2016 Arctic Sea Ice Outlook
August Report (Using July Data)

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Group: Met Office

Projection Type: Model based estimate.

September Monthly Averaged Extent Projection: $(4.1 \pm 0.7) \times 10^6 \text{ km}^2$

Model: HadGEM3, Global Coupled Model 2.0 [Williams et al., 2015] in use within the GloSea5 seasonal prediction system [MacLachlan et al., 2014].

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., 2014]

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 15 Jul and 4 Aug (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]

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using observations from the previous day. Special Sensor Microwave Imager (SSM/I) ice concentration observations from ESA OSI-SAF [OSI-SAF] 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 been bias correction upward by $1.2 \times 10^6 \text{ km}^2$ due to a mean under forecast of the ice extent relative to the observed NSIDC ice extent over the hindcast period 1993 to 2015 [Peterson et al., 2015]. This is up considerably from biases in our June and July outlooks. The bias is endemic along most of the ice edge (see Figure 2).

Projection Uncertainty: $\pm 0.7 \times 10^6 \text{ km}^2$ representing two standard deviations of the (42 member) ensemble spread around the ensemble mean. Note, however, that this spread (Figure 1) is somewhat asymmetric with a much larger spread amongst the values below the mean, but more members above the mean.

Executive Summary: Using the Met Office GloSea5 seasonal forecast systems we are issuing a model based mean September sea ice extent outlook of $(4.1 \pm 0.7) \times 10^6 \text{ km}^2$. This has been assembled using startdates between 15 Jul and 4 Aug to generate an ensemble of 42 members.

Additional Information: Validation and calibration of the forecast was done using our extended 1993-2015 historical re-forecast (hindcast) using startdates of 17 & 25 Jul and 1 Aug (3 members each). Over the hindcast period, the correlation between the GloSea5 forecast and NSIDC sea ice extent observations was 0.94 which reduces to a correlation of 0.80 if the trend is removed from the time series. Figure 1 shows the time series of September sea ice predictions in the hindcast, along with the forecast for 2016. Both the full and detrended correlation values are significantly different from 0 at the 95% confidence level, and are both better predictors than respectively persistence and detrended persistence — using the July sea ice anomaly as a predictor of the September anomaly — although below that of using the August anomaly as a predictor (see Figure 3). Furthermore, the value of the full correlation between the two time series suggests that our forecast is historically a better predictor than predicting the trend. After bias correcting, the hindcast has a root mean square error (rmse) of $0.5 \times 10^6 \text{ km}^2$ comparable to the quoted error. The September ice extent forecast has steadily increased over the course of the summer — up 0.5 and 0.3 million sq. km. from respectively our June and July outlooks.

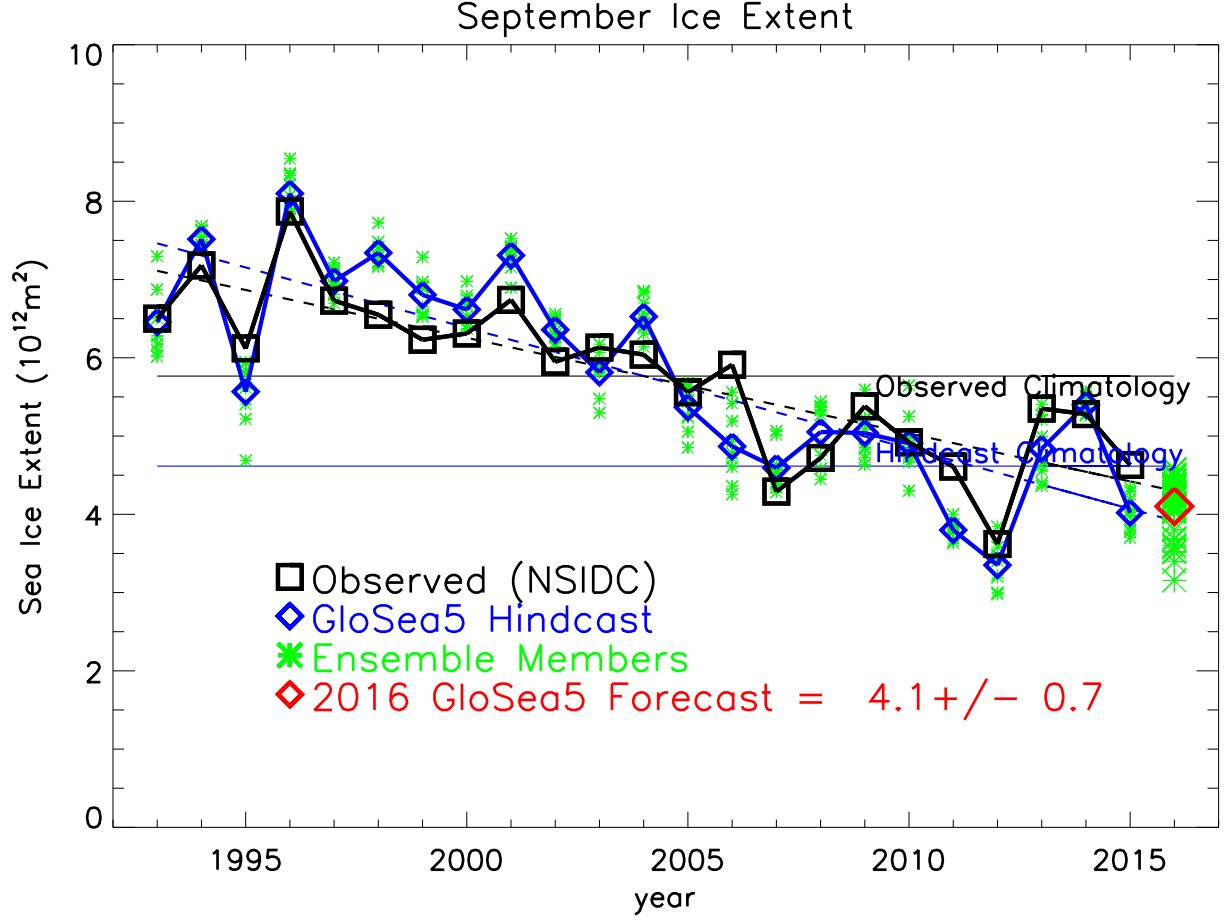


Figure 1: Time series of ensemble mean September sea ice extent from GloSea5 (blue and red \diamond) and observations (NSIDC; black \square). Individual ensemble member sea ice extents are denoted by * (green). The blue and black horizontal lines denote the hindcast and observed (1993-2015) climatology respectively. The forecast and hindcast values have all been adjusted upward by the amount between the two lines ($0.6 \times 10^{12}\text{m}^2$). The blue and black dashed lines are the forecast and observed trends in the timeseries over the 1993-2015 hindcast period.

September 2016 Bias Corrected Probability of Ice

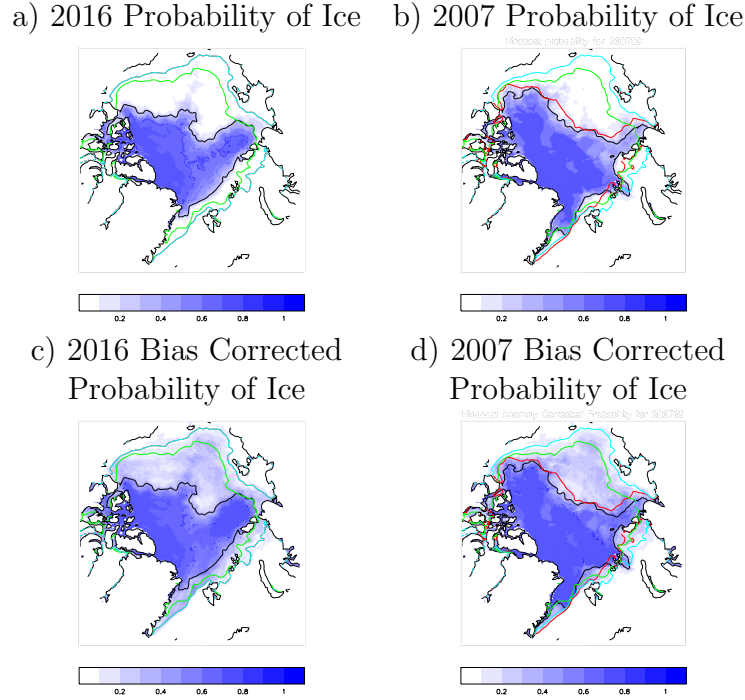


Figure 2: September a) 2016 and b) 2007 monthly mean (non-corrected) probability of ice (fraction of ensemble members with ice concentration > 0.15). 2007 was a closer analog to 2016 than 2012. Bias corrected September c) 2016 and d) 2007 monthly mean probability of ice. Model grid point probability has been adjusted downward or upward by the amount model historically over or under predicts the likelihood of ice in that grid box between 1993 and 2015. The nature of this correction, along with the trend in sea ice extent, means that it tends to increase the probability where the ice extent has been historically under-forecast, and does not necessarily concentrate this near to the present day ice edge, as can be seen with the low probability of ice spread throughout the Beaufort, Chukchi and East Siberian Seas, far from where the ice edge is likely to be (or was in 2007) in the bias corrected probabilities (c and d). The black line is the ice edge of the ensemble mean ice concentration, while the green and cyan lines are the ice edges of the 1993-2015 sea ice concentration climatologies for the hindcast and observations respectively. The red line in 2007 is the observed ice edge.

September Forecast April Through June

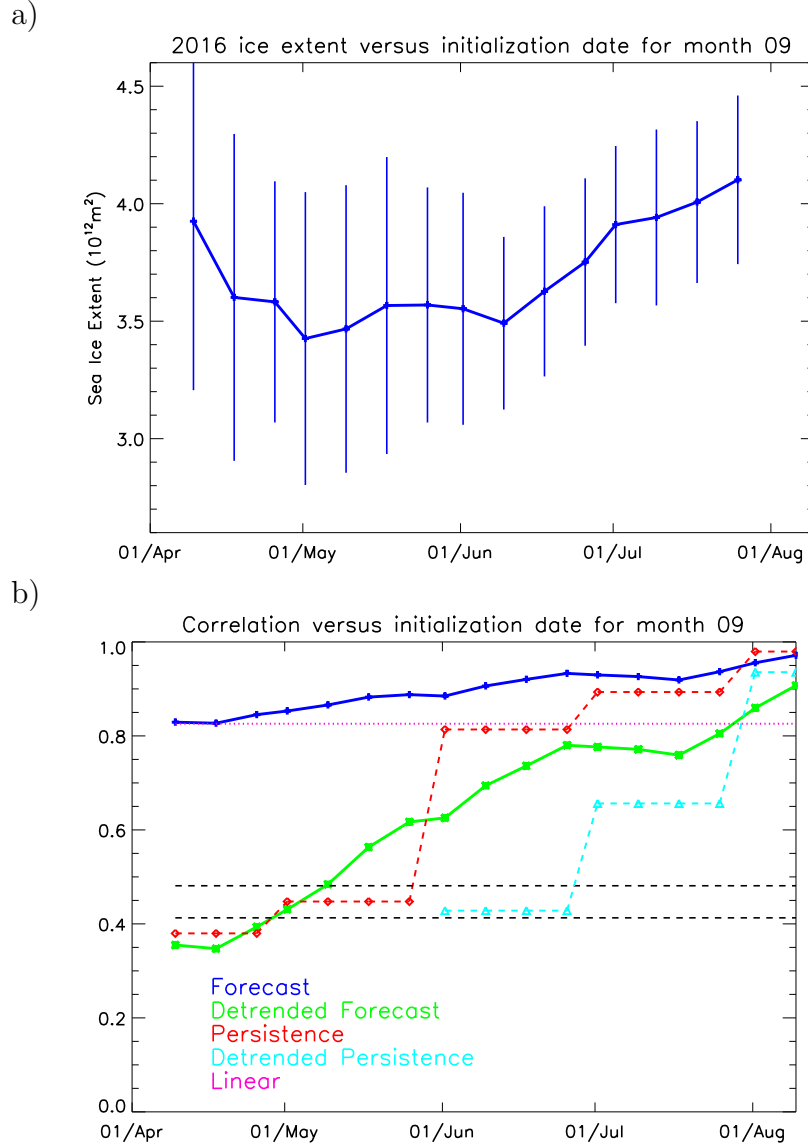


Figure 3: a) The forecast September 2016 sea ice extent, including uncertainty, from forecasts starting from various dates in April through July. b) Correlation skill over the 1993-2015 hindcast for our September forecasts from these same dates. The blue line corresponds to the anomaly correlation for the full anomalies, while the green line corresponds to the correlation skill for detrended anomalies. The red (cyan) dashed line is the skill of persisting the observed (and detrended) anomalies forward as the September forecast. The horizontal magenta dotted line is the correlation skill of forecasting the observed September trend. Horizontal black lines denote the threshold for the 90% and 95% confidence level that the correlations are significantly different from zero.

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