Met Office
September 2018 Arctic Sea Ice Outlook
June Report (Using May Data)

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1. **Projection Type:** Model based estimate.

2. **September Monthly Averaged Extent Projections:**

   a Pan Arctic Projection: $(\mathbf{4.9 \pm 0.6}) \times \mathbf{10^6}$ $\mathrm{km}^{\mathbf{2}}$

3. **Group:** Met Office. **Contributors:** K.A. Peterson (primary), C. MacLachlan, E.W. Blockley, A.A. Scaife, Met Office, FitzRoy Road, Exeter, UK.

5. **Executive Summary:** Using the Met Office GloSea5 seasonal forecast systems we are issuing a model based mean Northern Hemisphere September sea ice extent outlook of $(\mathbf{4.9 \pm 0.6}) \times \mathbf{10^6}$ $\mathrm{km}^{\mathbf{2}}$. This has been assembled using startdates between 15 May and 4 June to generate an ensemble of 42 members.

6. **Method:** Ensemble coupled model seasonal forecast from the GloSea5 seasonal prediction system [MacLachlan et al., 2015], 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 May and 4 June (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 observations from the previous day. Special Sensor Microwave Imager Sensor (SSMIS) ice concentration observations from EUMETSAF 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.

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7. **Sea Ice Concentration Initialization Dataset:** Met Office Forecast Ocean Assimilation Model (FOAM) ocean and sea ice analysis [Blockley et al., 2014] using the SSMIS brightness temperature observations of sea ice concentration product of the EUMETSAT Ocean and Sea Ice Satellite Application Facility (OSI-SAF, www.osi-saf.org) [OSI-SAF]. The average May sea ice concentration field is shown in Figure 4.

8. **Sea Ice Thickness Initialization Dataset:** Met Office FOAM ocean and sea ice analysis [Blockley et al., 2014] as evolved by model dynamics and thermodynamics. No assimilation of thickness observations is performed. The average May sea ice mean grid cell thickness field in our analysis is shown in Figure 5.

9. **Model:** HadGEM3 [Hewitt et al., 2011], Global Coupled Model 2.0 [Williams et al., 2015] in use within the GloSea5 seasonal prediction system [MacLachlan et al., 2015].

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

   - **Initialization:** Met Office FOAM ocean and sea ice analysis [Blockley et al., 2014] using the SSMIS sea ice concentration observation product from EUMETSAT OSI-SAF.

   Ocean Component: NEMO [Madec, 2008], Global Ocean 5.0 [Megann et al., 2014].

   - **Initialization:** Met Office FOAM ocean and sea ice analysis [Blockley et al., 2014] assimilating in-situ and satellite observations of SST [GHRSST], satellite observations of sea level anomaly [AVISO/CLS] and temperature and salinity sub-surface profiles [Good et al., 2013].

   Atmospheric Component: Met Office Unified Model (UM) [Brown et al., 2012], Global Atmosphere 6.0 [Walters et al., 2017].

   - **Initialization:** Met Office operational numerical weather prediction (NWP) 4D-Var data assimilation system [Rawlins et al., 2007].

   Land Component: Joint UK Land Environment Simulator (JULES) [Best et al., 2011], Global Land 6.0 [Walters et al., 2017].

   - **Initialization:** Soil temperature and snow over land from atmospheric 4D-Var analysis [Rawlins et al., 2007]. Soil moisture is model climatology.

   Coupler: OASIS3 [Valcke, 2006]

10. **Projection Uncertainty:**

    (a) **Uncertainty Estimate:** $\pm 0.6 \times 10^6$ km^2 representing two standard deviations of the (42 member) ensemble spread around the ensemble mean.

    (b) **Basis for Uncertainty:** Validation of the forecast was done using our 1993-2015 historical re-forecast (hindcast) using startdates of 17 & 25 May and 01 June (7 members each). The root mean square error of the hindcast with observations is

0.4×10^6 km^2 after removing a 0.5×10^6 km^2 bias for the hindcast to over forecast the extent. This is consistent with the quoted error. Over the hindcast period, the correlation between the GloSea5 forecast and NSIDC sea ice extent observations was 0.89 which reduces to a correlation of 0.60 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 2018. 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 May sea ice anomaly as a predictor of the September anomaly. Furthermore, the value of the full correlation between the two time series suggests that our forecast is historically a better predictor than simply predicting the trend.

(c) **Post Processing:** Over the 1993-2015 hindcast, there is a forecast bias of 0.5×10^6 km^2 over the observed sea ice extent climatology. Due to uncertainties in applying this bias correction to forecast biases, no bias correction has been applied to the forecast.

11. **Regional Alaskan Outlook:** Total forecast sea ice extent in the Alaskan Region (Beaufort, Bering and Chukchi Seas) for September 2018 is 0.58×10^6 km^2. The total ocean area represented by this region of ocean in our system is 3.56 million square kilometers. Over the 1993-2015 hindcast, the model climatology overpredicts the ice extent in this region by 0.31×10^6 km^2. Due to uncertainties in the application of this to the forecast, the forecast has been reduce by half this value (0.15×10^6 km^2) from the model forecast value of 0.73×10^6 km^2. Furthermore, over the 1993-2015 hindcast, the correlation between the observed value and the modelled value is 0.86 reducing to 0.73 if the linear trend is removed. Figure 3 shows the time series of September sea ice predictions in the hindcast, along with the forecast for 2018 for this region.

2018 forecast with historical (1993-2015) hindcast

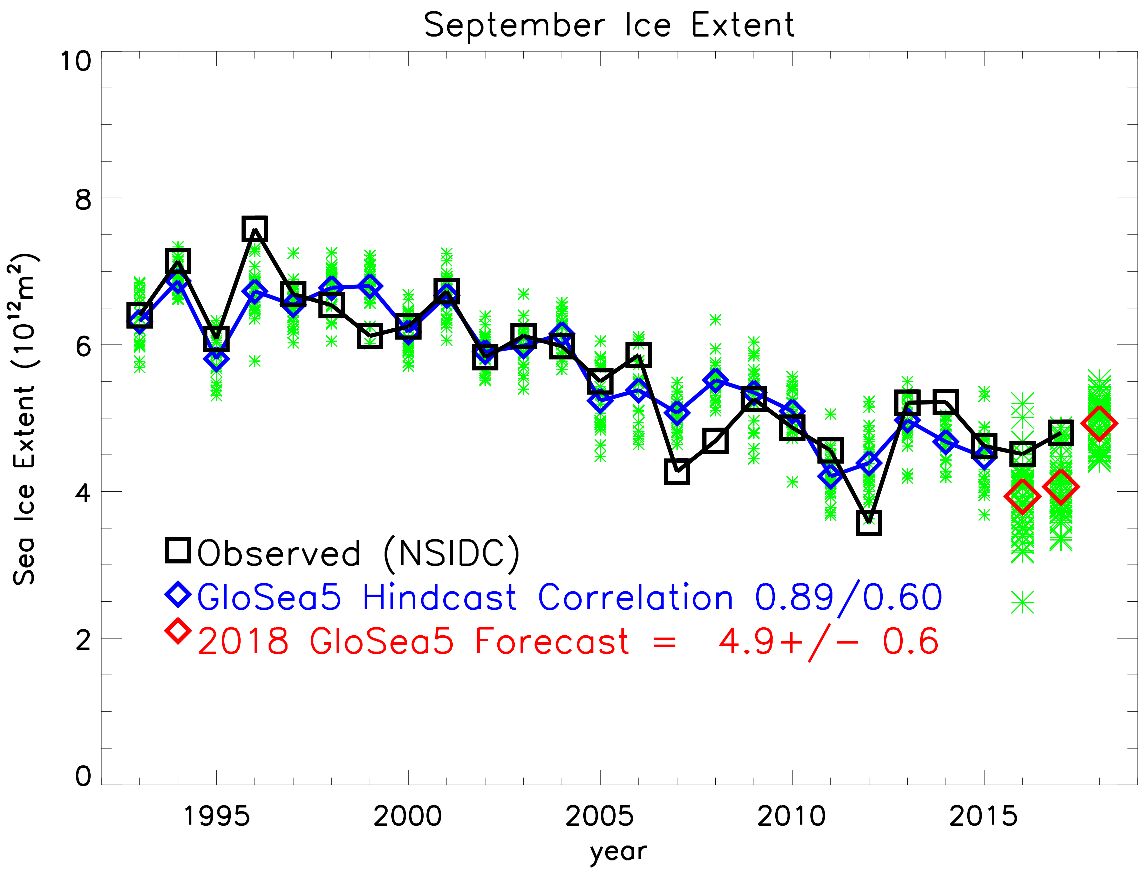

Figure 1: Time series of ensemble mean September sea ice extent from GloSea5 (blue and red ⋄) and observations (NSIDC; black □). Individual ensemble member sea ice extents are denoted by ∗ (green).

September 2018 Probability of Ice

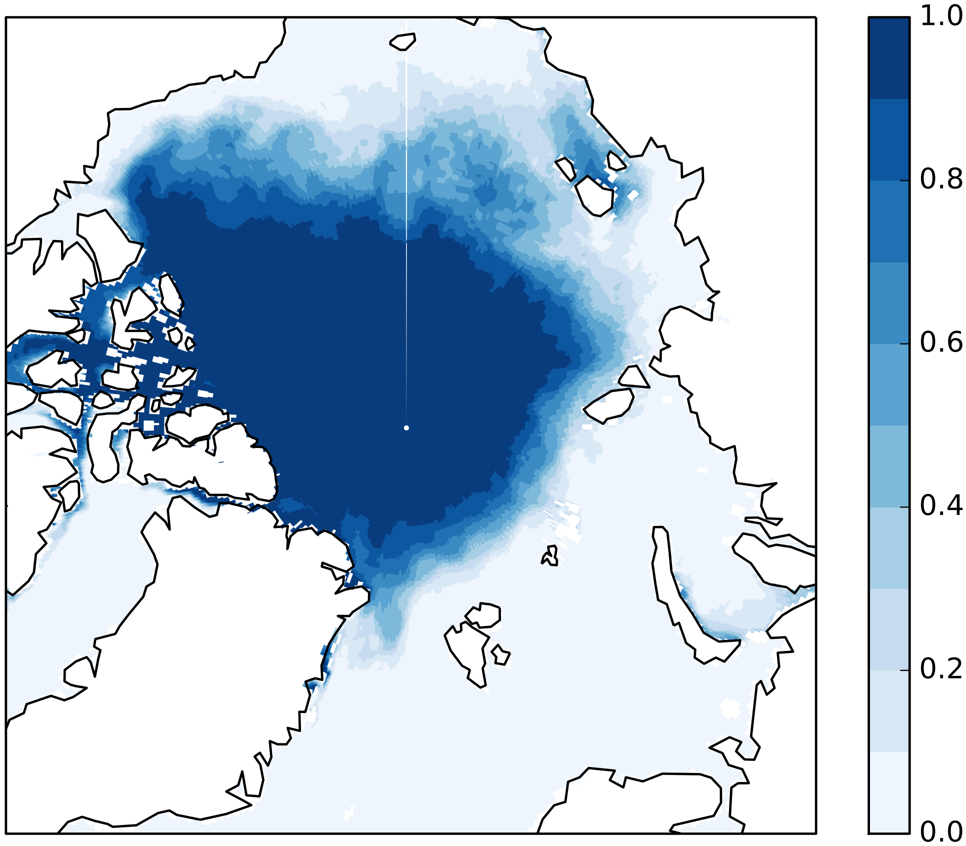

Figure 2: September 2018 monthly mean probability of ice (fraction of ensemble members with ice concentration > 0.15). Note: The numerical value of our sea ice forecast, $4.9 \times 10^{12}\mathrm{m}^2$, will be the area integral of the ice probabilities represented by this figure.

Alaskan Regional Outlook

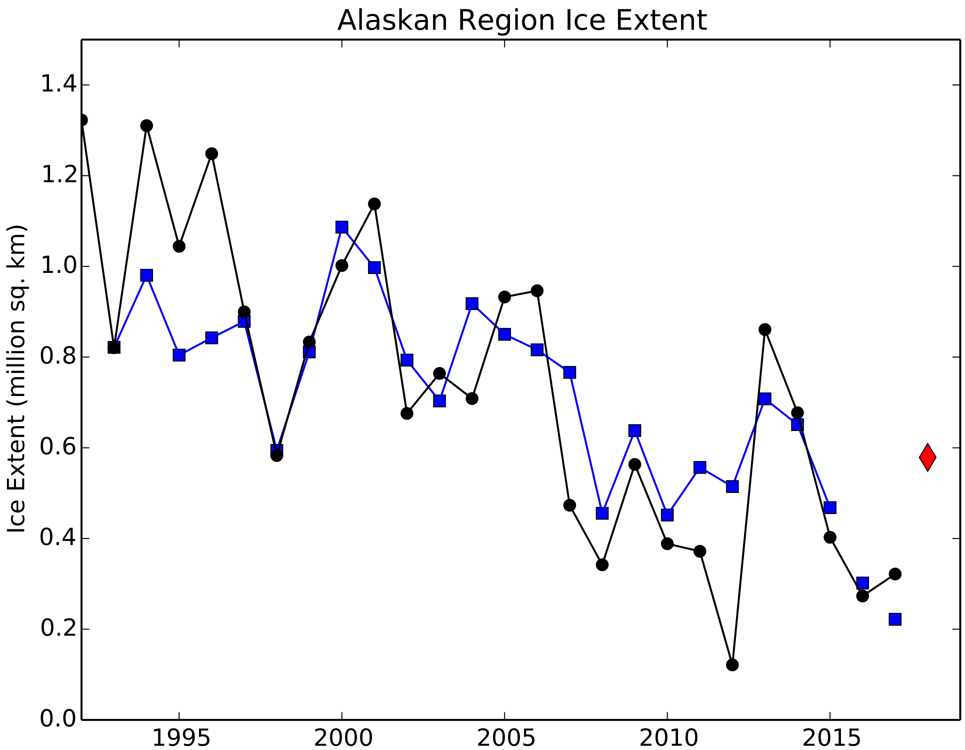

Figure 3: Time series of Alaskan Regional ice extent. Black circles are observations as determined by the NSIDC regional ice extent tables, while blue circles are the Alaskan region ice extent over the 1993-2015 hindcast period. The red diamond is the 2018 regional forecast of $0.58 \times 10^{12} \mathrm{m}^2$. The correlation between observations and forecast values during the hindcast period is 0.86 reducing to 0.73 if the linear trend is removed.

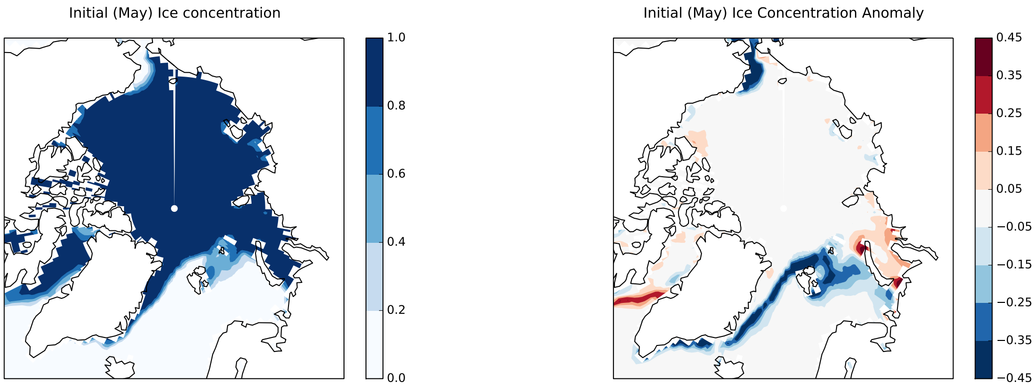

Figure 4: a) Initial sea ice concentration from the FOAM analysis for May. b) Anomalies in May sea ice concentration relative to the 1993-2015 hindcast initial conditions.

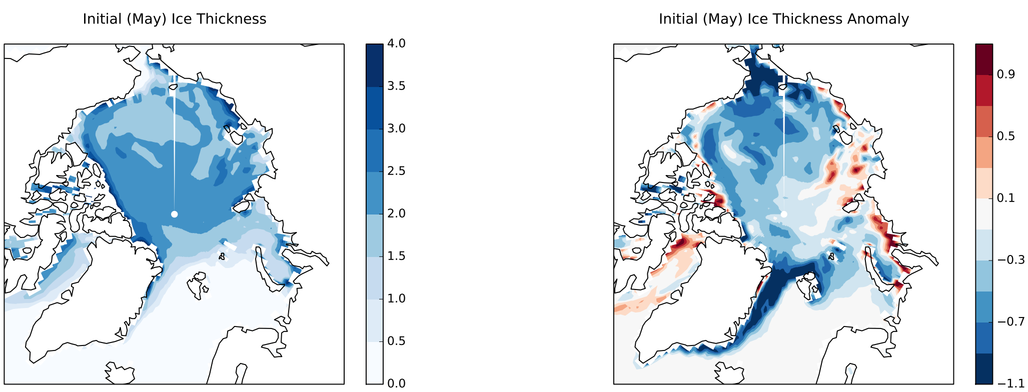

Figure 5: a) Initial sea ice mean grid cell thickness from the FOAM analysis averaged for May. b) Anomalies in sea ice thickness relative to the 1993-2015 hindcast initial conditions.

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