Met Office
September 2014 Pan-Arctic Sea Ice Outlook
June Report (Using May Data)

K. Andrew Peterson*, Ann Keen, Alberto Arribas, Anca Brookshaw, Helene Hewitt, and Adam Scaife

Met Office Hadley Centre, FitzRoy Road, Exeter, EX1 3PB, UK

July 14, 2014

Group: Met Office

Projection Type: Model based estimate.

September Monthly Averaged Extent Projection: $(\mathbf{4.1 \pm 1.0}) \times \mathbf{10^6}$ $\mathbf{km^2}$

Model: HadGEM3

Ice Component: CICE [Hunke and Dukowicz, 2002, Hunke and Lipscomb, 2010], Global Sea Ice 3.0

Ocean Component: NEMO [Madec, 2008], Global Ocean 3.0

Atmospheric Component: Met Office Unified Model (UM) [Brown et al., 2012, Walters et al., 2011], Global Atmosphere 3.0

Land Component: JULES [Best et al., 2011], Global Land 3.0

Coupler: OASIS3 [Valcke, 2006]

Method: Ensemble coupled model seasonal forecast from the GloSea5 seasonal prediction system [MacLachlan et al., 2014], using 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., 2014] and a atmospheric analysis (MO-NWP/4DVar) [Rawlins et al., 2007] using observations from the previous day. Special Sensor Microwave Imager (SSM/I) ice concentration observations from ESA OSI-SAF [OSI-SAF]

*Electronic address: drew.peterson@metoffice.gov.uk; Corresponding author

was 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 has been bias corrected downward 0.1×10^6 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., 2014].

Projection Uncertainty: $\pm 1.0 \times 10^6$ 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 $(\mathbf{4.1 \pm 1.0}) \times \mathbf{10^6}$ km$^\mathbf{2}$. This has been generated using startdates between 30 March and 19 April to generate an ensemble of 42 members.

Caveat: The ensemble mean forecast is but one of many realizations of possible September sea ice extent produced by the seasonal forecast system. Whilst the system is devised to accurately account for the range of possible outcomes, as expressed by our ensemble spread and error estimate, there is still a possibility of the actual outcome falling outside this estimate.

Additional Information: Validation and calibration of the forecast was done using a 1996-2009 historical re-forecast (hindcast) using startdates of 1/9/17 of April (3 members each). Over the hindcast period, the correlation between the GloSea5 forecast and NSIDC sea ice extent observations was 0.86 which reduces to a correlation of 0.33 if the trend is removed from the time series. See the accompanying figure showing the time series of September sea ice predictions in the hindcast, along with forecasts for 2013 and 2014. 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 than a simple trend analysis. The 1996-2009 climatology generated by the hindcast was 0.1×10^6 km^2 higher then the 1996-2009 observed climatology. Thus we have adjusted both the hindcast and forecast downward by this amount to account for the model bias. After bias correcting, the hindcast has a root mean square error (rmse) of 0.5×10^6 km^2 comparable to the quoted error.

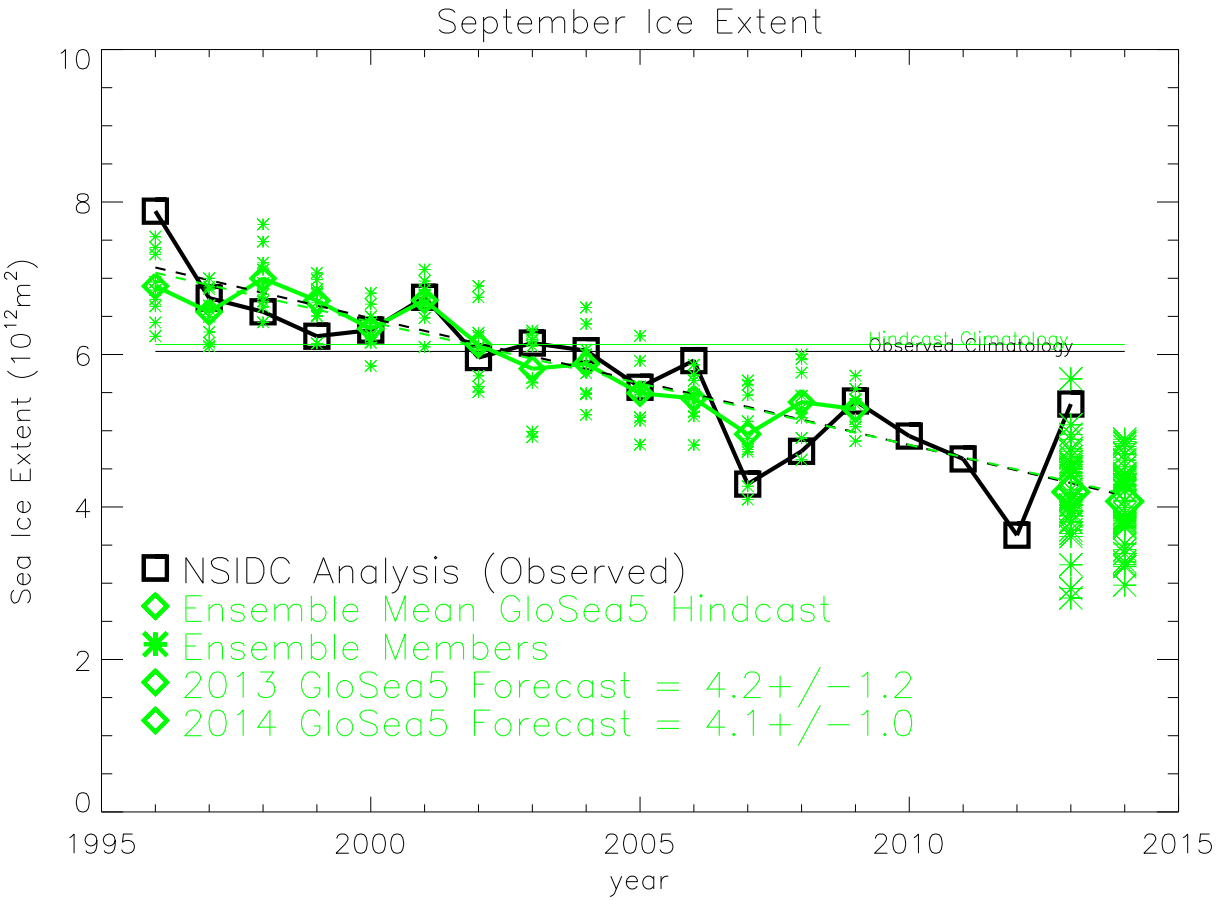

Figure 1: Time series of ensemble mean September sea ice extent from GloSea5 (green $\diamond$) and NSIDC observations (black $\square$). Individual ensemble member sea ice extents are denoted by $*$ (green). The green and black horizontal lines denote the hindcast and observed (1996-2009) climatology respectively. The forecast and hindcast values have all been adjusted downward by the amount between the two lines ($0.1 \times 10^{12}\mathrm{m}^2$). The green and black dashed lines are the forecast and observed trends in the timeseries. Forecast trend is calculated using hindcast values, plus 2013 and 2014 forecast values. The observed trend is calculated using 1996-2013 observations. Note: The 2013 forecast value was calculated using forecasts performed in 2013 with an almost identical system that nonetheless had a higher hindcast climatology. It has been adjusted downward by the 1996-2009 hindcast climatology generated by that system ($0.8 \times 10^{12}\mathrm{m}^2$).

References

M. J. Best, M. Pryor, D. B. Clark, G. G. Rooney, R .L. H. Essery, C. B. Ménard, J. M. Edwards, M. A. Hendry, A. Porson, N. Gedney, L. M. Mercado, S. Sitch, E. Blyth, O. Boucher, P. M. Cox, C. S. B. Grimmond, and R. J. Harding. The Joint UK Land Environment Simulator (JULES), model description part 1: Energy and water fluxes. *Geoscientific Model Development*, 4(3):677–699, 2011. doi: 10.5194/gmd-4-677-2011. URL `http://www.geosci-model-dev.net/4/677/2011/`.

E. W. Blockley, M. J. Martin, A. J. McLaren, A. G. Ryan, J. Waters, D. J. Lea, I. Mirouze, K. A. Peterson, A. Sellar, and D. Storkey. Recent development of the met office operational ocean forecasting system: an overview and assessment of the new global foam forecasts. *Geoscientific Model Development Discussions*, 6(4):6219–6278, 2014. doi: 10.5194/gmdd-6-6219-2013. URL `http://www.geosci-model-dev-discuss.net/6/6219/2013/`.

Andrew Brown, Sean Milton, Mike Cullen, Brian Golding, John Mitchell, and Ann Shelly. Unified modeling and prediction of weather and climate: a 25-year journey. *Bull. Amer. Meteor. Soc.*, 93:18651877, 2012. doi: 10.1175/BAMS-D-12-00018.1. URL `http://dx.doi.org/10.1175/BAMS-D-12-00018.1`.

H. T. Hewitt, D. Copsey, I. D. Culverwell, C. M. Harris, R. S. R. Hill, A. B. Keen, A. J. McLaren, and E. C. Hunke. Design and implementation of the infrastructure of HadGEM3: the next-generation Met Office climate modelling system. *Geoscientific Model Development*, 4(2):223–253, 2011. doi: 10.5194/gmd-4-223-2011. URL `http://www.geosci-model-dev.net/4/223/2011/`.

E. C. Hunke and J.K. Dukowicz. The elastic-viscous-plastic sea ice dynamics model in general orthogonal curvilinear coordi-nates on a sphere incorporation of metric terms. *Mon. Weather Rev.*, 130:1848 – 1865, 2002.

E. C. Hunke and W. H. Lipscomb. CICE: The Los Alamos sea ice model documentation and software users manual, version 4.1. Technical Report LA-CC-06-012, Los Alamos National Laboratory, 2010.

C. MacLachlan, A. Arribas, K.A. Peterson, A. Maidens, D. Fereday, A.A. Scaife, M. Gordon, M. Vellinga, A. Williams, R. E. Comer, J. Camp, P. Xavier, and G. Madec. Global seasonal forecast system version 5 (GloSea5): a high resolution seasonal forecast system. *Quarterly Journal of the Royal Meteorological Society*, 2014. ISSN 1477-870X. doi: 10.1002/qj.2396. URL `http://dx.doi.org/10.1002/qj.2396`.

Gurvan Madec. NEMO ocean engine. Technical Report Note du Pole de modélisation No 27, ISSN No 1288-1619, Institut Pierre-Simon Laplace (IPSL), France, 2008.

OSI-SAF. EUMETSAT Ocean and Sea Ice Satelitte Application Facility. Global sea ice concentration reprocessing dataset 1978-2009 (v1.1, 2011). online, 2011. Available from http://osisaf.met.no.

K. Andrew Peterson, A. Arribas, H.T. Hewitt, A.B. Keen, D.J. Lea, and A.J. McLaren. Assessing the forecast skill of Arctic sea ice extent in the GloSea4 seasonal prediction system. *Climate Dynamics in Press*, 2014.

F. Rawlins, S. P. Ballard, K. J. Bovis, A. M. Clayton, D. Li, G. W. Inverarity, A. C. Lorenc, and T. J. Payne. The met office global four-dimensional variational data assimilation scheme. *Quarterly Journal of the Royal Meteorological Society*, 133(623):347–362, 2007. ISSN 1477-870X. doi: 10.1002/qj.32. URL `http://dx.doi.org/10.1002/qj.32`.

S. Valcke. OASIS3 User Guide (prism 2-5). Technical Report PRISM Support Initiative No. 3, 2006.

D. N. Walters, M. J. Best, A. C. Bushell, D. Copsey, J. M. Edwards, P. D. Falloon, C. M. Harris, A. P. Lock, J. C. Manners, C. J. Morcrette, M. J. Roberts, R. A. Stratton, S. Webster, J. M. Wilkinson, M. R. Willett, I. A. Boutle, P. D. Earnshaw, P. G. Hill, C. MacLachlan, G. M. Martin, W. Moufouma-Okia, M. D. Palmer, J. C. Petch, G. G. Rooney, A. A. Scaife, and K. D. Williams. The Met Office Unified Model Global Atmosphere 3.0/3.1 and JULES global land 3.0/3.1 configurations. *Geoscientific Model Development*, 4(4):919–941, 2011. doi: 10.5194/gmd-4-919-2011. URL `http://www.geosci-model-dev.net/4/919/2011/`.