SEA ICE OUTLOOK
2016 Report

Core Requirements for Pan-Arctic Contributions:

1. *Name of Contributor or name of Contributing Organization and associated contributors as you would like your contribution to be labeled in the report (e.g., Smith, or ARCUS (Wiggins et al.)).

   Naval Research Laboratory (NRL), Oceanography Division. Label as NRL_ocn-ice.

1b. (Optional but helpful for us): Primary contact if other than lead author; name and organization for all contributors; total number of people who may have contributed to your Outlook, even if not included on the author list.

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*Note, the NRL ocean-ice modeling group includes many more scientists. This author list only represents the main contributors to this report.

2. * Contributions submitted by a person or group not affiliated with a research organization, please self-identify here:
   _____ Yes, this contribution is from "Citizen Scientists."

3. * Do you want your contribution to be included in subsequent reports in the 2016 season?
   ____X___ Yes, use this contribution for all of the 2016 SIO reports (this contribution will be superseded if you submit a later one).
   _____ No, I/we plan to submit separate contributions for subsequent reports.
   _____ No, I only want to participate this time.

4. *"Executive summary" of your Outlook contribution: in a few sentences (using 300 words or less) describe how and why your contribution was formulated. To the extent possible, use non-technical language.

   The Global Ocean Forecast System (GOFS) 3.1 was run in forecast mode without data assimilation, initialized with July 1, 2016 ice/ocean analyses, for ten simulations using National Centers for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (CFSR) atmospheric forcing fields from 2005-2014. The mean ice extent in September, averaged across all ensemble members is our projected ice extent. The GOFS 3.1 outlook for the 2016 September minimum ice extent is 5.2 Mkm^2 with a range of 4.3 – 6.1 Mkm^2.

5. *Type of Outlook method:
   _X_dynamic model ___statistical ___heuristic ____mixed or other (specify)

6. *Dataset of initial Sea Ice Concentration (SIC) used (include name and date; e.g., "NASA Team, May 2016"):

   The ensemble forecasts were initialized using the July 1, 2016 GOFS 3.1 restart file which assimilated SSMIS and AMSR2 ice concentration products.

7. Dataset of initial Sea Ice Thickness (SIT) used (include name and date):

   The ensemble forecasts were initialized using the July 1, 2016 GOFS 3.1 restart file which does not assimilate ice thickness products.

8. If you use a dynamical model, please specify:

   a) Model name: Global Ocean Forecast System (GOFS 3.1)

   b) Information about components, for example:

Component	Name	Initialization (e.g., describe Data Assimilation)
Atmosphere	NCEP CFSR and CFSv2	prescribed 2005-2014
Ocean	HYCOM	DA – NCODA* system
Ice	CICE	DA – NCODA* assimilating SIC only

*Navy Coupled Ocean Data Assimilation

   c) Number of ensemble members and how they are generated:

   The GOFS 3.1 seasonal projection was made using an ensemble of forecasts. Ten model forecasts were made, using CFSR/CFSv2 forcing from 2005-2014. Each model forecast was initialized with July 1, 2016 GOFS 3.1 ice (and ocean) conditions, and run forward for 3 months using CFSR/CFSv2 forcing for each specific year. The ensemble of ten members gives an indication of how sea ice can respond to variable atmospheric conditions during summer.

   d) For models lacking an atmosphere or ocean component, please describe the forcing:

   GOFS 3.1 uses prescribed atmospheric fields from CFSR and CFSv2 for the years 2005-2014.

9. *Prediction of September pan-Arctic extent as monthly average in million square kilometers. (To be consistent with the validating sea ice extent index from NSIDC, if possible, please first compute the average sea ice concentration for the month and then compute the extent as the sum of cell areas > 15%.)

   The sea ice extent of each ensemble member was calculated using all grid cells with 15% or greater ice concentration in the monthly mean. The GOFS 3.1 predicted 2016 September mean sea ice extent is the average of the ten members, 5.2 Mkm^2 with a range of 4.3 – 6.1 Mkm^2.

10. Prediction of the week that the minimum daily extent will occur (expressed in date format for the first day of week, taking Sunday as the start of the week (e.g., week of 4 September).

The GOFS 3.1 predicted minimum daily extent will occur the week of 4 Sept 2016 (minimum on 6 Sept).

11. *Short explanation of Outlook method (using 300 words or less). In addition, we encourage you to submit a more detailed Outlook, including discussions of uncertainties/probabilities, including any relevant figures, imagery, and references.

The Global Ocean Forecast System (GOFS) 3.1 is a global coupled ice-ocean system (Metzger et al., 2015) that assimilates passive microwave ice concentration daily and is run with a horizontal resolution of approximately 3.5 km near the North Pole. It was developed by the Oceanography Division of the Naval Research Laboratory to produce 7 day forecasts of the global ocean including the Arctic and Antarctic sea ice states. This system was transitioned to the Naval Oceanographic Office and is currently undergoing operational testing. The system is configured and validated for its capability in producing an accurate 7 day sea ice forecast. The results presented here are preliminary and additional work is required in validating the capability of this model for seasonal projections.

The GOFS 3.1 ocean component is the HYbrid Coordinate Ocean Model (HYCOM) (Metzger et al. 2010, 2014), and is two-way coupled to the Los Alamos National Laboratory Community Ice CodE (CICE) (Hunke and Lipscomb 2008) via the Earth System Modeling Framework (ESMF). The ocean and ice models are run in an assimilative cycle with the Navy Coupled Ocean Data Assimilation (NCODA) system (Cummings and Smedstad, 2013). The system is run once per day, assimilating both SSMIS and AMSR2 ice concentration into CICE to provide an initial condition for a 7 day forecast. Atmospheric forcing used in the real-time system is from the Fleet Numerical Meteorology and Oceanography Center Navy Global Environmental Model, but for these September forecasts, NCEP CFSR/CFSv2 (Saha et al., 2010) forcing is used.

The GOFS 3.1 seasonal projection was made using an ensemble of forecasts. Ten model forecasts were made, using CFSR/CFSv2 forcing from 2005-2014. Each model forecast was initialized with July 1, 2016 GOFS 3.1 ice (and ocean) conditions (Fig. 1), and run forward for 3 months using CFSR forcing for each specific year. The ensemble of ten members gives an indication of how sea ice can respond to variable atmospheric conditions during summer.

12. If available from your method for pan-Arctic extent prediction, please provide:

a) Uncertainty/probability estimate such as median, ranges, and/or standard deviations (specify what you are providing).

The GOFS 3.1 predicted 2016 September mean sea ice extent is the average of the ten members, 5.2 Mkm^2 with a range of 4.3 – 6.1 Mkm^2.

b) Brief explanation/assessment of basis for the uncertainty estimate (1-2 sentences).

The GOFS 3.1 uncertainty range for the 2016 September mean sea ice extent is the minimum and maximum September mean sea ice extent from the ten members, 4.3 Mkm^2, which occurred in 2007 and 6.1 Mkm^2 which occurred in 2006.

c) Brief description of any post processing you have done (1-2 sentences).

After all the ensembles completed, the sea ice extent (SIE) of each ensemble member was calculated using all grid cells with 15% or greater ice concentration in the ensemble's monthly mean.

For Sea Ice Probability (SIP): We computed SIP as requested: converted Sept mean SIC into SIE for each ensemble member. Then averaged the ensemble across the Sept mean SIE. Hence, SIP is the probability of sea ice cover in the ensemble and ranges from 0 to 100%.

For Ice-Free Day (IFD): We computed the first ice-free day when SIC falls below 15% for all points where there is at least 15% SIC on the day we initialized the model. If the point is ice free (SIC<15%) at initialization, IFD will be ordinal day 183 (July 1). If the point is always covered in ice (SIC>=15%), the IFD will be ordinal day 274 (Sept 30). We then computed the average and standard deviation of IFD across the ensemble.

d) Raw (and/or post processed) forecasts for this year and retrospective forecasts in an excel spreadsheet with one year on each row and ensemble member number on columns (specifying whether raw or post processed).

Sea Ice Extent calculated from Sept monthly mean
2005 – 5.4 Mkm^2
2006 – 6.1 Mkm^2
2007 – 4.3 Mkm^2
2008 – 5.3 Mkm^2
2009 – 5.5 Mkm^2
2010 – 5.2 Mkm^2
2011 – 5.0 Mkm^2
2012 – 5.0 Mkm^2
2013 – 5.6 Mkm^2
2014 – 5.0 Mkm^2
Mean – 5.2 Mkm^2

Submitting an Alaskan Regional Outlook (Optional, yet encouraged):

9. *Prediction of September Alaskan Regional extent as monthly average in million square kilometers. (To be consistent with the validating sea ice extent index from NSIDC, if possible, please first compute the average sea ice concentration for the month and then compute the extent as the sum of cell areas > 15%.)

The sea ice extent of each ensemble member was calculated using all grid cells with 15% or greater ice concentration in the monthly mean. The GOFS 3.1 predicted Alaskan Regional 2016 September mean sea ice extent is the average of the ten members, 0.6 Mkm^2 with a range of 0.4 – 0.8 Mkm^2.

10. Prediction of the week that the minimum daily extent will occur (expressed in date format for the first day of week, taking Sunday as the start of the week (e.g., week of 4 September).

The GOFS 3.1 predicted minimum daily extent will occur the week of 18 September 2016 (minimum on 19 September).

11. *Short explanation of Outlook method (using 300 words or less). In addition, we encourage you to submit a more detailed Outlook, including discussions of uncertainties/probabilities, including any relevant figures, imagery, and references.

The methodology used for the Alaskan regional outlook was the same as the full Arctic prediction.

12. If available from your method for Alaskan Regional extent prediction, please provide:

a) Uncertainty/probability estimate such as median, ranges, and/or standard deviations (specify what you are providing).

The GOFS 3.1 predicted 2016 September mean sea ice extent is the average of the ten members, 0.6 Mkm^2 with a range of 0.4 – 0.8 Mkm^2.

b) Brief explanation/assessment of basis for the uncertainty estimate (1-2 sentences).

The GOFS 3.1 uncertainty range for the 2016 September mean sea ice extent is the minimum and maximum September mean sea ice extent from the ten members, 0.4, which occurred in 2007 and 0.8 Mkm^2 which occurred in 2013.

c) Brief description of any post processing you have done (1-2 sentences).

After all the ensembles completed, the sea ice extent (SIE) of each ensemble member was calculated using all grid cells with 15% or greater ice concentration in the ensemble's monthly mean.

d) Raw (and/or post processed) forecasts for this year and retrospective forecasts in an excel spreadsheet with one year on each row and ensemble member number on columns (specifying whether raw or post processed).

Alaskan Regional Sea Ice Extent calculated from Sept monthly mean
2005 – 0.7 Mkm^2
2006 – 0.8 Mkm^2
2007 – 0.4 Mkm^2
2008 – 0.6 Mkm^2
2009 – 0.7 Mkm^2

2010 – 0.5 Mkm^2
2011 – 0.6 Mkm^2
2012 – 0.5 Mkm^2
2013 – 0.8 Mkm^2
2014 – 0.7 Mkm^2
Mean – 0.6 Mkm^2

13) Tell us how you defined the region: either say NSIDC definition, or if you must use your own definition, describe it.

The NSIDC definition was used.

14) Tell us the maximum possible ice extent if every ocean cell in your region were ice covered. For example, if your model uses exactly the same grid as the satellite data, the area would be 4.00x10^6 km^2. The maximum possible extent is probably much larger than your actual Alaskan Regional Outlook. Be sure to exclude land and islands.

The maximum possible ice extent of every ocean cell in the region is 3.98 Mkm2. We simplified the mask to a 0/1 mask with 1s for the Bering, Chukchi and Beaufort regions, and applied it to the GOFS 3.1 grid via interpolation.

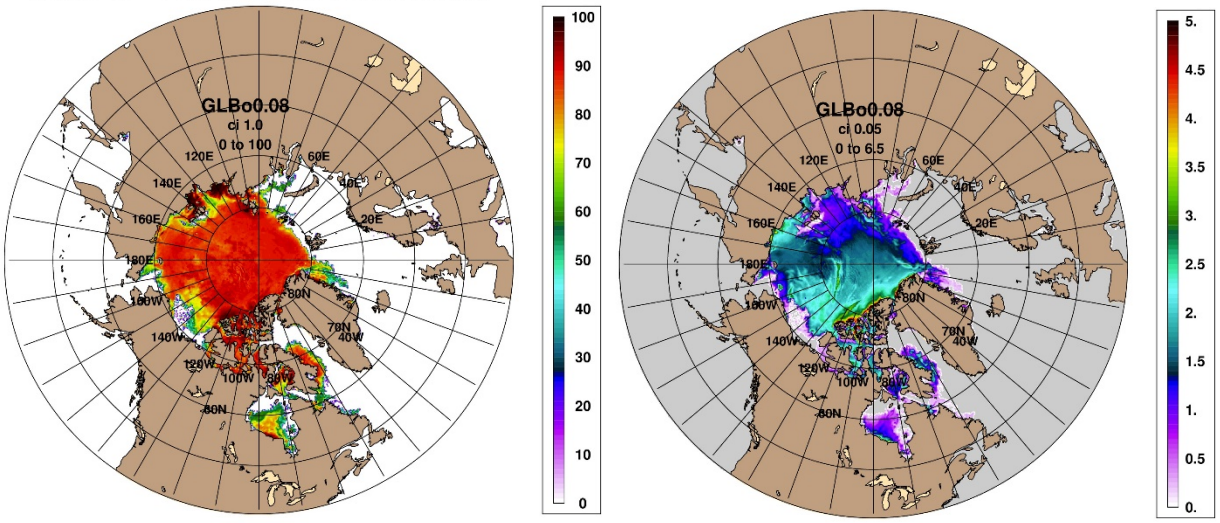

Figure 1: Sea ice concentration (%) and thickness (m) from GOFS 3.1 valid July 1, 2016. These are the initial ice conditions for each ensemble member.

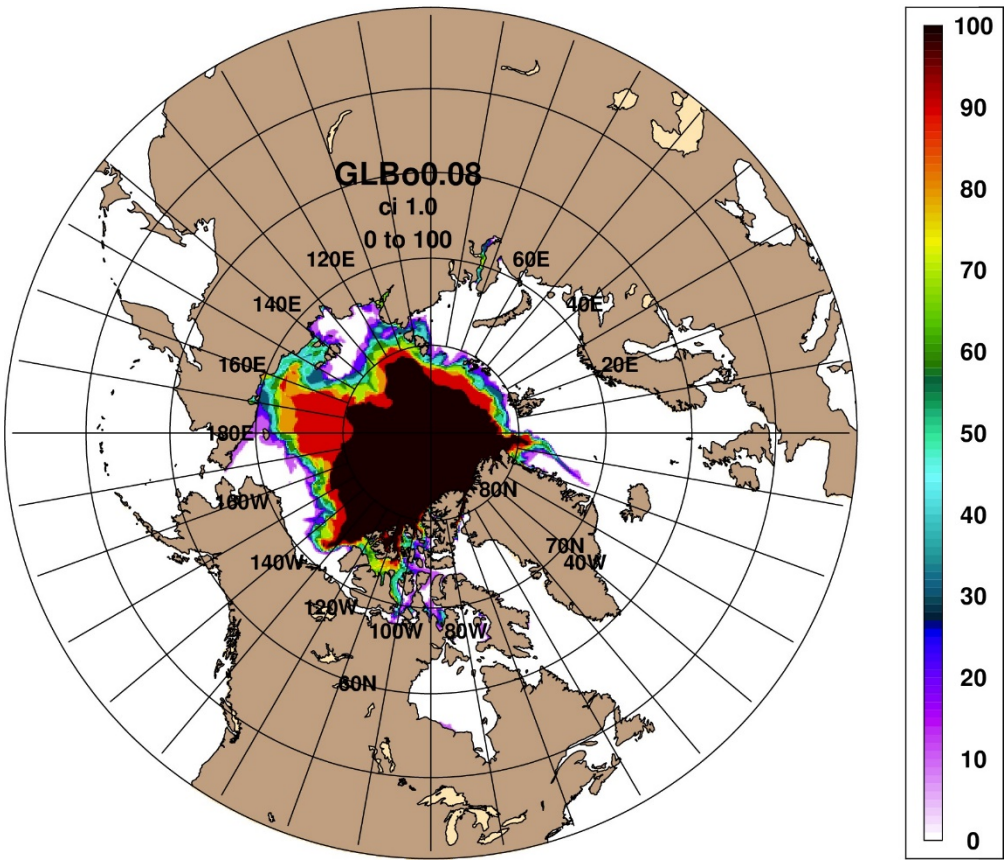

Figure 2: Sea Ice Probability (%) of the projected GOFS 3.1 September 2016 mean ice extent.

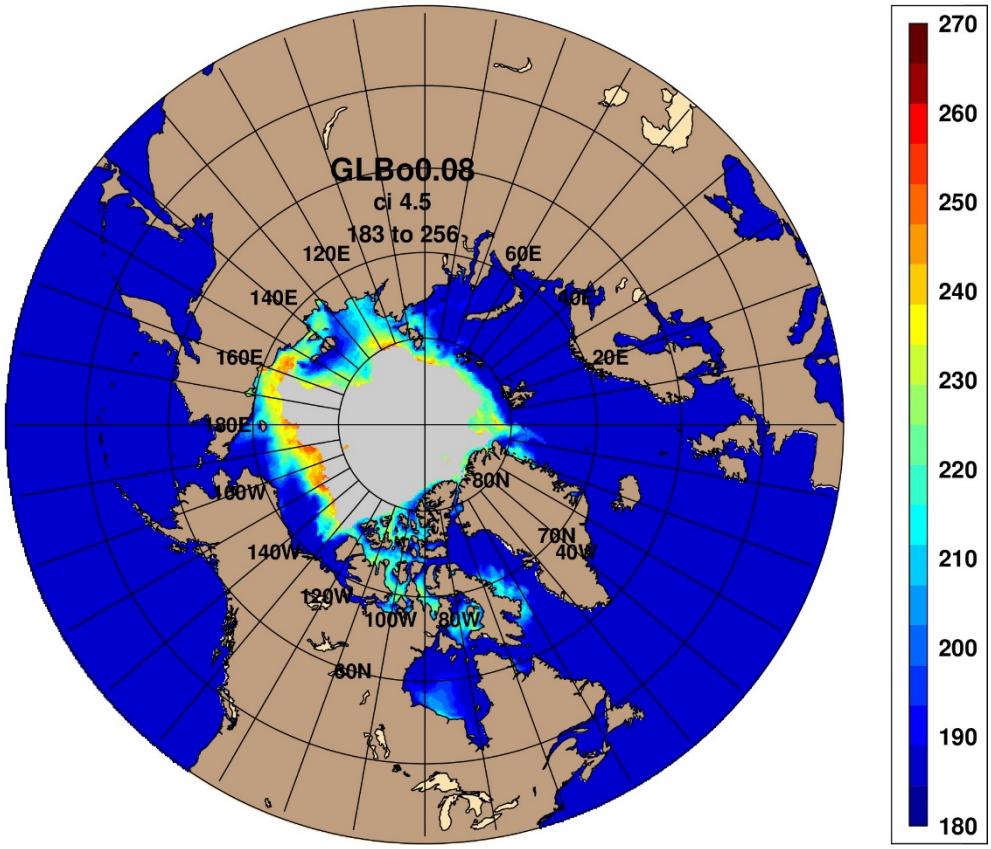

Figure 3: First ice-free ordinal date, with grey indicating a data void (i.e., no ice free days as the most likely outcome) of the projected GOFS 3.1 September 2016 mean ice extent.

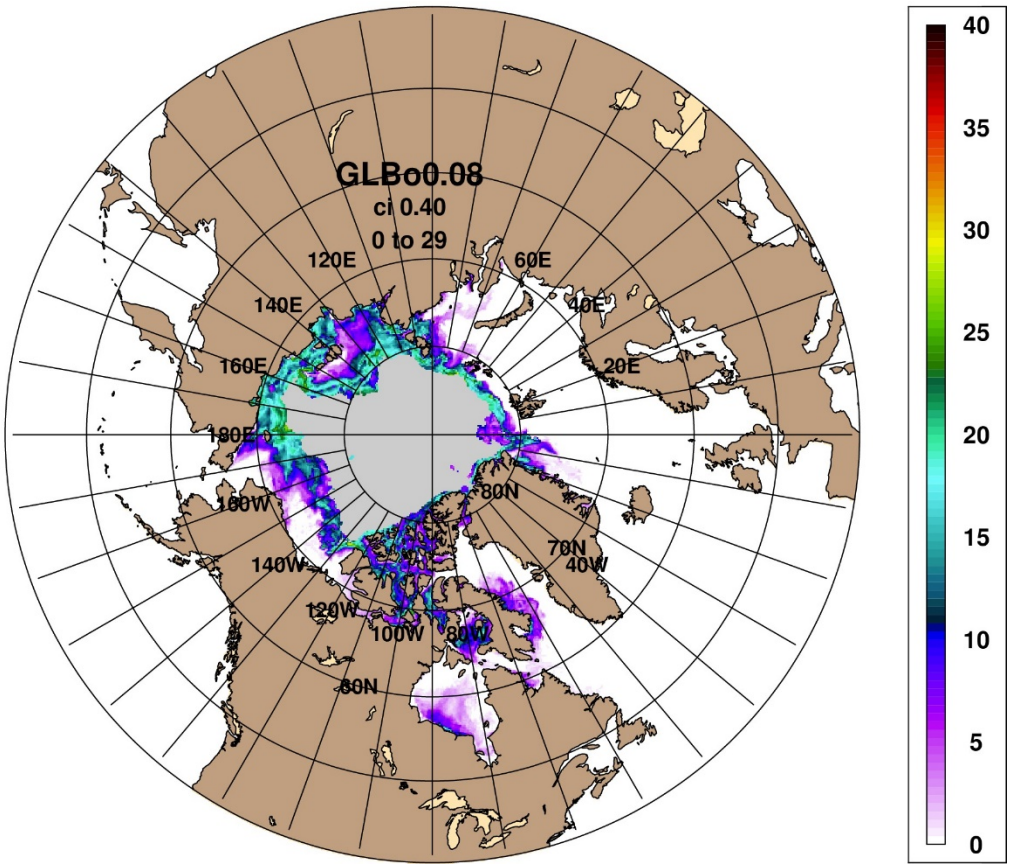

Figure 4: Standard deviation of first ice-free ordinal date, with grey indication a data void (i.e., no ice free days as the most likely outcome) of the projected GOFS 3.1 September 2016 mean ice extent.

References

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