Predicted Arctic sea ice cover in the GEOS S2S system, version 3

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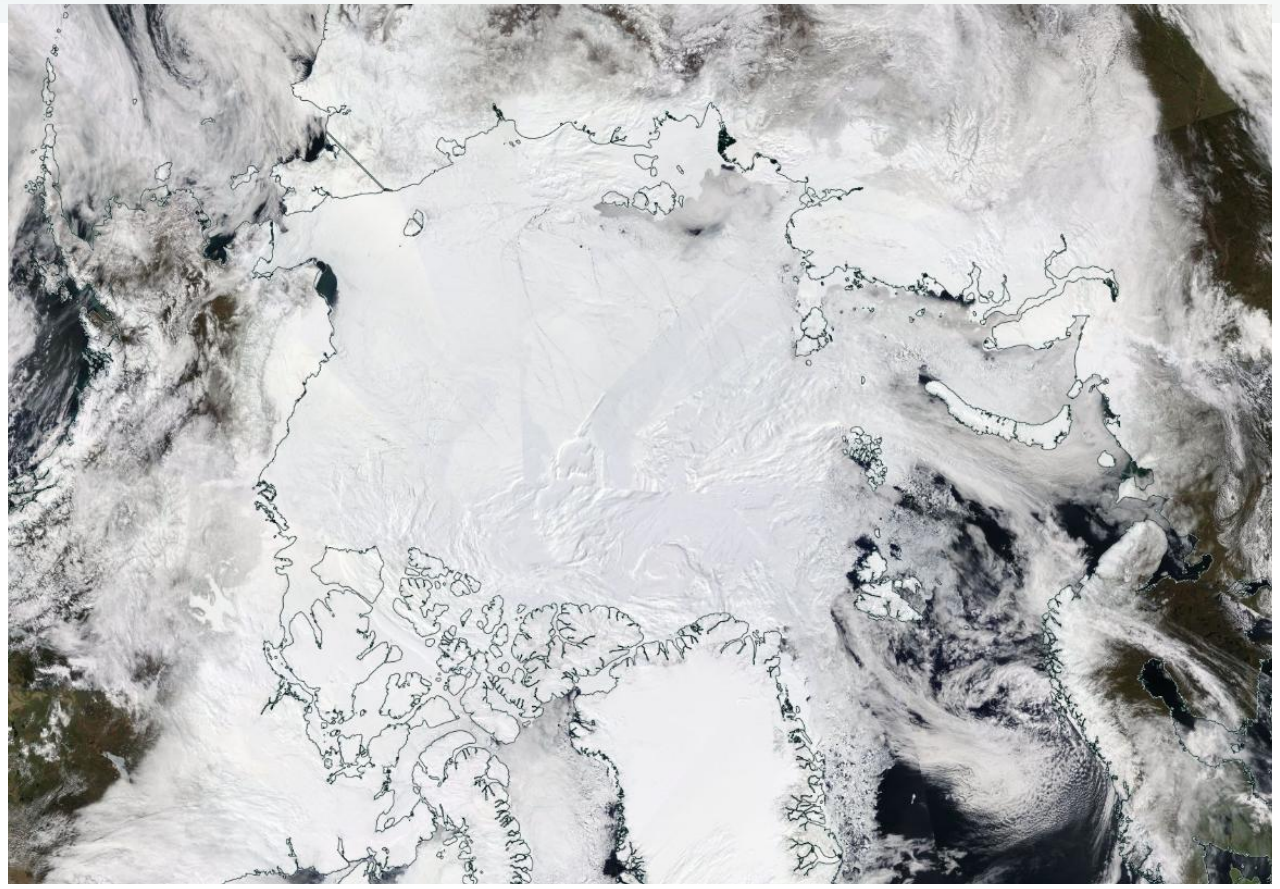
Arctic Sea Ice

- Arctic sea ice extent is a significant climate variable and a key indicator of Arctic conditions.
- With less sea ice, there is an expectation of an increased human presence in the Arctic related to commerce, military, and indigenous activities.
- Seasonal predictions of the sea ice cover are important for assessing our understanding of the associated physical processes, and for the adequate planning of various endeavors.
- Many centers continue to provide routine seasonal forecasts of sea ice extent; methods continue to be explored.



Worldview Terra /MODIS, 13-May 2025

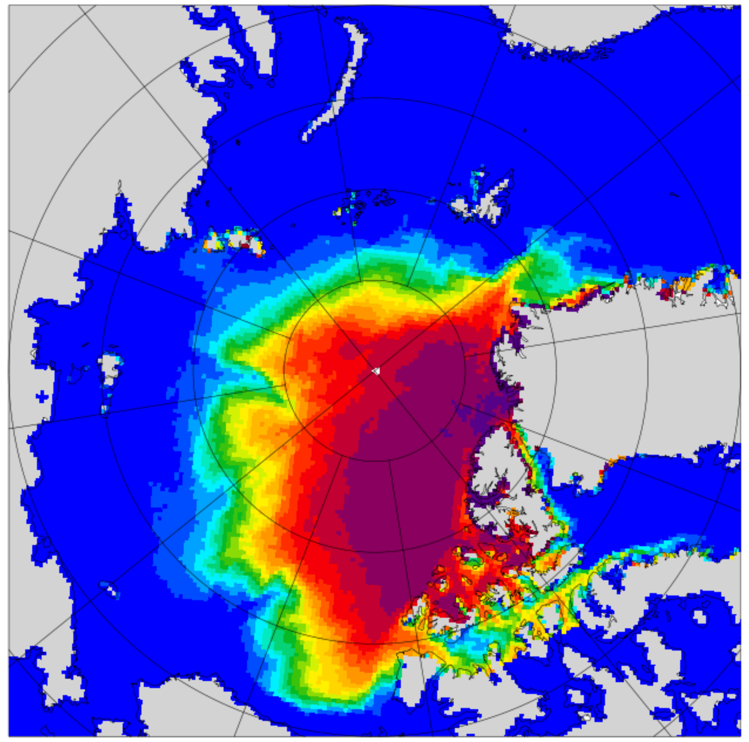
Yale Environment360 / Nordic Bulk Carriers

Goddard Seasonal Forecasting

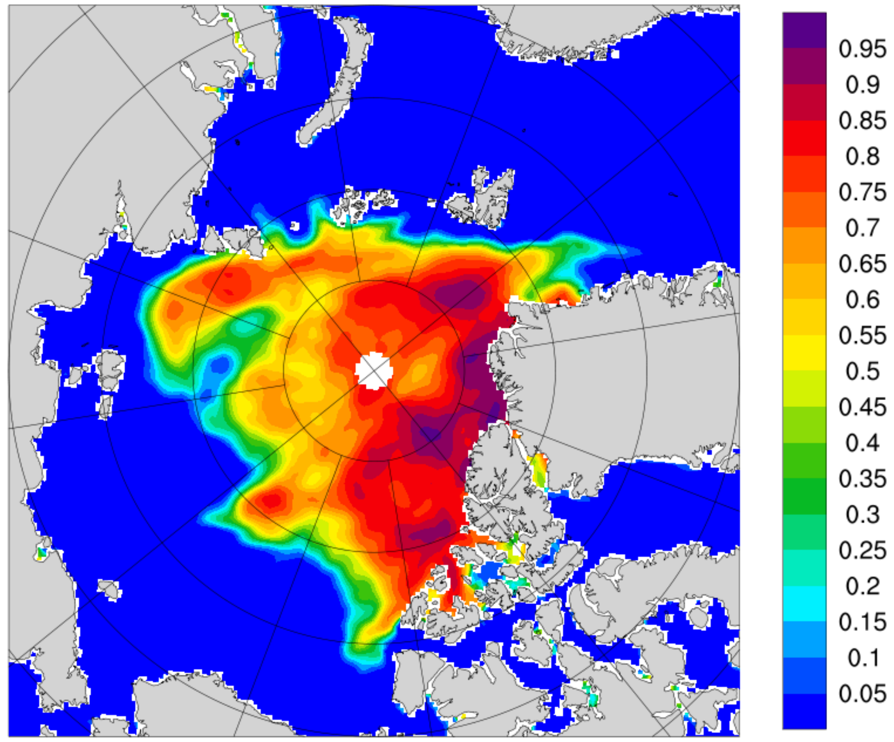
- The NASA Global Modeling and Assimilation Office (GMAO) at Goddard Space Flight Center has produced subseasonal-to-seasonal forecasts as part of the North American Multi-Model Ensemble (NMME) with a focus on El Niño/Southern Oscillation conditions.
- Version 1: 2011 – 2017 ; Version 2: 2017- 2025 ; Version 3: 2025 -
- Goals are to utilize NASA remote sensing observations for seasonal prediction and to improve our understanding of the Earth system.
- We have (irregularly) participated in the ARCUS Sea Ice Outlook (SIO) since 2013.

Submission	System Version	Forecast Value [10^6 km^2]	NSIDC Value [10^6 km^2]
June 2013	v. 1	4.4	5.208
June 2014	v. 1	5.3	5.22
June 2015	v. 1	5.03	4.616
July 2016	v. 1	5.2	4.528
June 2017	Offline variation of v. 2	5.3	4.822
July 2018	Offline var. of v. 2 using Kurtz & Harbeck CryoSat-2 thickness initialization	3.91	4.785
June 2019	Offline var. of v. 2 using Kurtz & Harbeck CryoSat-2 thickness initialization	4.27	4.364
July 2020	Offline var. of v. 2 using Kurtz & Harbeck CryoSat-2 thickness initialization	4.87	4.001
July 2021	Offline var. of v. 3 using AWI CryoSat-2 / SMOS thickness initialization	4.09	4.952
June 2022	Offline v. 3	4.75	4.897
June 2023	Offline v. 3	4.46	4.371
August 2023	Offline v. 3	5.38	4.371

GEOS S2S Ensemble Average
June Init Fcst for Sep 2023



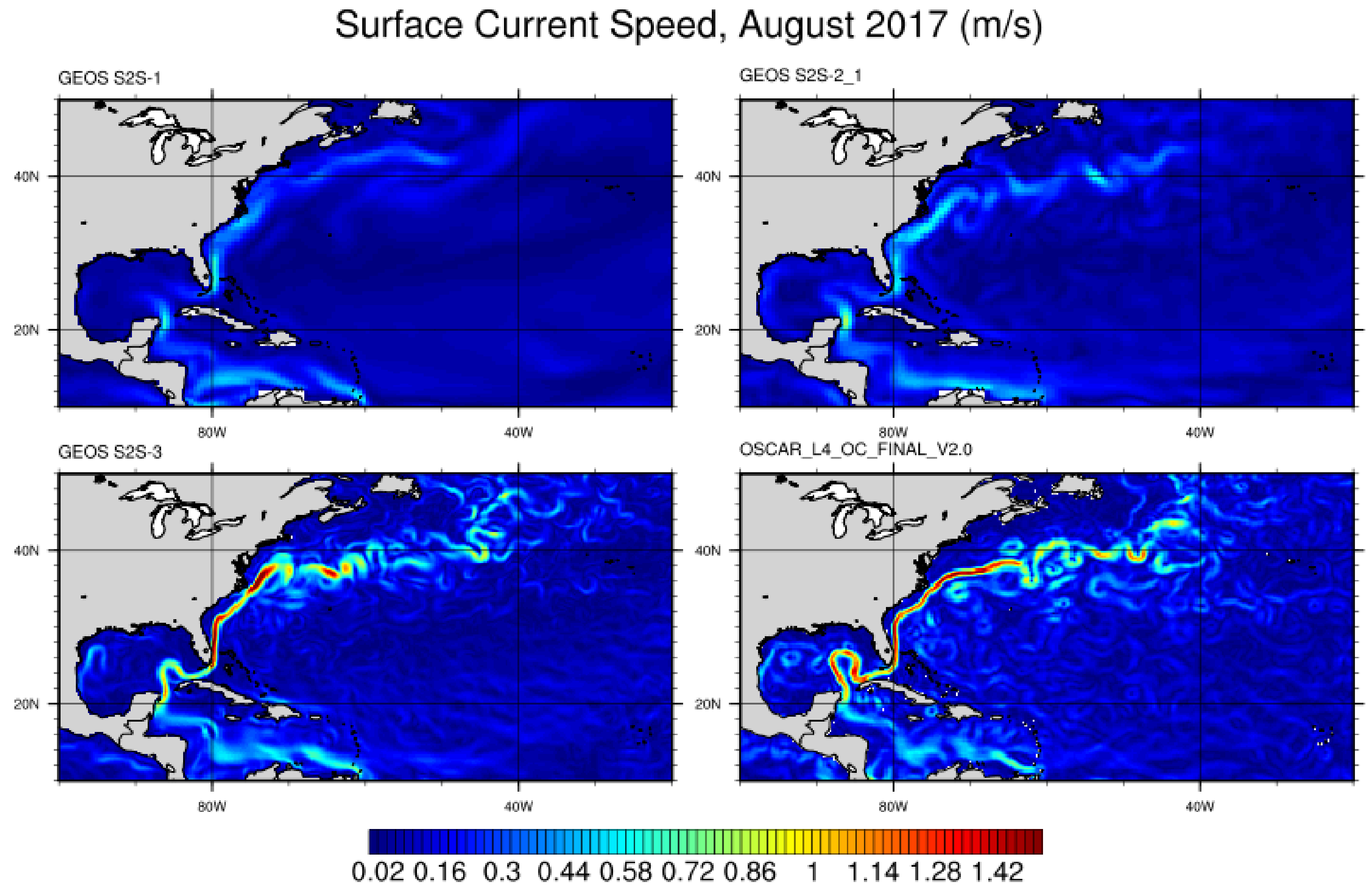
Goddard/NSIDC SSMIS, Sep 2023



GEOS_S2S_V3 Configuration

Model

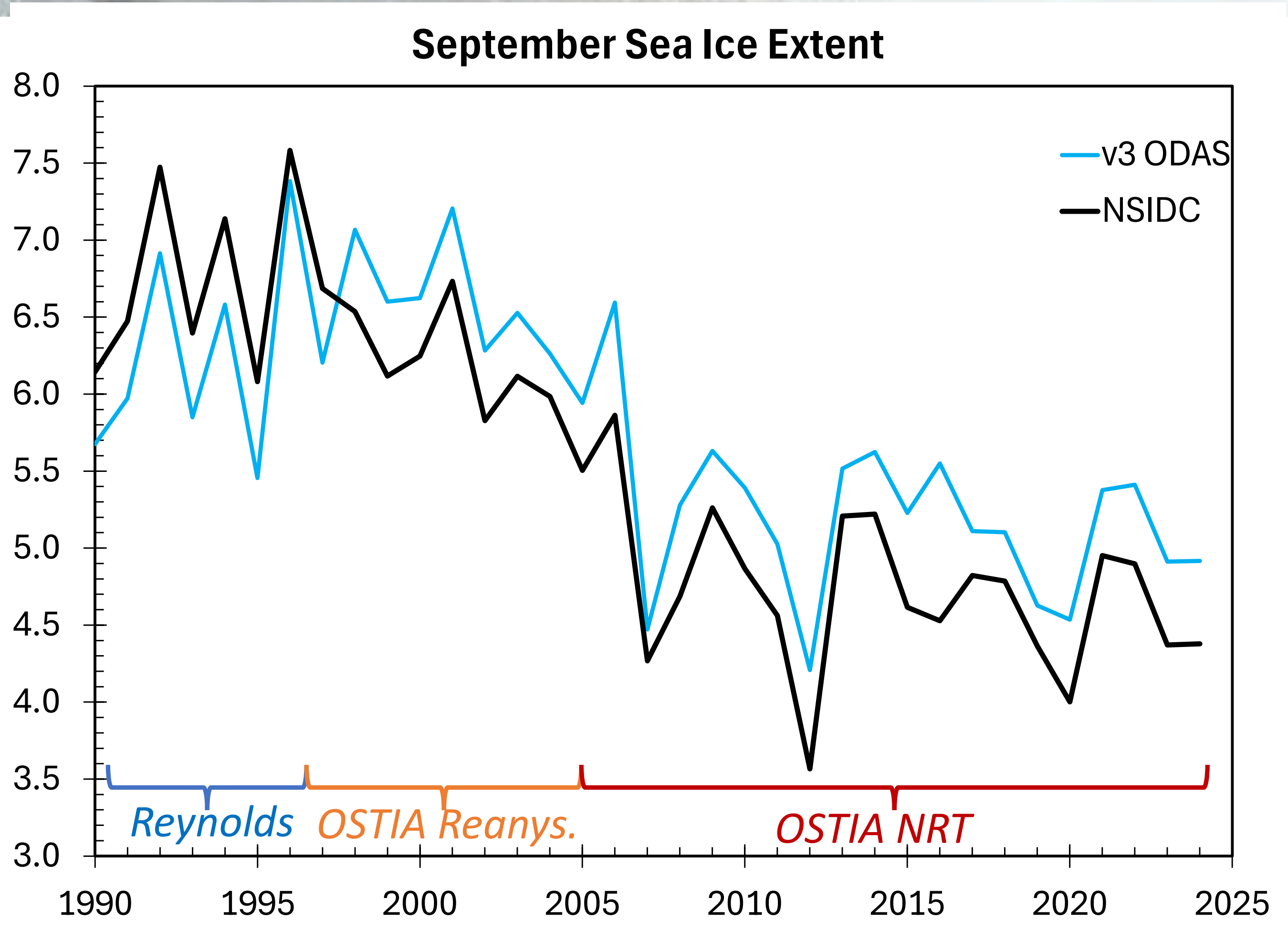
- Atmosphere: GEOS v. 9.3.3p2, ½° cubed sphere × L72 resolution; RRTMG atmospheric radiation; two-moment cloud microphysics; GOCART interactive aerosols
- Ocean: MOM5, ¼° tripolar × L50 resolution; KPP, parameterized tides, anisotropic mixing.
- Sea ice: CICE4.1 modified for our system.

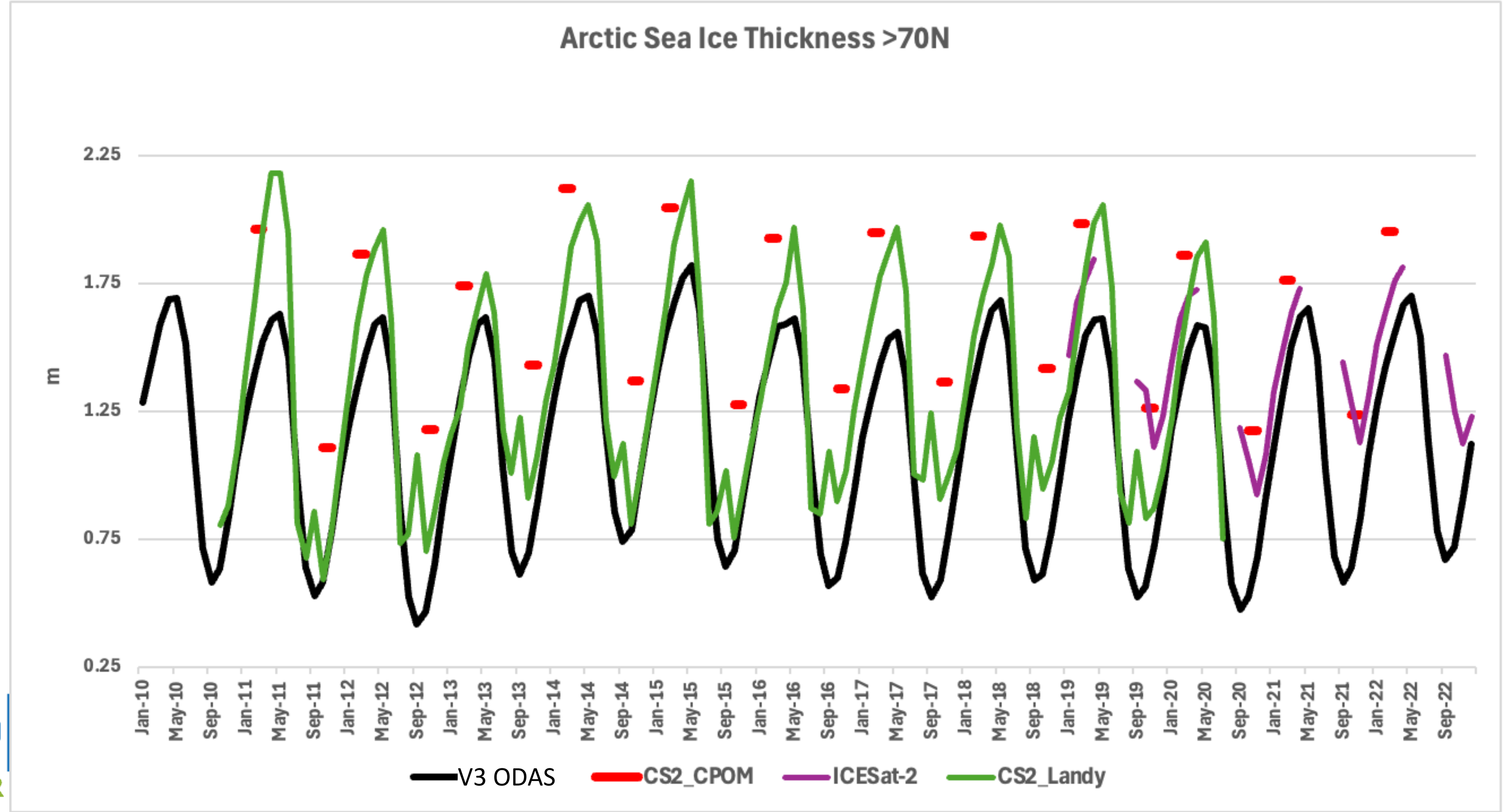


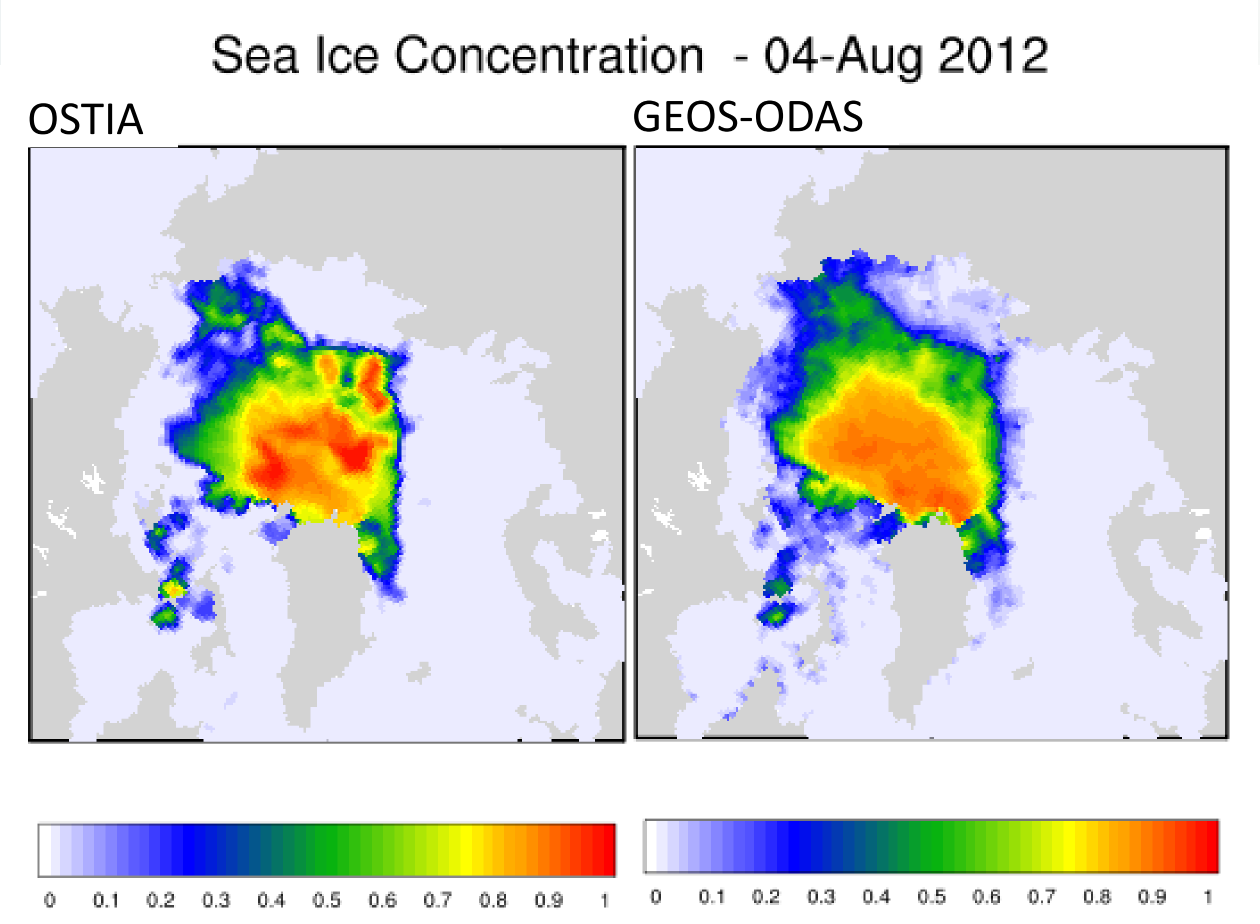
Assimilation

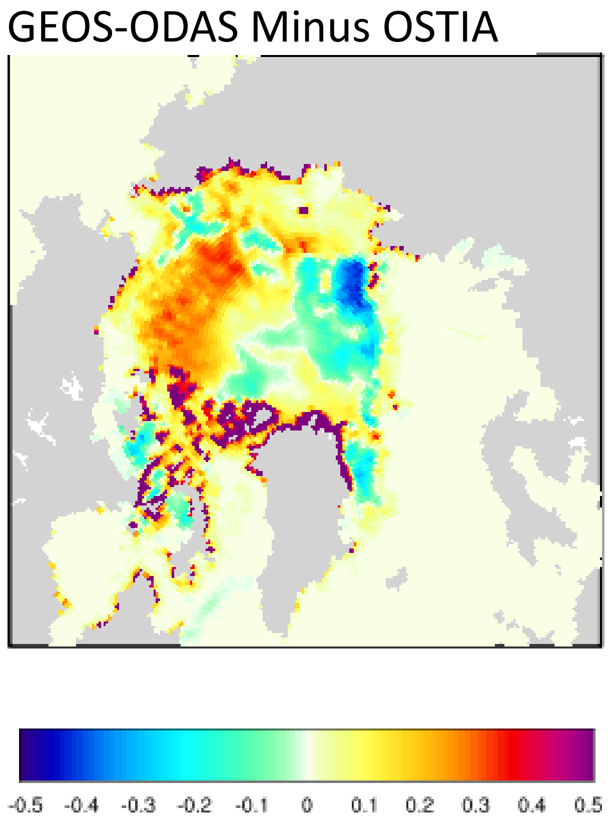
- Atmosphere: Grid point Statistical Interpolation 3DVar
- Ocean: LETKF, 5-day predictor/corrector window
- Sea ice: Continuous nudging to prescribed ice concentration.
- Reynolds SST & sea ice 1990-1997; OSTIA Reanalysis (OSI-409) 1998-2006; OSTIA NRT thereafter (OSI-401-d).

GEOS v3 ODAS





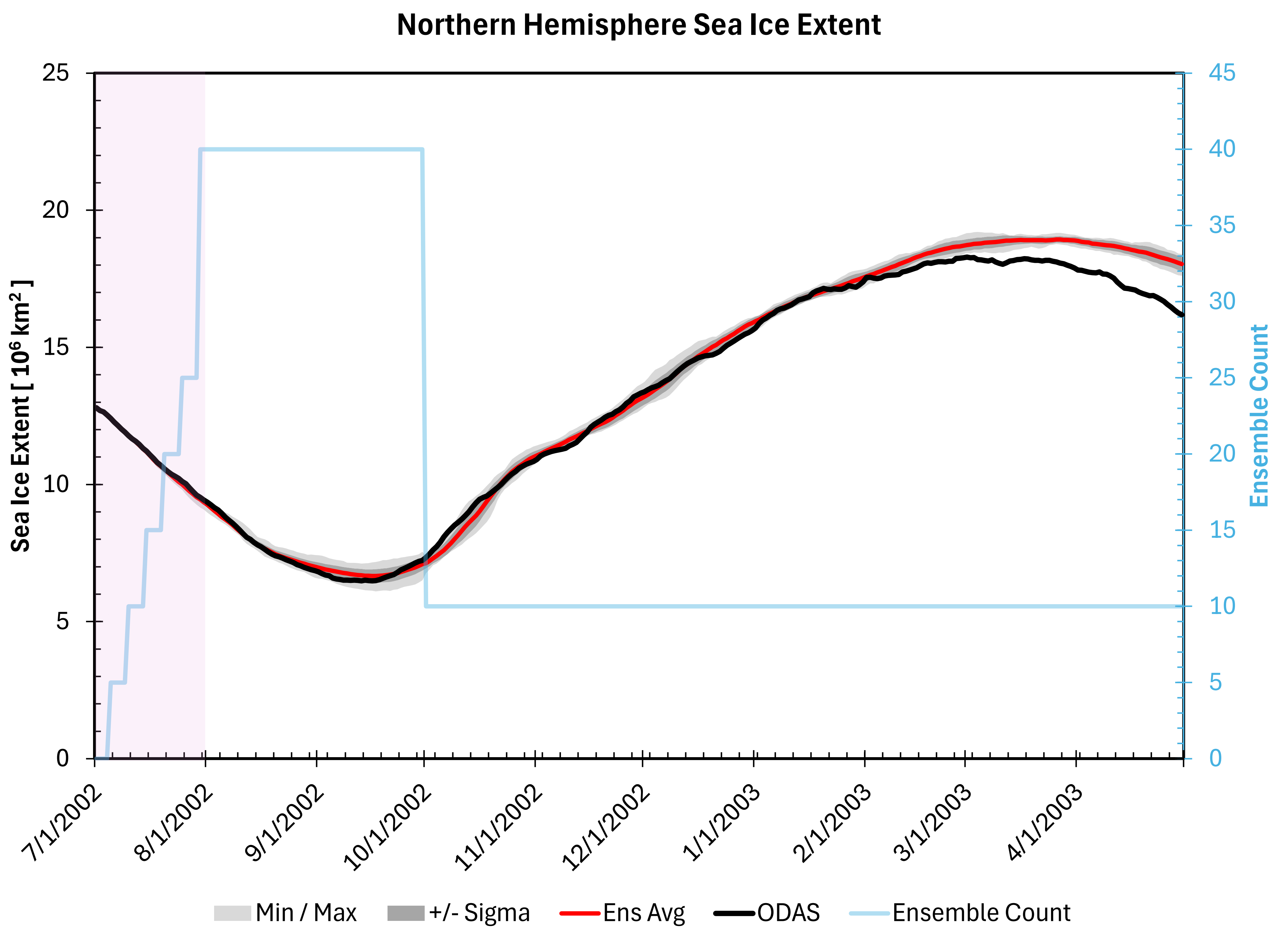




Global Modeling & Assimilation Office

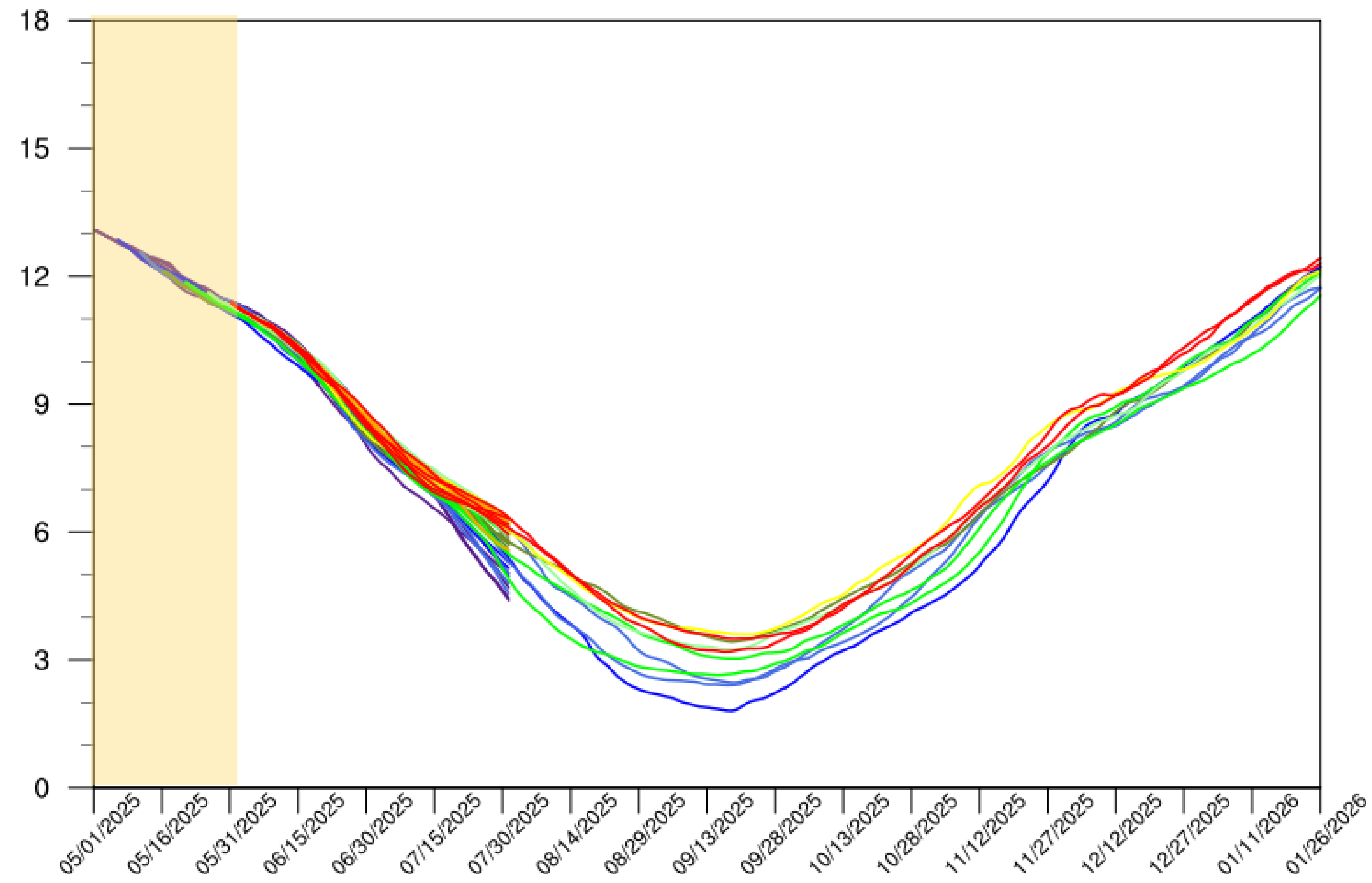
Forecast Ensemble

- Staggered initialization of 5 atmosphere-perturbed ensemble members starting on every fifth day of the month, and a burst of 15 atmosphere and ocean-perturbed members on the last day of the period.
- Total of 45 ensemble members run through July (2-months): the sub-seasonal forecast.
- The forecast ensemble is then globally characterized into several strata. Representative ensemble members are then selected from each strata using a strategy known as Neyman allocation. A total of 10 ensemble members are produced from the sub-setting to run through the seasonal forecast period to 9-months.

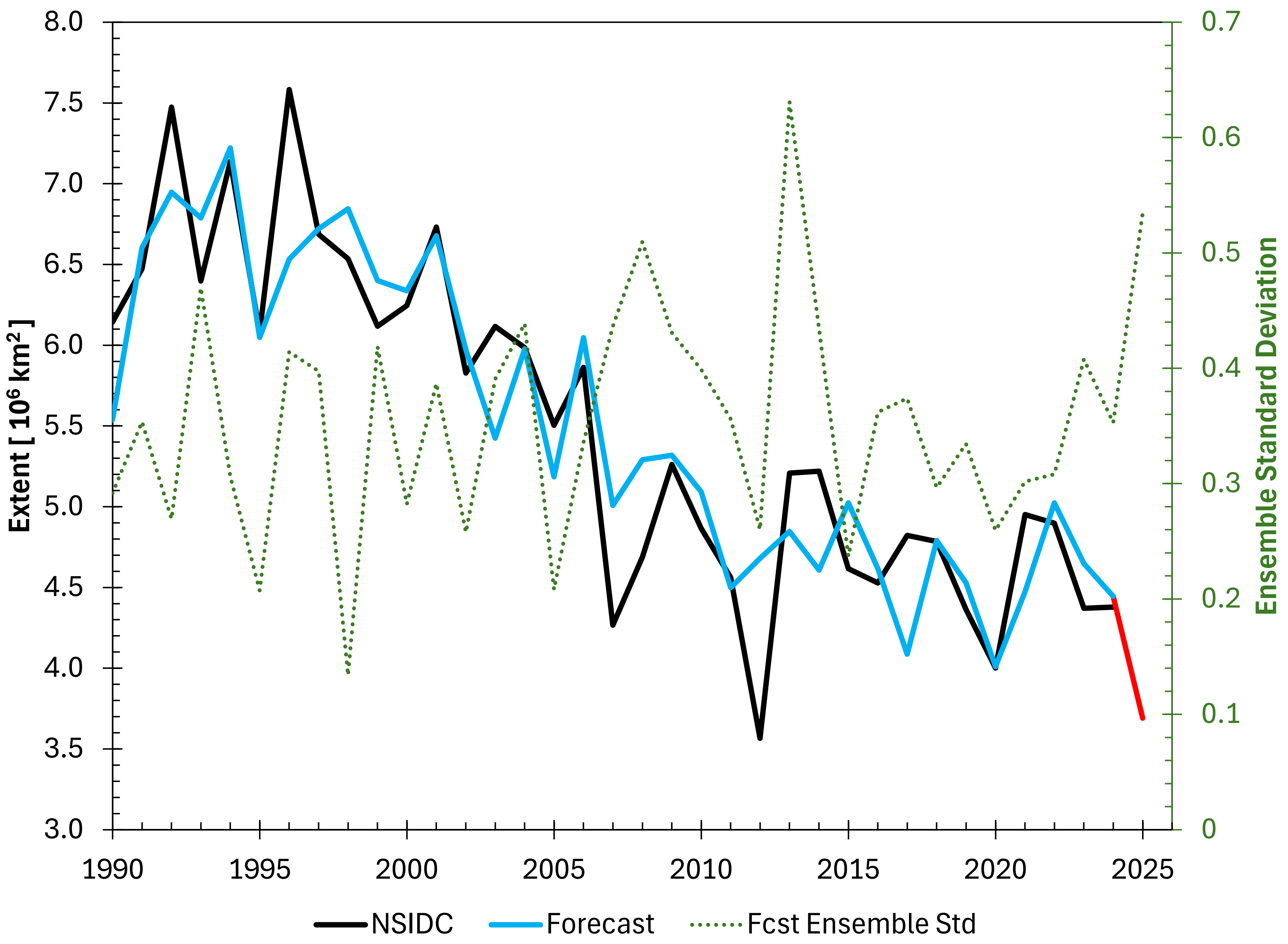


Forecast Ensemble

Arctic Sea Ice S2S June 2025 Forecast (i.e., the SIO contrib.)

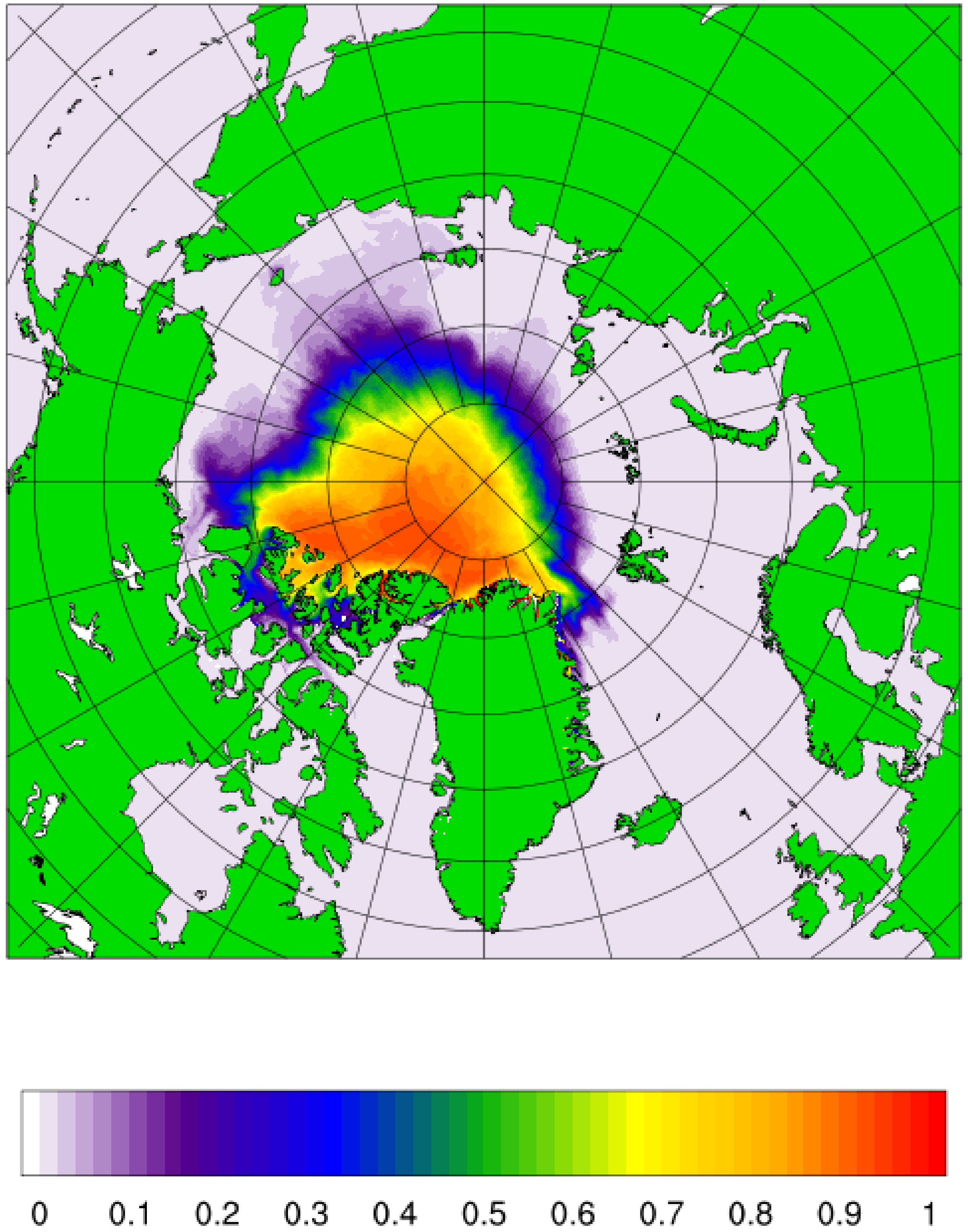


September Arctic Sea Ice
S2S Corrected Hindcasts and Forecasts

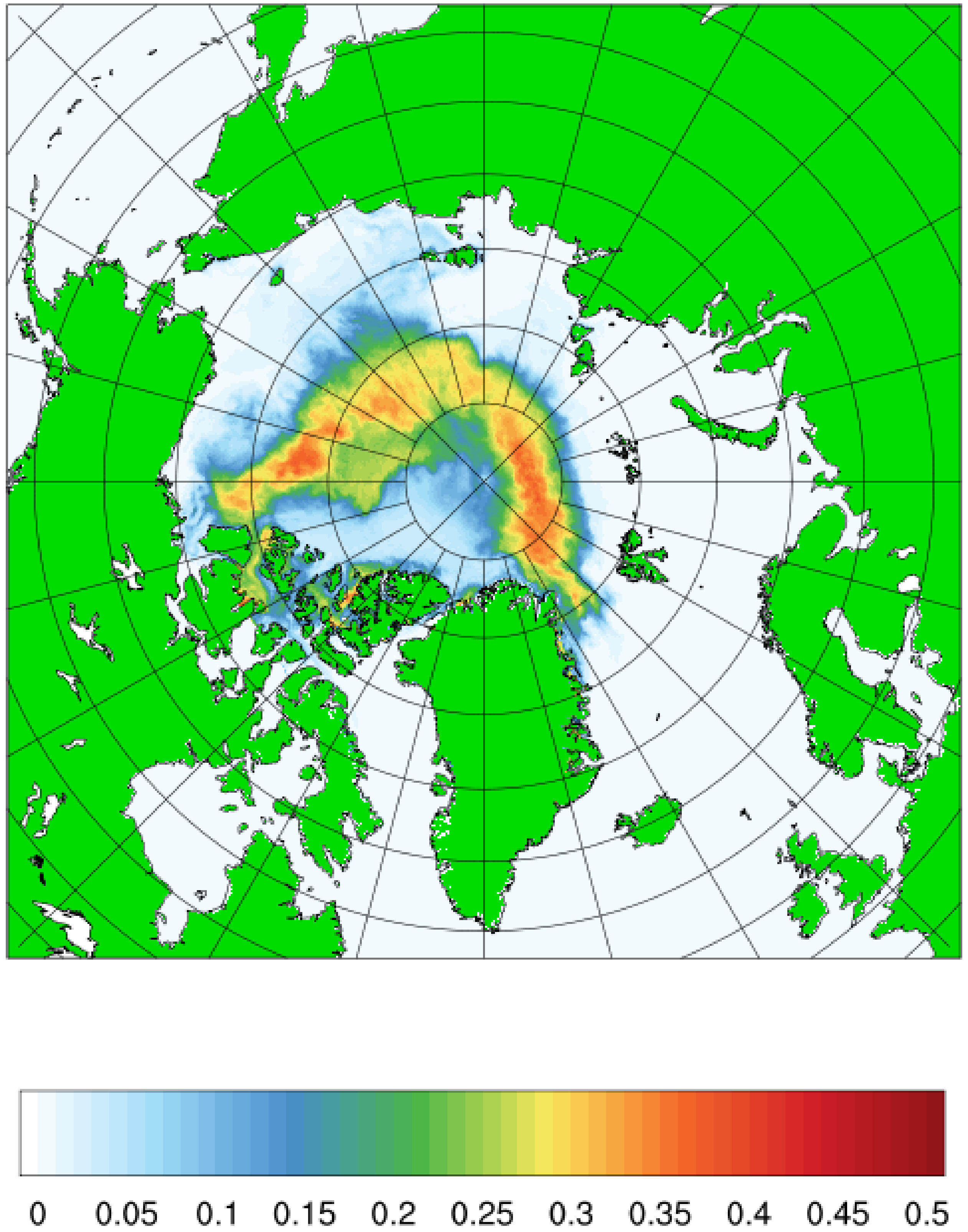


2025 SIO Forecast

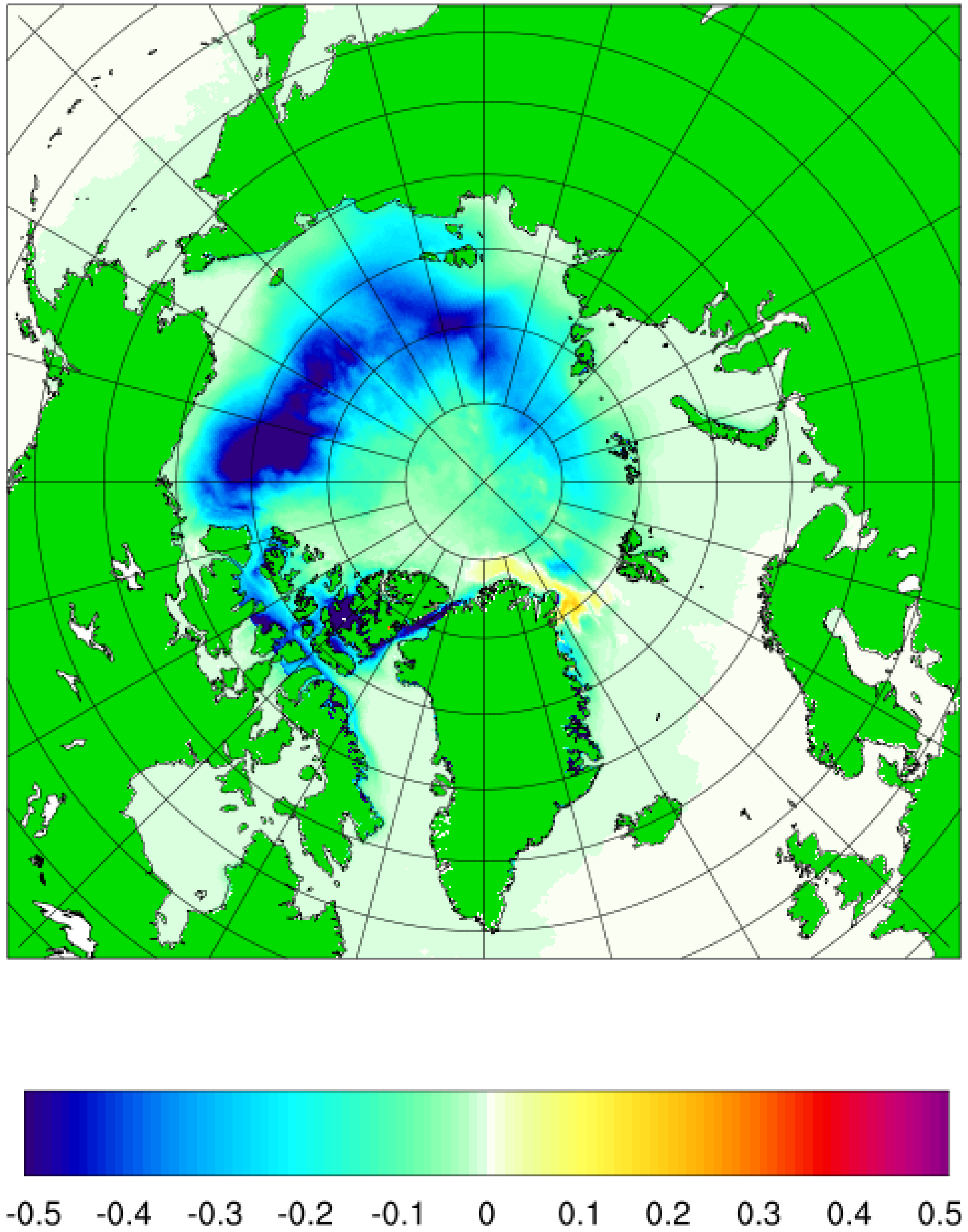
Ensemble Mean Ice Concentration



Ensemble Standard Deviation for Ice Concentration



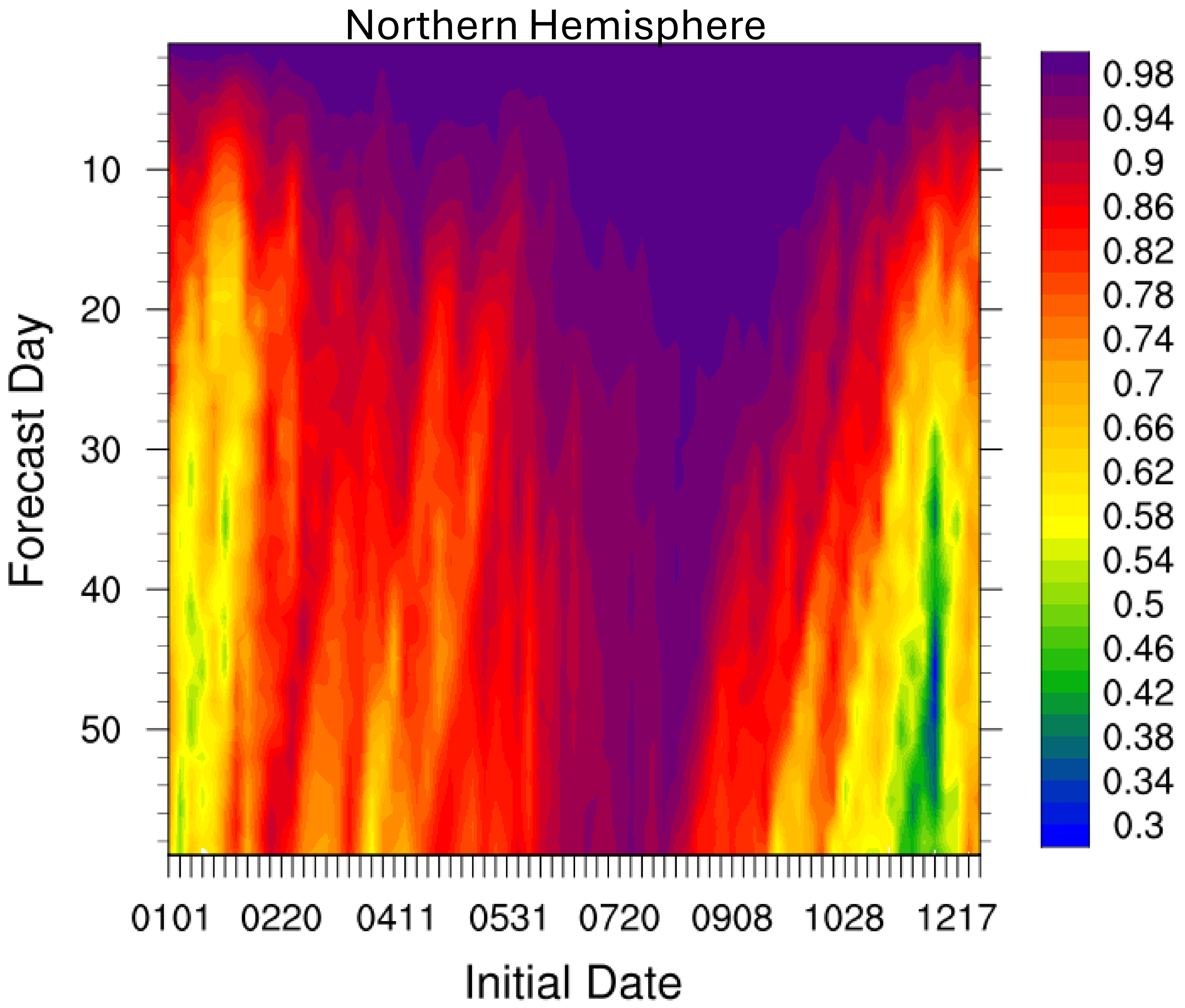
Ensemble Mean Ice Concentration Anomaly 1991-2020 Base Period



GODDARD EARTH SCIENCES

GMAO Global Modeling & Assimilation Office

Correlation, Northern Hemisphere Ice Extent With ODAS, 2001-2020



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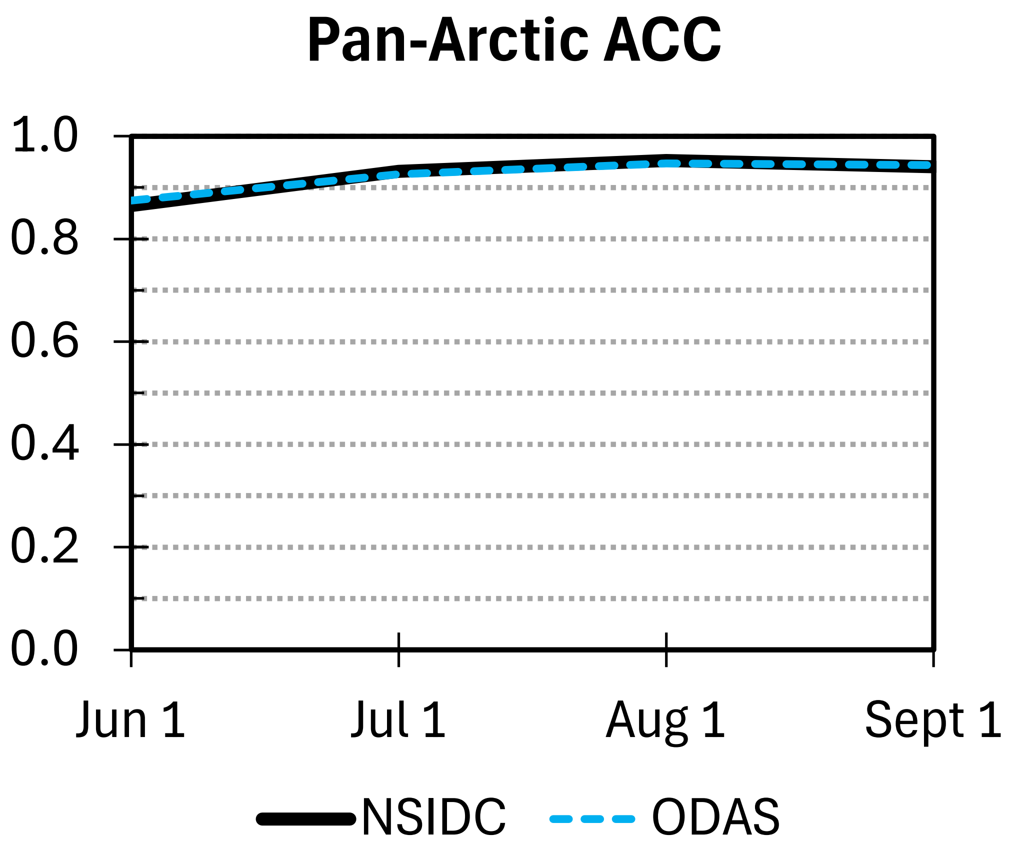
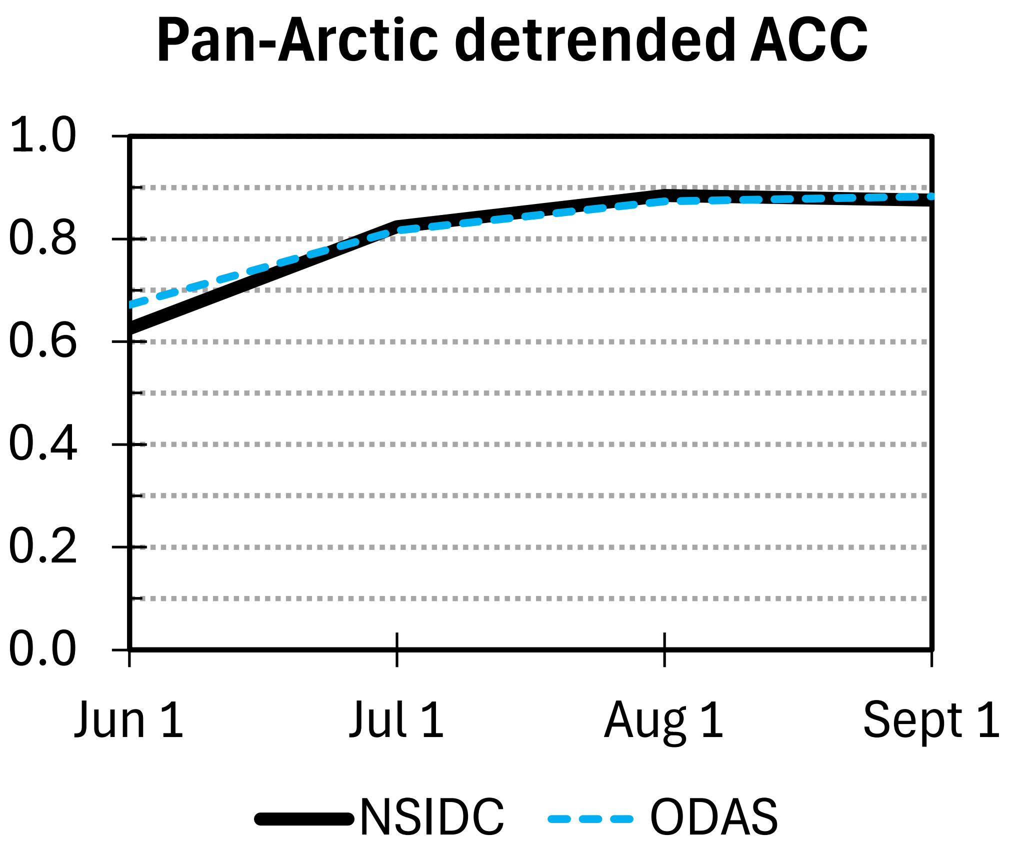
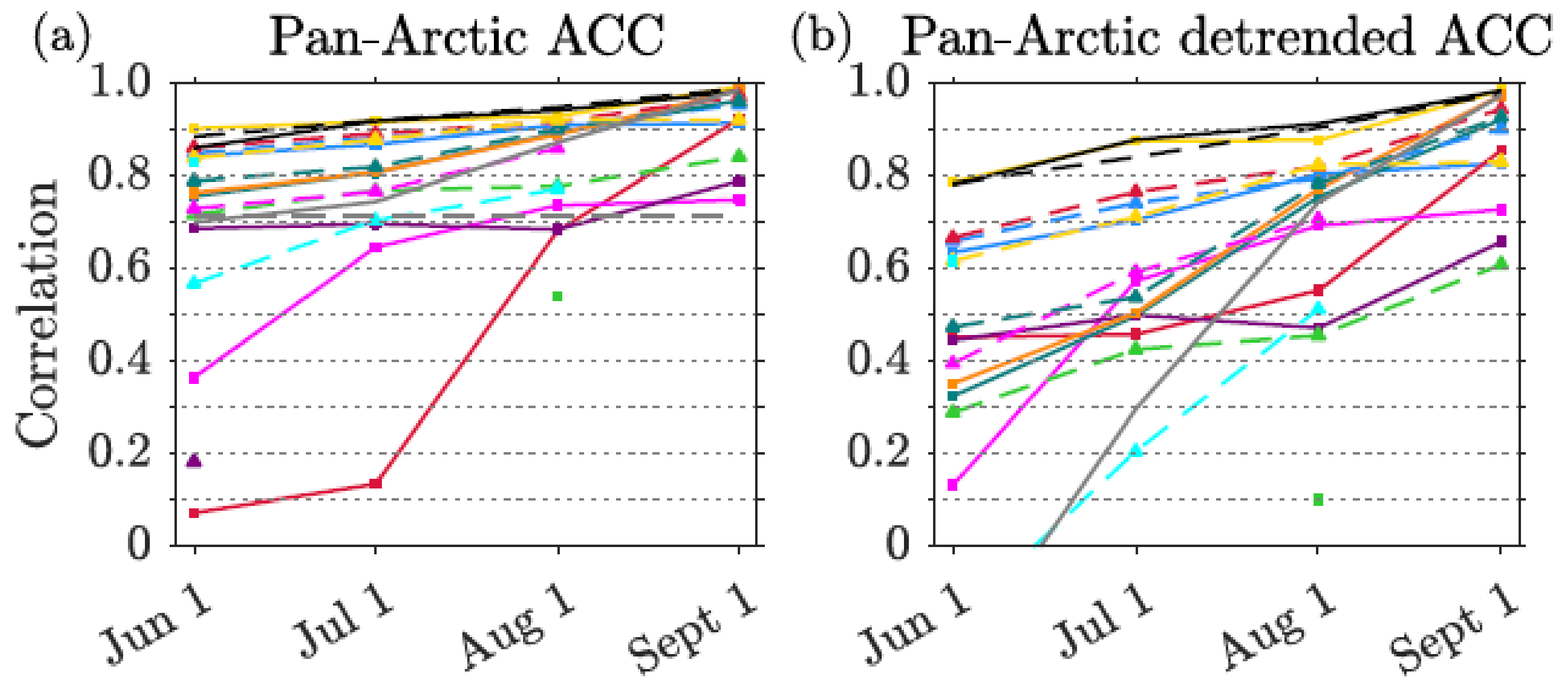
Arctic Forecast Skill







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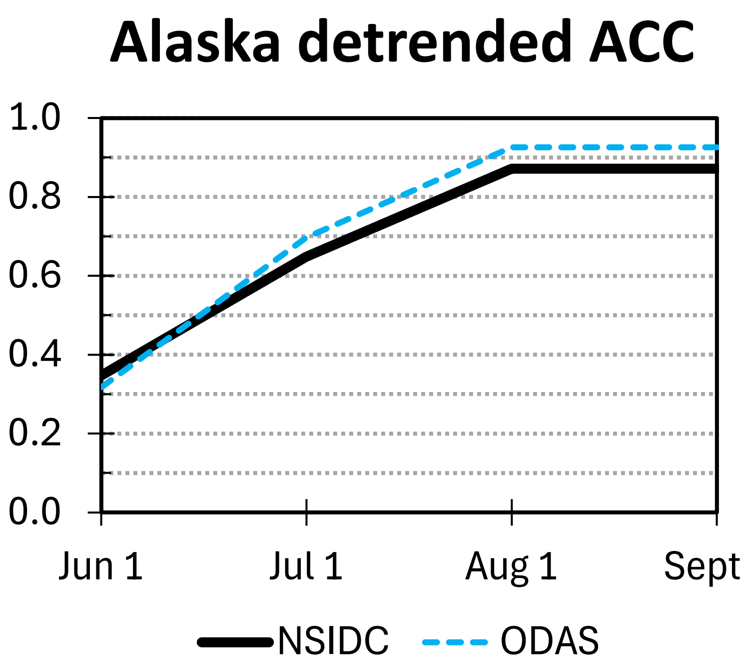
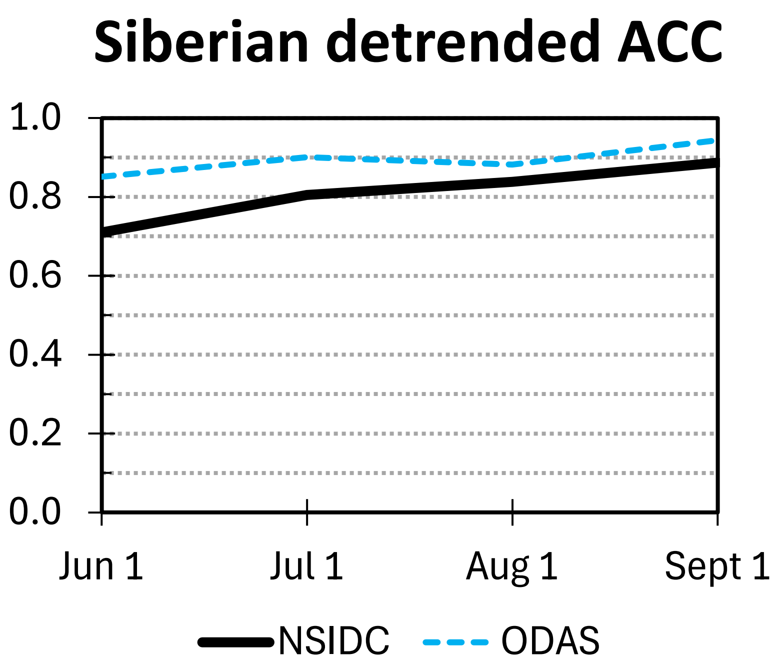
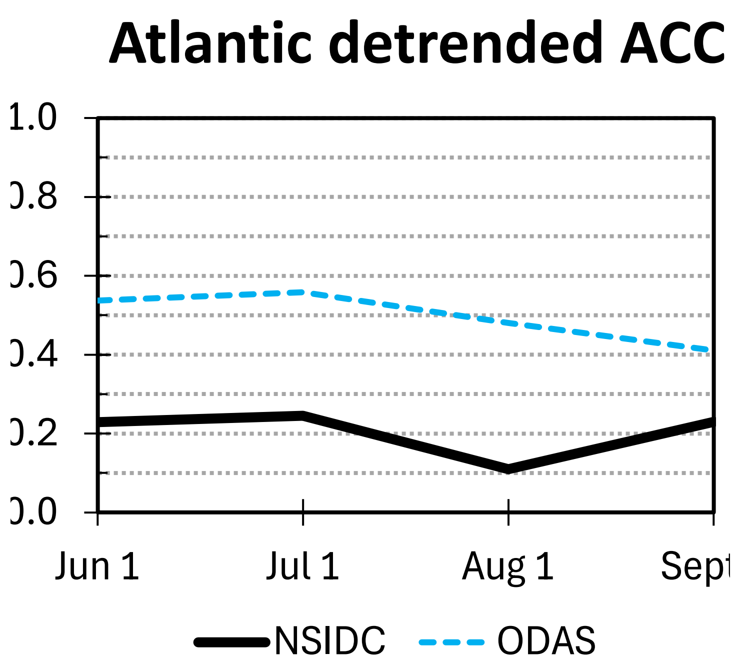
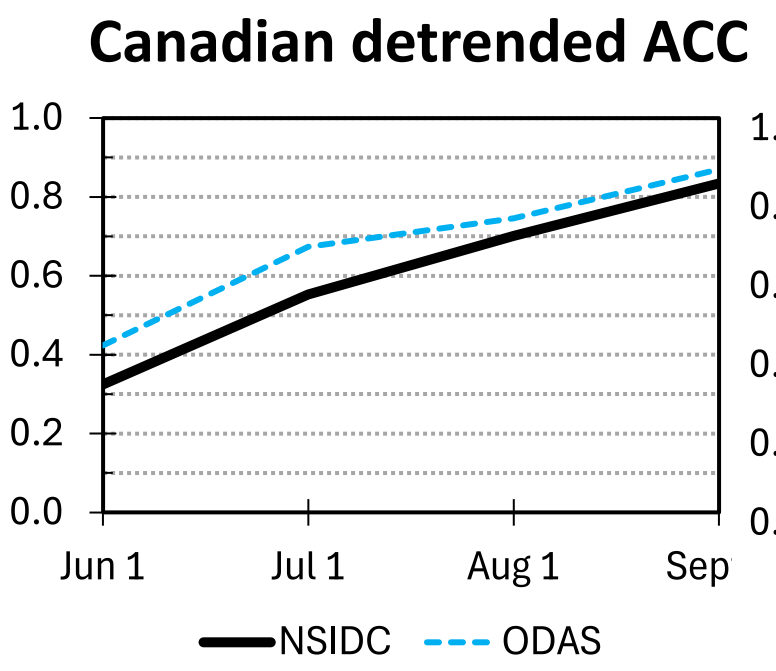
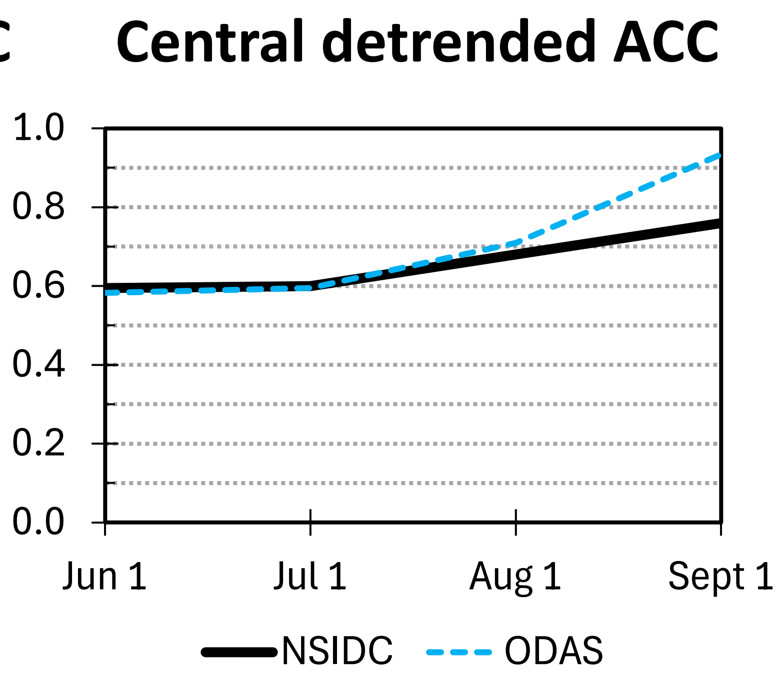
Arctic Regional Forecast Skill

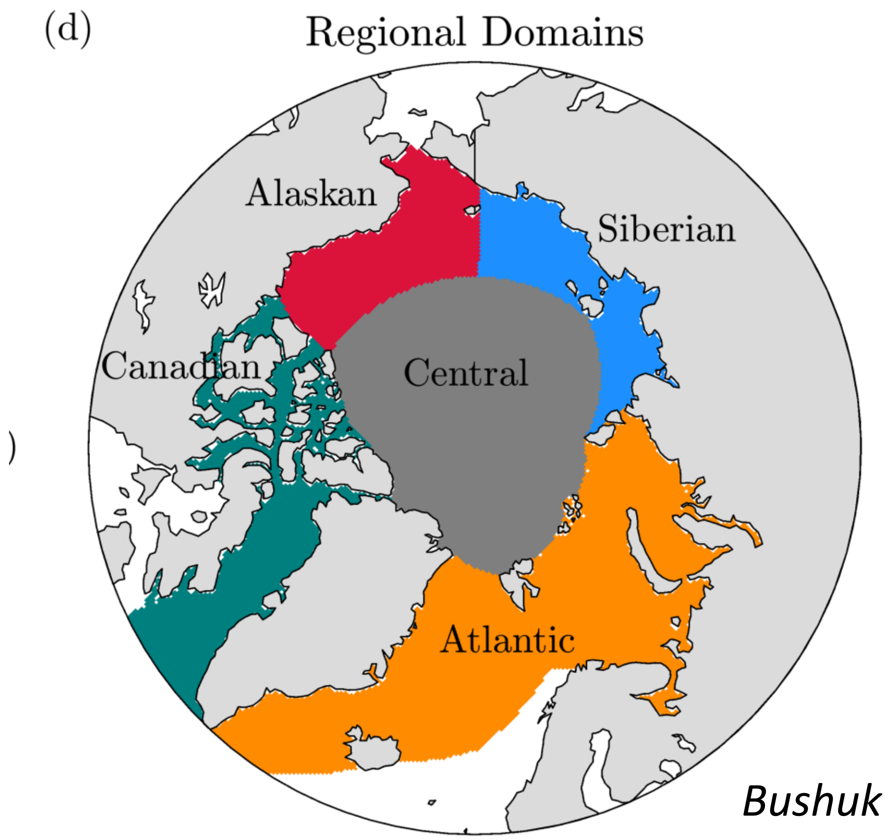












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Summary

- GEOS S2S v3 provides some innovation in S2S forecasting based on
  - Atmospheric model
  - Resolution
  - Ensemble size and scheme
- Preliminary evaluation
  - Model has a good representation of sea ice climatology, with some amplification of the seasonal cycle.
  - The ODAS system has characteristic summertime differences with other sea ice data sets, with higher concentrations in the Beaufort/Chukchi seas and lower concentrations in the central Arctic.
  - The sub-setting scheme as applied to sea ice appears to work. We do not find significant discontinuities in daily variables during the transition from sub-seasonal to seasonal forecast periods.
  - Hindcast skill appears to correspond on the higher-end of available forecast systems. The system appears to show relatively higher skill in the Siberian Arctic.
- In addition to continued evaluation, we will focus on a better understanding of the sub-seasonal forecasting skill.
- Future S2S versions will utilize the Joint Effort for Data assimilation Integration (JEDI) framework.