Predictions for September 2021 Polar Sea Ice Concentration and Extent by Linear Markov Models: July Report

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Executive Summary: A linear Markov model is used to predict monthly Arctic sea ice concentration (SIC) at all grid points in the pan-Arctic region (Yuan et al., 2016). The model is capable of capturing the co-variability in the ocean-sea ice-atmosphere system. The September pan-Arctic sea ice extent (SIE) is calculated from predicted SIC. The model predicts negative SIC anomalies throughout the pan-Arctic region. These anomalies are relative to the 1979-2012 climatology. The September mean pan-Arctic SIE is predicted to be 4.59 million square kilometers (mskm) with an RMSE of 0.42 mskm, at the three-month lead. The RMSE is estimated based on our model forward forecasts from 2013-2020. The Alaskan regional SIE is predicted to be 0.72 mskm. A Similar statistical model was also developed to predict the SIE in the Antarctic (Chen and Yuan, 2004). The September mean pan Antarctic SIE is predicted to be 18.37 mskm, lower than September 2020 (18.77), with an RMSE of 0.42 mskm based on model cross-validation experiments.

Predictions

Pan-Arctic Sea Ice concentration and Extent Predictions: Based on the observations of sea ice concentrations, SST, surface air temperature, GH300 and vector winds at 300mb in June, the model predicts negative sea ice concentration anomalies in all areas within the Arctic Basin relative to the climatology for the period of 1979-2012 (figure 1). Particularly large anomalies (<-40%) occur in the East Siberia Sea, and Laptev Sea. Negative SIC anomalies in other areas will be smaller than -40%. The model predicts that the pan-Arctic SIE will be 4.59 mskm in September 2021.

Alaskan regional Sea Ice Concentration and Extent predictions: The regional model predicts that the SIE in the Alaskan region will be 0.72 mskm (figure 2), which is significantly above the Alaska SIE in last year (0.42). Large areas in the Laptev Sea, East Siberia Sea and Chkchi Sea have SIC anomalies of 32-40% below the climatology. This regional model runs in the area of 40°-85°N and 120°-240°E. The Alaska region SIE is calculated using the regional mask provided by NSIDC.

Pan-Antarctic Sea Ice Concentration and Extent Predictions: Initialized by the observations of sea ice concentration, surface air temperature and GH300 and vector winds height at 300mb in June, the model predicts the Antarctic SIC with positive anomalies in the Amundsen Sea and negative anomalies in the Bellingshausen Sea and Weddell Sea in September (figure 3). The total SIE is calculated from the predicted SIC. The Antarctic SIE is estimated to be 18.37 mskm in September 2021.

Models

The linear Markov model has been developed to predict sea ice concentrations in the pan Arctic region at the seasonal time scale. The model employs 6 variables: NASA Team sea ice concentration, sea surface temperature (ERSST), surface air temperature, GH300, vector winds at GH300 (NCEP/NCAR reanalysis) for the period of 1979 to 2012. It is built in multi-variate EOF space. The model utilizes first 11 mEOF modes and uses a Markov process to predict these principal components forward one month at a time. The pan Arctic sea ice extent forecast is calculated by summarizing all cell areas where predicted sea ice concentration exceeds 15%.

Bias corrections have been applied to ice concentration predictions at grid points as well as the total sea ice extent prediction. The predictive skill of the model was evaluated by anomaly correlation between predictions and observations, and root-mean-square errors (RMSE) in a (take one-year out) cross-validated fashion. On average, the model is superior to the predictions by anomaly persistence, damped anomaly persistence, and climatology (Yuan et al, 2016). For the three-month lead prediction of September sea ice concentrations, the model has the higher skill (anomaly correlation) and lower RMSE in the Chukchi Sea and Beaufort Sea than in other regions (figure 4). The skill of the three-month lead prediction of the pan Arctic sea ice extent in September is 0.73 with an RMSE of 0.82 million square kilometers based on cross-validation experiments with a constant SIE bias correction. The RMSE reduce to 0.42 in forward forecast (2013-2020) with additional grid point and resolution bias corrections. The Alaskan regional SIE prediction is produced by a regional linear Markov model developed by using SIC, SST, SAT (unpublished). Following the NSIDC regional mask, the Alaska SIE forecast is calculated from predicted SIC. A similar model is used for Antarctic SIE forecast (Chen and Yuan 2004).

Uncertainty

The uncertainty of SIC prediction was measured by root-mean-square error (RMSE). They were estimated based on 34 years (take-one-year-out) cross-validated model experiments (Yuan et al. 2016). RMSE in figure 4b is based on 34-year predicted SIC in September. Bias corrections at grid points were applied. This year we provide SIE uncertainty using forward forecast from 2013-2020 with an additional SIE bias correction. The SIE uncertainty measured by RMSE is 0.42 million square kilometers for the three-month lead prediction of the pan-Arctic sea ice extent. The RMSE of the Alaska SIE prediction is 0.22 million square kilometers based on 34-year cross-validation experiments. For the Antarctic SIE prediction, the RMSE of 0.42 million square kilometers was estimated from the errors of the last fifteen years' forward predictions.

Post processing

First, a constant bias correction was applied to Arctic SIC prediction at each grid point. These biases were estimated based on the take-one-year-out cross-validated predictions for 1979-2012. Then a constant SIE bias also derived from the cross-validation experiments from 1979 to 2012 was corrected from the September SIE prediction. Finally, the model uses lower resolution sea ice concentration data (2-degree longitude x 0.5-degree latitude), introducing a 0.10 million square kilometers bias compared to 25kmx25km original satellite data. This resolution bias is corrected in the final Arctic SIE prediction.

For the Antarctic SIE prediction, we applied a bias of 0.35 million square kilometers between Bootstrap and NASA-Team SIE climatology since the model was developed using Bootstrap SIC but initialized with NASA-Team SIC. Furthermore, like the post-prediction processing for the Arctic SIE, we also applied a resolution bias correction of 0.04 million square kilometers. Last, we apply a model systematic SIE bias correction of 0.59 million square kilometers to the final SIE prediction.

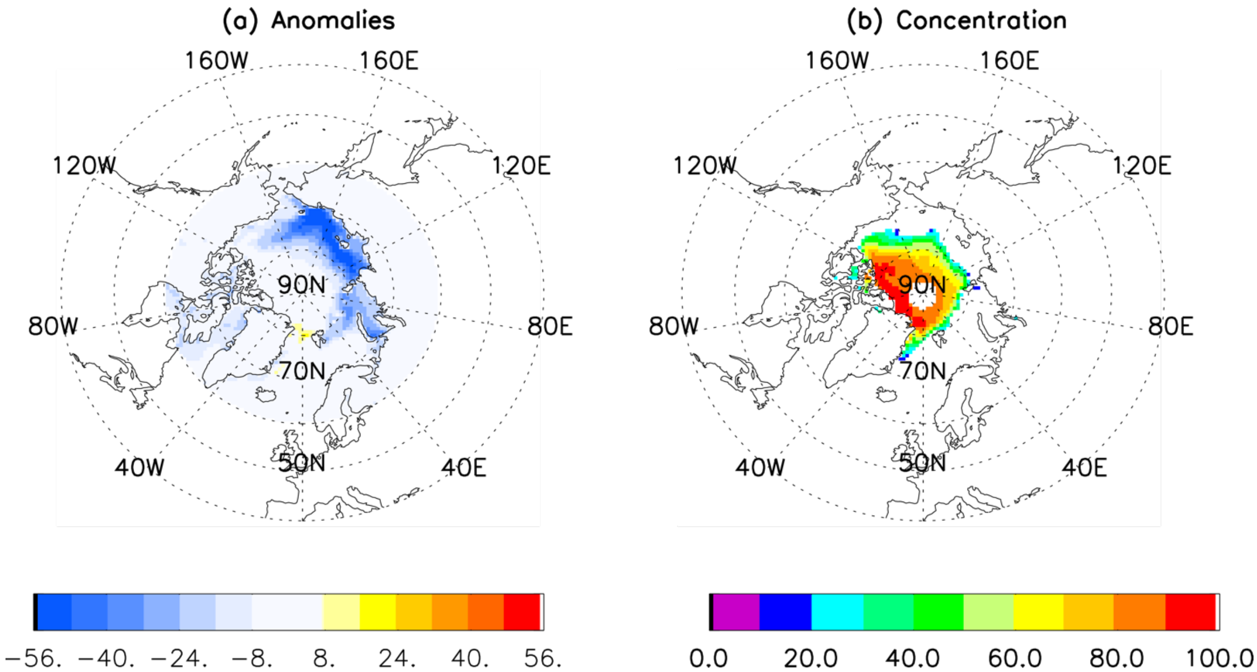

Figure 1 Three-month lead prediction of 2021 September Arctic sea ice concentration anomaly (a) and concentration (b) by the linear Markov model initialized with observed June SIC, SST, SAT, GH300 and vector winds at 300mb.

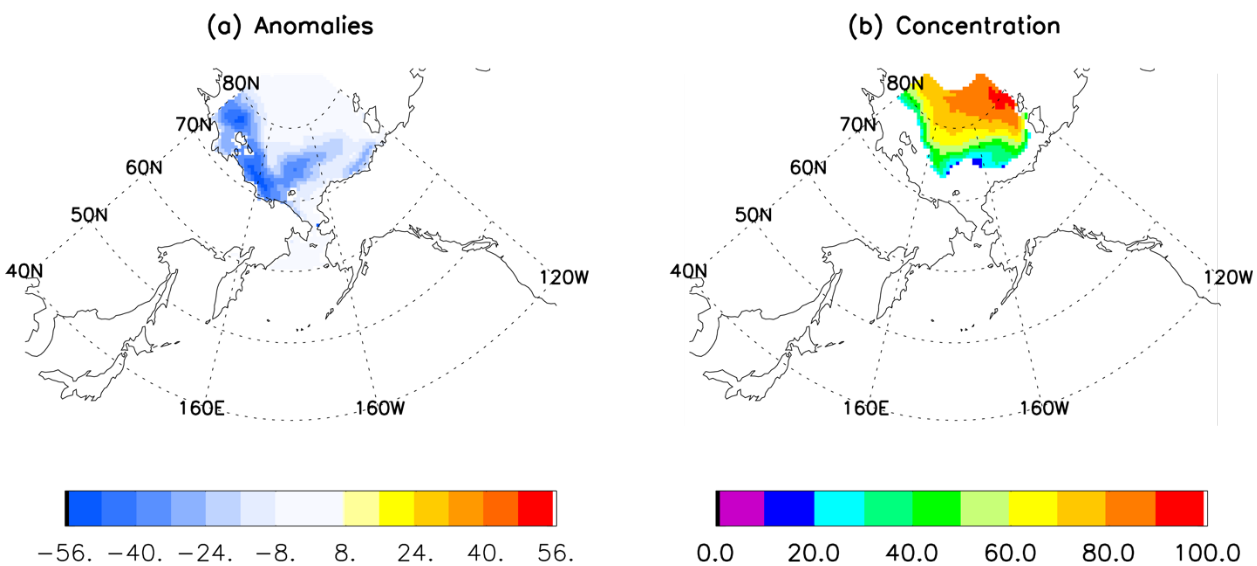

Figure 2 Three-month lead prediction of September 2021 sea ice concentration anomaly (a) and concentration (b) in the Alaskan region by a regional linear Markov model initialized with observed June SIC, SST, SAT, GPH and winds at 500mb and 200mb.

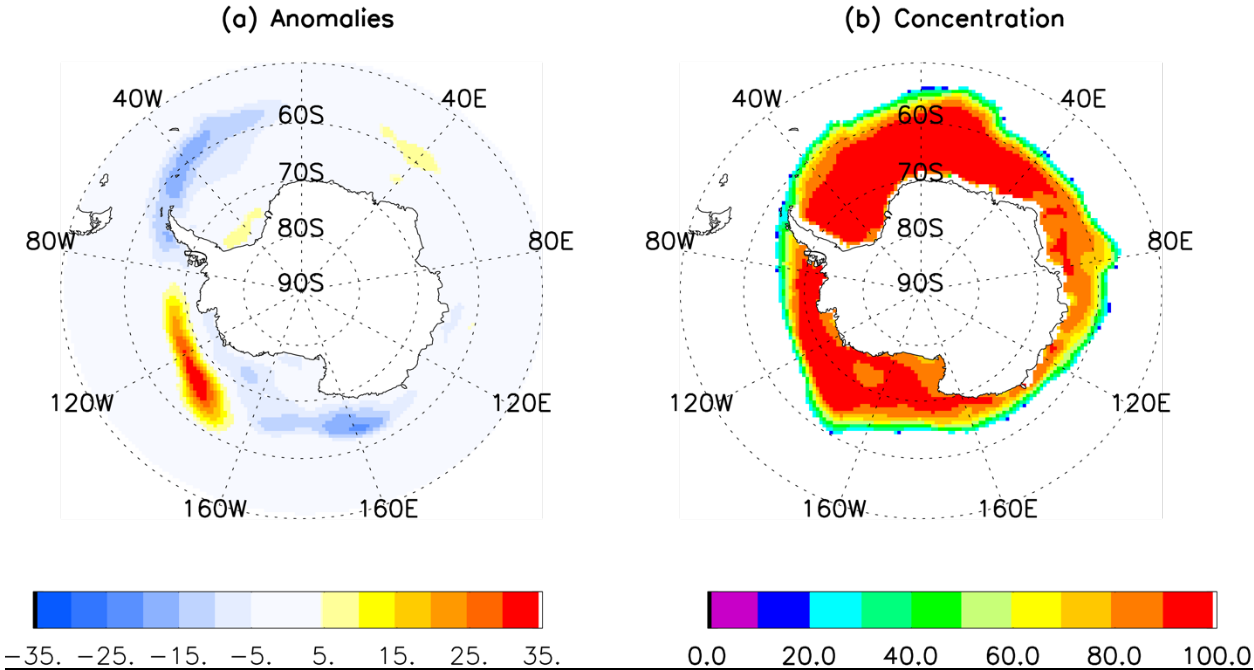

Figure 3 Three-month lead prediction of September 2021 Antarctic sea ice concentration anomaly (a) and concentration (b) by a linear Markov model initialized with observed June SIC, SAT, GH300 and vector winds at 300mb.

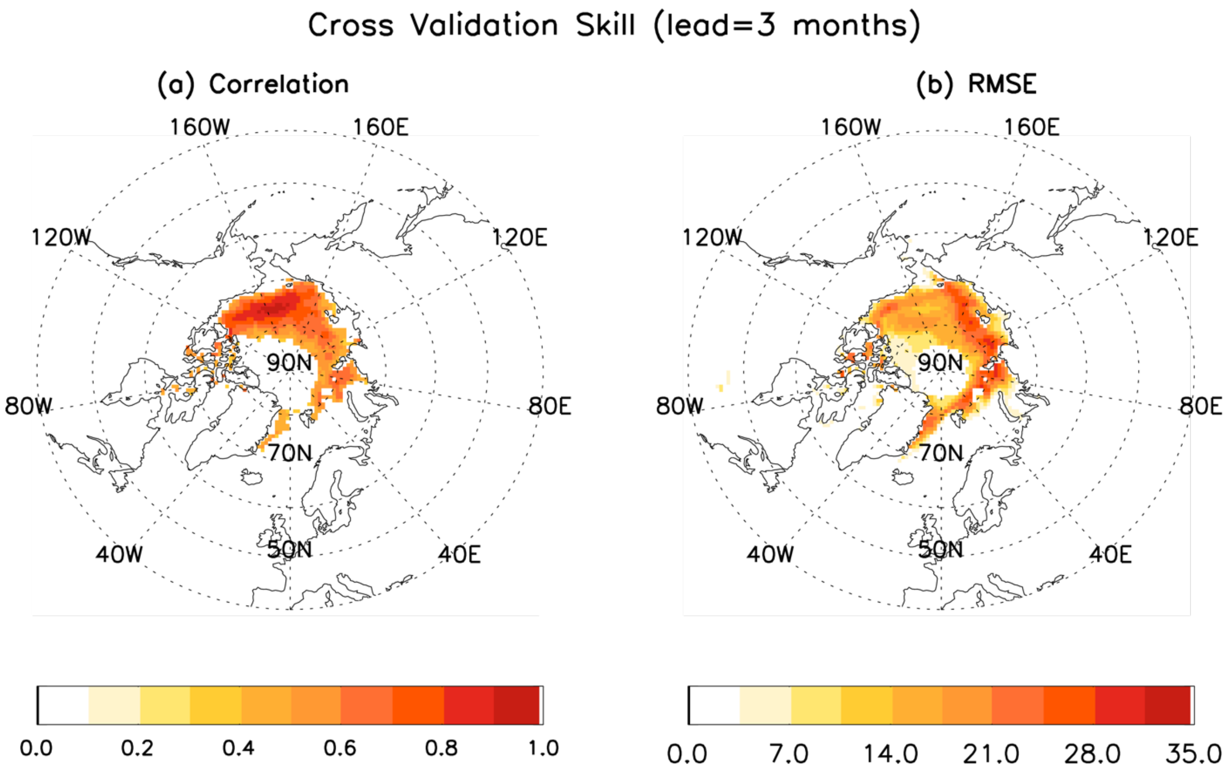

Figure 4. Cross-validated model skill measured by correlations between model predictions and observations of Arctic sea ice concentration anomalies (a) and model RMSE (b) for three-month lead prediction of September sea ice concentration. Only the correlations that pass the 95% confidence level are shown in (a). The units in (b) are in percentages. The low correlations and low RMSE near the North Pole Hole (the satellite blind spot) are due to low ice variability (Yuan et al. 2016).

Datasets

Sea ice concentration: NSIDC NASA Team, https://nsidc.org/data/nsidc-0081, https://doi.org/10.5067/U8C09DWVX9LM.

Atmospheric variables: NOAA NCEP/NCAR Reanalysis-1 http://iridl.ldeo.columbia.edu/SOURCES/.NOAA/.NCEP-NCAR/.CDAS-1/

Sea surface temperature: NOAA NCDC ERSST version3b: Extended reconstructed sea surface temperature data

References

Chen, D. and X. Yuan, 2004: A Markov model for seasonal forecast of Antarctic sea ice. *J. Climate,* 17(16), 3156-3168.

Yuan, X., D. Chen, C. Li and L. Wang, 2016: Arctic Sea Ice Seasonal Prediction by a Linear Markov Model. *J. Climate*, Vol. 29, DOI: 10.1175/JCLI-D-15-0858.1.