Predictions for September 2020 Polar Sea Ice Concentration and Extent by Linear Markov Models: June 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 4.64 million square kilometers (mskm) with an RMSE of 0.48 mskm, at the four-month lead. It is 0.32 mskm above September SIE in 2019. Similar statistical models were also developed to predict the SIE in the Alaskan region and the Antarctic (Chen and Yuan, 2004). The Alaskan regional SIE is predicted to be 0.53 mskm with an RMSE of 0.22 mskm, which is about 50% above the last year Alaska SIE. The September mean pan Antarctic SIE is predicted to be 18.57, higher than September 2019 (18.24), with an RMSE of 0.57 mskm.

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 May, 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 Chukchi Sea, East Siberia Sea, Laptev Sea and Kara Sea. Negative SIC anomalies in other areas will be smaller than 24%. The model predicts that the pan-Arctic SIE will be 4.64 mskm in September 2020.

Alaskan regional Sea Ice Concentration and Extent predictions: The regional model predicts that the SIE in the Alaskan region will be 0.53 mskm (figure 2), which is above the Alaska SIE in last year. Large area in the Chukchi Sea has SIC anomalies of 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 May, the model predicts the Antarctic SIC in September (figure 3) and the total SIE is calculated from the predicted SIC. The Antarctic SIE is estimated to be 18.57 mskm in September 2020.

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 four-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 four-month lead prediction of the pan Arctic sea ice extent in September is 0.87 with an RMSE of 0.48 million square kilometers. The Alaskan regional SIE prediction is produced by a regional linear Markov model developed by using SIC, SST, SAT, and in a rotated-EOF space (Li et al., in revision). Following the NSIDC regional mask, the Alaska SIE forecast is calculated from predicted SIC. The skill of the regional SIE is 0.90 (correlation using cross-validated experiments) with RMSE of 0.22 million square kilometers. 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 cross-validated model experiments. It was achieved by subtracting one-year of data from principal components and re-build Markov model for that year's prediction. The process was repeated for each year of 34-year time series (Yuan et al., 2016). RMSE in figure 4b is based on 34 predicted September Arctic SIC including grid point bias corrections. The uncertainty of the four-month lead prediction of the pan Arctic sea ice extent in September is measured by a RMSE of 0.48 million square kilometers. The RMSE of the Alaska SIE prediction is 0.22 million square kilometers. For the Antarctic SIE prediction, the RMSE of 0.57 million square kilometers was estimated from the errors from the last fifteen years of forward predictions.

Post processing

A constant bias correction was applied to Arctic SIC prediction at each grid point. The biases were estimated based on the cross-validated predictions for 1998-2012. Then a content SIE bias derived from cross-validation experiments for the period of 1979-2012 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), which introduces 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. Similar to 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 0.56 million square kilometers to the final SIE prediction.

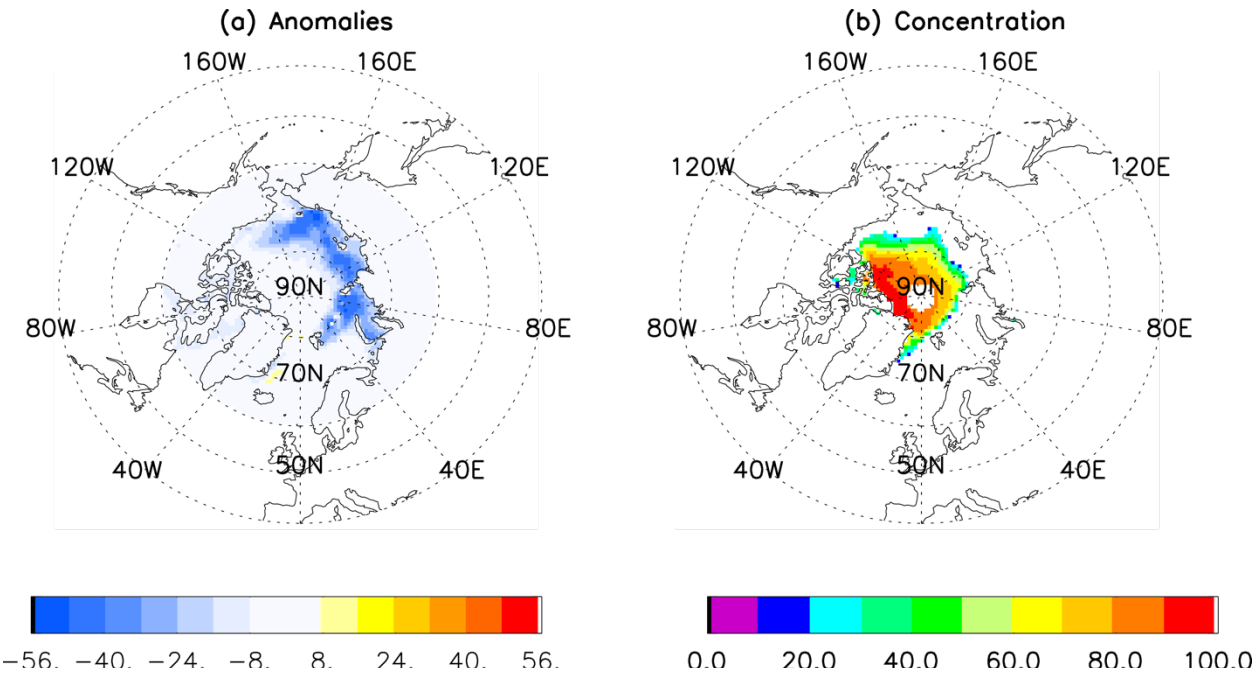

Figure 1 Four-month lead prediction of 2020 September Arctic sea ice concentration anomaly (a) and concentration (b) by the linear Markov model initialized with observed May SIC, SST, SAT, GH300 and vector winds at 300mb.

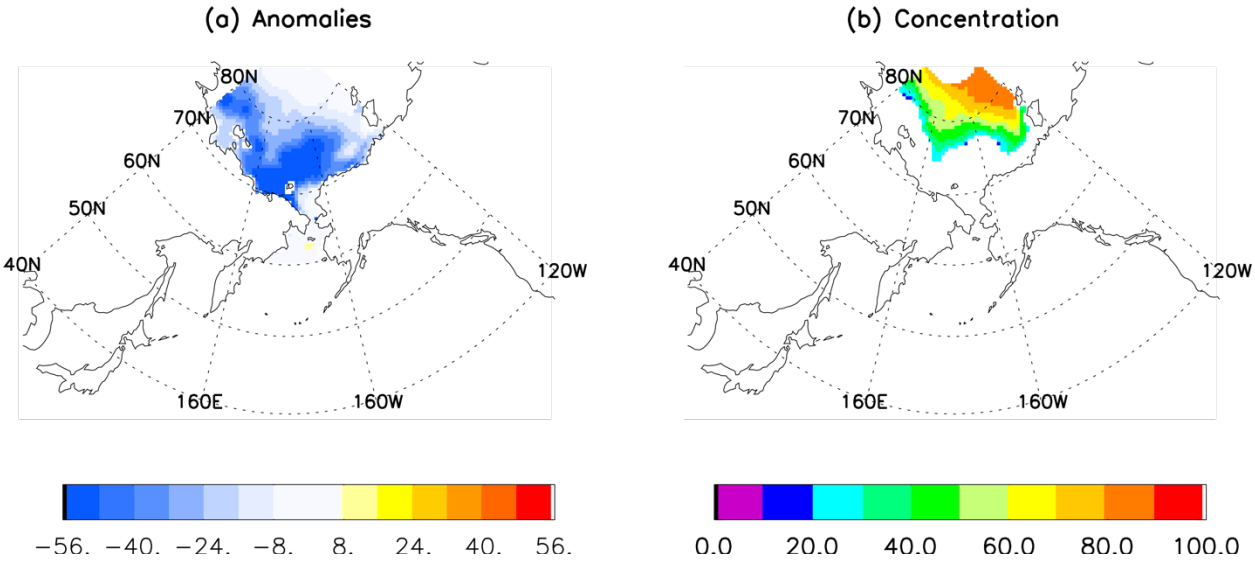

Figure 2 Four-month lead prediction of September 2020 sea ice concentration anomaly (a) and concentration (b) in the Alaskan region by a regional linear Markov model initialized with observed May SIC, SST, SAT, GPH and winds at 500mb and 200mb.

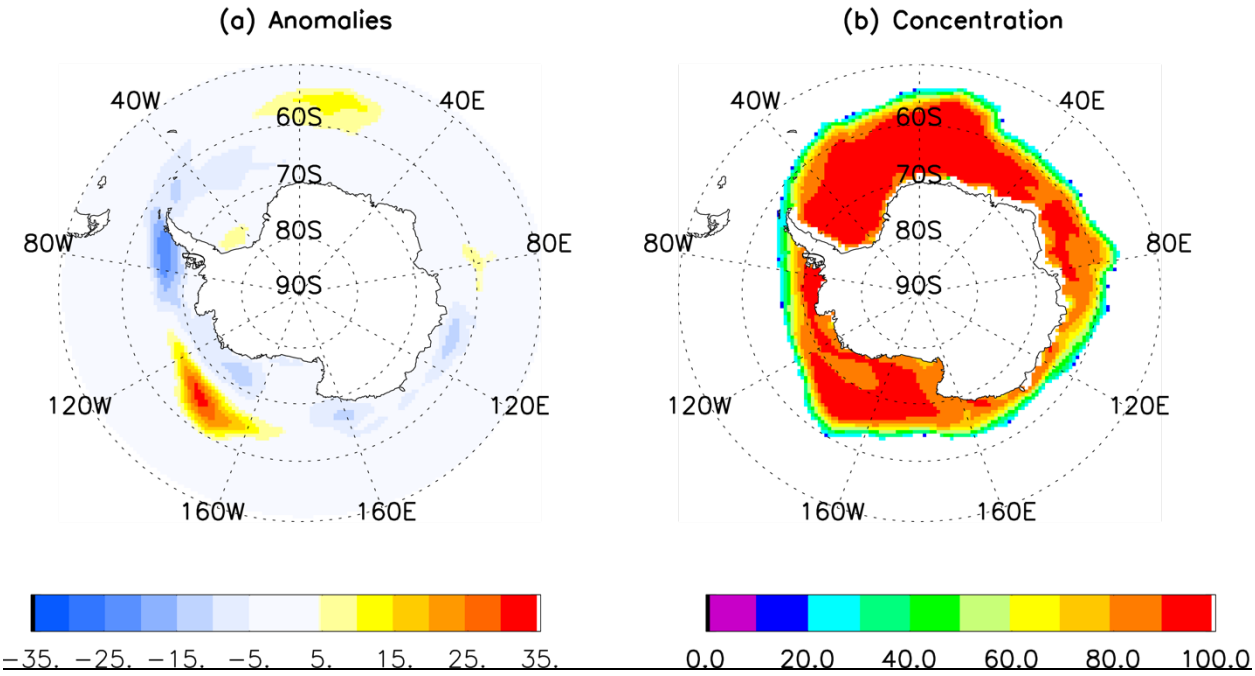

Figure 3 Four-month lead prediction of September 2020 Antarctic sea ice concentration anomaly (a) and concentration (b) by a linear Markov model initialized with observed May SIC, SAT, GH300 and vector winds at 300mb.

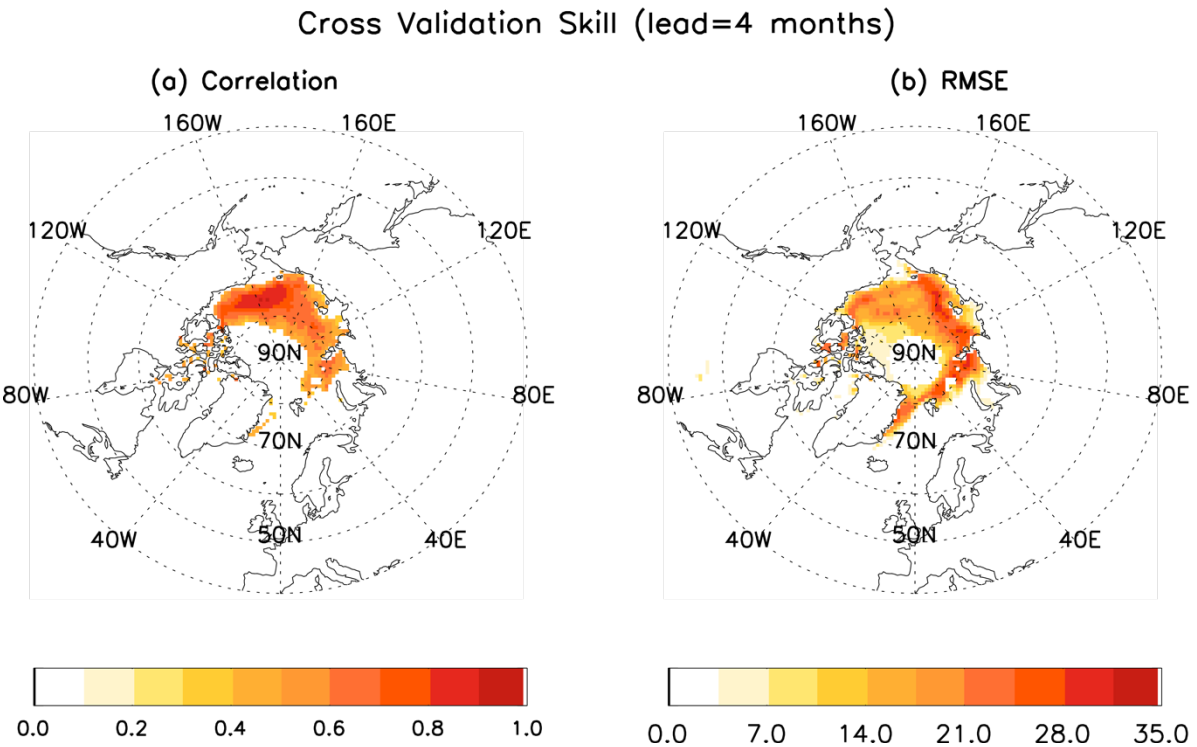

Figure 4. Cross-validated model skill measured by correlations between model predictions and observations of Arctic sea ice concentration anomalies (a) and model RMSE (b) for four-month lead prediction of September sea ice concentration. Only the correlations that pass the 95%

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.