Predicting Laptev Sea Ice Concentration via Deep Neural Networks.

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Abstract

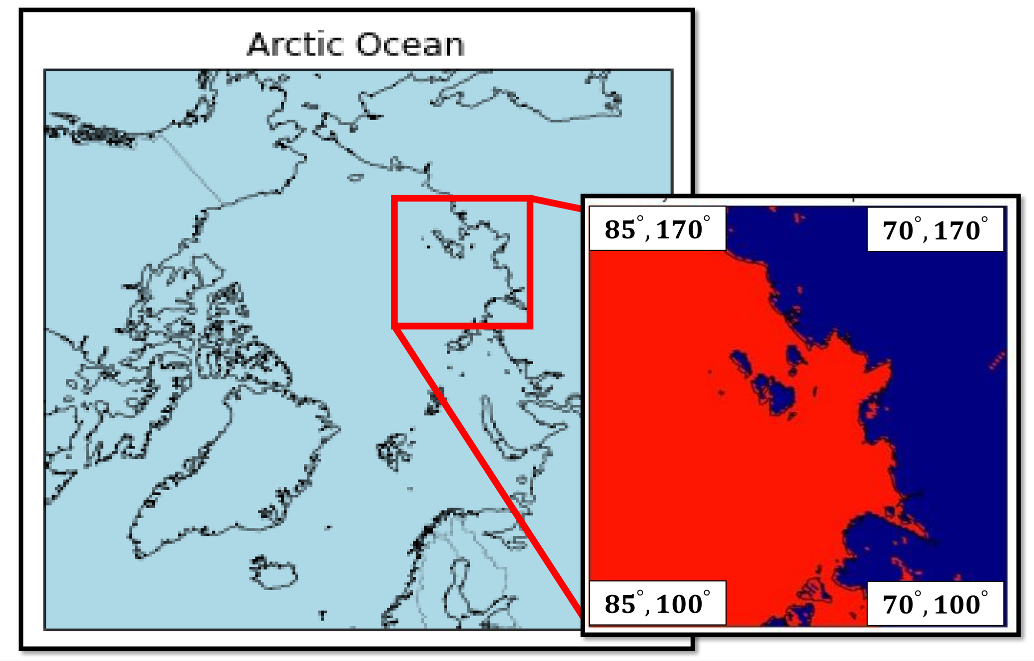
Observation of sea ice activity in the Arctic Ocean is limited due to its remote environment; therefore, as Arctic conditions change due to amplified warming and sea ice retreat new methods of sea ice prediction are necessary to forecast sea ice concentration (ESOTC, 2020). Understanding the flux of Arctic Sea ice is critical as it plays a practical role in transportation, resource extraction, and national security (N. et al., 2022). Annual ice retreat during summer melt and the progression of autumn freeze-up in the Laptev Sea contribute greatly to arctic sea ice spatial variability (Eicken et al., 1997). Therefore, focusing on the Laptev Sea is of great importance for modeling sea ice dynamics.

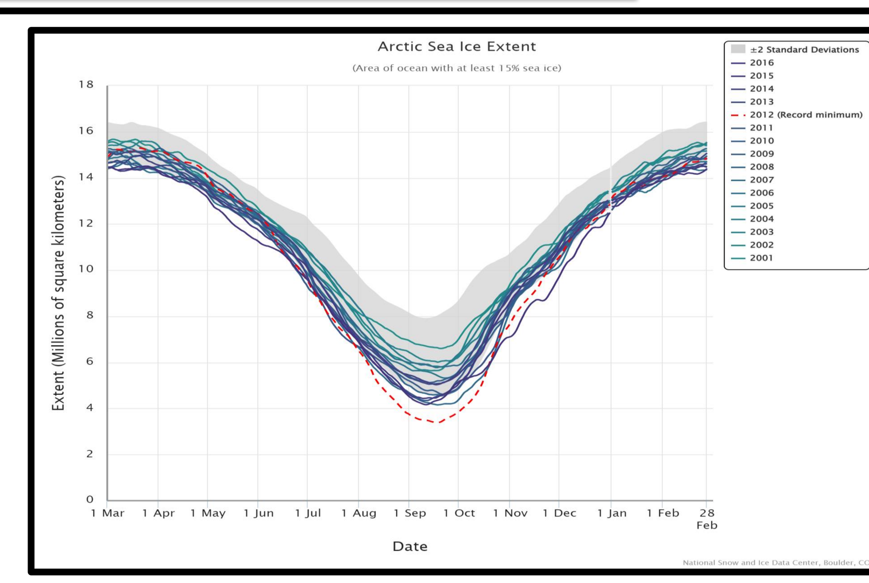
In this ongoing study, we examine polar weather research and forecasting reanalysis data in conjunction with surface data. Through statistical analysis, we derive factors that significantly impact sea ice deviation and subsequently establish correlations with those defined factors, which are then plotted and used to train a deep neural network (DNN). Correlated data is input into a DNN in order to develop projections of sea ice concentration throughout annual growth cycles between the years 2001 and 2016.

The role of DNNs in climate and polar research is still being established; thus, it is critical to pursue this approach to sea ice concentration prediction. The intention of this research is to develop a DNN foundation for sea ice prediction that can be applied to additional Arctic and Antarctic regions. The resulting Laptev DNN predictions will eventually undergo comparative analysis against actual sea ice data in order to determine sea ice variable correlations and validate the accuracy of the study's DNN predictions.

Introduction

In the isolated environment of the Arctic Ocean, sea ice dynamics play a pivotal role as indicators of climate change. This study focuses on the Laptev Sea, a region situated to provide insights into broader Arctic conditions. By examining sea ice behavior in the Laptev Sea, we aim to unravel the intricate dynamics influencing the Arctic and Antarctic regions, with the goal of advancing our understanding of climate change impacts on a global scale.





Arctic Sea Ice Extent 2001 - 2016. (1)

Methodology

Assumptions

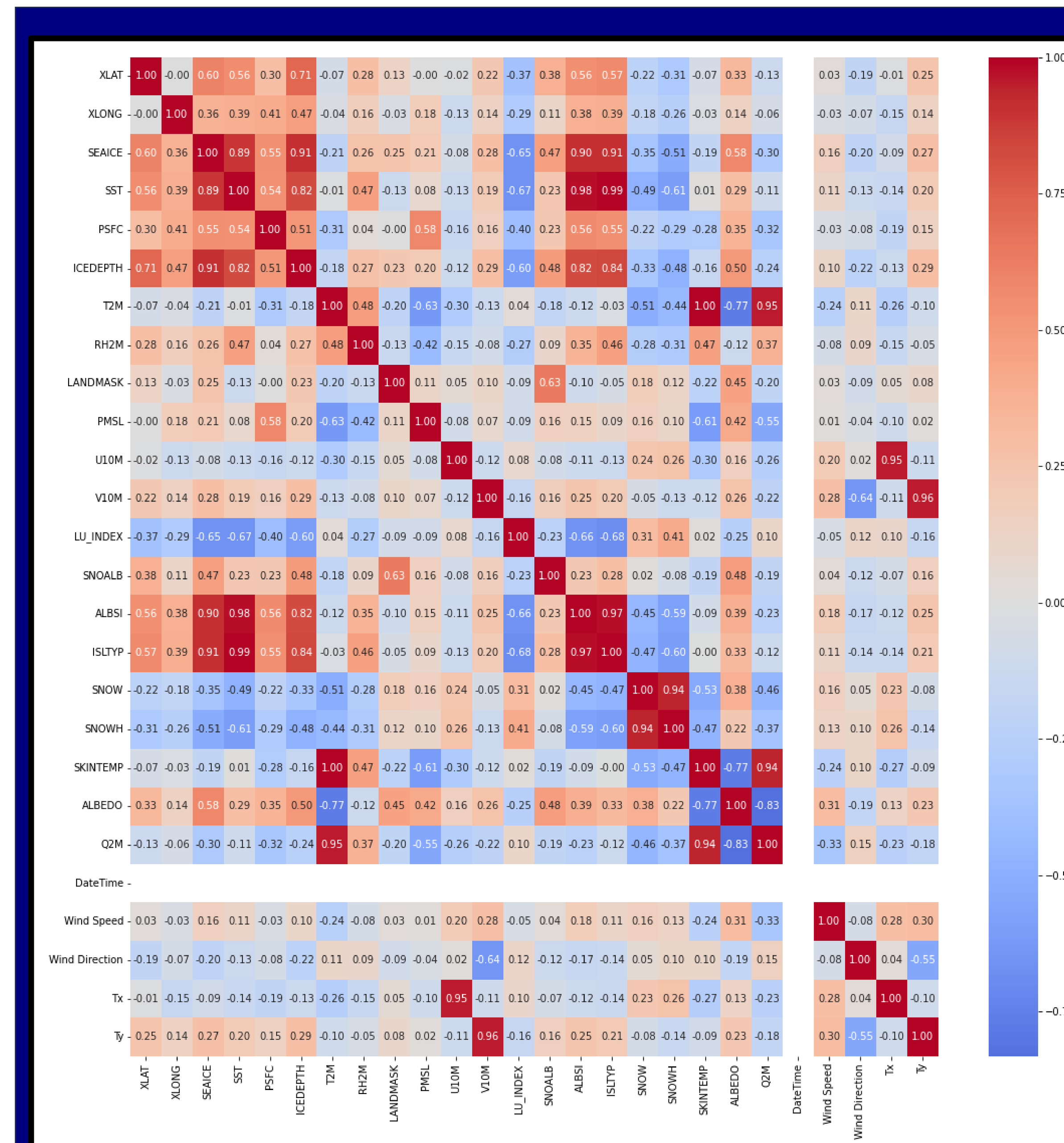
- In this study the annual sea ice cycle was assumed to be freezing period between October and February, while melting period between March and September.
- The annual minimum was determined to be in September.
- The annual maximum was determined to be in March.

Limitations

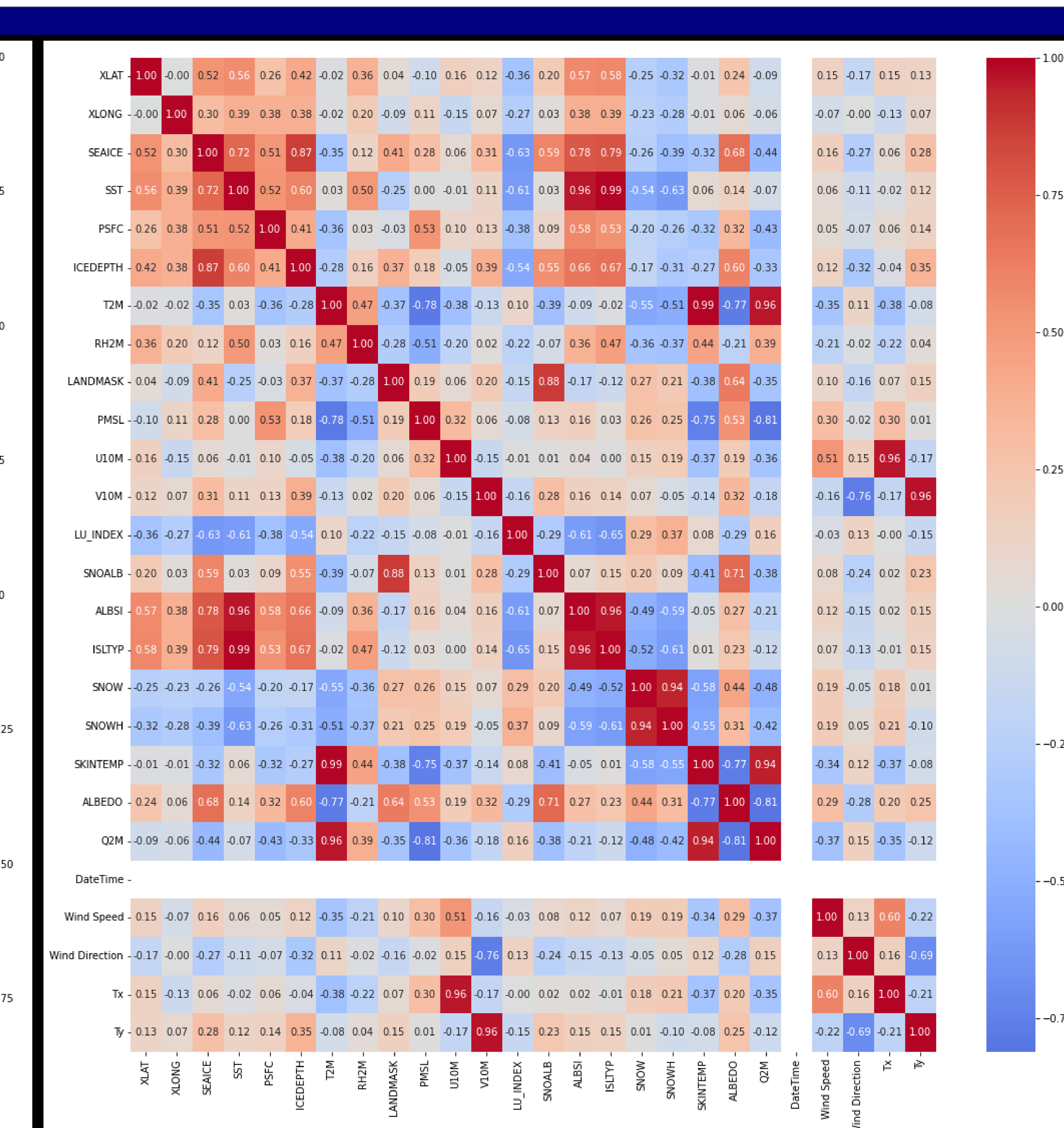
- Annual growth cycles from 2001 to 2016 as the temporal scope.
- Specific Focus on Laptev Sea
  - Coordinates used throughout study [100,170,70,85]
- Project timeline of Fall/Winter 2023 limits accuracy of model and current results.
- Time to train model and available computing power

Procedure

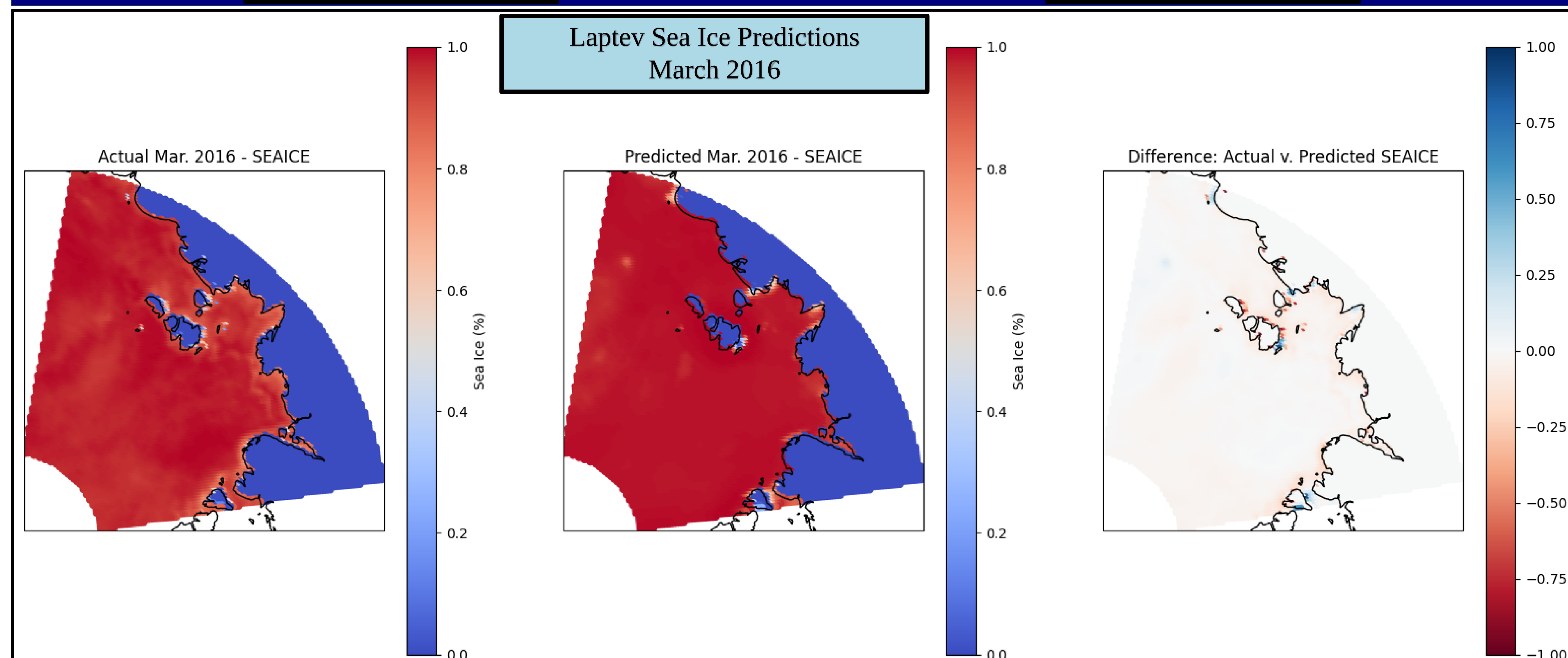
1. Statistical analysis to identify factors influencing sea ice deviation
2. Correlation establishment with identified factors
3. Using Correlations to establish DNN Model parameters
4. Train a DNN for sea ice concentration projections
5. Use DNN model to get sea ice predictions
6. Comparative Analysis against actual sea ice data by plotting projection differences

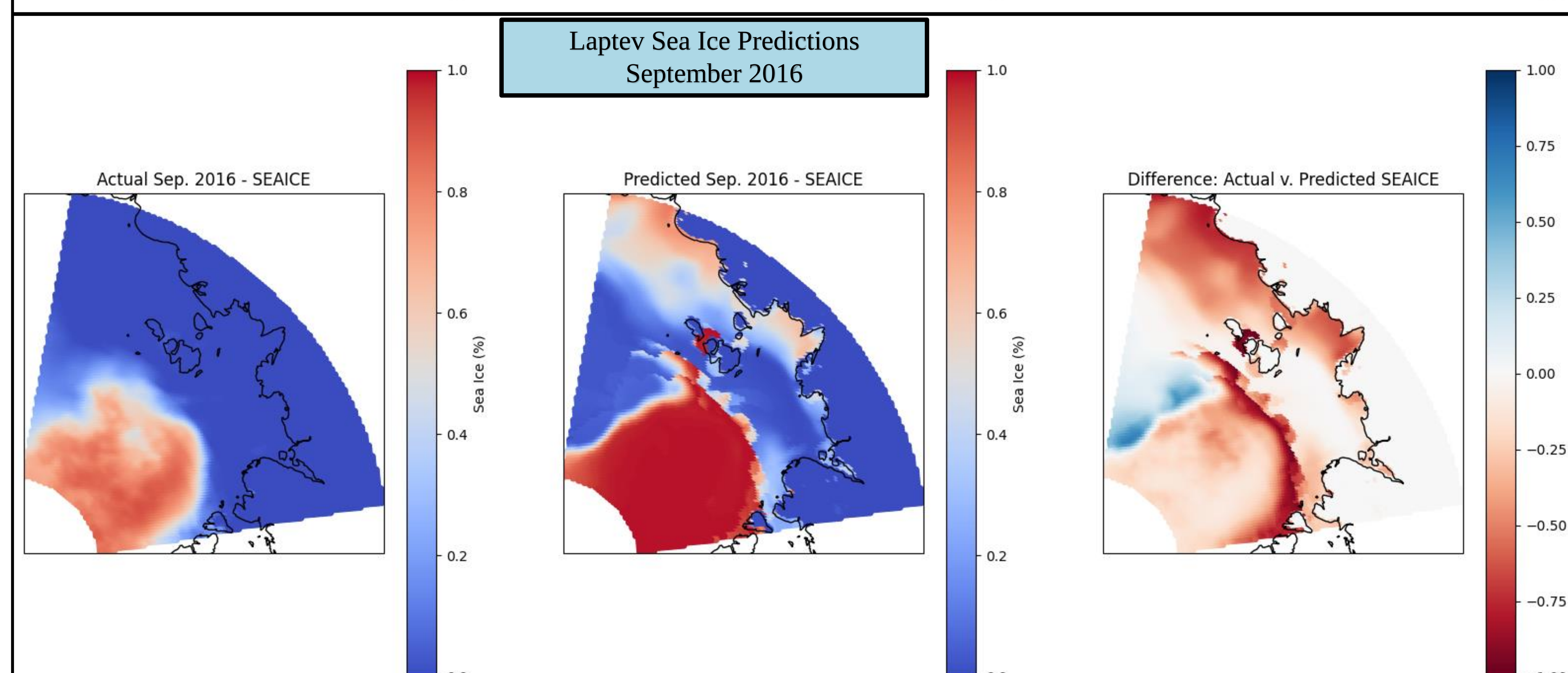


2001 Correlation Heatmap



2012 Correlation Heatmap





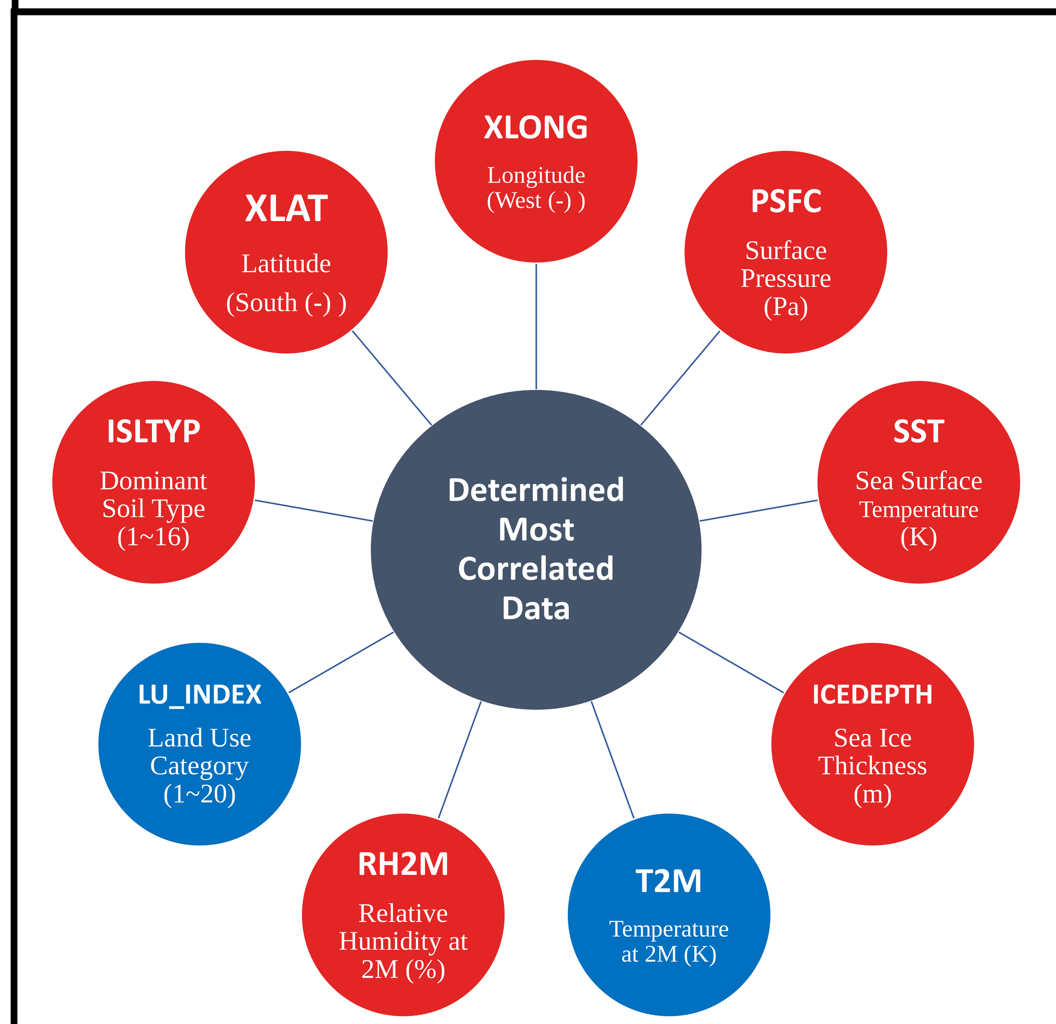
Discussion & Conclusion

Research Objective

- Addressing Arctic observational limitations through innovative approaches
- Utilizing polar weather research and forecasting reanalysis data in conjunction with surface data to project future sea ice concentration

Current Results

- The current model utilizes the features 'XLAT','XLONG,'SST','ICEDEPTH','T2M','PSFC','ISLTYP','LU_INDEX' is fed 15 years of reanalysis data, and contains a DNN density architecture of three layers (128,128,64).
- Presented are current DNN model projections for sea ice concentration during annual minimum and maximum, March and September for 2016.



Projection Validation & Error

- Comparative analysis against actual sea ice data for validation.
- Feedforward Neural Network (FNN) model projections will be compared to a Convolutional Neural Network (CNN) and Recurrent Neural Network (RNN) model projections in order to conclude the most accurate neural network for future model development.
- Current DNN Model predominately over predicts sea ice during the annual minimum, September. Sea ice projection errors for June 2016 are also less accurate due to this tendency.
- The intended model has projection errors less than 0.1 and r-squared (R2) scores close to 1.

Summary of current projection errors	March 2016	June 2016	September 2016	December 2016
Mean Absolute Error (MAE)	0.0206	0.0792	0.2168	0.0424
Mean Squared Error (MSE)	0.0034	0.0185	0.1036	0.0058
Root Mean Squared Error (RMSE)	0.0586	0.1360	0.3219	0.0765
R-squared (R2) Score	0.9817	0.8814	-0.1089	0.9669

Future Application

The primary objective of this study is to develop a DNN capable of predicting sea ice concentration in the Laptev Sea region with minimal error. The envisioned application of this predictive model extends to providing valuable insights into the dynamics of sea ice concentration in the broader Arctic domain. By achieving a high level of accuracy in sea ice predictions, the developed DNN is poised to contribute significantly to polar meteorology.

Future Research

Future research endeavors will extend the scope to encompass additional Arctic regions and the Arctic as a whole. The expansion of research is anticipated to refine the predictive capabilities of the developed model, leading to improved accuracy and reliability in forecasting sea ice concentration in the Arctic. Future research will incorporate satellite observations to enhance the accuracy of the prediction model. Additional models using Recurrent Neural Networks, (RNN), and Convolutional Neural Networks, (CNN), will be created to compare against the study's most accurate DNN model.

Intended Results

The long-term goal of this research is to establish a DNN that exhibits minimal error in predicting sea ice concentration in the Arctic. The intended results include the development of a predictive model but also the application of modifications specifically tailored to the unique characteristics of this current study on the Laptev Sea. By achieving this, the study aims to deliver a significant advancement in the field of polar meteorology, providing researchers, policymakers, and stakeholders with a powerful tool for informed decision-making. The intended results aim to contribute to a more accurate understanding of sea ice dynamics in the Arctic.

References & Data

(1) https://nsidc.org/arcticseaicenews/charctic-interactive-sea-ice-graph

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