SYMPOSIUM OP'24 ADVANCING OCEAN PREDICTION SCIENCE FOR SOCIETAL BENEFITS

Deep Learning for the Arctic: Short-Term Sea Ice Forecasts in the Kara Sea

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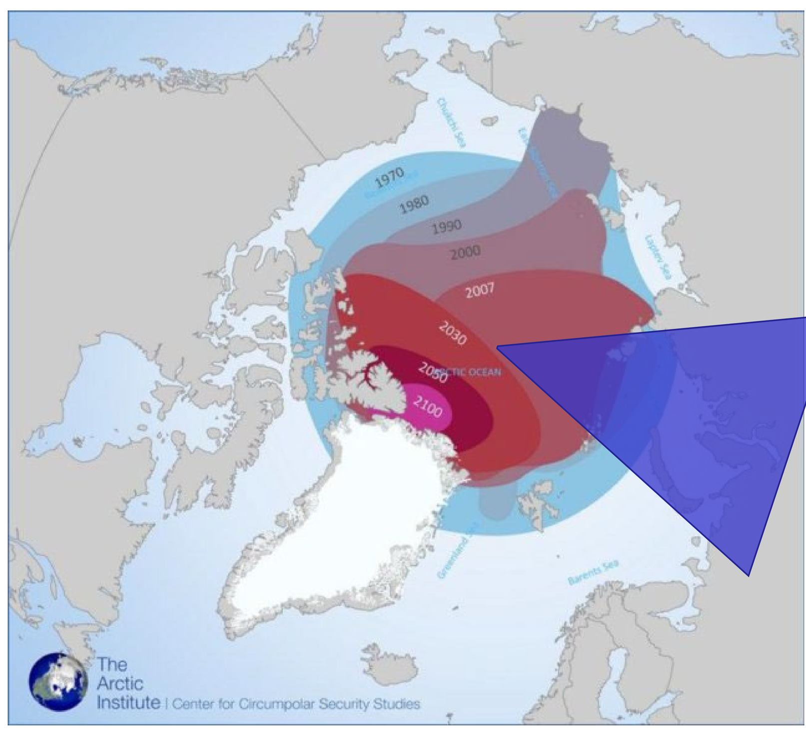
In this study, we present an innovative Artificial Intelligence-based sea ice forecasting system designed to predict sea ice concentration up to three days in advance. By leveraging satellite imagery, marine and atmospheric forecast data, our system focuses on the Kara Sea with a high spatial resolution of 0.05x0.05 degrees, continuously refines its predictions, providing reliable and timely information for decision-making in maritime operations and environmental monitoring. It is crucial for ensuring navigational safety and optimizing resource management in the Arctic region. Furthermore, the system's scalability and adaptability to other regions underscore its potential for broader application in the Arctic sea ice monitoring.

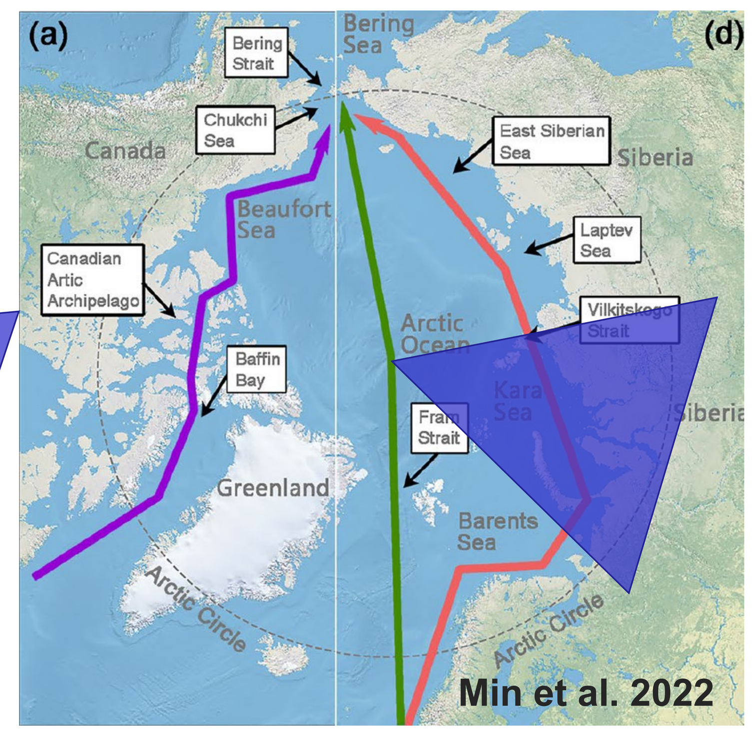
The Arctic Ocean:

- Rapidly loses perennial sea ice
- Emerging as a critical maritime route
- Requires an operational sea ice forecasting system

For the project, we choose the Kara Sea because it has:

- Intense sea ice dynamics
- Significant economic importance
- Complex environmental interactions and sources of variability

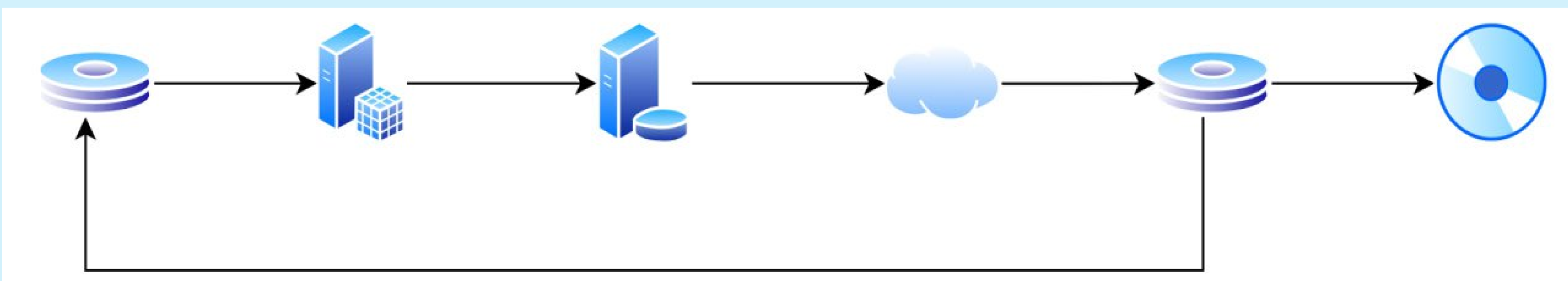




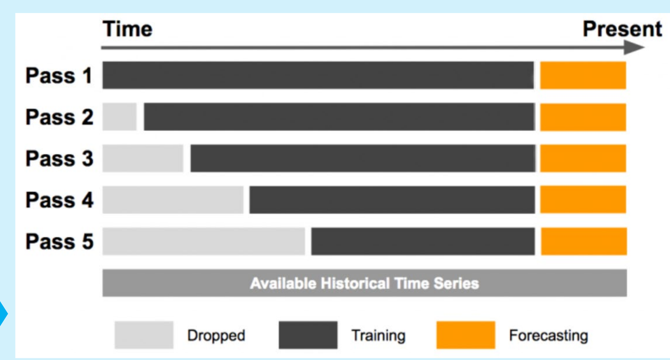
Methods

Evolutionary Programming

Generation of an initial population of neural networks → Training the population of models on the training dataset → Evaluating the models on the test dataset → Sending neural networks with their evaluations and genetic rules to the LLM → Generation new architectures using the LLM → Stopping upon reaching the required model accuracy



Model Ensembling



The top 10 neural networks are selected based on accuracy and diversity.

Each model is trained on five time segments of the dataset, each with a different distance to the present time.

$$y_{\mathrm{f}} = \sum_{i=1}^{N} w_i \cdot \hat{y}_i$$

Finally, individual models with predictions $\hat{y}_i$ are given weights (ω_i) proportional to rolling estimates of their accuracy and ensembled into y_f

Data

Copernicus Marine Data Store (CMEMS):

✓Global Ocean Physics Analysis and Forecast (0.083° × 0.083°, 1 Nov 2020 to now)
✓Global Ocean Physics Reanalysis (0.083° × 0.083°, 1 Jan 1993 to 31 Dec 2020)
✓Arctic Ocean - High resolution Sea Ice Concentration and Sea Ice Type (1 × 1 km, 1 Dec 2020 to now)
✓Global Ocean - Arctic and Antarctic - Sea Ice Concentration, Edge, Type and Drift (OSI-SAF) (10 × 10 km, 1 March 2005 to present)
✓Global Ocean Sea Ice Concentration Time Series REPROCESSED (OSI-SAF) (25 × 25 km, Since 1 Jan 1979)
✓Global Ocean OSTIA Sea Surface Temperature and Sea Ice Analysis (0.05° × 0.05°, since 1 Jan 2007)
✓Global Ocean OSTIA Sea Surface Temperature and Sea Ice Reprocessed (0.05° × 0.05°, 1 Oct 1981 to 31 May 2022)

Copernicus Climate Data Store (CDS):

✓ERA5 (0.25° x 0.25°, 1940 to present)

Variables for the research: sea ice concentration*, sea ice thickness, sea ice drift*, sea water temperature, salinity, dynamics, SST*

*target variables

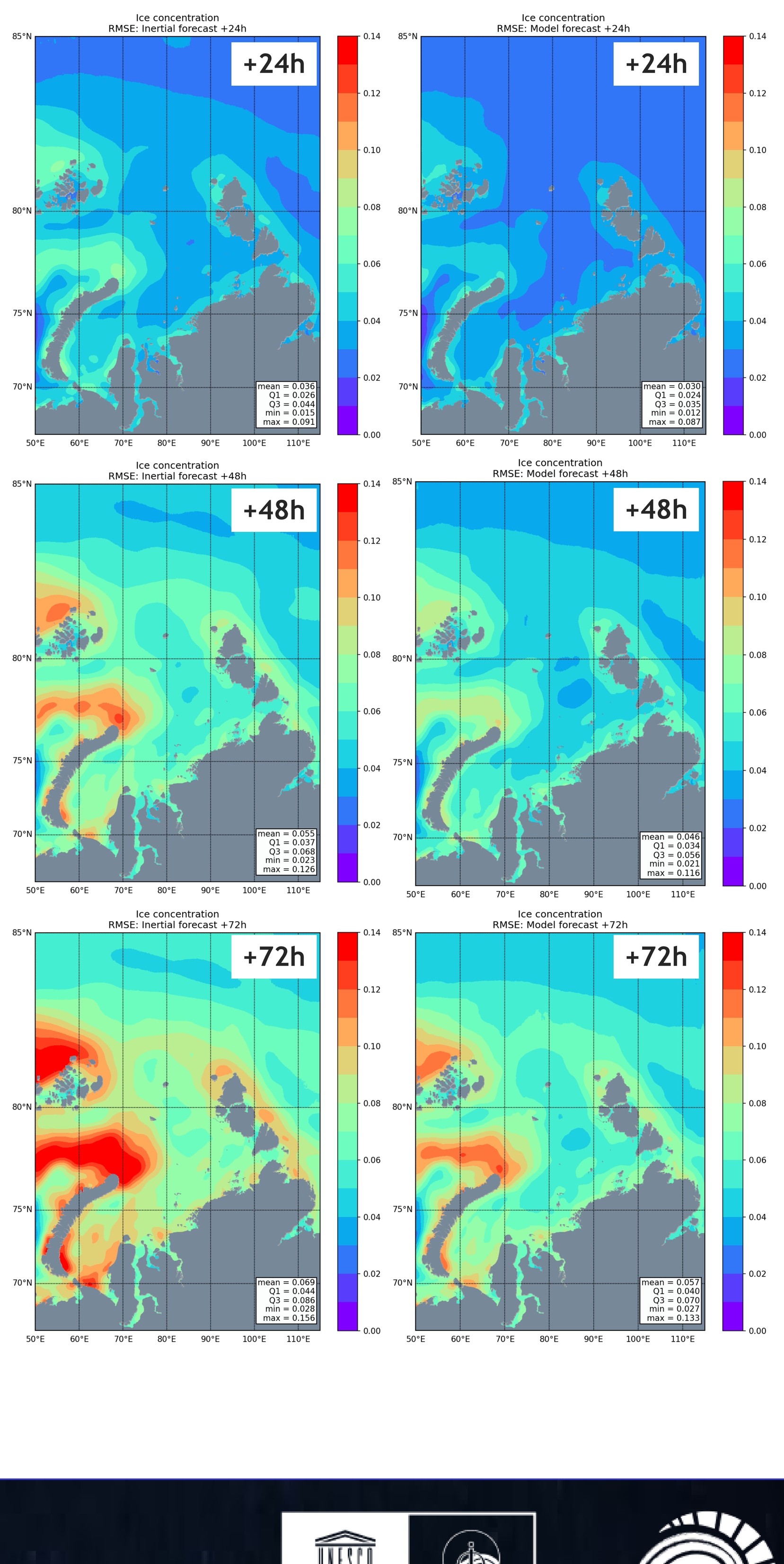
Acknowledgments:

We acknowledge the use of data from the ERA5 dataset (Hersbach et al., 2023) provided by the Copernicus Climate Change Service (C3S) Climate Data Store. We thank the EU Copernicus Marine Service for providing essential datasets (DOIs: 10.48670/moi-00016, 10.48670/moi-00021, 10.48670/moi-00122, 10.48670/moi-00134, 10.48670/moi-00136, 10.48670/moi-00165, 10.48670/moi-00168).

Accessed on August 30, 2024.

Results and Conclusion

Inertial RMSE | Ensemble RMSE



RMSEs for inertial and ensemble sea ice concentration forecasts indicate that our ensemble system consistently outperforms the inertial forecast, which is essential for accurate short-term sea ice prediction, and maintains stability throughout the forecast period. Correlation coefficients and bias metrics confirm these findings.

The next steps of the research include:

- Further model verification
- Integration of traditional numerical hydrodynamics with neural network models and development of Physics-Informed Neural Networks (PINNs),
- Development of a data assimilation module for neural network models
- Extension of the forecasting system to a larger domain

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