Norwegian Meteorological Institute

Regional Sea Ice predictions in northern Norway, Svalbard and the Barents Sea using Deep Learning

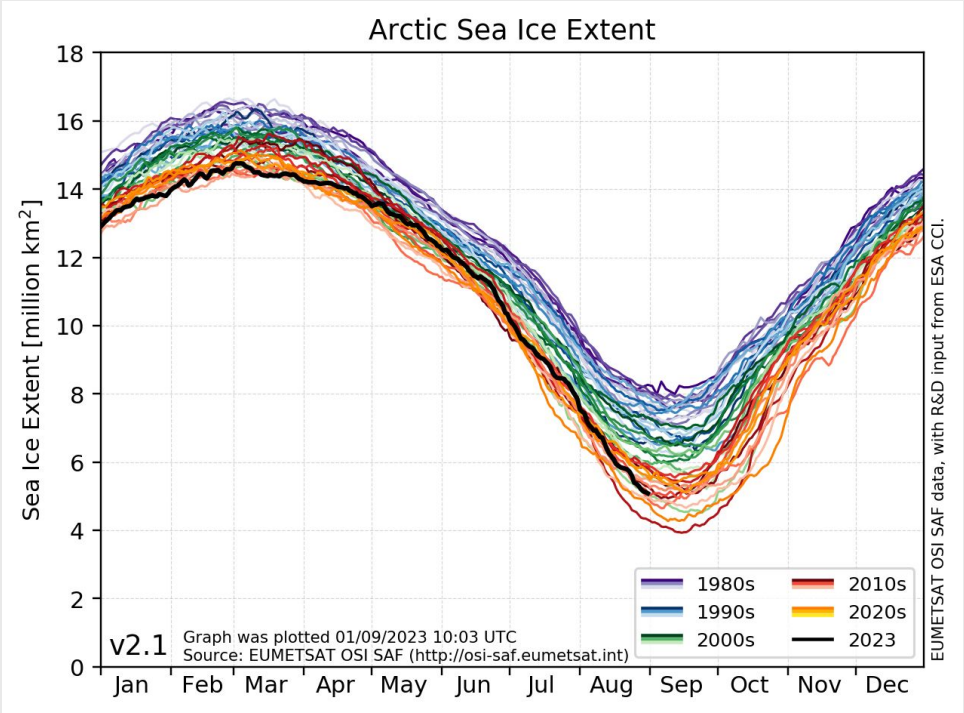
Are Frode Kvanum

04.11.2024

SuperIceWorkshop - Frascati, Italy

Problem description

- Arctic sea ice is retreating, socio-economic interest and activity in the Arctic is increasing
- Regional scale ice-condition forecasting provide valuable information to maritime operators
- Precise ice-cover information is critical for accurate Arctic weather forecasts.



Norwegian Meteorological Institute

Weather forecasts are sensitive to sea ice cover

- Different sea-ice products can lead to T2M variations of up to 5°C in AROME Arctic
- The atmospheric response is not only local, differences can develop hundred of kilometers away from the sea ice

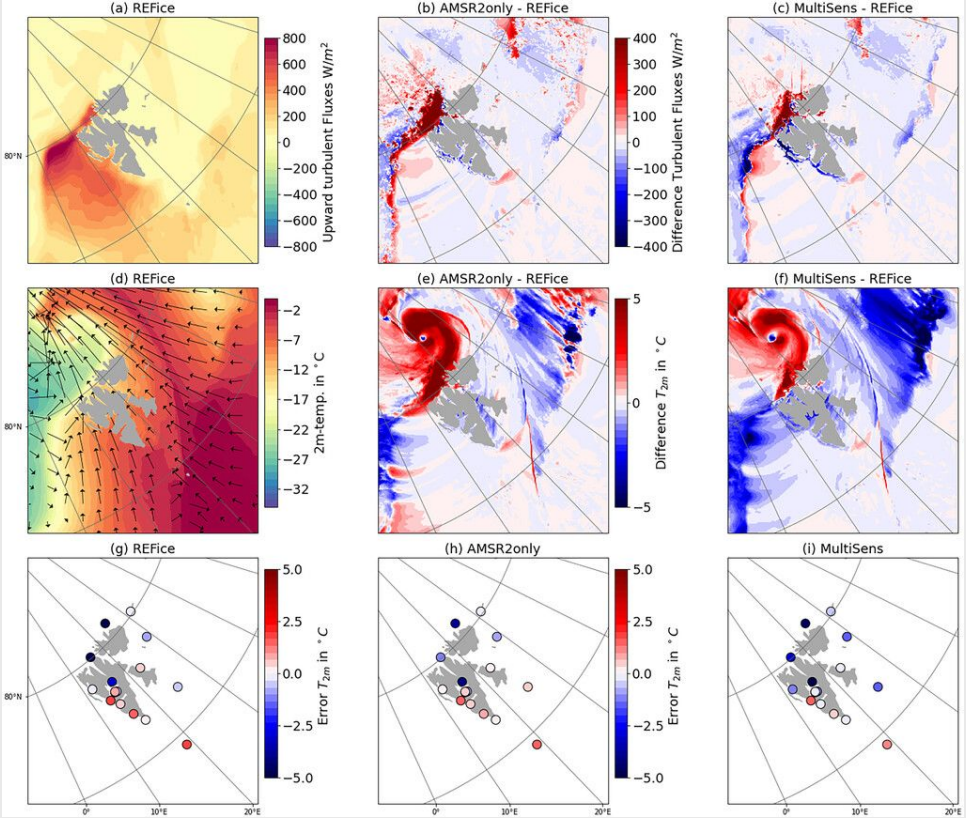
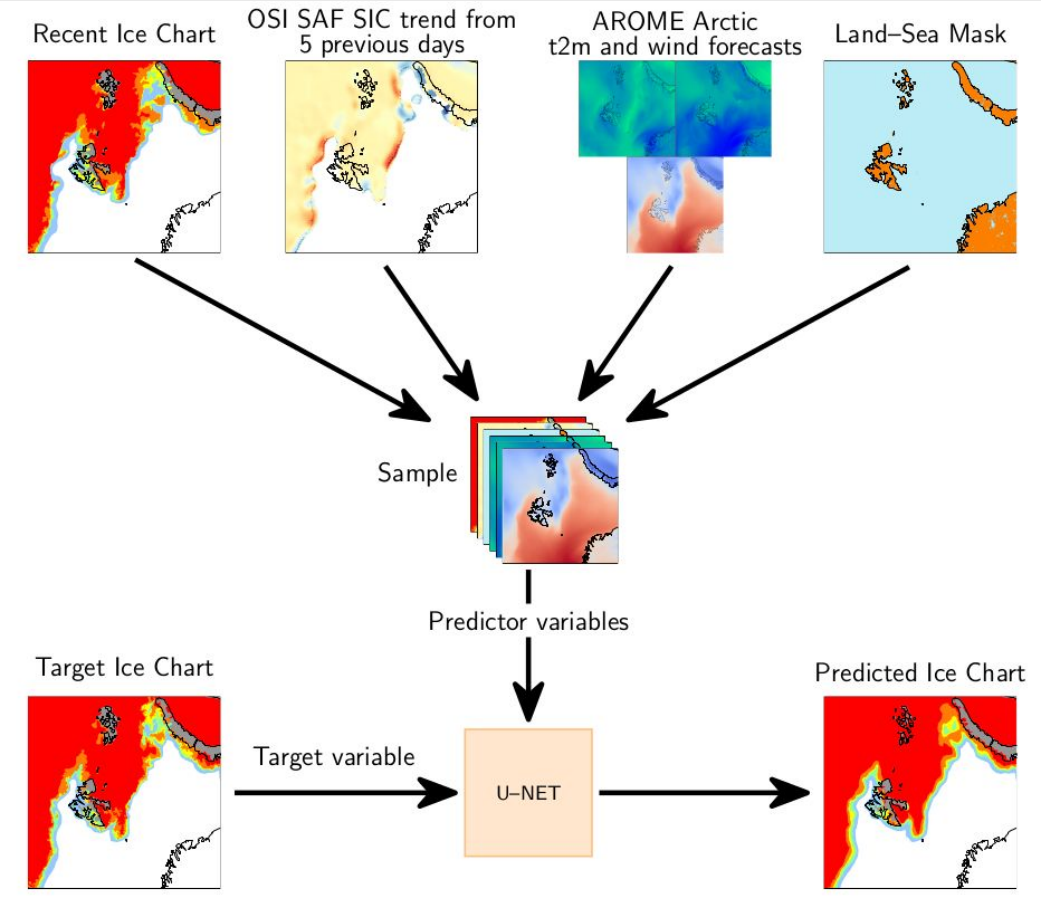


Figure from: Müller, M., Batrak, Y., Dinessen, F., Grote, R., and Wang, K.: Challenges in the Description of Sea Ice for a Kilometer-Scale Weather Forecasting System, Weather and Forecasting, 38, 1157–1171, https://doi.org/10.1175/WAF-D-22-0134.1, 2023.

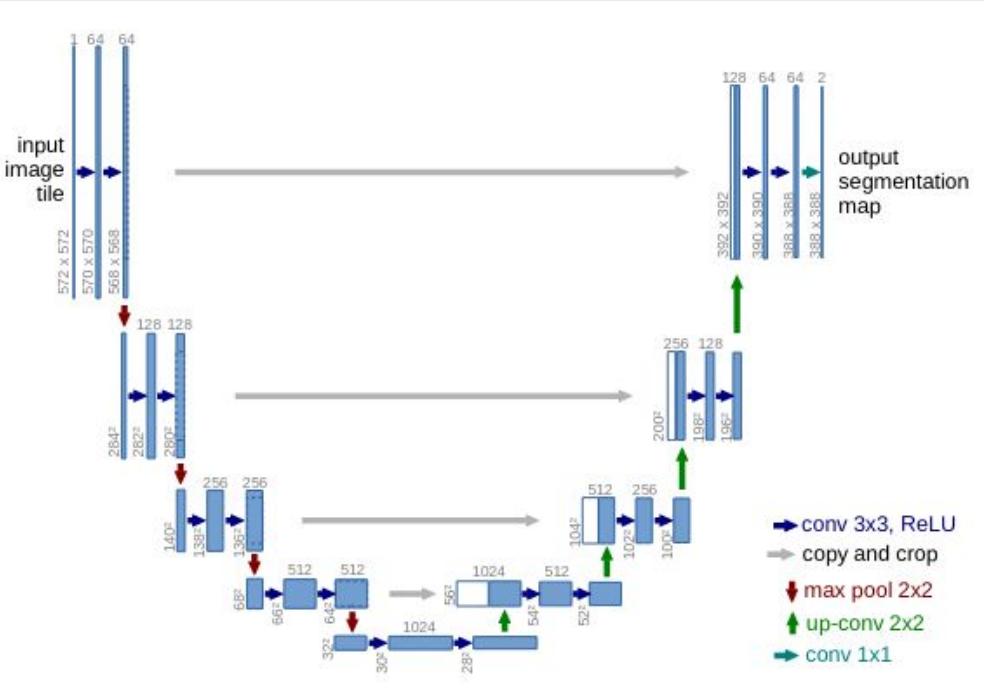
Norwegian Meteorological Institute

Developing a short-term (3 days) and high-resolution (1 km) regional sea ice prediction system (Kvanum et al., 2024)

- **Predictors:**
  - Latest ice chart
  - Sea ice concentration trend from OSI-SAF
  - AROME-Arctic weather forecasts
  - Land-Sea mask
- **Target variable:**
  - Ice charts from the Norwegian Ice Service



Deep learning model implementation, U-Net



- Predicting cumulative contours

$$c_{i,j}^{n} = \begin{cases} 1 & \text{if } s_{i,j} \geq k_n \\ 0 & \text{if } s_{i,j} < k_n \end{cases}$$

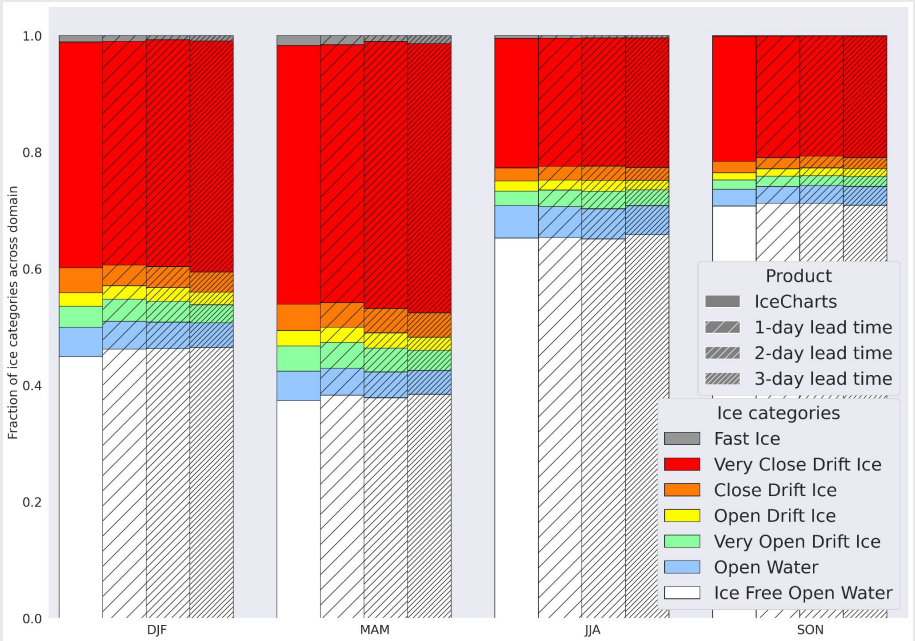
- Separate output layer for each cumulative contour (shared decoder)

Ronneberger, O., Fischer, P., and Brox, T.: U-Net: Convolutional Networks for Biomedical Image Segmentation, in: Lecture Notes in Computer Science, pp. 234–241, Springer International Publishing, https://doi.org/10.1007/978-3-319-24574-4_28, 2015.

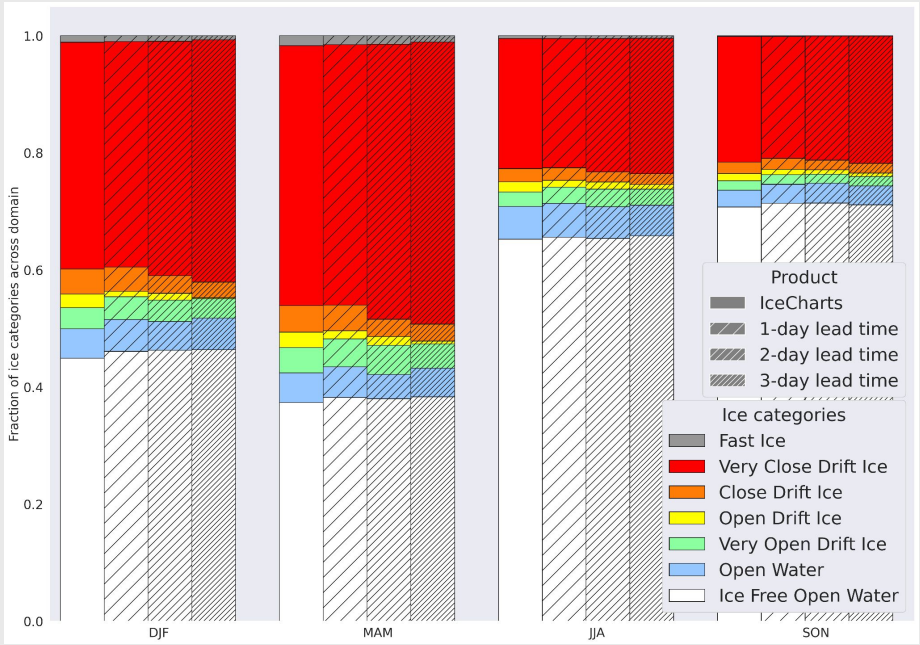
Norwegian Meteorological Institute

Target reformulation into cumulative contours

Cumulative contours

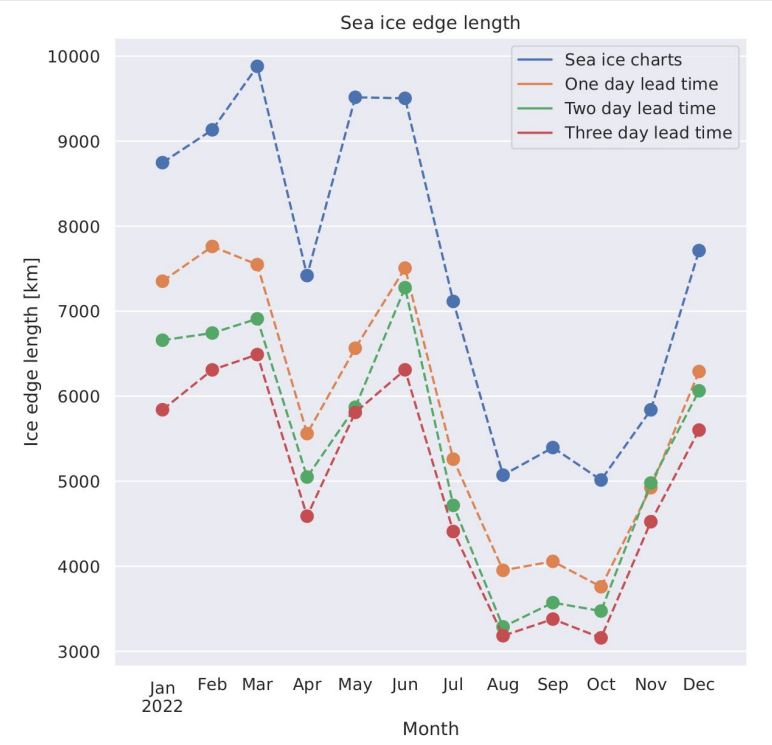


Single output, multiple labels

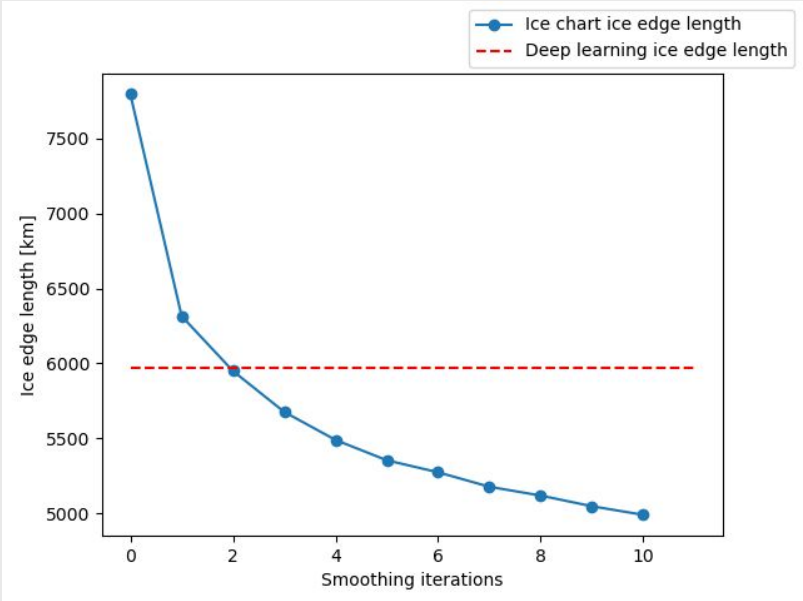


Norwegian Meteorological Institute

Predicting with the deep learning model

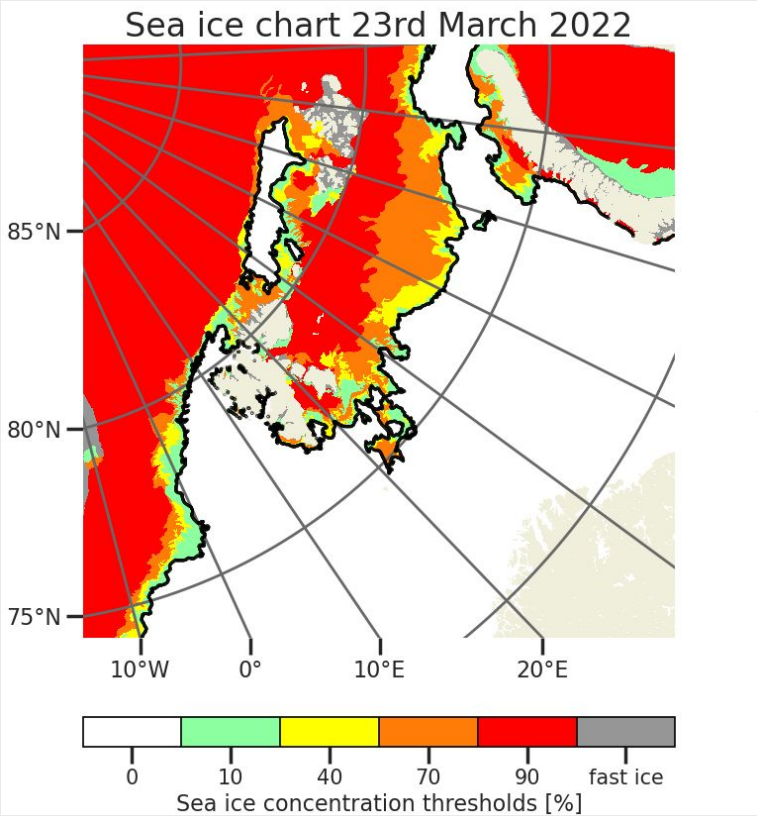


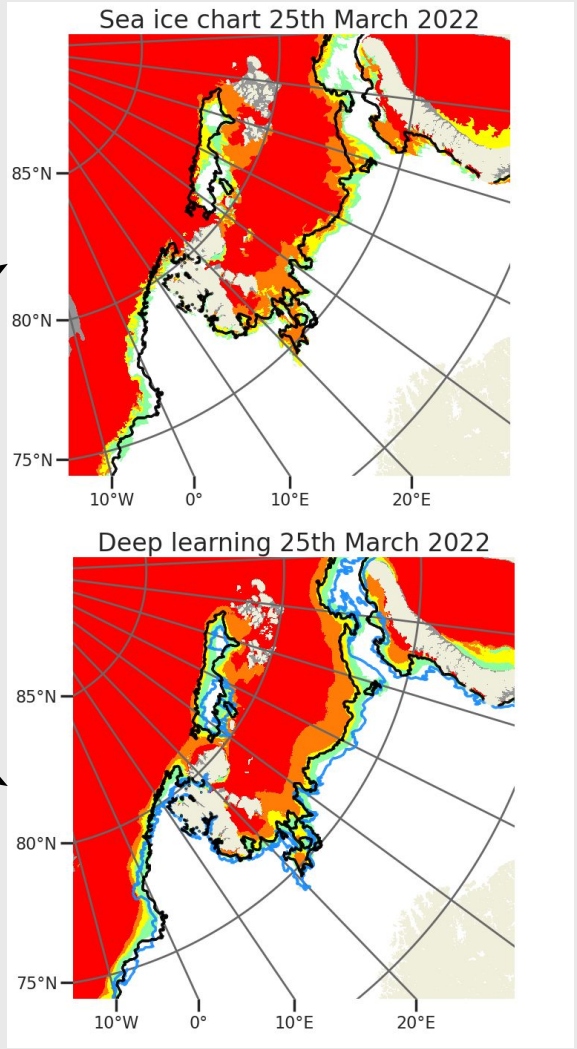
- Progressively shorter ice edge
- Blurrier forecasts at longer lead times



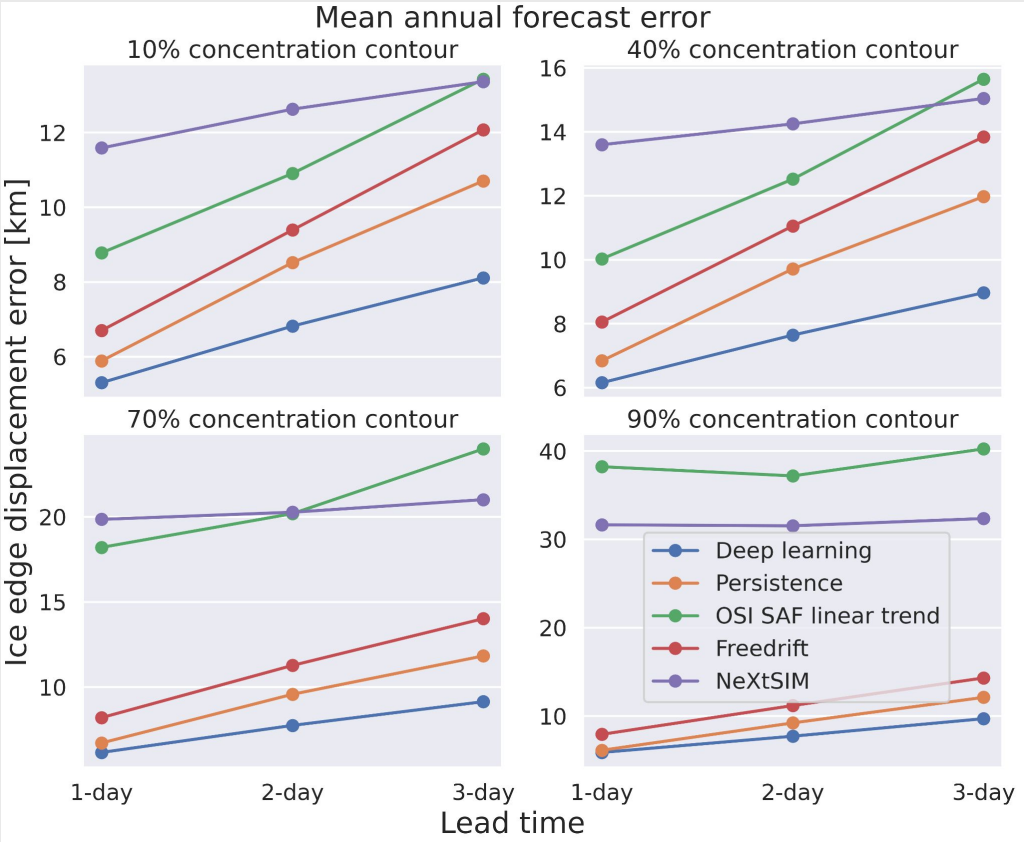
Norwegian Meteorological Institute

Predicting with the deep learning model





Forecast intercomparison (annual mean 2022)



- The deep learning forecasts achieves the lowest ice edge displacement error (mean) for all considered sea ice categories
- Consistent improvement against persistence, deep learning forecasts exerts some level of skill

Norwegian Meteorological Institute

Sub-daily regional sea ice drift forecasting with regression trees

- Predictors:
  - Buoy trajectories from IABP buoys (point based regression)
  - Wind speed -and direction from AROME Arctic forecasts
  - SIC from AMSR2 Passive Microwave observations
  - Geographic information
    - distance/angle to land
    - sector angle

- Train: 2016 - 2022, Test: 2023
- Fit Random Forest and XGBoost estimators

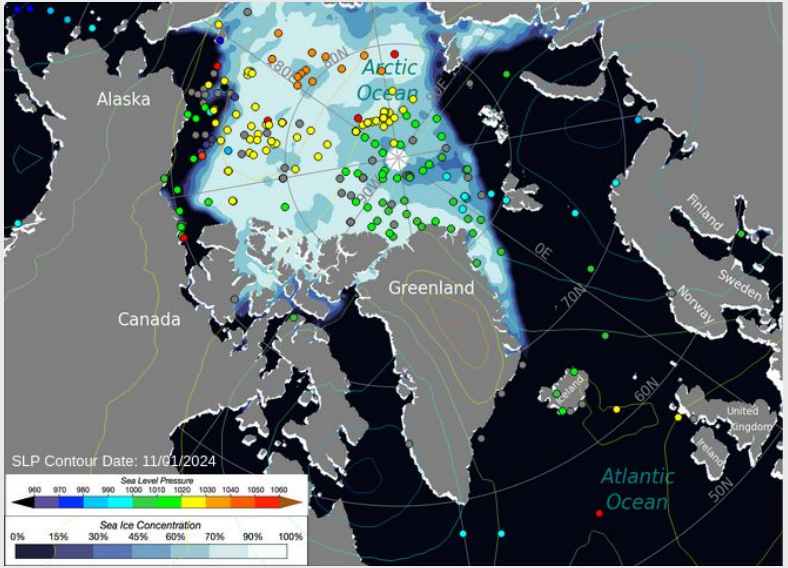
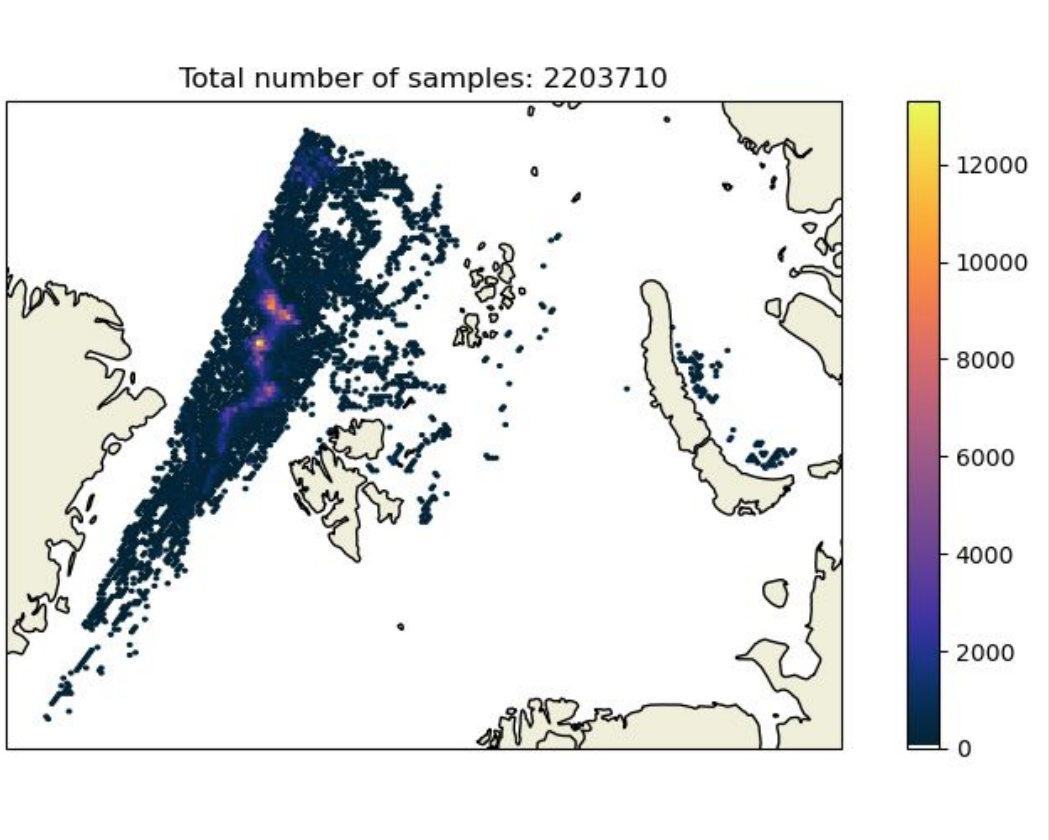


Figure from: https://iabp.apl.uw.edu/IABP_Maps.html
(Downloaded 02/11-24)

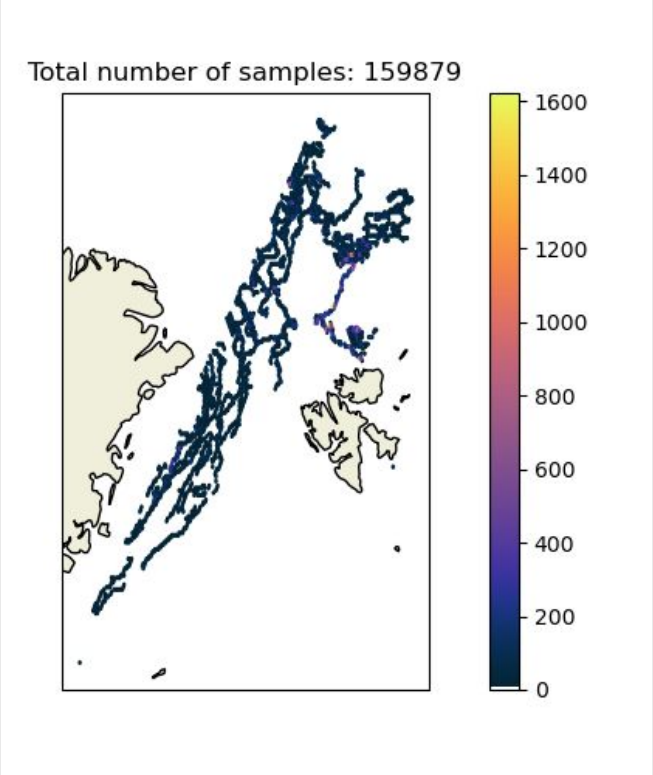
Norwegian Meteorological Institute

Sub-daily regional sea ice drift forecasting with regression trees

Training samples (2016 - 2022)

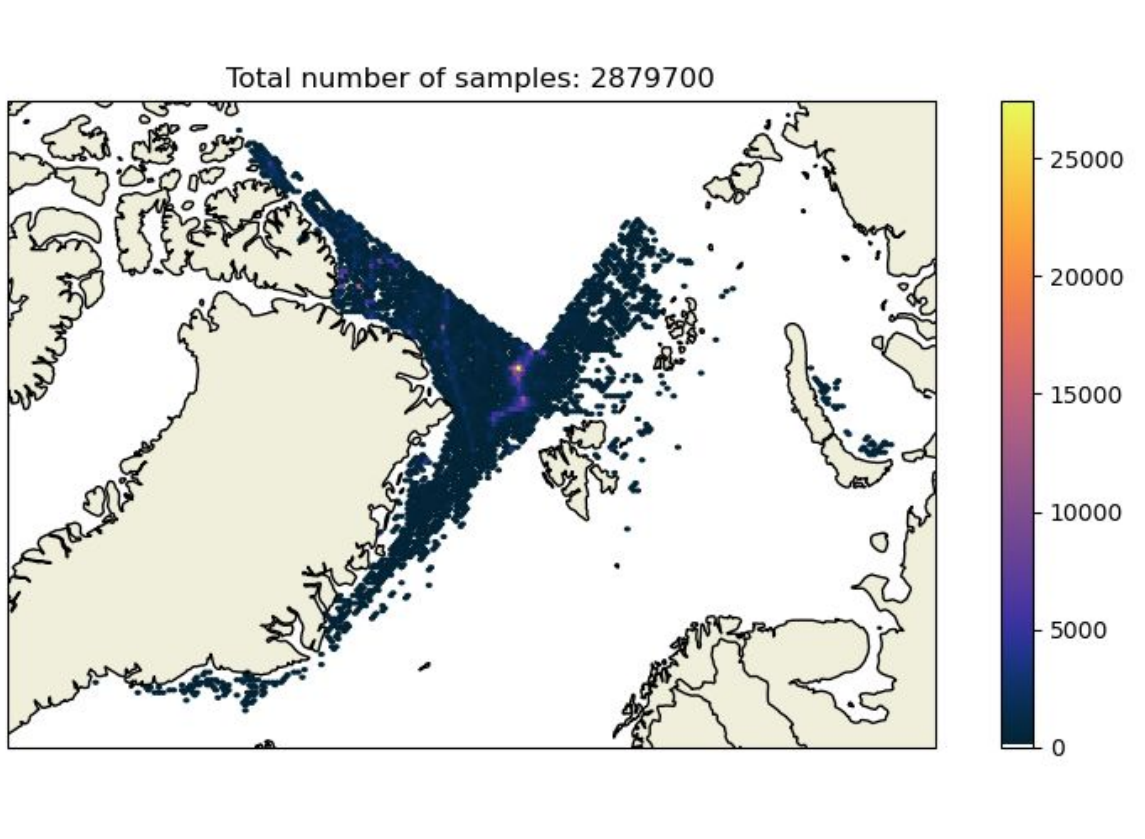


Test samples (2023)



Norwegian Meteorological Institute

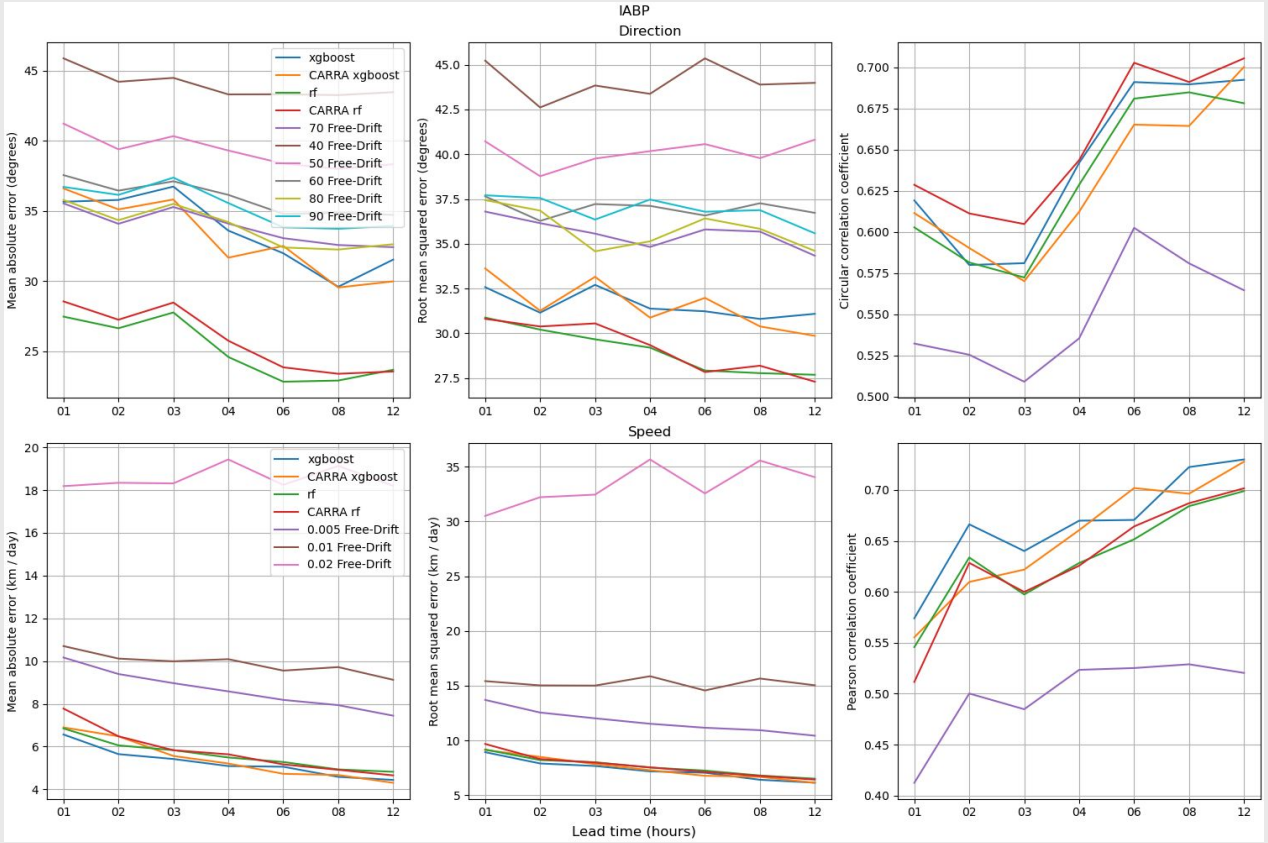
Sub-daily regional sea ice drift forecasting with regression trees
Regional reanalysis



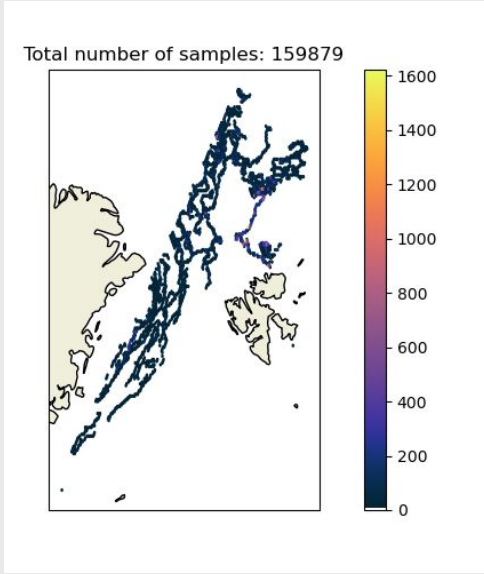
- Replace AROME Arctic and Barents domain with Copernicus Arctic Regional Reanalysis
- Extend training period (2010 - 2023) and domain (CARRA West + East)

Norwegian Meteorological Institute

Sub-daily regional sea ice drift forecasting with regression trees
Preliminary results

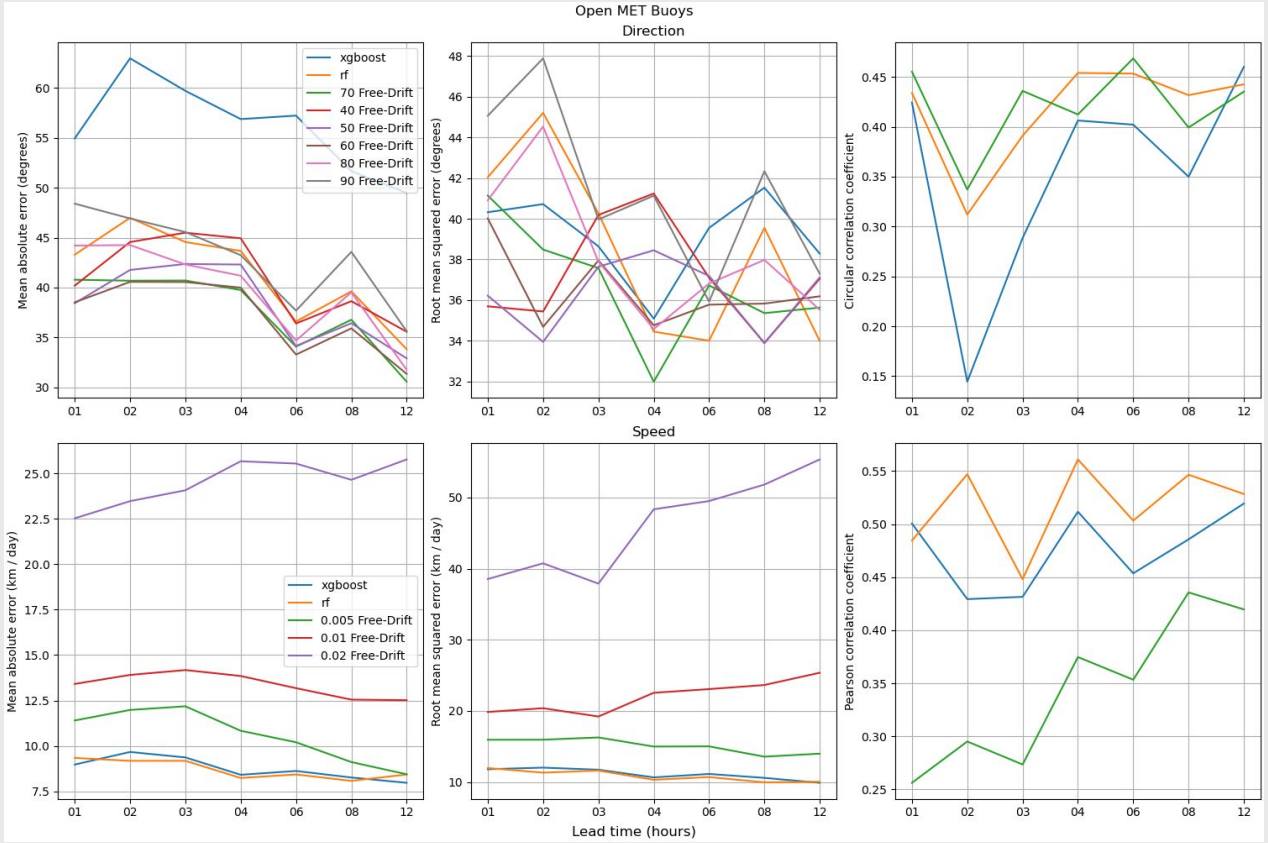


Test samples (2023)

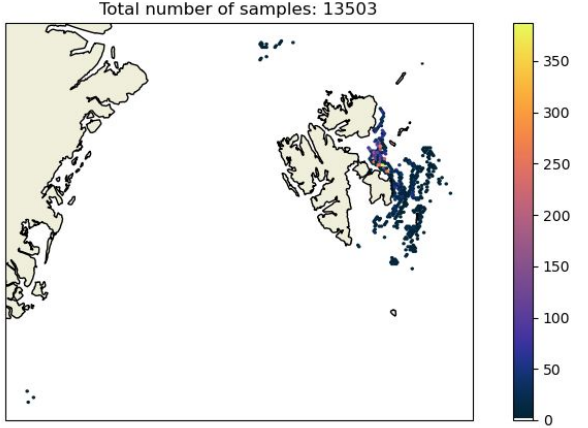


Norwegian Meteorological Institute

Sub-daily regional sea ice drift forecasting with regression trees
Comparison with OpenMETBuoys

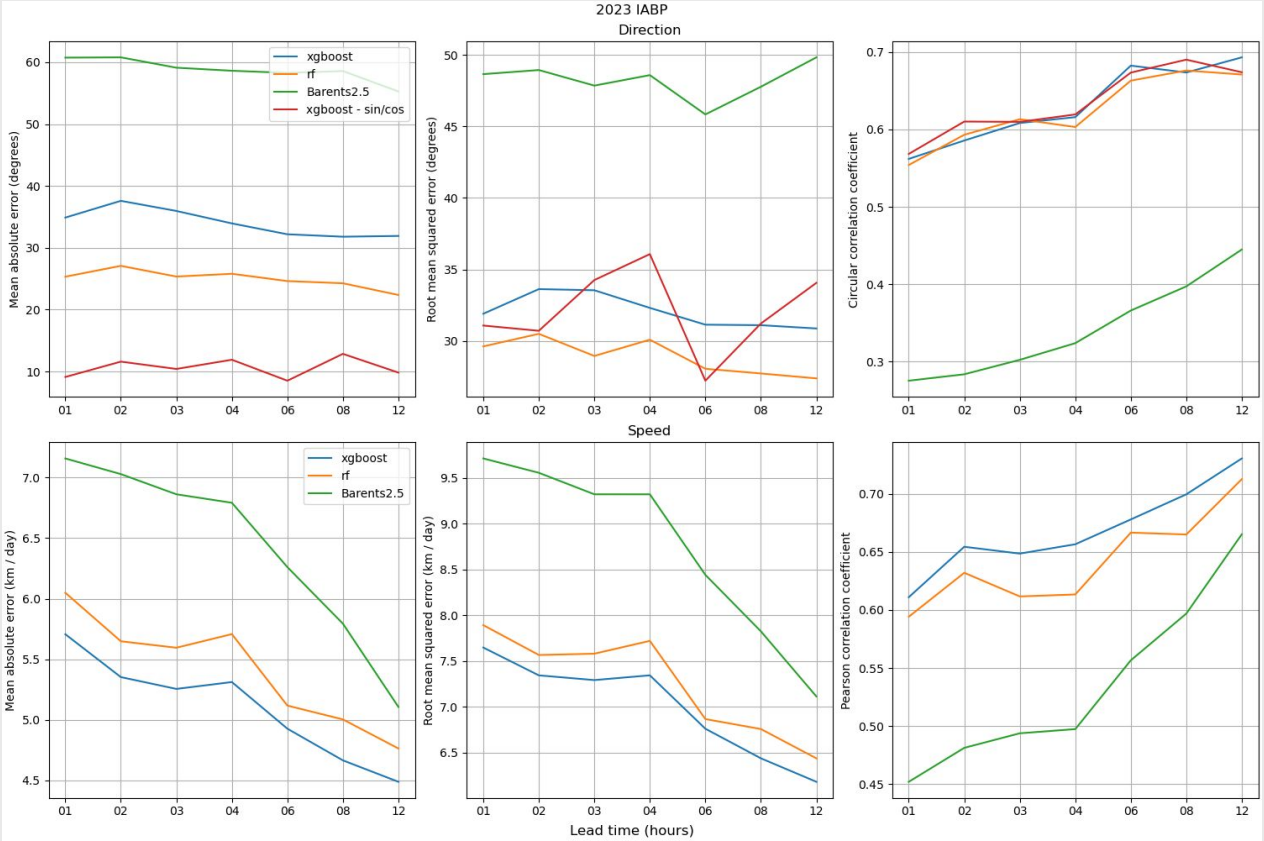


OpenMETBuoys
(2018 - 2022)

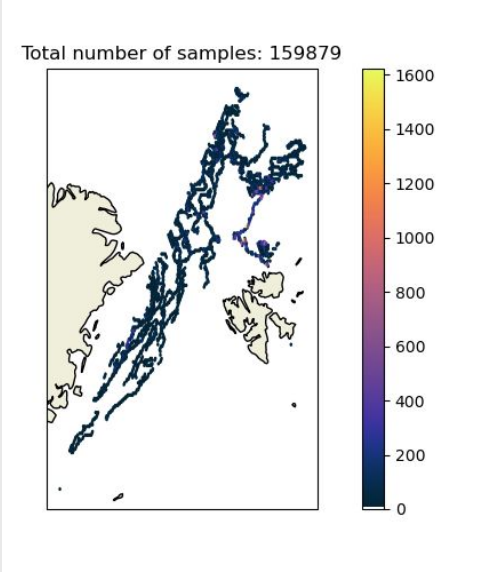


Norwegian Meteorological Institute

Sub-daily regional sea ice drift forecasting with regression trees
Comparison with Barents2.5



Test samples (2023)



Norwegian Meteorological Institute

Summary

- Lightweight machine learning based models demonstrate predictive skill considering sea ice concentration and drift for short lead times
- Input and predictions are restricted to a limited model domain
- Updates to operational forecasting systems can systematically alter input data over time
- AROME Arctic currently have a static sea ice concentration, **ongoing work** to couple numerical weather forecasts with machine learning sea ice forecasts to achieve a dynamic sea ice cover

contact: arefk@met.no

doi: 10.5194/egusphere-2023-3107 (Kvanum 2024, under review)