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Improving short term sea ice concentration forecasts using deep learning

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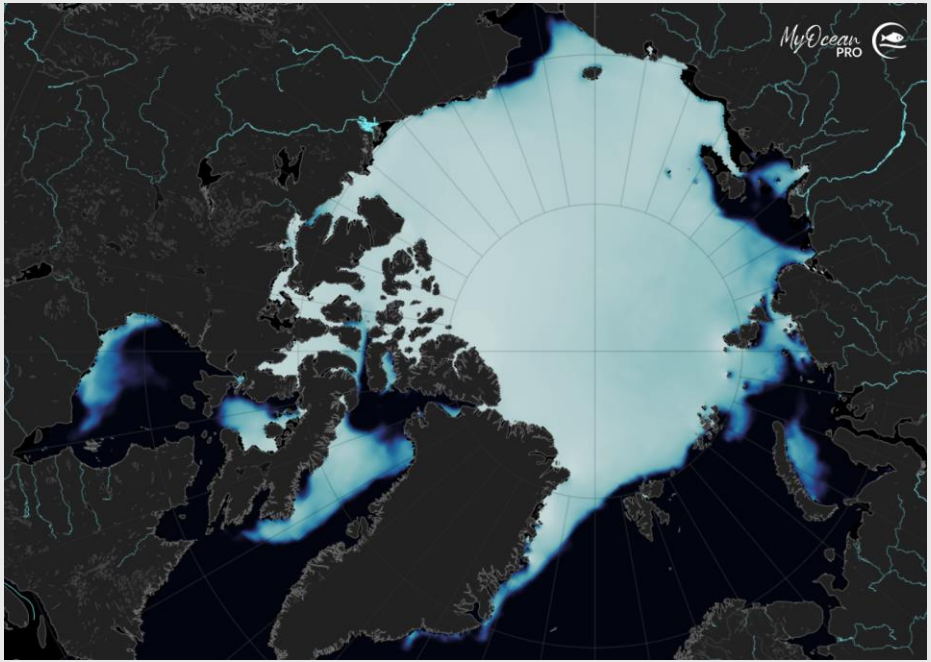
The COSI project (CMEMS, 2022-2024)



- **Main objective:**
  - *Improve 10-day pan-Arctic sea-ice concentration forecasts from TOPAZ4 using machine learning*
- **Secondary objective**
  - *Develop a new satellite-based Pan-Arctic sea-ice concentration product at 5 km resolution*

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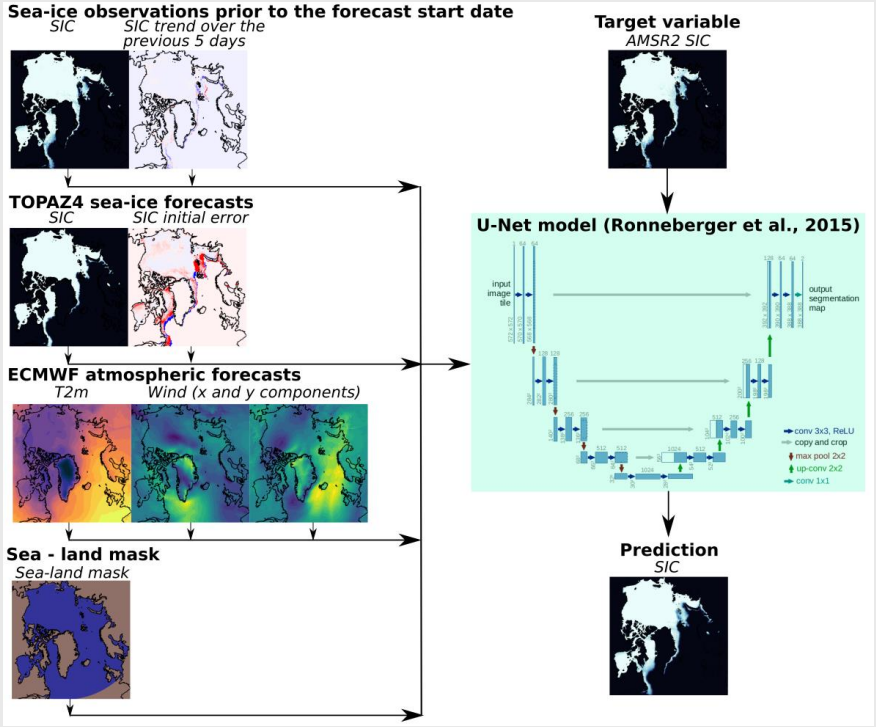
Development of post-processing methods *(Palerme et al., 2024)*

- **Target variable:**
  - *AMSR2 sea-ice concentration observations (Rusin et al., 2024)*
- **Predictors:**
  - *AMSR2 sea-ice concentration observations*
  - *Sea-ice concentration forecasts from TOPAZ4*
  - *Weather forecasts from ECMWF*
  - *Land - sea mask*
- **Architecture:**
  - *Attention residual U-Net*
- **Datasets:**
  - *Training period: 2013 - 2020*
  - *Validation period: 2021*
  - *Test period: 2022*



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Model architecture, spatial attention blocks (Oktay et al., 2018)

- Designed to identify and give more attention to relevant areas (in medical imagery)

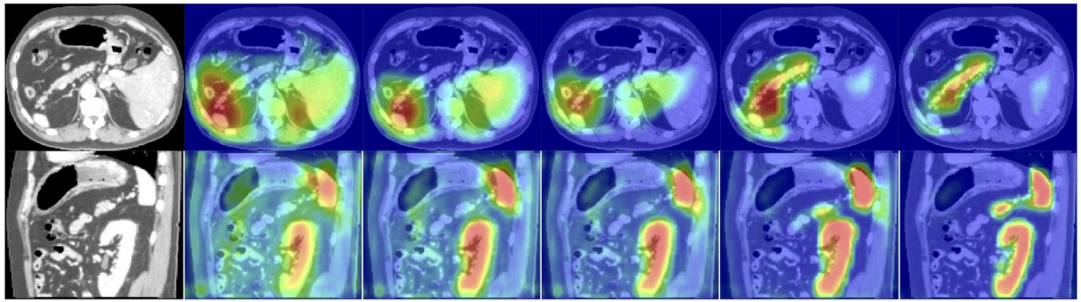
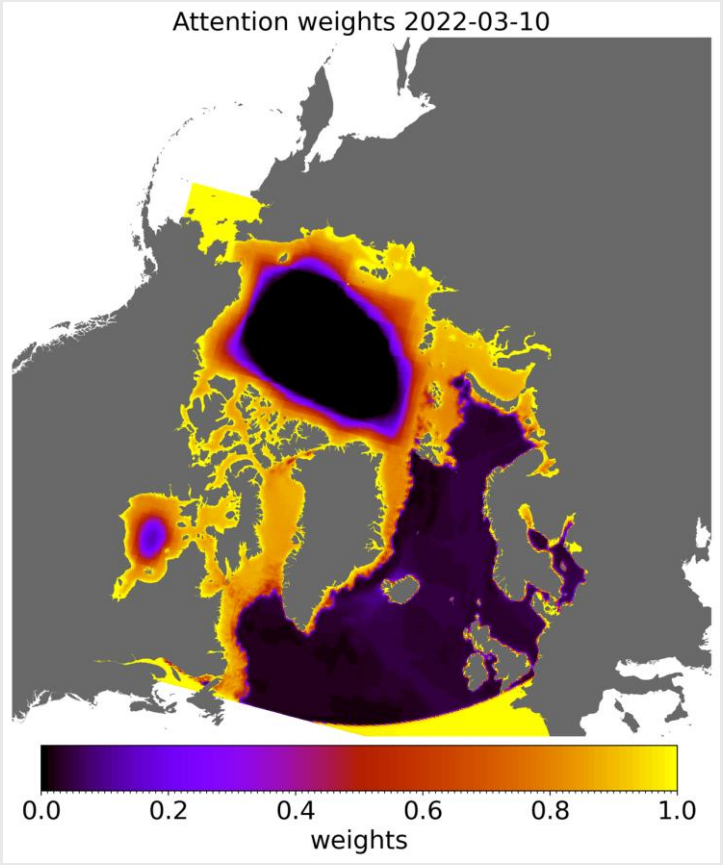


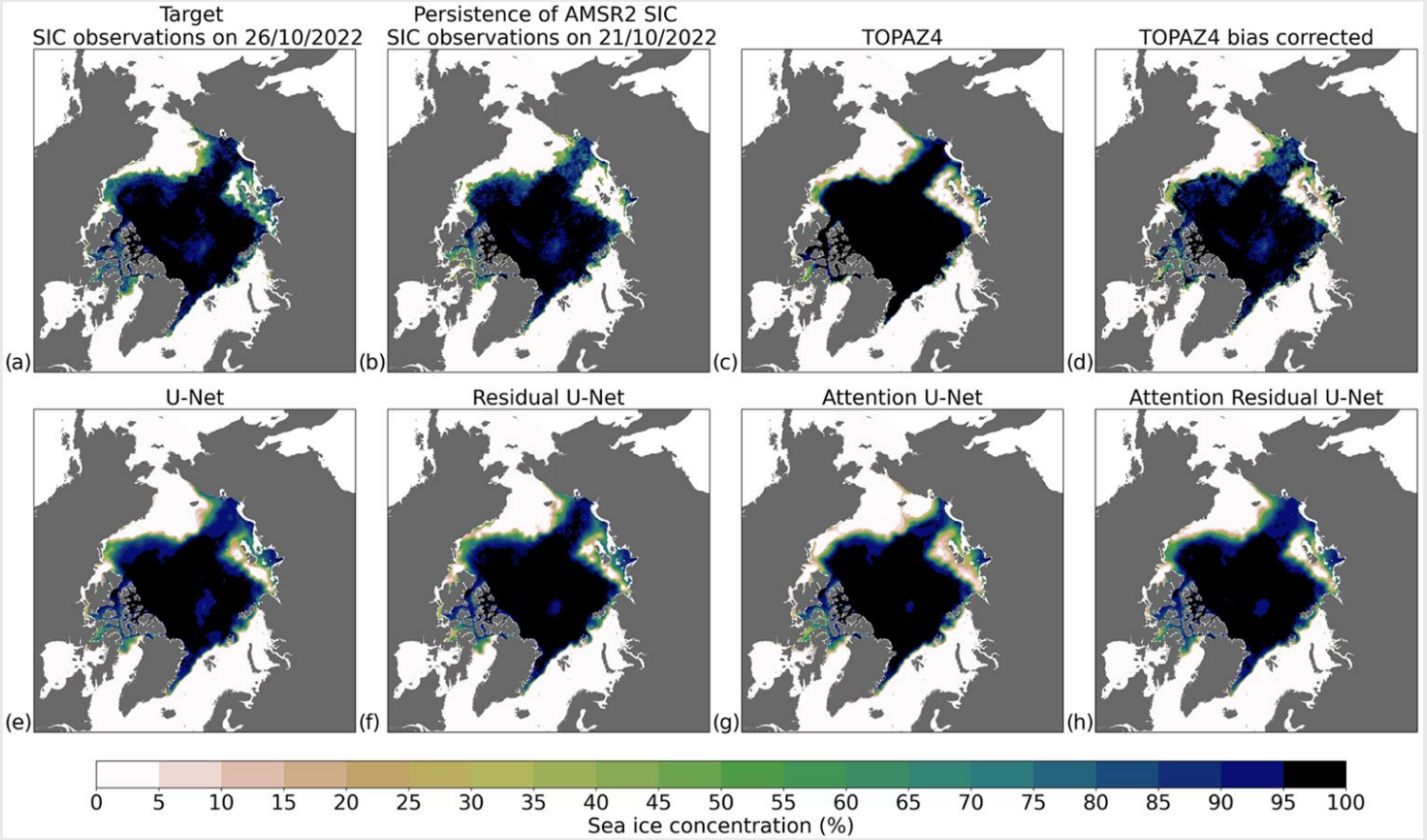
Figure 4: The figure shows the attention coefficients ($\alpha^{l_{s_2}}$, $\alpha^{l_{s_3}}$) across different training epochs (3, 6, 10, 60, 150). The images are extracted from sagittal and axial planes of a 3D abdominal CT scan from the testing dataset. The model gradually learns to focus on the pancreas, kidney, and spleen.

Oktay et al., 2018

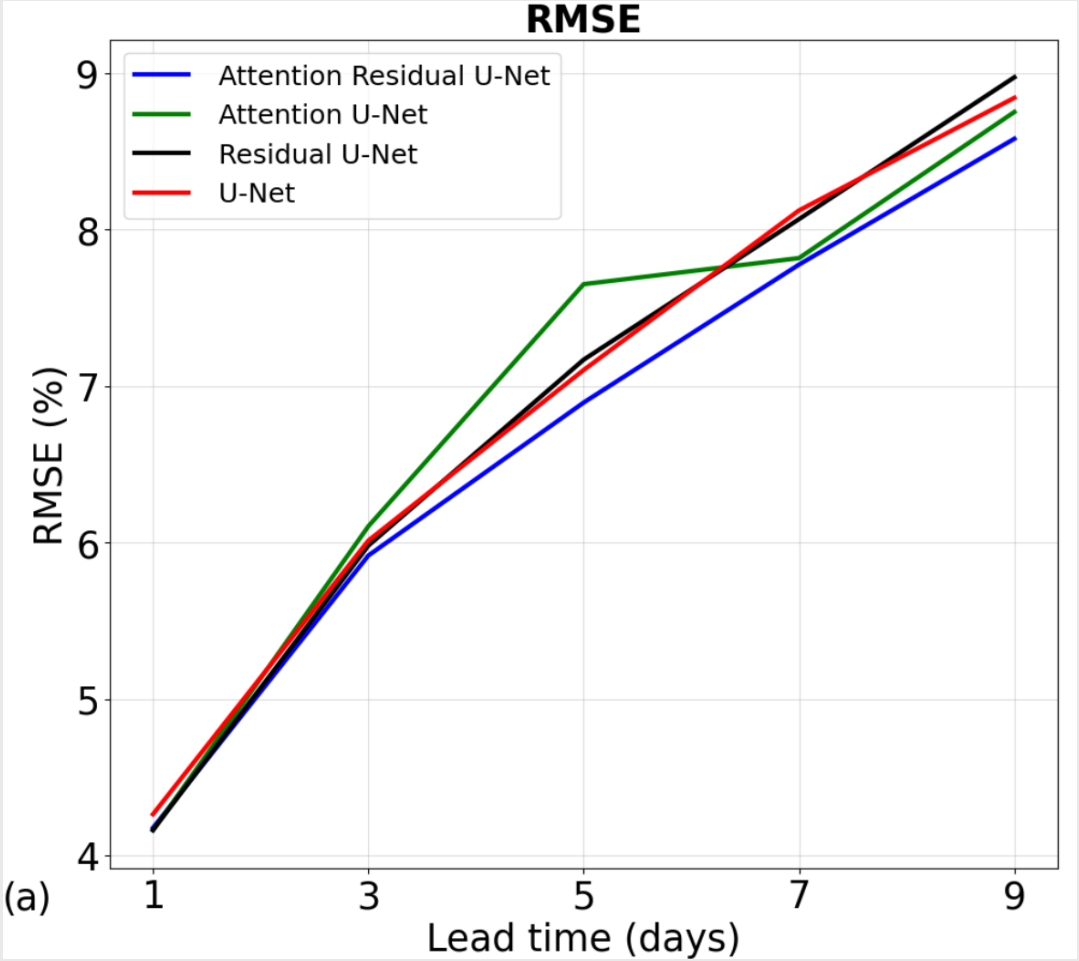


How do the deep learning forecasts look like ?

5-day forecasts initialized on 22/10/2022



Model architecture



- The Attention Residual U-Net model has a RMSE for the sea ice concentration about 2.8 % lower on average than the U-Net model (between 1.6 and 4.3 % depending on lead time)
- The Attention Residual U-Net architecture has been selected

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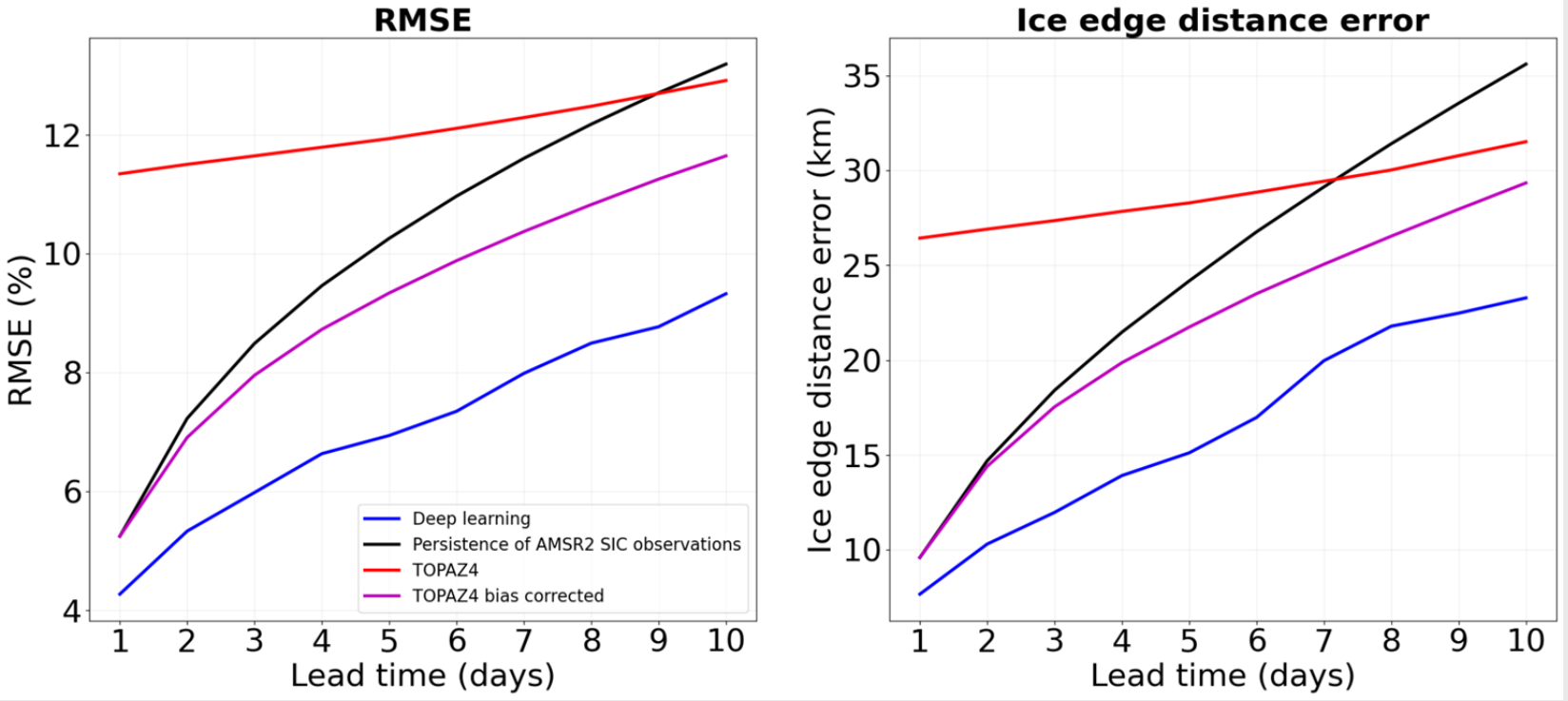
Performances of the deep learning forecasts



- On average, the RMSE from the deep learning forecasts:
  - 41 % lower than from TOPAZ4
  - 29 % lower than from persistence of AMSR2 observations
  - 23 % lower than from TOPAZ4 bias corrected

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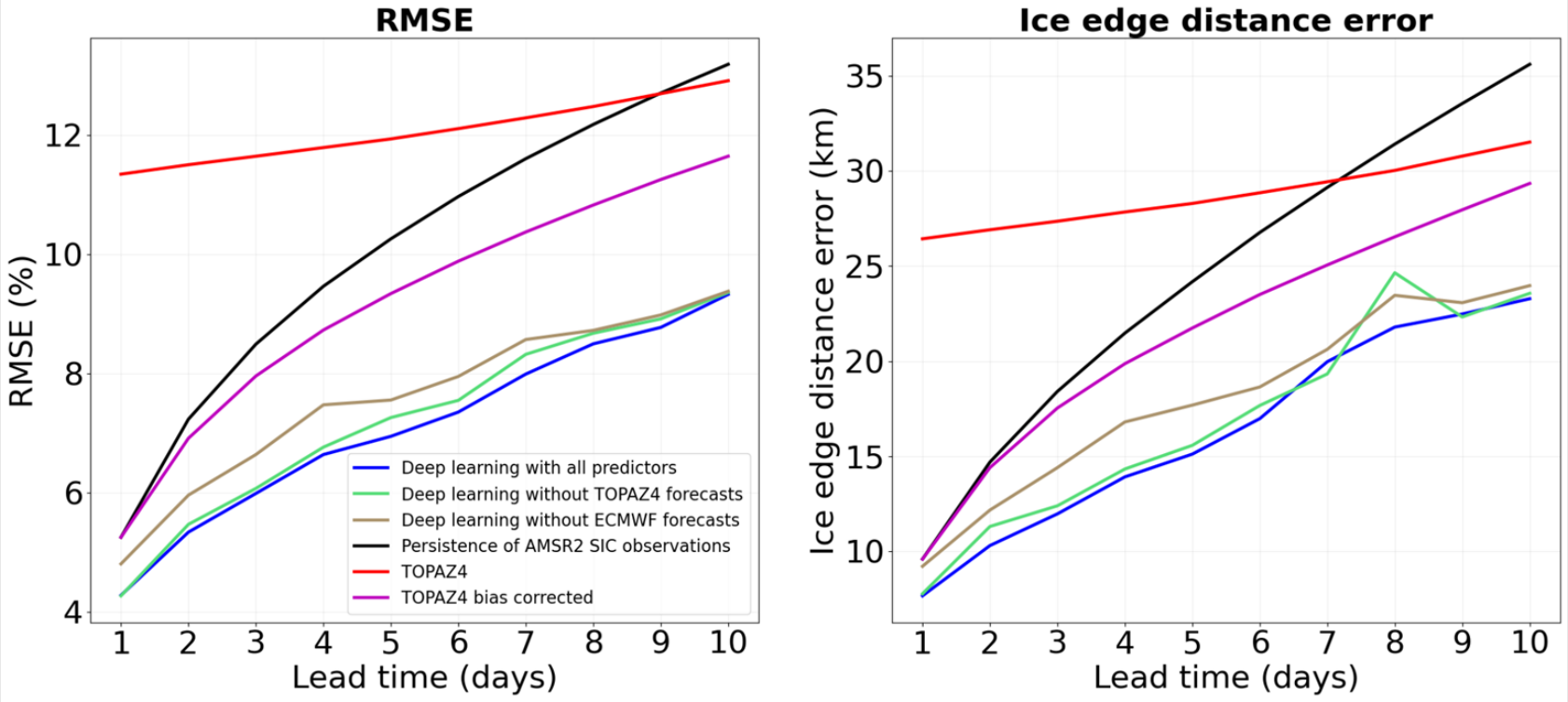
Importance of the predictors



- On average, the RMSE is improved by:
  - 2.1 % if TOPAZ4 sea ice forecasts are used
  - 7.7 % if ECMWF weather forecasts are used

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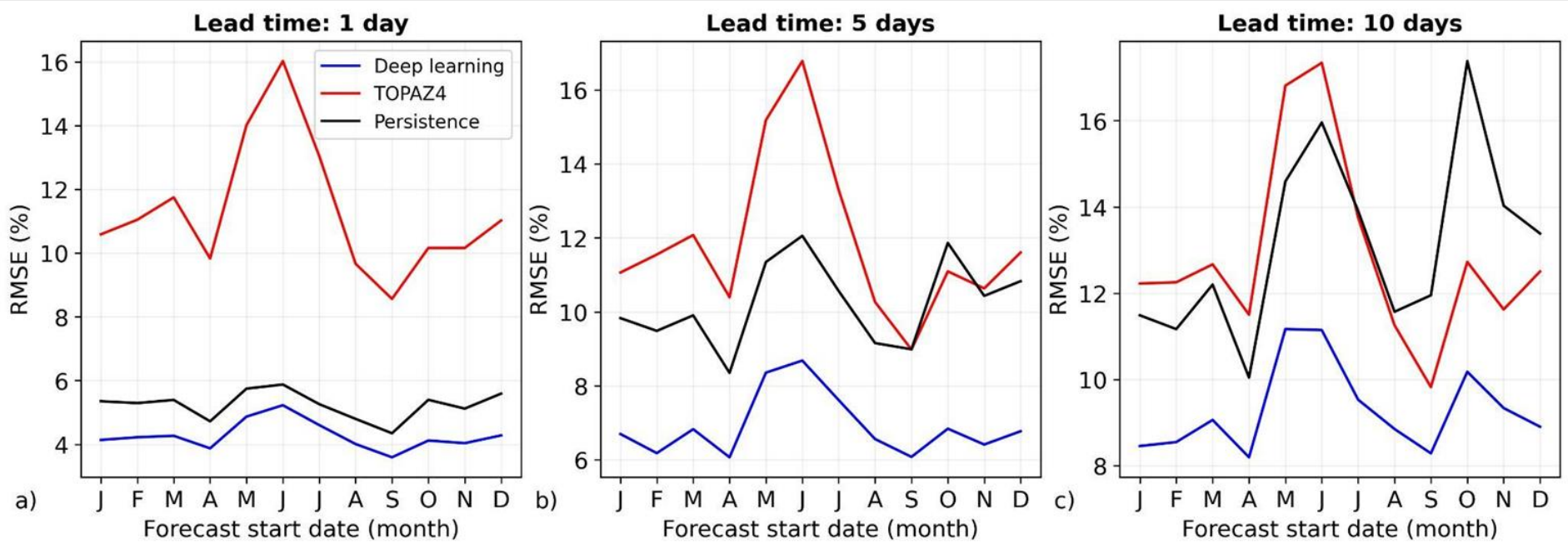
Seasonal performances of the deep learning models



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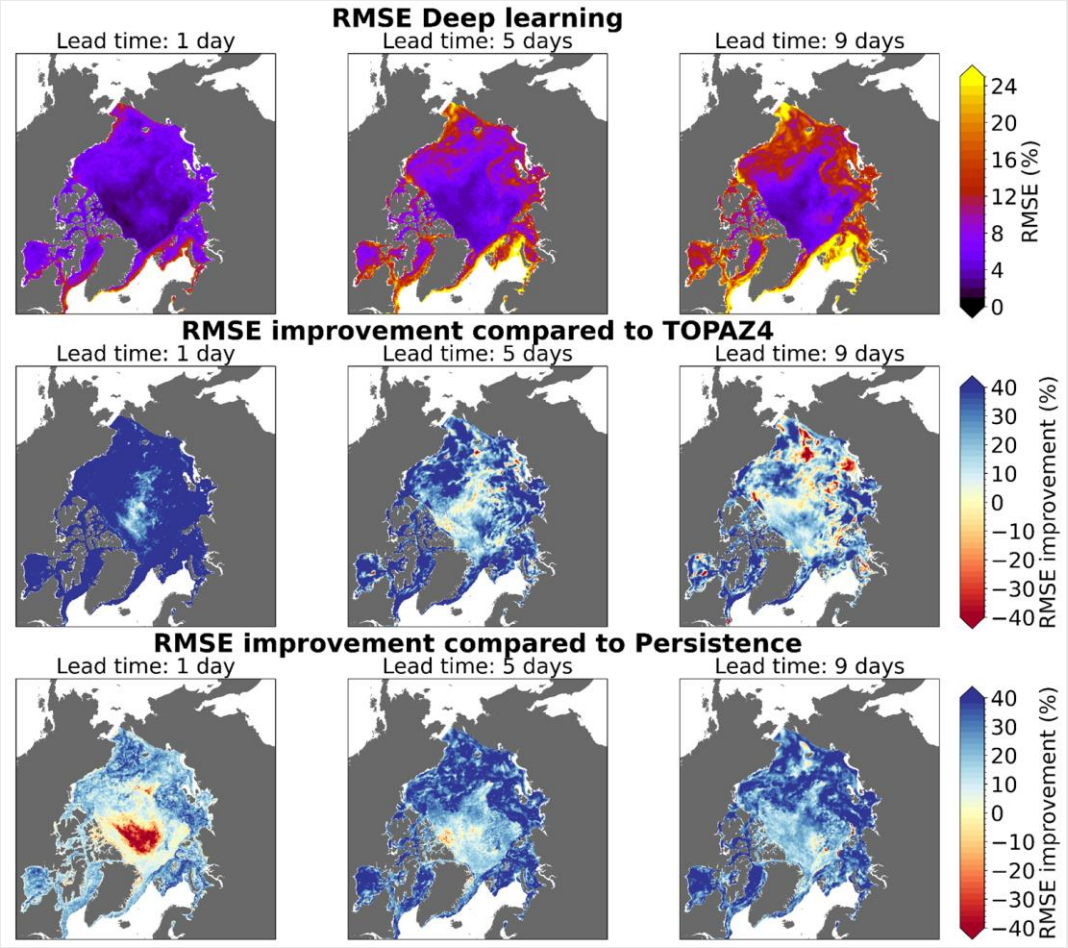
Spatial variability in the performances of the deep learning models



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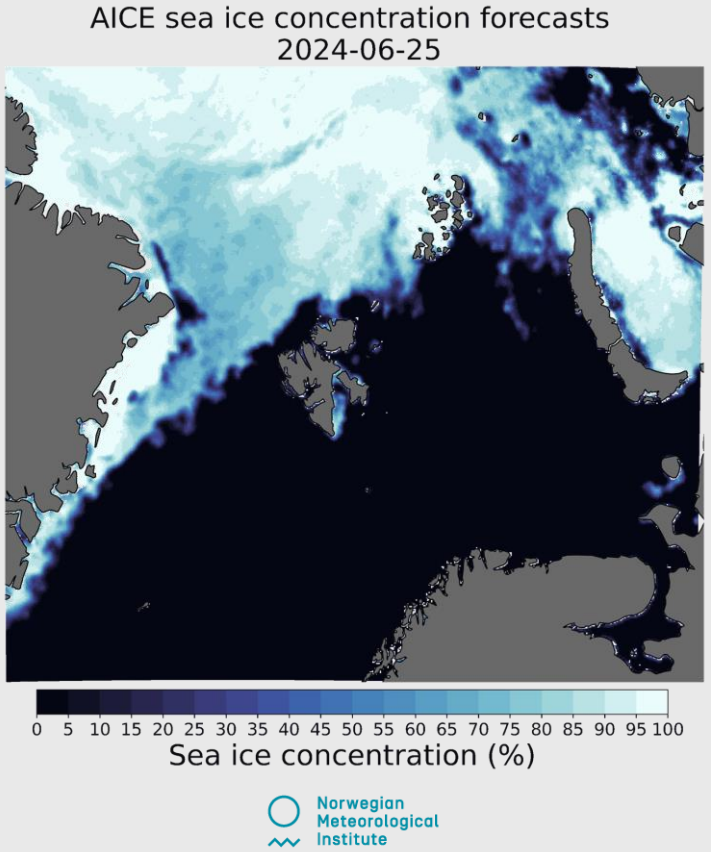
Operationalization of data-driven sea ice concentration forecasts: AICE

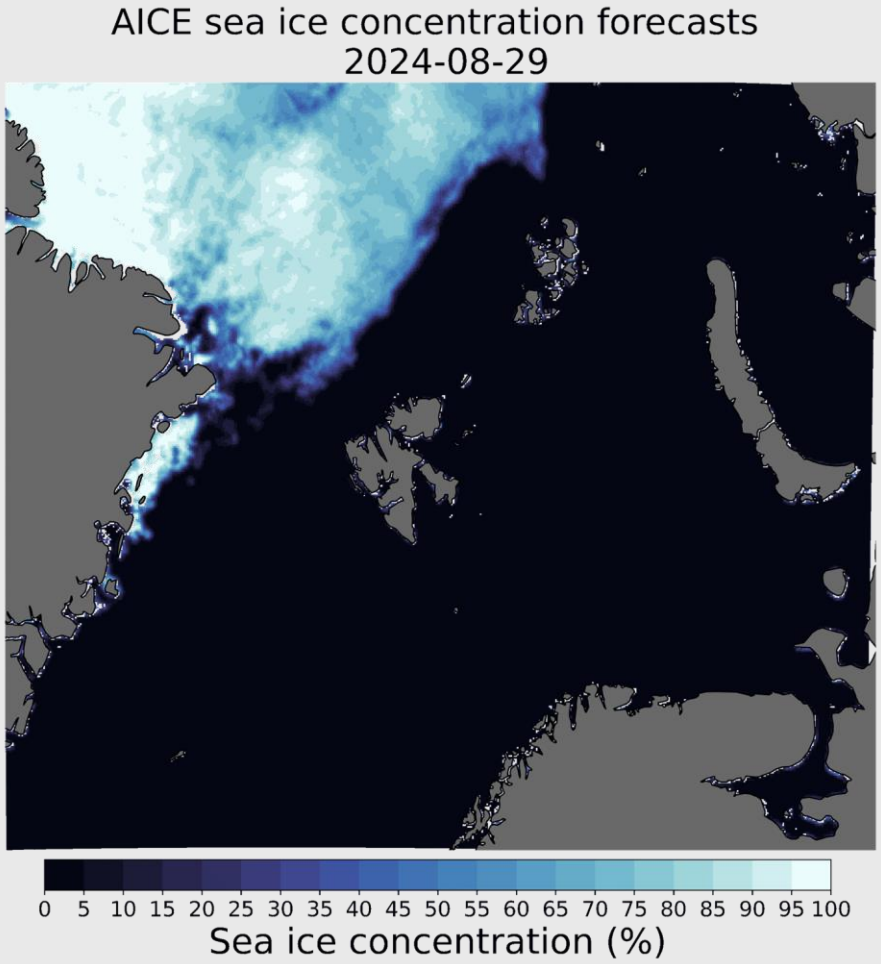
- Issues with the data-driven forecasts developed in COSI:
  - COSI AMSR2 observations are not available in near real time for the Pan-Arctic
  - The production of TOPAZ4 forecasts was stopped in April 2024
- Solutions:
  - No sea ice forecasts in the predictors
  - Forecasts developed for the European Arctic
  - 10-day forecasts with daily time steps
  - 5 km resolution (same as AMSR2 observations)



Knowledge gaps & deficiencies, opportunities, and recommendations

- **Lack of re-forecast datasets:**
    - Training on operational forecasting systems that are constantly developed is not ideal
    - Post-processing methods cannot be applied immediately after a new forecasting system is put into operation
- **Developing observation datasets suitable for machine learning prediction:**
    - Near real time products for the predictors
    - Time spans matching the forecast time steps
- **Explainability of machine learning models**

AICE sea ice concentration forecasts



Reference:

Palerme, C., Lavergne, T., Rusin, J., Melsom, A., Brajard, J., Kvanum, A. F., Macdonald Sørensen, A., Bertino, L., and Müller, M.: Improving short-term sea ice concentration forecasts using deep learning, The Cryosphere, 18, 2161–2176, https://doi.org/10.5194/tc-18-2161-2024, 2024.

Thanks for your attention !

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