

## 1 Supporting Figures

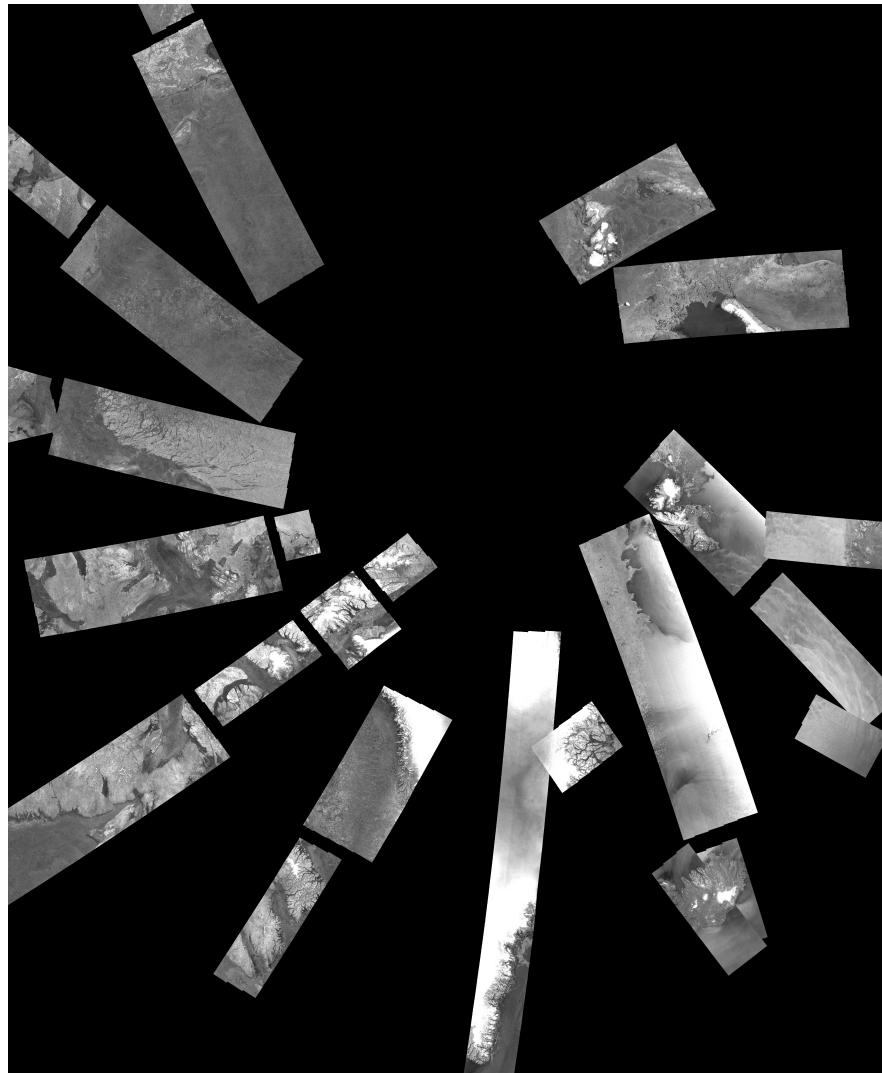


Figure 1: Daily SAR observations of the Arctic from Sentinel 1A 23 Jan 2023

## 2 Poster contribution to The 11th International Workshop on Sea Ice Modelling, Assimilation, Observations, Predictions and Verification

# Developing a deep learning model for short term and high resolution prediction of WMO sea ice concentration categories

Are Frode Kvanum<sup>1</sup>, Cyril Palerme<sup>1</sup>, Malte Müller<sup>1</sup>, Jean Rabault<sup>1</sup>, Nick Hughes<sup>2</sup>

<sup>1</sup> Norwegian Meteorological Institute, Oslo, Norway (Contact: [arefk@met.no](mailto:arefk@met.no))

<sup>2</sup> Ice Service, Norwegian Meteorological Institute, Tromsø, Norway



## Summary of forecast production

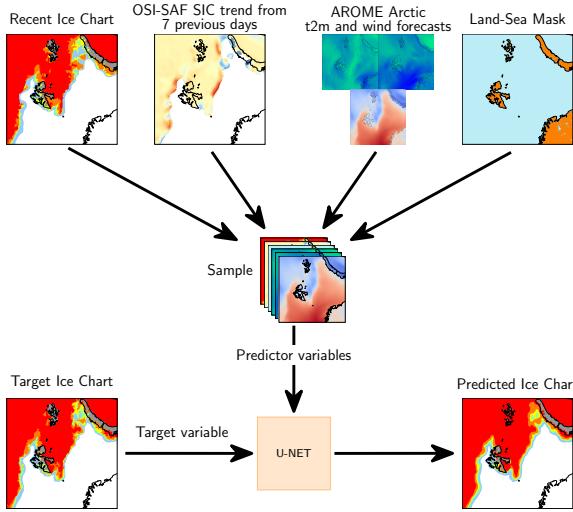


Figure 1: The deep learning forecasting system workflow

## Model development

- The deep learning model is based on the U-Net architecture (image to image, pixelwise prediction).
- Each WMO sea ice concentration category is predicted separately.
- The final forecast is the pixelwise sum of the individually predicted sea ice concentration contours.
- 1km resolution ( $1792 \times 1792$  grid points) with (1 – 3) day lead time.
- Training period: 2019 – 2020 (288 samples).
- Testing period: 2022 (147 samples).

## Input variables

- Sea ice concentration from the sea ice charts at  $t_0$  produced by the Norwegian Ice Service (1km).
- Linear sea ice trend derived from Ocean and Sea Ice Satellite Application Facility passive microwave (SSMIS) using the seven previous days (10km).
- 2 meter temperature and 10 meter winds from a regional NWP system (AROME Arctic) (2.5km). Time steps between forecast bulletin date and target valid date is reduced to a mean-value field that projects temporal information onto a single time step.
- Land sea mask from AROME Arctic (2.5km).

## Target variables

- Sea ice charts at time  $t_0 + (1 - 3)$  days relative to the predictor date.
- The target sea ice concentration is divided into sea ice concentration contours following the WMO sea ice categories

## U-Net architecture

- 2,359,047 trainable parameters
- Training is performed on an Nvidia A100 GPU, and takes ~3 hours
- During training, the U-Net uses 52Gb of memory
- After training, a single prediction is made in 6 seconds with a CPU

## Introduction

- Sea ice concentration prediction targeting km-scale resolution is challenging.
- Maritime operators in the Arctic are lacking high resolution and high frequency sea ice forecasts for tactical decision making
- Deep learning systems are computationally lightweight, and can create a forecast on a consumer computer in minutes. Training the deep learning system is done on a cluster, once.

## Results

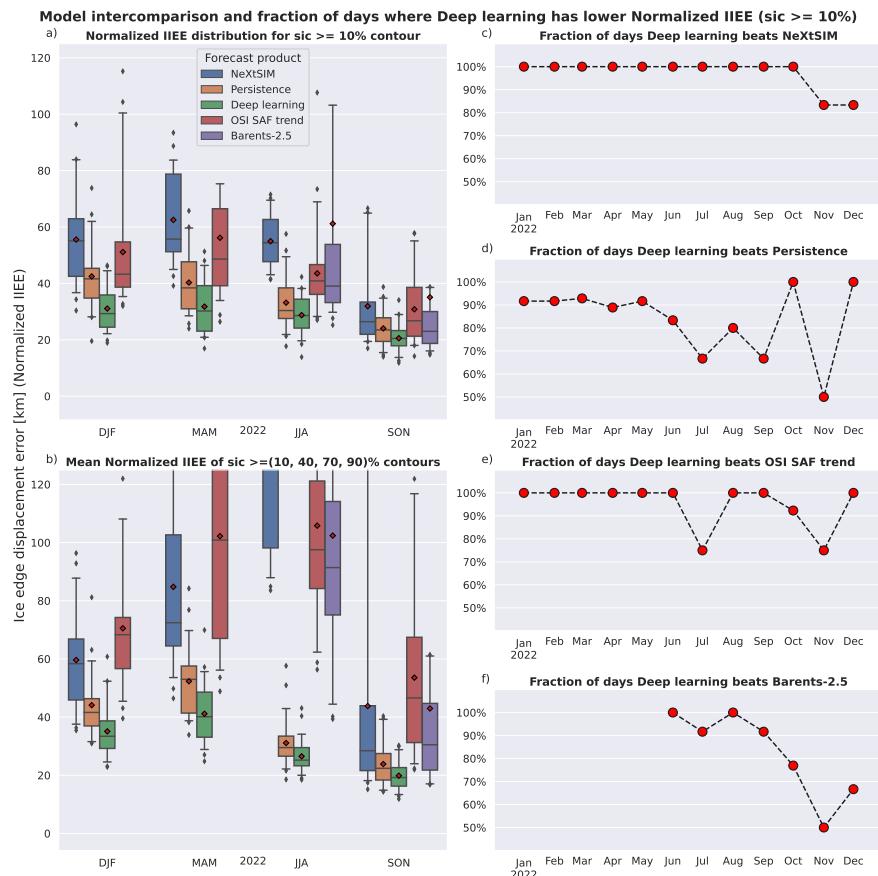


Figure 2: (a, b) Box and whisker plot of Normalized IIEE for different forecasting products as well as two benchmarks (Persistence and OSI SAF linear trend). The boxes cover the interquartile range. Whiskers denote the 5<sup>th</sup> and 95<sup>th</sup> percentiles. (c,d,e,f) Percentage of days where the Deep learning forecast achieves a lower Normalized IIEE score than the compared to product. (e) OSI SAF trend is a linear trend computed from the past 7 days. (f) Barents-2.5 is an in-development ocean and sea ice model implemented at MET Norway.

## Model intercomparison

- The ice edge displacement error (Normalized Integrated Ice Edge Error) for an ice edge defined at the  $\geq 10\%$  WMO sea ice concentration contour has on average been improved by **28%** between the four validation products.
- The deep learning model improves **90%** of the forecasted dates between the four validation products, with regards to achieving a lower Normalized IIEE for the  $\geq 10\%$  concentration contour.

## Comparing persistence with a deep learning prediction

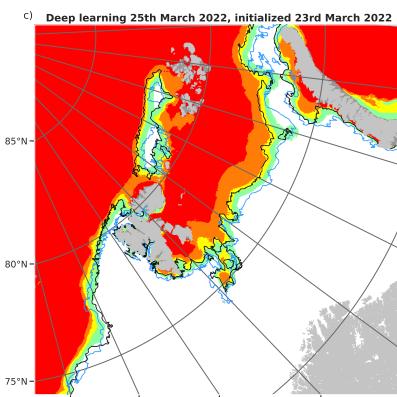
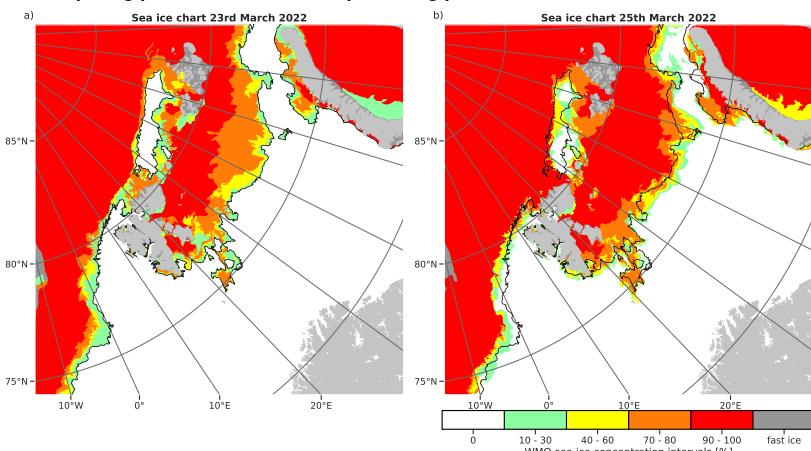


Figure 3: (a) Sea ice chart produced on 23 March 2022. (b) Sea ice chart produced on 25 March 2022. (c) Deep learning prediction for 25 March 2022, initialized 23rd March 2022. The sea ice chart in (a) was among the input variables for (c). The black line in (a,b,c) is the ice edge for (a) given a  $\geq 10\%$  threshold. The blue line in (c) is the ice edge for (b) given a  $\geq 10\%$  threshold.

- Persistence sea ice edge displacement error = **65km**.
- Deep learning sea ice edge displacement error = **37km**.
- The displacement error was computed with regards to the  $\geq 10\%$  concentration contour.