Initial Results from SAR-Based Validation of Sea Ice Drift Forecast Models

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Introduction

- Optimal shipping routes through drifting sea ice increasingly important for navigation in polar regions
- Sea ice drift information obtained from Synthetic Aperture Radar (SAR) [5]
- Evaluation of usability of sea ice drift forecast models for multi-day sea ice analysis

- Improvements for high-resolution forecast Predictive Ice Image application (PRIIMA) [2]

- Forecast model trajectories derived with Lagrangian Tracking
- Sea ice drift vector fields obtained from successive SAR-scene pairs
- Comparison of forecast model trajectories and SAR-based drift vector fields

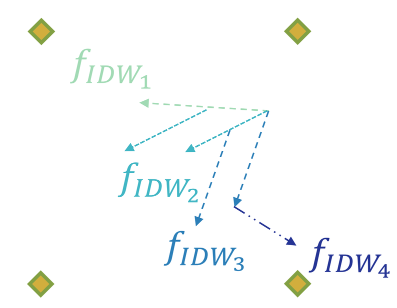
Data and Methodology

- Historical TOPAZ4 [4] and neXtSIM [3] forecasts from December 2021
- 7 Sentinel-1 SAR-scene pairs from 2 regions of interest (ROIs) in the Lincoln Sea

- Vector model for data processing
  - high flexibility
  - floating-point number resolution
- Object-oriented-programming (OOP), topology, hashing and spatial indexing

- Trajectories and measurements both calculated starting from a regular grid
- Forecast model sea ice drift interpolated in every grid point with cubic splines
- Runge-Kutta 4th-order (RK4) [6] combined with Inverse Distance Weighting (IDW) to a refined approach (RK4-IDW)

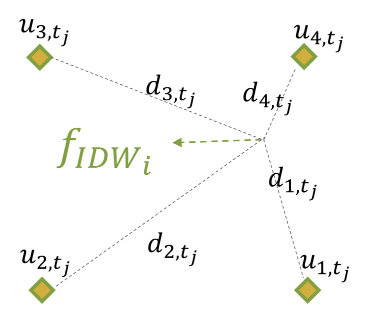
Performing Lagrangian Tracking with RK4-IDW



RK4:

$$X_{IDW_{k+1}} = X_{IDW_k} + f_{IDW_{k+1}} \Delta t$$
$$f_{IDW_{k+1}} = \frac{1}{6}\left(f_{IDW_1} + 2 f_{IDW_2} + 2 f_{IDW_3} + f_{IDW_4}\right)$$

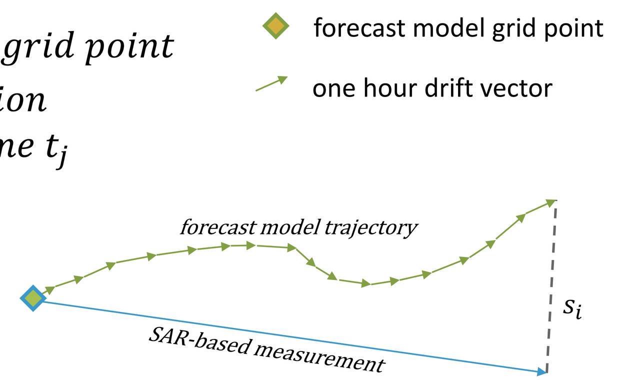
$$f_{IDW_1} = f\left(X_{IDW_k}, t_k\right)$$
$$f_{IDW_2} = f\left(X_{IDW_k} + f_{IDW_1} {}^{\Delta t}/_2, t_k + {}^{\Delta t}/_2\right)$$
$$f_{IDW_3} = f\left(X_{IDW_k} + f_{IDW_2} {}^{\Delta t}/_2, t_k + {}^{\Delta t}/_2\right)$$
$$f_{IDW_4} = f\left(X_{IDW_k} + f_{IDW_3} \Delta t, t_k + \Delta t\right)$$



IDW:

d_{p,t_j} = distance between grid point and current location
u_{s,t_j} = sea ice drift at time t_j

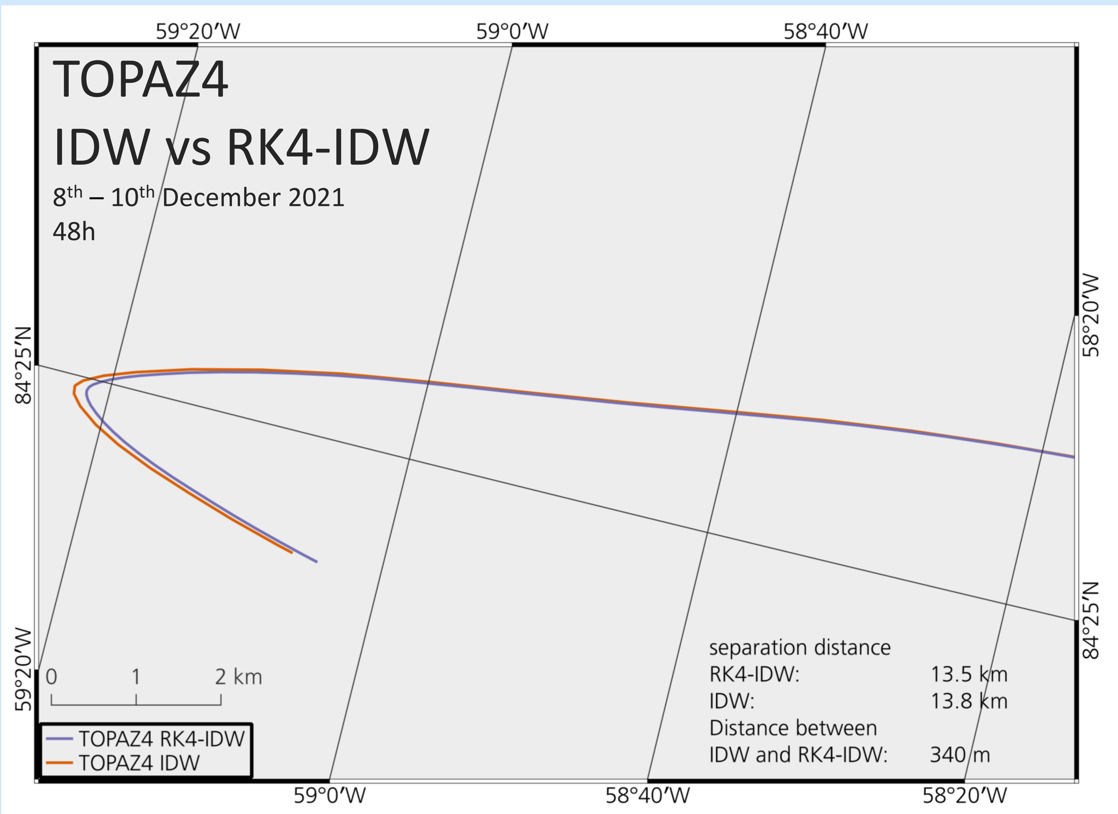
$$f_{IDW_i} = \frac{\sum_{i=1}^{3} \frac{u_{i,t_j}}{d_{i,t_j}}}{\sum_{i=1}^{3} \frac{1}{d_{i,t_j}}}$$

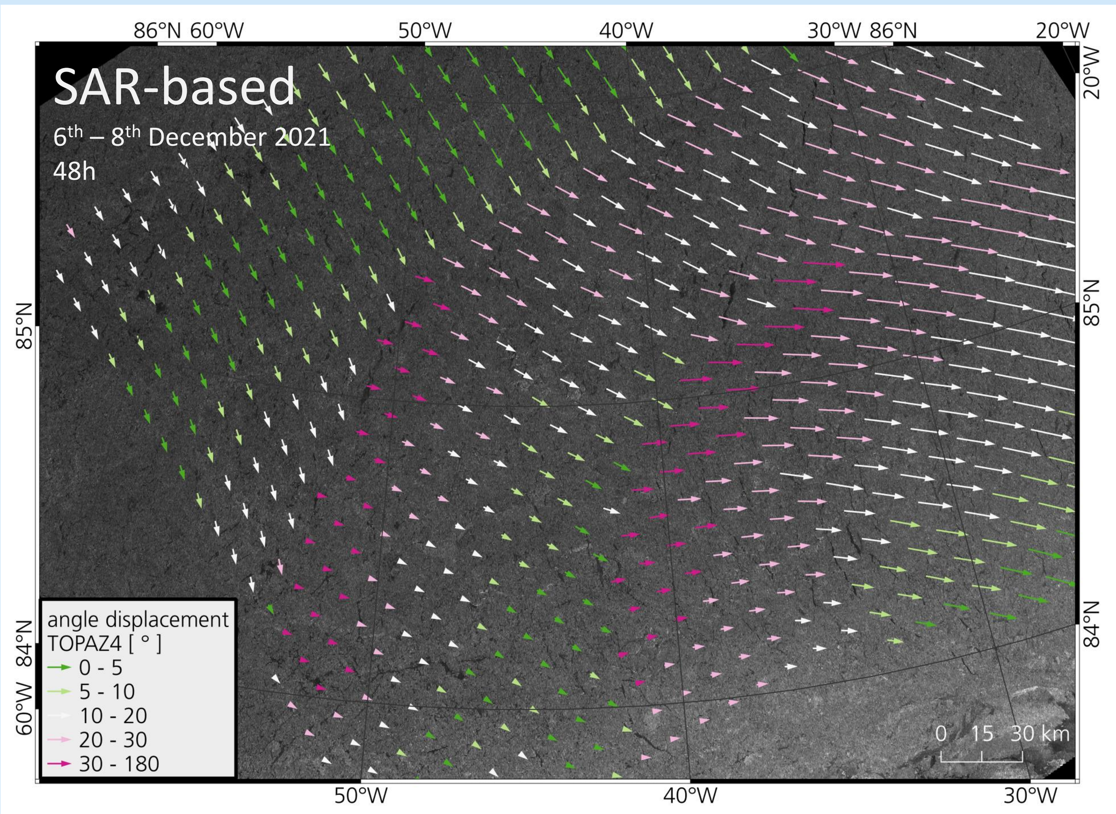


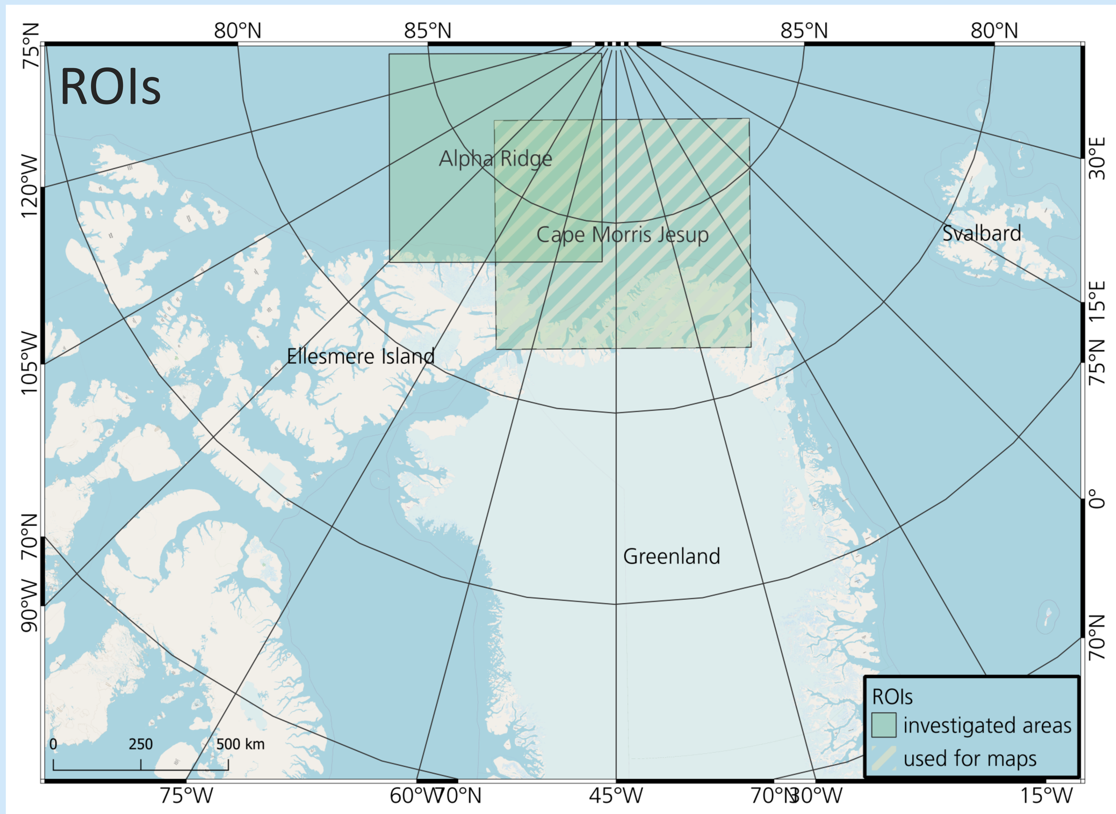
s_i = seperation distance

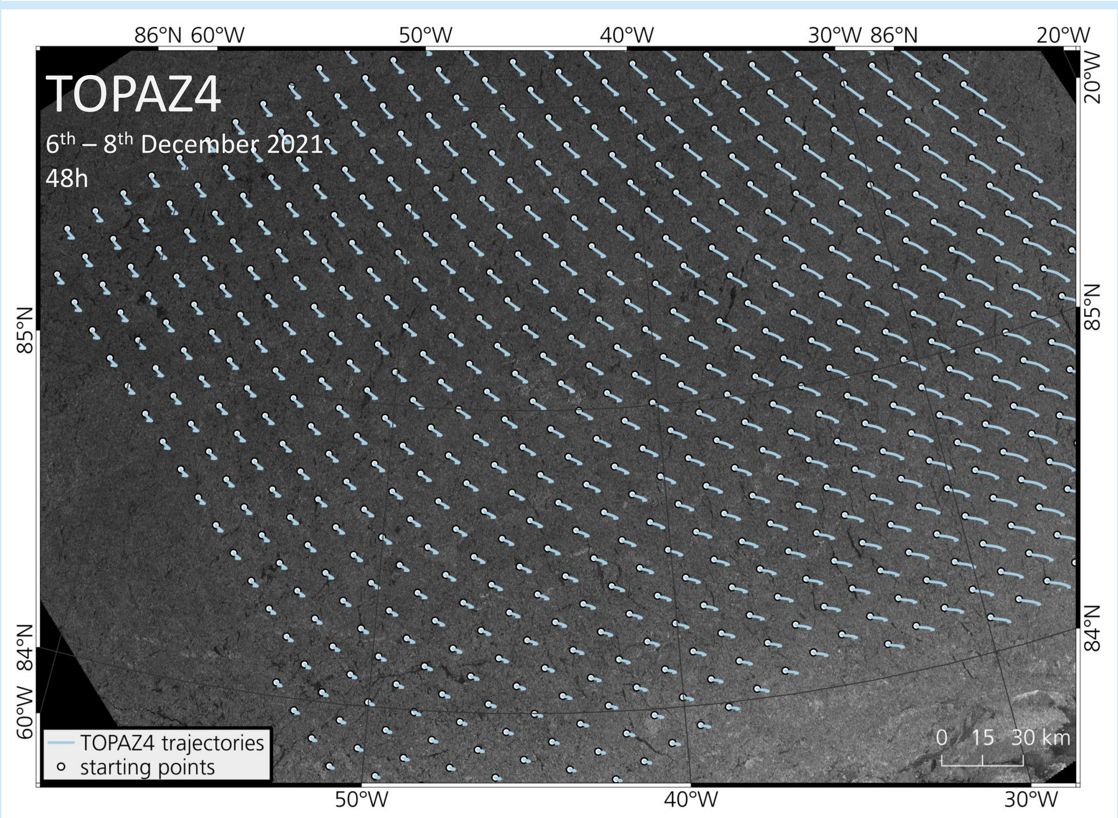
$$RMS\ seperation\ distance = \sqrt{\frac{\sum_{i=1}^{n} {s_i}^2}{n}}$$

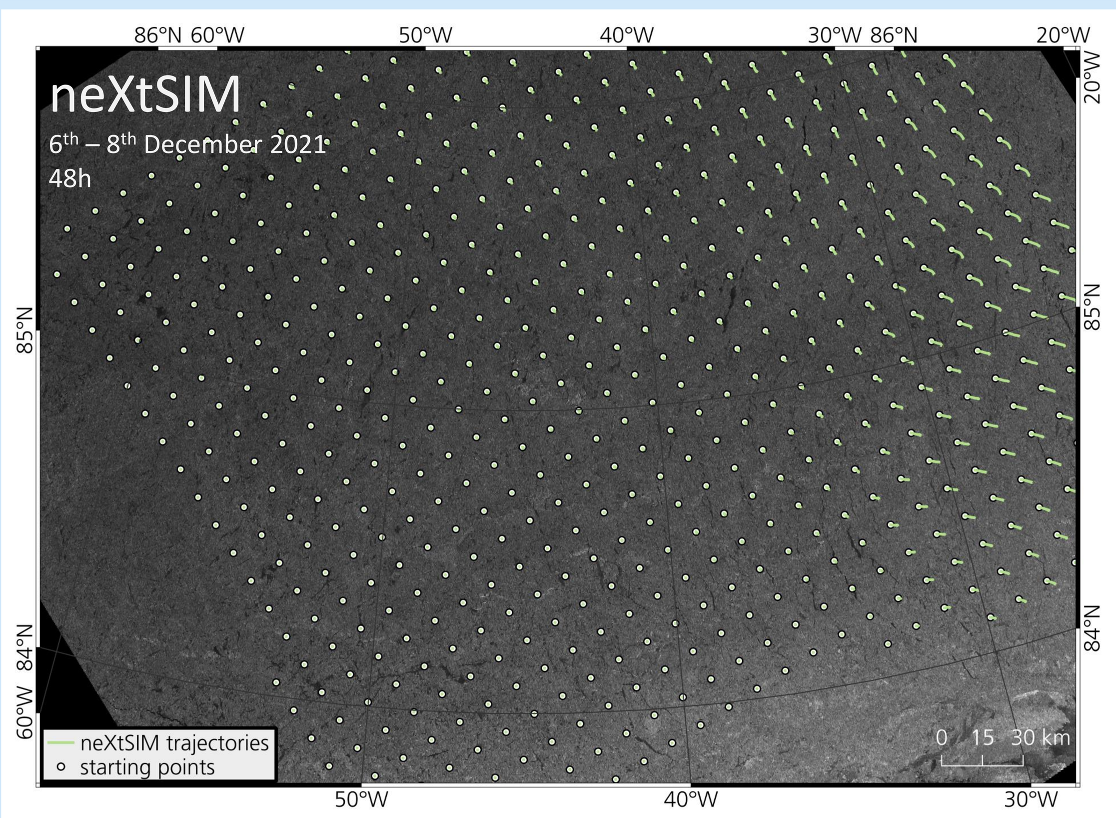
Initial Results

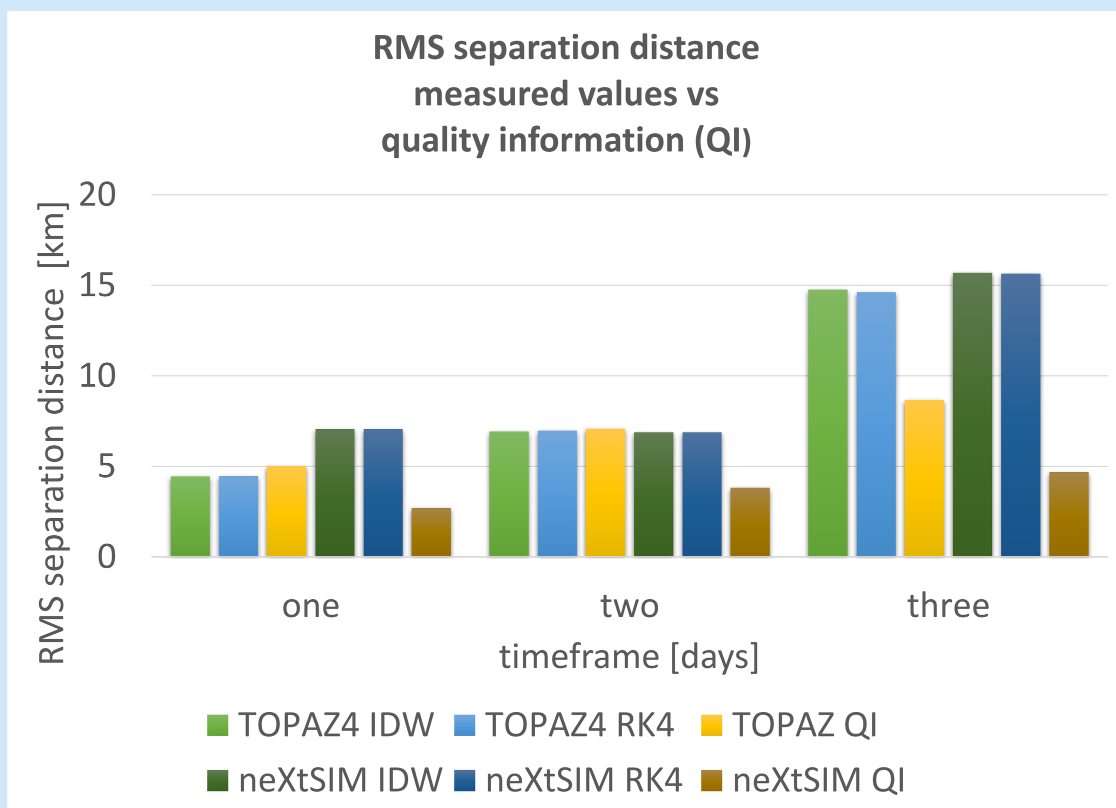








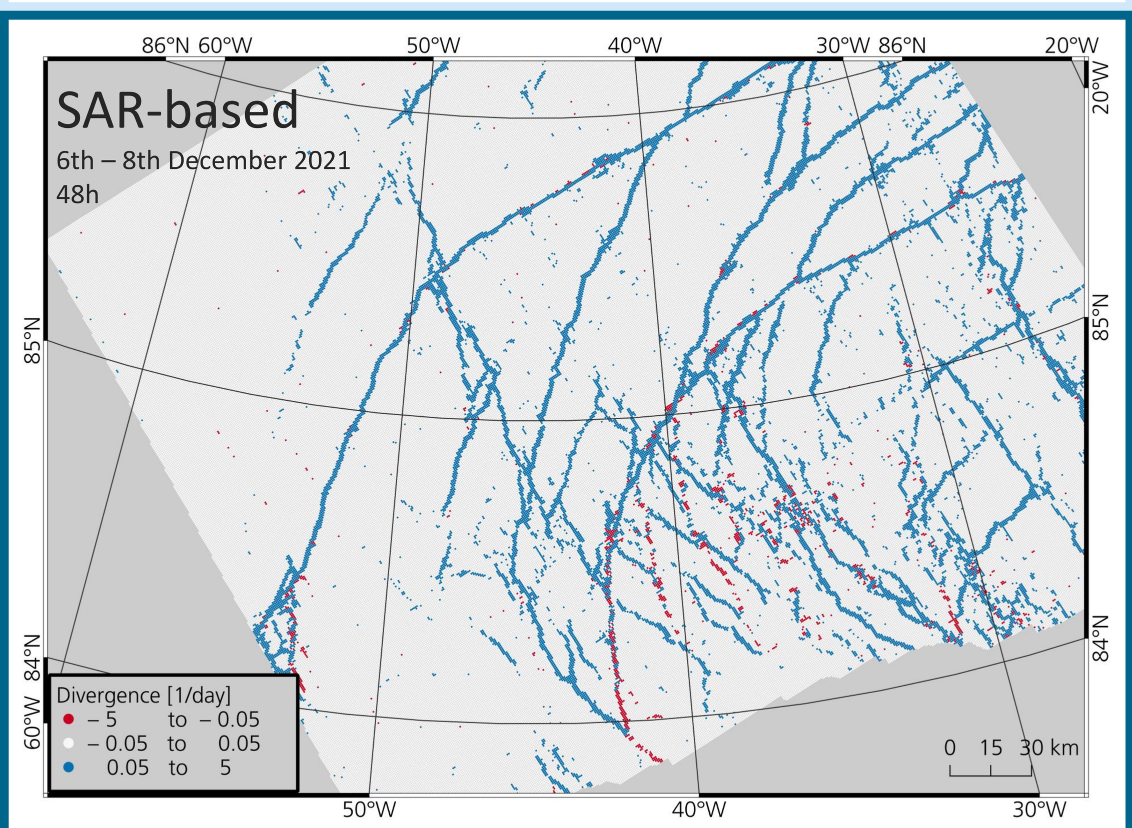


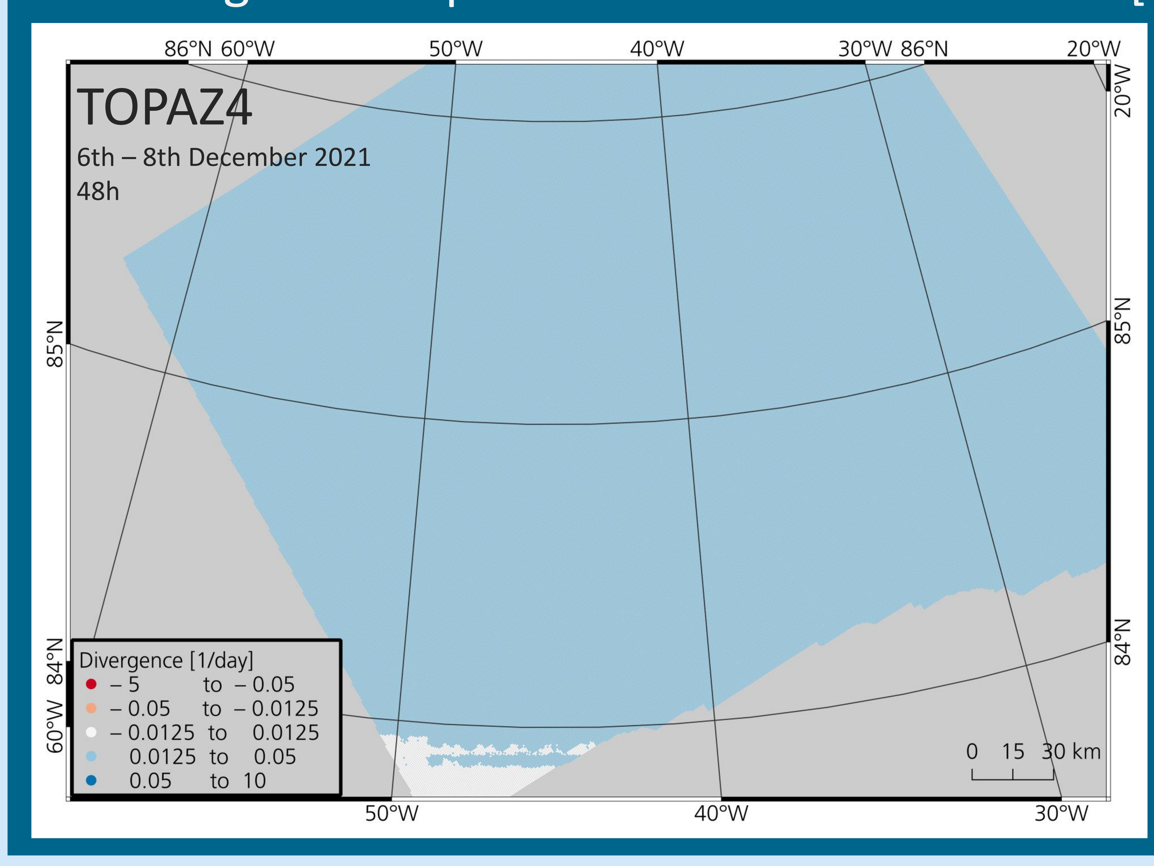


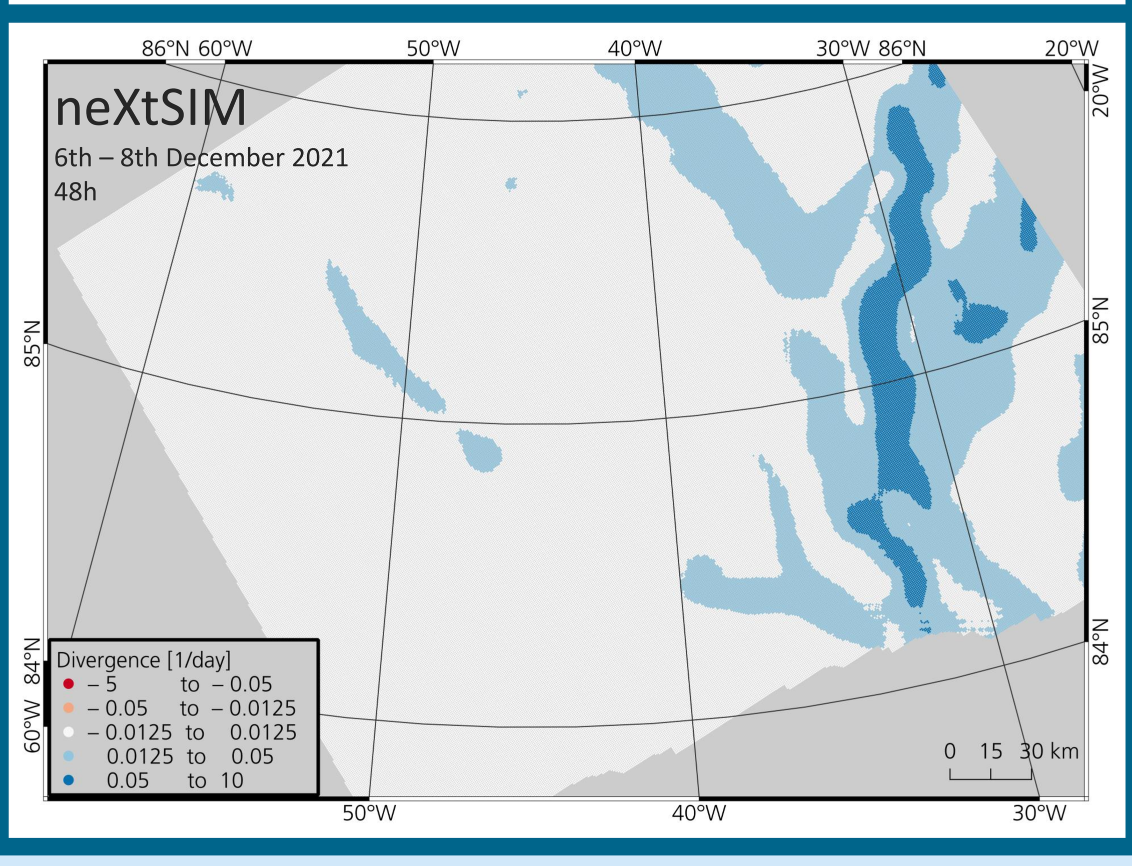
Further Research

- How is the measured sea ice deformation represented in the forecast models?
- How can the influence of the sea ice rheology be derived by evaluating the forecast model input data (e.g. winds and ocean currents)?
- Which other solutions for sea ice analysis can be put into practice with the available OOP approach?

- Divergence maps derived with Sobel kernels [1]







Conclusions

- Trajectories
  - RK4-IDW yields smoother trajectories
  - Small difference (ca. 200 m) between IDW and RK4-IDW
- TOPAZ4: viscous-plastic rheology
  - Rheology without brittleness of sea ice, but good overall drift
  - Difficult to derive deformation fields
- neXtSIM: brittle rheology
  - Problems of low drift near land
  - Divergence field is promising
- Only small case study so far
- Overall RMS separation distance of TOPAZ4 and neXtSIM between 3 and 5 ${}^{km}/_{day}$

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