Analysis of tidal sea-ice movement using a drifting ice beacon array in the Barents Sea

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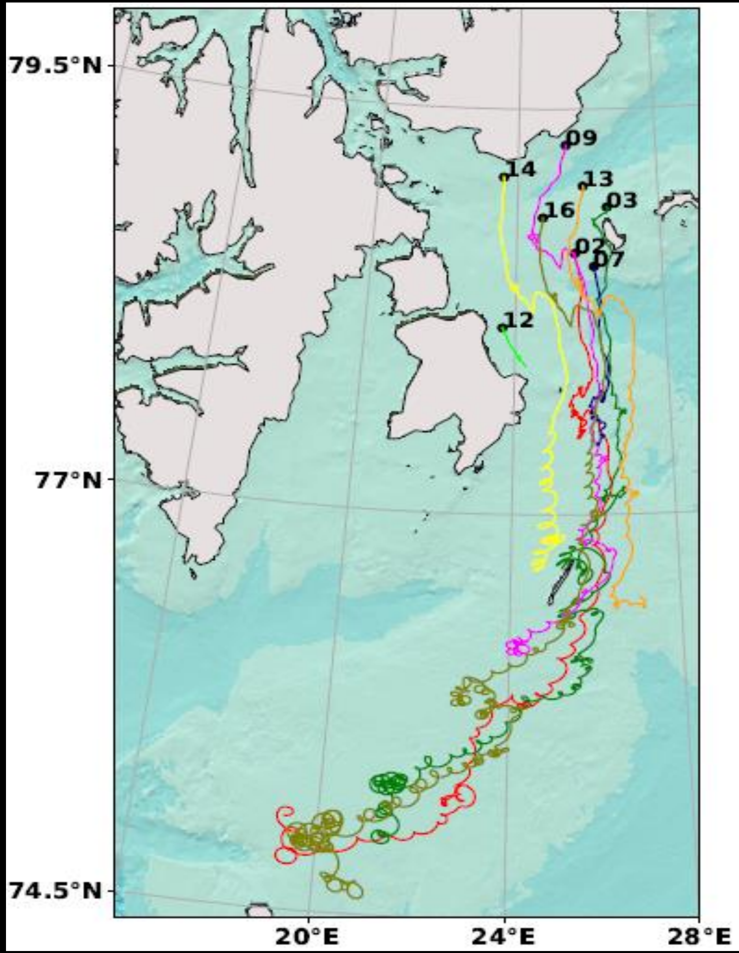

Fig 1: *8 Beacon trajectories starting from 16March*

Objective:
Develop the understanding of forces and parameterizations in the tidally induced Arctic Sea ice motion by conducting sensitivity studies using a simple 2D *free drift* model.

- Ice beacon (buoys) trajectories sampled at a frequency of 15mins.
- Drifting ice movements on **sub daily timescales** like inertial and tidal are observed.
- A simple 2D *free drift* model is developed to track and **study beacon trajectories**.

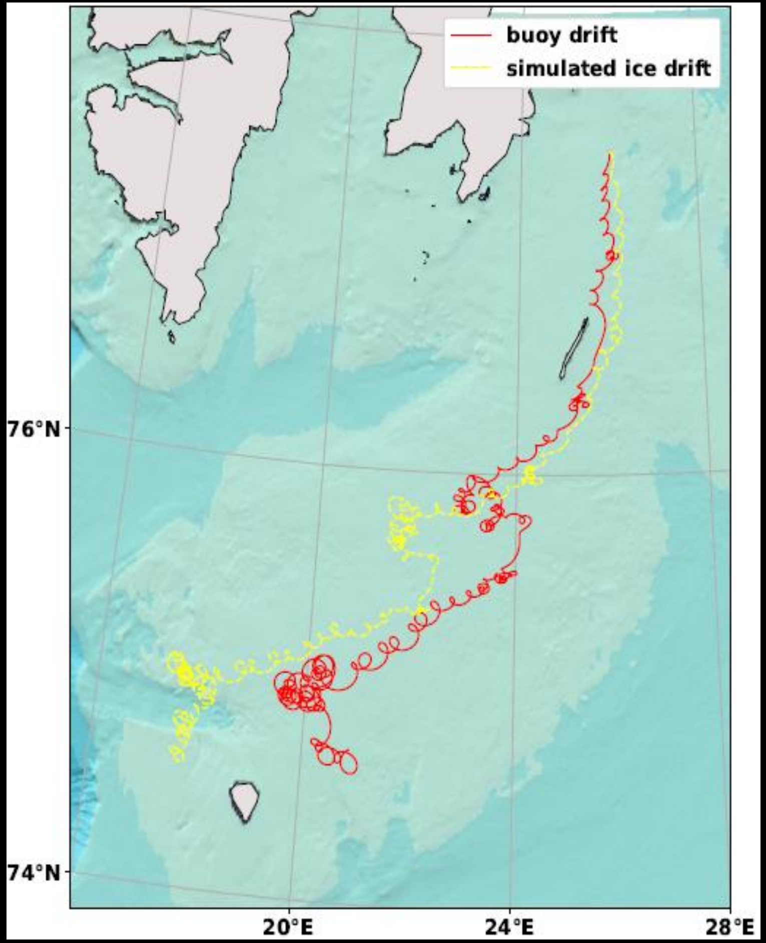

Fig 2: *Modelled v/s observed trajectory for beacon 16*

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Motivation

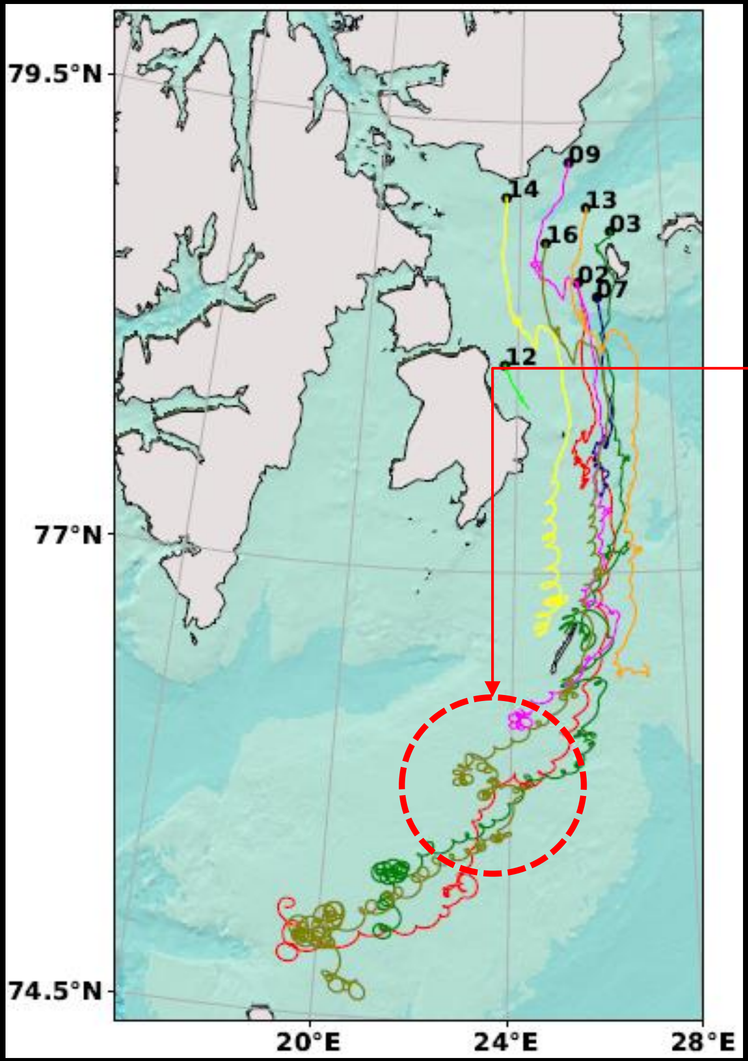

Fig 1: 8 Beacon trajectories starting from 16March

- Beacons released for an experiment to test a ship route optimization system.
- 7 out of 15 beacons remained operational long after the experiment.

Clockwise circular motion due to tidal and inertial forces.

No time series analysis is possible to separate M2 and Coriolis forces as these frequencies are almost the same.

- Instead, a model based on the physics of drifting ice is developed to understand such tidal and inertial forces.

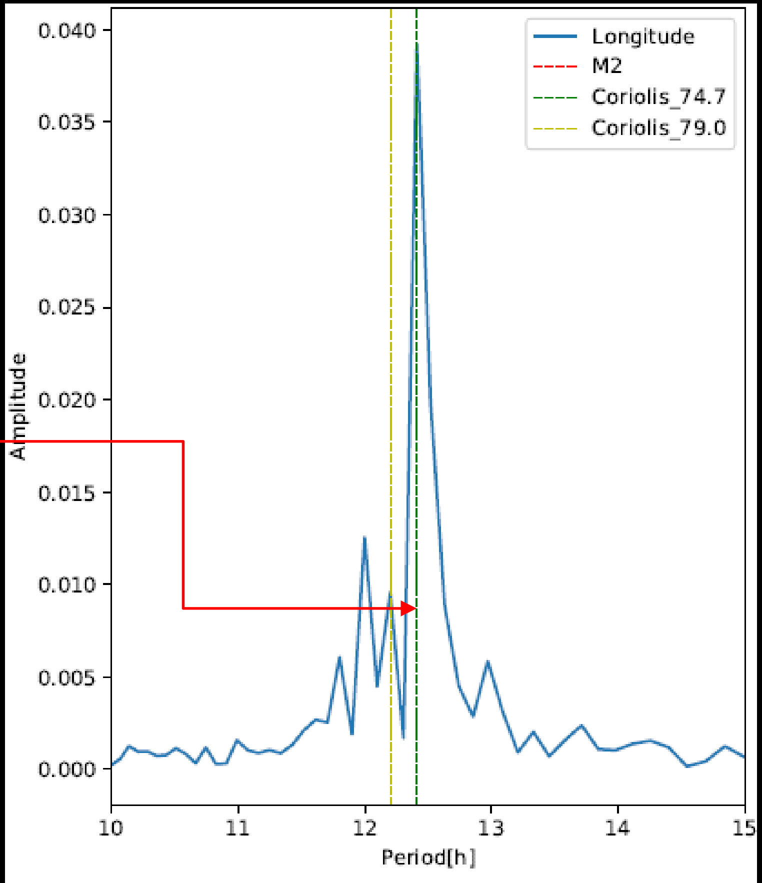

Fig 2: Fourier transform of mean drift filtered time series for Beacon 16

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Free-Drift model

Assumptions:

- Free-drift (no internal stresses in the ice field).
- Advection term and air pressure gradients approx. zero.
- One way coupling to ocean velocities.
- Water velocities sum of ocean and tidal currents.
- Uncertain parameters are: Ice Thickness h_i, Ice-Air drag coefficient, C_a, Ice-water drag coefficient, C_w

Coriolis parameter

Thickness of ice

Density of ice

$$\rho_i h_i \left(\frac{d\mathbf{u_i}}{dt} + f\mathbf{k} \times \mathbf{u_i}\right) = \boldsymbol{\tau_{ai}} + \boldsymbol{\tau_{wi}} - \rho_i h_i \boldsymbol{g}\nabla\zeta$$

Velocity of ice

Gradient of sea surface height

The shear stress components are given by quadratic drag laws.

$$\boldsymbol{\tau_{ai}} = \rho_a C_a \mathbf{u_a}|\mathbf{u_a}|$$
$$\boldsymbol{\tau_{wi}} = \rho_w C_w (\mathbf{u}_w - \mathbf{u_i})|(\mathbf{u}_w - \mathbf{u_i})|$$

Ice-Air drag coefficient

Ice-water drag coefficient

Data Sources:

- ERA5 weather model from ECMWF for 10m wind velocity components.
- GLOBAL ANALYSIS FORECAST PHY 001 024 ocealn model from CMEMS for surface ocean currents and sea surface elevation ζ.
- GTSMv3 tidal model from Deltares to obtain tidal velocities.

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Results

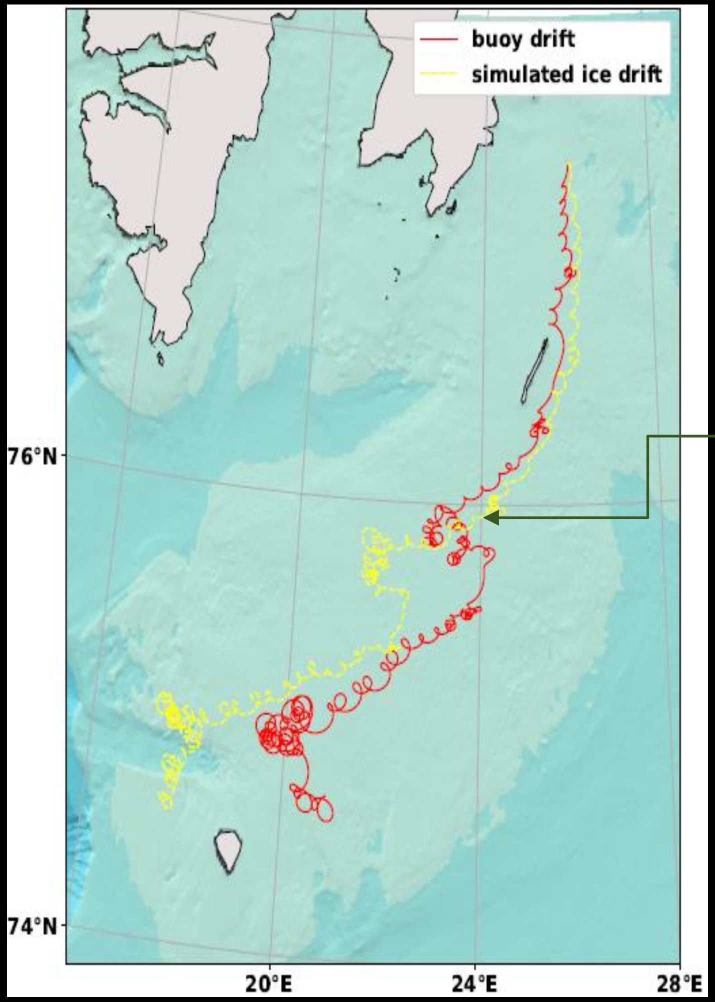

Fig 1: 8 Model v/s observed trajectory for beacon 16 with h_i =1 m, $C_a = 1.2\text{x}10^{-3}$, $C_w = 5.5\text{x}10^{-3}$

- Model simulations are done for all the 7 beacons.
- Results for only 1 beacon are shown here.

Modelled trajectories seem to follow the overall trend of the observations.

Tidal trends of the observations like the frequency of maximum amplitude are also seen in the model.

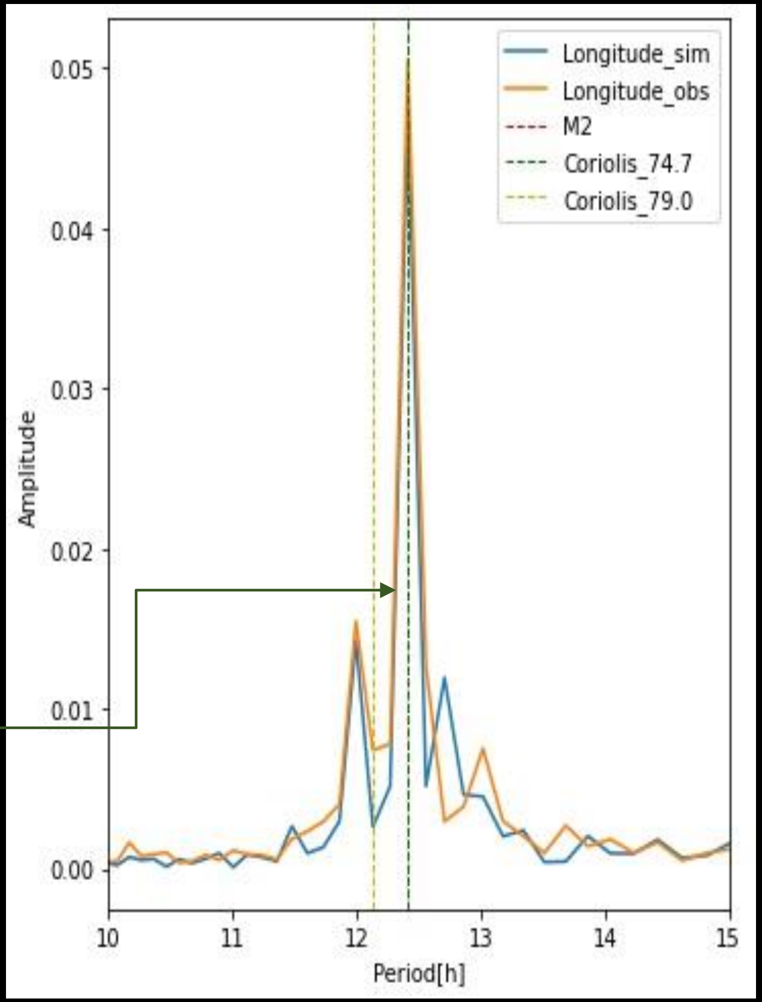

Fig 2: 8 Fourier transform of mean drift filtered time series for Beacon 16

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Conclusions & Future Work

- This simple model is a good tool to understand the drifting ice motion under tidal and inertial forces.
- Sensitivity tests on forces (e.g. Coriolis) and the parameterizations (e.g. ice thickness) are in process.
- An EnKF is in place to conduct experiments to obtain optimum drag parameters for drifting ice under tides.
- The aim is to enhance the body of knowledge for the effect of tides on the sea ice for the Arctic Ocean systems.
- Another goal is obtaining a physically consistent parameterization for our global tidal model.

Model sensitivity to Coriolis force

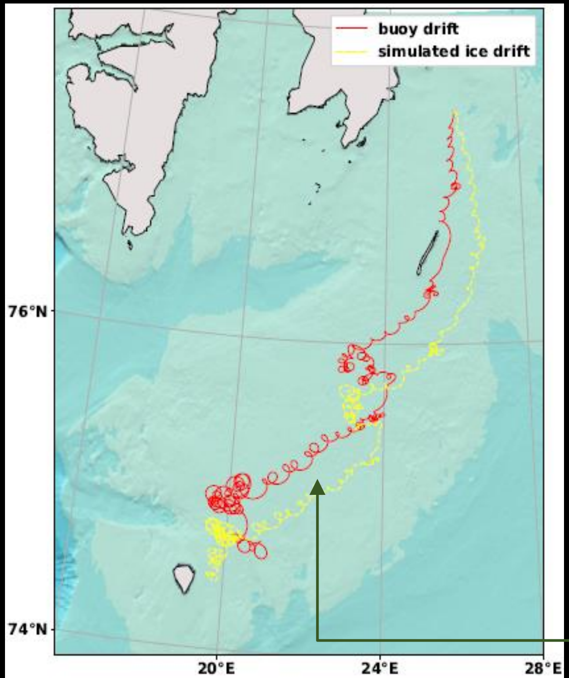

Fig 1: Without Coriolis beacon 16

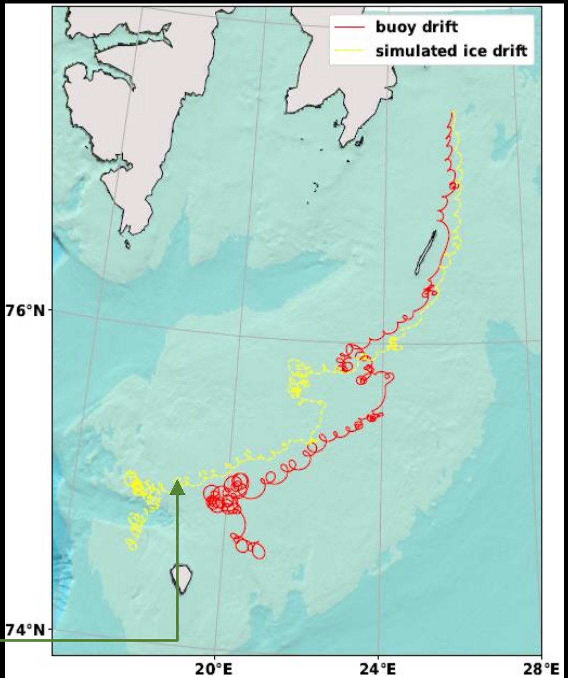

Fig 2: With Coriolis beacon 16

Preliminary analysis shows that Coriolis tends to rotate the drift trajectories

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Procurement and application of CALIB-I drift buoys from Metocean (Canada) funded through DFG EXC177 (PI. L. Kaleschke)

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