Understanding what controls the ocean circulation in the Arctic is crucial for predicting how the region responds to ongoing changes.

In order to understand what the controlling dynamics are, we examine an analytical model and test it against high-resolution numerical simulations.

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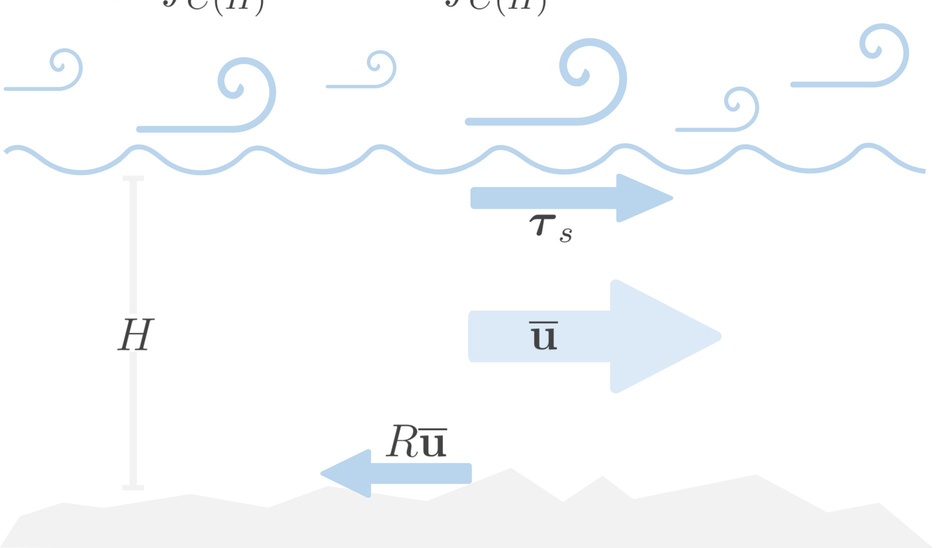
ANALYTICAL MODEL FOR WIND-DRIVEN OCEAN FLOW PREDICTS **CIRCULATION** IN **ARCTIC MEDITERRANIAN**

Analytical model

We work with an analytical model derived from the linear shallow-water momentum equation integrated around a contour of constant depth, motivated by strong topographic steering at high latitudes. Only surface stress and bottom friction are considered as driving forces, giving the following expression for the time varying depth-averaged circulation:

$$\frac{\partial}{\partial t}\oint_{C(H)} \bar{\mathbf{u}} \cdot d\mathbf{s} = \oint_{C(H)} \frac{\boldsymbol{\tau}_s}{H} - \frac{R\bar{\mathbf{u}}}{H} \cdot d\mathbf{s}$$



The analytical model was first presented in Isachsen et al. (2003)[1], where they found good agreement between the model and numerical simulations in the Nordic Seas, but weaker correlations in the Arctic Ocean. Limitations then were:

- Low resolution simulations, effectively comparing the linear analytical model with linear simulations.
- Poor representation of surface stress in the presence of sea ice.

To get a more realistic evaluation of the analytical model, we improve on the following points:

- Compare with high resolution (4 km) simulations.
- Better representatoin of surface stress.

Main results

Despite its extreme simplicity, the analytical model agrees well with the high resolution numerical simulations in all basins (Figure B). The model was originaly developed to describe the depth-averaged circulation, but fit better to the bottom circulation, likely due to a more correct representation of the bottom friction in this case.
The good agreement indicates that much of the variability in the circulation can be explained by linear processes.

However, contrary to earlier examinations, we find that the performance of the analytical model depends on the direction of the circulation, with the analytical model overestimating anti-cyclonic circulation (Figure C). This observation suggests that additional processes, not captured in the analytical model, play an important role in anti-cyclonic circulation. We propose stationary topographic Rossby waves interacting with the topography as a possible explanation for the observed asymmetry.

Conclusion

We show that the time varying bottom circulation in a highly complex numerical simulation of the Arctic Mediterranean can be reproduced by a linear model only considering surface stress and bottom friction.
We also see indications of an asymmetry in dynamics between cyclonic and anti-cyclonic circulation.

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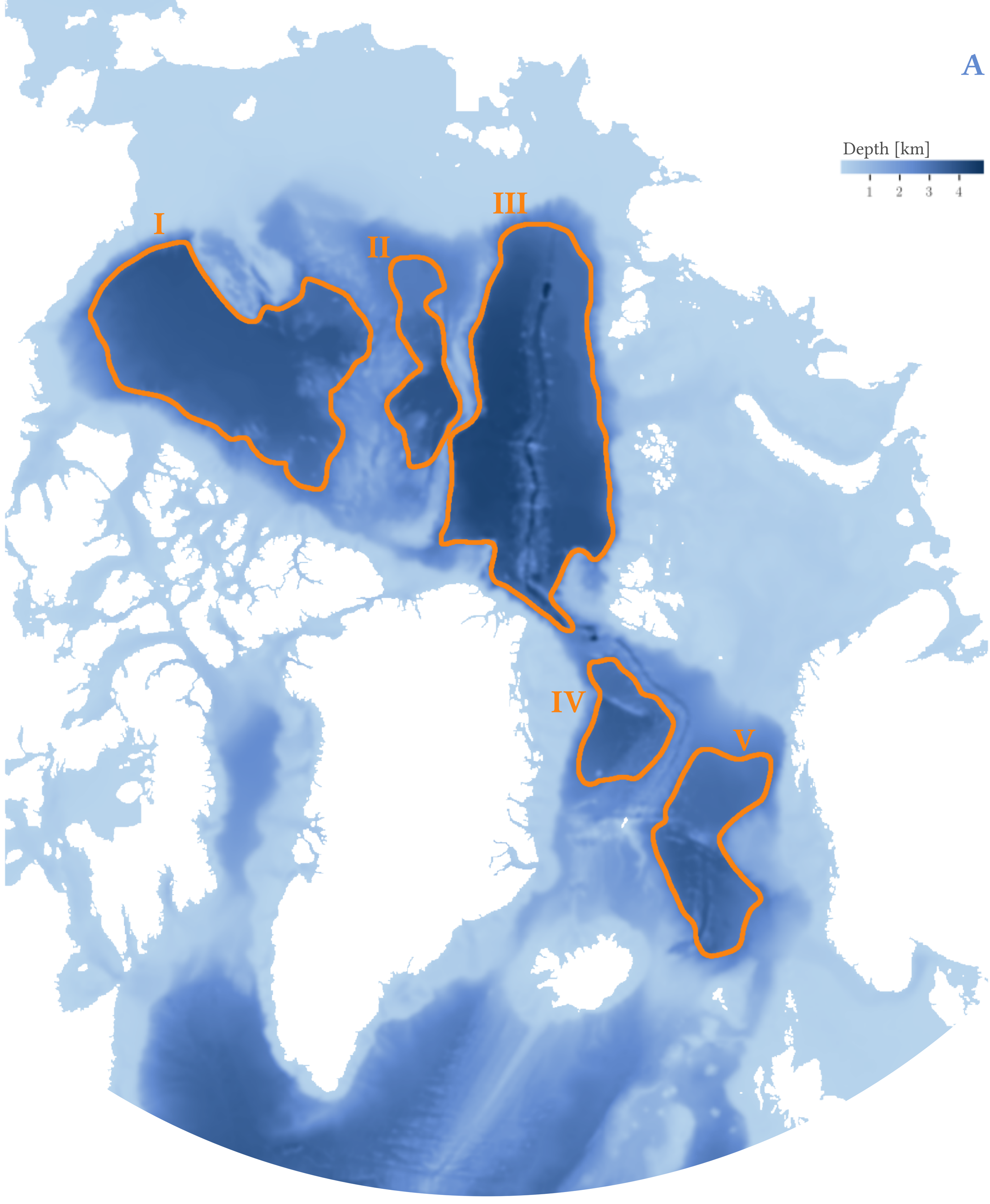

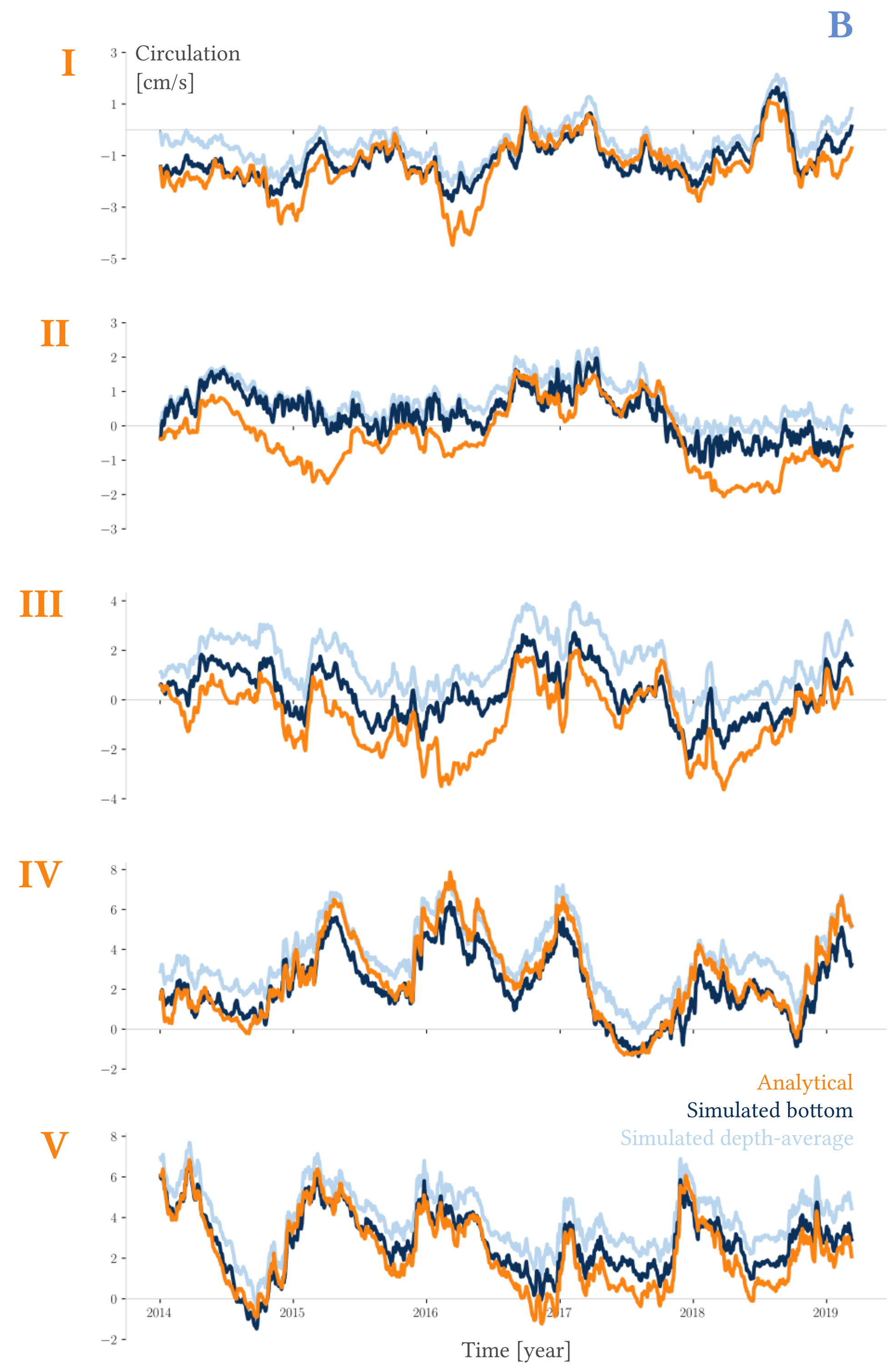

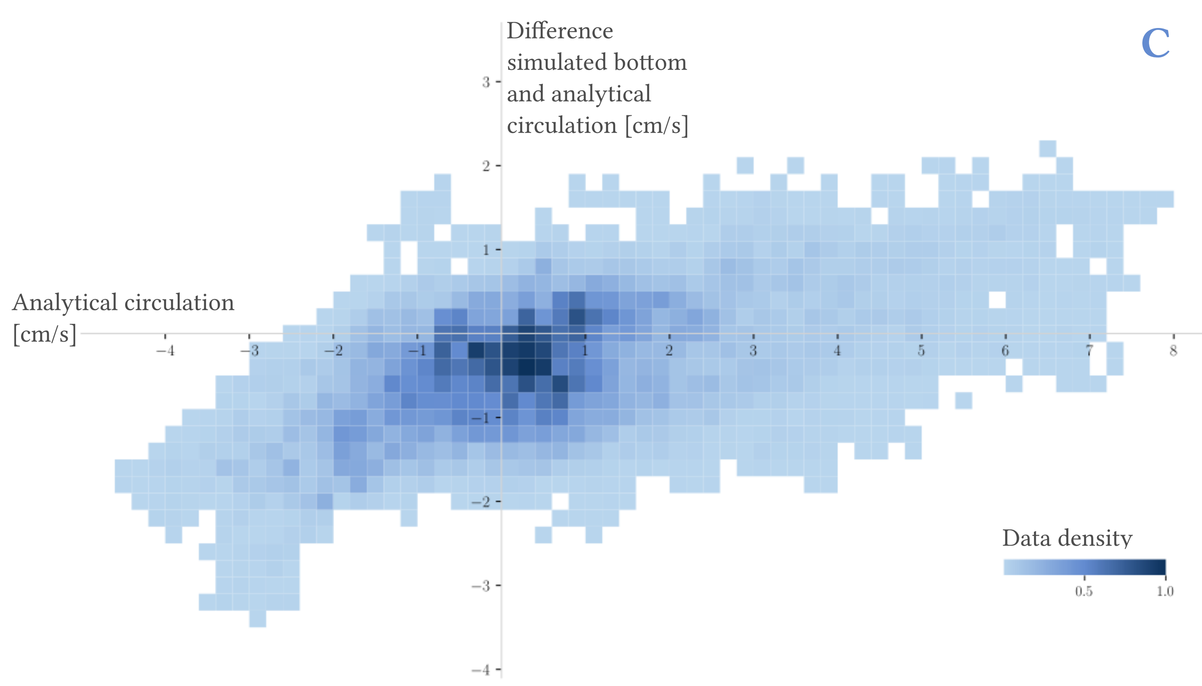

A Selected contours C(H) in the major Arctic Mediterranean basins are marked on a map of the simulation bathymetry.

B Time series of analytical circulation agree well with simulated circulation, especially in the Greenland (IV) and Norwegian (V) basins. In the Canadian (I), Makarov (II) and Eurasian (III) basin, we see a tendency of a more pronounced offset between simulations and the analytical model during periods of predicted anti-cyclonic (negative) circulation.

C The asymmetry indicated in B is made further explicit when comparing the difference between the analytical and simulated circulation as a function of the analytical circulation. The difference is centered around zero for cyclonic (positive) circulation, while it increases as we move to stronger anti-cyclonic (negative) circulation.

[1] Isachsen, P.E. et al. (2003) "Wind-driven variability of the large-scale recirculating flow in the Nordic Seas and Arctic Ocean," Journal of physical oceanography, 33(12), pp. 2534–2550.

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