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Title: Exploring salinity and density fluxes variability in the Nordic Seas through new satellite products: Insights from ESA's Polar Science Cluster ARCTIC-FLOW project

Abstract: The Atlantic Meridional Overturning Circulation (AMOC) plays a central role in the climate system by transporting and redistributing heat to depth, thereby regulating the effective heat capacity of the ocean under global warming. Observations and projections indicate a potential decline of the AMOC in response to climate change, with far-reaching climate consequences. The Nordic Seas are a key region for the overturning circulation, as dense water formation north of the Greenland–Scotland Ridge feeds the lower limb of the AMOC.

Within this context, the ARCTIC-FLOW project aims to improve our understanding of water mass transformation and overturning processes in the Nordic Seas. The project focuses on identifying the principal regions of surface water transformation, quantifying water mass transformation rates, characterizing the temporal and spatial scales of dense water formation, and assessing the impact of extreme freshening events across different subregions of the Nordic Seas. Especially in these regions all the processes under investigation are strongly modulated by variations in salinity.

To support these objectives, we have developed a novel 11-year satellite-based time series of freshwater and density fluxes for the Arctic and sub-Arctic regions. This dataset is constructed from satellite-derived sea surface salinity, sea surface temperature, and surface velocity fields, combined with mixed layer depth estimates.

This study introduces a kinematic framework for estimating ocean surface fluxes (salinity and density) based primarily on remote-sensing observations, proposed as an alternative to traditional model-based and thermodynamic approaches to air–sea interaction. Methodologically, the approach evaluates the material derivative of the observed variables integrated over the mixed layer, thereby accounting simultaneously for air–sea exchanges and mixed-layer dynamical processes.

Comparison with model outputs (FESOM2 and ERA5) reveals strong agreement in large-scale spatial patterns. However, substantial discrepancies arise at daily timescales. The spatially incoherent component of these differences is attributable to uncertainties in satellite measurements. In contrast, a second component is associated with high-frequency geophysical processes, such as wind forcing, which are captured by satellite observations but are not adequately represented in model simulations.

This work has demonstrated the feasibility of estimating fluxes across the ocean surface using exclusively observational data, predominantly derived from satellite remote sensing, without reliance on atmospheric datasets.

The results confirm that satellite-derived surface physical variables provide sufficient information to reconstruct key oceanic processes, highlighting its relevance for studying variability of water-mass transformation processes in the Nordic Seas. Although instrumental uncertainties in the input data currently represent the primary limitation, the improvement afforded by this methodology is substantial, both in terms of spatiotemporal resolution and in the accuracy with which the underlying physical processes are described.

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