Four-dimensional variational data assimilation with a sea-ice thickness emulator

Operational assimilation systems for sea ice are mostly based on Ensemble Kalman Filter methods due to the absence of an adjoint for sea-ice models. The currently advanced sea-ice model neXtSIM is built around a novel rheology paradigm, which provides access to high-fidelity sea-ice dynamics at mesoscale resolutions around 10 km. We developed an emulator for neXtSIM's sea-ice thickness, using a deterministic neural network and resulting in accurate forecasts with significant time savings. Additionally, we present a 4D-Var data assimilation system based on the emulator and its adjoint. Firstly, we perform twin experiments to demonstrate the capabilities of such methods and to test different approximations to the background covariance matrix. Estimating the analysis in the empirical orthogonal functions space spanned by the climatology thereby improves the analysis by 16 % compared to a more commonly used diagonal approximation of the covariance matrix. We also show that the use of an adaptive inflation scheme simplifies the tuning of the minimization and improves the results even further. Secondly, we propose the assimilation of real satellite observations into this setup, allowing a general bias correction of our model towards the observations and a better positioning of the marginal ice zone. With these results, we show a promising way to enable the innovative use of four-dimensional variational data assimilation for sea-ice models and more generally neural networks-based emulators for sea-ice prediction.

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