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A data-driven sea-ice model with generative deep learning

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The current generation of sea-ice models with Brittle rheologies can represent the observed temporal and spatial scaling of the sea-ice dynamics at resolutions of around 10 km. However, running those models is expensive, which can prohibit their use in coupled Earth system models. The promising results of neural networks for the fast prediction of the sea-ice extent or sea-ice thickness offer an opportunity to remedy this shortcoming. Here, we present the development of a data-driven sea-ice model based on generative deep learning that predicts together the sea-ice velocities, concentration, thickness, and damage. Trained with more than twenty years of simulation data from neXtSIM, the model can extrapolate to previously unseen conditions, thereby exceeding the performance of baseline models.

Relying on deterministic data-driven models can lead to overly smoothed predictions, caused by a loss of small-scale information. This is why the ability to perform stochastic predictions can be instrumental to the success of data-driven sea-ice models. To generate stochastic predictions with neural networks, we employ denoising diffusion models. We show that they can predict the uncertainty that remains unexplained by deterministic models. Furthermore, diffusion models can recover the information at all scales. This resolves the issues with the smoothing effects and results in sharp predictions even for longer horizons. Therefore, we see a huge potential of generative deep learning for sea-ice modelling, which can pave the way towards the use of data-driven models within coupled Earth system models.