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Reconstructing Sea Surface Dynamics Using a Linear Koopman Kalman Filter

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Spatio-temporal interpolation applications are important in the context of ocean surface modeling. Current state-of-the-art techniques typically rely either on optimal interpolation or on model-based approaches which explicitly exploit a dynamical model. While the optimal interpolation suffers from smoothing issues making it unreliable in retrieving fine-scale variability, the selection and parametrization of a dynamical model, when considering model-based data assimilation strategies, remains a complex issue since several trade-offs between the model's complexity and its applicability in sea surface data assimilation need to be carefully addressed. For these reasons, deriving new data assimilation architectures that can perfectly exploit the observations and the current advances in signal processing, modeling and artificial intelligence is crucial.

In this work, we explore new advances in data-driven data assimilation to exploit the classical Kalman filter in the interpolation of spatio-temporal fields. The proposed algorithm is written in an end-to-end differentiable setting in order to allow for the learning of the linear dynamical model from a data assimilation cost. Furthermore, the linear model is formulated on a space of observables, rather than the space of observations, which allows for perfect replication of non-linear dynamics when considering periodic and quasi-periodic limit sets and providing a decent (short-term) forecast of chaotic ones. One of the main advantages of the proposed architecture is its simplicity since it utilises a linear representation coupled with a Kalman filter. Interestingly, our experiments show that exploiting such a linear representation leads to better data assimilation when compared to non-linear filtering techniques, on numerous applications, including the sea level anomaly reconstruction from satellite remote sensing observations.