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Measurement-Constrained Reduced-Order Surrogates for Flexible-Mesh Coastal Ocean Models

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Reduced-order surrogate models based on Koopman autoencoders have recently shown strong potential for accelerating flexible-mesh coastal ocean simulations while maintaining physically meaningful dynamics. In this contribution, we extend a previously validated Koopman autoencoder framework by explicitly incorporating information from in-situ measurements during training.

The proposed approach augments the surrogate training objective with measurement-based constraints, penalizing deviations from observed water surface elevations at selected locations and times. This enables the surrogate to remain consistent with sparse observations while preserving the learned large-scale dynamical structure driven by meteorological forcing and boundary conditions.

The method is evaluated on two realistic MIKE 21 HD coastal-ocean configurations published as open WaterBench datasets: the Southern North Sea and the Øresund Strait. Performance is assessed against both full physics-based simulations and independent in-situ observations, focusing on accuracy, temporal stability, and generalization beyond the training period.

Results demonstrate that measurement-constrained training can reduce local prediction errors near observation points without degrading global performance, while retaining the substantial inference speed-ups characteristic of Koopman-based reduced-order models. The proposed framework represents a step toward tighter integration of observations and machine-learning surrogates for efficient, observation-aware coastal ocean modelling, with relevance for ensemble forecasting and long-term scenario analysis.