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Variational data assimilation of sea level into a regional storm surge model: benefits and limitations

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Storm surges are coastal sea-level variations caused by meteorological conditions. It is vital that they are forecasted accurately to reduce the potential for financial loss and loss of life. An area historically prone to destructive surges is the North Sea, thanks largely to its shallow nature, semi-enclosed geometry and large surrounding areas of low-lying land.
In this study, we investigate how effectively the variational assimilation of sparse sea level observations from tide gauges can be used for operational forecasting. A new shortest path method based on Dijkstra's algorithm is introduced and evaluated for dealing with coastal boundaries and a dynamic covariance model, incorporating information from the model state itself, is also considered. For our experiments, a specific case study is used: the December 2013 Cyclone Xaver event in the North Sea.
We validate our covariance models by removing selections of tide gauges from the assimilation. These experiments show widespread improvements in RMSE and correlation, reaching up to 16cm and 0.7 (respectively) at some locations, implying our assimilation setup is reasonable. Mock forecasts show RMSE improvements of up to 5cm are found for the first 24 hours of forecasting, which is useful operationally. Beyond 24 hours, improvements quickly diminish however. During all experiments, the dynamic covariance model performs better than the non-dynamic covariance models however there is little difference between the Dijkstra and Euclidean based setups.
This work places an upper bound on how effective variational assimilation of sea level data can be for storm surge forecasting in semi-enclosed, tidal, shallow seas.