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The role of flow-dependent oceanic background-error covariance information in air-sea coupled data assimilation during tropical cyclones: a case study

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In variational data assimilation, background-error covariance structures have the ability to spread information from an observed part of the system to unobserved parts. Hence an accurate specification of these structures is crucially important for the success of assimilation systems and therefore of forecasts that their outputs initiate. For oceanic models, background-error covariances have traditionally been modelled by parametrisations which mainly depend on macroscopic properties of the ocean and have limited dependence on local conditions. This can be problematic during passage of tropical cyclones, when the spatial and temporal variability of the ocean state depart from their characteristic structures. Furthermore, the traditional method of estimating oceanic background-error covariances could amplify imbalances across the air-sea interface when weakly coupled data assimilation is applied, thereby bringing a detrimental impact to forecasts of cyclones. Using the case study of Cyclone Titli, which affected the Bay of Bengal in 2018, we explore hybrid methods that combine the traditional modelling strategy with flow-dependent estimates of the ocean's error covariance structures based on the latest-available short-range ensemble forecast. This hybrid approach is investigated in the idealised context of a single-column model as well as in the UK Met Office's state-of-the-art system. The idealised model helps inform how the inclusion of ensemble information can improve coupled forecasts. Different methods for producing the ensemble are explored, with the goal of generating a limited-sized ensemble that best represents the uncertainty in the ocean fields. We then demonstrate the power of this hybrid approach in changing the analysed structure of oceanic fields in the Met Office system, and explain the difference between the traditional and hybrid approaches in light of the ways the assimilation systems respond to single synthetic observations. Finally, we discuss the benefits that the hybrid approach in ocean data assimilation can bring to atmospheric forecasts of the cyclone.