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A Variational Data Assimilation Scheme for Prediction of Ocean Bathymetry from Surface Waves

Accurate mapping of ocean floor topography is a multi-faceted process, needed for safe and efficient navigation on shipping routes as well as for predicting tsunami waves. Currently available bathymetry data does not always provide a resolution high enough to capture the dynamics of such nonlinear waves accurately. However, collection of accurate mapping data is difficult, costly, and often a dangerous affair. As an alternative, theoretical approaches use propagation of free surface waves to extrapolate the shape of the bathymetry. In this study we implement a variational data assimilation scheme on the shallow water equations to improve estimates of the bathymetry, using observations of surface wave height to optimise our predictions. We show that a necessary condition is that the amplitude of the initial condition wave be much smaller relative to the amplitude of the bathymetry. If our objective is to use this reconstructed bathymetry to accurately predict tsunami waves, we observe that a relatively higher error in the optimal reconstruction of the bathymetry still yields a highly accurate prediction of the surface wave, suggesting low sensitivity of surface waves to higher frequencies in the bathymetry. We also analytically derive the sensitivity of our optimisation to perturbations in the observations. These conclusions are based on numerical experiments for both periodic and non-periodic bathymetry, and with different observation operators. These results can potentially have a significant impact in the real world, where computational cost can be minimised through a priori knowledge of sufficient error tolerances needed for accurate tsunami prediction.