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Variational data assimilation for the shallow water equations

The shallow water equations (SWE) are a widely used model for the propagation of surface waves. In particular, the SWE are used to model the propagation of tsunami waves in the open ocean. We consider the associated data assimilation problem of optimally determining the initial conditions for the one-dimensional SWE equations from a small set of observations of the sea surface height. We derive variational data assimilation methods for both the linear and nonlinear SWE and implement them numerically. In the linear case we solve the assimilation equations analytically and prove a theorem giving sufficient conditions for convergence to the true initial conditions. At least two observation points must be used and at least one pair of observation points must be spaced more closely than half the effective minimum wavelength of the energy spectrum of the initial conditions. We confirm our analysis in numerical implementations of the both the linear and nonlinear SWE assimilation problems. At least three observation points are required for the practically useful results. This paper is a first step in understanding the conditions for observability of the SWE for multiple observation points in more physically realistic settings.