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Variational assimilation of sea-surface data into a tidal model

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The scope of modelling environmental systems extends from mimicking observed dynamics to accurate forecasting capabilities as numerical weather forecasts. A central problem for accurate modelling is the knowledge of the underlying dynamical processes as well as the physical parameters and initial conditions.
It is ubiquitous that environmental systems have nonlinear components displaying chaotic behaviour. Thus, also small errors e.g. in the initial conditions or parameterizations will lead to quickly dropping forecast-ability. To increase accuracy, the advantage of geophysical numerical models is often combined with accurate observational data. Therefore, different assimilation methods have been proposed. Due to the nonlinear nature of environmental numerical models, we propose to use the inverse adjoint method which respects the nonlinearity of the underlying system. It tries to minimize the deviation of calculated model-values from observational data under the constraint that the governing physical equations remain unchanged, instead of introducing additional constraints or relaxation terms. The adjoint assimilation tries to improve the model itself, changing terms and conditions which are not known accurately enough in order to come closer to the observed dynamics.
Using the example of a tidal model, we demonstrate the feasibility of the adjoint technique for environmental systems. The barotropic tidal model used is a module of the Ocean Model for Circulation and Tides (OMCT), solely forced by the tidal potential, including the dynamic effects of loading and self-attraction (LSA) of the water-column. As assimilated data, the st103 pelagic data set is used to validate sea-surface heights induced by partial tides. We show that by identifying different adjustable parameters as e.g. the forcing, the LSA or diffusivity, the adjoint technique is able to improve the model by reducing misfits compared to the observed sea-surface heights by up to 15%. Being closer to the observed dynamics, the assimilated model allows calculating dependent values more accurately. For example, oceanic tidal angular momentum (OTAM) values are expected to be closer to real values. The re-calculated OTAM values increase for the semi-diurnal tides and decrease for the diurnal tides.