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Dynamically constrained ensemble perturbations. Application to tides on the West Florida Shelf

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In numerous modelling applications, the uncertainty of the model results needs to be estimated. An estimation of this uncertainty is often obtained by realizing a stochastic ensemble forecast: inputs to the model are perturbed within the bounds of their respective uncertainty and for each of those perturbations the model is integrated forward. For ocean models, the model uncertainty stems, among others, from the forcing fields and initial conditions. The spread of an ensemble forecast using perturbed forcings fields and initial conditions gives the estimation of the model uncertainty. This uncertainty (often formally expressed as model error covariance) is also required in various data assimilation techniques. The success of the data assimilation depends crucially on the realism of the model error covariance which in turns depends on the realism of the applied perturbations.

A method is presented to create an ensemble of perturbations that satisfies linear dynamical constraints. A cost function is formulated defining the probability of each perturbation. It is shown that the perturbations created with this approach take the land-sea mask into account in a similar way as variational analysis techniques. The impact of the land-sea mask is illustrated with an idealized configuration of a barrier island. Perturbations with a spatially variable correlation length can be also created by this approach. The method is applied to a realistic configuration of the West Florida Shelf to create perturbations of the M2 tidal parameters for elevation and depth-averaged currents. The perturbations are weakly constrained to satisfy the linear shallow-water equations. Despite that the constraint is derived from an idealized assumption, it is shown that this approach is applicable to a non-linear and baroclinic model. The amplitude of spurious transient motions created by constrained perturbations of initial and boundary conditions is significantly lower compared to perturbing the variables independently or to using only the momentum equation to compute the velocity perturbations from the elevation.