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4D variational data assimilation for locally nested models

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A common way to develop regional ocean modeling systems consists in embedding a high resolution local model into a coarse resolution model covering a larger domain. The local model then takes its boundary conditions from its parent model (one-way interaction), while the parent model solution may additionally be periodically updated using the local fine resolution solution (two-way interaction).

However, for data assimilation purposes, the multi-resolution structure of the modeling system is generally ignored. One assimilates data either in one of the two models only, or in both models separately, but without properly taking into account the interactions between the two numerical solutions.

We address the problem of 4D variational data assimilation in such locally nested models, for the control of the initial conditions on both models. The adjoint system is derived in both cases of one-way and two-way interactions. It is shown that the adjoint formulation adds new interactions between the grids, in the opposite sense of the interactions existing in the direct formulation. In particular, in the one-way case, the adjoint formulation creates a retroaction term from the fine grid onto the coarse grid. The design of the multigrid background error covariance matrix is also discussed, as well as the addition of a new control variable corresponding to the errors in the interactions between the coarse resolution and fine resolution solutions.

These formulations are illustrated and discussed in the idealized test case of a 2D shallow water model. In particular, it is shown that this multi-resolution approach leads to improved results with regard to the usual method consisting in the assimilation of data on the local fine resolution model only, with a control of its corresponding initial condition and of its boundary values.