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An ensemble filter for nonlinear dynamics with local updating

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Recently, ensemble data-assimilation methods based on importance sampling have been tested for highly nonlinear geophysical flows that include processes like meander formation, eddy-mean-flow interactions, ring formation, interactions of rings with each other, flow-bottom interactions, etc. Traditional methods like variants of the Kalman filter and 4D-VAR are based on linearizations. Although they work fine for weakly nonlinear dynamics, by increasing model resolution the problems become so nonlinear that several ad-hoc solutions to the data assimilation problems are necessary in these traditional methods. In the ensemble filters based on importance sampling this is not needed. Disadvantage is the relatively high costs of these filters, of the order of 500-1000 model runs.

All ensemble methods that are used today in large-scale ocean and atmospheric models use local updating, i.e. the analysis is done independently in relatively small areas so that the number of degrees of freedom increases dramatically, roughly the ensemble size times the number of analysis areas. This is the basis of the success of e.g. the Ensemble Kalman filter for large-scale models. This local updating seems problematic for methods based on importance sampling, because the relative weighting of the ensemble members is global.

The analysis step in importance sampling is in fact a two-step procedure, and one of the steps can be rewritten in the form of 'state-vector nudging'. Nudging a state vector to another state vector is straightforward because all model variables are nudged, while in traditional nudging to observations the state vector is only partially updated. Furthermore, the nudging coefficient is well defined in our case. This state-vector nudging allows one to nudge ensemble members to different ensemble members in

different location, allowing for local updating, without approximating the nonlinear filter characteristics!

Results of this new method will be shown for a large-scale multilayer primitive equation ocean model in a highly nonlinear regime. It is shown that size of the ensemble can be reduced significantly by this new procedure, while keeping the advantages of the nonlinear filtering, like positive definiteness, (almost) balanced states, nonlinear measurement operators, no inversions, higher moments available.