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Ocean Data Assimilation and the Moan Filter: Spatial Regularity

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ABSTRACT

Ocean circulation models are infinite-dimensional dynamical systems. If the Kalman filter is used to assimilate data into such systems, then their infinite-dimensionality must be recognized. In other words, numerical approximations to the Kalman gains must converge to smooth functions of position, as spatial resolution is improved. It is shown here, by asymptotic analysis and numerical experiment, that the Kalman gains converge if and only if the wavenumber spectrum of the system noise is suitably colored.

For a quasi-geostrophic ocean model without eddy viscosity, the wavenumber spectrum of the vorticity system noise must be $o(n^{-1})$ as n->∞, in order to ensure a continuously differentiable vorticity gain. It the model includes eddy viscosity then a milder requirement holds, but the streamfunction and vorticity gains have unphysical boundary layer structure near measurement points.

The analysis and experiments described here employ linear ocean models, and include the cases of data available continuously in time and discretely in time. The experiments show that, in the case of continuous data, the matrix Riccati equation for the streamfunction covariance matrix is numerically well-conditioned provided the streamfunction system noise is colored. The analysis shows that the covariance matrix is banded only in the case of discrete data and only if the system covariance greatly exceeds the measurement noise variance.

We also find that, if the spatial regularity of the Kalman filter has been ensured, then the gains may be computed at modest resolution. This yields considerable computational savings. It is concluded that rigorously correct applications of the Kalman filter to linear ocean circulation models may be achieved with reasonable computational overhead.

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