Local Ensemble Transform Kalman Filter for Semi-Lagrangian Barotropic Model of Atmosphere

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Local ensemble transform Kalman filter (LETKF) data assimilation system is developed for global semi-Lagrangian barotropic model of atmosphere with external forcing.

The governing equation of the model is:

$$\frac{d\Omega}{dt} = F_{ext} \qquad (1),$$

where $\frac{d\Omega}{dt} = \frac{\partial\Omega}{\partial t} + \frac{u}{a\cos\varphi}\frac{\partial\Omega}{\partial\lambda} + \frac{v}{a}\frac{\partial\Omega}{\partial\varphi}$,

$\Omega = \Delta\psi + f + kH$, $\Delta\psi + f$ denotes vertical component of absolute vorticity, H stands for the orography, k is orography normalization coefficient, F_{ext} denotes external forcing, ψ – stream function, f – Coriolis parameter.

Equation (1) is discretized spatially like in [1]. The resolution of the model is 1.5°×1.5°, time step is 45 minutes.

The external forcing F_{ext} is chosen so that the mean state of the system is close to the mean state of the actual atmosphere for the $\Delta\psi$ field at 300mb (averaged for the 5 days around the date of analysis) calculated from the NCEP/NCAR reanalysis.

Let $\Omega = \overline{\Omega} + \Omega'$, then

$$F_{ext} = \overline{\frac{u'}{a\cos\varphi}\frac{\partial\Omega'}{\partial\lambda} + \frac{v'}{a}\frac{\partial\Omega'}{\partial\varphi}} + \frac{\overline{u}}{a\cos\varphi}\frac{\partial\overline{\Omega}}{\partial\lambda} + \frac{\overline{v}}{a}\frac{\partial\overline{\Omega}}{\partial\varphi} - r\nabla^4\Omega + r\nabla^4\overline{\Omega}, \qquad (2)$$

where r is the diffusion coefficient.

The analysis of the properties for this system can be found in [2].

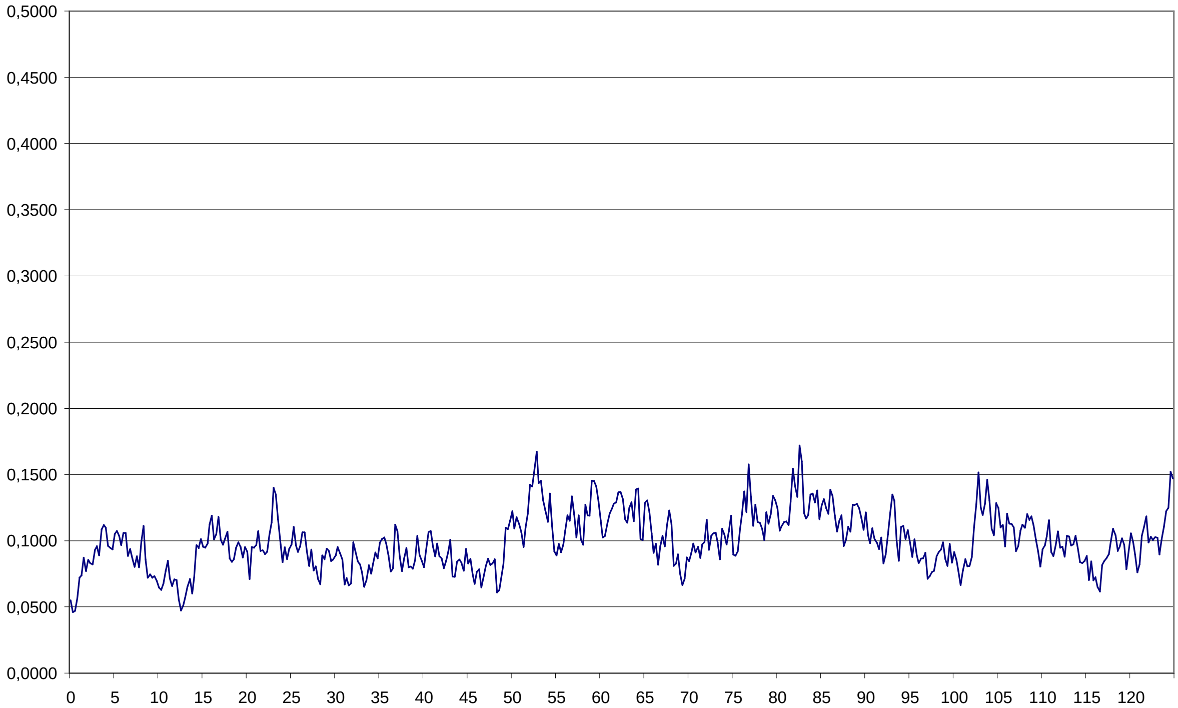
Local Ensemble Transform Kalman Filter [3, 4] is used for data assimilation. The only analysis variable is the vertical component of absolute vorticity. Pseudoobservations (the vertical component of absolute vorticity at 300mb calculated from the NCEP/NCAR reanalysis) are generated at random grid points and assimilated every 6 hours. The analysis ensemble consists of 40 members. The initial ensemble members of the background states are 40 'true' fields (NCEP/NCAR reanalysis) of the vertical component of absolute vorticity at 300 mb, taken at the period from -20 to +19 dates from the first assimilation cycle date. All observations have equal weight within a 500 km radius of the grid point, beyond which the weight of the observations decreases exponentially with e-folding distance 800 km. Temporally varying adaptive covariance inflation algorithm [5] is applied.

Assimilation algorithm is parallelized via MPI for the number of processes equal to the number of ensemble members.

LETKF assimilation for the model (1) works stable for more than 4 months of assimilation. Time evolution of the L_2-norm for the analysis error with respect to the 'truth' (averaged over the randomly chosen observations) for the first 125 days (500 steps) of analysis is shown on Figure 1.

The goal of future research is to try different background covariance inflation algorithms (including spatially varying inflation), investigate the use of random perturbations and further investigate the properties of the system. It is planned to apply the implementation of the LETKF algorithm to a more sophisticated model.

Figure 1



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