Sensitivity experiments with a LETKF data assimilation system based on the WRF model

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Motivation and Objective

There are few studies concentrated on data assimilation and related issues in South America, where most of the operational and research forecast systems use the NCEP-GDAS analysis to define the initial atmospheric state. Given that the GDAS analysis provides global initial fields at ~30 km resolution, our aim is to understand how can we benefit from a high resolution analysis generated with a regional model. Our strategy is based on the use of the Local Ensemble Transform Kalman Filter (LETKF) data assimilation system and the WRF model , using a perfect model experiment to define the true state and then perform sensitivity studies.

What is LETKF?

LETKF stands for Local Ensamble Tranformed Kalman Filter and our implementation is based in Hunt et al (2007), adapted to WRF environment by Miyoshi T and S Yamane (2007).

Suppose we have an ensemble of k estimations of the state of the atmosphere (x^b) obtained from a perfect model that evolves the system from a given time t-1 to a time t. In addition to this, we also have observations of the system at time t (y^o) whose errors have Gaussian distribution and zero mean.
The purpose of LETKF is to find an ensemble of analysis x^a, so as their mean minimizes the Kalman Filter cost function:

$$J(x) = (x - \overline{x^b})^T (P^b)^{-1} (x - \overline{x^b}) + [y^o - H(x)]^T R^{-1} [y^o - H(x)]$$

Where the overbar denotes the mean, P^b and R are matrices representing the covariance error of the forecasts and of the observations, respectively, whereas H is an operator that transports the model variables to the observations.

Since k is much less than the total degrees of freedom of the model, the minimization is carried out in the subspace spanned by the ensemble of x^b . This reduces the dimensionality of the problem, making it advantageous from the point of view of efficiency. On the other hand, it is necessary to have enough number of members, since if k is too small, there could be instabilities not accounted by the ensemble. For this reason, the analysis is done locally in every grid point of the model. In this way, the system will behave as a low dimensionally unstable system.

LETKF solves the problem of minimizing the cost function in a k-dimensional space, performing a linear transformation and after linearizing the observation operator H around the background ensemble mean, assuming that the spread of the ensemble is not too large.

The analysis members $x^{a(i)}$ are obtained by this way: $x^{a(i)} = \overline{x^b} + X^b w^{a(i)}$

Where X^b is a matrix whose *i*th column is $x^{b(i)}$-x^b., and w^a are weight vectors that specify what linear combinations of the background ensemble to add to the background mean to obtain the analysis ensemble.

True atmosphere state

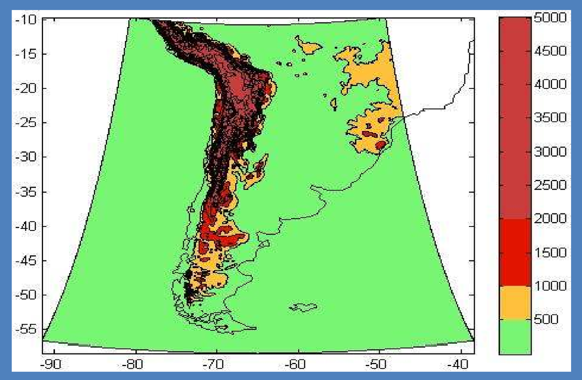
•Represented with WRF model version 3.1.

• Regional domain covering southern South America (see figure), with 10 km horizontal resolution and 40 vertical levels.

•The true state represents the period between June 1st and September 1st, 2010. Our objective is to reproduce weather patterns corresponding to winter season, where we expect to find sensitivity to data assimilation, while avoiding frequent convective activity typical of springtime and summer, particularly over Southeastern South America.

•Boundary conditions: GDAS analyses.

•Model output information is archived at 1 hour intervals.



Regional domain of experiments with topography height in meters

Observations

•Observations are generated from the true state.

• "Observed" variables are: temperature (T), wind (u,v), relative humidity (RH), specific humidity (q), and surface pressure (Ps).

•Random errors with Normal distribution are added to the observations. These errors are assumed to be independent of the observation location, and their mean value has been set as follows:

•Typical errors (ε) are:
ε(T)= 1°K
ε(u,v)=1 m/s
ε(RH)=10%
ε(Ps)=1.5 hPa
ε(q)= 2%*

•this variable has a relative error, instead of an absolute error.

• An observation of specific humidity (q) is assimilated only if the RH observation at a given point is out of range.

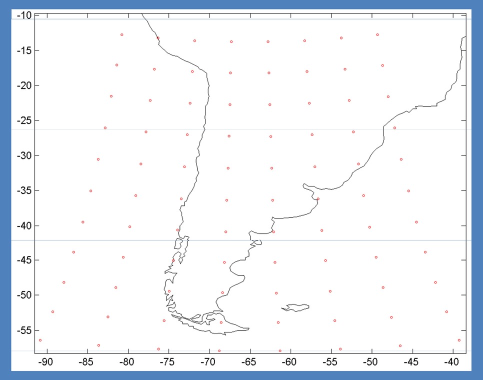
•Different sets of observations are generated, with different temporal resolution and spatial distribution.

LETKF data assimilation experiments

• Current status of research: we are now performing a test experiment of only one week length, since the 3-month true state is not yet available. In this experiment the total ensemble members are 20, while the horizontal resolution of the model is 20 km. Observations are generated at 1 hour intervals in a regular net of 500 km resolution (see figure).

•Sensitivity with respect to the following aspects will be tested:

- Number of members
- Model's horizontal resolution.
- Spatial distribution, temporal resolution and window length for observations assimilation



Spatial distribution of observation points in the test experiment

References and Acknowledgements

Hunt, B. R., E. J. Kostelich, and I. Szunyogh, 2007: Efficient data assimilation for spatio temporal chaos: a local ensemble transform kalman filter. Physica D: Nonlinear Phenomena, 77, 437-471.

Miyoshi, T., and S. Yamane, 2007: Local ensemble transform Kalman filtering with an AGCM at a T159/L48 resolution. Mon. Wea. Rev, 135,3841-3861.

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