Observation operator and estimation of uncertainty in the assimilation of AIRS radiances using ensemble Kalman Filter

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ABSTRACT

In this work we consider the uncertainty of a 40 ensemble member run with an ensemble Kalman filter on the GEOS-4, both in the atmospheric model ensemble space and in the corresponding radiances space, obtained by applying the CRTM forward model to each model state over whole domain to the subset of 324 channels of AIRS. By calculating the weighting function profile and finding the level of its maximum, we are able to indicate the atmospheric levels where the satellite observation will most strongly affect the model state in the LETKF analysis. The radiance fields obtained show where the model uncertainties in the ensemble are and also where the assimilation of AIRS radiances should have a significant impact on the reduction of forecast error.

INTRODUCTION

AIRS, the Atmospheric Infrared Sounder, is the first of a new generation of high resolution infrared sounders with thousands of channels rather than a few tens of channels. A subset of AIRS radiances, currently 324 of the 2378 channels were selected for use in numerical weather prediction, with channels that are sensitive to the temperature, humidity, ozone, carbon dioxide, methane, and other gases. The higher spectral resolution of AIRS sensor allows temperature and humidity features in the atmosphere to be better resolved in the vertical (~1km) than with the current ATOVS radiances (~3km).

We present the framework developed to assimilate radiances in the Local Ensemble Transform Kalman Filter (LETKF). The radiances of the ensembles are obtained through the application of the Community Radiative Transfer Model (CRTM) to input profiles. We developed a tool to estimate the uncertainty in the radiances present inside the ensemble. Using the 40 member ensemble we are able to calculate the spread (uncertainty) of the simulated meteorological satellite observations, which measure radiances (mW (m2 Mr. cm-1)).

The CRTM itself constitutes a basic part for the step of assimilation of the satellite observations directly in to the LETKF. An observation operator H that generates the radiances from the model state variables is needed to map the background state into satellite observation space. Here we built the H operator from the CRTM forward model, which simulates radiances and temperature of brightness for each vertical profile and surface characteristics of each model grid point of the first guess (FG). LETKF obtains an analysis by finding the linear combination of the ensemble members that best fits the observations. This can be done in 3 or 4-dimensions (Hunt et al, 2004, 2006)

Methodology

- Developmental version of CRTM used to construct the observation operator ***H;***
- Use with the subset of 324 AIRS channels (NWP);
- Constant satellite geometry information for every profile;
- Surface parameters derived from land-water-ice mask;
- The background states from the perfect model experiment of Liu et al. (2006).
- 40 ensemble members, NASA GEOS4 fvGCM atmospheric model (Lin, 2004).
- 5 degrees in longitude and 4 degrees in latitude, 55 vertical levels (top at 0.01 hPa).
- Background ensemble forecast valid to 12z January 01, 2003

Results

TEMPERATURE

- Largest WF (Fig.1) occurs near 500 hPa, as in the minimum and in the maximum WF line; ensemble radiance produced by the ***H*** operator reproduce the background uncertainty.

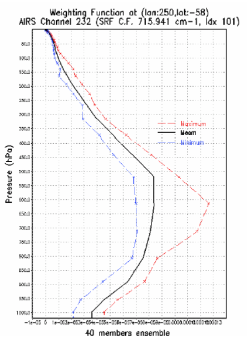

Figure 1 - Minimum (blue line), Mean (black line) and Maximum (red line) weighting function for AIRS channel 232 at (250E, 58S) in 40 members ensemble background.

- High uncertainty in the 40 ensemble members found in the simulated radiances and 500 hPa temperature (Fig. 2- a,b)).
- The high uncertainty is related to the fact that the background used in this experiment comes from an analysis that only assimilates conventional surface, with no ship, and rawinsonde observations.
- Large the potential for reduction in the ensemble uncertainty by the assimilation of AIRS radiances.

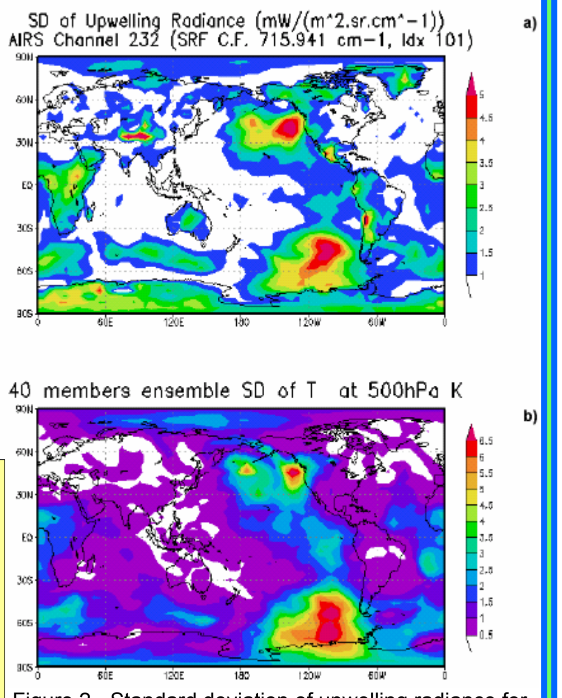

Figure 2 - Standard deviation of upwelling radiance for AIRS channel 232 (a) and standard deviation of temperature at 500 hPa (b) (Mean for 40 members ensemble background).

WATER VAPOR

- The uncertainty in the humidity of the ensemble, represented in the form of SD of UPRAD of AIRS channel 1449 (Figure 3a) and SD background specific humidity at 850 hPa (Fig. 3b), also show larger values in the areas where there are few observations available, over the oceans and over the South Hemisphere.
- A good relationship between the SD of UPRAD and SD of the SH can be observed, especially in the tropical and subtropical regions.

OZONE

- A significant surface response of the SD of UPRAD can be observed for this ozone channel (Fig4.a).
- Over the ocean areas it is possible to note some similarity between SD of UPRAD and SD of ozone (Fig 4.b).
- The uncertainty in the ozone field can be reduced with in some areas.

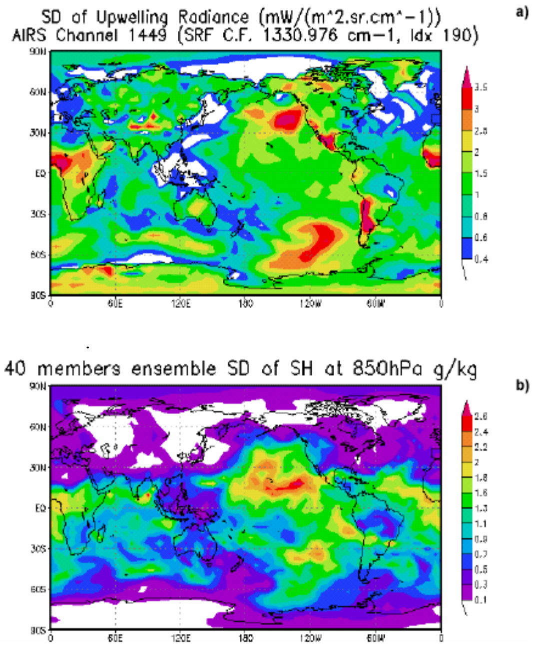

Figure 3 -Standard deviation of upwelling radiance for AIRS channel 1449 (a) and standard deviation of specific humidity at 850 hPa (b) (Mean for 40 members ensemble background).

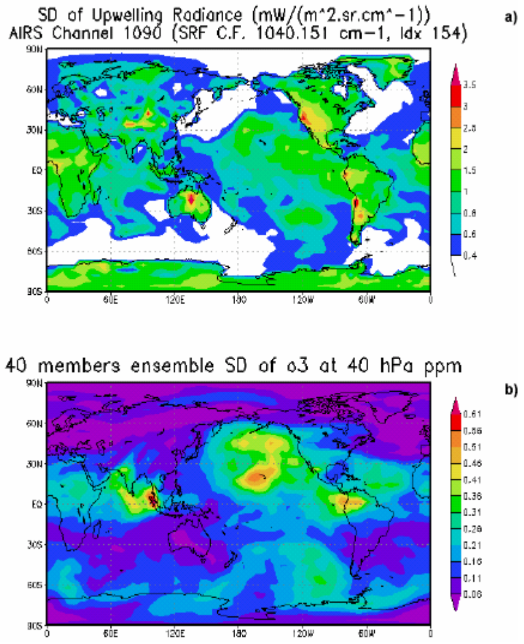

Figure 4 - Standard deviation of upwelling radiance for AIRS channel 1090 (a) and standard deviation of ozone at 40 hPa (b) (Mean for 40 members ensemble background).

Summary

The main results are:

- The ***H*** operator for AIRS satellite observations was constructed from the CRTM forward model can now be used to been assimilate AIRS radiances in the LETKF; we do not need its linear tangent or adjoint.
- A good relationship between the standard deviation of simulated ensemble radiances and the standard deviation of the background variables were obtained. This relationship indicates where and when assimilating radiances can reduce the uncertainty of the ensemble analysis and improve the forecasts;
- Computer time for the ***H*** operator is not a problem (2 minutes of computer time for each ensemble member to simulate radiances for 18048 profiles, in a non-dedicated 2.8 GHz machine, without any optimization);

We plan to compute the difference between the model radiances given by the ***H*** operator and observed satellite radiances for each ensemble member to use the 4D-LETKF to assimilate AIRS radiances

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