

Improved analyses and forecasts with AIRS retrievals using the Local Ensemble Transform Kalman Filter

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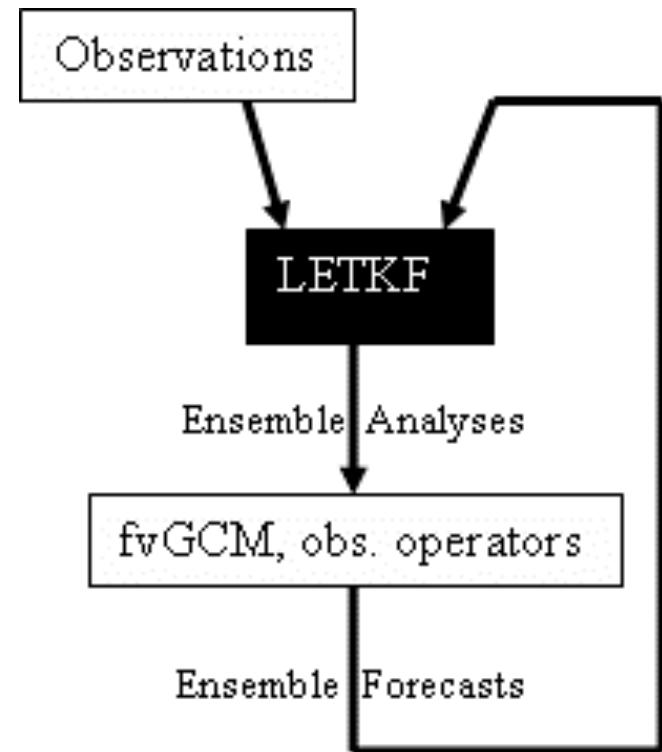
January 2007

Outline

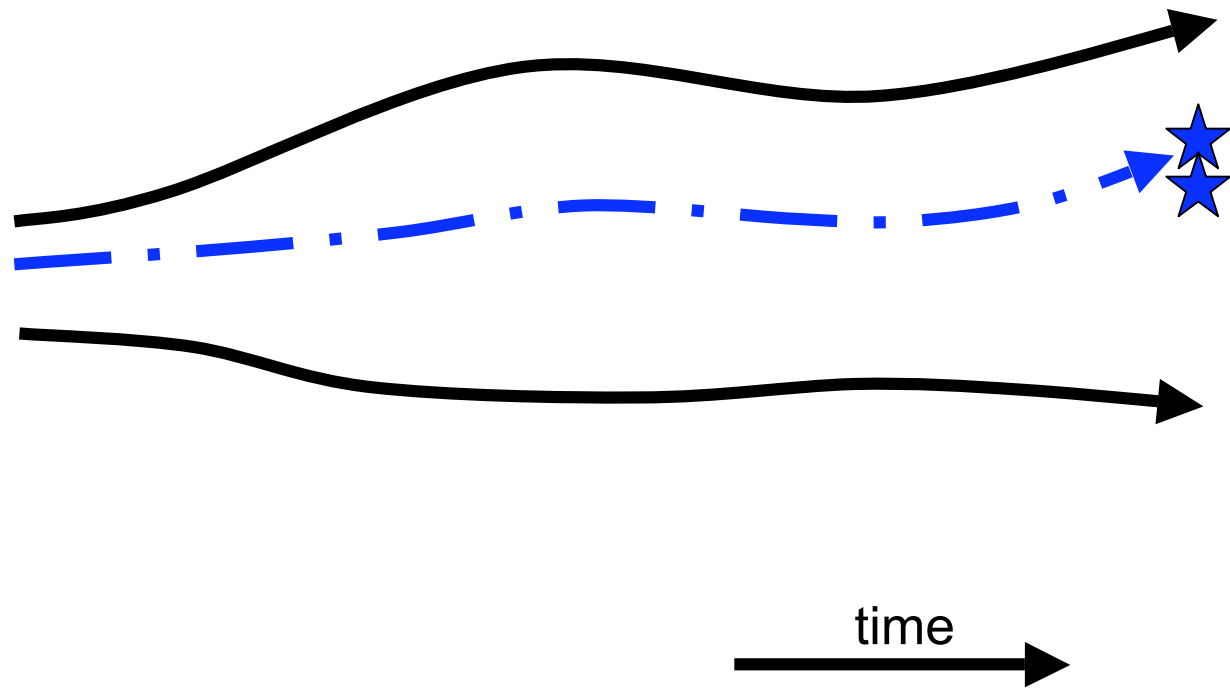
- Background
 - 3D-LETKF and 4D-LETKF extension
- Assimilation of AIRS temperature retrievals on NCEP GFS
 - Improved analyses
 - Improved forecasts
- Future Plans
 - Optimize assimilation of AIRS retrievals (correlated errors)
 - Assimilate AIRS humidity retrievals
 - Assimilate AIRS **cloud-cleared** radiances

Summary of LETKF

- Matrix computations are done in a very **low-dimensional** space: both **accurate** and **efficient**, needs **small ensemble**.
- The analysis is computed **independently** at each grid point, highly **parallel!**
- Very **fast!** 5 minutes in a 20 PC cluster with 40 ensemble members.
- Model independent, **does not** require **adjoint** of the **model** or the **obs. operator**.
- It knows about the “**errors of the day**” through P^f .



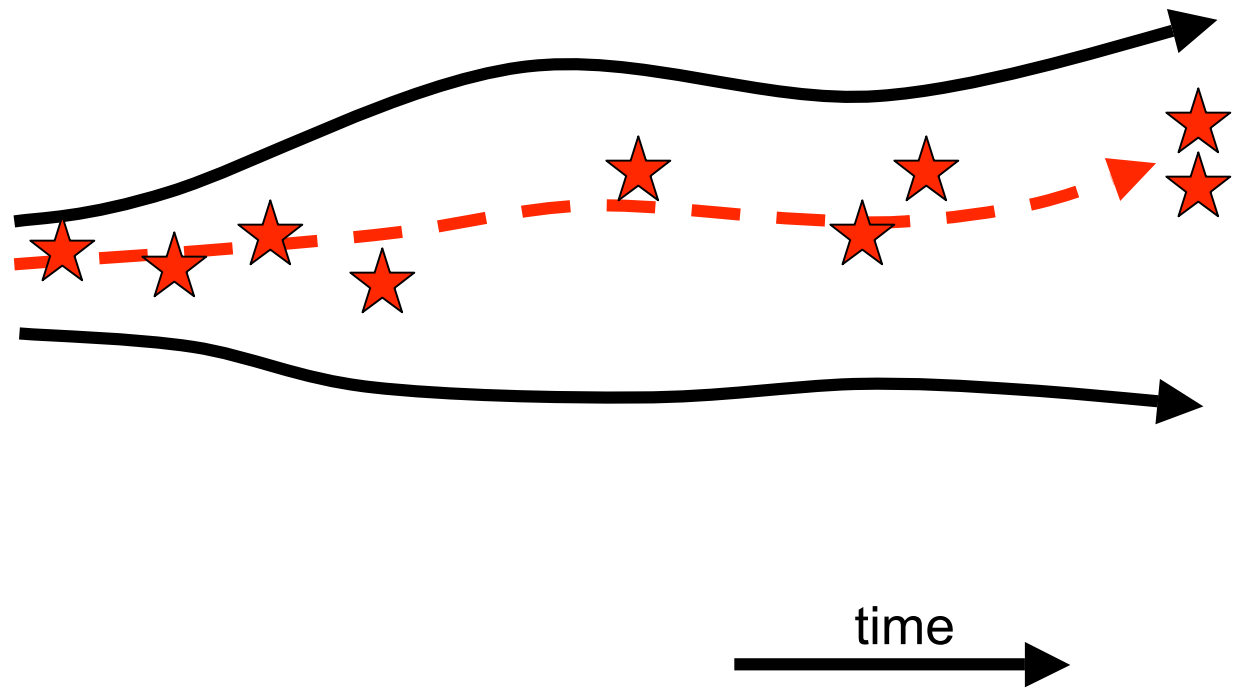
3D-LETKF (used before)



3D-LETKF finds **the best linear combination** of the ensemble members fitting the observations **at the analysis time**

4D-LETKF

(better for continuous satellite data)

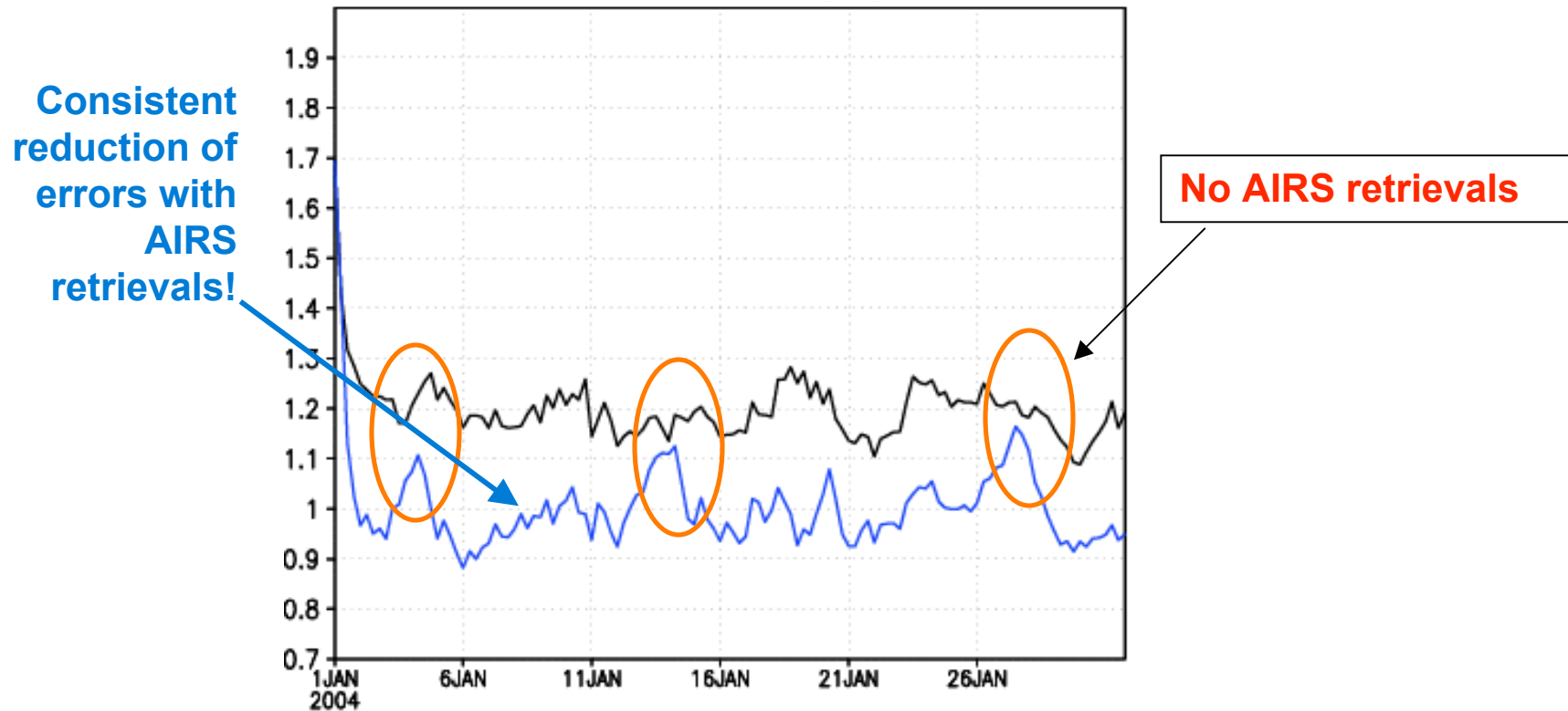


4D-LETKF finds **the best linear combination** of the ensemble trajectories **fitting the observations within the analysis window**

Assimilation of AIRS temperature retrievals

- *System* : NCEP GFS (T62L28) and 4D-LETKF
- *Control Run*: All operational observations except for radiances (Non-radiance data, Szunyogh et al. 2007, Whitaker et al. 2007)
- *AIRS Run*:
 - 📁 Non-radiance plus AIRS temperature retrievals [Chris Barnet (NOAA)]
 - 📄 v5 emulation with 3 deg*3 deg resolution
 - 📄 Ignored retrieval error correlations, but increase the error variances
$$R = \begin{bmatrix} (2 * e_1)^2 & 0 & 0 \\ 0 & (2 * e_2)^2 & 0 \\ 0 & 0 & (2 * e_3)^2 \end{bmatrix}$$
- *Verification*: Operational NCEP analysis at T254L64, assimilating all operational observations. (Not “truth”!).

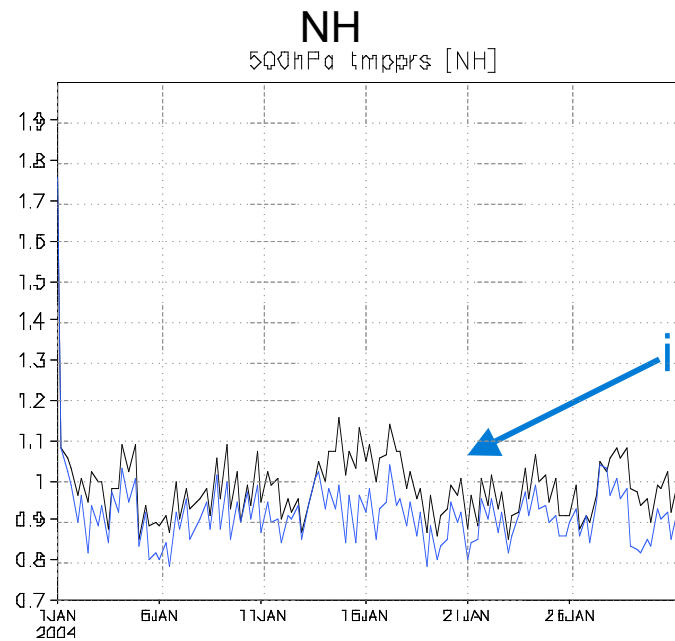
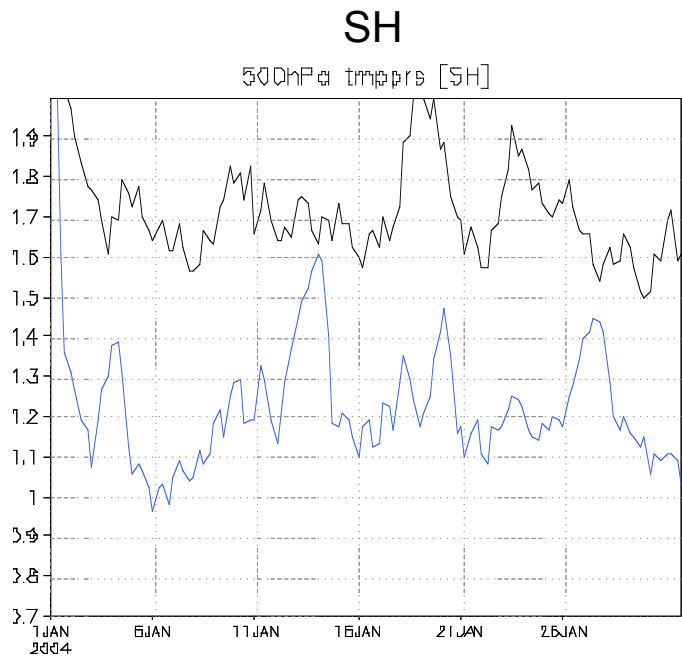
500 hPa Temperature analysis error averaged over Globe



Non-radiances Non-radiances + AIRS temperature retrieval

Result are similar to non-radiance when there are no available retrievals

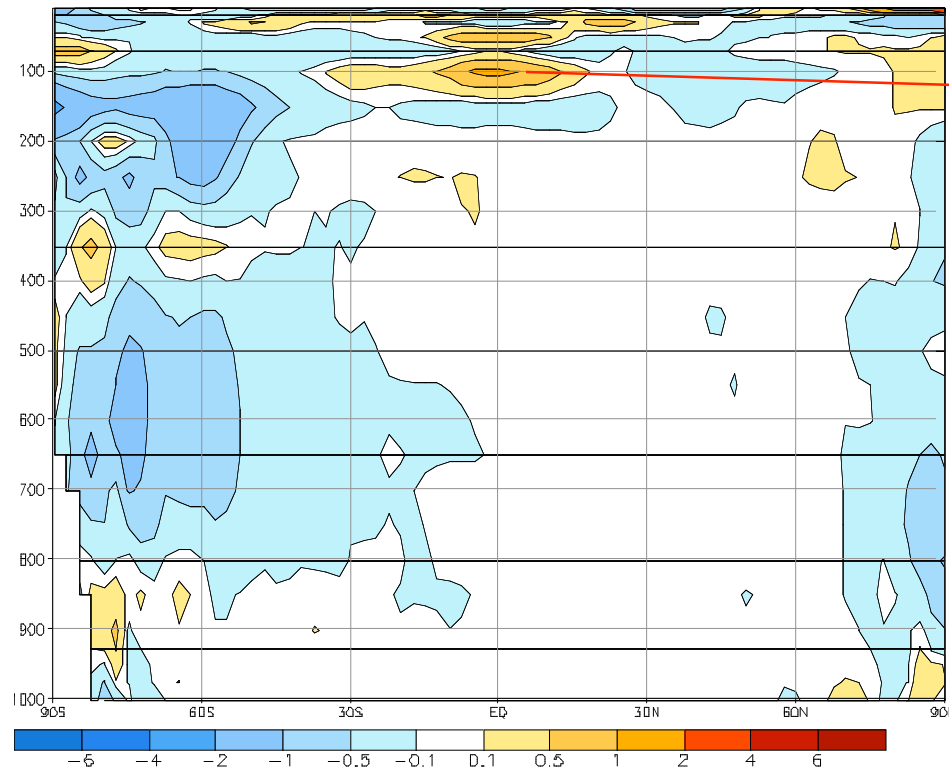
500 hPa Temperature analysis error



Non-radiances Non-radiances + AIRS temperature retrieval

Zonal Average temperature analysis error

RMS (AIRS run) – RMS (control run)



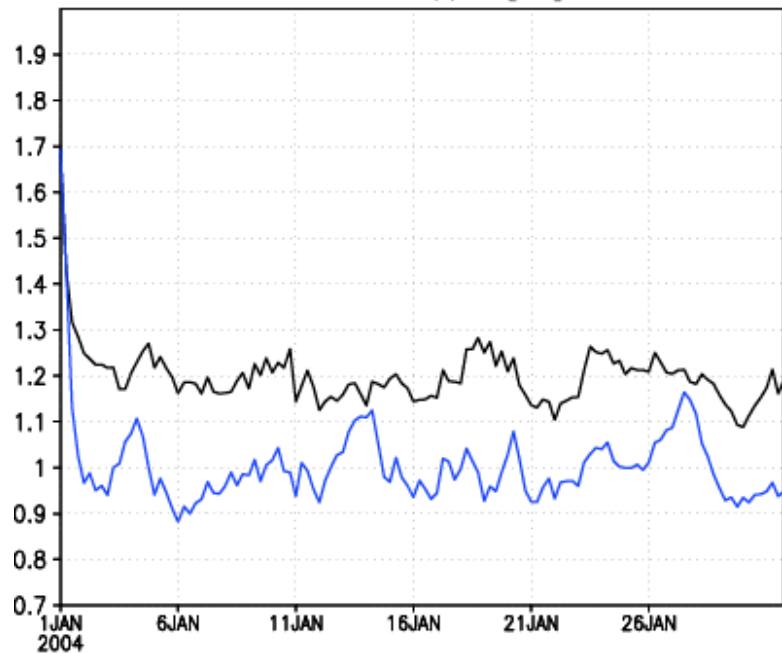
Analysis may be wrong?

Blue means retrievals improve analysis

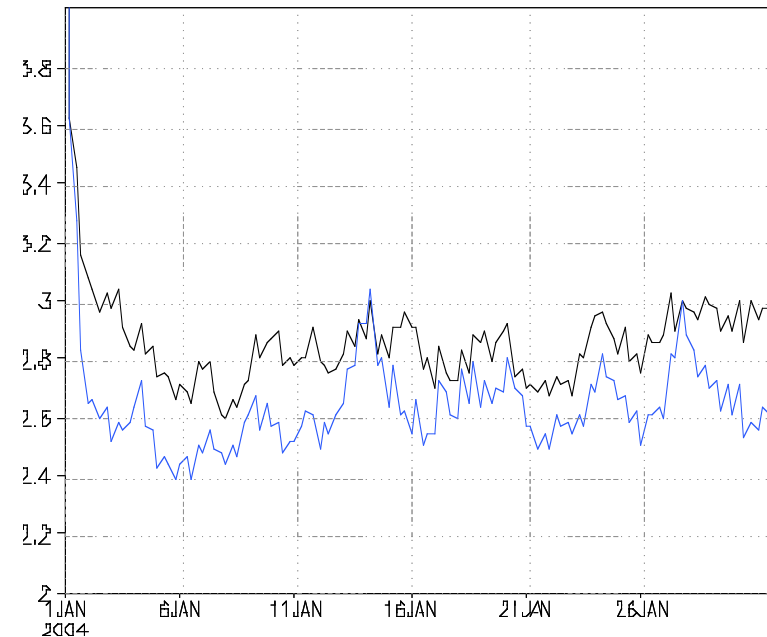
AIRS Temperature retrievals have **positive impact in both **NH and SH**, and little impact on tropics.**

Impact of AIRS Temperature retrievals on zonal wind

500 hPa **Temperature**

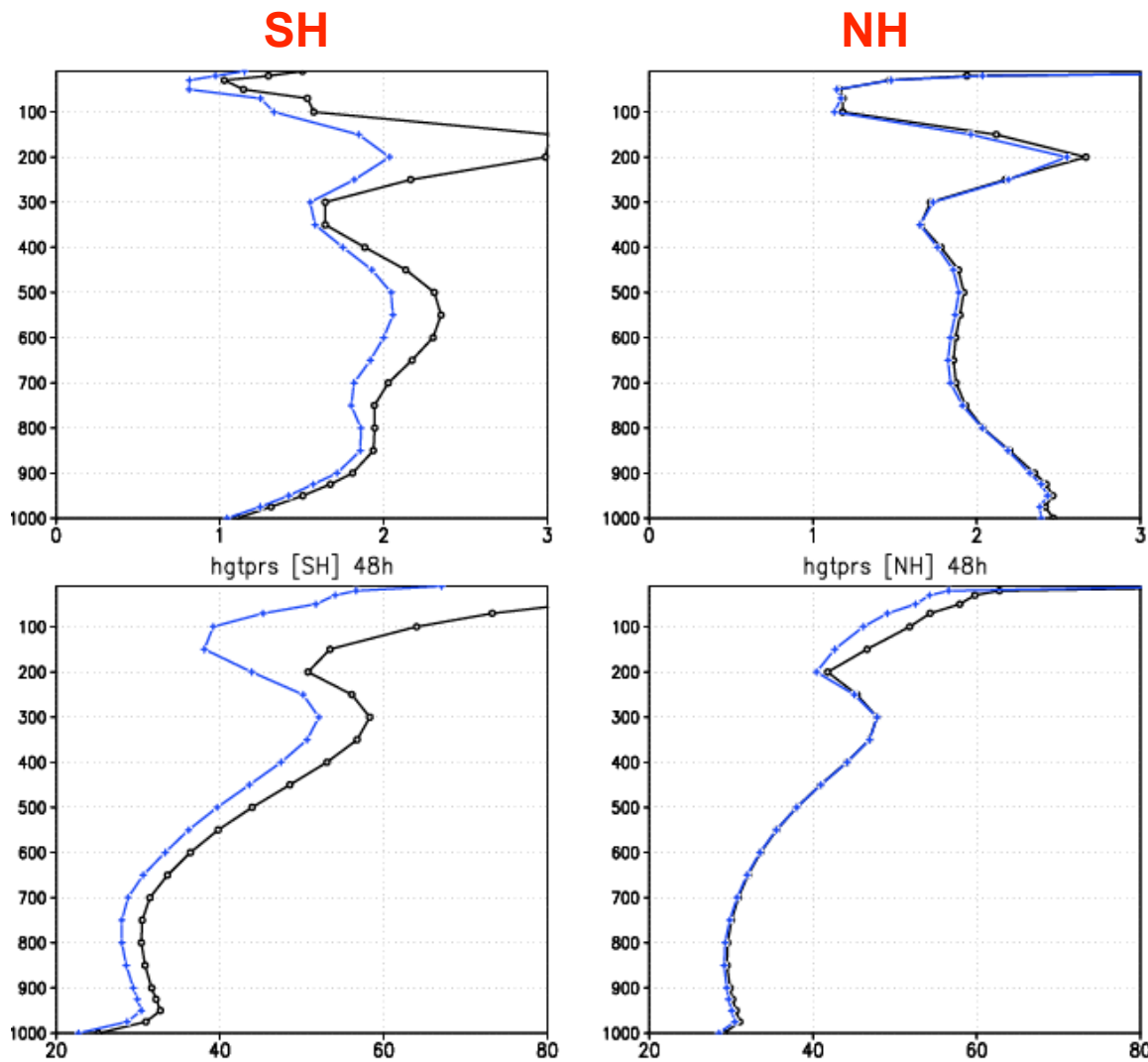


500 hPa **zonal wind**



AIRS Temperature retrievals also have **positive**
impact on **other variables**

48 Hour Forecast RMSE

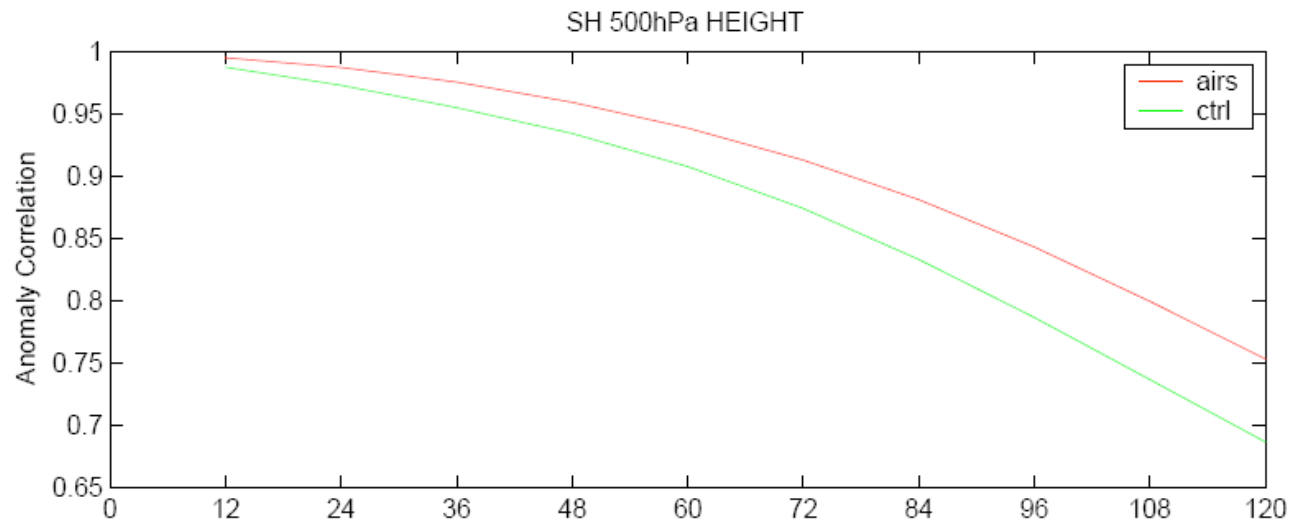


Temperature

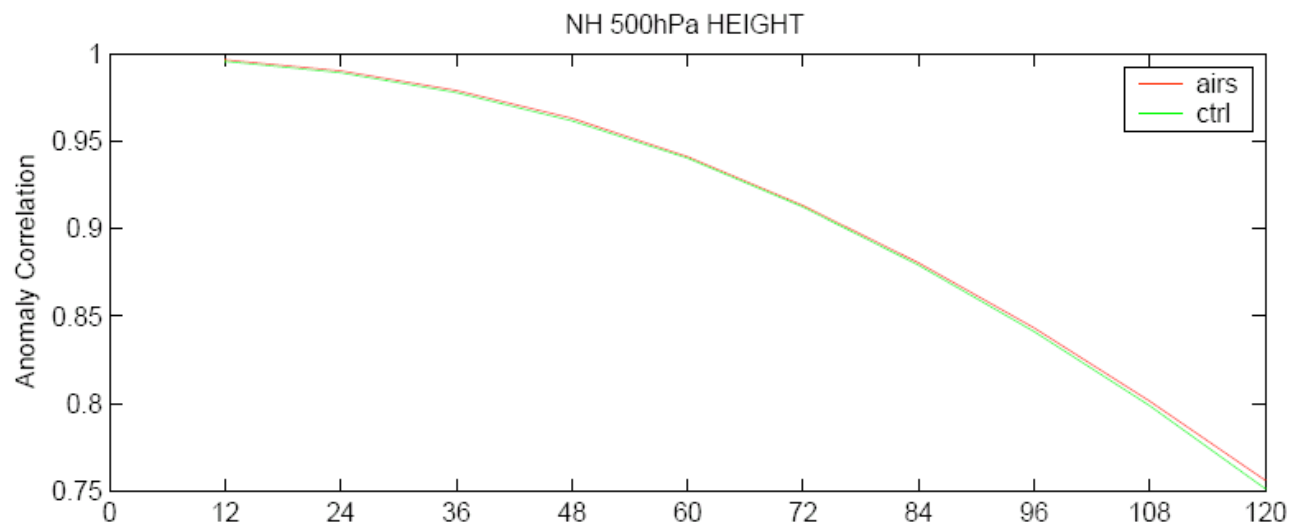
Geopotential
Height

Non-radiances Non-radiances + AIRS temperature retrievals

5-Day Forecast Skill



SH

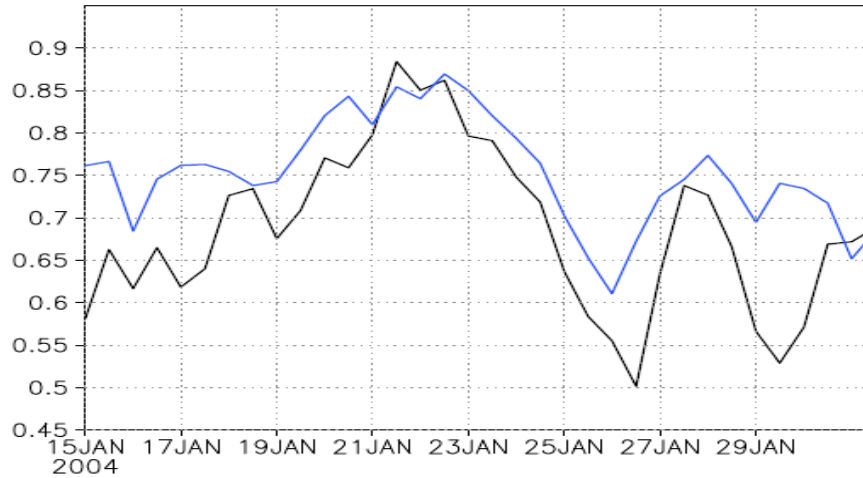


NH

Day 5 Forecast (AC)

500 MB Geopotential Heights [SH]

— AIRS
— Control

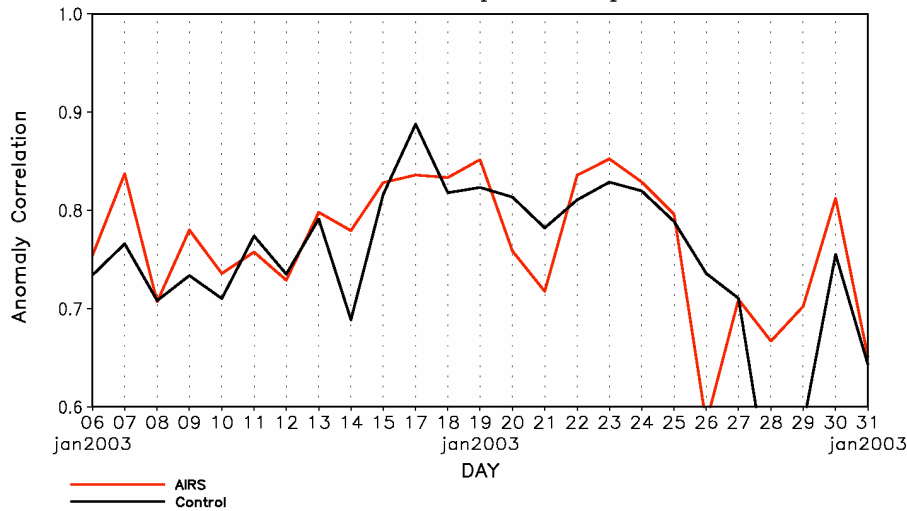


LETKF

positive impact: 27/32

DAY 5 500 MB GEOPOTENTIAL HEIGHTS Southern Hemisphere XTropics

— AIRS
— Control



NASA fvSSI – v3

positive impact: 16/26

(courtesy of Bob Atlas)

Summary

- LETKF is an **efficient** and **parallel** method of data assimilation. **5** minutes in a **20 PC cluster** with **40** ensemble members.
- The AIRS temperature retrievals have consistent **positive** impact on both **analyses** and **forecasts**, found not only in the temperature field but also in the other variables.
 - This positive impact is large in Southern Hemisphere.
 - Small but still consistently positive in Northern Hemisphere.
- The improved forecasts skill by assimilating the AIRS retrievals using **LETKF** is more **consistently positive** than most previous data impact experiments obtained by using an operational **3D-Var** data assimilation system.
 - Inclusion of “errors of the day” in the EnKF background error covariance.

Planned Experiments

1) *Estimate AIRS temperature retrieval error*

correlation: optimize observation error covariance for AIRS retrievals using a new adaptive technique. (Kalnay et al. 2007, afternoon section)

2) *Include AIRS humidity retrievals:* should provide dense and accurate information.

3) *Assimilate clear AIRS radiances:* Very accurate but sparse.

Local Ensemble Transform Kalman Filter

Perform Data Assimilation in local patch (3D-window)

- The state estimate is updated at the central grid **red** dot
- All observations (**purple diamonds**) within the local region are assimilated

