Improved Use of AIRS Data at ECMWF

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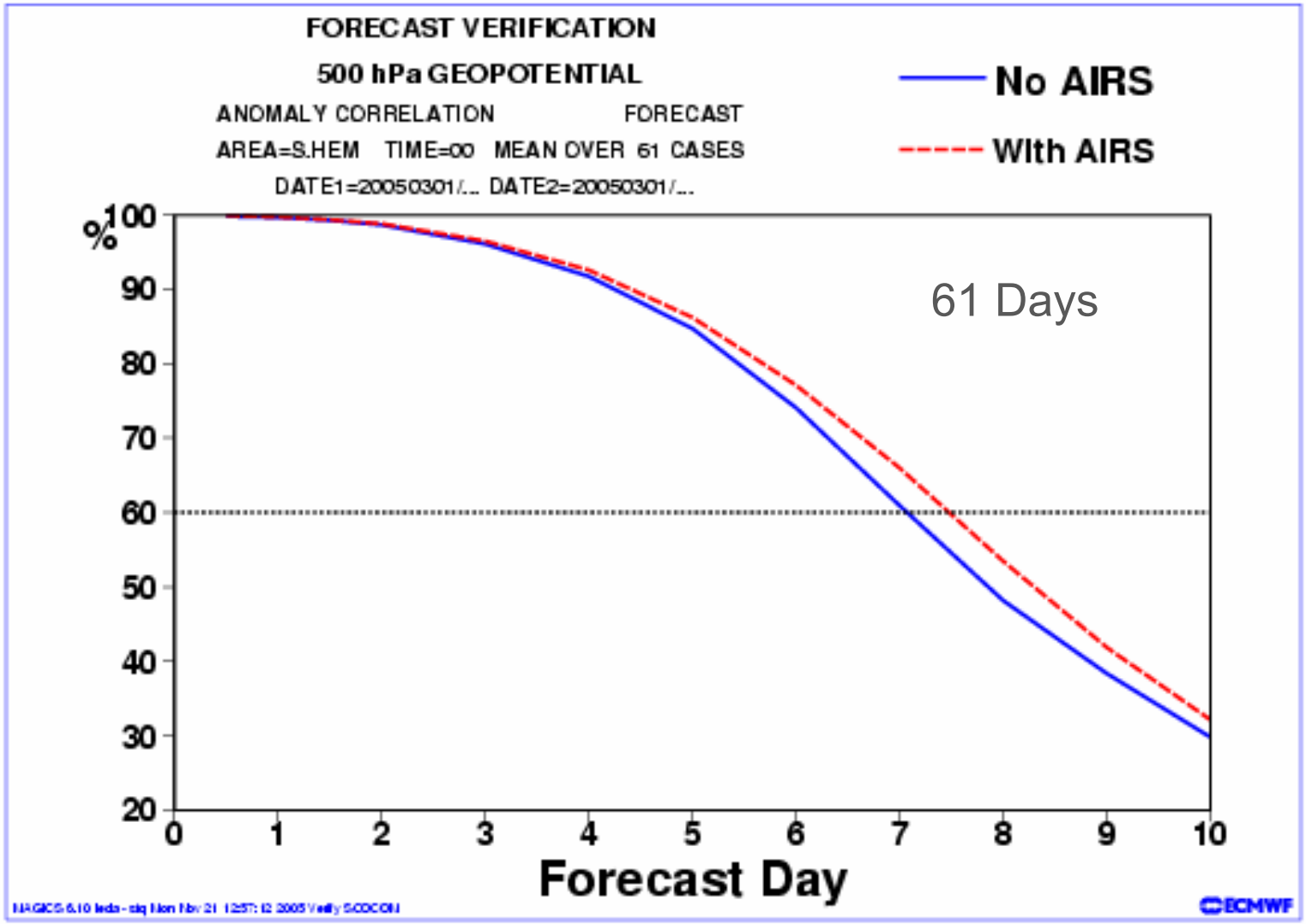
AIRS/IASI Advances

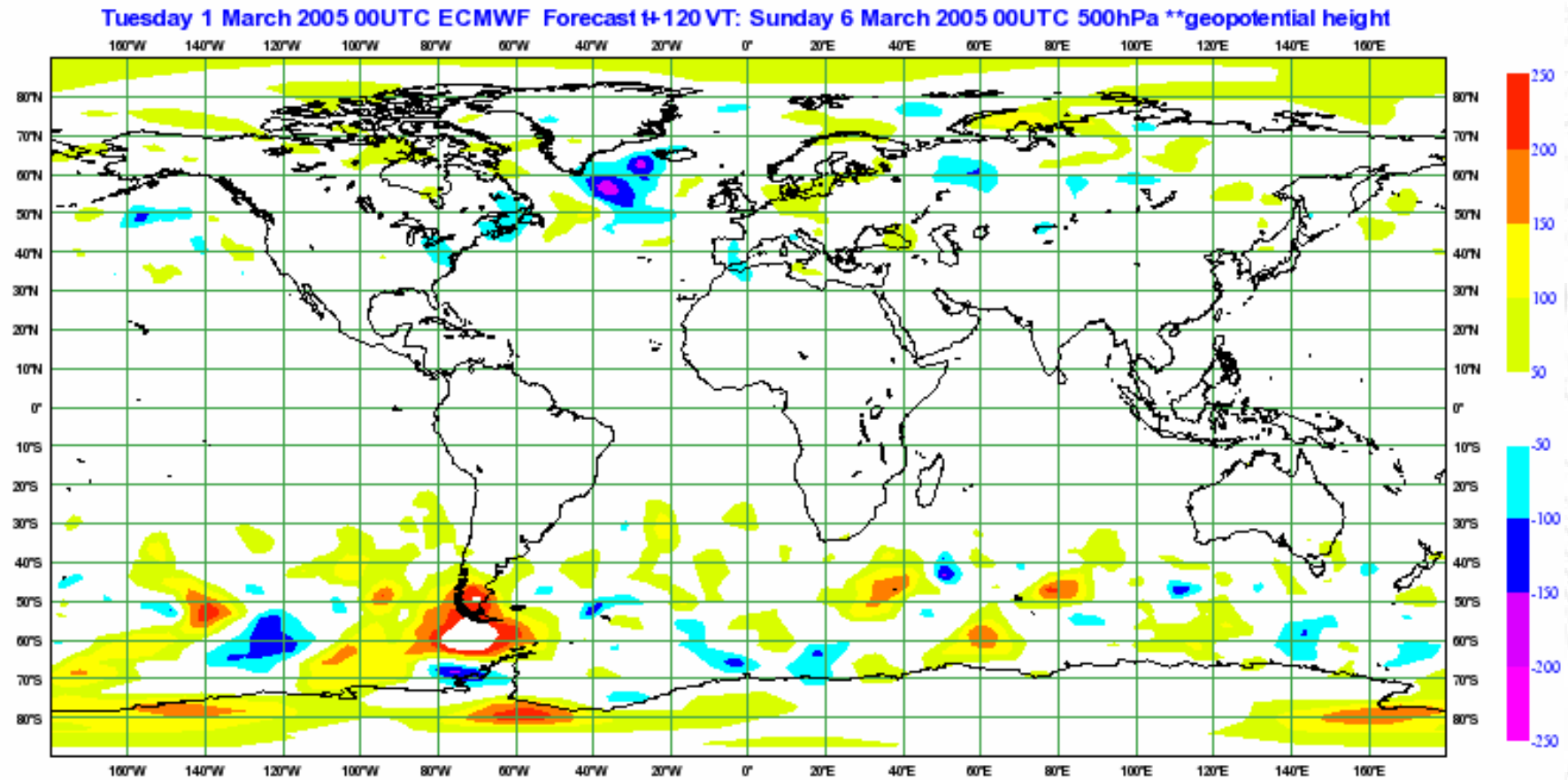
- Experiments with Reconstructed Radiances
- NWPSAF deliverables
  - Cloud Detection
  - Advanced Sounder Preprocessor

AIRS Impact up to 10 hours at 7 days



5 Day Forecast Improvements on Adding AIRS

AIRS Improves FC



AIRS Degrades FC

1st March – 30th April 2005

Spectral data compression with PCA*

The complete AIRS spectrum can be compressed using a truncated principal component analysis (e.g. 200PCAs v 2300 rads)

Leading eigenvectors (200,say) of covariance of spectra from (large) training set

Mean spectrum

$$\mathbf{p} = \mathbf{V}^{T}(\mathbf{y} - \bar{\mathbf{y}})$$

Coefficients

Original Spectrum

- To use PCs in assimilation requires an efficient RT model to calculate PCs directly
- PCs are more difficult to interpret physically than radiances

N.B. This is usually performed in noise-normalised radiance space

This allows data to be transported efficiently

*Principal Component Analysis

Spectral data compression and de-noising

The complete AIRS spectrum can be compressed using a truncated principal component analysis (e.g. 200PCAs v 2300 rads)

Leading eigenvectors (200,say) of covariance of spectra from (large) training set

Mean spectrum

Reconstructed spectrum

$$\mathbf{p} = \mathbf{V}^{T}(\mathbf{y} - \bar{\mathbf{y}})$$

$$\mathbf{y}_{R} = \bar{\mathbf{y}} + \mathbf{V}\mathbf{p}$$

Coefficients

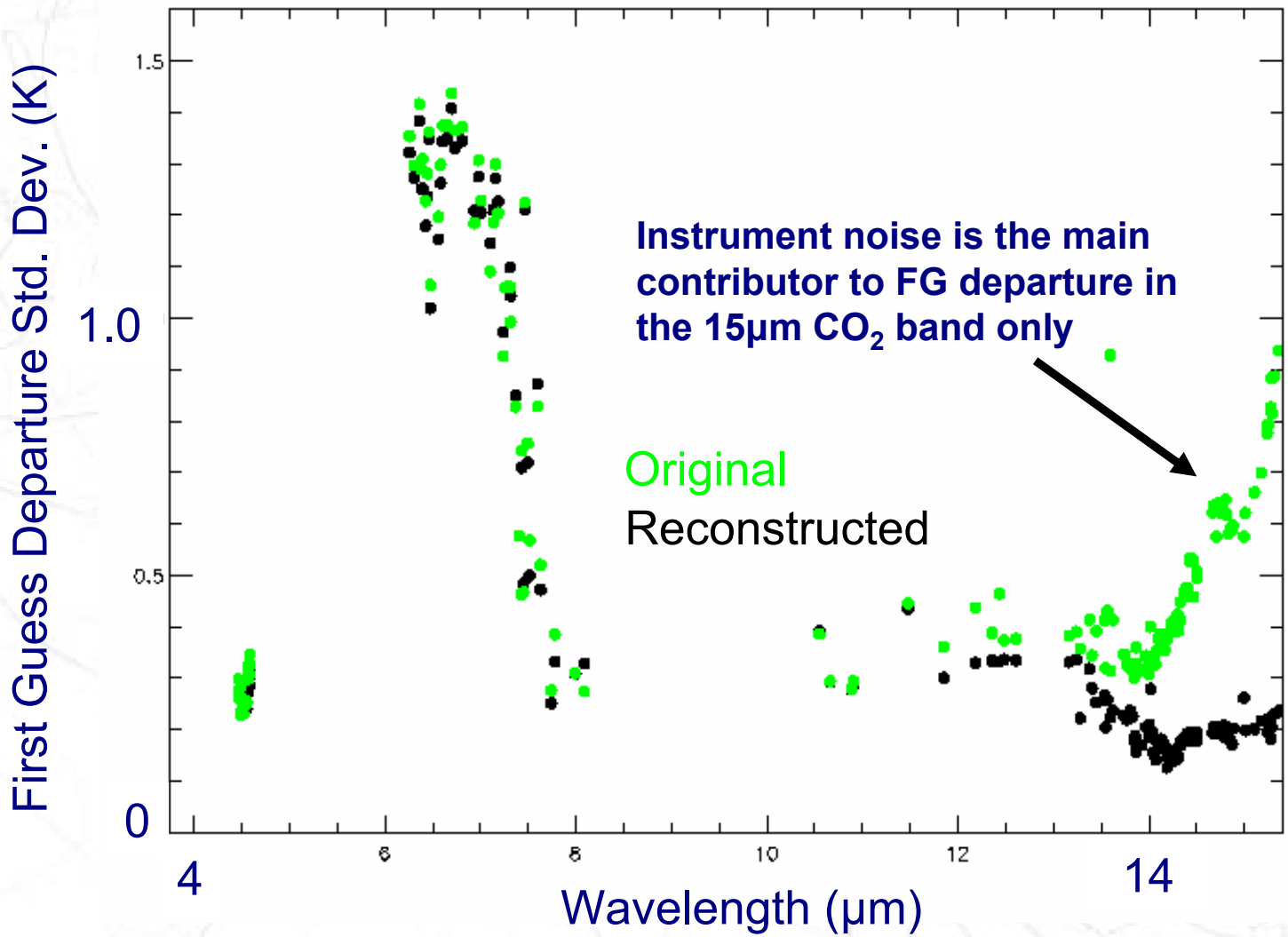
Original Spectrum

N.B. This is usually performed in noise-normalised radiance space

Each reconstructed channel is a linear combination of all the original channels and the data is significantly de-noised.

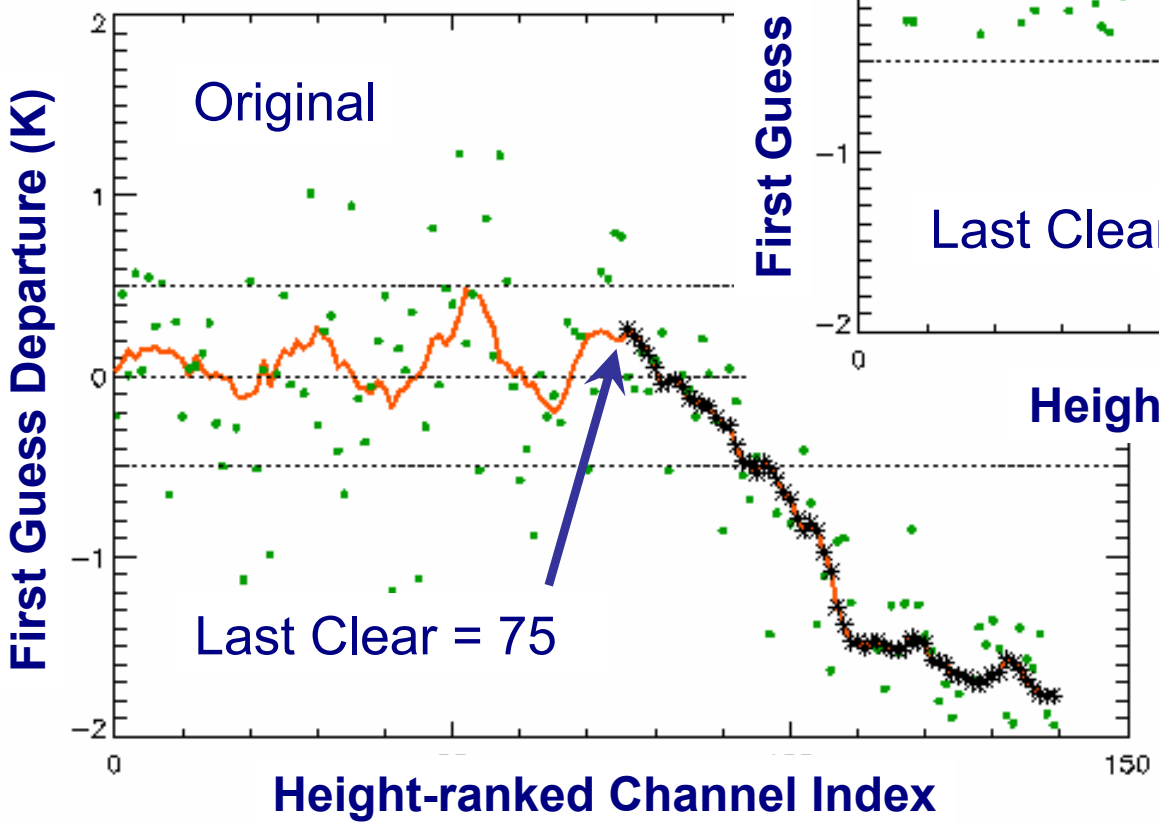
If *N* PCs are used all the information is contained in *N* reconstructed channels (theoretically)

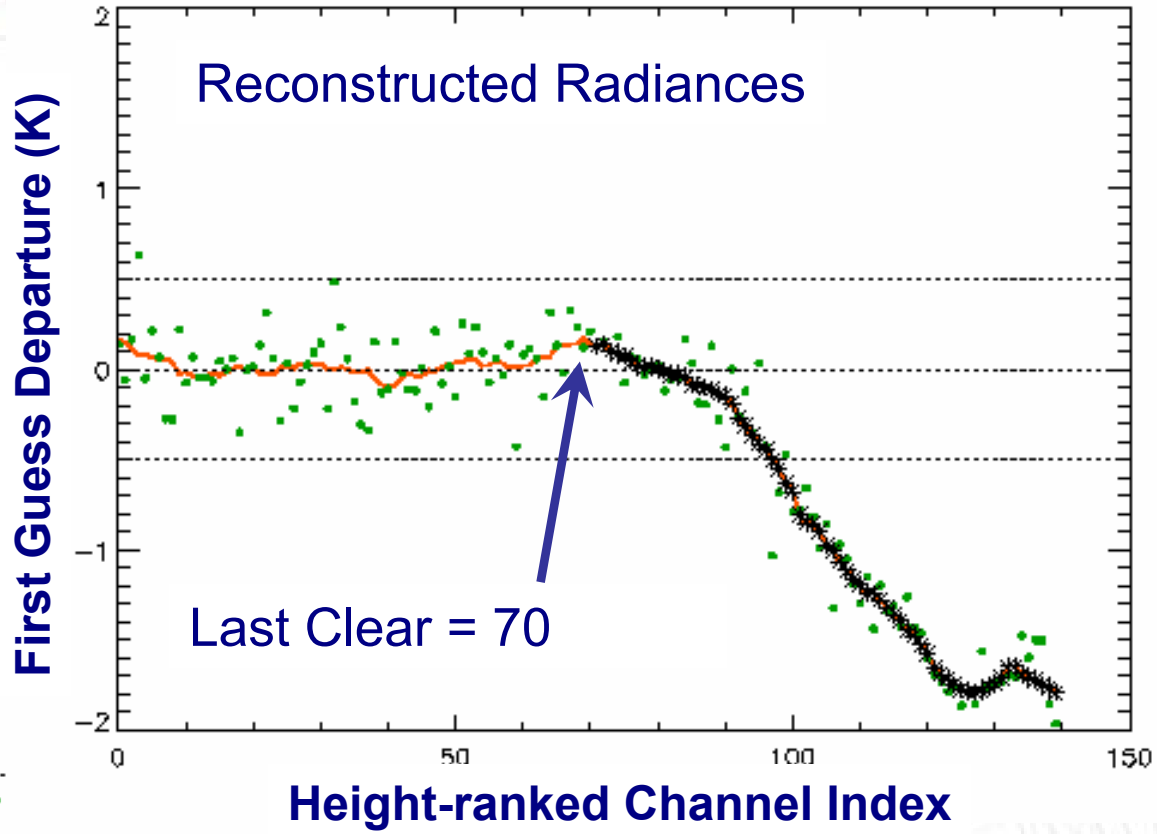
First Guess Departures for AIRS are Reduced



Improvements in Cloud Detection

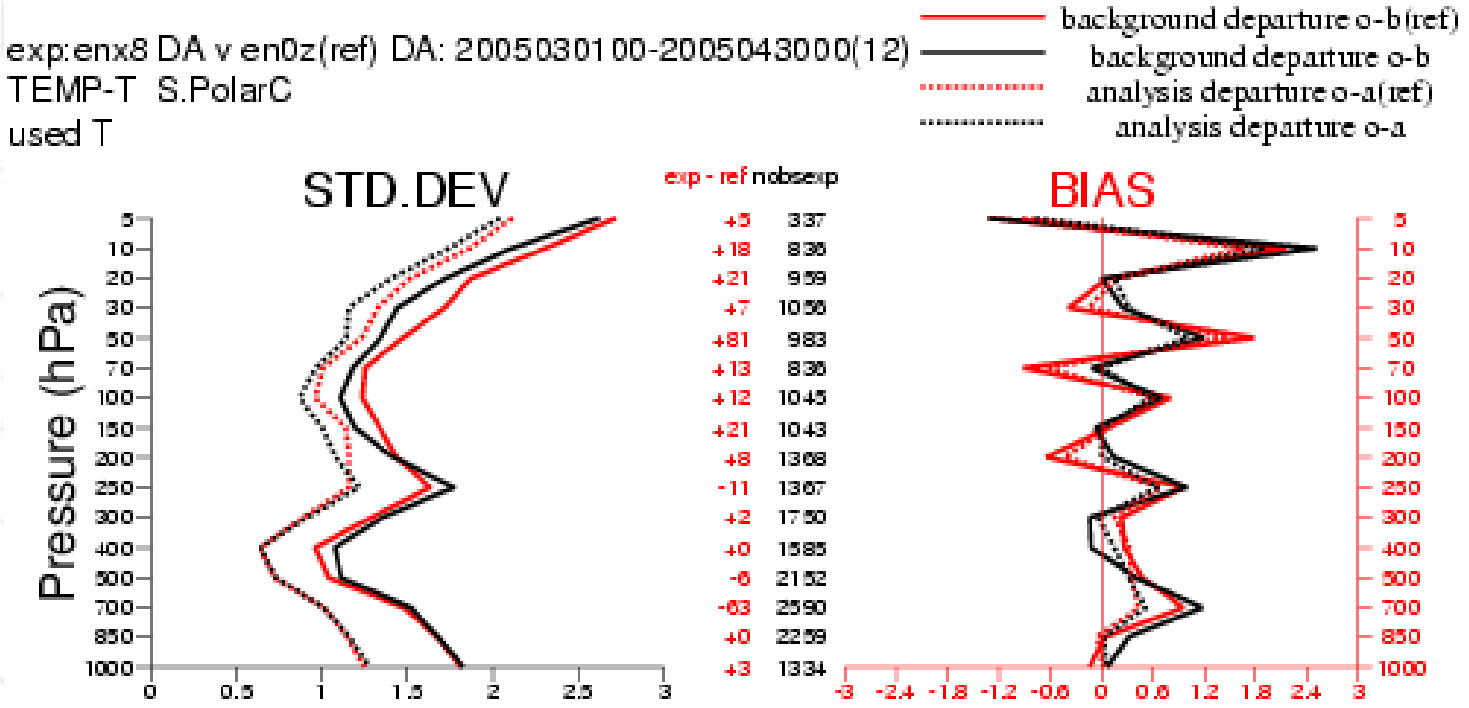
ECMWF Scheme:
- Ranks Channels Height
- Applies low-pass filter
- Tests for non-zero gradient





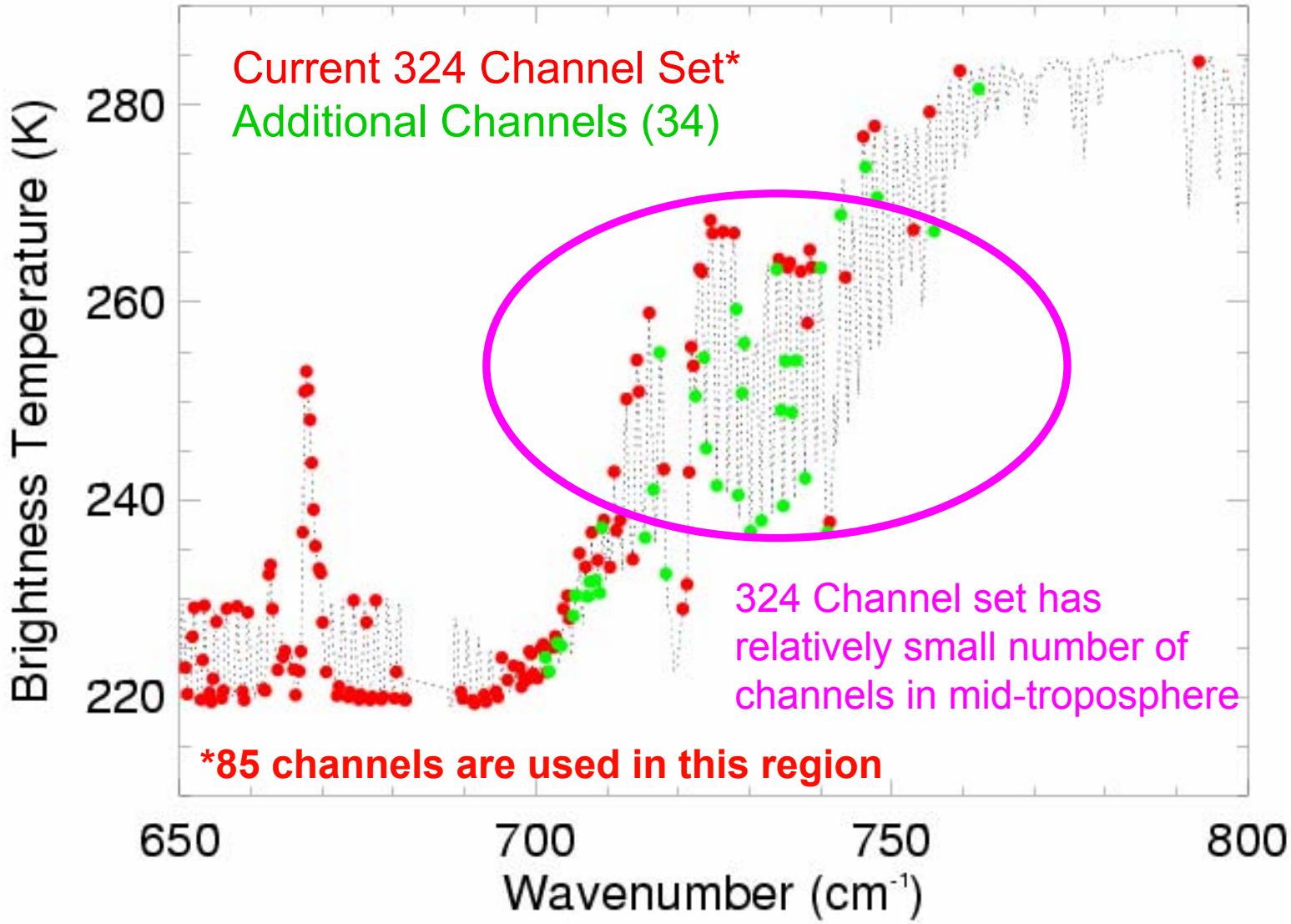
< 2% of Channels are flagged differently for RR vs Normal radiances

Improvements to Antarctic Stratosphere



"Stratospheric Oscillation" in comparison to Antarctic radiosondes is greatly reduced on moving to reconstructed radiances

Adding Extra AIRS Reconstructed Radiance Channels



How to reconstruct additional channels

We are supplied with *N* reconstructed radiances, $\tilde{\mathbf{y}}_N$, derived from the the full spectrum, **p**, via

$$\tilde{\mathbf{y}}_N = \mathbf{L}_{N,M}\mathbf{L}_M{}^{\mathrm{T}}\mathbf{y}$$

where $\mathbf{L}_{N,M}$ and $\mathbf{L}_M$ are the leading *M* eigenvectors of the observed variability of **y**, with the former restricted to the *N* supplied channels

If $N \geq M$ and the choice of channels is sufficiently representative, we may take the *N* reconstructed radiances and derive the remaining reconstructed radiances thus:

$$\tilde{\mathbf{y}} = \mathbf{L}_M\mathbf{V}_N\boldsymbol{\Lambda}_N{}^{-1}\mathbf{U}_N{}^{\mathrm{T}}\tilde{\mathbf{y}}_N$$

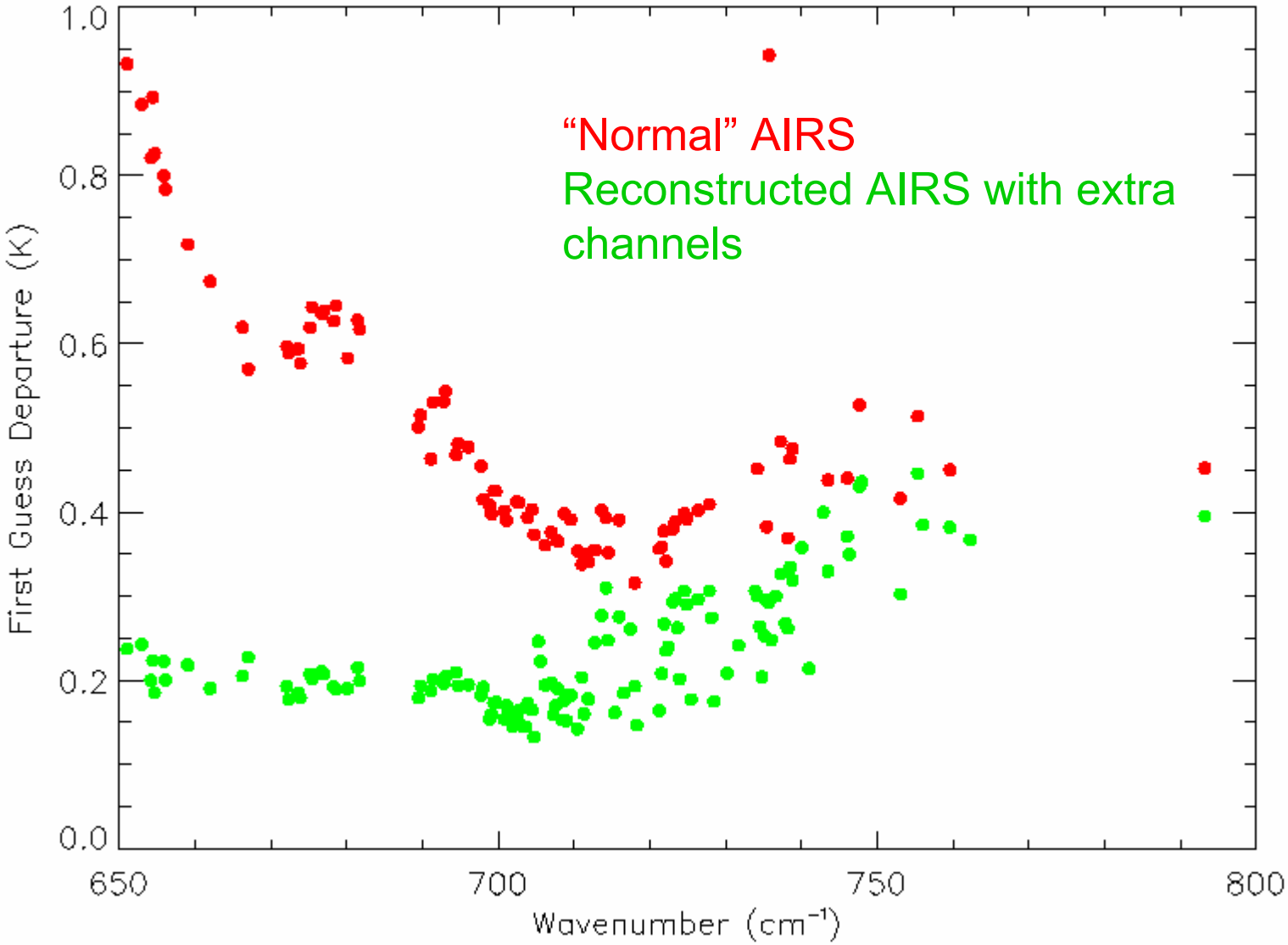
We

Where $\mathbf{V}_N\boldsymbol{\Lambda}_N^{-1}\mathbf{U}_N$ is the generalised-inverse of $\mathbf{L}_M$ using SVD.

a

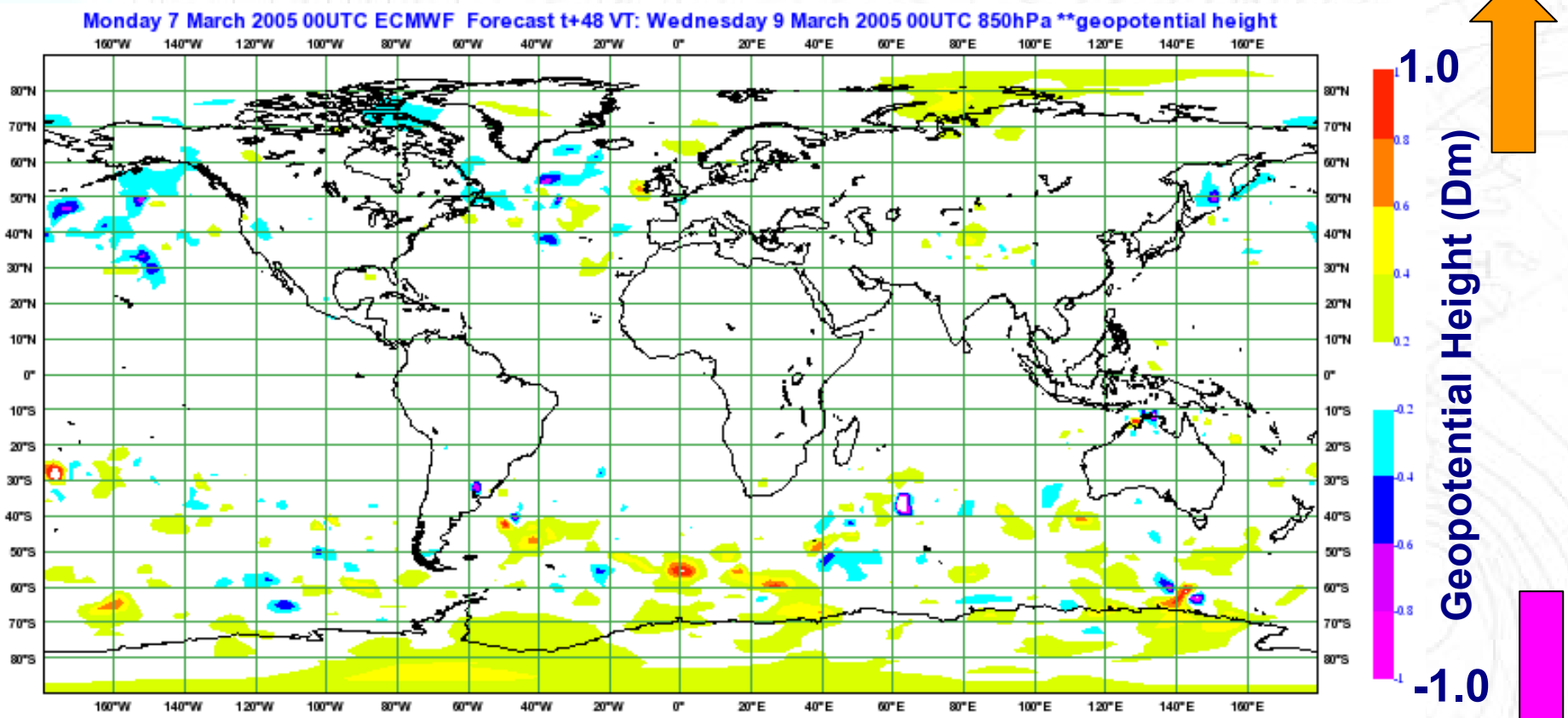
e

First Guess departures



48-hour Forecast Error Differences: 850hPa

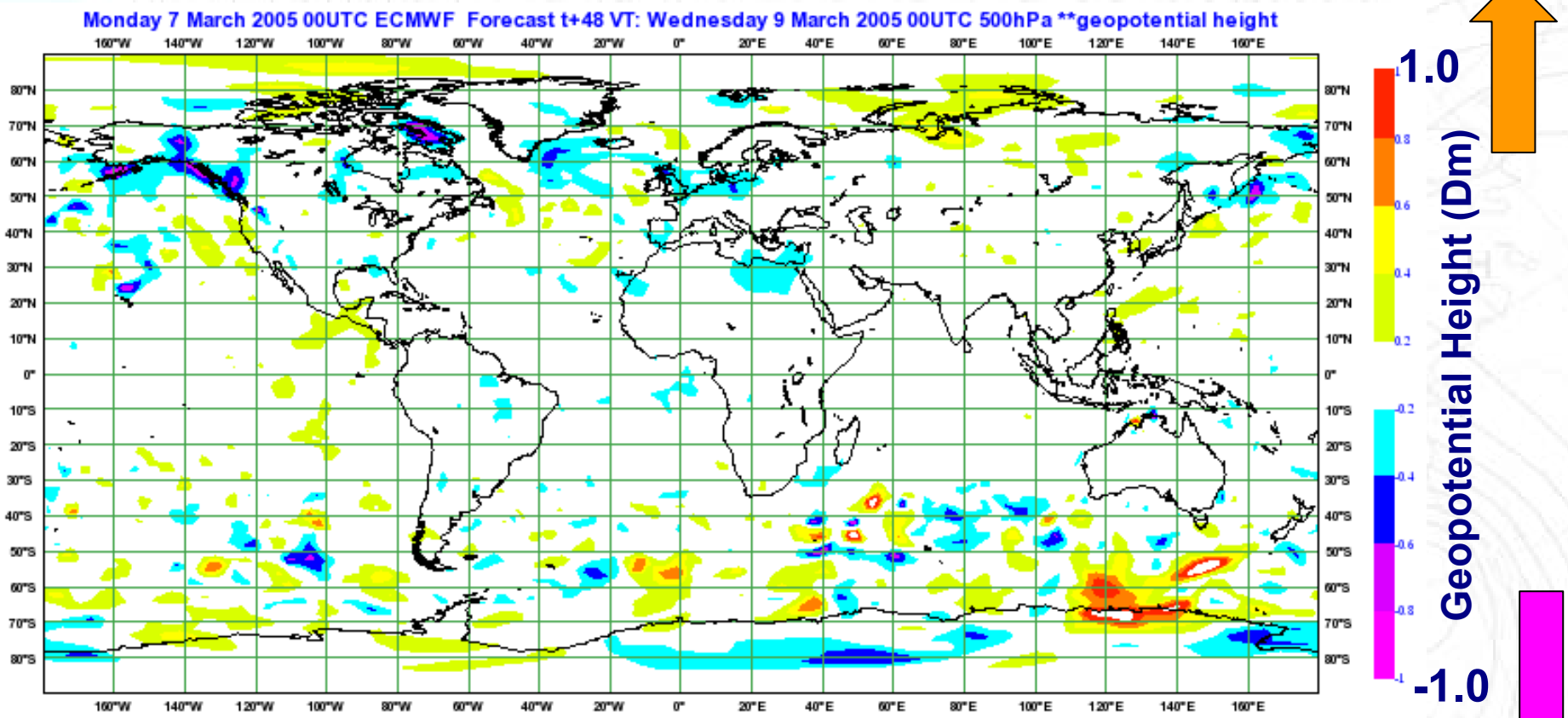
Control Better



Experiment Better

48-hour Forecast Error Differences: 500hPa

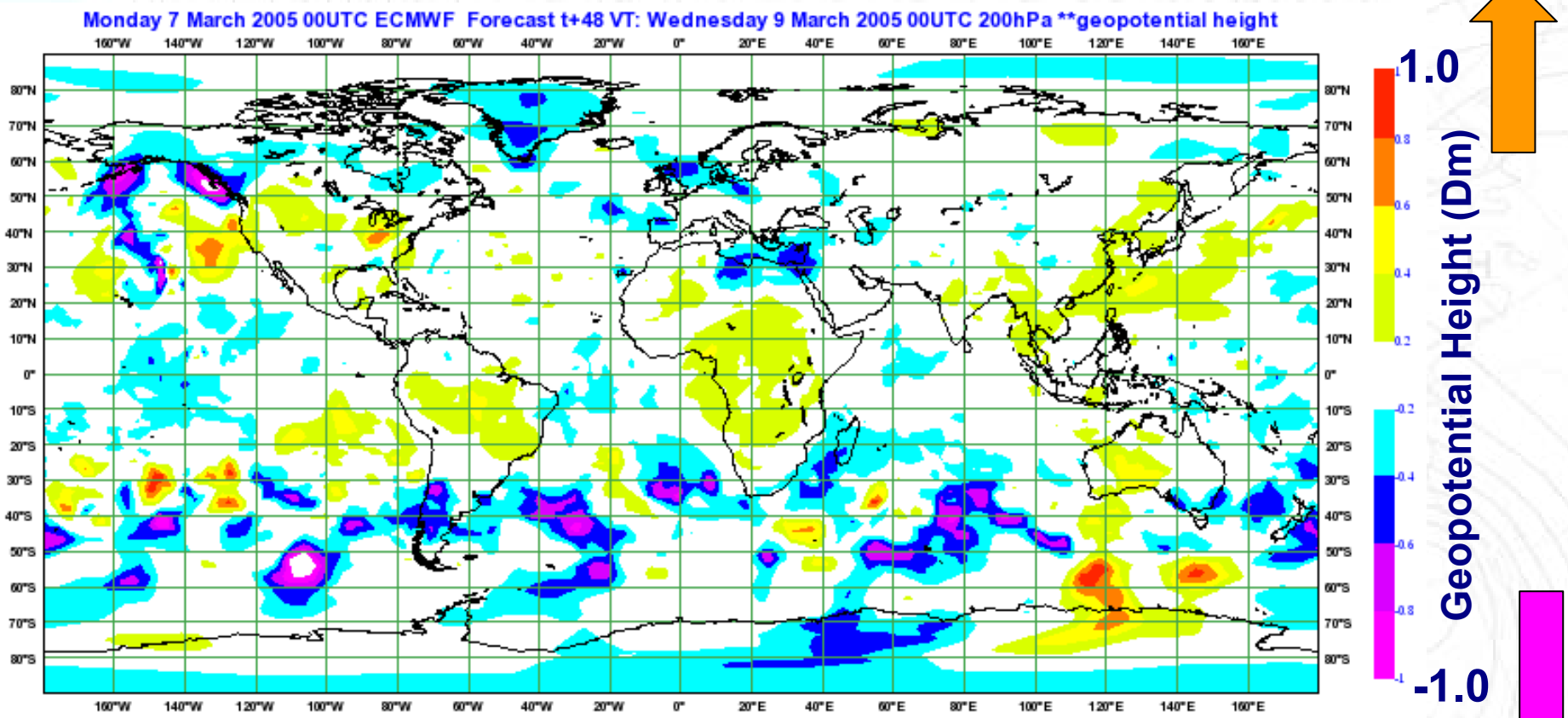
Control Better



Experiment Better

48-hour Forecast Error Differences: 200hPa

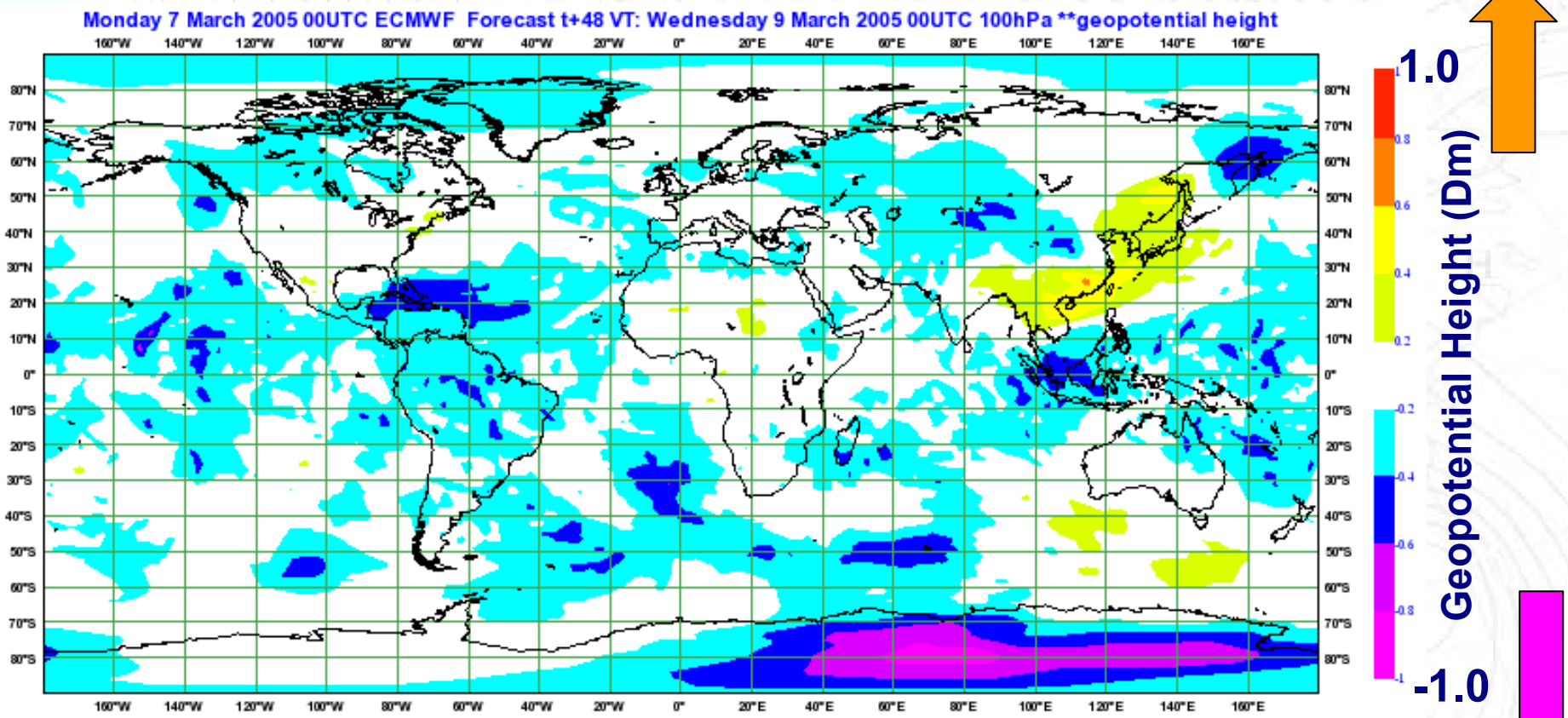
Control Better



Experiment Better

48-hour Forecast Error Differences: 100hPa

Control Better



Experiment Better

Summary of Reconstructed Radiances

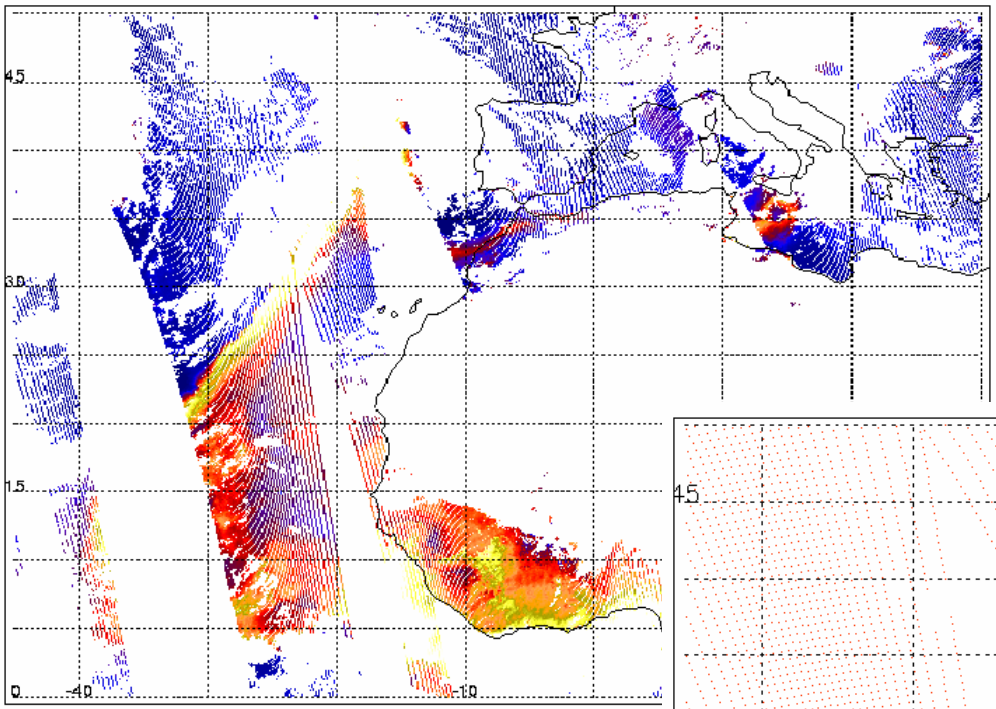
- Reconstructed radiances improve certain aspects of the assimilation system:
  - Reduction of AIRS instrument noise
  - Cloud detection algorithm
  - Fit to polar radiosondes in stratosphere
- However, changes in forecast scores on using reconstructed radiances have been neutral at best
  - Experiments where assumed observation errors have been varied (including the introduction of spectral error correlations) have not yielded significant positive results
  - Work is continuing…..
- Reconstructed radiances contain information on the entire spectrum
  - This is demonstrated by the ability to reconstruct additional channels
    - This would more properly be done directly from PC amplitudes
  - Preliminary results indicate that using additional channels derived this way can possibly help improve forecasts

NWPSAF Deliverables

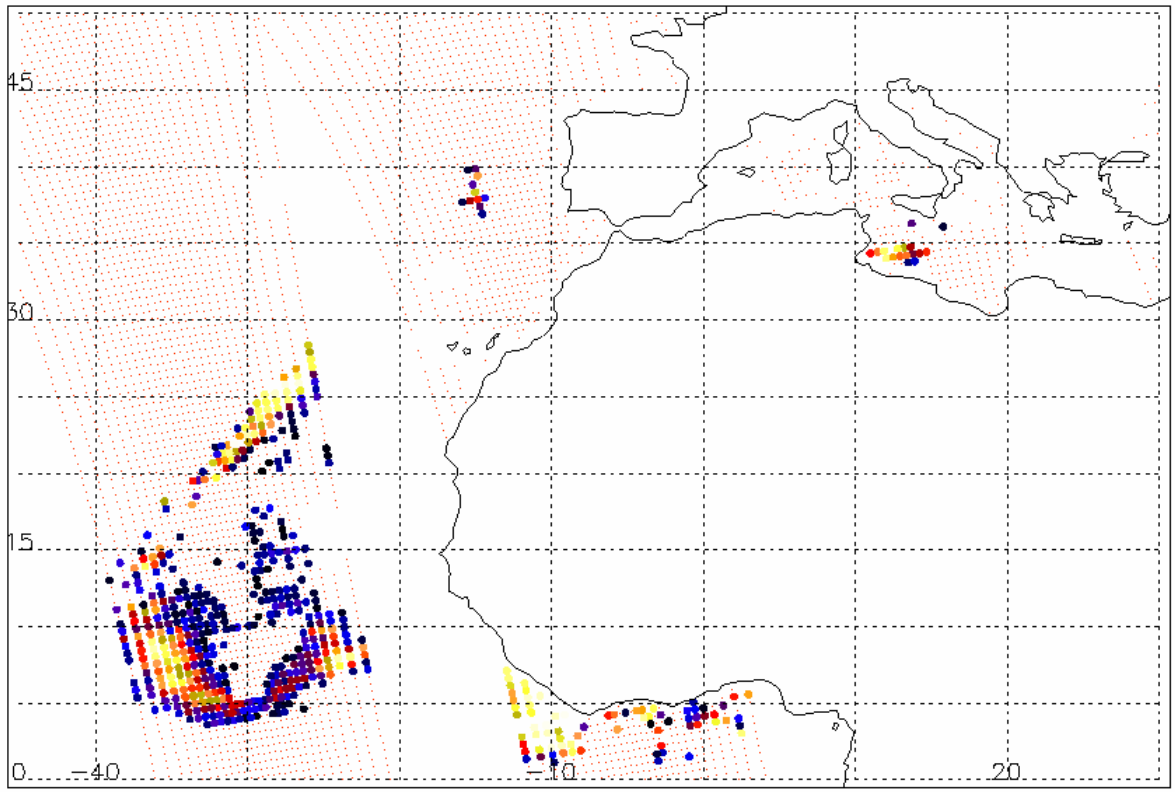
Cloud/Aerosol Detection

- **Cloud detection has been re-written to allow greater portability and to allow cloud detection of IASI**
- **Aerosol detection module added which uses information from RTIASI aerosol simulations to distinguish between aerosol and cloud opacity**
- **Used in conjunction with cloud (opacity) detection scheme**

Dust blown off the Sahara



MODIS Product
(uses visible channels)



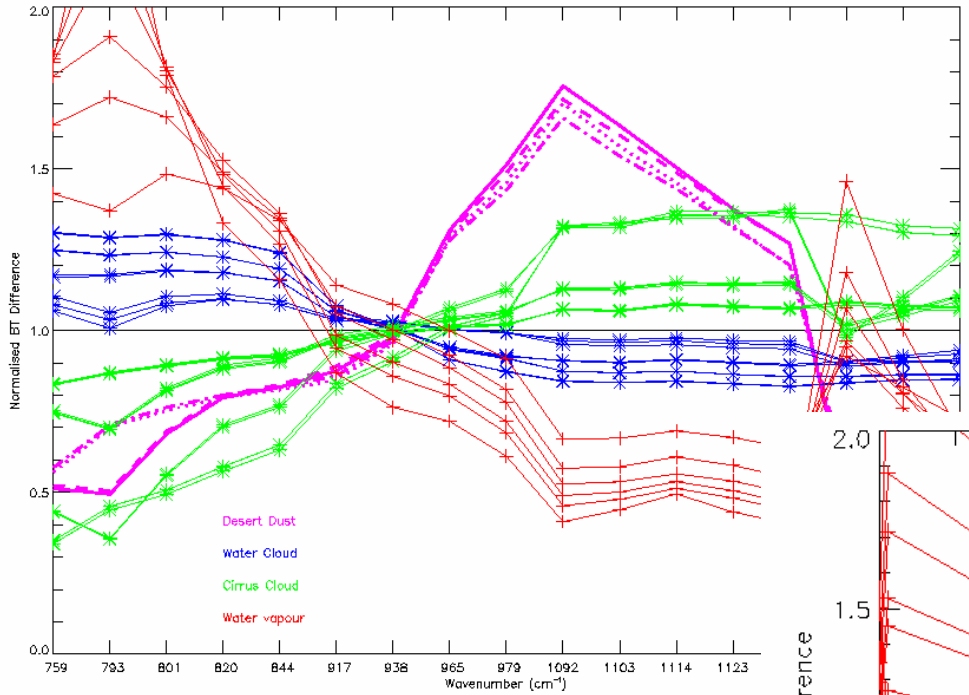
AIRS Product
(uses LW IR window only)


Thankyou

Reconstructed Radiances

- **Reconstructed radiances compress the information from the full spectrum (~1600 AIRS channels are used) into a subset of channels.**
- **NOAA/NESDIS supplied reconstructed radiances for 324 channels.**
- **So far, using reconstructed radiances has at best yielded neutral impact.**
- **Alternative strategies for the use of these data are explored…**

Aerosol Detection

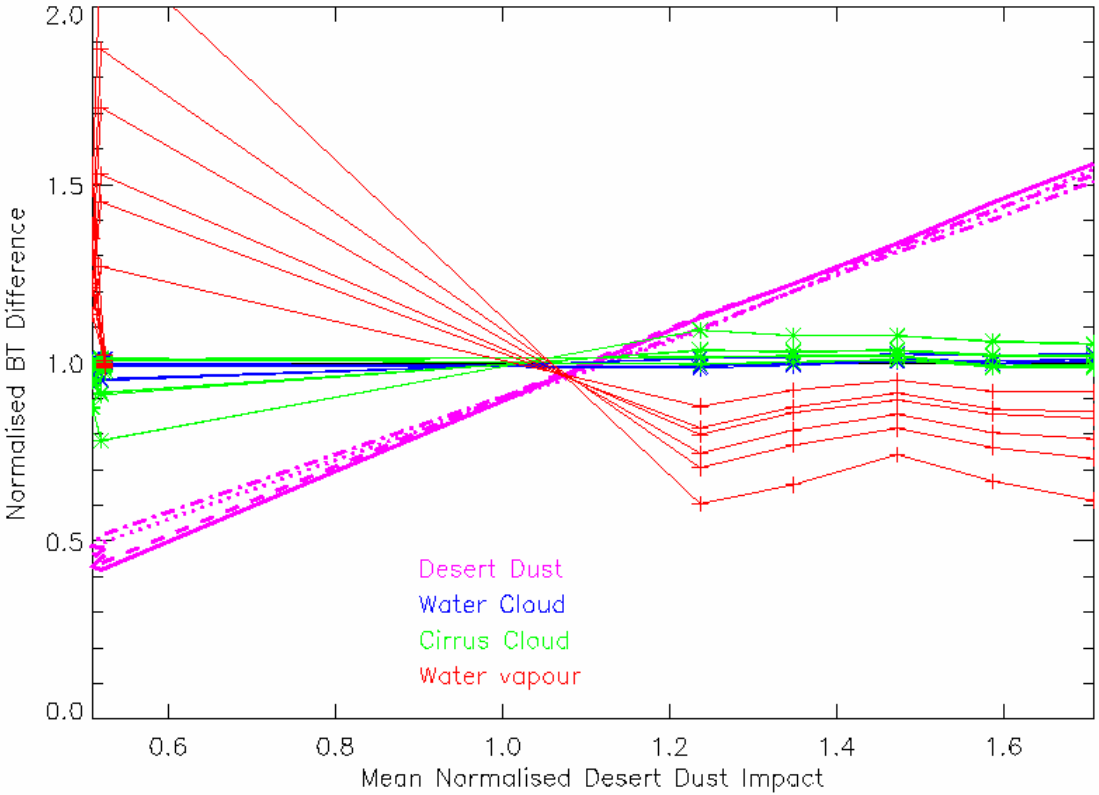


Desert Dust

Liquid Water Cloud

Cirrus Cloud

Water Vapour



Take ordinate of magenta curve here…

…and use it as the abscissa here

Why is data compression important?

- Very large data volumes need to be communicated in near-real time (e.g., EUMETSAT to NWP centres)
- Simulation of spectra (needed for assimilation) is costly
- Data storage

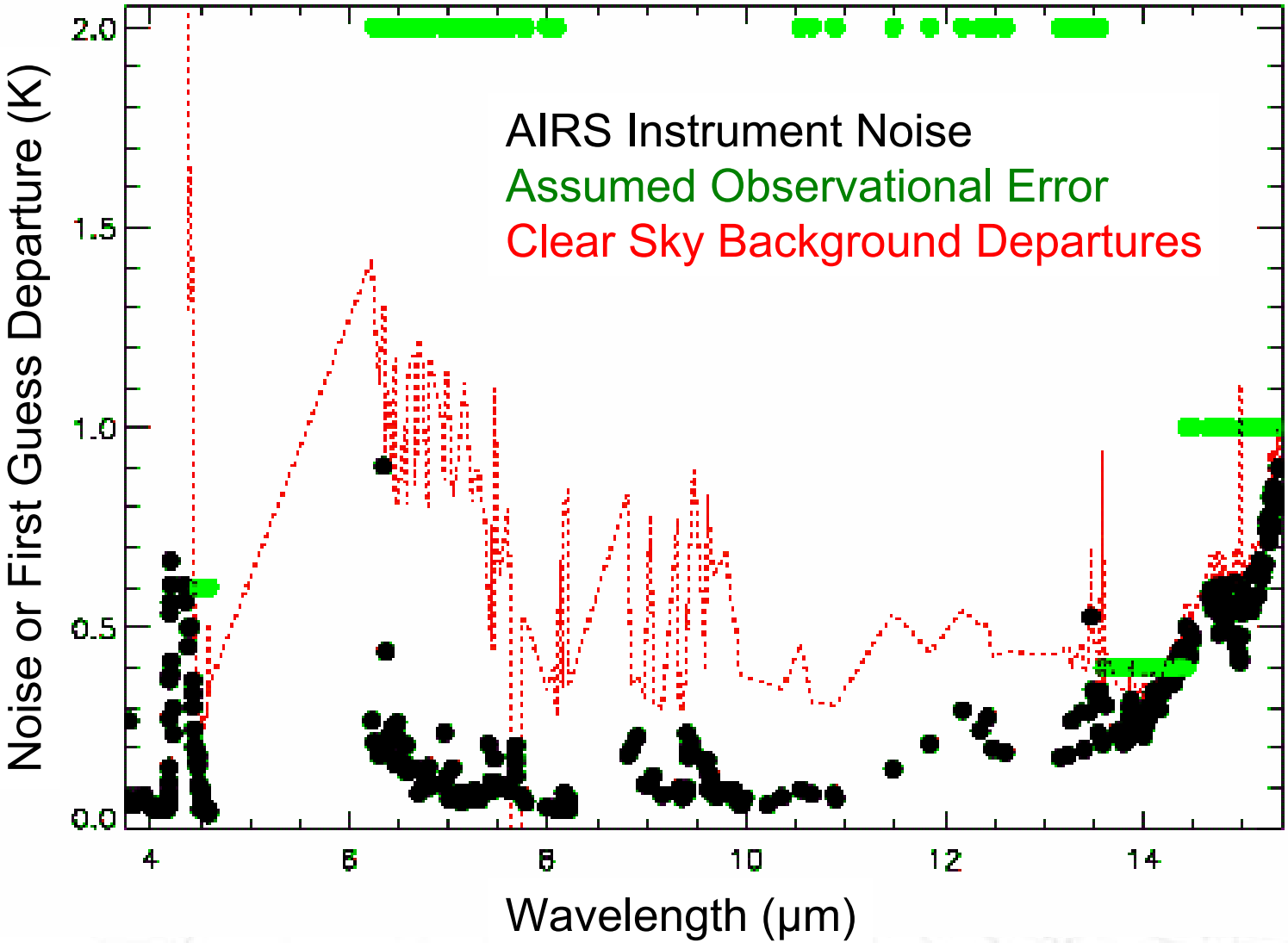
Satellite data assimilated operationally at ECMWF

- 4xAMSU-A (NOAA-15/16/18 + AQUA)
- 3xAMSU-B (NOAA-16/17/18)
- 3 SSMI (F-13/14/15) in clear and rainy conditions
- 1xHIRS (NOAA-17)
- AIRS (AQUA)
- Radiances from 4 GEOS (Met-5, Met-8, GOES-10/12)
- Winds from 4 GEOS (Met-5/8 GOES-10/12) and MODIS/TERRA+AQUA
- Scat winds from QuikSCAT and ERS-2 (Atlantic)
- Wave height from ENVISAT RA2 and ASAR, JASON
- Ozone from SBUV (NOAA 16) and SCIAMACHY (ENVISAT)

29 different satellite sources

Coming soon: SSMIS, radio occultation (GPS),…and IASI!

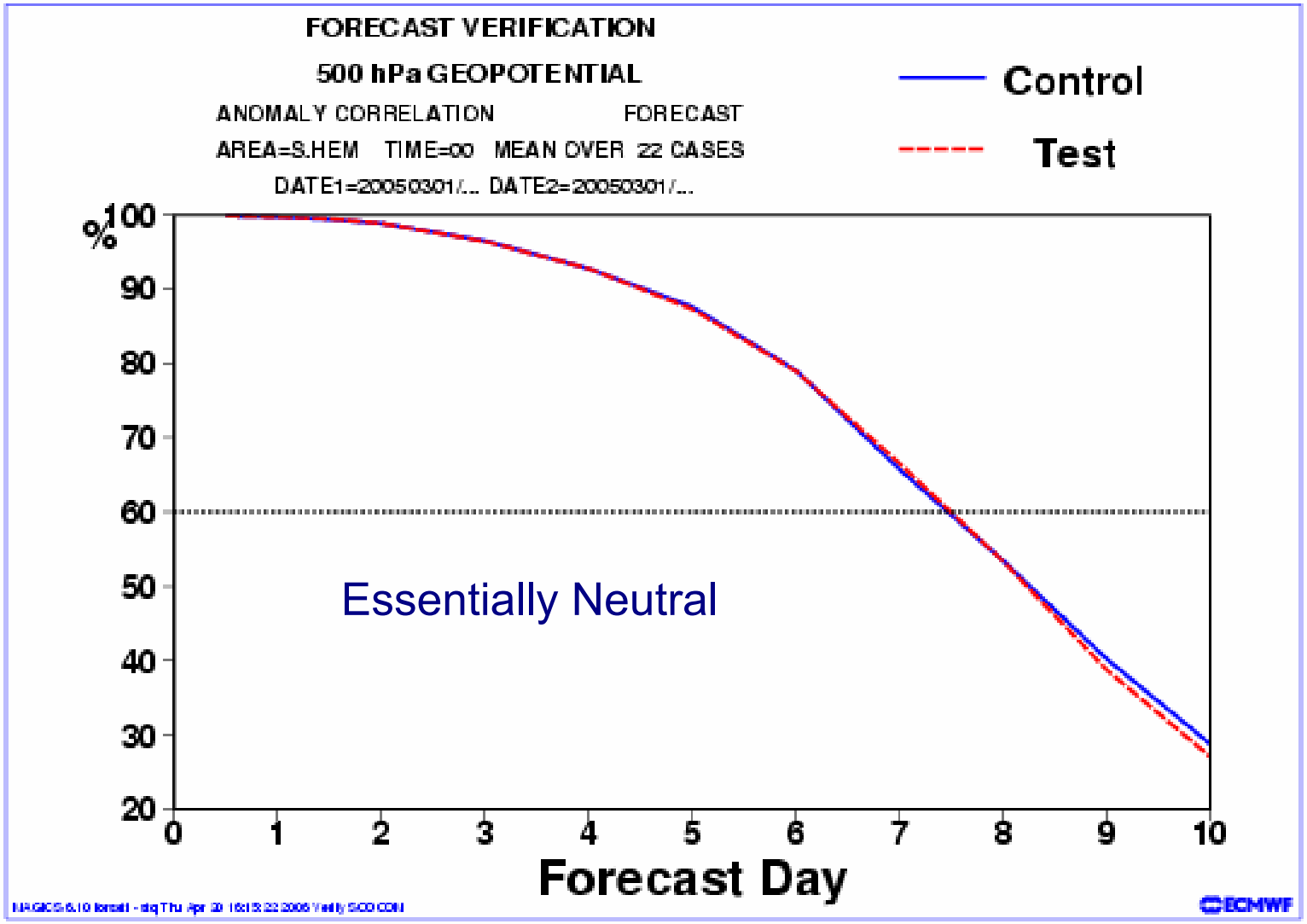
Assumed Noise for AIRS Assimilation



AIRS Reconstructed Radiances

- Data are supplied in near-real time by NOAA/NESDIS in the same format as the "real" radiances.
- The same channels are supplied, except some "popping" channels are missing
- Based on 200 PCs
- QC Flag supplied

Forecast Impact of Reconstructed Radiances



300 Channels for IASI