First results of IASI assimilation experiments

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IASI Conference, Anglet   13th November 2007

Thanks to my other colleagues!

Brett Candy, Steve English, James Cameron, Bill Bell

Roger Saunders, Peter Rayer, John Eyre

Stu Newman, Jon Taylor

Mike Thurlow, Mark Naylor

Pascal Brunel (Meteo France)

Overview

- How are we using IASI at the Met Office?

- Assimilation Trials

- The Trouble with Water Vapour

- Summary and future work

How are we using IASI at the Met Office?

Data Selection

- 1 pixel in 4
  - collocated-AVHRR "Most Homogeneous" field of view

- No data used over sea ice

- No data used where IR cloud tests failed
  - Cost test (English et al. 1999)
  - Compare IASI with AMSU (Cheng et al. 2006)
  - Threshold on SD of 4 IASI pixels (Cheng et al. 2006)

Channel selection for data storage

- 300 channels selected with information content method (Collard 2007, submitted to QJRMS)

- Choose successive channels which contain most information content for atmospheric profile

- Avoid adjacent channels to reduce correlated error

  - (only use diagonal error covariance matrix in VAR)

- Avoid channels affected by trace gases we don't model

- Add 14 extra channels for monitoring to give 314 in total

- (cf AIRS: 324 channels)

Channel selection for data processing

- Reject some problematic channels (inc highest peaking)

- Reduce number of water vapour channels used
  - (will come back to this later)
  - But note we are using water vapour channels!

- Left with 183 channels used in 1D-Var retrieval

- Reject low-peaking channels
  - over land
  - where AMSU detects cloud (by-product of surface type test)

- 138 used in 4D-Var where high-peaking channels are removed to avoid stratospheric ringing

- (cf AIRS: 63 channels)
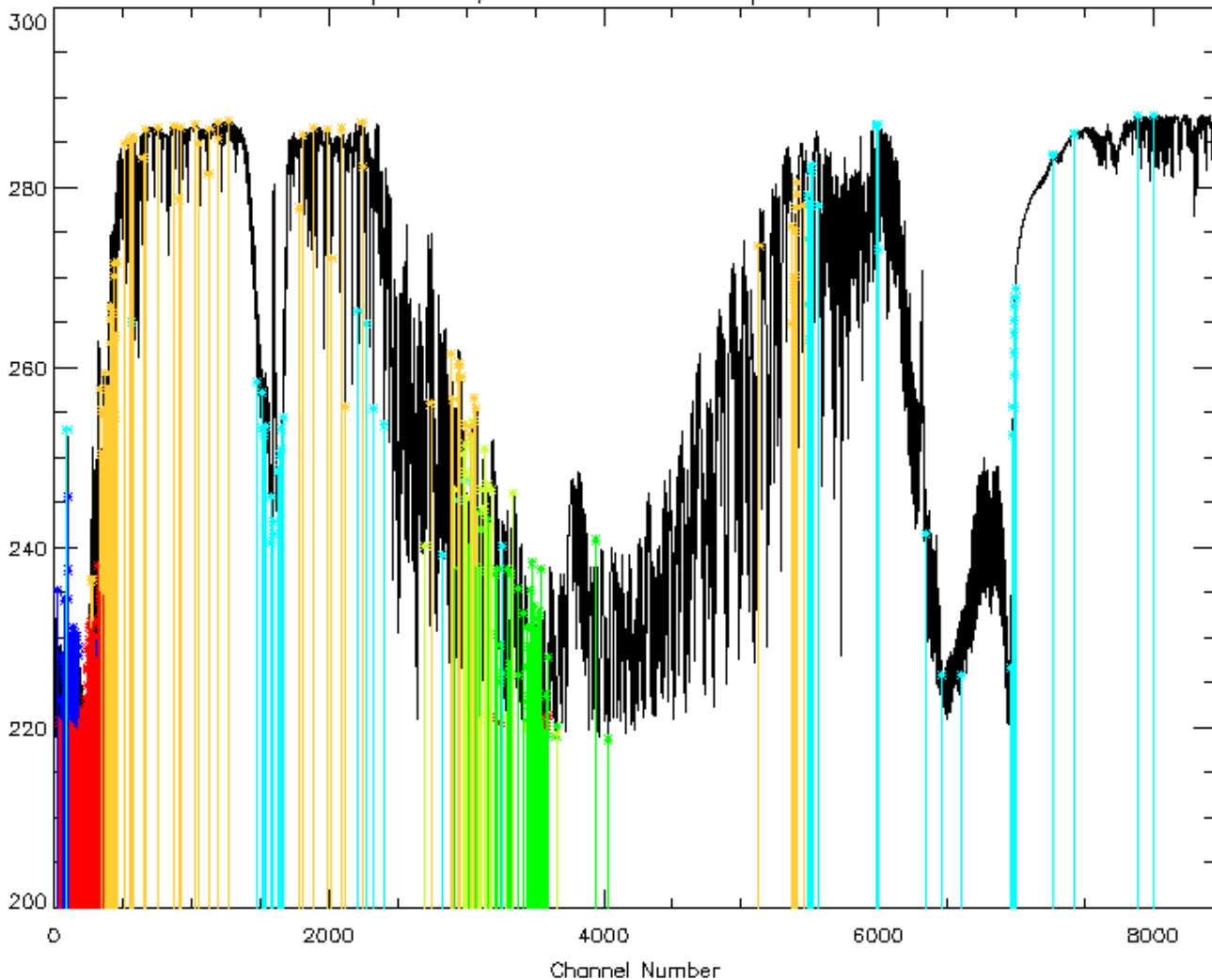
Data Processing

- We use RTTOV 7

    - kCARTA coefficients

- Observations are processed through a 1D-Var scheme before assimilation in 4D-Var

- Observation error (SD) of

    - 0.5 K 15 µm CO_2 band (c.f. O-B fit of ~0.3 K)

    - 1 K window channels (c.f. O-B fit of ~0.6 K)

    - 4 K water vapour channels (c.f. O-B fit of ~1.4 K – see later!)

Channel Selection

IASI Spectrum, US Standard Atmosphere – AllChans

Red – Used (Sea/Land, Clear/MWcloud)

Yellow – Used (Sea/Clear only)

Blue – Used (1D-Var preprocessor only)

Cyan – Rejected

Green / Lime – Rejected water vapour channels

Assimilation Trials June 2007

Assimilation trials

- Pre-operational testing via one-month trials 24th May to 24th June 2007

- Processing very similar to existing ATOVS/AIRS processing

- Eight different configurations tested with
  - Differing channel selections
  - Different model resolutions (N216,N320; 50L,70L)
  - Recalculated bias corrections
  - Different observation errors
 - It has also been tested with two different model physics packages

Trial results

- Results fairly stable throughout trial period which was a difficult period for the Met Office Unified Model operationally

- Results proved robust to different trial configurations

- We measure trial performance using the "NWP Index"

  - Combines 22 key variables of interest to our customers

  - Weighted mean skill relative to persistence

  - Measured using both observations and analyses as verification, and the two values averaged

- All trials showed positive impact

Trial results

- Preferred configuration
  - inc water vapour channels
  - 0.5 K/1 K/4 K obs errors

- Score
  - +1.21 v Obs
  - +0.80 v Anl
  - +1.01 Overall

- Compare with AIRS for same period
  - +0.63 v Obs
  - +0.12 v Anl
  - +0.375 Overall
  - Note we normally expect more impact from AIRS!

IASI NEW R VS CONTROL (JUN2007)
VERIFICATION VS OBSERVATIONS – DAILY NWP INDEX AND RUNNING MEAN
OVERALL CHANGE IN NWP INDEX = 1.213
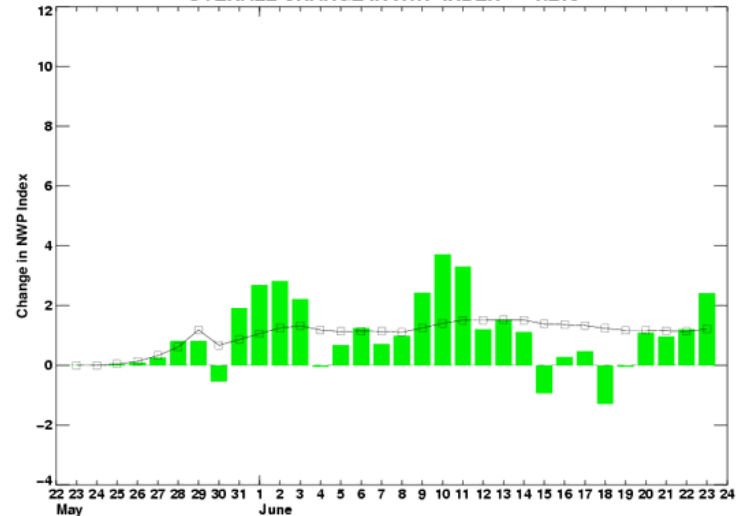
VERIFICATION VS ANALYSIS – DAILY NWP INDEX AND RUNNING MEAN
OVERALL CHANGE IN NWP INDEX = 0.804
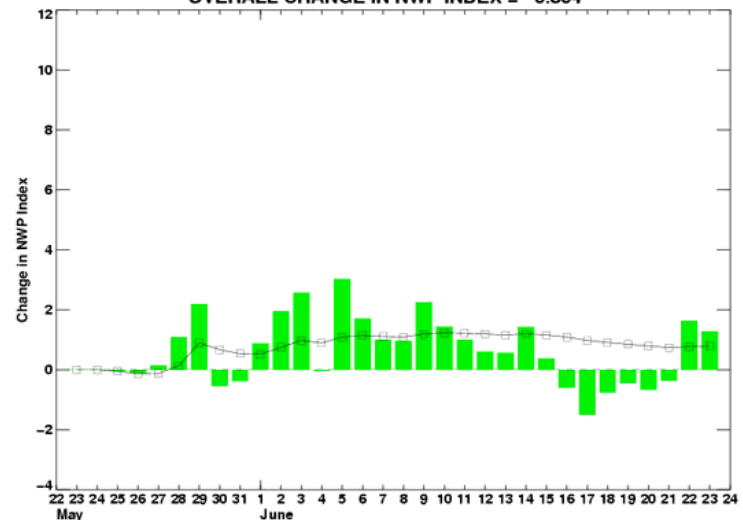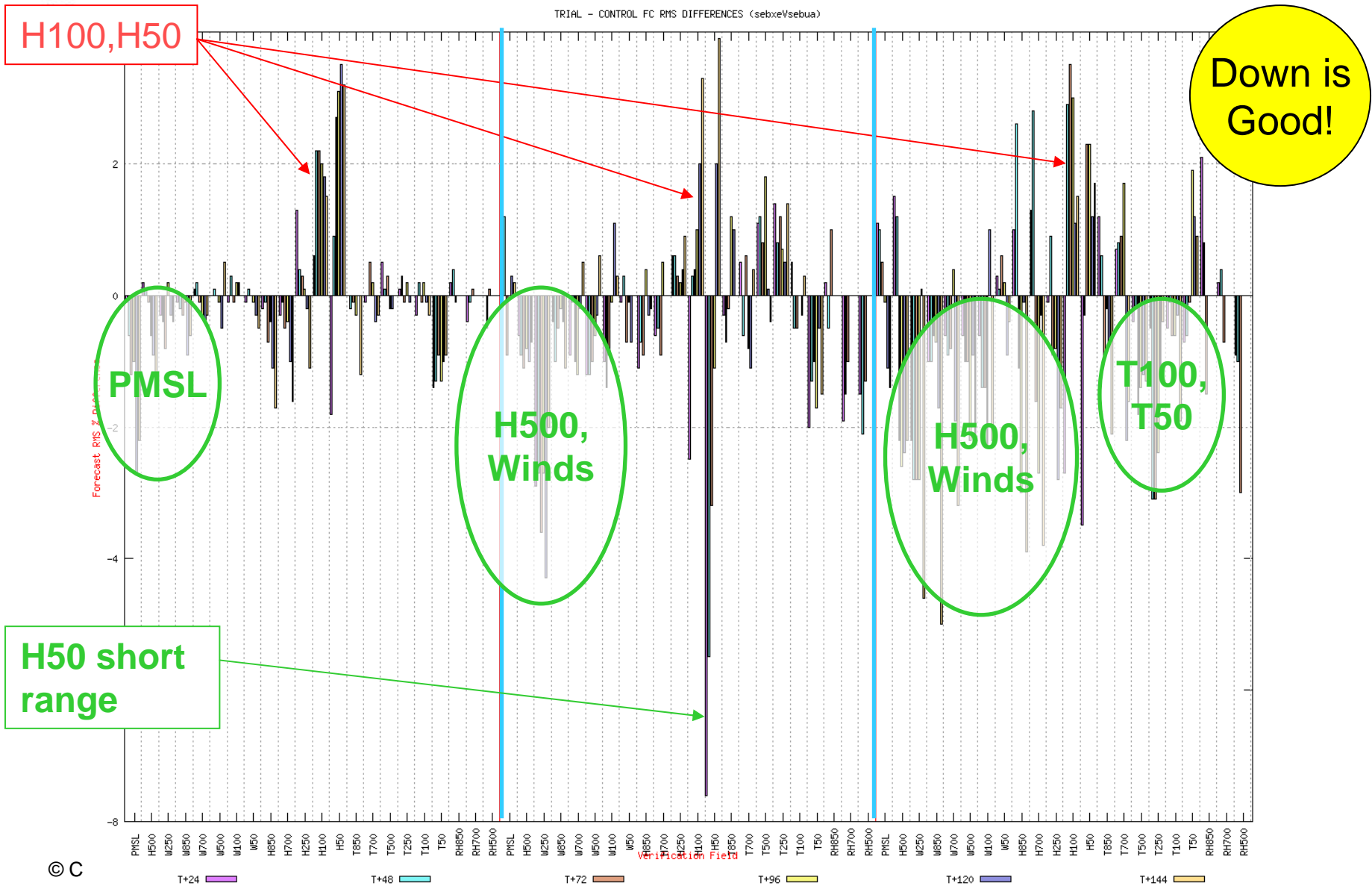
Change in RMS Forecast Error v Analyses

© Crown copyright 2007
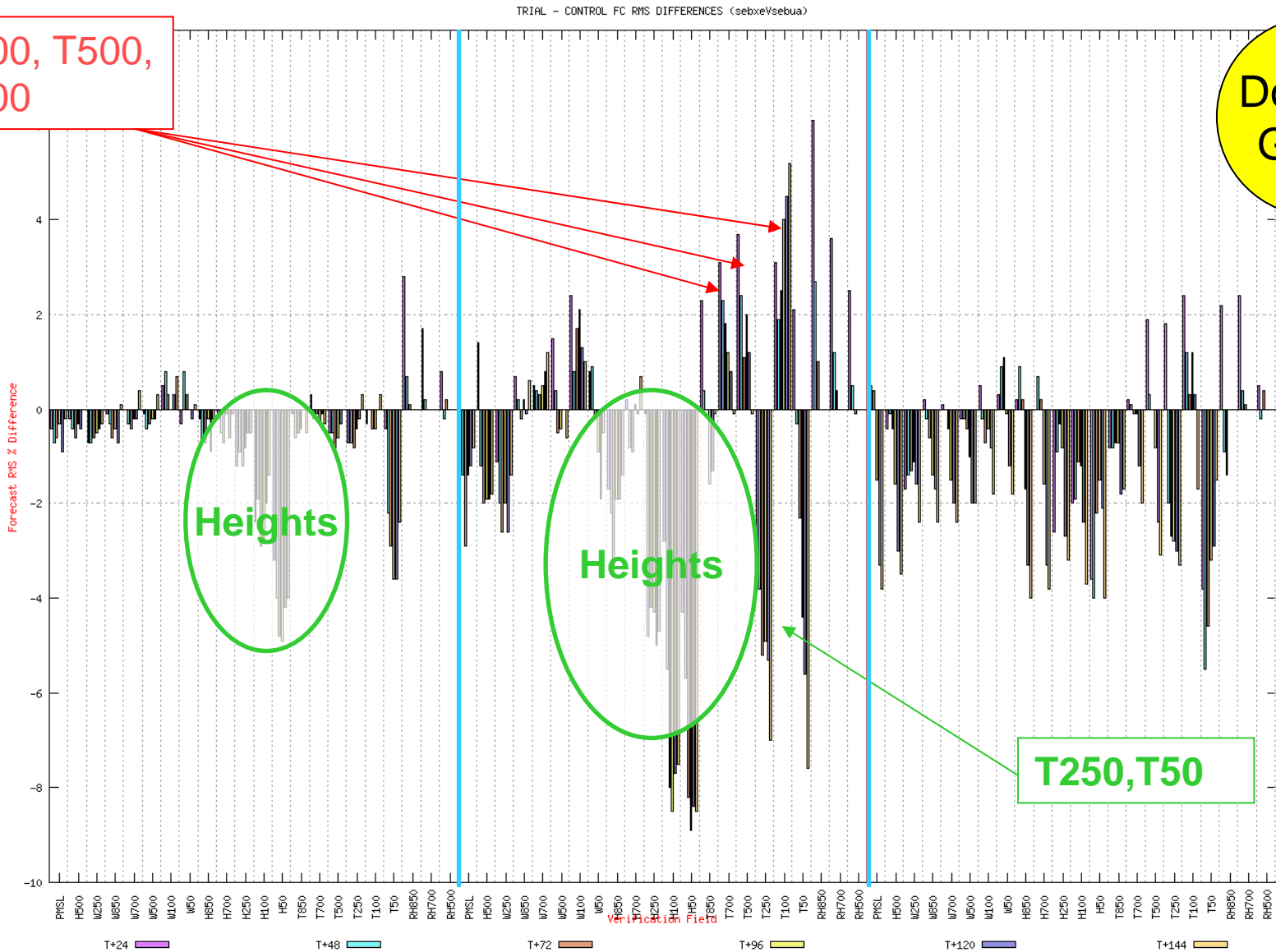
Change in RMS Forecast Error v Obs

The take-home message

- +1 point on the index is a very good score considering that IASI has been tested on top of:

  - 3 x ATOVS on NOAA platforms

  - ATOVS on MetOp itself

  - AIRS

  - SSMIS

Improvement to model fields

- I wanted to show some nice plots of improvements to model fields…

- …but the changes are minor improvements across the board adding up to a good increase in the index overall. They don't show up in plots!

- Results are more robust to changes in configuration and model physics

Mean Error : PS15.5 IASI - PS15.5 Control, T+24
V WIND (m/s) at 250hPa
min: -1.4 max: 1.42 mean: 0 RMS: 0.25 SD: 0.25
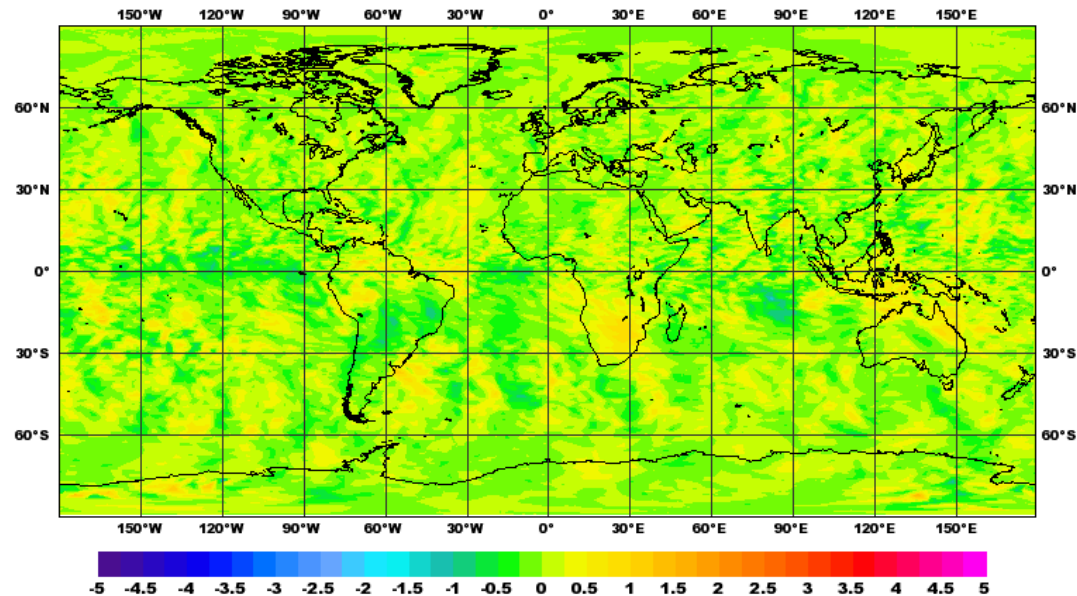
Southern Hemisphere Height Profile T+24, Mean Forecast Error – Verification vs Sonde

Height (metres): Sonde Obs
Southern Hemisphere (CBS area 20S–90S)
Meaned from 23/5/2007 12Z to 23/6/2007 12Z

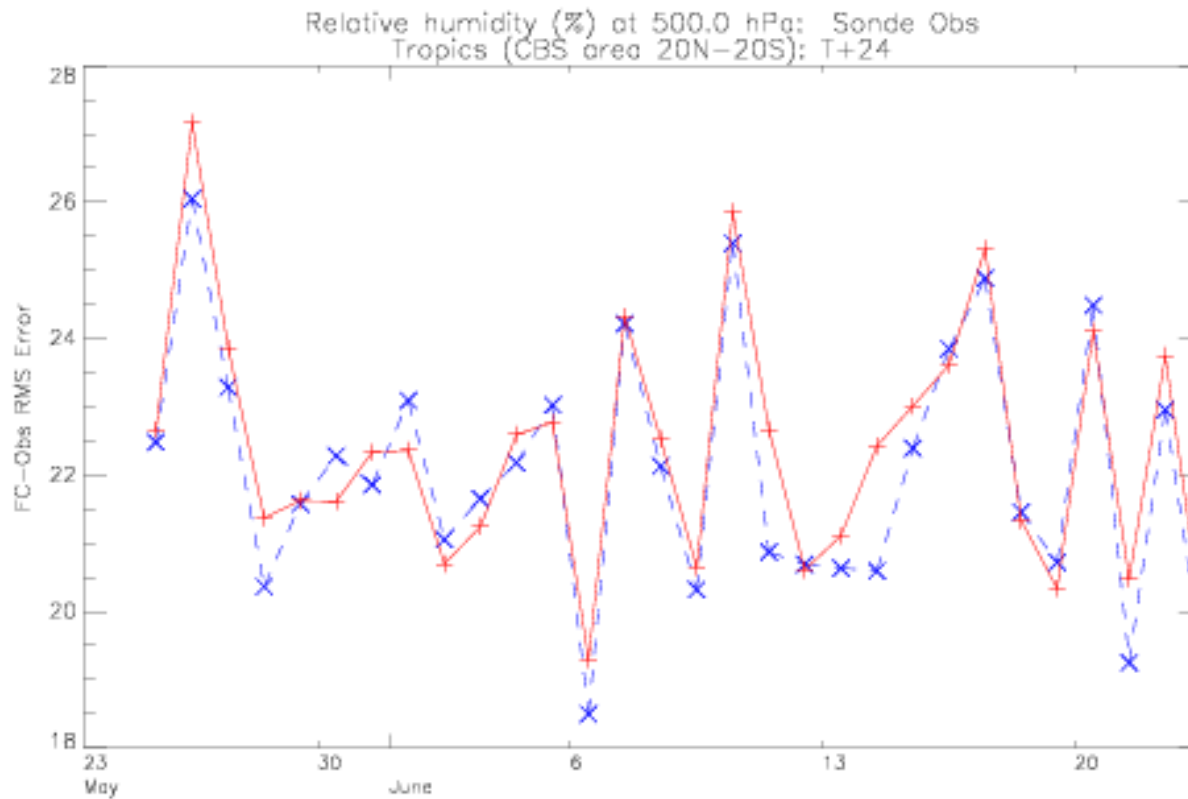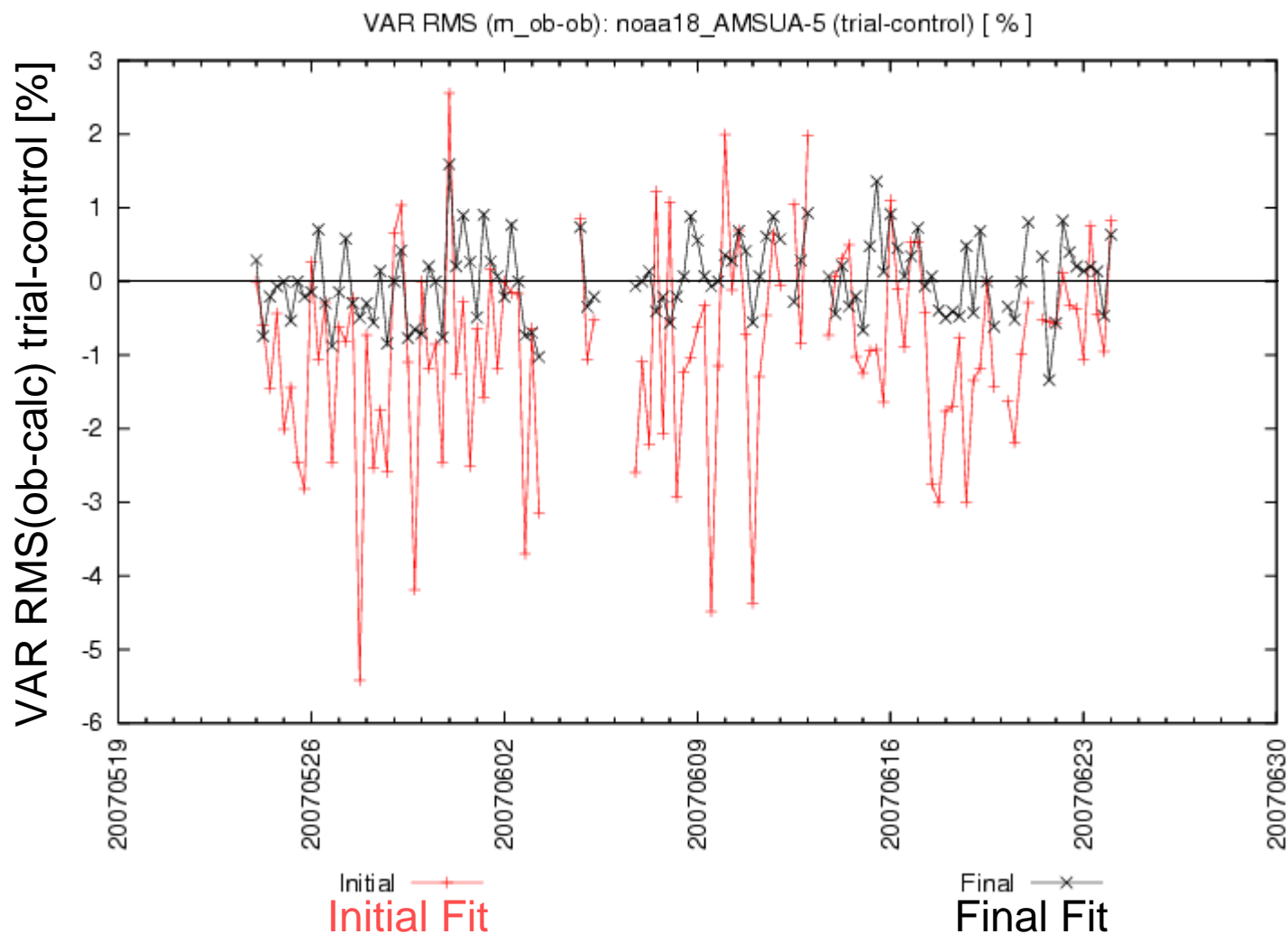Cases: ── PS15.5 Control ✕─✕ PS15.5 Plus IASI – New Biases and Obs Errors

T+24
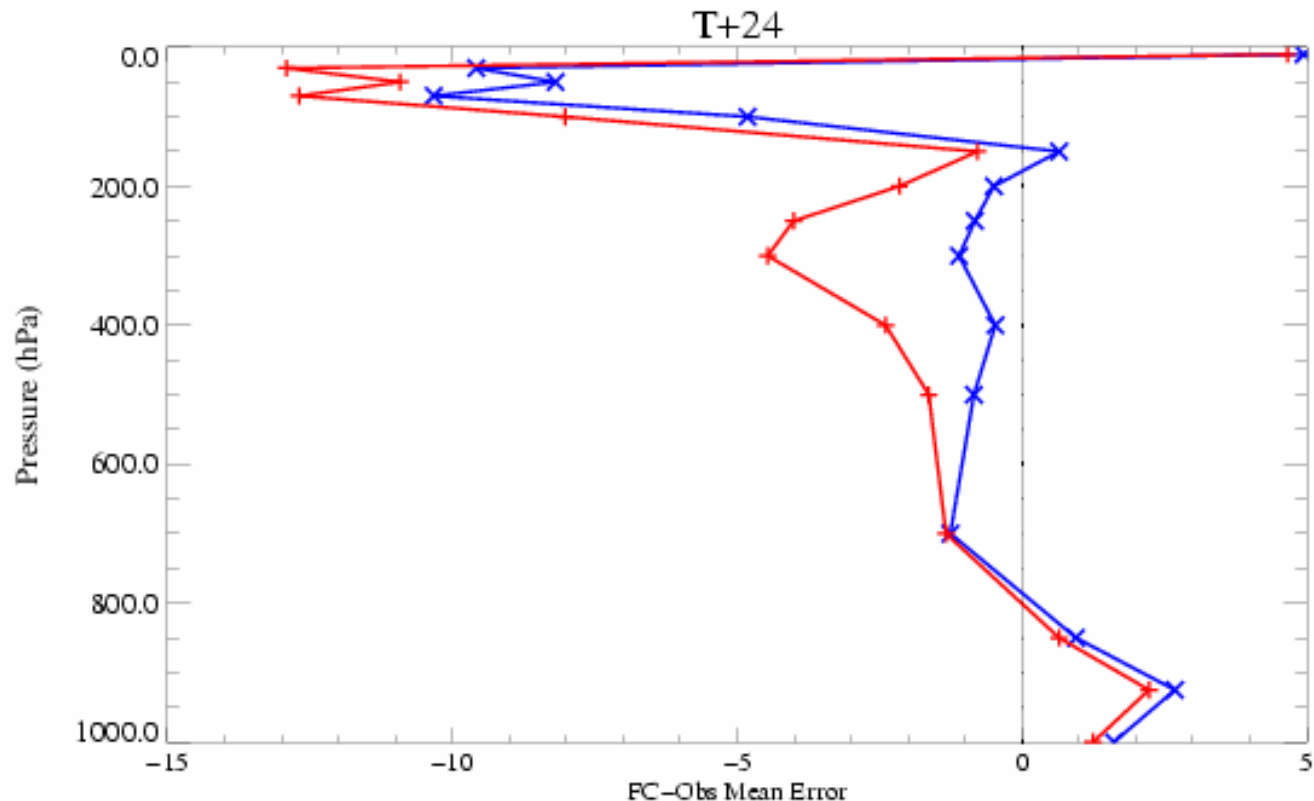
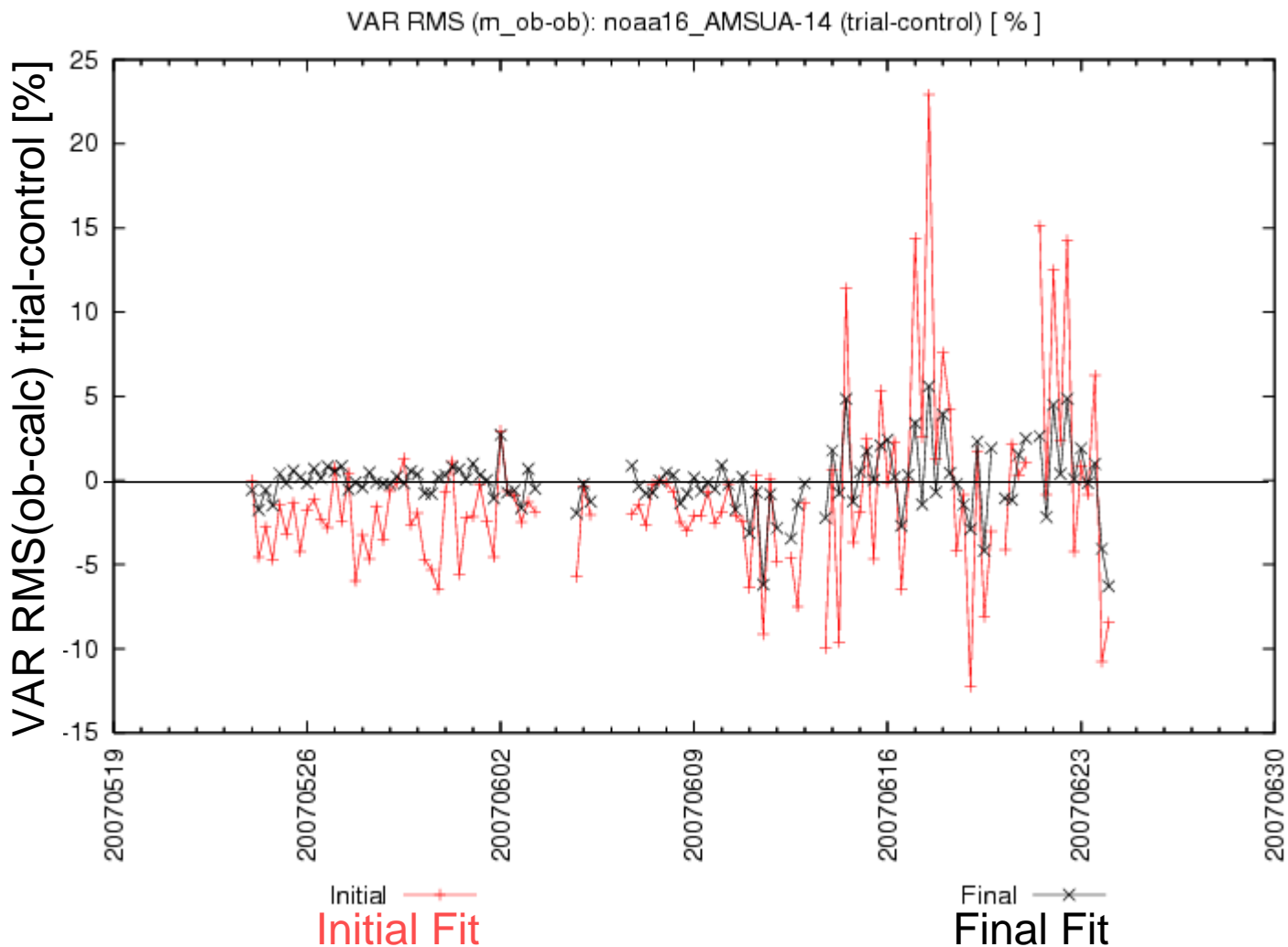# Tropics Relative Humidity 500 hPa T+24 time series RMS Forecast Error – Verification vs Sonde

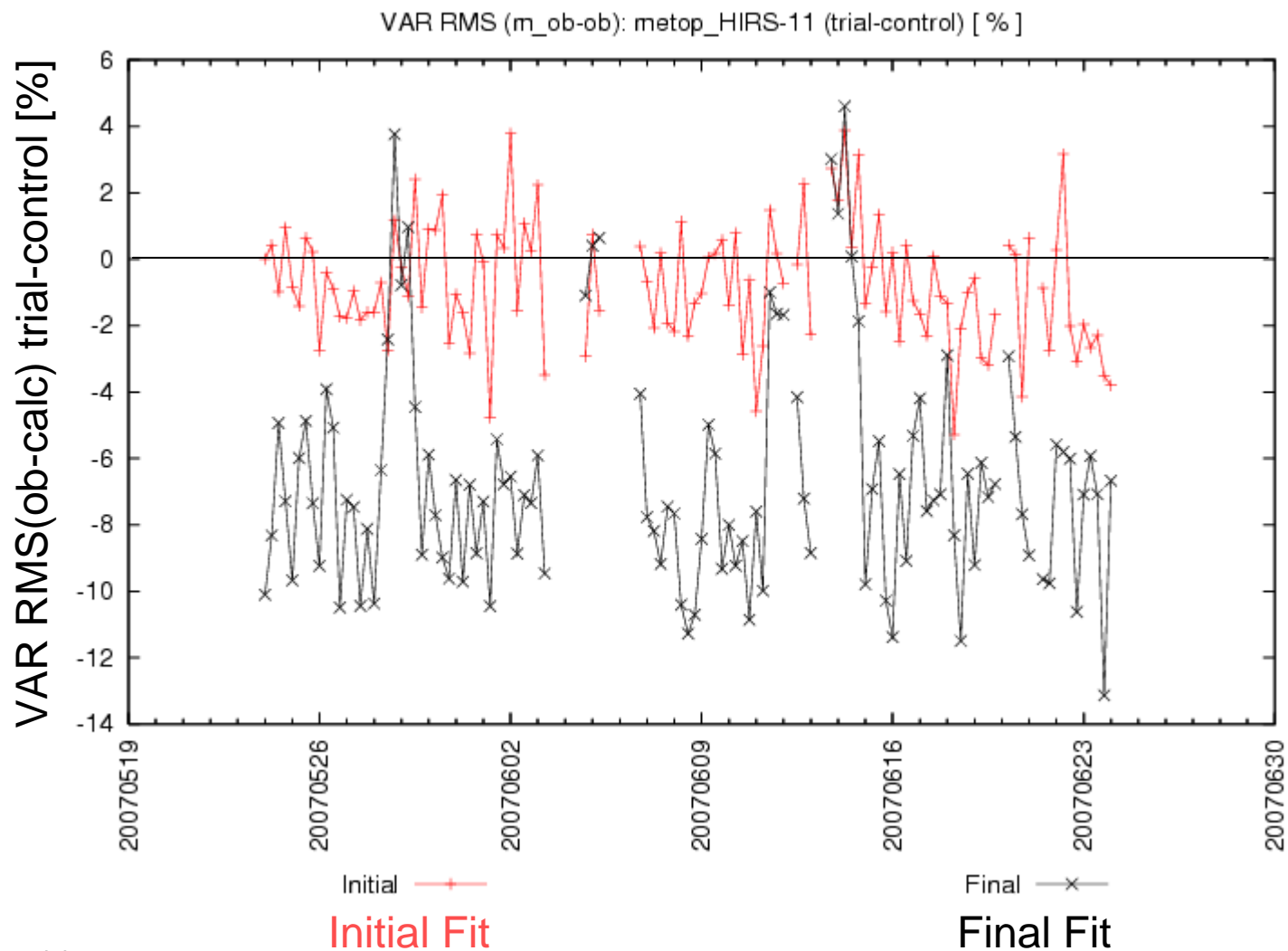# Improvement in fit to other satellite data
NOAA-18 AMSU-A Channel 5 (750 hPa)

VAR RMS (m_ob-ob): noaa18_AMSUA-5 (trial-control) [%]

Improvement in fit to other satellite data
NOAA-16 AMSU-A Channel 14 (stratosphere)

VAR RMS (m_ob-ob): noaa16_AMSUA-14 (trial-control) [%]

Initial Fit

Final Fit

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Improvement in fit to other satellite data
MetOp HIRS Channel 11 (water vapour)

VAR RMS (m_ob-ob): metop_HIRS-11 (trial-control) [%]

Initial — Initial Fit

Final — Final Fit

Operational Implementation

- IASI has been accepted for operational implementation in the global model configuration on November 27th 2007 along with:
    - ASCAT scatterometer winds from MetOp
    - Extra COSMIC GPS radio occultation data
    - Linear convection model in 4D-Var

- Expecting impact of about
    - +3 overall
    - Of which about +2 from satellite data introduction

- Currently being tested in Parallel Suite. As of 07/11/07 with 18 days verification stats
    - +3.2 so far

- IASI has also been accepted for inclusion in the North Atlantic and European model configuration (NAE)
    - Impact neutral but some improvement in PMSL forecasts
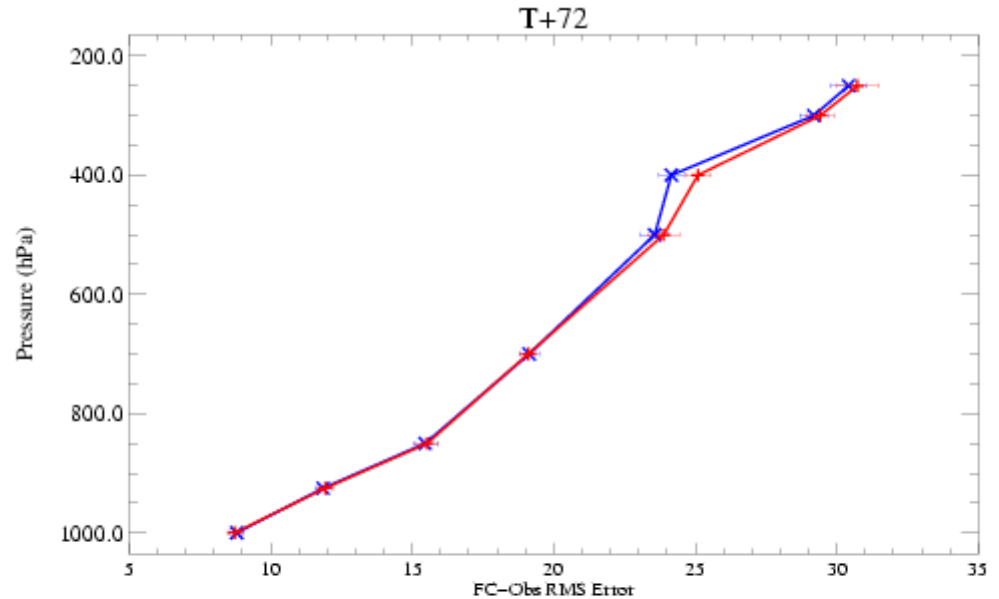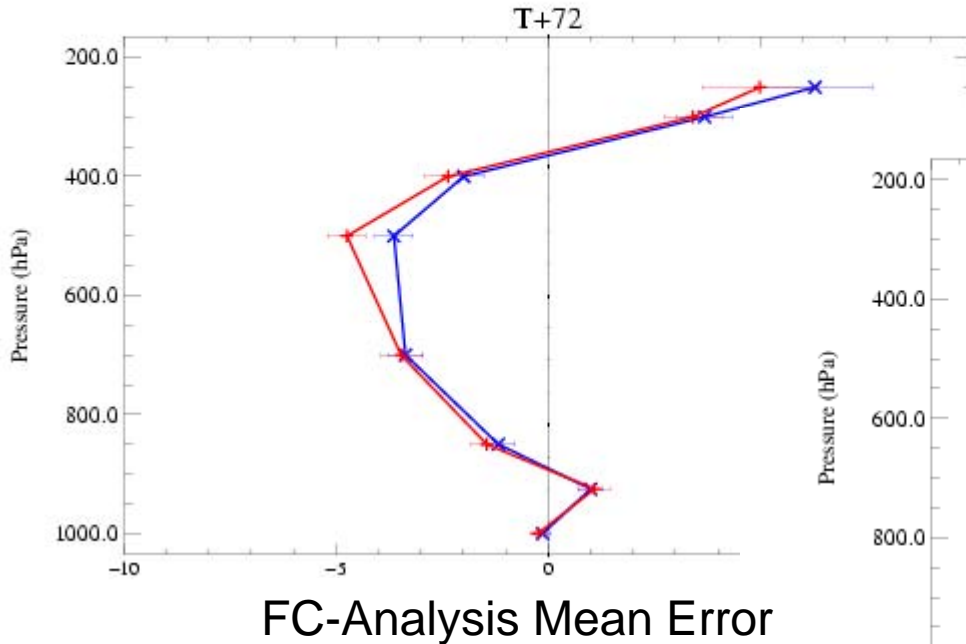
Parallel Suite Verification (2)

Tropics

Relative Humidity T+72

Verification vs Sonde

Relative humidity (%): Sonde Obs
Tropics (CBS area 20N–20S)
Equalized and Meaned from 21/10/2007 00Z to 7/11/2007 12Z

Cases: ——+—— Operational Suite   ——✕—— Parallel Suite 17

T+72

FC-Analysis Mean Error

T+72

FC-Analysis RMS Error
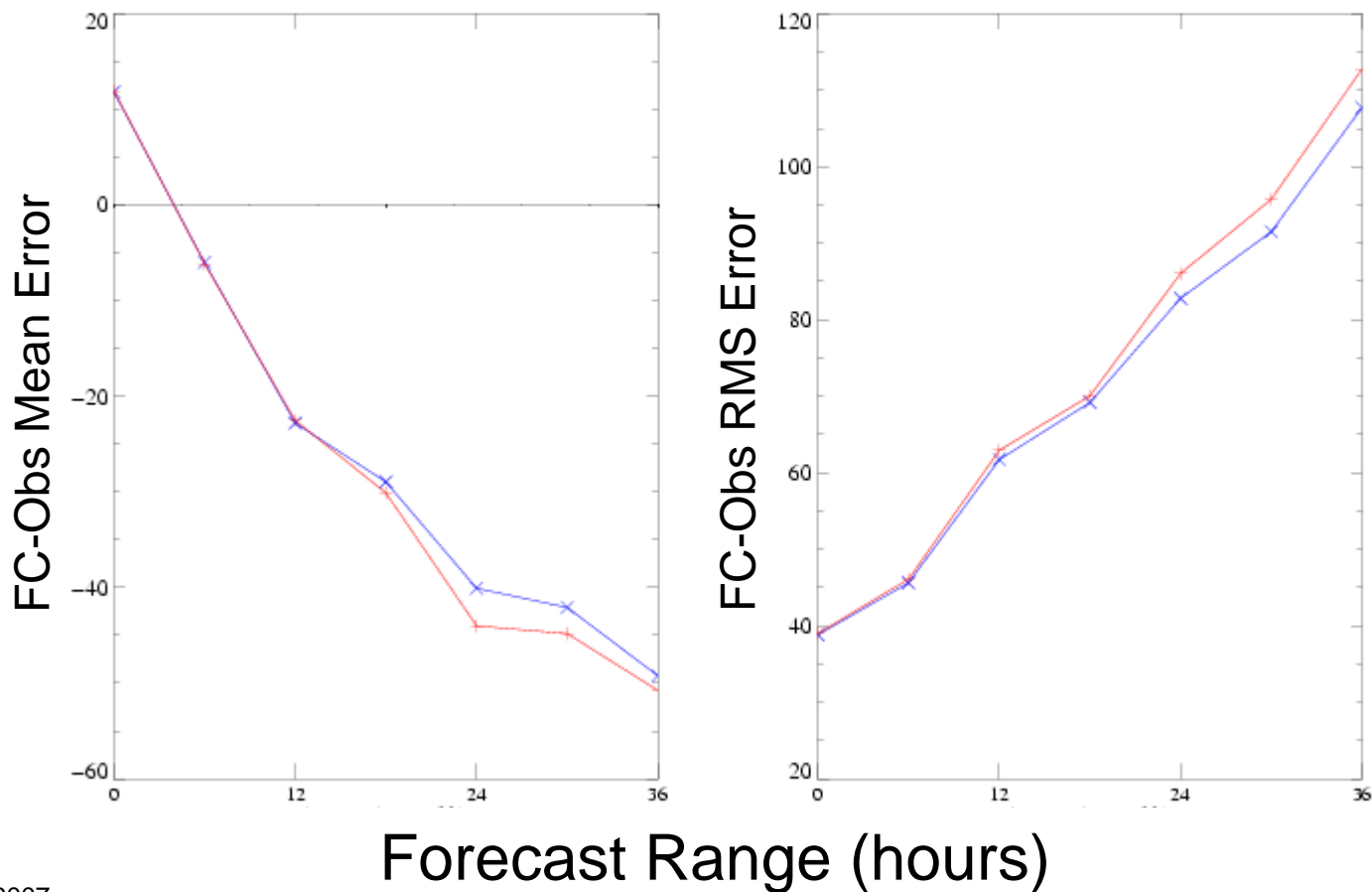
68% error bars calculated using $S/(n-1)^{1/2}$

NAE Parallel Suite Verification

PMSL vs Obs

Mean Sea Level Pressure (Pa): Surface Obs
UK Index station list
Equalized and Meaned from 25/5/2007 00Z to 25/6/2007 18Z

Cases: Control IASI

Forecast Range (hours)

Water vapour channel assimilation

Water vapour channel assimilation

- There is evidence that using water vapour channels does improve performance

  - Trial without water vapour channels was down about 0.15 index points relative to preferred configuration

  - Definitely some effect on RH fields

- However there are difficulties using water vapour channels

Assimilation of water vapour channels from AIRS and IASI

- Met Office AIRS – ~30 water vapour channels used out of 62 channels

- Met Office IASI – 31 water vapour-sensitive channels out of 138

- These channels generally not high-peaking

- ECMWF do not assimilate water vapour channels for IASI

Problems with assimilation of water vapour channels

- In order to achieve assimilation, observation errors have to be set much larger than the model fit to observations.

- Met Office AIRS+IASI use a standard deviation of 4 K

- We fit chosen IASI water vapour channels at worst 1.4 K

- We fit AIRS water vapour channels at worst 1.7 K

Problems with assimilation of water vapour channels (2)

- In the 1D-Var pre-processor there are increases convergence failures and RTTOV errors when:
    - Adding high-peaking water vapour channels
    - Using too many water vapour channels

	Low-peaking only	More mw channels	All wv channels
Failures during 1D-Var	409	634	1021

- In 4D-Var the number of iterations to convergence increases (undesirable as extremely expensive)

	Low-peaking only	More channels	All channels
Number of iterations	49	59	69

- Only subtle effects on analyses
- But two week trial increasing the number of water vapour channels was down 0.25 NWP index points
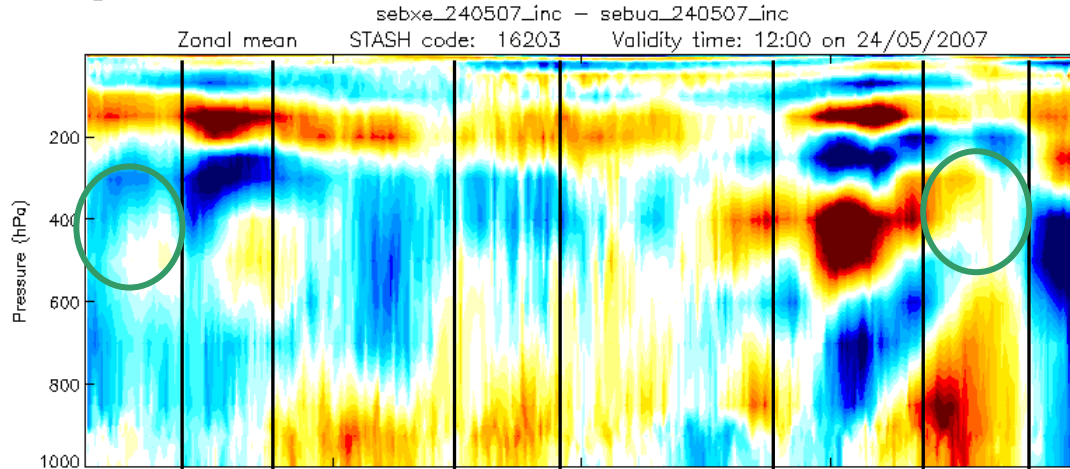
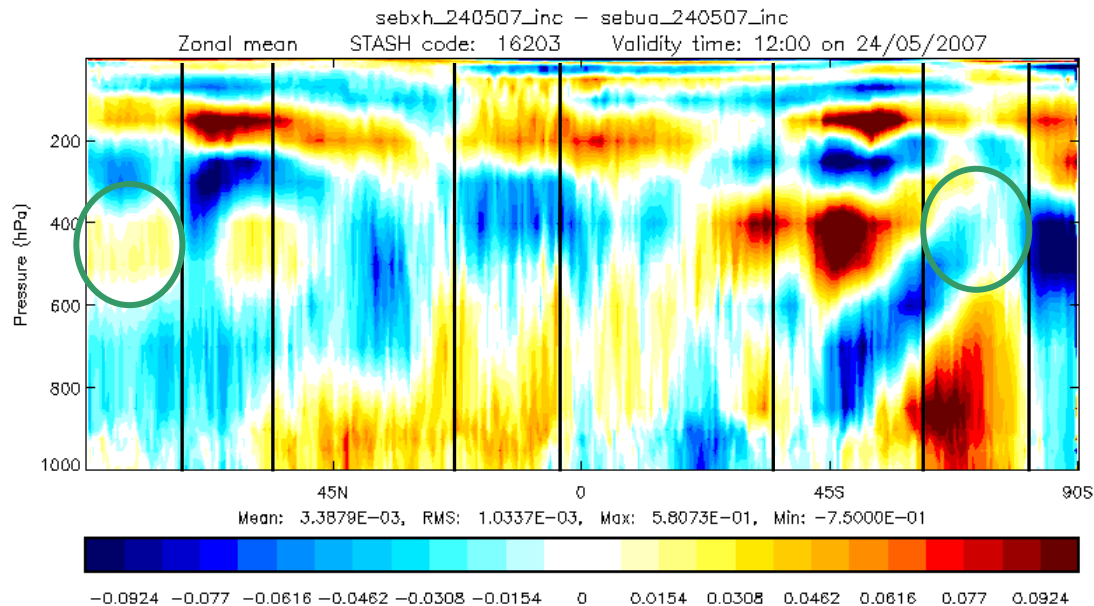# Differences in RH increments adding in more water vapour channels
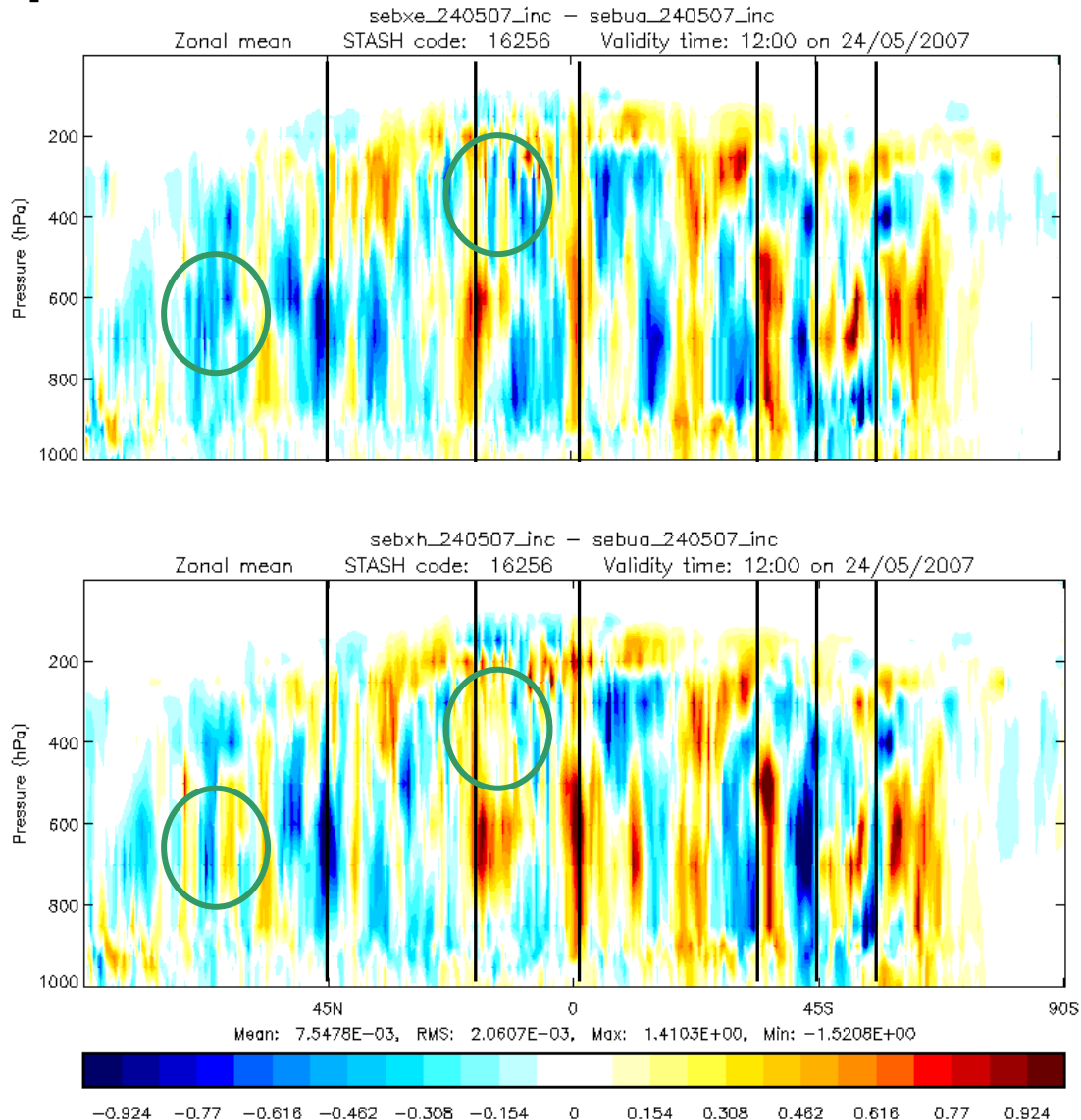
Preferred configuration

More water vapour channels

Differences in T increments adding in more water vapour channels

Preferred configuration

More water vapour channels

Summary and future work

Future work

- Make better use of spectral information

  - Principal component assimilation?

- Use data in cloudy areas

  - Code under development for AIRS

- Use more data over land

Summary

- Nine months of monitoring have shown IASI data to be of a high standard and stable

    - See monitoring plots here:
      http://www.metoffice.gov.uk/research/nwp/satellite/infrared/sounders/iasi/index.html

- Assimilation of IASI data provides significant forecast benefit on top of all the existing sounding data

- IASI data will be assimilated in Met Office Global and NAE model configurations from Nov 27th

- Although we see benefit from using water vapour channels, there are still issues to be solved in their use

Thank you for listening!

Comparison of IASI radiances with NWP models from four operational centres

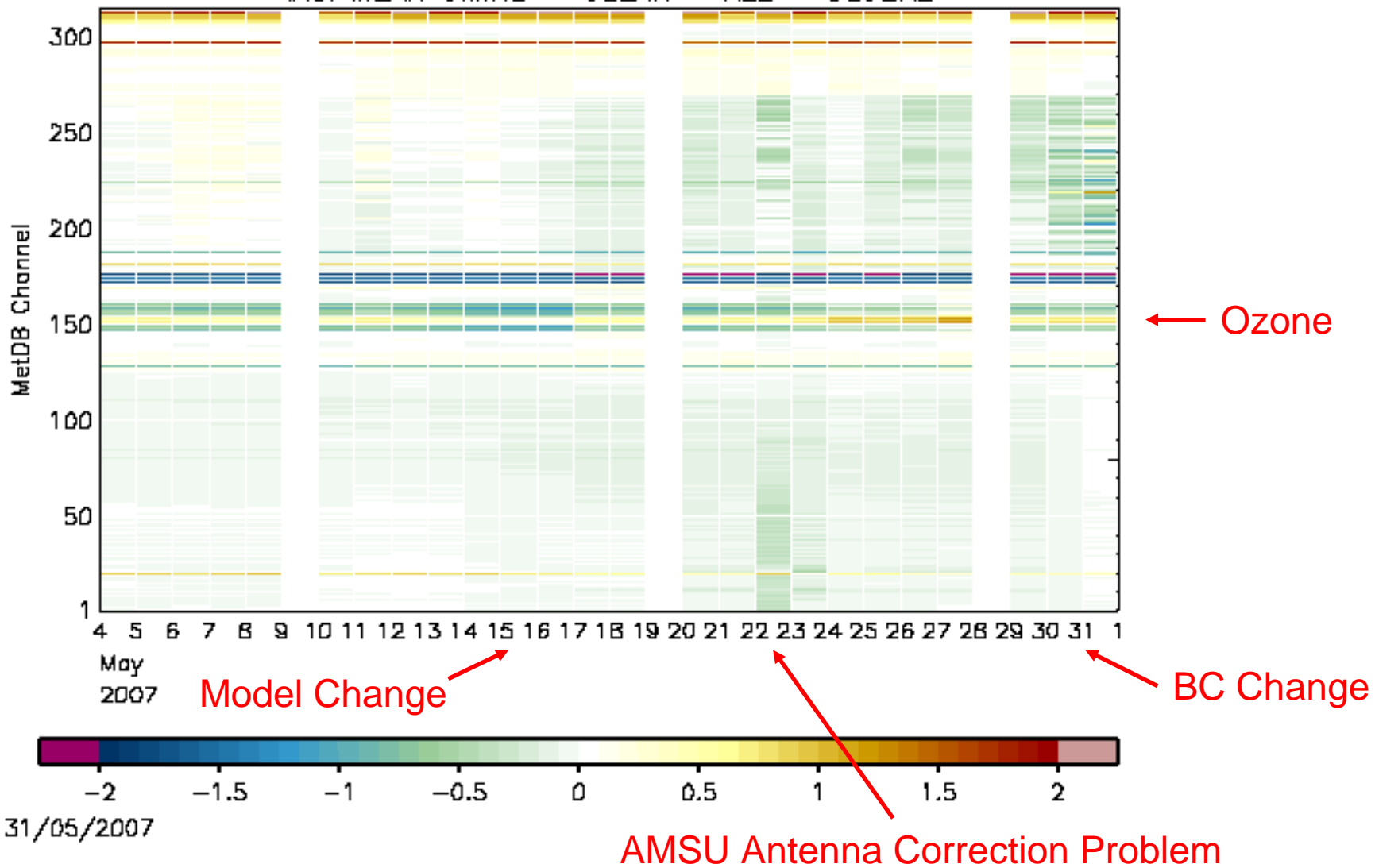**Fiona Hilton[1], Andrew Collard[2], Lars Fiedler[3],Lydie Lavanant[4]**

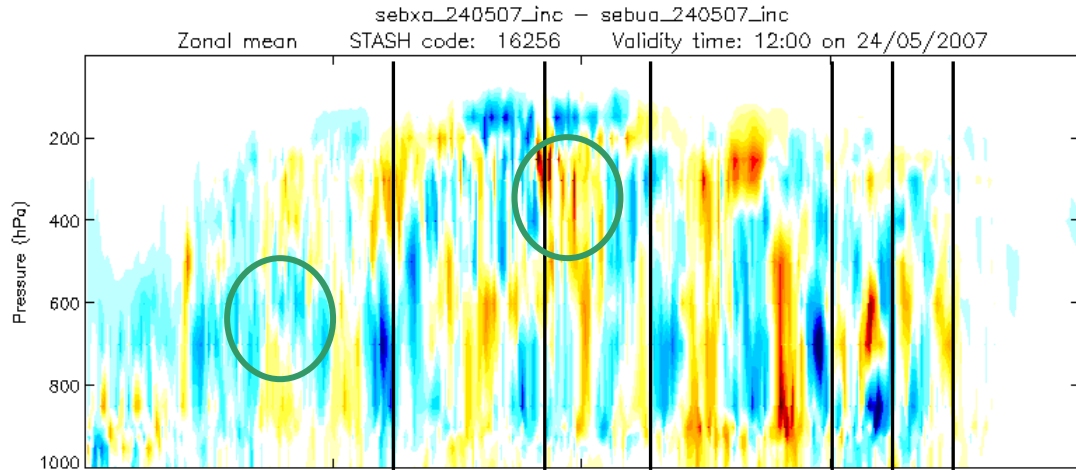**[1]Met Office   [2]ECMWF   [3]EUMETSAT   [4]Météo-France/CMS**

Mean(Obs – Calc) Night/Sea/Clear No Bias Correction
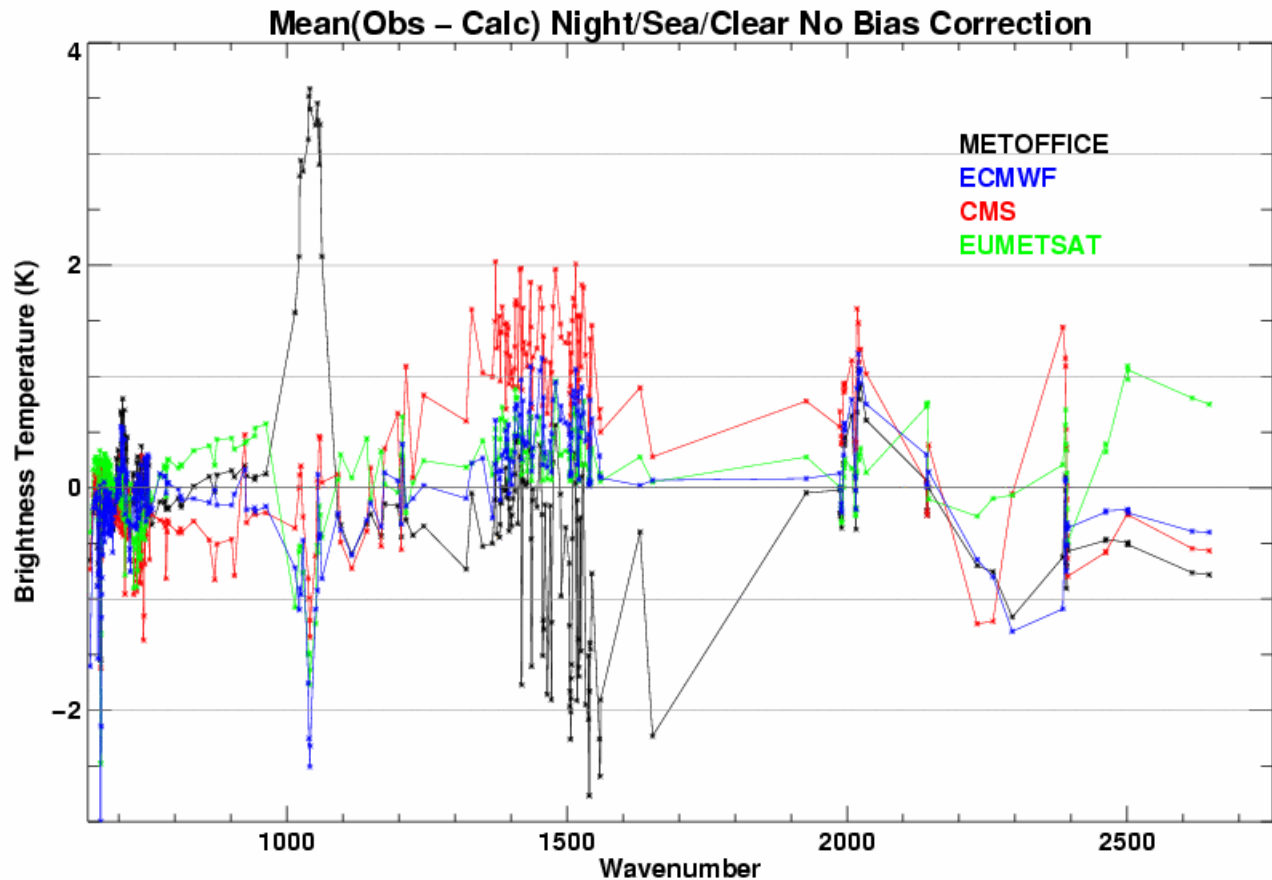
Obs minus Background After Bias Correction

IASI MEAN CMINB — CLEAR — ALL — GLOBAL

Ozone

Model Change

AMSU Antenna Correction Problem

BC Change

31/05/2007

Differences in RH increments removing water vapour channels

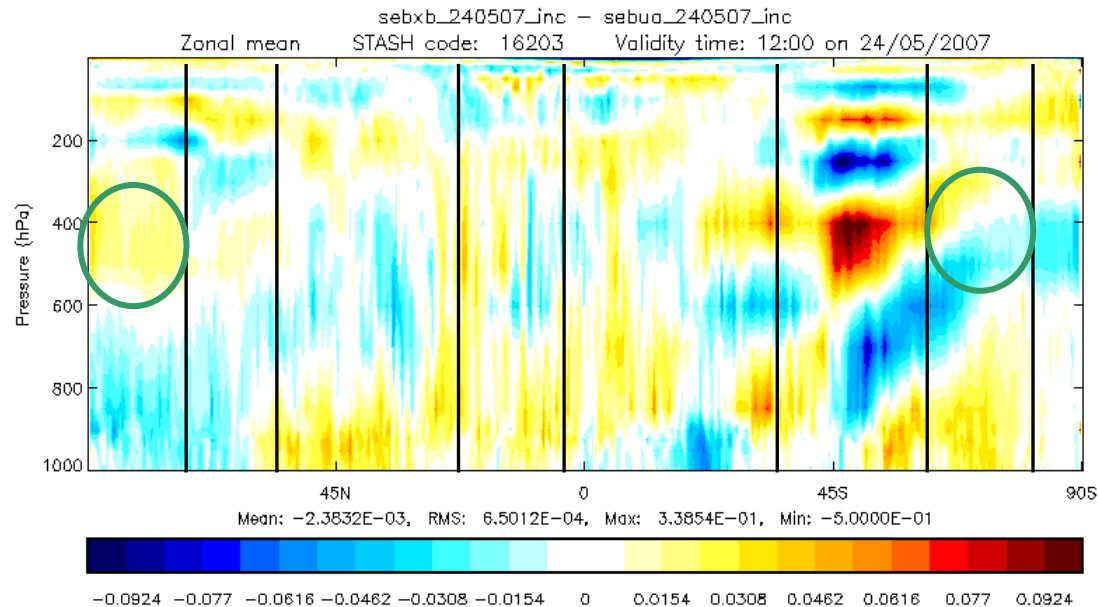
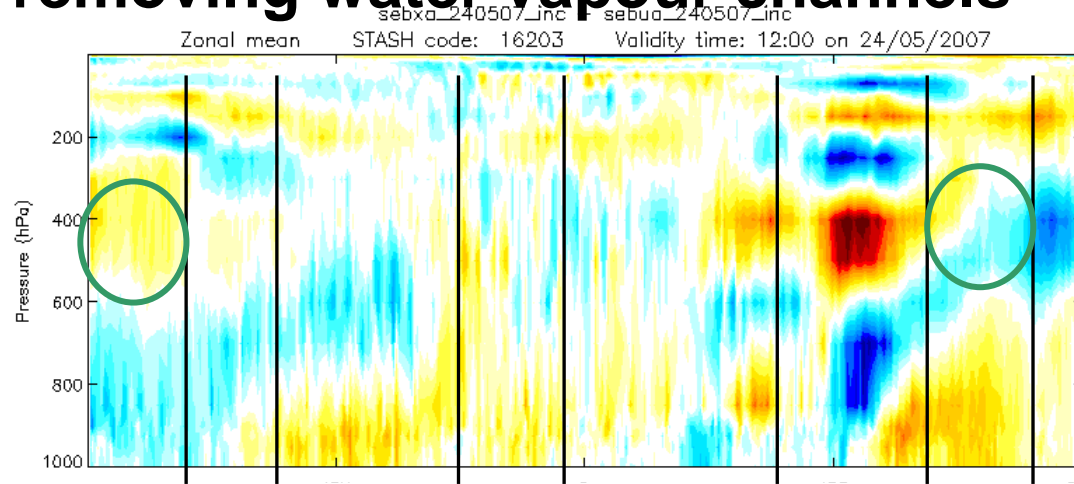PS17 channels
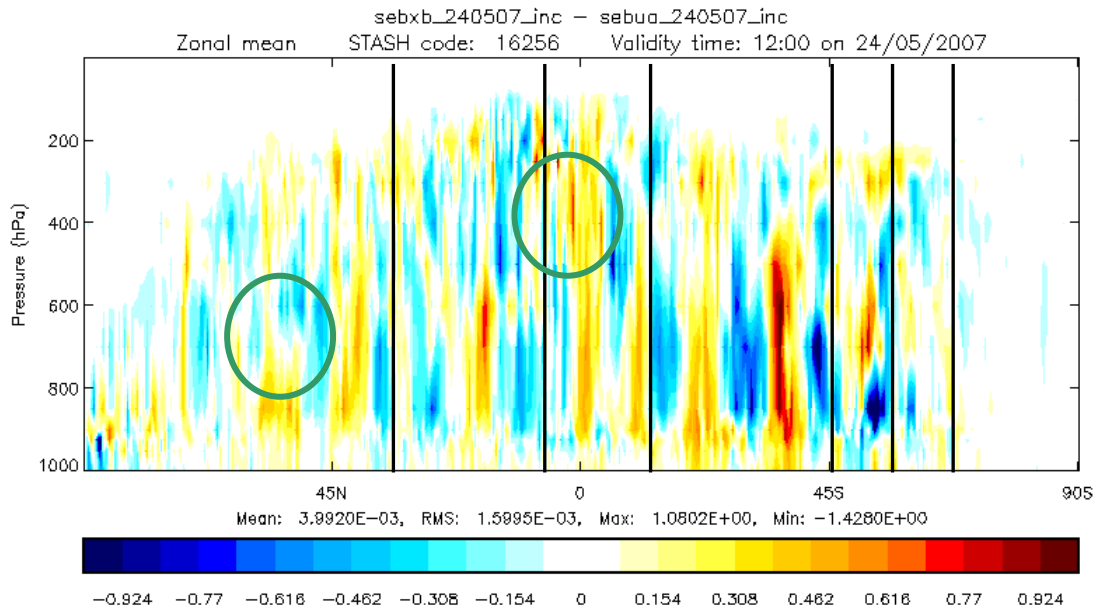
No water vapour channels

Differences in temperature increments removing water vapour channels

PS17 channels

No water vapour channels

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Improvement in fit to other satellite data
NOAA-18 AMSU-B Channel 3 (water vapour)

VAR RMS (m_ob-ob): noaa18_AMSUB-3 (trial-control) [%]
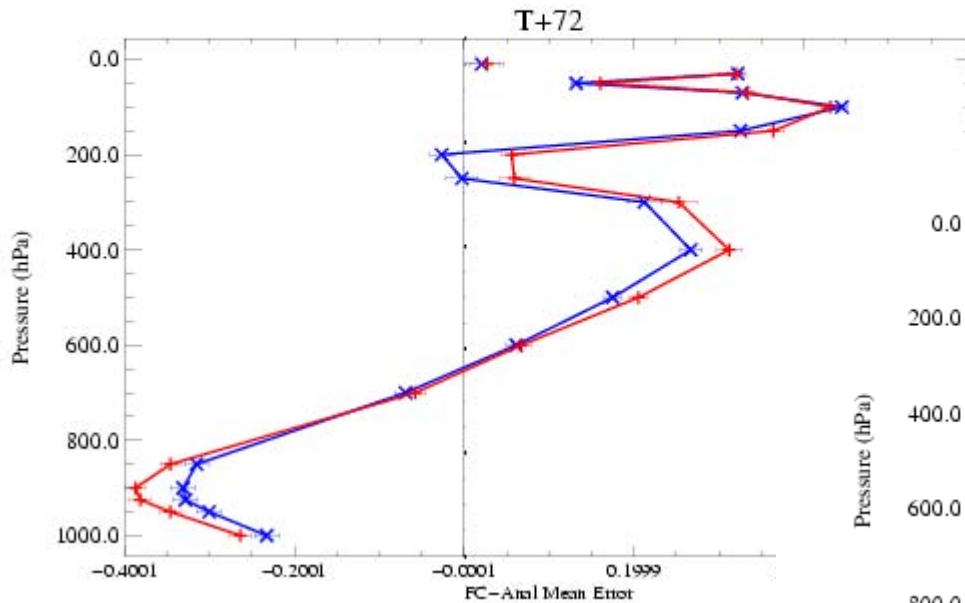
Initial Fit

Final Fit
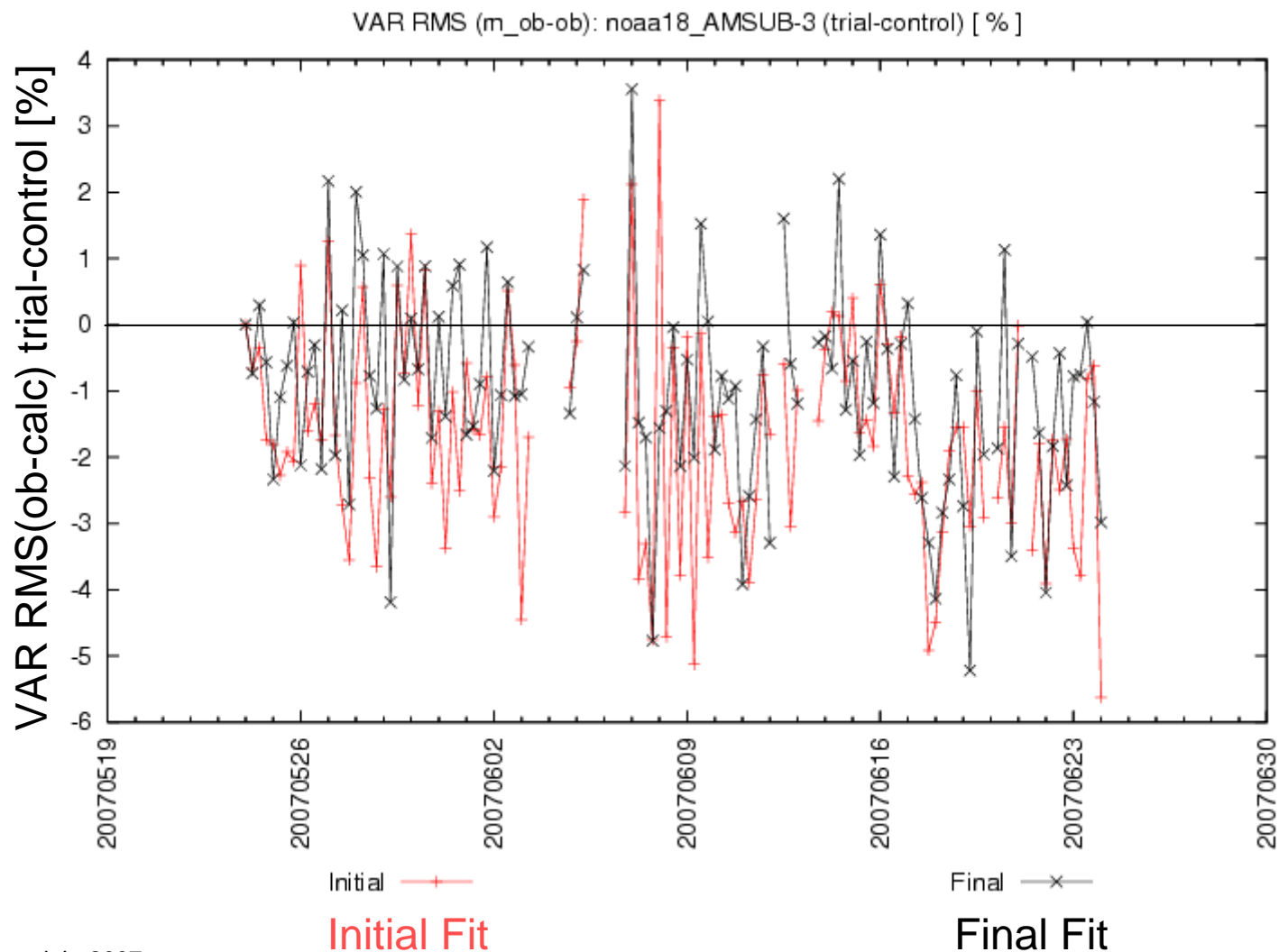
Parallel Suite Verification (1)
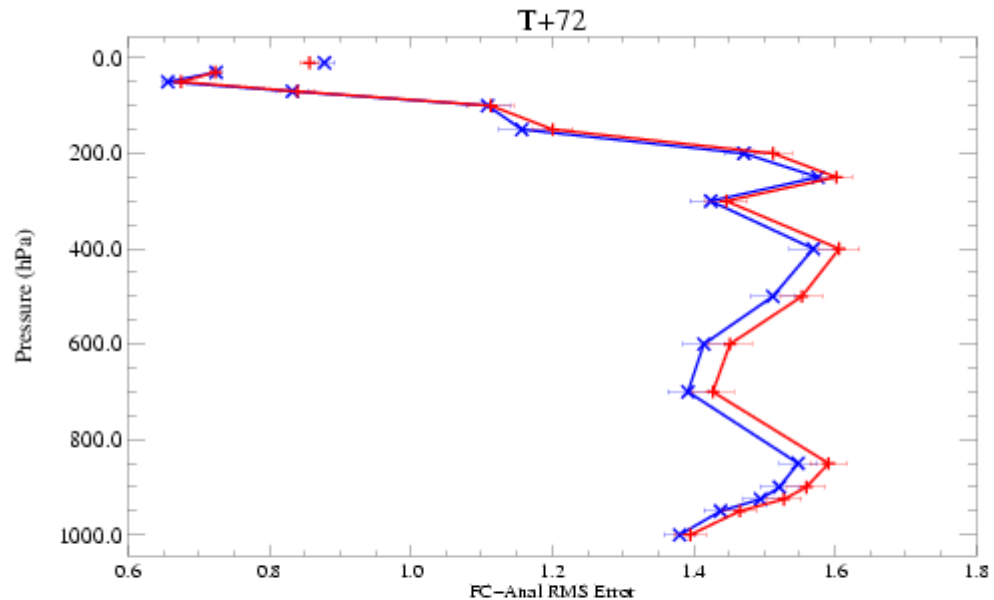

Northern Hemisphere
Temperature T+72

Verification vs Analysis

Temperature (Kelvin): Analysis
Northern Hemisphere (CBS area 90N−18.75N)
Equalized and Meaned from 21/10/2007 00Z to 7/11/2007 12Z

Cases: Operational Suite   Parallel Suite 17

FC-Analysis Mean Error

FC-Analysis RMS Error

68% error bars calculated using $S/(n-1)^{1/2}$