Assimilation of IASI data at the Met Office

Fiona Hilton

Nigel Atkinson

ITSC-XVI, Angra dos Reis, Brazil 07/05/08

Thanks to my other colleagues!

Andrew Collard (ECMWF)

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?
- Pre-operational assimilation trials June 2007
- IASI impact assessment December 2007
- Limited area model results
- Summary and current/future work

How are we using IASI at the Met Office?

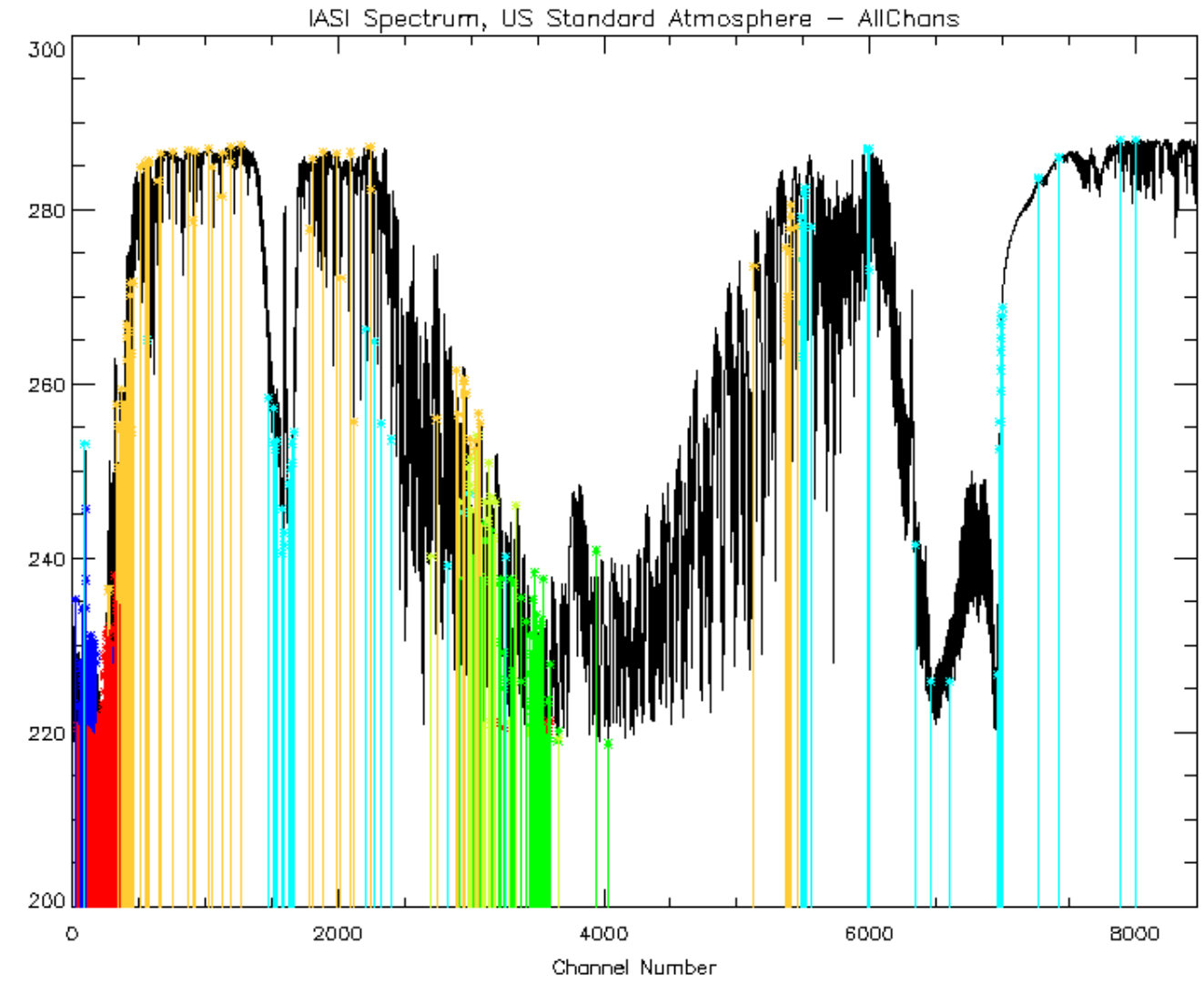
Data Selection

- Data reduction before storage
  - 1 pixel in 4 collocated-AVHRR “Most Homogeneous” field of view
  - 300 channels selected with information content method (Collard 2007, QJRMS) + 14 extra monitoring channels
- 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. ITSC 2006)
  - Threshold on SD of 4 IASI pixels (Cheng et al. 2006)

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)

Channel Selection



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

Data Processing

- We use RTTOV 7
  - kCARTA coefficients
- Observations are processed through a 1D-Var scheme before assimilation in 4D-Var
- Observation error (SD) in 4D-Var of
  - 0.5K 15 μm CO_2 band (c.f. O-B fit of ~0.3K)
  - 1K window channels (c.f. O-B fit of ~0.6K)
  - 4K water vapour channels (c.f. O-B fit of ~1.4K – see later!)

Pre-Operational Assimilation Trials
June 2007

Pre-Operational Assimilation trials

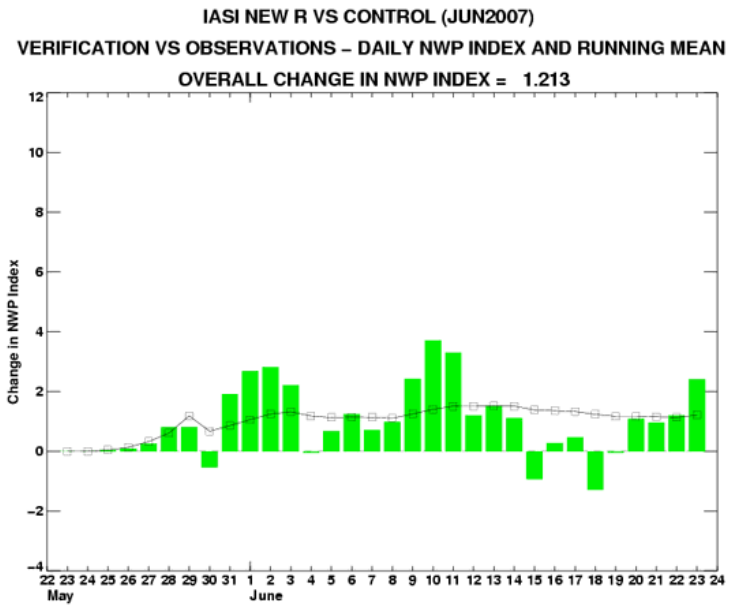
- Processing very similar to existing ATOVS/AIRS processing
- Eight different configurations tested with
  - Differing channel selections
  - Different model resolutions (N216,N320; 50L,70L)
  - Recalculated bias corrections
  - Different observation errors
  - It has also been tested with two different model physics packages

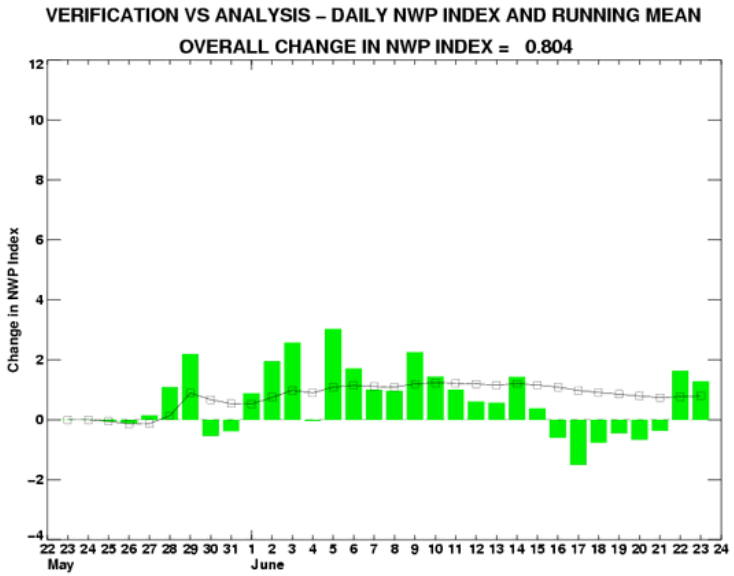
Trial results

- 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
    - PMSL, 250hPa winds, 850hPa winds, 500hPa height
  - 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

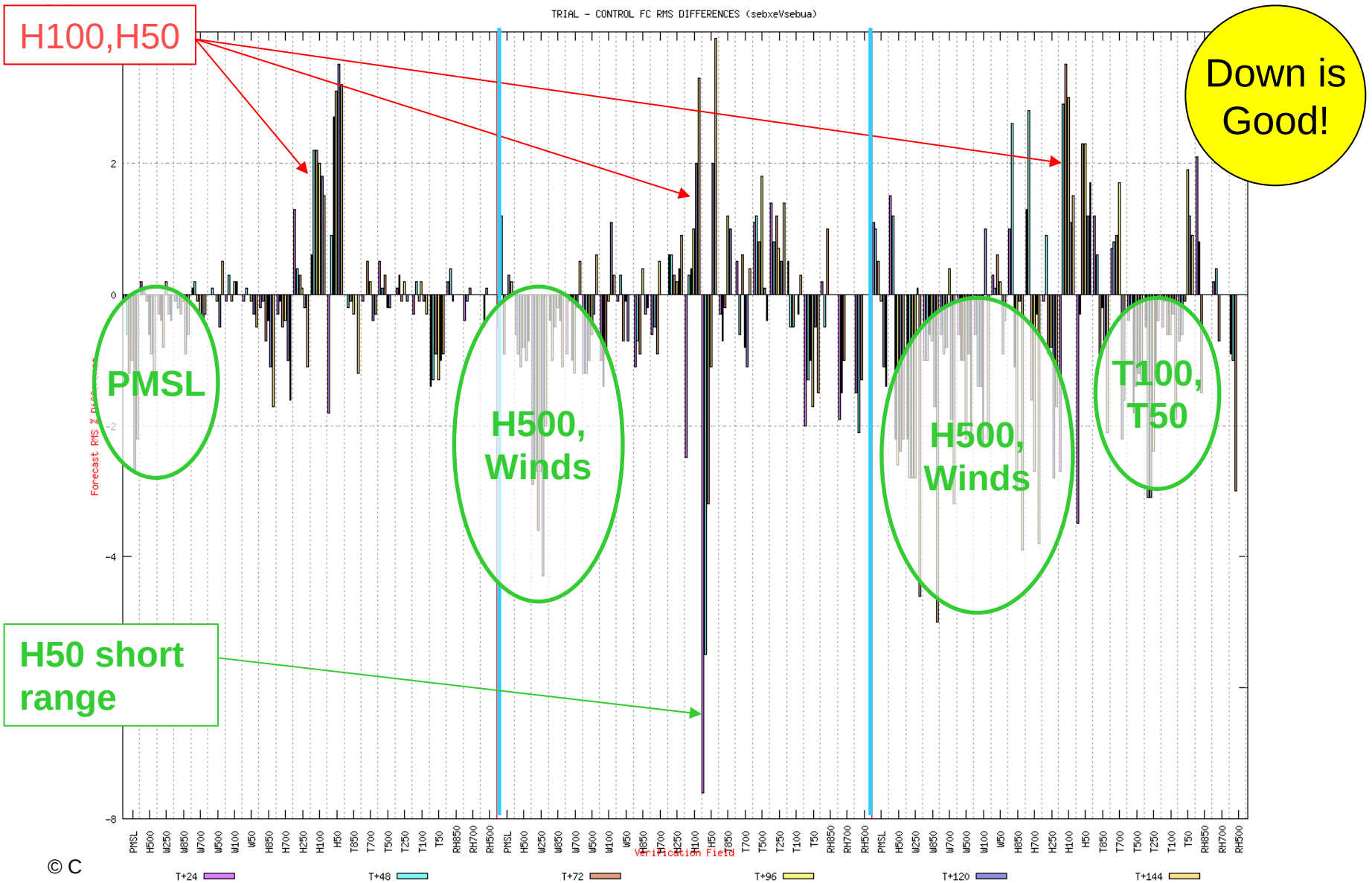
- Preferred configuration
  - inc water vapour channels
  - 0.5K/1K/4K obs errors
- Score
  - +1.21 v Obs
  - +0.80 v Anl
  - +1.01 Overall
- Compare with AIRS for same period
  - +0.63 v Obs
  - +0.12 v Anl
  - +0.375 Overall
  - Note we normally expect more impact from AIRS!





Change in RMS Forecast Error v Analyses

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

Operational Implementation

- IASI was made operational in the global model on November 27th 2007 along with:
  - ASCAT scatterometer winds from MetOp
  - Extra COSMIC GPS radio occultation data
  - Linear convection model in 4D-Var
- Overall impact of about +3.2 Index points
- IASI is also operational in the North Atlantic and European model (NAE)
  - Impact neutral – see later!

IASI Impact Assessment
December 2007

IASI impact Dec 07 vs Jun 07

June:

+1.2 v Obs

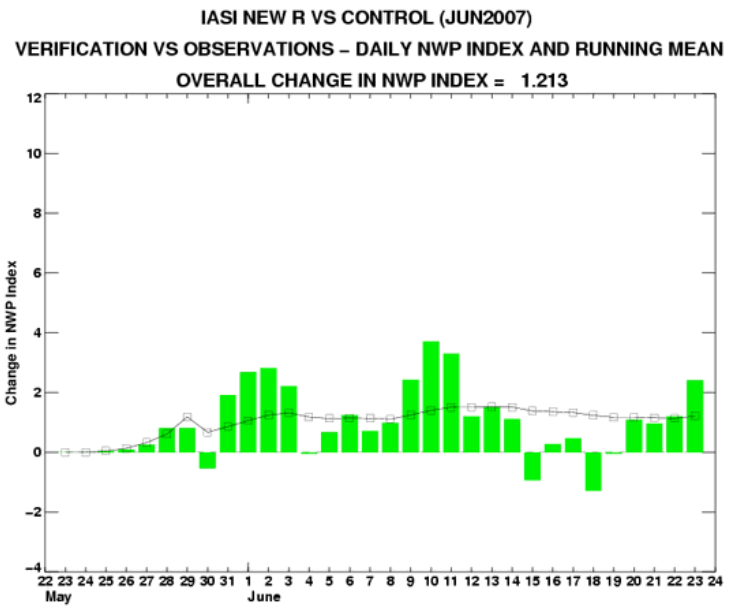
+0.8 v Anl

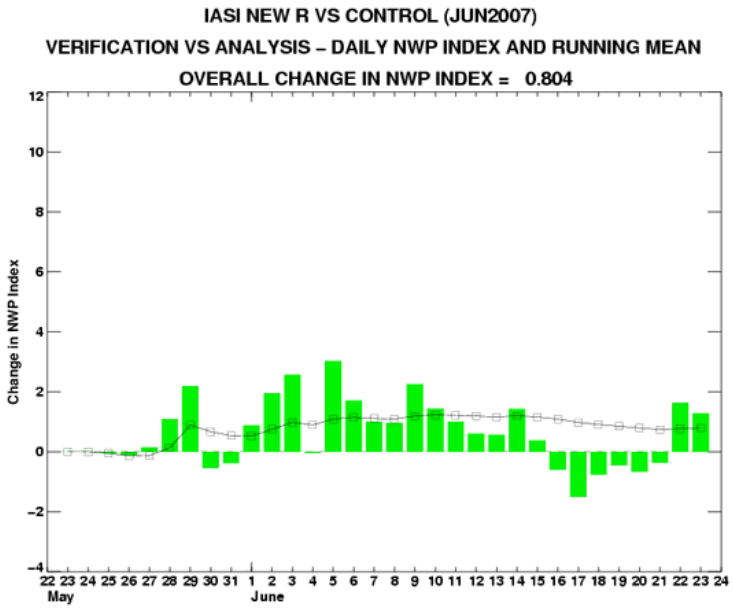
December plots "upside down"!

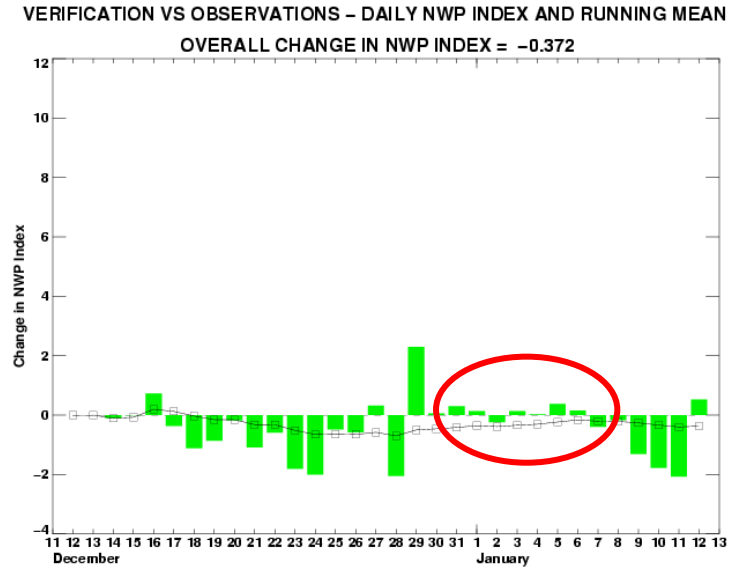
December:

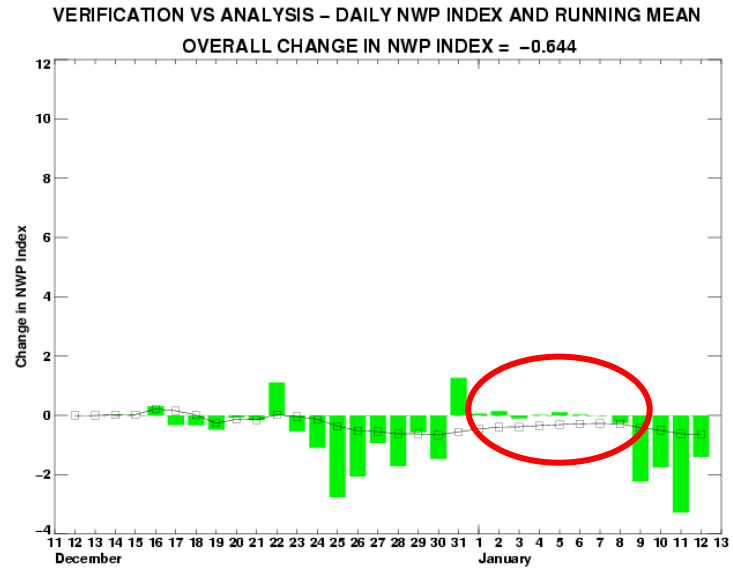
+0.37 v Obs

+0.65 v Anl

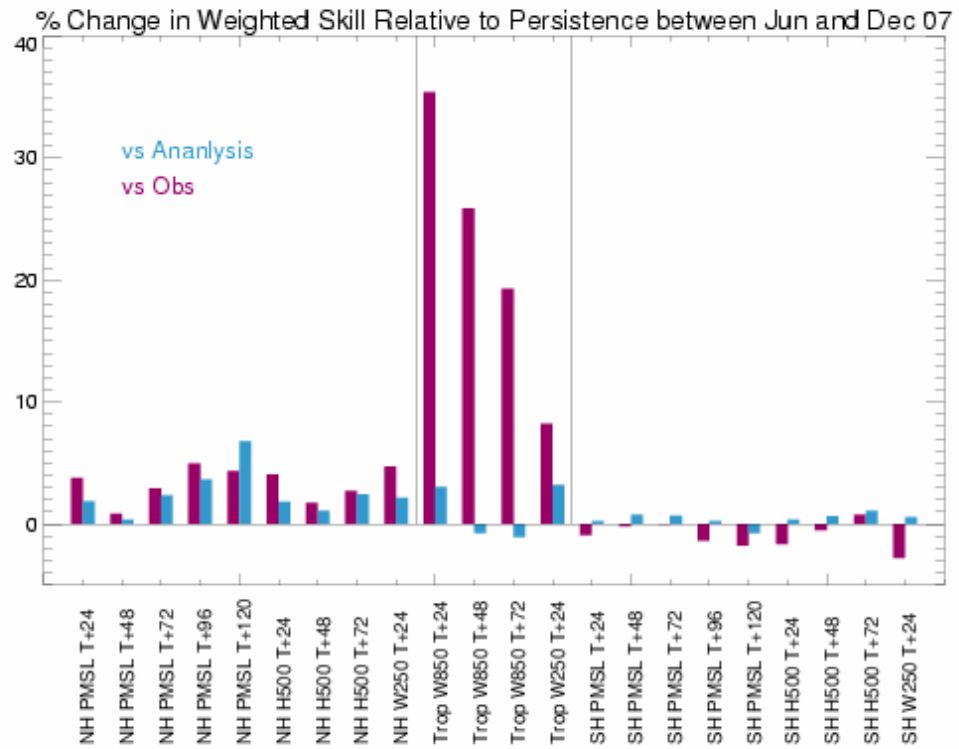








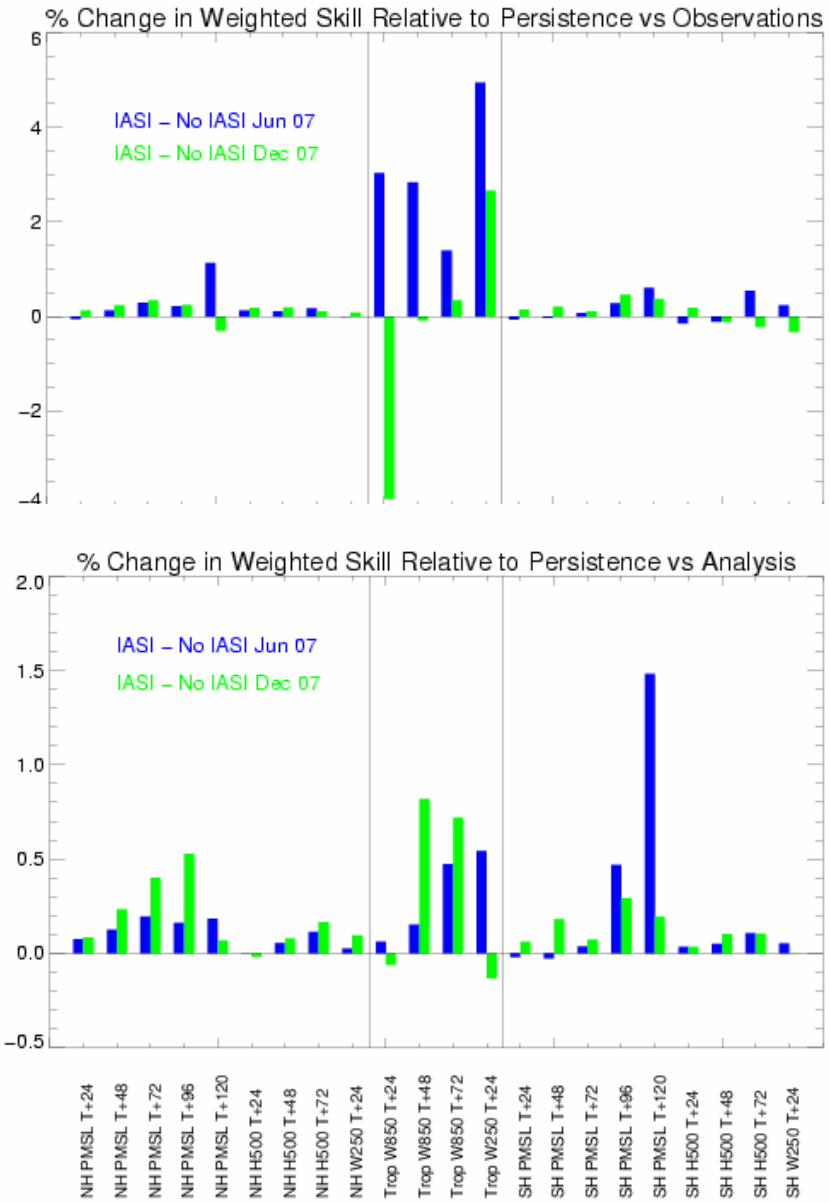
Why is the impact smaller in December?



- The control forecasts have greater skill relative to persistence in December than in June
- Particularly strong performance vs observations in the tropics

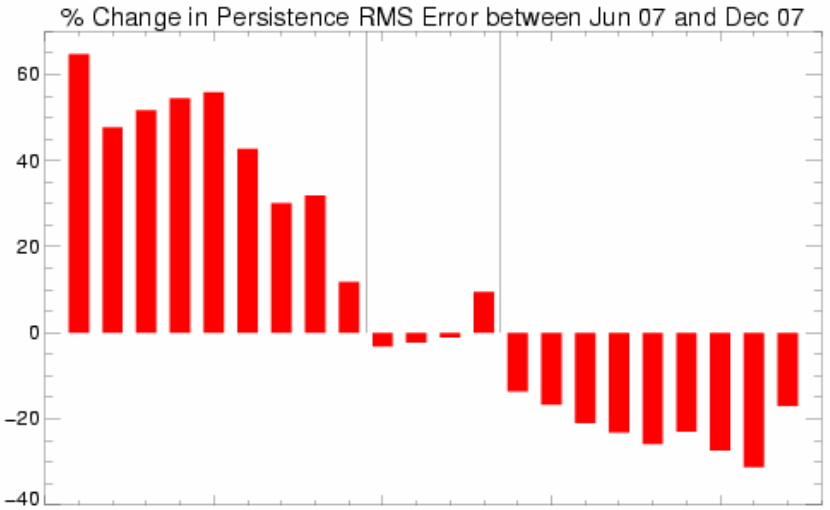
Why is the impact smaller in December?

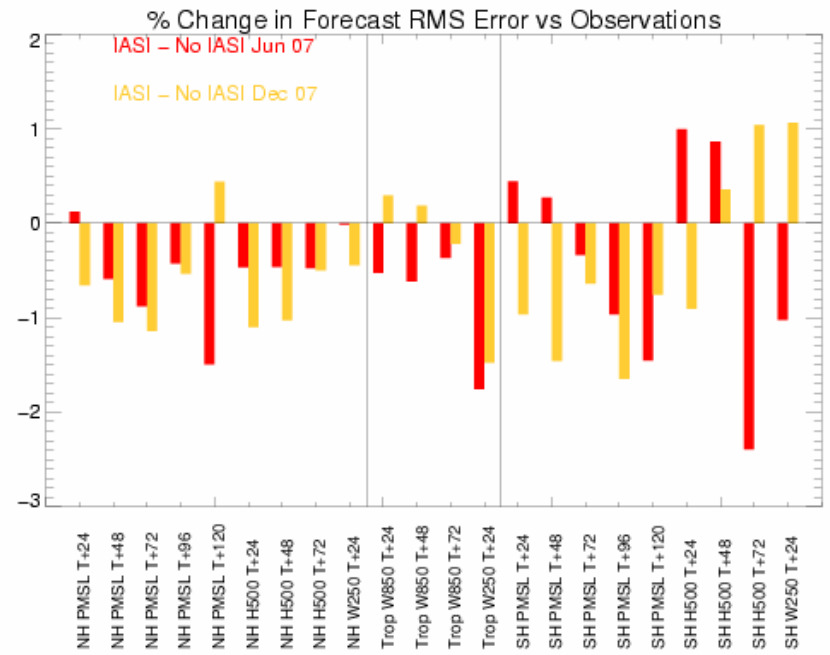
- % Change in skill between IASI and No IASI is an order of magnitude smaller than the seasonal fluctuation in the skill of the control
- IASI particularly strong against Obs in the tropics in June and loses this impact in December
- Index result very sensitive to tropical scores



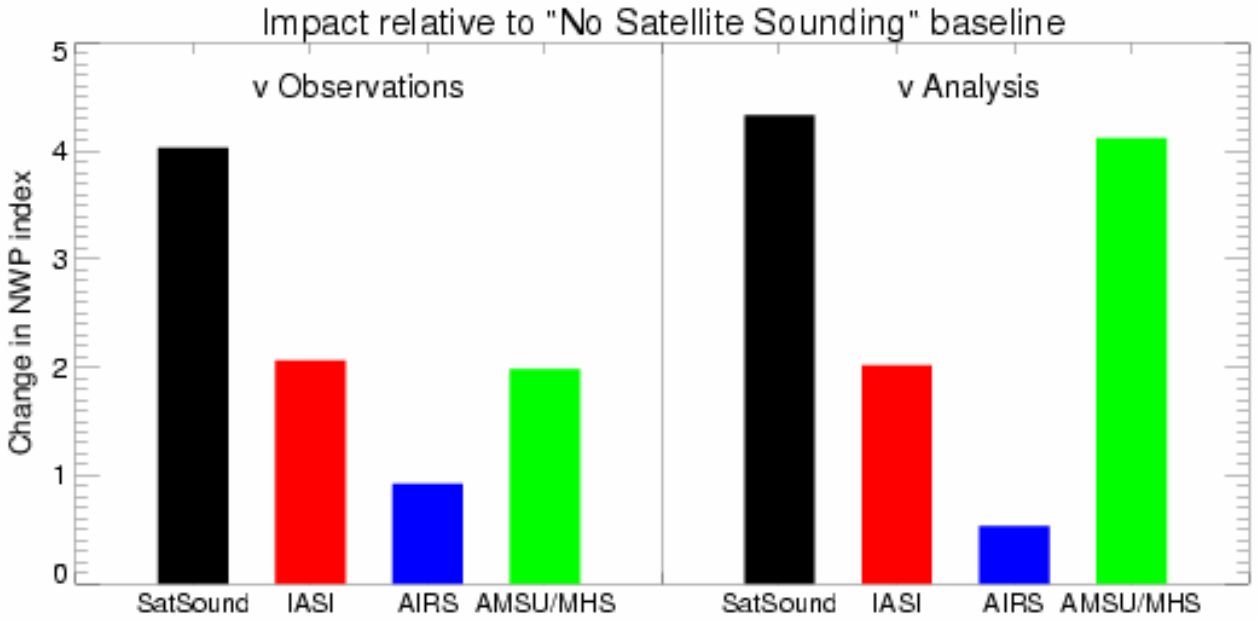
Why is the control better in December?

- Persistence is less good as a forecast during the winter so the control performs better relative to persistence in the NH in December
- On the other hand, there is little change in persistence RMS error in the tropics
- % change in RMS error adding in IASI is an order of magnitude smaller than % change in persistence RMS error





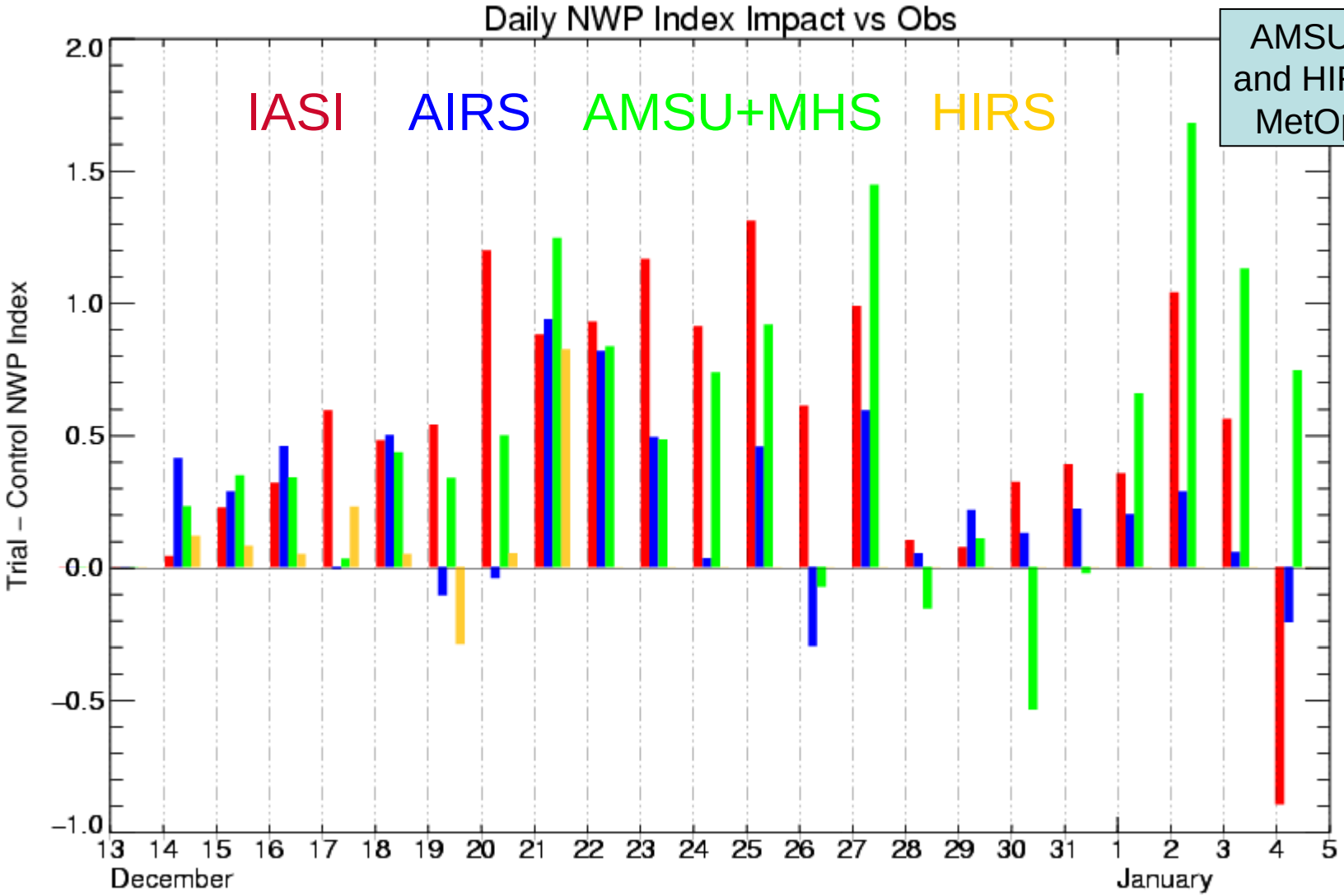
IASI Relative to other instruments



AMSU/MHS is MetOp only

- Verification vs “Analysis” not really valid as the analysis is data poor
- Overall picture is the same vs Obs and vs Analysis

Daily change in NWP Index for each instrument



Limited Area Model results – North Atlantic and European Model June 2007

NAE Verification results

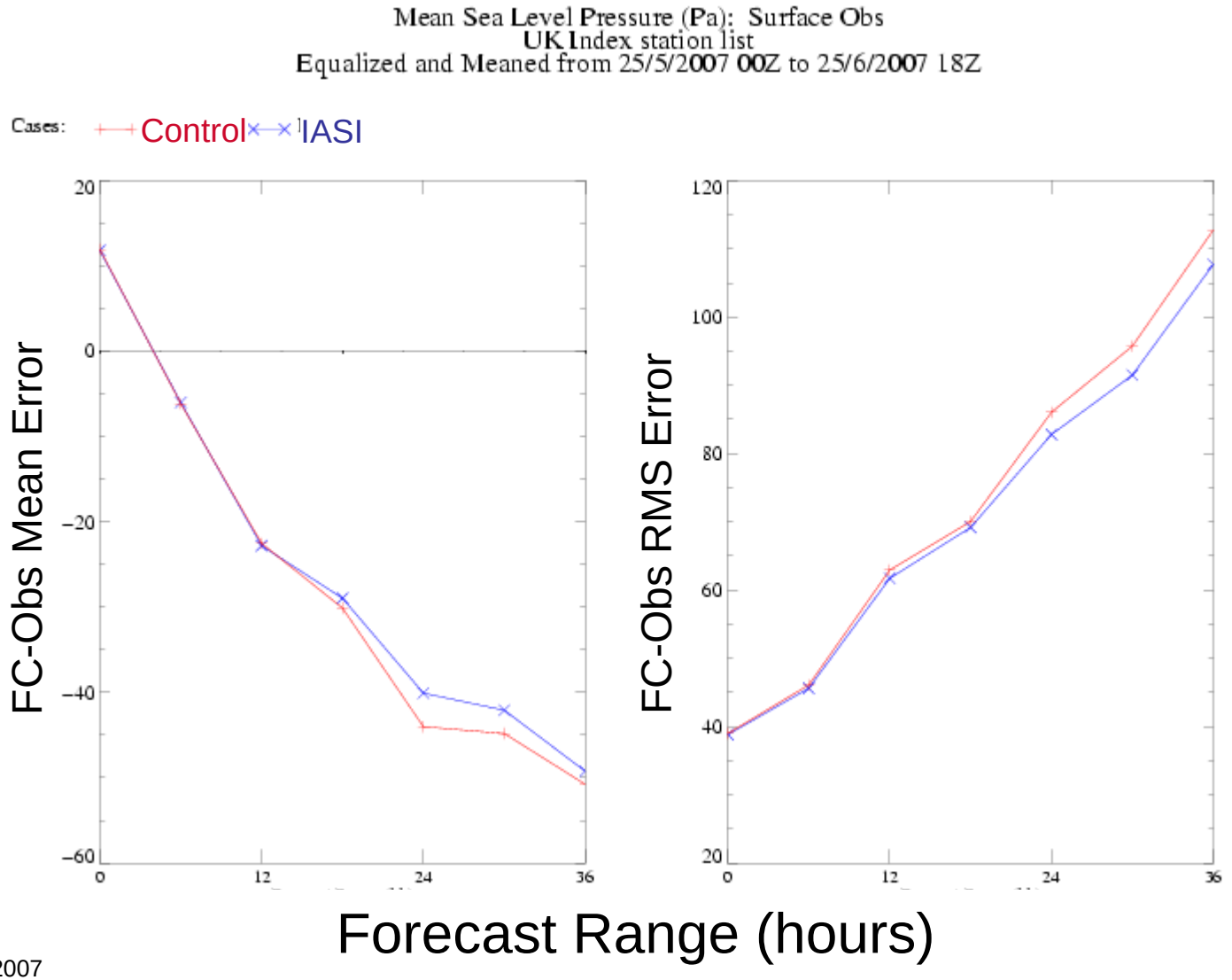
- NAE Index calculated vs observations over four domains, here I show results from the largest and smallest

	Full NAE Area	UK Index List Area
Weighted ETS difference		
Surface Visibility	-0.016	0.032
6hr Precip Accum	0.032	0.035
Total Cloud Amount	0.000	-0.034
Cloud Base Height	-0.011	-0.017
Weighted Skill difference		
Surface Temp	0.013	-0.080
Surface Wind	0.022	0.031
Overall Change in Index	**0.12%**	**-0.08%**

0.3% would be significant

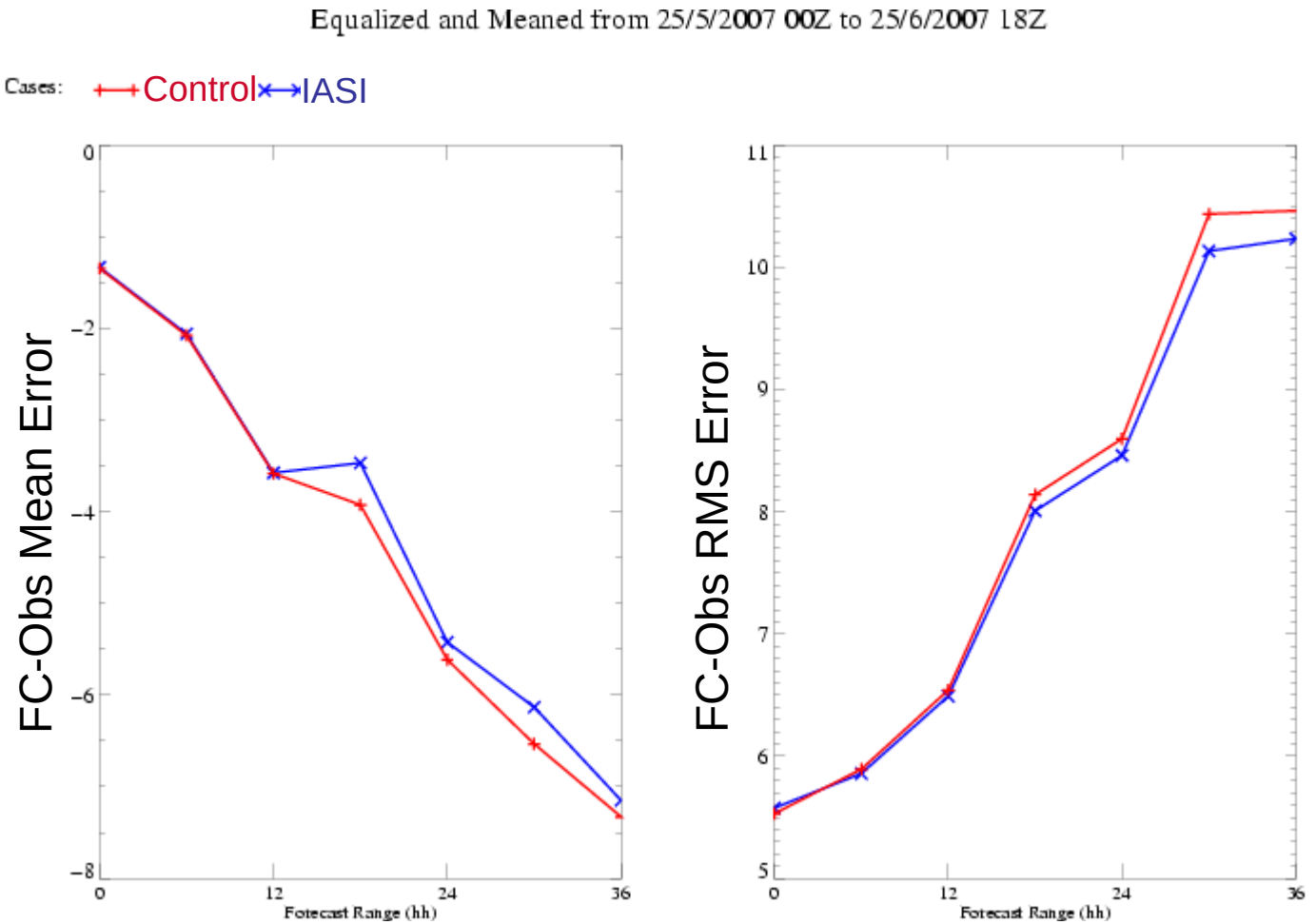
NAE Verification

PMSL vs Obs



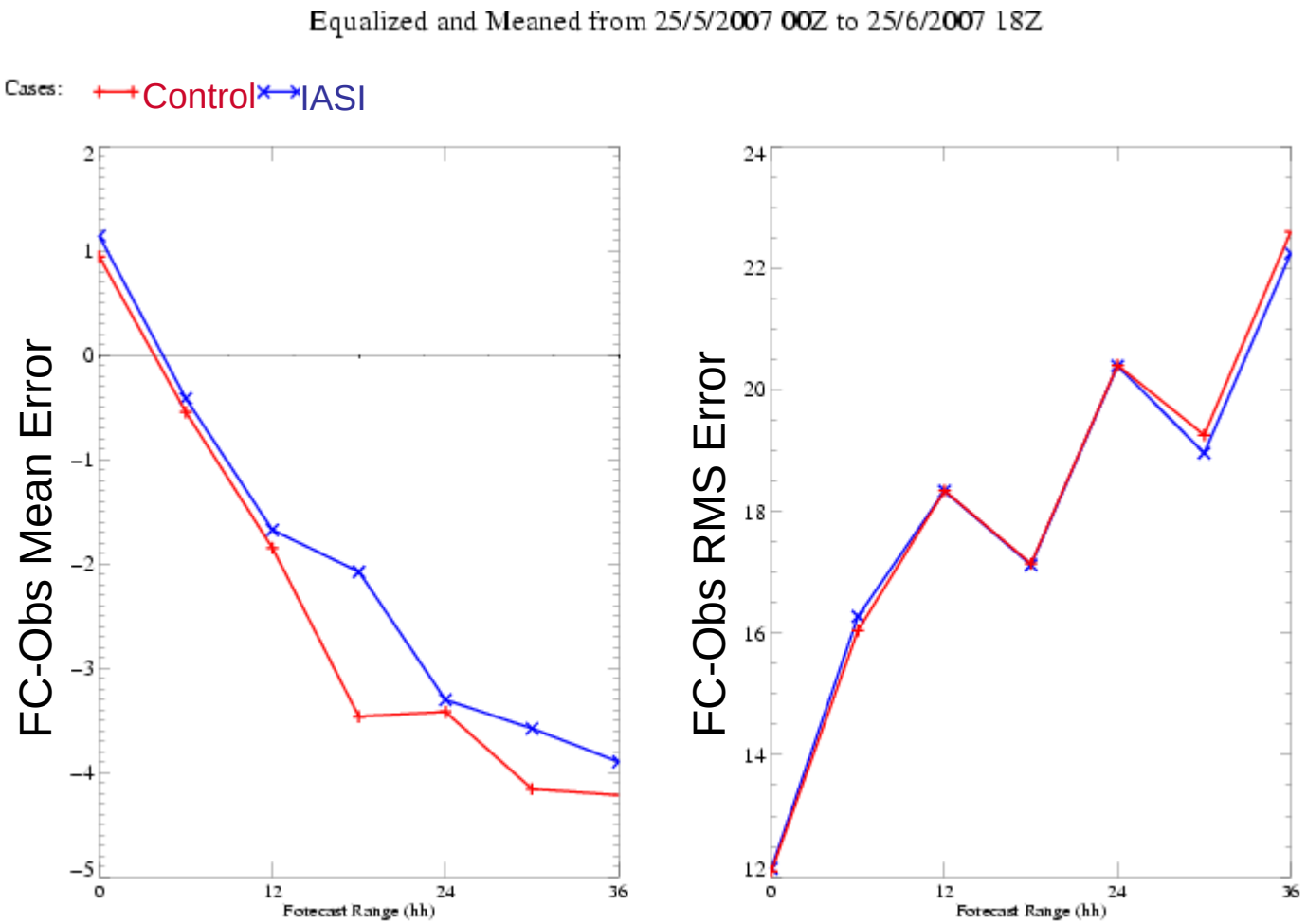
NAE Verification

1000hPa Geopotential Height



NAE Verification

700hPa Relative Humidity



Why do we see so little impact?

- We treat IASI the same in the NAE as in the Global
- We get excellent impact in the Global
- Why do we not see the same in the NAE?
  - Method of verification?
  - Parameters verified?
- IASI does impact the upper air and large-scale fields but this information does not feed through into the surface “weather” variables

Summary and future work

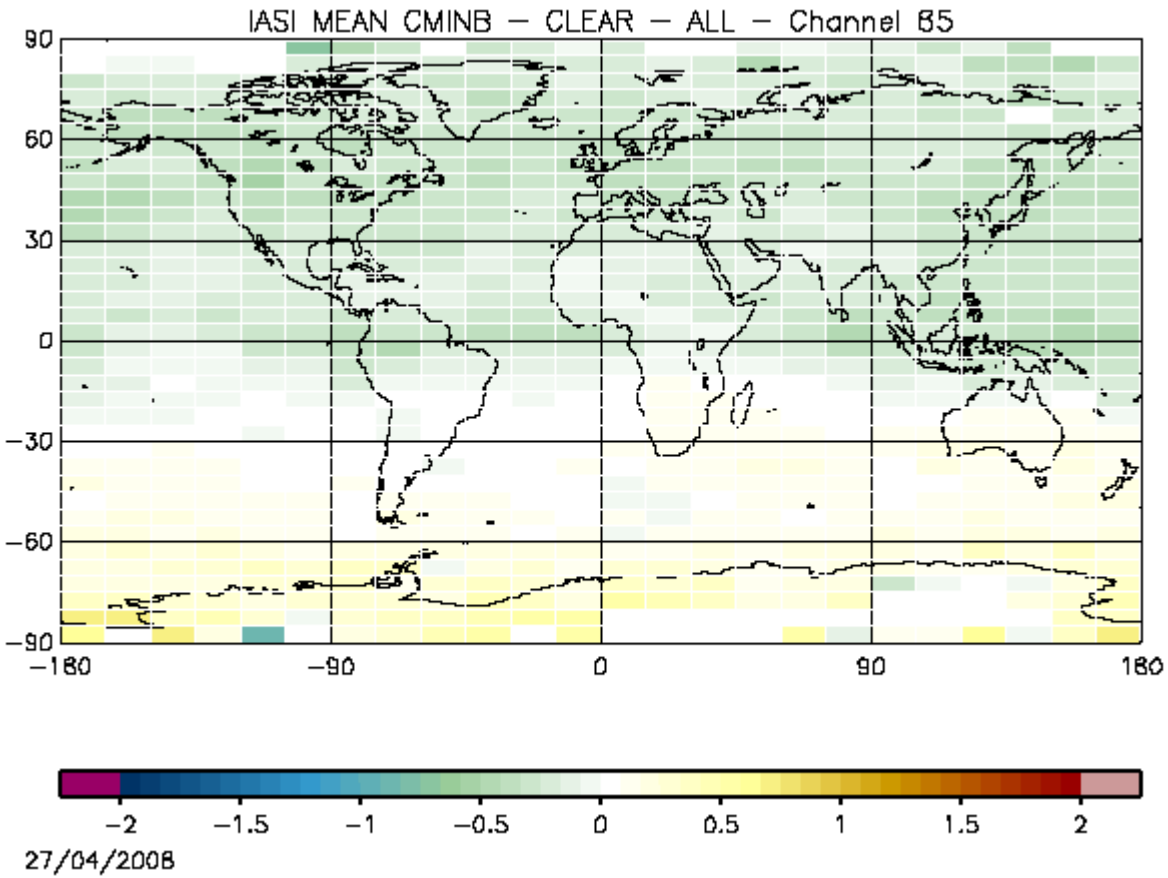
Current and future work (1)

- Make better use of spectral information
  - Reconstructed radiances?
  - Principal component assimilation?
  - Aim to get detailed structure from assimilation of IASI observations
- Look for better impact from water vapour channels
  - Problems with model bias? – see poster Newman et al A06
  - Problems with data assimilation techniques?

Current and future work (2)

- Improved treatment of O_3 and CO_2-sensitive channels to reduce biases
  - See poster by James Cameron A26
- Use data in cloudy areas
  - Code under development for AIRS
- Use more data over land

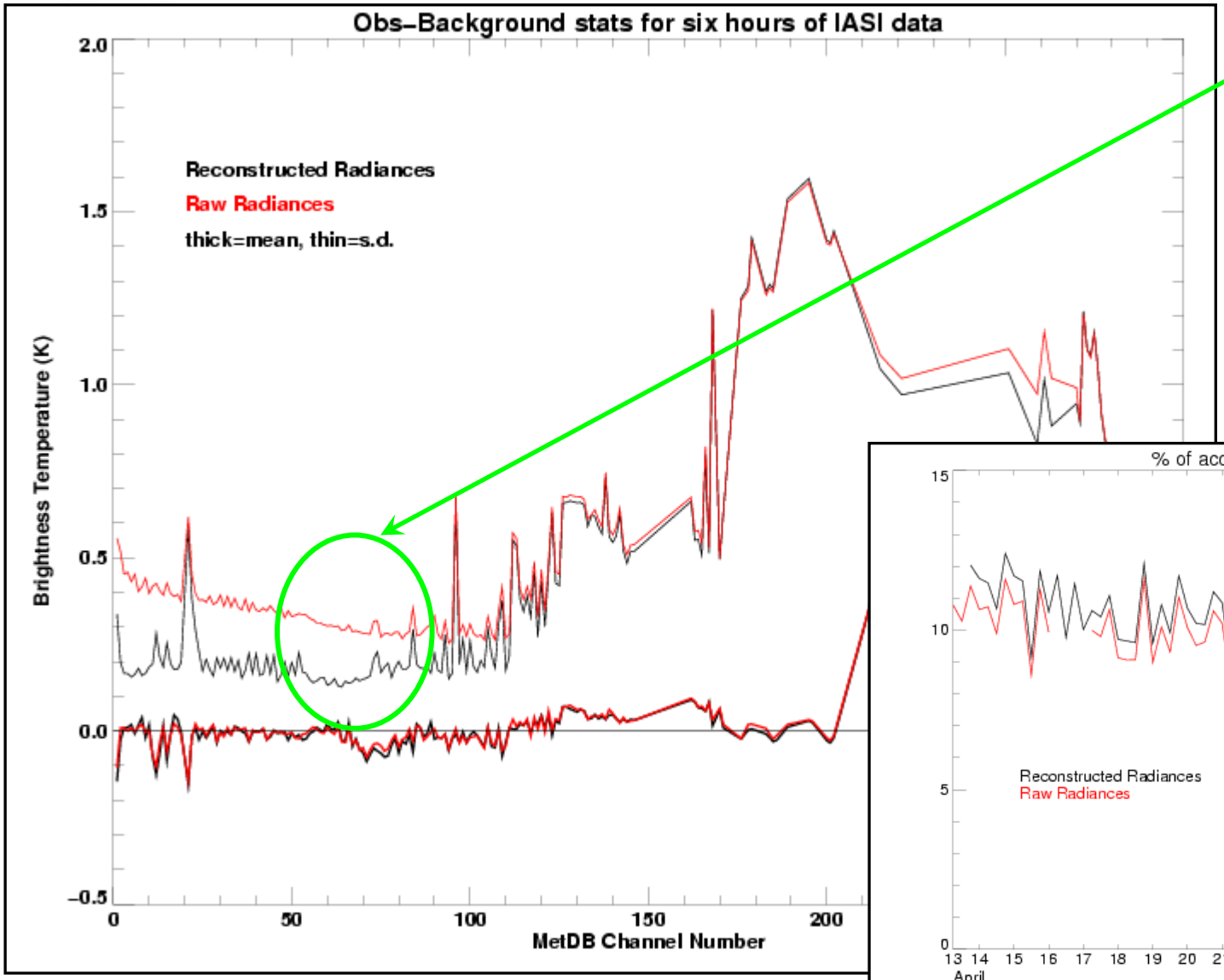
Northern Hemisphere biases – ozone?



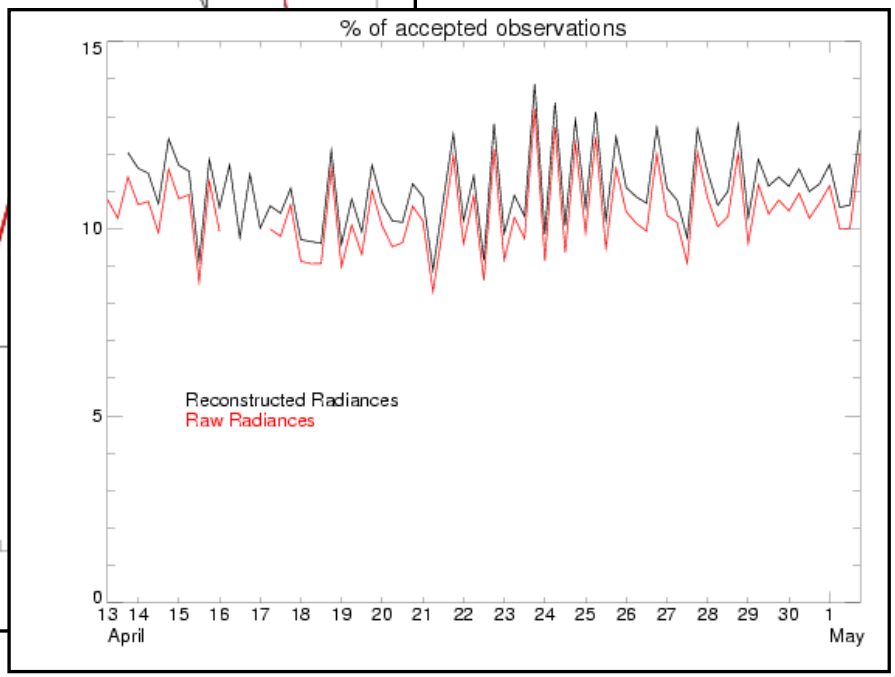
NH bias similar magnitude to standard deviation

Channel 280 - 714.75cm^{-1}

Reconstructed Radiances



Biases in the northern hemisphere possibly due to poor treatment of ozone-sensitivity become very significant!



Summary

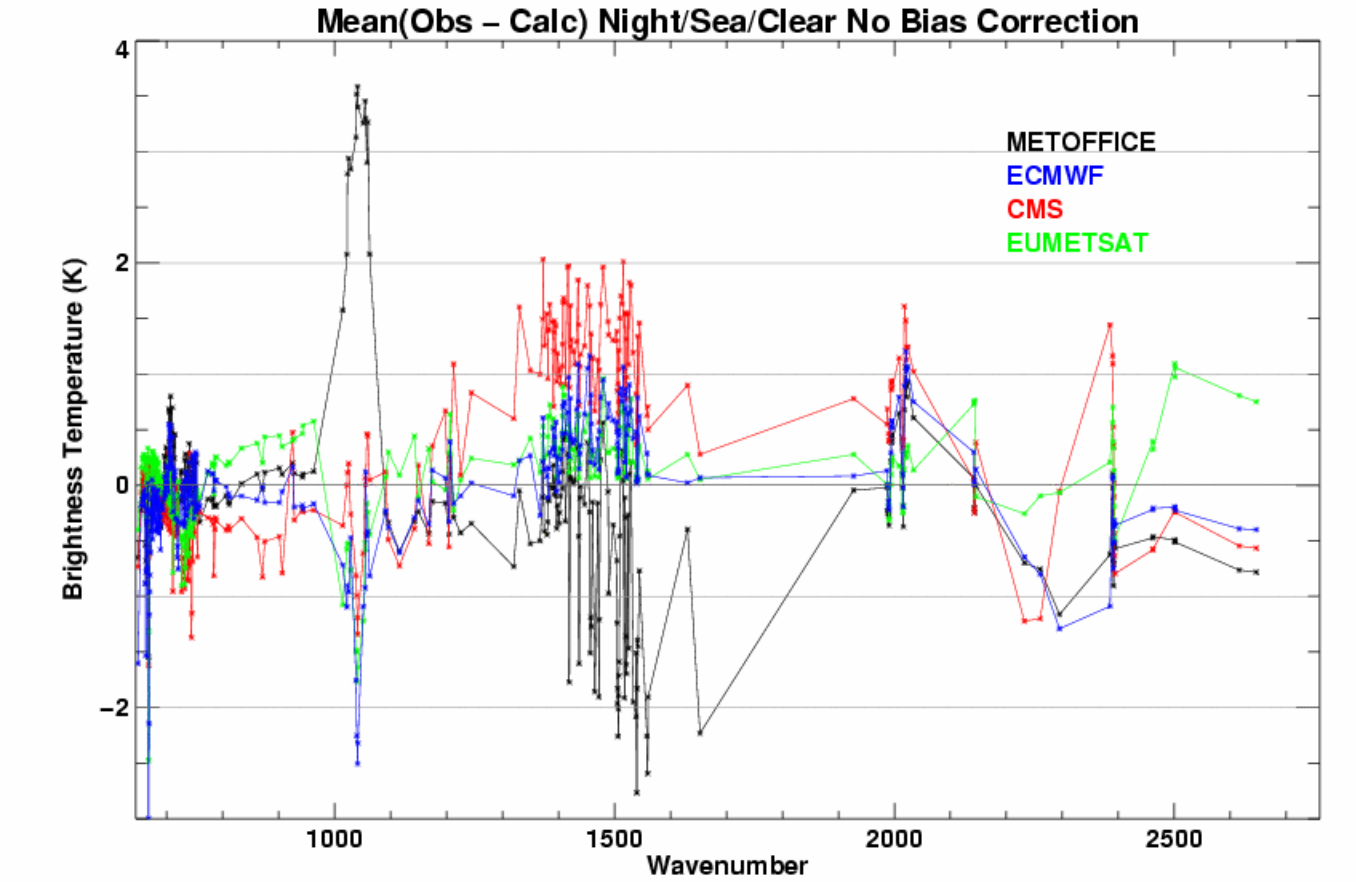
- Assimilation of IASI data provides significant forecast benefit on top of all the existing sounding data
- Impact on large-scale fields very good, less benefit seen on the mesoscale for “weather” verification
- Still so much more to get from IASI!

Thank you for listening!

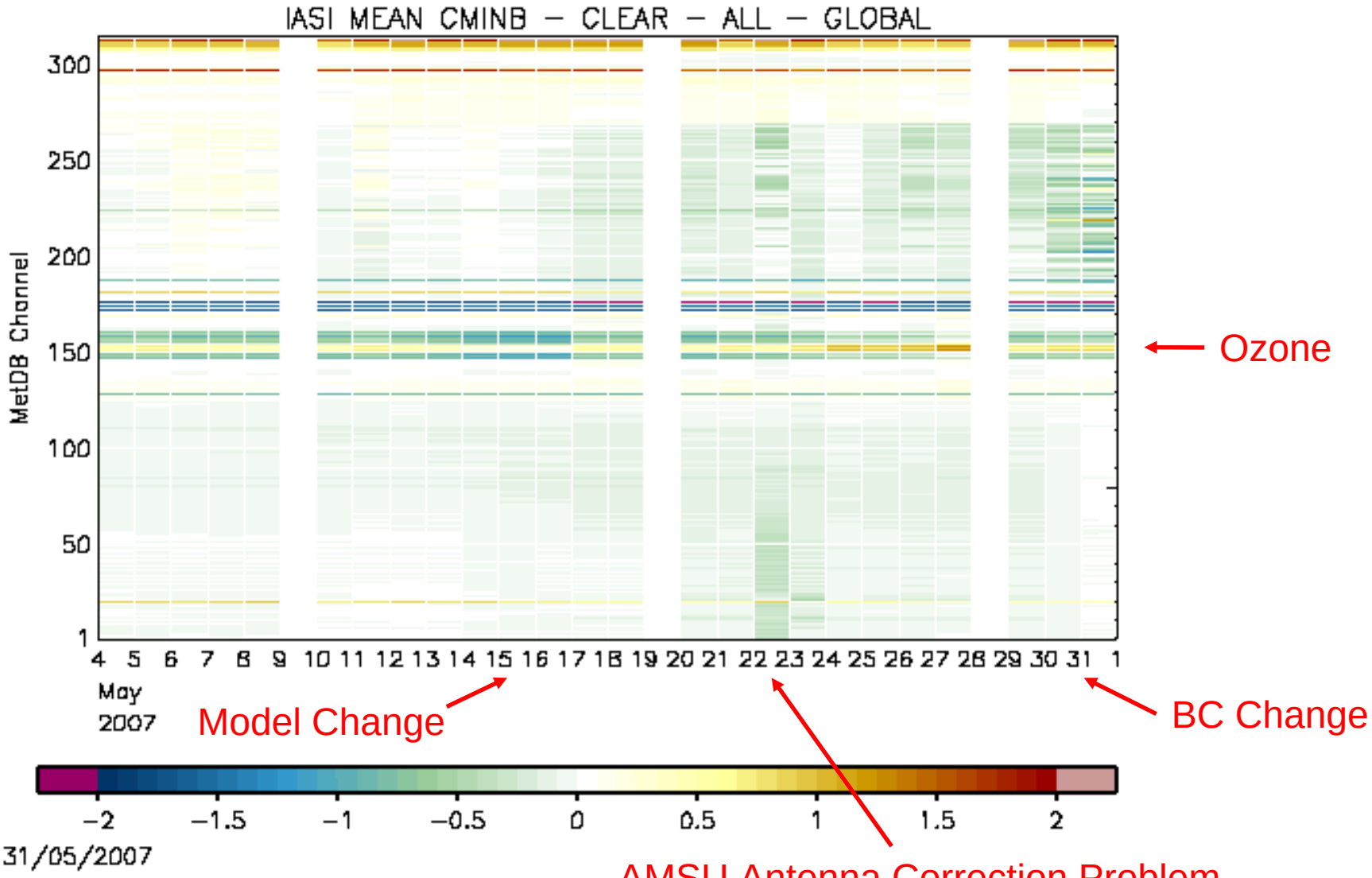
Comparison of IASI radiances with NWP models from four operational centres

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

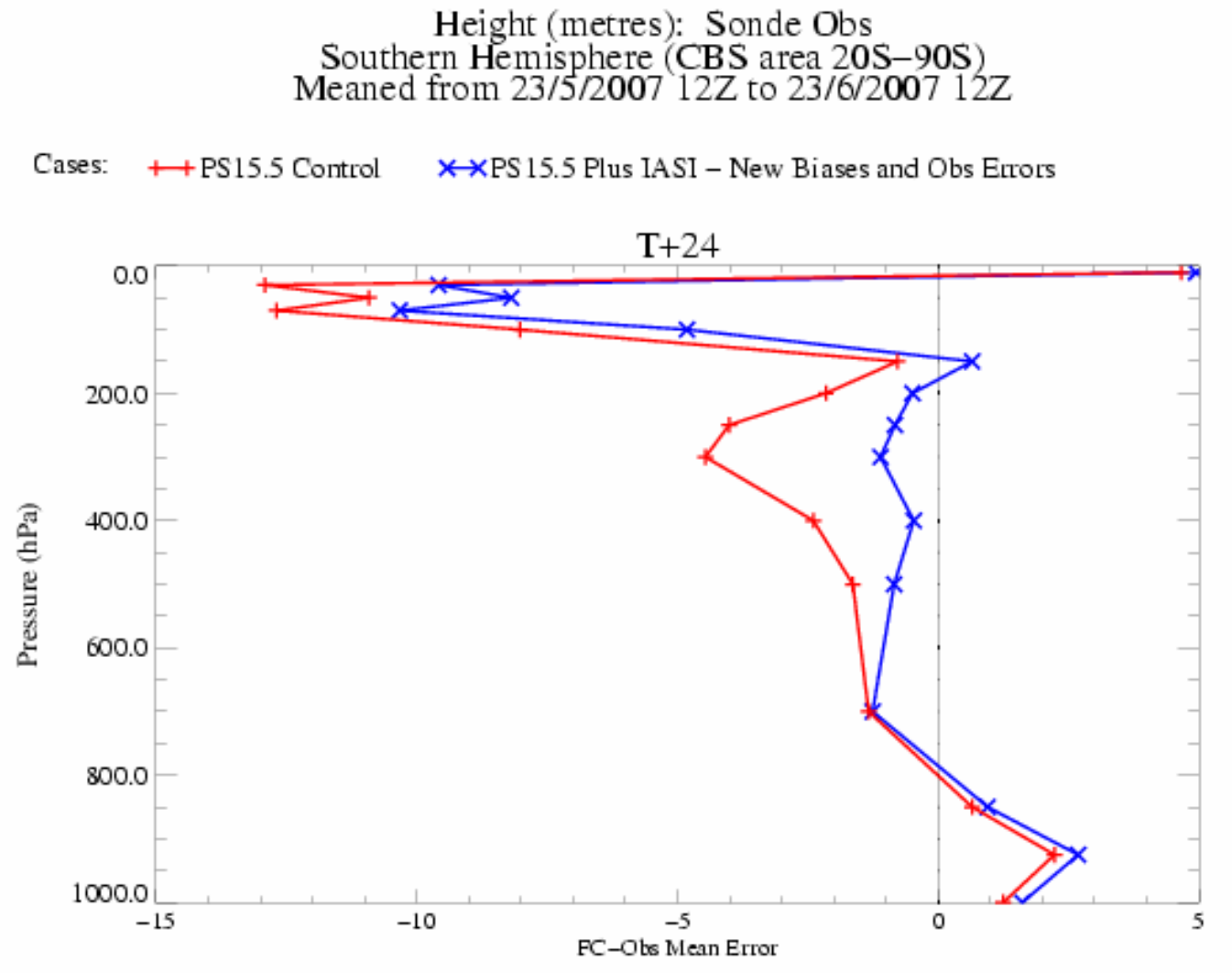
[1]Met Office [2]ECMWF [3]EUMETSAT [4]Météo-France/CMS



Obs minus Background After Bias Correction



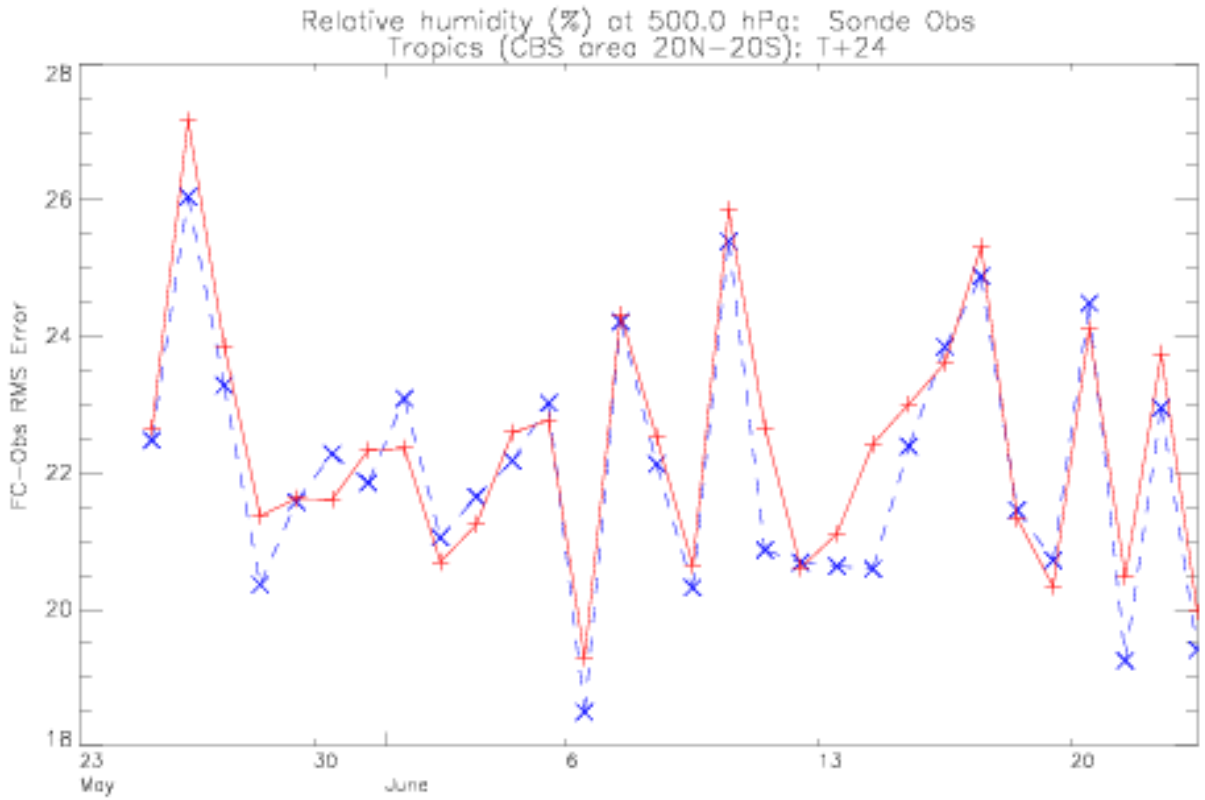
Southern Hemisphere Height Profile T+24, Mean Forecast Error – Verification vs Sonde



Tropics Relative Humidity 500hPa T+24 timeseries

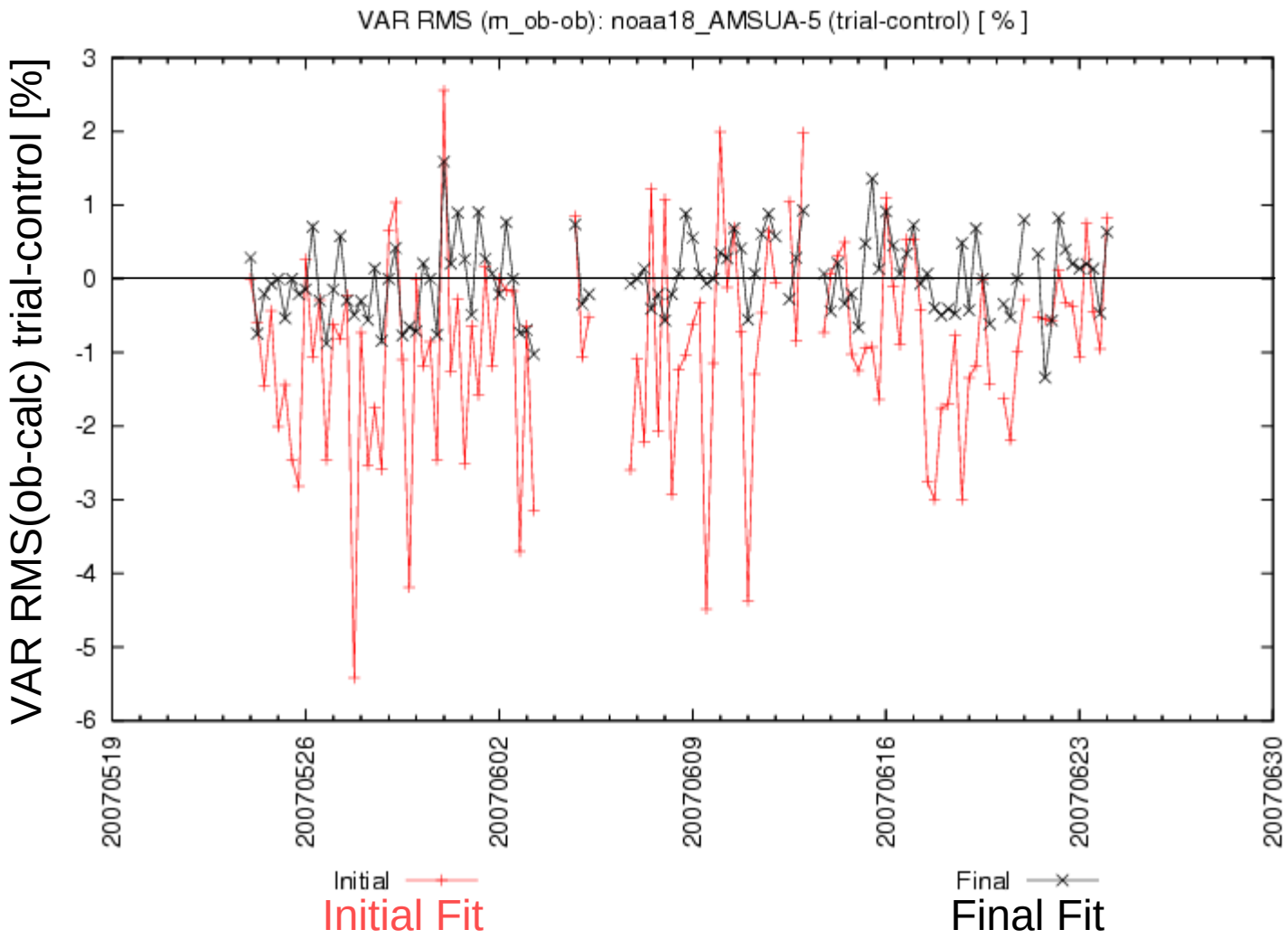
RMS Forecast Error – Verification vs Sonde

Cases: Control IASI



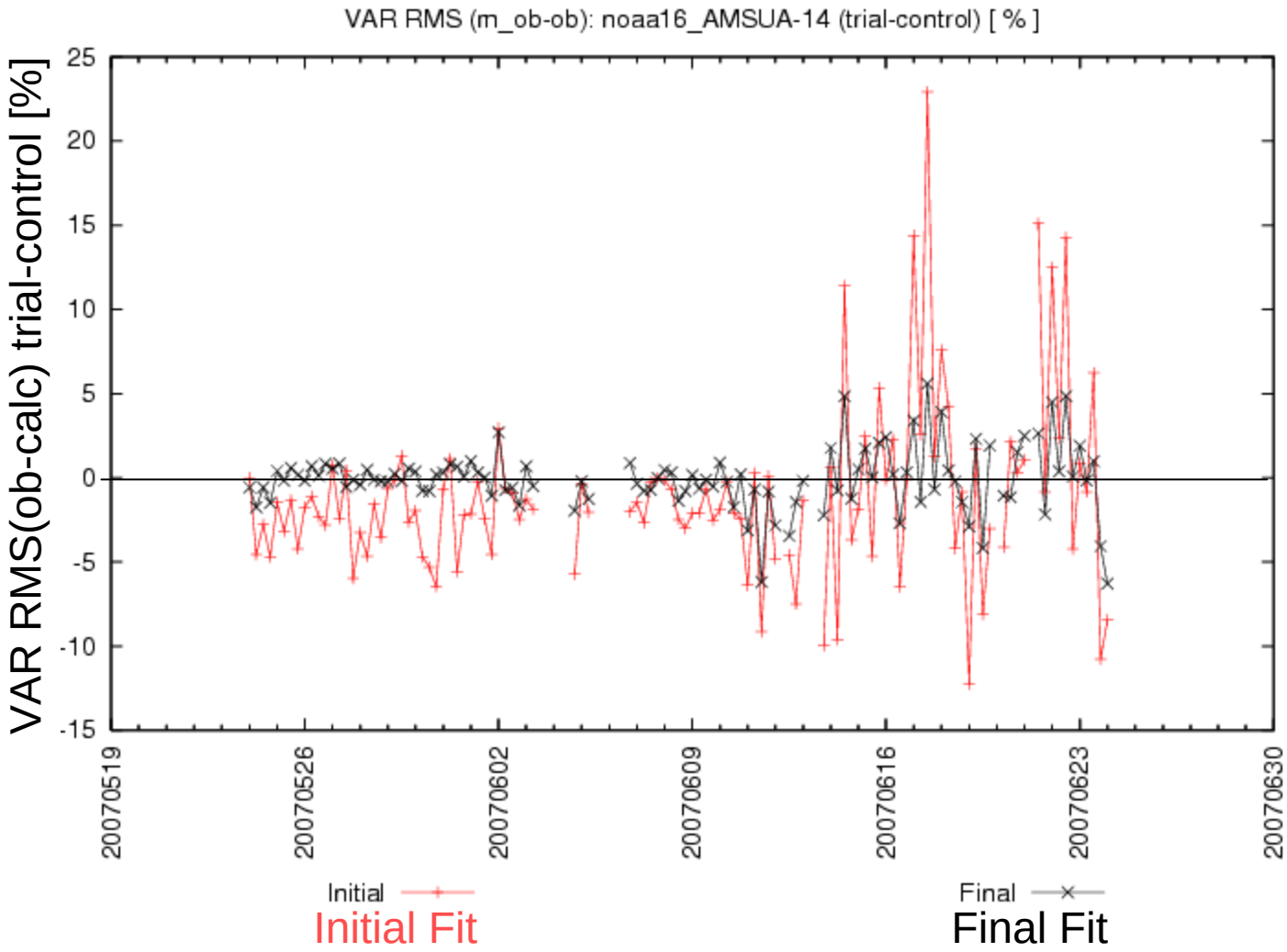
Improvement in fit to other satellite data

NOAA-18 AMSU-A Channel 5 (750hPa)



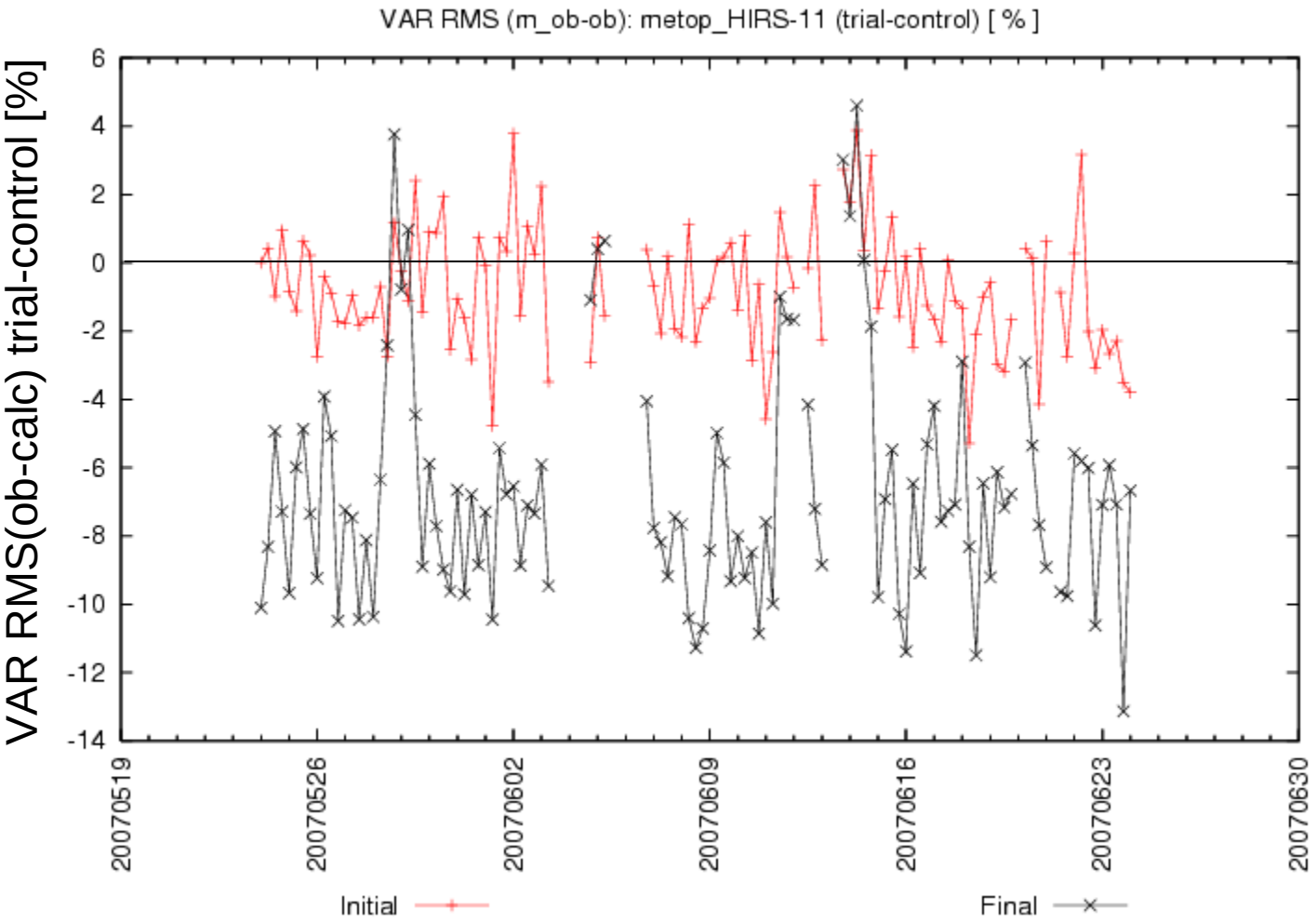
Improvement in fit to other satellite data

NOAA-16 AMSU-A Channel 14 (stratosphere)



Improvement in fit to other satellite data

MetOp HIRS Channel 11 (water vapour)

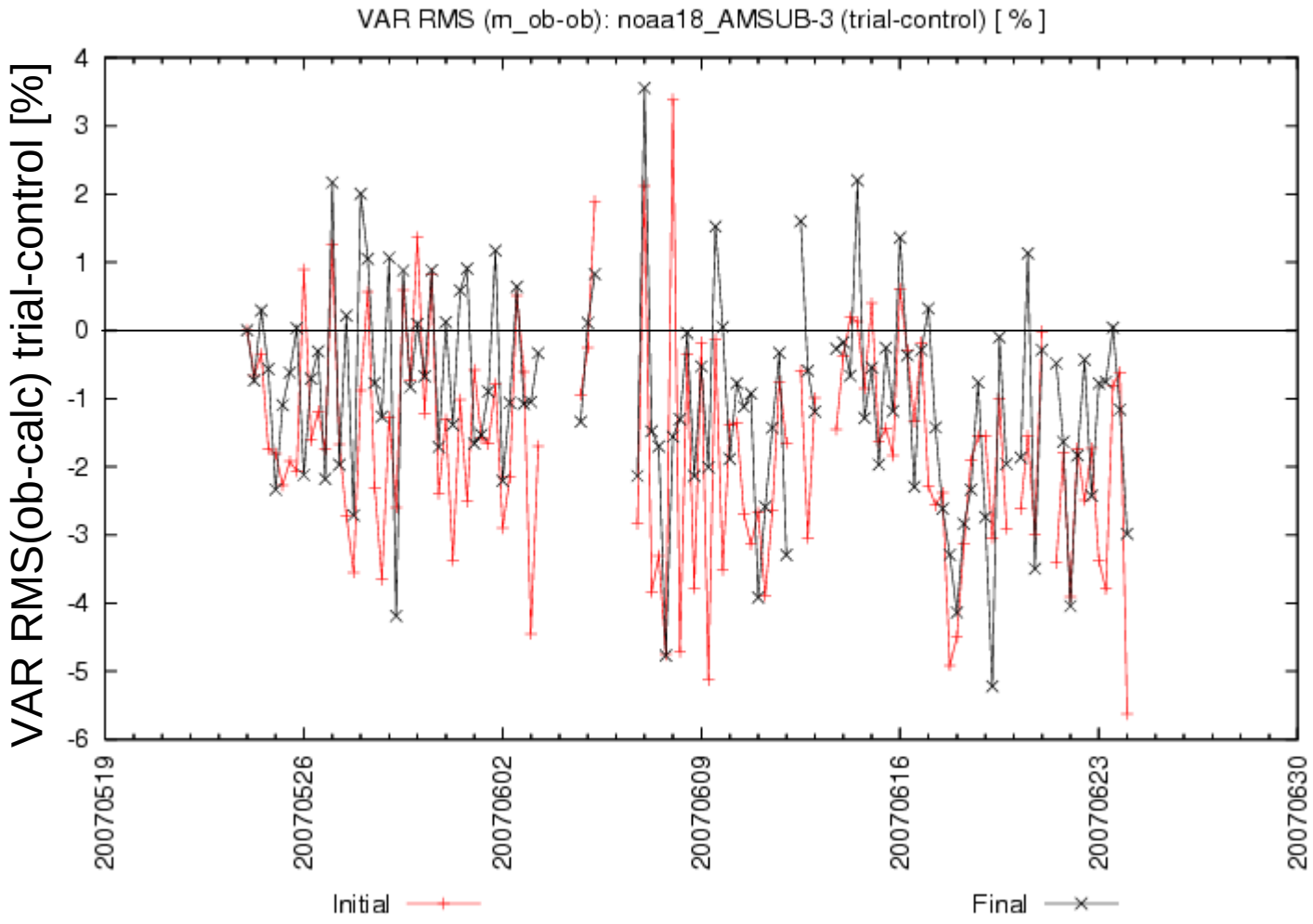


Initial Fit

Final Fit

Improvement in fit to other satellite data

NOAA-18 AMSU-B Channel 3 (water vapour)



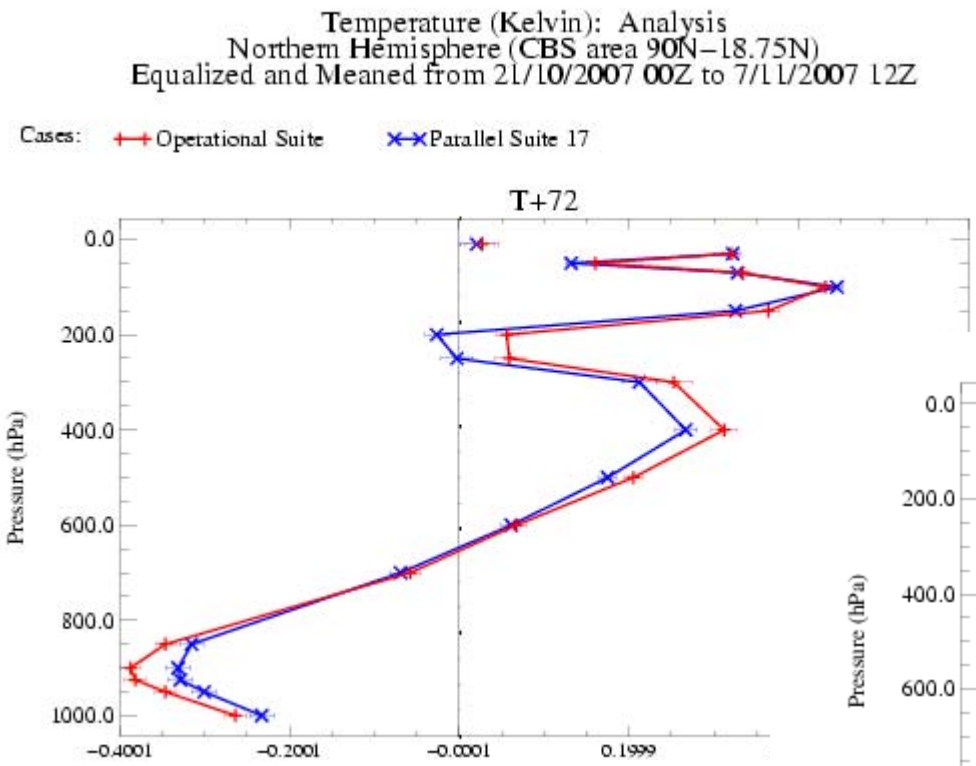
Initial Fit

Final Fit

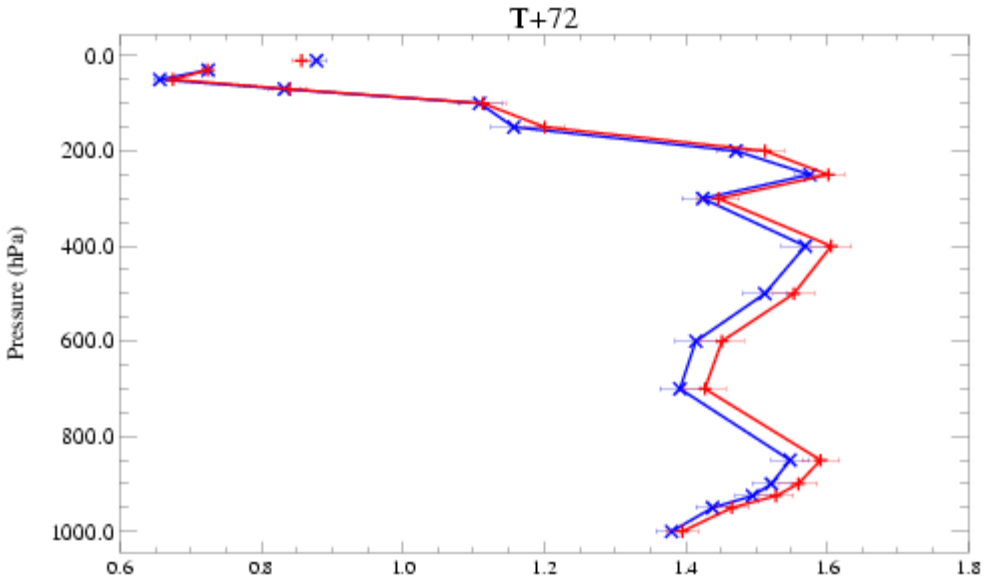
Parallel Suite Verification (1)

Northern Hemisphere
Temperature T+72

Verification vs Analysis



FC-Anal Mean Error



FC-Anal RMS Error

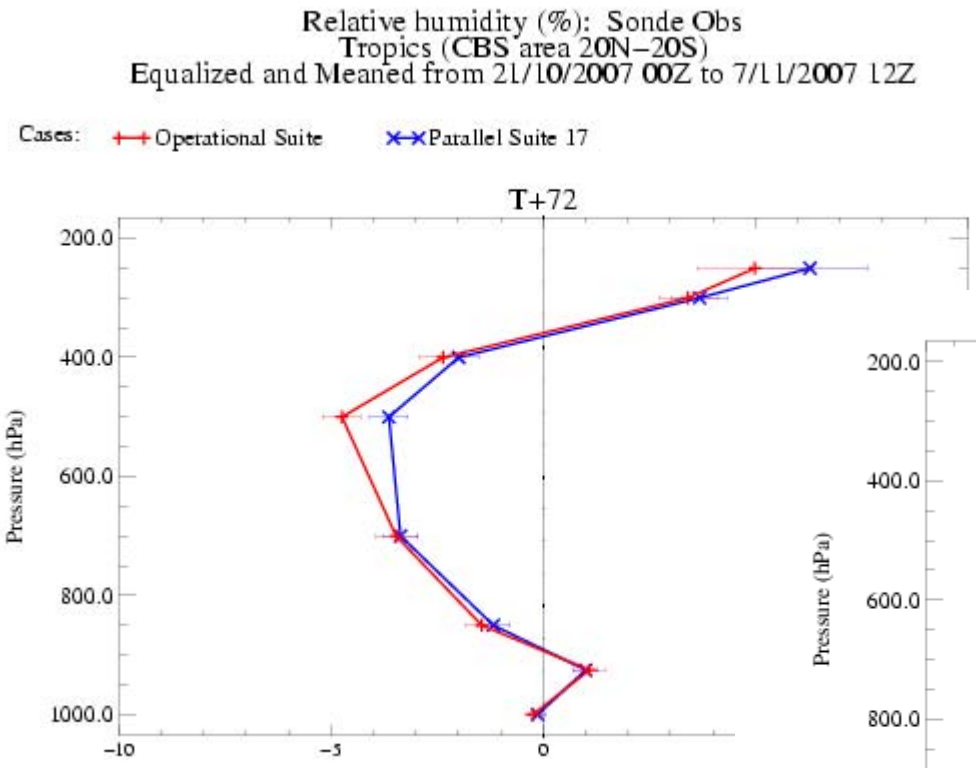
68% error bars calculated using $S/(n-1)^{1/2}$

Parallel Suite Verification (2)

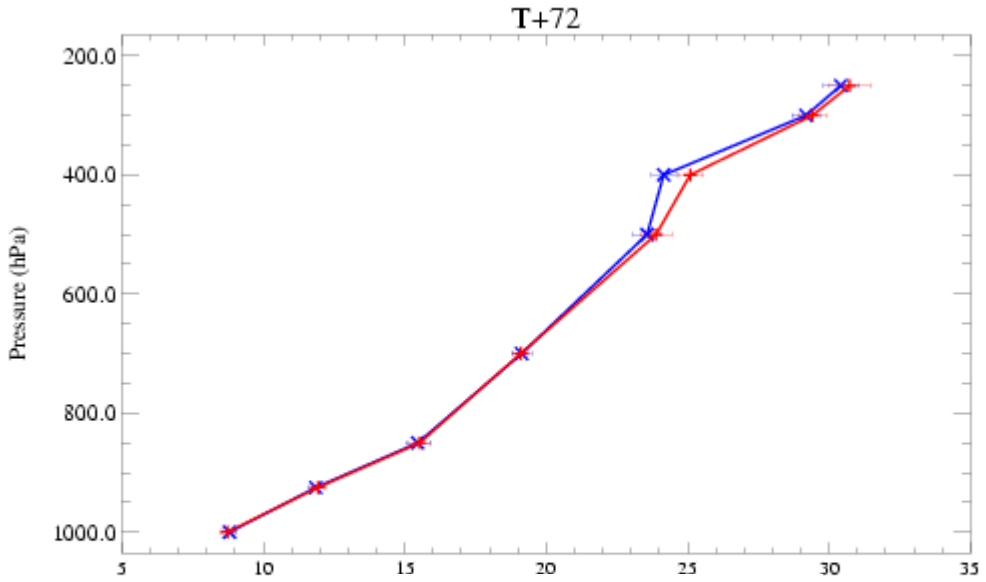
Tropics

Relative Humidity T+72

Verification vs Sonde



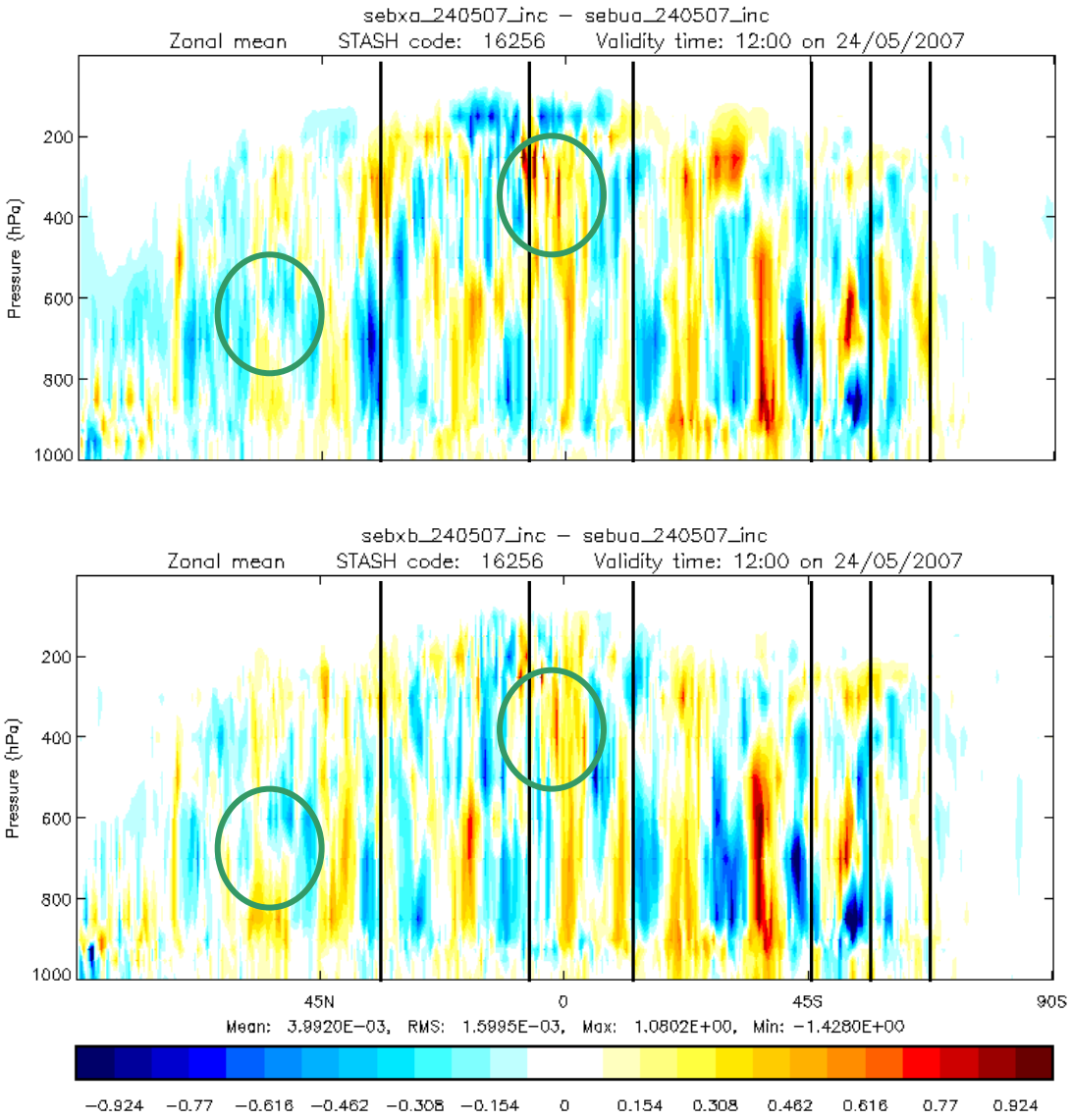
FC-Anal Mean Error



FC-Anal RMS Error

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

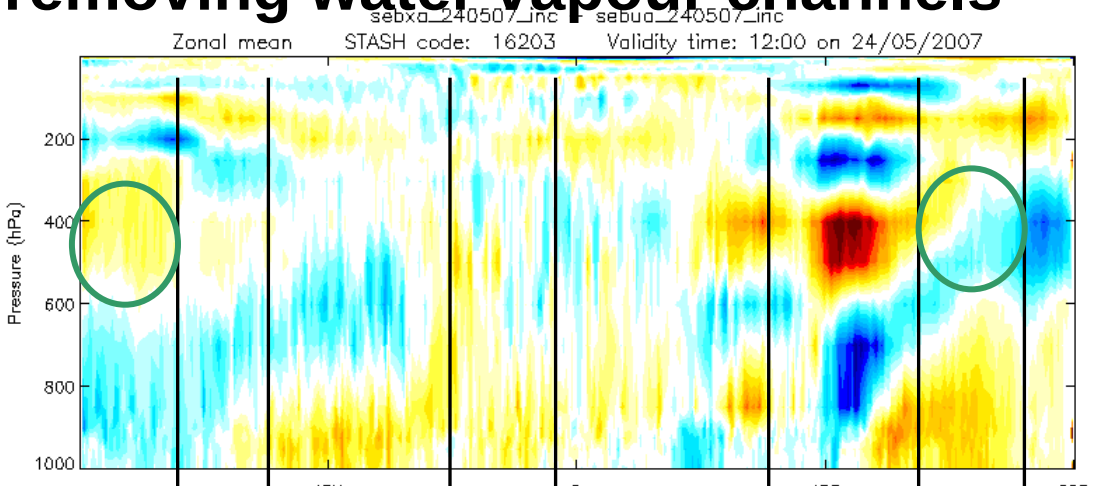
Differences in RH increments removing water vapour channels



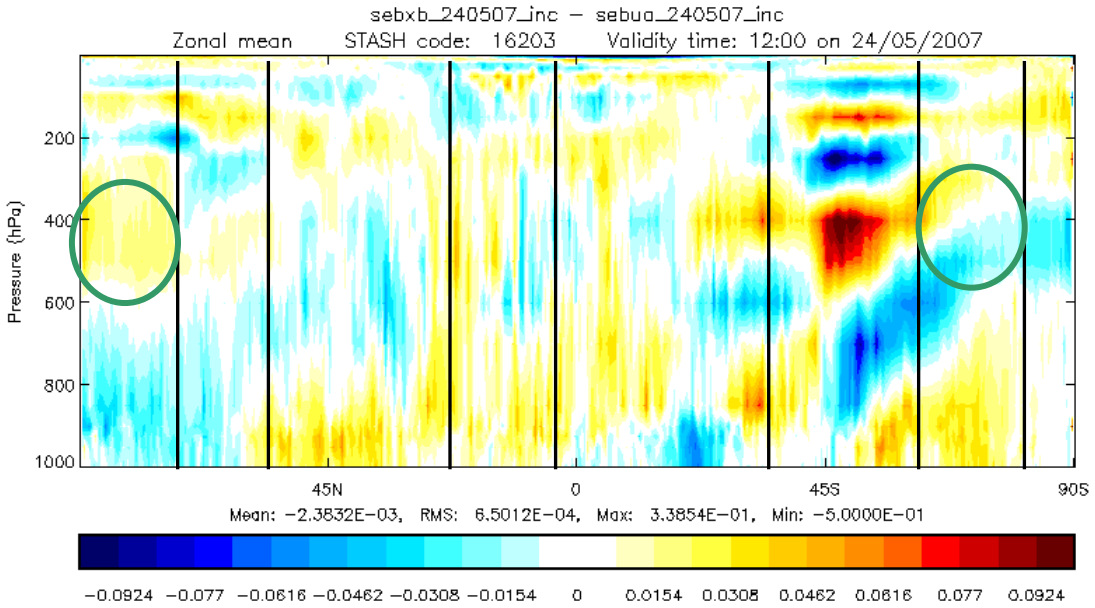
PS17 channels

No water vapour channels

Differences in temperature increments removing water vapour channels



PS17 channels



No water vapour channels

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 4K

- We fit chosen IASI water vapour channels at worst 1.4K
- We fit AIRS water vapour channels at worst 1.7K

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

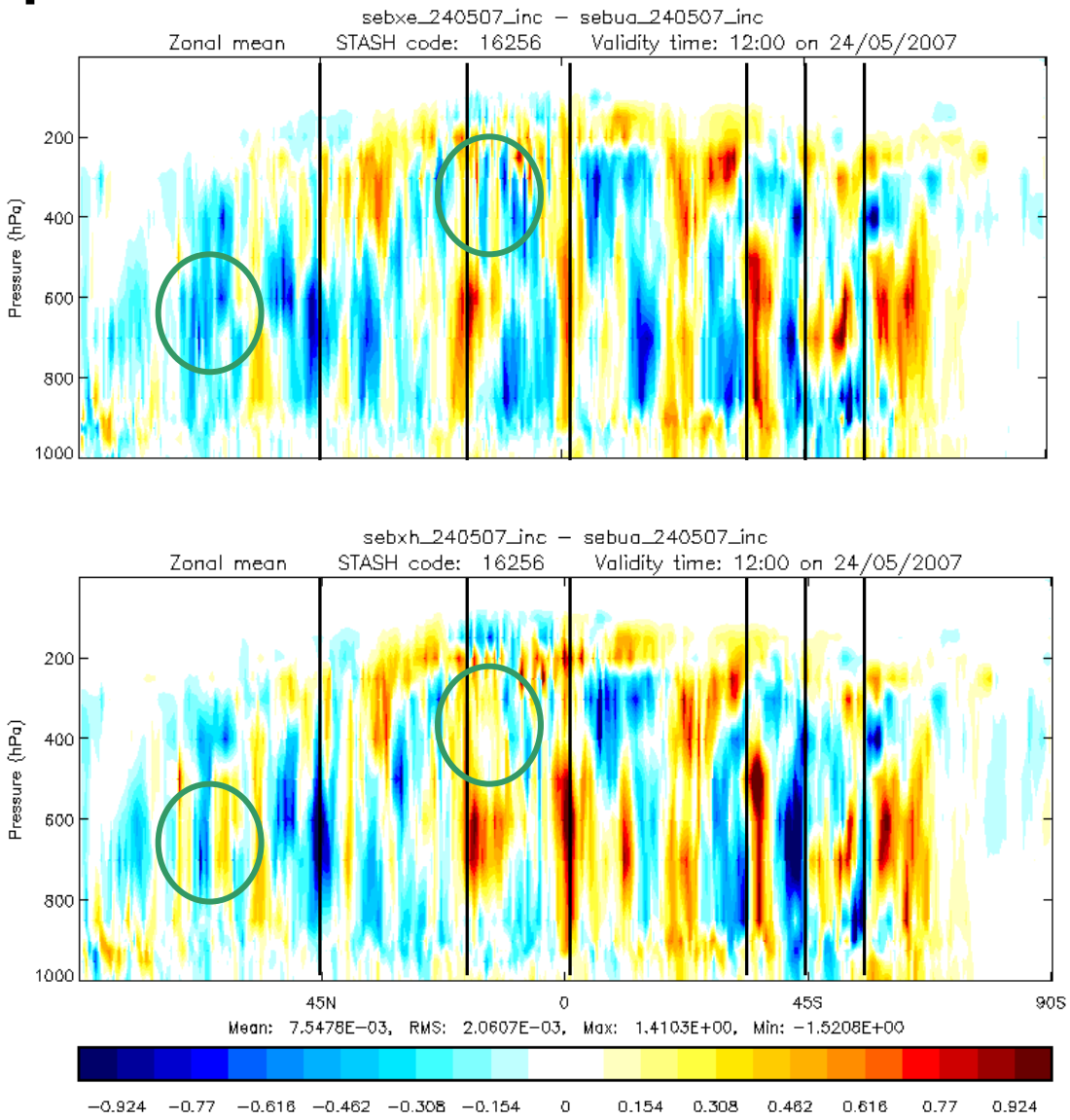
	Low-peaking only	More mw channels	All wv channels
Failures during 1D-Var	409	634	1021

- 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

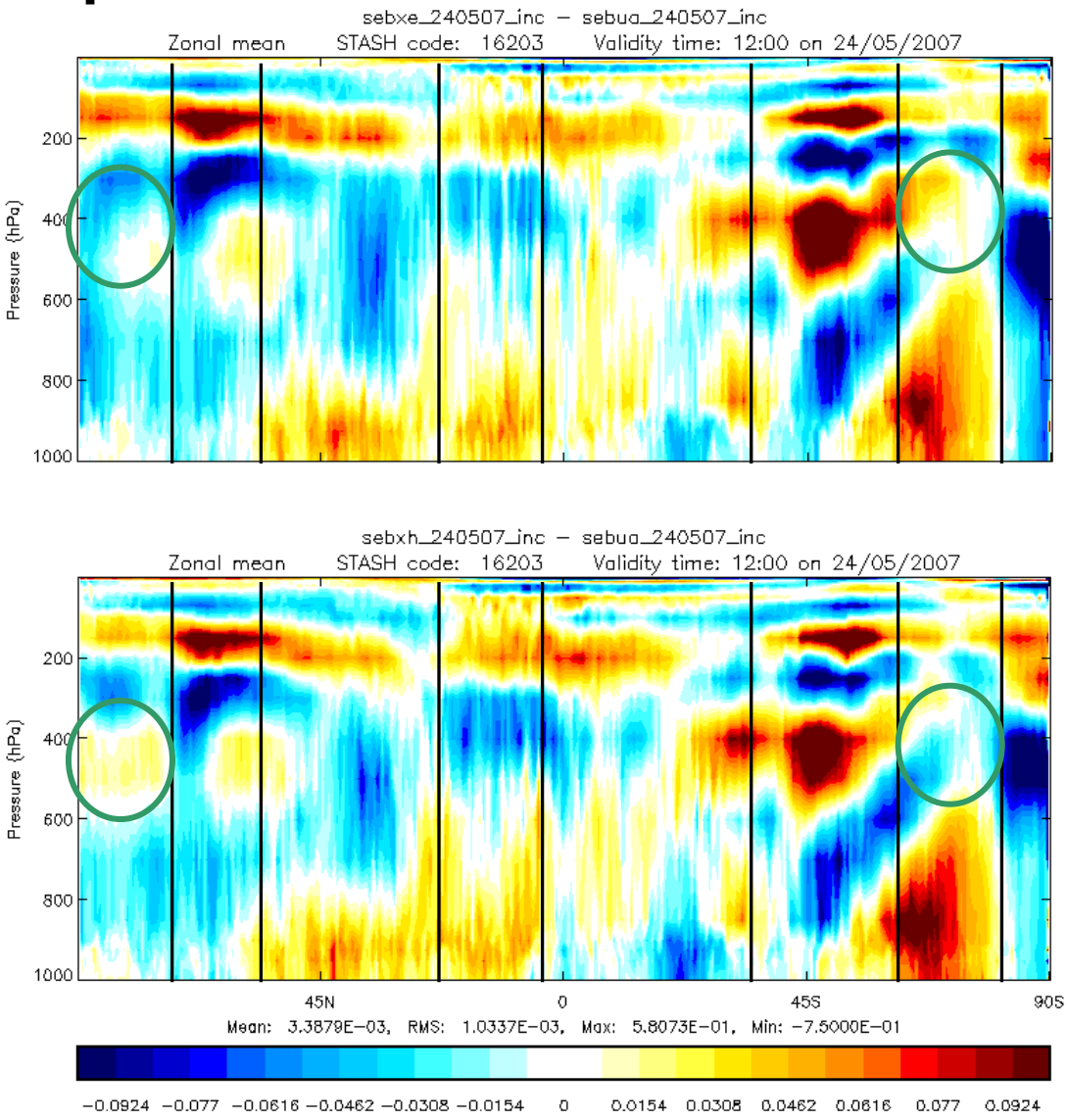
Differences in RH increments adding in more water vapour channels



Preferred configuration

More water vapour channels

Differences in T increments adding in more water vapour channels



Preferred configuration

More water vapour channels