Assimilation of Reconstructed Radiances

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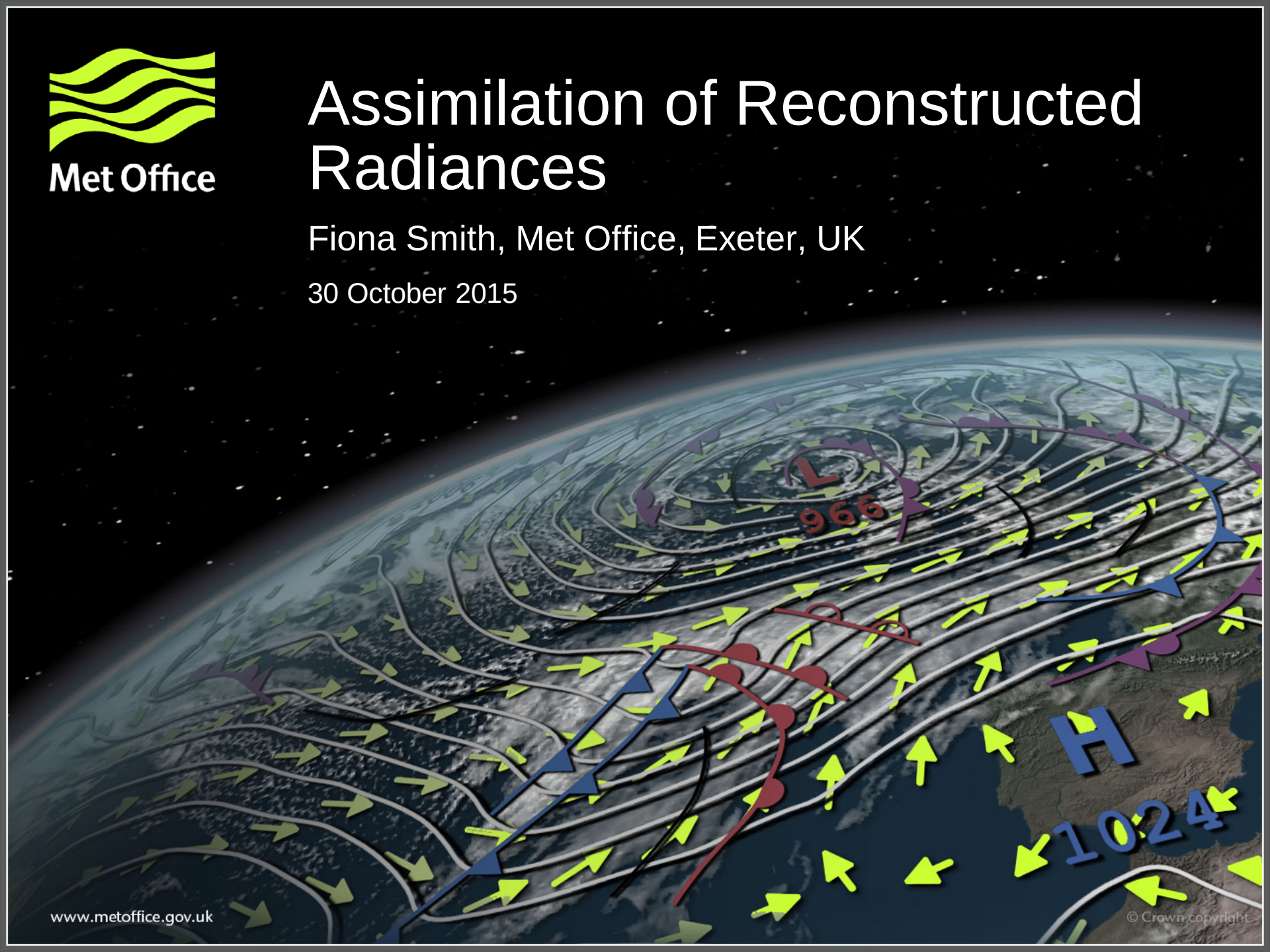

Outline

- What are reconstructed radiances and why do we want to use them?
- How do reconstructed radiances compare in terms of O-B and 4D-Var increments
- Results of assimilation trials

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What are reconstructed radiances, and why do we want to use them?

What are reconstructed radiances?

- Radiance spectra can be compressed for dissemination (or assimilation) using Principal Component techniques
  - 8000 channels down to 300 PC scores
  - Discarded components contain random noise
- Reconstructed radiances (RRs) are the spectra that you calculate from the PC scores
  - Spectra have lower random noise
  - But the noise that remains is heavily correlated

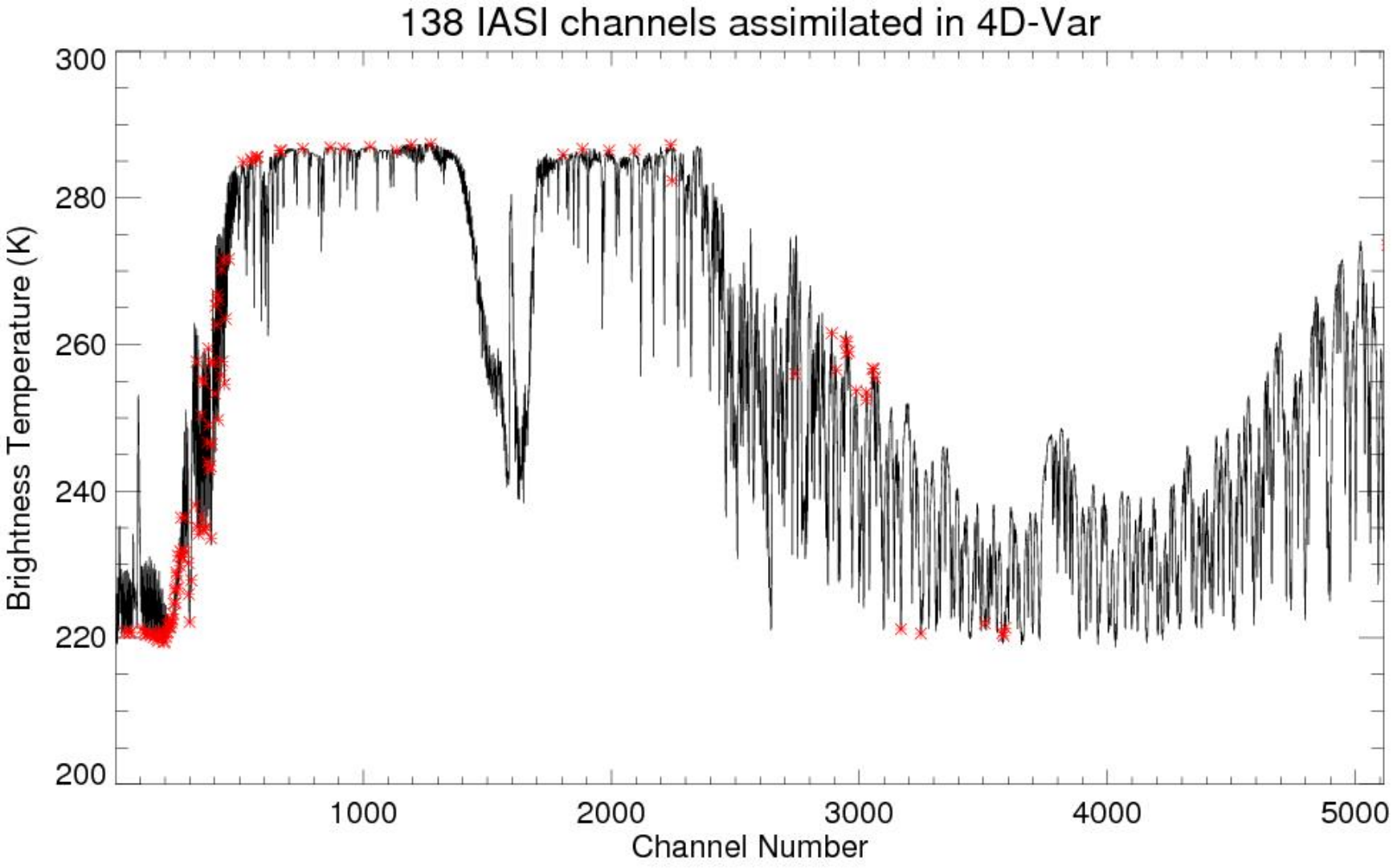
Why reconstructed radiances?

- Reconstructed radiances should allow us to access
  - all of the signal
  - with reduced noise
  - in radiance space
  - a few hundred channels
- Also, PC-compression is the baseline dissemination for MTG-IRS

Error Correlations

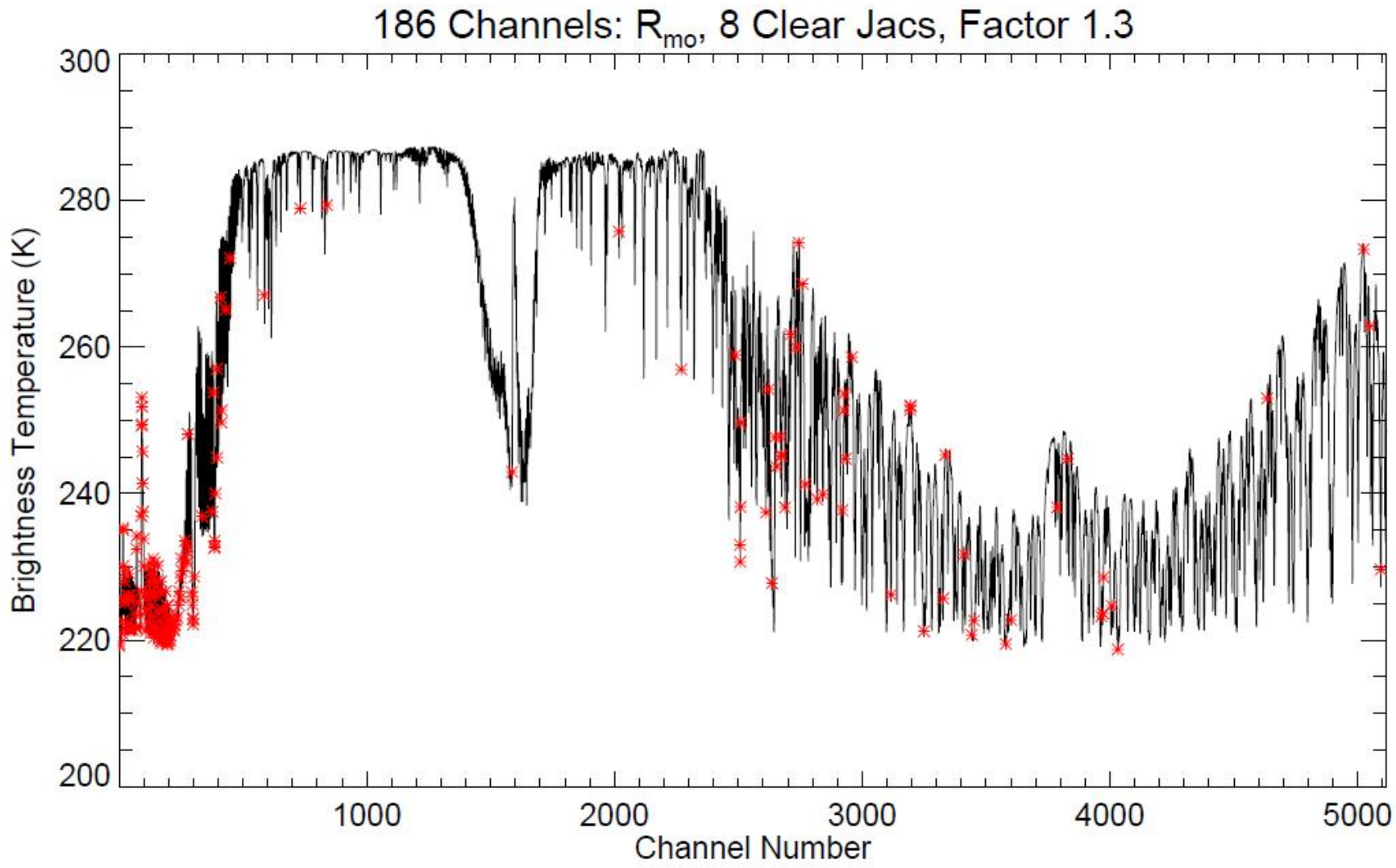
- The drawback is that instrument error correlation for RRs is significantly increased
- Yesterday we heard that there are other non-diagonal error terms that most centres have ignored until recently
- Consequently, channel selections used in NWP were generally made assuming diagonal error matrices
  - This assumption is very wrong for reconstructed radiances
  - We should have a new channel selection that takes account of these errors

Operational Channel Selection
based on diagonal error term

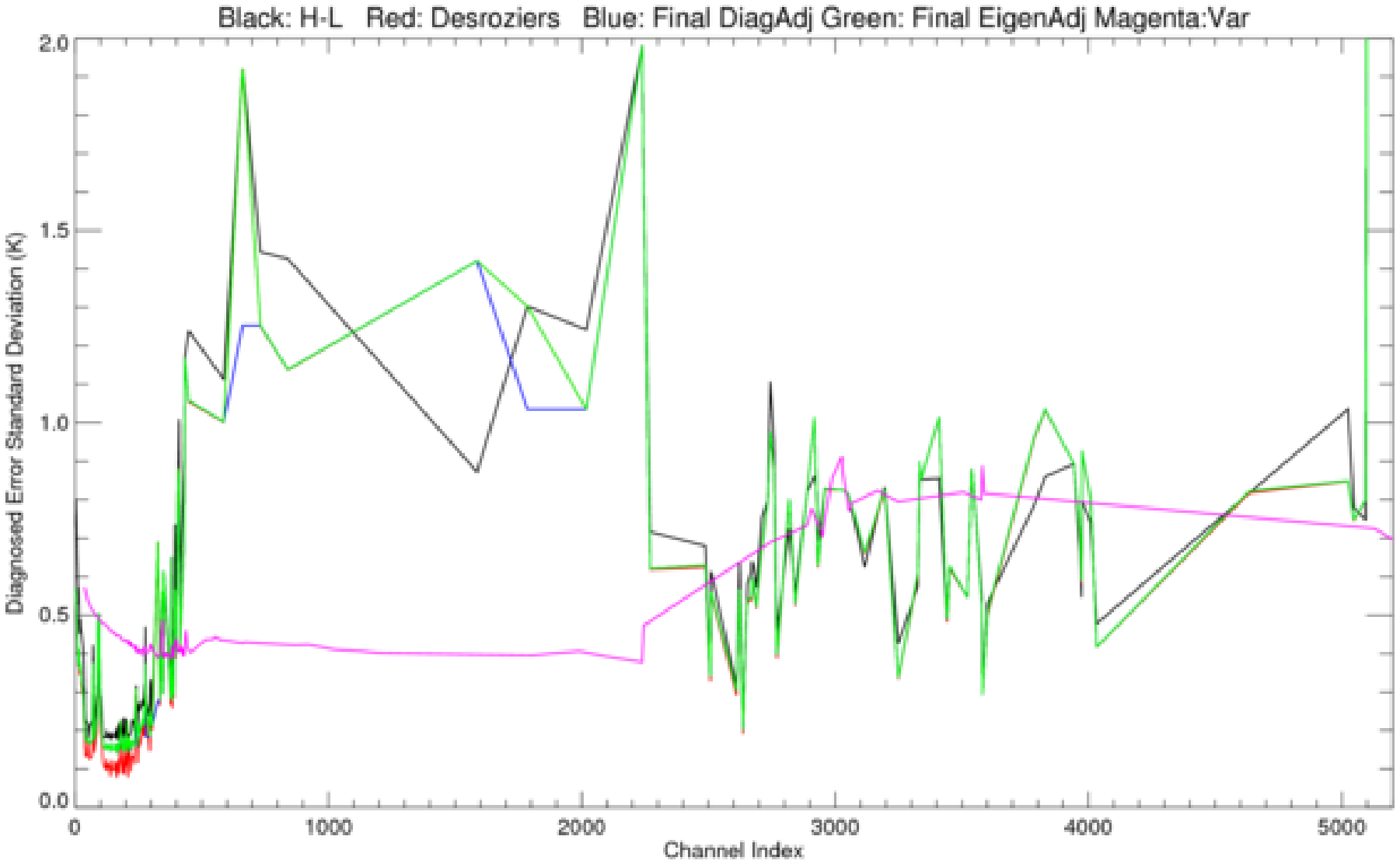


New Channel Selection

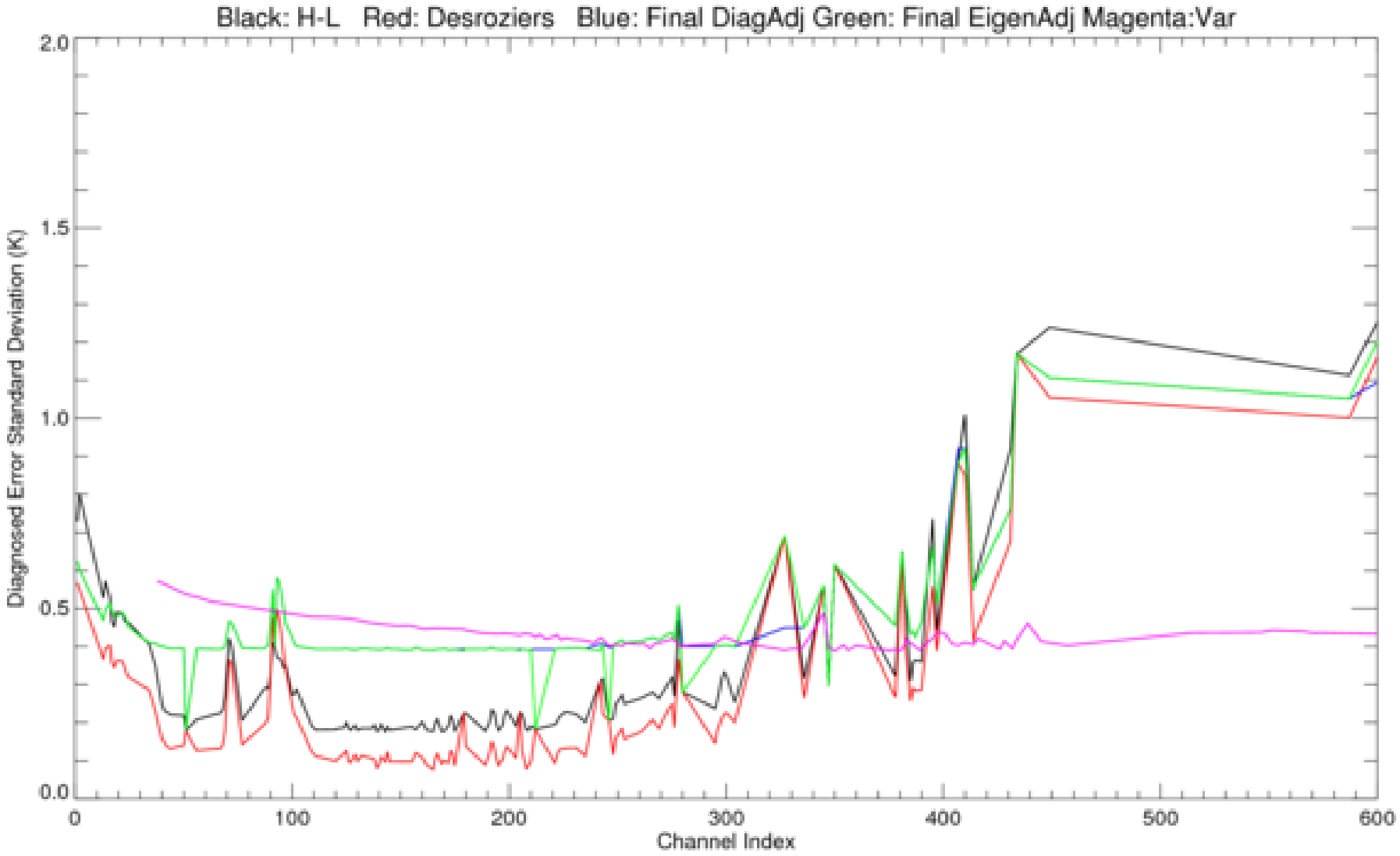
based on Hollingsworth-Loennberg error covariance for Reconstructed Radiances



Diagonal of full R-matrix



R-matrix diagonal – Band 1

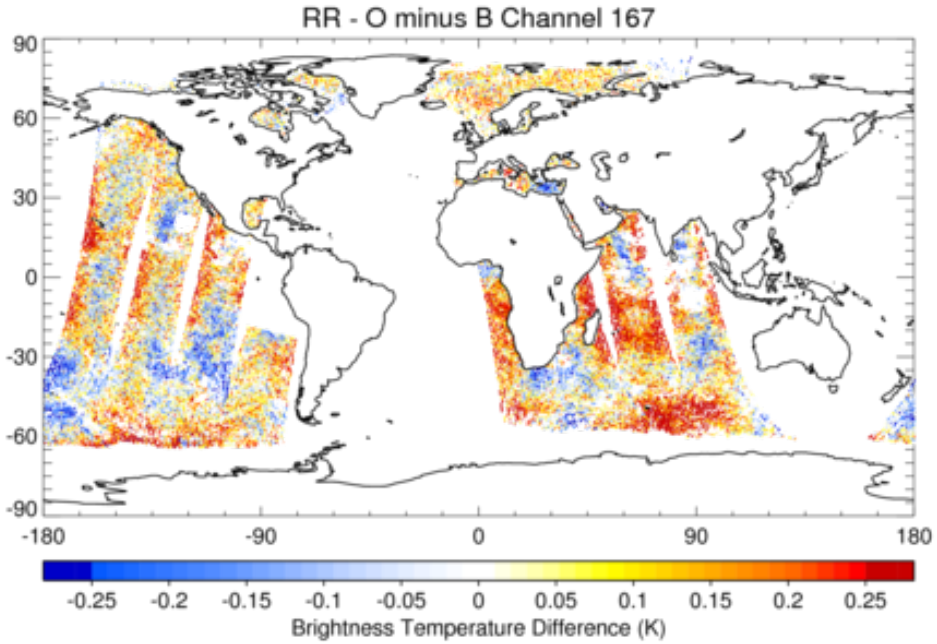


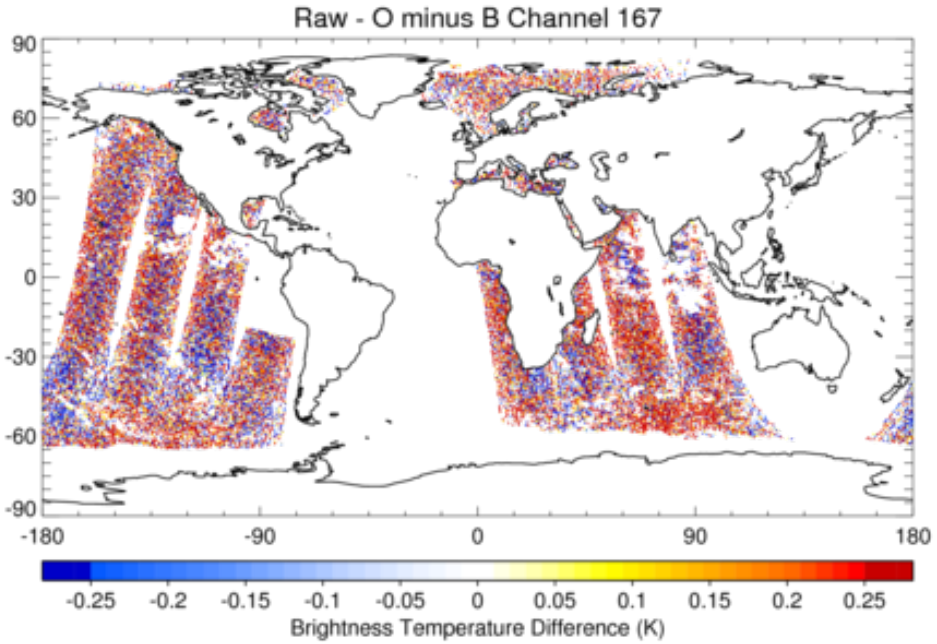
Experimental Set-up

- Use the channel selection of 186 channels chosen as above
  - Only assimilating over sea, because there aren't enough window channels to do emissivity analysis
- Reconditioned R-matrix from Desroziers analysis, starting from Hollingsworth-Loennberg matrix
- Metop-A only (for technical reasons)
- RTTOV-9 forward model
  - No attempt to forward model the PC-compression, just the original radiance Jacobians are used.

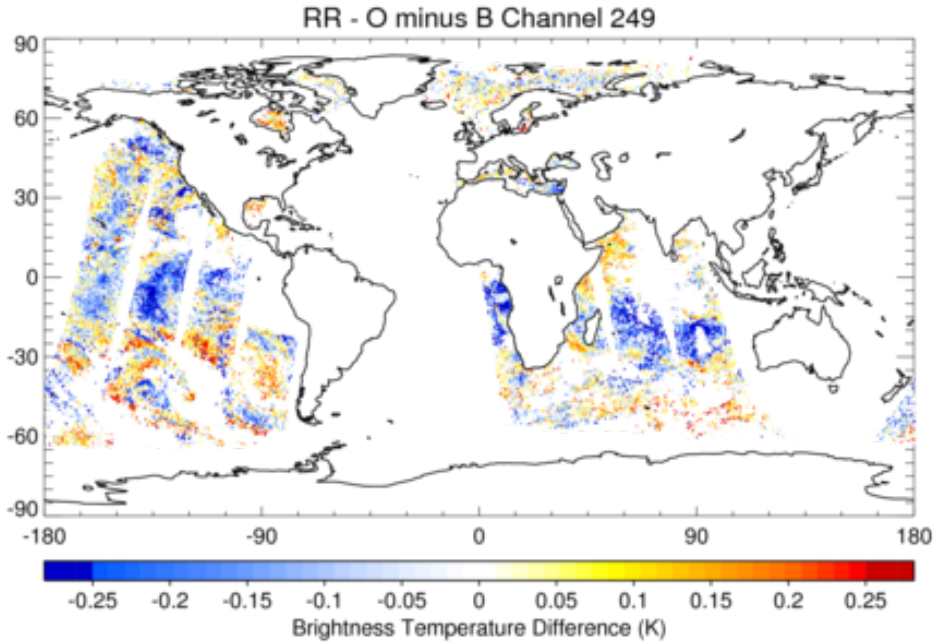
How do reconstructed radiances compare in terms of O-B and 4D-Var increments

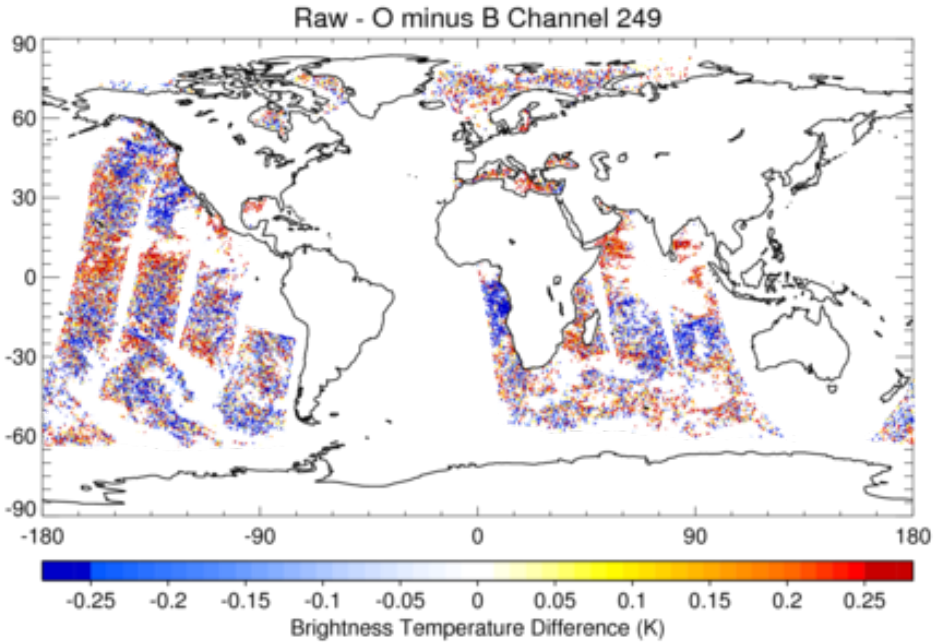
O-B Channel 167 – 70hPa





O-B Channel 249 – 340hPa

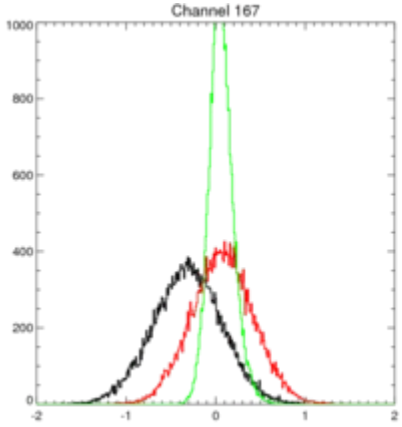




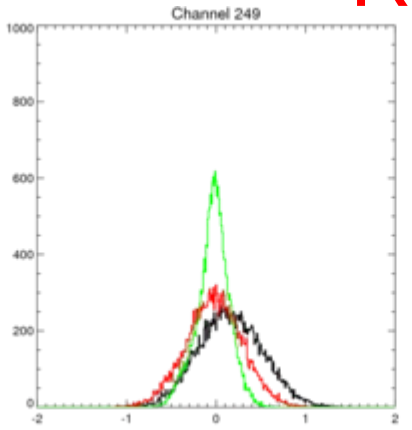
Obs-Calc Histograms

Obs - Background
Corr - Background
Ret - Background

Raw



167



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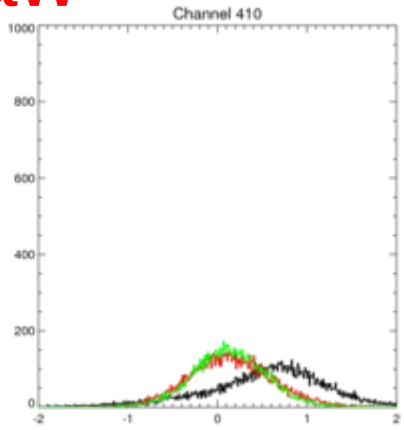

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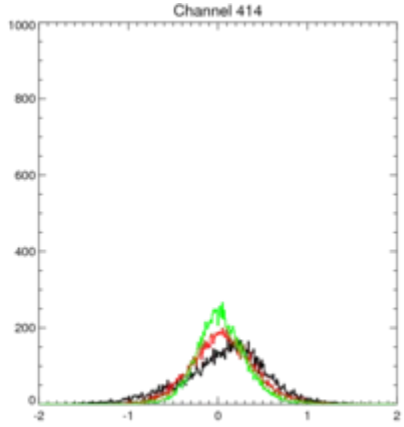
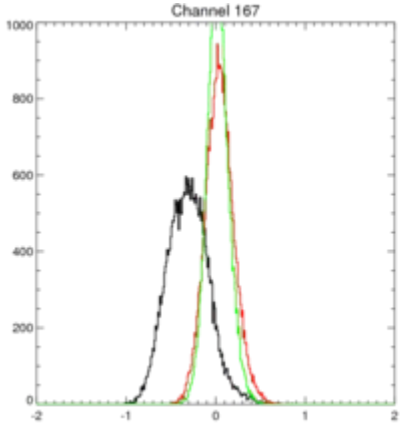
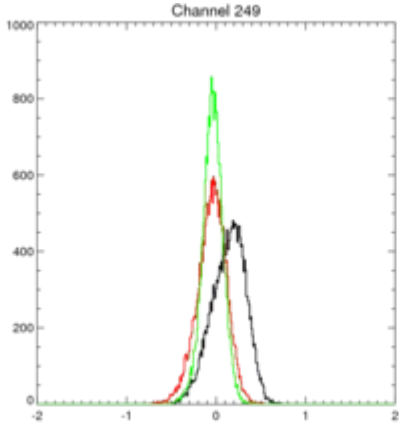
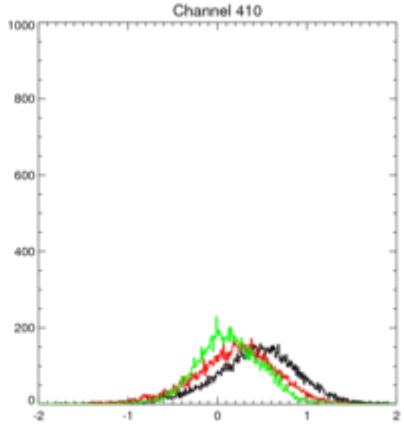


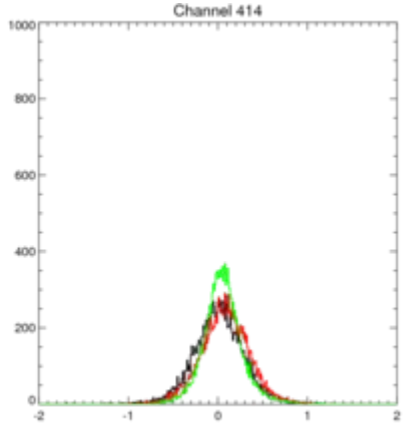
414

Reconstructed

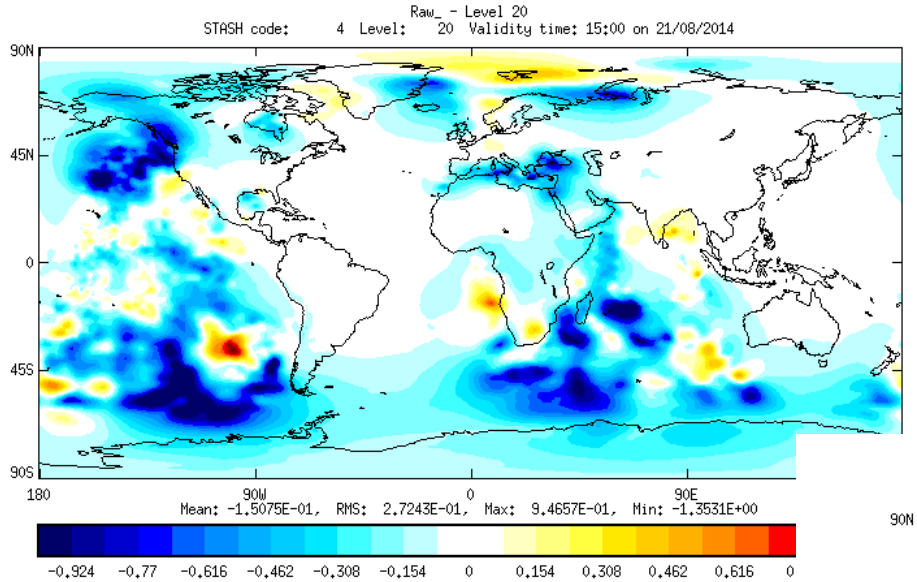






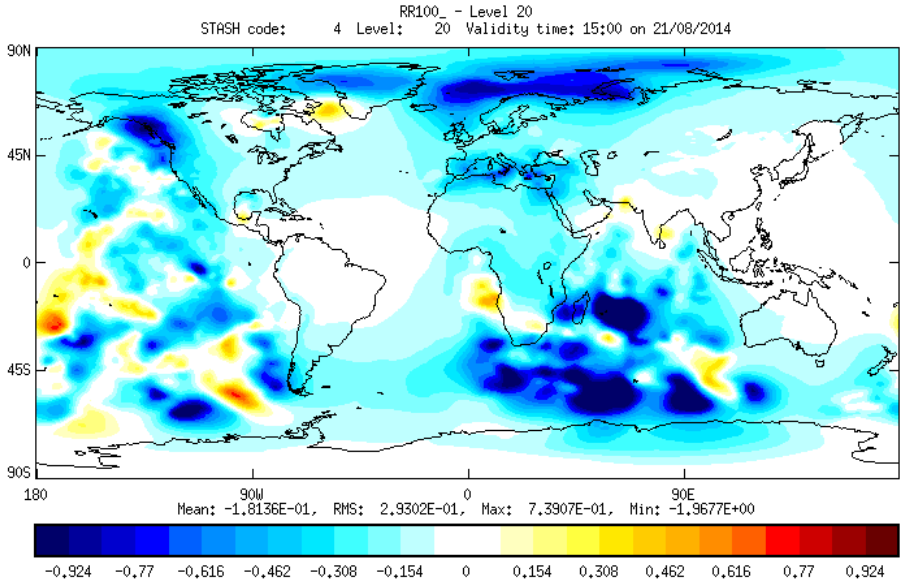


4D-Var analysis increment from single cycle - Theta Level 20

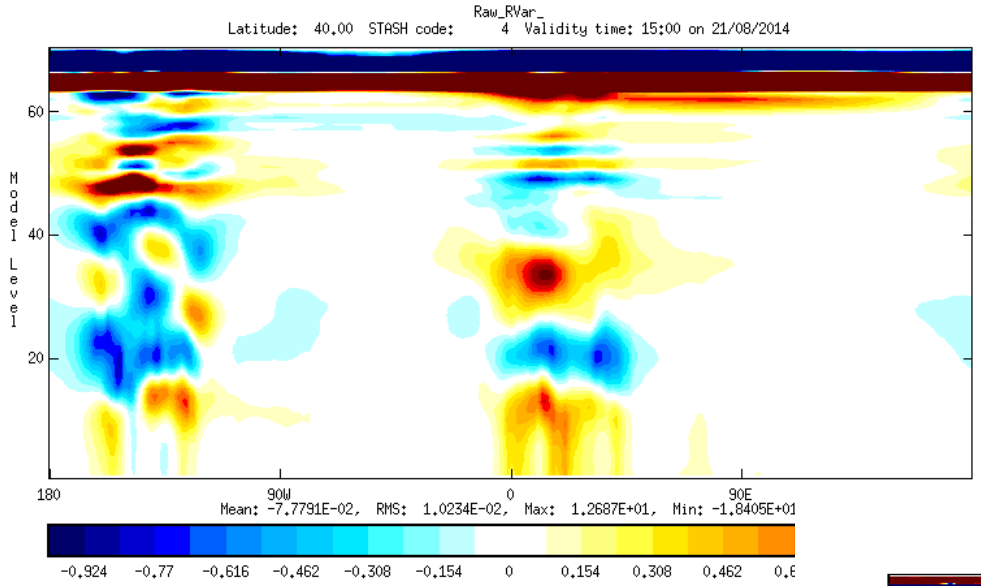


Raw

Reconstructed

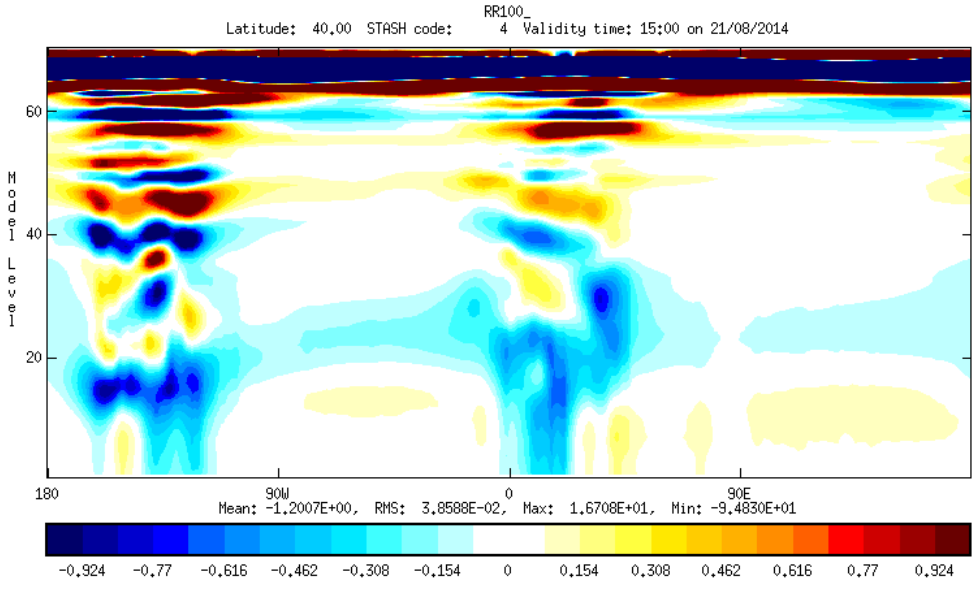


Cross-section Latitude 40N Theta

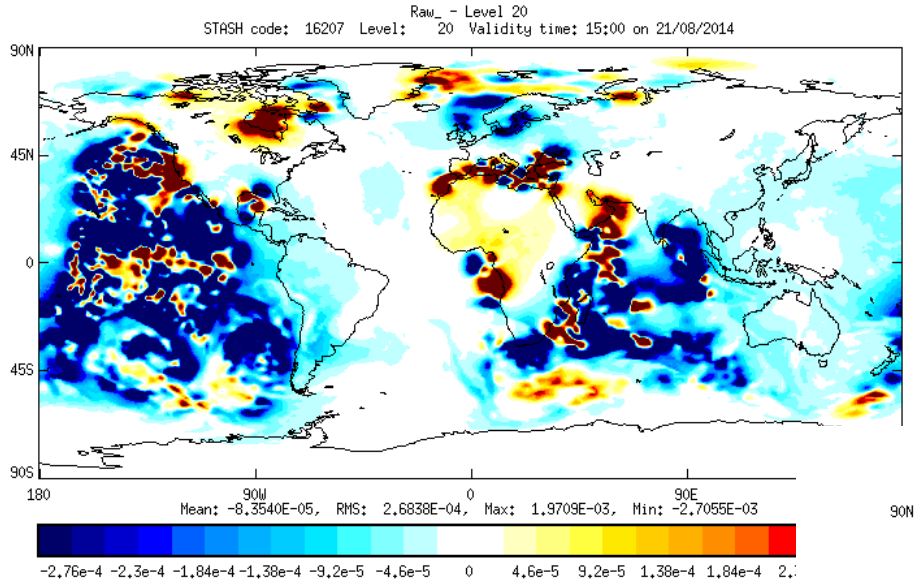


Raw

Reconstructed

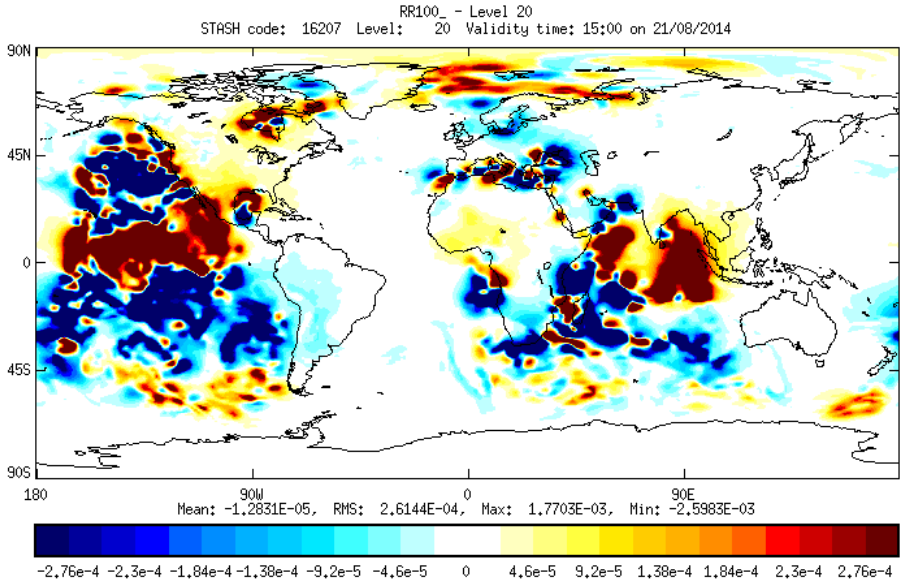


4D-Var analysis increments from single cycle - Qtot Level 20

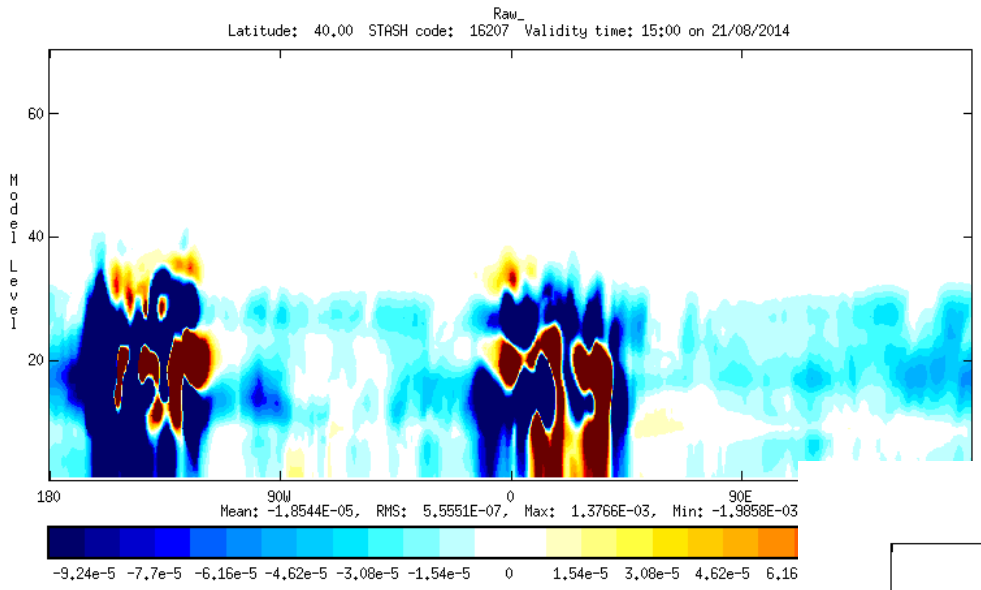


Raw

Reconstructed

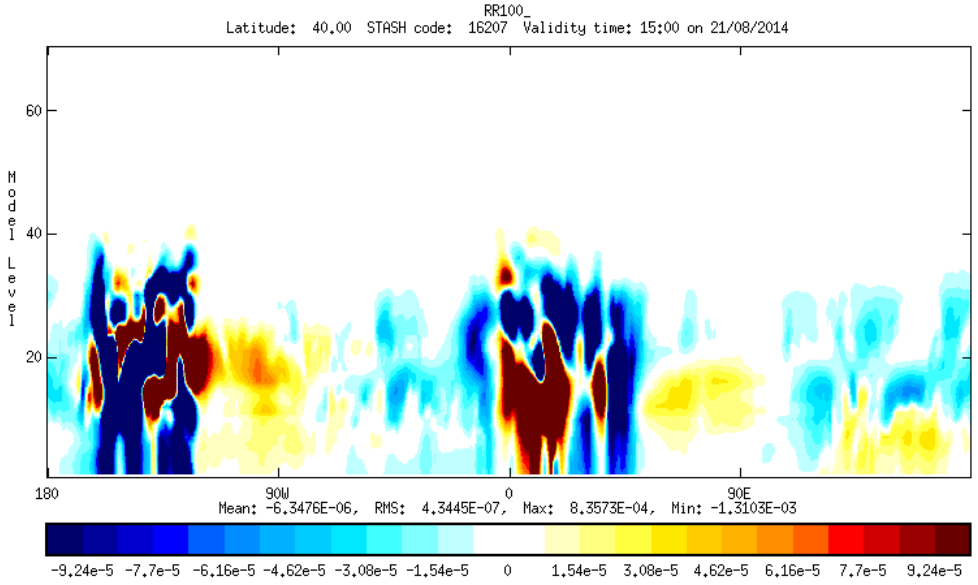


Cross-section Latitude 40N Qtotal



Raw

Reconstructed



Assimilation Trials

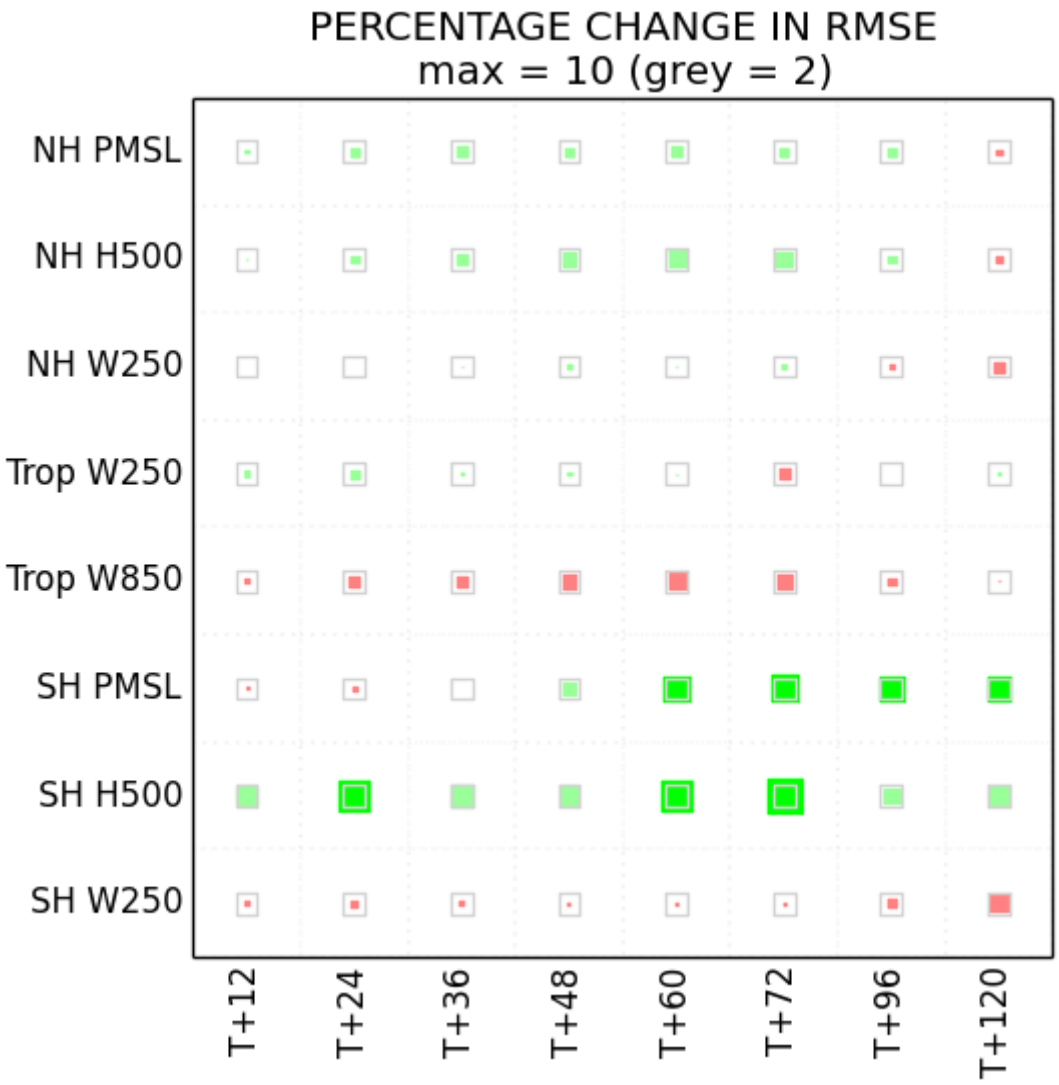
Round 1: Full Observing System (IASI Metop-A only)

- Verification vs Raw Radiances

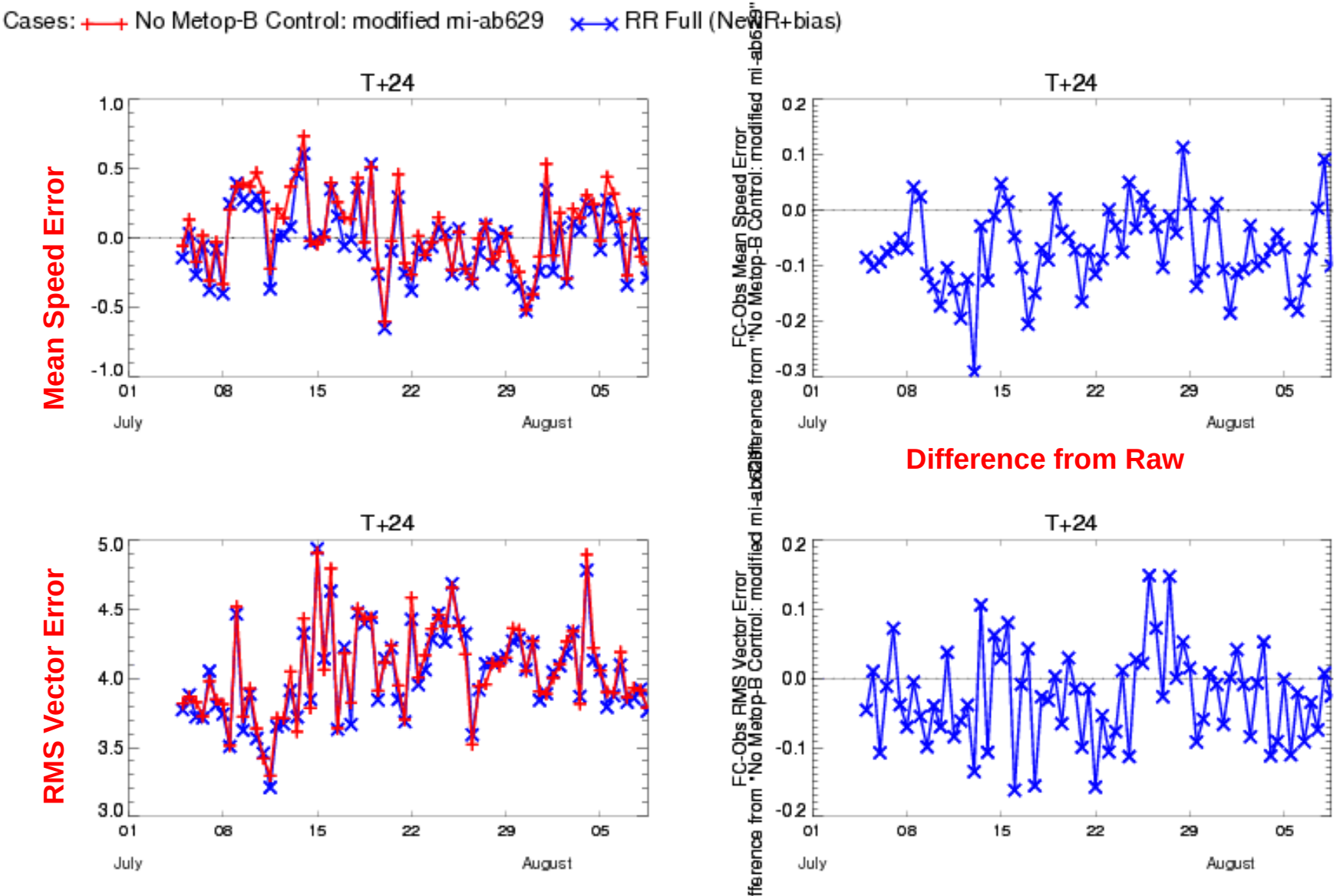
	New NWP Index	Verification of 198 Variables
RR New Chans	-0.055	51 Better 38 Worse
RR New Chans minus highest peaking	-0.651	26 Better 90 Worse

- Conclusion: the channel selection works well together: removing channels removes information
  - Much stronger effect than with Raw Radiances
- But a rather disappointing result overall!

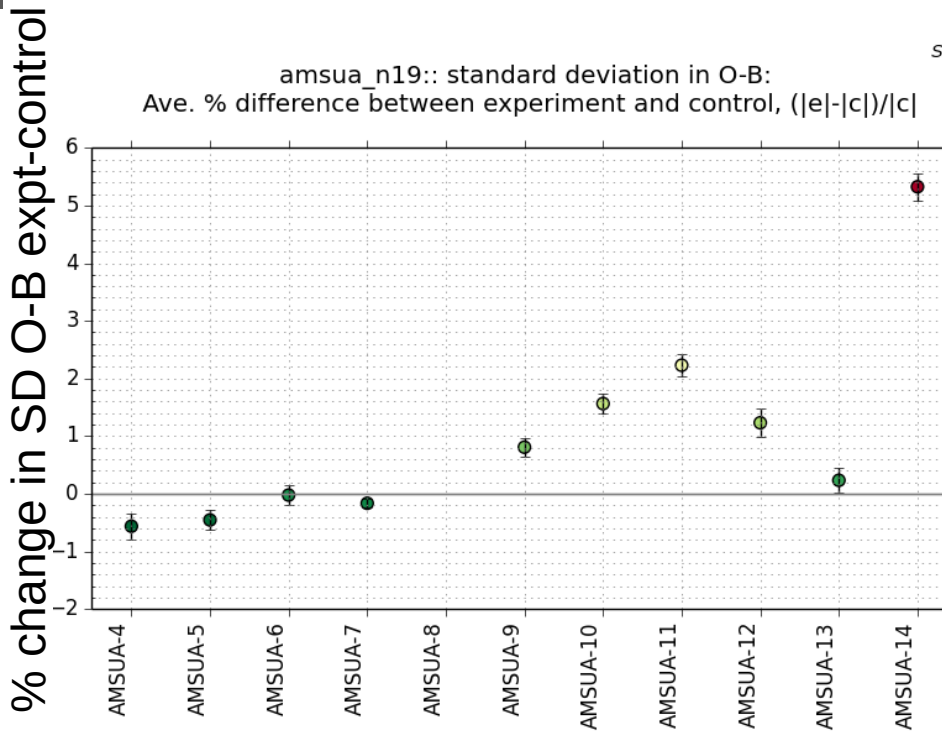
Verification table RR vs Raw

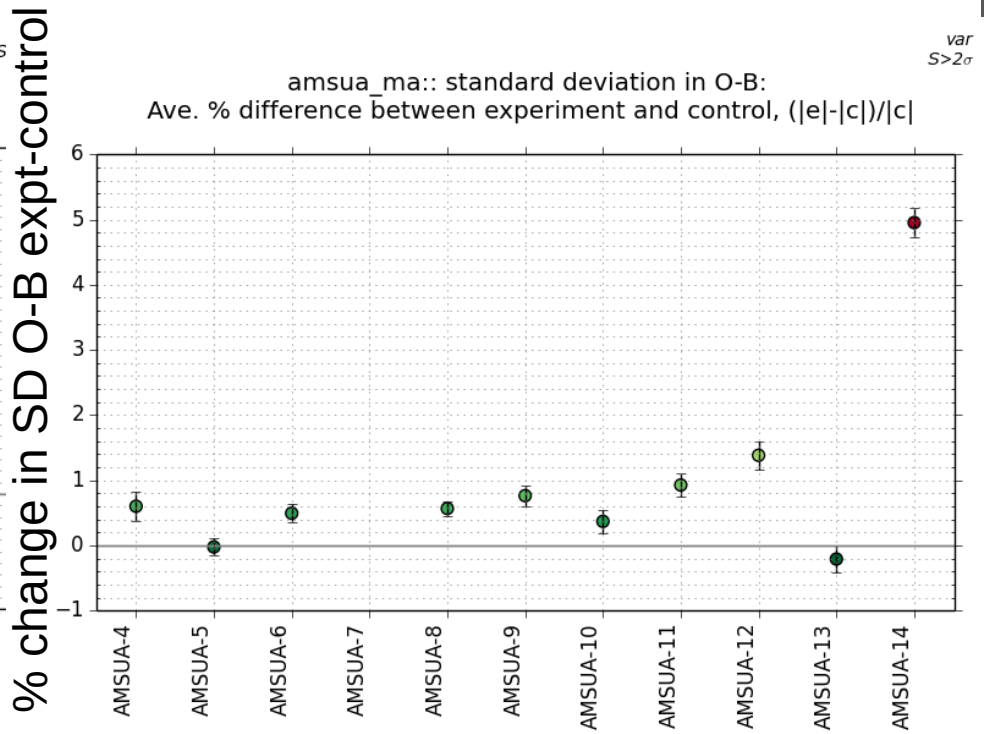


850hPa wind Verification vs Sonde (Tropics) RR vs Raw



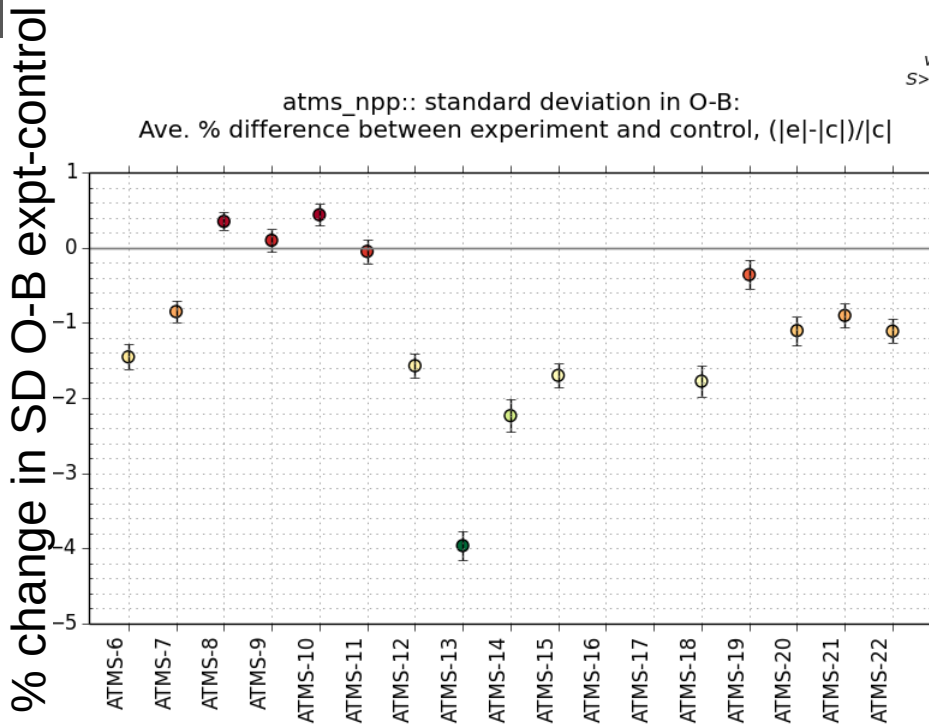
Background fit to AMSU-A
Left N19, Right Metop-A

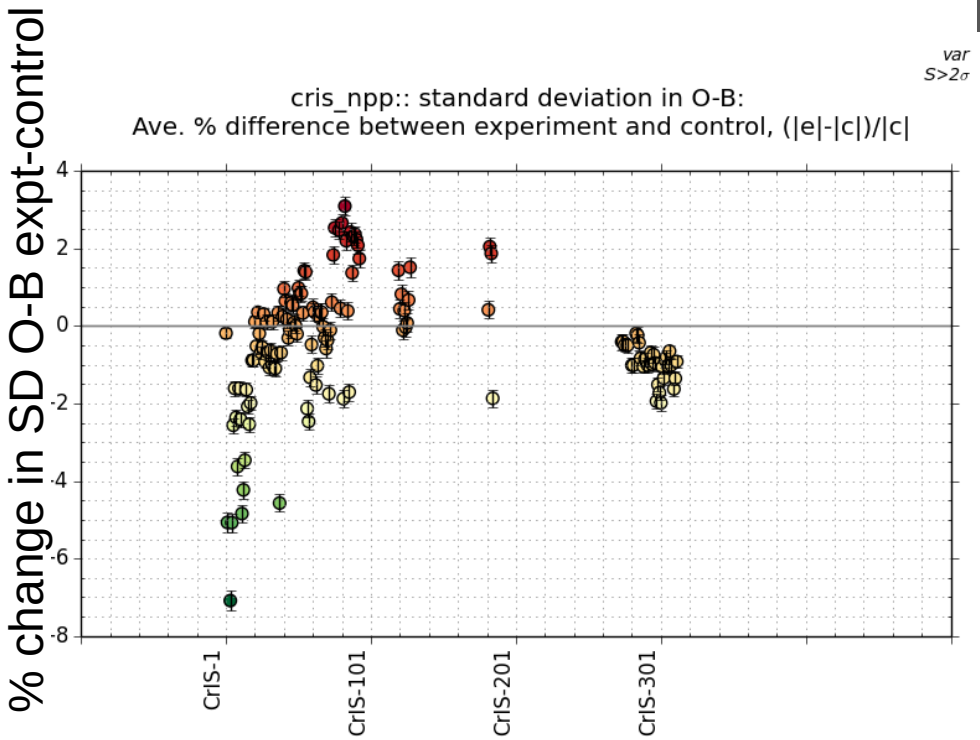




1-2 % increase (i.e. fit is worse in trial) for most channels

Background Fit to ATMS (left) and CrIS (right)





1-2 % decrease (i.e. fit is better in trial) for most channels

A mixed bag – some channels up to 5% improvement. Window channels worse fit?

Round 2: ATMS Baseline (+RO, Scatt, SatWind) (IASI Metop-A only)

Verification v. No IASI control

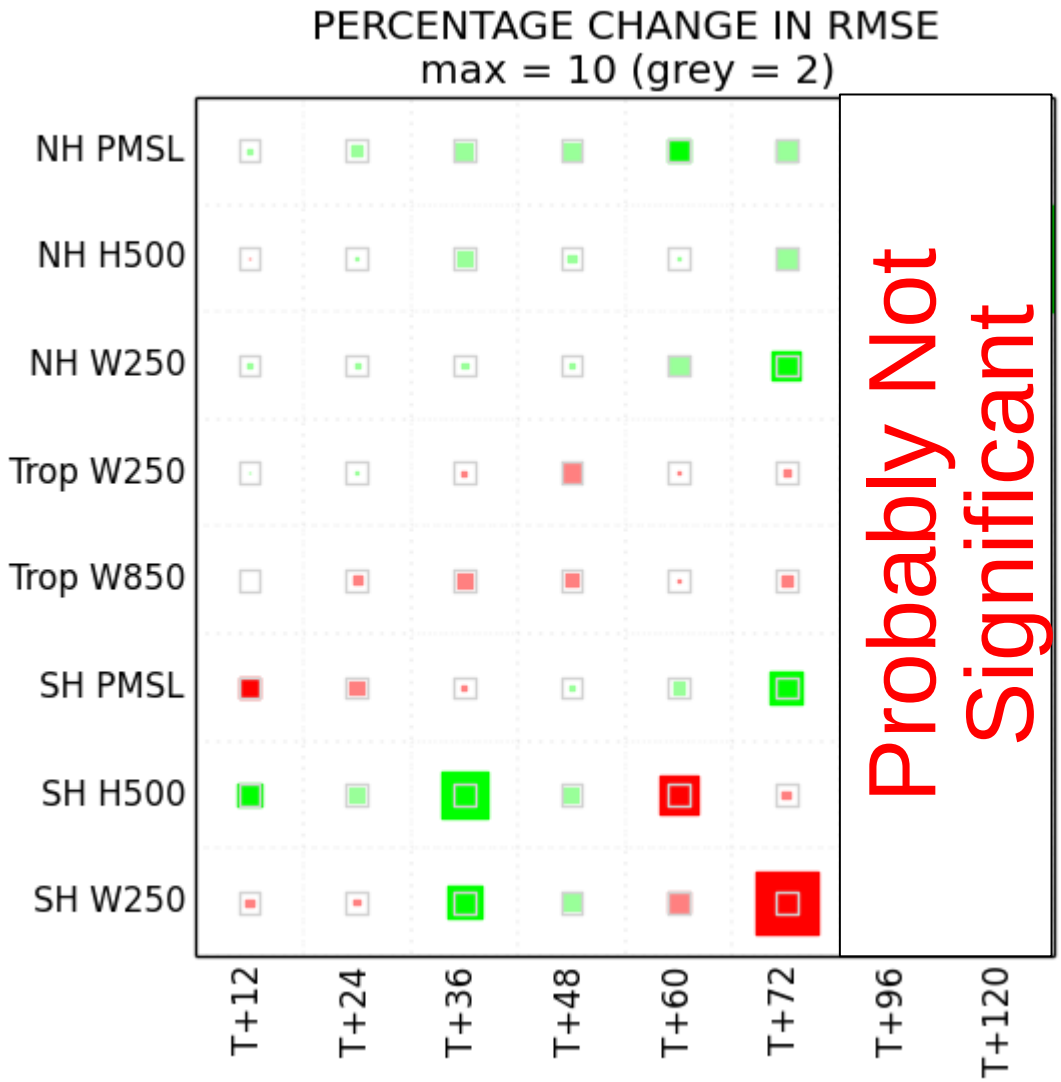
	New NWP Index
Raw Radiances	+0.363*
RR New Chans	+0.383

* Note this gave around +1 on the "Old Index" in 2007 with clear scenes and no error correlations on top of full system!

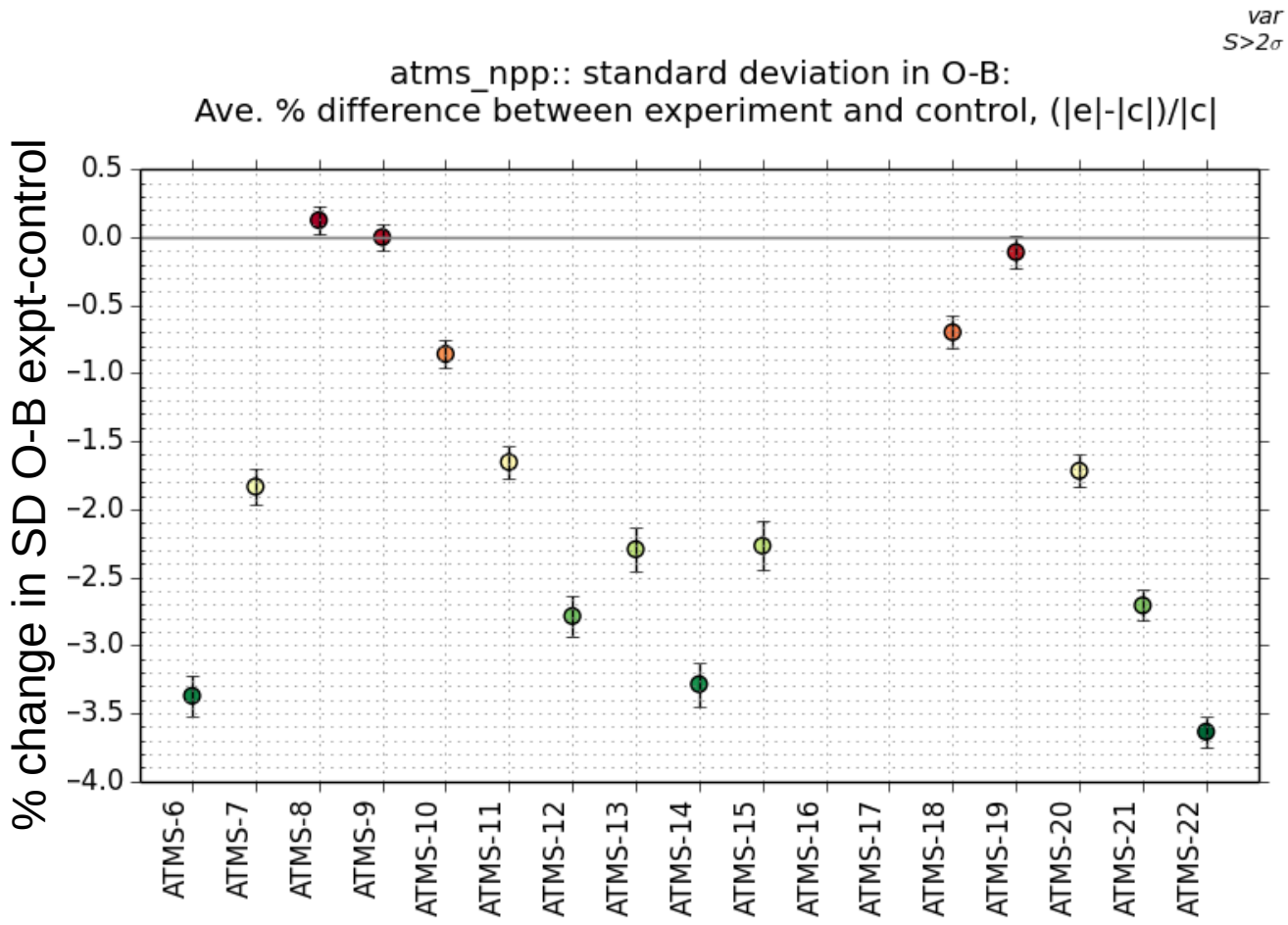
Verification of RR vs Raw

	New NWP Index	Verification of 198 Variables
RR v. Raw	+0.02	104 Better 52 Worse

Verification Table RR vs Raw (ATMS baseline)



Change in Background fit to ATMS RR v. Raw



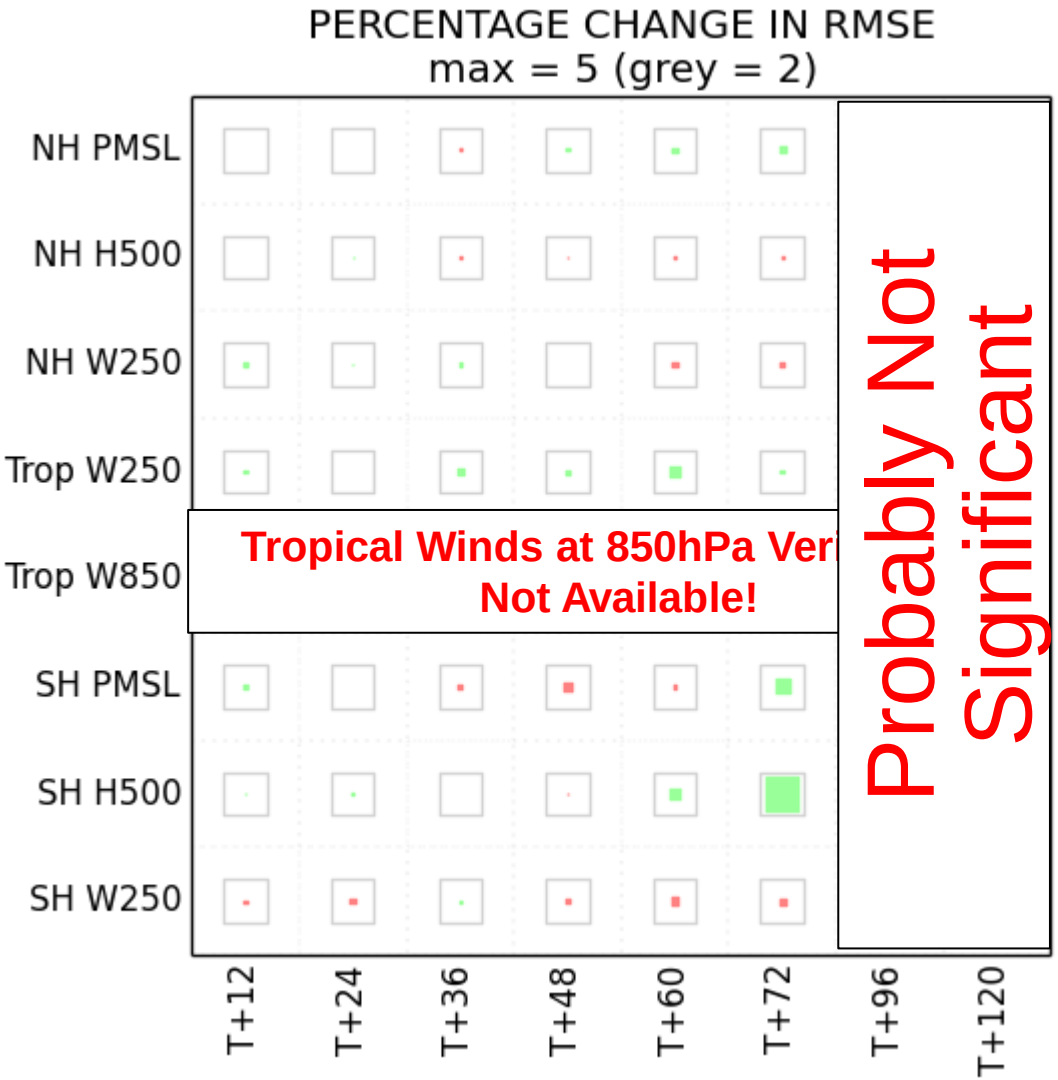
Up to 3.5% decrease (i.e. fit is better in trial) for almost all channels

RRs from operational channel selection

Some comments

- Have tried this before when we used a diagonal error covariance in 4D-Var
  - Neutral to slightly positive scores over-all because of reduced instrument noise
- Shouldn’t really work with correlated errors
  - The error correlations for RRs are significantly different from raw radiances

Verification Table
RR Orig Chans vs Raw



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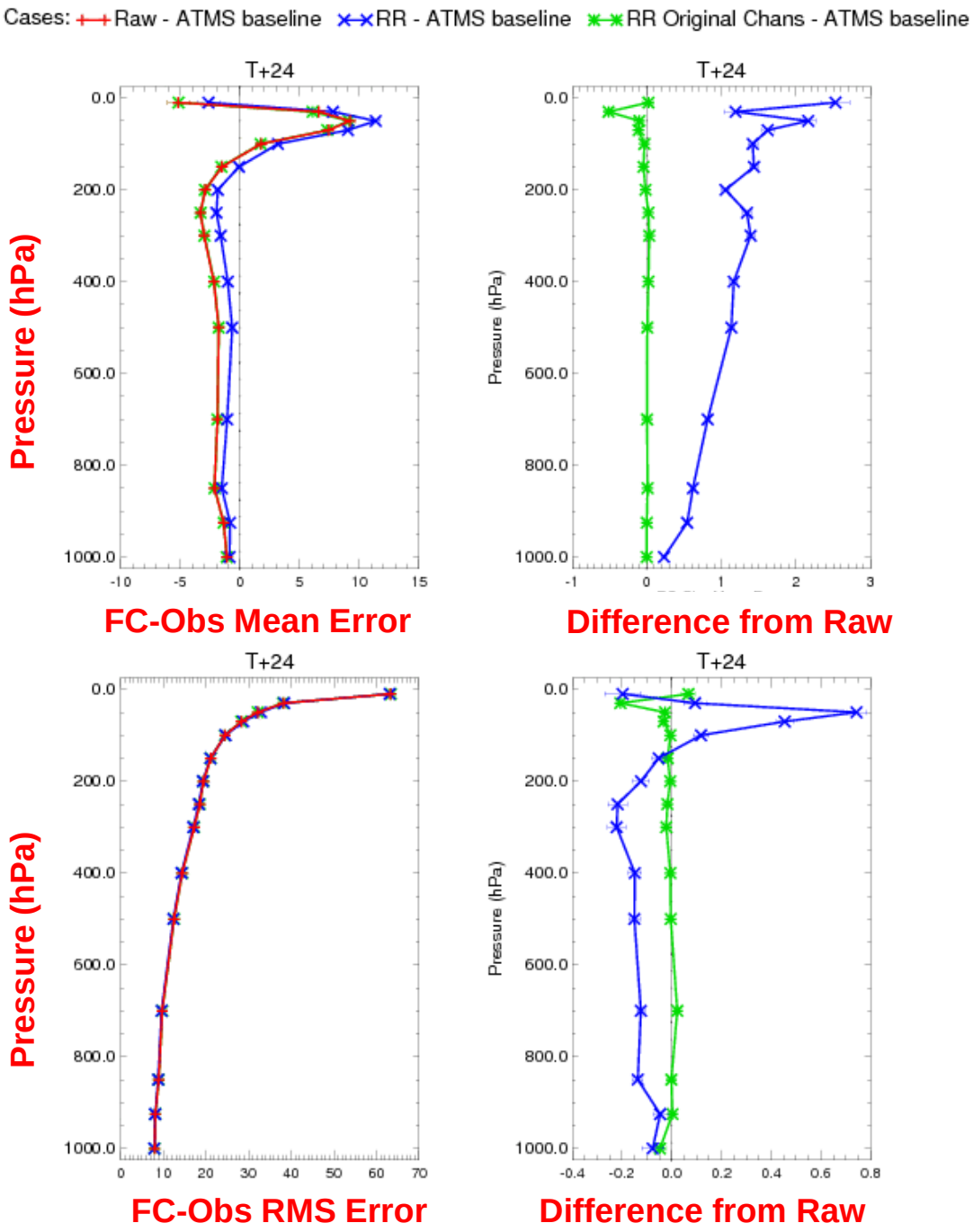
Verif vs Sonde

Northern Hemisphere

Height at T+24



Summary of Results

- Basically neutral impact from reconstructed radiances
- Do see some benefit from dedicated RR channel selection
- Detrimental impact to Tropical W850
  - No window channels in dedicated selection
  - Lack of window channels is likely a result of high errors for window channels in Hollingsworth-Loennberg matrix
    - Want to try to fix this
- Greatest impact of PC compression is on longwave CO_2 channels, but errors overall greatest for water vapour channels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Principal Component Compression

based on EUMETSAT L1 PC Scores

$$y_{pc} = \mathbf{L}^{T}\,\mathbf{E}^{-1/2}\,(y_{chan} - y_{mean})$$

- y_{chan} is the observation in channel space
- y_{pc} is the observation in PC space
- *npc* is the numper of retained PCs (290)
- **L** is the PC eigenvector matrix (size *nchan* x *npc*)
- **E** is the noise covariance matrix

- Note that here, the observation is noise-normalised but other norms are used when PCs are designed for assimilation rather than dissemination

Radiance Reconstruction

based on EUMETSAT L1 PC Scores

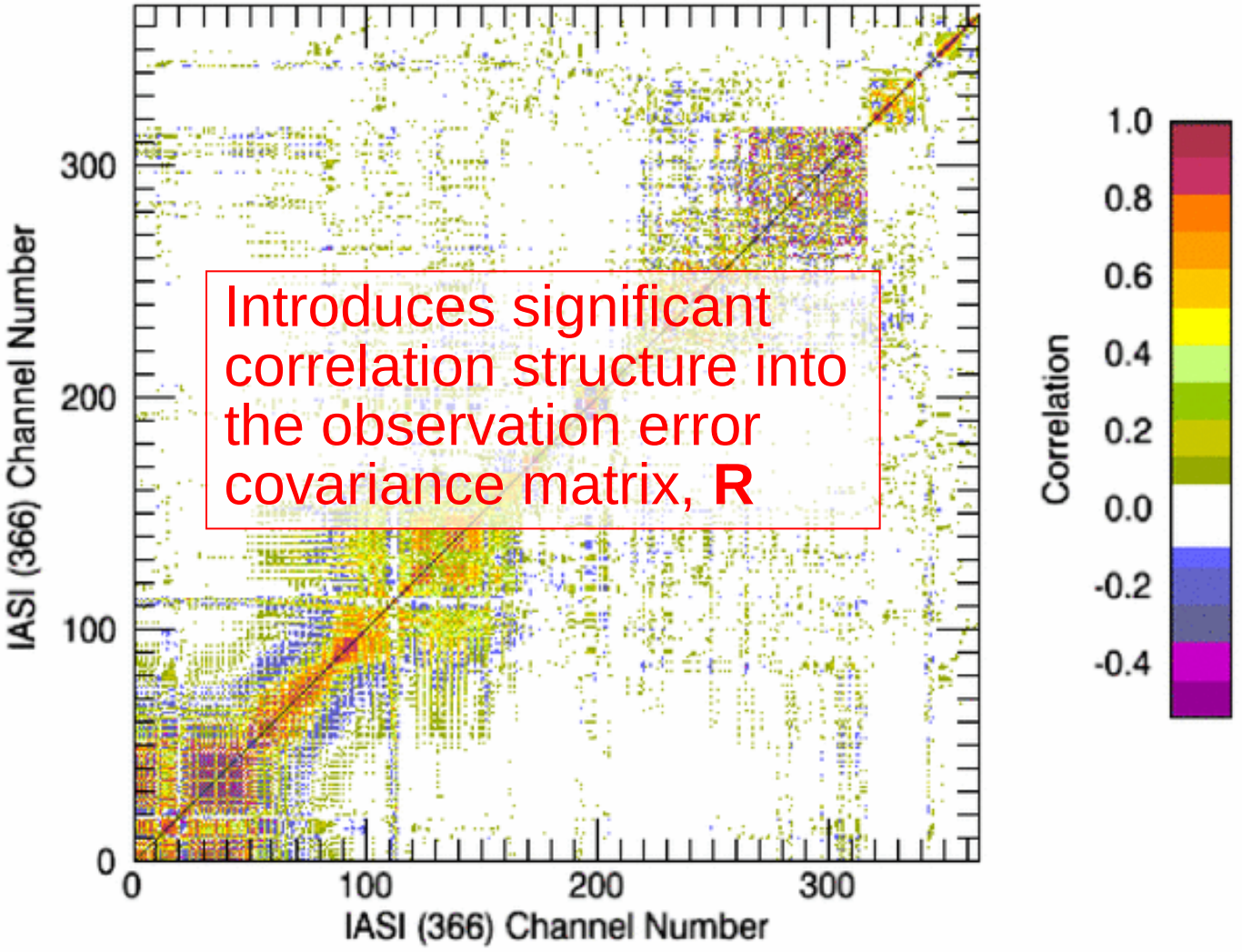
$$y_{rr} = y_{mean} + \mathbf{E}^{1/2}\,\mathbf{L}_{rr}\,y_{pc}$$

$$= y_{mean} + \mathbf{E}^{1/2}\,\mathbf{L}_{rr}\,\mathbf{L}^{T}_{pc}\,\mathbf{E}^{-1/2}\,(y_{chan} - y_{mean})$$

- (You could work in noise-normalised space and omit the premultiplication by $\mathbf{E}^{1/2}$)

- **The critical point is this:**
- $\mathbf{L}^{T}_{pc}$ is size (*npc* x *nchan*)
- $\mathbf{L}_{rr}$ is size (*nrr* x *npc*)
- *nrr <= npc*

Transformation matrix from raw radiances to reconstructed



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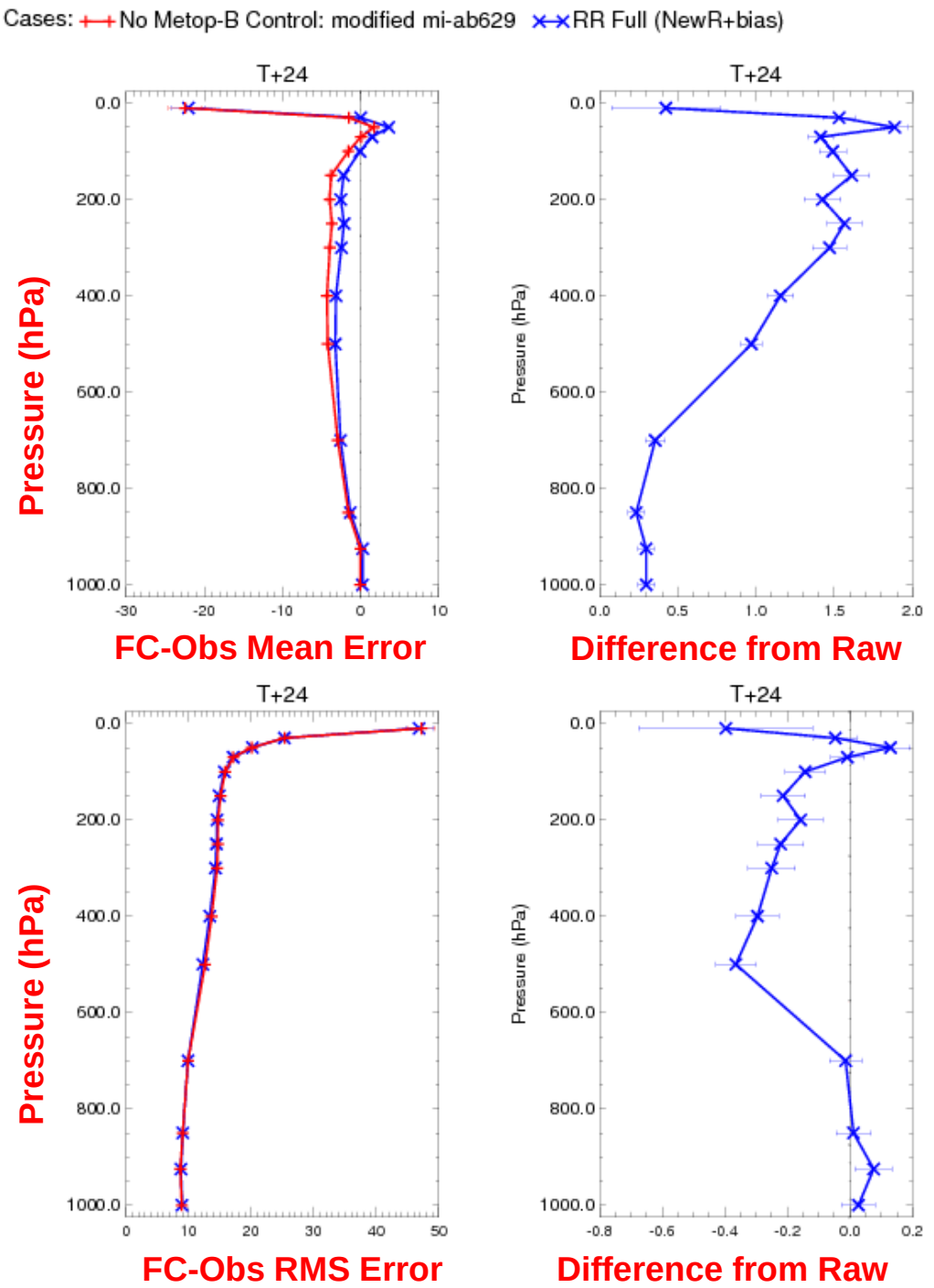
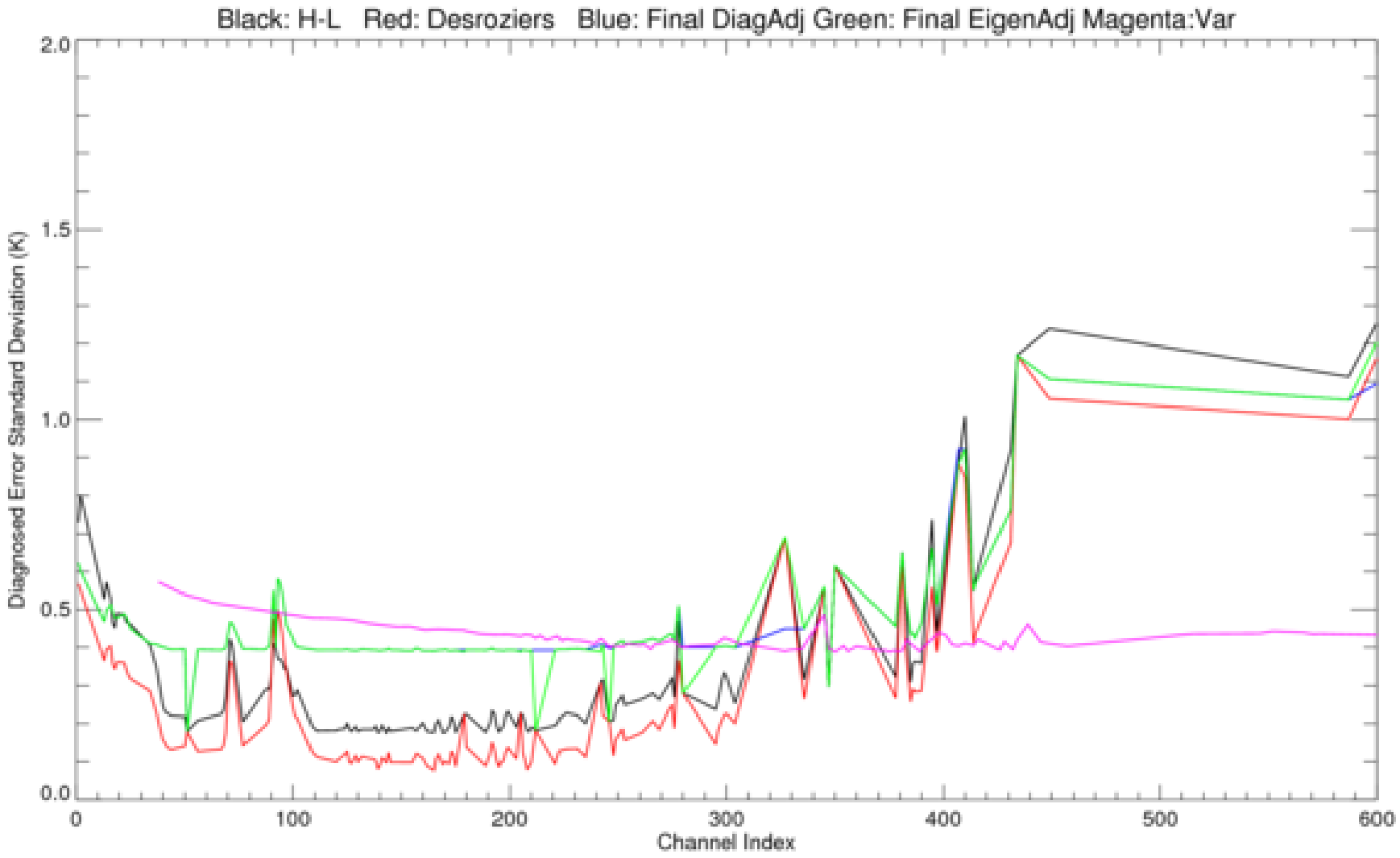
Verif vs Sonde

Southern Hemisphere

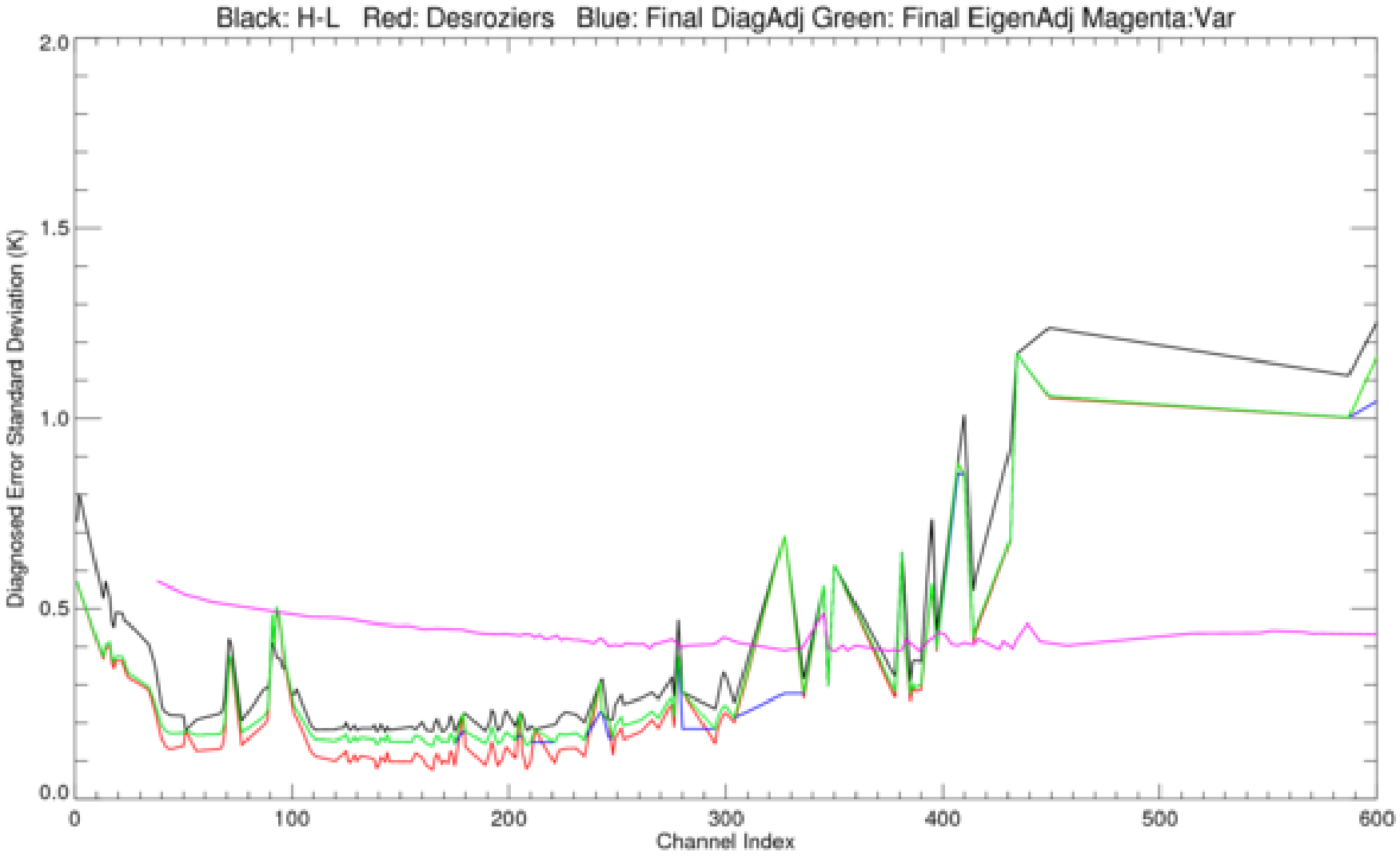
Height T+24



Is the reconditioning wiping out the benefit of the noise reduction?
Matrix from Original Trial: Condition Number 100



Is the reconditioning wiping out the benefit of the noise reduction?
Condition Number 1000



Round 2: ATMS Baseline (+RO, Scatt, SatWind) (IASI Metop-A only)

		NWP Index vs RR
1	RR New Chans – tighter errors OPS	+0.01
2	RR New Chans – tighter errors VAR + 1)	-0.879 *

* Stopped after a couple of weeks!