Water vapour assimilation in the lower stratosphere

Elías Valur Hólm - ECMWF

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1. Assimilation and radiance observations
2. Assimilating MIPAS and MLS

Acknowledgements:

- MLS data assimilation in cooperation with L. Feng and R. S. Harwood, University of Edinburgh, and R. Brugge and A. O.'Neill, University of Reading.
- MIPAS data assimilation done by N. Bormann, ECMWF.

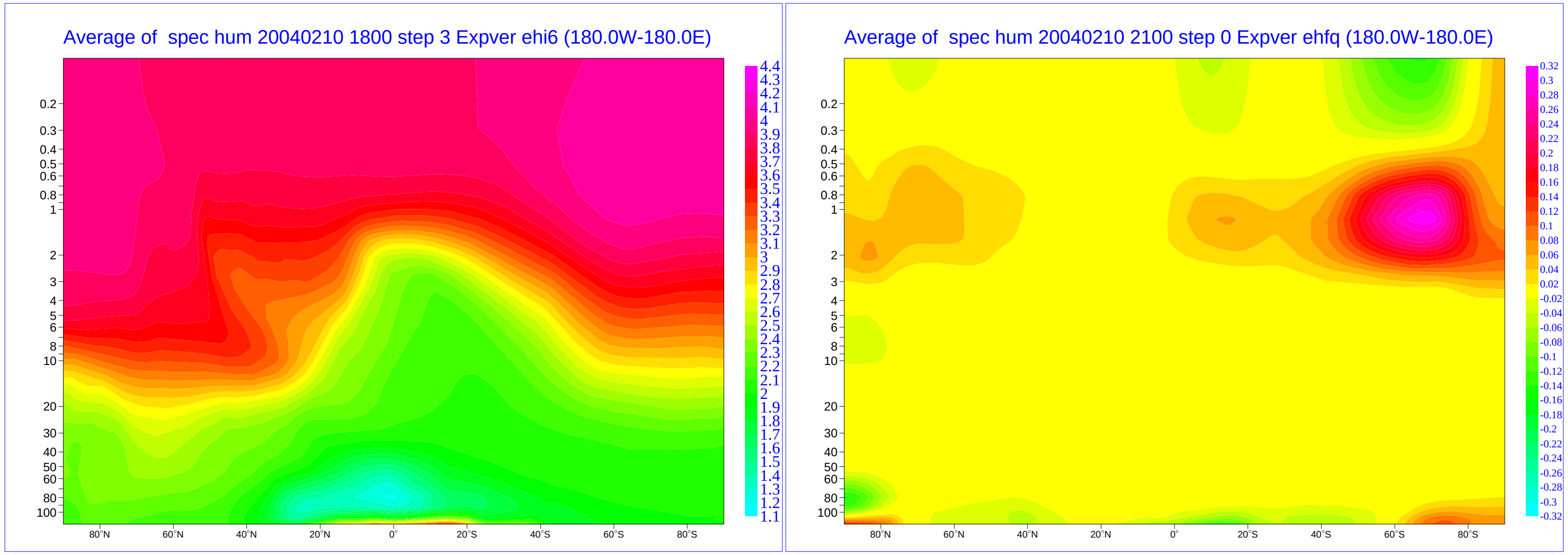
“Issues” in Assimilating Stratospheric Humidity

- Availability of observations
- Use of radiance observations
- Choice of humidity variable for the analysis

Stratospheric Humidity Observations?

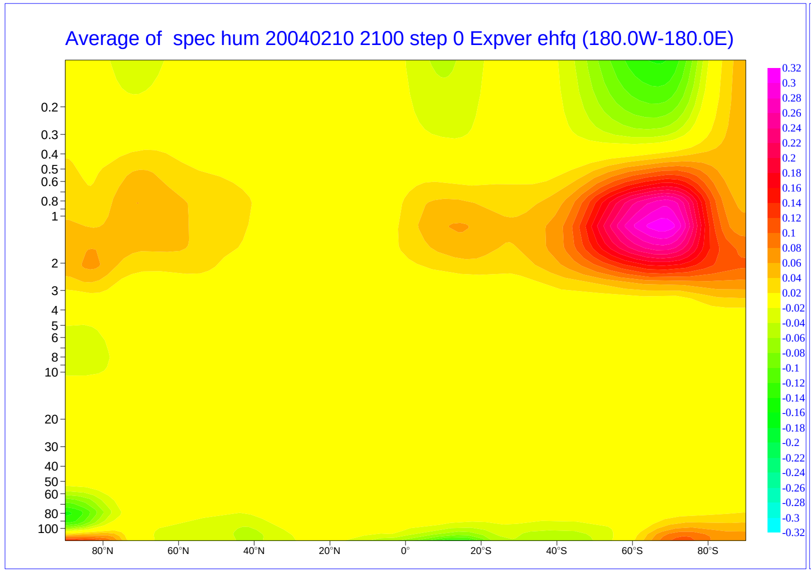
- MIPAS limb sounding radiances/retrievals: no longer fully operational.
- MLS limb sounding radiances/retrievals: not available in real time.
- Infrared/microwave radiances METOPS/GOES/HIRS/AMSU/AIRS: broad sensitivity peaking in troposphere, with residual "tails" of the sensitivity in the stratosphere.
- In summary, no useful real time stratospheric humidity observations.

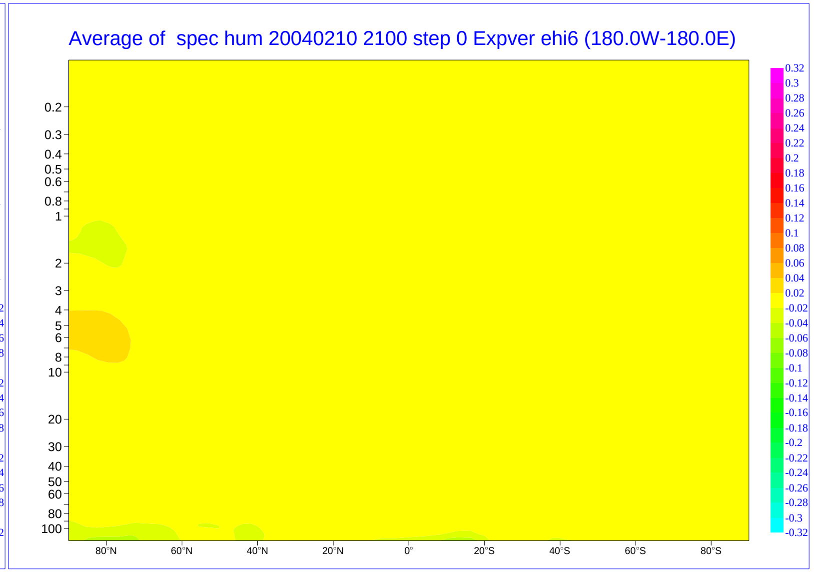
Stratospheric Humidity Analysis in an NWP System



- In the ECMWF system humidity background errors are set to very low values above the calculated tropopause.
- Without stratospheric humidity observations, upper tropospheric radiance observations sensitive to humidity put artificial increments into the stratosphere.
- Realistic humidity background errors gives humidity increments (right) at 1 hPa which are large fraction of the humidity (left, ppmm).

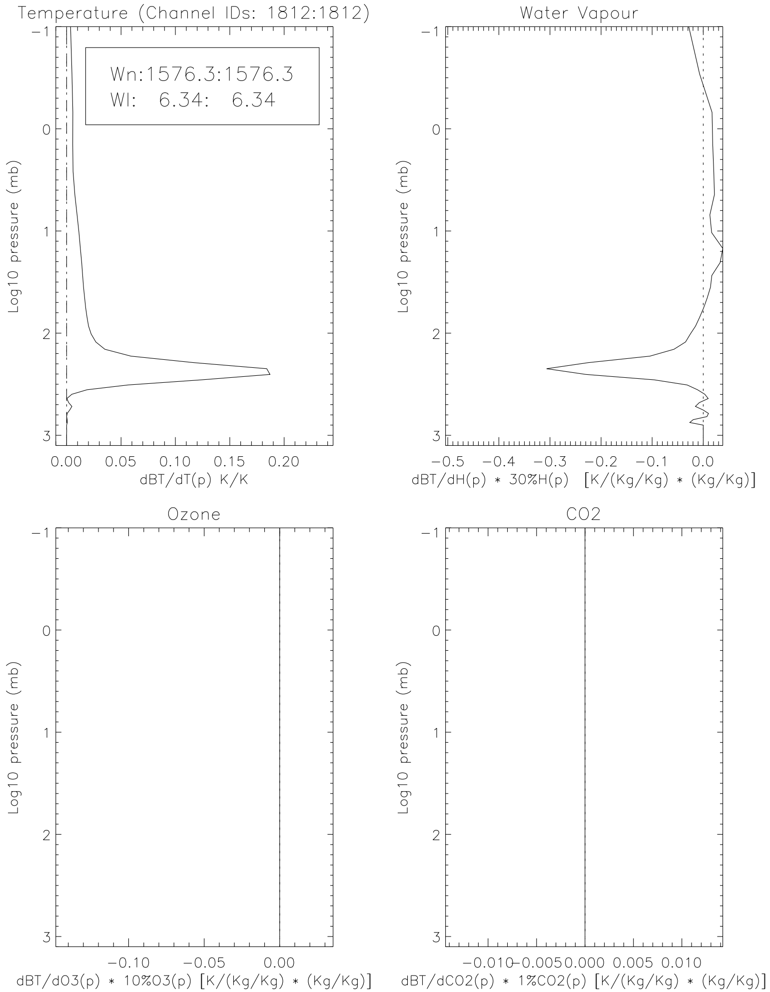
Preventing Radiances "Polluting" the Stratosphere





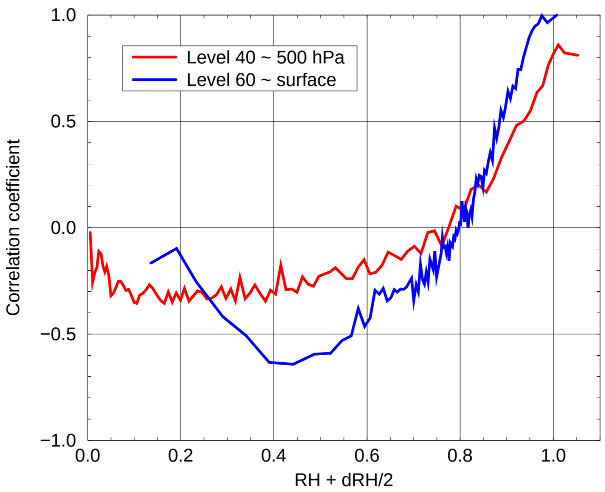
- These increments are from nadir sounding radiances which see and couple T and q at different levels in the atrmosphere: one radiance gives a complete profile of T, q, O_3 etc. increments.
- Removing sensitivity of the radiance observation operator to humidity above calculated tropopause: no q increments.
- Removing all AIRS radiances: no q increments.

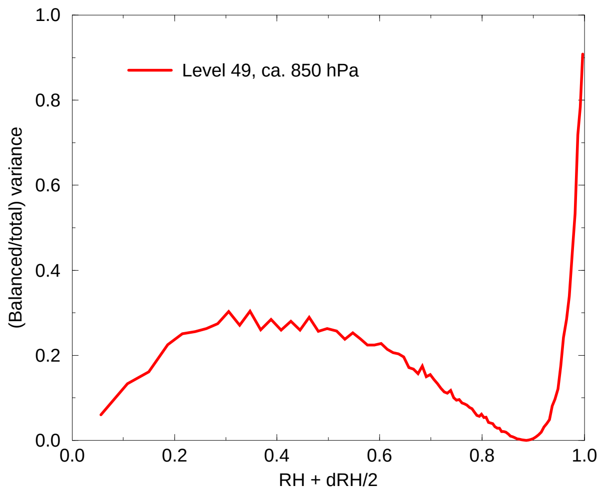
Selected AIRS Jacobian (observation sensitivity to model)



- Removing 10 AIRS water vapour channels with "stratospheric tail" in their humidity sensitivity: no q increments.

Humidity analysis variable: normalised Rh, q



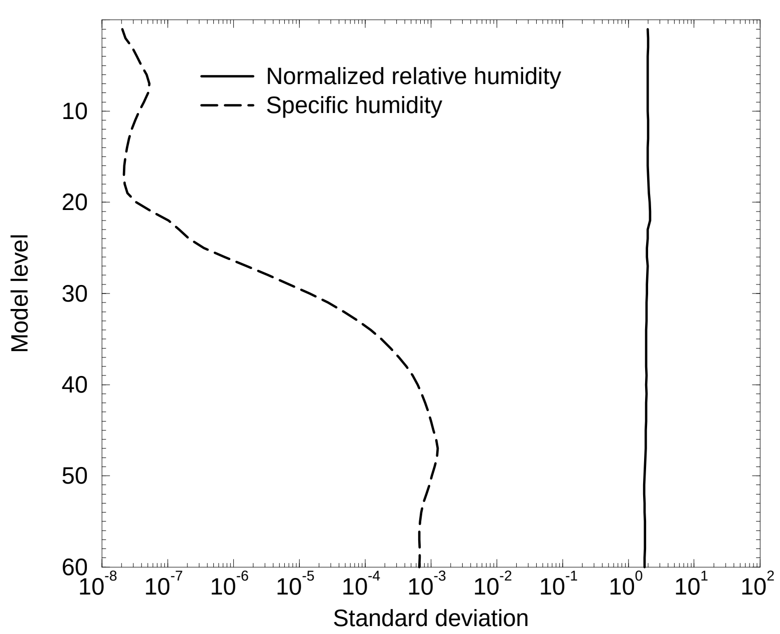


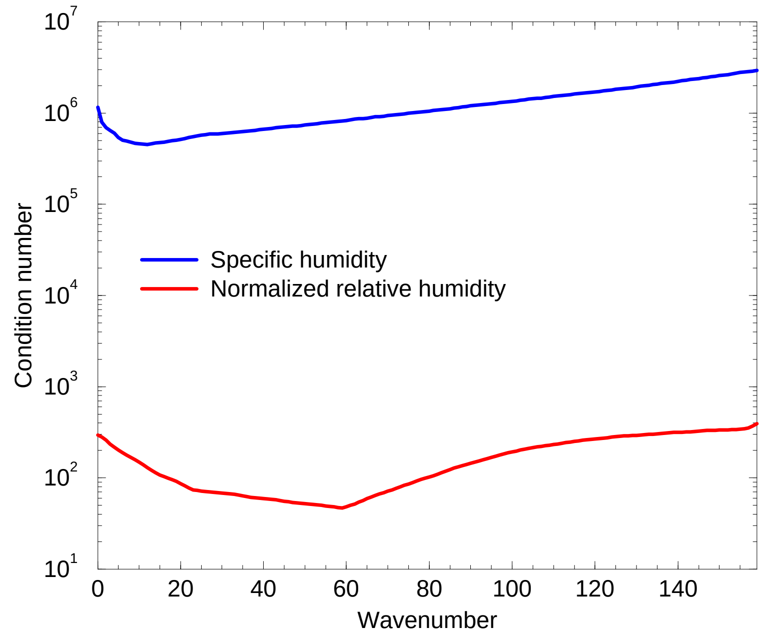
The humidity-temperature correlation coefficient Q varies with relative humidity

$$\frac{\delta q}{q_s^b} = (\frac{\delta q}{q_s^b})_u + Q(rh^b)\frac{rh^b L^b \delta T}{R_v (T^b)^2}$$

In the stratosphere humidity and temperature errors are uncorrelated, i. e. $Q = 0$. Smooth transition at calculated tropopause. Normalization with state dependent variances $\sigma(Rh)$.

Normalization and condition number

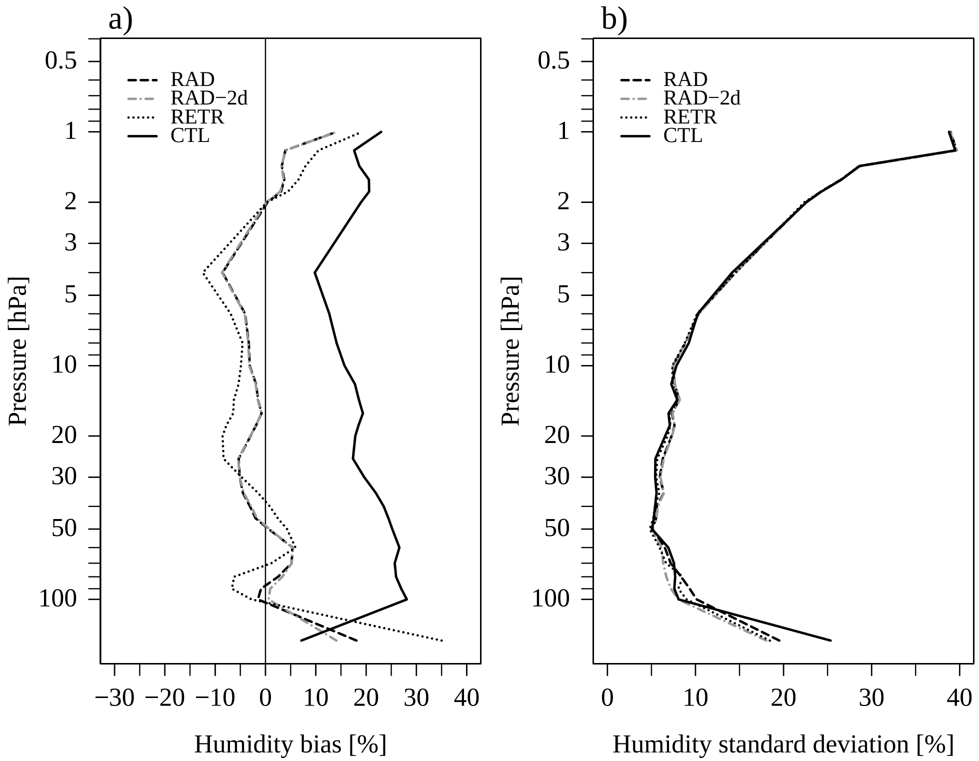




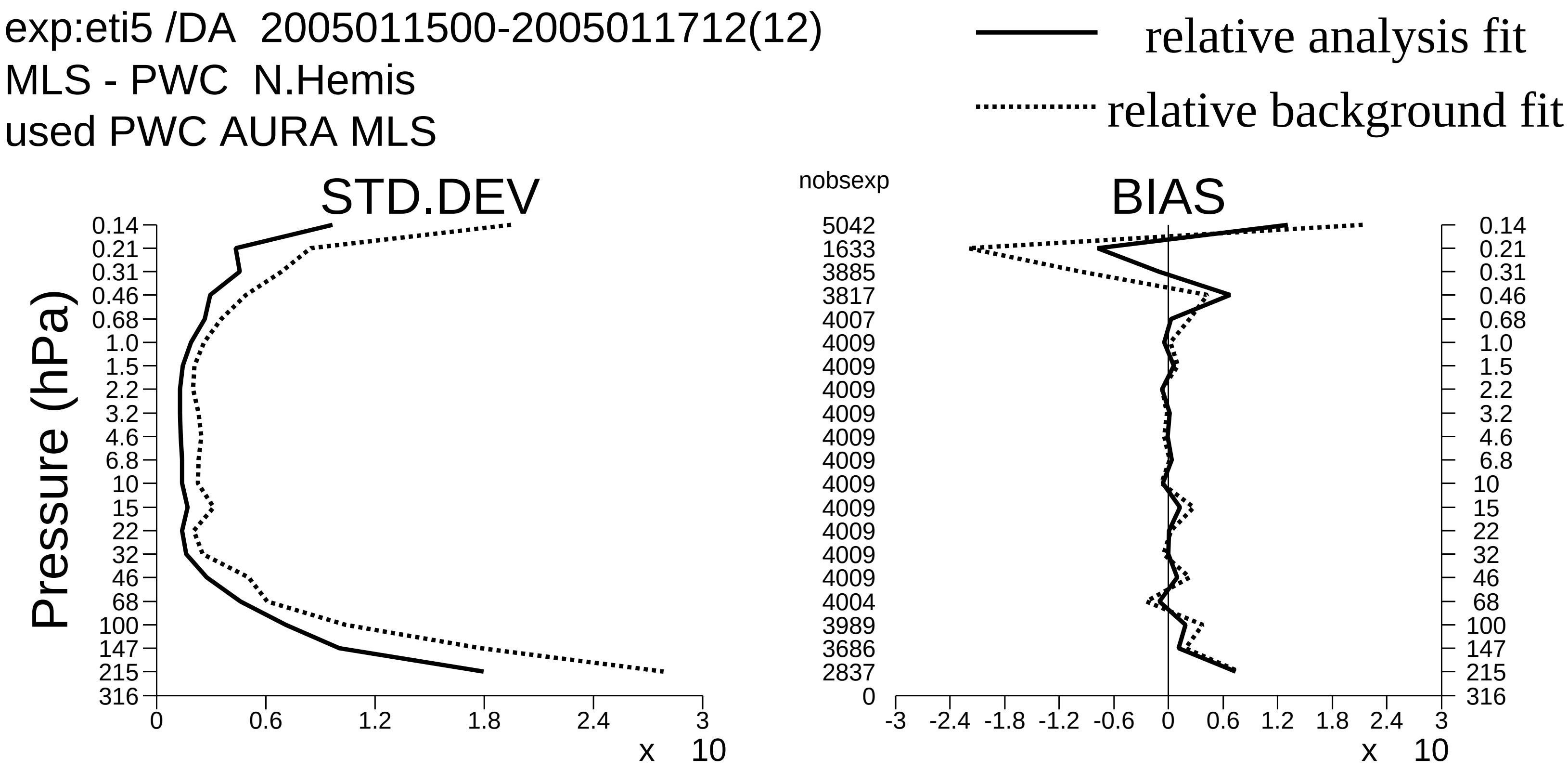
- The variance of the normalized control variable is uniform (≈ 1).
- The condition number of the B matrix is greatly improved, which helps in implementing stratospheric humidity analysis.

Stratospheric Water Vapour from MIPAS (N. Bormann, ECMWF)

- Retrievals (RETR), 1D-radiances (RAD), or 2D-radiances (RAD-2d) accounting for horizontal variation along limb give T, q, O_3 simultaneously. Reference without MIPAS (CTL).
- All three assimilation approaches give similar quality results.
- Compared with SAGE II retrievals (1-29/9 2003, 60-74N) biases (left) reduced but standard deviation (right) not changed much.

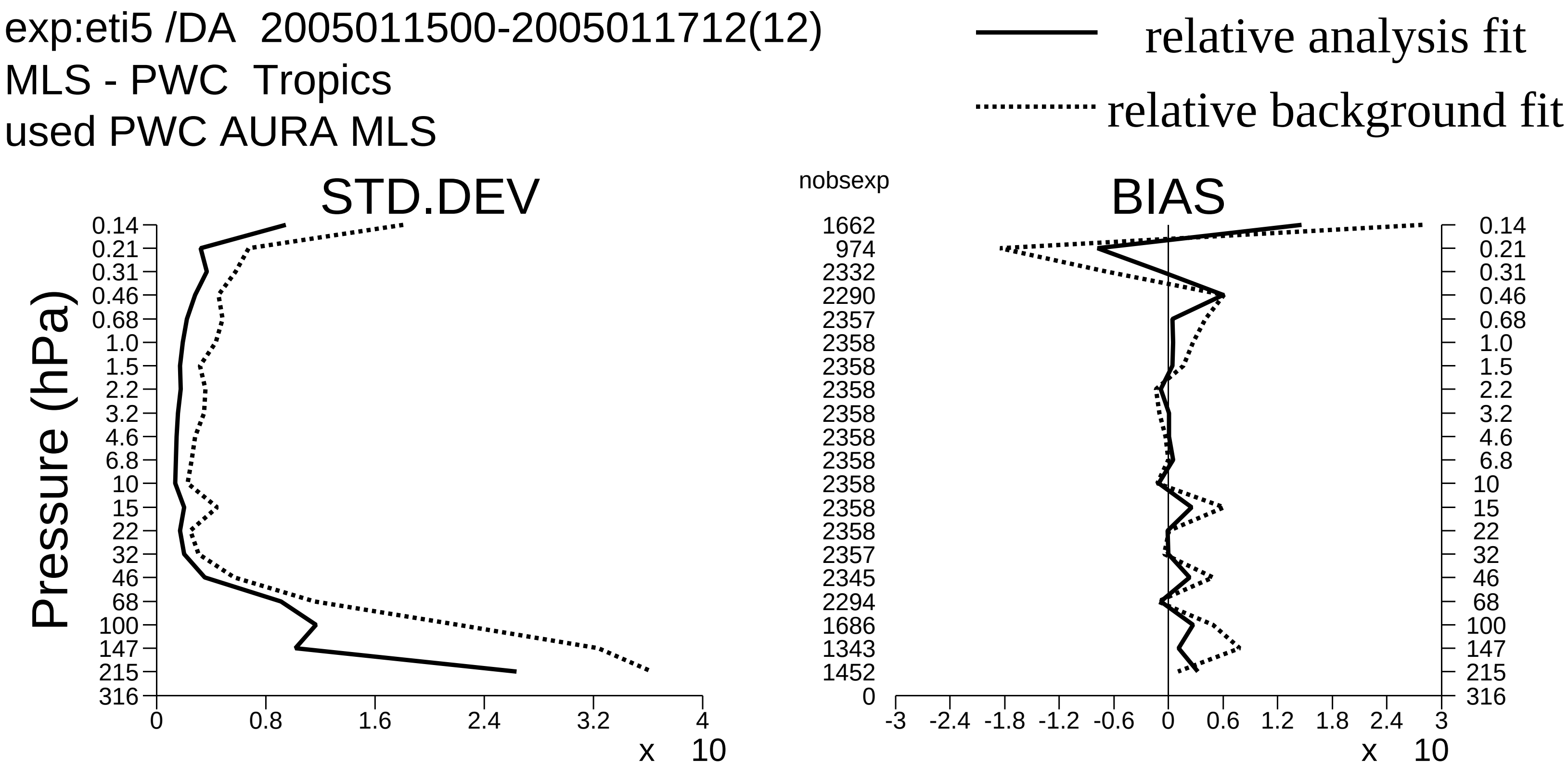


MLS normalized fit $(y - H(x))/H(x^b)$ (in percent)



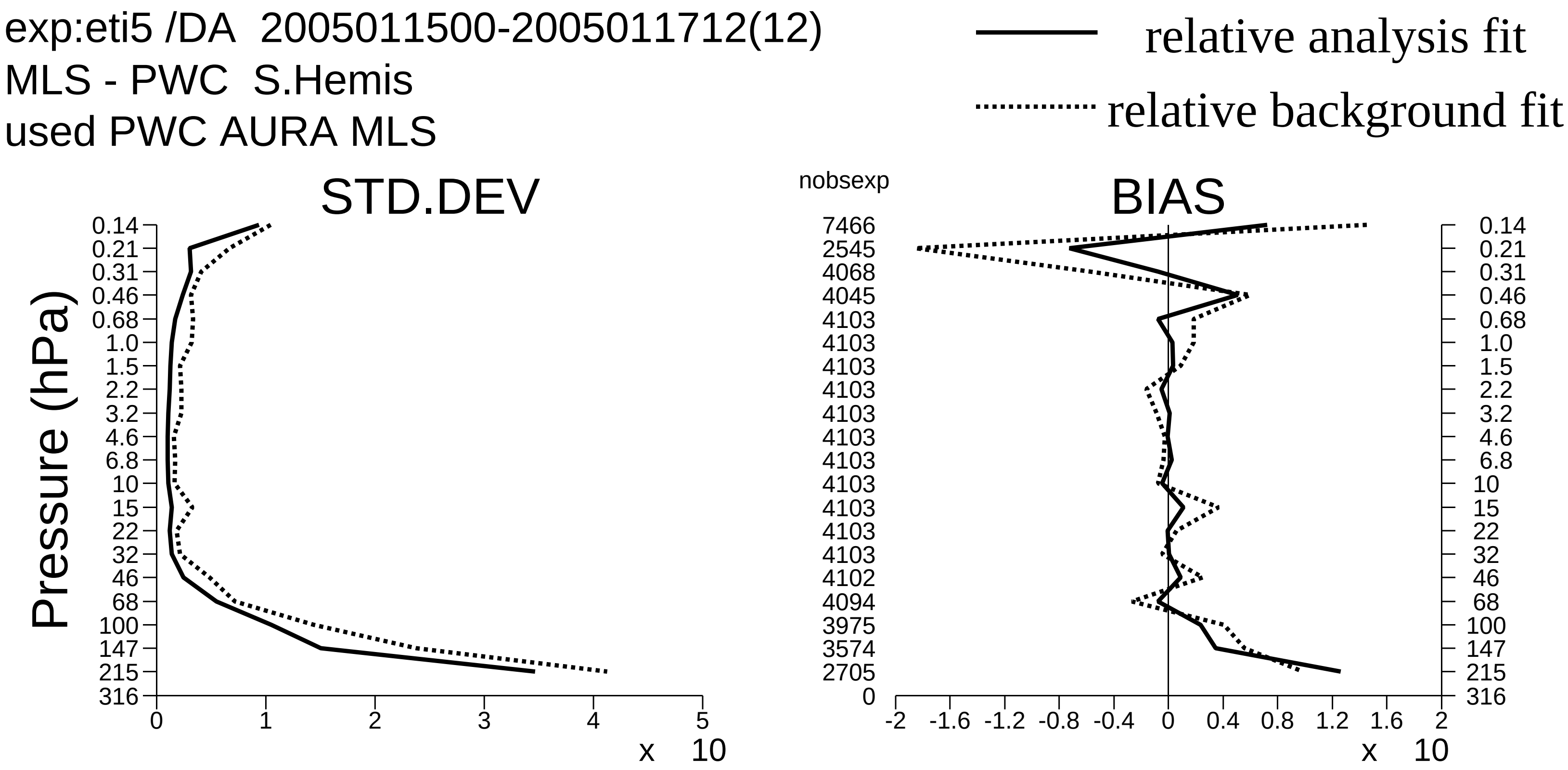
Northern hemisphere 20N-90N

MLS normalized fit $(y - H(x))/H(x^b)$ (in percent)



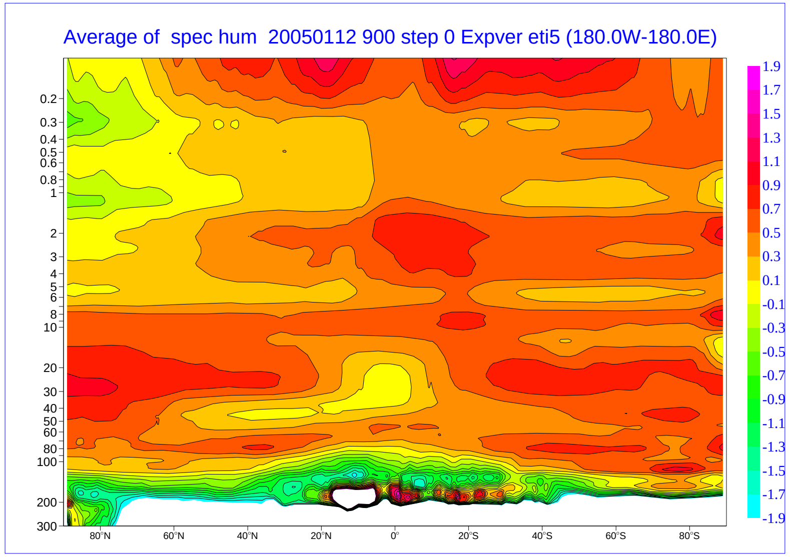
Tropics 20S-20N

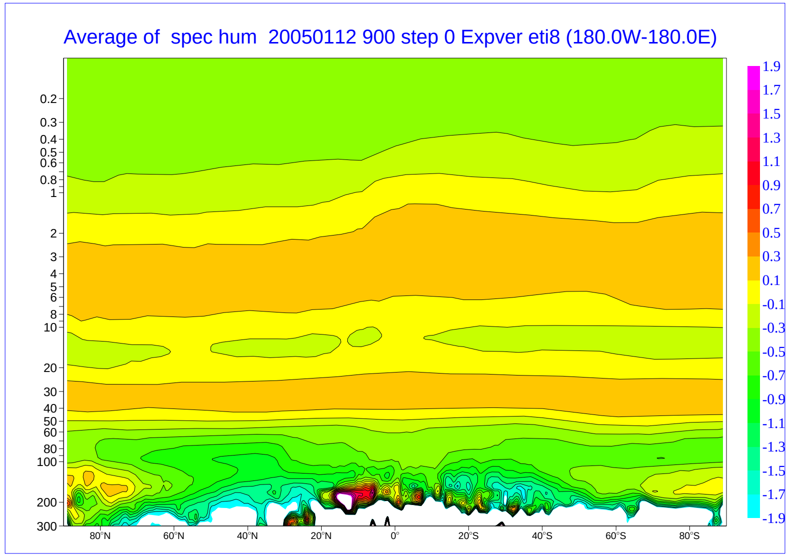
MLS normalized fit $(y - H(x))/H(x^b)$ (in percent)



Southern hemisphere 20S-90S

Differences in zonal average q after 12 day assimilation

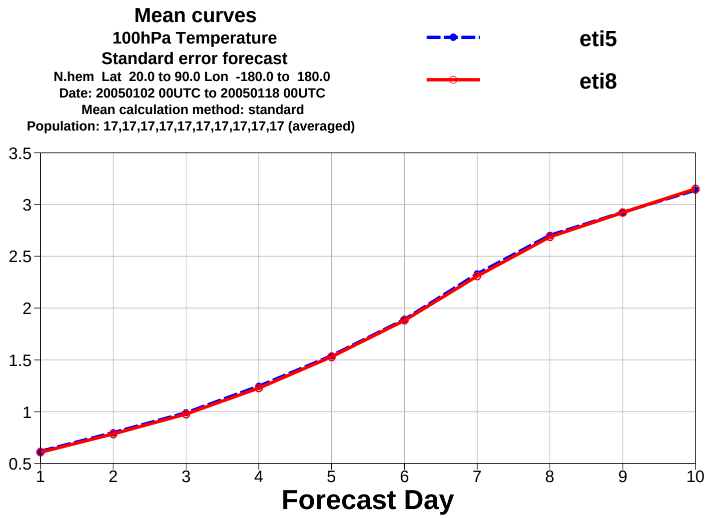


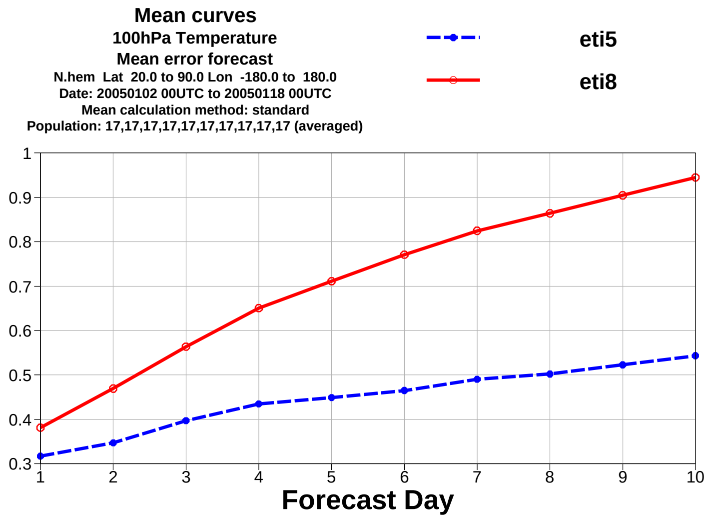


- Left: MLS assimilation - Reference with negligible humidity background errors in stratosphere.
- Right: Experiment with humidity errors in stratosphere - Reference.
- MLS changes structure quite significantly, but need longer runs for full evaluation.
- Leaving humidity analysis "on" in stratosphere creates significant differences just above the tropopause. Not advisable without LS observations.

Verification against operational analyses

- Experiment eti5 assimilates MLS humidity retrievals.
- Experiment eti8 has same background errors in stratosphere.
- Similar scores. MLS does at least not interfere destructively...
- Looking at T, NH, 100hPa, different humidity in LSUT now gives different drift towards model climatology.





MLS Assimilation

- Analysis draws to observations. Longer experiments needed to evaluate meteorological impact.
- Use of data around tropopause is challenged by the presence of clouds, but microwave (MLS) is less sensitive than infrared (MIPAS).

Conclusions and Further Work

- Stratospheric water vapour assimilation needs new real time data. MLS?
- Radiance observations create artificial troposphere-stratosphere interaction which needs to be controlled.
- Given the significance of the tropopause, develop analysis in tropopause-following coordinate.