METEO FRANCE
Toujours un temps d'avance

Assimilation of GPS radio occultation measurements at Météo-France

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GRAS-SAF Workshop
« Applications of GPS radio occultation measurements »
ECMWF, 16-18 June 2008

Outline

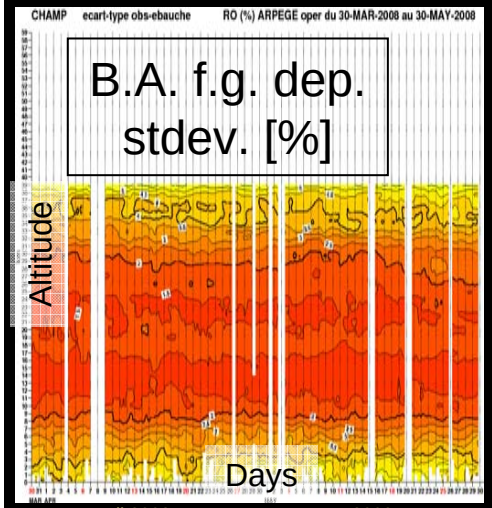
1. Status of GPSRO operational assimilation at MF
2. Next improvements
3. Data impact studies
4. Recent changes in the model that affected O-B fit
5. Assessment of different datasets: estimation of observation errors
6. First-look at GRAS (SAF) data

Status of GPSRO assimilation

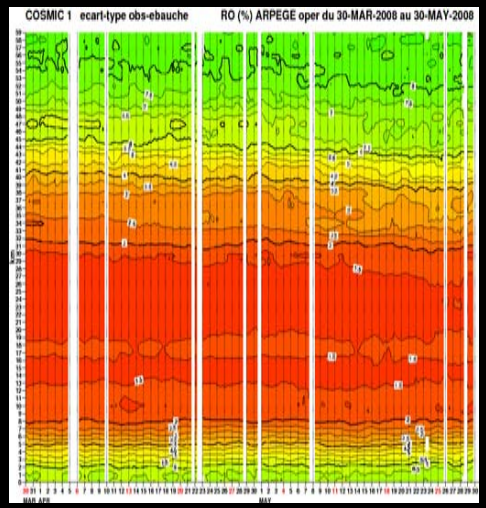
- Operational assimilation:
  - In the global 4DVAR and European LAM 3DVAR, since Sep2007
  - Bending angles (1D operator+TL/AD from GRAS-SAF)
  - CHAMP and GRACE-A, data from GFZ *via* GTS
  - FORMOSAT-3/COSMIC 1—6, data from UCAR *via* GTS
- Rising and setting occultations
- Up to 18 km altitude
- Down to 6 km (NH and tropics) … 1 km (SH pole)
- Vertical thinning: 1 datum per model vertical layer
- QC: retain bending angle data only if:
  - $-0.01\ km^{-1} > dN/dz$
  - dN/dz at all levels above $> -50\ km^{-1}$
  - $|\ d^2N/dz^2\ |$ at all levels above $< 100\ km^{-2}$
  - Occultations extend down to 10 km altitude or below

Status of GPSRO assimilation

CHAMP



F3C-1



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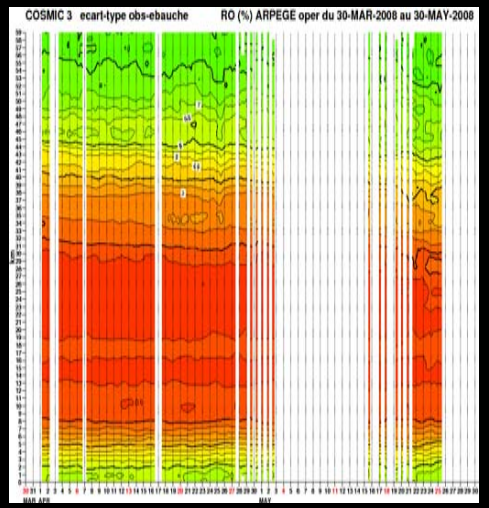

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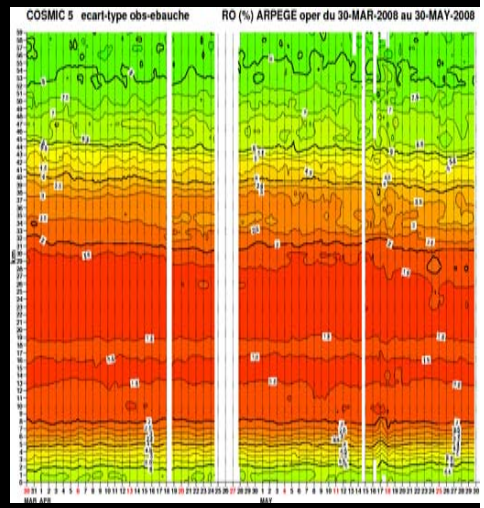
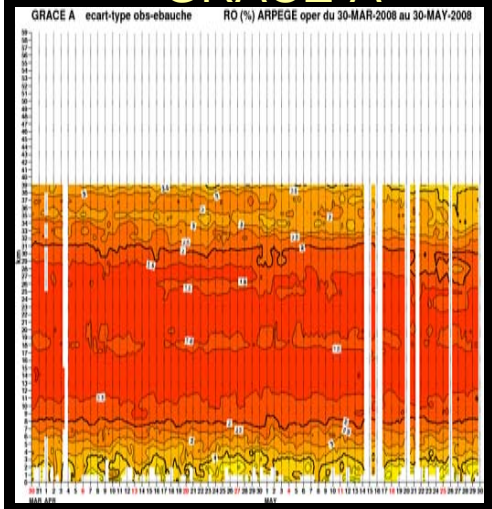
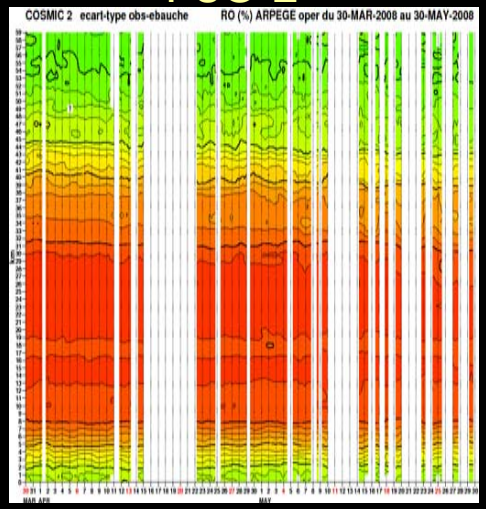


DPREVI/COMPAS

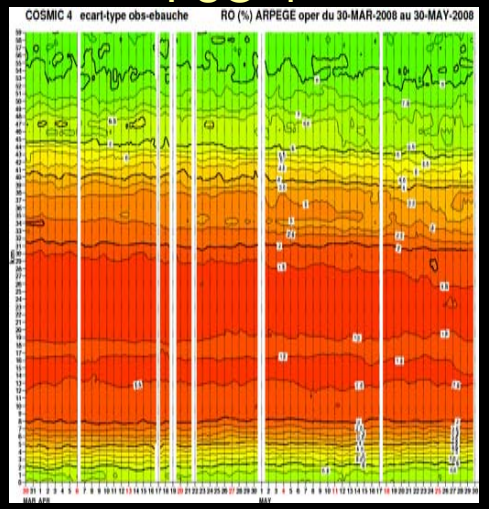
GRACE-A



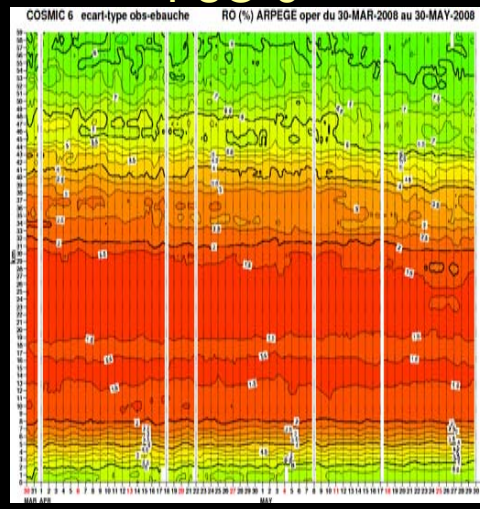
F3C-2



F3C-4



F3C-6



Next Improvements

- Current experimental suite (started Feb 2008)
  - Extend upper limit from 18 to 25 km altitude
  - Extend lower limit in NH pole from 6 to 1 km altitude
  - Revise thinning
    - Use the lowest observation within each model vertical layer
  - Apply the BUFR quality flag to remove profiles:
    - With per cent confidence <= 99.9%
    - Marked as any of the following:
      - Non-nominal quality
      - Excess phase processing non-nominal
      - Bending angle processing non-nominal
      - Background profile

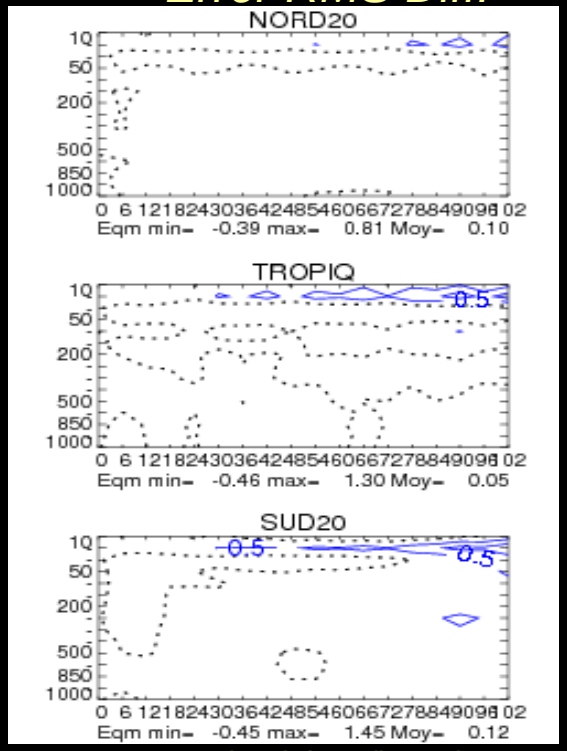
Impact of the Next Improvements on Forecast Skill

Δ =
- GPSRO assimilation between 18-25 km
- GPSRO assimilation below 6 km in the NH

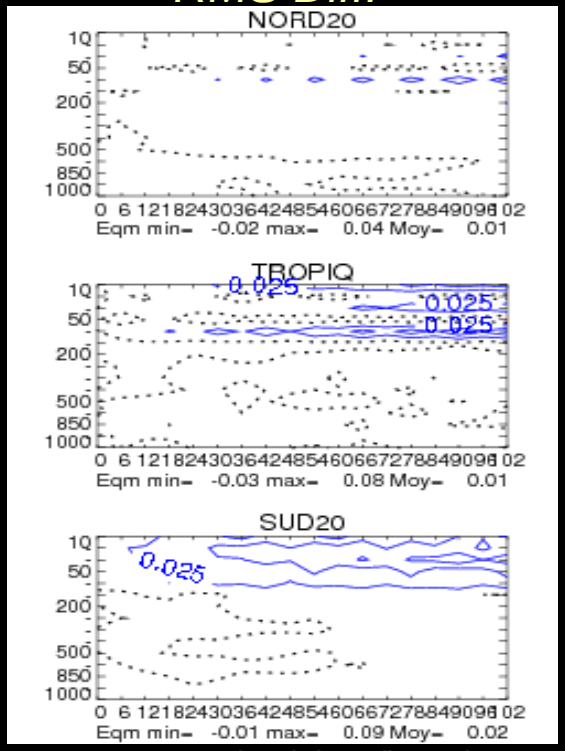
BLUE=better
RED=worse

36 forecasts
6 Sep – 15 Oct 2007
Verification : analyses

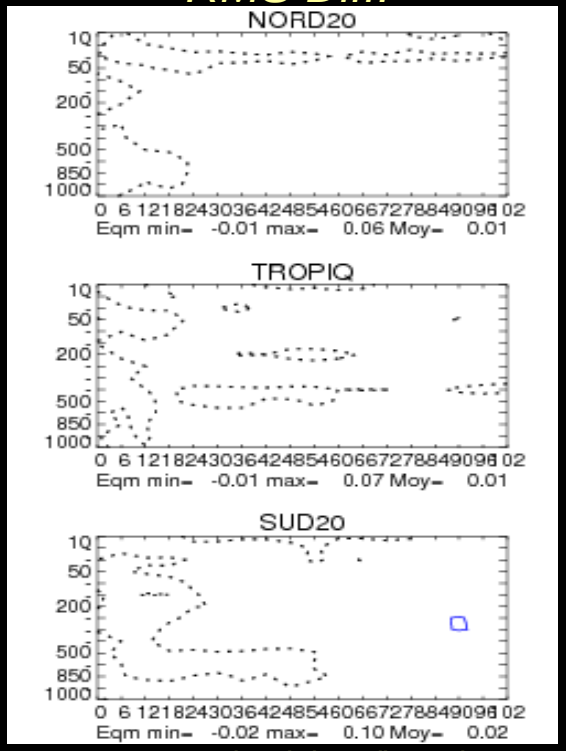
Geopotential Height Error RMS Diff.



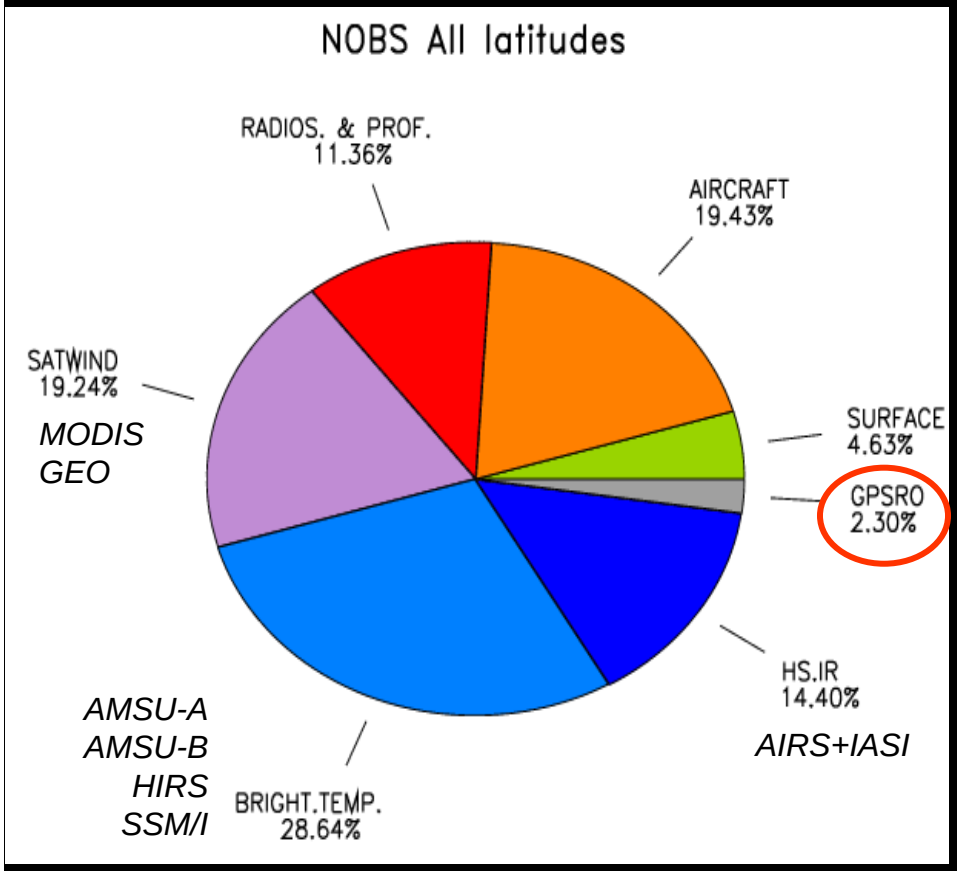
Temperature Error RMS Diff.



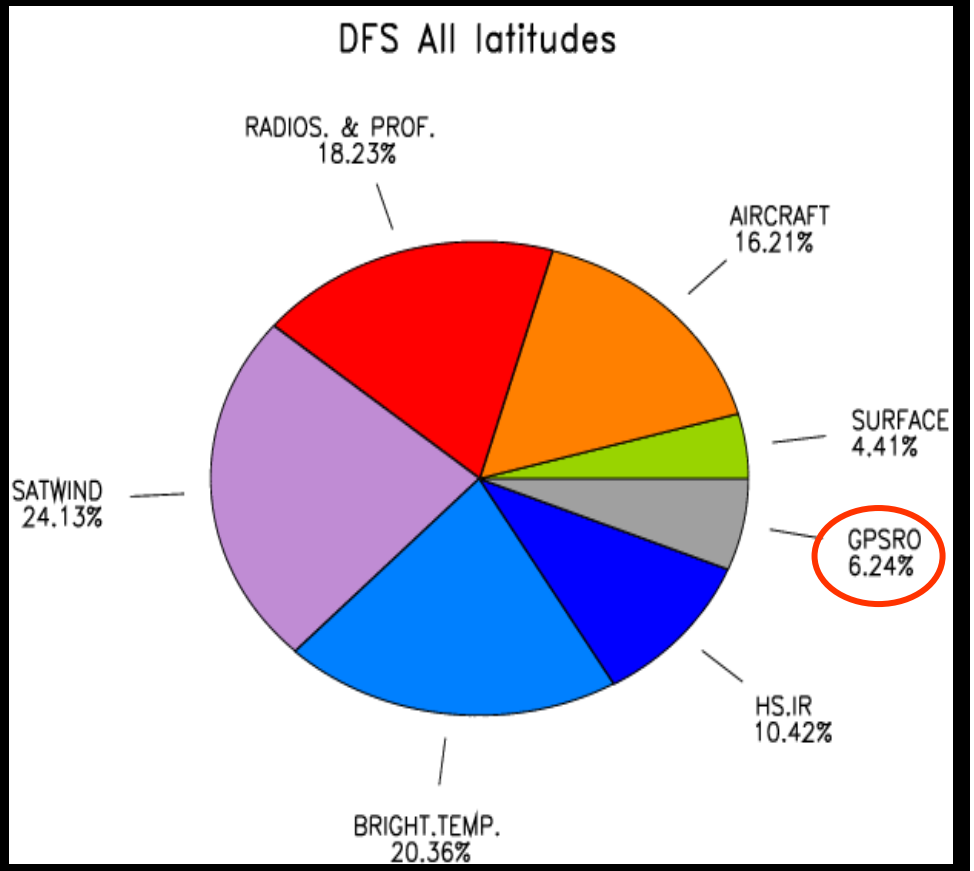
Wind Error RMS Diff.



Impact on analyses: DFS

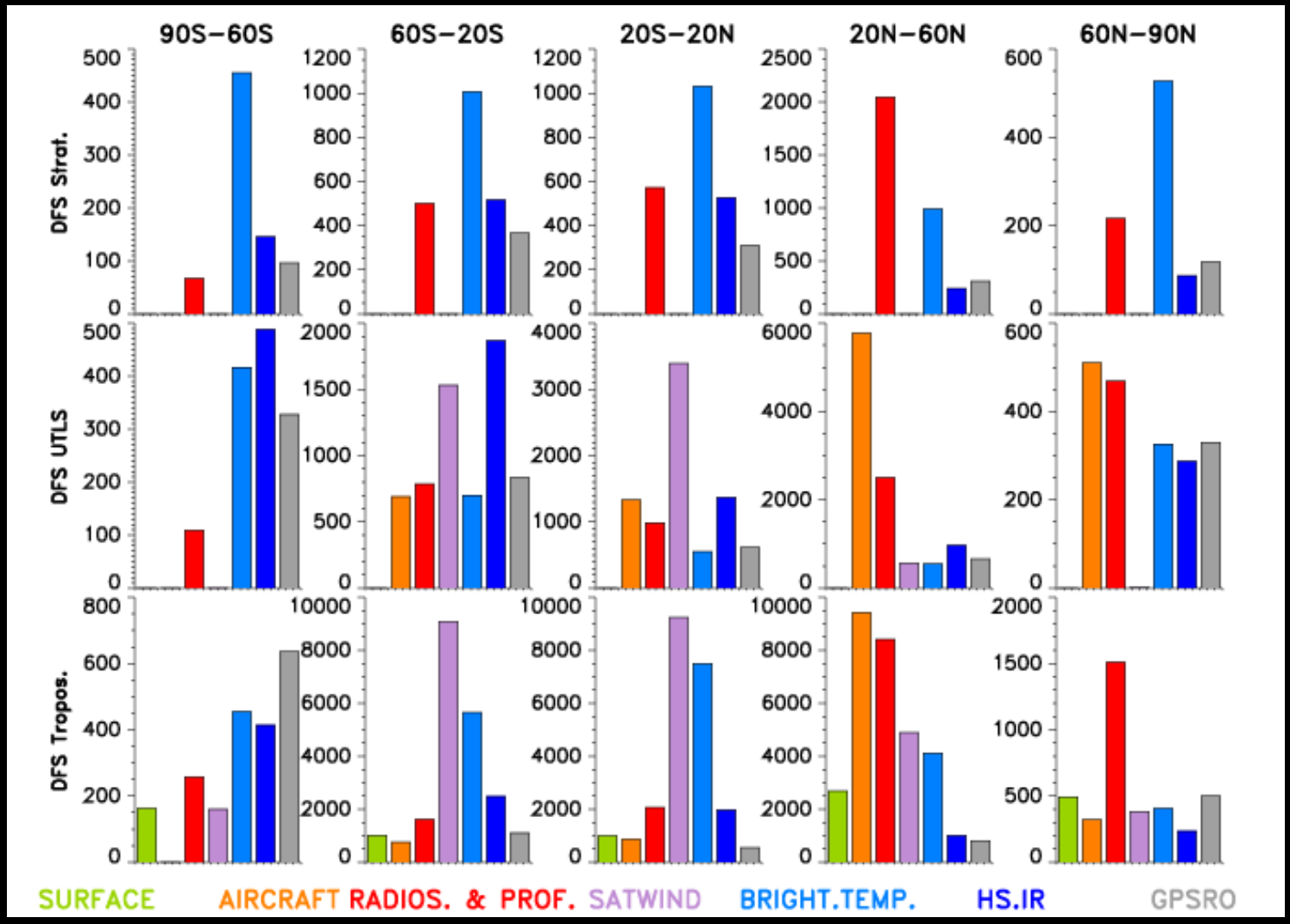


Number of observations assimilated in one day in the global 4DVAR



Degrees of Freedom for Signal (DFS)

Regional DFS



Impact on Weather Forecasts

- 4DVAR assimilation and forecast experiments:

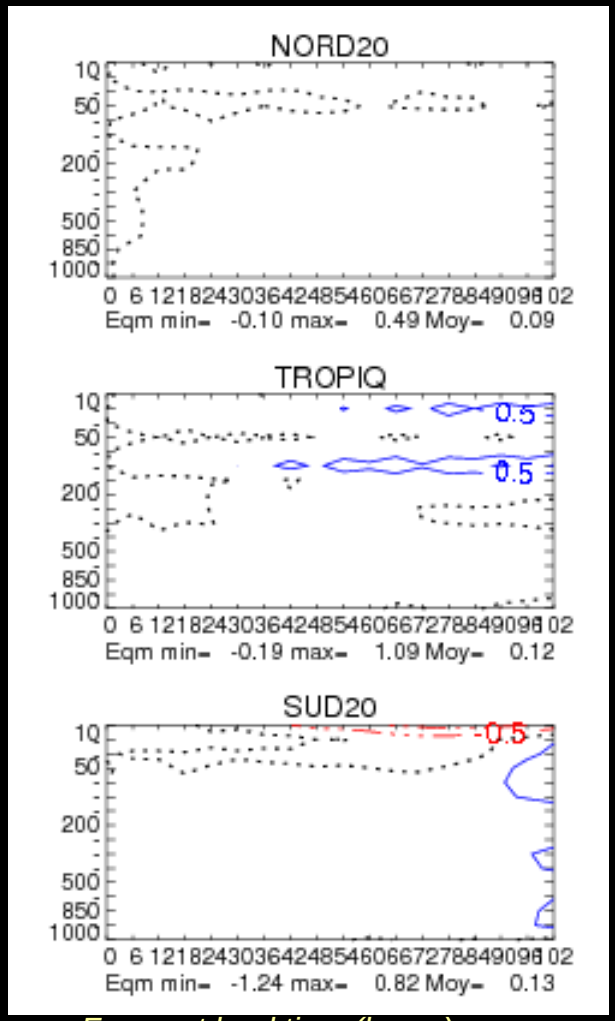
CONTROL	copy of operational suite without GPSRO data (all other observations assimilated)
GPSRO_FULL	CONTROL + GPSRO data
GPSRO_HALF	CONTROL + half of the GPSRO data exclude one profile out of two @ obs extraction

- Use GPSRO setup of the latest experimental suite
- 21 forecasts, 6—30 Sep 2007 ; Verification: analyses

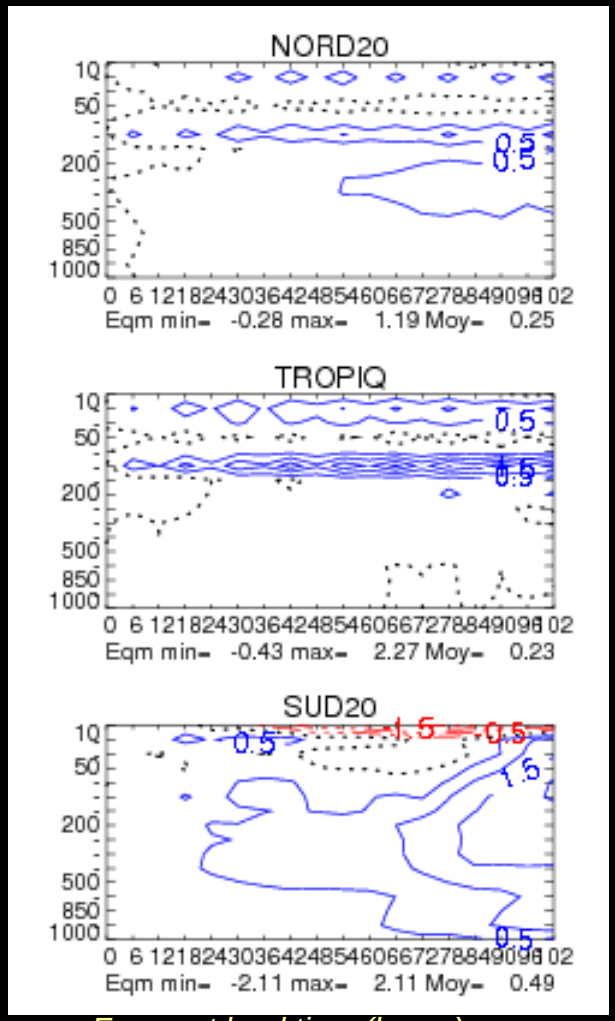
- Goal is to determine whether the improvement in forecast skill scales as the number of GPSRO soundings available

Impact on the geopotential forecast skill

CONTROL - GPSRO_HALF



CONTROL - GPSRO_FULL



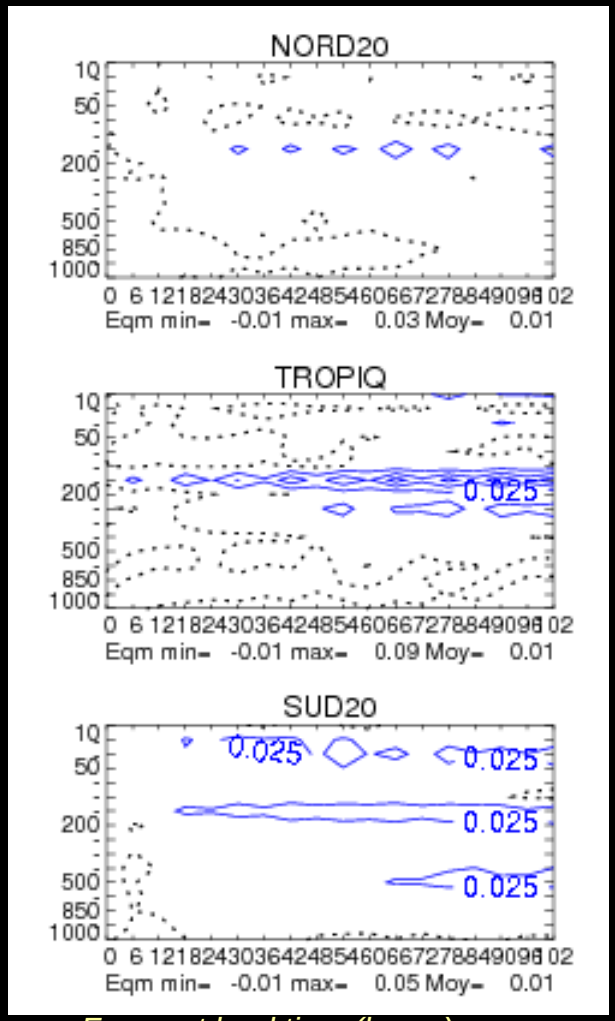
ΔRMSE

BLUE=better than CONTROL

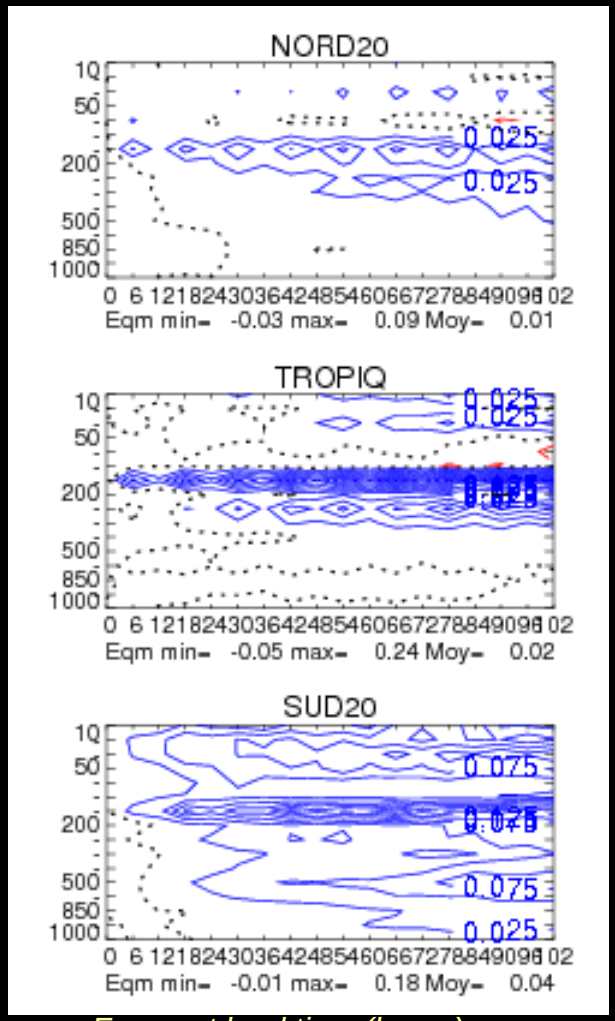
RED=worse than CONTROL

Impact on the temperature forecast skill

CONTROL - GPSRO_HALF



CONTROL - GPSRO_FULL



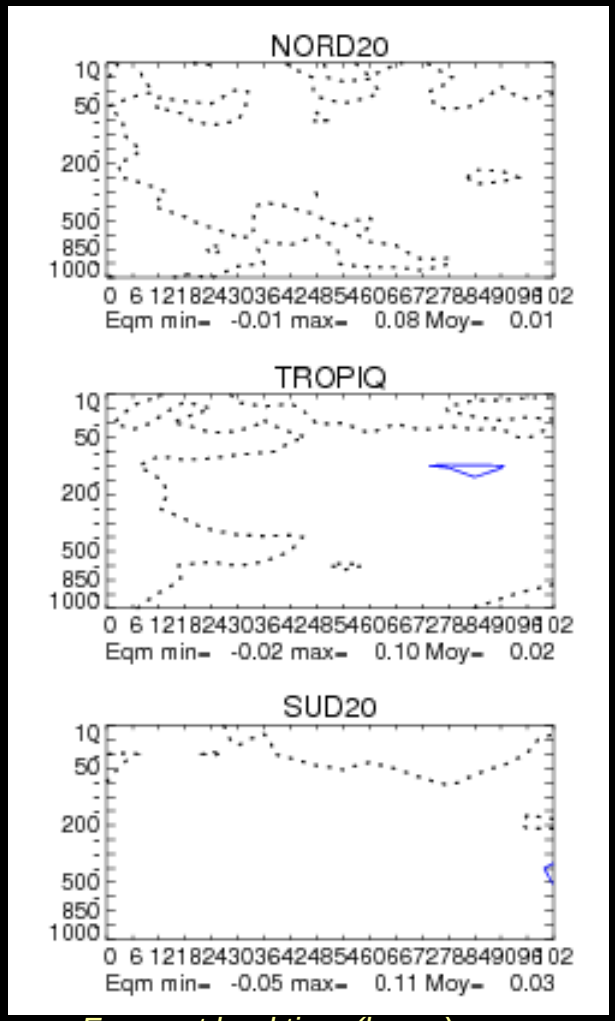
ΔRMSE

BLUE=better than CONTROL

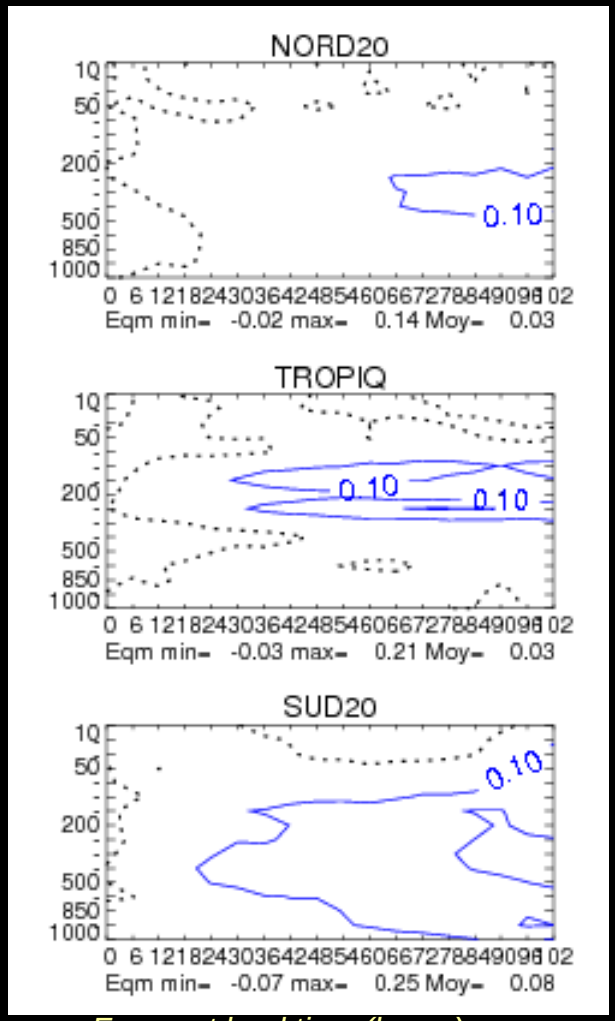
RED=worse than CONTROL

Impact on the wind forecast skill

CONTROL - GPSRO_HALF



CONTROL - GPSRO_FULL



ΔRMSE

BLUE=better than CONTROL

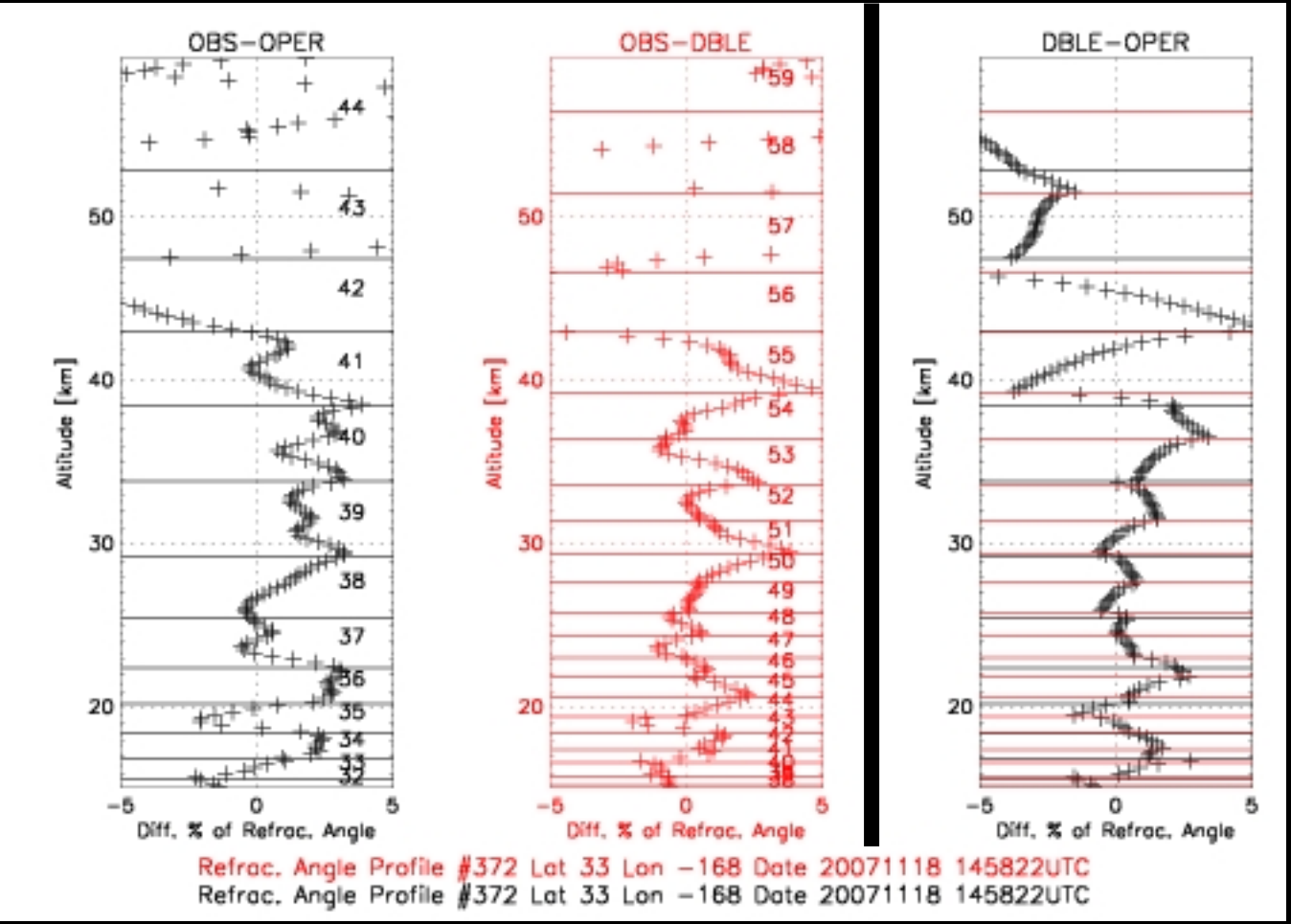
RED=worse than CONTROL

Recent difficulties for high altitudes

- Model resolution changed from 46L to 60L in Autumn 2007, *using a new vertical discretization and finite elements*
- Noticed spurious oscillations in O-B for GPSRO above ~25 km in the resulting data assimilation system
- Initially believed that GPSRO data were the cause of the problem
- Investigation: looked at profiles in detail

O-B changes with finite elements

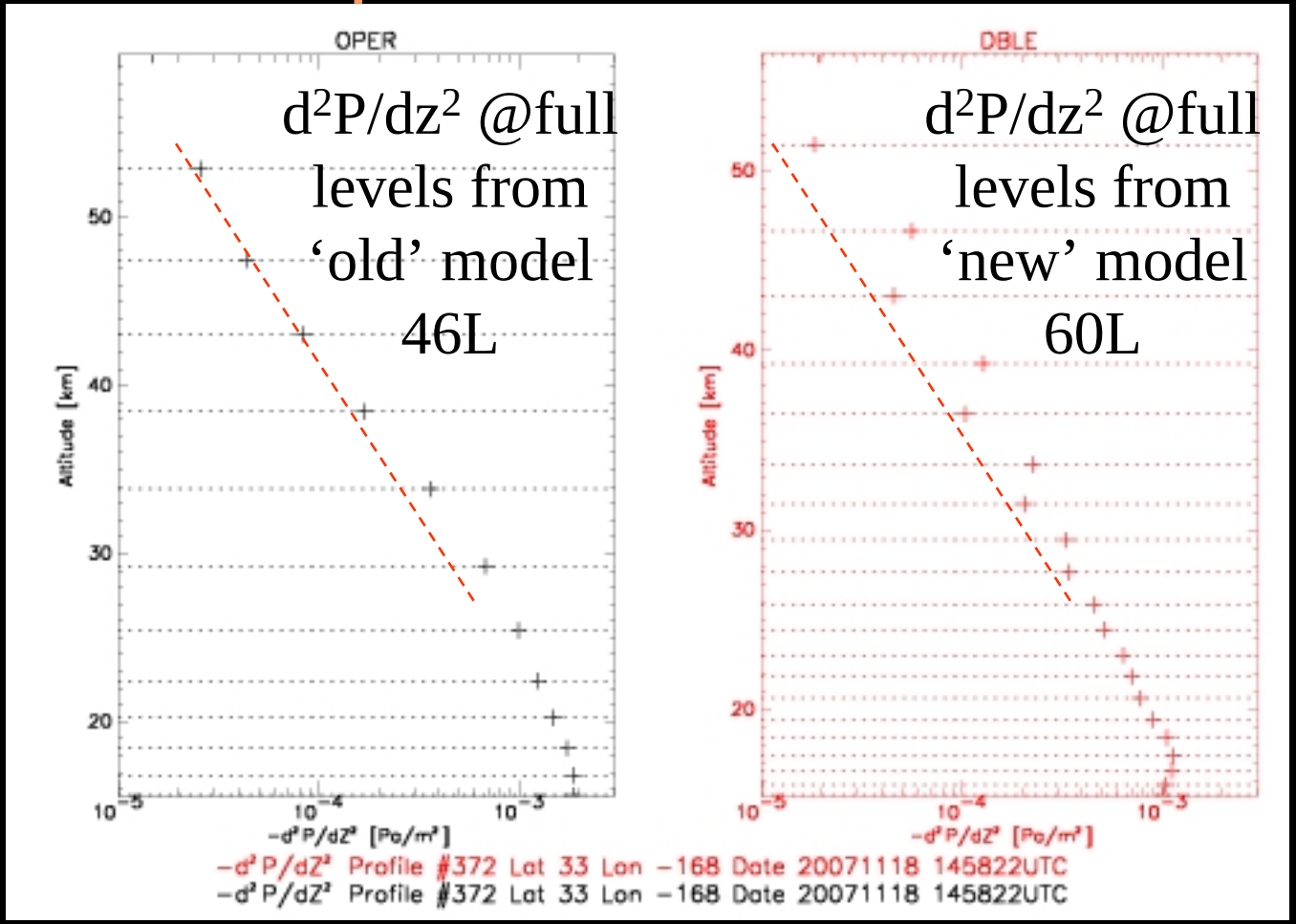
O - B 46L O - B 60L B 60L – B 46L



Explanation

Investigation:
1D Abel transform integrates *dN/dz*, which is proportional to $d\rho/dz$, itself proportional to d^2P/dz^2

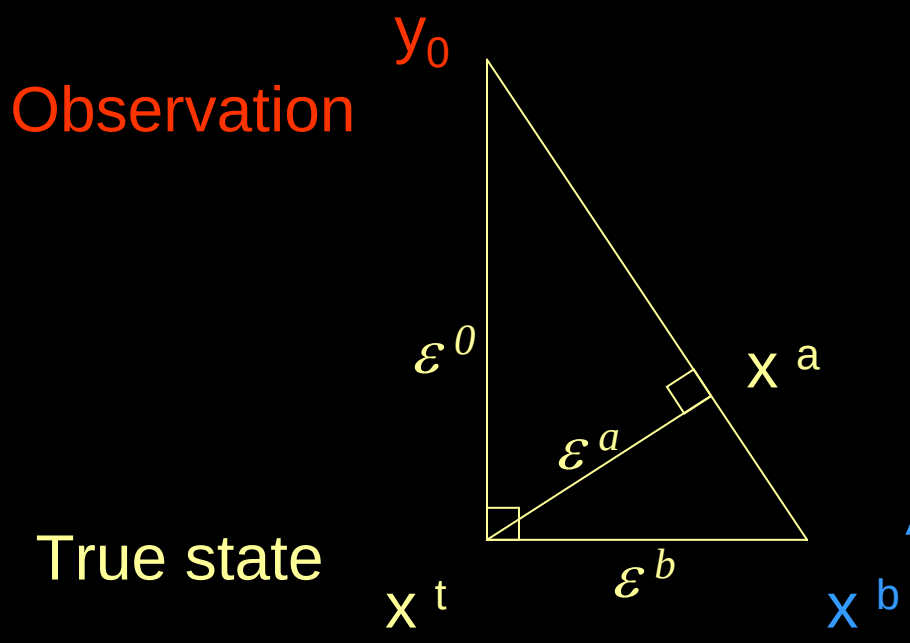
➔ *Show here d^2P/dz^2 from the old and new models:*



➔ Identified and recognized cause: fields at the full model levels are not completely consistent with fields at half model levels

Investigations of data quality (1/2)

- Use the diagnosis from Desroziers et al. (2005) to estimate the observation error covariance matrix **R**



Desroziers' triangle

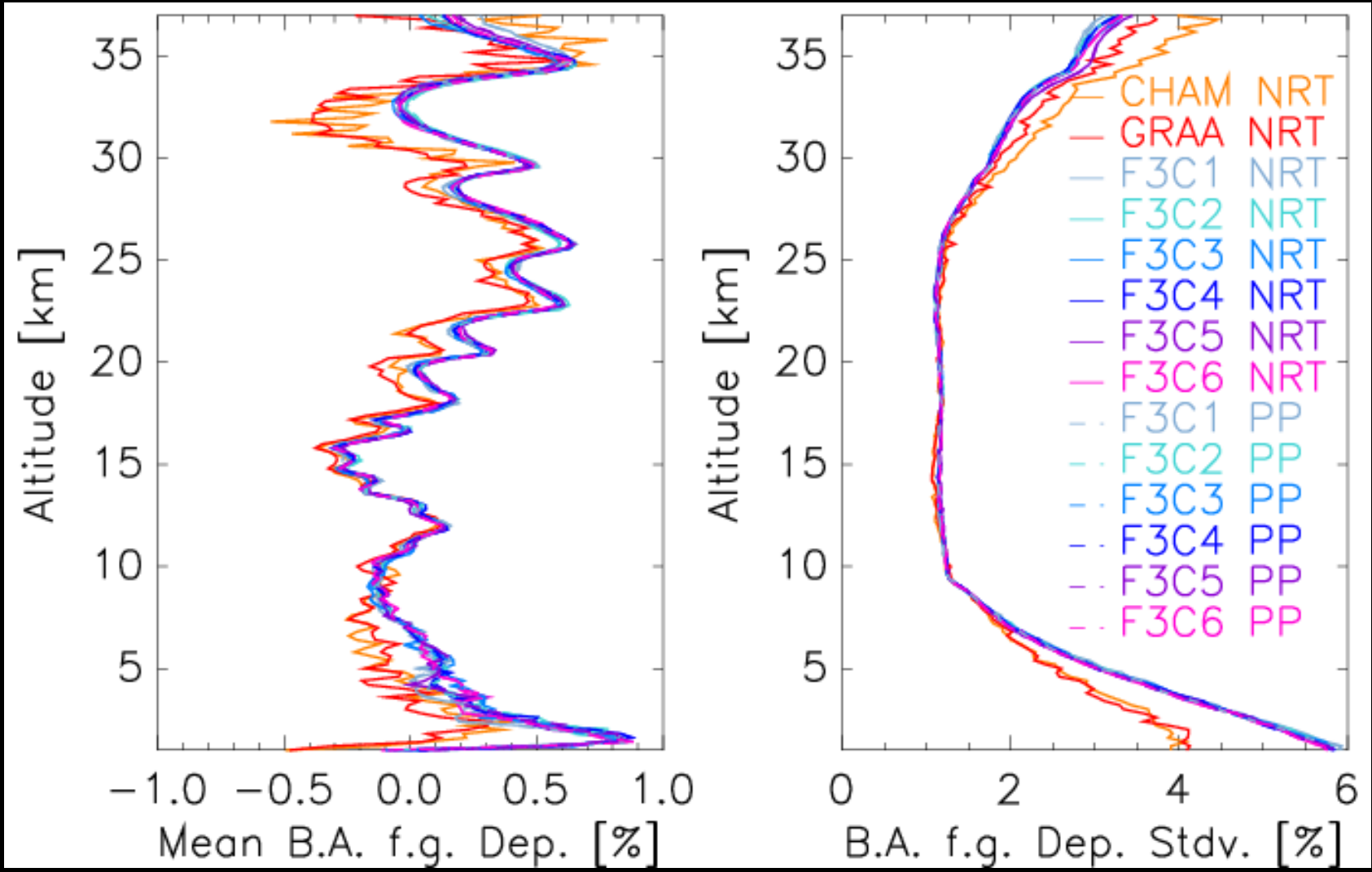
Investigations of data quality (2/2)

- Methodology
  - Run analyses (non-cycling) with 4DVAR assimilation
  - Using GPSRO data, alongside all other observations
  - Assuming observation errors std. dev.
    - 6% between 0-10 km, 1% above (max. 6 microrad)
  - Assimilate all data provided they passed the following QC:
    - Background check between 0-40 km, with a maximum f.g. departure of 20%
    - No other QC is applied
  - Apply Desroziers' triangle formula

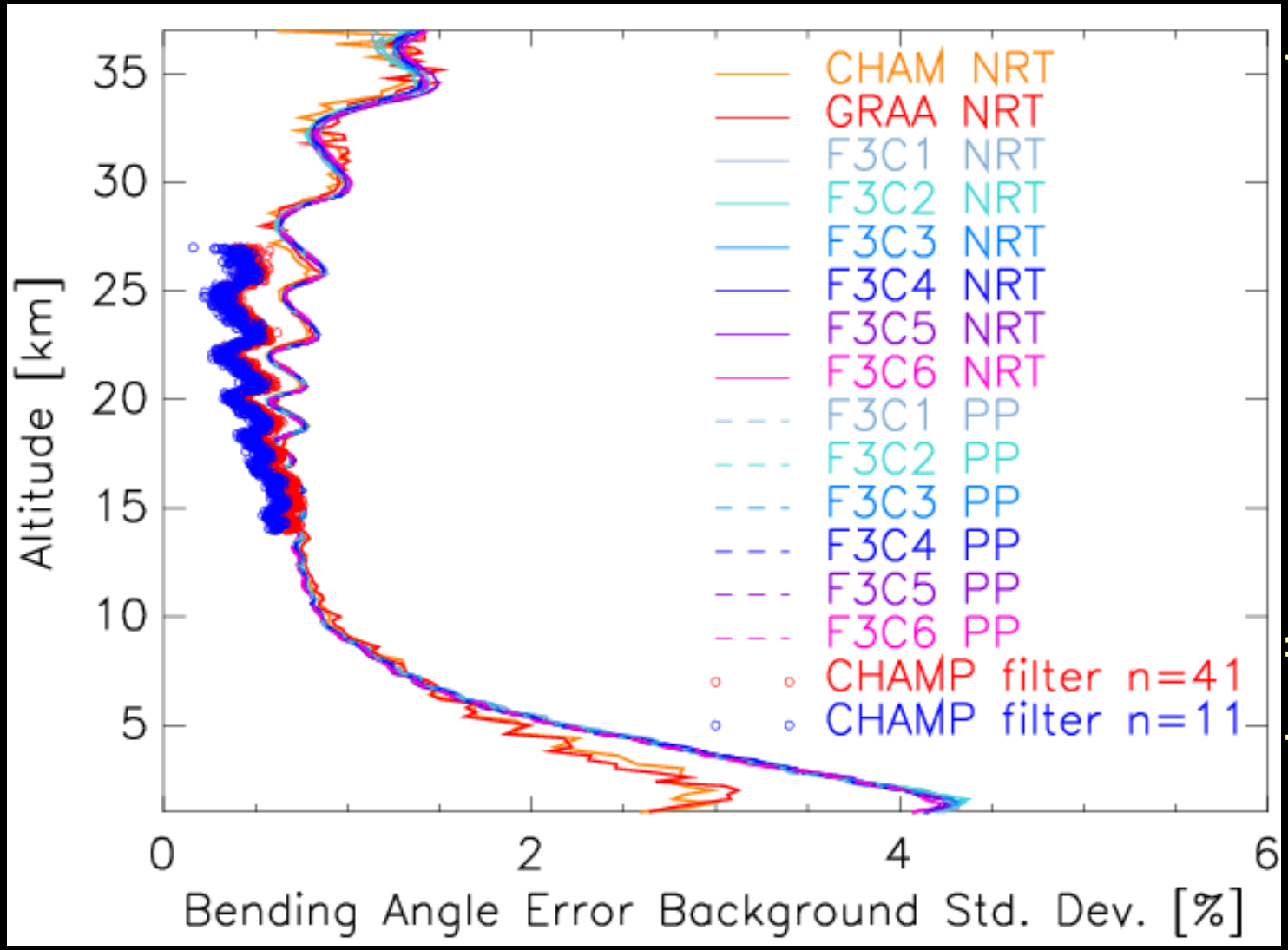
GPS RO Datasets Investigated

Satellites	*Type*	*Source*	*Approx Sampling*	*Date*
F3C 1-6	NRT	UCAR via CDAAC	200 m	Dec 2007
CHAMP & GRACE-A	NRT	GFZ via GTS	200 m	Dec 2007
F3C 1-6	Post-processed	UCAR via CDAAC	200 m	Dec 2007
CHAMP	Experimental processing: polynomial filter order 3, no wave optics, no statistical optimization	GFZ via FTP	10 m	Jan 2007

Comparison of the f.g. departures for Dec 2007



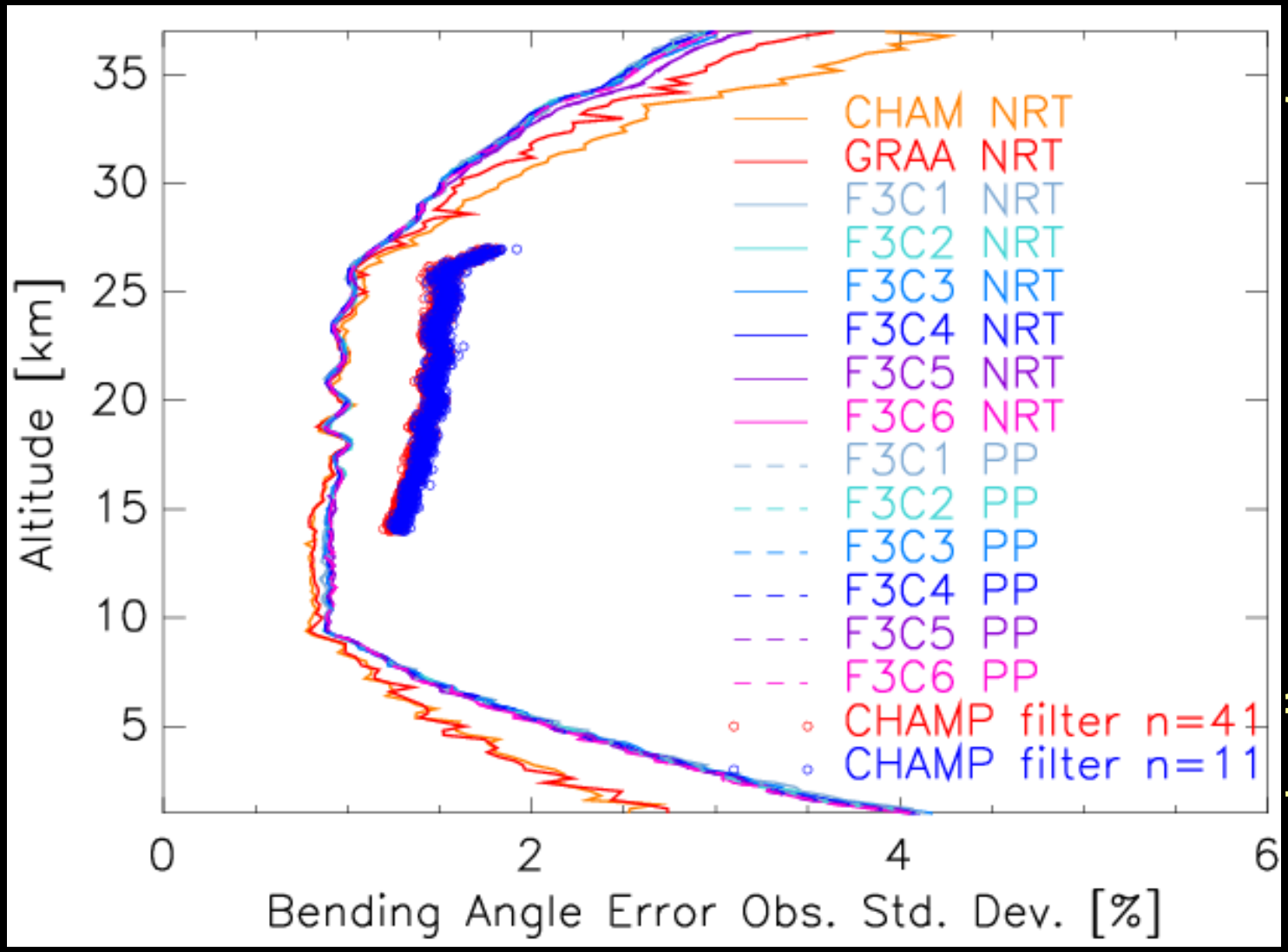
Background error estimate



Dec 2007
200 m vert. resol.

Jan 2007
10 m vert. resol.

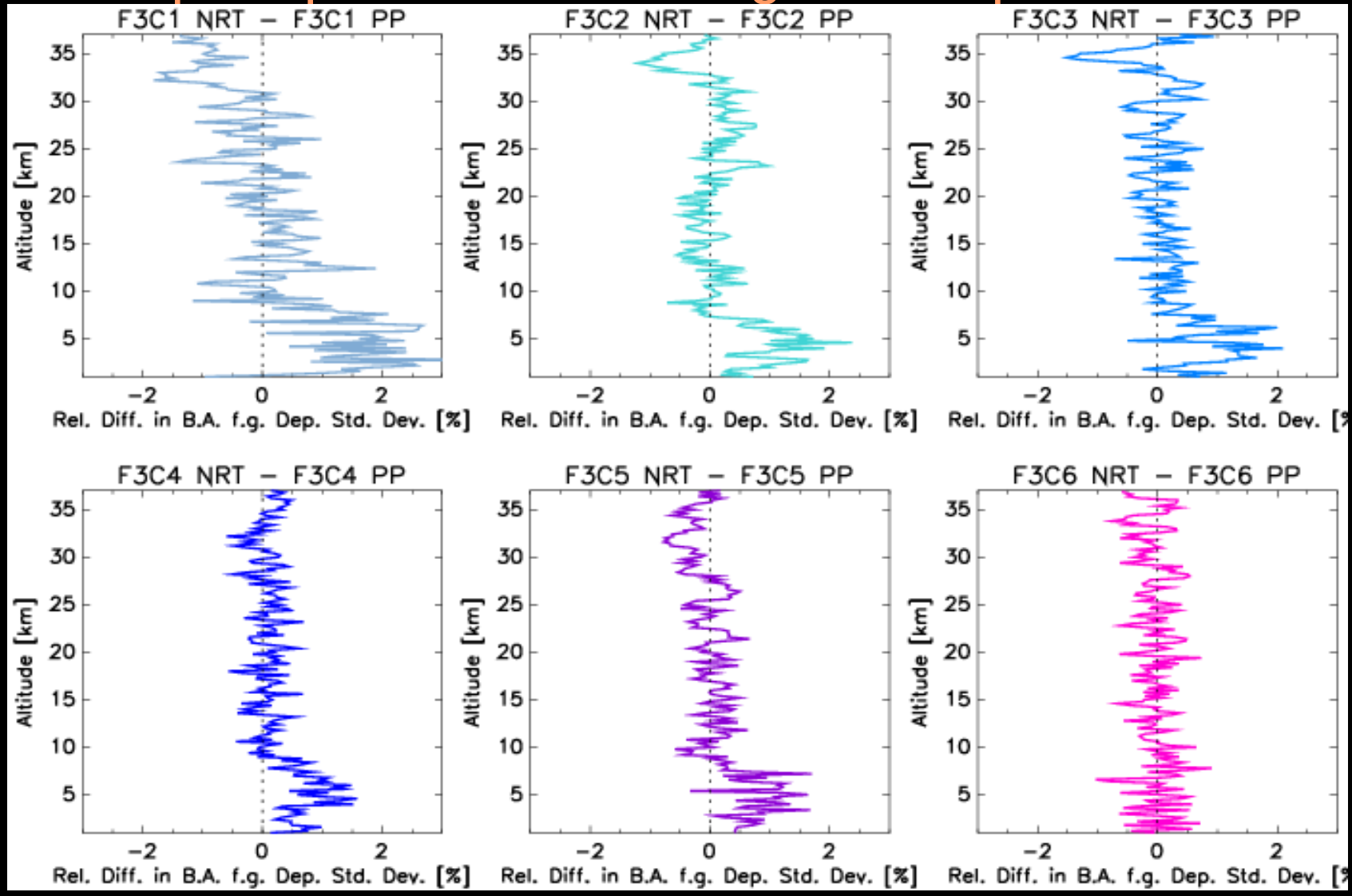
Observation error estimate



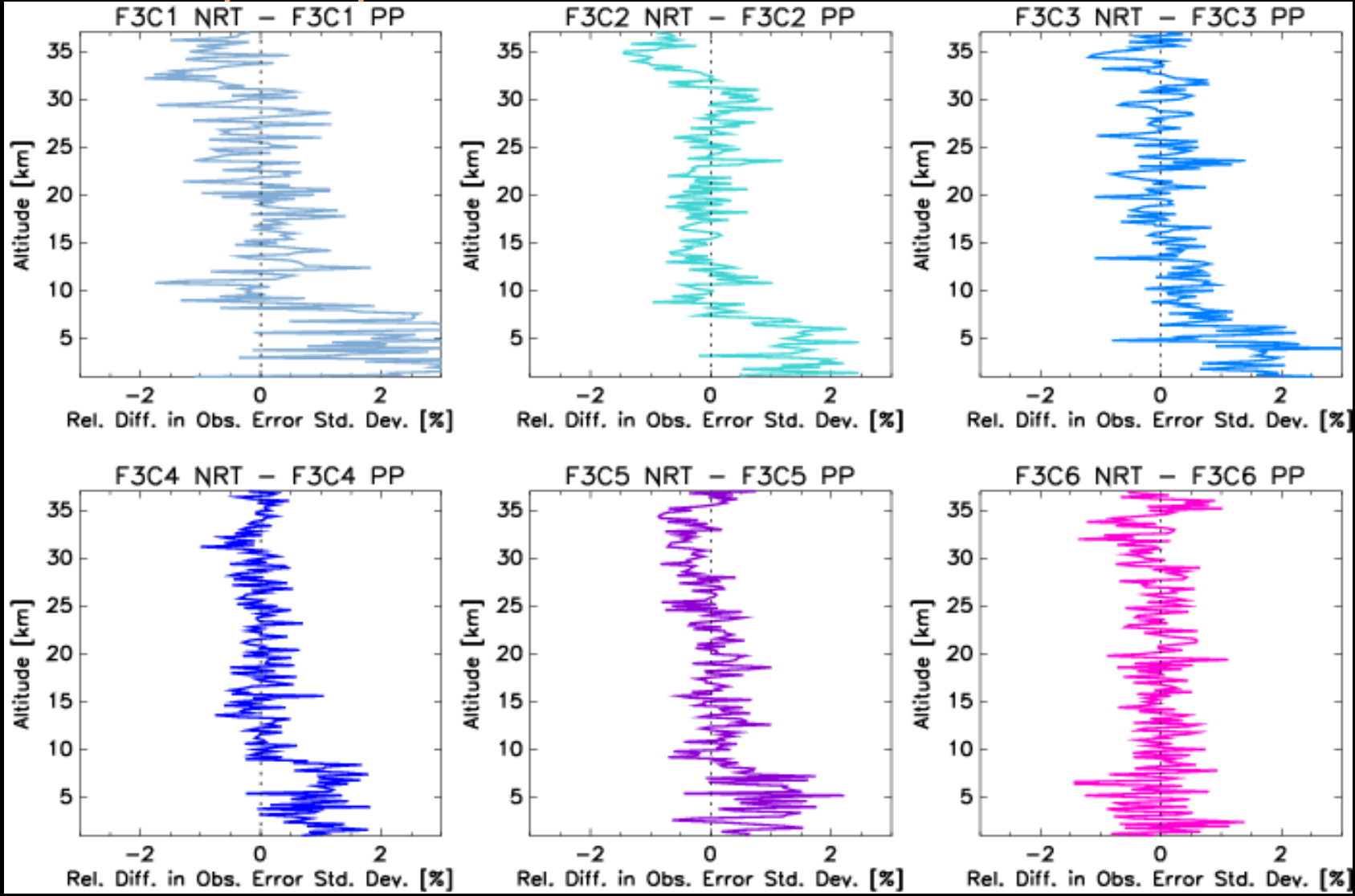
Dec 2007
200 m vert. resol.

Jan 2007
10 m vert. resol.

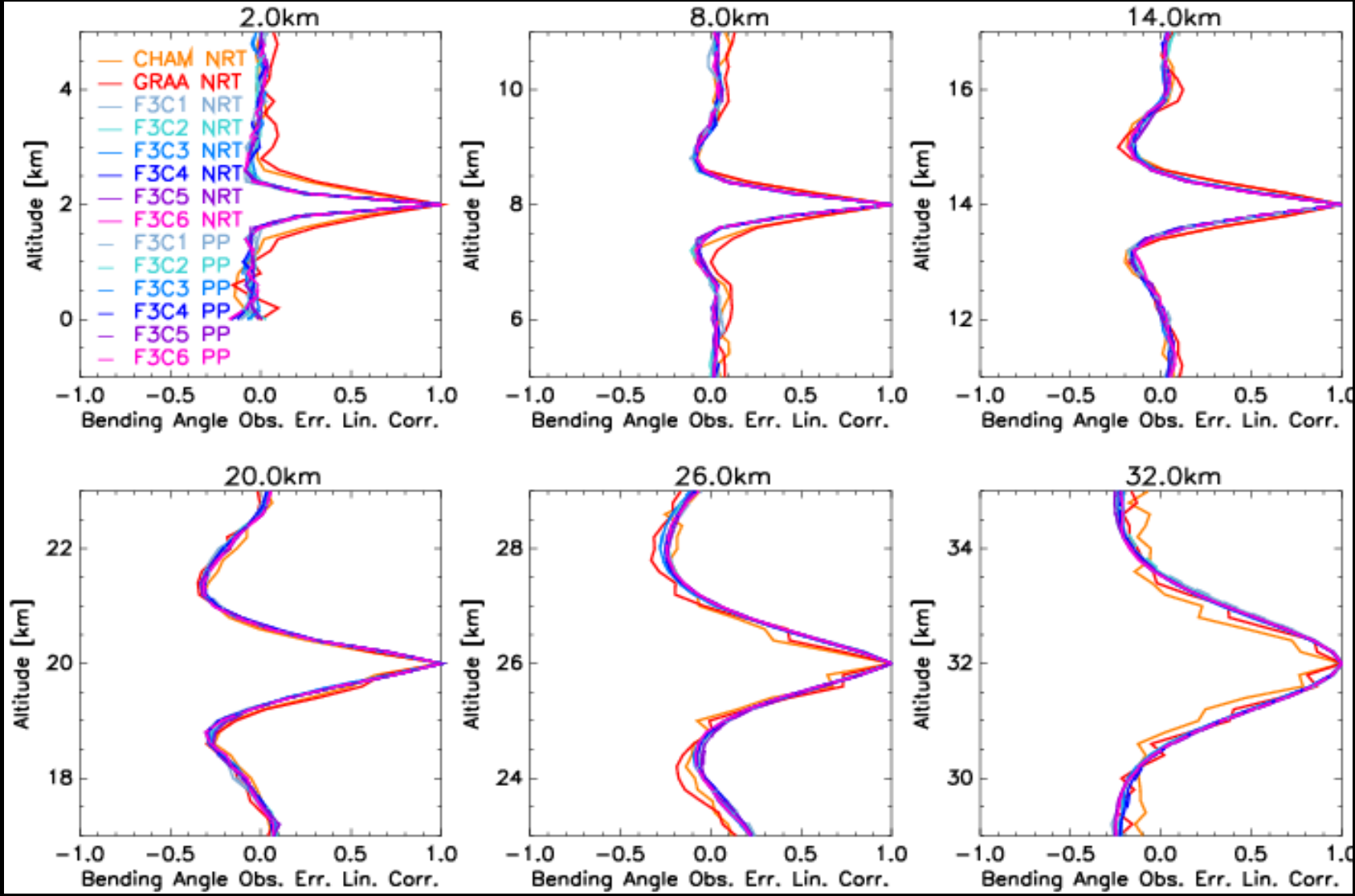
Differences between COSMIC NRT and COSMIC post-processed: First-guess departures



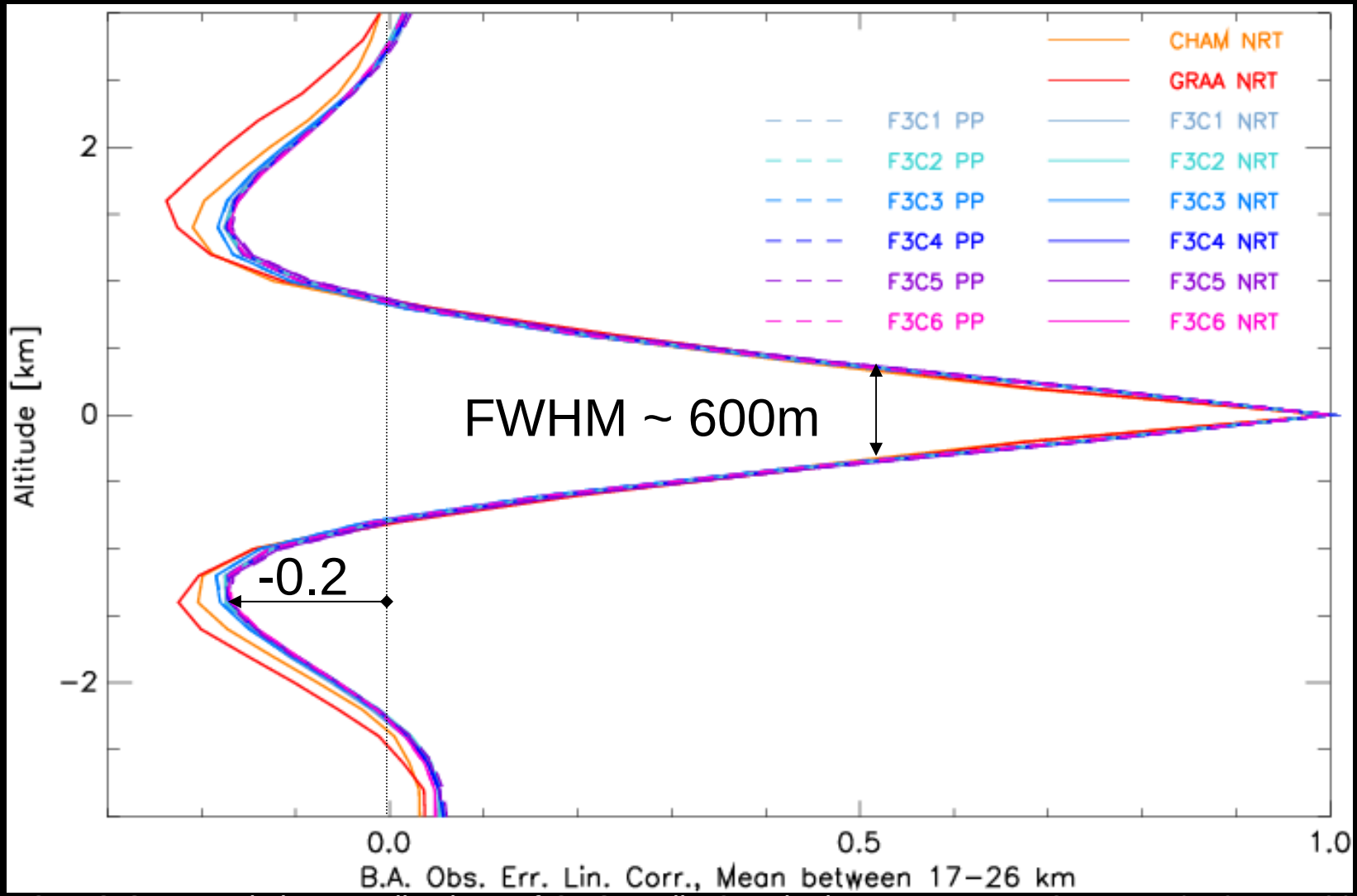
Differences between COSMIC NRT and COSMIC post-processed: Observation errors



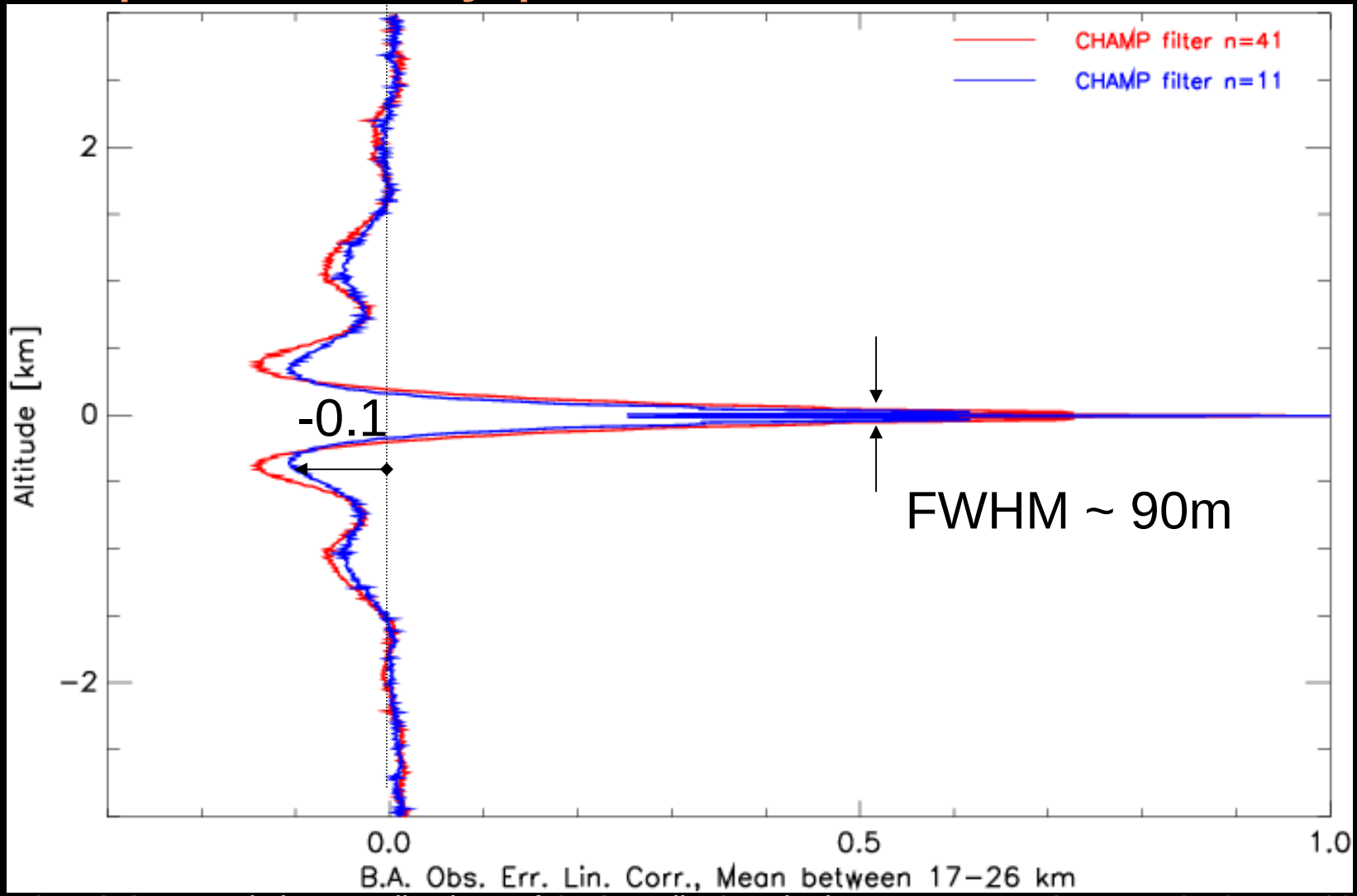
Obs. Error Vertical Correlations



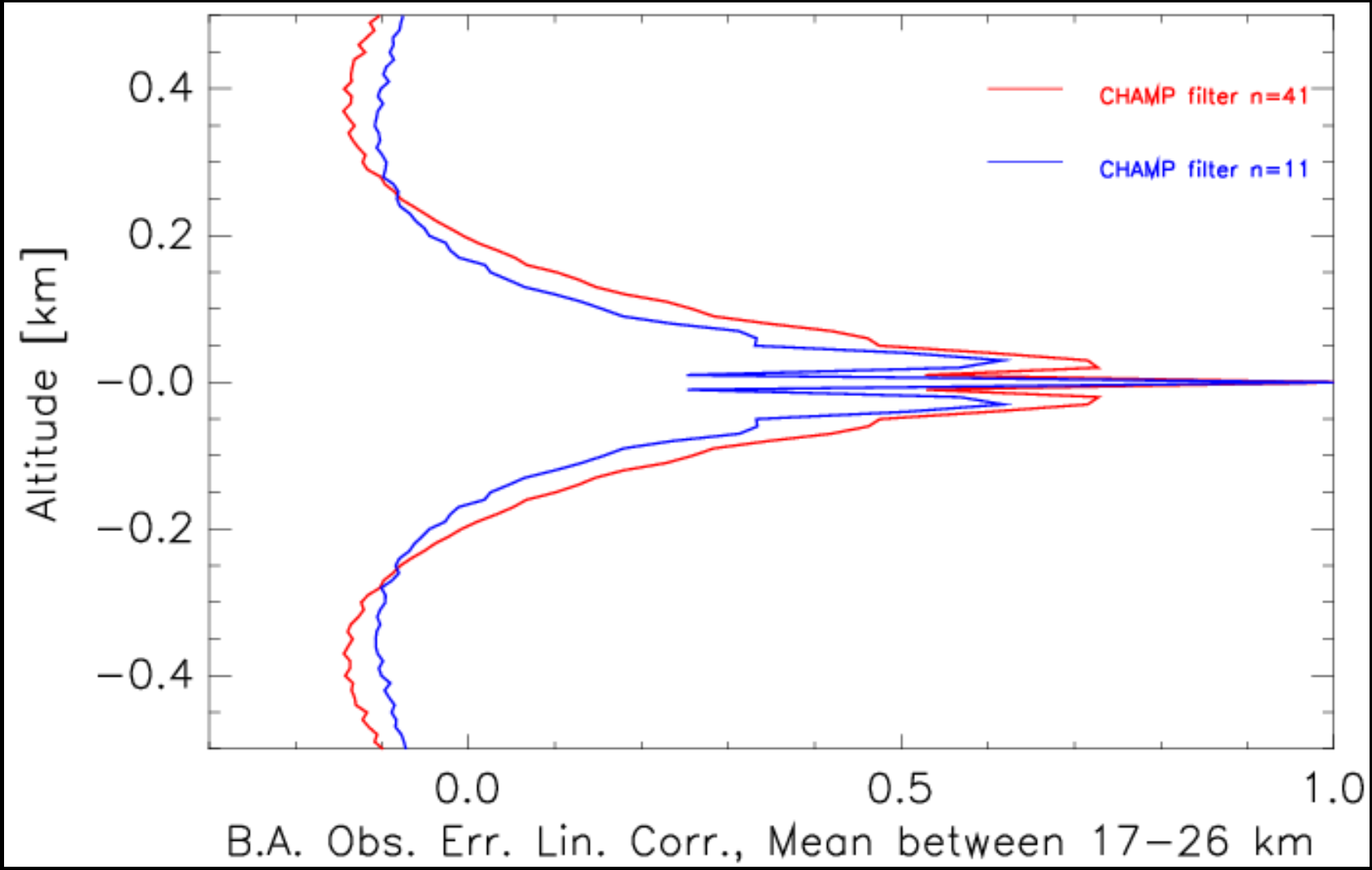
Average Obs. Error Vertical Correlation



Average Obs. Error Vertical Correlation for experimentally processed CHAMP dataset



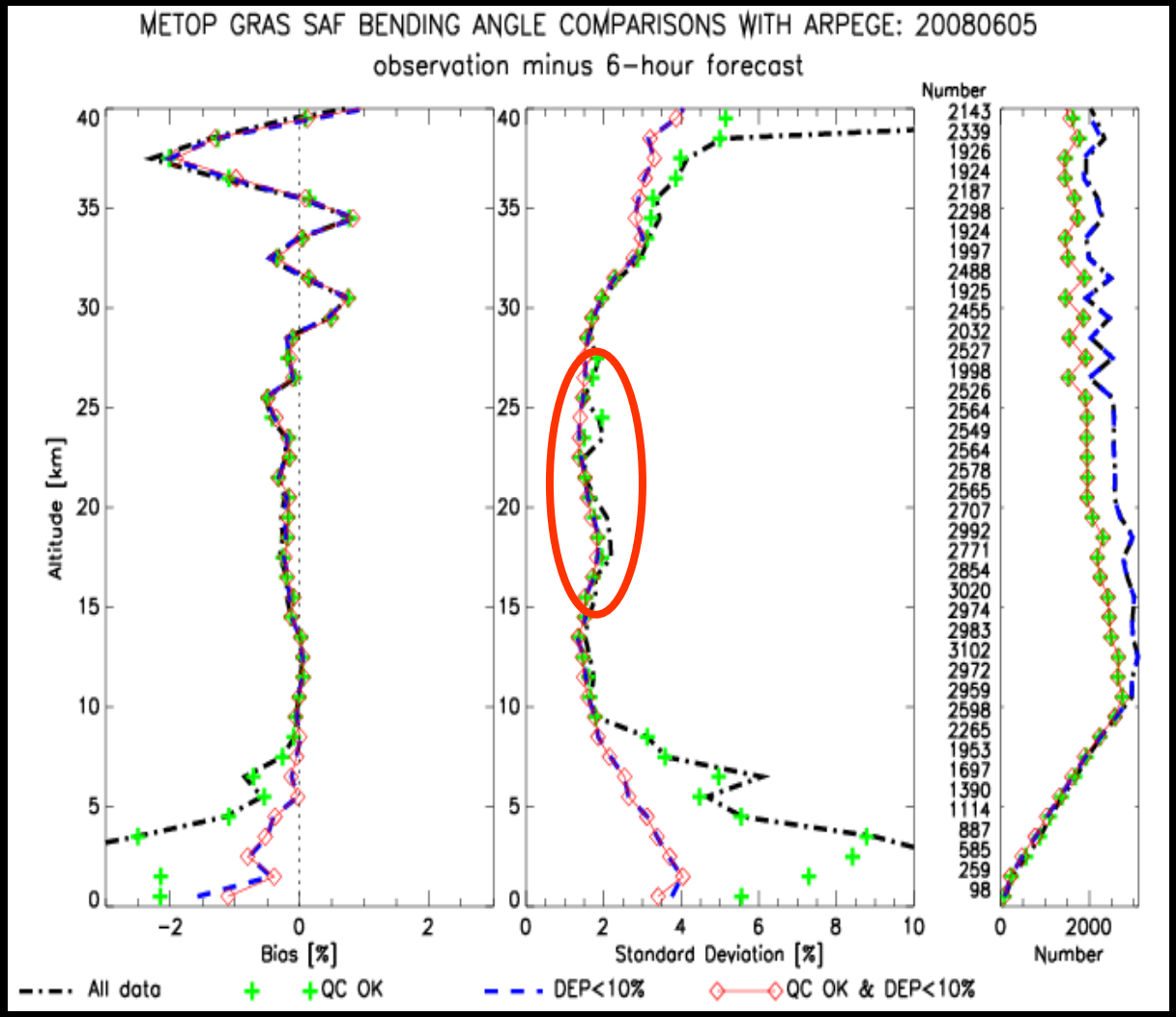
Average Obs. Error Vertical Correlation for the experimentally processed CHAMP dataset >> Zoom



First-look at GRAS data

- First GRAS instrument, MetOp launched Oct 2006
- Level-1b data: two products
  - First received May 2008
  - Bending angle only, full dataset: 30 m vertical resolution data, sometimes non-monotonous imp. param.
  - Bending angle only, thinned dataset: 150-250 m vertical resolution
- Level-2 data products from the GRAS SAF
  - First received 2 June; first full day 5 June
  - 150-250 m vertical resolution
  - Bending angle and refractivity (useful for our QC)

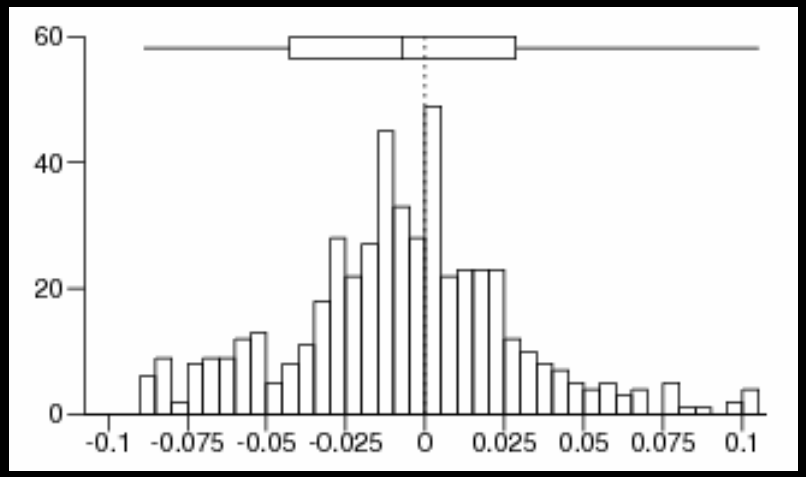
First look at GRAS data



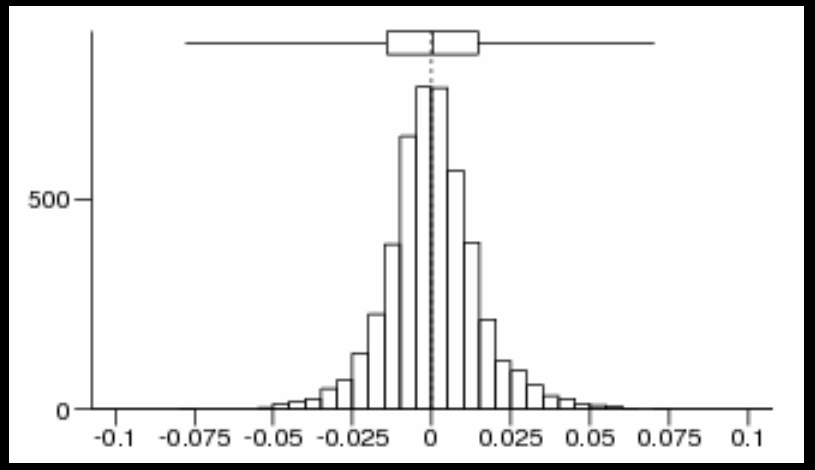
- 691 GRAS SAF profiles for that day
- 50 GRAS SAF profiles without refractivity products: actually containing mostly large departures [OUTLIERS]
- Show here the 641 GRAS SAF profiles for which there is a refractivity product available

First look at GRAS data

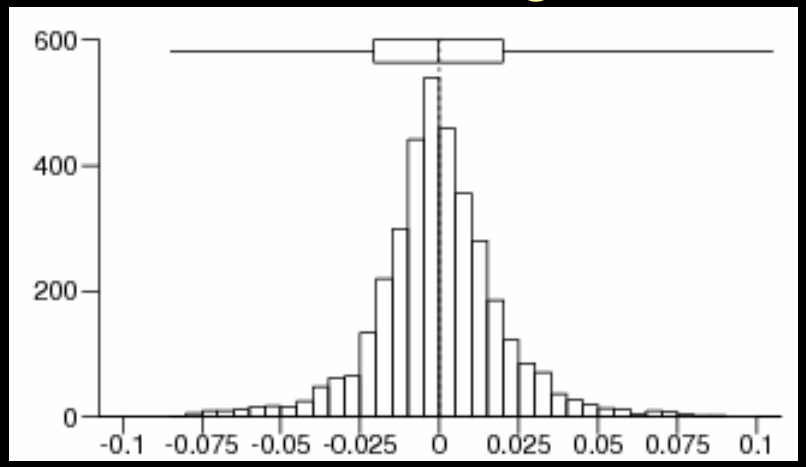
Passed screening 0-5 km



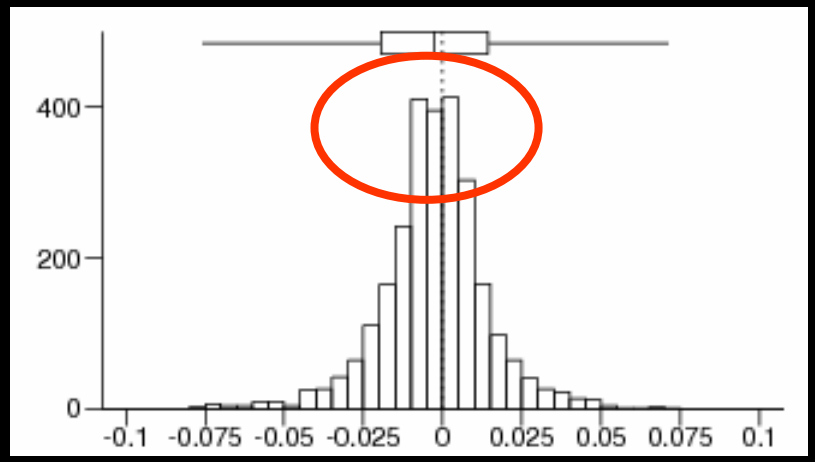
Passed screening 10-15 km



Passed screening 5-10 km



Passed screening 15-20 km



Conclusions and future work

- Assimilation of GPSRO bend. angle from 8 satellites since Sep 2007
- Next improvement: extend assimilation from 18 km up to 25 km
- Impact study testing the impact of an increase in GPSRO soundings
  - Preliminary results indicate (so far) that forecast skill scales at least as the number of available soundings
- Investigation of observation errors using Desroziers' triangle
  - Noticeable improvement in quality in post-proc. CDAAC product vs NRT
  - CHAMP and GRACE-A feature larger errors in the stratosphere
  - GFZ and CDAAC products do not sample similarly the lower trop.
    - Different climatologies may be expected
  - Vertical error correlations for CDAAC products similar to GFZ:
    - FWHM ~600m with anti-correlations centered @ +/- 1500m
  - Spread in vertical error correlations and anti-correlations may be reduced using different smoothing algorithms
    - Trade-off: larger observation errors
- First assessment of GRAS SAF data
- Future work: investigation of GRAS SAF data assimilation