Impact of GPS-RO on NWP and climate reanalyses

Sean Healy, Mi Liao (CMA), Andras Horanji, Adrian Simmons.

ECMWF

EUMETSAT ROM SAF

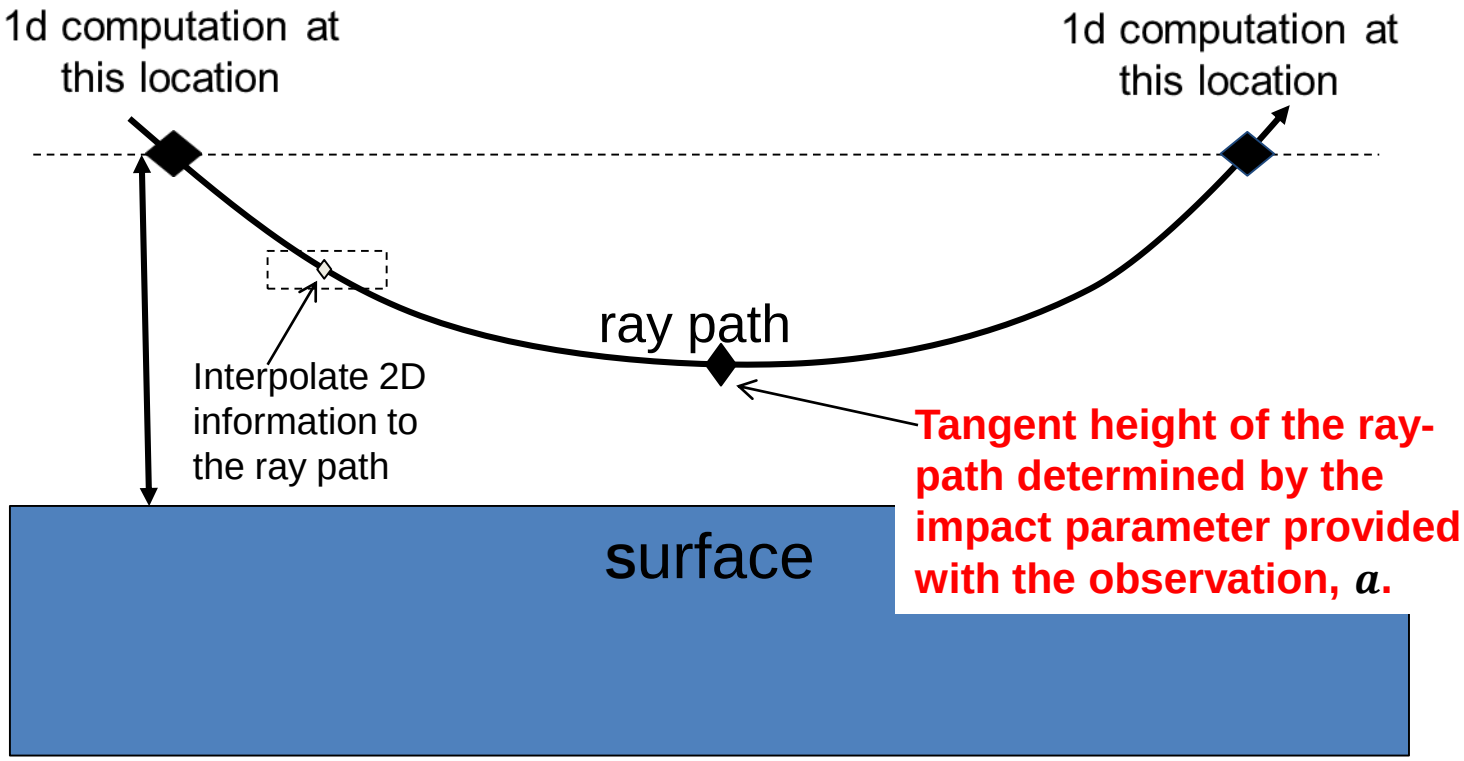
Outline

- NWP
  - Assimilation of GRAS to the surface.
  - Overview of current impact of GPS-RO (forecast scores, departure statistics).
  - GNOS data quality (Mi Liao, CMA, ROM SAF visiting scientist).
  - **Reminder:** EDA estimates of COSMIC equatorial/polar impact (with EUMETSAT).

- GPS-RO is ESSENTIAL for climate reanalyses because its an *anchor*.
  - Consistency of climate temperature reanalyses since COSMIC.
  - GPS-RO constraining model biases in the new ERA-5 system.
  - Experiments with GPS/MET data (primetime and AS-ON).

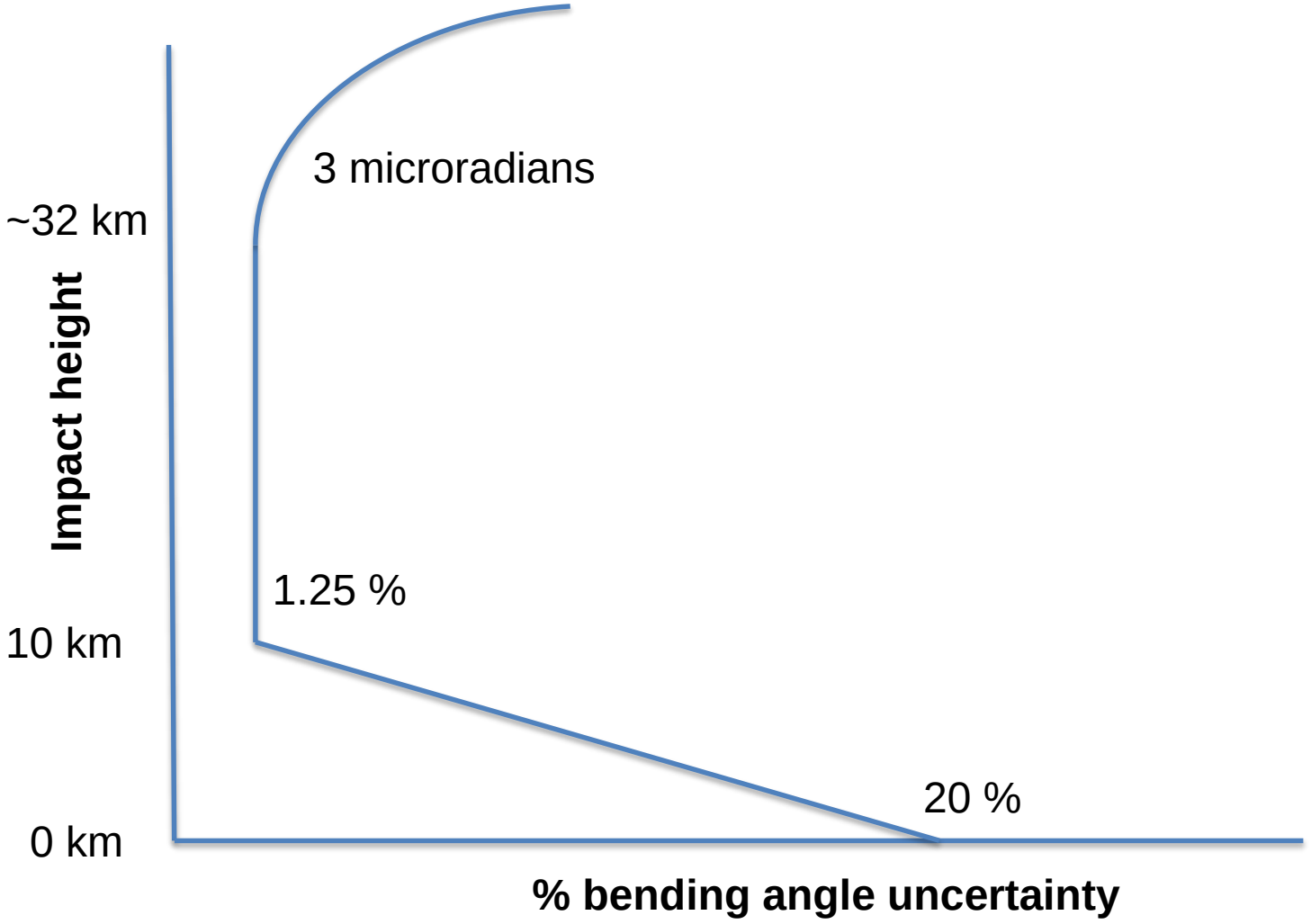
- Summary/Future work.

SOPHISTICATED assimilation with the 2D forward model. Solving a set of ray path equations rather than the BA integral



The outer loop uses 31 profiles to describe the 1200 km "occultation plane".

Reminder: Assumed global error statistic model **(CRUDE)** Same model used for all GPS-RO (GRAS, COSMIC).



Assimilation of tropospheric GRAS data from Metop-a,b

- **GRAS data friom Metop-a,b provide >60 % of the GPS-RO data assimilated at ECMWF** (Metop-a,b ~1300 profiles per day; GPS-RO total number~ 2000).

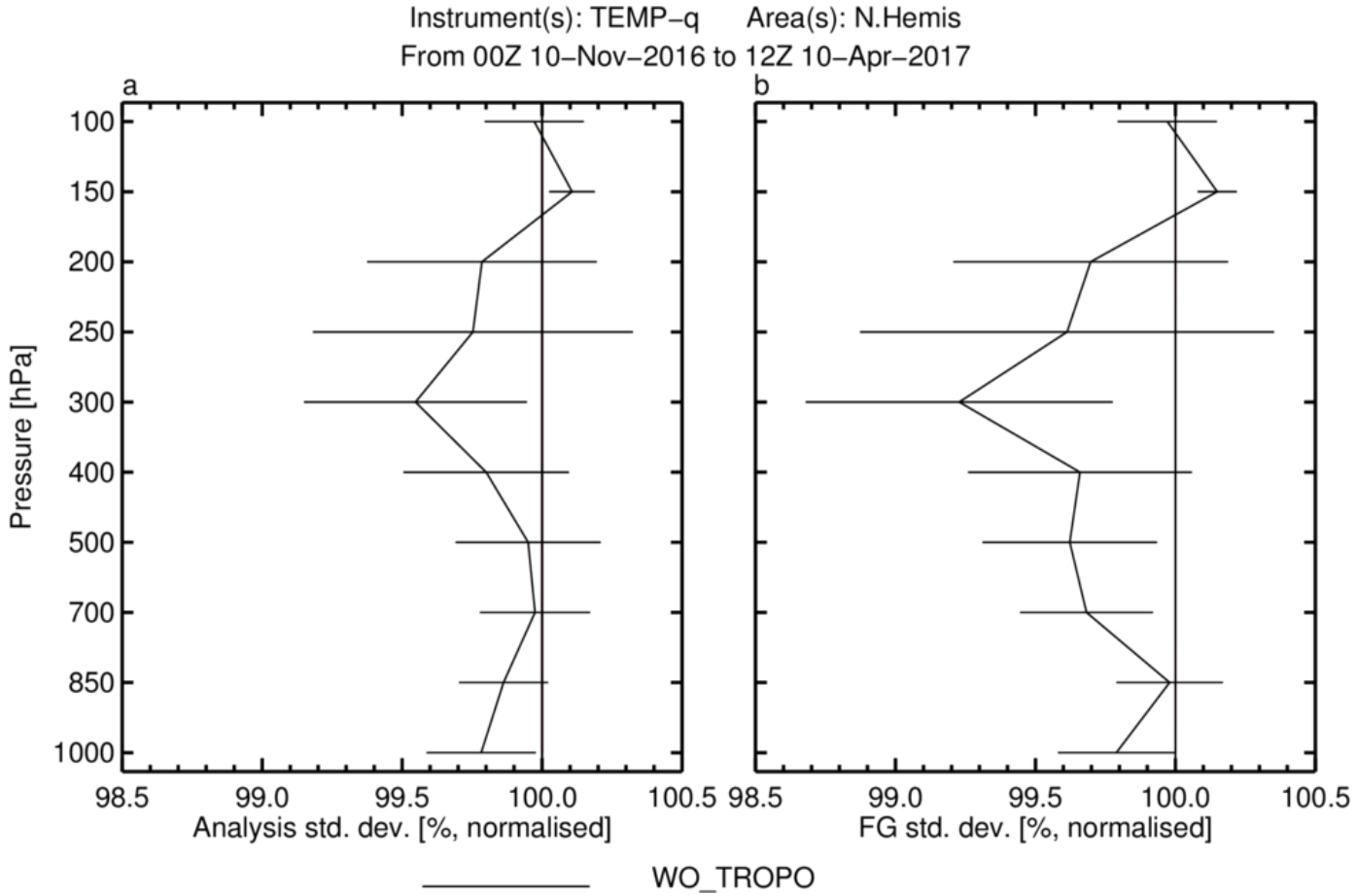
- EUMETSAT changed their operational processing of GRAS data to a wave optics approach (FSI) November 2016.

- We tested the assimilation of this data in the troposphere, assimilating to the surface.

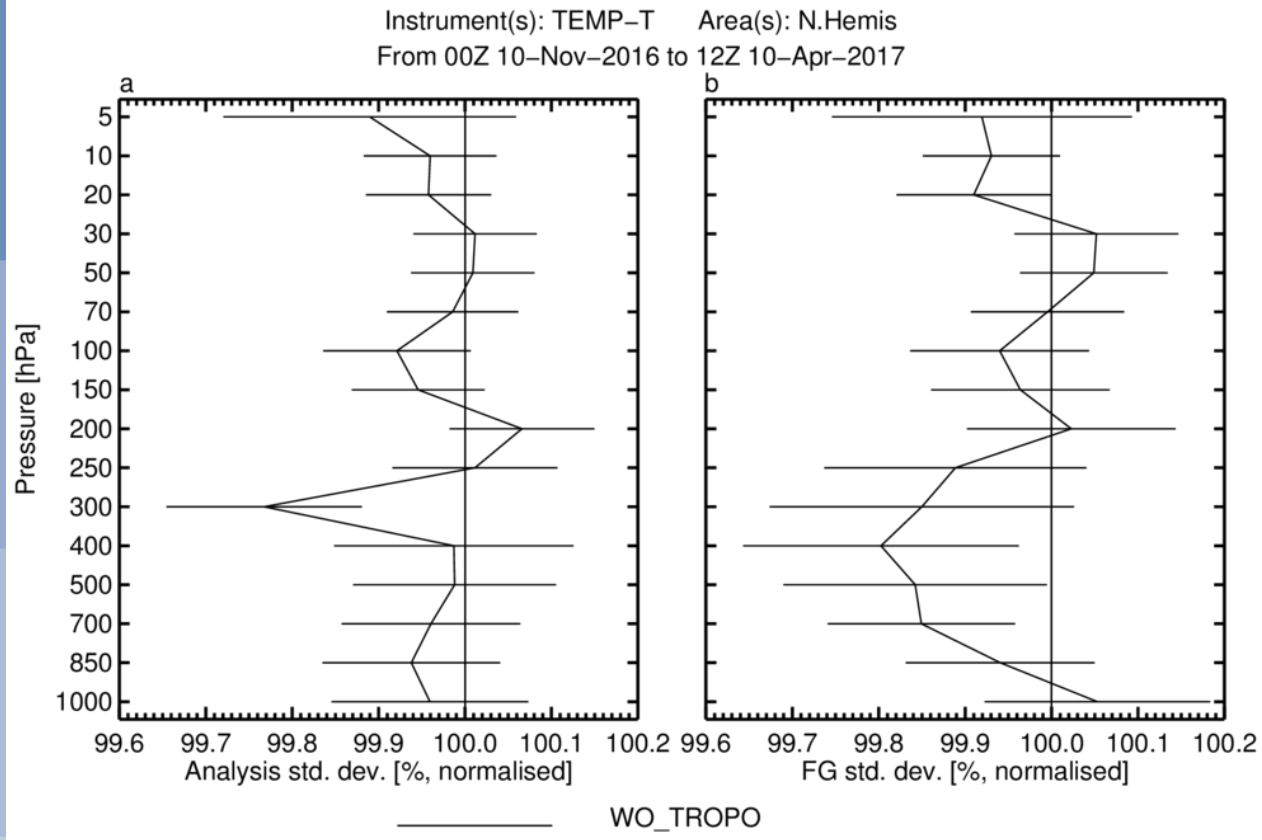
- Medium-range scores ~neutral. **Some clear improvements in the short-range conventional data statistics. Mainly in NH. Note that we treat GPS-RO the same over land/sea.**

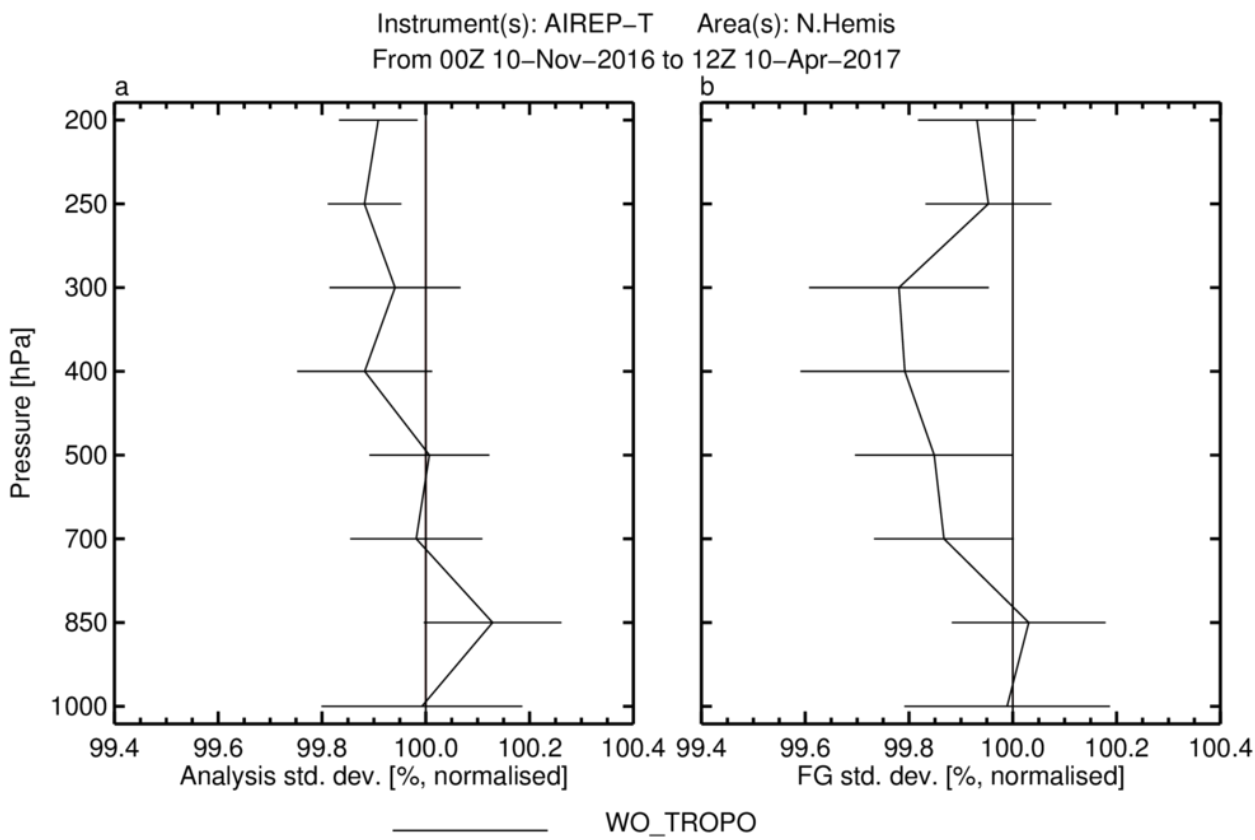
Tropospheric GRAS assimilation

- Operational June 7, 2017 after 150 days of experimentation. Some improvements in short-range forecast fit to other observations. EG, sonde humidity

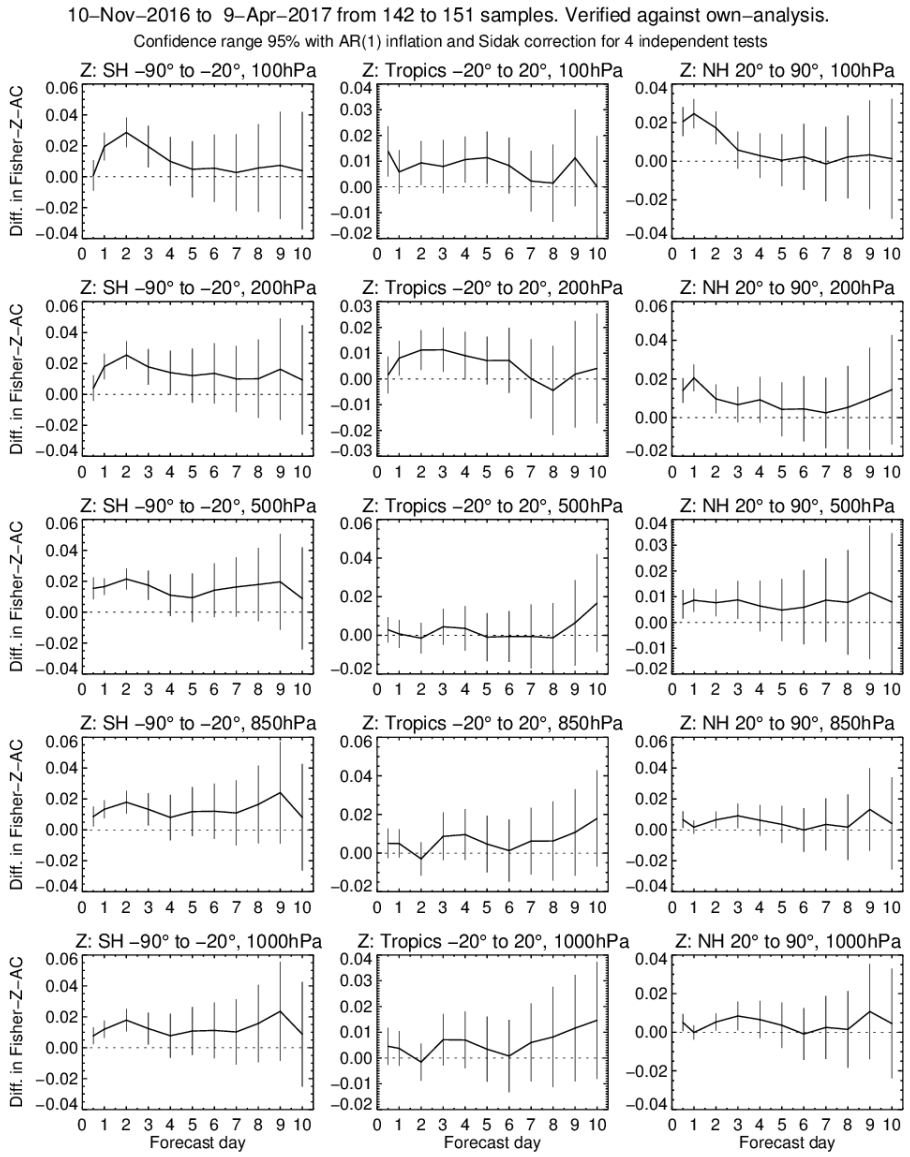


Sonde temp/aircraft temp

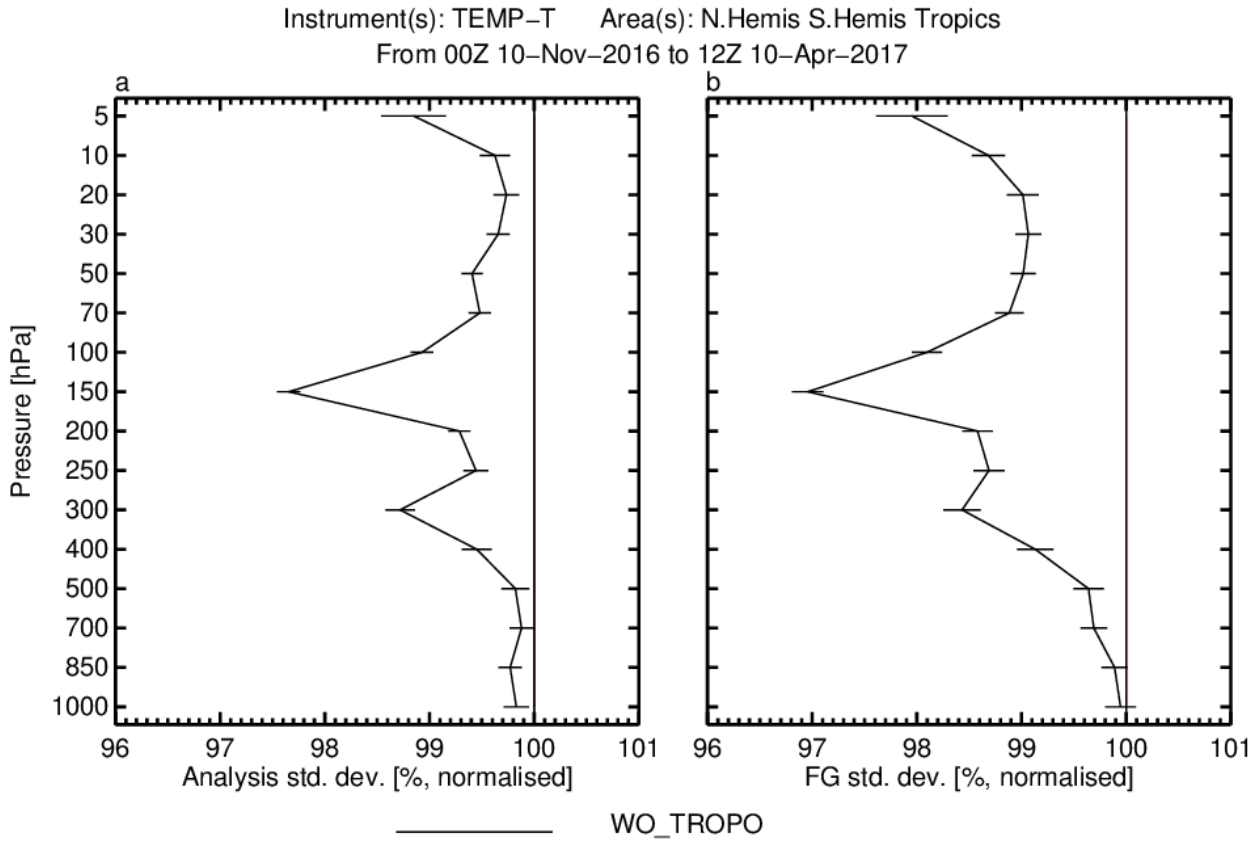




Overall impact of **GPS-RO, Z**
(Increase in anomaly corr.,own analysis)



Short-range fit to radiosondes
(Global, temperature.)



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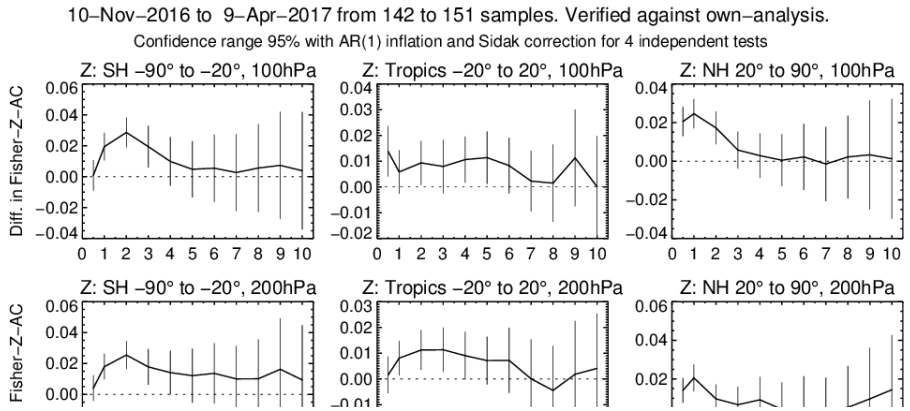

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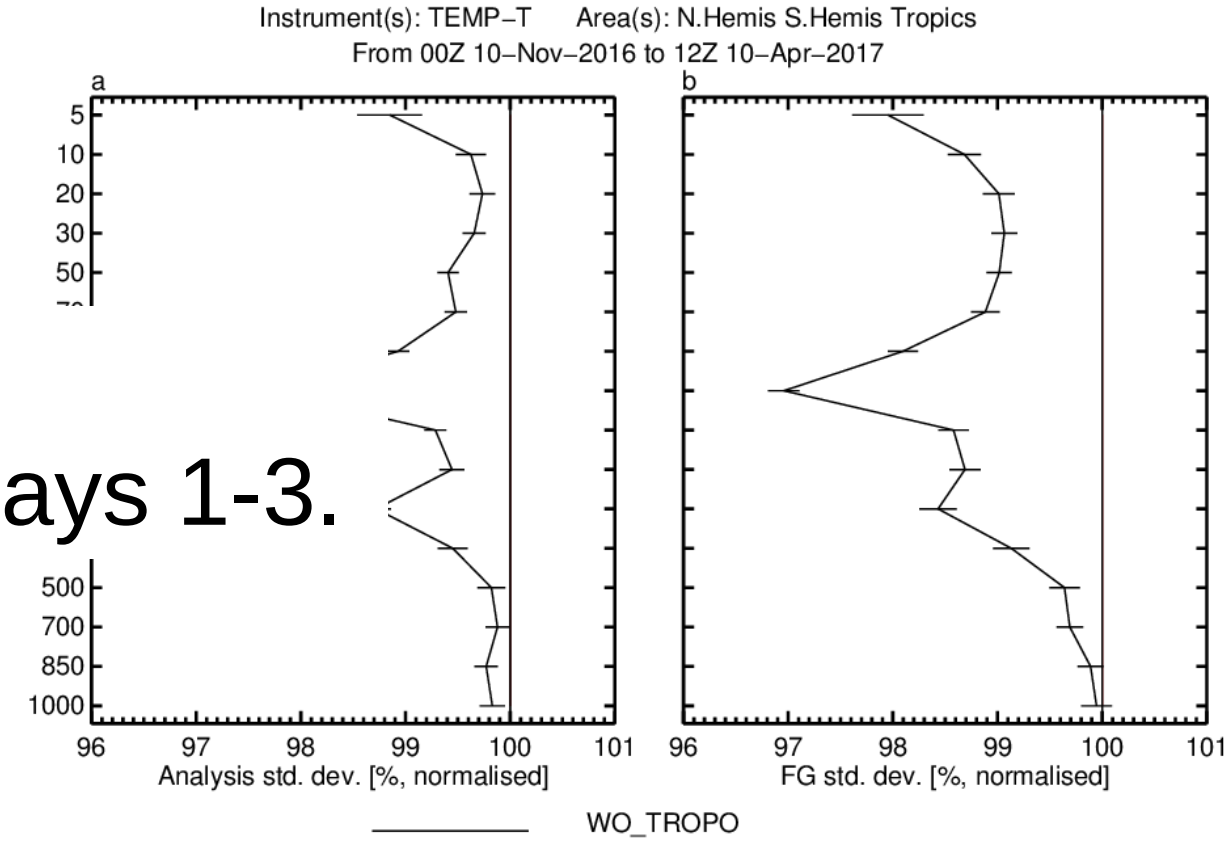
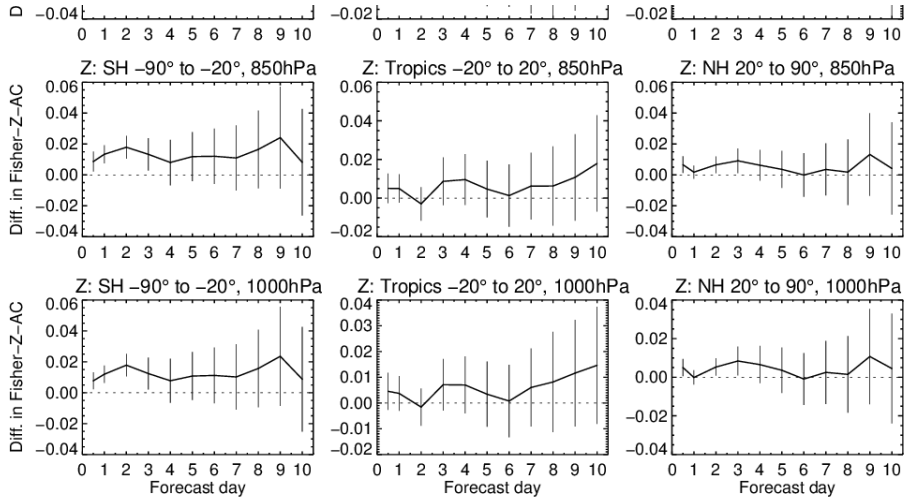


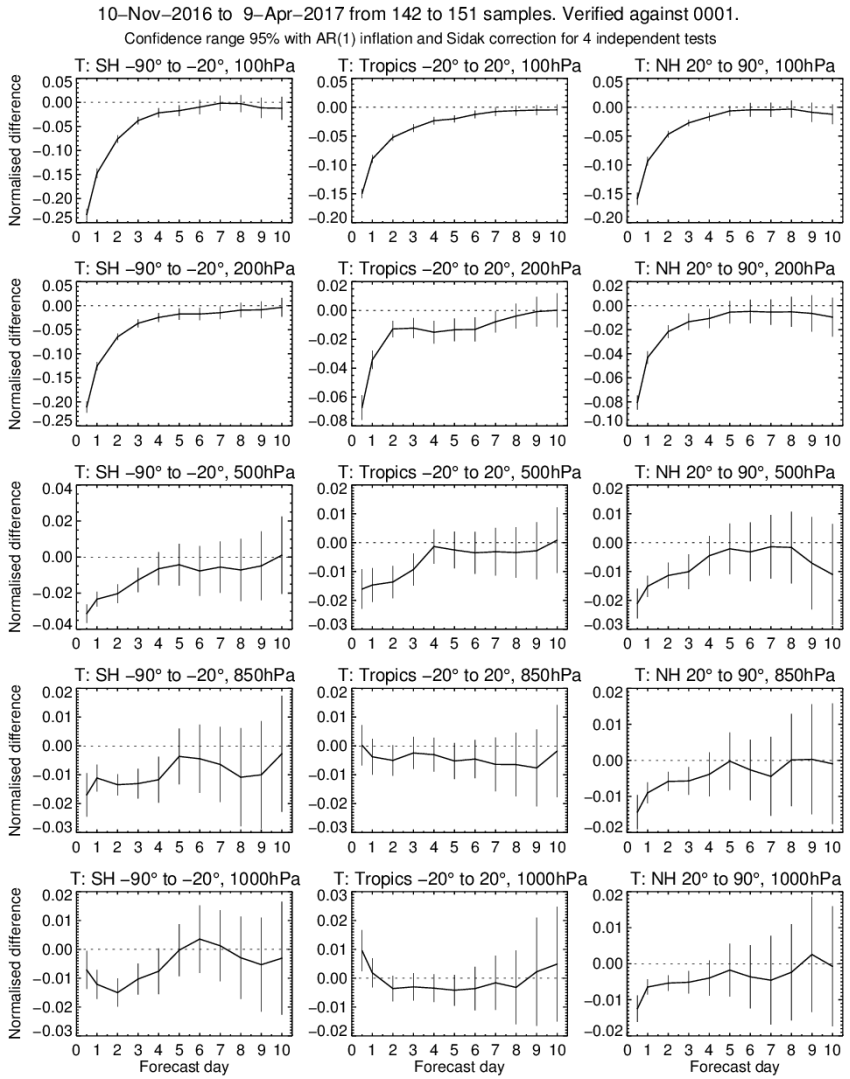
Generally +ve.

Statistically significant for days 1-3.

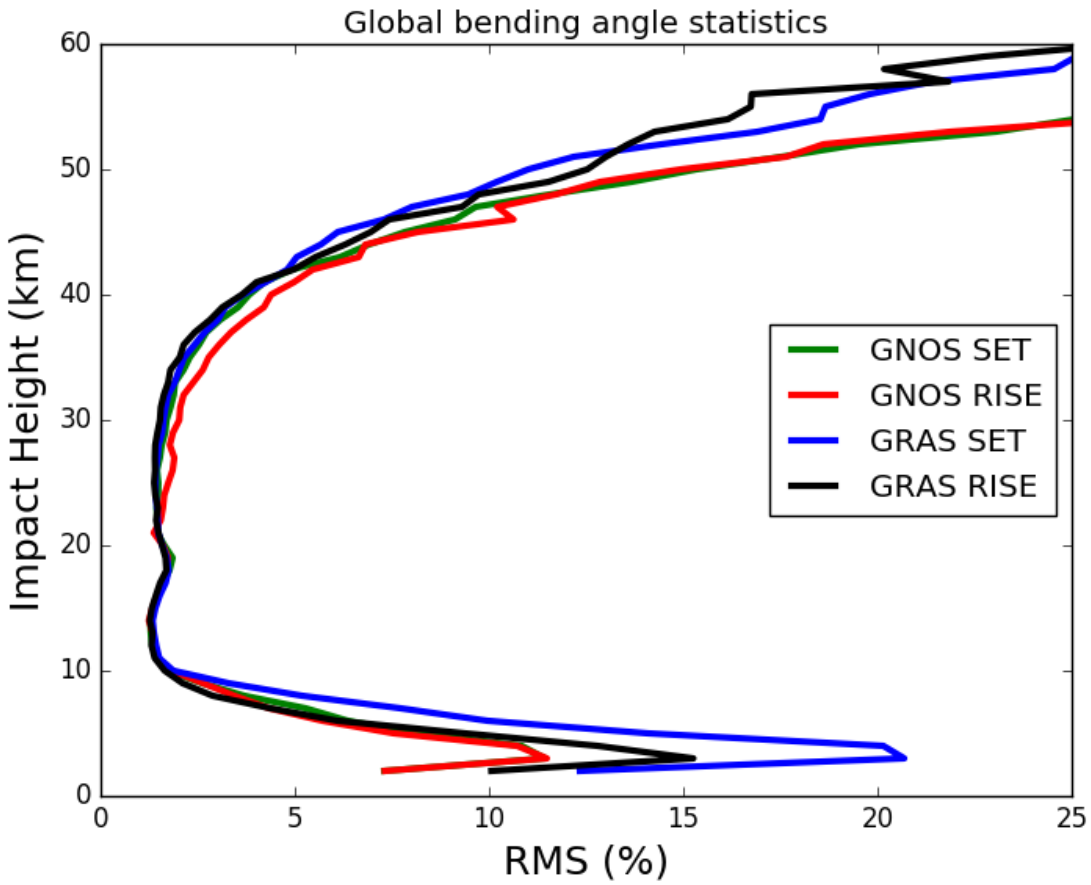


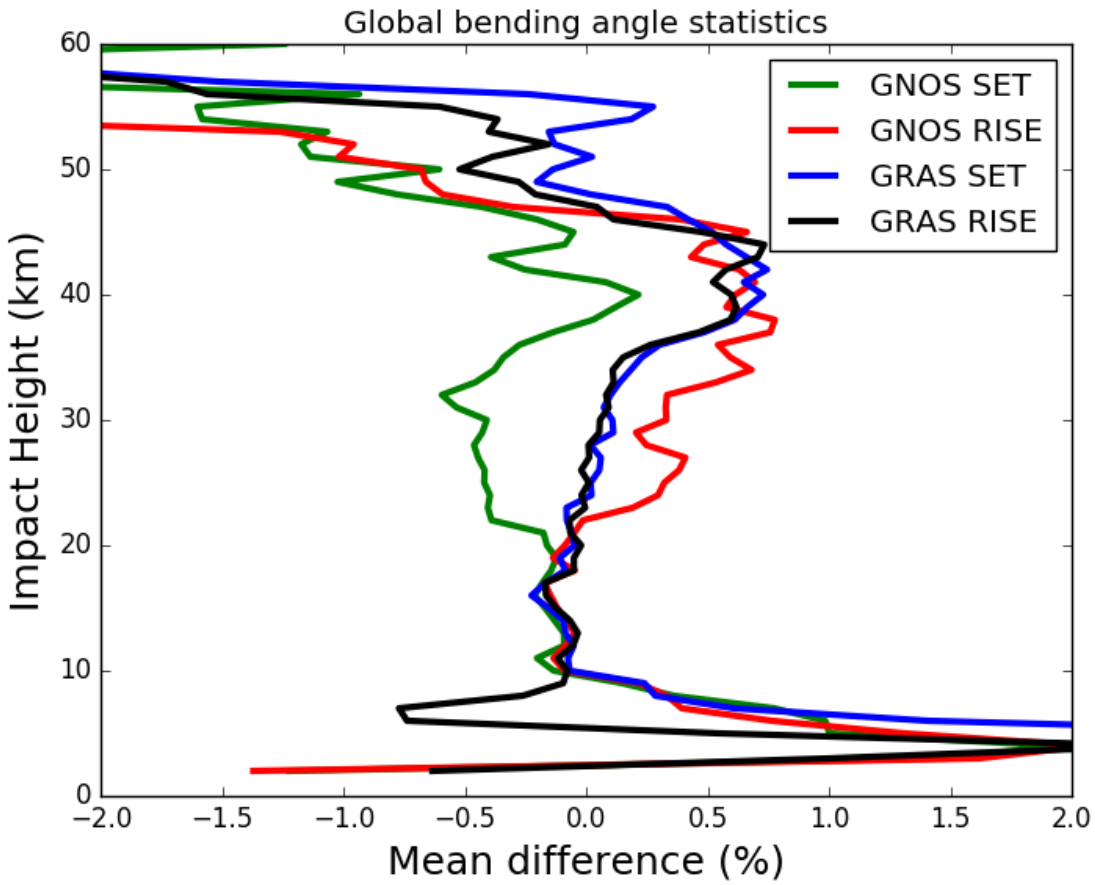
Reduction in standard deviation of forecast error verified against OPERATION

improvement



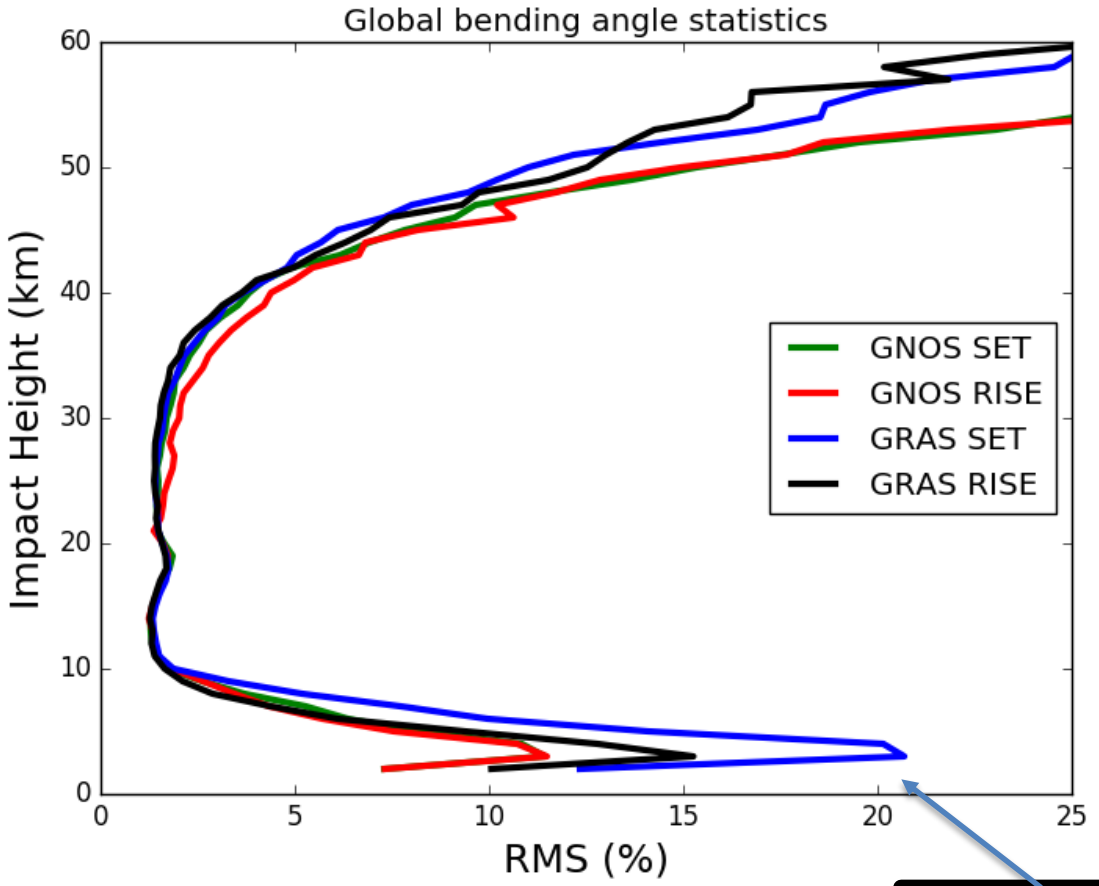
GNOS: Bending angle statistics (o-b)/b using the IFS. Passive, Data for Feb 16-22, 2017. Passed FG-check.

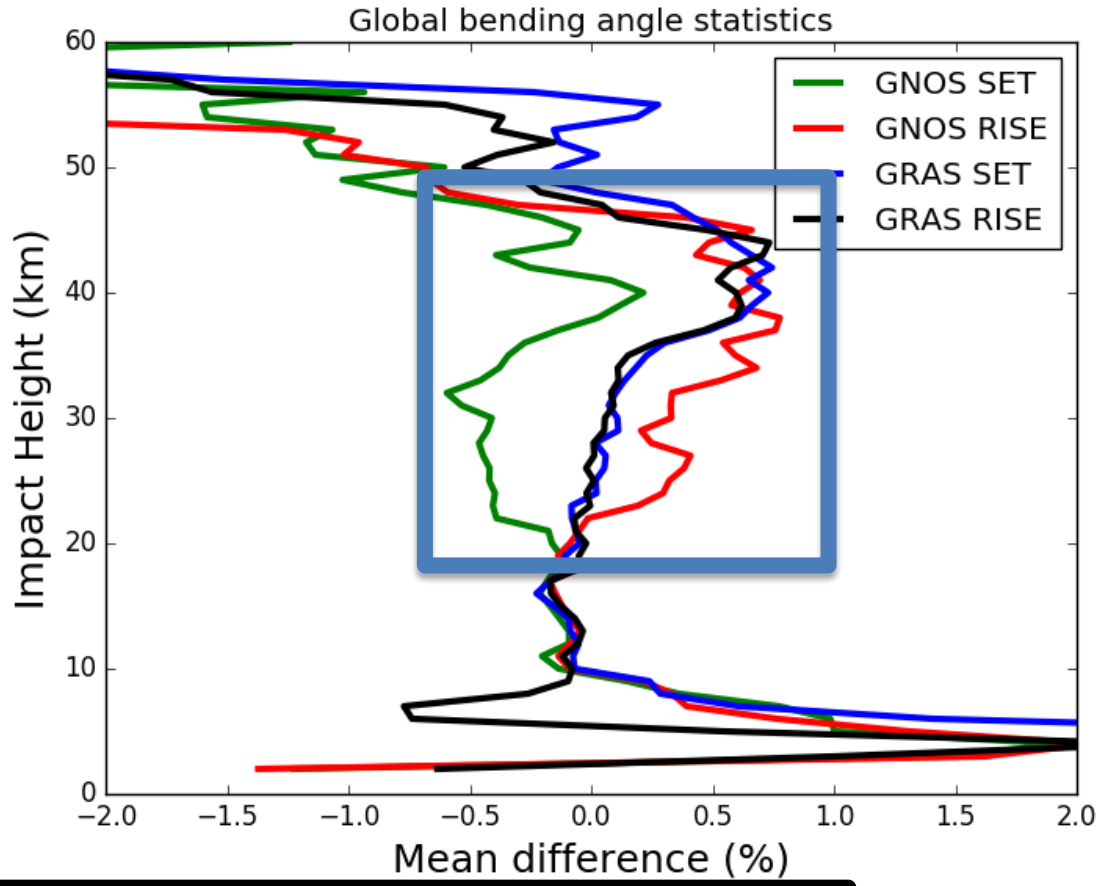




ECMWF

GNOS: Bending angle statistics (o-b)/b using the IFS. Passive, Data for Feb 16-22, 2017. Passed FG-check. **(SEE ROM SAF web-pages for Mi's visiting scientist report: *http://www.romsaf.org/visiting_scientist.php*)**





GRAS tends to penetrate deeper. Includes more difficult cases in the statistics.

ECMWF

The Impact of different Radio Occultation Constellations on NWP and Climate Monitoring

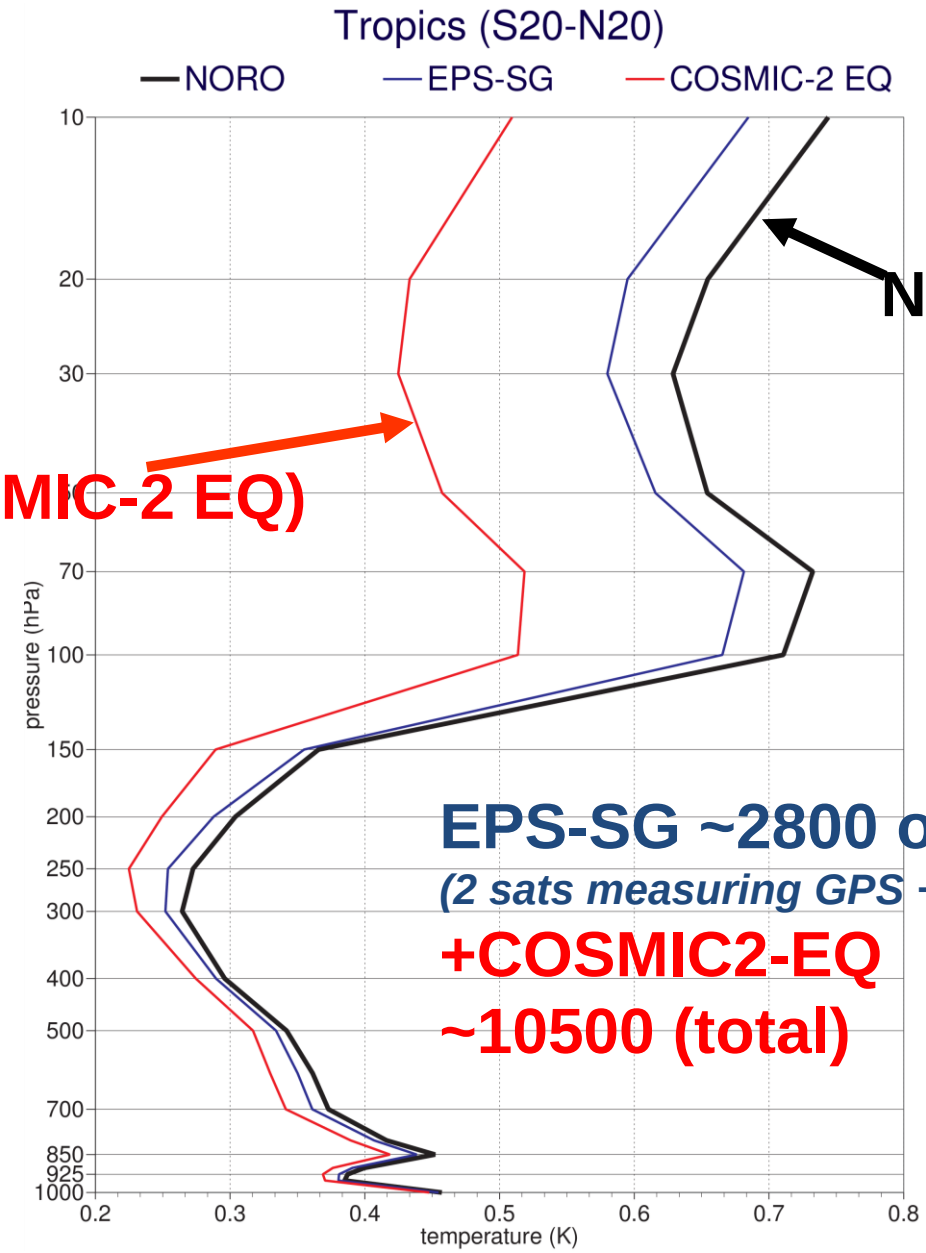
András Horányi, Sean Healy (ECMWF)

and

Axel von Engeln, Yago Andres (EUMETSAT)

IROWG-4 workshop

The impact of COSMIC-2 Equator (tropics)



No RO

(EPS-SG+COSMIC-2 EQ)

EPS-SG ~2800 occs per day

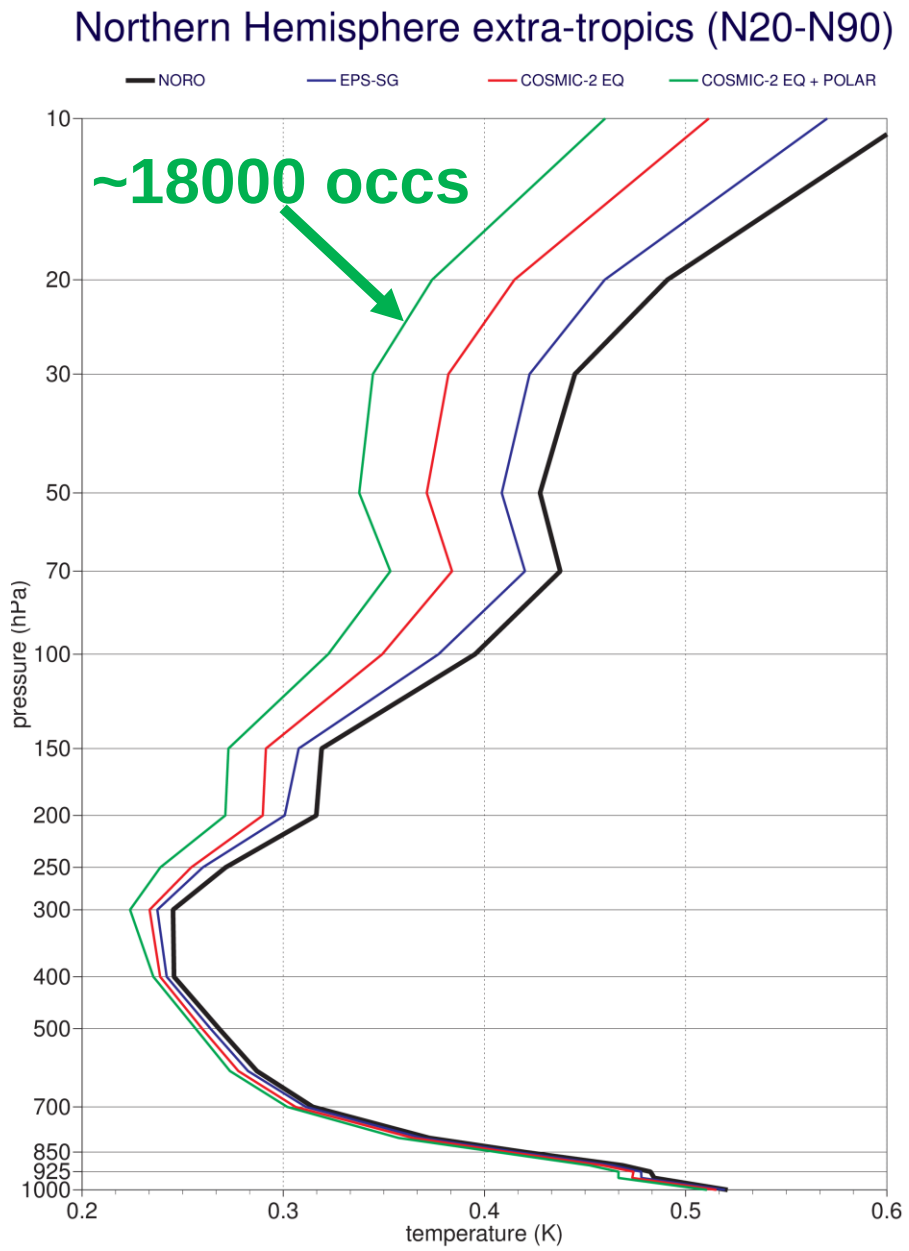
(2 sats measuring GPS + Galileo)

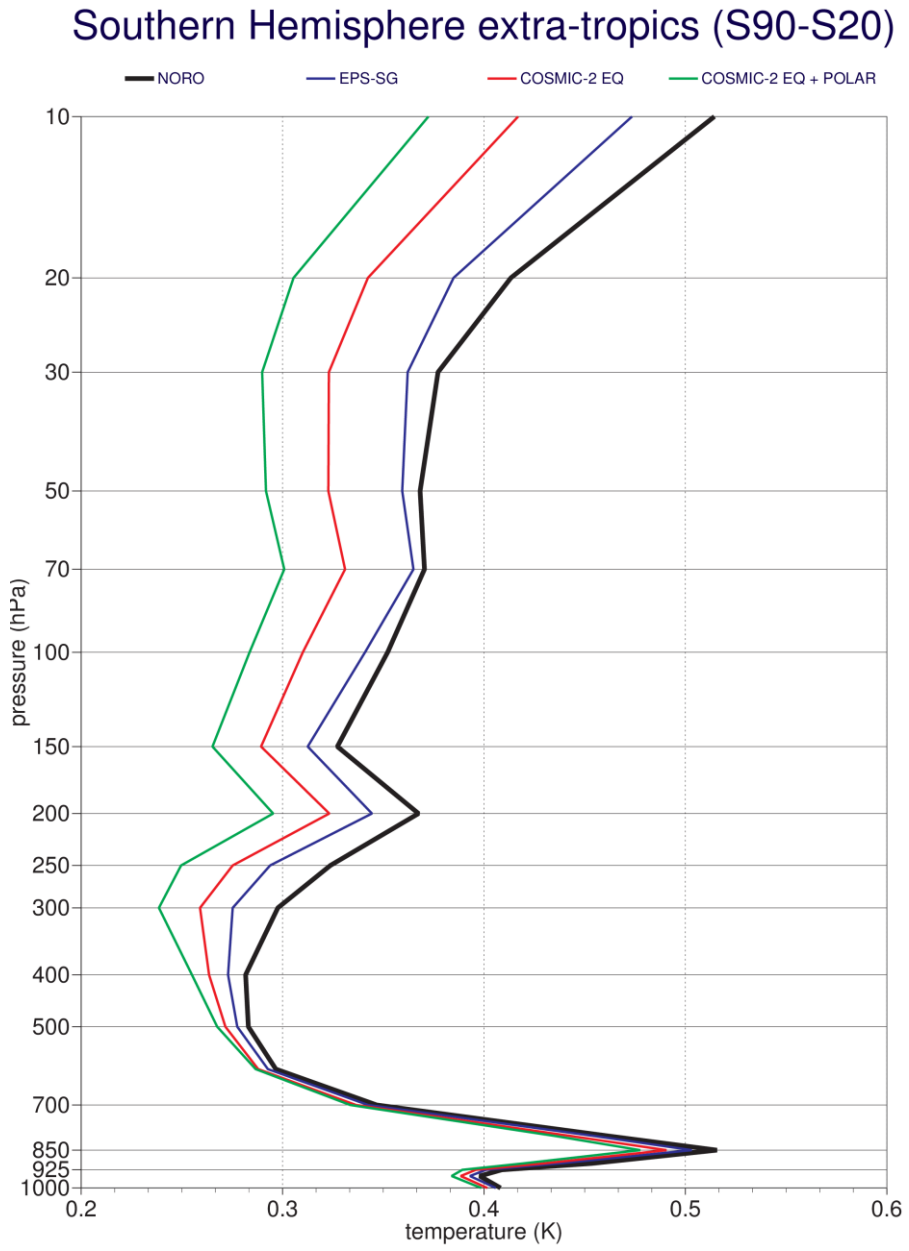
+COSMIC2-EQ

~10500 (total)

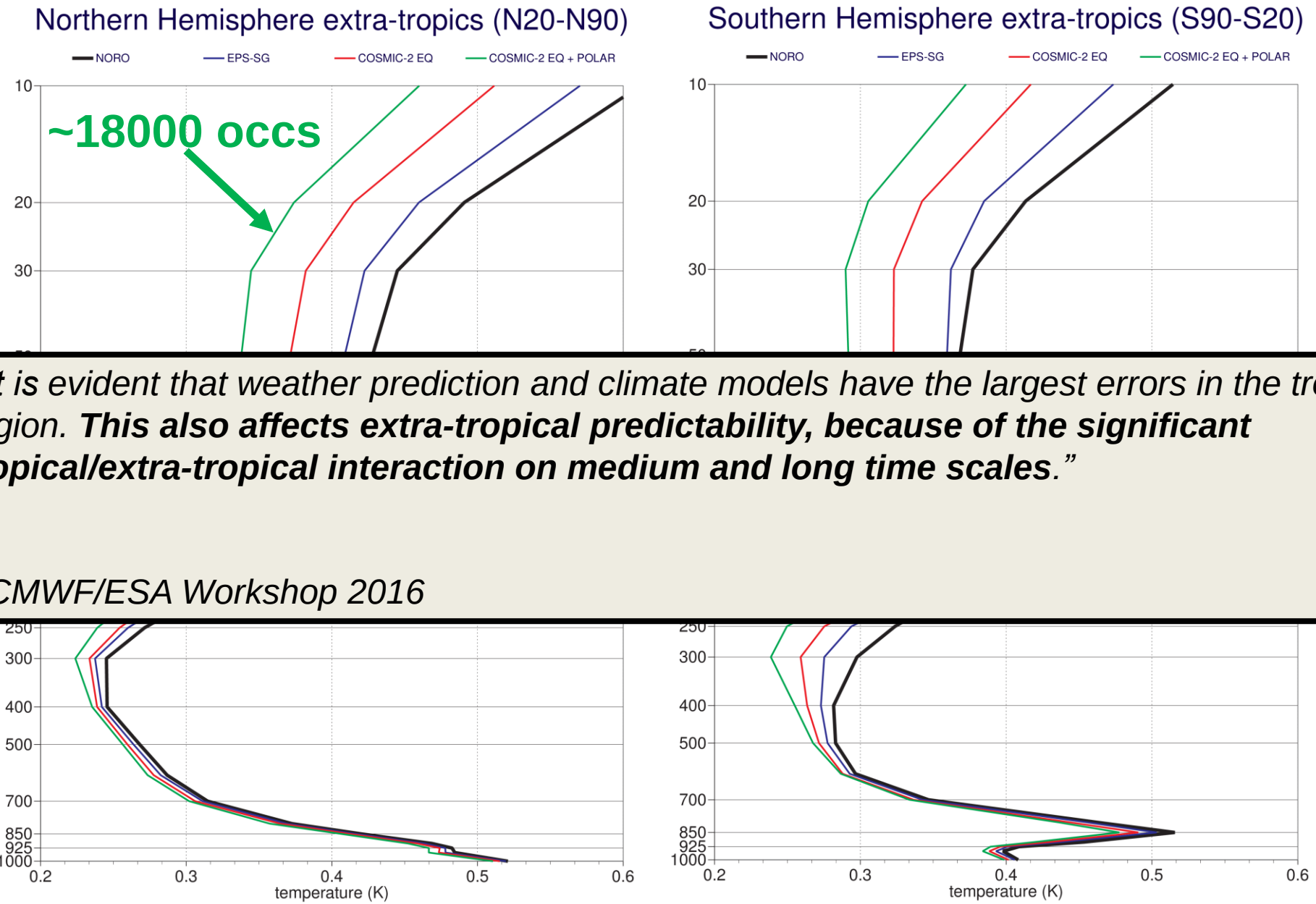
ECMWF

COSMIC-2 Polar + (EPS-SG +COS2-EQ)





COSMIC-2 Polar + (EPS-SG +COS2-EQ)



" It is evident that weather prediction and climate models have the largest errors in the tropical region. ***This also affects extra-tropical predictability, because of the significant tropical/extra-tropical interaction on medium and long time scales****."*

ECMWF/ESA Workshop 2016

Reanalyses (Adrian Simmons)

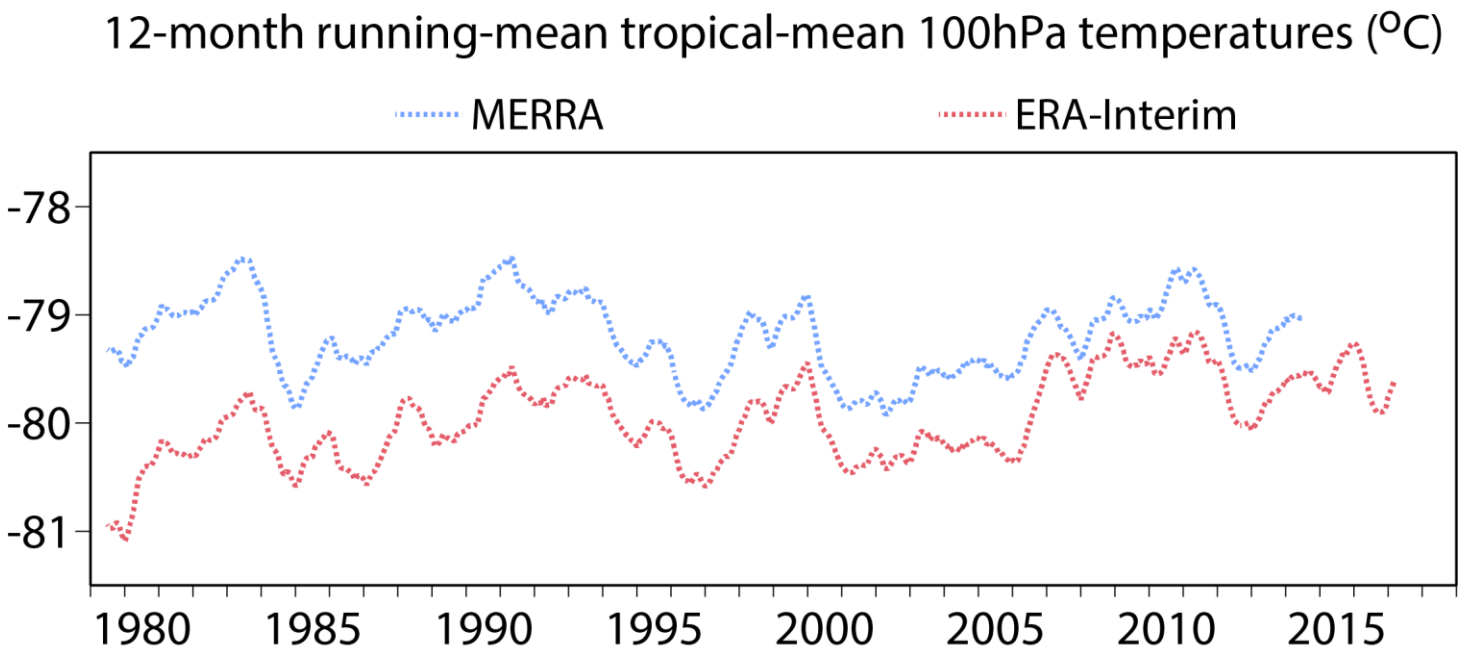
- GPS-RO is now considered an essential measurement for climate reanalyses (e.g., ERA-5, ERA-Interim, JRA-55, MERRA, MERRA-2).

  - Anchor measurements: assimilated without bias correction.

- The consistency of different climate reanalyses in the lower/mid stratosphere has improved significantly since the assimilation of COSMIC in 2006.

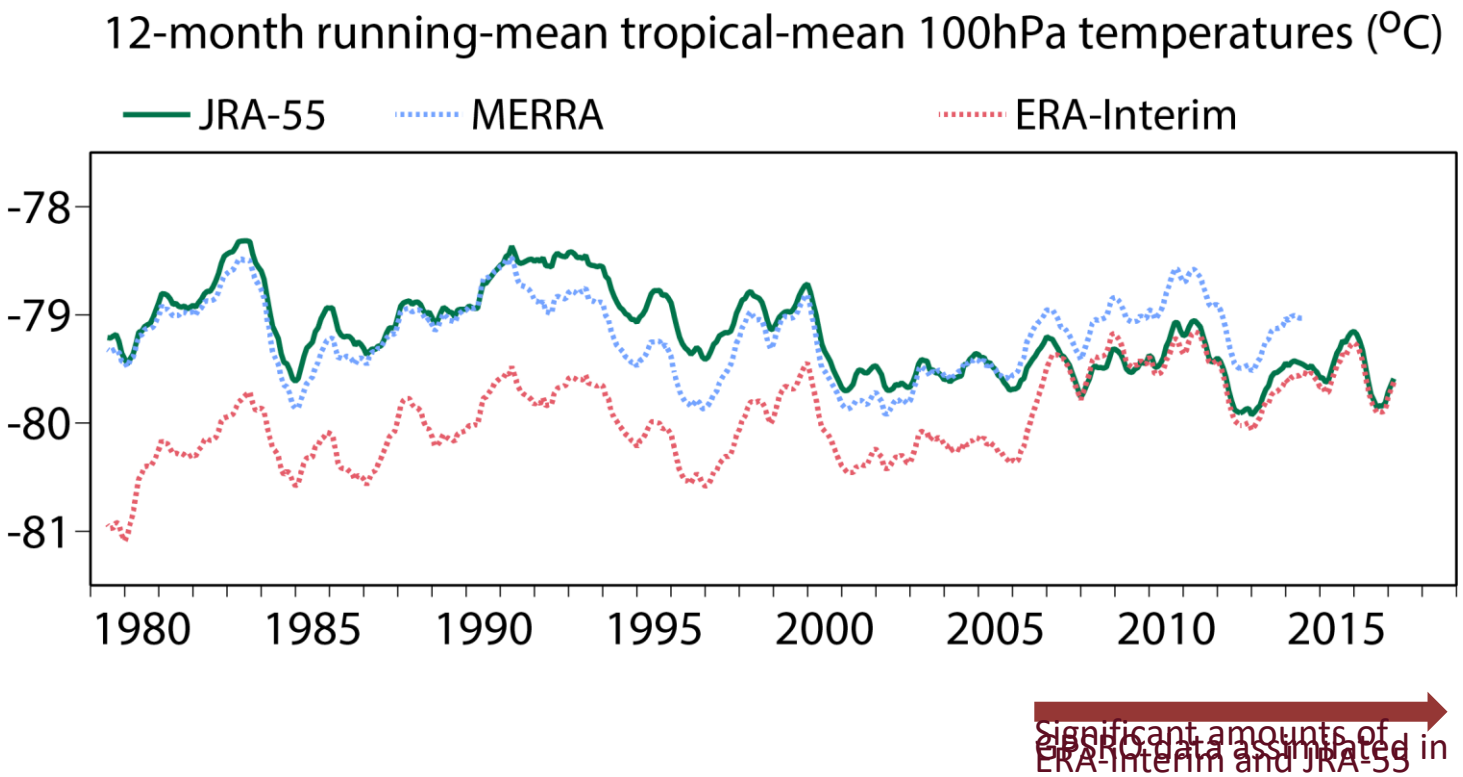
- Suggests the observation set prior to COSMIC was not sufficient to constrain the mean state.

Tropical tropopause temperature



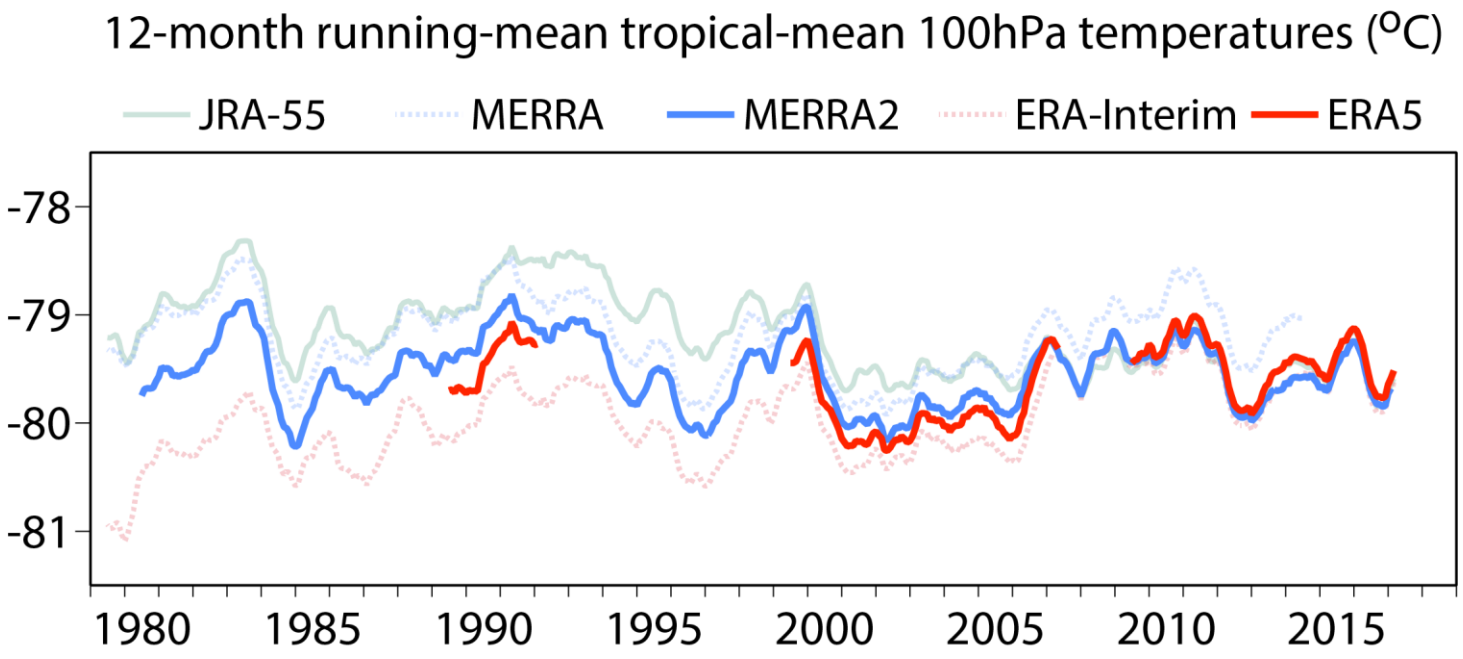
MERRA is warmer than ERA-Interim throughout.

Tropical tropopause temperature



MERRA is warmer than ERA-Interim throughout.
ERA-Interim and JRA-55 assimilate GPSRO data, and come together in 2006.
ERA-Interim warms and JRA-55 cools when significant amounts of GPSRO data start to be assimilated.

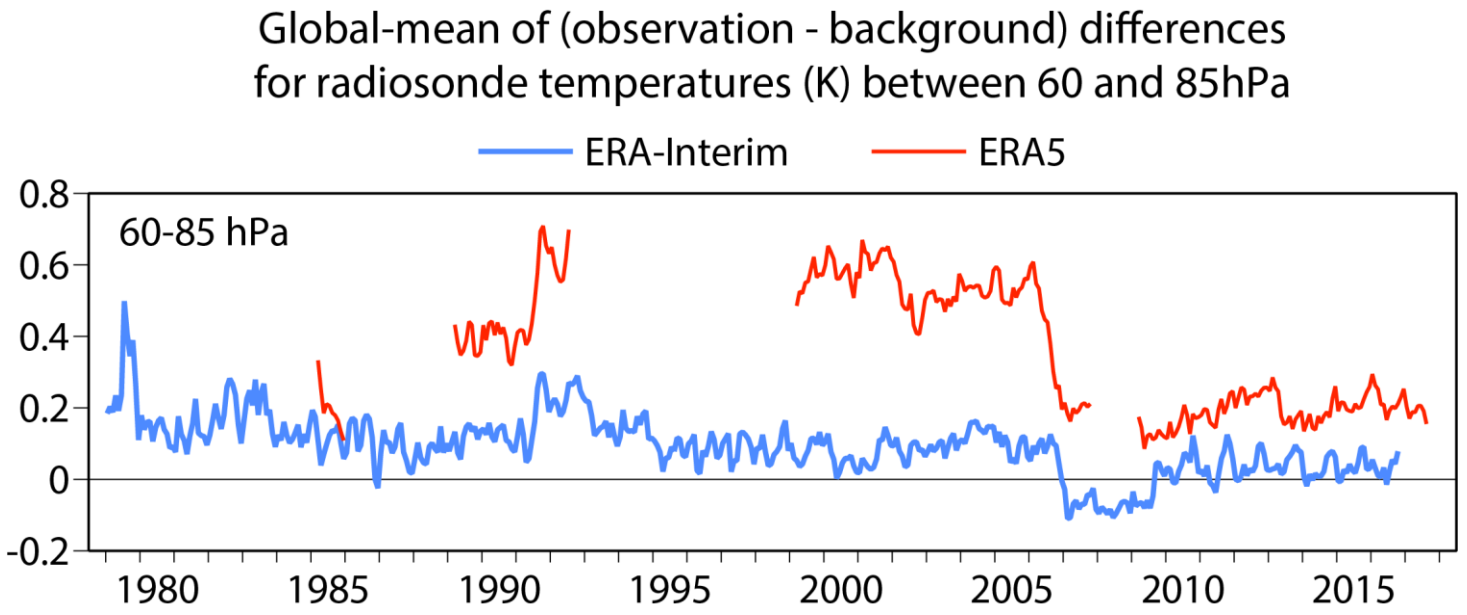
Tropical tropopause temperature



Significant amounts of GPSRO data assimilated in ERA-Interim, JRA-55 and MERRA-2

MERRA is warmer than ERA-Interim throughout.
ERA-Interim and JRA-55 assimilate GPSRO data, and come together in 2006.
ERA-Interim warms and JRA-55 cools when significant amounts of GPSRO data start to be assimilated.
ERA5 and MERRA2 assimilate GPSRO data. They come together in 2006 along with ERA-Interim and JRA-55, but are much closer throughout.

Lower stratospheric global temperature bias



Data assimilation error statistics have been re-derived using the observing system as it was at the start of the period

Assimilation of significant amounts of GPSRO data substantially improves fit to radiosonde data in ERA5

The version of the assimilating model used for ERA5 has a larger cold bias in the lower stratosphere than the version used for ERA-Interim.

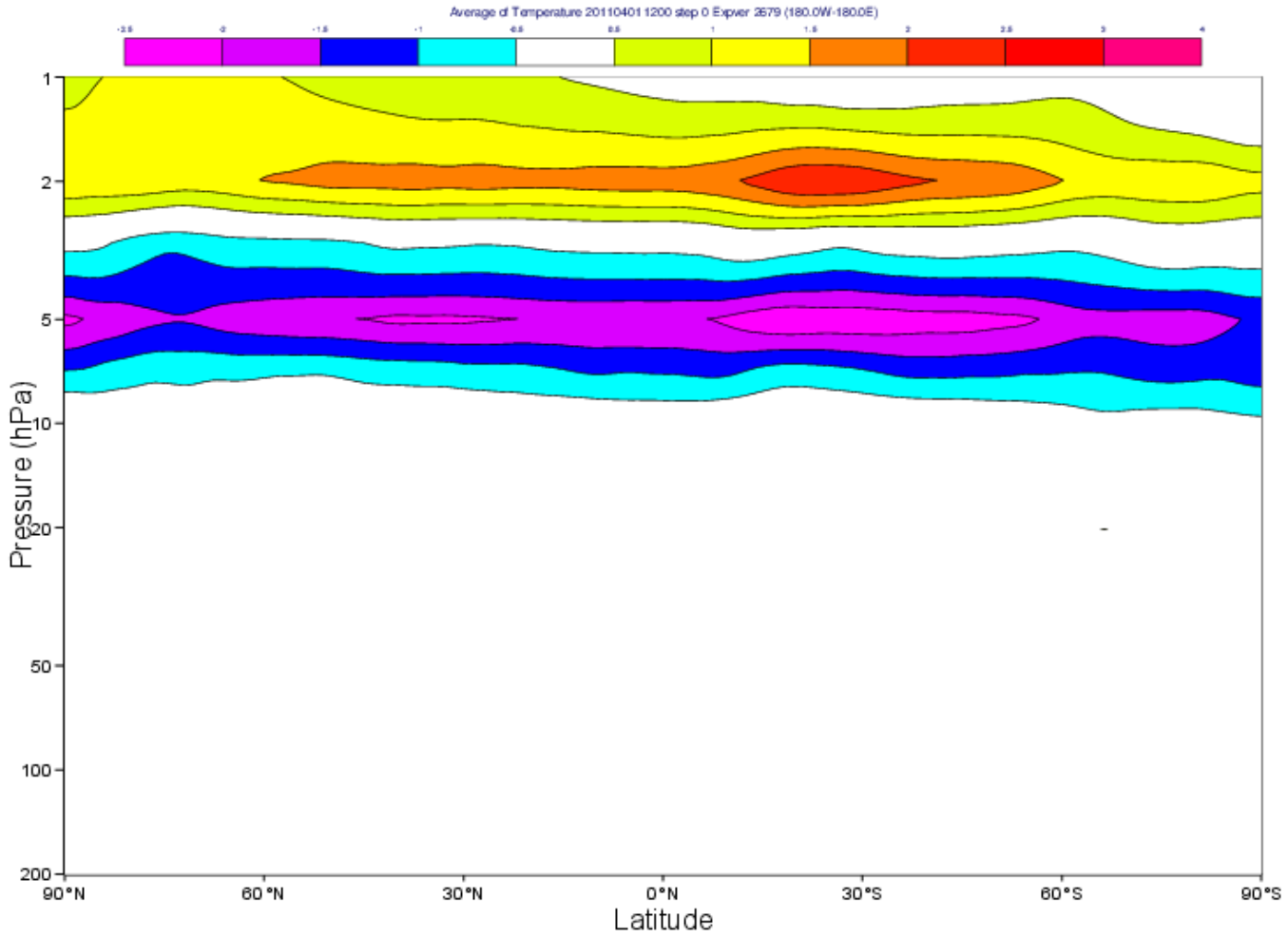
The cold bias is controlled by assimilating GPSRO data.

Radiosonde data exert a less-effective control in ERA5 than they do in ERA-Interim.

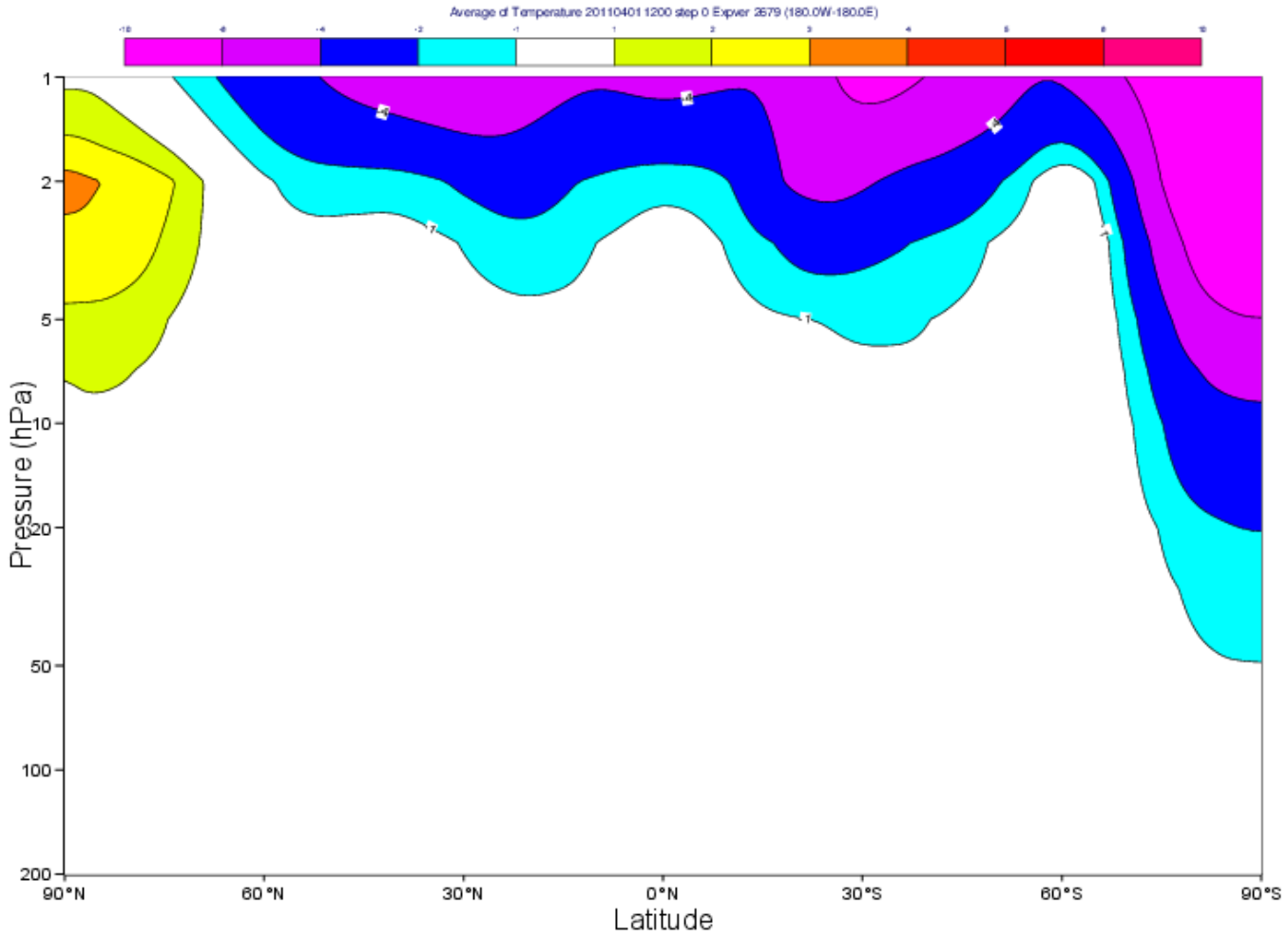
Some experiments: T159, Jan-June 2011

- **CTL**: Everything. The GPS-RO data you use in ERA5.
- **NoRO**: CTL minus GPS-RO.
- **REF**: No radiances, no aircraft T.
- **CH14**: REF **+ AMSU-A ch 14 as an anchor**.
- **CH14_noRO**: CH14 but no GPS-RO

CTL vs NoRO mean Temp. 2 month average



CTL v REF (ie removing all radiances)



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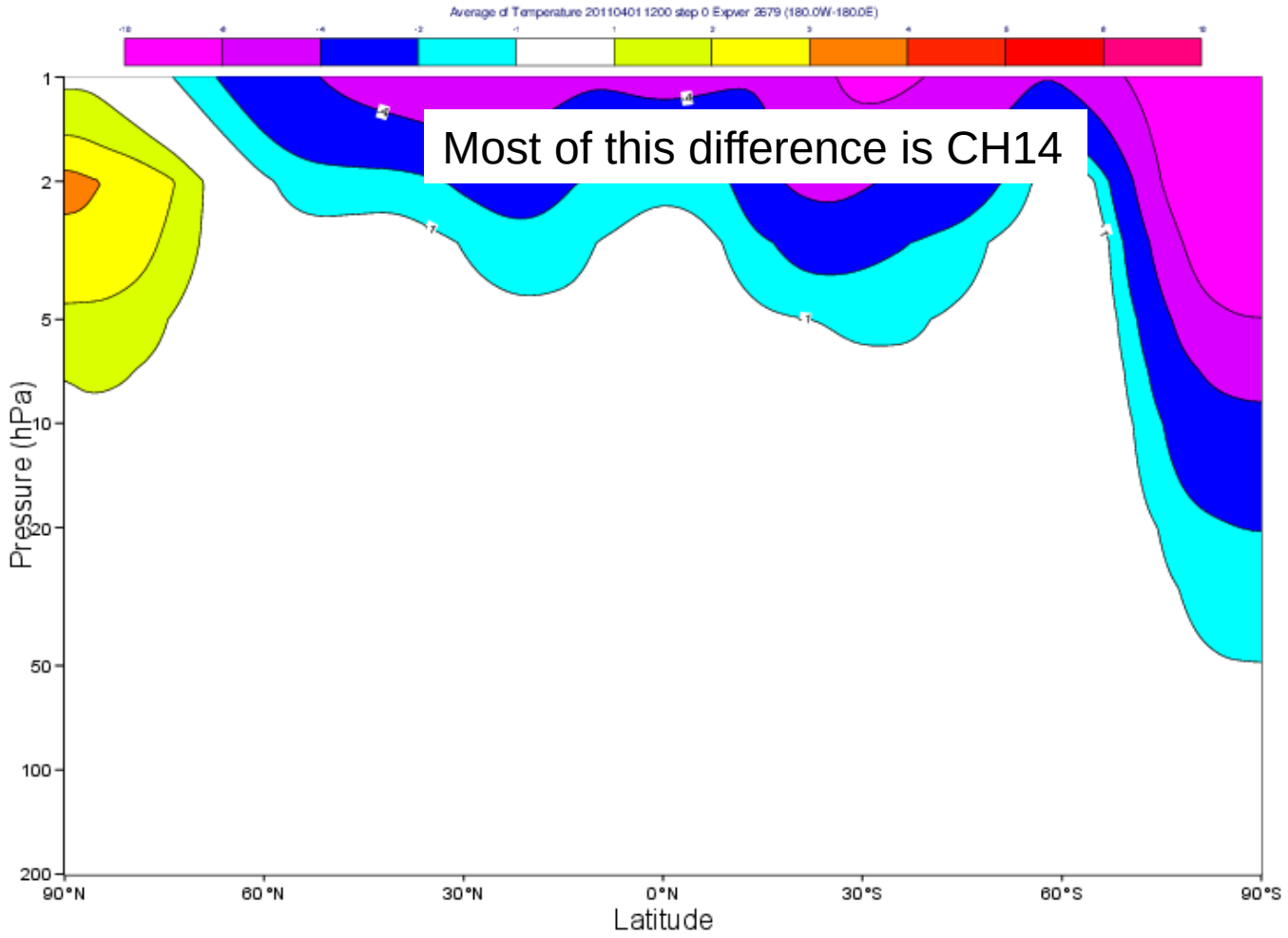

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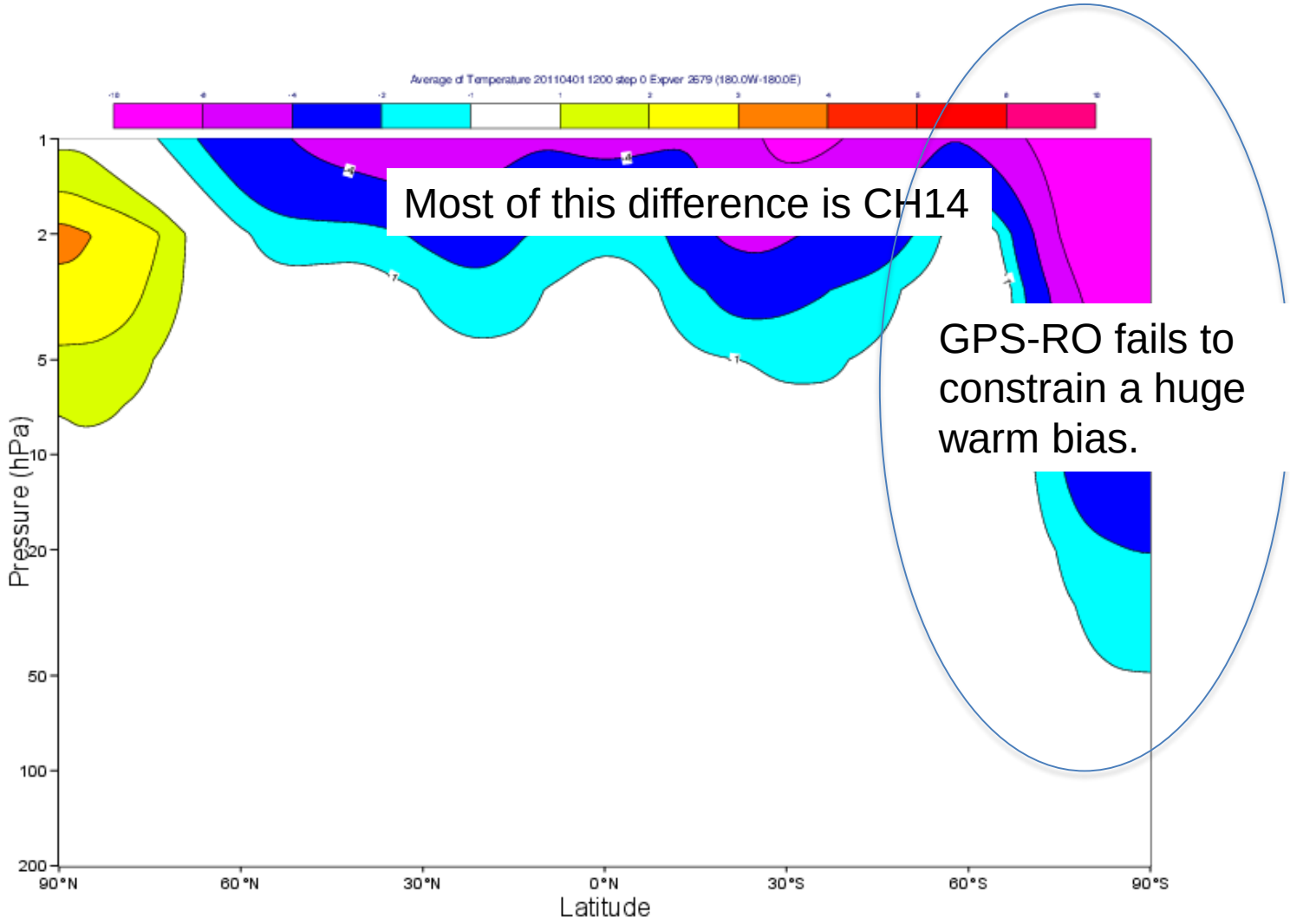
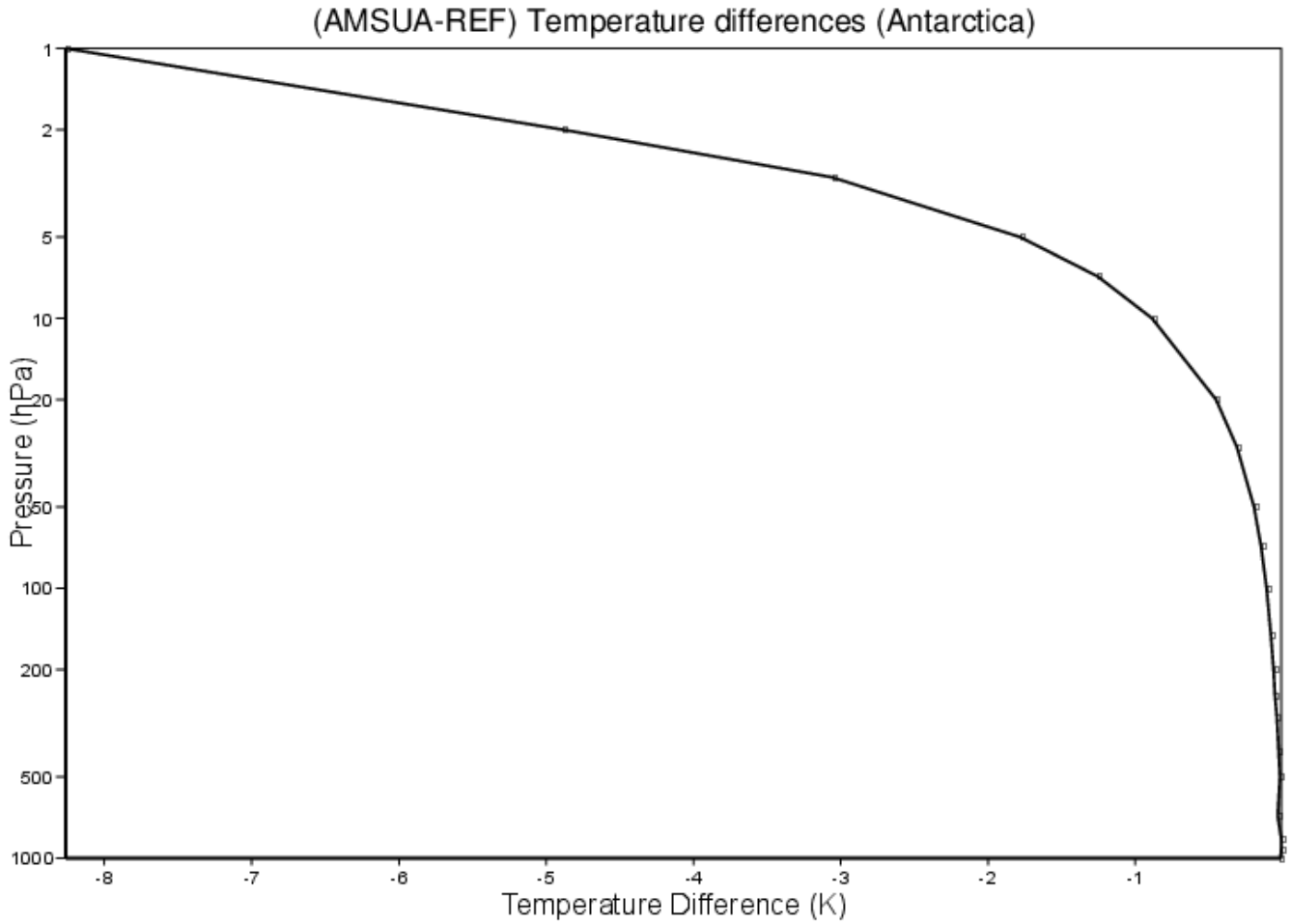
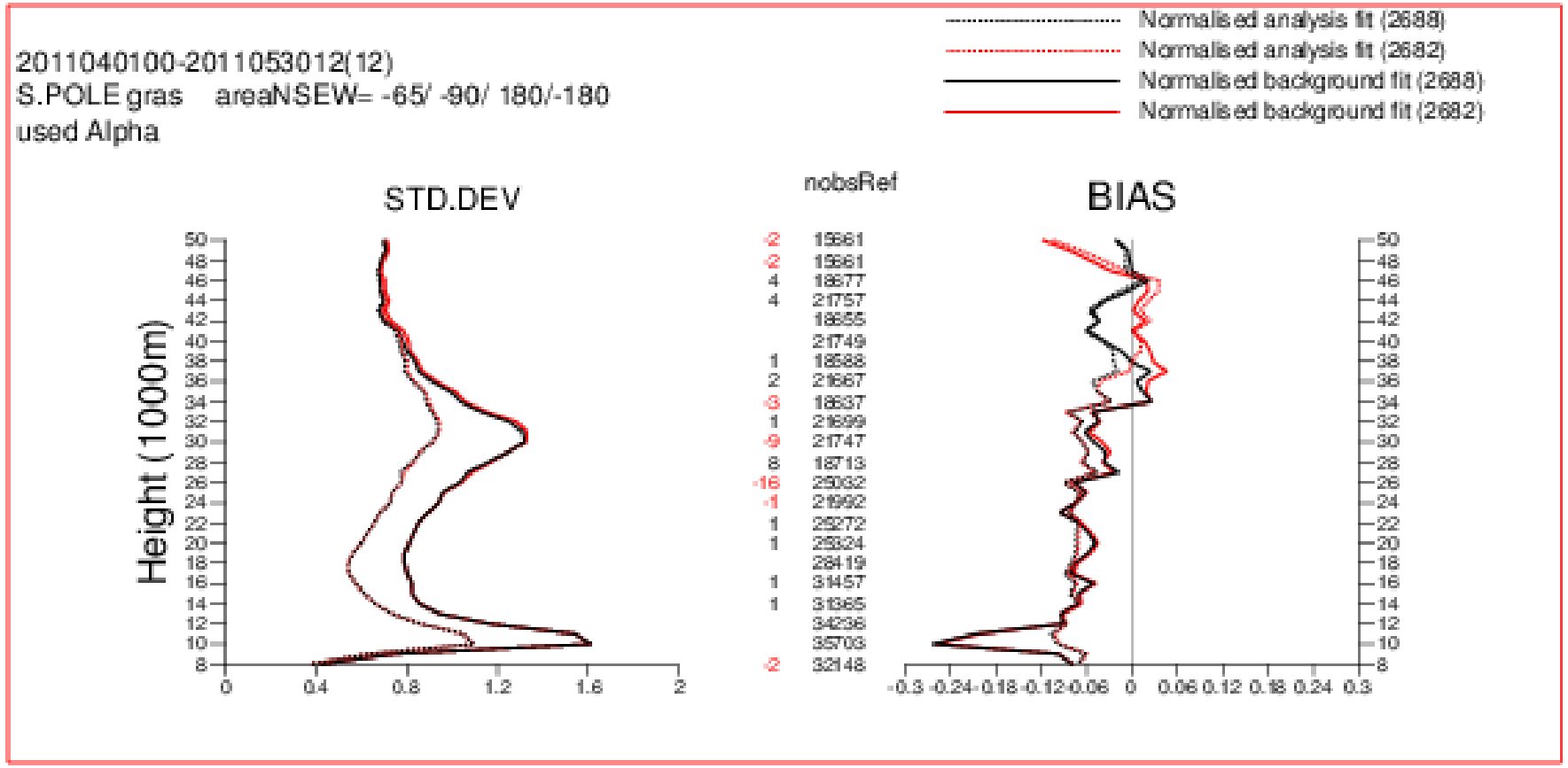


Impact of CH14 in **S.Polar region** (April/May 2011) (CH14-REF). Mean Temp difference (GPS-RO **NULL SPACE**)



GRAS bending angle departure at S.Pole (-65 lat <)
BLACK=AMSU+GPS-RO, **RED=GPS-RO**

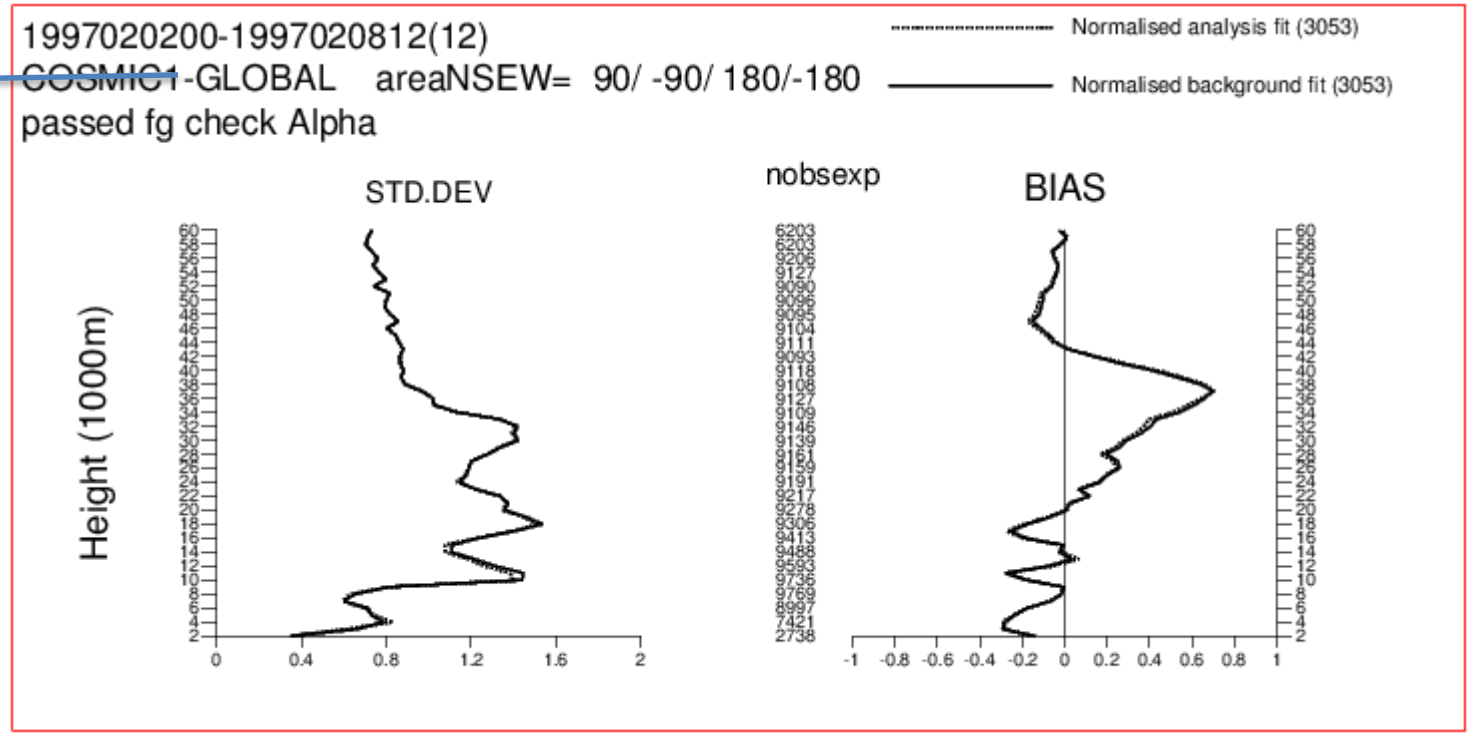


Stats are (**o-b)/sigma_o**, **(o-a)/sigma_o**

GPS/MET

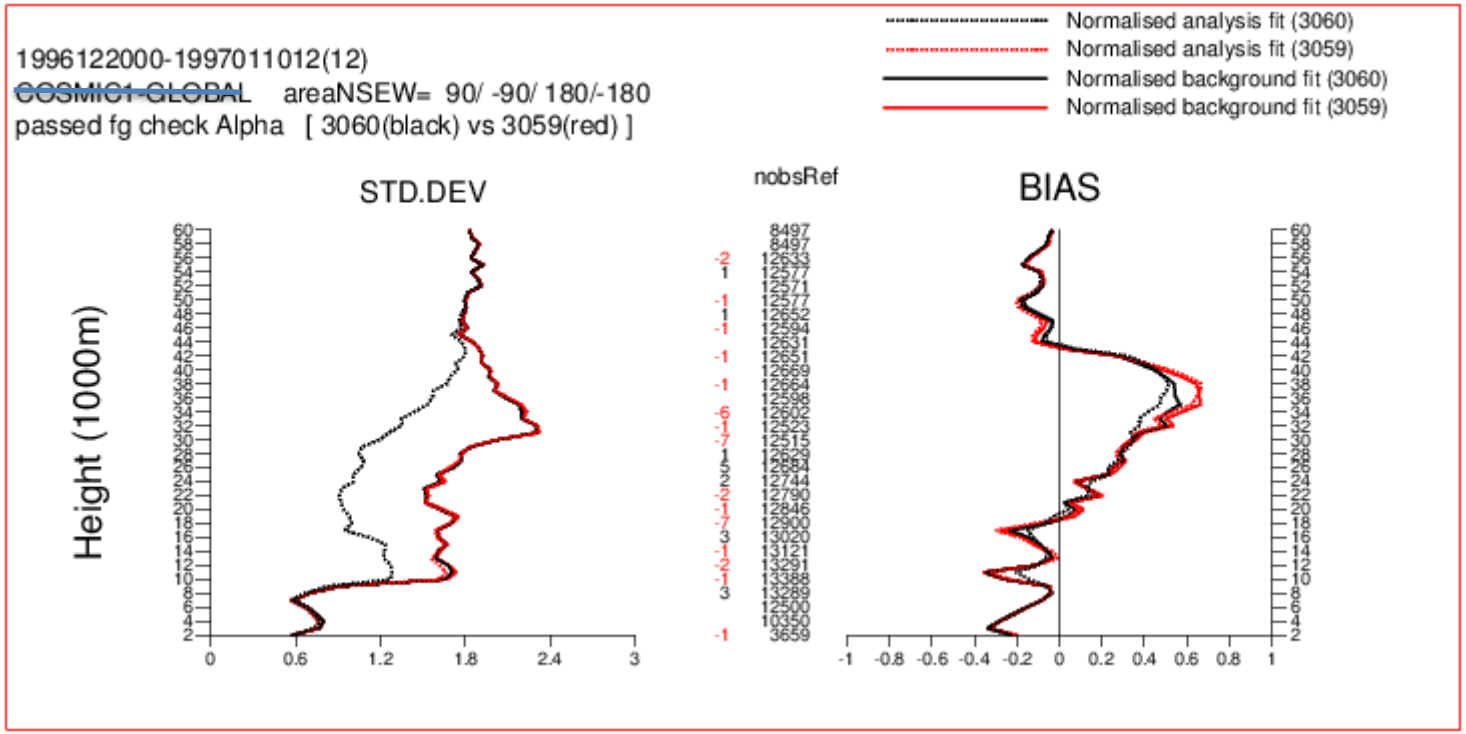
- We have performed reanalysis experiments with GPS/MET.
- Both prime-time and AS/ON data.

Prime-time GPS/MET: Feb 2-8, 1997 (PASSIVE)



sigma(O-B) above 30 km ~ 2 mu-rad.

GPS-MET in reanalysis system



Ignore the <u>COSMIC-1</u> name. **Black = GPS/MET active**, **RED=passive.**

(o-b)/sigma_o stats.

A/S on (ie, not prime-time) ~***5-6 mu-rad noise*** in stratosphere. Useful data for reanalysis. Prime-time noise more like ~***2 mu-rad***. Have UCAR processed all the data from 1995-97?

Summary

- NWP
  - **GRAS** assimilated to the surface. GRAS now constitutes > 60 % of the data.
  - GPS-RO has strong impact to day-3.
  - **GNOS data looks very promising**. Rising/setting bias needs to be investigated.
  - EDA results **from IROWG-4** suggest that COSMIC-2 EQ will have an impact in the extra-tropics.
- Climate reanalysis
  - GPS-RO data are now essential for reanalyses. (*We must ensure that commercial data is available for reanalyses.*)
  - Much better consistency in the stratosphere.
  - We have performed experiments with **GPS/MET** data. Estimated noise values above 30 km of ~2 mu-rad (PRIME-TIME) and ~ 5 mu-rad (AS/ON).
  - Potentially useful dataset for reanalyses. Has everything been processed?