

The use of GPS-RO at ECMWF

Sean Healy

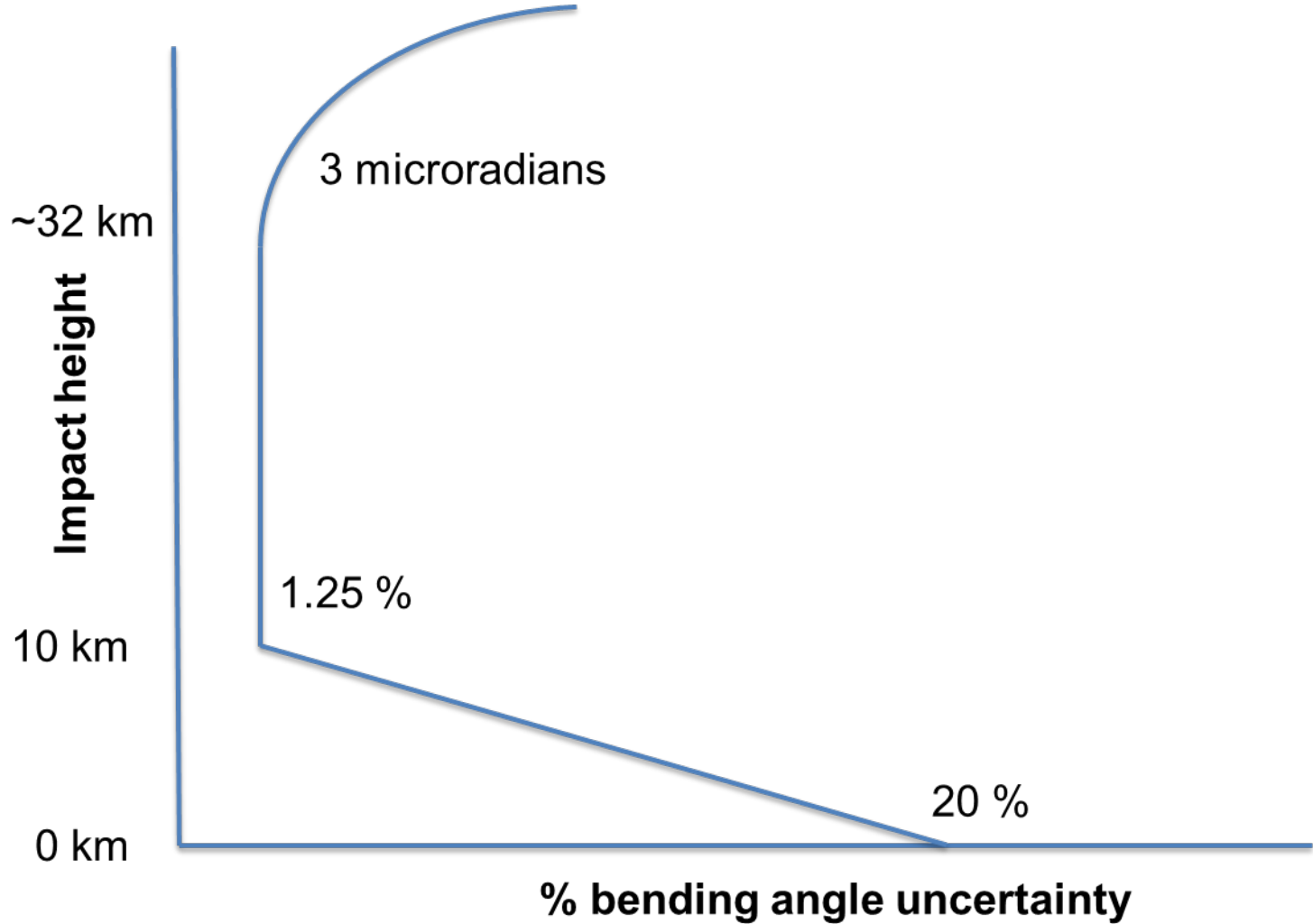


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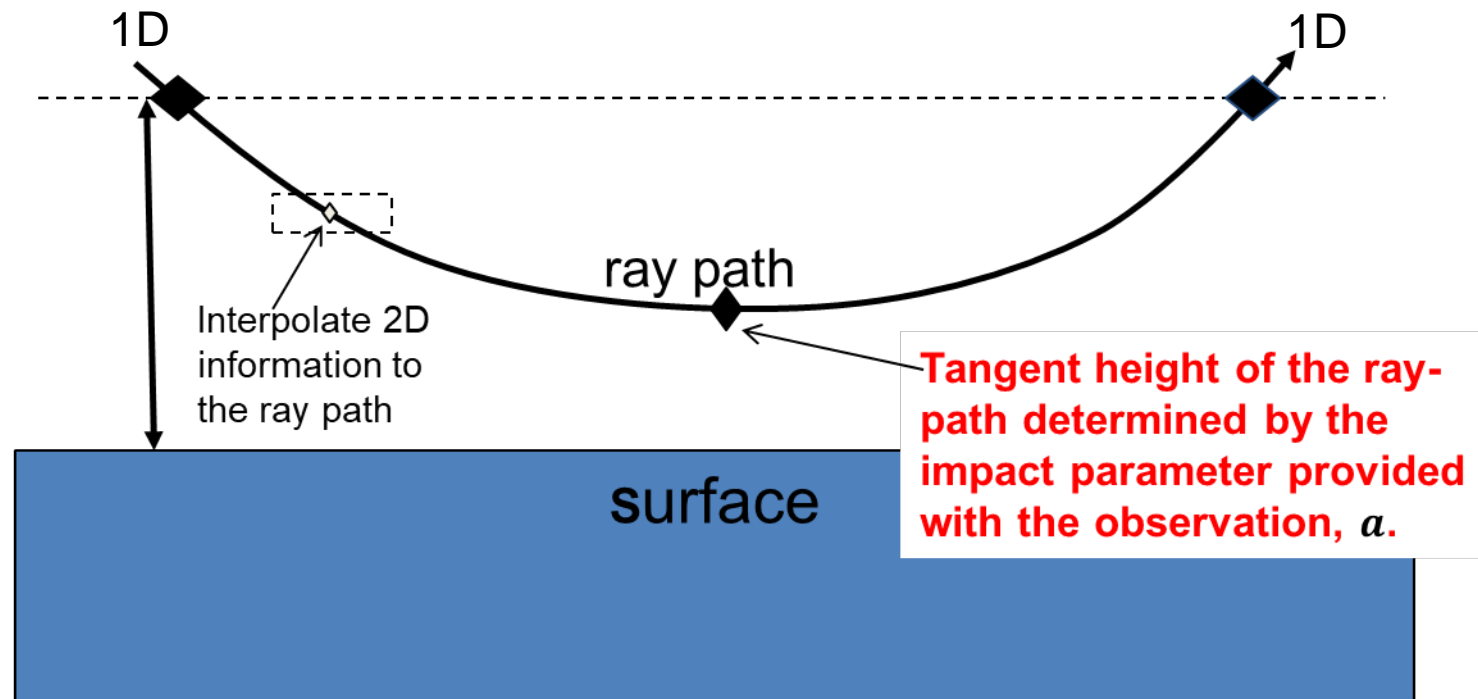
Outline

- Assimilation approach.
- Summarise a few operational changes.
- New spline interpolation in the 2D operator being tested for next operational cycle.
- Impact of the three GRAS instruments versus all GPS-RO.
- Sensitivity studies where I bias the the forward model.
- Summary.

Assumed error statistic model for all obs (CRUDE)

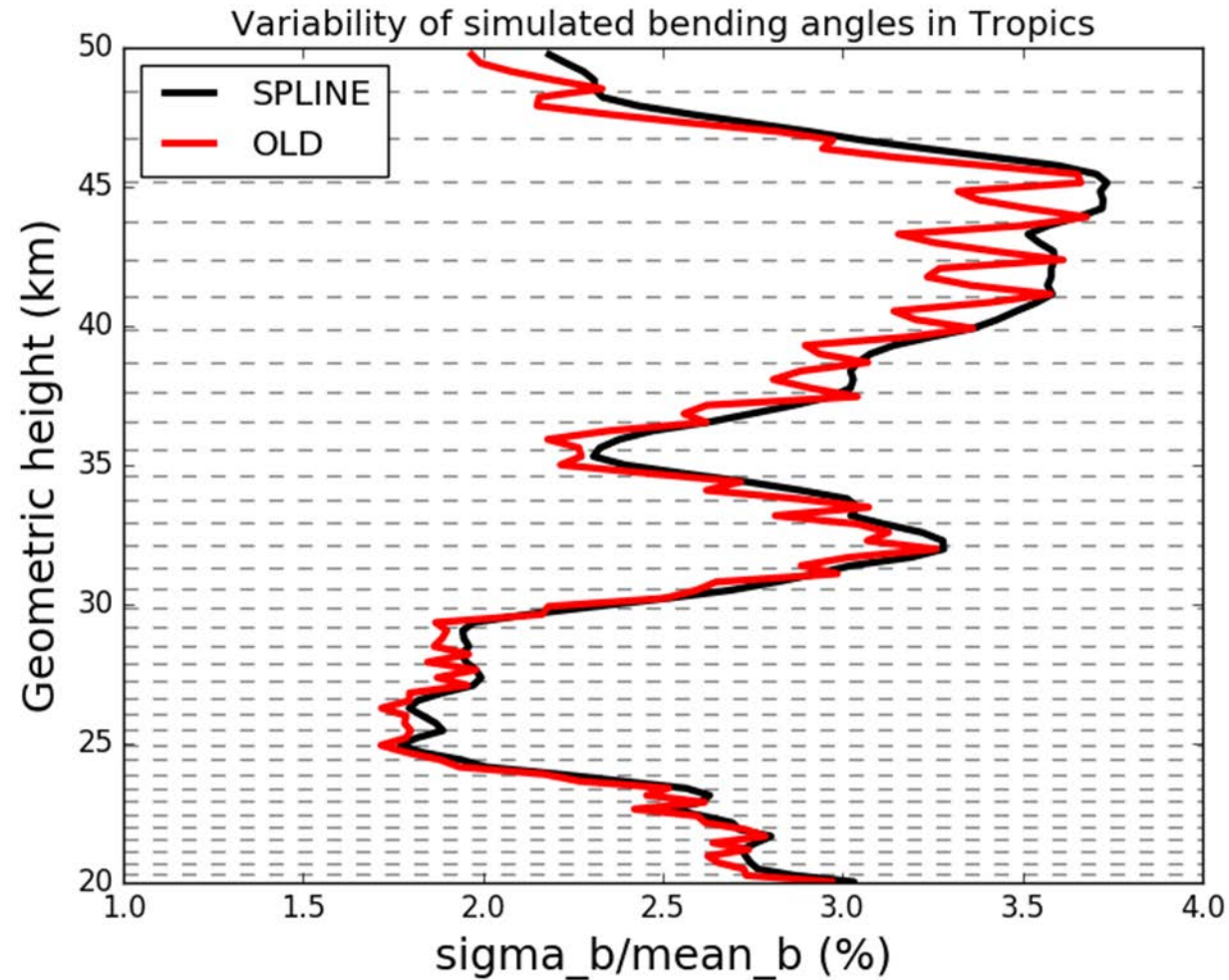


2D operator (available in ROPP with TL and AD code)

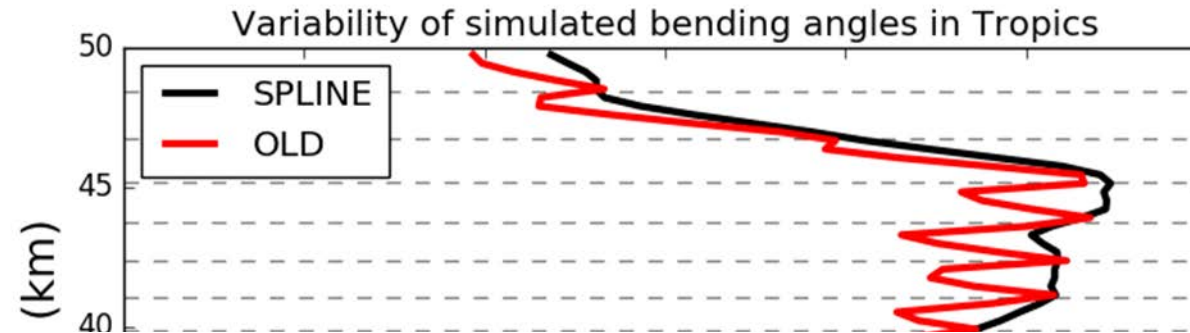


The outer loop uses 31 profiles to describe the 1200 km "occultation plane".

Cubic spline interpolation being tested for next operational change (47R1)



Cubic spline interpolation being tested for next operational change (47R1,)



I went back to check this because of Estes Park,

Gilpin, S., Anthes, R., & Sokolovskiy, S. (2019). Sensitivity of forward-modeled bending angles to vertical interpolation of refractivity for radio occultation data assimilation. *Monthly Weather Review*, 147, 269-289. doi:10.1175/MWR-D-18-0223.1

DWD already use spline interpolation.

Data usage up to 50 km

- Three Metop GRAS.
 - Metop-C GRAS March 2019
- TSX,TNDX.
- FY-3C GNOS
- COSMIC-6
- KOMPSAT-5 (July 2019)

We also monitor FY-3D

I used the introduction of Metop-C to test the combined impact of the Metops

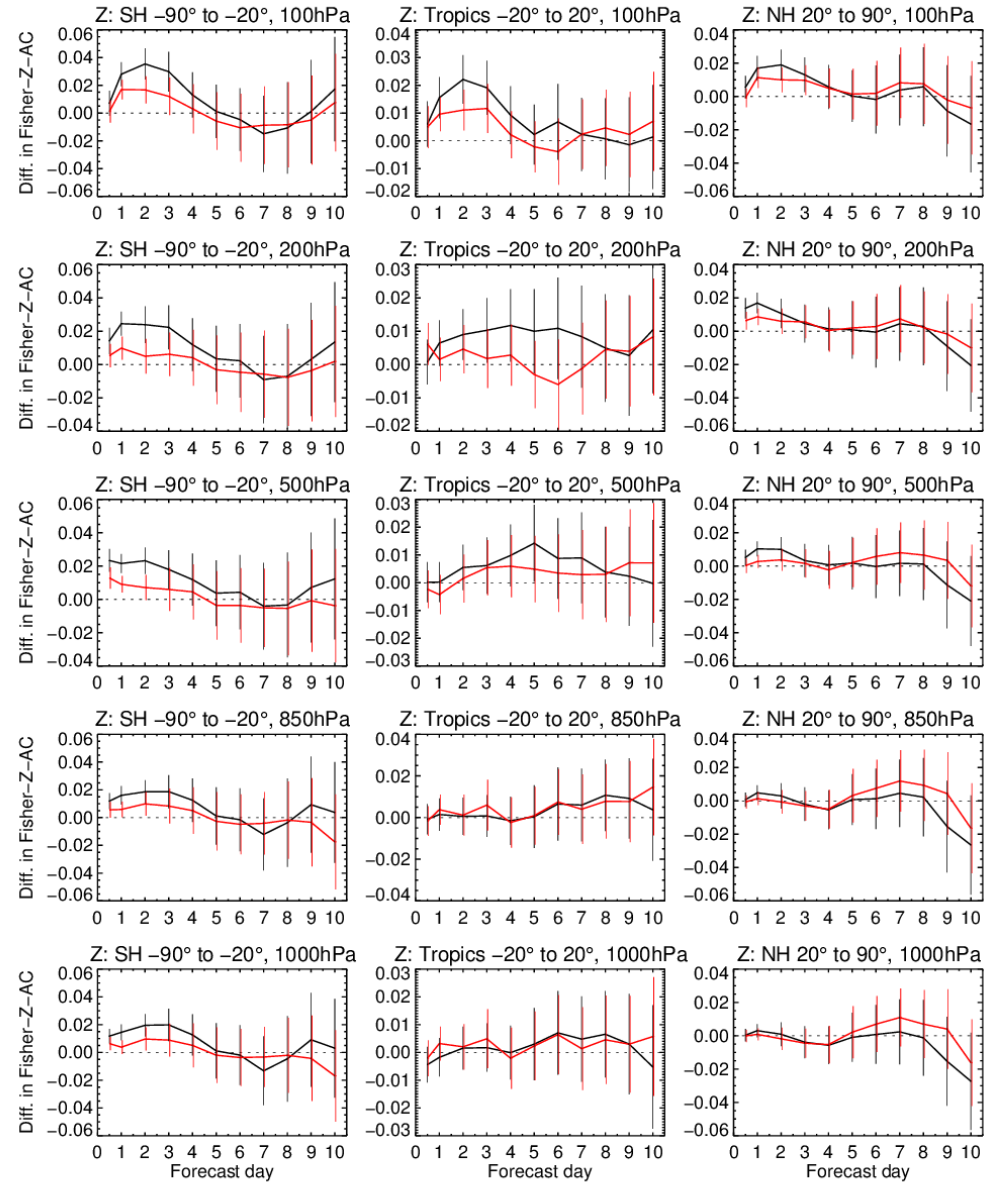
- All-RO
- No GRAS
- No RO

GRAS impact

Improvement in the anomaly correlation of the height fields.

27-Nov-2018 to 23-Mar-2019 from 214 to 233 samples. Verified against own-analysis.

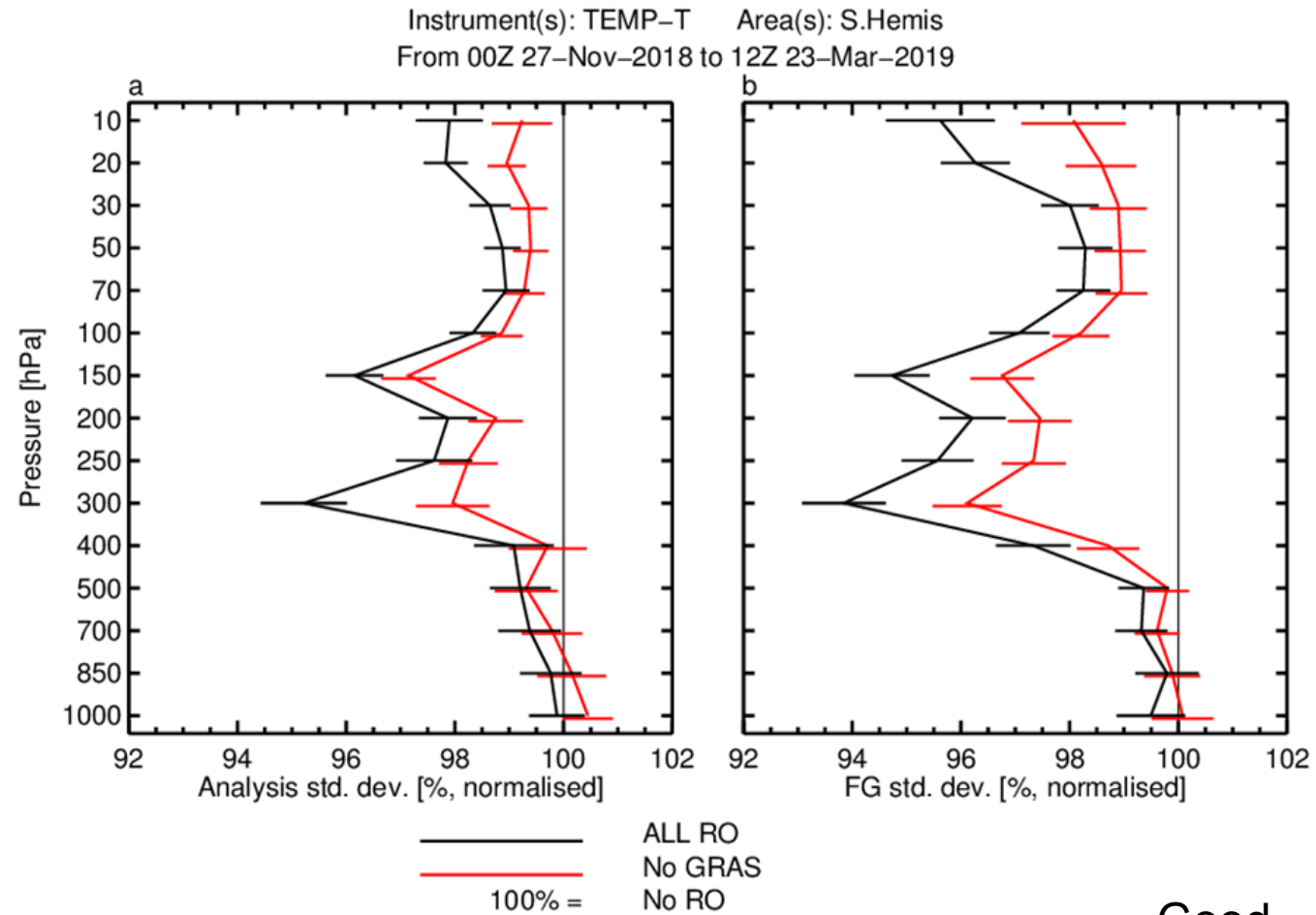
Confidence range 95% with AR(2) inflation and Sidak correction for 8 independent tests.



— ALL RO - No RO
— No GRAS - No RO



Short-range forecast fit to radiosonde temps (SH)



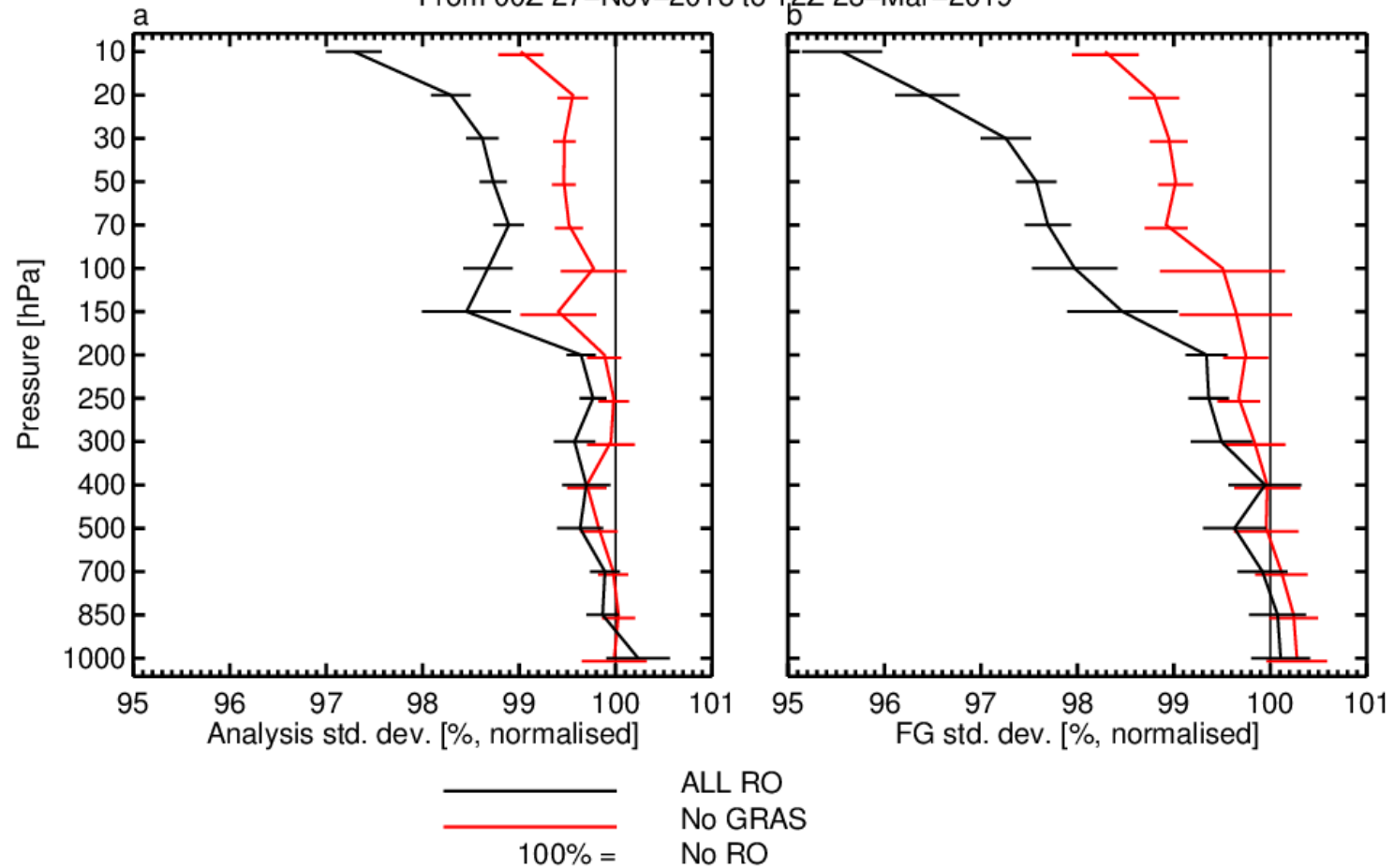
Good
←

Vector winds in the tropics!

Instrument(s): AIREP EUprofiler JPprofiler PILOT TEMP – Uwind Vwind

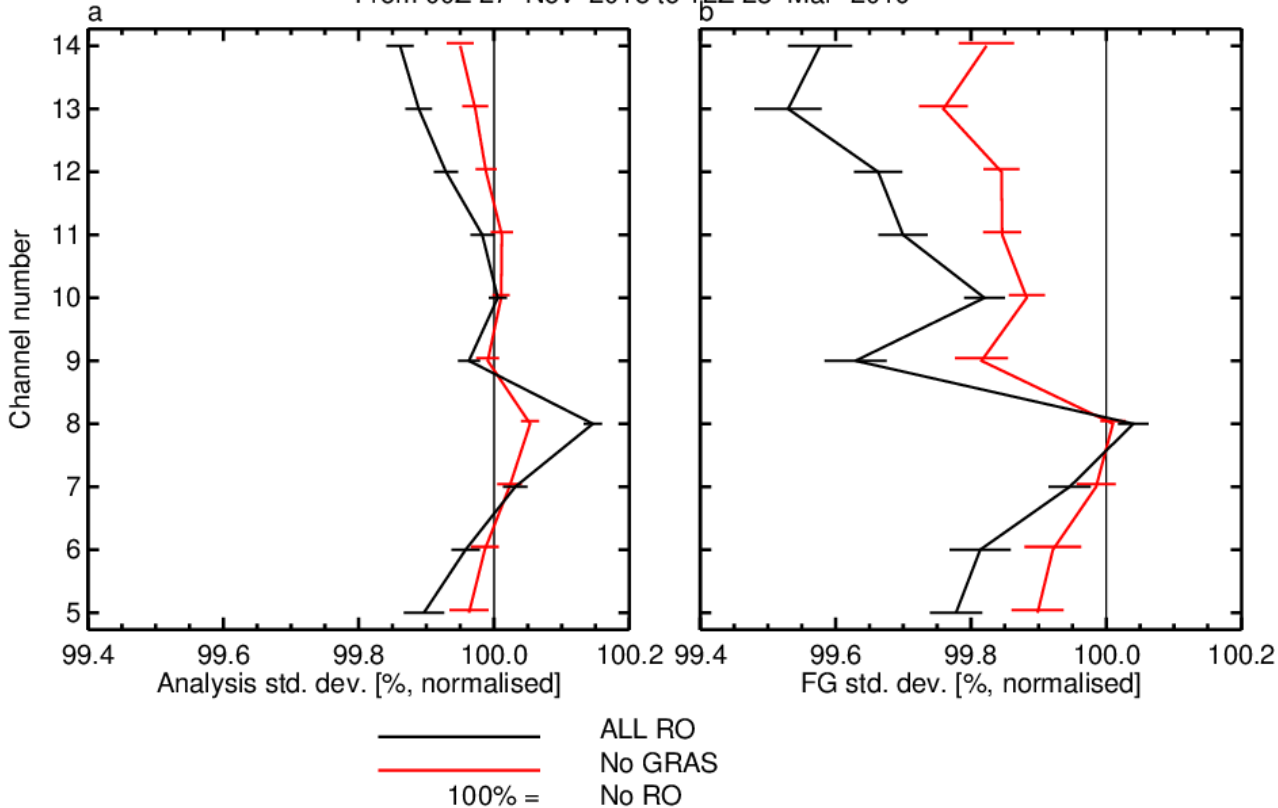
Area(s): Tropics

From 00Z 27–Nov–2018 to 12Z 23–Mar–2019

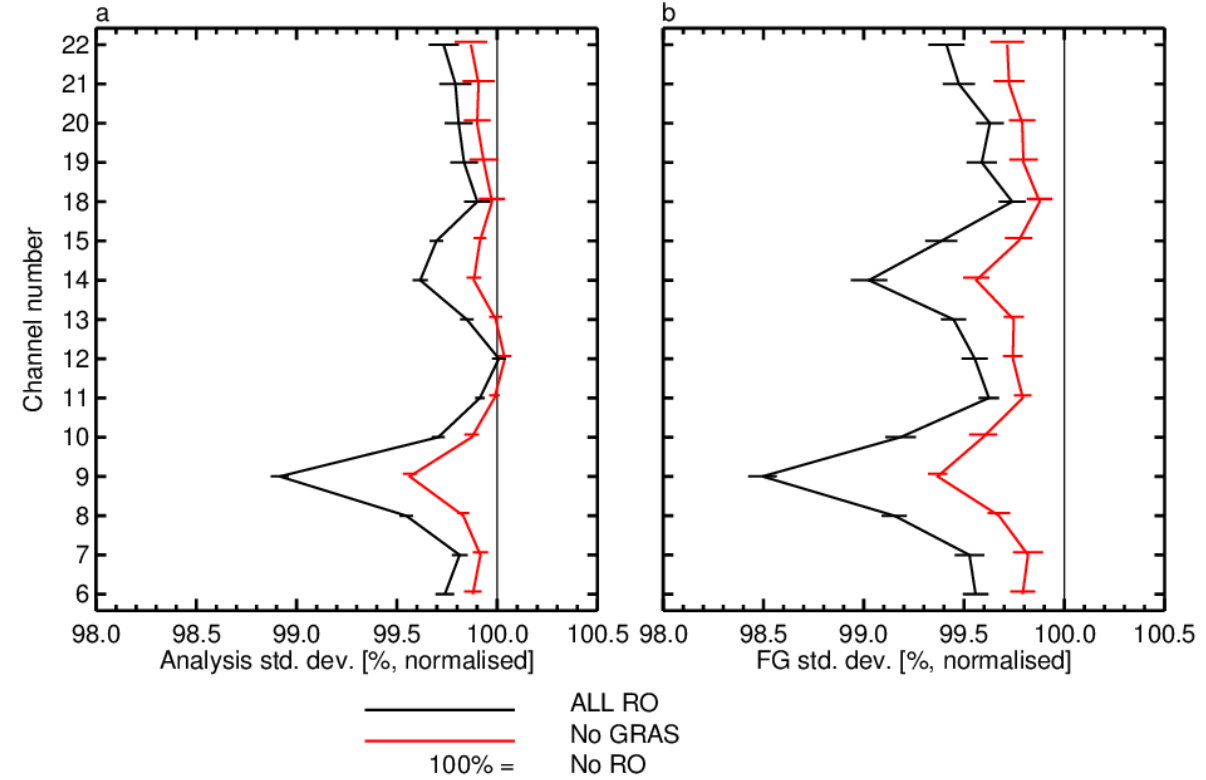


AMSU/ATMS fits

Instrument(s): AQUA metop-a metop-b metop-c noaa-15 noaa-18 noaa-19 sky - AMSU-A
 Area(s): N.Hemis S.Hemis Tropics
 From 00Z 27-Nov-2018 to 12Z 23-Mar-2019



Instrument(s): NOAA-20 ATMS Tb NPP ATMS Tb Area(s): N.Hemis S.Hemis Tropics
 From 00Z 27-Nov-2018 to 12Z 23-Mar-2019



Sensitivity study – introducing a bias in the forward model

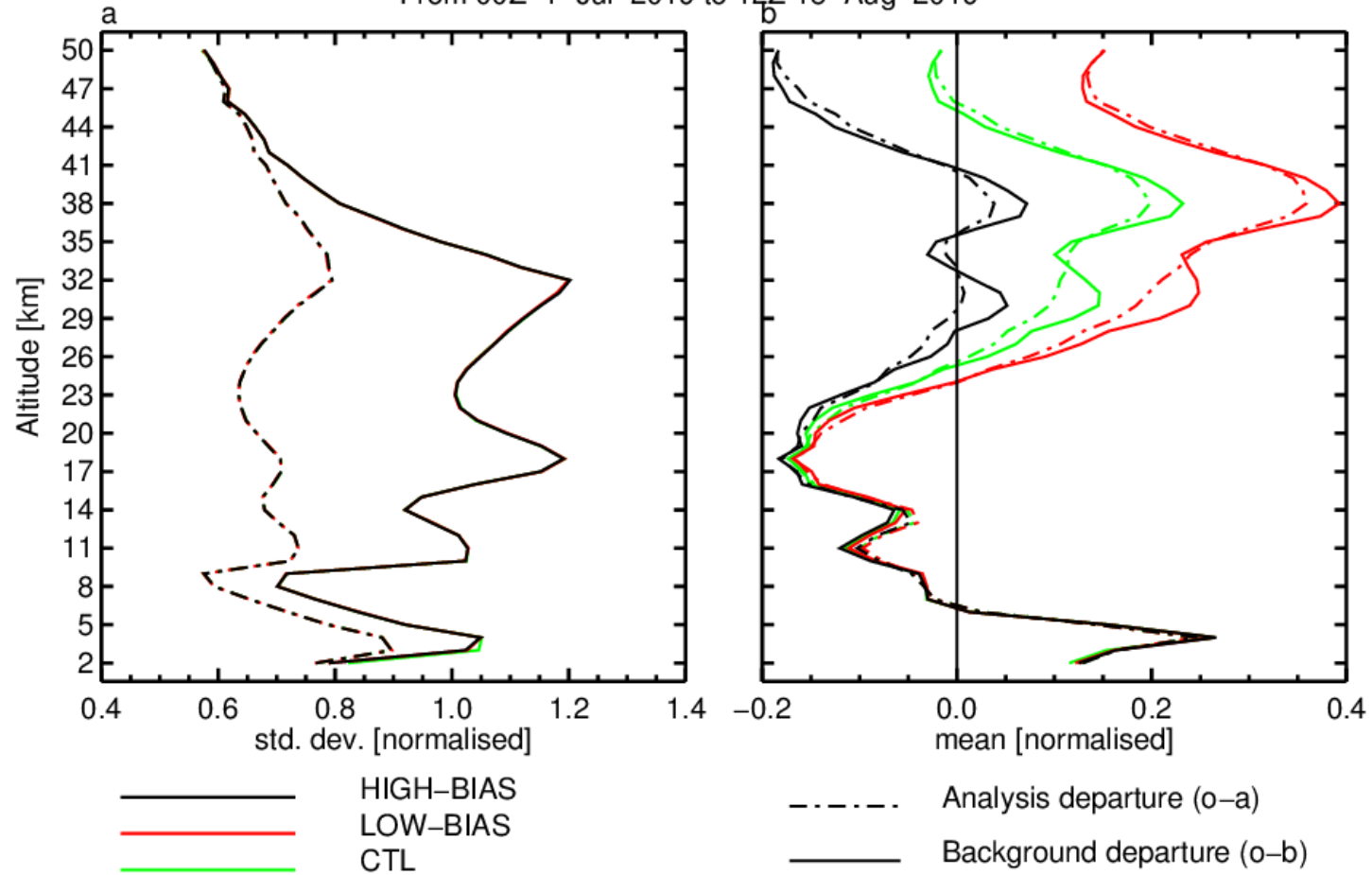
- Six week experiment from July 1 to Aug 15, 2019.
- **Control experiment: CTL**
- **Added a +ve forward model bias of 0.5 mu-rad to the profile: HIGH-BIAS**
 - $y-(H(x)+0.5 \text{ mu-rad})$
- **Subtracted 0.5 mu-rad from the forward model: LOW-BIAS**
 - $y-(H(x)-0.5 \text{ mu-rad})$
- 0.5 mu-rad is ~10 % bias at 60 km. For context, climatological residual ionospheric error is around 0.3 mu-rad at day/solar max.

Bias in bending angle departures $(o-b)/\sigma_o$

Instrument(s): METOP-AR,AS,BR,BS,CR,CS COSMIC-1R,1S,6R

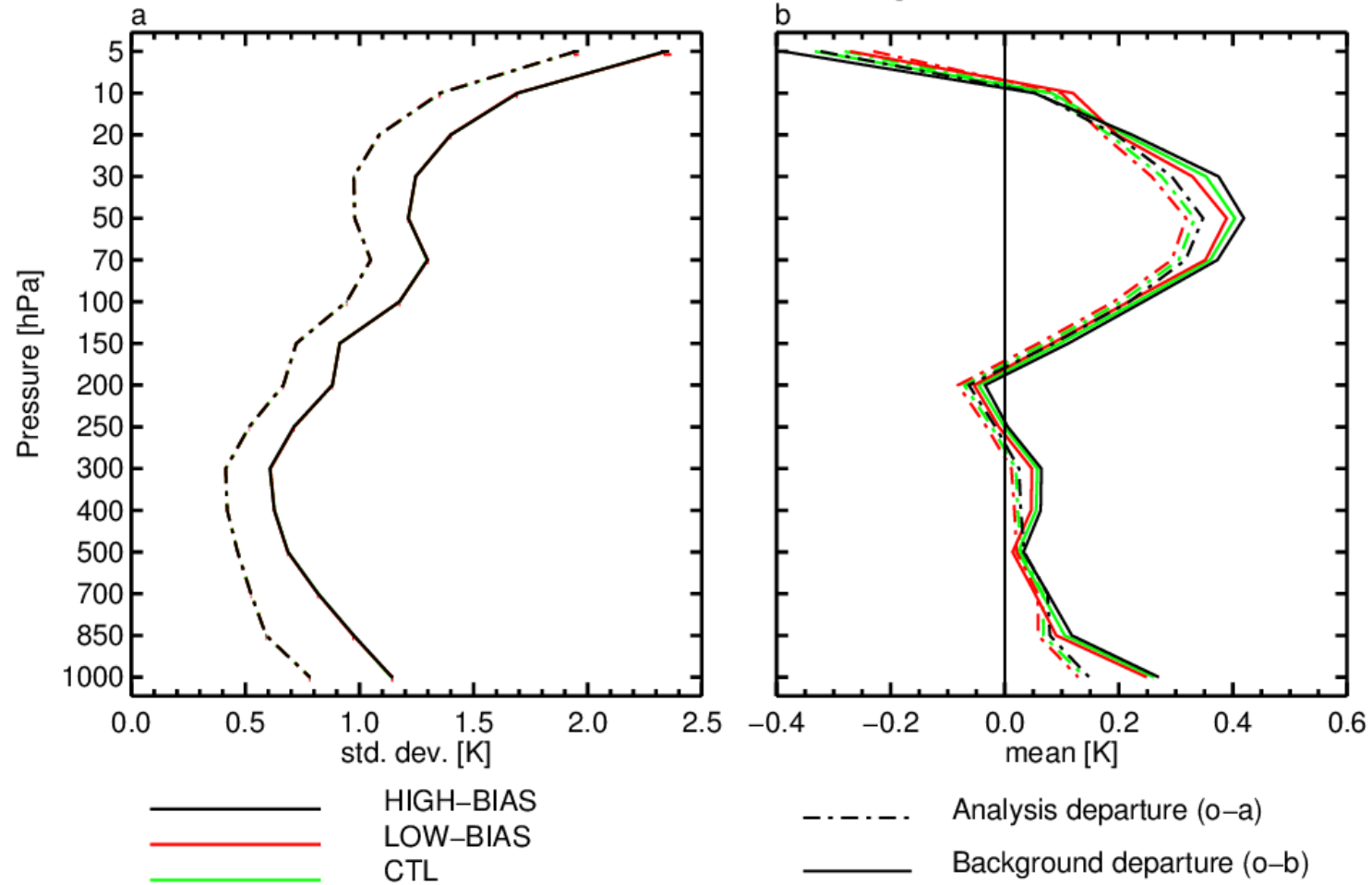
Area(s): N.Hemis S.Hemis Tropics

From 00Z 1-Jul-2019 to 12Z 15-Aug-2019



Impact on radiosonde temperature (global)

Instrument(s): TEMP-T Area(s): N.Hemis S.Hemis Tropics
From 00Z 1-Jul-2019 to 12Z 15-Aug-2019

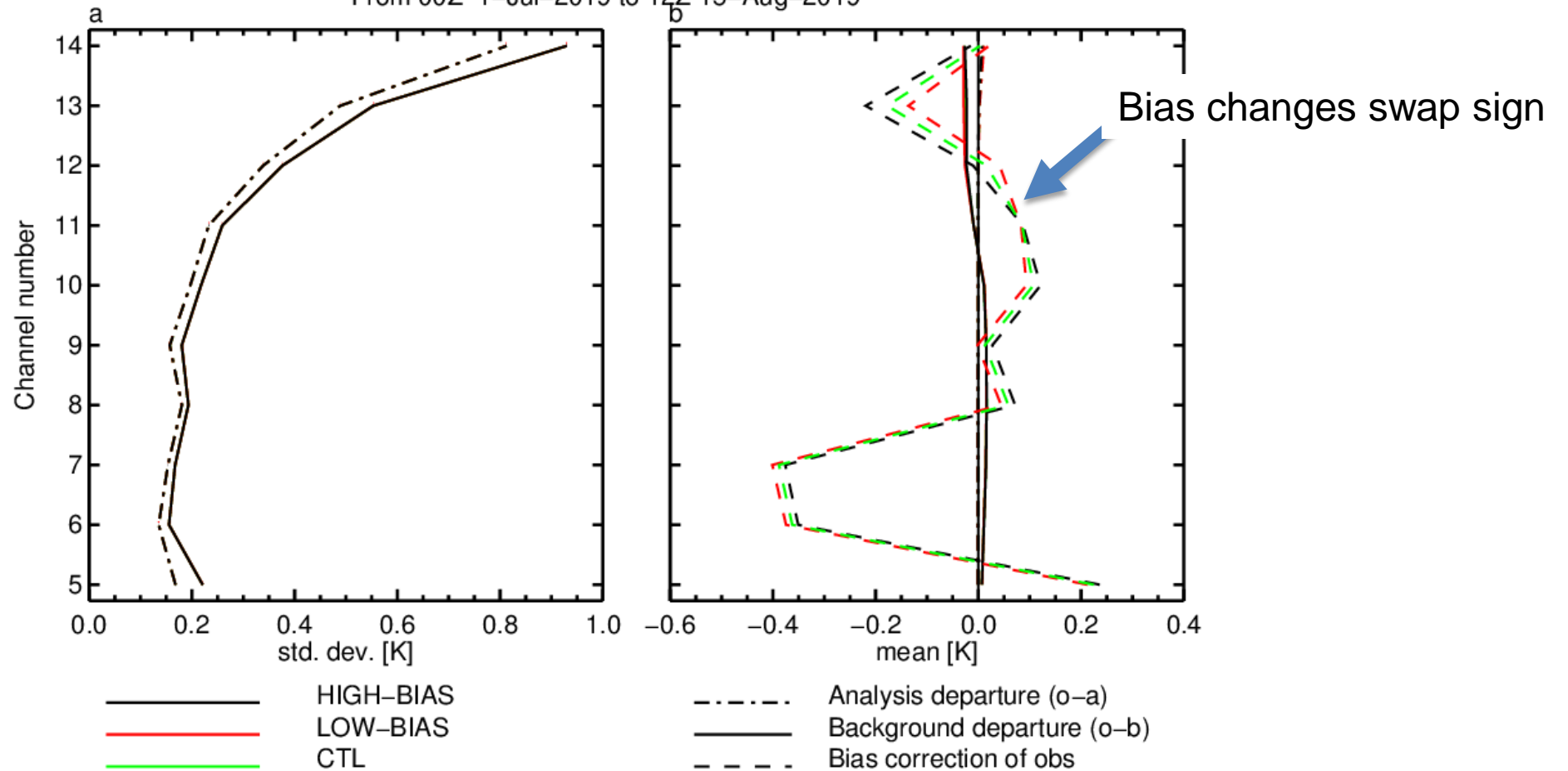


amsu radiances

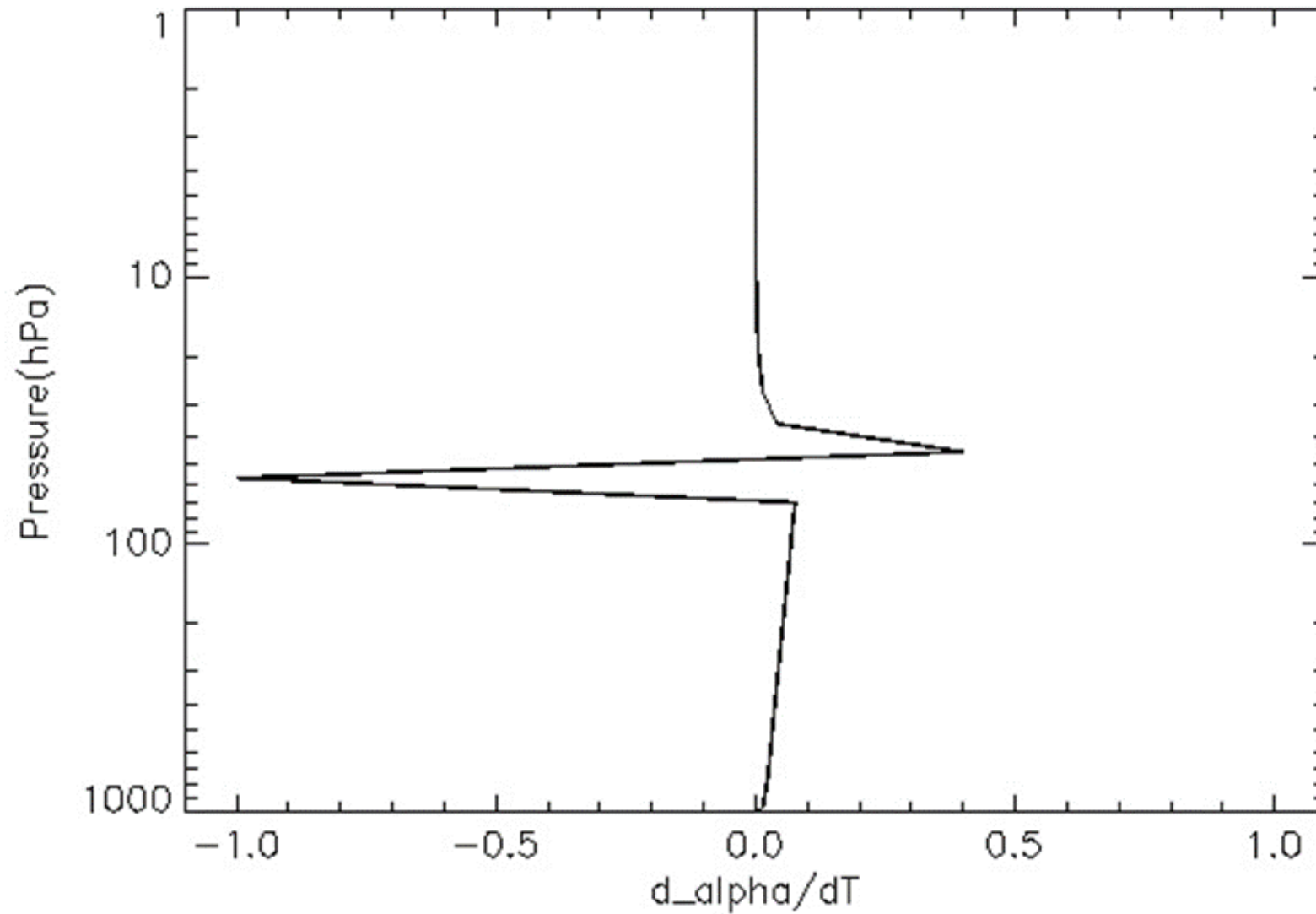
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Area(s): N.Hemis S.Hemis Tropics

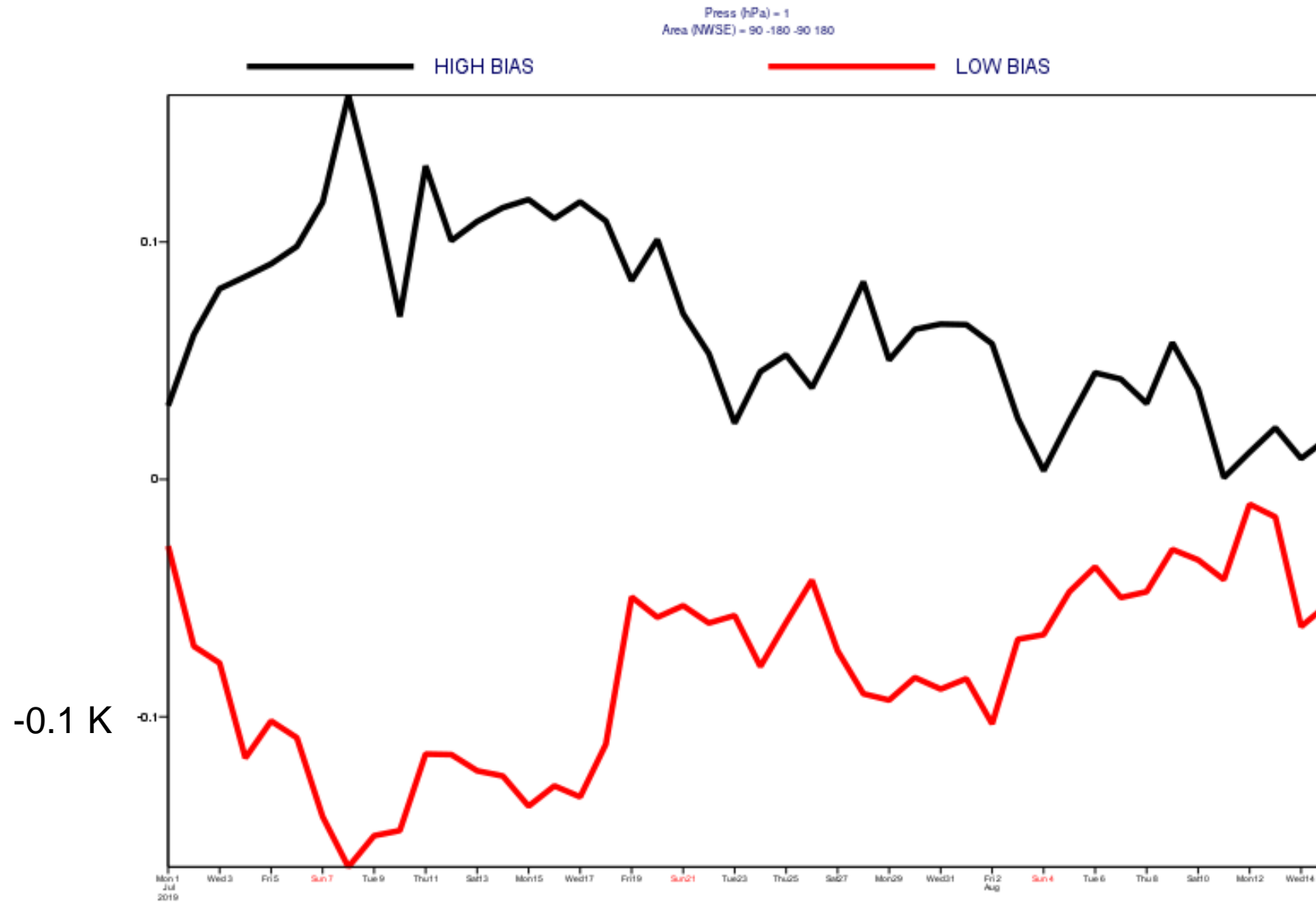
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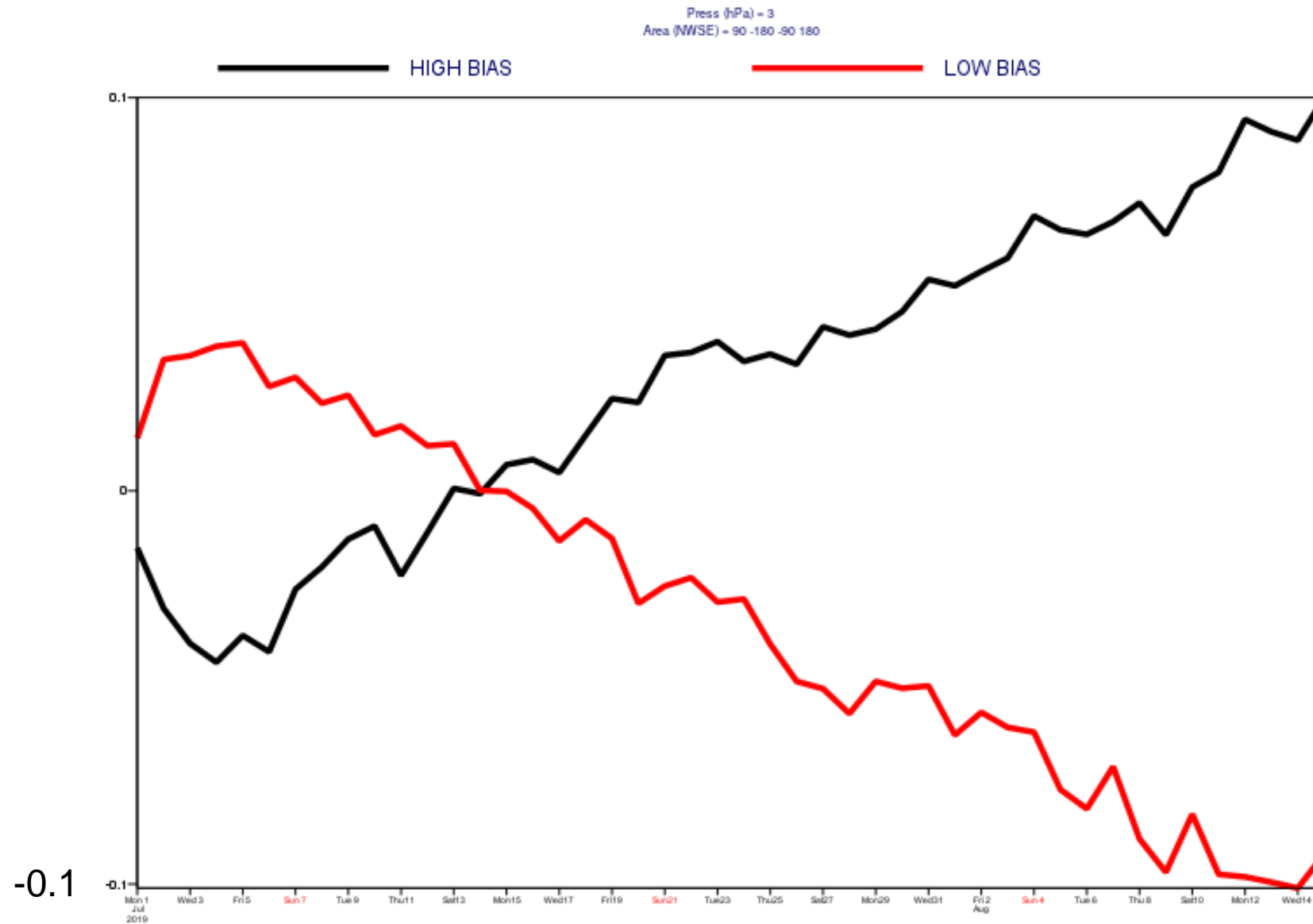
Weighting function (Eyre 1994)



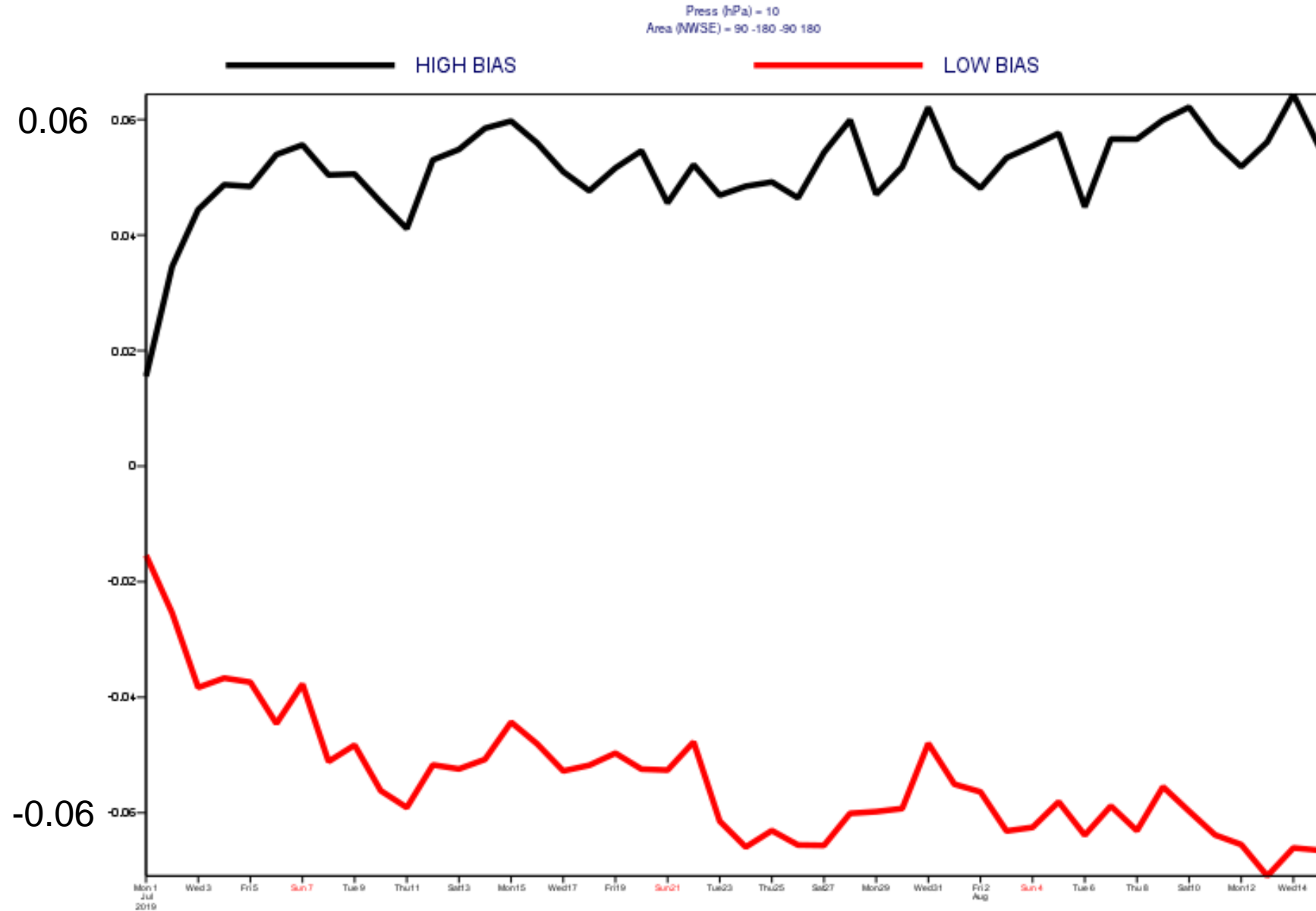
1 hPa



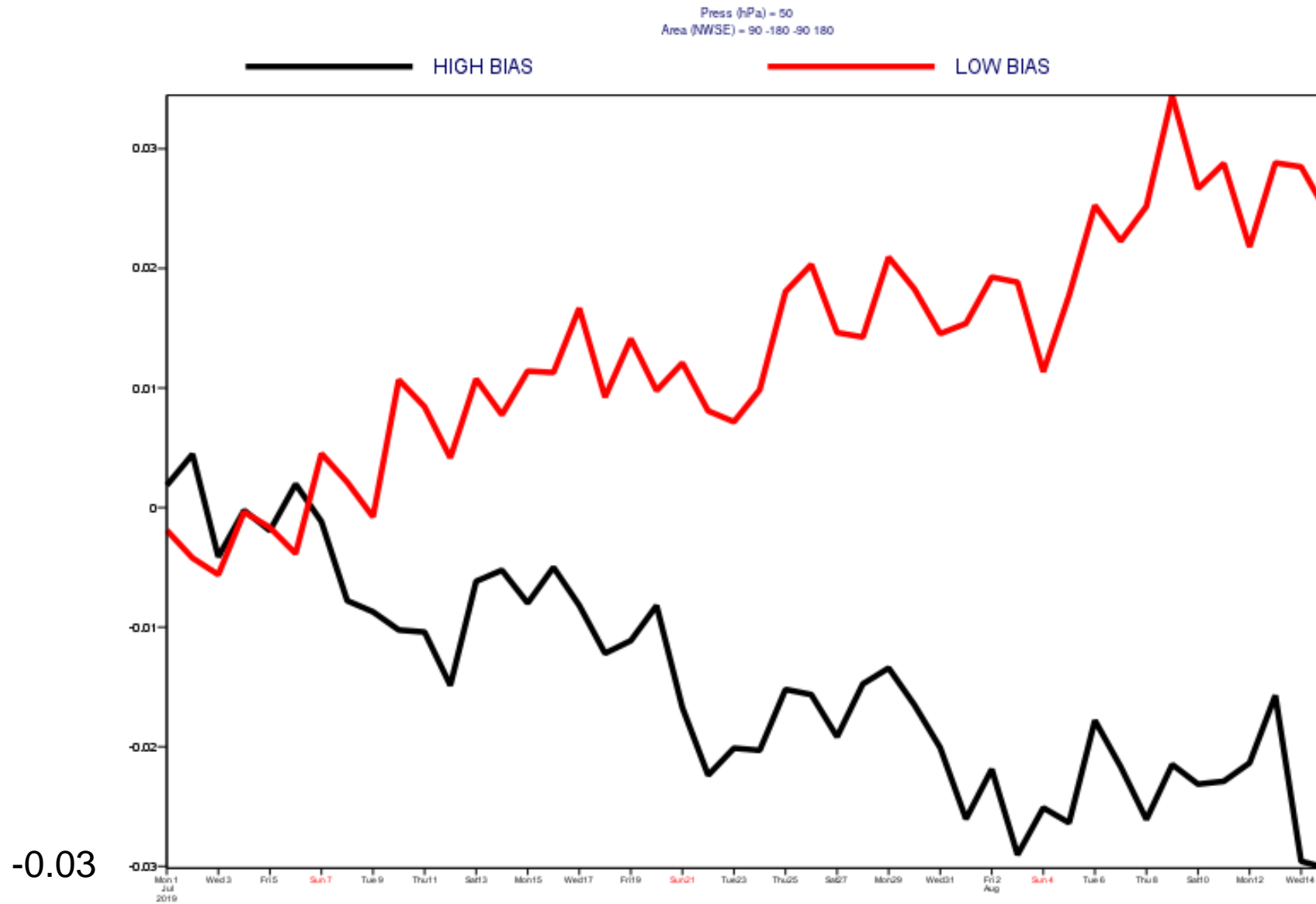
3 hPa



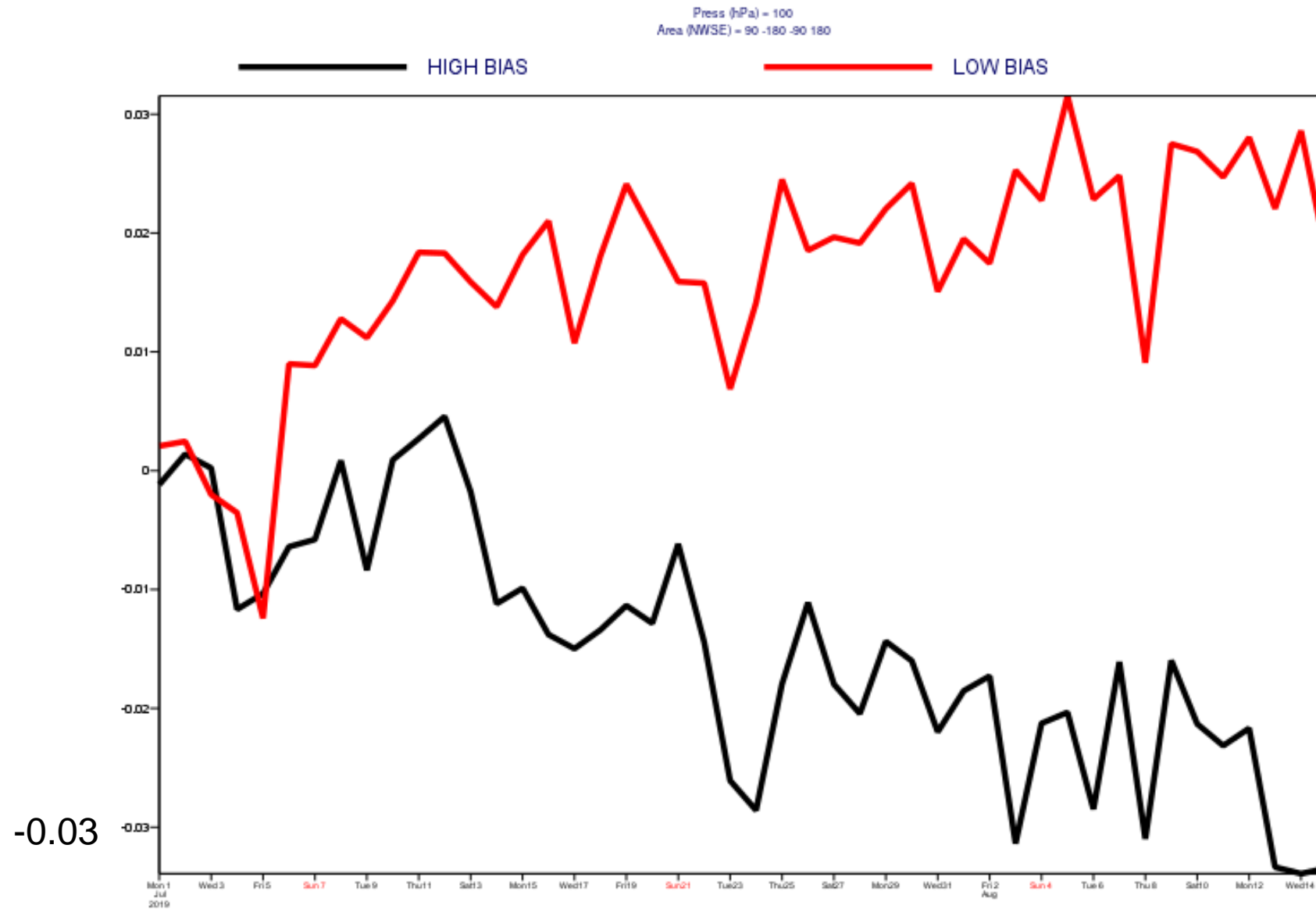
10 hPa



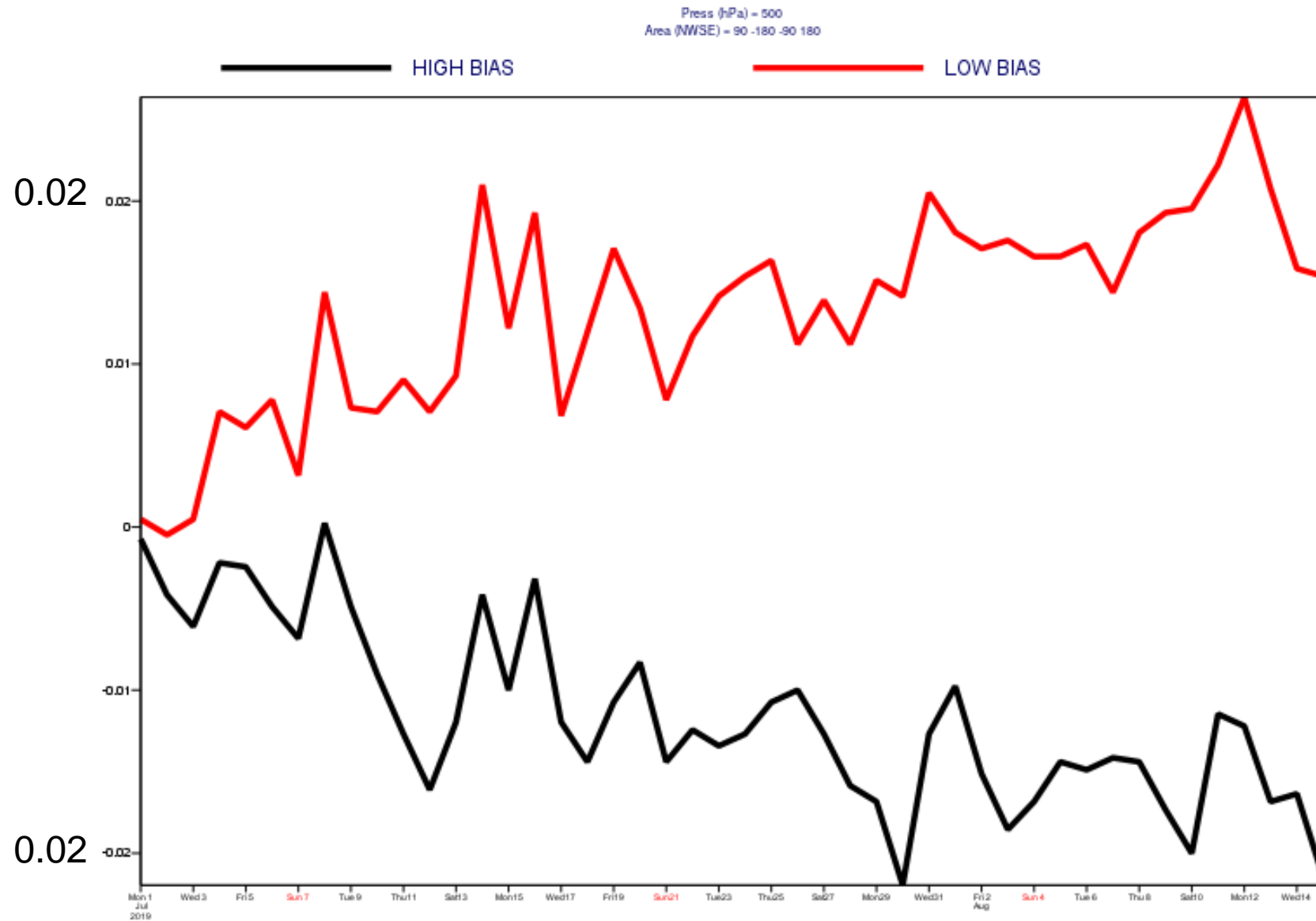
50 hPa



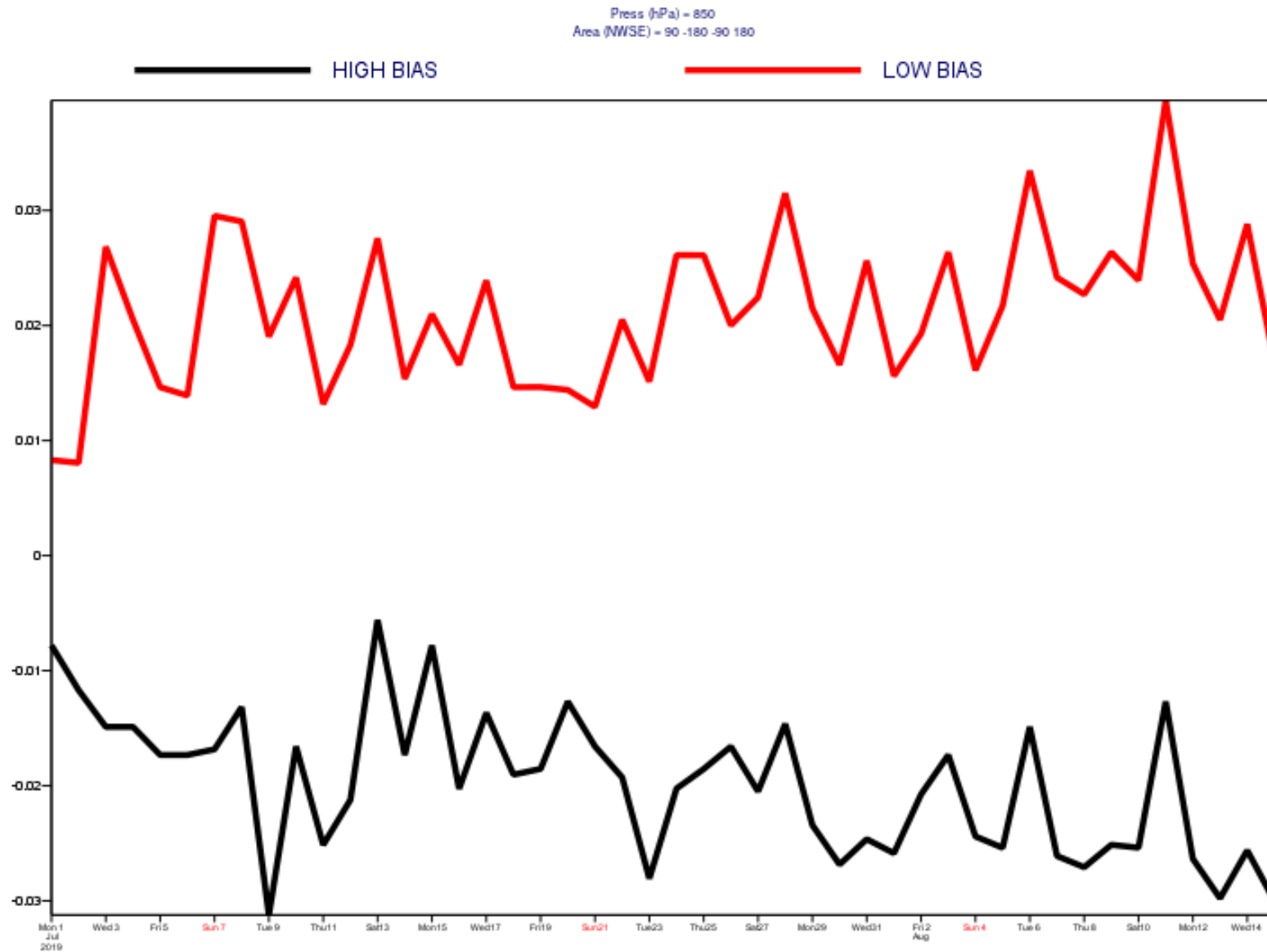
100 hPa



500 hPa



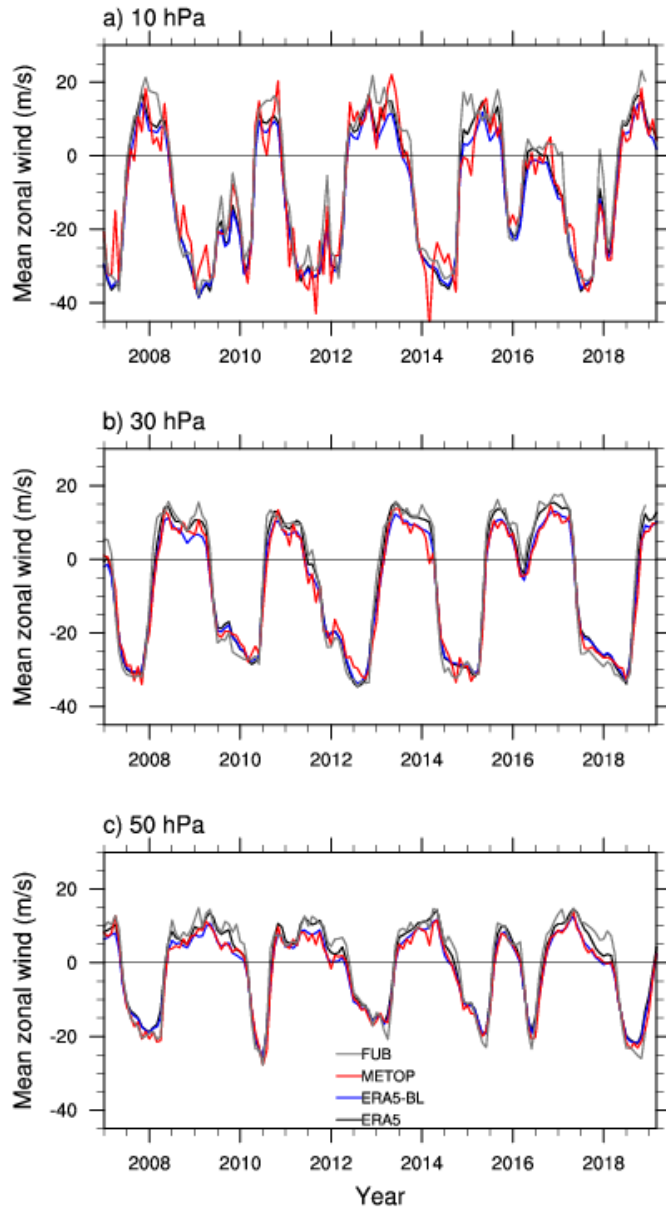
100 hPa



Summary

- Outlined assimilation approach and data usage.
 - 2D approach in ROPP could compute the path for airborne RO, LEO-LEO and PAZ operators.
- Positive impact of Metops.
- Sensitivity to imposed forward model biases of +/- 0.5 mu-rad bias in bending angle space.

Zonally averaged zonal winds retrieved from a ROM SAF monthly mean GPS-RO geopotential climatology



Compute the “balanced” GPS-RO zonal winds from the second derivative of the zonally averaged geopotential height

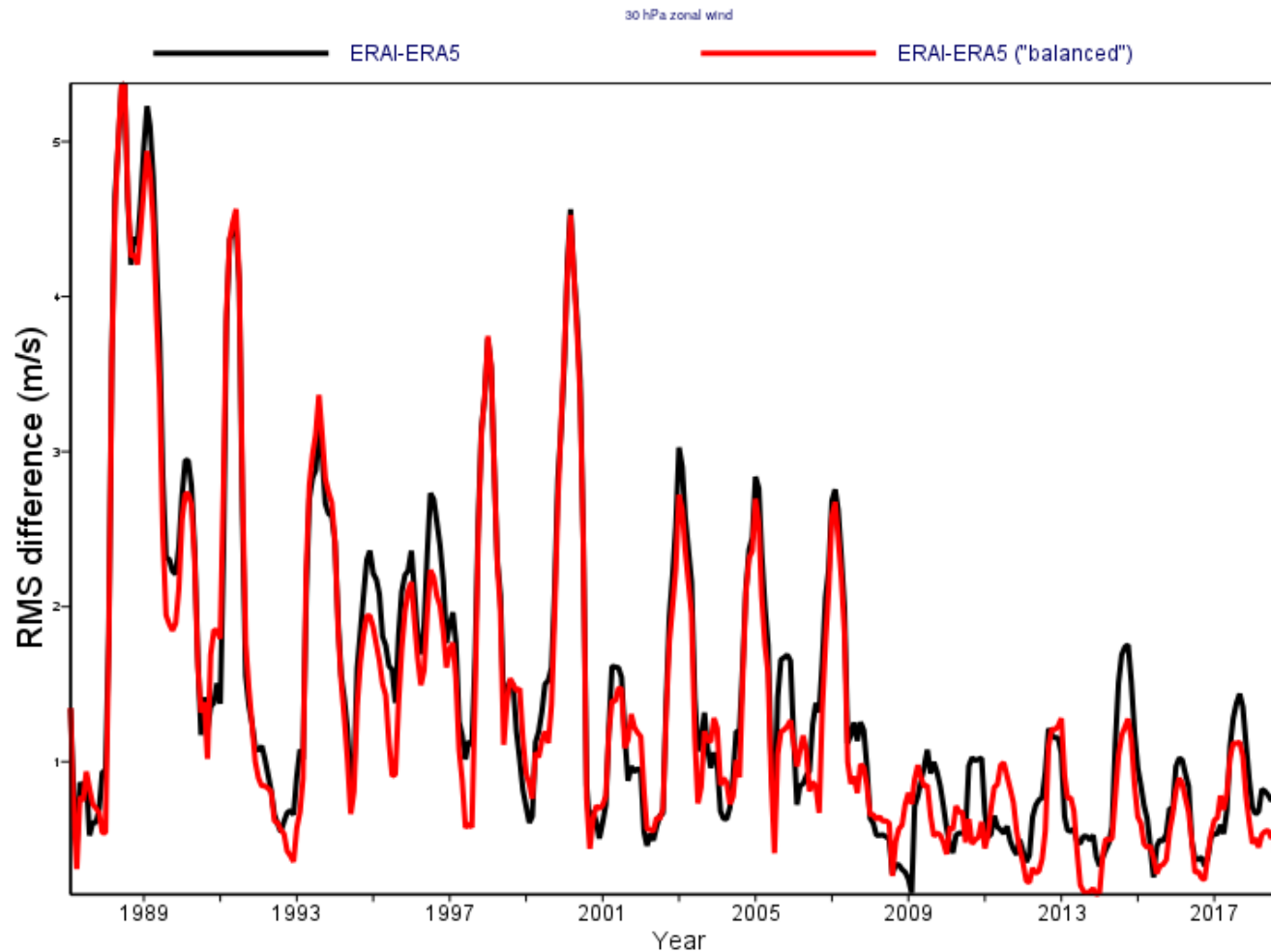
$$\bar{U} ; -\frac{1}{\beta} \frac{\partial^2 \bar{\phi}}{\partial y^2}$$

$$\beta = \frac{2\Omega}{a}$$

FUB is the Free University Berlin radiosonde zonal wind climatology at Singapore.

Impact on reanalysis

(30 hPa ERA5-ERA-Interim differences, ± 1 lat)

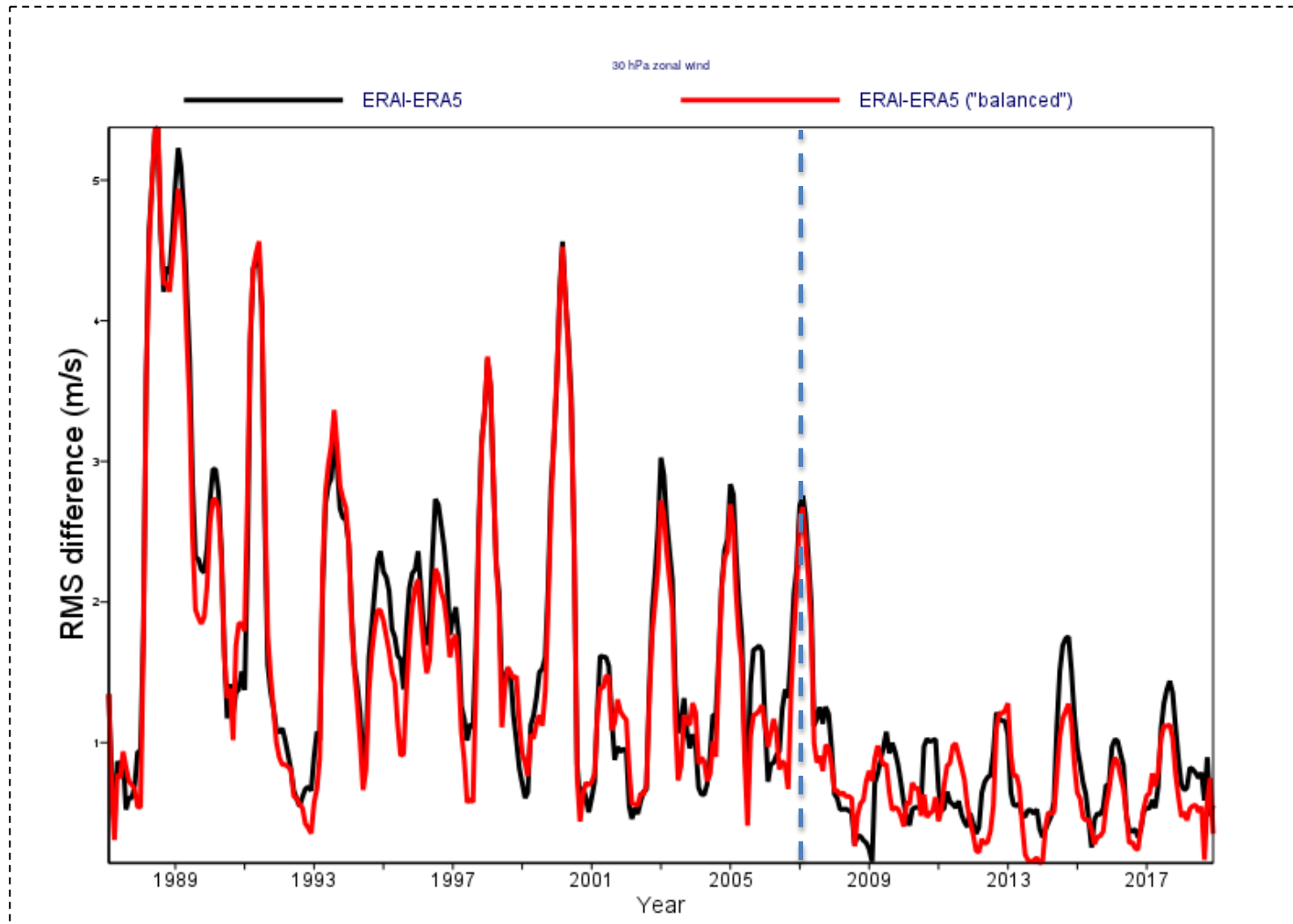


RMS differences of 4
month running average.

Balanced differences

$$\overline{\delta U} ; -\frac{1}{\beta} \frac{\partial^2 \overline{(\phi_{E5} - \phi_{EI})}}{\partial y^2}$$

Impact on reanalysis (30 hPa ERA5-ERA-Interim differences, ± 1 lat)



RMS differences of 4
month running average.

Balanced differences

$$\overline{\delta U} ; -\frac{1}{\beta} \frac{\partial^2 (\overline{\phi_{E5} - \phi_{EI}})}{\partial y^2}$$

Future

- PAZ, FY-3D
- COSMIC2 should be available in November. Will get the status at IROWG.
 - 4-5000 occultations per day in ± 40 lat.
- Multiple GNSS signals (GPS, GLONASS, GALILEO).
- Possible assessment of commercial data – funded by ESA.

Extra (daily at 30 hPa, ro only +/- 1 degree lat)

