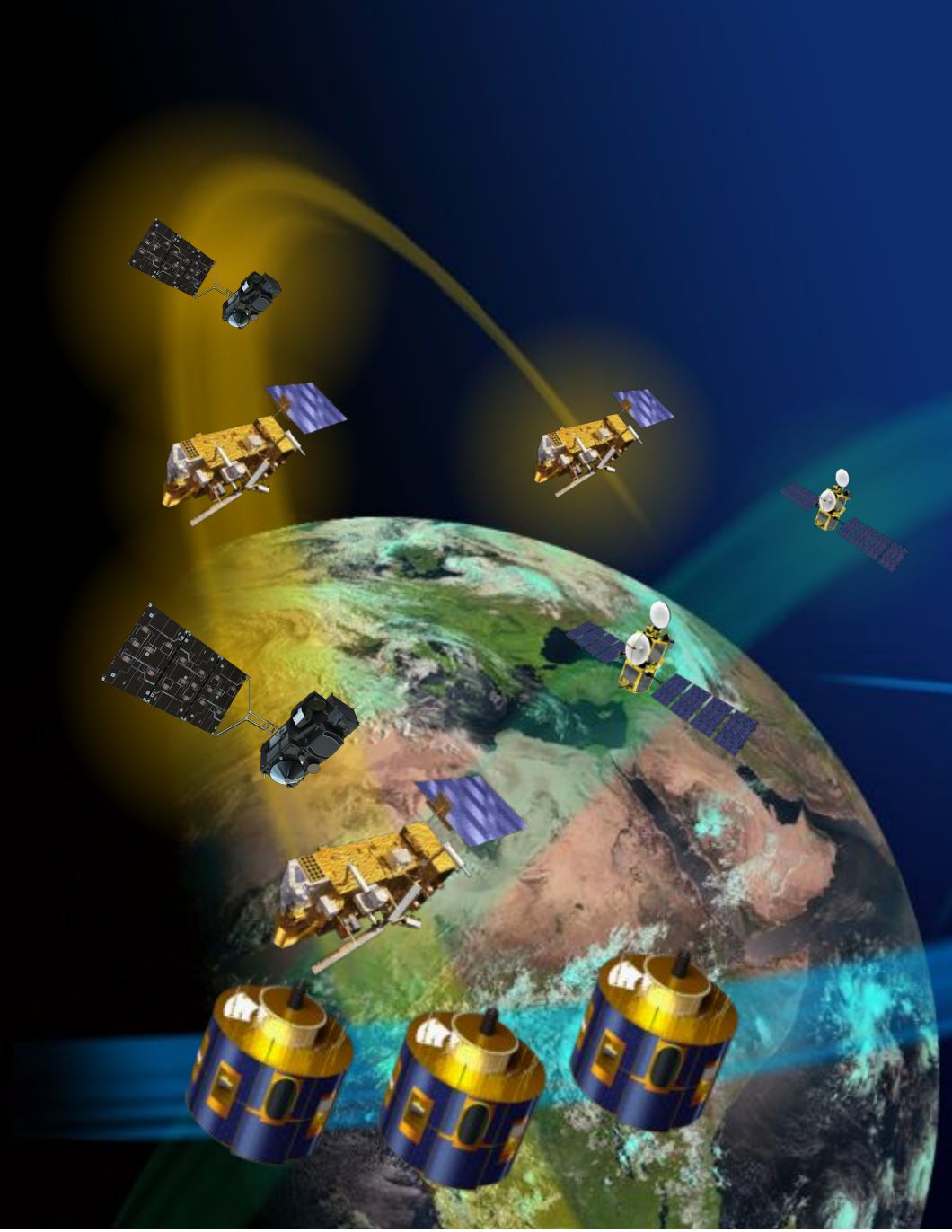


Precise Orbit Determination for RO missions at EUMETSAT

Yago Andres, Sebastiano Padovan, Christian Marquardt,

Axel Von Engeln, Riccardo Notarpietro, Saverio Paolella,

Leonid Butenko, Francisco Alemany

J. Innerkofler Wegener Center for Climate and Global Change (WEGC)

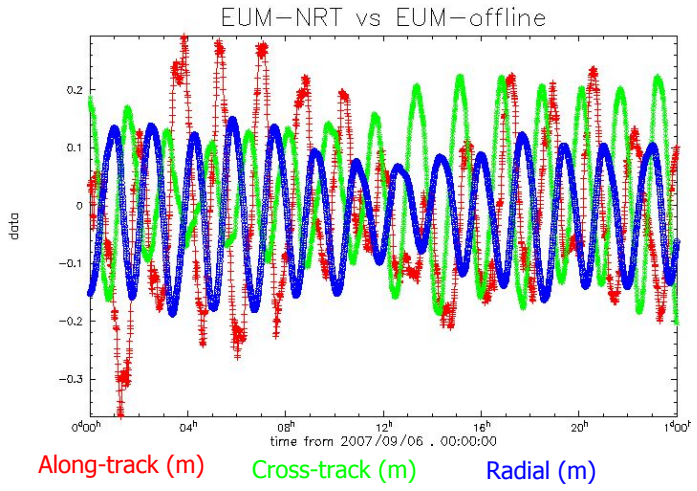
- POD at EUMETSAT
  - History / GNSS support / NRT / reprocessing / RO / Altimetry
- POD results for several RO Missions
  - Metop
  - Third party (Cosmic/Champ/Grace)
- Metop-A high altitude bias in rising occultations / SNR drop
- Assessing effect of Antenna Phase Centre errors
- Summary

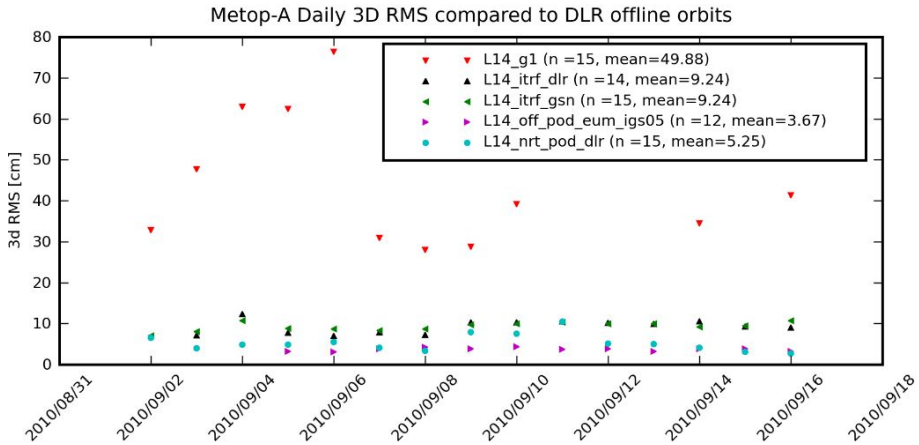
History

- 2006 Metop-A Napeos -sequential filter Near Real Time SRIF (Square Root Information Filter)
  - Napeos batch (offline-monitoring)
- 2006 GRAS Ground Support Network (GSN)
  - Provision of operational GPS support data (orbits/clocks/EOPs)
  - Accuracy in NRT ~10cm radial
  - Issues with stability (along track, solar activity, data gaps, etc.)

Table 1. Accuracy requirements on the Metop/GRAS NRT POD products.

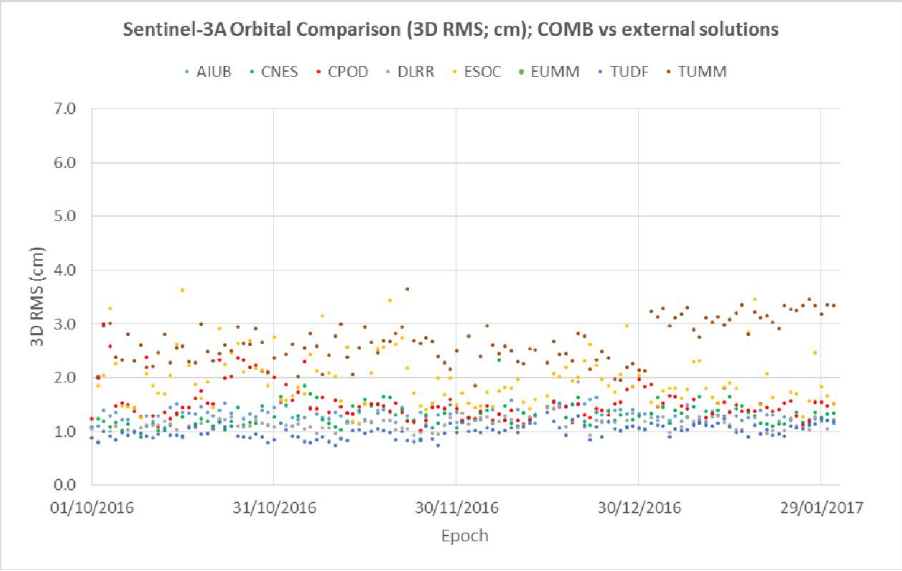
Product	Requirement
Metop position error	≤ 1 m (2σ)
Metop radial position error	≤ 10 cm (2σ)





History (cont)

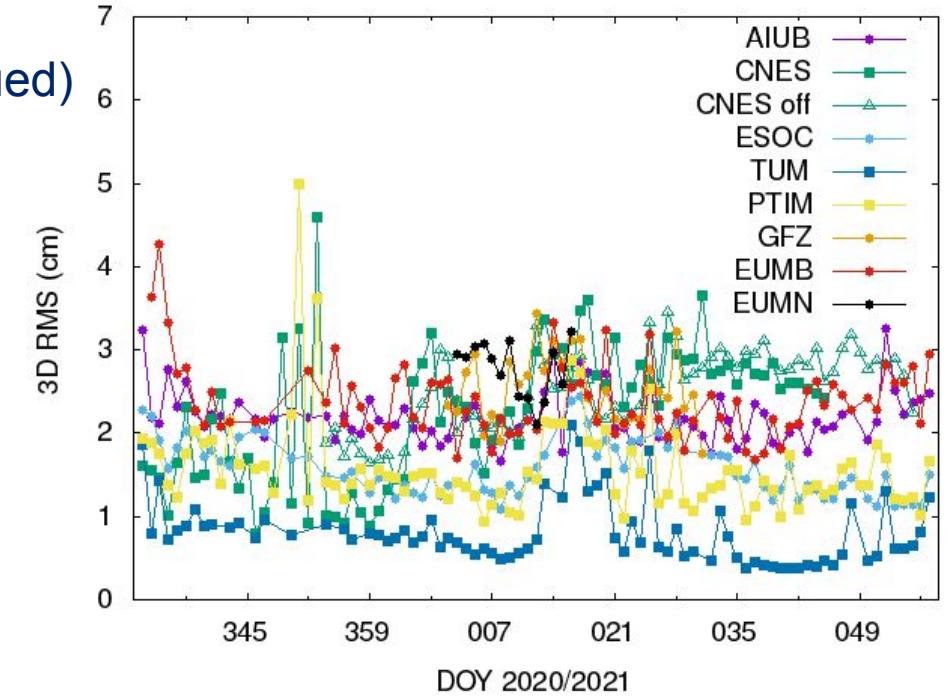
- 2009 Jason-2 based NRT POD (monitoring)
- 2012 Metop-B
- 2014 ERACLIM project: reprocessing of ‘third party’ missions(Cosmic, Champ, Grace)
- 2015 Introduction of batch POD in Near Real Time Metop RO operations
- 2016 Jason-3 / Sentinel-3A (Copernicus POD Quality Working Group)



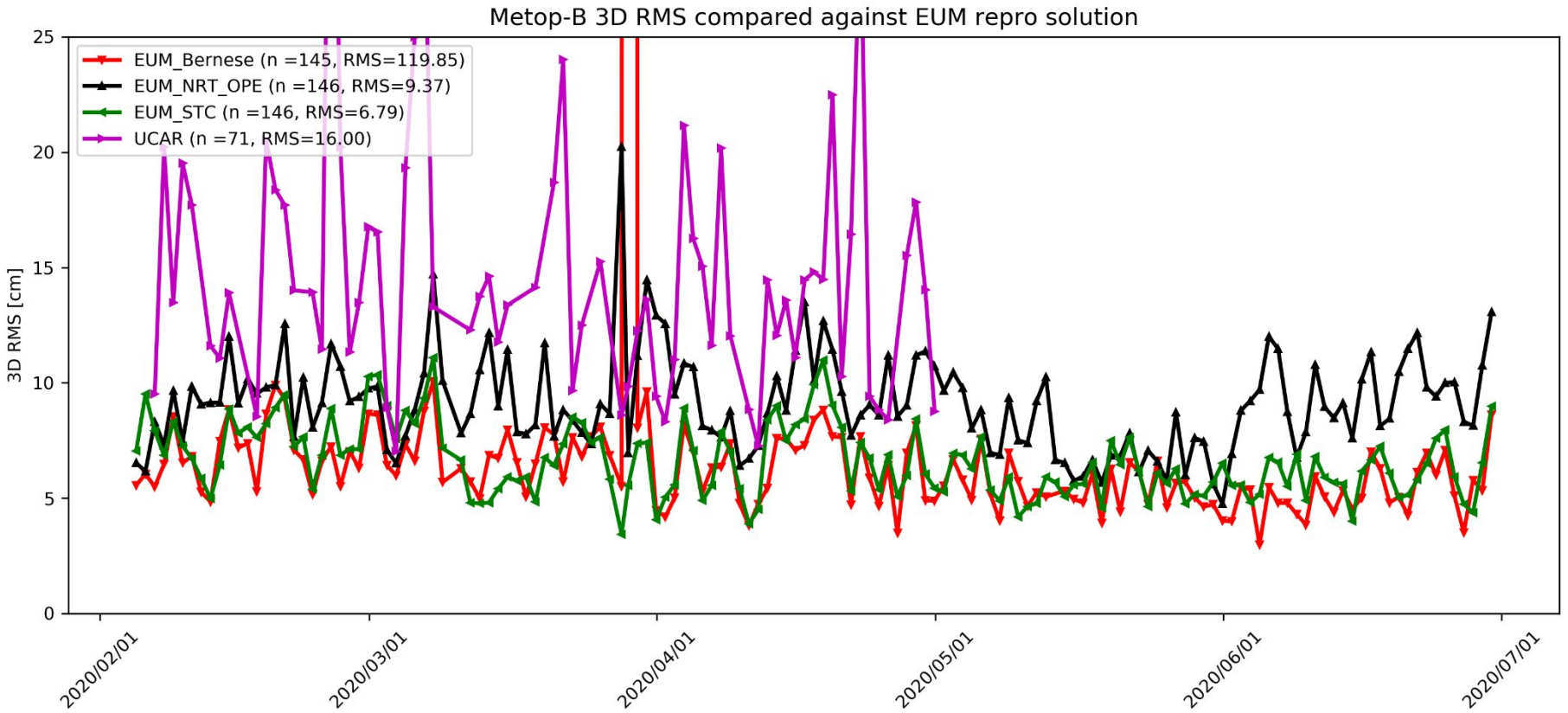
	Radial	Along-track	Cross-track	3D	Typical
AIUB	0.73	1.01	0.49	1.34	0.77
CNES	0.52	1.03	0.59	1.30	0.75
CPOD	0.56	1.05	0.98	1.55	0.89
DLRR	0.58	0.79	0.60	1.15	0.66
ESOC	0.59	1.13	1.49	1.99	1.15
EUM	0.51	1.22	1.22	1.81	1.04
TUDF	0.51	0.73	0.50	1.02	0.59
TUMM	1.37	1.87	1.23	2.69	1.55

History (cont)

- 2017-2019 Substitution of GRAS GSN by ‘RSN’ Radio Occultation Support Network
  - Preparation for EPS-SG: GPS(L1/L5) + GAL (Bei/Glo)
  - Operational since 2019
- 2018 Metop-C
- 2019 Procurement of Bernese (Napeos releases from ESA discontinued)
- 2019 Evaluation (including POD) of commercial missions
- 2020 Sentinel-6A (Non-Time-Critical processing) using Bernese

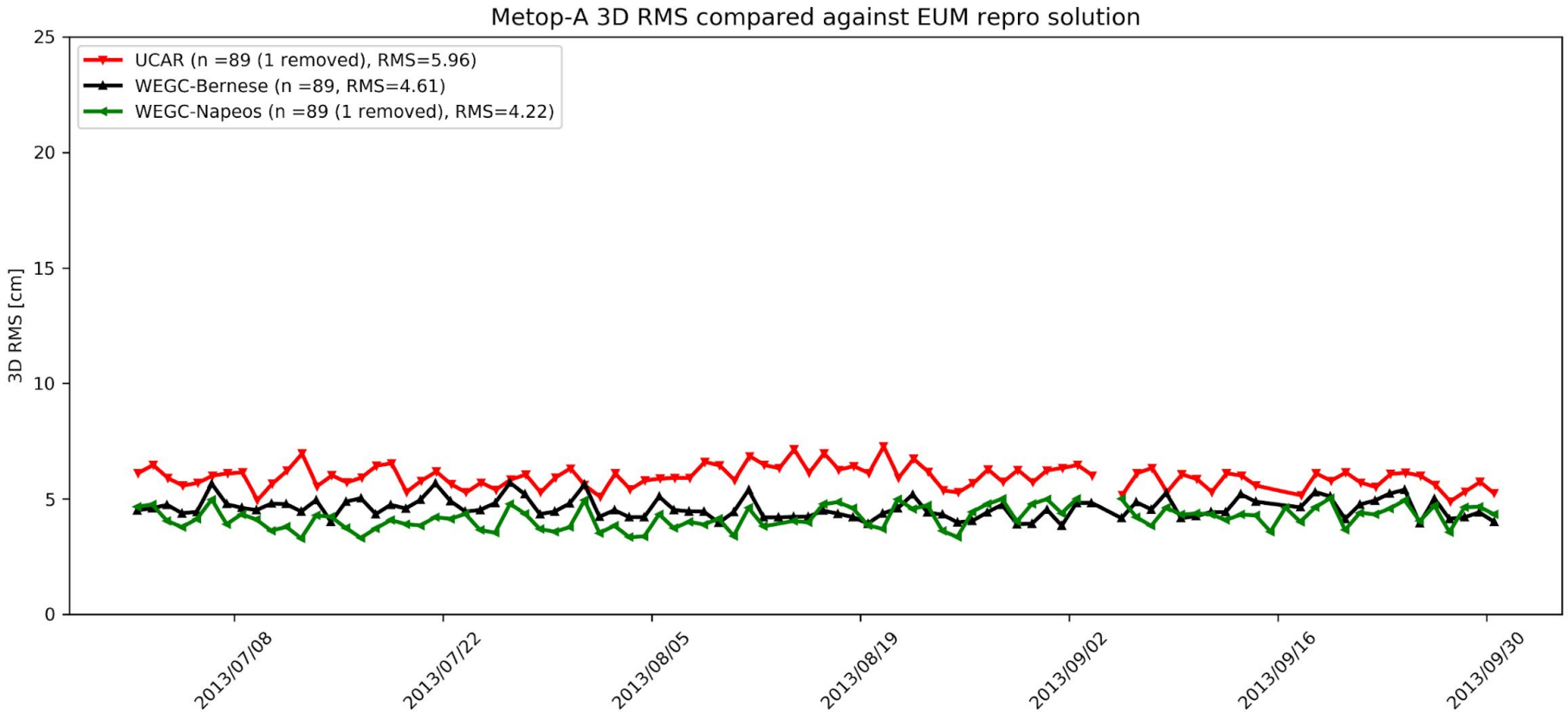


Metop (NRT)



Metop NRT (black) ~ 10cm 3D RMS, offline independent solutions ~5cm 3D RMS

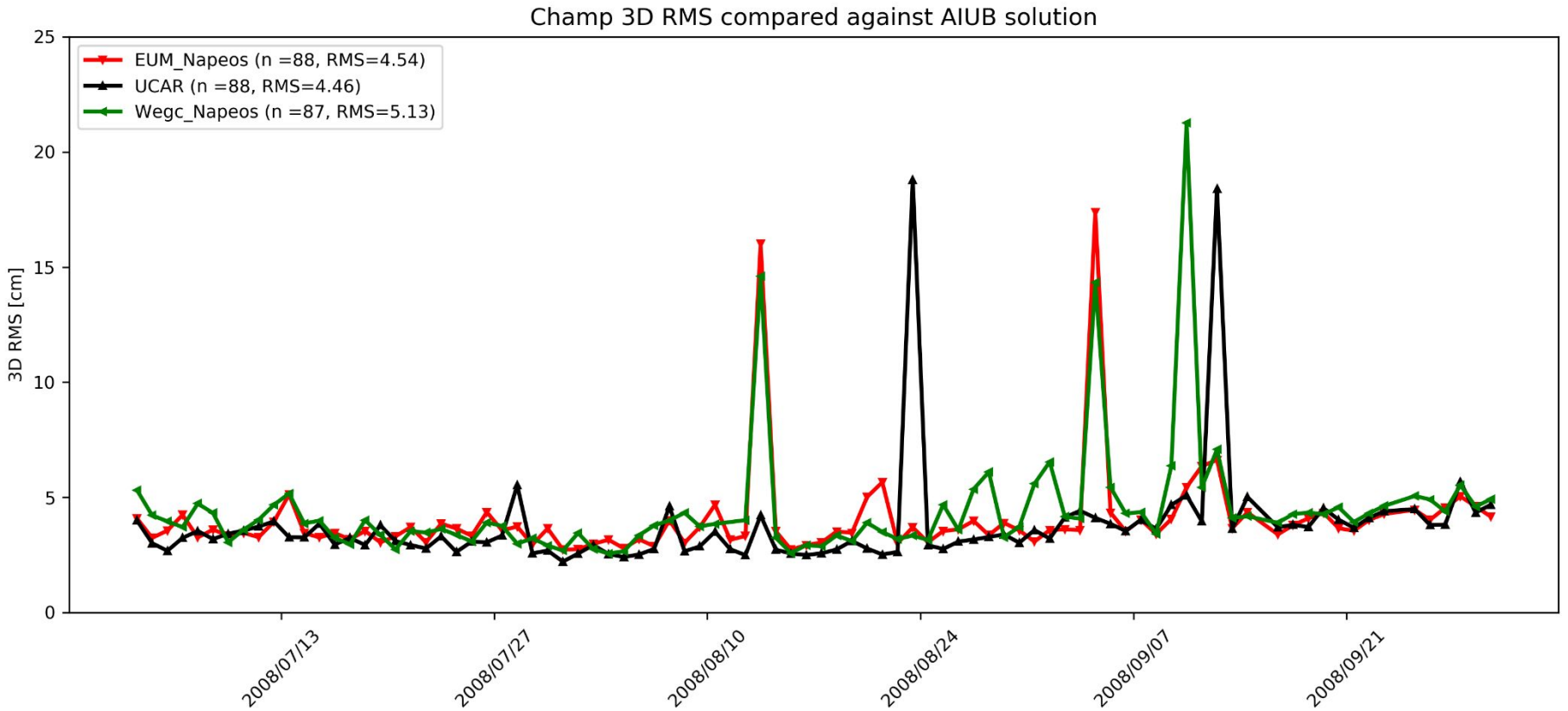
Metop (Repro)



Metop-A 3D RMS offline solutions ~5cm 3D RMS

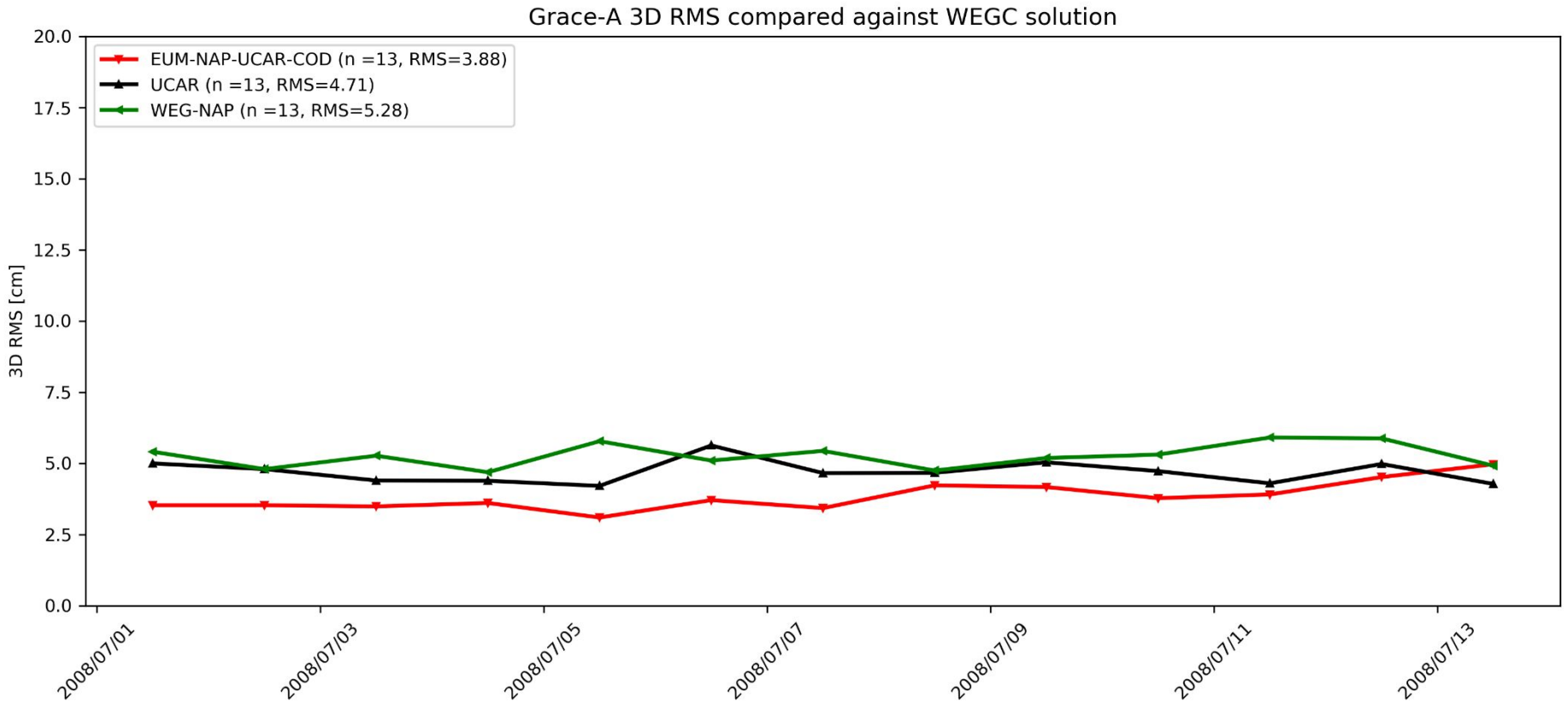
Metop/Champ/Grace => Remote Sensing: Precise Orbit Determination for Climate Applications of GNSS Radio Occultation including Uncertainty Estimation (J. Innerkofler et al)

Champ



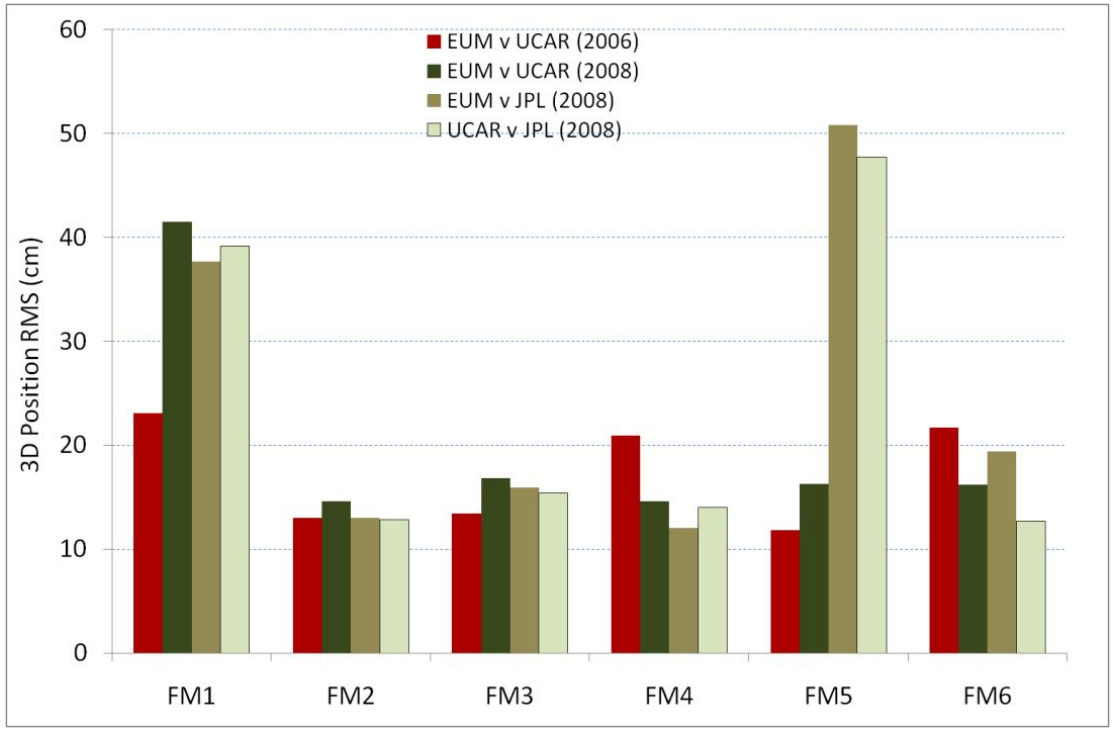
Champ 3D RMS offline solutions ~5cm 3D RMS

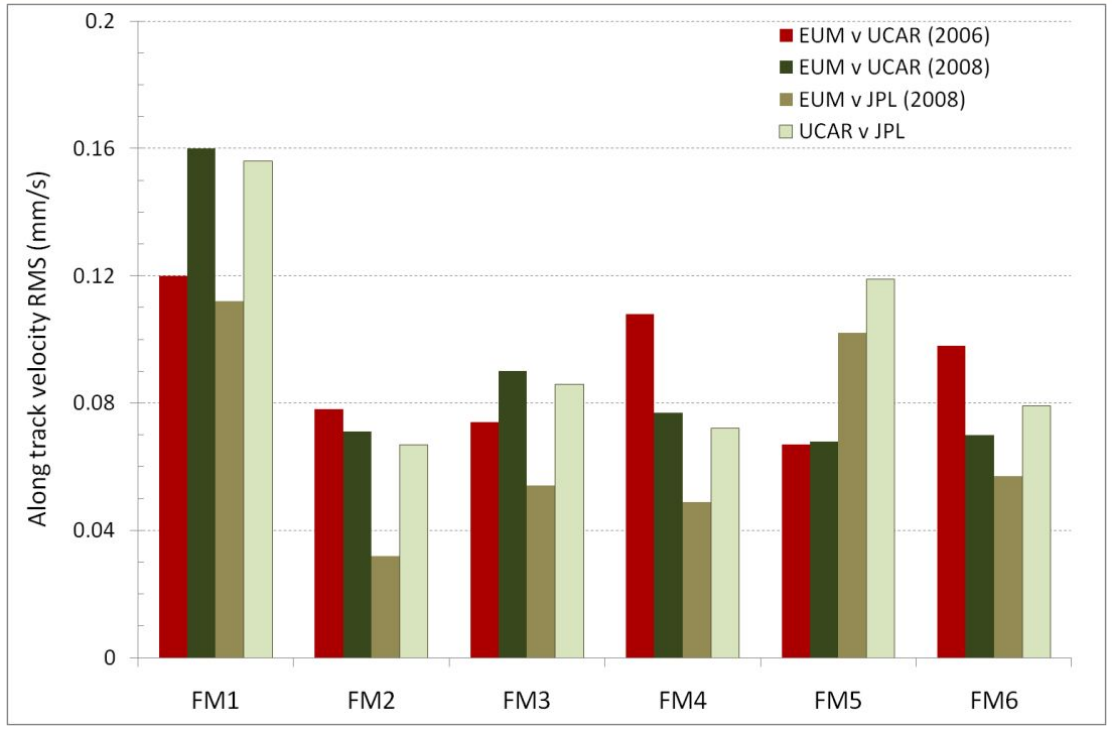
Grace-A



Grace-A 3D RMS offline solutions ~5cm 3D RMS

Cosmic

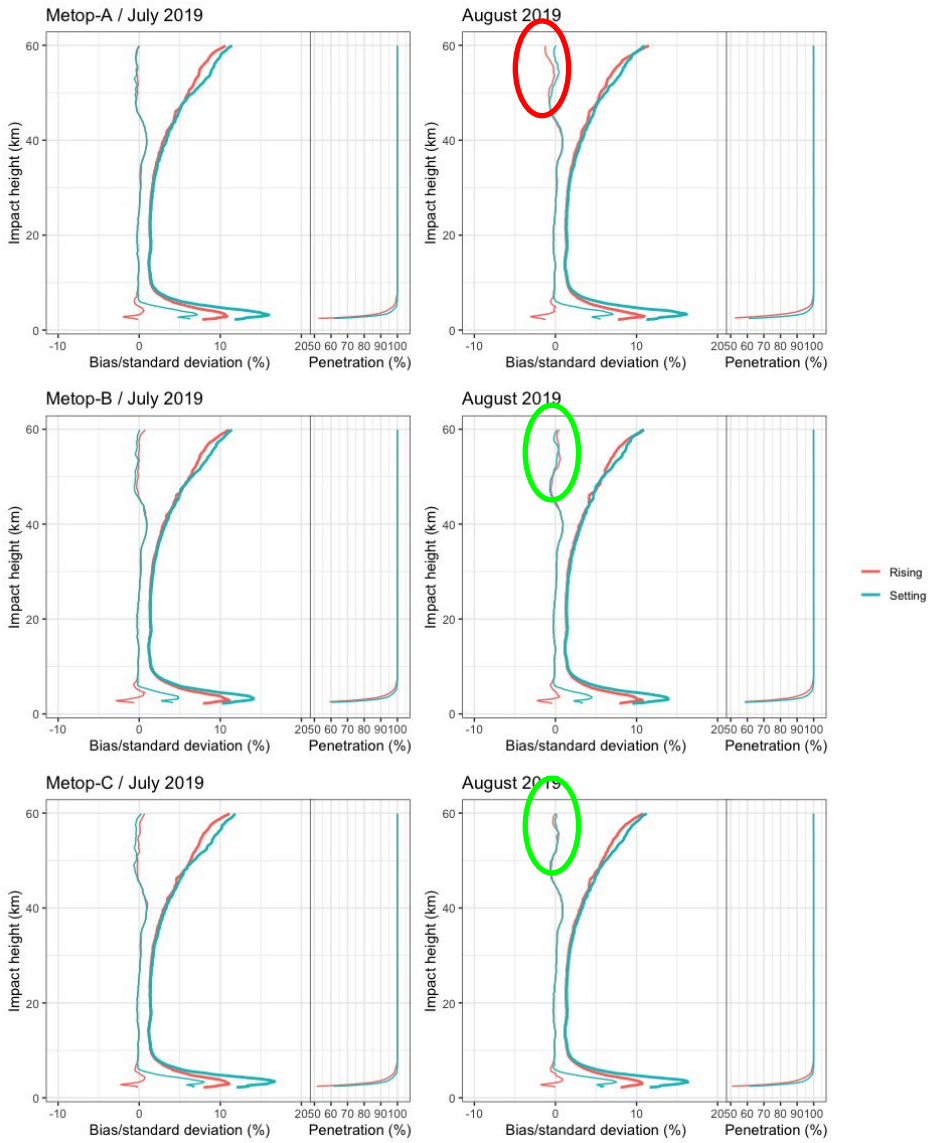




Cosmic 3D RMS offline solutions ~15-20cm 3D RMS

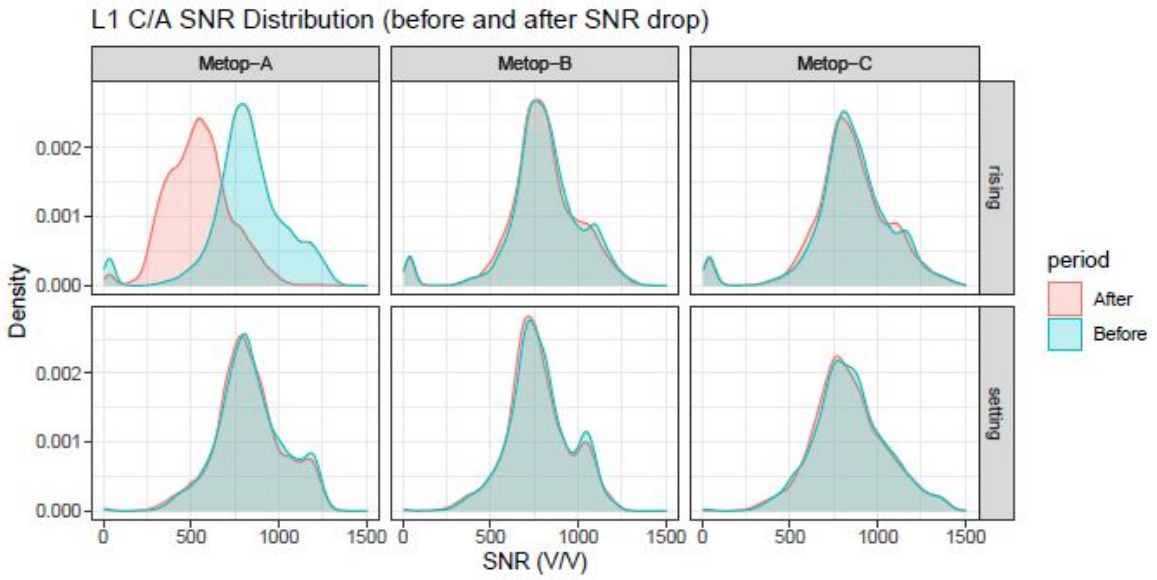
Metop-A high altitude bias in rising occultations

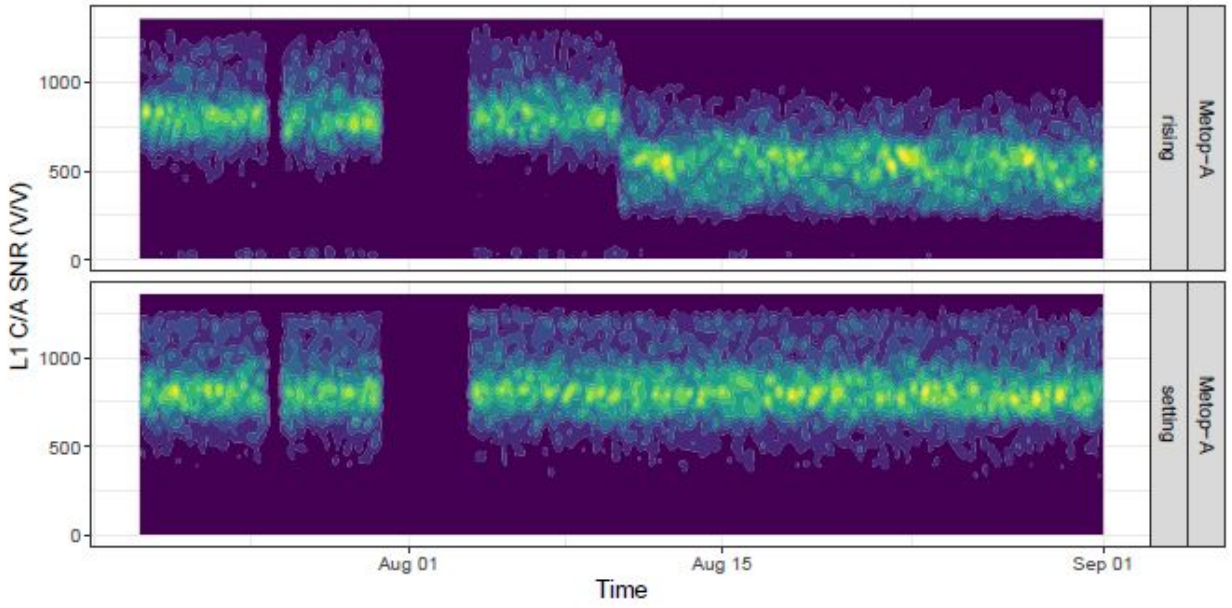
- ROM SAF found increasing biases between rising and setting occultations on Metop-A since August 2019.
- Cannot be observed for the other two Metop satellites.
- The bias corresponds approximately to 1% at 60km
- No concern for NWP centres



Metop-A high altitude bias in rising occultations

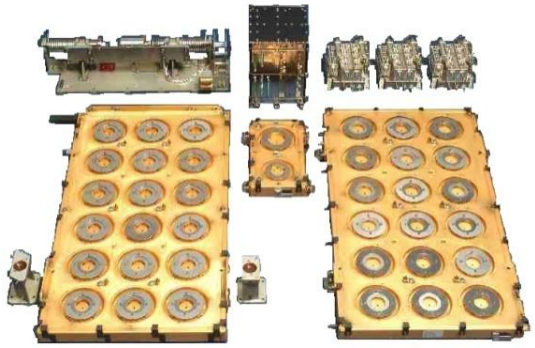
- Drop of SNR for rising occultations only for Metop-A
- Most plausible explanation, issue with Antenna, reducing gain and changing APC location

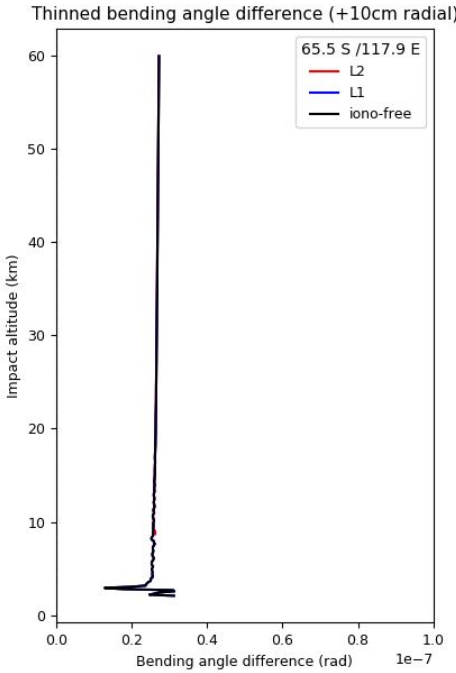




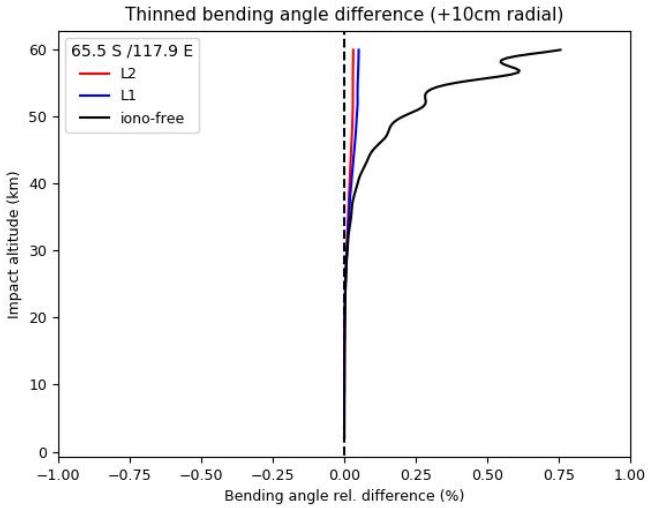
Antenna Phase Centres / POD errors

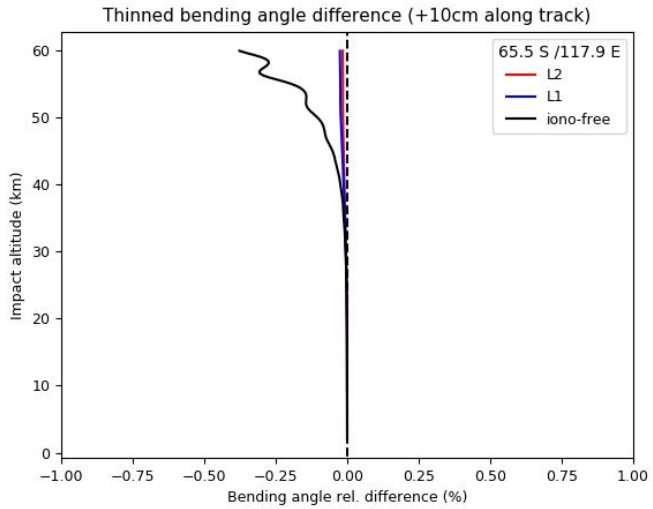
- Introduction of a priory APC offsets to assess magnitude of effect on bending angle profiles
- Metop-A data of 2012
- 10 cm in all three directions for rising/setting occultation
- Qualitative analysis, only two occultations considered, effect depends on the individual occultations
- As a reference, ionospheric Kappa correction 0.03-0.04 10^{-6} rad high solar activity

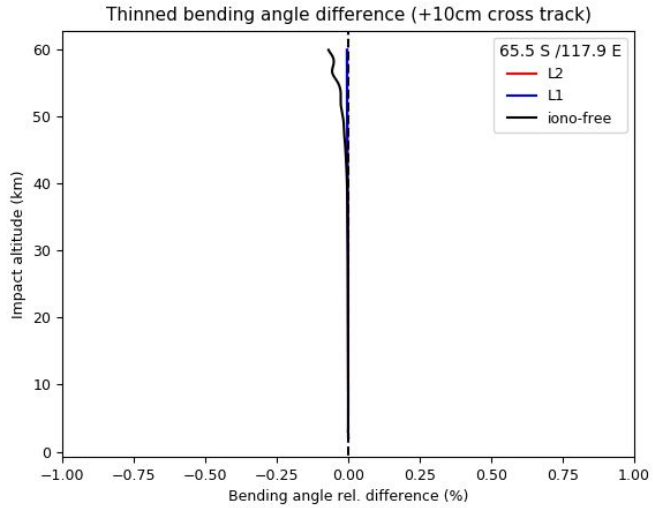


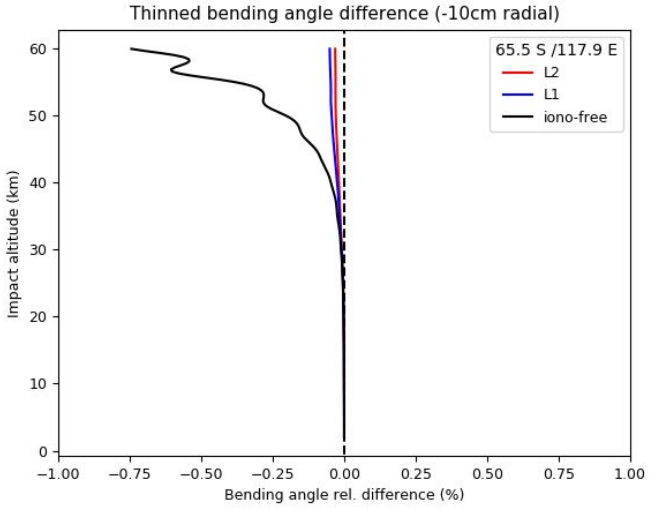


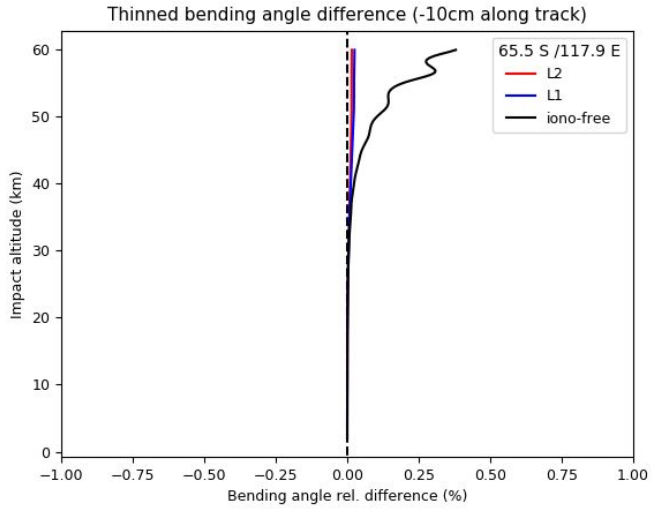
Antenna Phase Centres / POD errors (G17- rising)

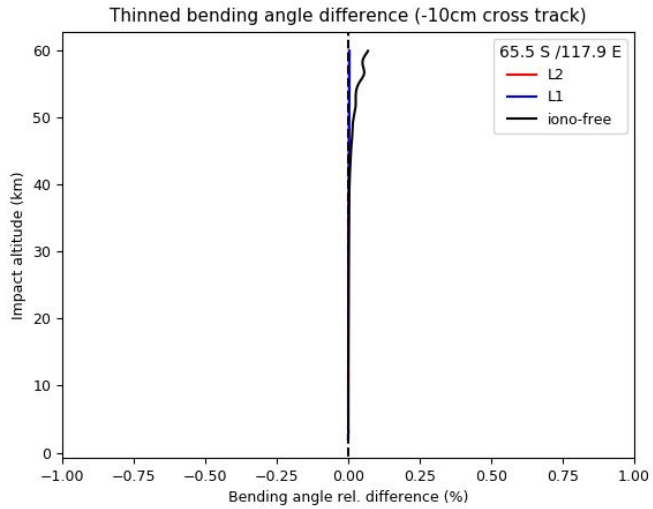




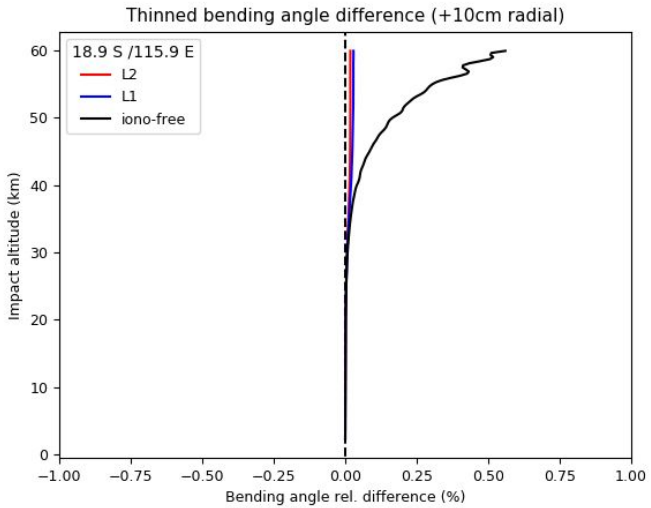


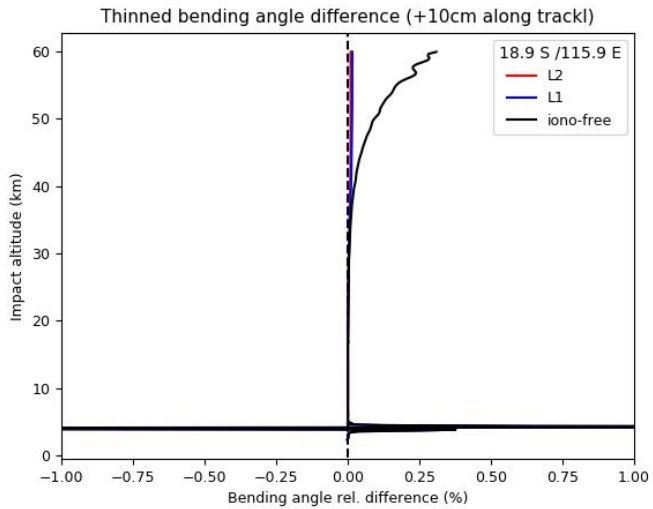


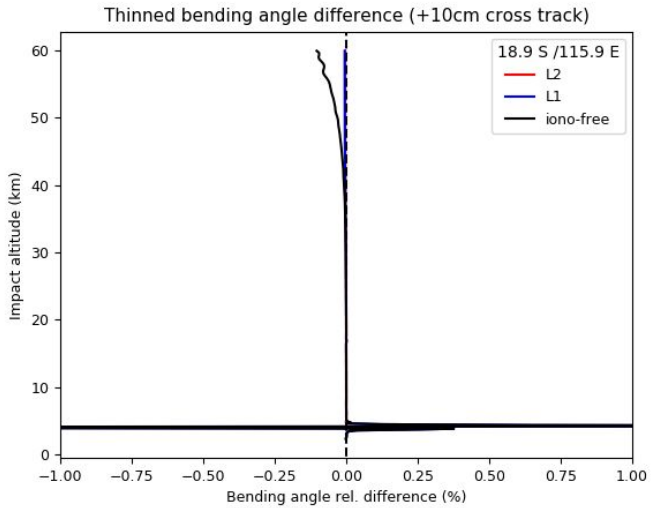


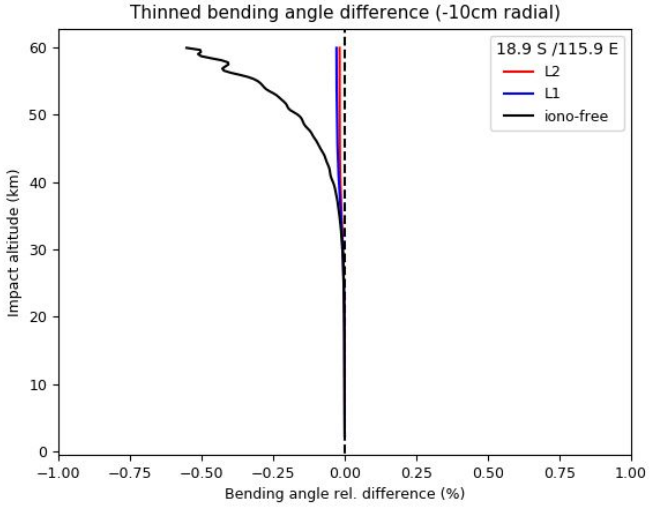


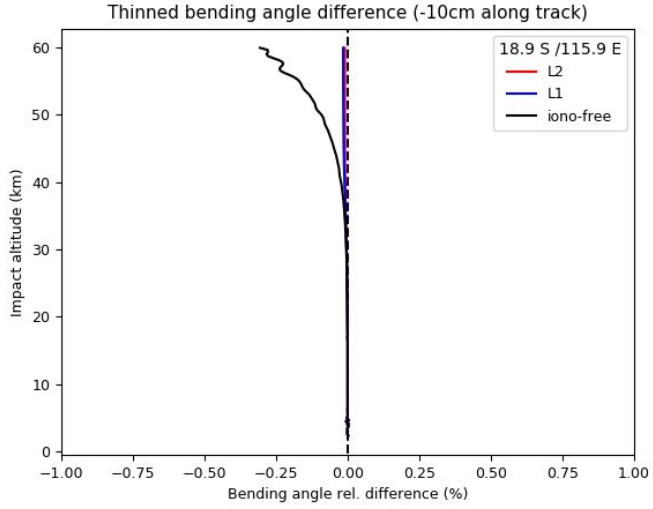
Antenna Phase Centres / POD errors (G23 - setting)

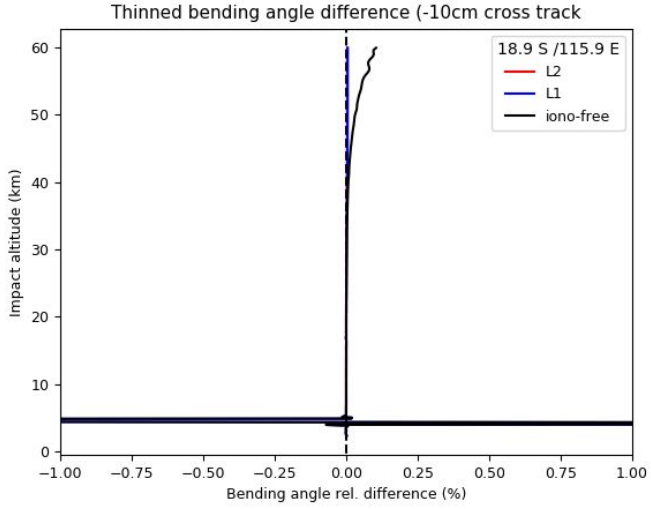






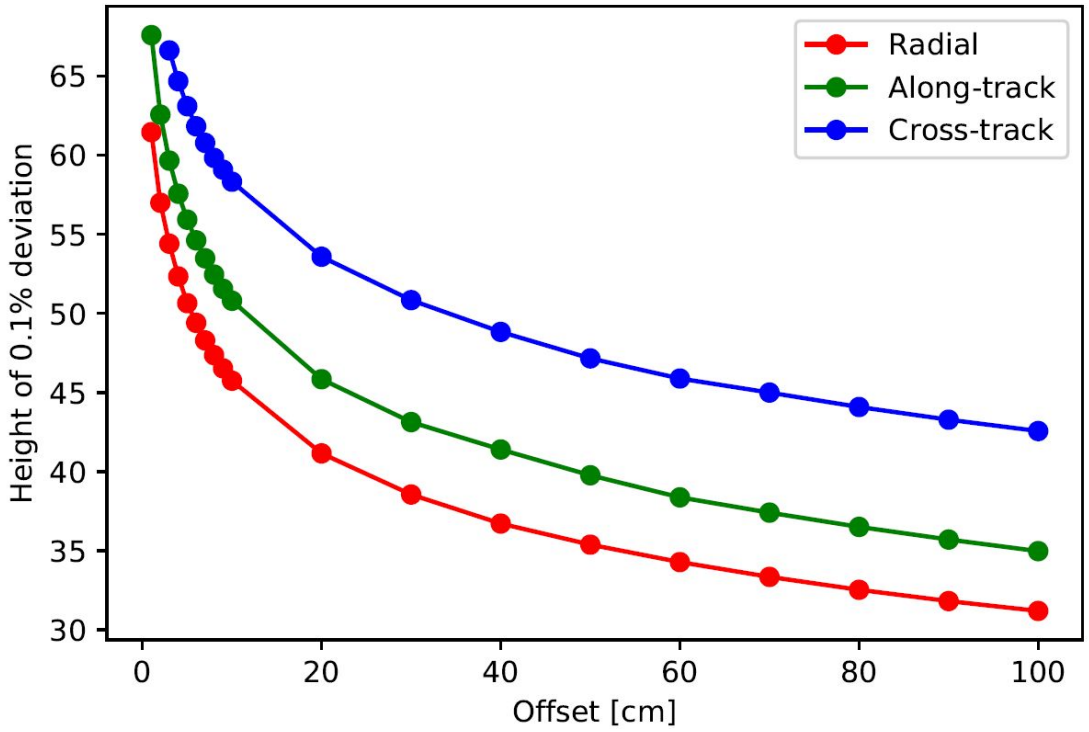




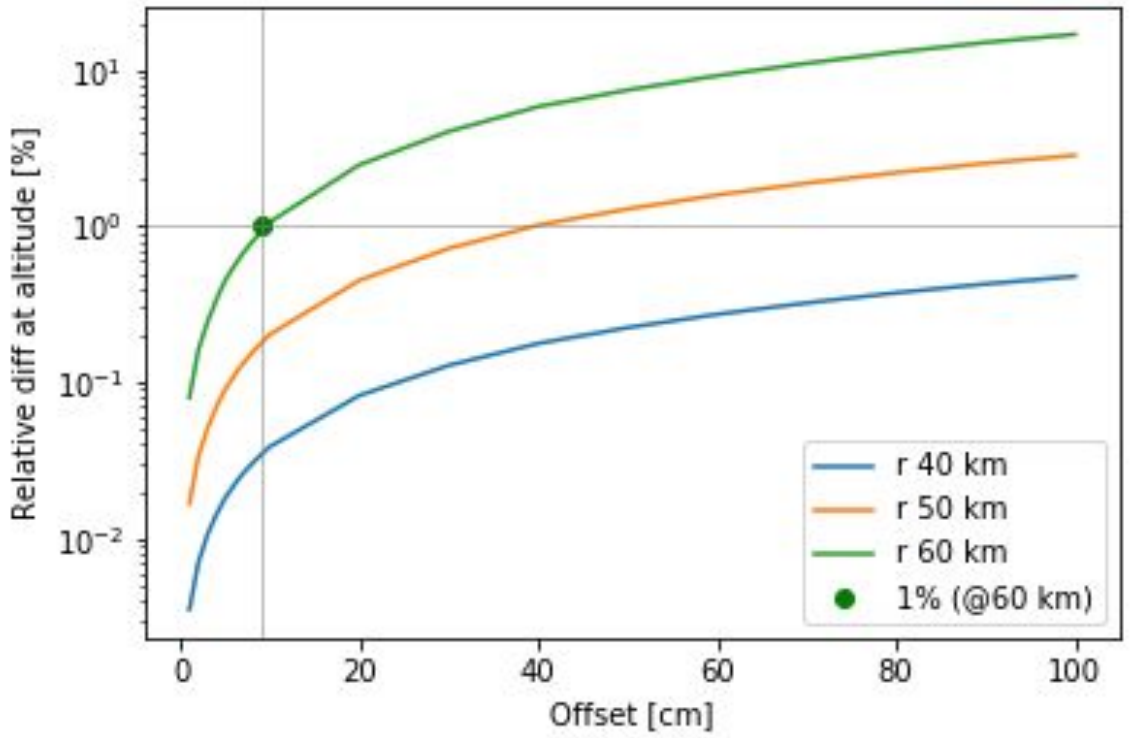


Antenna Phase Centres / POD errors

altitude where bending angle bias is equal to 0.1% as a function antenna phase centre offset



% of bending angle bias as a function of antenna phase centre offset for different heights



Summary

- EUMETSAT is able to process RO data in a consistent way for many missions from raw level0 (including POD) up to bending angle profiles
- EUMETSAT POD solutions show very good agreement with other leading institutions (altimetry closer than RO)
- Systematic errors in Antenna positions / POD introduce biases in bending angle profiles for high altitudes (impact on climate applications).
- Metop-A anomaly in Aug 2019, bias could be explained by a change of the APC of the velocity Antenna by 10-15cm

Thank you for your attention ☺