EUMETSAT

L1-L2 bending angle fitting and L2 extrapolation in the troposphere

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Agenda

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General info about the Sentinel-6 RO-NTC processor

Sentinel-6 Commissioning findings
Unphysical L2 bending angles and the simple L2 signal cut-off.

Effect of solar activity
Improved L2 signal cut-off.

L1-L2 ionospheric bending angle model fitting
General statistics changing the fitting routine.

L1/L2 signal cut-off based on SNR
Change in the bias structure in troposphere.

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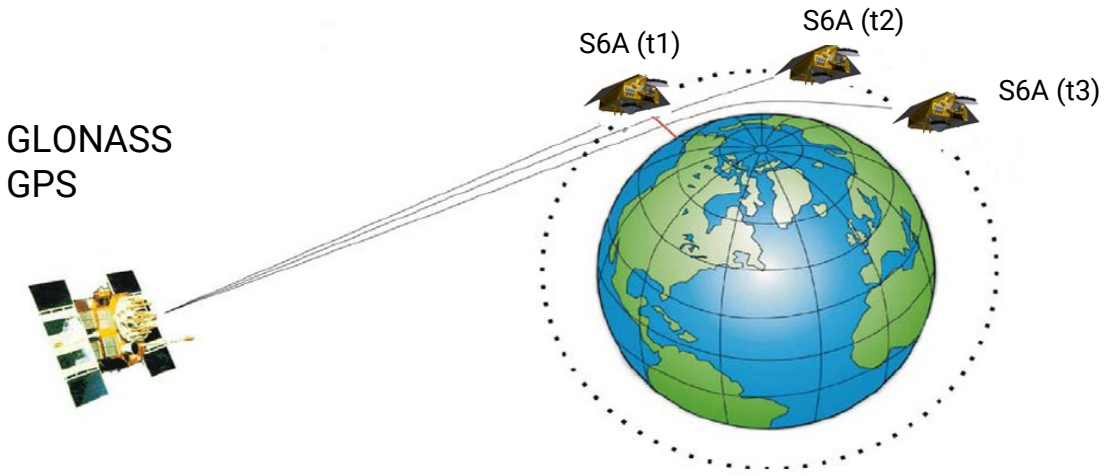
Effect of the signals phase half cycle slip correction on the signal cut-off routines.

Conclusions

Introduction

- The GNSS-RO instrument on S6A is built by JPL/NASA
- Observe GNSS signals from GPS and GLONASS satellites (L1 C/A, L2C, L2P)
- Limb sounding of rising and setting events
- More that 900 occ/day (~60% GPS, ~40% GLONASS)
- Neutral atmospheric occultations: ground to about 90km, < 1km vertical resolution
- Bending angles profiles generated by the EUMETSAT RO-NTC (Non-Time-Critical) processor (available within 3 weeks)
- EUMETSAT RO processing: multi-mission approach



Radio Occultation Principle: Observation of GNSS satellite signals through the atmosphere; changing refractivity leads to bending of rays.

Sentinel-6 Commissioning findings

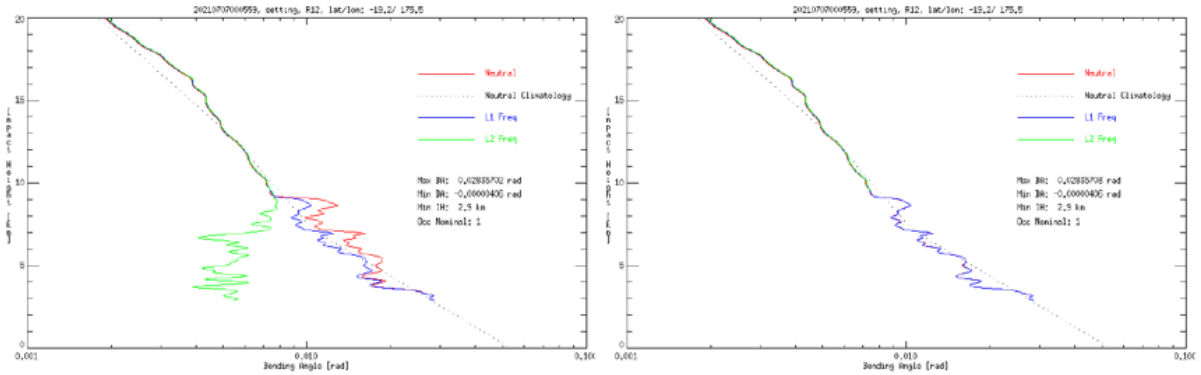
- Unphysical L2 bending angles impacting the results of the ionospheric correction routine in the Sentinel-6 RO-NTC processor.

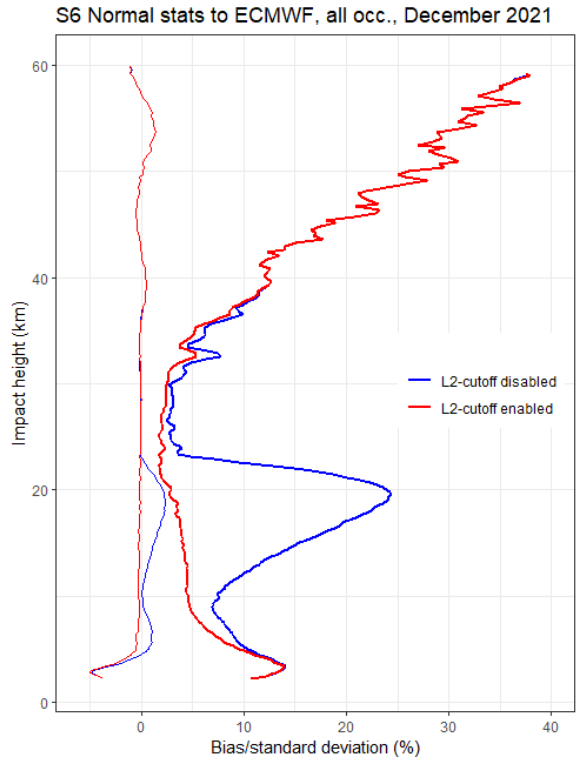
$$\alpha_n(p) = \alpha_{L_1}(p) + \frac{f_2^2}{f_1^2 - f_2^2}\left(\alpha_{L_1}(p) - \alpha_{L_2}(p)\right) + k(p)\left(\alpha_{L_1}(p) - \alpha_{L_2}(p)\right)^2$$

- Removing all L2 data below 20km (e.g. UCAR C2 processing, JPL S6A) introduces larger vertical error correlation in higher level products.

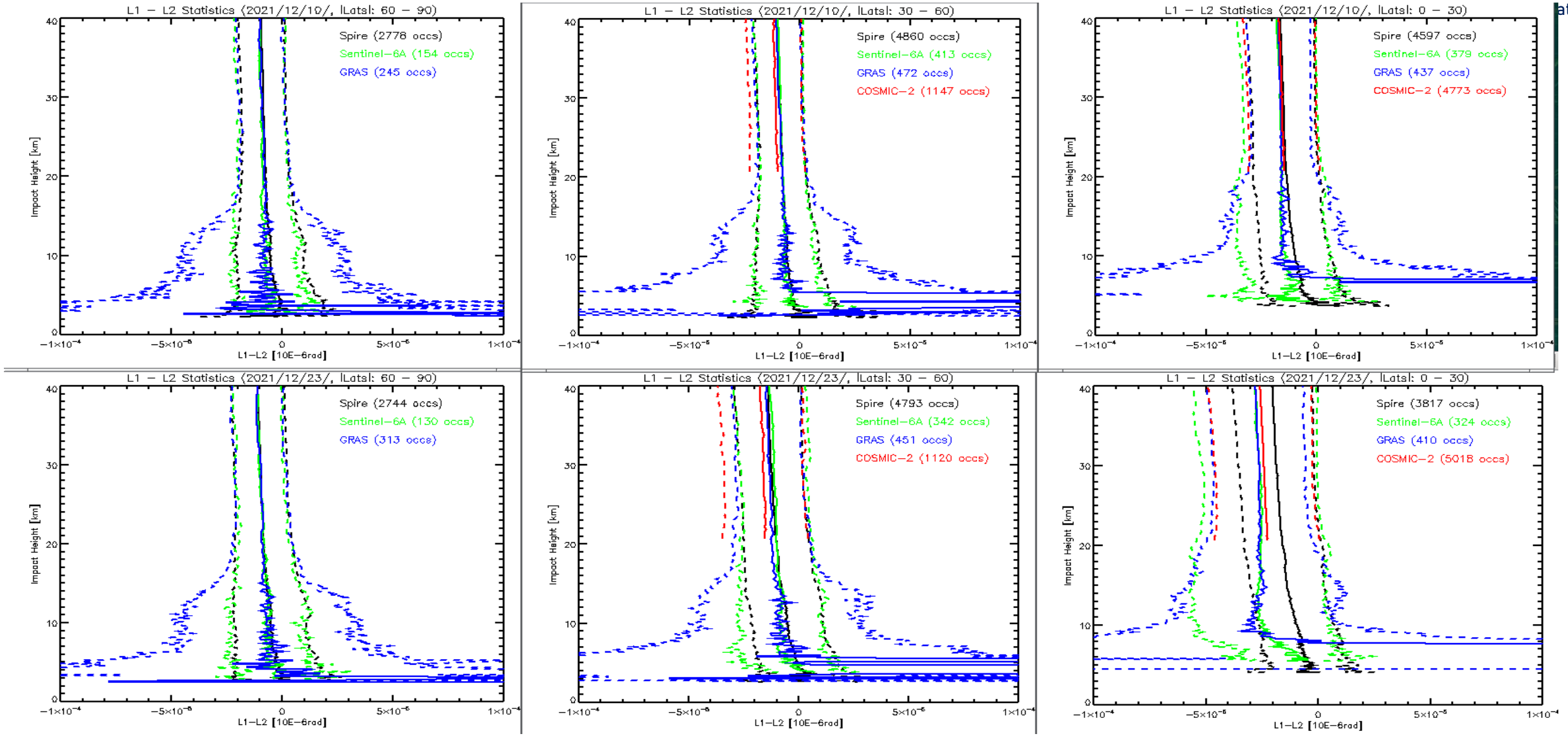
- L2 signal cut-off based on L1-L2 bending angles residuals.

- L2 missing signal replaced by a fitted ionospheric model based on a single Chapman layer (2015 - Culverwell and Healy – ROM SAF Report 17).



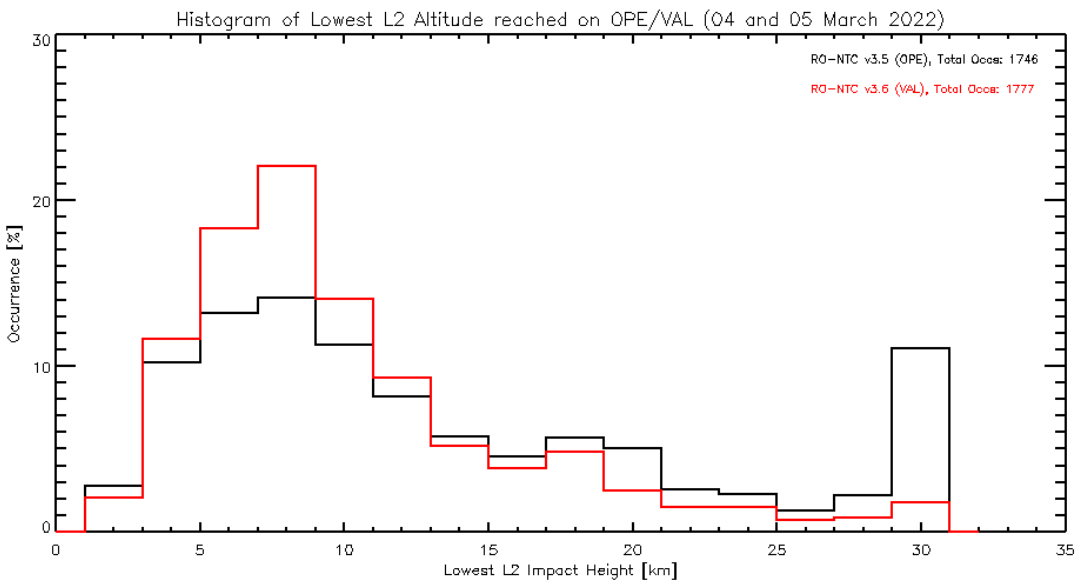


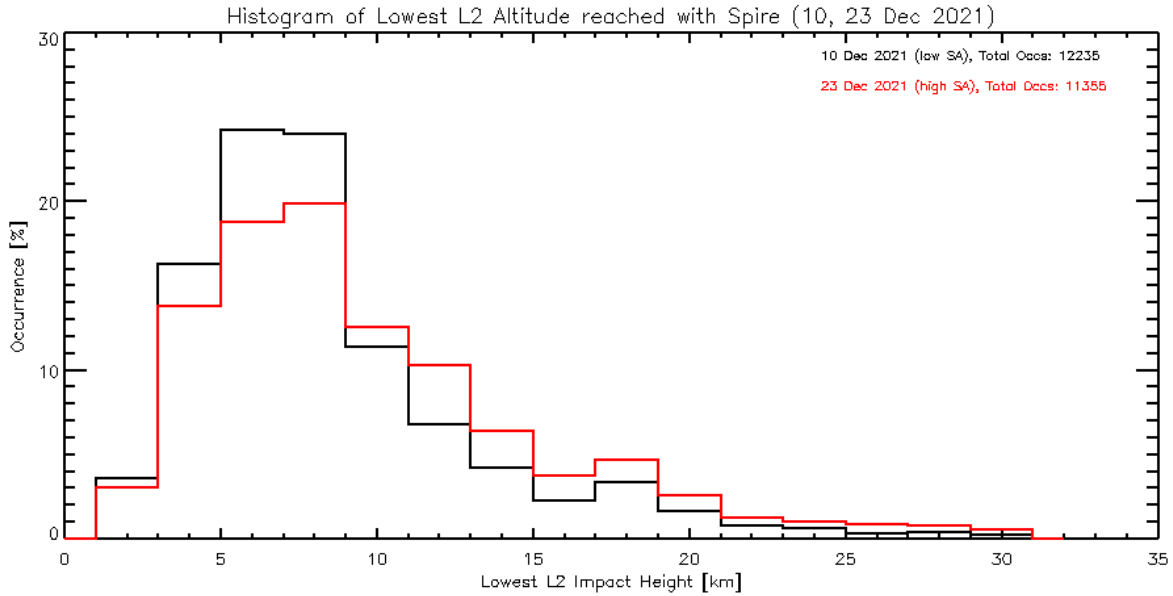
Effect of solar activity (L1-L2 bending angles statistics)

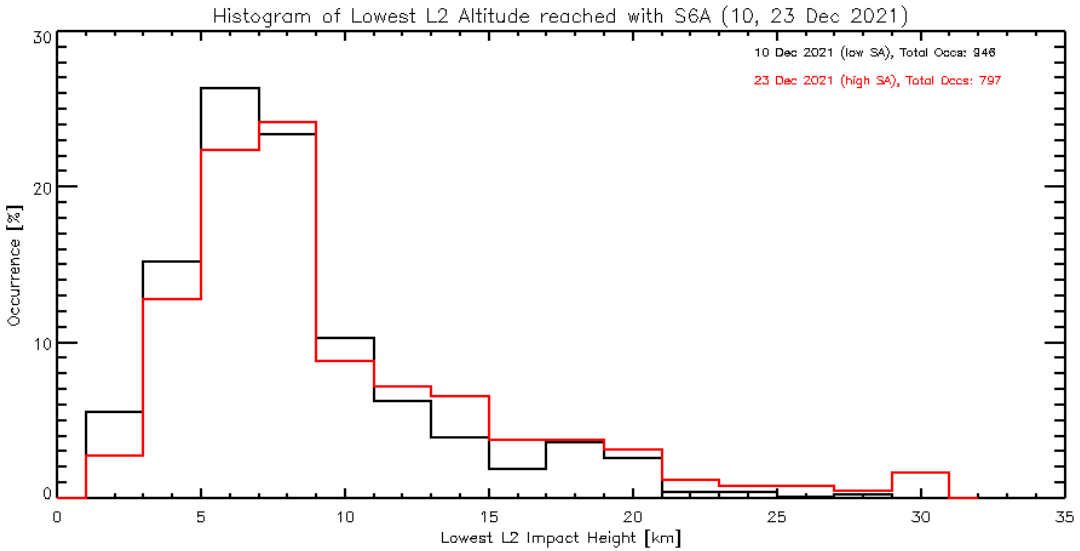


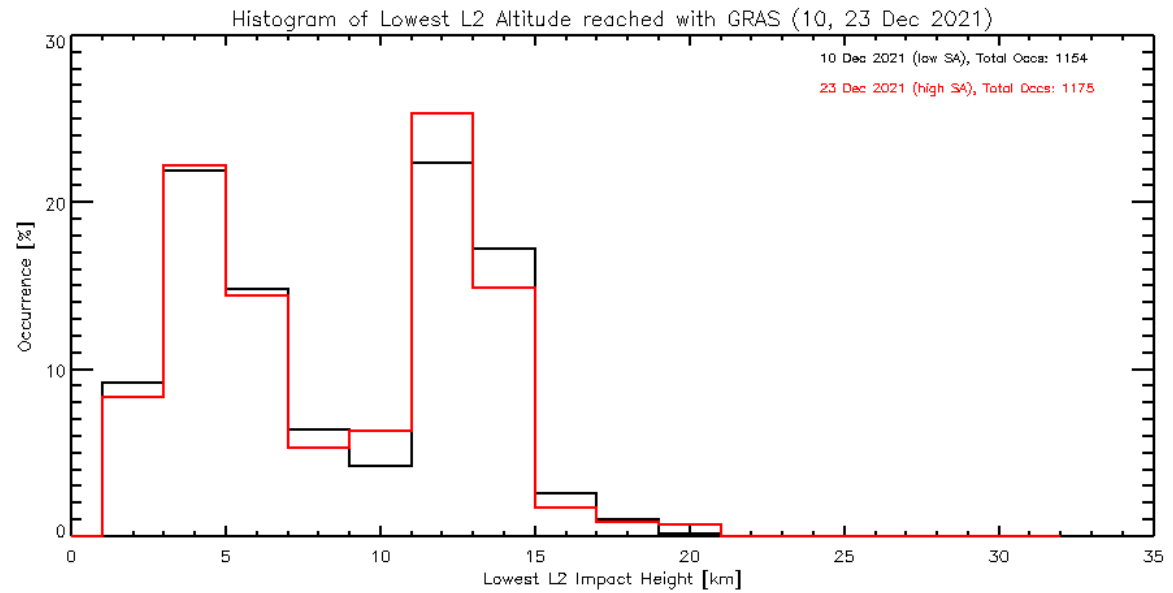
Robust L1-L2 statistics for different latitude bands (left to right) and different days (top, bottom). Note: a ±50E-6 rad threshold from zero (Spire) or mean L1-L2 (S6A) is used to cut off L2 data below. L2 cut-off disabled for GRAS.

Effect of solar activity (tropospheric penetration)



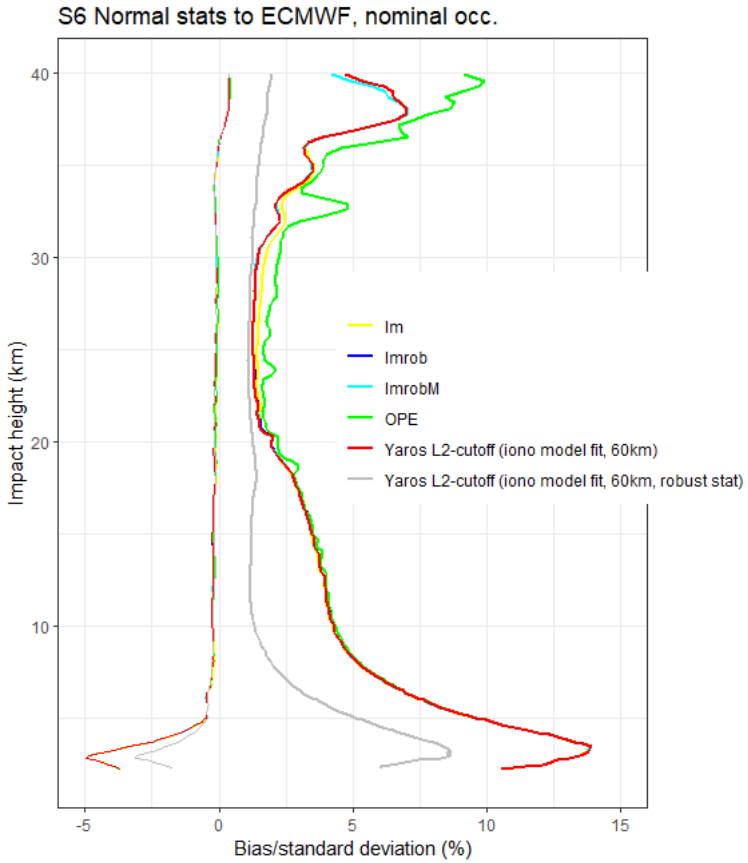


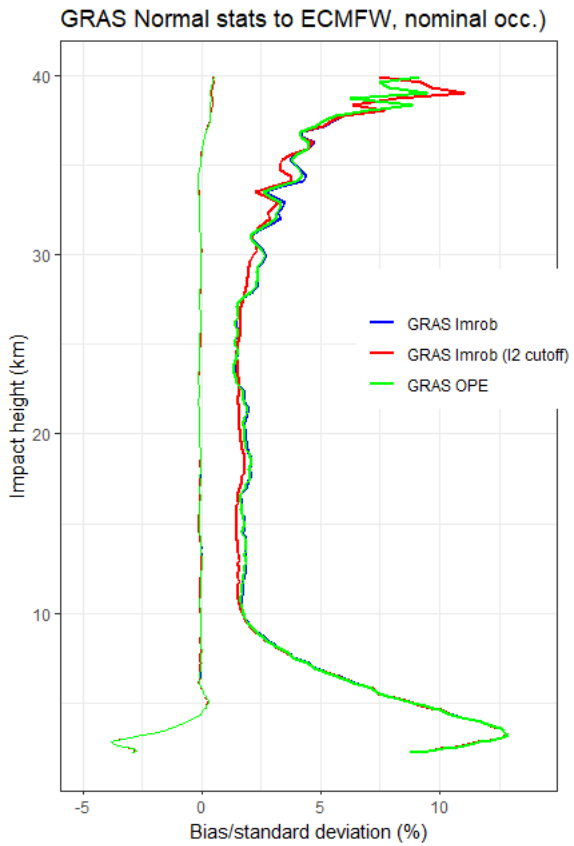




L1-L2 ionospheric bending angle model fitting

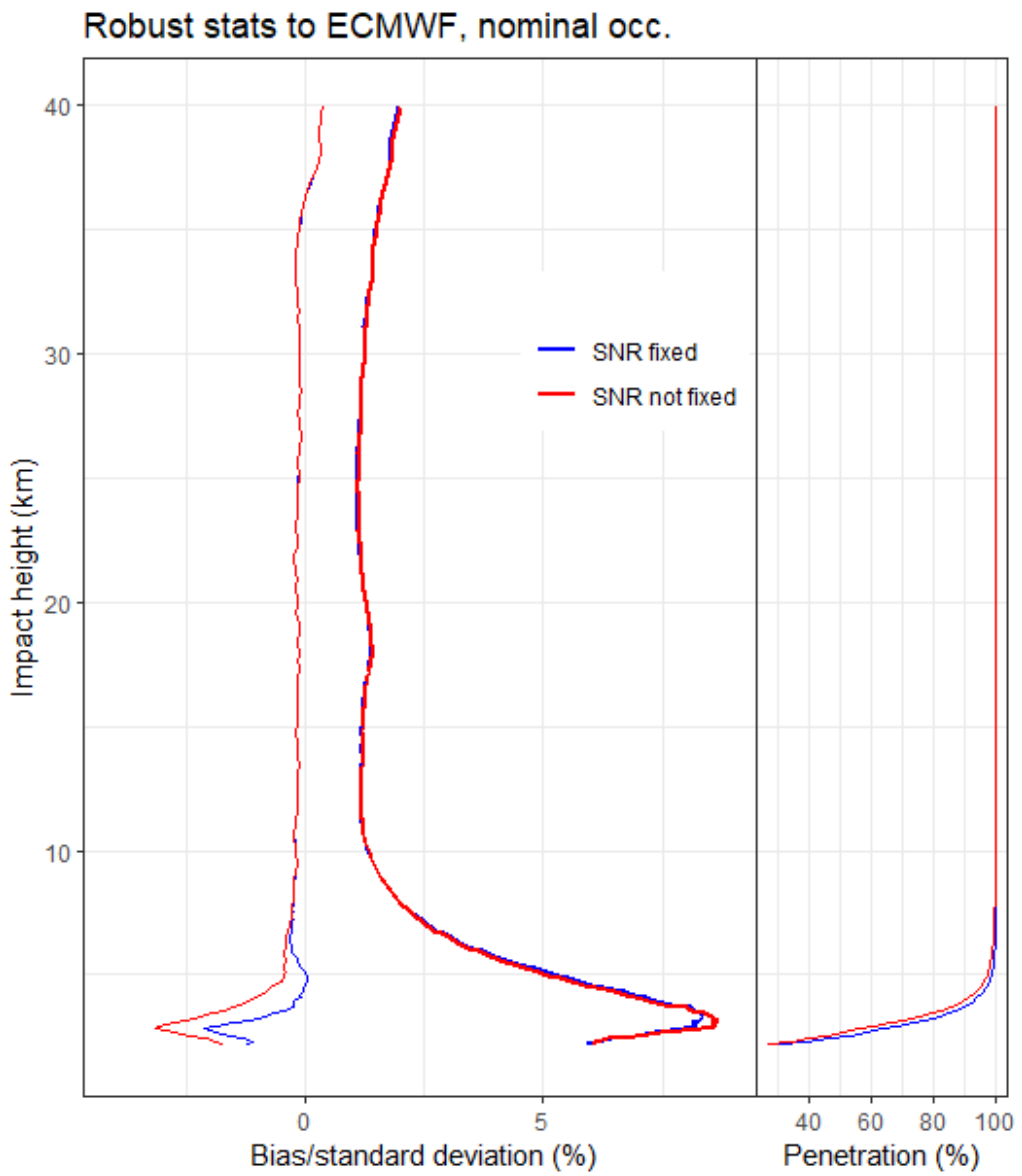
- L2 cut-off performed by comparing the L1-L2 bending angles residuals against the fitted ionospheric model based on a single Chapman layer (threshold ±50E-6 rad, max cut-off height of 30km, transition range 10km)
- L2 extrapolation down from where the L2 is cut.
- Dataset December 2021, ~25000 occultations for both S6 and GRAS
- Benefits from using the ionospheric fitted model confirmed by S6 and also by GRAS
- Benefits from using different fitting algorithms still under investigation





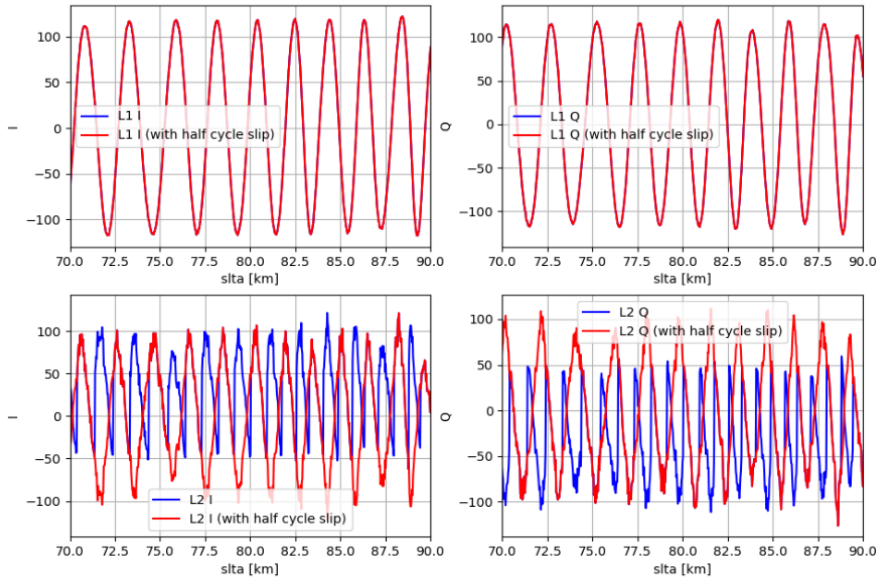
L1/L2 signal cut-off based on SNR

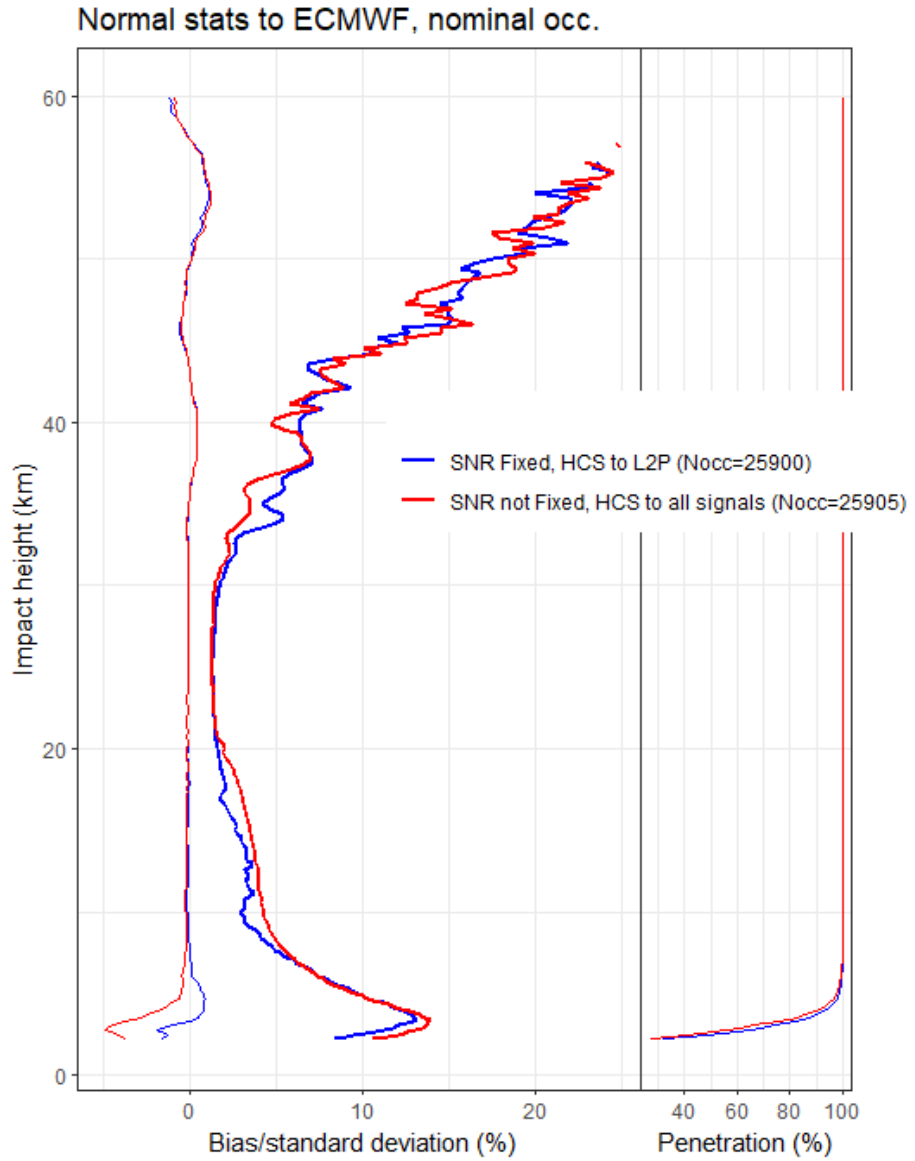
- From Spire occultations processing experience: an unexpected bias was visible in troposphere because of the signal cut-off based on SNR routine.
- It was performing the signals cut-off too high in troposphere.
- Reduced negative bias and tropospheric penetration improved.
- Reference paper: Sokolovskiy et al. - 2010 - On the uncertainty of radio occultation inversions in the lower troposphere.



Half cycle slip correction

- The Sentinel-6 RO-NTC processor executes the half cycle slips (HCS) correction after the navigation bits removal to both L1 and L2 signals. Details about the algorithm can be found in "Sokolovskiy et al., 2009, Postprocessing of L1 GPS radio occultation signals recorded in open-loop mode - Radio Science"
- Further investigation revealed that the HCS correction is necessary only for the L2P signal.
- Improved standard deviation below 20km and improved tropospheric penetration (L2 cut-off performed lower down)
- Benefits coming from the application of the HCS correction still under investigation...





Conclusions

- L2 signal cut-off based on the L1-L2 bending angles residuals is required for the Sentinel-6
- It would be beneficial for GRAS.
- Solar activities have a substantial impact on the L2 signal cut-off. The implementation has to take this into account.
- Statistics improve significantly when the L2 signal cut-off is performed by using the L1-L2 fitted ionospheric bending angles model as a reference.
- Benefits from the different choices of the robust linear fitting algorithms still under investigation.
- An improved signal cut-off based on SNR solves the problem of the negative bias in the lower troposphere and improves the penetration.
- The half cycle slip correction only applied to the L2P signals improves the statistics below 20km and improves the penetration in troposphere.

Thank you!

Questions are welcome.