GRAS on Metop-A ionospheric extension: preliminary results and future perspectives

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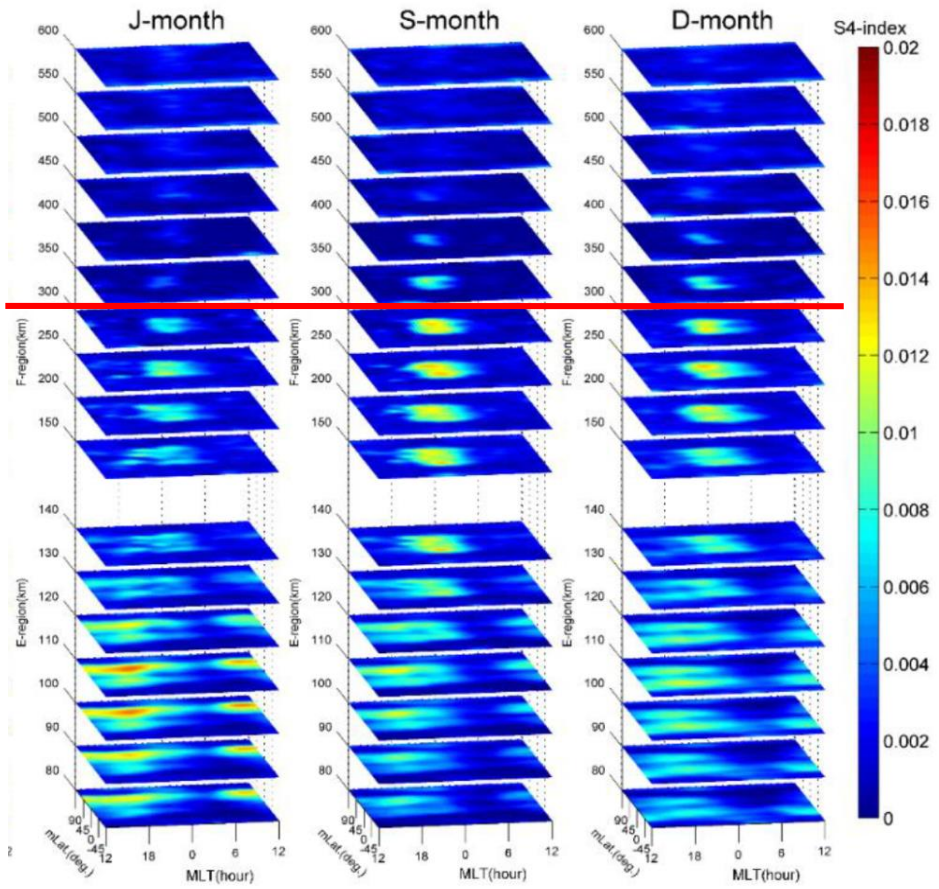
Outline

- Rationale for the GRAS ionospheric extension experiment (Metop-A End-of-Life technology test)
- Opportunities / limitations
- Overview on the ionospheric products
- Tracking capabilities and data gap analysis
- Scintillations distribution

Rationale

- **EPS/GRAS** measurements go up to 80 km, only covering the neutral atmosphere.
- **EPS-SG/RO** will measure up to 500 km, covering the F-layer.
- During the Metop-A End-of-Life test campaign in 2020, we temporarily extended the vertical measurement range of GRAS on **Metop-A** into the lower ionosphere:
  - Up to 300 km altitude as candidate for a future operational implementation
  - Up to 600 km to gather science data

	SLTA coverage [km]
23/06 ÷ 14/07	-250/300
15/07 ÷ 26/08	-200/600
27/08 ÷ 09/09	-300/300



Summer, Autumn and Winter (left to right) S4 scintillation indices from COSMIC during low solar activity in 2008 (Liu et al., 2016)

Limitations / Opportunities

- Because of instrument design, GRAS is limited to 2 occultations in either directions.

- Ionospheric measurements take longer and thus reduce number of neutral atmospheric ones.

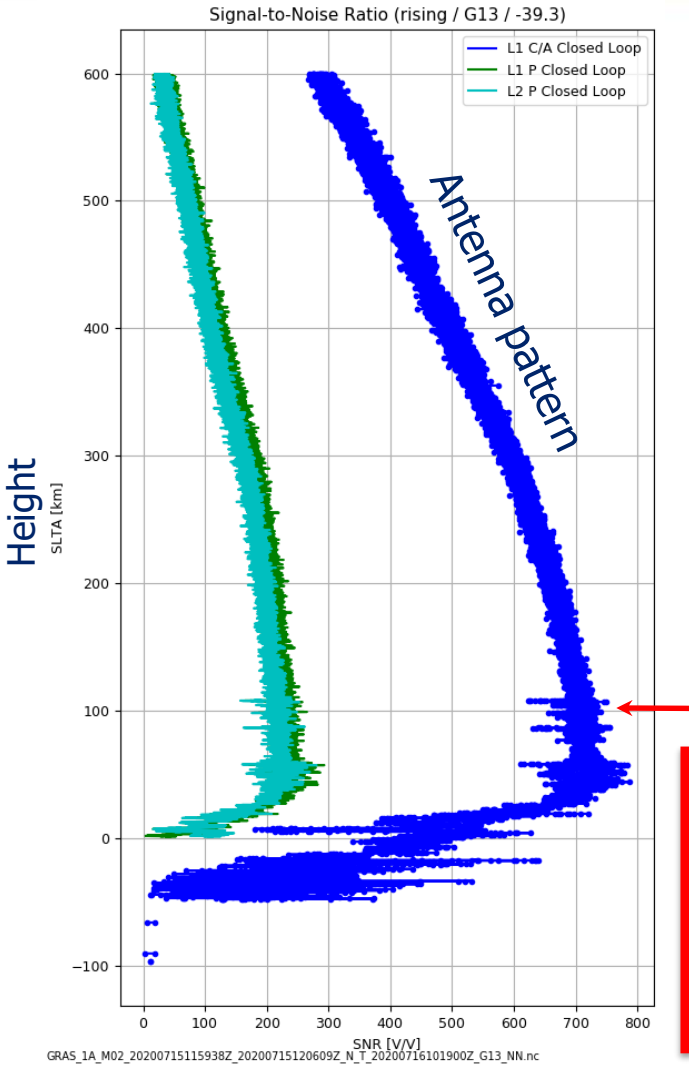
  → But, for the extension up to 300 km, losses in daily occultation numbers have been marginal (produced ~1% less neutral bending angle profiles).

- Antenna pattern falls off rapidly above 100 km.

  → But this did not represent a big issue for the ionospheric monitoring (even for the experiment up to 600 km).

- By tracking higher up with GRAS, we envisage to develop products in the space weather domain:
  - Ionospheric scintillations (S_4/σ_φ indices);
  - Bending angles and electron density profiles;
  - Information on ionospheric E-layers;

Ionospheric SNR and bending angles

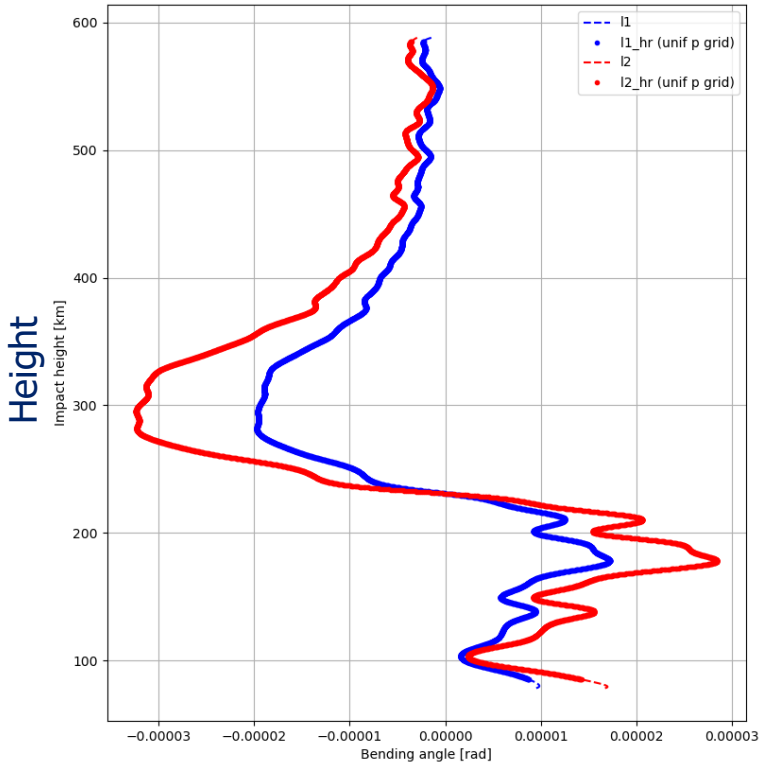


- Note the decrease of SNR above ~100 km due to the antenna gain patterns.
- In almost all cases, dual-frequency bending angles can be retrieved even up to 600 km.

(Weak) scintillations

Nominal GRAS coverage

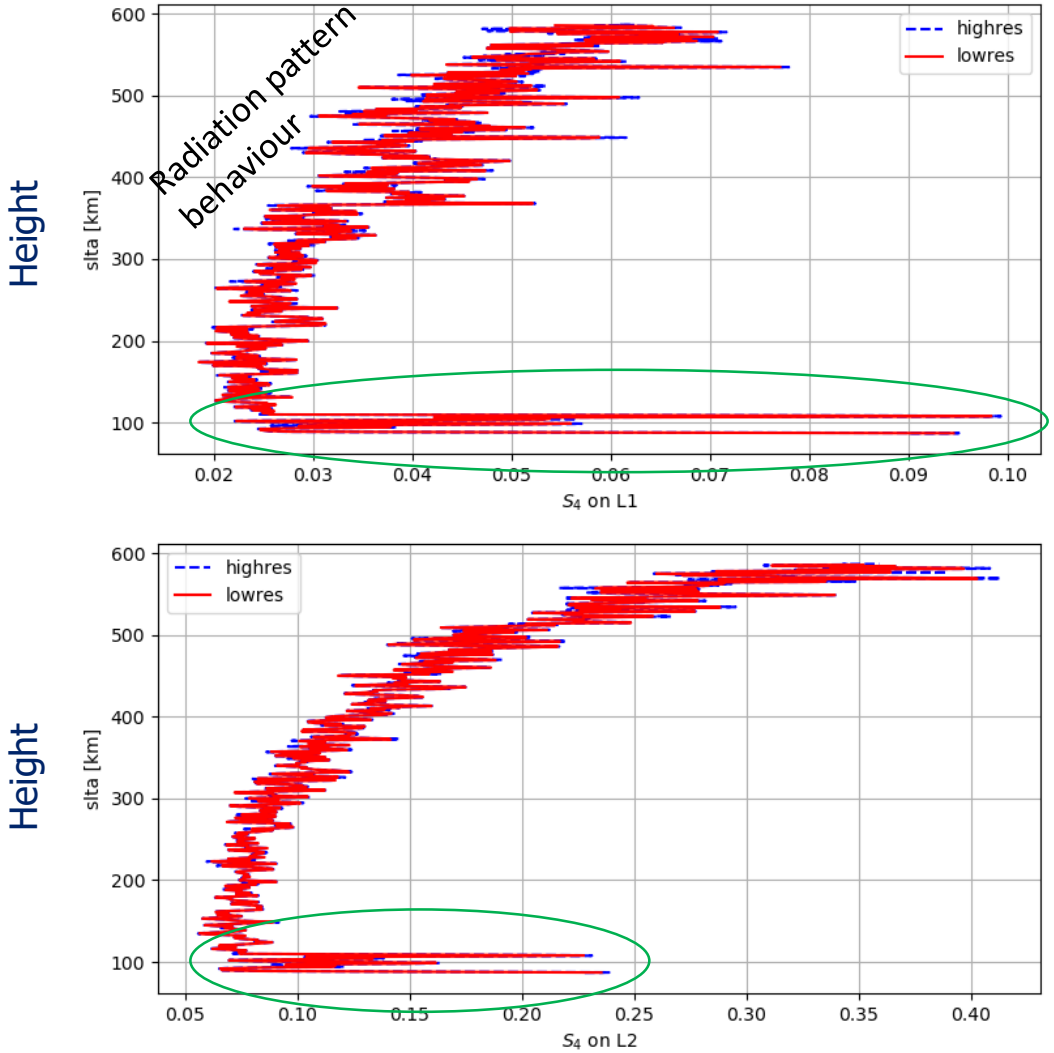
L1 and L2 Signal-to-Noise Ratios



L1 and L2 Bending angle profiles

Scintillation profiles

- Scintillation indices (S_4 and σ_φ) can also be retrieved.
- Antenna patterns probably limit meaningful altitude range for weak scintillations to below 300-400 km.

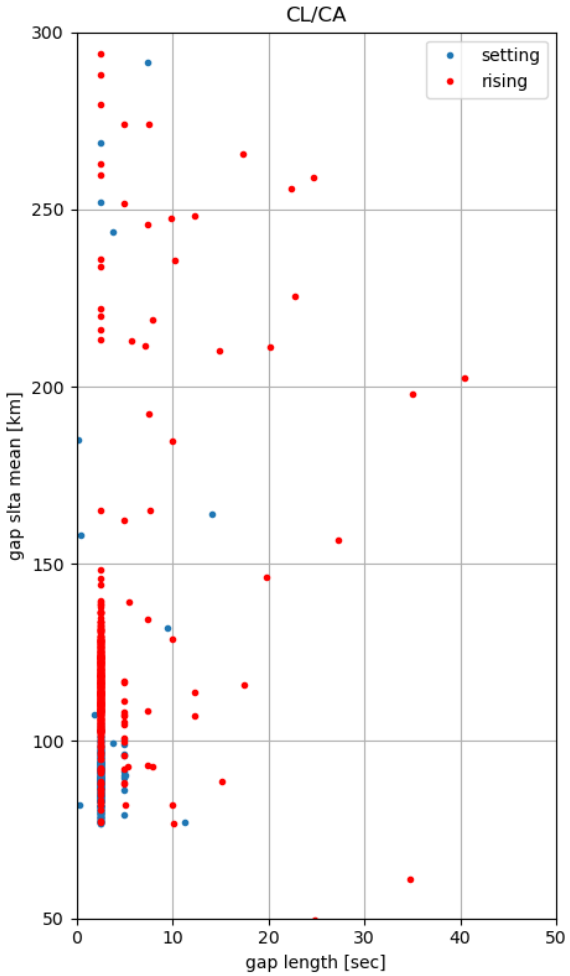


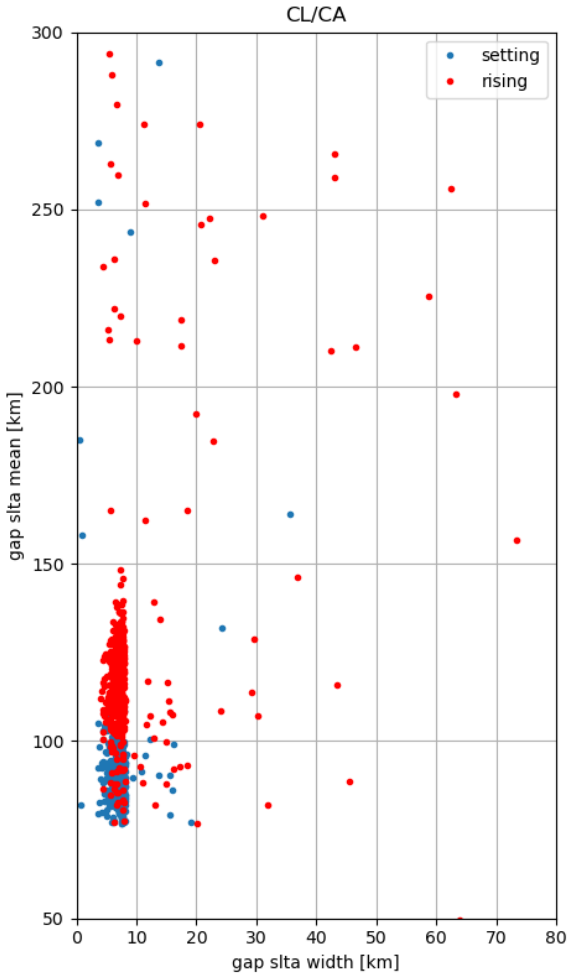
Tracking statistics / data gaps in ionosphere

		Occultations	Data gaps (h > 80 km)
v1.12.b (-250/300 km)	23/06÷14/07	9440	4.9%
v1.12.c (-200/600 km)	15/07÷26/08	25142	14.9%
v1.12.d (-300/300 km)	27/08÷09/09	5605	1.3%

- Tracking up to 300 km seems optimal. Only ~ 5% of ionospheric measurements suffered from data gap in the 80-200 km SLTA range during June/July. Even much better in September.
- Tracking up to 600 km shows more issues (e.g. data gaps). Similar (small) % of occultations impacted by data gap in the lower ionosphere. Majority of data gap are above. Somehow expected due to the decreasing of the antenna gain.

Data gap length





Jun/Jul (-250/300 km)

Data gaps impact ~5% of the occultations.

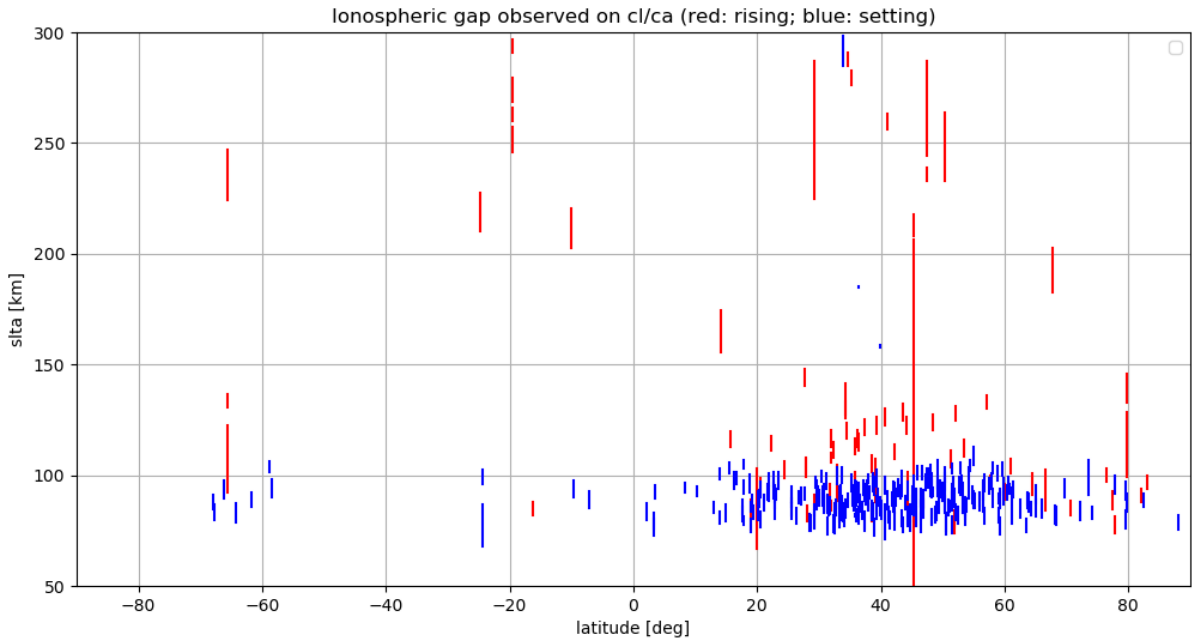
Majority of data gaps last 2.5 sec for L1, and 10 sec for L2 (not shown).

Between 80 and 100 km for setting occultations, higher up for rising occultations.

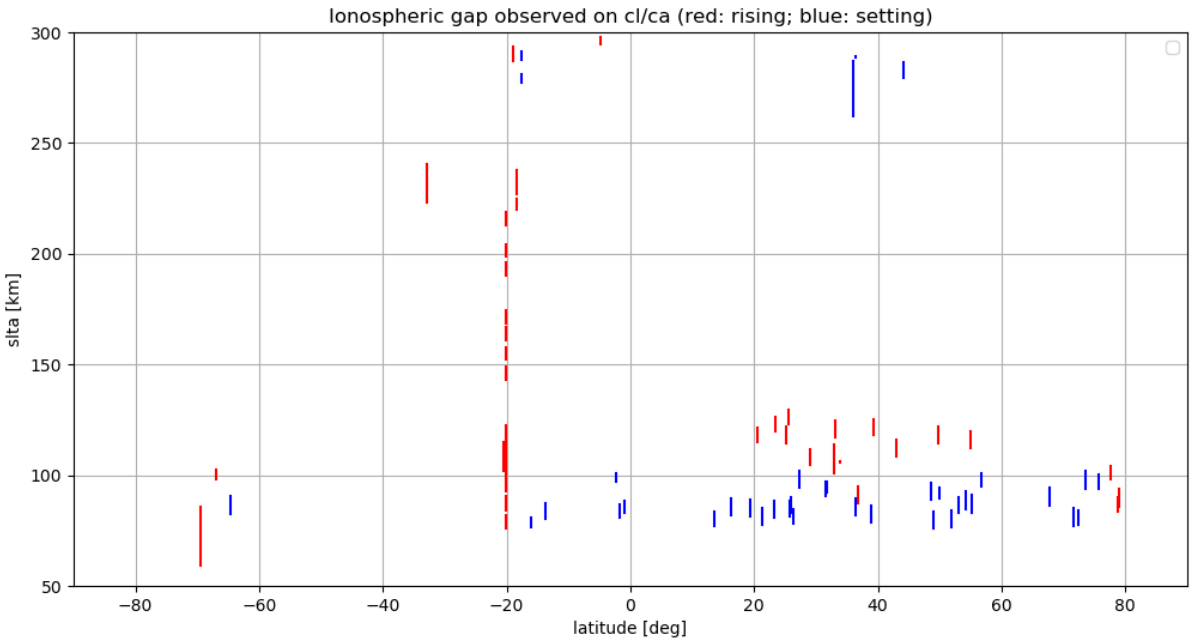
Same situation for the September experiment (but with less data gaps).

Data gap latitudinal distribution

v1.12.b - June/July
(-250/300 km)

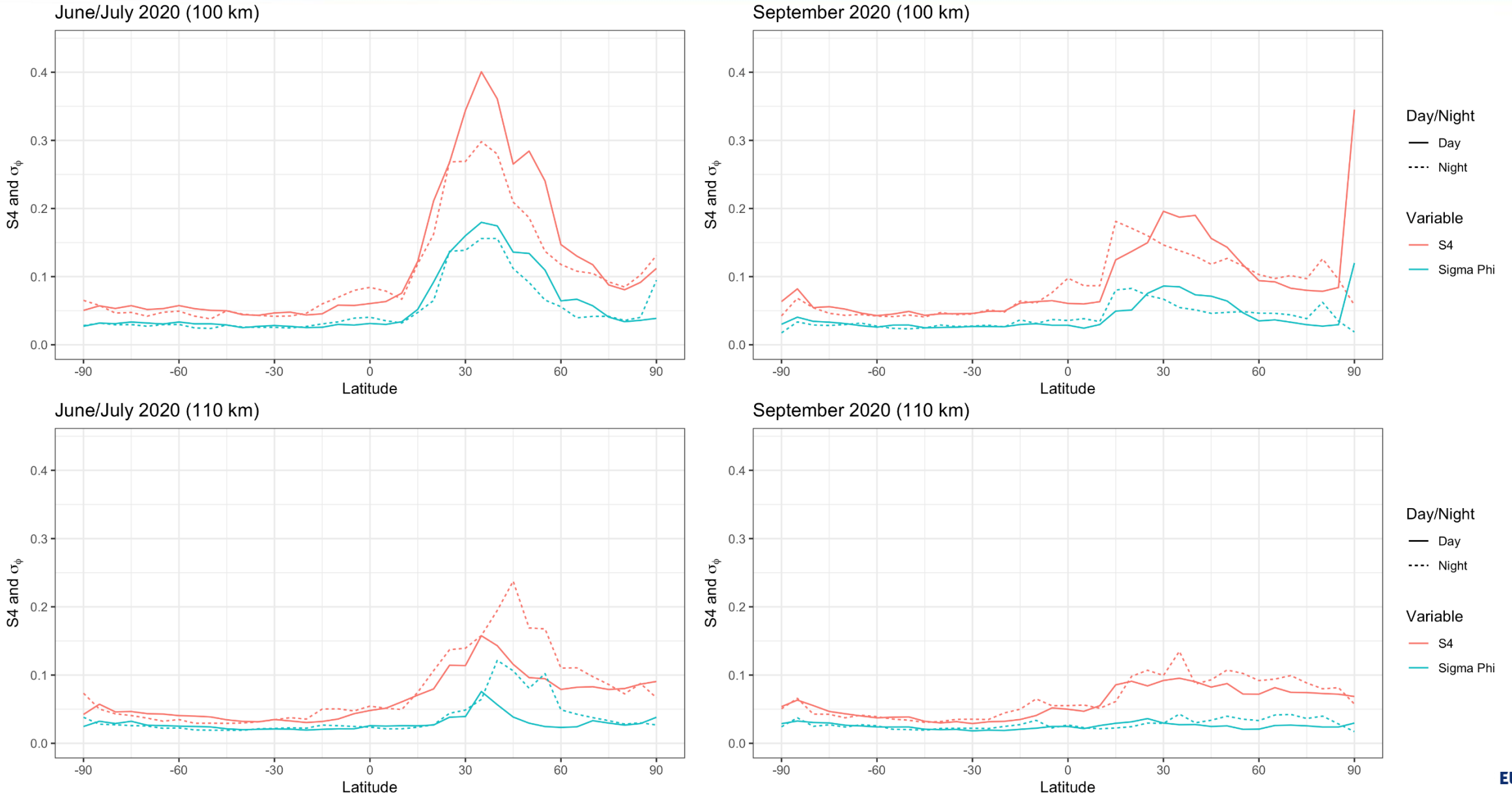


v1.12.d - September
(-300/300 km)

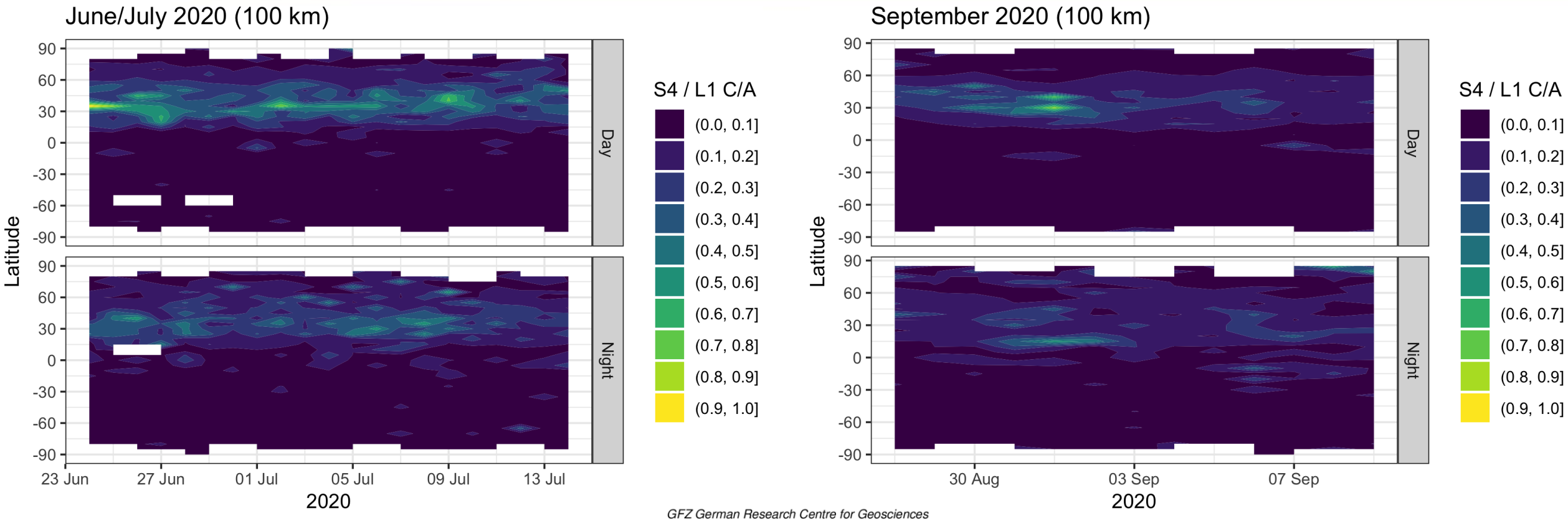


Majority of data gaps are affecting occultations in the northern hemisphere.

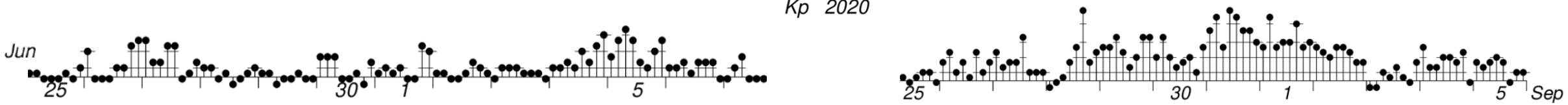
Scintillations zonal mean distribution (L1 signal)



Scintillations Hovmöller plots (S4 on L1 signal)



Bartels music diagram



ftp.gfz-potsdam.de/pub/home/obs/kp-ap/

Summary

- Extending GRAS measurements up to 300 km is feasible:
  - with marginal losses in daily occultation numbers
  - without impact on neutral atmospheric data quality.
- Extending GRAS measurements up to 300 km has scientific value:
  - Scintillation observations possible (though not much higher due to antenna pattern drop-off);
  - 95% of occultations provide continuous measurements.
- Analysis of the measurements is still on-going.
- Summer/autumn 2021: Probable extension of **all** GRAS instruments and release of experimental ionospheric products (scintillation indices, bending angles).
- Through 2021: Study for validating prototyped ionospheric products and application of the data in ionospheric data assimilation; also feasibility of electron density retrievals. Outcome of the study will guide validation of operational ionospheric products.
- Data is available on request.

THANK YOU!

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