Refining Sentinel-1 radiometric and pointing calibration by on-board temperature compensation emulation

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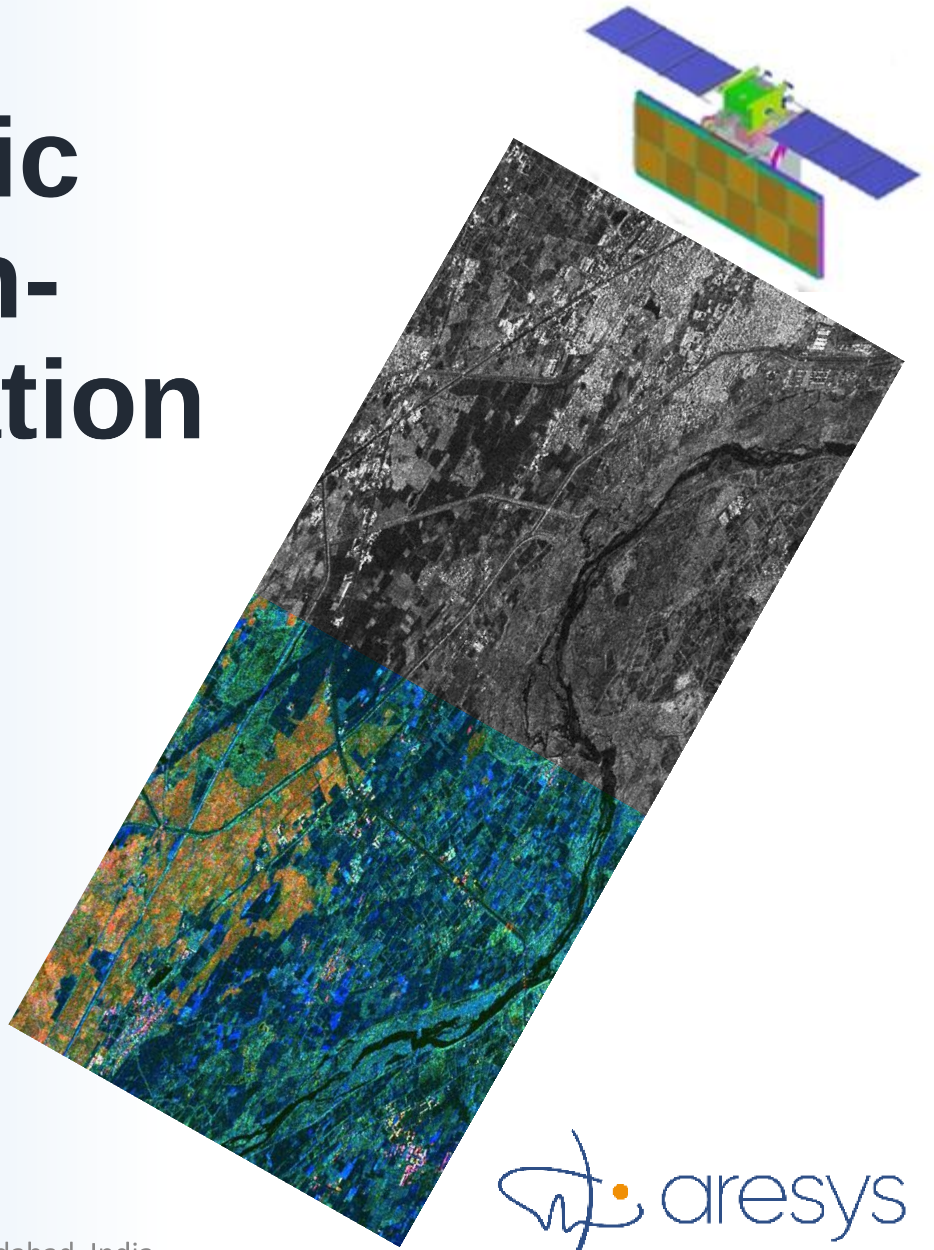

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Session: 5: Innovative concepts and processing algorithms

Outline

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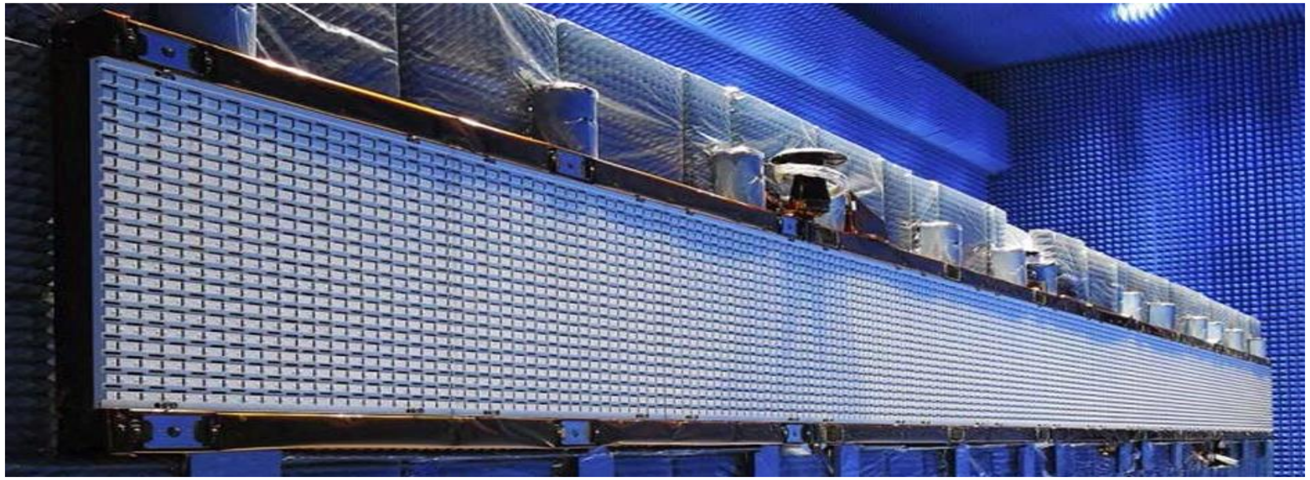
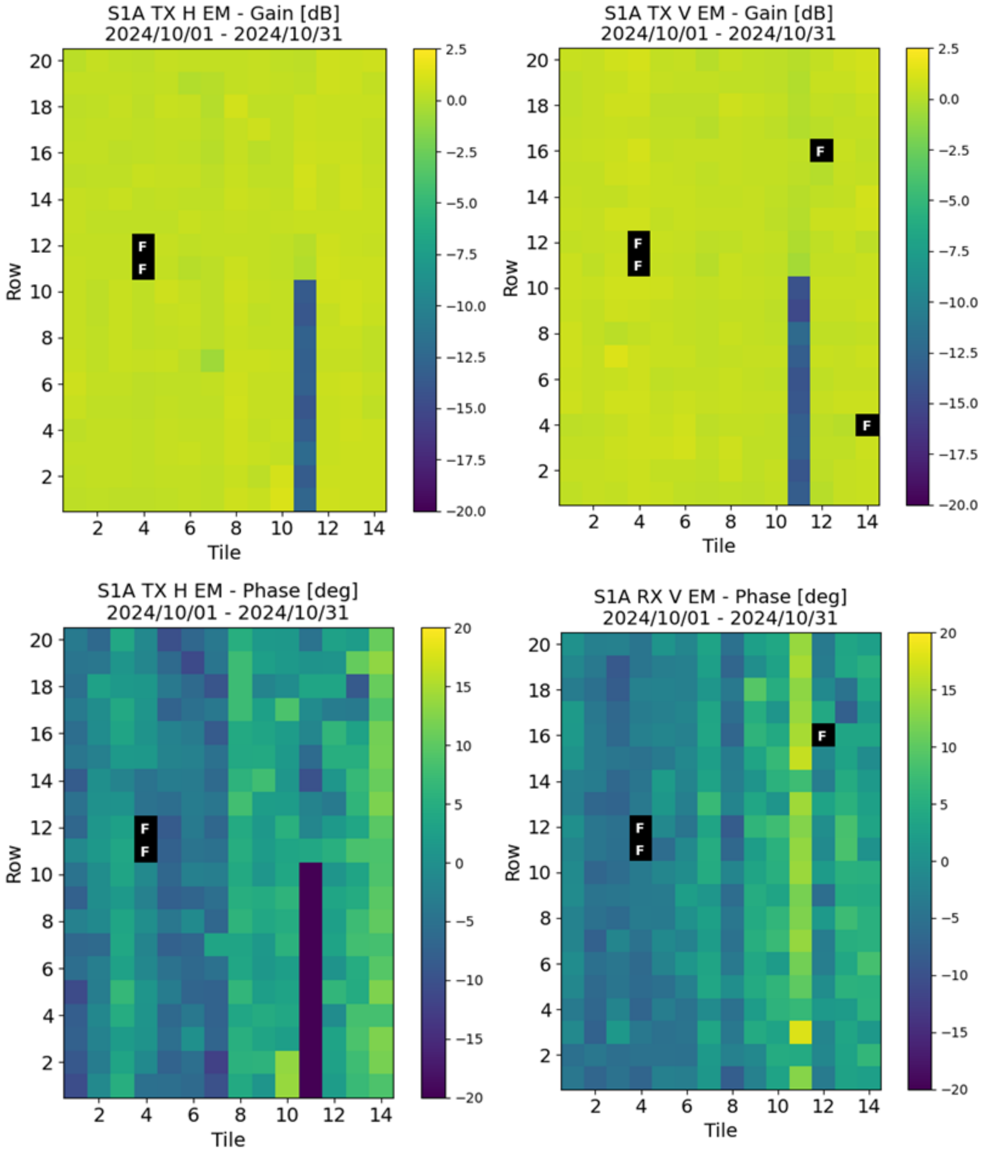
- Sentinel-1 antenna monitoring
- On-board temperature compensation strategy
- Temperature compensation emulation for RFC data
- Observation of real data for RVL calibration
- Temperature compensation emulation for imaging acquisitions
  - Doppler Centroid jumps
  - Emulation over a full data cycle
- Observation of real data for OWI calibration
  - Antenna pattern variations
- S1C evolutions
- Conclusions

Sentinel-1 antenna monitoring

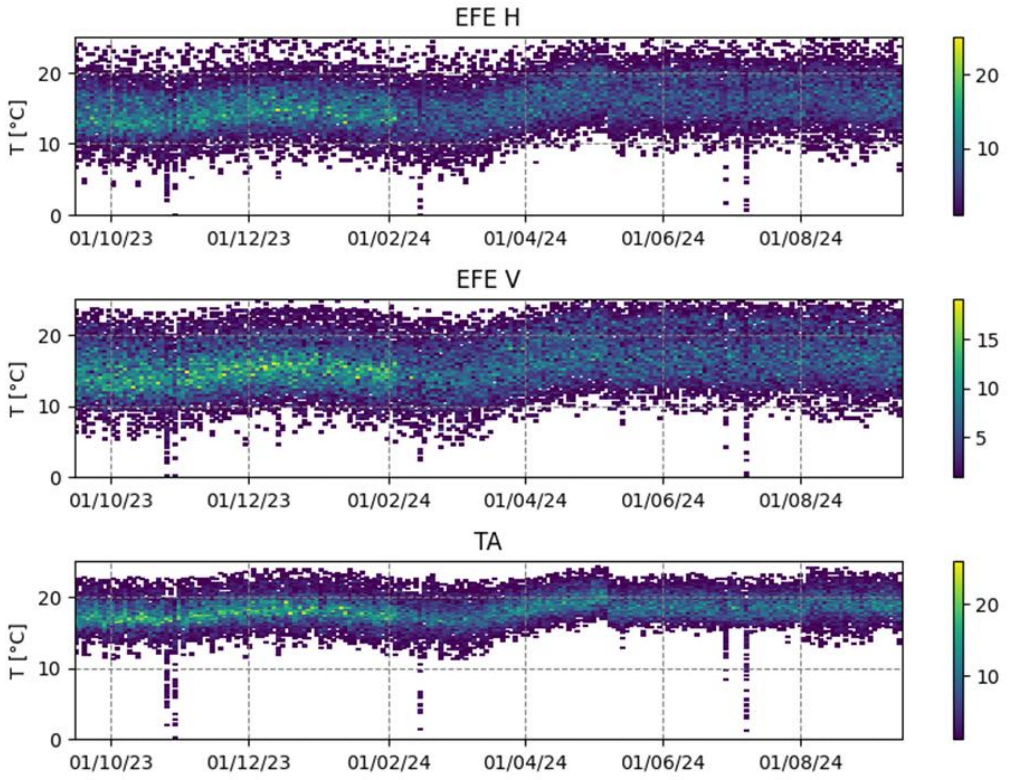
- Active phased array antenna
- 1120 elements: 14 azimuth x 20 elevation x Tx/Rx x H/V pol
- 16 elevation beams and 1024 azimuth beams (for TopSAR)
- Antenna status continuously monitored by SAR MPC through RFC products
- Antenna status is an input to S1 Antenna Model for patterns prediction

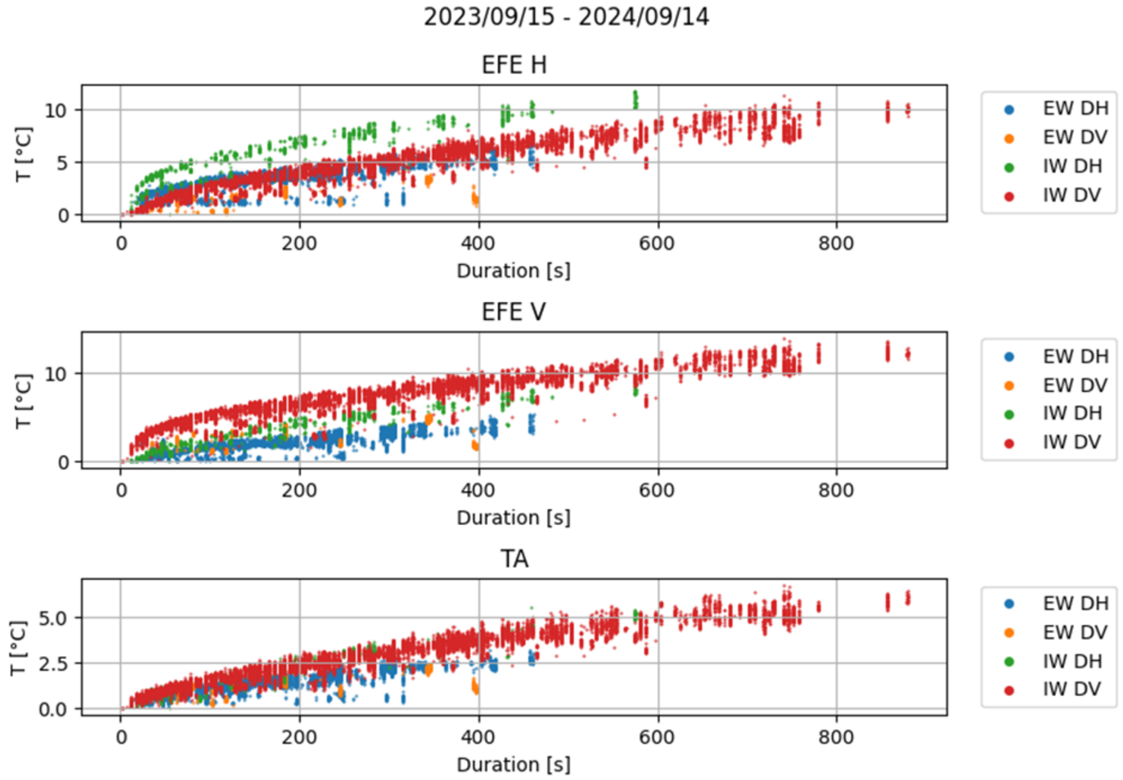




Sentinel-1 antenna monitoring

- Temperature of the antenna elements is annotated in the SAR packets
- S-1 temperature change seasonally, according to sensor usage and within data takes





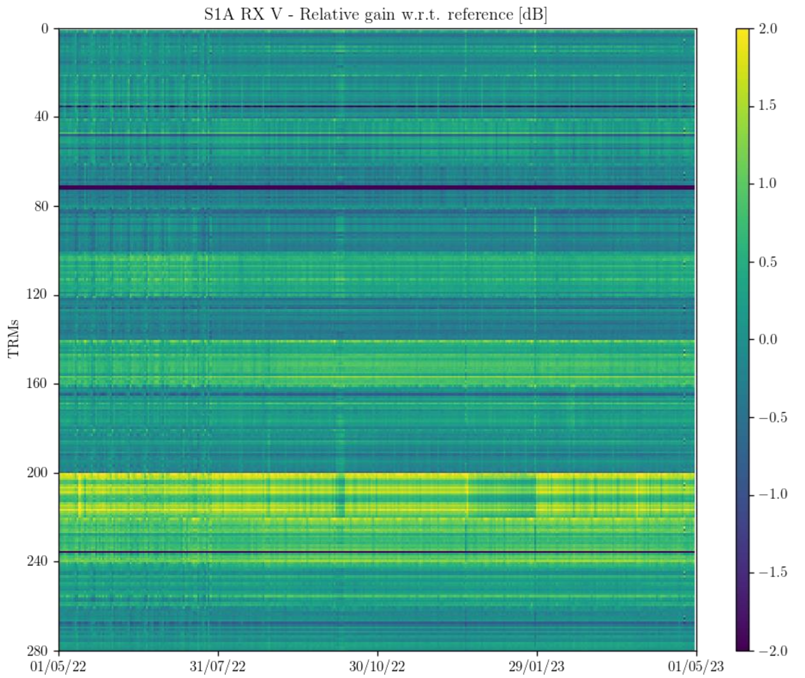
On-board temperature compensation strategy

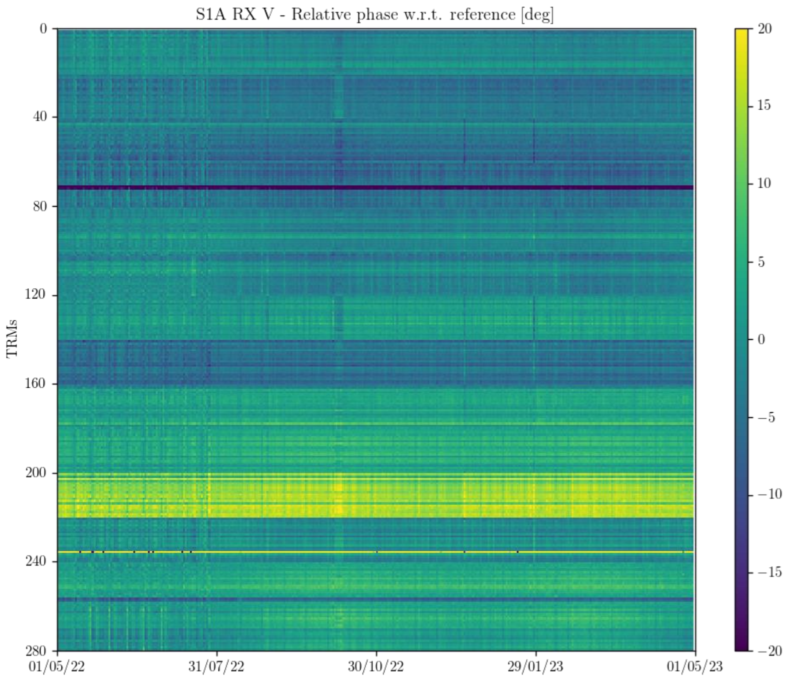
The on-board temperature compensation strategy implemented in the Sentinel-1 instrument:

- Copes with gain and phase drifts of the antenna elements induced by temperature increase during long acquisitions
- Ensures very good long-term stability of the instrument
- Can have some small potential impact on S1 imagery:
  - **azimuth pointing variations** during acquisitions resulting in **residual doppler jumps** in L2 Radial Velocity (RVL) products
  - small **radiometric discontinuities** between adjacent sub-swaths in L1 products

On-board temperature compensation strategy

- The TRM are controllable with **steps** of
  - 0.5 dB in gain
  - 5.625 degrees in phase
- Temperature compensation is applied:
  - At **single element** level
  - At **tile amplifier** level (affecting 20 elements at the same time)

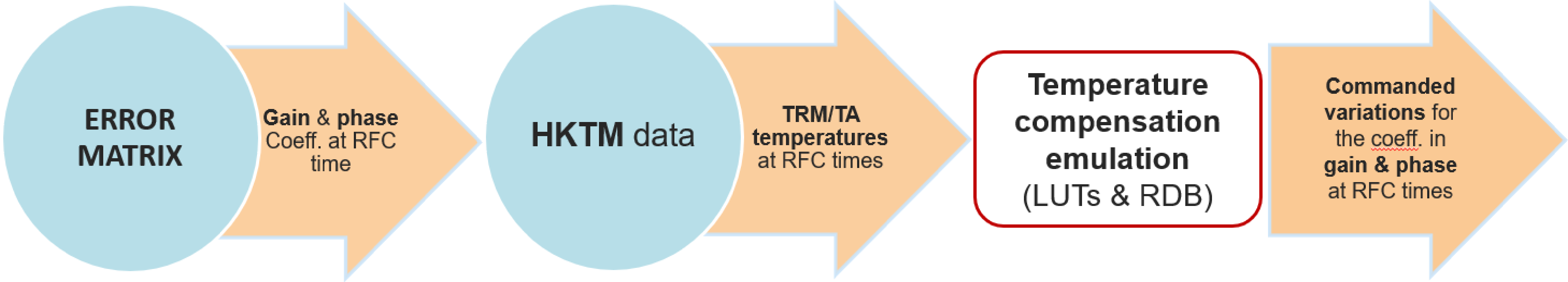




- Temperature compensation is applied in **specific points within the timeline** of each acquisition mode
- Effects of temperature compensation are clearly visible in RFC products

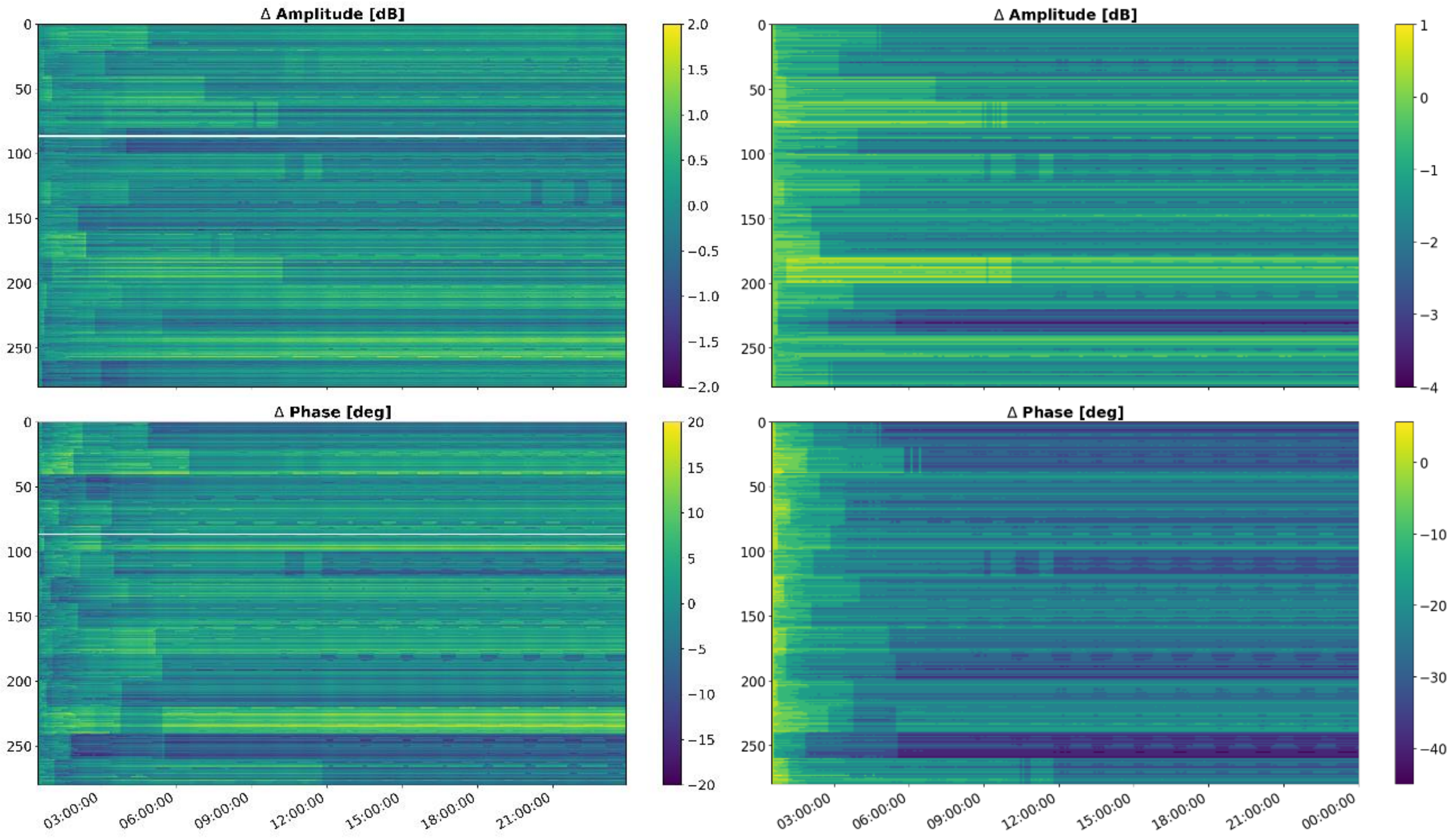
Temp comp emulation for RFC data

- During **S1B CP**, the instrument was warmed up to ~ 20 °C
- **RFC was acquired for 24h every 5mins**, while the instrument was cooling down
- Observed temperature decrease of ~ 30 °C
- **House Keeping Telemetry** (HKTM) can provide temperature info for each TRM and TA with a sampling step of 16s



Emulation for RFC data (RX V example)

- On-board temperature compensation works well **ensuring stable excitation coefficients** in the presence **of large temperature variations**
- Small differences could come from **linear interpolation of telemetry data** (sampled every 16s) used in emulations vs **real time** temperature readings used **on-board**



Observation of real data for RVL calibration

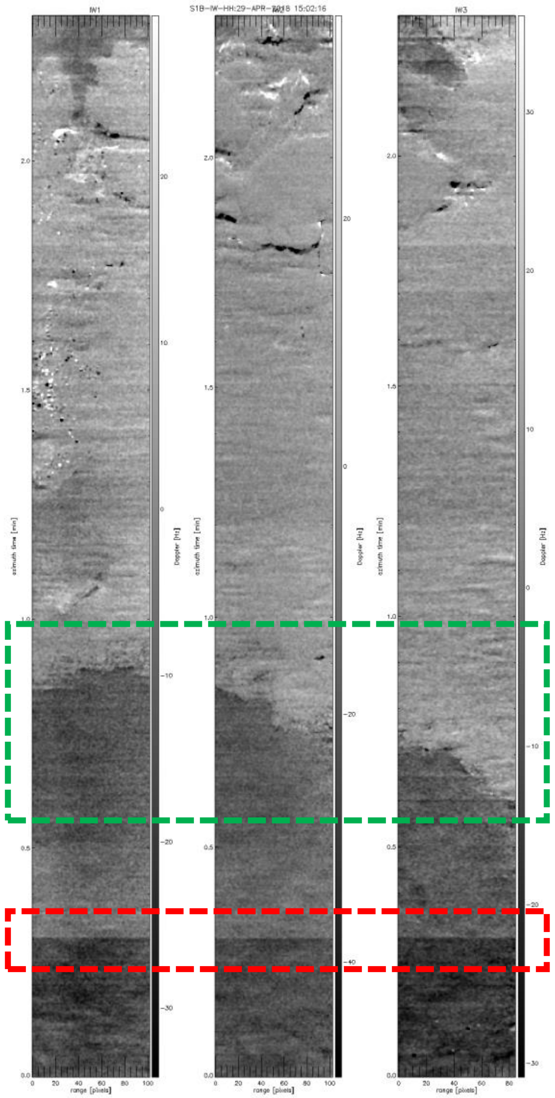
- RVL L2 products provide a measure of the ocean currents based on the DC estimates from data

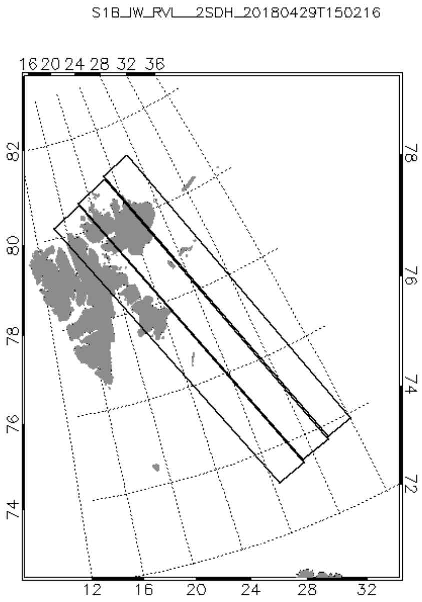
- RVL calibration is required to remove instrument related contributions:

$$f_{DC} = \boxed{f_{ATT} + f_{ANT}} \boxed{+ f_{GEO}} \boxed{+ ?}$$

- After calibration **residual azimuth jumps** not related to geophysical contributions can be observed

- Could they be temp comp induced? Can they be predicted?





Geophysical DC jump

“Instrument” DC jump?

Emulation for imaging acquisitions

RFC emulation

- **Gain** & **phase** Coeff. from closest RFC acquisition
- **TRM/TA temperatures** from HKTM data at RFC time

Acquisition emulation

- **Gain** & **phase** coefficients at temp. comp. activation times
- **TRM/TA temperatures** from HKTM data at temp. comp. activation times

Acquisition excitation coefficients

↓

Antenna Model

↓

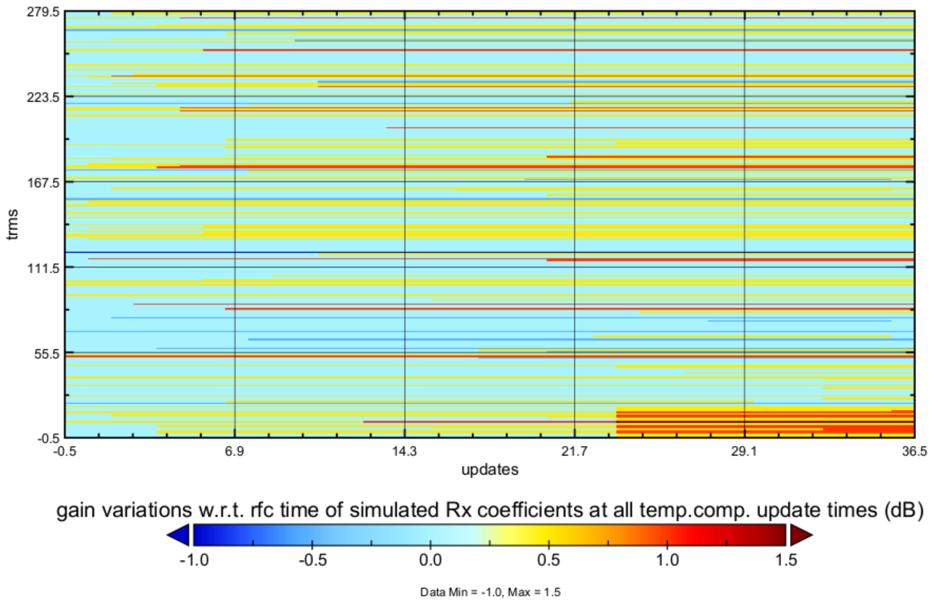
Acquisition antenna patterns

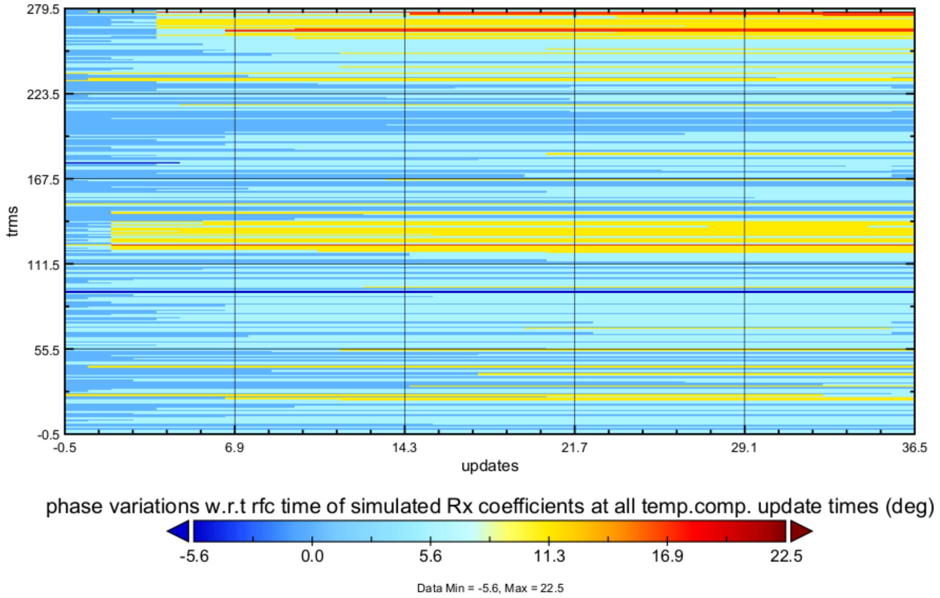
↓

Azimuth pointing variations

Emulation for imaging acquisitions

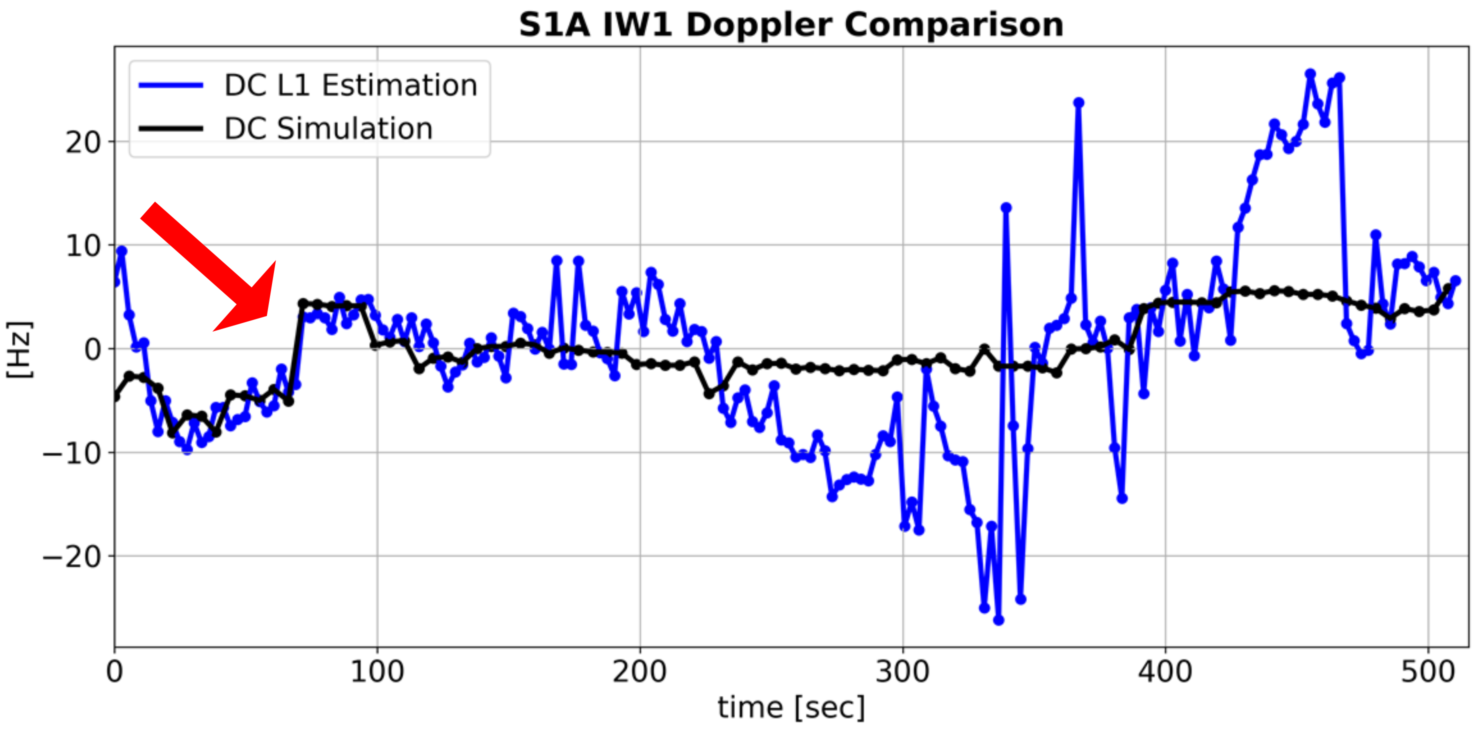
- Expected gain and phase variations are computed at the times of on-board temp. comp. activation
- Tx gain variations are simulated but not considered → in Tx all TRM work in saturation and all variations would be ineffective
- Emulated jumps combined with antenna status derived from RFC measures are provided to S-1 Antenna Model.
- The accuracy of the emulation could be impacted by the time “distance” between the datatake and the last previous RFC
- Antenna patterns evolution during the acquisition is predicted

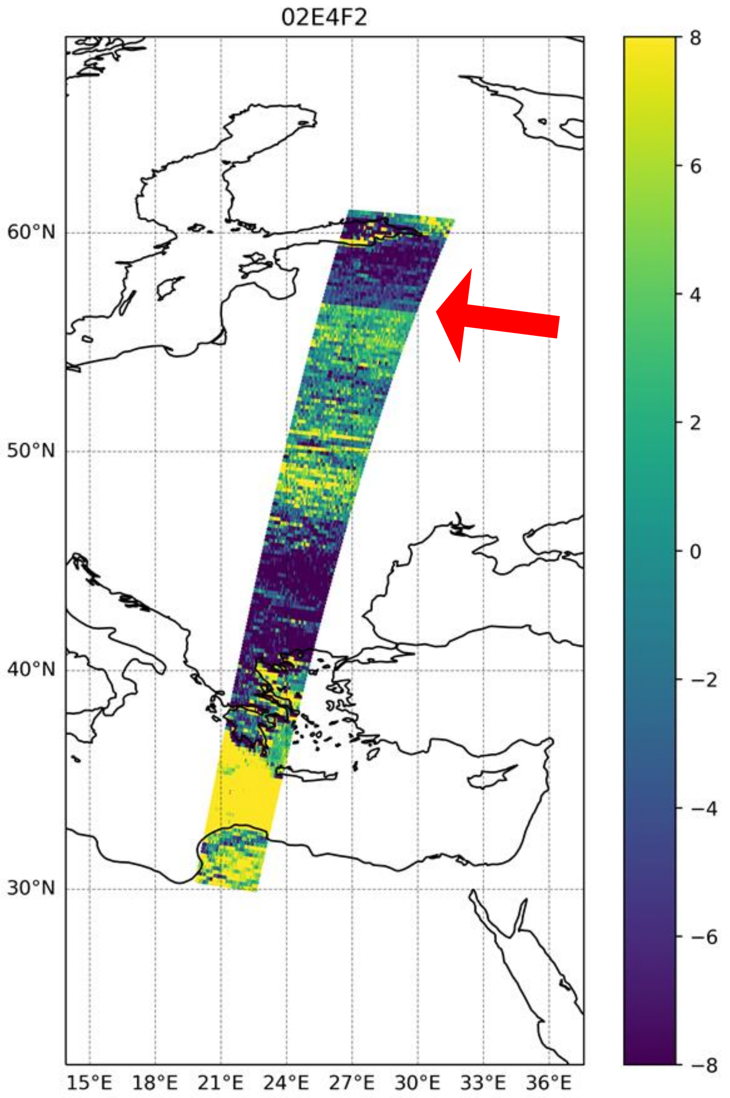




Doppler Centroid jumps: DT 02E4F2

IW mode



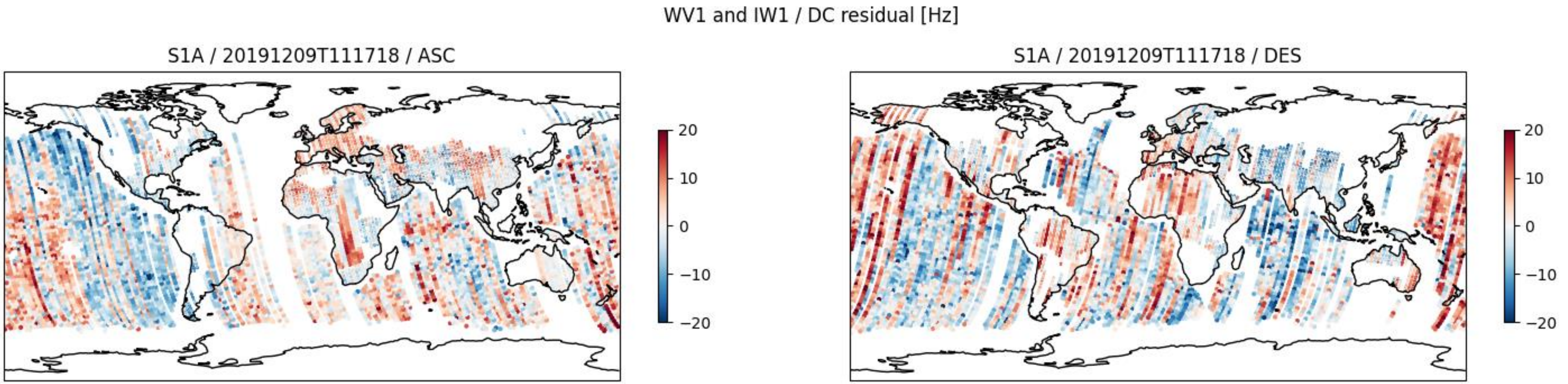


$$Dopp_{SHIFT} \simeq \frac{2 \cdot V_{SAT} \cdot \sin\theta_{AZ}}{\lambda}$$

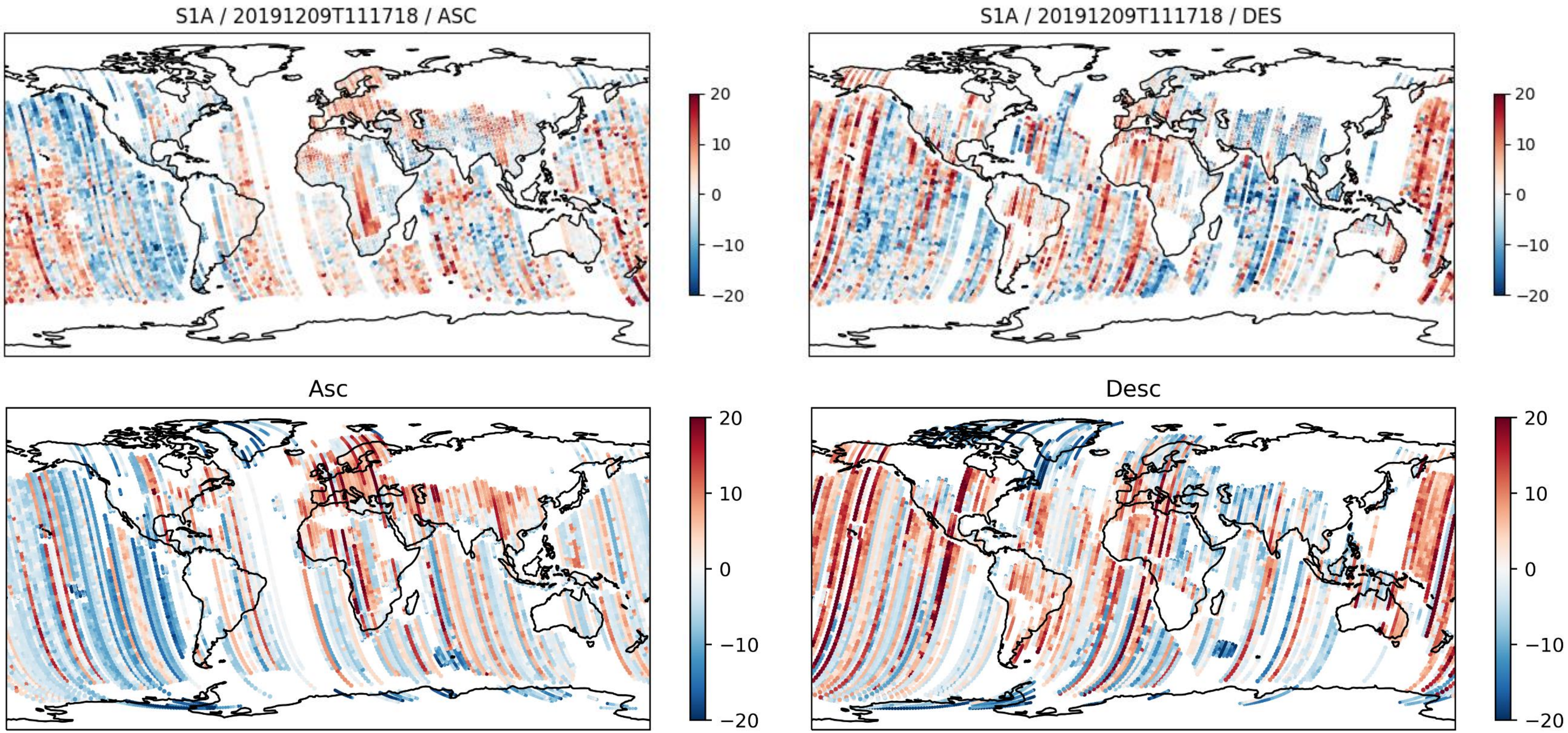
θ_{AZ} is the angular position of the maximum of the azimuth antenna pattern

WV/IW Doppler residual: geographical patterns

- For the cycle 2019/12/09 – 2019/12/21 after a full calibration involving **compensation** of:
  - geophysical doppler contributions (currents, wind over oceans)
  - attitude contribution (integration of on-board gyro rates, orbital harmonic)
  - a long term bias
- Residual geographical patterns cannot be easily explained in terms of geophysical signal or attitude



Full IW + WV comparison

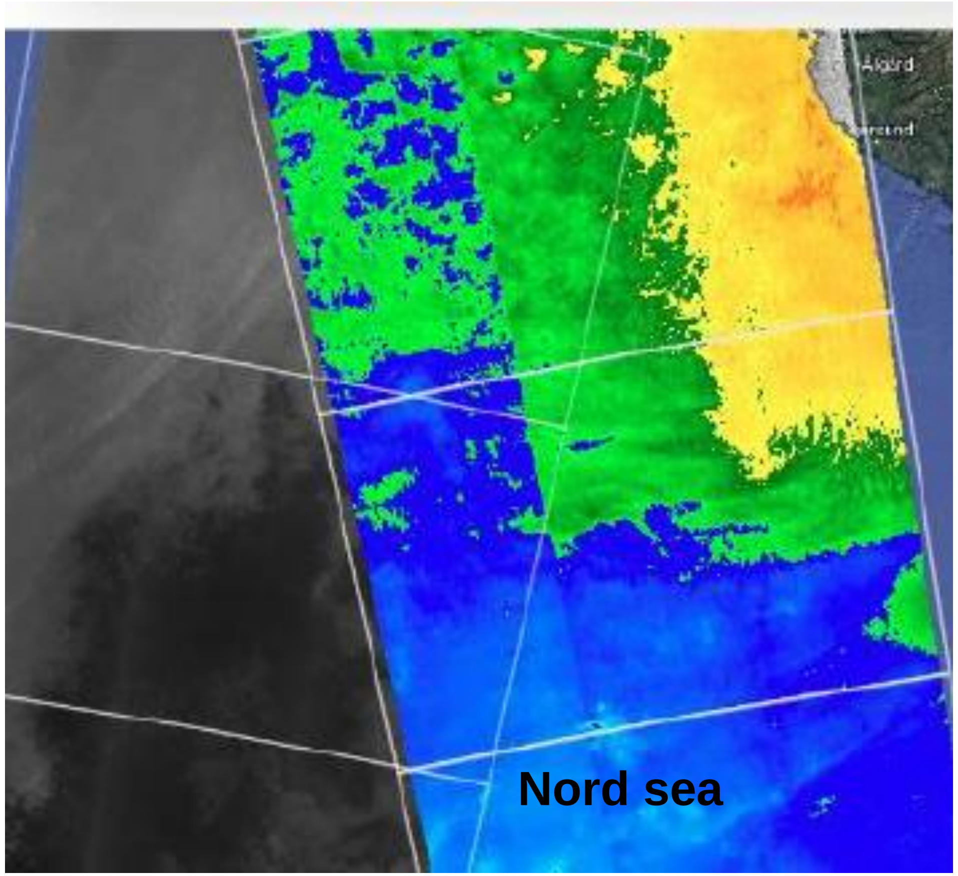


RVL

Temp. comp.

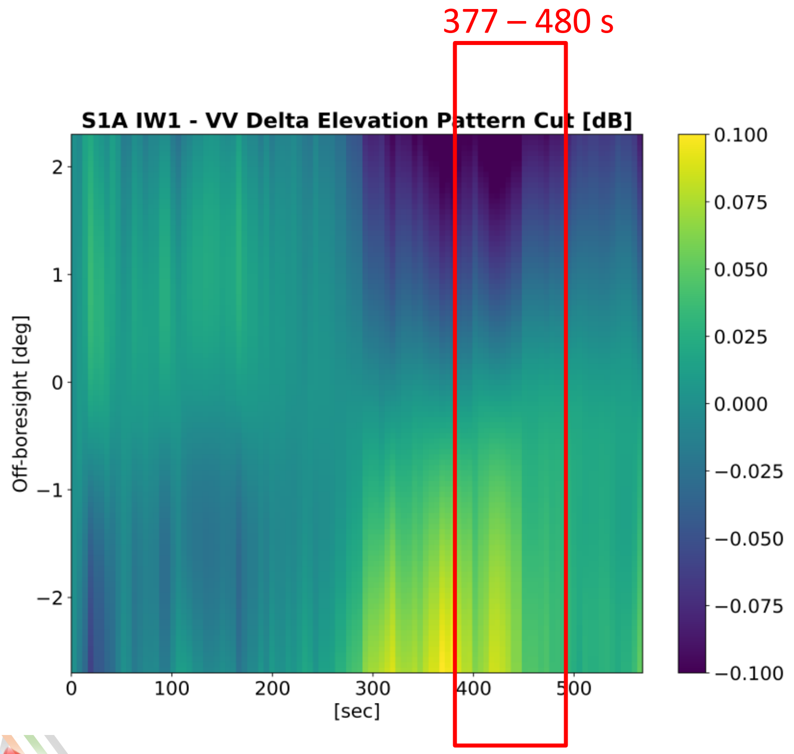
Calibration of L2 OWI product

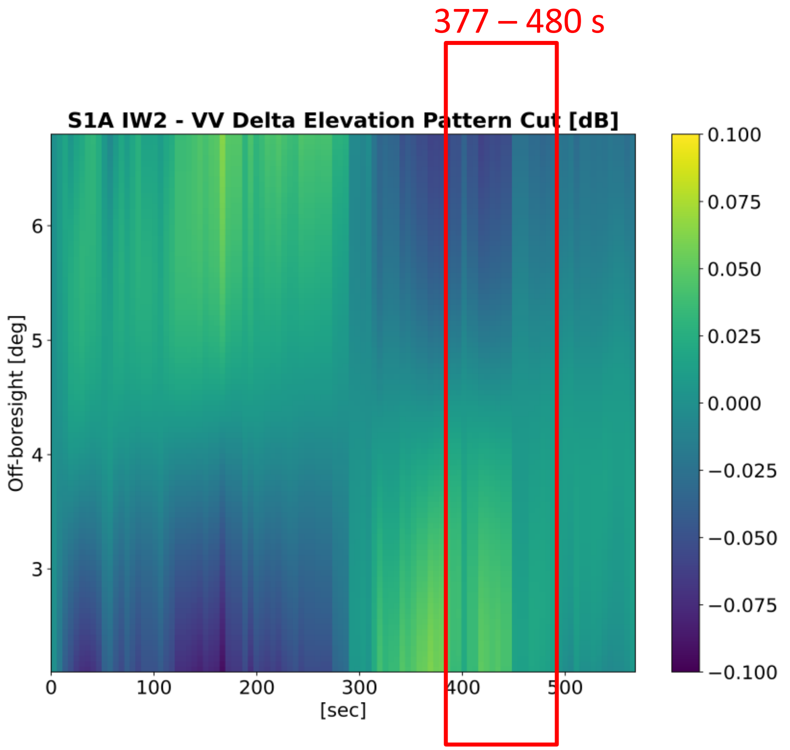
- S1 L2 Ocean Wind Fields (OWI) products provide wind information derived from S1 GRD products.
- The OWI product from S1A data take 052376 was investigated since discontinuities in the wind field were observed at sub-swath boundaries
- The variation of the Elevation Antenna Patterns during the data take were analysed since the OWI products are derived from the data radiometry

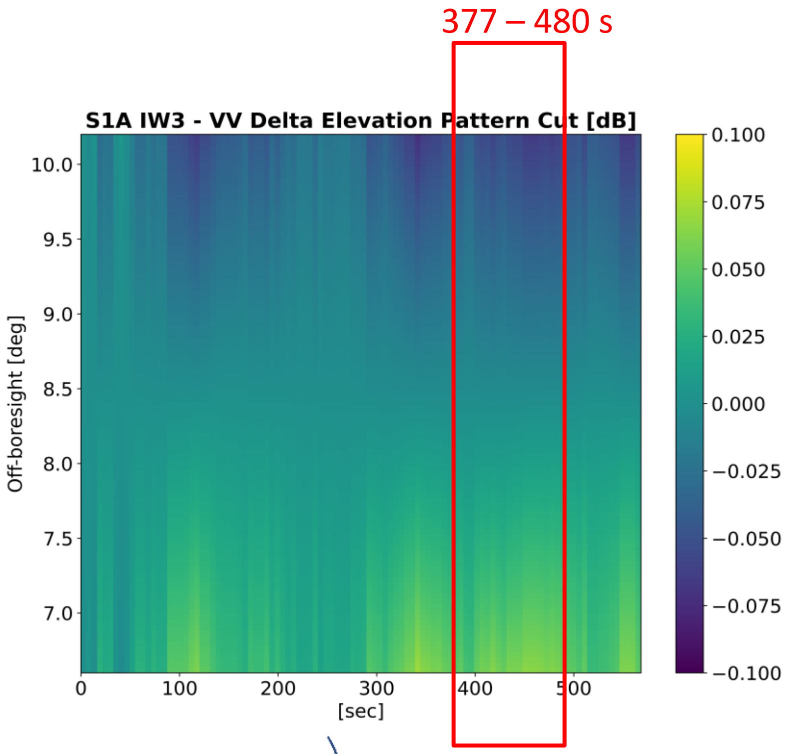


Elevation pointing variation (from temp comp)

- Plot of expected antenna pattern variations induced by on-board temperature compensation during the data take. The elevation pattern variations in time are computed as delta w.r.t. the first temp. comp. activation time.
- The red box indicates the relevant portion of the OWI product inside the data take.

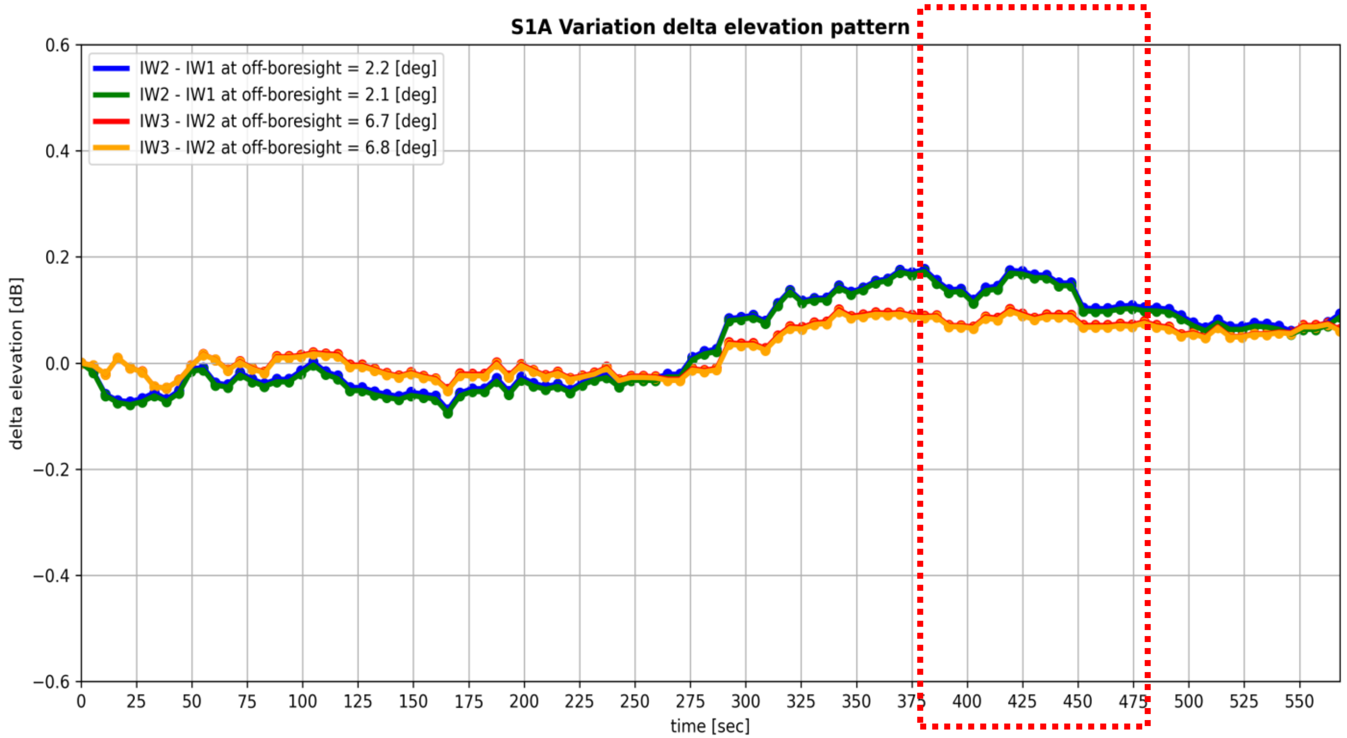


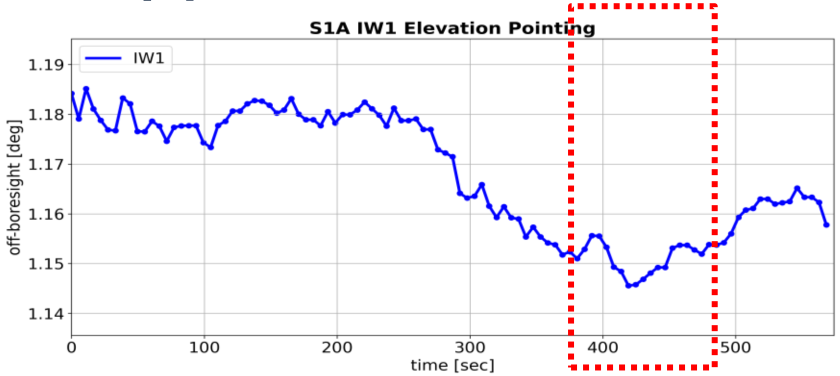


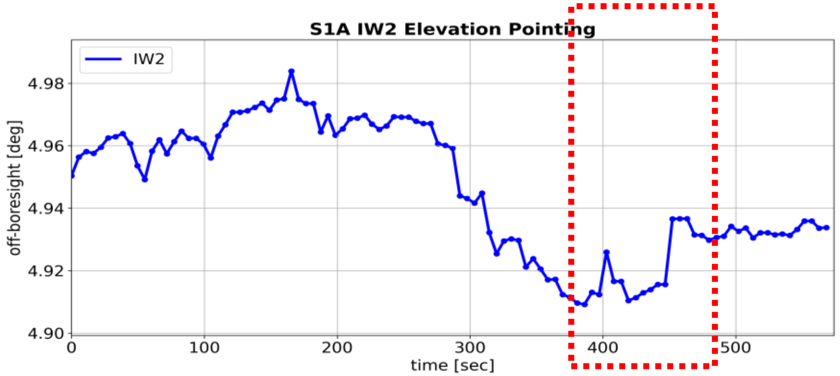


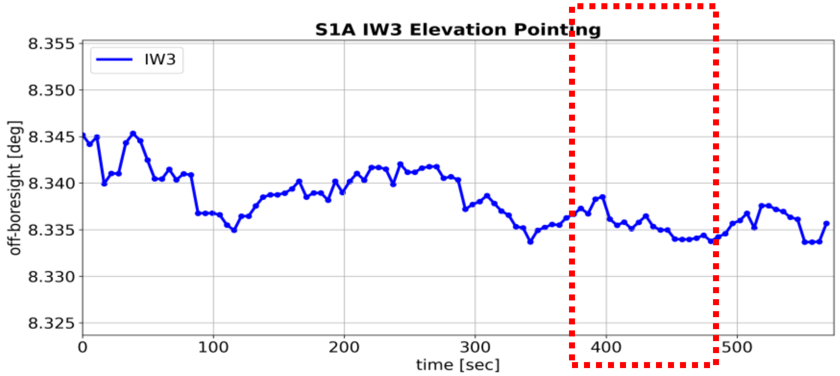
Elevation pointing variation (from temp comp)

- The tool predicts potential jumps up to 0.2 dB in the overlap area between the sub-swaths due to the evolution of the EAPs
- The jumps seems to be mainly related to a change in the elevation pointing direction (position of the pattern peak)
- Further investigations are on-going









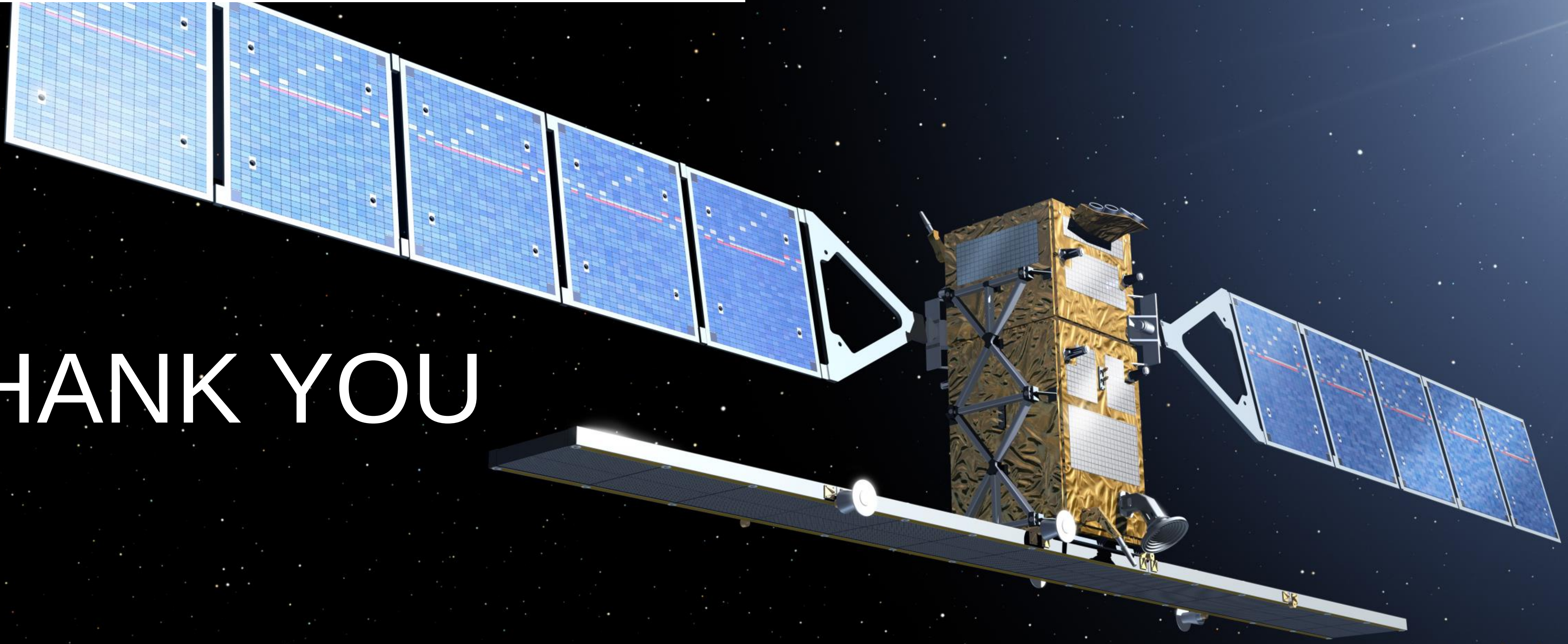
S1C temperature compensation

- The S1C temperature compensation strategy has been slightly updated: IW TopSAR mode temperature compensation is activated every burst cycle (2.7 s) instead of every 2 burst cycles (5.4 s)
- This is expected to result in smaller (but potentially more frequent) DC jumps
- A dedicated activity will be performed during the S1C Commissioning to assess the new temperature compensation strategy
- Dedicated TopSAR IW data takes over Africa (with RFC acquisitions before and after) will be exploited for the assessment
- Different temperature compensation strategies will be tested: no temp comp, standard temp comp and temp at TA and TRM level only

Conclusions

- S-1 implements an on-board temperature compensation strategy aimed at ensuring the long-term stability and the data quality
- The implemented temp comp strategy can be emulated on ground exploiting the antenna elements temperature stored in HKTM data
- The developed emulator allows to predict the evolution of the gain and phase of the TRMs of the SAR antenna during S-1 acquisitions
- The antenna pattern variations due to the gain and phase settings update can be predicted with the Antenna Model and used to improve the calibration of RVL products (removal of DC jumps)
- Temperature compensation next steps:
  - Investigation (and possible calibration) of radiometric jumps at sub-swath boundaries
  - Assessment of S1C temperature compensation strategy

THANK YOU



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