Hybrid DORIS+GPS measurements processing using the REGINA and DORIS networks and Sentinel-3A

Ground beacon and onboard clock corrections

H. Ait-Lakbir, A. Couhert, F. Mercier

Scope of the study

- Current clock corrections in POD DORIS processing
  - DORIS time-tagging: estimated 3-degree polynomials + ground beacon clock biases (referred to TLSB)
  - Orbit determination: frequency offset (df/f), estimated by passes, for all stations

- The common USO used by DORIS and GPS receivers on Sentinel-3x has already been proven to be useful to analyse and mitigate the SAA effects.
  - Idea : use of GPS-based clock corrections on both spacecraft and ground sides ?
    - Onboard side : GPS-based observation of the USO
    - Ground side : GPS-based observation for the DORIS/REGINA stations linked to the same USO (KRWB/KOUG, HBMB/HARB) and provided as products for IGS (.clk files)
- **Objectives**
  - **Assess the impact of the estimation of df/f on station/dynamic parameters**
  - **Assess the precision on DORIS phase measurements, assuming well-known clock corrections**
  - **Substitute the estimation of df/f by passes**

Using GPS clock corrections

Parameterization

$$\varphi = c * \left(T_{rec} + dh_{rec} - (T_{emi} + dh_{em})\right) - C_{pco,rec} + C_{pco,em}$$
$$+ C_{tropo,dry} + \tilde{C}_{tropo,wet} + \frac{\tilde{df}}{f} * \left(T_{rec} - T_{rec,0}\right) + \mathrm{N}$$

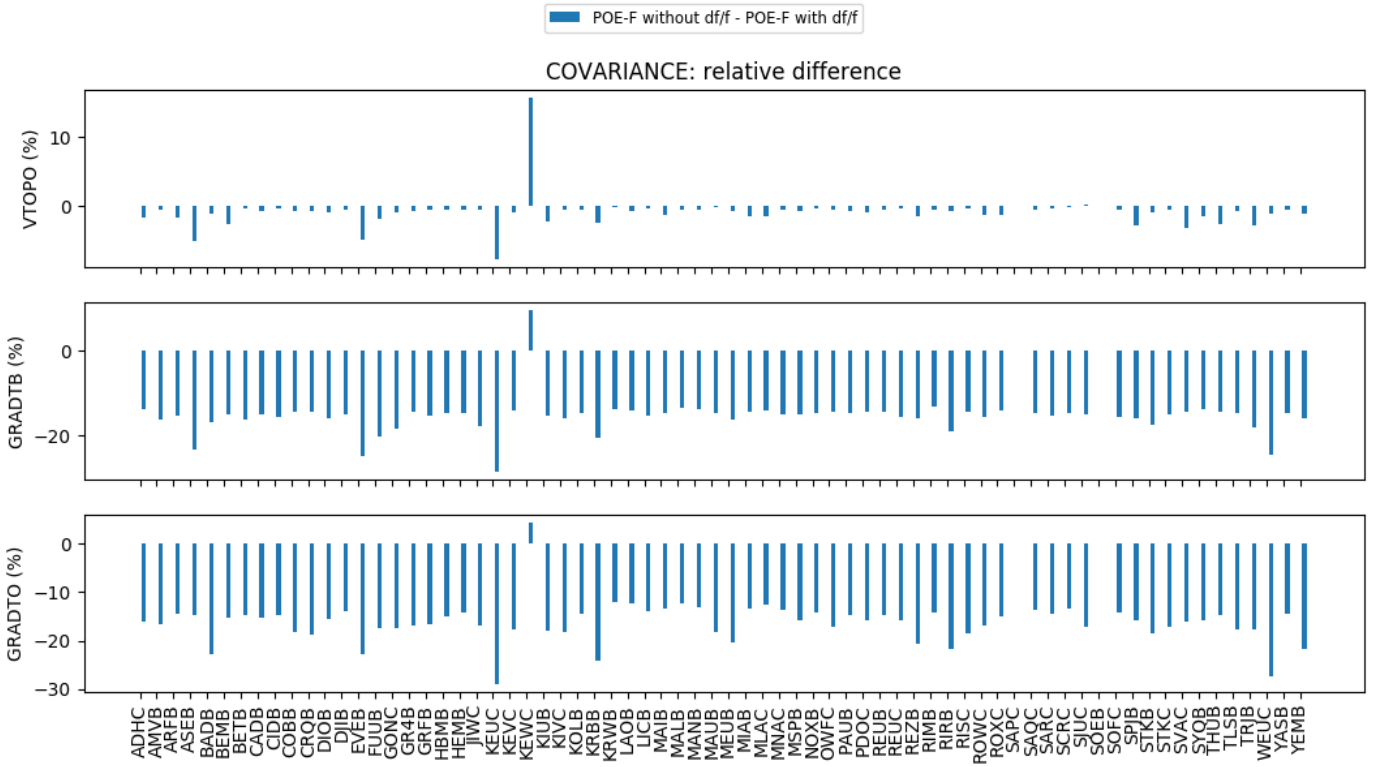
	DORIS-derived correction	GPS-derived correction
dh_{rec}	3-degree polynomial, adjusted with pseudo-range	clock correction per measurement epoch, estimated in GPS-only OD - without relativistic effect - corrected of the DORIS/GPS clock offset)
dh_{em}	linear correction, based on RINEX header + adjusted offset (w.r.t TLSB)	clock correction provided in the GNSS constellation solutions, every 30s
$\frac{df}{f}$	estimated per pass	none

Effects of the estimation of df/f
Stations parameters

- Limited on vertical positioning
- Slightly improved observability for tropospheric gradients (around 10 %)

Relative differences of formal covariances

Negative value means better observability without estimating df/f



Effects of the estimation of df/f
Empirical dynamic accelerations

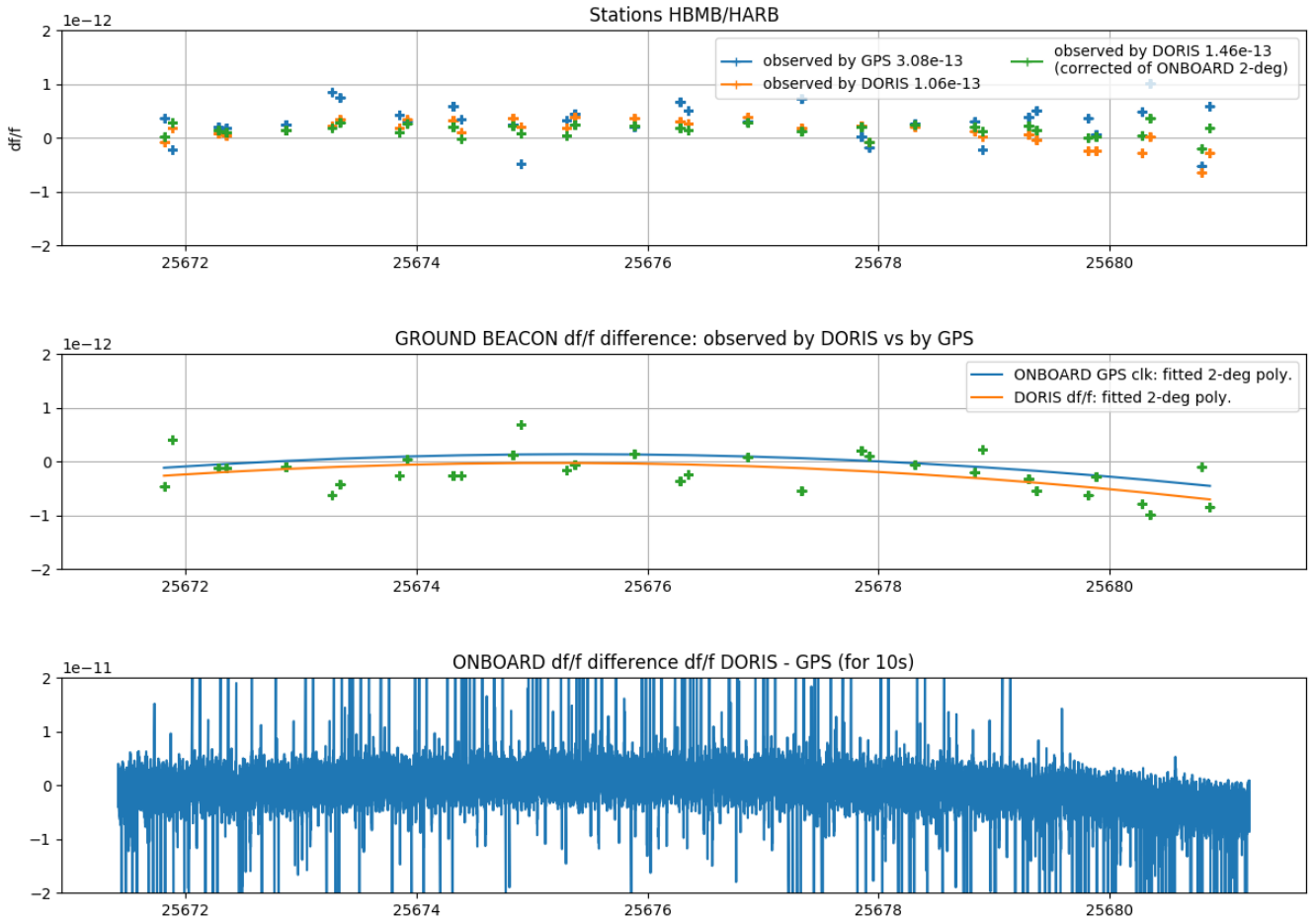
- The empirical parameters are better observed, in particular in the along-track direction (by nearly 50 %)

Formal covariance and relative differences to reference parametrization

10^{-9} m/s²		TCO		TSI		NCO		NSI		TK2	
Reference (POE-F)	Sentinel-3A	0.19		0.19		2.41		2.33		0.29	
	Cryosat-2	0.21		0.20		2.71		2.33		0.38	
Without estimating df/f (test)	Sentinel-3A	0.11	- 42 %	0.10	- 47 %	2.08	- 14 %	2.05	- 12 %	0.14	- 52 %
	Cryosat-2	0.11	- 48 %	0.11	- 45 %	2.28	- 16 %	2.09	- 10 %	0.18	- 53 %

df/f comparison : DORIS vs GPS

- DORIS and GPS observation of the USO are close within 1e-12.
- DORIS df/f estimation retrieves other sources of errors
  - ➢ Mismodeling of onboard USO



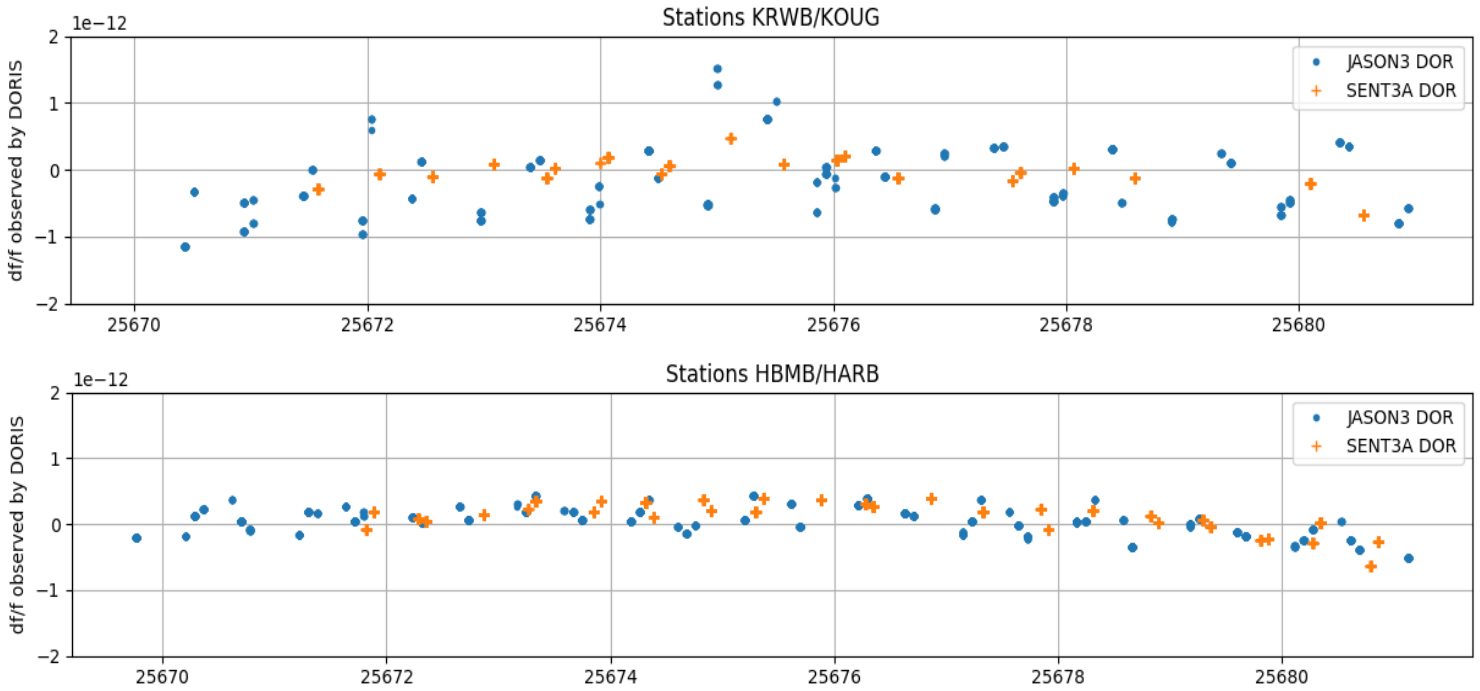
On the plots:

- On the upper plot : the frequency offset over a DORIS pass, observed by GPS or by DORIS
- On the middle plot : the difference between GPS- and DORIS-derived df/f (in green), and the degree-2 polynomials fitted on DORIS-derived df/f (orange) and on GPS-DORIS onboard corrections (blue)
- On the lower plot : the equivalent df/f (for 10s) computed from the difference between the onboard DORIS and GPS clock corrections

df/f comparison : DORIS vs GPS

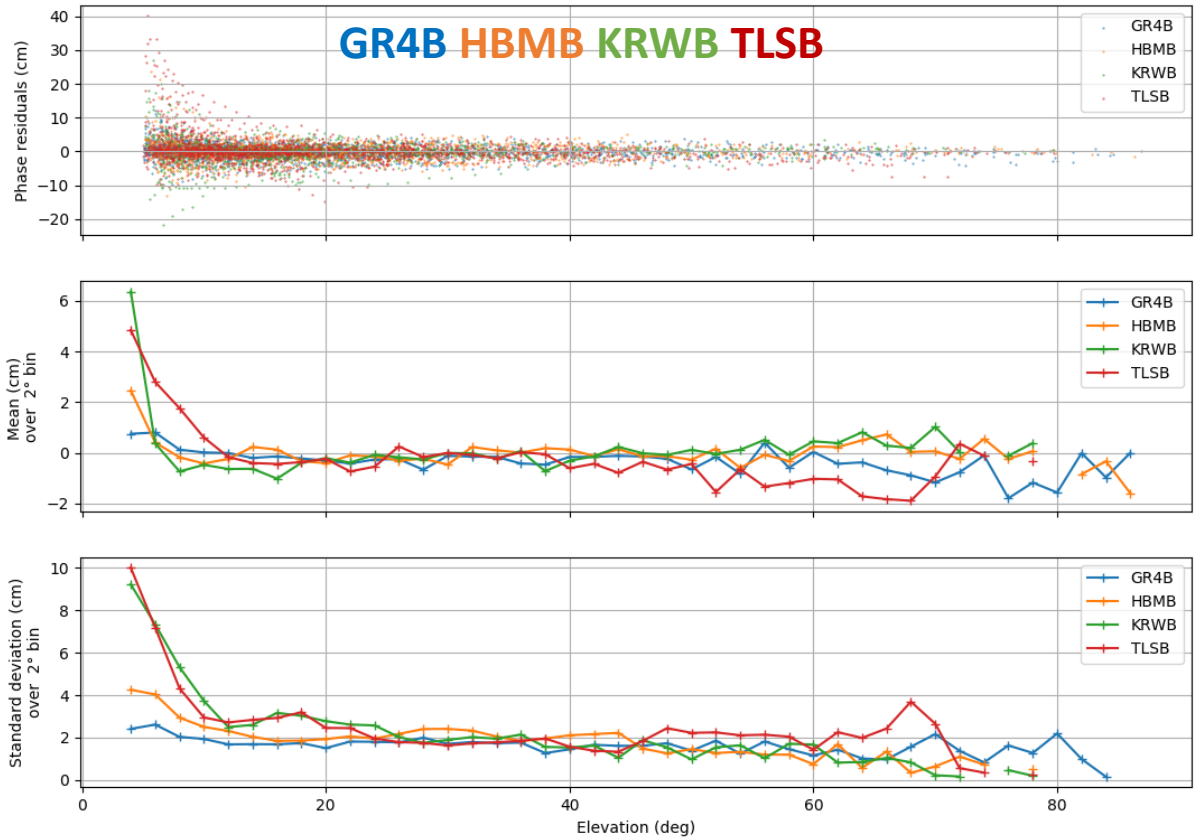
- DORIS and GPS observation of the USO are close by up to 1e-12.
- DORIS df/f estimation retrieves other sources of errors
  - ➢ Mismodeling of onboard USO
  - ➢ SAA effects

For example, the estimation of the frequency offset of Kourou is noisier for Jason-3 than for Sentinel-3A, while the DORIS residuals are similar for the two missions.



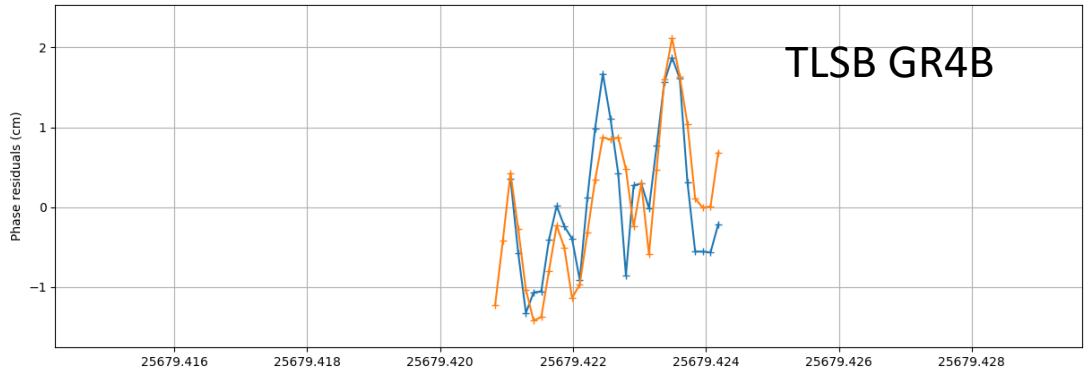
Effects on DORIS phase residuals

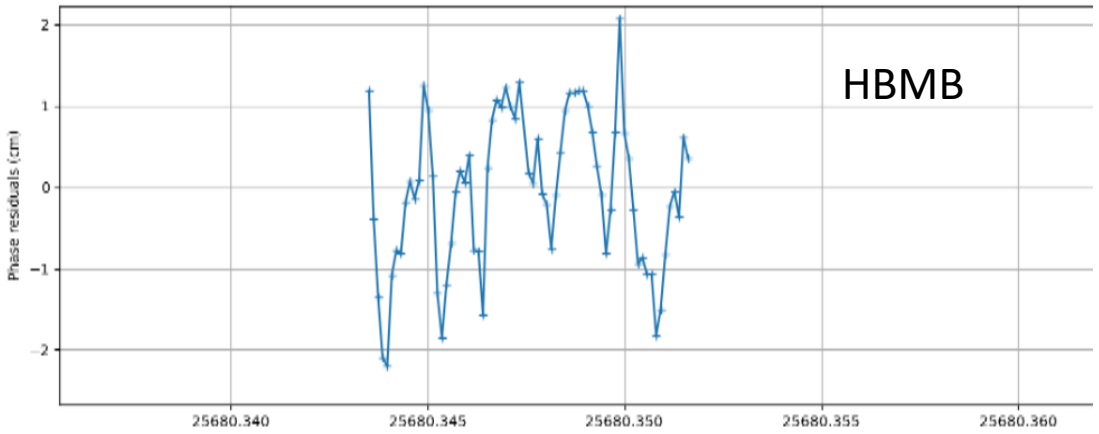
HBMB/KRWB vs TLSB/GR4B (station with “good clocks”)



Residuals and mean/standard deviation as a function of the elevation

Phase residuals



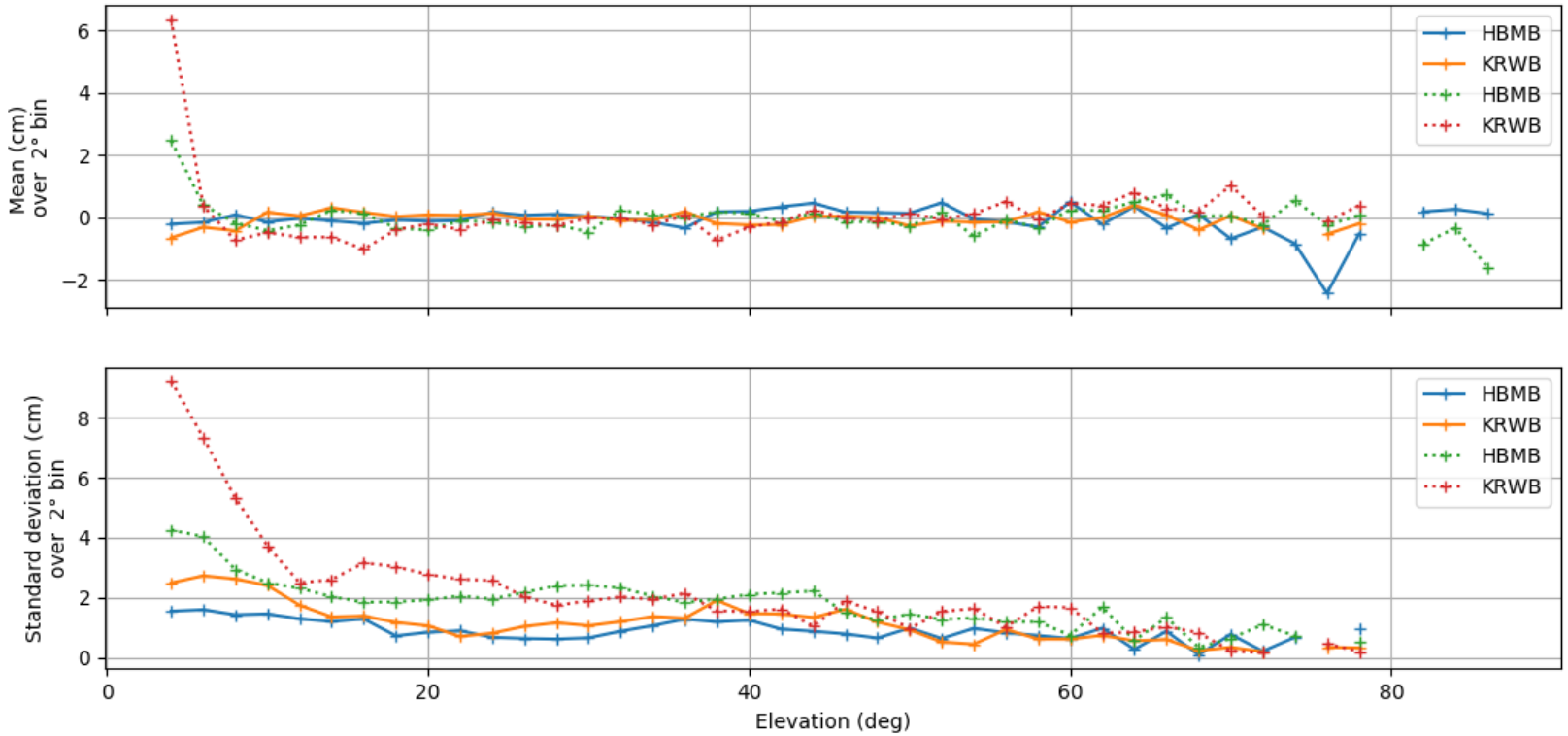


Effects on DORIS phase residuals

GPS vs DORIS-derived clock corrections

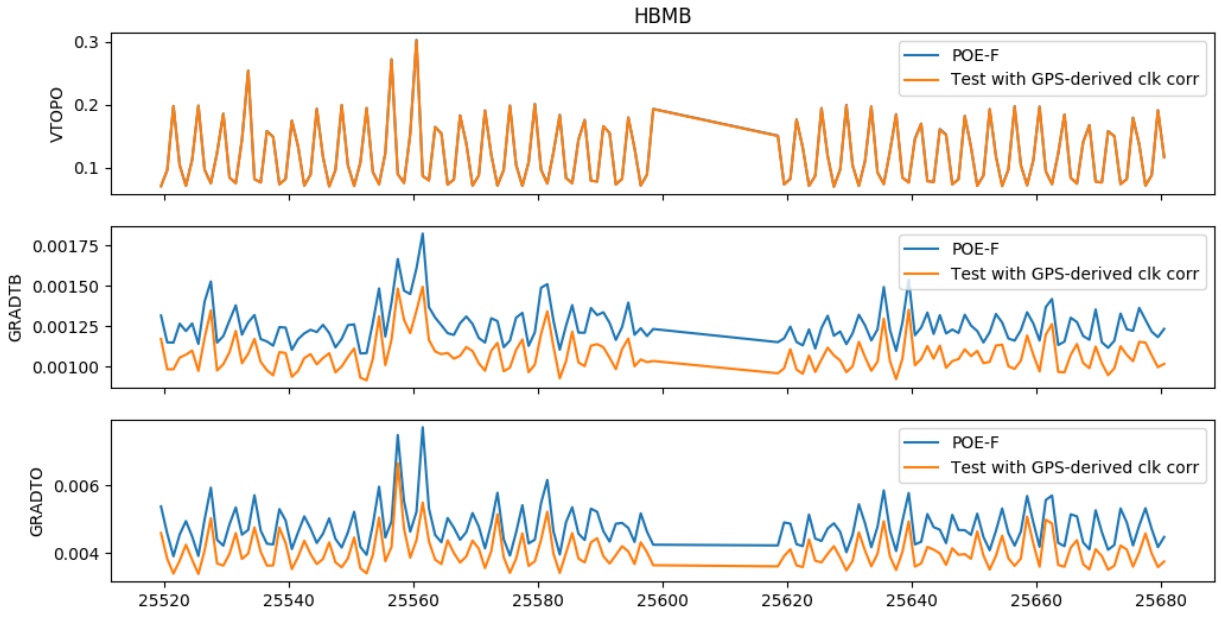
Solid : with DORIS-derived corrections

Dotted : with GPS-derived corrections

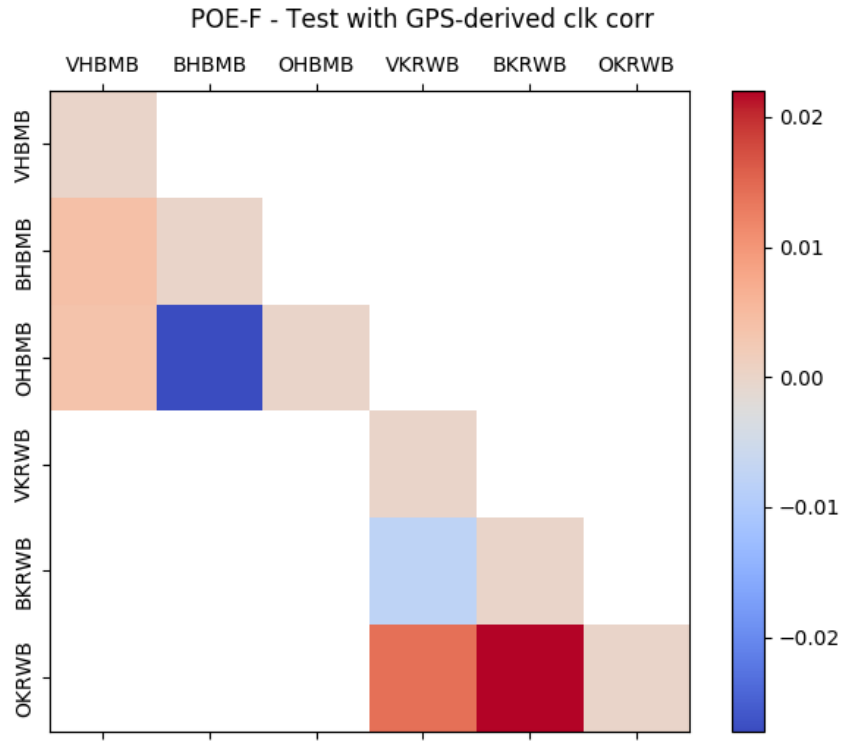


Using GPS clock corrections
Estimation of station parameters

Covariances of parameters
Top : vertical position,
Middle : tropospheric gradient in North,
Bottom : tropospheric gradient in East



Correlation difference
(warm color: the parameters are less correlated with the test)

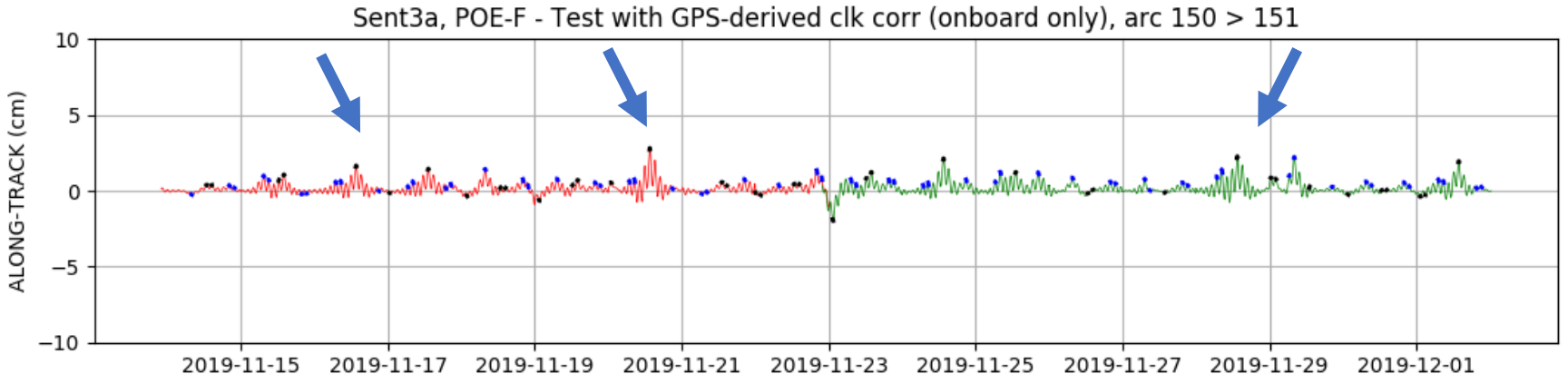


Using GPS clock corrections
Orbit differences

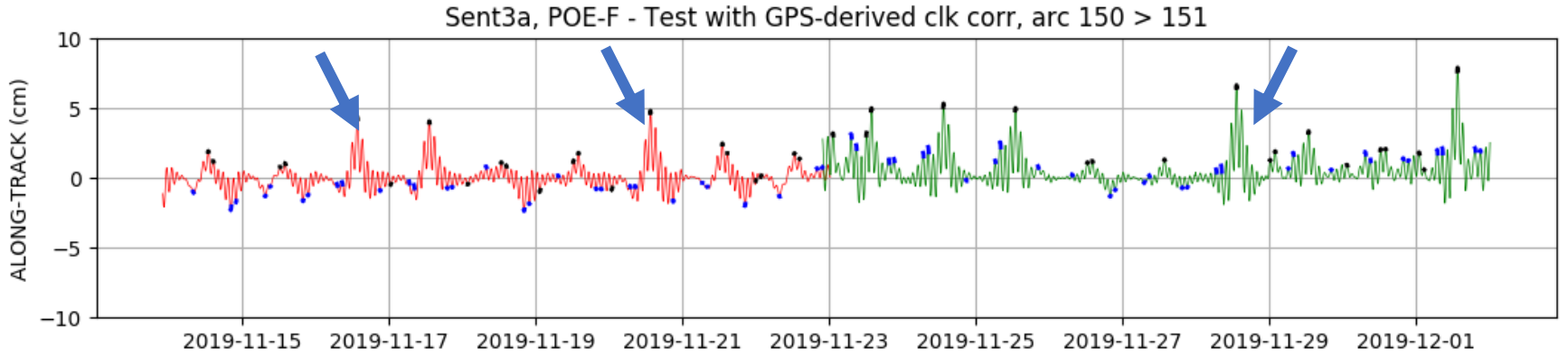
- The change of the ground clock correction seems to have a more significant effect (up to few centimeters)

Orbit comparison w.r.t orbit using DORIS-derived correction

<u>Onboard</u>
GPS-based correction



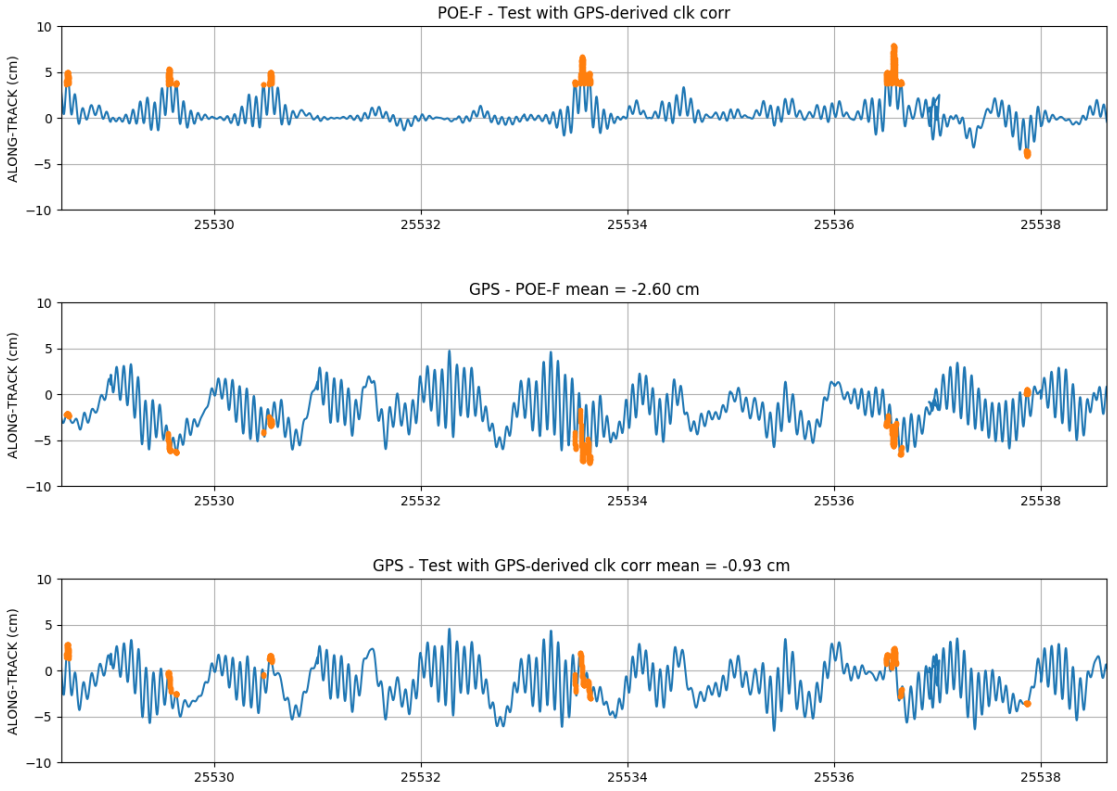
<u>Ground + onboard</u>
GPS-based correction



Using GPS clock corrections

Orbit differences – ONBOARD + GROUND side

- Despite the limited number of stations tested within the DORIS network, the along-track performance of the DORIS-only orbit is locally improved and gets closer to the GPS orbit.
- In average over the passes of KRWB and HBMB, it is reduced from -2.60 cm to -0.93 cm (mainly due to the reduction of noise).



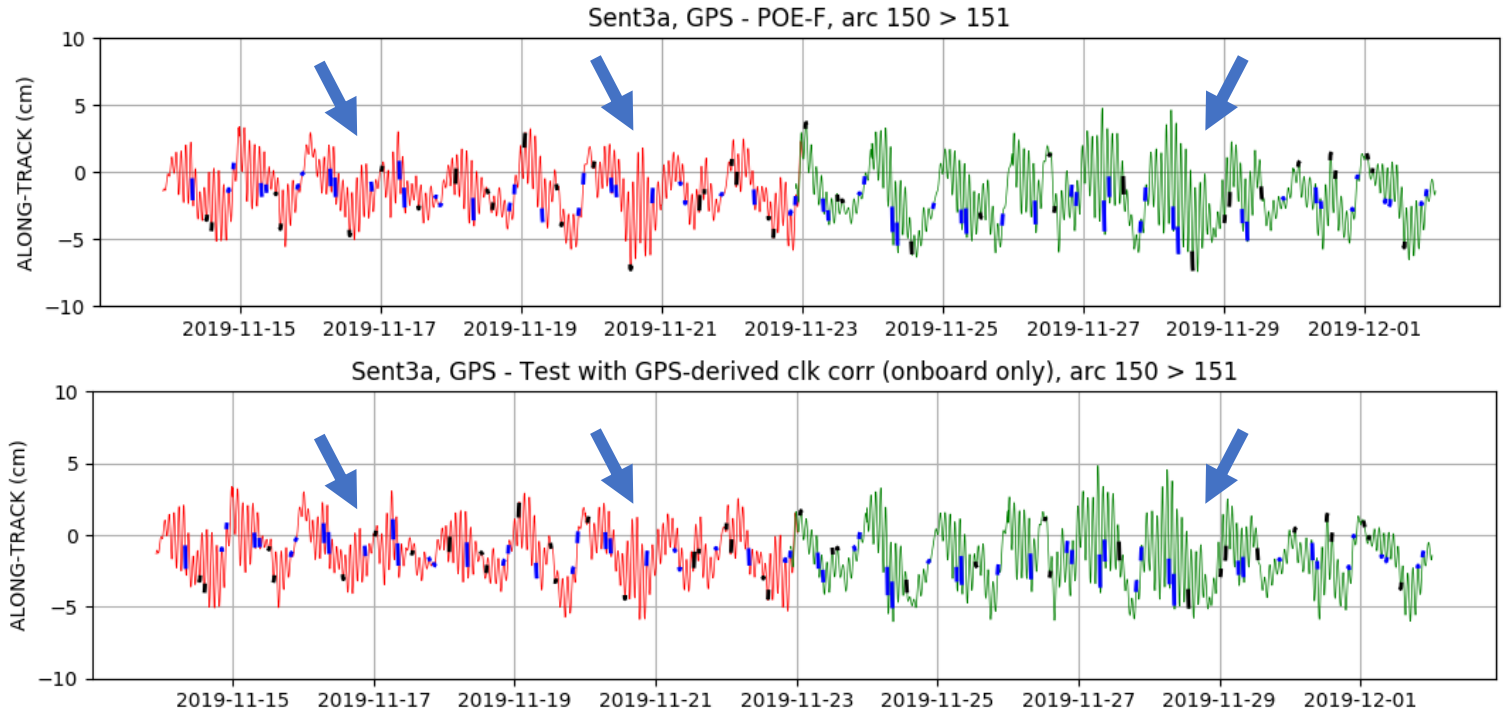
Conclusion

- **Objectives**
  - **Assess the impact of the estimation of df/f on station/dynamic parameters**
    - The impact of the estimation of these parameters is important on the observation of the along-track dynamic errors.
    - It affects the observation of the station parameters in a limited manner. However, the influence on the horizontal positioning has not been considered.
  - **Assess the precision on DORIS phase measurements, assuming well-known clock corrections**
    - The GPS-derived clock corrections lead to the same performances as the current DORIS-derived corrections, in terms of measurements modeling, and even better for high elevations.
  - **Substitute the estimation of df/f by passes**
    - The error in the clock correction explains partly the along-track signatures of the DORIS-only orbit.
    - The replacement of the estimated df/f parameters enables to improve locally the orbit performance in the along-track direction

➢ An even better improvement (up to 50 %) of the observability of along-track errors is expected with more DORIS/REGINA stations with the opportunity to observe the USO by DORIS and GPS.

Back up

Using GPS clock corrections
Orbit differences – ONBOARD side



Using GPS clock corrections

Orbit differences – ONBOARD + GROUND side

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