Current status of DORIS POD at DGFI-TUM

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Recent software developments

Status quo:

- DORIS orbits possible for TOPEX/Poseidon, Jason-1/-2
- DORIS observations only in the IDS2.2 format used
- Up to 0.9 mm/s arc RMS of observation residuals for TOPEX/Poseidon and 0.6 mm/s for Jasons

Major changes in DOGS-OC in recent time:

- Use of DORIS RINEX data
- Elevation-dependent weighting of DORIS observations
- Extended bias estimation during POD
- Implementation of Sentinel-6a in DOGS-OC

Use of RINEX data for DORIS POD in DOGS-OC

TOPEX/Poseidon, Jason-1/-2: IDS2.2
Jason-3, Sentinel-6a: RINEX (new) ⟷ Conversion from GINS format to DORIS RINEX format
Using the conversion package “lecture_rinex_doris.f90”

GINS (RINEX): computation of corrected counts

$$N_{\mathrm{obs}} = N - (f_{\mathrm{sta}} - \Delta f_{\mathrm{sta}} - f_{\mathrm{sat}}) \cdot dt$$

N_{obs}	Observed Doppler count
f_{sta}	Nominal beacon frequency (2 GHz)
Δf_{sta}	Satellite frequency offset
f_{sat}	Nominal satellite frequency
dt	Time span of the Doppler count

blue: as provided in the GINS observation file

IDS2.2: computation of counts

$$N_{\mathrm{obs}} = V_{\mathrm{r}} \cdot \frac{f_{\mathrm{sta}}}{c} \cdot dt$$

N_{obs}	Observed Doppler count
V_{r}	Range rate ($V_{\mathrm{r}} = V_{\mathrm{r}} + C_{\mathrm{tropo}} + C_{\mathrm{iono}}$)
dt	Time span of the Doppler count (µs → s)
f_{sta}	Nominal beacon frequency (2 GHz)
c	Speed of light

blue: as provided in the IDS2.2 observation file

$$N_{\mathrm{theo}} = df_{\mathrm{sta}} \cdot dt - \frac{f_{\mathrm{sta}}}{c} \cdot \Delta R - C_{\mathrm{rel}} - C_{\mathrm{pha}}$$

with $\Delta R = R_2 - R_1 = \left(D_2 - C_{\mathrm{mes}} + C_{\mathrm{trop}}\right) - \left(D_1 - C_{\mathrm{mes}} + C_{\mathrm{trop}}\right)$

N_{theo}	Theoretical Doppler count
df_{sta}	Bias of beacon freq. (updated per iteration by freq. offset/drift)
C_{rel}	Relativistic correction
C_{pha}	Phase centre correction of emitting station

D	Distance beacon-satellite (corrected by C_{mas})
R	Corrected range (beacon-satellite)
C_{mes}	IDS phase law
C_{trop}	Tropospheric correction

Elevation-dependent observation weighting

- Standard deviation of DORIS observations in DOGS-OC:

$$\sigma_{\text{obs}} = 0.4\ \frac{\text{mm}}{\text{s}}$$

- Observation weight:

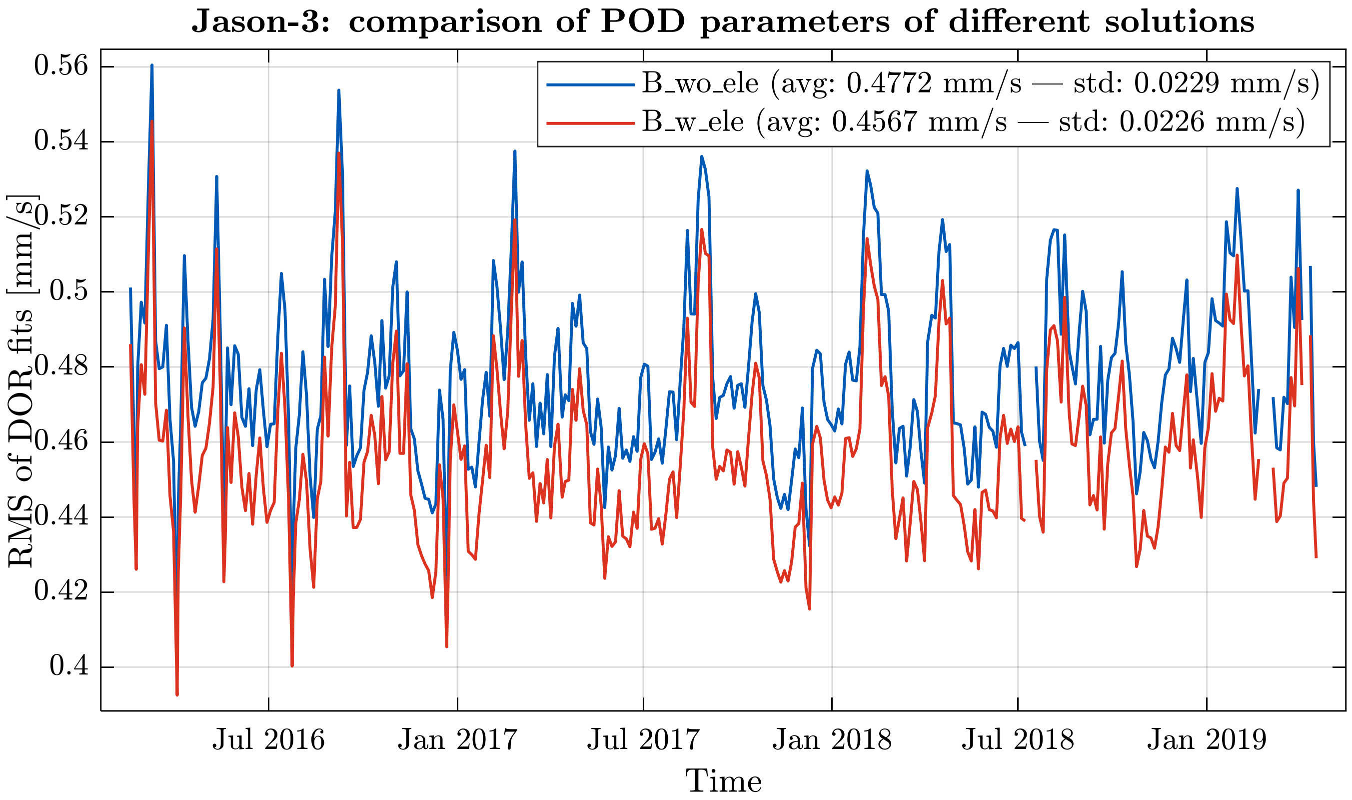
$$W = \frac{1}{\sigma_{\text{obs}}^2}$$

- Down-weighting law as suggested by CNES used for elevations ≤ 20 degrees:

$$W_{ele} = W \cdot \frac{(ele_{\text{deg}})^2}{400}$$

ele_{deg}: observation elevation in degrees

- Biases estimated in the right-hand case:
  - frequency offset (per pass)
  - frequency drift (per station)
  - troposphere scaling (per station)



blue: without elevation-dependent weighting
red: with elevation-dependent weighting

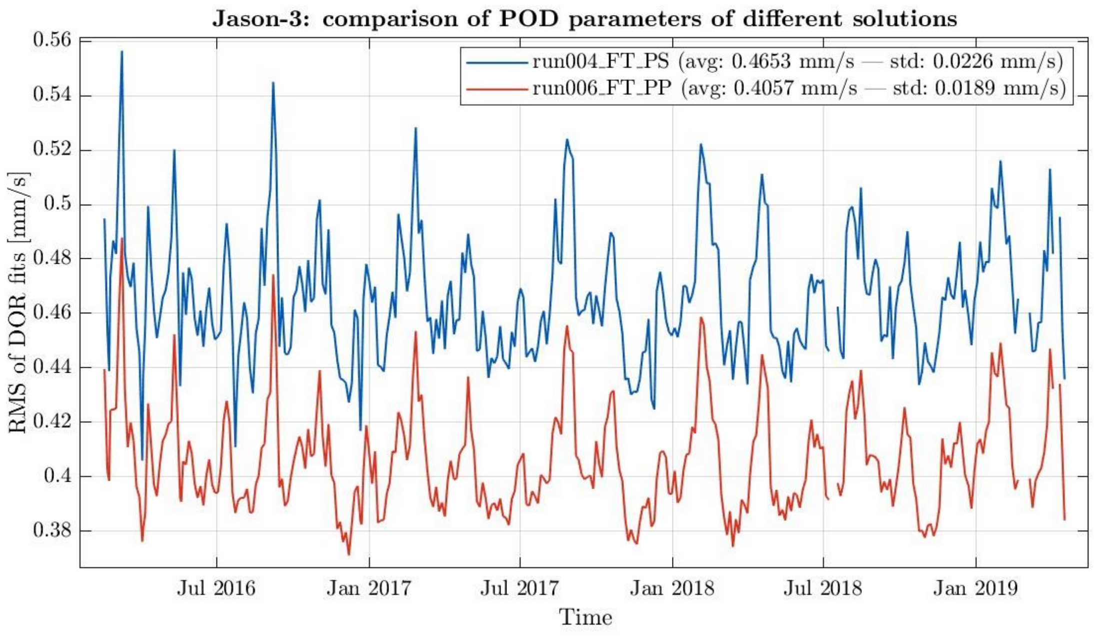
Estimation of biases

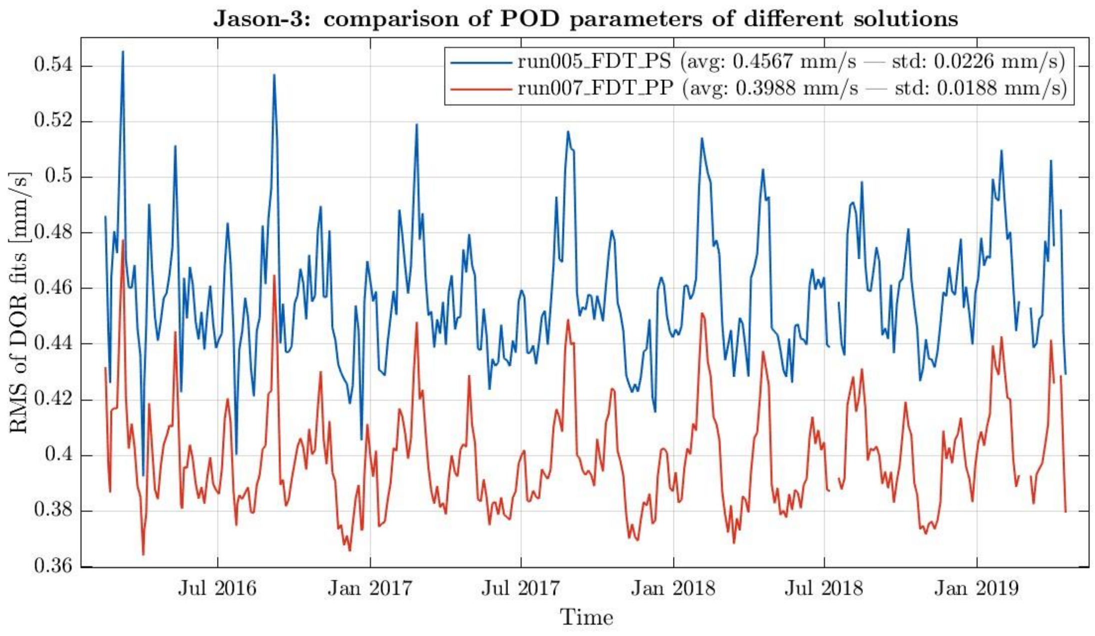
- New: estimation of 3 bias types per observation technique in an orbital arc

- Default DORIS POD setup:
  - Frequency bias: per pass
  - Frequency drift: per station
  - Tropospheric refraction: per station/pass (to be investigated)

- Current troposphere modelling (since DOGS-OC is originally an SLR POD software):
  - tropospheric delay by Collins (1999)
  - mapping functions (dry, wet) by Niell

Tropospheric refraction





In both cases: frequency bias (per pass) +

blue: tropospheric refraction (**per station**)
red: tropospheric refraction (**per pass**)

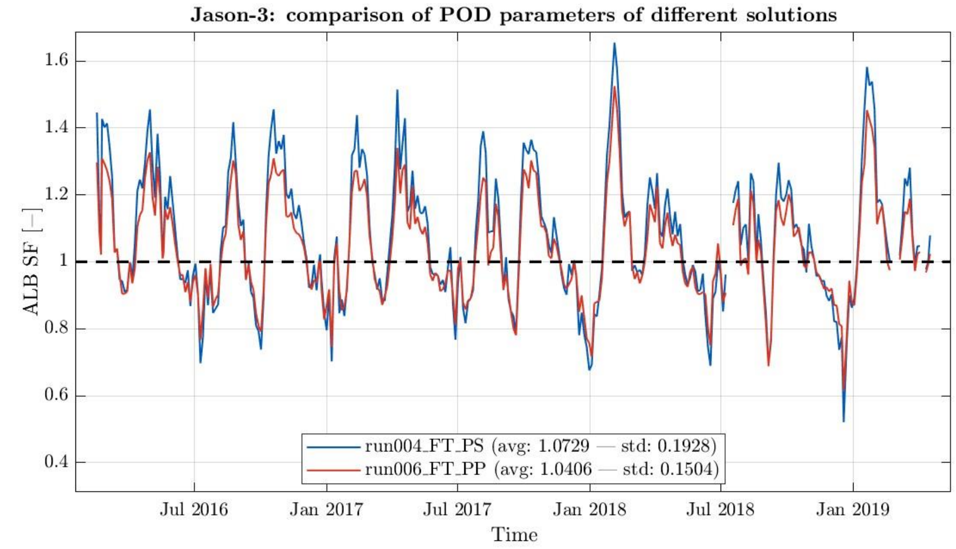
0.4653 → 0.4057 mm/s

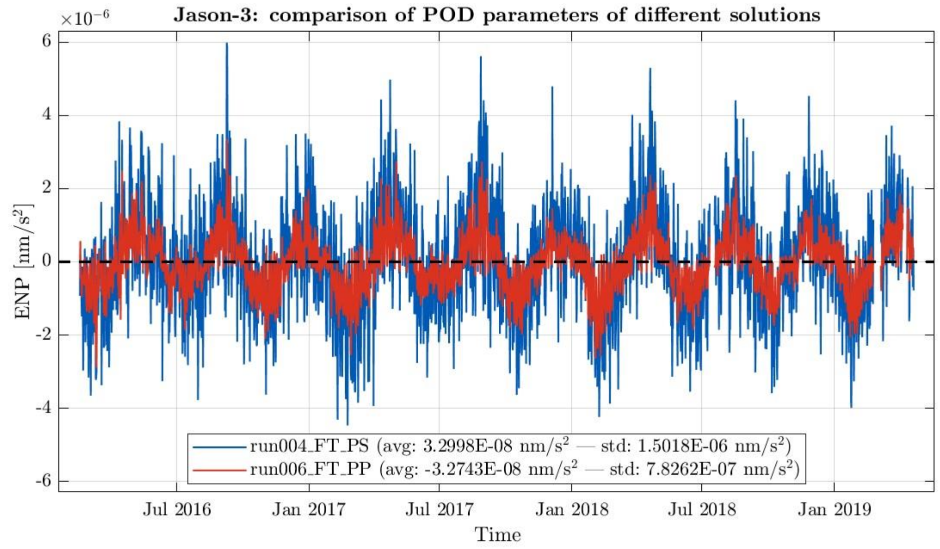
In both cases: frequency bias (per pass) +
frequency drift (per station) +
blue: tropospheric refraction (**per station**)
red: tropospheric refraction (**per pass**)

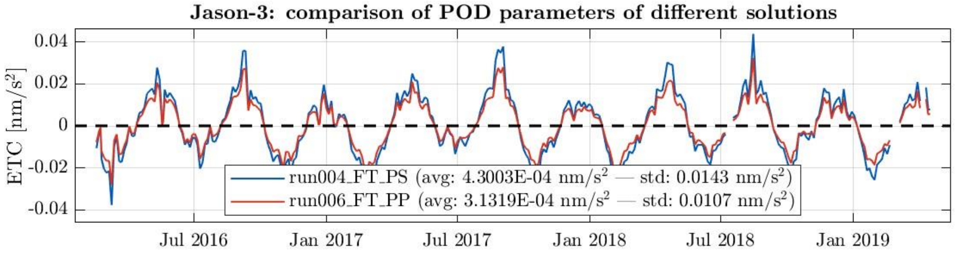
0.4567 → 0.3988 mm/s

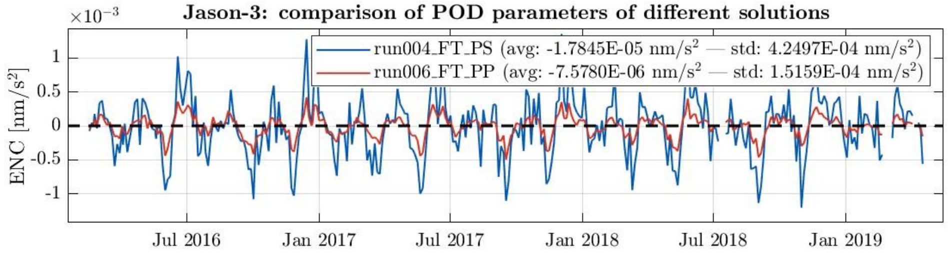
cf. previous example

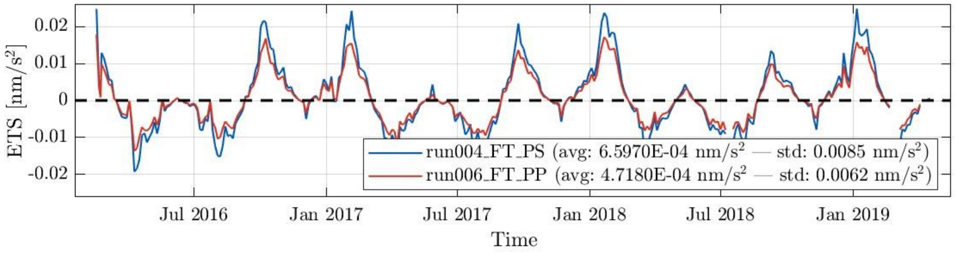
Tropospheric refraction

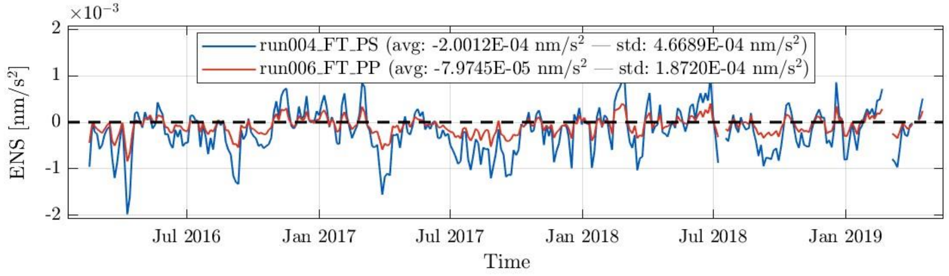












→ Reduced scattering of POD parameters when estimating tropospheric refraction scale factors (SF) per pass.

Estimation of biases

Test and analysis of 4 different bias setups:

Solution	Solution name	Frequency bias	Frequency drift	Tropospheric refraction	Test		
					A	B	C
Blue	run002	per pass			√		
Red	run003	per pass	per station		√	√	
Green	run006	per pass		per pass	√		√
Purple	run007	per pass	per station	per pass	√	√	√

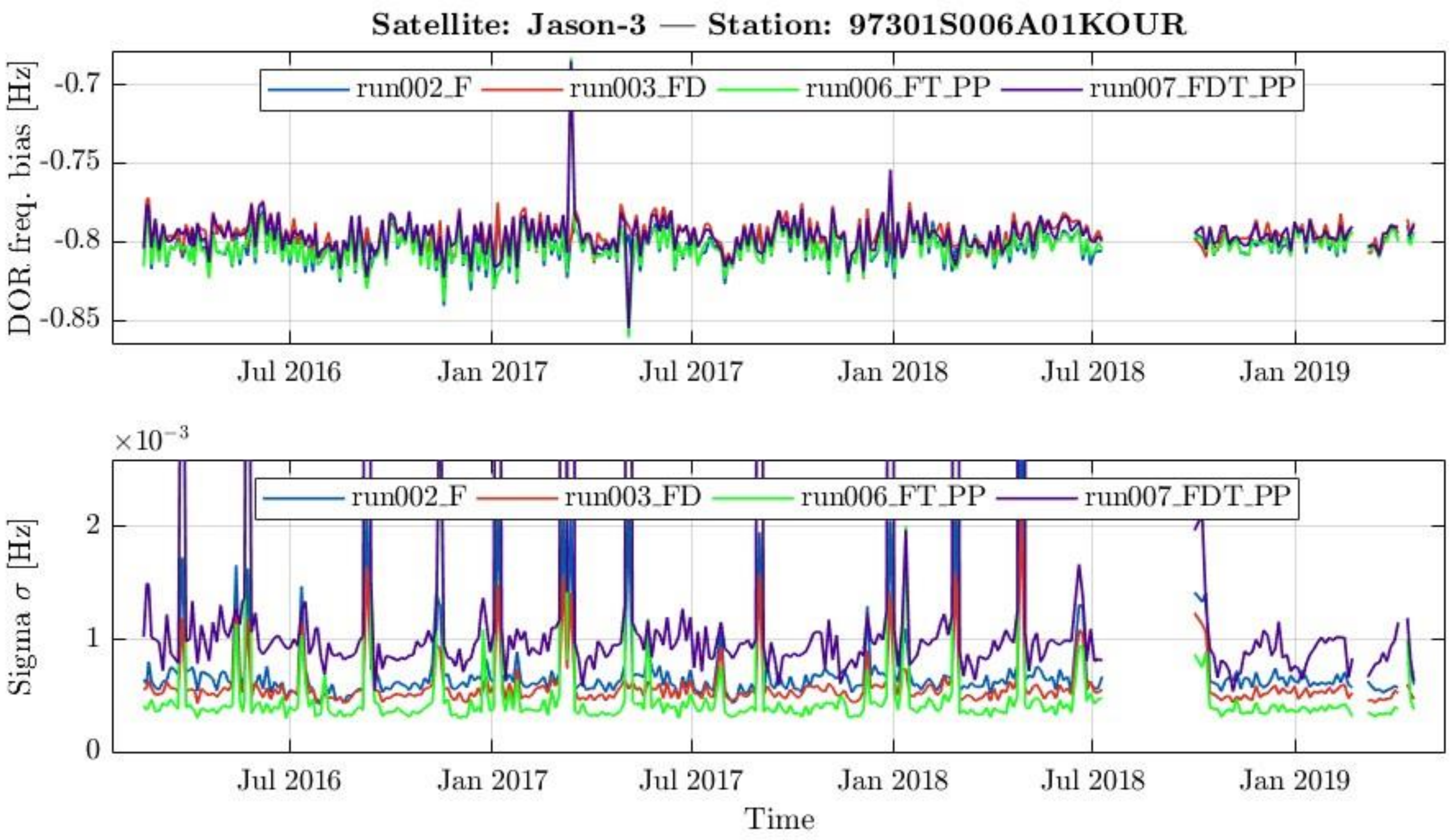
A: comparison of freq. bias estimates
B: comparison of freq. drift estimates
C: comparison of trop. ref. SF estimates

Tests show:

- Long-term stable frequency biases for master beacons
- Spurious signals (non-linear drifts, seasonal) in frequency bias time series for selected beacons
- Significant reduction of frequency drift scatter for selected beacons
- Estimated refraction coefficients reveal deficiencies in current tropospheric delay modelling in DOGS-OC (cf. outlook)

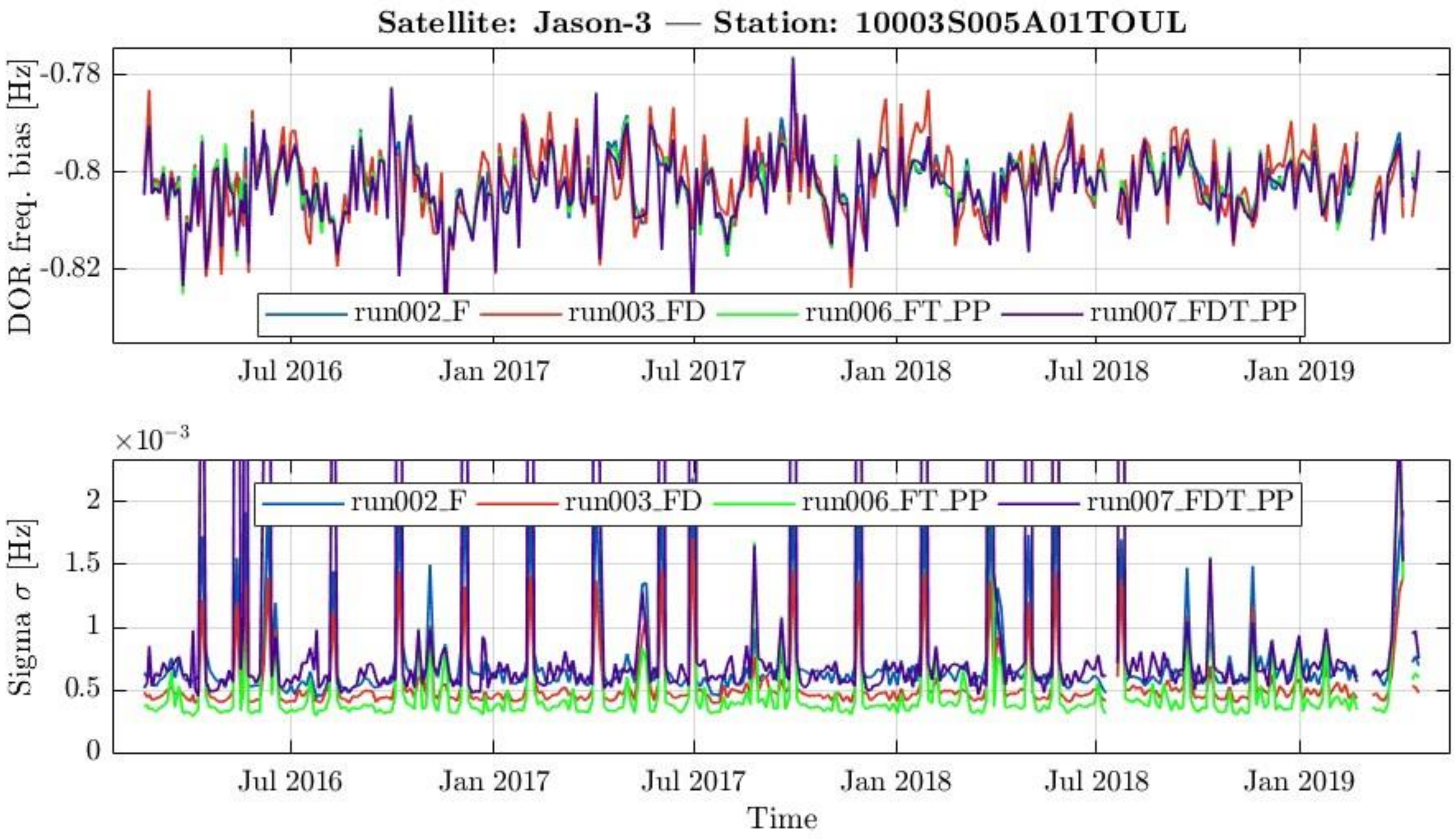
Frequency bias (KOUROU, FRENCH GUIANA)

A



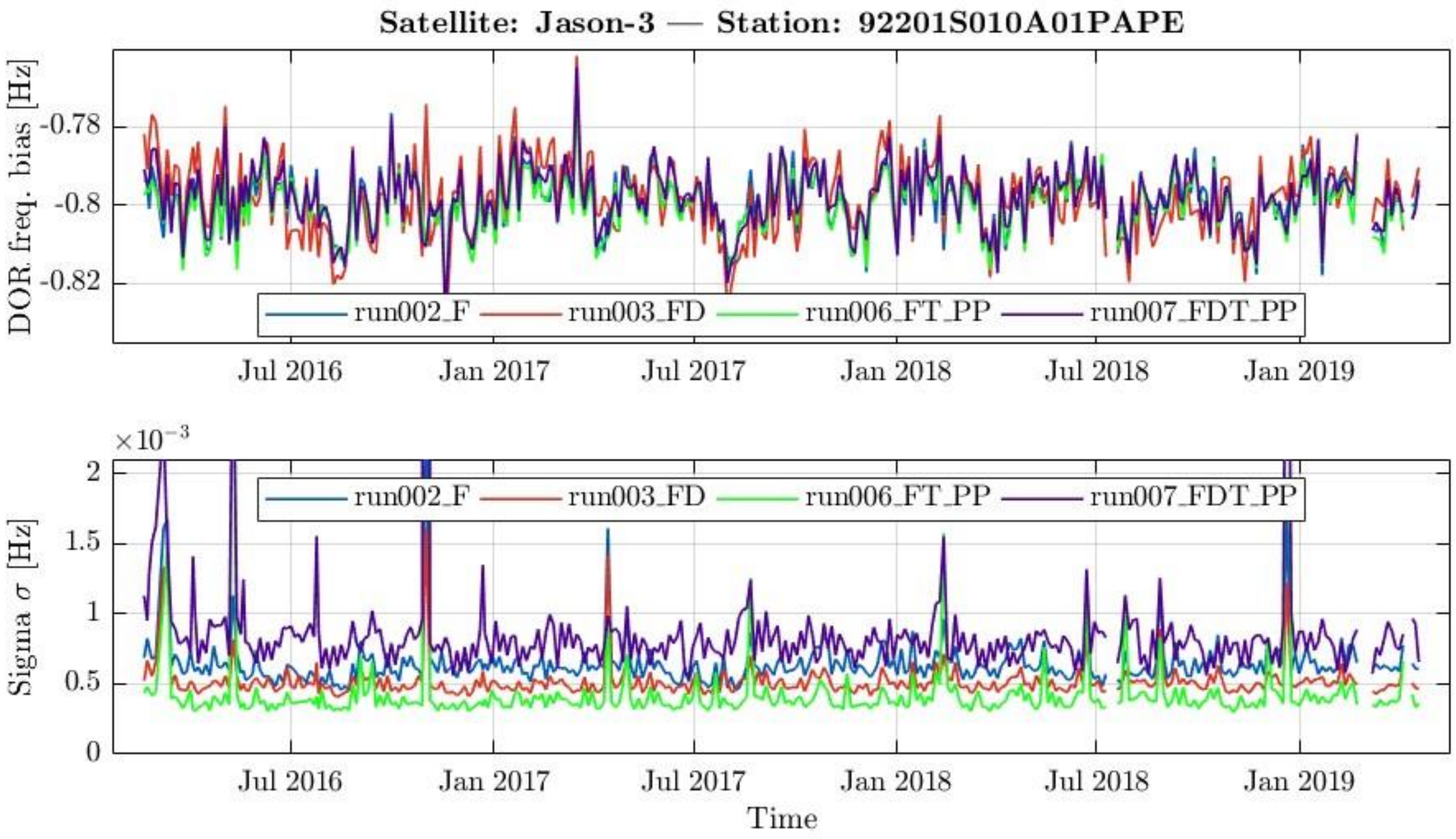
Frequency bias (TOULOUSE, FRANCE)

A



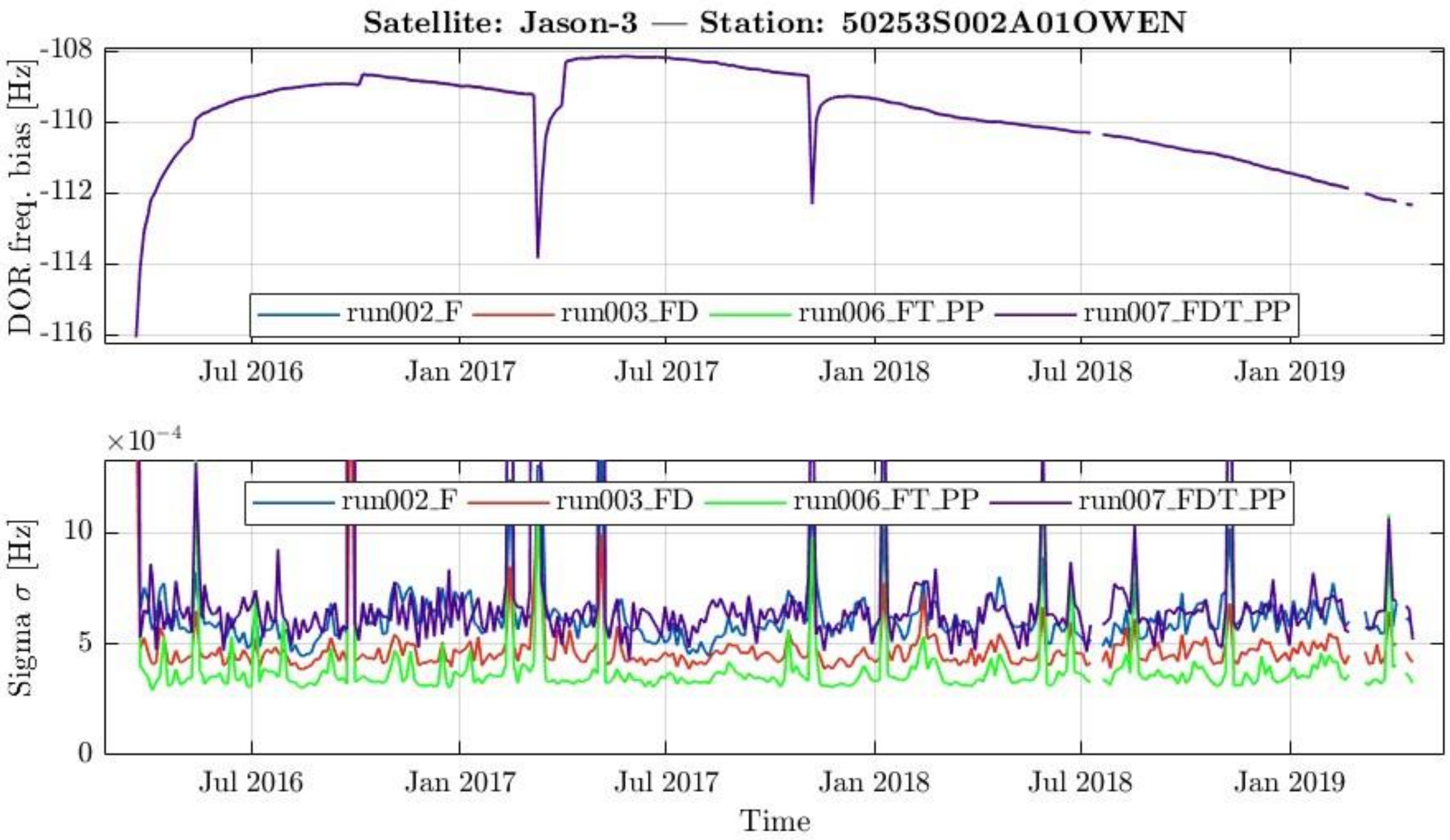
Frequency bias (PAPEETE, TAHITI)

A



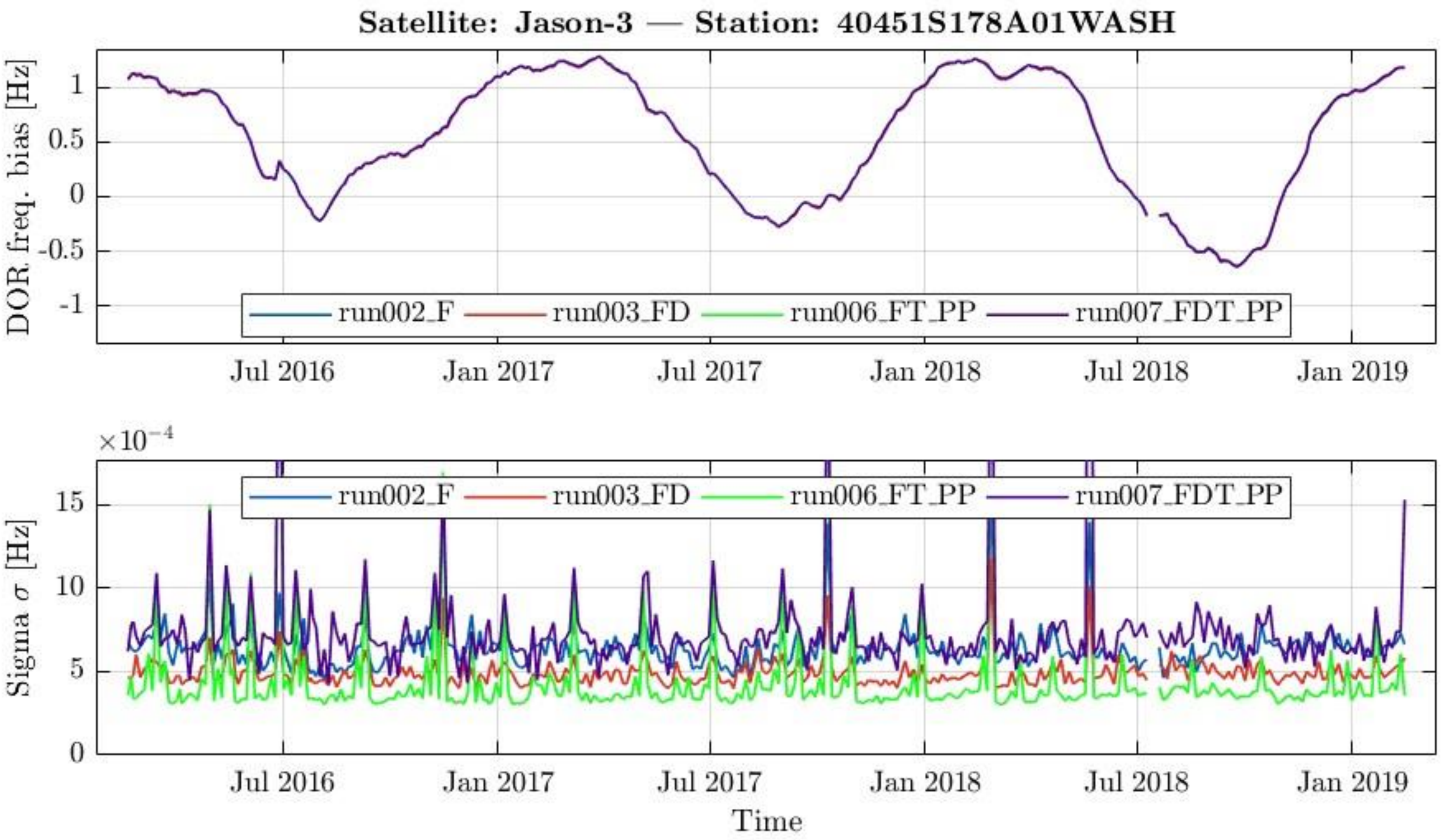
Frequency bias (OWENGA, NEW ZEALAND)

A



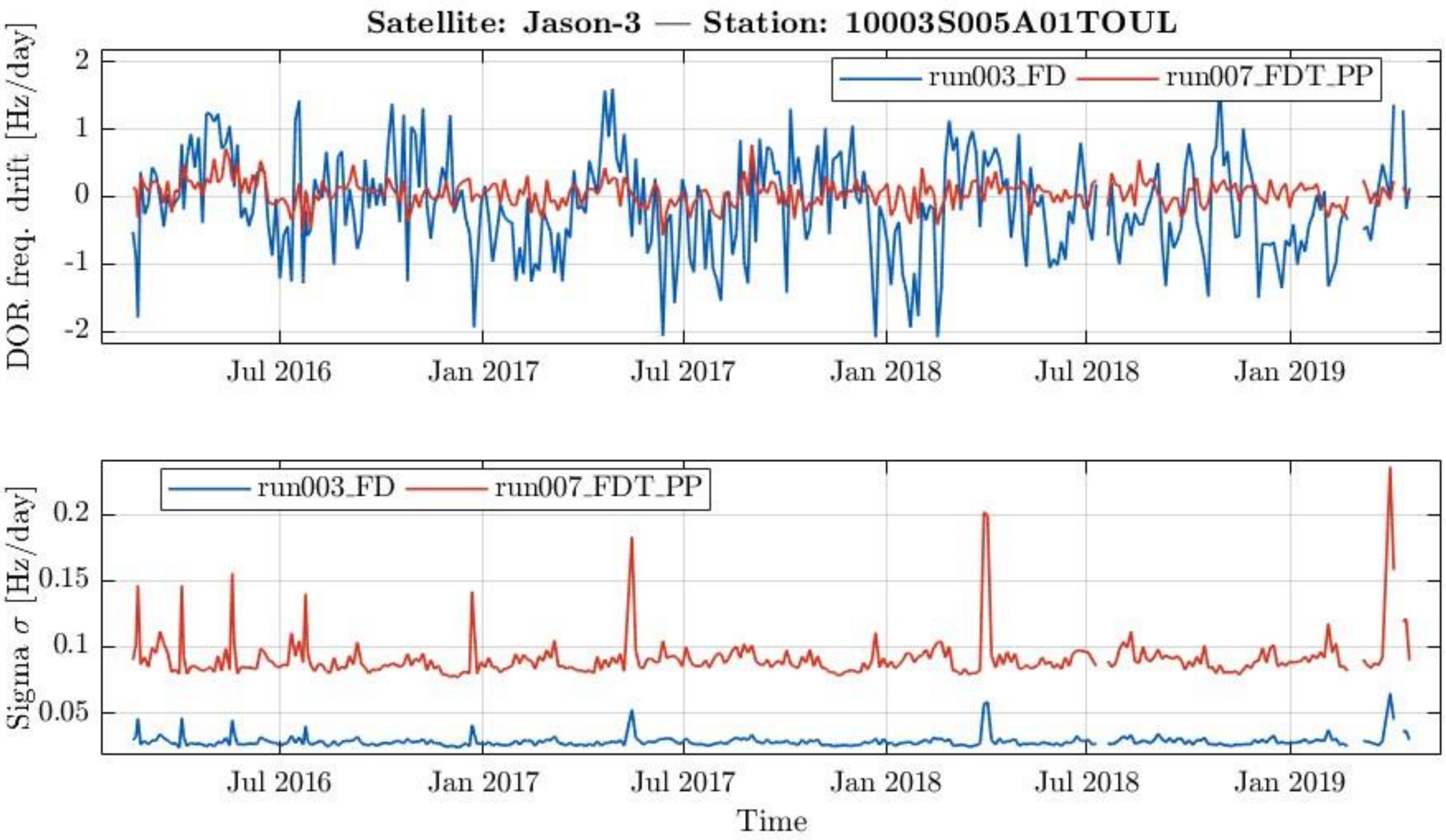
Frequency bias (WASHINGTON, USA)

A



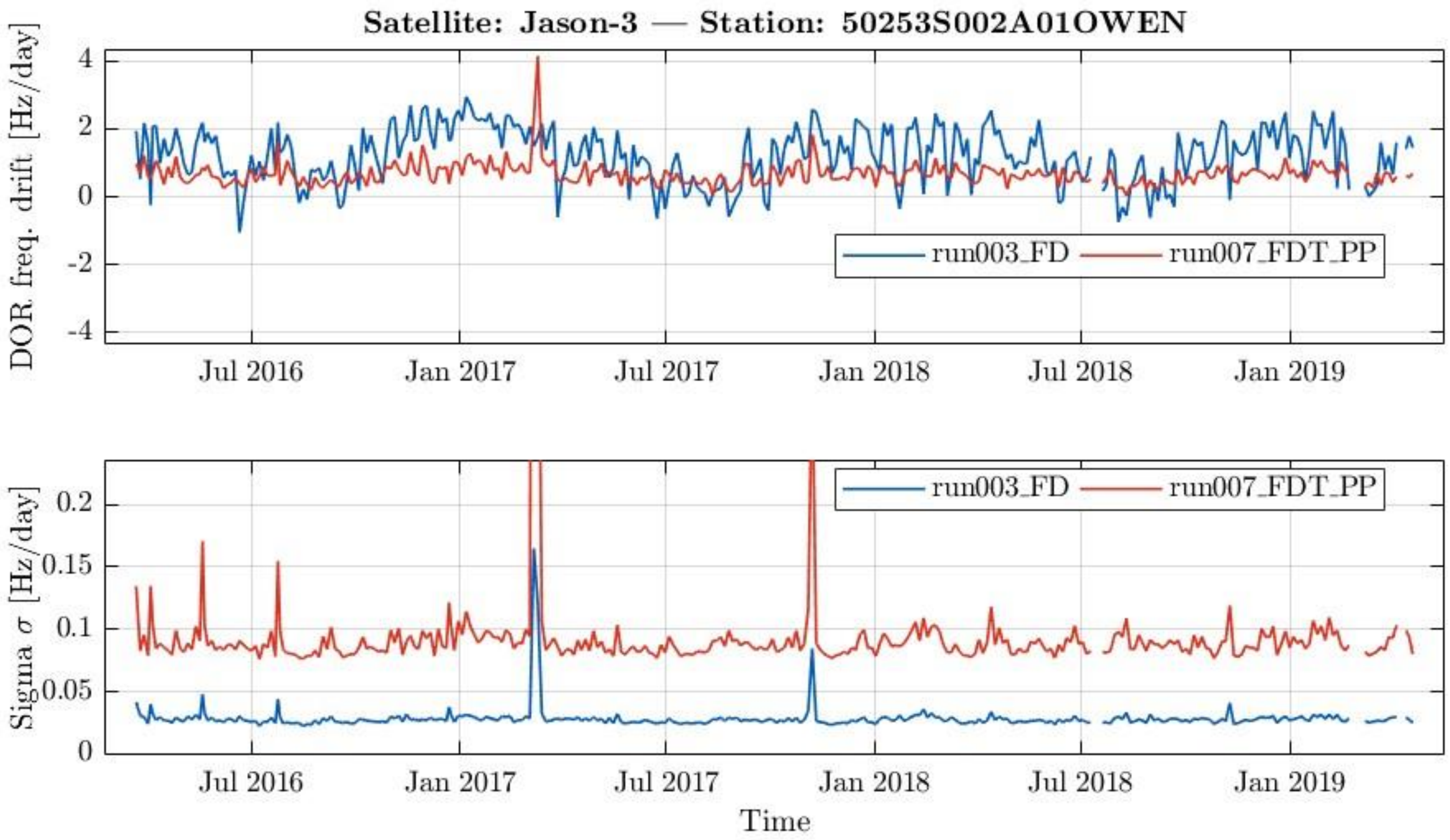
Frequency drift (TOULOUSE, FRANCE)

B



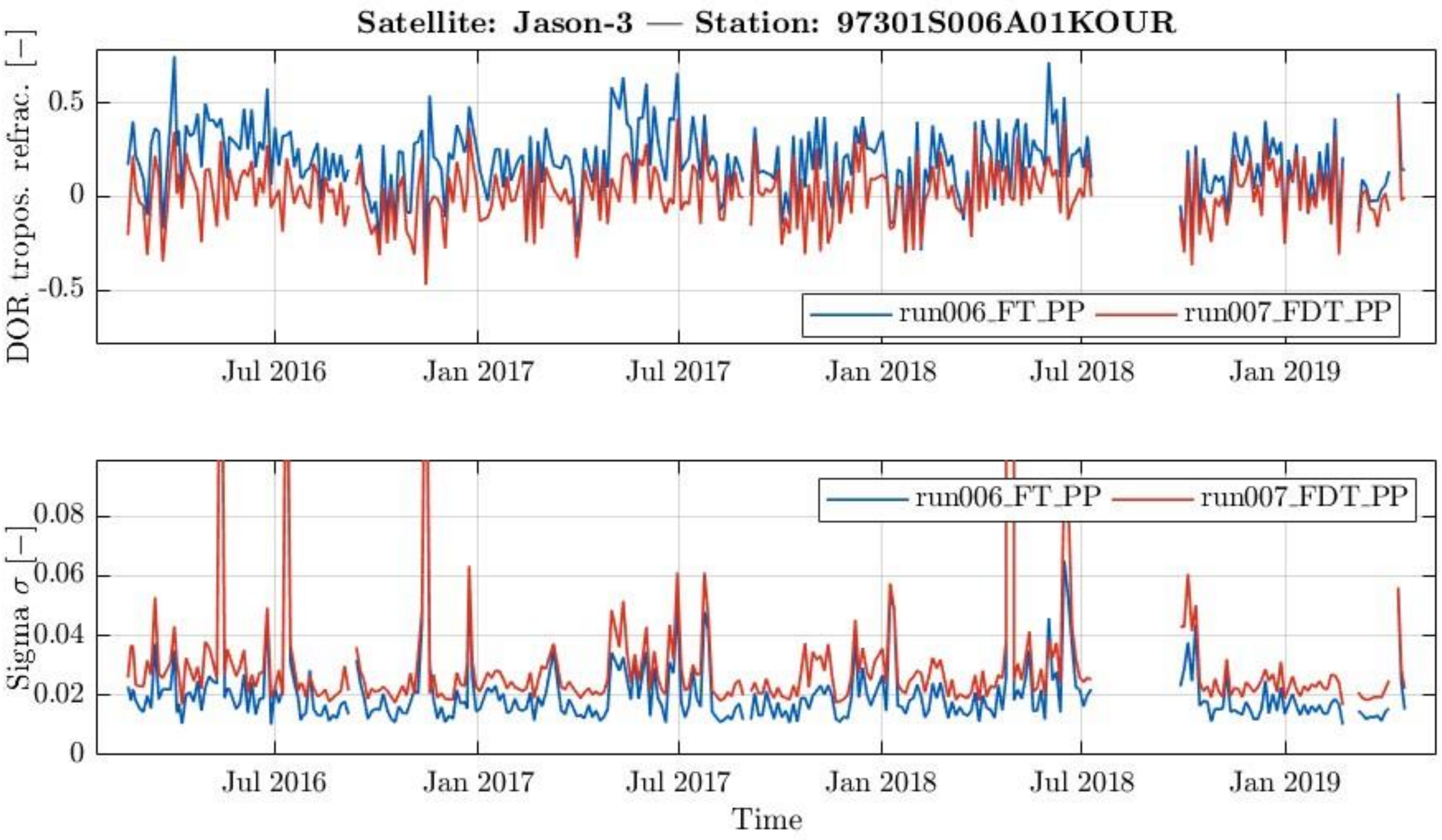
Frequency drift (OWENGA, NEW ZEALAND)

B



Tropospheric refraction (KOUROU, FRENCH GUIANA)

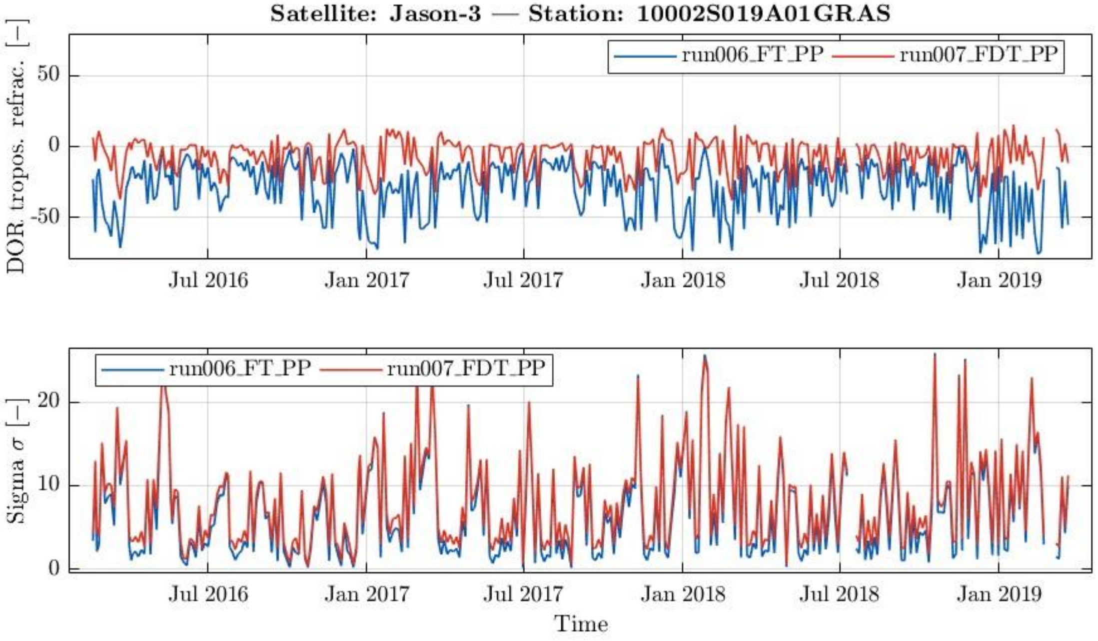
C



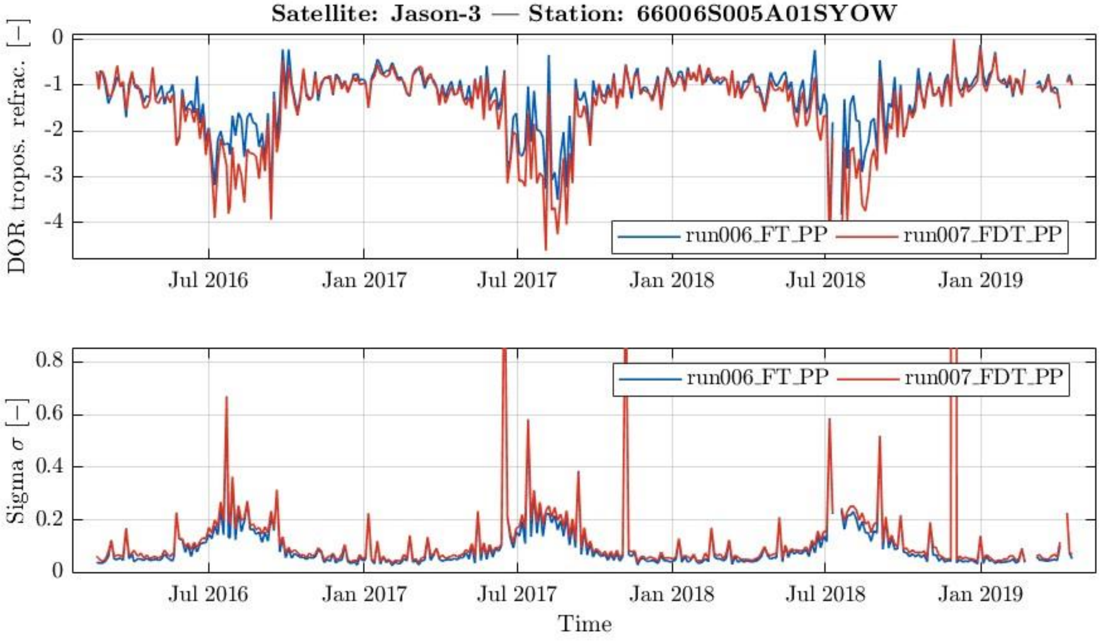
Tropospheric refraction

C

GRASSE, FRANCE



SYOWA, ANTARCTICA



Conclusions and outlook

Development of Jason-3 DORIS-only mission mean RMS values of observation residuals:

Case	RMS [mm/s]	Setup
C0	0.6950	Frequency bias (per pass)
C1	0.6747	C0 + elevation-dependent weighting
C2	0.4795	C1 + frequency drift (per station)
C3	0.3988	C2 + tropospheric refraction scaling factors (per pass)

Next steps:

- Relativistic correction applied twice for IDS2.2?
- Reprocessing of full mission of TOPEX/Poseidon, Jason-1/-2/-3 with new implementations and quaternion data
- **Implementation of new troposphere model (VMFx)**
- **Correlation analysis of bias parameters**
- Refine the parameter setup of DORIS-only and SLR-DORIS combined orbits
- Comparison between Jason-2 IDS2.2- and RINEX-derived orbits
- Orbit comparison with external orbit solutions
- (Implementation of new DORIS-tracked satellites in DOGS-OC)

Thank you very much for your attention!