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Outline

- IGN-IPGP/JPL solutions for ITRF2020u2025 : IGN v22 & v23

- Multi-satellite estimation at observation level with improved parametrization : preliminary results

- LOD estimation : preliminary results

- IDS Working Group on Tropospheric products : objectives

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IGN v22 & v23 solutions

- Implementation of solar panel quaternions for SWOT

- IGN solutions now include SWOT
  v23 : SWOT does not contribute to the combined scale

- Bug correction between v22 and v23

Overlap of 3h used for orbit estimation before and after the days not removed correctly to compute weekly solution in v22 and older solutions. However, no significant differences in term of station coordinates & EOPs. Corrected in v23.

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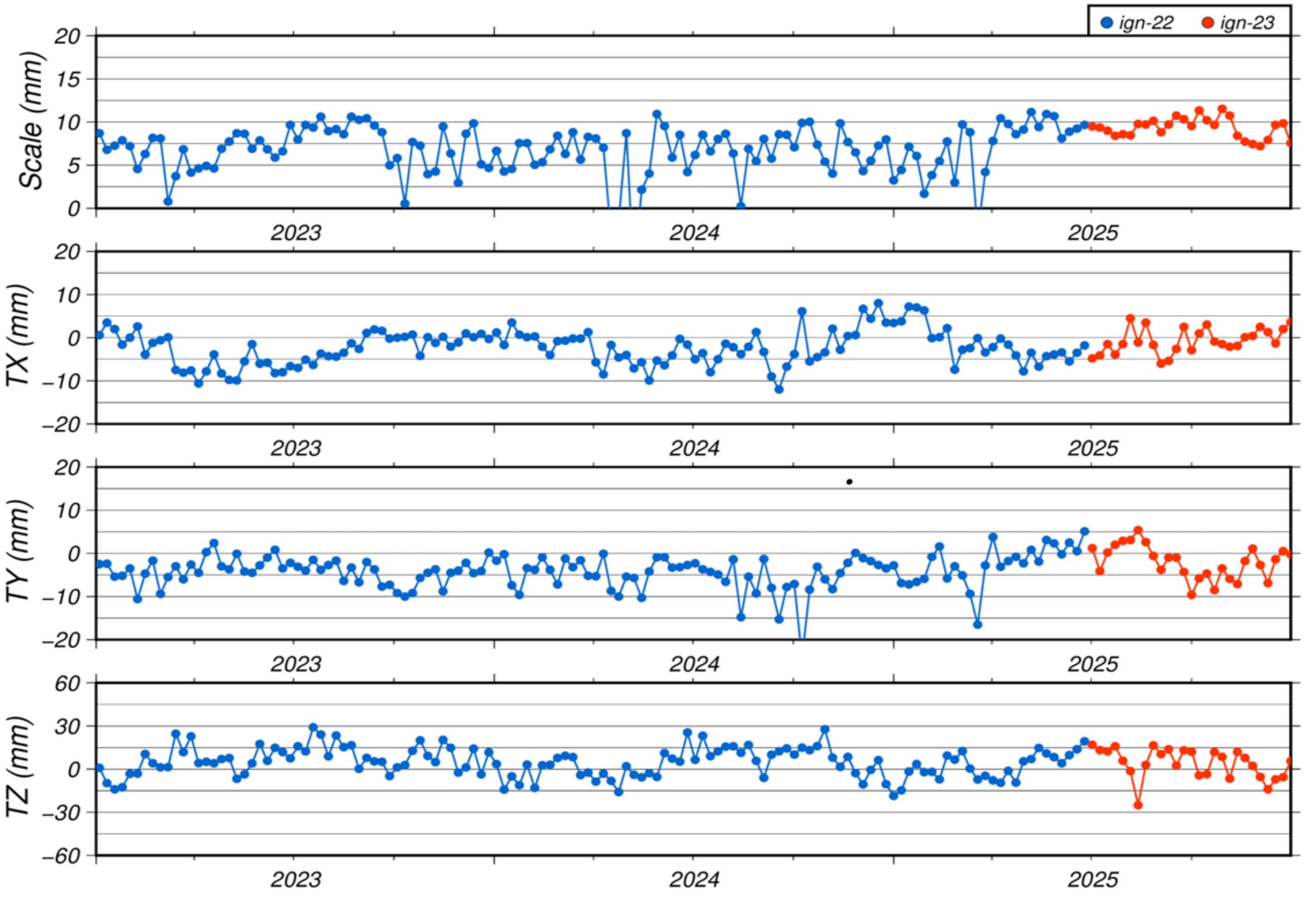
IDS Workshop

Helmert Parameters wrt DPOD2020v5.0



Source : [Moreaux, 2026] Evaluation of Operational Series Up to 2026.0,Version 1.0, IDS CC Report

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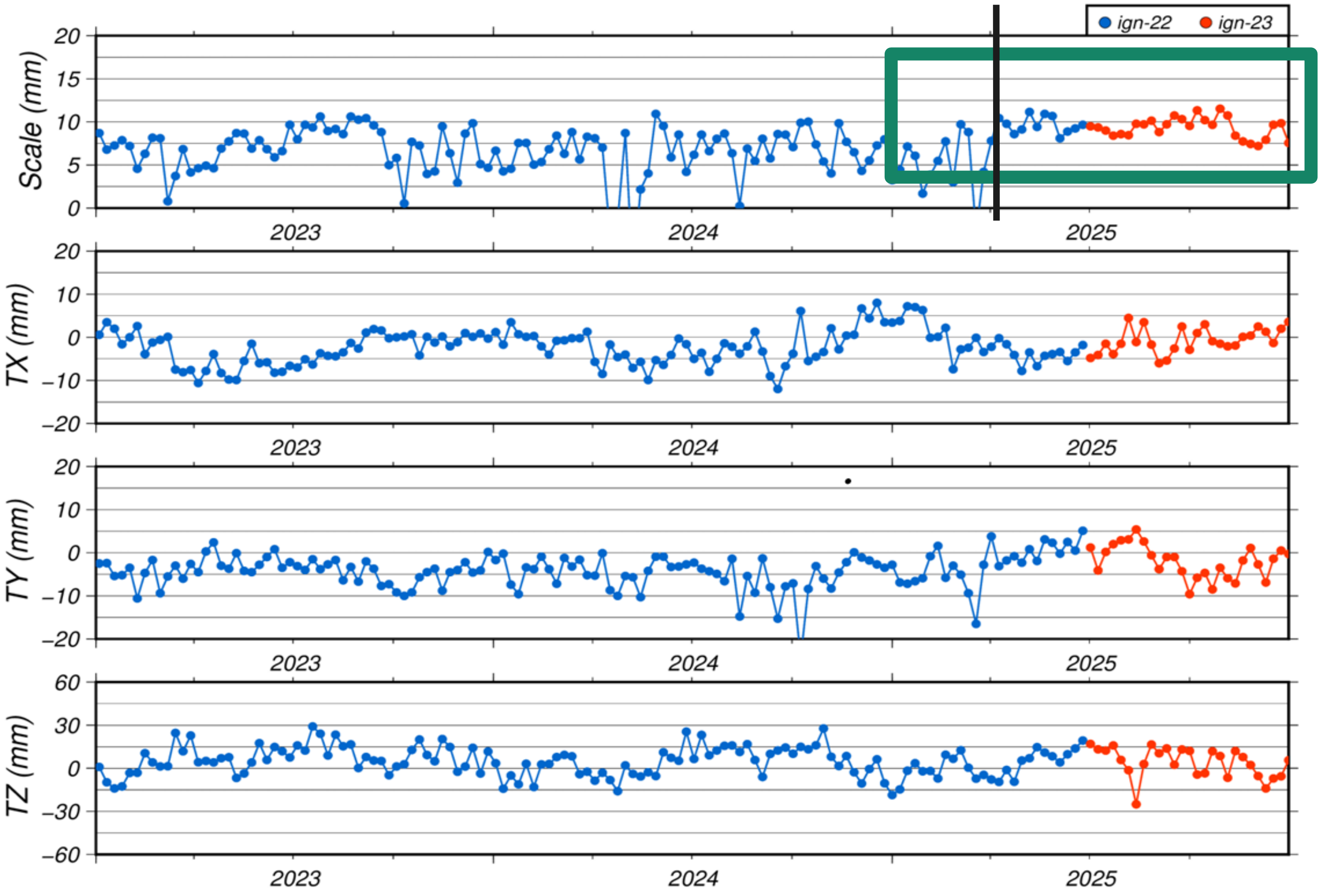

- **Scale more stable with SWOT** measurements, even if SWOT does not contribute to the combined scale.

- The other parameters are consistent with the rest of the ACs.

Source : [Moreaux, 2026] Evaluation of Operational Series Up to 2026.0,Version 1.0, IDS CC Report

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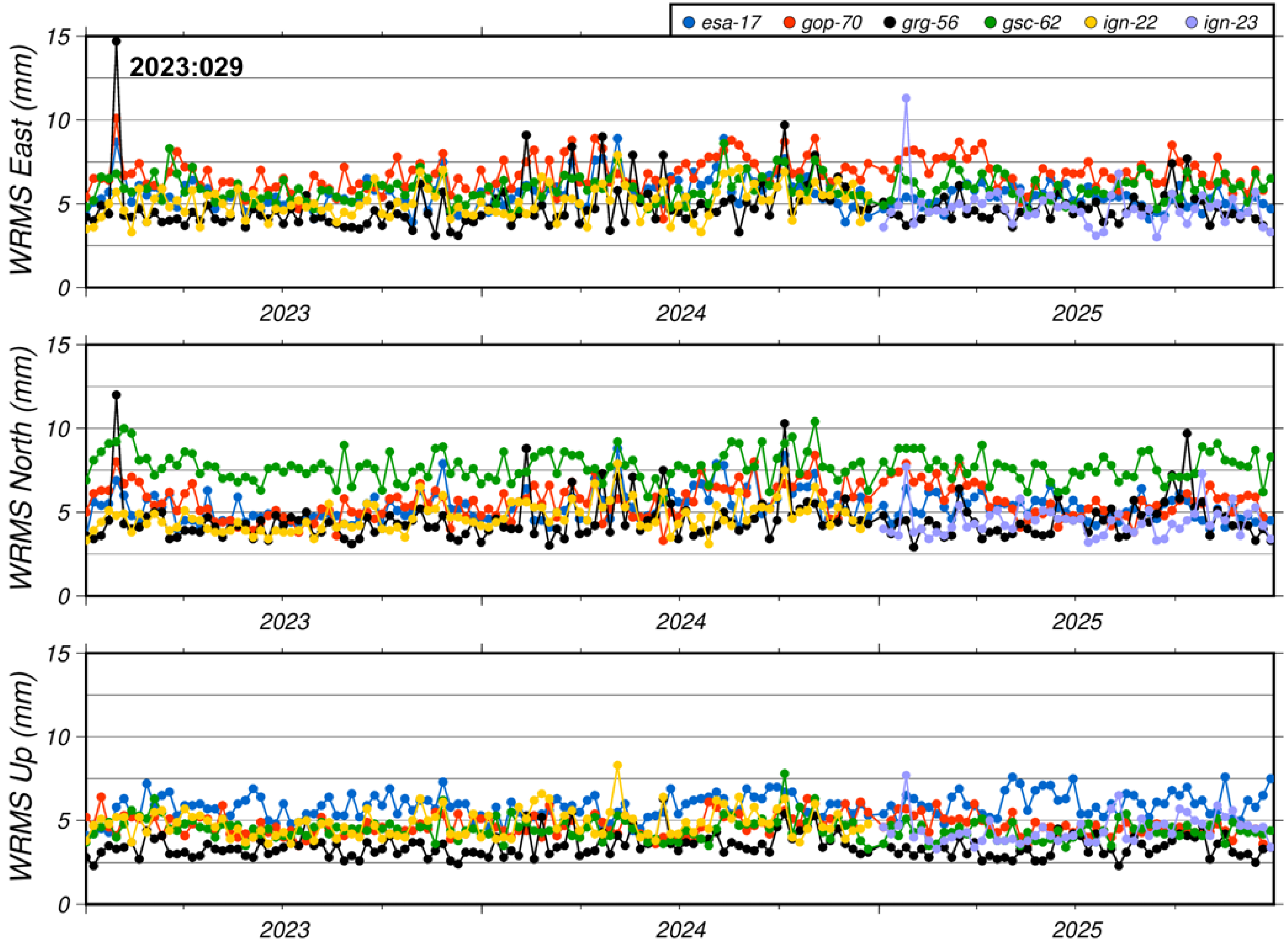

Station Position Residuals wrt. Combined Solution

Good repeatability
East / North / Up

Good consistency with other ACs

EOPs wrt. IERS C04	
X-Pole (µas)	**Y-Pole (µas)**
-2.27 ± 244.75	1.33 ± 257.61

Source : [Moreaux, 2026] Evaluation of Operational Series Up to 2026.0,Version 1.0, IDS CC Report

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Multi-satellite DORIS data processing, new approach

IGN-IPGP/JPL AC nominal approach : Mono-satellite daily solutions combined at NEQ level

Configuration :

- 1 clock rate parameter per station and satellite per pass : **we do not separate errors coming from satellite or from station.**

- 1 ZTD parameter per station, satellite and pass : **we can have different ZTD at the same time on the same station, one per satellite observing the station at the same time**

- During day of maneuver, process data with the longer time span (before or after the maneuver date) : a pragmatic workaround, due to the lack of time to properly account for maneuvers

- Remove observations from stations under SAA for impacted mission (JA3 & S6A)

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Multi-satellite DORIS data processing, new approach

New approach, closer to the real physic (only possible with enough satellite flying simultaneously) :
=> **Separation between errors coming from satellite and coming from station**

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Multi-satellite DORIS data processing, new approach

New approach, closer to the real physic (only possible with enough satellite flying simultaneously) :
=> **Separation between errors coming from satellite and coming from station**

- Stochastic clock rate parametrisation per station (more stringent for TAI stations) :

TAI stations : Random-walk process, with an initial uncertainty of 0.1 s/s, a process noise of **1e-6 s/s/√s** , and updates every **1800** s.

Other : Random-walk process, with an initial uncertainty of 0.5 s/s, a process noise of 1e-5 s/s/√s, and updates every 300 s.

Value corresponding to realistic variability of a cesium clock.

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Multi-satellite DORIS data processing, new approach

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- Stochastic clock rate parametrisation per station (more stringent for TAI stations) :

TAI stations : Random-walk process, with an initial uncertainty of 0.1 s/s, a process noise of ~~1e-6~~ **s/s/√s** , and updates every ~~1800~~ s.
Other : Random-walk process, with an initial uncertainty of 0.5 s/s, a process noise of 1e-5 s/s/√s, and updates every 300 s.

Tests have shown that this modeling approach is overly constrained, particularly during periods of high solar activity, when ionospheric disturbances can significantly affect DORIS radio signal propagation.

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Multi-satellite DORIS data processing, new approach

New approach, closer to the real physic (only possible with enough satellite flying simultaneously) :
=> **Separation between errors coming from satellite and coming from station**

- Stochastic clock rate parametrisation per station (more stringent for TAI stations) :

TAI stations : Random-walk process, with an initial uncertainty of 0.1 s/s, a process noise of **5e-6 s/s/√s** , and updates every **900** s.
Other : Random-walk process, with an initial uncertainty of 0.5 s/s, a process noise of 1e-5 s/s/√s, and updates every 300 s.

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Multi-satellite DORIS data processing, new approach

New approach, closer to the real physic (only possible with enough satellite flying simultaneously) :

=> **Separation between errors coming from satellite and coming from station**

- Stochastic clock rate parametrisation per station (more stringent for TAI stations)

- Stochastic clock rate parametrisation per satellite, more update for satellite with SAA issue

Random walk : 1e-3 s/s , 1e-5 s/s/√s and **120** s for satellite without SAA issue

Random walk : 1e-3 s/s, 1e-5 s/s/√s and **60** s for satellite with SAA issue (JA3, S6A)

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Multi-satellite DORIS data processing, new approach

New approach, closer to the real physic (only possible with enough satellite flying simultaneously) :

=> **Separation between errors coming from satellite and coming from station**

- Stochastic clock rate parametrisation per station (more stringent for TAI stations)

- Stochastic clock rate parametrisation per satellite, more update for satellite with SAA issue

Random walk : 1e-3 s/s , 1e-5 s/s/√s and 120 s for satellite without SAA issue

Random walk : 1e-3 s/s, 1e-5 s/s/√s and 60 s   for satellite with SAA issue (JA3, S6A)

- Stochastic ZTD parametrisation per station :

Random walk : 0.5 m, 0.02 m/√h and 300 s

* Direct implementation of maneuvers
* Down-weighting SAA observations (currently by a factor of 100^2) for impacted mission

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Multi-satellite DORIS data processing, new approach

Preliminary results (from last week !) :

		X-Pole wrt. EOPC04	Y-Pole wrt. EOPC04	WRMS E	WRMS N	WRMS U
IGN v23 réf. solution	Median	148 µas	-27 µas	6.2 mm	5.9 mm	9.2 mm
	IQR	308 µas	363 µas	1.0 mm	0.9 mm	0.9 mm
New approach	Median	124 µas	-6 µas	6.2 mm	7.1 mm	8.4 mm
	IQR	390 µas	307 µas	1.3 mm	2.5 mm	0.7 mm

- Multi-satellite solutions deliver **consistent EOPs** compared to mono-satellite solutions, with higher XP variability but stable YP.

- Global **station statistics remain consistent**, except for an **increase in WRMS N**.

- Global agreement hides local effects: SAA, atomic-clock, and island stations require deeper investigation.

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Multi-satellite DORIS data processing, new approach

Preliminary results (from last week !) :

		Tx wrt. DPOD2020	Ty wrt. DPOD2020	Tz wrt. DPOD2020	Sc. factor wrt. DPOD2020
IGN v23 réf. solution	Median	-2.5 mm	-2.7 mm	2.8 mm	1.40 ppb
	IQR	2.9 mm	2.8 mm	3.7 mm	0.45 ppb
New approach	Median	-0.7 mm	-3.2 mm	0.2 mm	1.32 ppb
	IQR	1.8 mm	2.5 mm	5.1 mm	0.21 ppb

- Consistent TRF, slight impact on Tz (lower bias but greater variability)
(Keep in mind : The 3-month time span is too short to reliably capture draconitic and annual signals)

- Maneuver handling requires improvement, particularly for long-duration maneuvers (several minutes or more)

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LOD estimation - VIF analysis

- VIF = Variance Inflation Factor
- VIF is a metric used to **detect correlation between explanatory variables in a model**.
  - A value close to 1 indicates no multicollinearity issue
  - The higher the value, the stronger the correlation between variables, which can affect model interpretation
  - **VIF_{LOD} / $VIF_{w/o\ LOD}$: greater than 1 implies increase of multi-colinearity issue when estimating LOD !**

	Sat.	X-Pole	Y-Pole	Satellite initial position			Satellite initial velocity			Along-track per rev.		Cross-track per rev.	
				X	Y	Z	X	Y	Z	Acc. Sin	Acc. Cos	Acc. Sin	Acc. Cos
$\frac{VIF_{LOD}}{VIF_{W/O\ LOD}}$	CS2 daily	~1.0	~1.0	~200	~68	~3.5	~5400	~200	~67	~1.1	~1.6	~5800	~1.1
	JA3 daily	~1.0	~1.0	~365	~1860	~1.1	~340	~3500	~1.1	~1.0	~1.0	~1080	~1.1
	SRL daily	~1.0	~1.0	~4000	~1520	~14	~2900	~1000	~32	~1.1	~5.6	~38000	~1.3
	JA3 weekly	~1.0	~1.0	~140	~980	~1.0	~150	~1200	~1.0	~1.0	~1.0	~830	~1.0

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LOD estimation - VIF analysis

	ALL SAT	X-Pole	Y-Pole	Satellite initial position			Satellite initial velocity			Along-track per rev.		Cross-track per rev.	
				X	Y	Z	X	Y	Z	Acc. Sin	Acc. Cos	Acc. Sin	Acc. Cos
$\frac{VIF_{LOD}}{VIF_{W/O\,LOD}}$	Daily	~1.0	~1.0	~140	~180	~23	~520	~220	~40	~1.1	~5.0	~600	~1.2
	Weekly	Work in progress											

VIF	Daily Mono-Sat.	Weekly Mono-Sat.	Daily Multi-Sat.	Weekly Multi-Sat.
X/Y-Pole	~1000	~100	~100	Work in progress
LOD	~500000	~50000	~40000	

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LOD estimation

Confirm [Stepanek et al., 2018] study, **clear correlation between LOD and cross-track per rev. acceleration. This correlation is reduced in a multi-satellitte processing.**

Four approach tested over three months of data:

1 & 2. **Mono-satellite** daily arc estimation + Use of **strong constraints** on the **sin (resp. sin and cos) per rev cross-track accelerations** + combination at NEQ level (approah **MONO_Daily_to_MULTI_week_NS** and **MONO_Daily_to_MULTI_week_NSC**)

3 & 4. **Multi-satellite** daily arc estimation + Use of **strong constraints** on the **sin (resp. sin and cos) per rev cross-track accelerations** + combination at NEQ level (approah **MULTI_Daily_to_MULTI_week_NS** and **MULTI_Daily_to_MULTI_week_NSC**)

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LOD estimation

Preliminary results :

		IGN v23 ref.	MONO_Daily_ to_ MULTI_week_ NS	MONO_Daily_ to_ MULTI_week_ NSC	MULTI_Daily_ to_ MULTI_week_ NS	MULTI_Daily_ to_ MULTI_week_ NSC
X-Pole wrt. EOPC04	Median	148 µas	159 µas	79 µas	156 µas	84 µas
	IQR	308 µas	300 µas	304 µas	387 µas	360 µas
Y-Pole wrt. EOPC04	Median	-27 µas	-46 µas	204 µas	-55 µas	65 µas
	IQR	363 µas	381 µas	382 µas	312 µas	305 µas
LOD wrt. EOPC04	Median	x	2 µsD	3 µsD	1 µsD	-2 µsD
	IQR	x	70 µsD	72 µsD	61 µsD	65 µsD

Consistent results regarding EOP estimations, station coordinates and TRF. However, further investigation needed. Orbits, Tropospheric parameters, etc.

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Conclusion

- Encouraging results have been obtained with the multi-satellite approach using the new parameterization.
- Some issues still need to be investigated, particularly during or immediately after periods of high solar activity, which currently require relaxing the constraints on TAI station parameters. In addition, results in the SAA region should be carefully assessed for both satellite clocks and station parameters.
- Encouraging LOD results have also been achieved, although the main question remains unresolved: which part of the estimated LOD parameter truly corresponds to an LOD correction, and which part reflects mis-modeling effects related to the cross-track component ? Ongoing tests are being carried out through modifications of the a priori EOPs or/and cross-track accelerations.

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IDS Working Group on Tropospheric products

Objectives :

Establish a coordinated IDS framework for the scientific assessment of DORIS-derived tropospheric products, with an initial focus on ZWD.

- Build a shared dataset of ZWD estimates from Analysis Centers with harmonized metadata
- Clarify methodology and diagnostics, and provide guidance for robust comparison and interpretation
- Assess internal consistency across processing strategies, satellites, and configurations (cf. [Nahmani et al, 2026])
- Investigate sensitivities to key modeling choices (orbits, TRF, processing strategies)
- Progressively evaluate external consistency using GNSS products and atmospheric reanalyses (e.g., ERA5)
- Explore extensions (gradients, stochastic modeling, impact on geodetic products) as maturity increases

Open participation: contributions from IDS Analysis Centers and the broader community (GNSS, meteorology, climatology, reanalyses) are welcome and encouraged.

Jun 24 2026, 14:40 - 15:00: Kumar et al, A Homogenized Global Comparison of DORIS- and GNSS-Derived Zenith Tropospheric Delay Time Series (2016–2025) Using GINS