IDS WG NO GLYPH Integrated Clock Correction Strategies for DORIS NO GLYPH – Status and first results

Schreiner P[1]

1) GFZ Helmholtz Centre for Geosciences, Potsdam, Germany

Athen – November 7, 2025

GFZ Helmholtz Centre for Geosciences

HELMHOLTZ

Content

1. Introduction
2. Results
    1. CLS / CNES / GET
    2. GFZ
    3. PosiTim
3. Objectives

1.1 Co-Location of DORIS Clocks

Clock Co-Location in Space

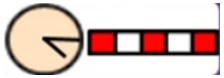
- DORIS and GNSS receiver are linked to the same USO
- E.g. Sentinel 3A, 3B, 6A (MF)

Clock Co-Location on Ground

- Ground clock co-location (REGINA project)

Map of the REGINA network (CNES, 2024)

GNSS receiver



Satellite
- **Clock link**
- **Geometric link**

DORIS receiver

GNSS receiver

Ground station
- **Clock link**
- **Geometric link**

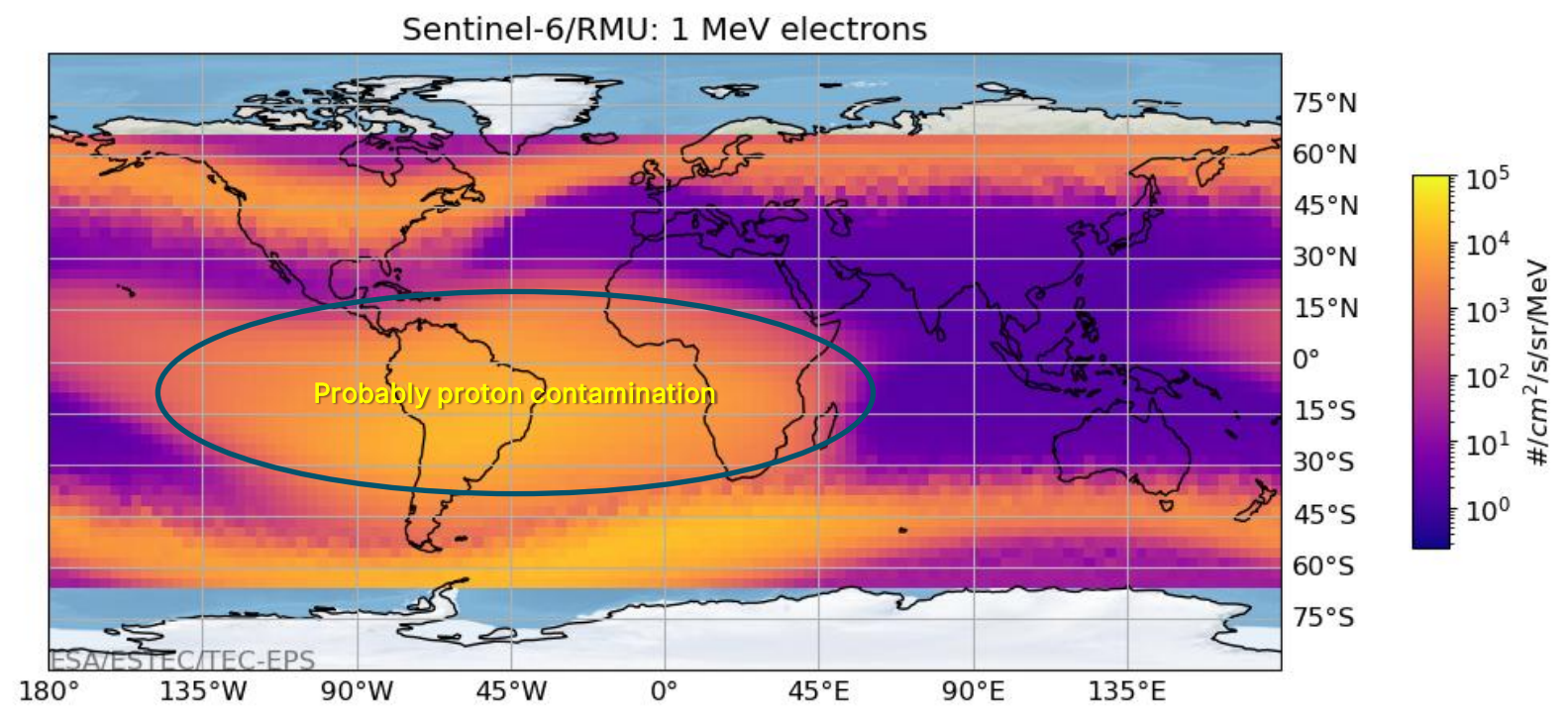
DORIS transmitter

1.2 General

Activities Overview:

- CNES+CLS
  - Clock solution and internal applications
- GFZ
  - Applying external CLK solution
  - Working on own CLK product
- GMV
  - Integrated DORIS processing into FocusPOD
  - Providing clock product
- GOP+TUM
  - DFG project on DORIS clocks
  - Master's thesis on DORIS clocks in cooperation with DTU
- PosiTim
  - Applying external clock solution

The Data for 2024 – 1 MeV electrons



1.3 Contributions

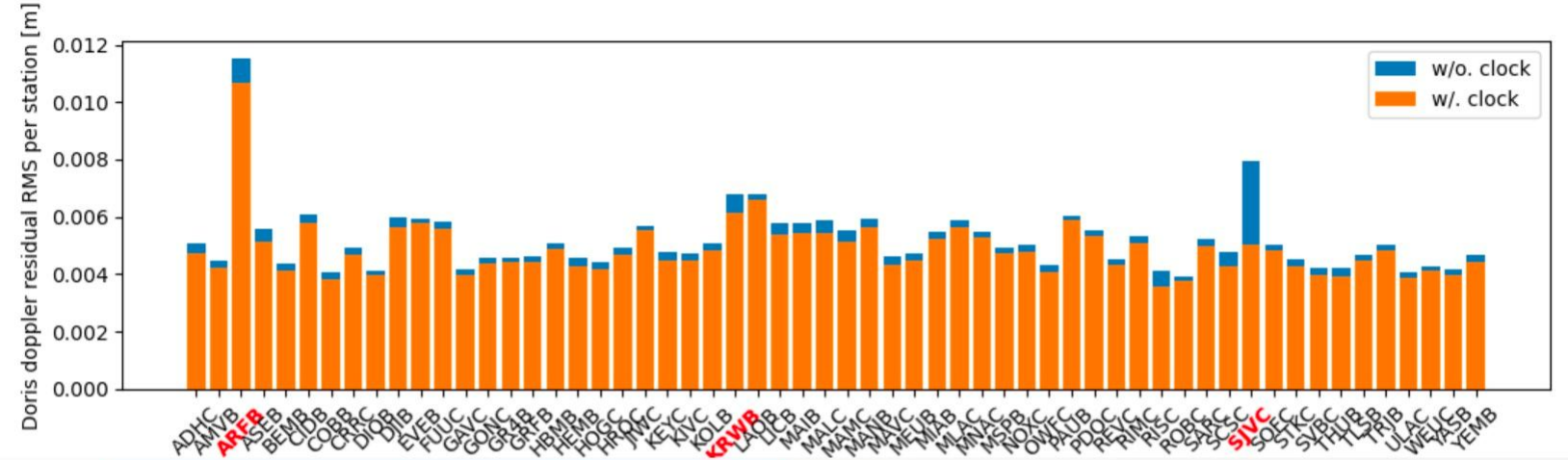
- Conference contributions
  - CNES/CLS presentation at IDS workshop 2024
  - CNES/CLS poster at EGU 2025
  - WG joint abstract submitted to REFAG 2026

- CPOD QWG meeting
  - Joint presentation on the use of clock products

2.1 CNES / CLS

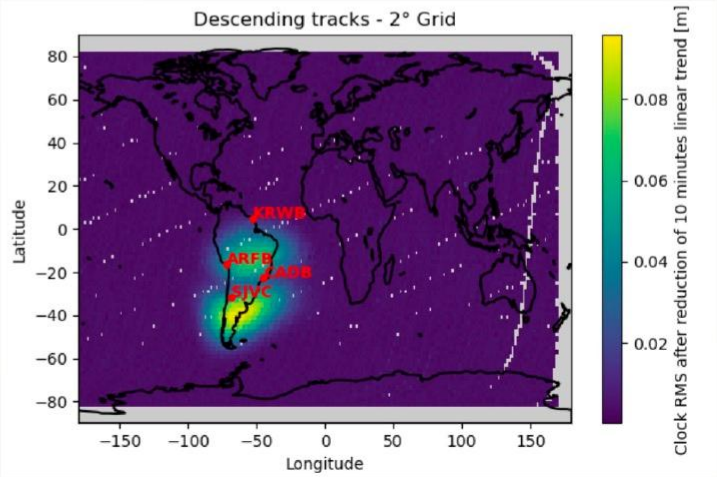
Results for 2024

Sentinel-3A



RMS w.r.t reference orbit			
	Radial	Tangential	Normal
w/. Clocks	1.279 cm	3.601 cm	1.681 cm
w/o. Clocks	1.293 cm	3.706 cm	2.060 cm

Also improvement w.r.t. usual DORIS dynamic orbit



Station positions

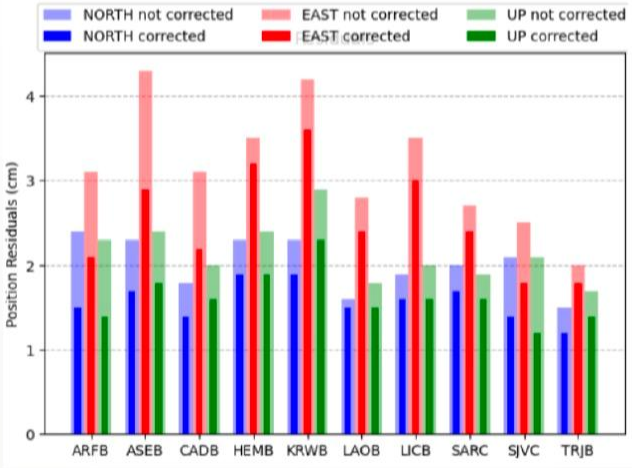
CNES/CLS IDS Analysis Center study – EGU2025

- **Positioning Residual STD**

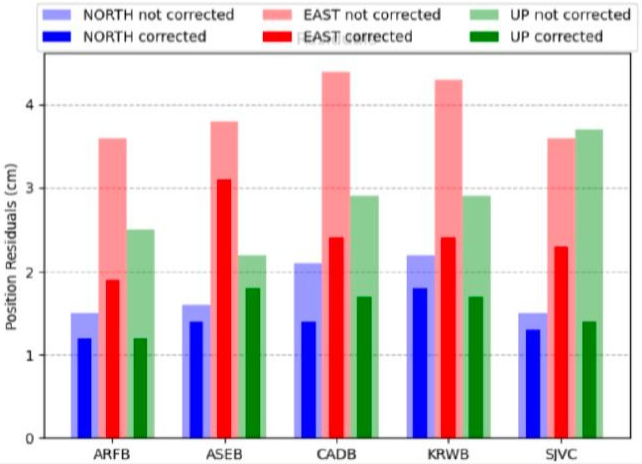
Time series of DORIS coordinates wo and w correcting the SAA stations.

After removing the long-term trend, we compare the residual noise levels (STD) in NEU components.

Sentinel-6A



Sentinel-3A



[Capdeville, H., Mezerette, A., Gravalon, T., Lemoine, J.-M., Moyard, J., Mercier, F., and Couhert, A.: Analyzing the Impact of GPS Clock as the modelled DORIS USO on Station Position Estimation for Sentinel Satellites, EGU General Assembly 2025, Vienna, Austria, 27 Apr–2 May 2025, EGU25-11124, https://doi.org/10.5194/egusphere-egu25-11124, 2025.]

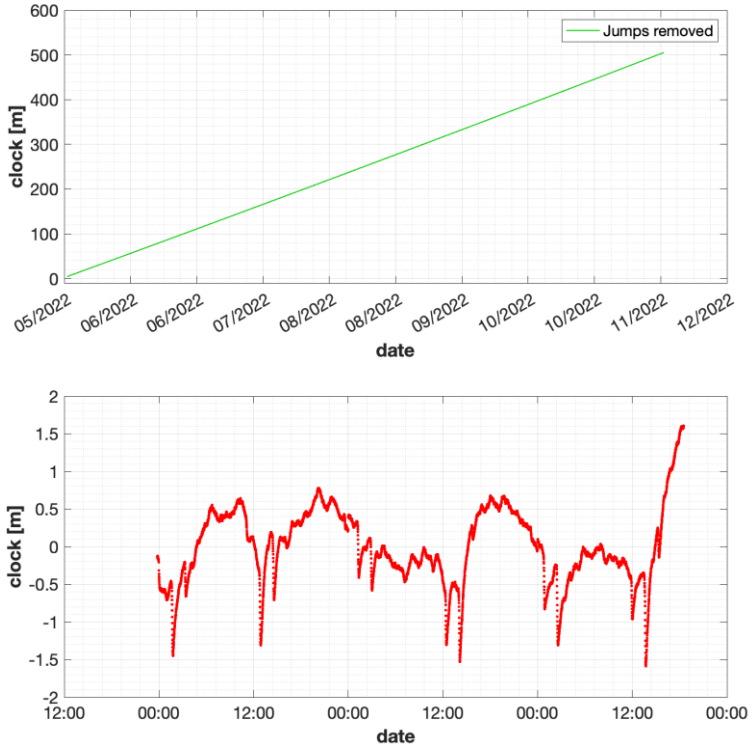
2021.0-2023.9 period

Improvement more important than on the orbits aspect !

2.2 GFZ

2.2.1 Clocks

- Raw clock from CNES/CLS
- 10 ms clock jumps are corrected
- Daily third degree polynomial fit is removed
  - The timestamp of DORIS RINEX is edited by this correction



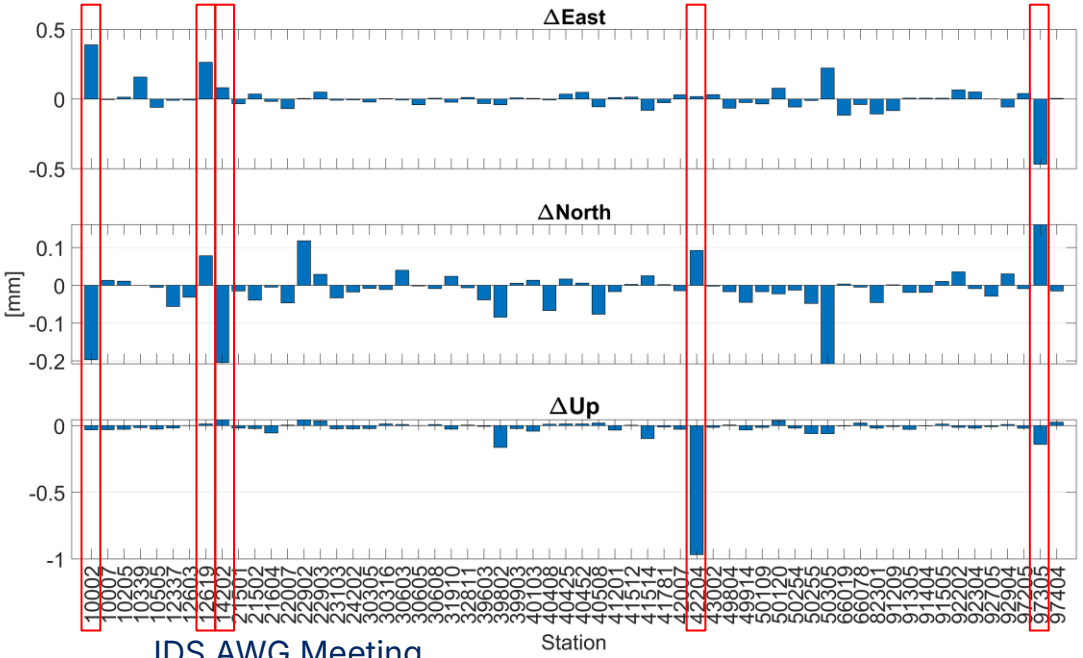
2.2.2 Station RMS

Estimation of station coordinates:

- Differences between mean RMS of station coordinate correction to a priori (reference solution vs. solution with corrected clock)

- 10002: Grasse
- 12619 : Gavdos
- 14202: Wettzell

- 42204: Arequipa
- 97305: Kourou



2.3 PosiTim

2.3.1 DORIS processing in NAPEOS

- Carrier phase observations from DORIS RINEX files are converted into Doppler observations, which are used in the orbit determination process (heritage from DORIS 2.2 observation files)

- The use of an external clock product impacts two things:
  - Receiver clock to get the exact measurement epochs
  - Frequency offset to get the proper frequency of the receiver

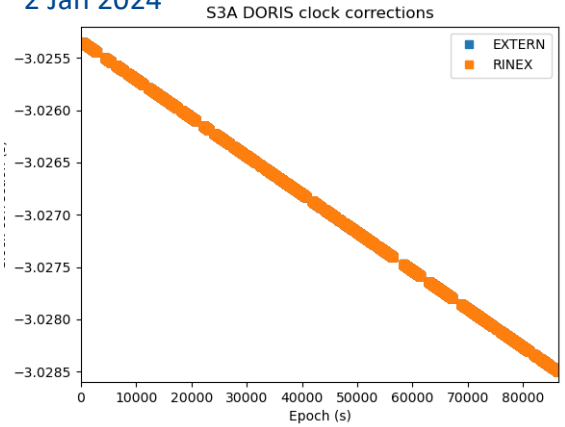
- Alignment of external clock corrections clk_{ext}

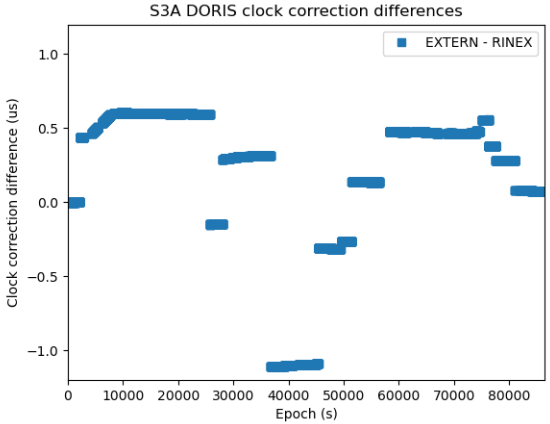
  $clk(t) = clk_{ext}(t) - clk_{ext}(t_{ref}) + clk_{RNX}(t_{ref})$ => is this correct?

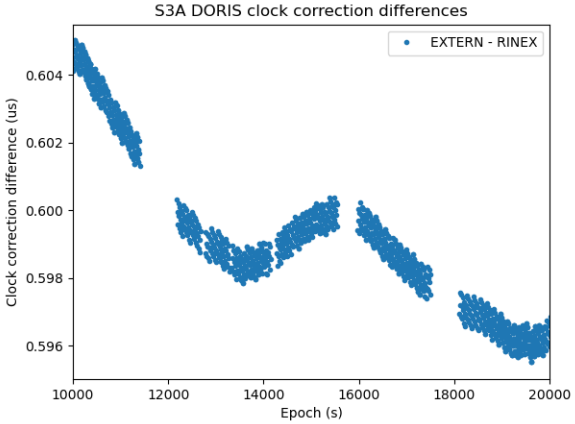
- Calculation of the frequency offset based on clk_{ext}
  - Polynomial fit (4^{th} order) to values of clk_{ext}
  - Frequency offset is first derivative of this polynomial

2.3.2 Clock corrections DORIS RINEX vs. external – S3A

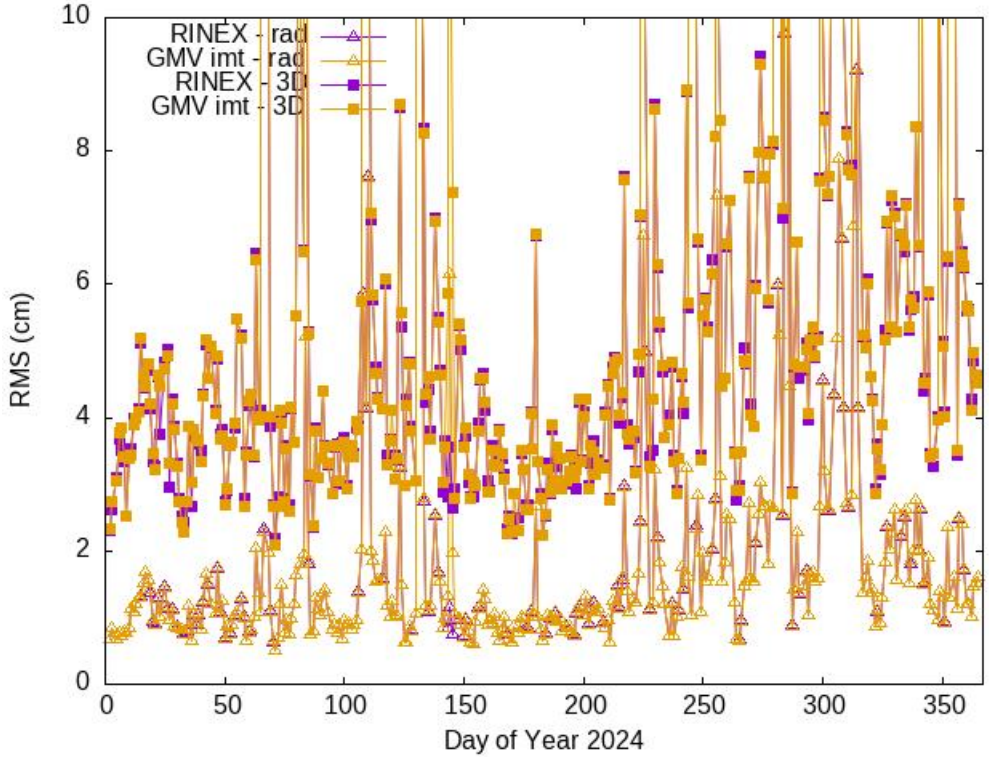
2 Jan 2024







2.3.3 S3A orbit comparisons to RSR combined orbit



- Sentinel-3A orbit comparison of DORIS-derived orbits to RSR#33 combined orbit
- RINEX => clock taken from entry in DORIS RINEX files
- GMV imt => clock taken from external clock file (GMV imt)

⇒ Similar performance of both orbit solutions

⇒ Several problem days with external clock file

2.3.4 Statistics of comparison to RSR combined orbit

Mean RMS (cm) of orbit comparison to RSR combined orbit – maneuver + clock problem days excluded

Solution	Radial	Along-track	Cross-track	3D
S-3A RINEX	1.35	3.60	2.00	4.42
S-3A GMV imt	1.36	3.62	2.02	4.45
S-3B RINEX	1.28	3.65	2.09	4.48
S-3B GMV imt	1.29	3.67	2.11	4.52
S-6A RINEX	0.80	2.54	2.61	3.82
S-6A imt	0.80	2.55	2.66	3.86

- Similar performance of orbits generated with external clocks compared to RSR combined orbits

4 Objectives

- **DORIS clock co-location**
  1. Create test clock series for testing of processing
  2. Modify DORIS data processing tools
  3. Investigate various correction strategies (sampling, smoothing) and run testing campaigns
  4. Create a product to be used by IDS and end users
- **Prepare a recommendation for routine production of the clock products and their archival at the IDS data centers as an official IDS product**
- **Prepare recommendations for future missions concerning DORIS-GNSS clock co-locations**