VTEC Estimation Performance of Real-Time PPP with Galileo High Accuracy Service

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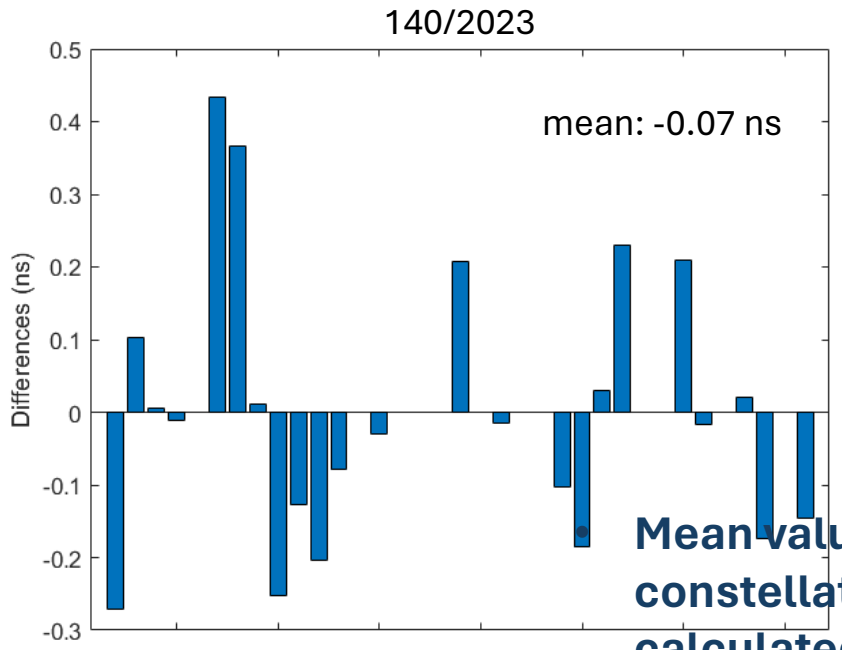
Performance of Galileo High Accuracy Service

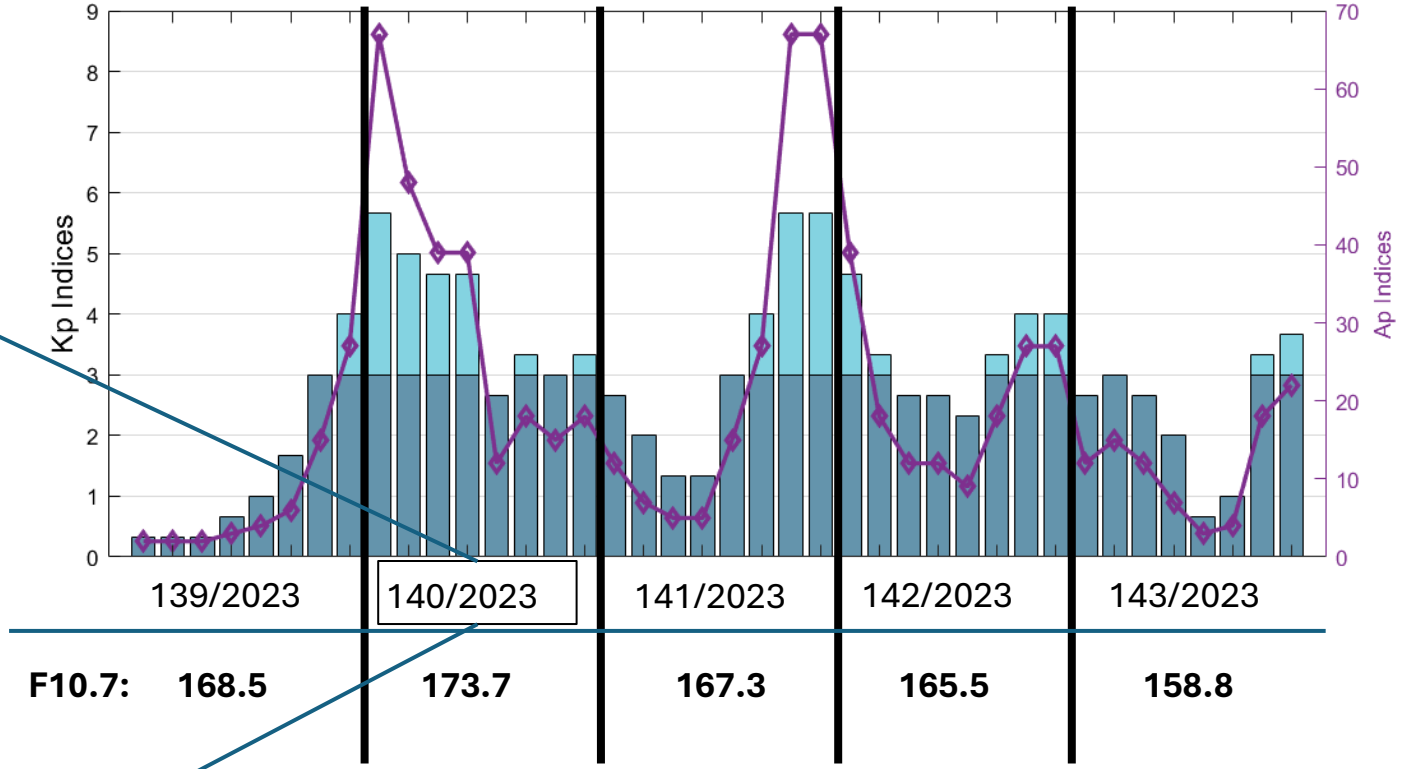
- Days with moderate ionospheric activities: Day of Year 140 to 143

C1C/C7Q DCB differences between HAS and DLR final products



Mean values for each constellation were calculated and removed.

Kp & Ap Indices from GFZ

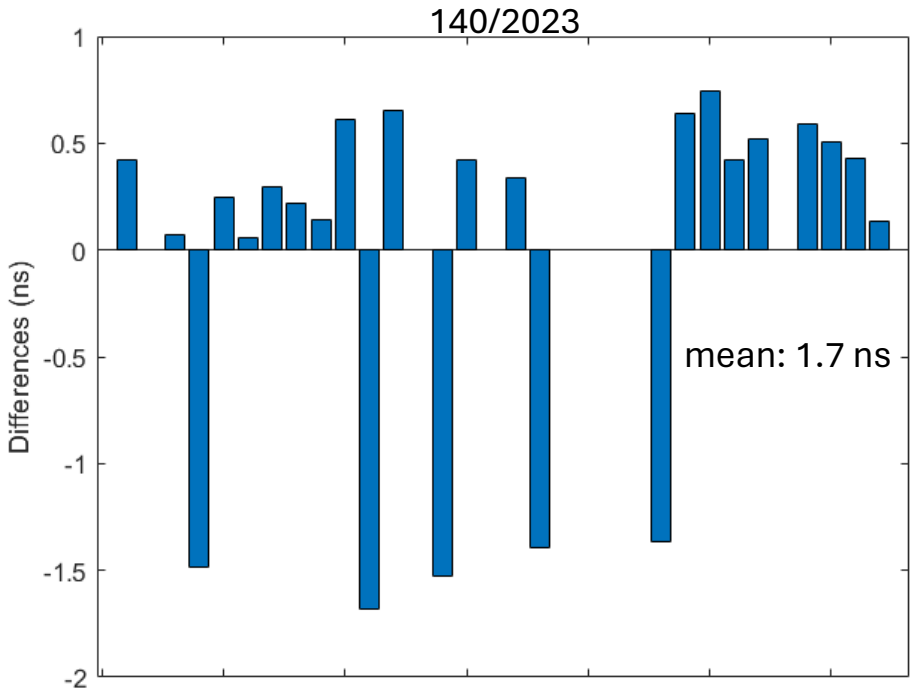


- Similar patterns were also observed in DoY 141,142 & 143…

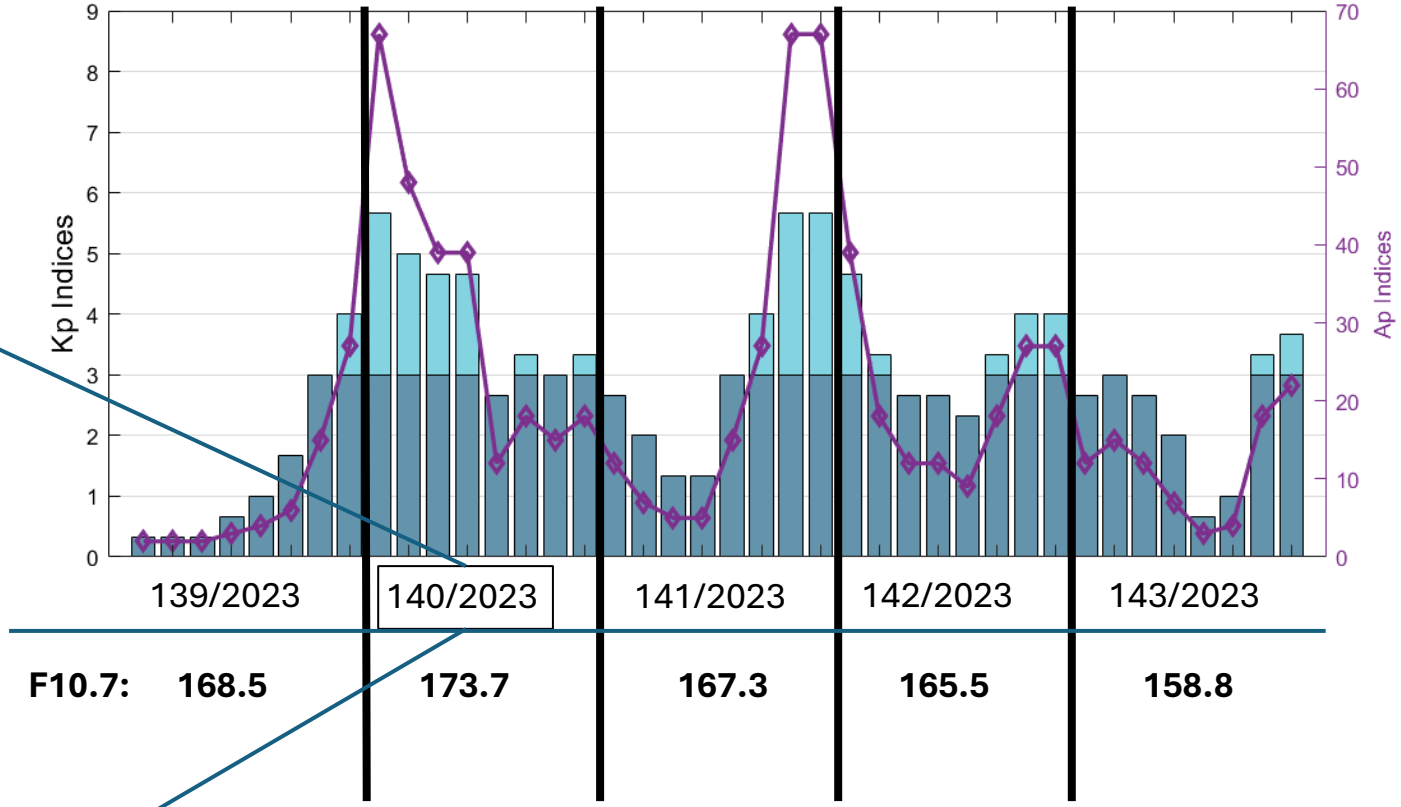
Performance of Galileo High Accuracy Service

- Days with moderate ionospheric activities: Day of Year 140 to 143

C1C/C2L DCB differences between HAS and DLR final products



Kp & Ap Indices from GFZ



- **DoY 140,141 & 143 were selected for data processing.**

Data processing with co-located stations

Settings for in-house developed software

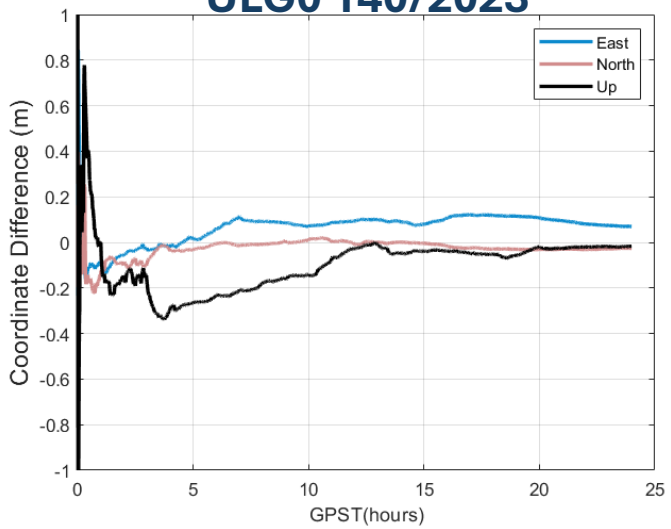
Item	Strategy
Positioning Mode	Static
Ambiguity	Float
Signals (GPS/GAL)	L1/E1C + L2/E5b
Satellite elevation mask	10°
Data interval	30s
Troposphere	
Nominal part	Modeled with UNB3
Residual part	Estimated as a random walk process ($10^{-8}\ m^2/s$)
Ionosphere	Estimated as a random walk process ($3 \times 10^{-4} m^2/s$)
Phase wind up	Modeled
Solid earth-tide	Modeled

Two Septentrio PolaRx5 receivers from the University of Liège, Belgium for DoY 140 & 143 (Disturbed & quiet days)

- Receivers are located inside the building
- 2nd order polynomial model for station-based VTEC modeling.
- Co-located stations can be used for assessing the performance of ionospheric delay estimation.
  - Galileo HAS stream retrieved by **BNC v2.12.18.**

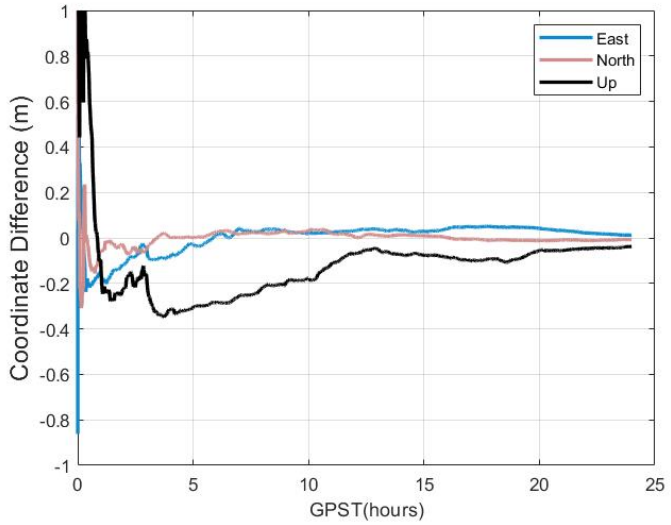
Results of co-located stations

ULG0 140/2023



Position RMS
East: 8.96 cm
North: 2.44 cm
Up: 5.49 cm

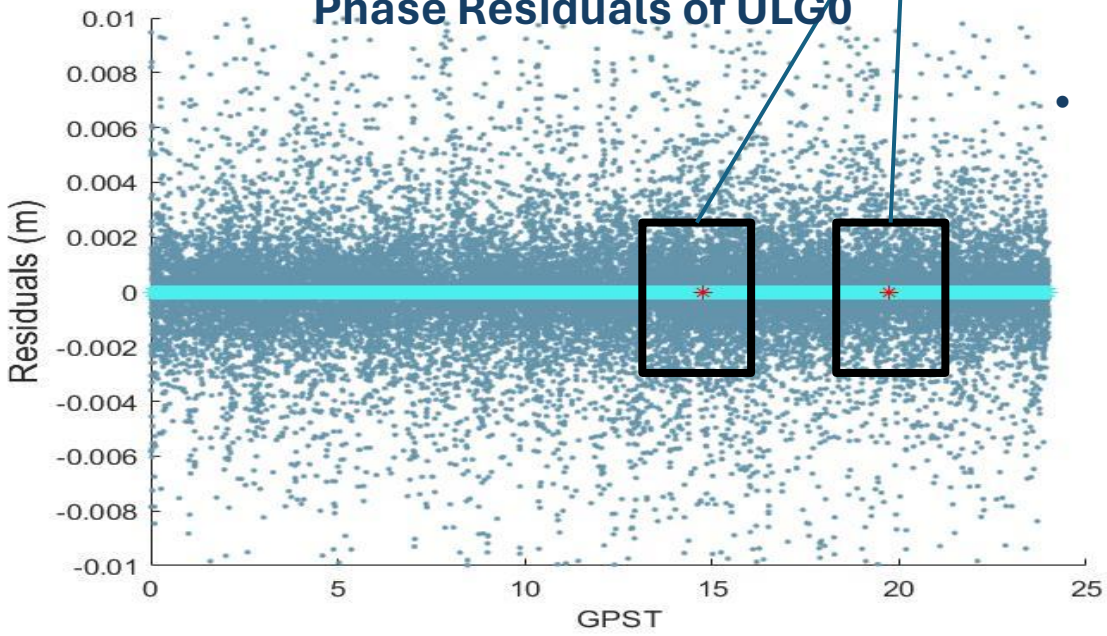
ULG1 140/2023



Position RMS
East: 3.48 cm
North: 1.14 cm
Up: 9.87 cm

- Active ionospheric conditions may complicate proper cycle-slip detection.

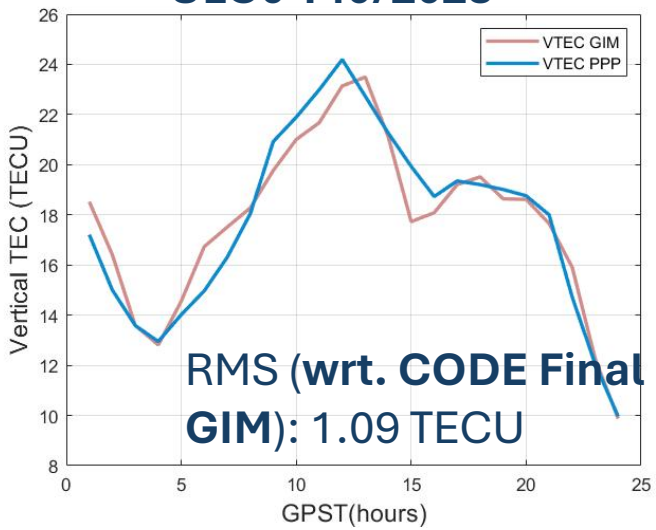
Phase Residuals of ULG0



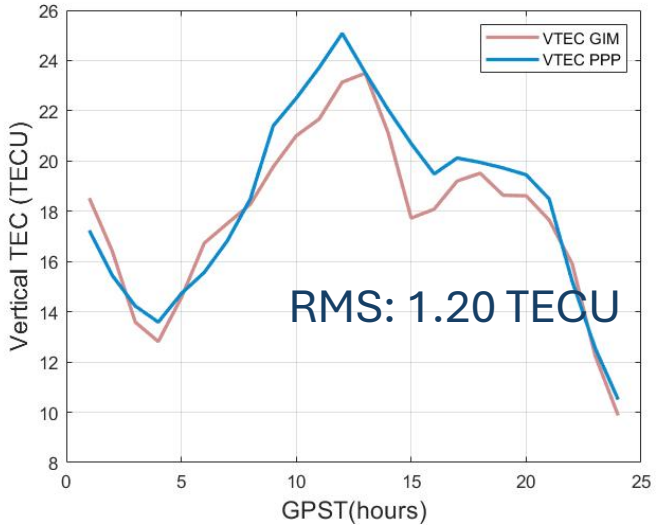
- Cycle-slips were detected only a few epochs using geometry-free combination + Melbourne-Wübbena combination + LLI

Results of co-located stations

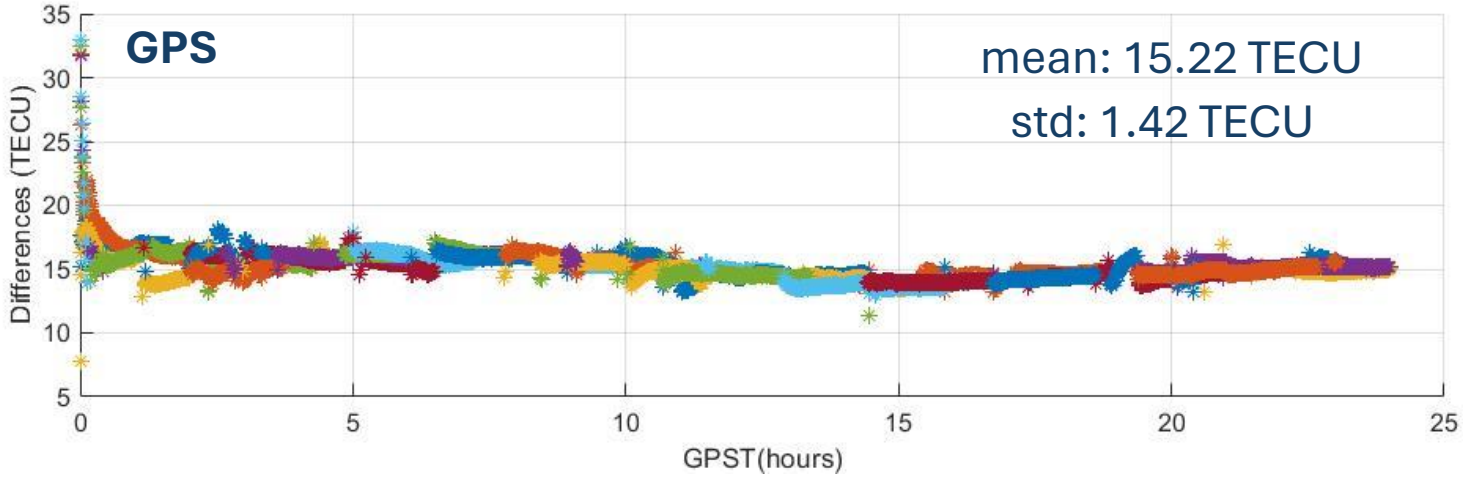
ULG0 140/2023

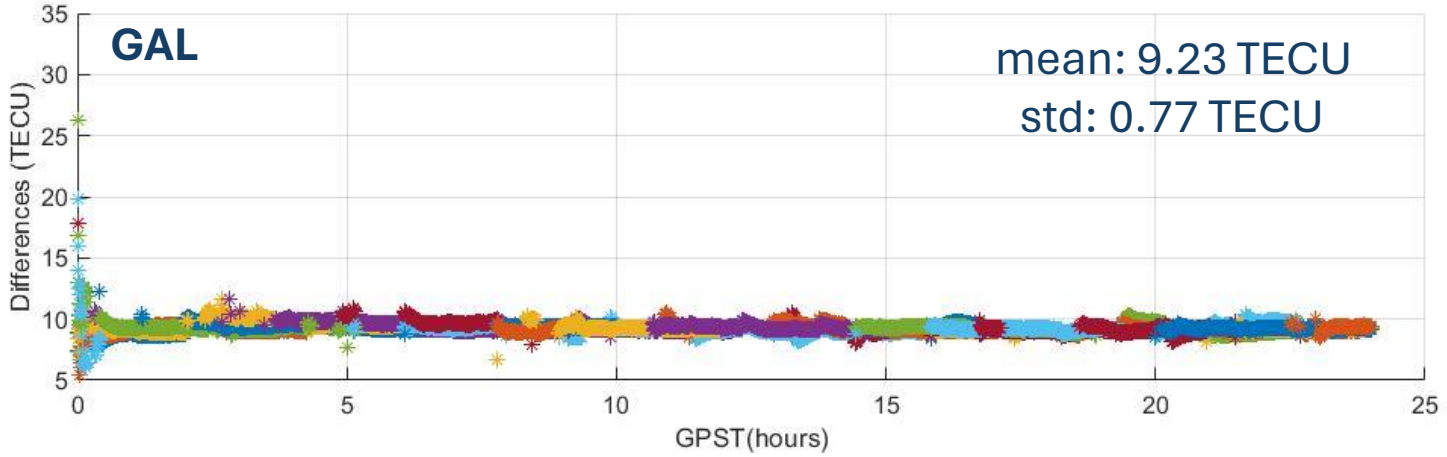


ULG1 140/2023



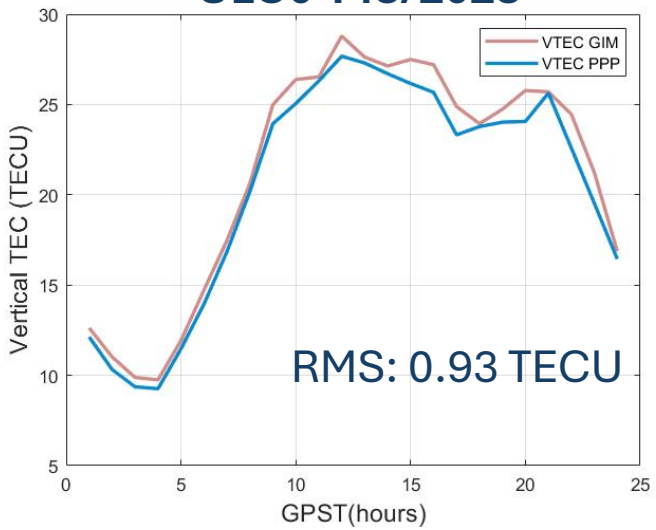
Single Differenced Ionosphere ULG0-ULG1





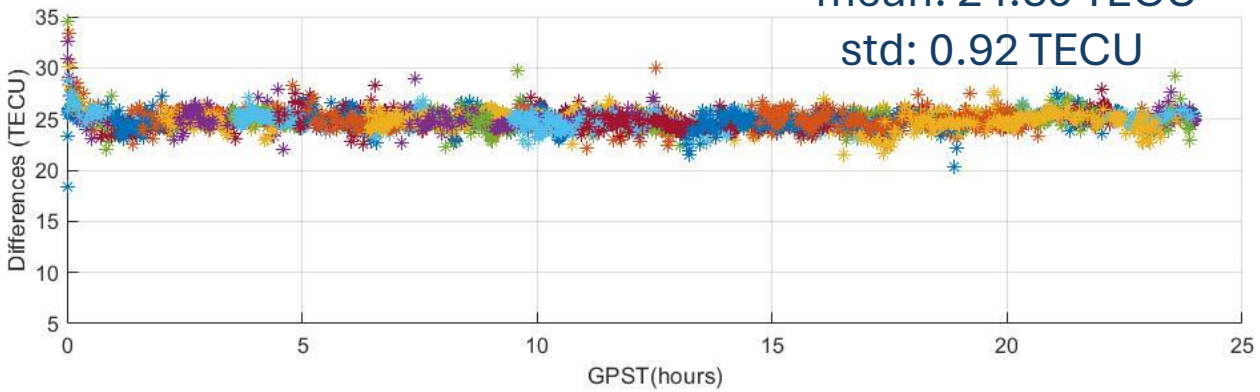
Results of co-located stations

ULG0 143/2023

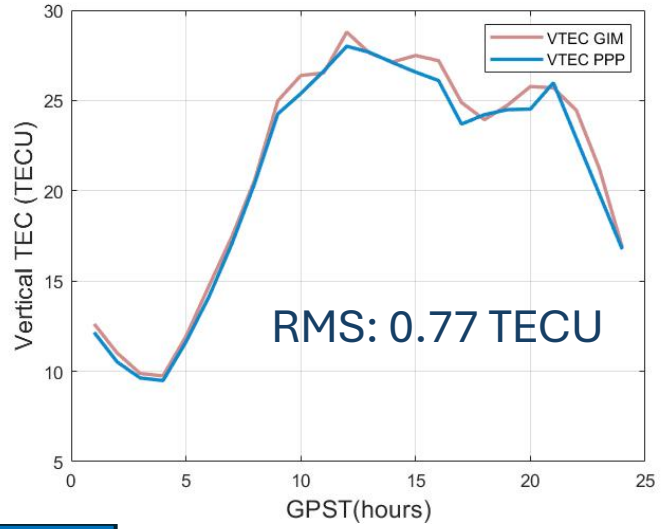


Position RMS
East: 8.66 cm
North: 4.17 cm
Up: 3.17 cm

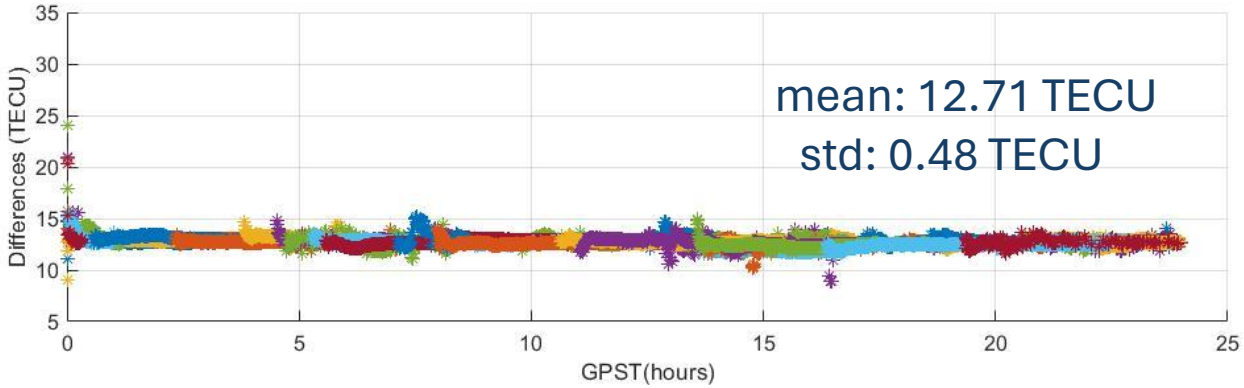
- **Results from DoY 143/2023: Relatively quiet day**



ULG3 143/2023

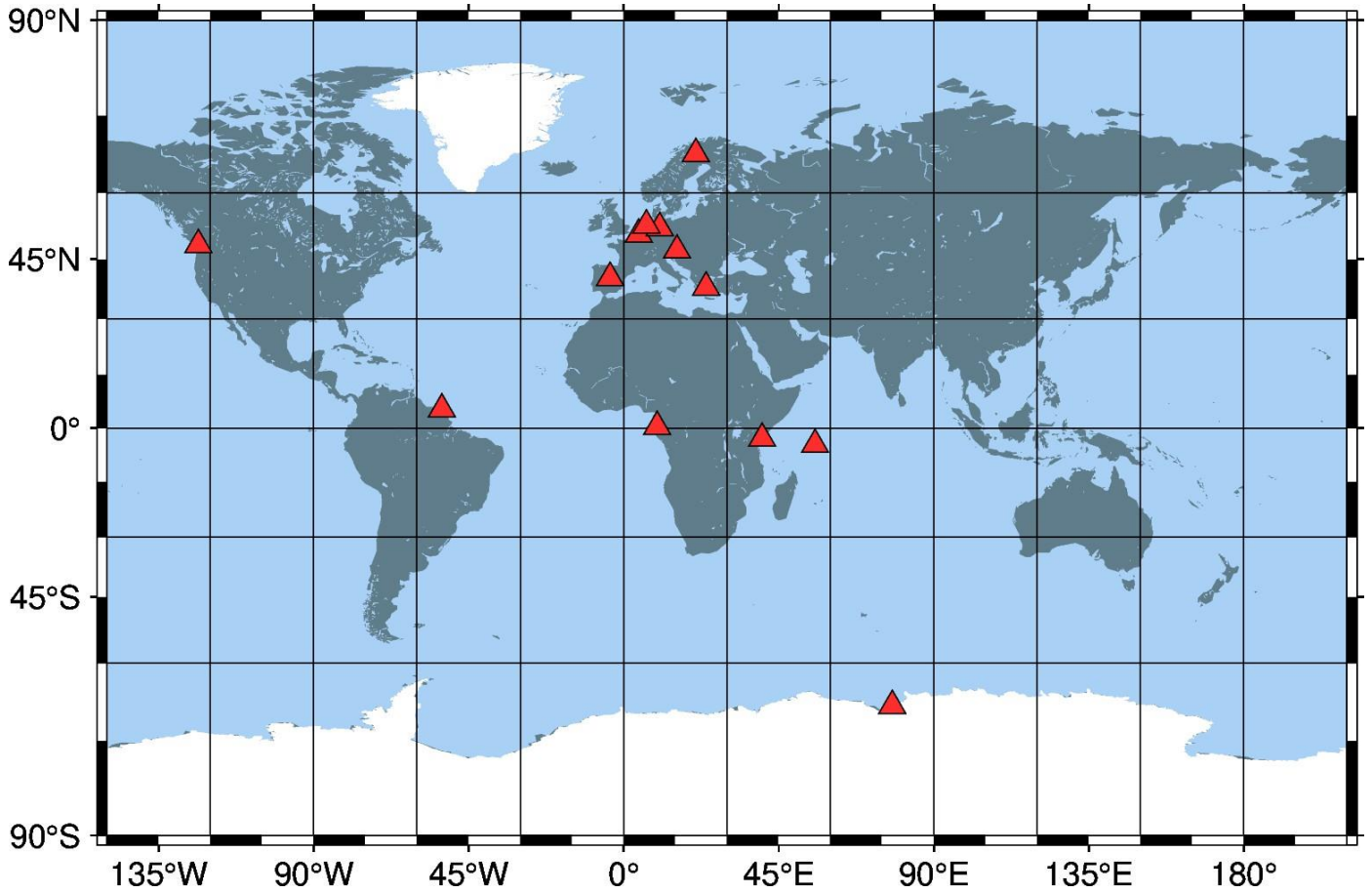


Position RMS
East: 6.40 cm
North: 1.90 cm
Up: 4.22 cm

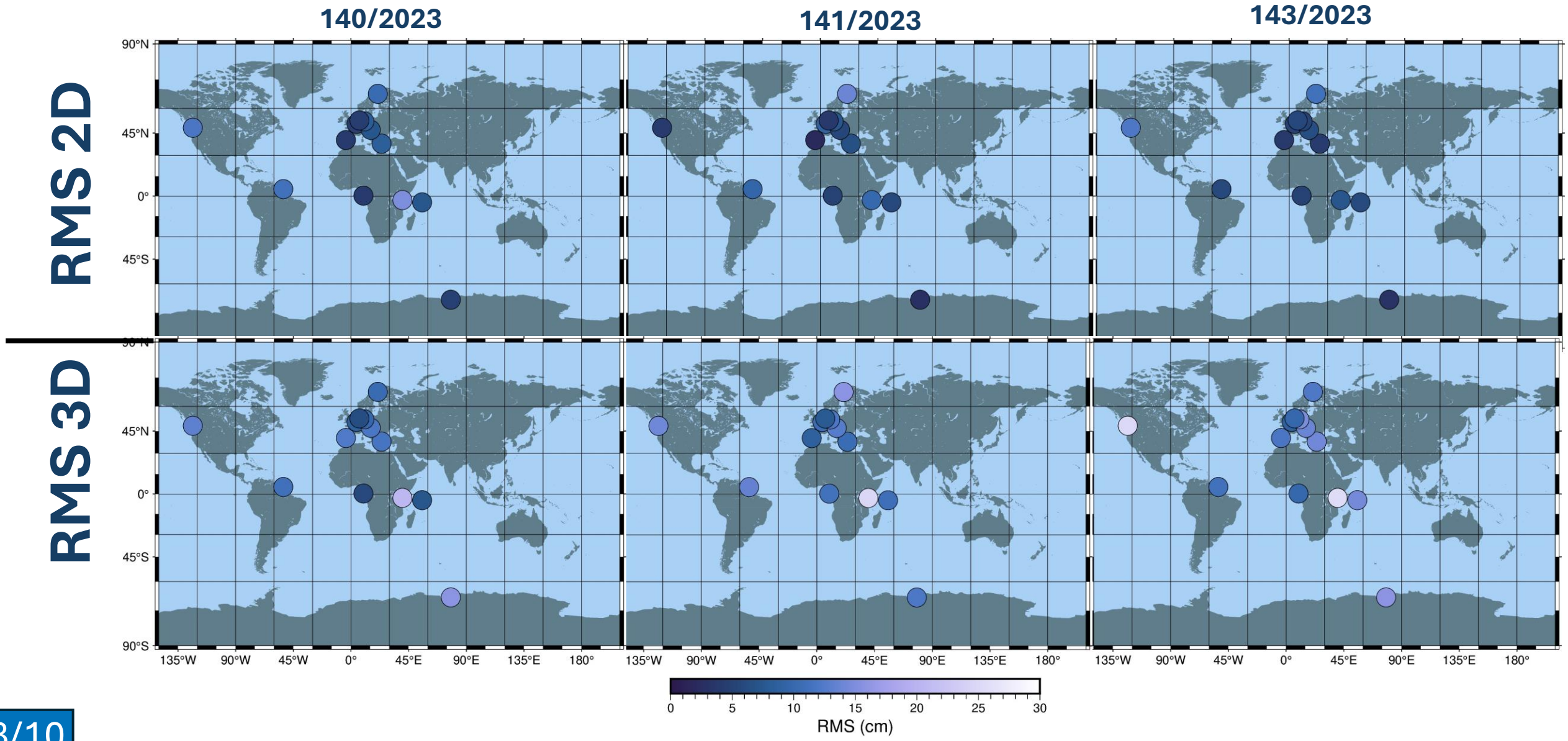


Data processing with world-wide IGS Stations

- 13 IGS Stations from **high/mid/low** latitudes were used in Uncombined Precise Point Positioning
- GPS: L1 + L2
- Galileo: E1C + E5b
- The same data processing strategy was applied.
- 2nd order polynomial model for station-based VTEC modeling.

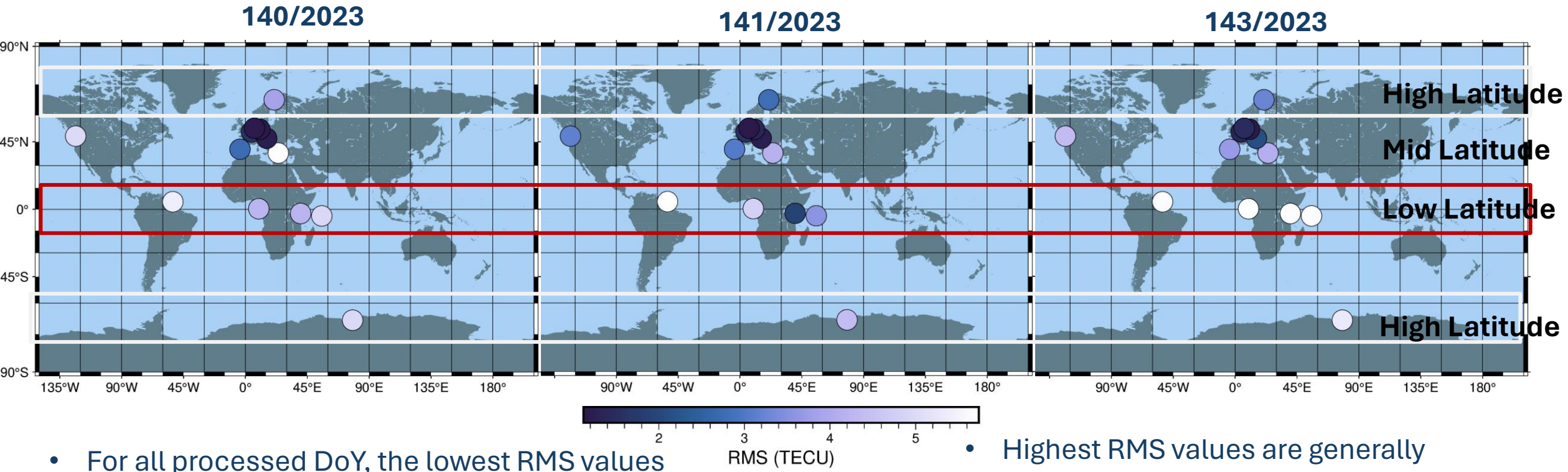


Results of IGS Stations: Positioning Performance



Results of IGS Stations: VTEC Performance

- PPP-VTEC RMSs computed w.r.t CODE Final GIM



- For all processed DoY, the lowest RMS values are placed at mid-latitude stations: ~1-4 TECU. For the DYNG (GRE) station, RMS reaches 4.97 TECU for DoY 140.
- Highest RMS values are generally observed at low-latitude stations. For DoY 143, RMS values vary between 5.2-5.7 TECU

Summary

- 13 IGS stations and two additional co-located stations were processed
- Initial positioning performance of Galileo HAS **in general**
  - Around 5 to 10 cm RMS for horizontal
  - Around 8 to 20 cm RMS for vertical
- **Initial PPP VTEC performance with Galileo HAS is promising**
- Closest values to CODE Final GIM were achieved at mid-latitude: ~1 to 4 TECU
- Results for high-latitude stations (from Sweden & Antarctica) → 3 to 5 TECU variations
- VTEC from Low-latitude stations have differences up to 5.7 TECU.

Thank you for listening!..

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All Results

DoY 140

		East	North	Up	TEC
Mid-Latitude	ALBH	6.78	7.19	8.7	4.3
	BRUX	3.04	2.51	7.93	1.26
	DYNG	6.16	3.58	9.36	4.97
	GRAZ	5.31	3.1	10.25	0.93
	PTBB	6.75	1.62	7.08	0.83
	VILL	3.44	0.67	11.83	2.29
	WRST	2.63	2.61	5.19	0.84
High-Latitude	DAV1	3.97	1.21	15.39	4.28
	KIRU	7.97	3.62	5.83	3.28
Equatorial	KOUR	4.55	8.25	5.98	4.67
	MAL2	8.27	9.41	16.33	3.6
	NKLG	3.46	0.92	4.61	3.62
	SEYG	4.53	4.25	4.12	4.25

DoY 141

		East	North	Up	TEC
Mid-Latitude	ALBH	3.6	2.28	13.49	3.16
	BRUX	9.05	0.57	5.41	1.6
	DYNG	5.86	2.93	8.38	4.15
	GRAZ	4.66	2.94	11.53	1.22
	PTBB	6.77	3.41	9.48	1.38
	VILL	1.45	1.48	8.52	3.04
	WRST	2.8	2.87	6.72	1.12
High-Latitude	DAV1	1.55	2.4	11.73	4.41
	KIRU	13.61	2.83	7.82	2.78
Equatorial	KOUR	3.75	8.91	9.36	5.74
	MAL2	7.5	6.63	22.71	1.9
	NKLG	4.4	2.71	10.06	4.81
	SEYG	5.26	2.84	9.23	3.56

DoY 143

		East	North	Up	TEC
Mid-Latitude	ALBH	7.25	9.75	21.88	3.73
	BRUX	4.74	1.68	7.25	0.79
	DYNG	3.96	1.81	13.6	3.47
	GRAZ	6.29	1.42	12.29	1.5
	PTBB	5.18	0.95	14.02	0.53
	VILL	3.94	0.59	11.21	3.06
	WRST	5.04	2.82	8.07	0.87
High-Latitude	DAV1	2.95	1.23	15.67	4.64
	KIRU	9.7	5.76	4.77	2.61
Equatorial	KOUR	5.82	1.14	9.69	5.02
	MAL2	6.86	2.62	24.5	5.04
	NKLG	3.71	3.35	8.57	5.07
	SEYG	5.96	1.02	13.15	5.03