Galileo Terrestrial Reference Frame

(GTRF)

Activities performed by GGSP Consortium
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Outline

- GGSP Consortium
- GGSP Function
- GTRF Implementation
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GGSP Consortium

The Galileo Geodetic Service Provider (GGSP) Consortium consists of 5 partners :

AIUB	**Astro. Institute University of Bern**	**Switzerland**
BKG	**Bundesamt fuer Kartogr. und Geodaesie**	**Germany**
ESOC	**European Space Operations Centre**	**ESA**
GFZ	**Geo Forschungszentrum Potsdam**	**Germany**
IGN	**Intitute Geographique National**	**France**

Consortium Leader is ESOC

The GGSP FOC activities are managed since Sept. 2013 by ESA – Galileo Project through the EC TGVF-OVF contract. Prime contractor for the TGVF contract is GMV, Spain

Main GGSP Functions

- Realisation and maintenance of a highly precise and stable Galileo Terrestrial Reference Frame (GTRF), the basis for all Galileo products and services

Requirement for GTRF:

- The GTRF shall be compatible with the International Terrestrial Reference Frame (ITRF) at a precision of 3 cm (2 Sigma)
- Provide positions and velocities for all Galileo Sensor Stations (GSS)

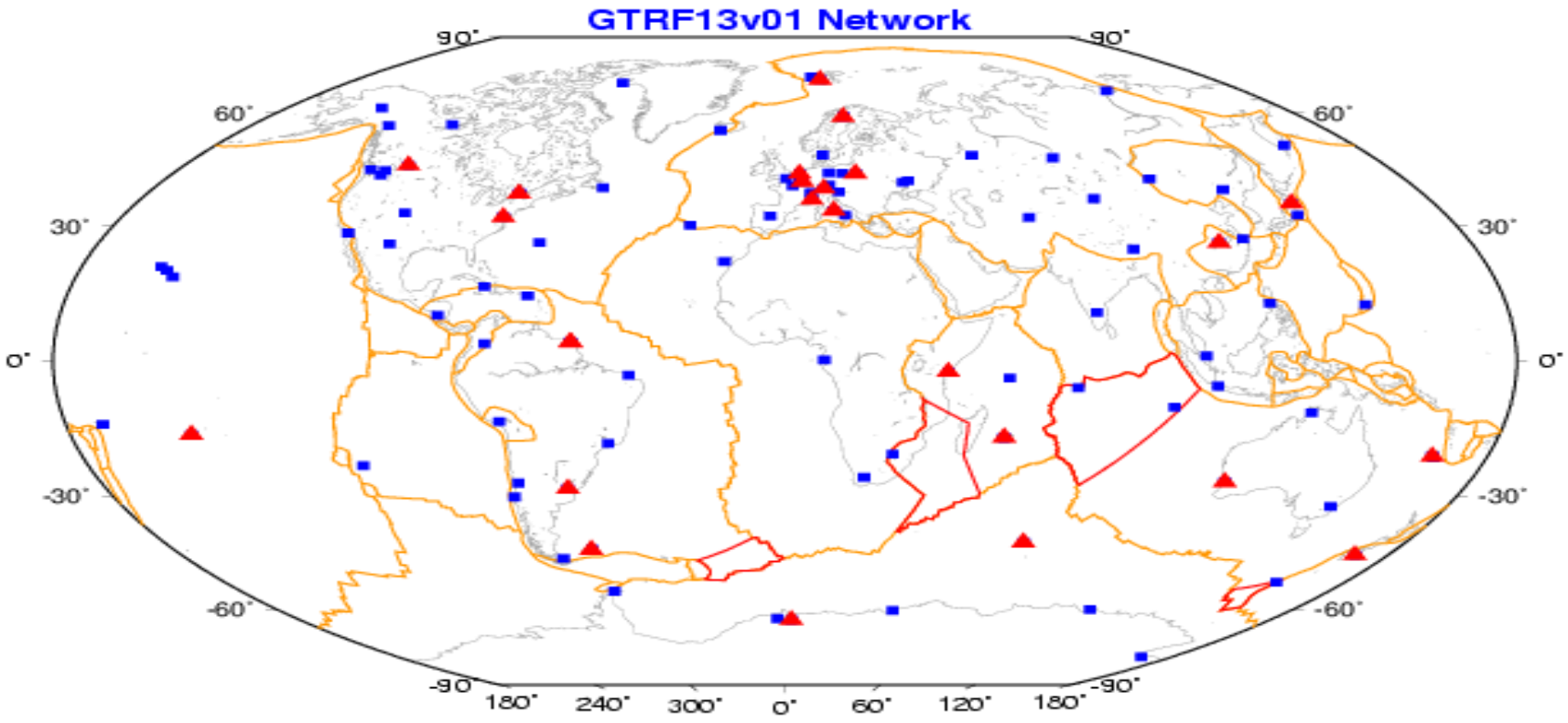
- Additional GGSP products:

  Generation of precise products for

  - Satellite orbits
  - Clock parameters for satellites and stations
  - Earth Rotation Parameters (ERPs)

- Monitoring the quality of products of the Galileo Mission Segment (GMS)

GTRF Tracking Network



GTRF13v01 network.
blue squares: ITRF/IGS stations
red triangles: GESS/GSS sites

GTRF Implementation

- Weekly solutions (station positions and ERPs) generated by 3 independent Processing Facilities (PF) (AIUB, GFZ and ESOC)
- Weekly combination of station positions and ERPs
  - Detailed analysis with summary report
  - Combined solution provided in SINEX
  - Quality assessment
  - Transformation to ITRF
- Weekly orbit and clock combination
- Initial GTRF (station positions & velocities) and its updates:
  - Latest GTRF releases
    - GTRF13v01 – on 18 May 2013
    - GTRF13v02 – update of GTRF 13v01 on 27 May 2013

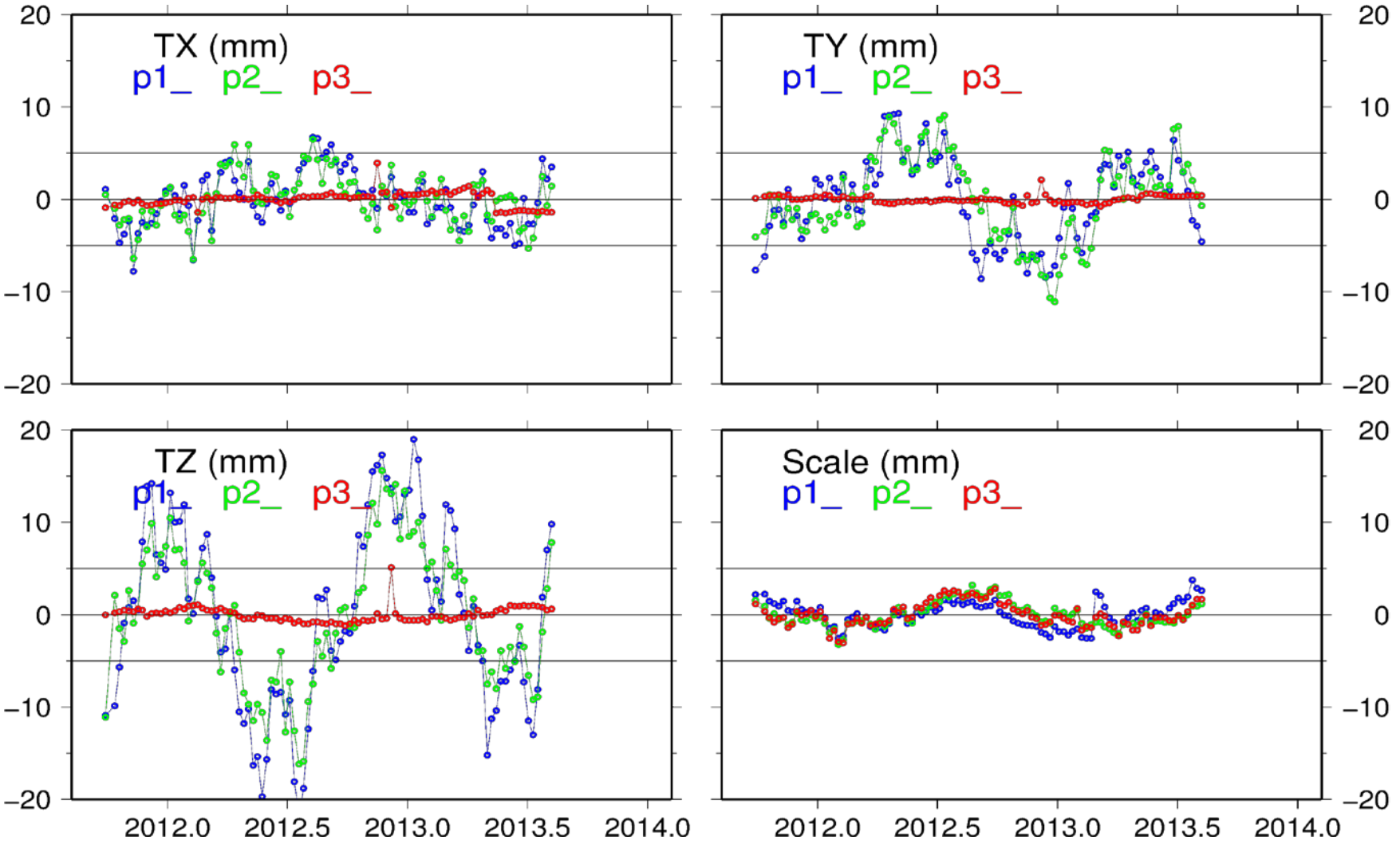
Combination Strategy

- Use Normal Equations from the 3 independent PFs
- Analyse and combine a 3 solutions
- Combine TRF using Minimum Constraint

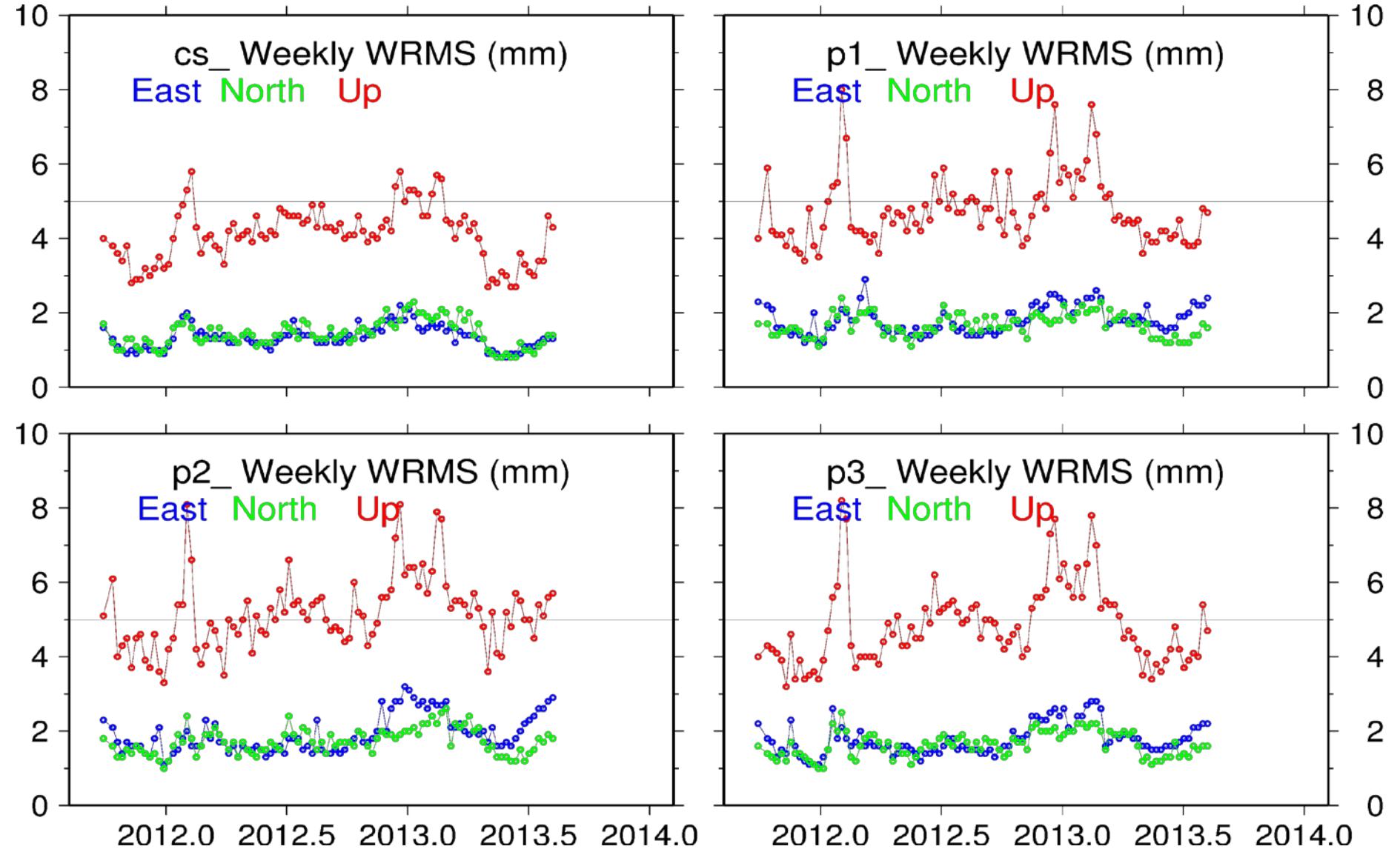
$$X_R = X_c + A\theta \xrightarrow{\boldsymbol{\theta = 0}} (A^T A)^{-1} A^T (X_R - X_c) = 0$$

ITRF — Combined Solution (GTRF)

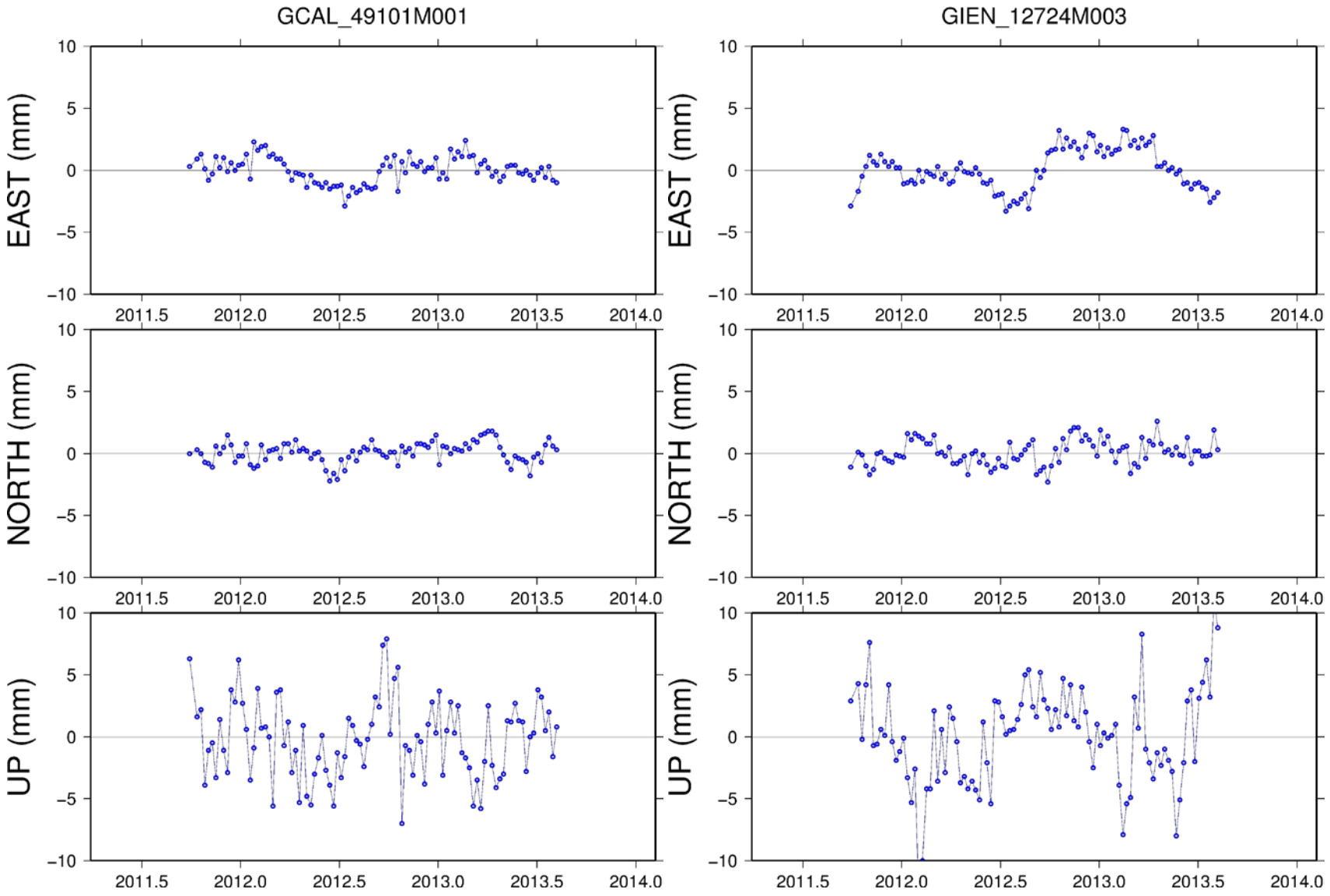
Origin and Scale



Repeatability – Internal Precision



GESS Residuals



Comparison of GTRF13v01 to ITRF2008

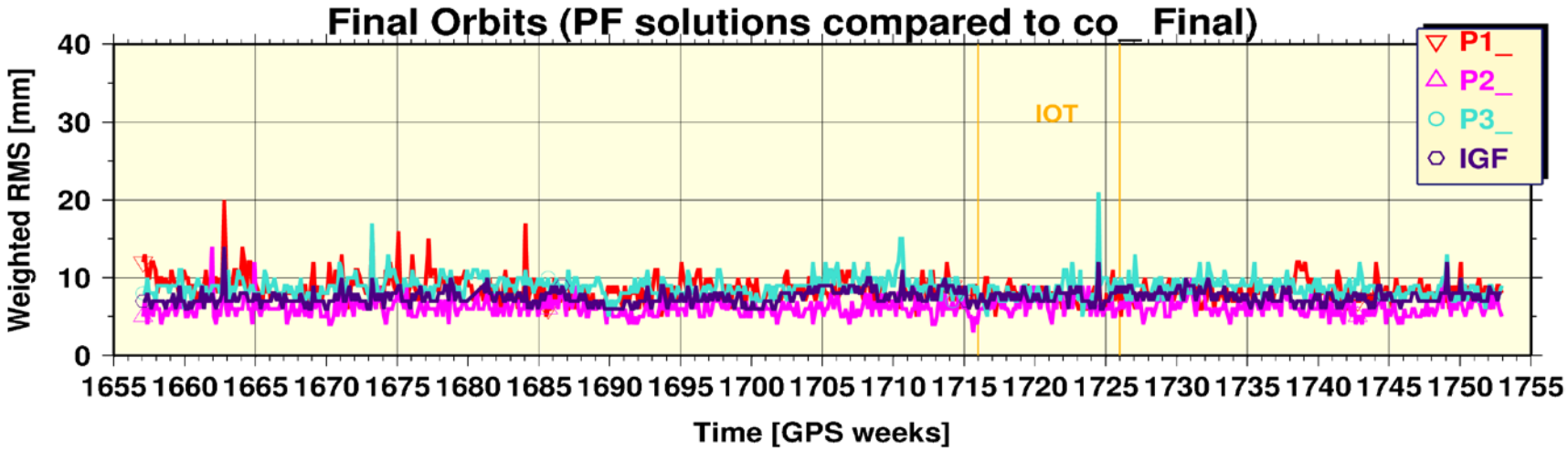
Transformation parameters from GTRF13v01 to IGb08 (ITRF2008)

	T1 mm	T2 mm	T3 mm	D 10-9	R1 mas	R2 mas	R3 mas	Epoch y
	0.0	0.0	0.0	0.00	0.000	0.000	0.000	10:285
+/-	0.2	0.2	0.2	0.04	0.009	0.009	0.010	
Rates	0.0	0.0	0.0	0.00	0.000	0.000	0.000	
+/-	0.2	0.2	0.2	0.04	0.009	0.009	0.010	

RMS differences between GTRF13v01 and IGb08 (ITRF2008) station coordinates and velocities

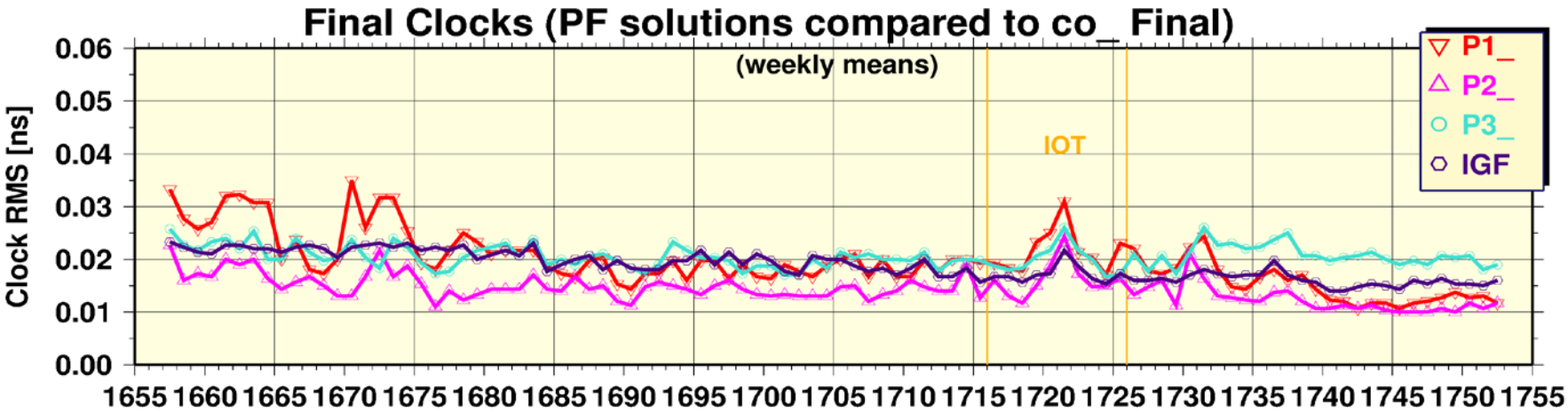
Station #	RMS-Pos. E	N	U mm	Epoch y	RMS-Vel. E	N	U mm/y
91	2.1	1.8	3.7	10:285	0.7	0.7	1.4

Orbit Combination



- **Orbit RMS agreement btw PFs and combined (co_) orbits for GPS satellites**
  - **mostly in the level of 5-10 mm**
  - **co_ difference to the IGS Final is at the same level**

Clock Combination



- **agreement for the clocks shows RMS of about 15 to 25 ps (all biases subtracted)**

Conclusion

- **Very good performance of PFs and GTRF combined solutions repeatability**:
  - 1 - 2 mm Horizontal
  - 2 - 5 mm Vertical
- **Good agreement between PF solutions in origin and scale**
- **GTRF Maintenance**
  - Maintenance as planned
  - The latest release of the GTRF is GRTF13v02
  - Performance meets requirements (with very good margin)
- **Perfect alignment to the ITRF at the sub-mm level**