Galileo Terrestrial Reference Frame (GTRF)

Zuheir Altamimi and the GGSP team

ICG-4 Meeting, Saint-Petersburg, 14-18 Sept., 2009

Outline

- GGSP Consortium
- GGSP Function
- Work performed
- Results
- Conclusion

GGSP Consortium

- "GALILEO Geodetic Service Provider " (GGSP)

  Consortium of 7 partners

AIUB	Astronomical Institute Uni Bern	(Switzerland)
BKG	Bundesamt für Kartogr. und Geodäsie	(Germany)
ESOC	European Space Operations Center	(ESA)
GFZ	GeoForschungsZentrum Potsdam	(Germany)
IGN	Institut Géographique National	(France)
WHU	Wuhan University	(China)
NRCan	National Resources Canada	(Canada)

  lead by GFZ.

The GGSP project was managed by the European GNSS Supervisory Authority (GSA) through EU 6FP funds

Main GGSP Function

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

  Requirement:

  - The GTRF shall be compatible with the International Terrestrial Reference Frame (ITRF) at the precision of 3 cm (2 sigma).

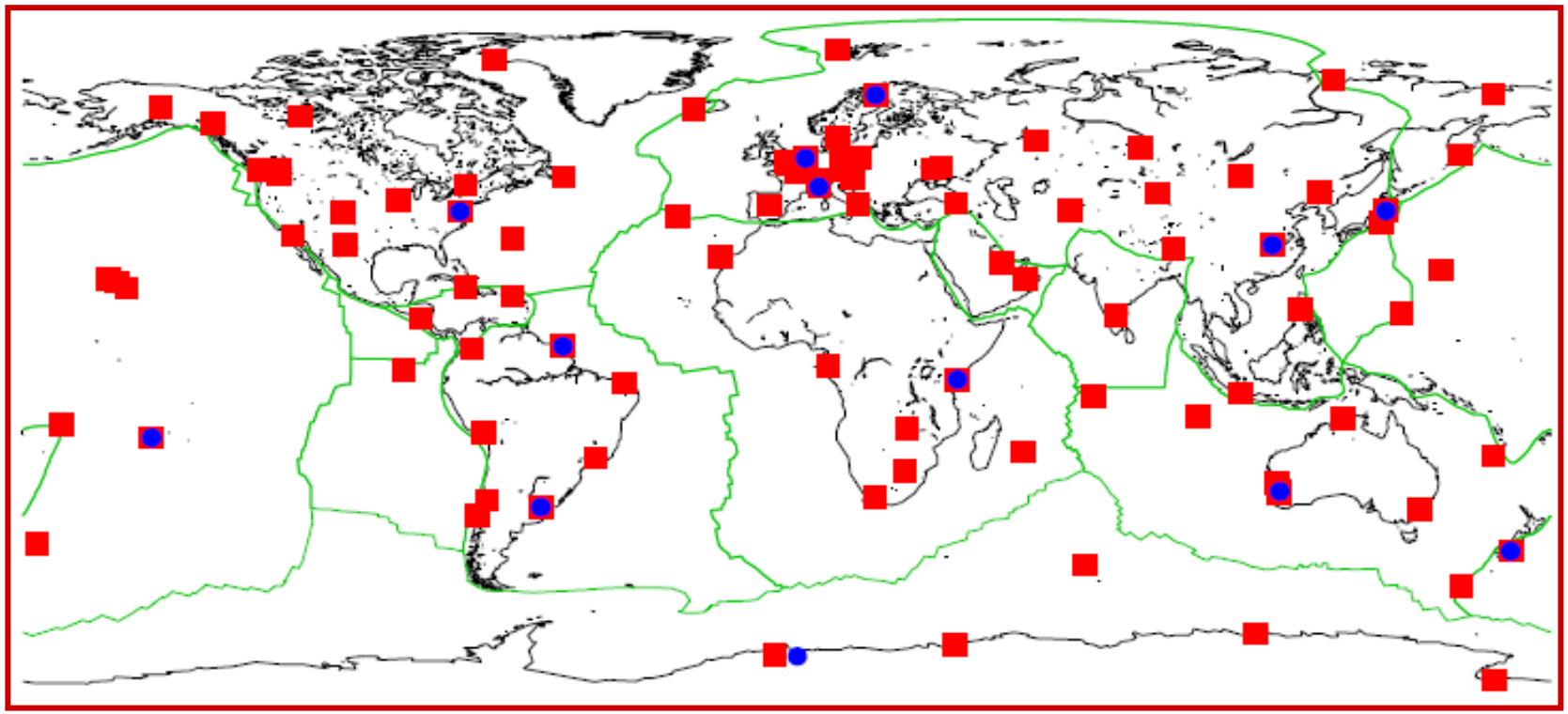
  - Provide positions and velocities for all Galileo Sensor Stations (GSS)

Additional GGSP products:

- **Generation of precise products for**
  - **satellite orbits**
  - **clocks parameters for satellites and stations**
  - **Earth Rotation Parameters (ERPs)**

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

Current GTRF Network

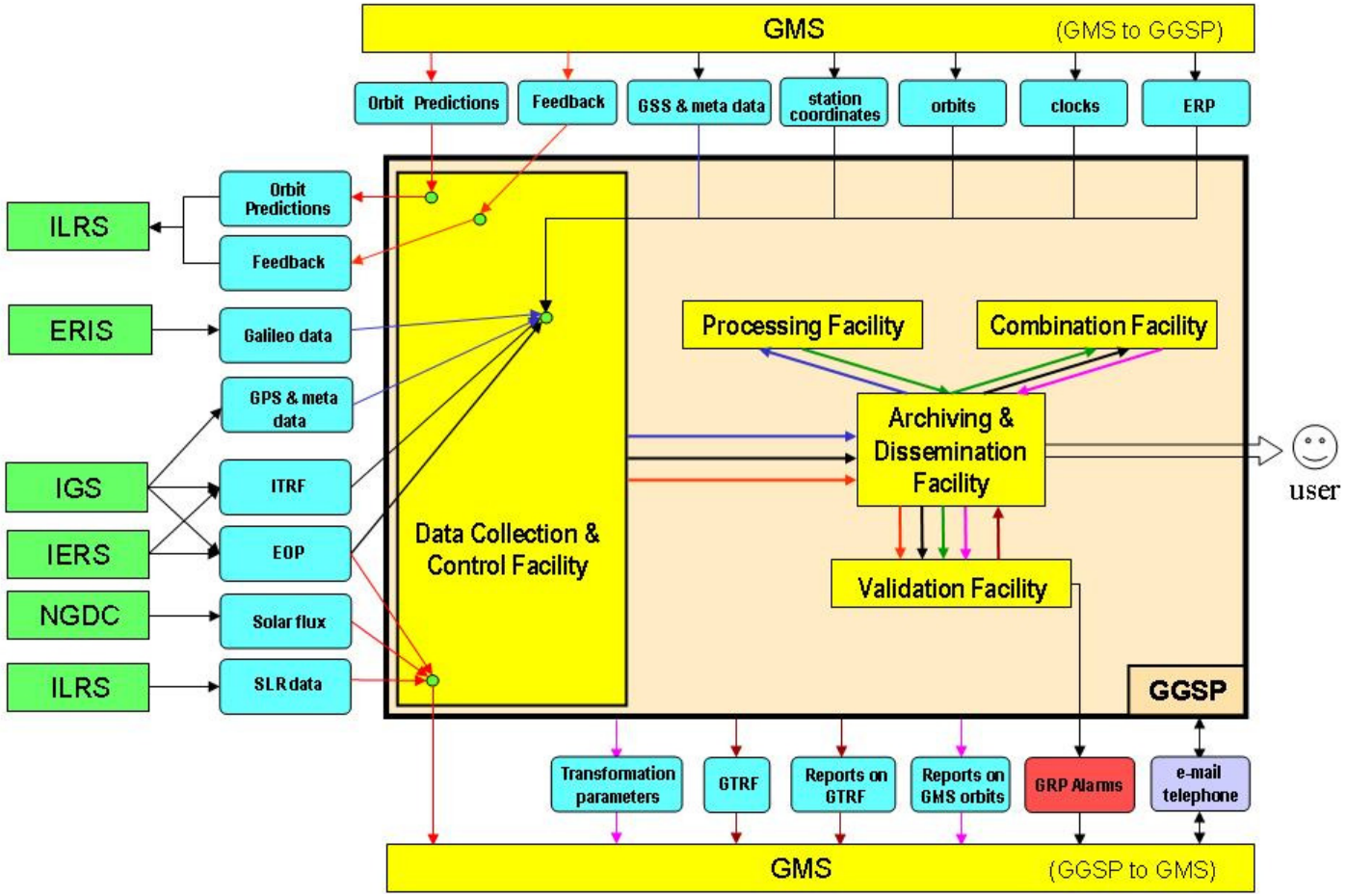


GESS (13) IGS station (~120)

- Initial GSS positions&velocities are determined using GPS observations
- Subsequent GTRF versions using GPS & Galileo observations
- Ultimately Galileo Observations only

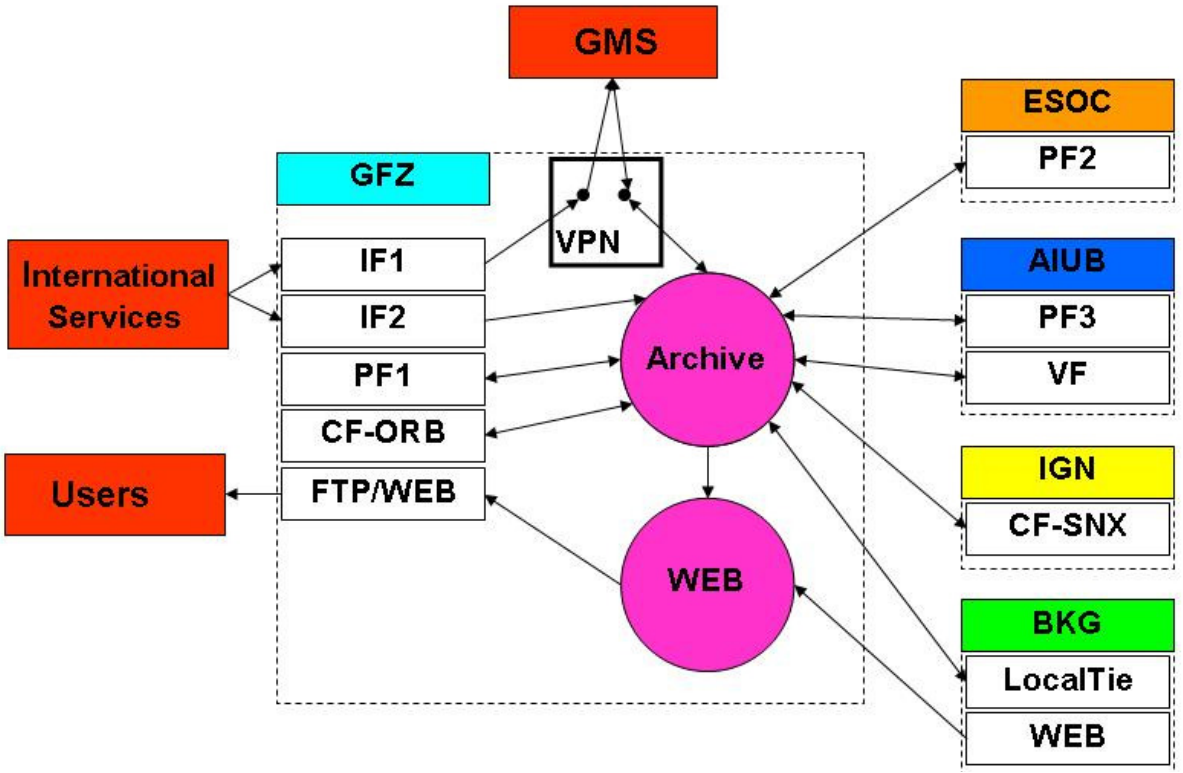
GGSP Facilities

- Data Collection and Control Facility (DCCF)
- 3 Processing Facilities (PF)
- Combination Facility (CF)
- Validation Facility (VF)
- Archiving and Dissemination Facility (ADF)



Location of GGSP Facilities

- Distributed approach for higher reliability
- 3 PFs to ensure quality and reliability of the products



- IF1 –Interface 1 (external for GMS & to GMS)
- IF2 –Interface 2 (for GGSP internal use)

GTRF Implementation

- **Prototype example using 13 GESS stations:**
  - **7 campaigns: 4 weeks each 3 months**
  - **Fictive IOV: continuous processing during 6 months**
  - **Total time span: 2.34 years**

- **Weekly solutions (station positions and ERPs) generated by the 3 Processing Facilities (AIUB, ESOC, GFZ)**

- **Weekly combination of station positions and ERPs**
  - **Detailed analysis with summary report**
  - **Combined Solution provided in SINEX (X & ERPs)**
  - **Quality assessement**
  - **Transformation to ITRF**

- **Weekly orbit and clock combination**

- **Initial GTRF (station positions & velocities) and its updates:**
  3 GTRF versions are available so far.

Combination Strategy

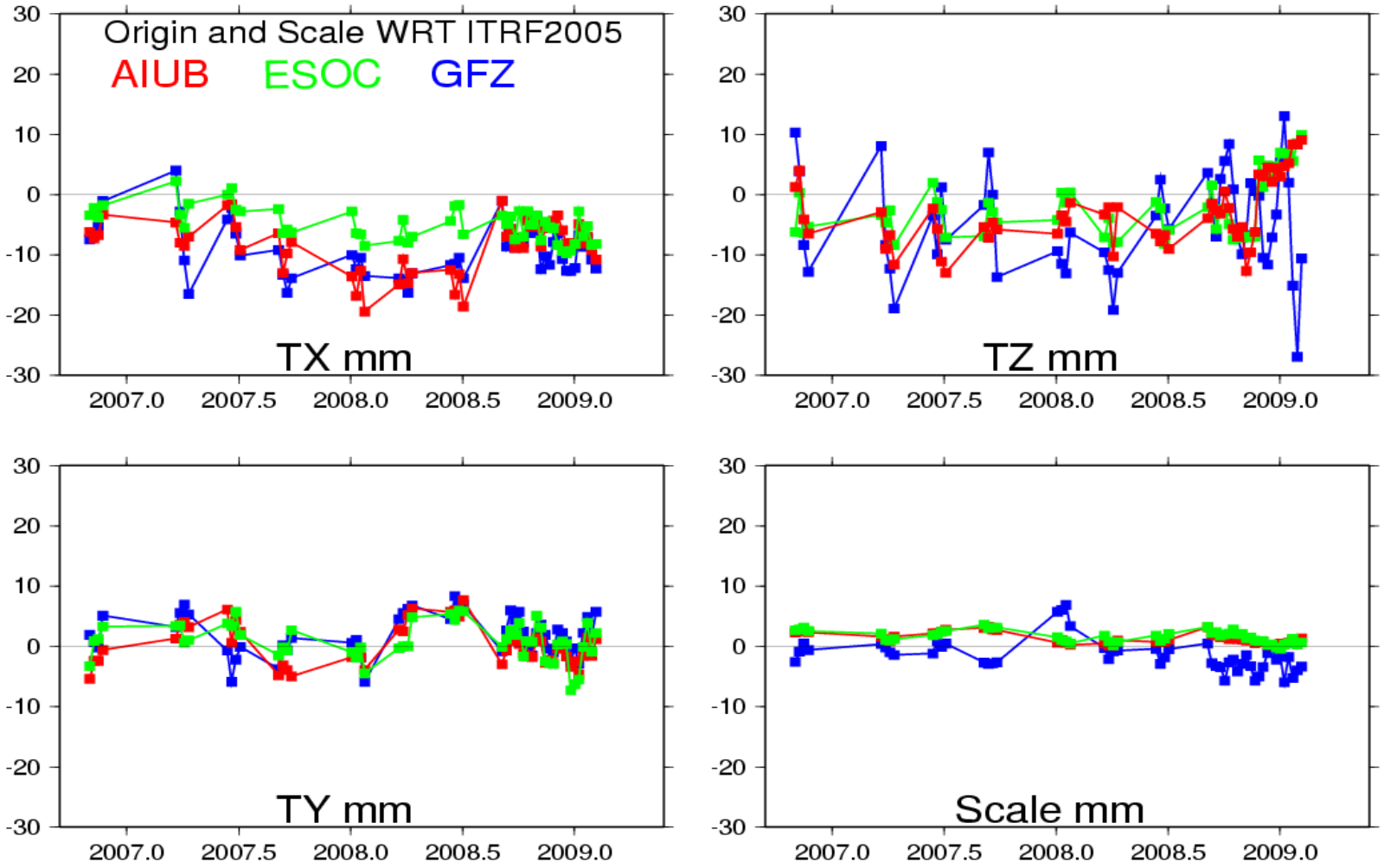
- Use Normal Equations from the 3 PFs
- Adequate for weigthing
- Analyse and combine all 3 solutions
- Combined TRF using Minimum Constraints

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

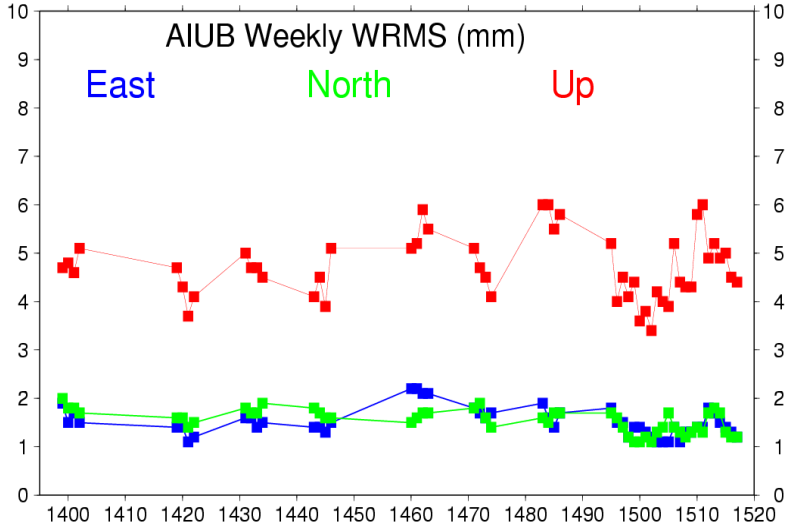
ITRF

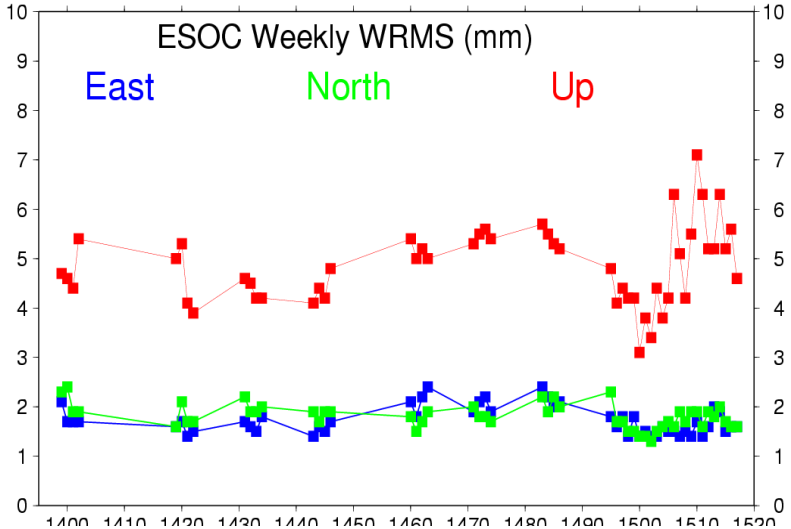
Combined Solution (GTRF)

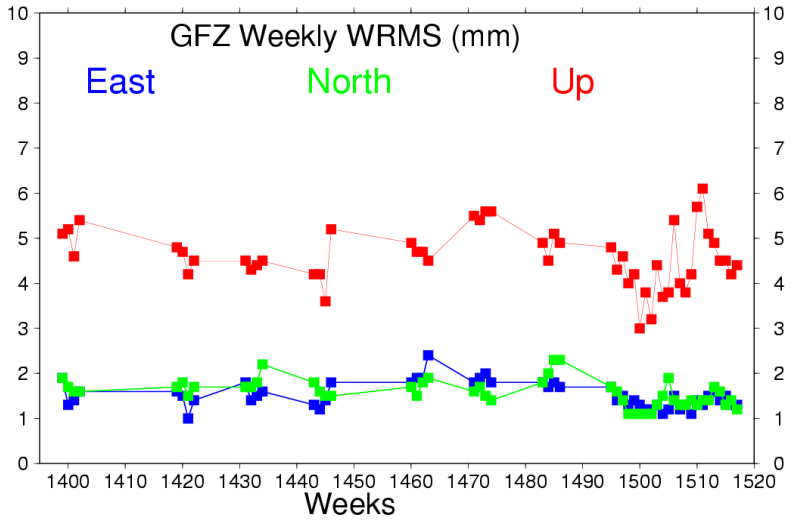
Origin & Scale

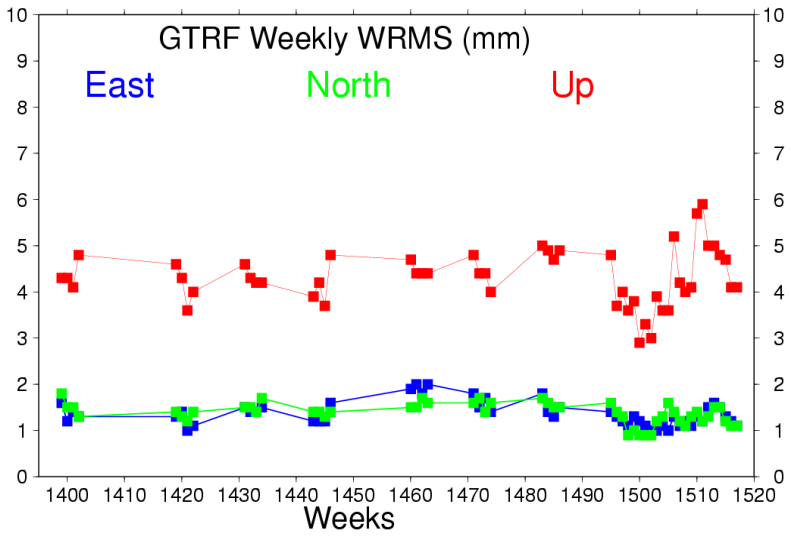


Repeatability – Internal Precision

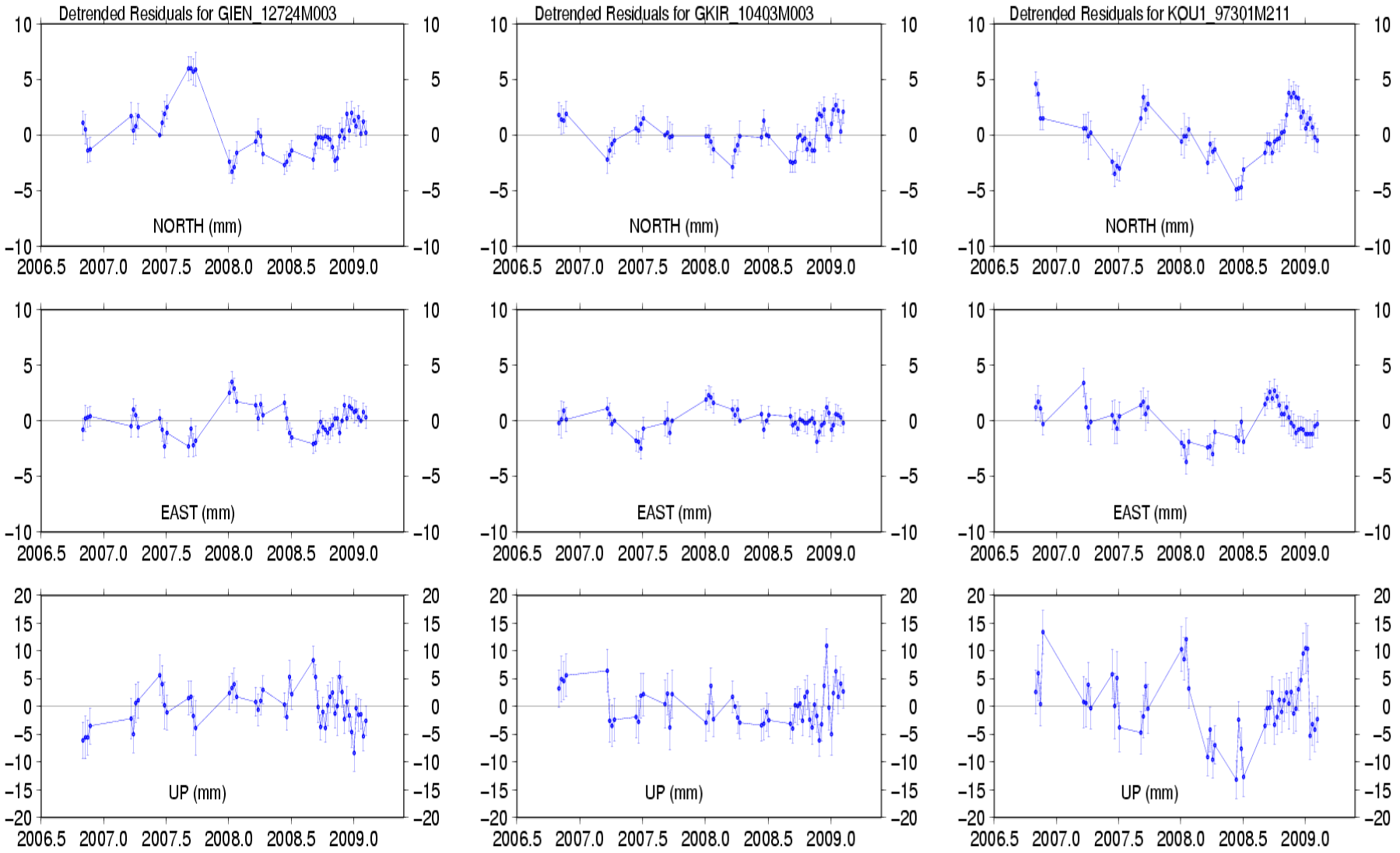




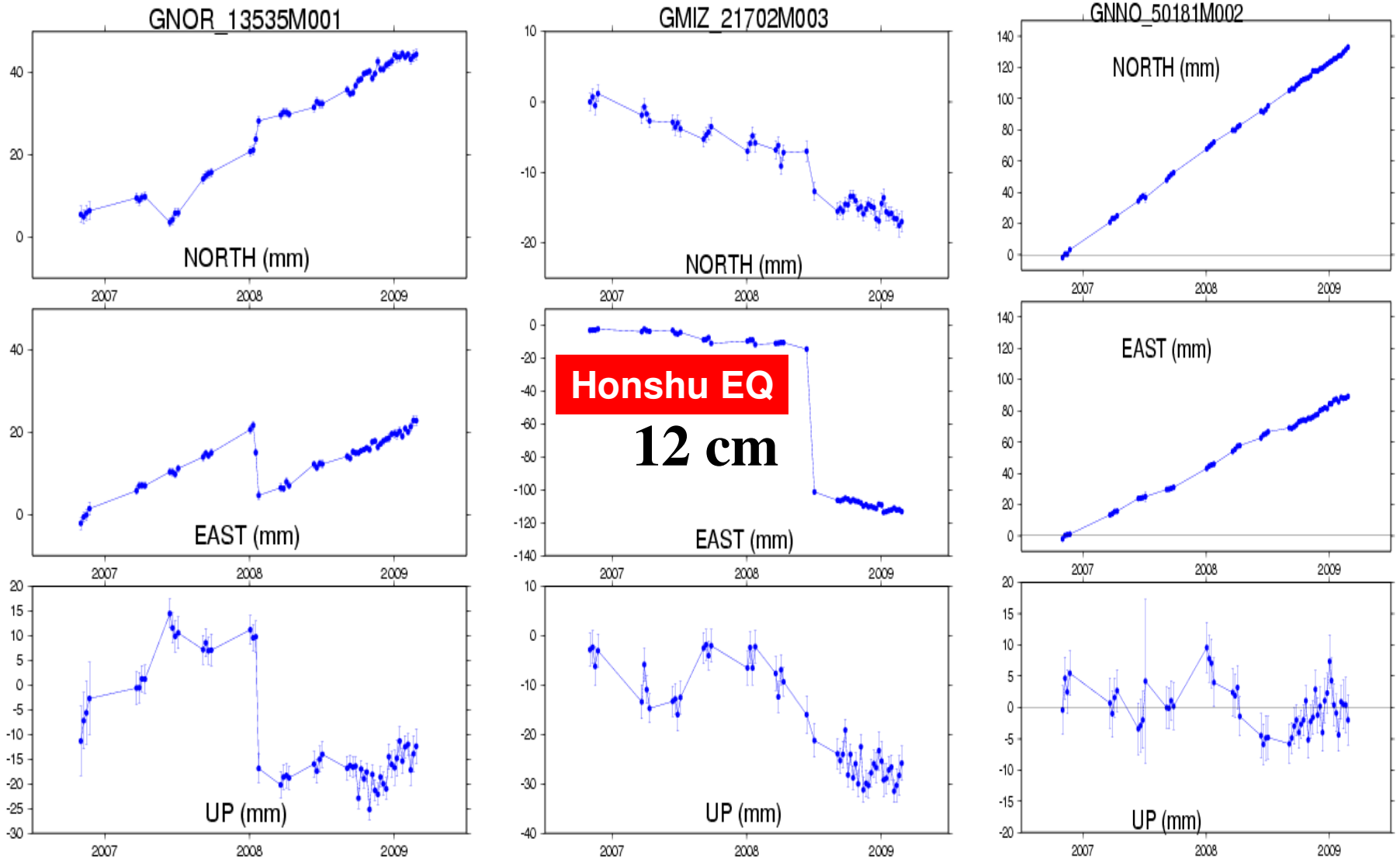




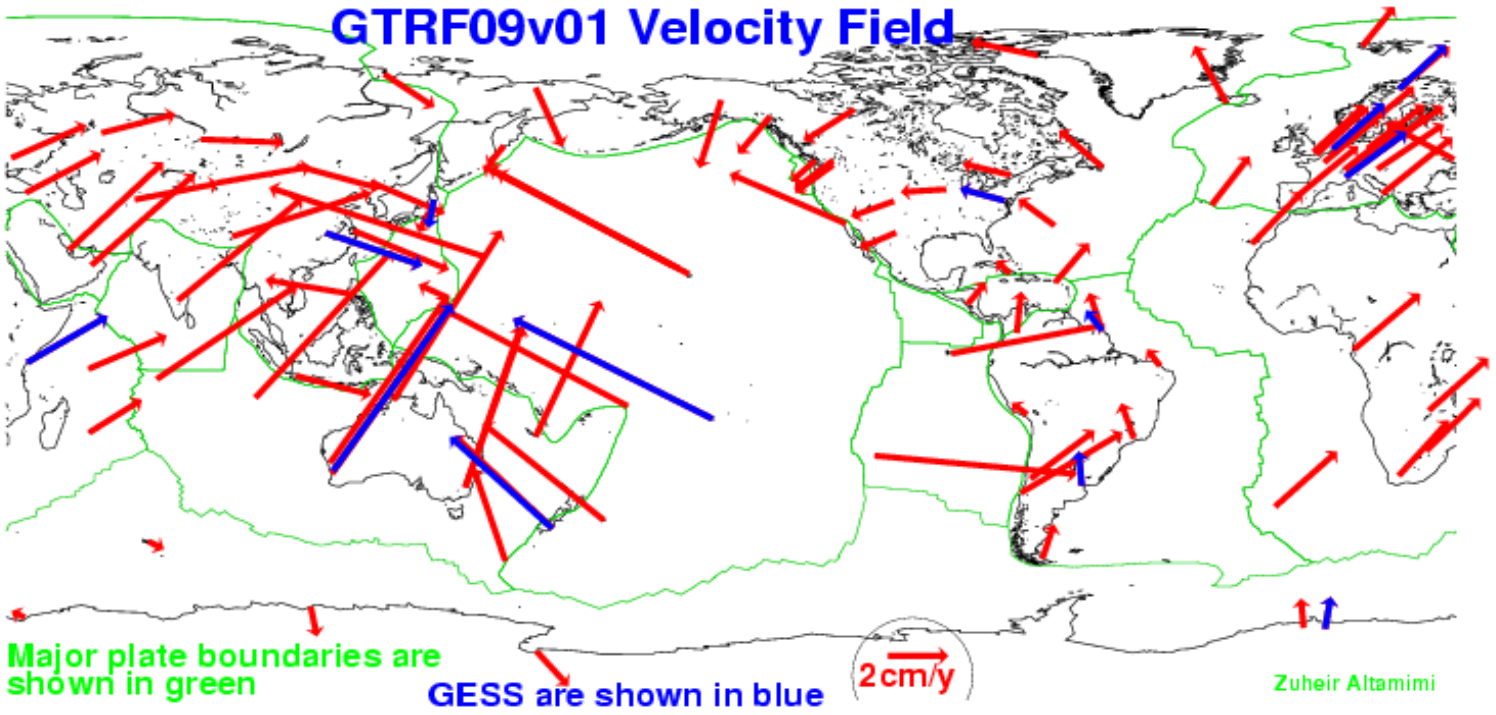
GESS Residuals



GESS Trended time series



GTRF09v01 horizontal velocities



Comparison of GTRF09v01 to ITRF2005

- **Transformation parameters**

	T1 mm	T2 mm	T3 mm	D 10-9	R1 mas	R2 mas	R3 mas	Epoch y
ITRF2005	0.3	-0.3	-0.2	-0.02	-0.003	-0.007	-0.006	7:360
±	0.2	0.2	0.2	0.03	0.007	0.008	0.008	
Rates	0.0	-0.1	-0.1	0.01	-0.001	-0.002	-0.001	
±	0.2	0.2	0.2	0.03	0.007	0.008	0.008	

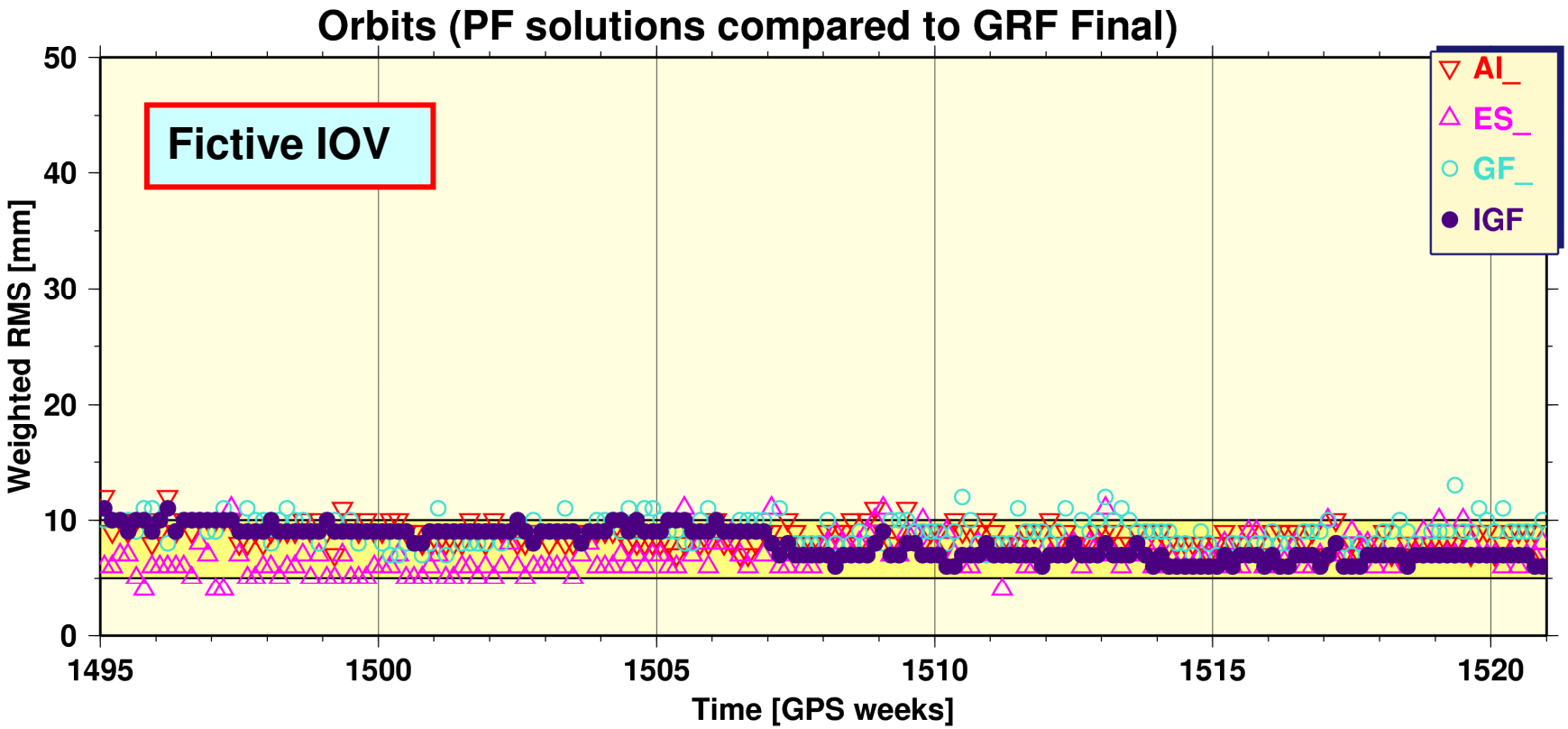
==> Perfect GTRF alignment to the ITRF at the sub-mm level

- **RMS difference between stations coordinates and velocities**

	N	WRMS-Pos. E mm	WRMS-Pos. N mm	WRMS-Pos. U mm	Epoch y	WRMS-Vel. E mm/y	WRMS-Vel. N mm/y	WRMS-Vel. U mm/y
ITRF2005	89	1.0	1.2	2.6	7:360	0.3	0.3	0.6

Orbit Combination

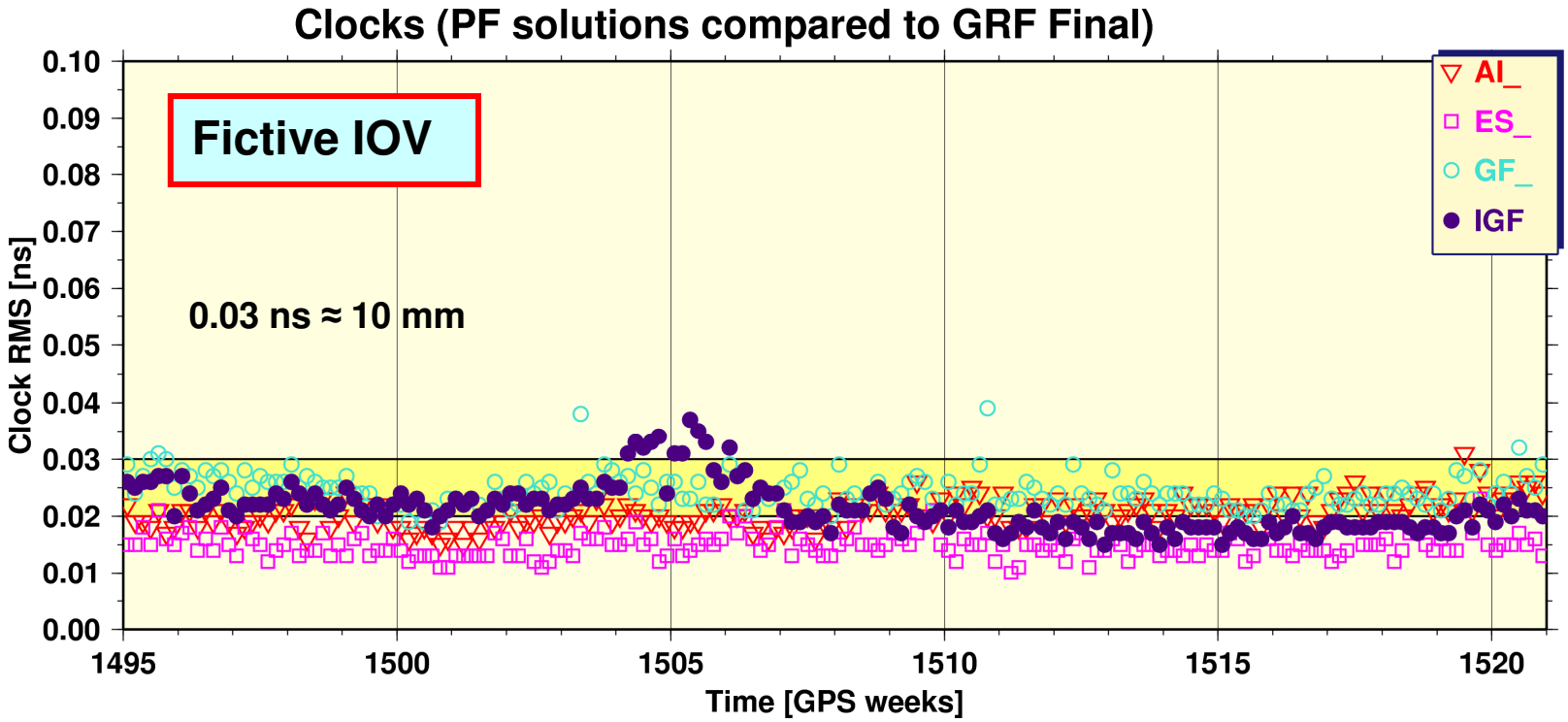
- Orbit comparison (solutions of PFs and IGS Final to combi)
  RMS over all satellites compared to GGSP combi



- PFs compare to combined product by 5 to 12 mm
- GRF orbits agree to official IGS Finals at 7 to 10 mm level (precision of IGS itself).

Clock Combination

- **Clock comparison**
  RMS over all satellites & stations compared to GGSP combi



- **GRF clocks agree to official IGS Finals at 0.02 to 0.03 ns level (RMS).**
  - **Precise Point Positioning with sub-cm accuracy possible**

Conclusion

- **Very good performance of PFs and GTRF combined solutions: repeatability:**
  - **1-3 mm Horizontal**
  - **4-5 mm Vertical**
- **Good agreement between PF solutions in origin and scale**
- **GTRF Maintenance**
  - **Maintenance as planned**
  - **Performance meets requirements**
- ***Three GTRF versions were released so far***
- ***Perfect alignment to the ITRF at the sub-mm level***
- ***The GTRF is a key element and will be available for the IOV phase***