THE GALILEO TERRESTRIAL REFERENCE FRAME AND THE GALILEO ORBIT VALIDATION FACILITY

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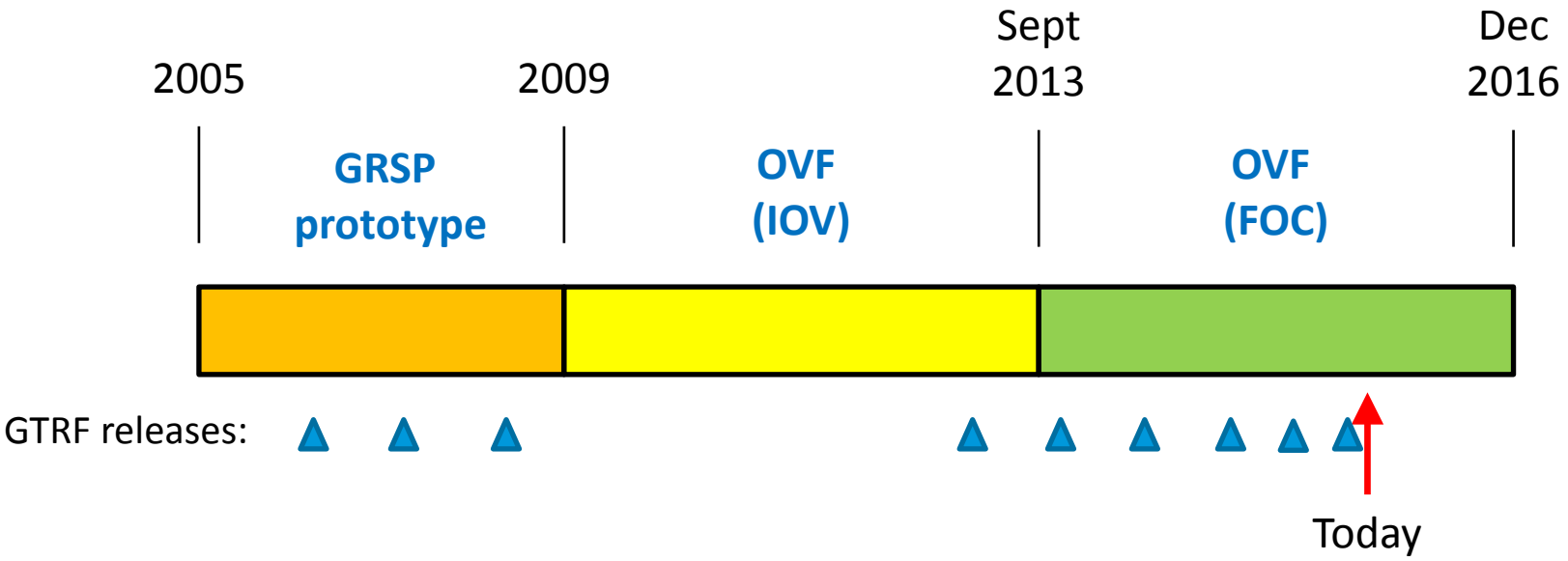
the ESA Project Team
(see last slide)

Scientific and fundamental aspects of the Galileo Programme
Braunschweig, 27-29 October 2015

Overview



Early Stages (1)

- Galileo Joint Undertaking (GJU) 6th framework project: Prototype for Galileo Geodetic Service Provider
- Consortium of 7 partners:
  - GFZ / Helmholtz-Zentrum, GeoForschungsZentrum, Potsdam
  - AIUB / Astronomical Institute University of Bern
  - ESOC / European Space Operations Centre, Darmstadt
  - BKG / Bundesamt für Kartographie und Geodäsie, Frankfurt
  - IGN / Institut National de l'Information Géographique et Forestière (* new name since 2013)
  - NRCan / Natural Resources Canada, Ottawa
  - Wuhan University, Wuhan, China

Important : The 2 non-European partners participated only in the early stage of the project and did not contribute to the GTRF

Early Stages (2)

- Purpose of the activity was:
  - Definition …
  - Realisation …
  - Maintenance …
- of a Galileo Terrestrial Reference Frame prototype
- Kicked off July 2005, extended until 2009
- Based on precise orbit and clock determination by three independent processing facilities (“PF”), all three with a long IGS background

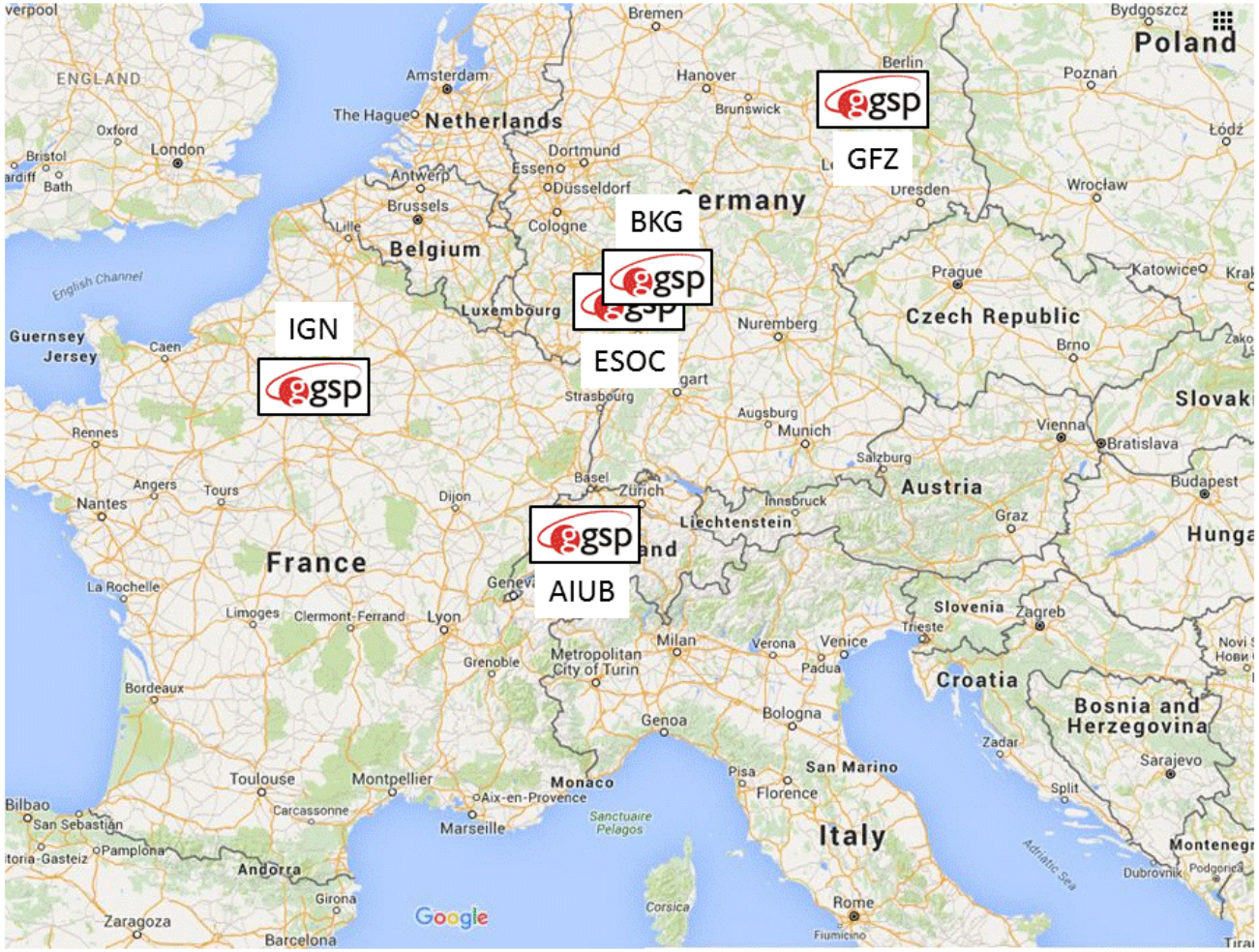
Early Stages (3)

- Initial campaign-based processing
- Continuous processing since September 2008
- Inclusion of Giove-A and Giove-B data
- Three realisations of a GTRF:
  - GTRF 07v01
  - GTRF 08v01
  - GTRF 09v01

From GRSP Prototype to OVF

- New activity defined in 2009: “Time and Geodesy Validation Facility” (**TGVF**)
- Includes “Orbit Validation Facility” (**OVF**)
- Original GTRF deliverables become “OVF service products”
- Additional deliverables: “OVF validation products”
- Five European partners of the original 7 continuing with OVF service delivery as the “GGSP consortium”:
    - AIUB, BKG, ESOC, GFZ, IGN (all European institutes with a strong emphasis on research)

GGSP Consortium



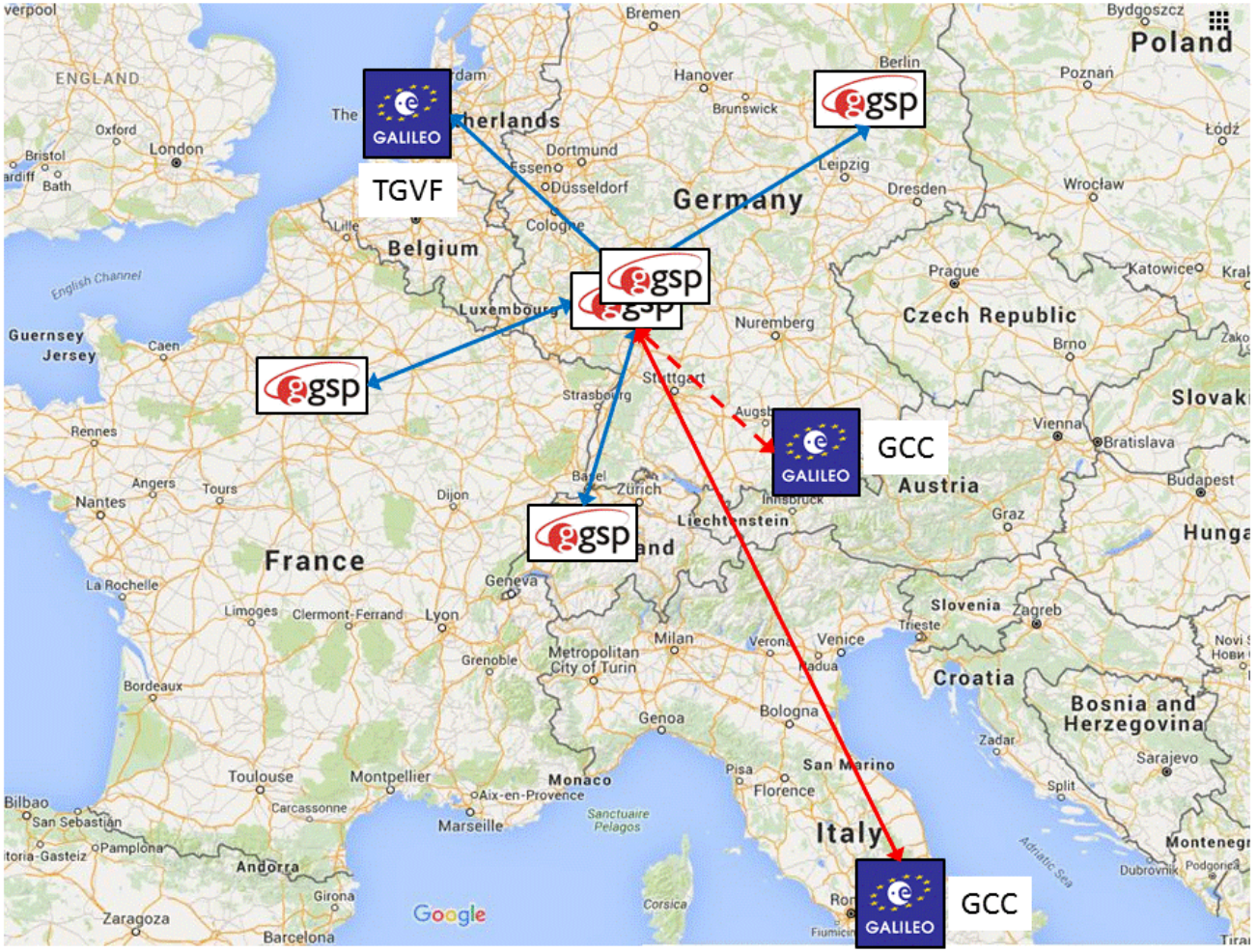
OVF Validation Products Include Weekly…

- Precise Orbit products (from individual PF)
- Precise Clock products (from individual PF)
- Ionospheric and Tropospheric products (PF…)
- SINEX products (PF…)
- Combinations of all above products
- Validation of all above products
- SLR-related products
- … all used for comparison and evaluation purposes in the TGVF

IOV and FOC OVF

- “IOV Phase” from 2009 – 2013
- “FOC Phase” from September 2013, still running
- Changes for FOC phase:
  - Daily (‘rapid’) products delivered in addition to the weekly (‘final’) products
  - Service Level Agreement, with definition of Key Performance Indicators based on accuracy, availability and timeliness
  - Minimum required (average) KPI at 99%

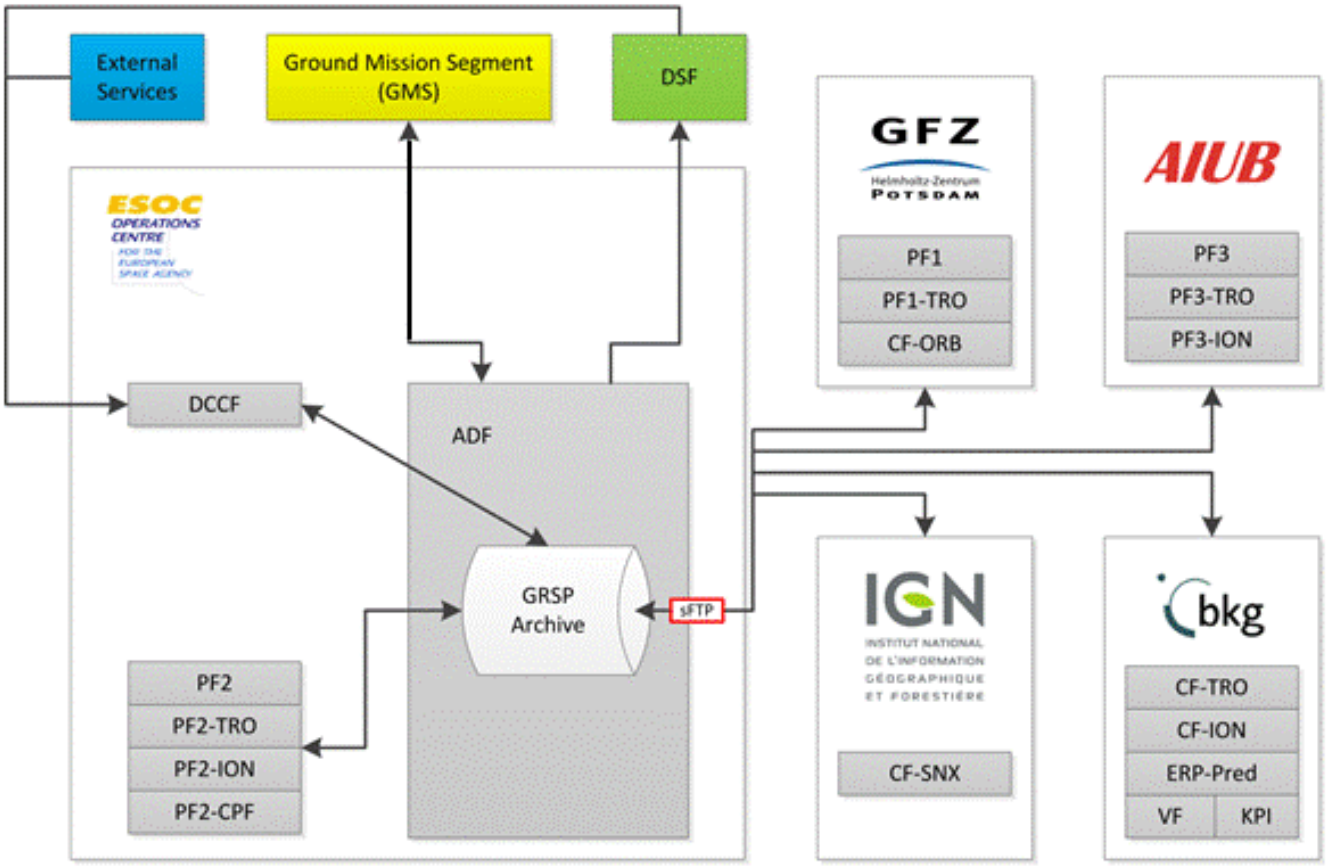
GGSP and Galileo: Interfaces



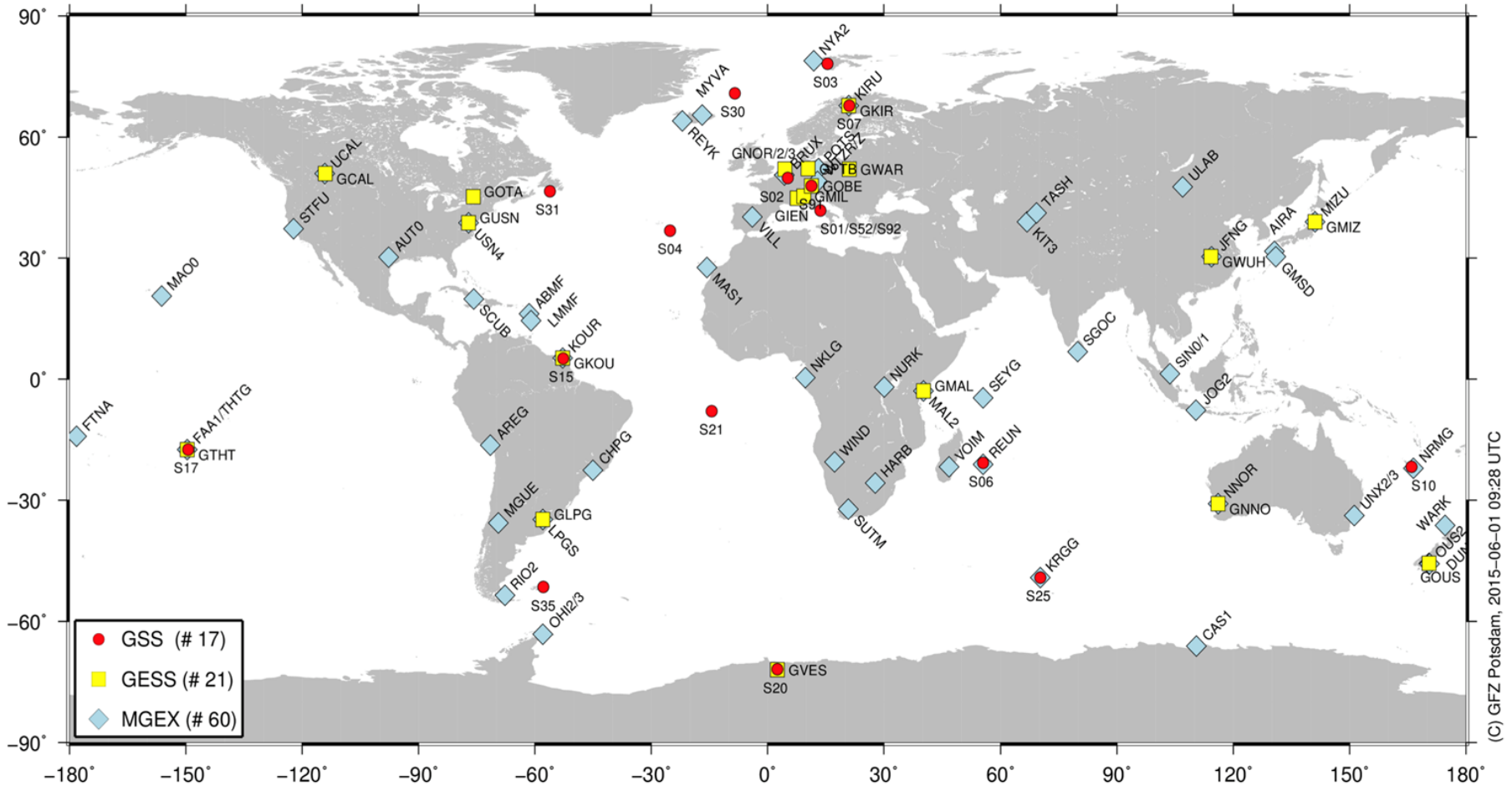
OVF Processing Scheme

- All OVF data stored in central repository at ESOC
- Retrieval and storage of all input data, a.o.:
  - Galileo Sensor Stations (GSS) from GCC
  - Experimental Sensor Stations (GESS) from TGVF
  - External data from various sources
- PF's compute and deliver daily solutions
- Combination Facilities (CF) compute and deliver combinations
- Delivery of Service and Validation products
- Similar cycle repeated weekly for the final products

OVF Task Distribution (FOC)

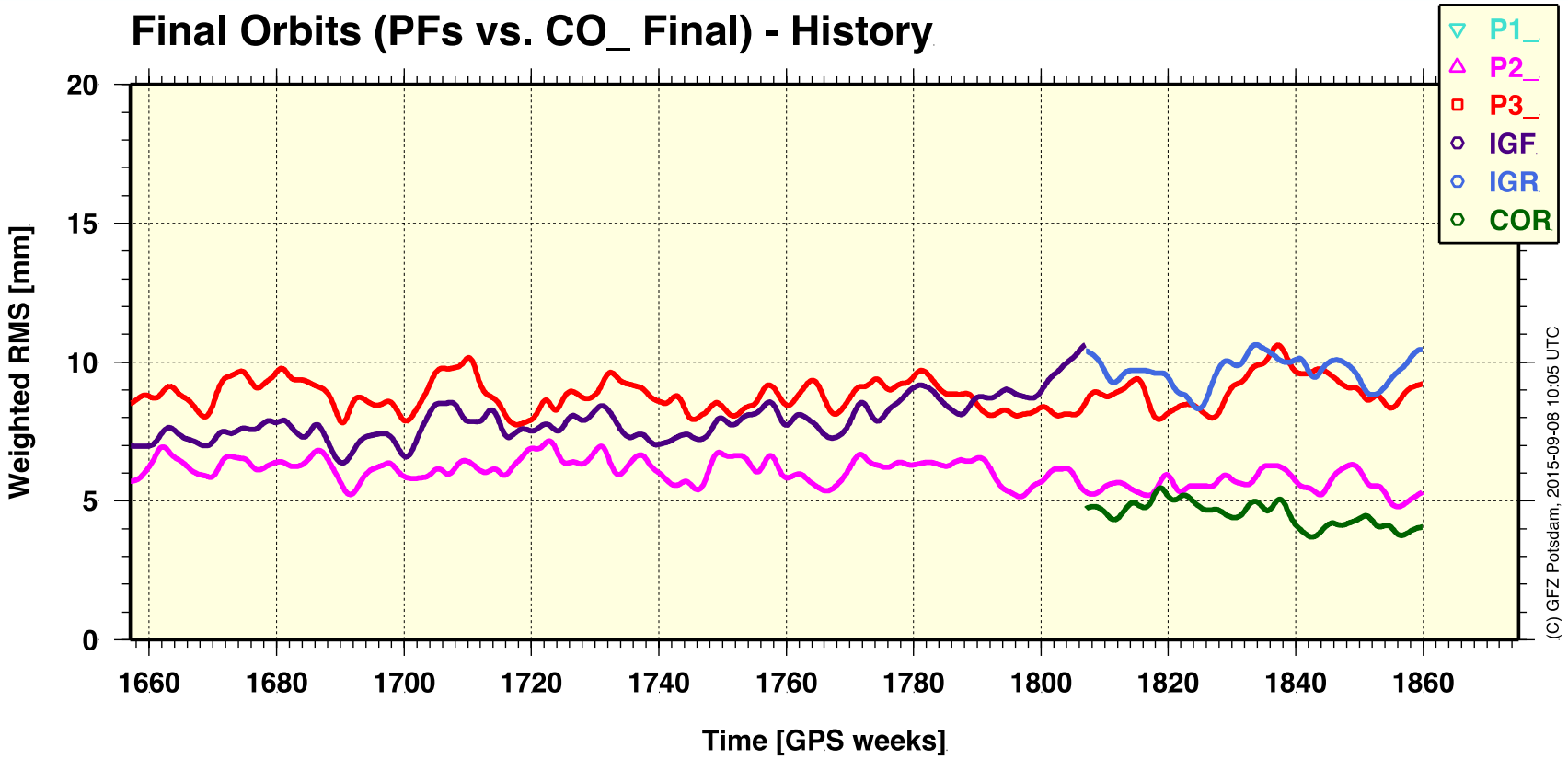


Galileo Tracking Network Used in OVF



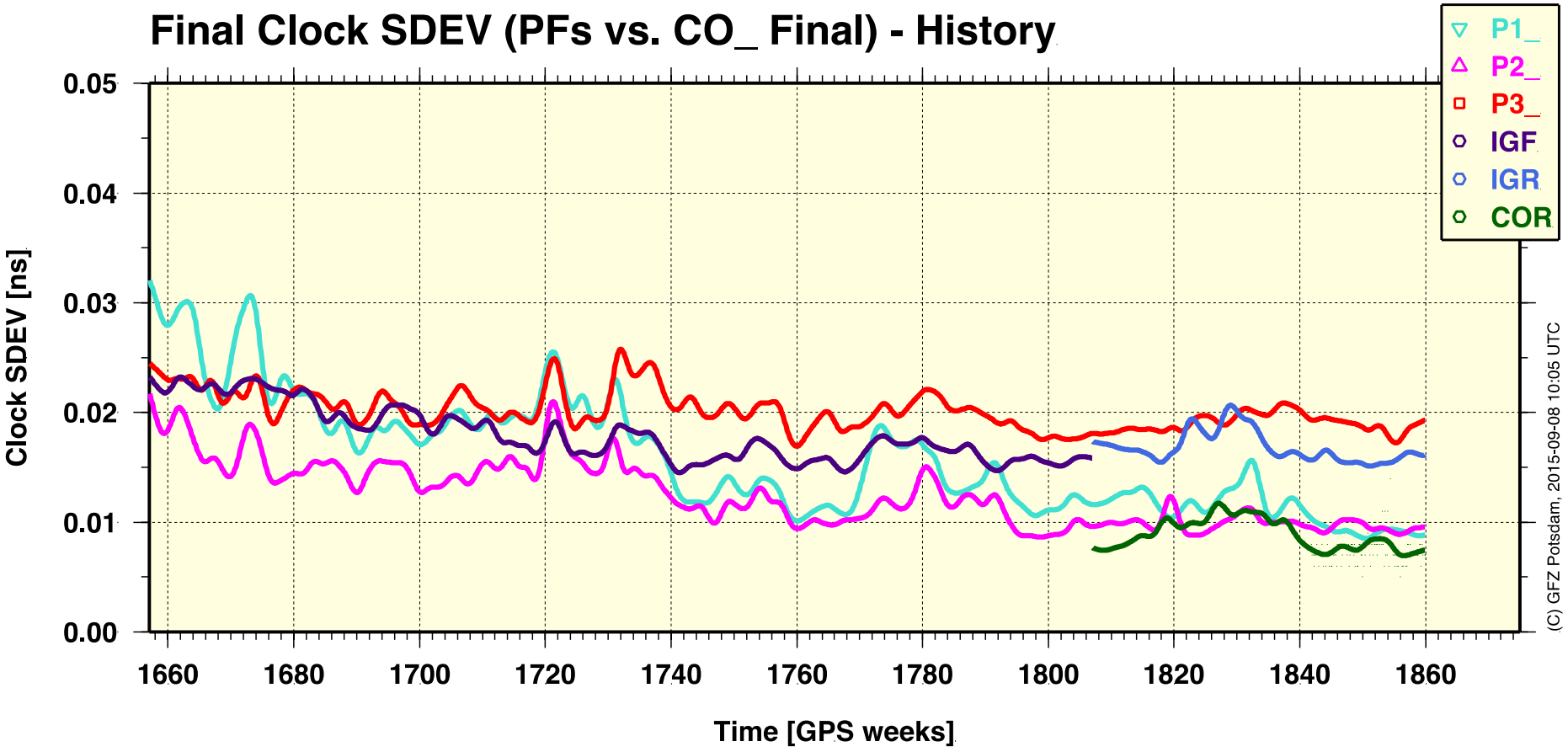
11 MGEX stations are operated by partners of the GGSP consortium

OVF Orbit Quality (from Combination)



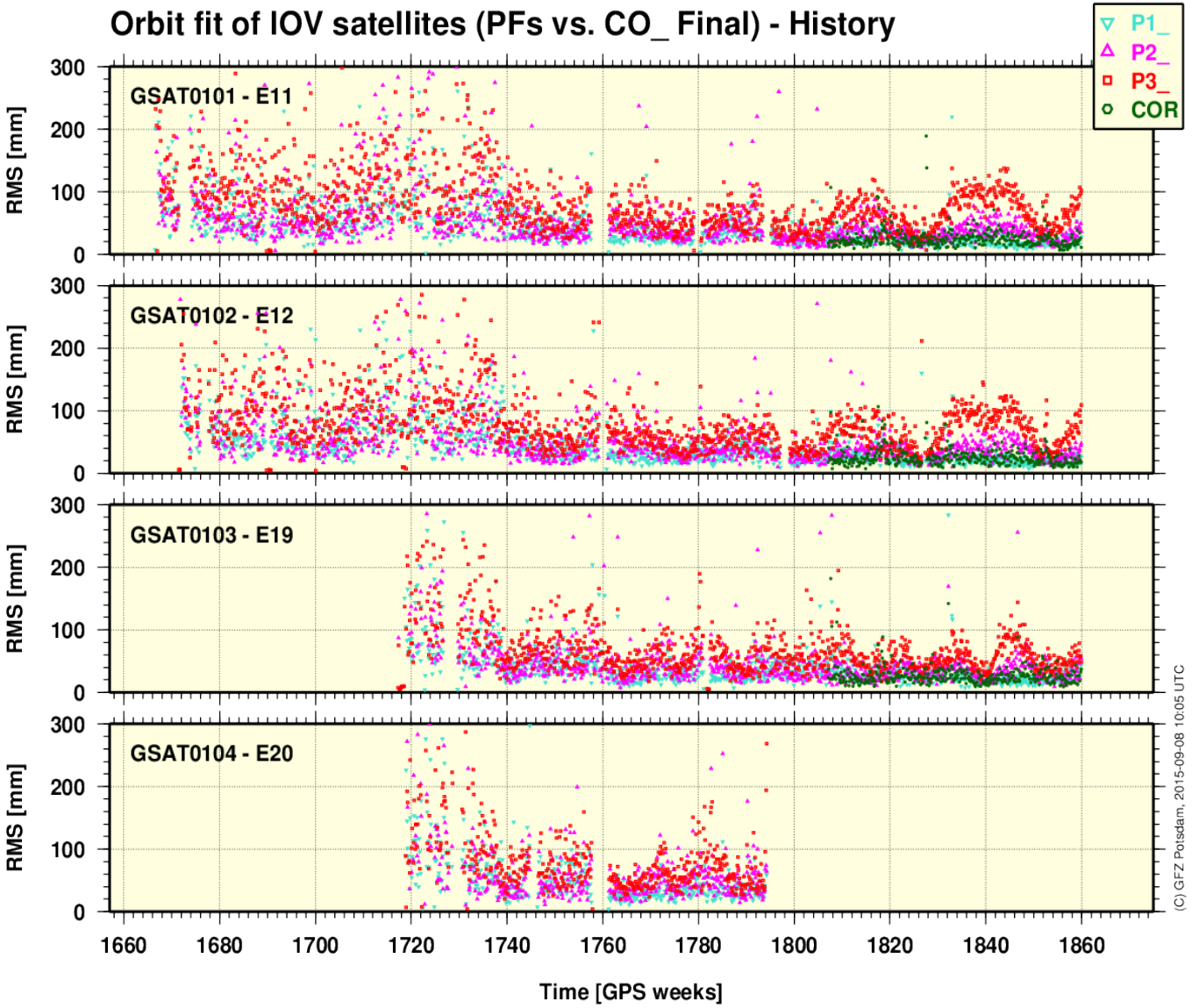
- Orbit RMS agreement btw PFs and combined (CO_) orbits for GPS satellites
  - Agreement mostly at the level of 5-10 mm
  - Combination difference to the IGS Final (IGF) and Rapid (IGR) at the same level
  - COR is the combined rapid product

OVF Clock Quality (from Combination)



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

Galileo Final PF and OVF Rapid Orbit Solutions Compared to OVF Final (IOV)



- Difference between PF and CO_ Galileo orbits are in the range of 5 to 15 cm (with outliers in case of data problems)
- MGEX included since week 1739
- Week 1821/1822: Extension of MGEX station list

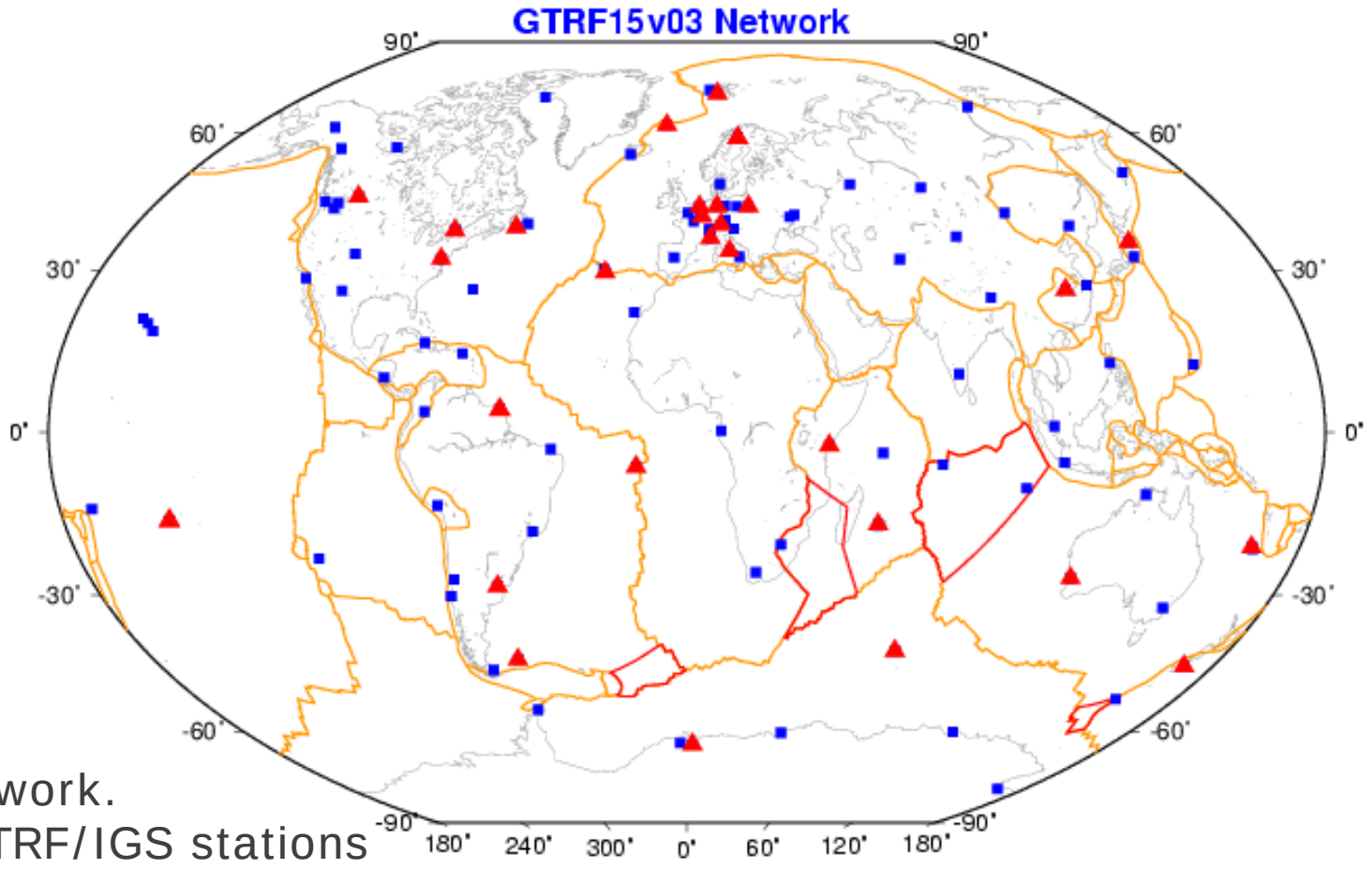
GTRF Generation (1)

- Due to the deployment of new GSS, more frequent GTRF updates were needed:
  - two in 2013
  - one in 2014
  - three in 2015
- GTRF15v03 was released 1 October 2015
- Rigorously aligned to ITRF2008
- In use by Galileo system
- Next update is expected end of 2015 after inclusion of new stations

GTRF Generation (2)

- **GTRF15v03 was obtained by:**
- accumulating (rigorously stacking) the 261 weekly GTRF combined solutions (since 2006)
- Using minimum constraint approach
- It contains 151 stations located in 112 sites
- It is aligned to the IGb08 (ITRF2008) frame over a set of 83 IGS/ITRF stations located in 59 sites
  - 41 in the northern hemisphere
  - 18 in the southern hemisphere

Tracking Network for the GTRF – All Stations

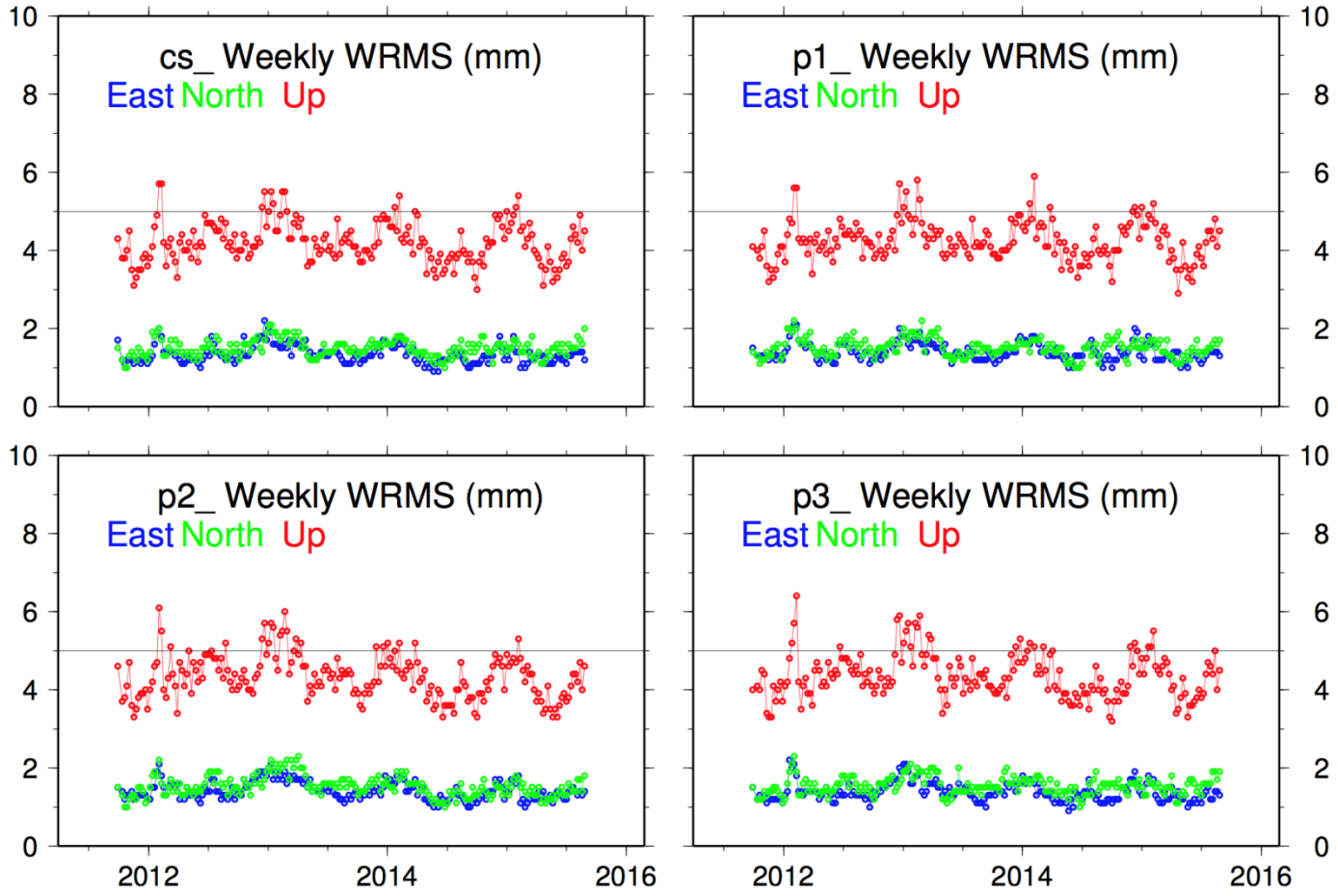


GTRF15v03 network.
blue squares: ITRF/IGS stations
red triangles: GESS/GSS sites

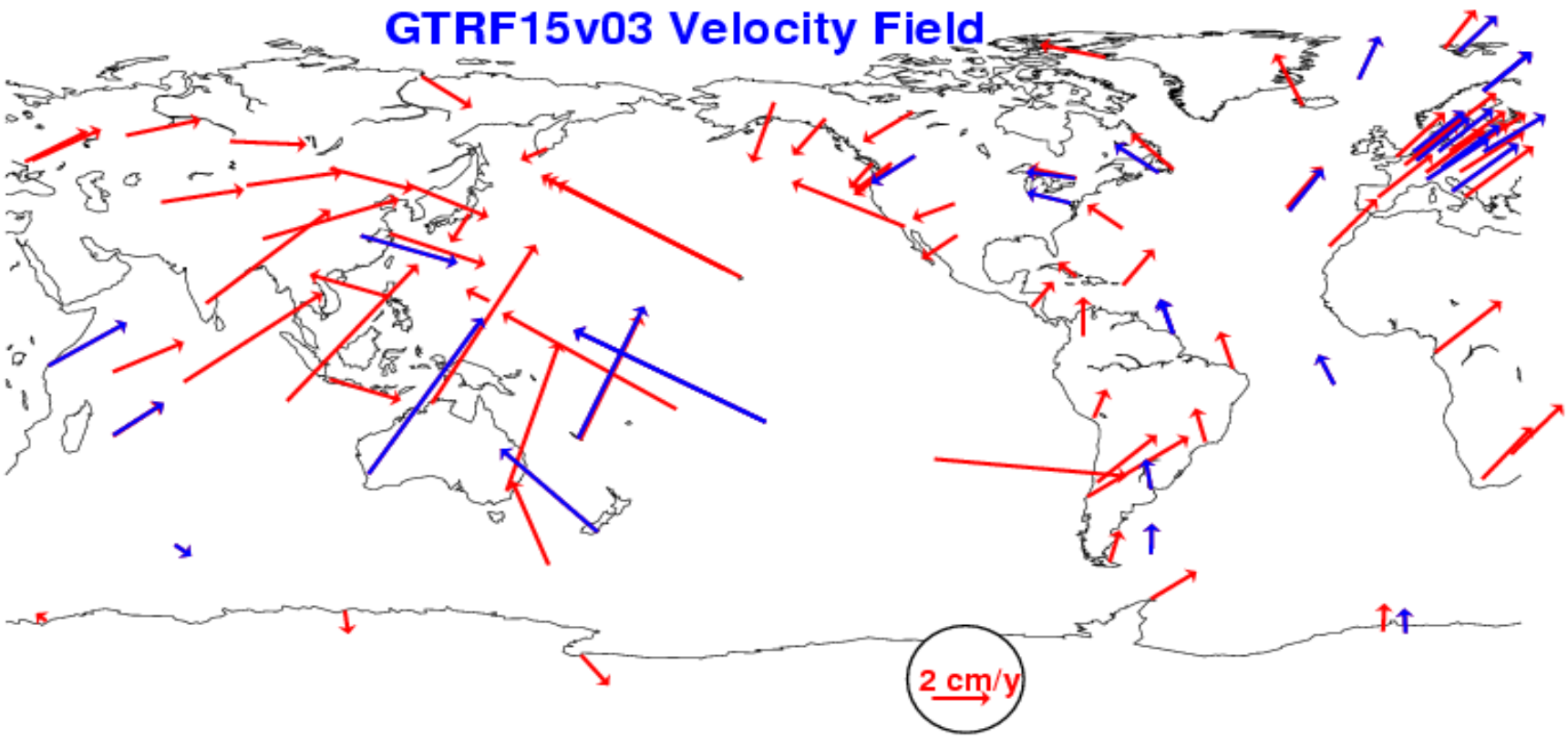
GTRF - Station Coordinates

Weekly WRMS accuracy of all PF's and Combined Solutions station positions is at the level of

- **1 to 2 mm for horizontal components and 3 to 6 mm for the height**



GTRF - Station Velocities



Validation

- Validation is carried out on a weekly basis when the last reference product is available (in general, the IGS troposphere solution)
- Validation result is a weekly summary file
- Example from summary file (week 1859)
- High quality, demonstrated by the RMS of Helmert-transformation (in mm)

		#sites	North [mm]	East [mm]	Up [mm]
GTRF15V02	RMS / COMPONENT	113	2.34	1.80	5.53
IGb08	RMS / COMPONENT	54	4.10	3.41	6.29
IGb08week	RMS / COMPONENT	111	2.14	2.02	5.31

GTRF15v03 Transformation Parameters

- Transformation parameters from GTRF15v03 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	12:212
+/-	0.3	0.3	0.3	0.05	0.012	0.011	0.012	
Rates	0.0	0.0	0.0	0.00	0.000	0.000	0.000	
+/-	0.3	0.3	0.3	0.05	0.011	0.011	0.011	

Acknowledgment to the Teams

GGSP consortium

Bern Univ.: R. Dach, E. Orliac, L. Prange

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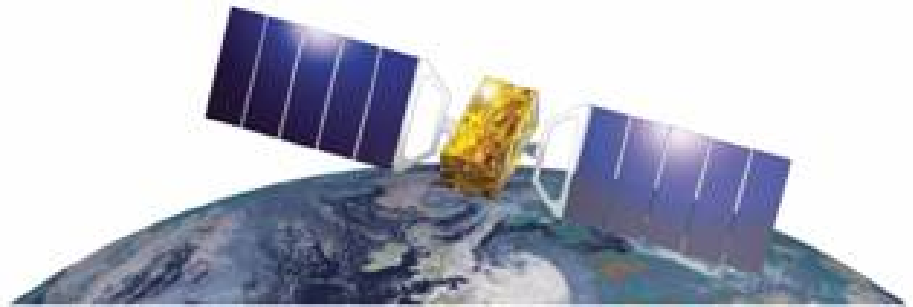
- The TAS-France team during the IOV Phase of TGVF
- The GMV team during the on-going FOC Phase of TGVF

Thank you for your attention, please visit our web site

esa NAVIGATION FACILITY



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