GNSS space clocks assessment based on different IGS and MGEX data

Tung Thanh Thai, Giovanna Signorile, Ilaria Sesia

INRIM and GNSS Time Metrology

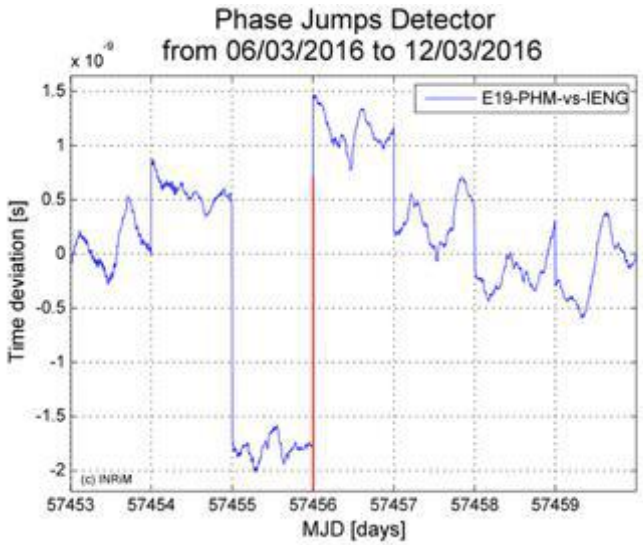
- INRIM is involved in characterization of atomic clocks and timescales in GNSS applications since about 15 years, through different projects with ESA, GSA, Thales Alenia Space, etc.
- Investigations on GNSS experimental data are done on a regularly basis for research activities (automatic detection of clock nonstationarities, statistics on clock frequency jumps, assessment of space clocks performances..) based on IGS and MGEX public data for
  - GPS
  - **Galileo**
  - Beidou
  - GLONASS
- Analysis of space clocks is made in terms of:
  - Time offset after second order drift removal,
  - Normalised frequency offset,
  - Frequency stability (Allan deviation),
  - Frequency drift.

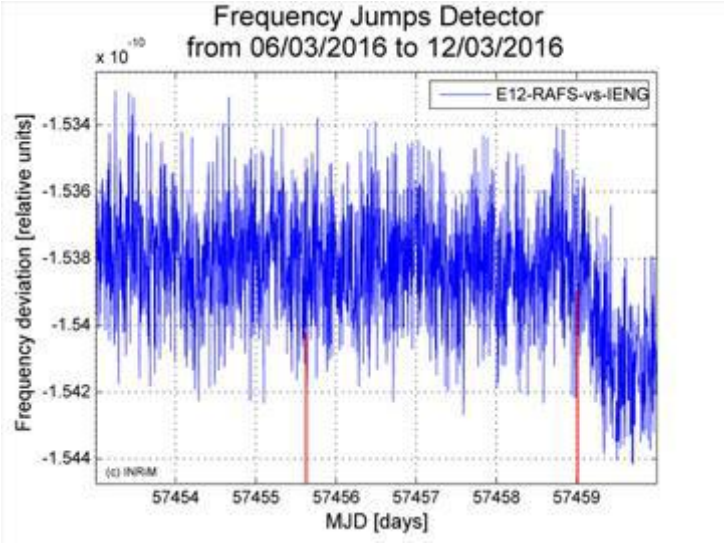
INRIM and the H2020 DEMETRA project

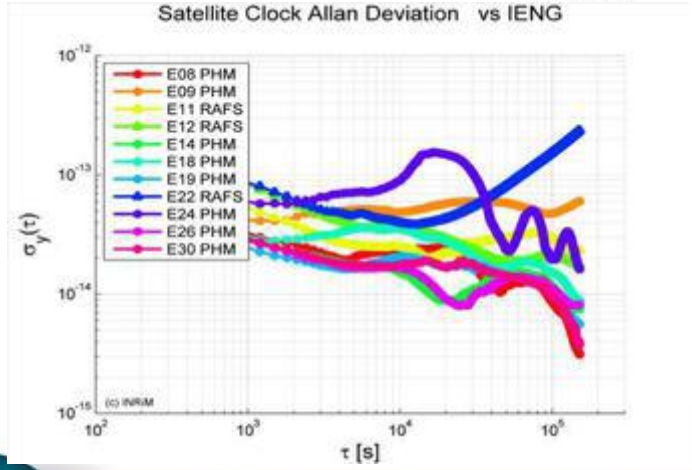
- A project exploiting 9 new time services has been carried out.
- The service **TIME INTEGRITY** is a first step towards a GNSS time integrity service and during the experimentation it was based on the RINEX for clocks available on the IGS/MGEX website.
- An error in the estimate of on board satellites clocks leads directly to a user degraded performance, so a detection in almost real time of possible feared events is crucial for GNSS systems.
- The service **monitor the status of the Galileo satellites detecting possible anomalies and generating automatic alerts in case the satellite have not to be used by the final user**.

https://www.demetratime.eu

DEMETRA project: Time Integrity Service







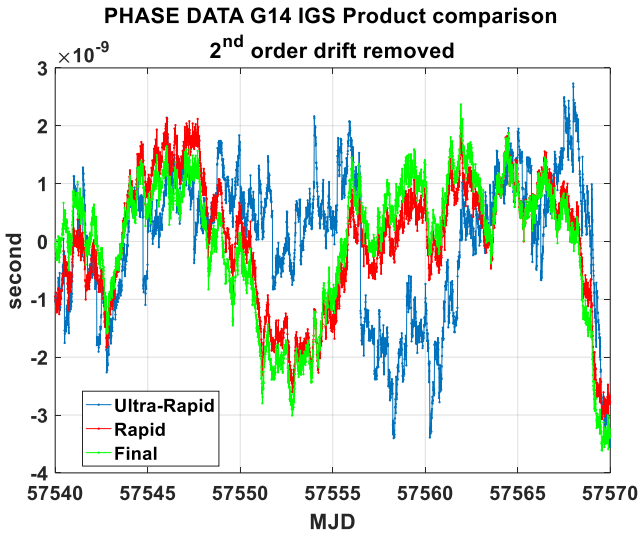
###SVN###	####MJD####	#########DATE#########	###AMPLITUDE###	###UNITS###	###DETECTED ANOMALY##
E12	57455.6285	2016-03-08 15:05:00	4.72e-13	[rel.units]	Frequency Jump
E12	57459.0035	2016-03-12 00:05:00	4.86e-13	[rel.units]	Frequency Jump
E19	57456.0000	2016-03-09 00:00:00	3.22e-09	[seconds]	Phase Jump

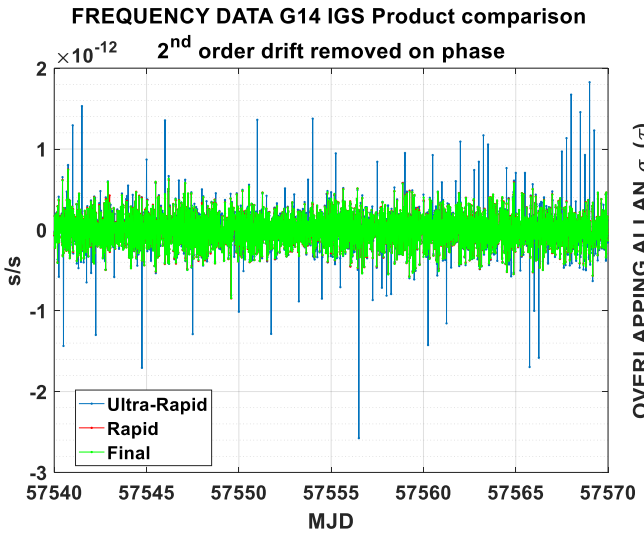
IGS product availability

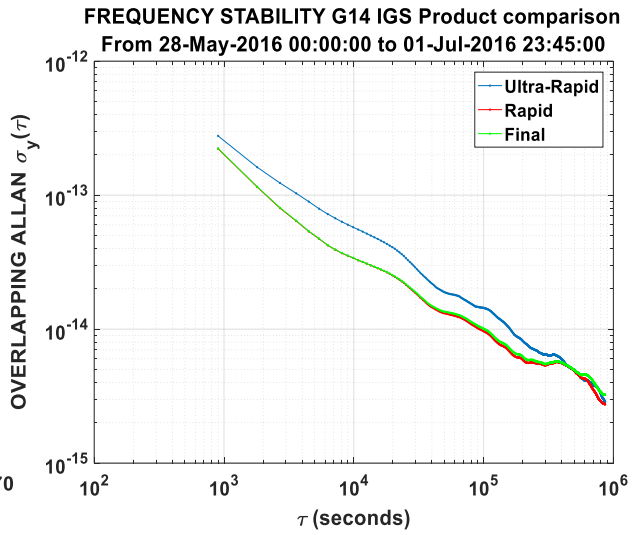
GPS Satellite Ephemerides / Satellite and Station Clock		Sample Interval	Latency	Continuity
Ultra-rapid (predicted half)	Orbits	15 mins	Predicted	Daily, at 03, 09, 15, 21 UTC
	Sat. Clocks			
Ultra-rapid (observed half)	Orbits	15 mins	3-9 hours	Daily, at 03, 09, 15, 21 UTC
	Sat. Clocks			
Rapid	Orbits	15 mins	17-41 hours	Daily, at 17 UTC
	Sat. & Stn. Clocks	5 mins		
Final	Orbits	15 mins	12-18 days	Weekly, every Thursday
	Sat. & Stn. Clock	Sat.: 30s; Stn.: 5 mins		

http://www.igs.org/products

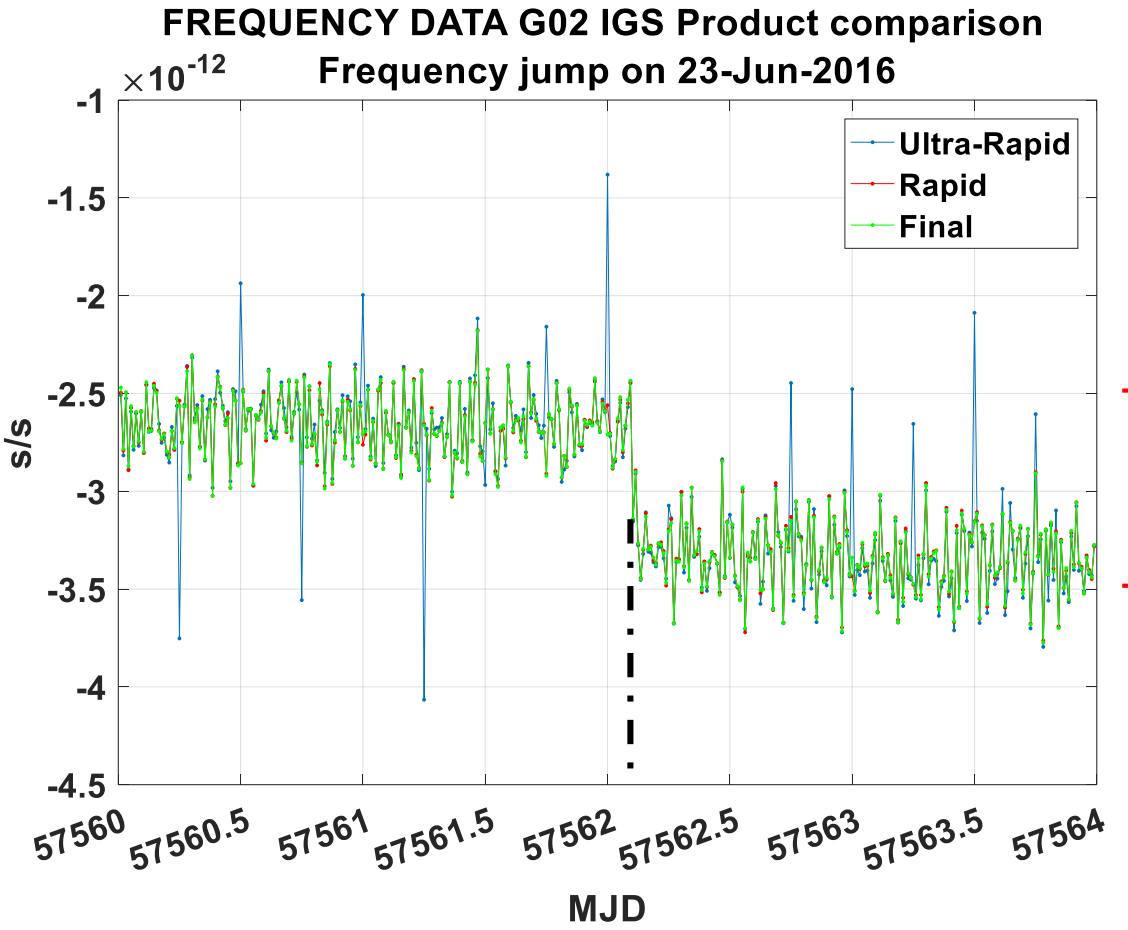
GPS space clocks assessment using IGS clock products







GPS space clocks ***anomalies detection*** using IGS clock products



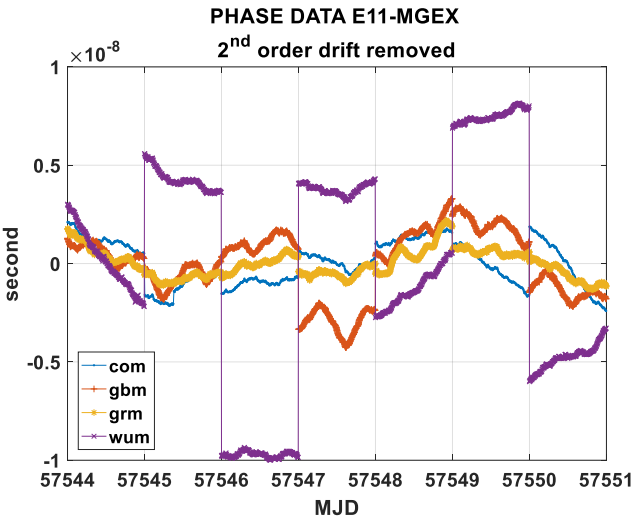
1×10^{-12} $rel.units$

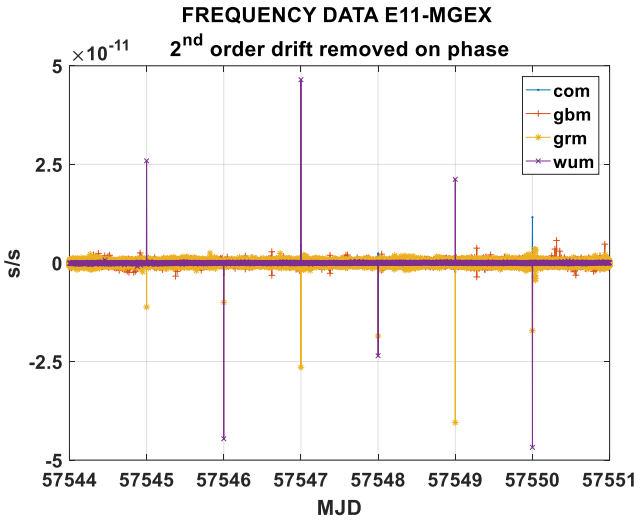
MGEX product availability

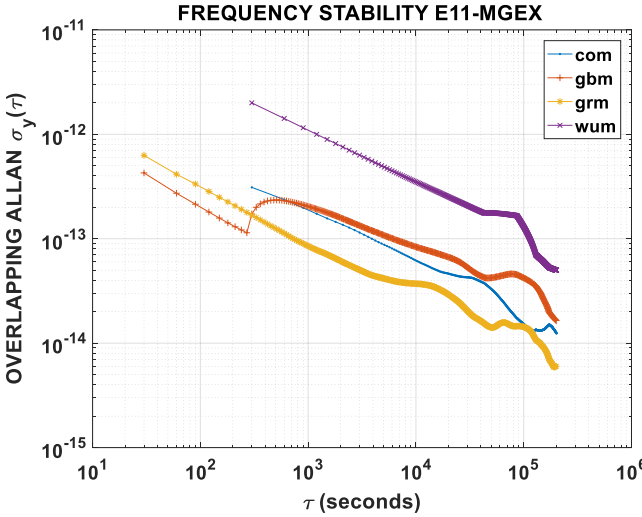
Institution	Source ID	Products	Sample Interval	Latency
CODE	com	Clk	300 s	14 days
		Sp3	900 s	
Wuhan University	wum	Clk	300 s	3 days
		Sp3	900 s	
CNES/CLS	grm	Clk	30 s	5 days
		Sp3	900 s	
GFZ	gbm	Clk	30 s	1 day
		Sp3	900 s	

http://mgex.igs.org/IGS_MGEX_Products.html

Galileo space clocks assessment using MGEX clock products





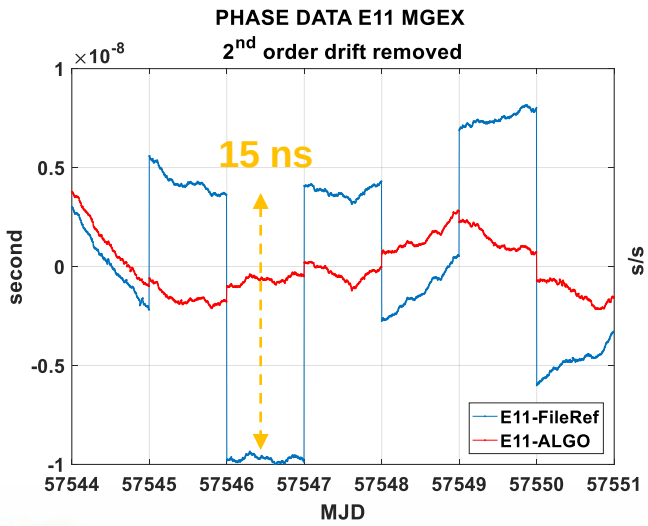


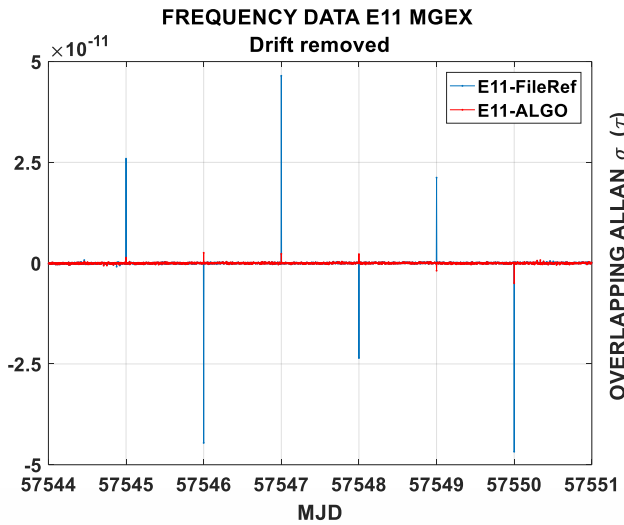
Galileo space clocks assessment using MGEX clock products

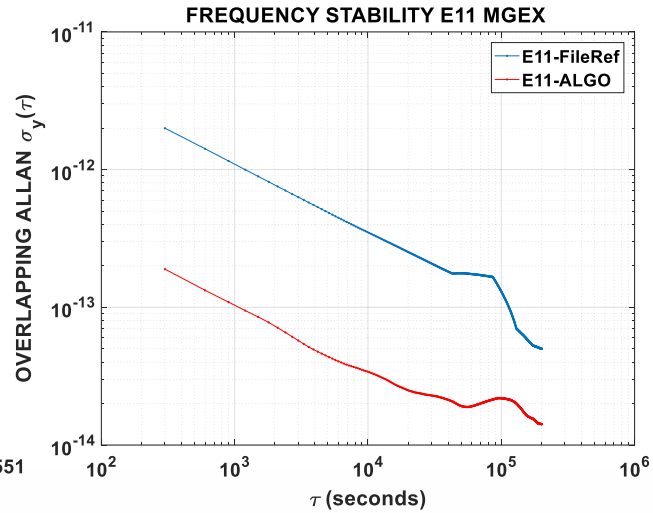
- Each analysis center has freedom in choosing algorithms and reference clocks

→ might change on a daily basis, which can explain significant day boundary jumps.

⇒ *Choose one station (STN) as reference throughout analysed period:*
(SVN-REF) - (STN-REF) = SVN - STN







Conclusions

- IGS clock products can be used to assess space clocks performances.
  - Ultra-rapid products have to be properly treated with outliers removal.
- MGEX clock products broaden the analysis to other constellations.
  - Data pre-processing actions have to be taken to reveal true behaviour of space clocks (change of reference station, outliers removal,..).
- INRIM uses IGS and MGEX public clock products for different research activities; GNSS clock characterization can be useful for:
  - GNSS users, in order to improve both position and timing accuracy,
  - Space clocks manufacturers to understand clocks behaviour after launching,
  - Scientist interested in GNSS space clocks nonstationarities detection and performances.

References

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- L. Galleani and P. Tavella, "**Robust Detection of Fast and Slow Frequency Jumps of Atomic Clocks**," IEEE Trans. Ultra. Ferro. Freq. Contr., vol. 64, no. 2, pp. 475-485, Feb. 2017.

Thank you for your attention