

# CODE's Update of the Clock Products

*A. Villiger<sup>1</sup>, S. Lutz<sup>2</sup>, A. Susnik<sup>1</sup>, L. Prange<sup>1</sup>, S.Schaer<sup>1,2</sup>,  
R.Dach<sup>1</sup>, P. Stebler<sup>1</sup>, A. Jäggi<sup>1</sup>*

*<sup>1</sup>Astronomical Institute, University of Bern, Switzerland*

*<sup>2</sup>swisstopo, Wabern, Switzerland*

IGS Workshop 2017

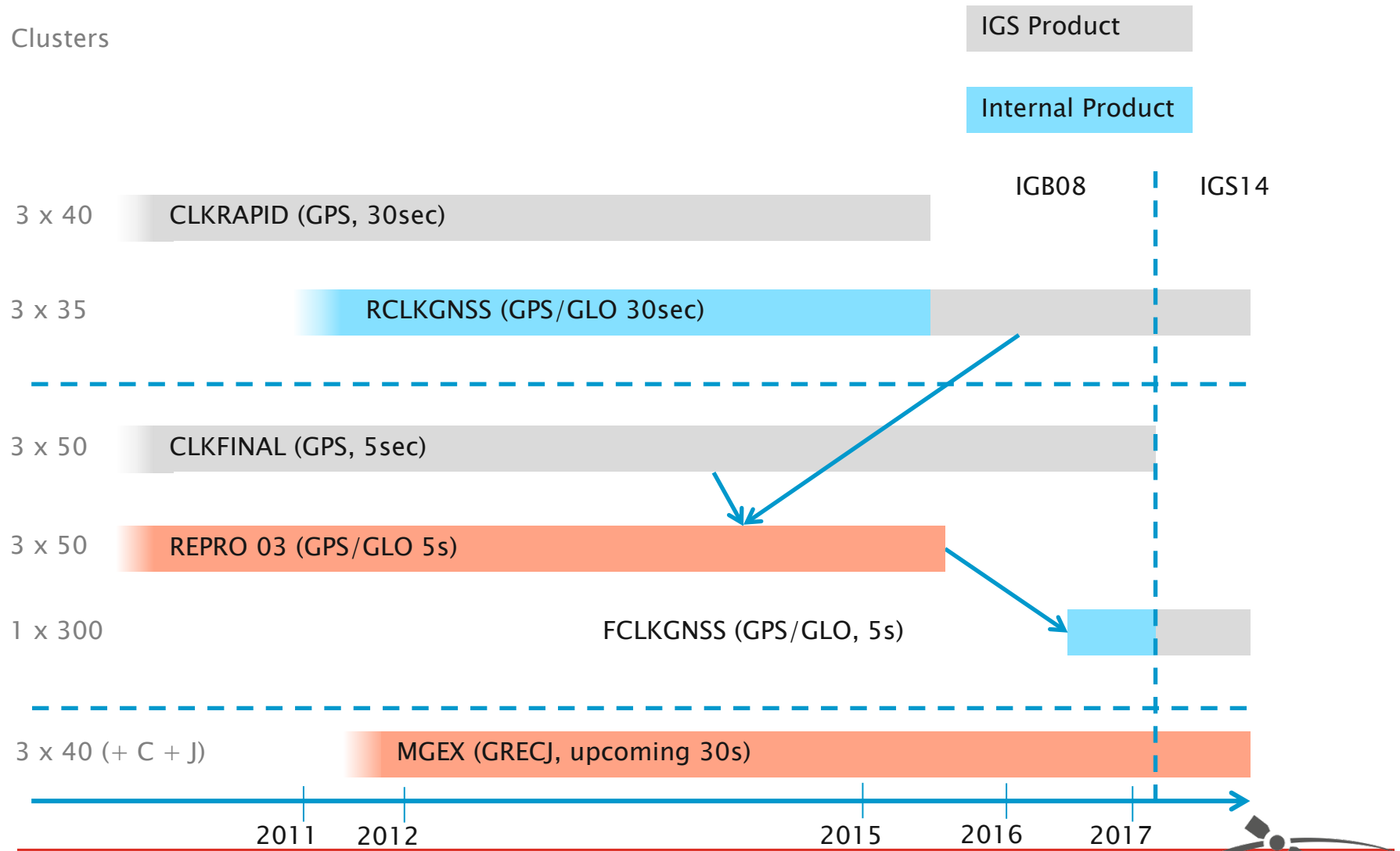
5. July 2017, Paris

# Content

---

- Evolution of CODE's Clock products
- Updated IGS Final Clock product
  - What's new
  - Updated inversion scheme using pre-elimination
  - Behavior in the IGS combination
  - Bias handling
- Multi-GNSS Clock product (MGEX)
  - Estimation of multi-GNSS clocks
  - Comparison using different clustering approaches
  - MGEX-Clock densification (30sec)
- Conclusion

# Evolution of CODE's Clock Products



---

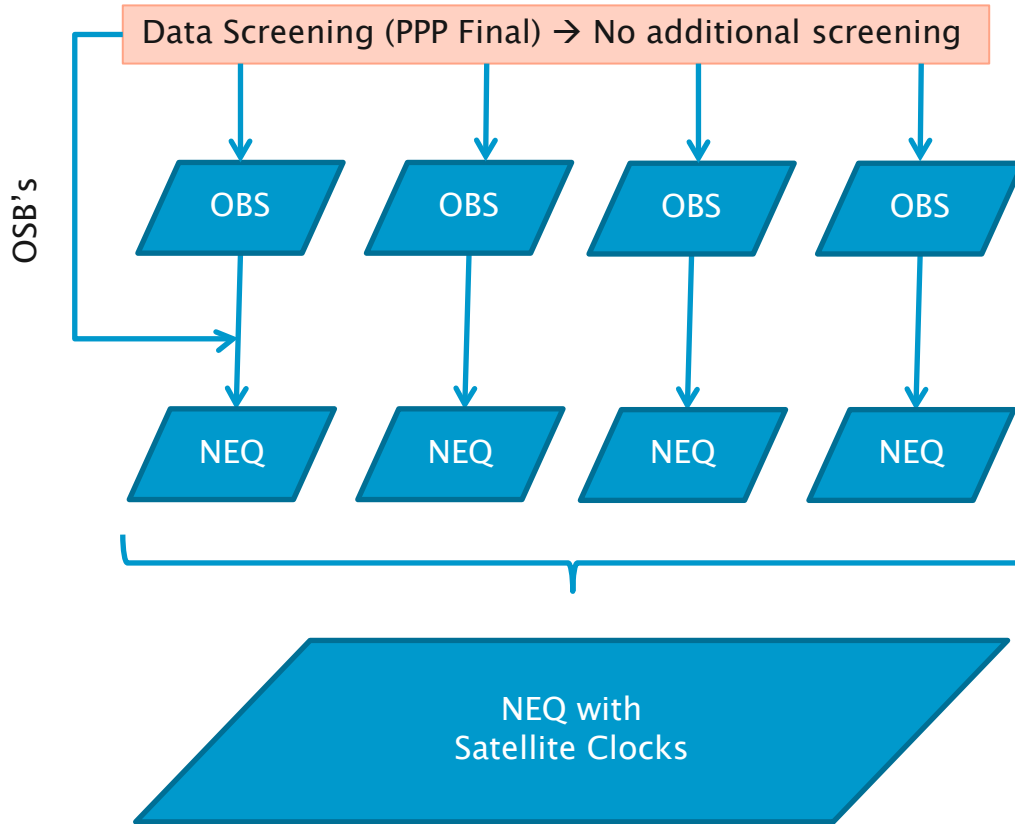
# New IGS Final Clock Product

# Updated IGS Final Clock Estimation

---

- Updated clock product since week 1934 (switch to IGS14)
- Extension from GPS to **GPS/GLONASS**
- **5 second clocks** for GPS and **GLONASS**
- From 150 to 300 processed stations
- Data screening based on PPP
- Adapted processing scheme to handle  $> 300$  sites
- Bias handling (GLONASS as satellite–receiver biases):
  - Code biases are estimated during PPP screening
  - Bias solution is aligned to CODE's 30 day bias product (GPS satellites)
  - Introducing aligned bias to clock estimation

# New Clock Estimation Approach



Observation files from PPP

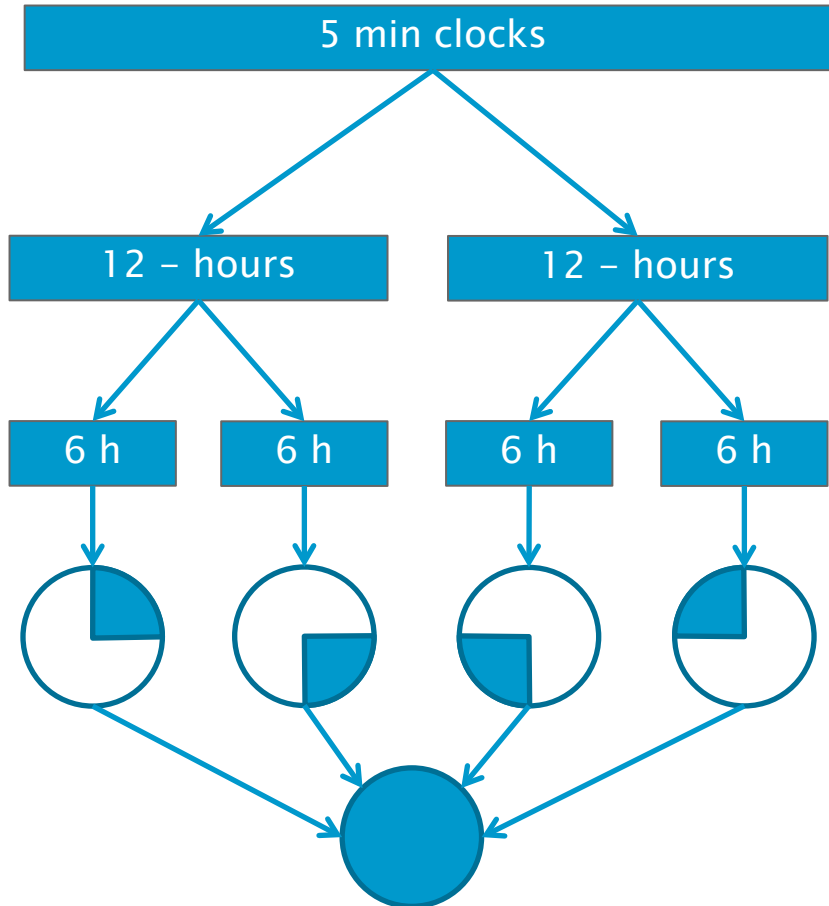
*Station-wise clock setup  
(Receiver clocks pre-eliminated)*

NEQ's with satellite clocks

*Stacking station-wise  
satellite clocks*

Full NEQ with all satellite clocks  
approx.  $(32+24)*288$  clocks  
→ > 16'000 parameters

# Satellite Clock Estimation



After 2 hours finished

Full Inversion: > 6 hours

*Pre-elimination*

12-hours NEQs

*Pre-elimination*

6-hours NEQs

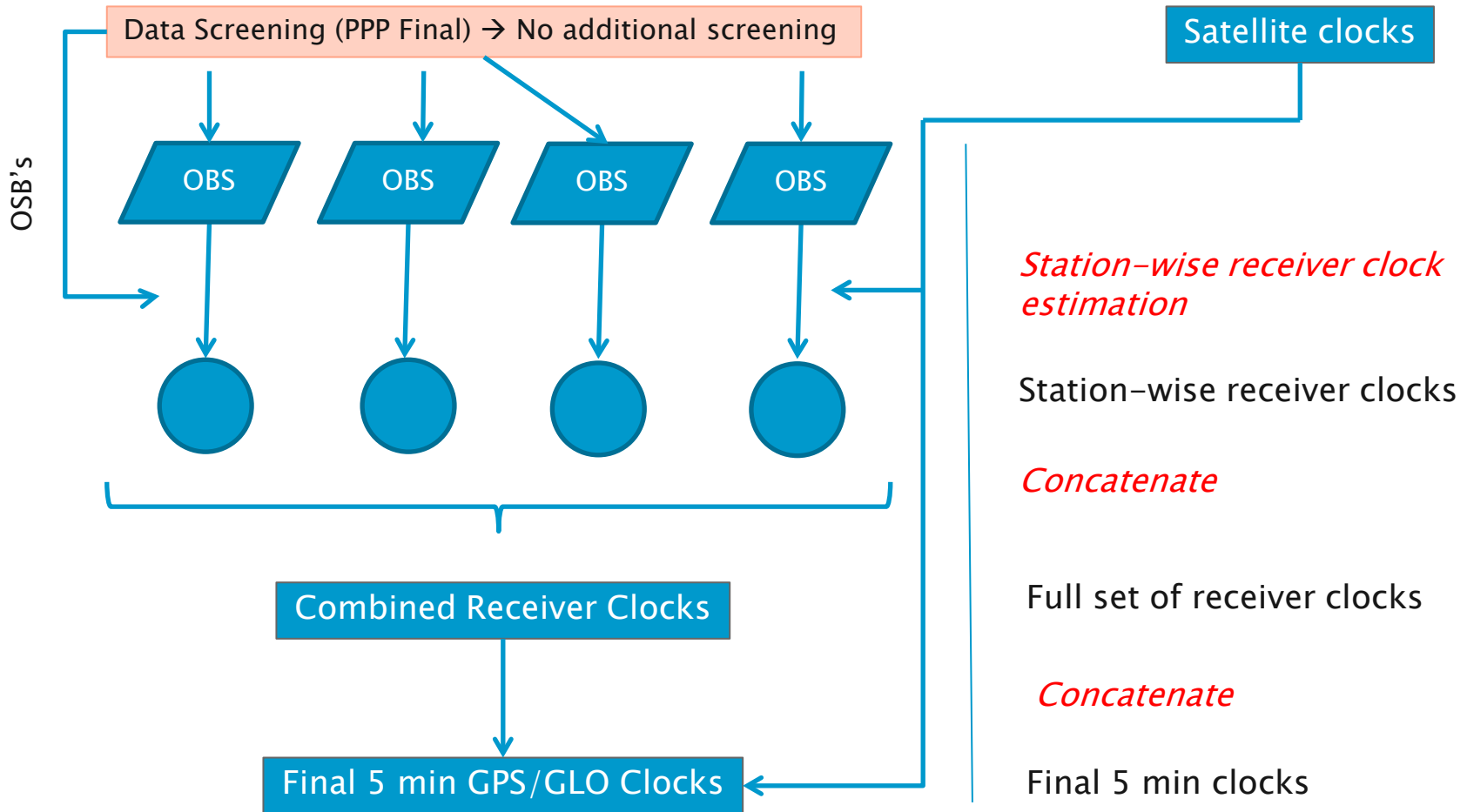
*Inversion*

6-hours clocks

*Concatenate*

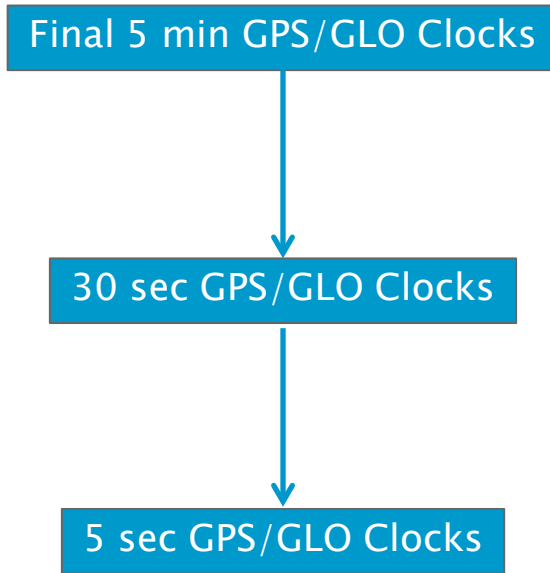
Full set of satellite clocks

# Receiver Clock Estimation





# Clock Densification



Station-wise receiver clocks

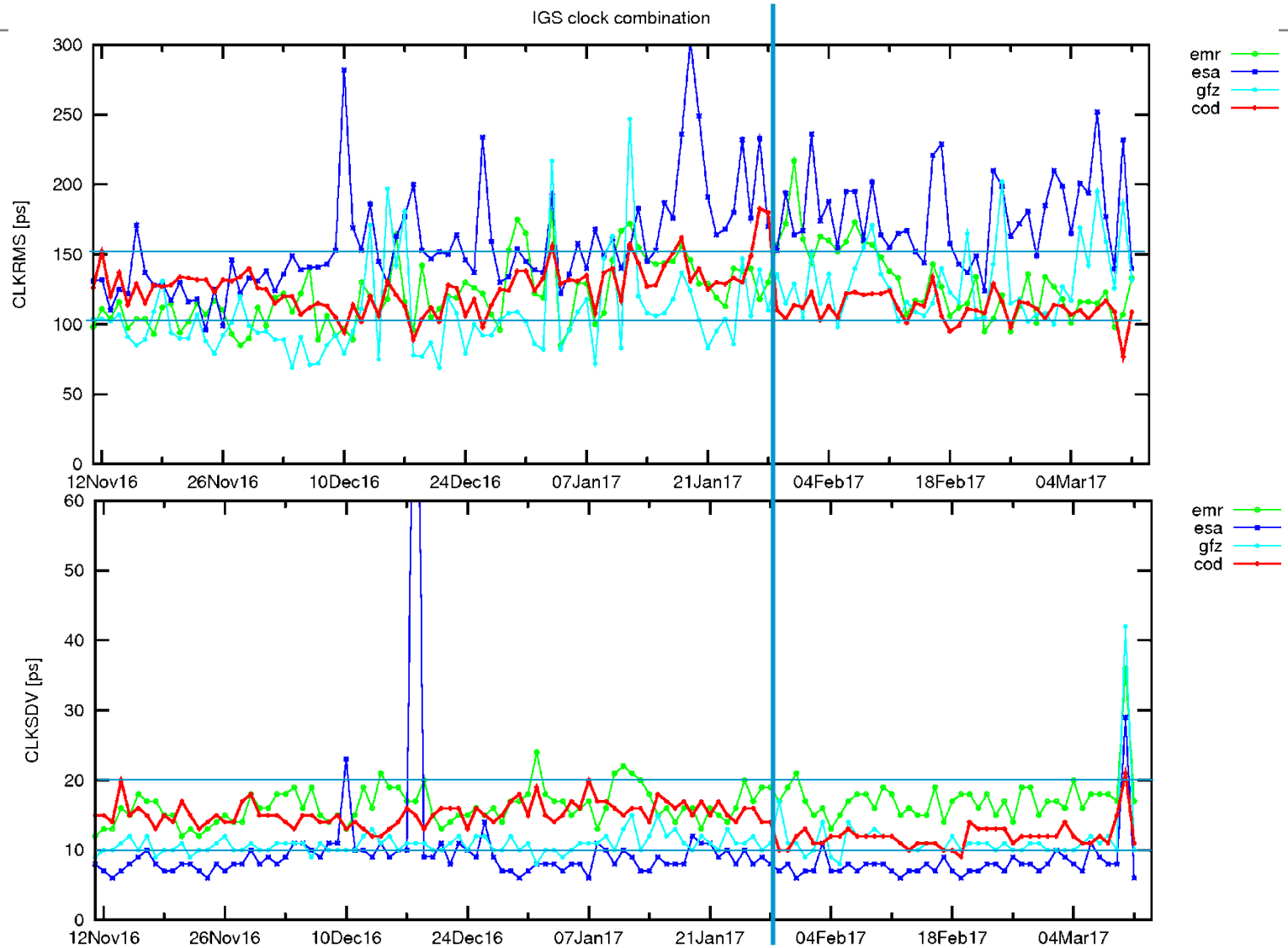
*30 second densification*

30-second clocks

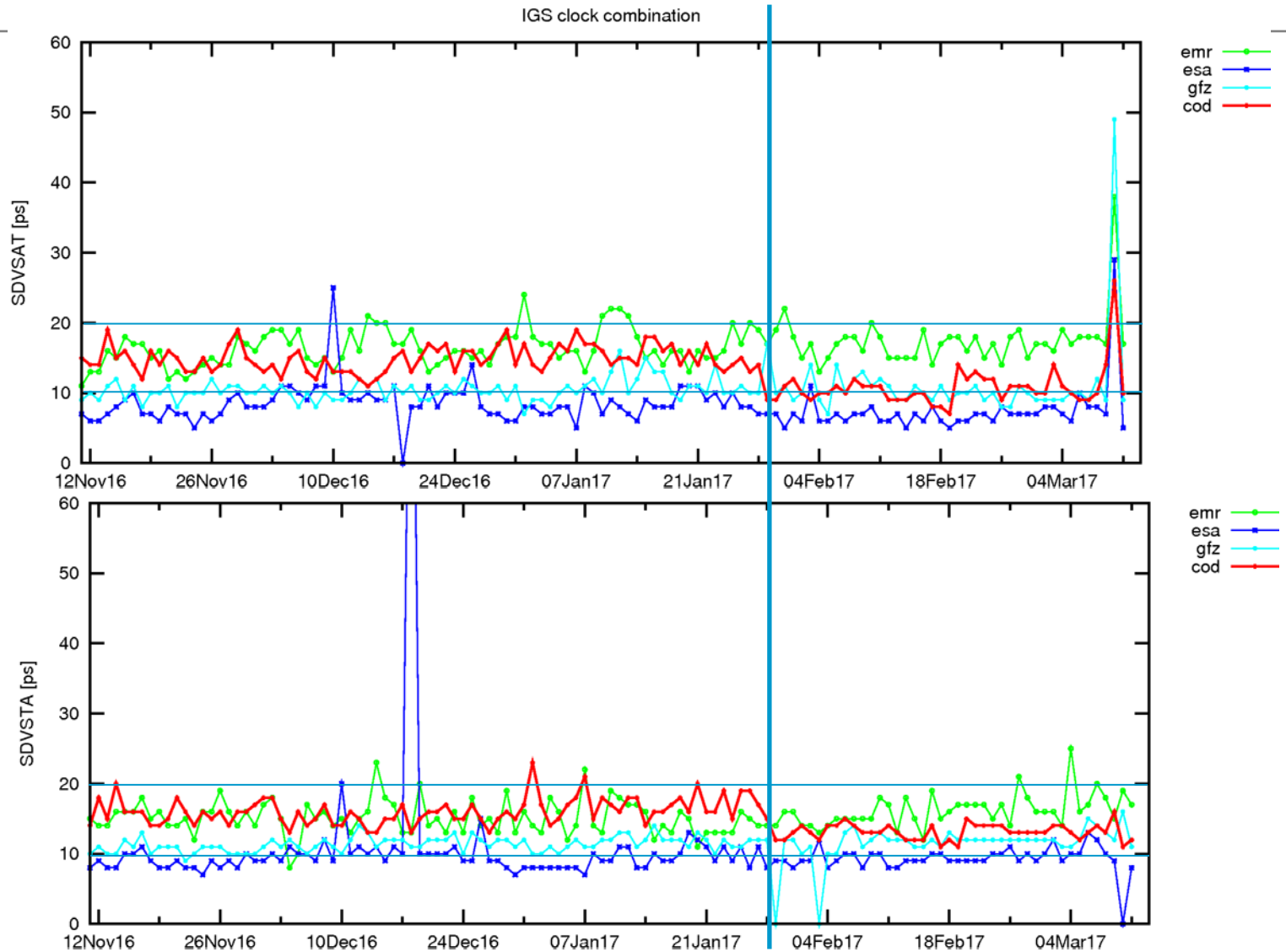
*5 second densification*

Final 5 sec clocks

# IGS Combination Statistics



# IGS Combination Statistics



---

# Multi-GNSS Clock Product (MGEX)

# Revision of currently used cluster approach

---

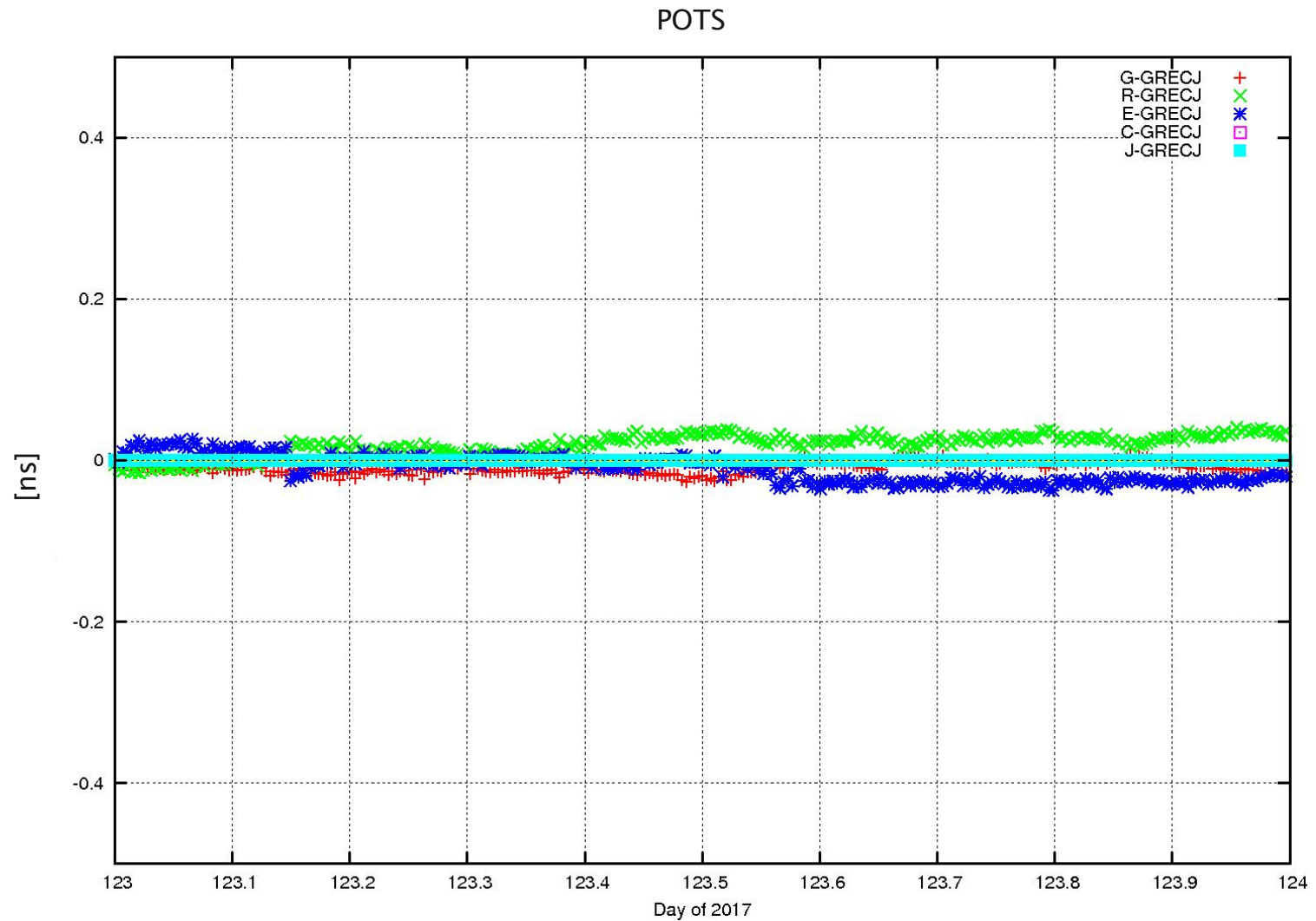
- Revision of current clock clustering:
  - **3 GRE clusters** (3x40 stations)
  - Additional cluster for **BeiDou and GPS** (GC)
  - Additional cluster for **QZSS and GPS** (GJ)
  - Combination of all five clusters
- Phase based clock interpolation (30s clocks)
- Revised code bias handling for clock estimation

# PPP analysis of CODE's MGEX clocks

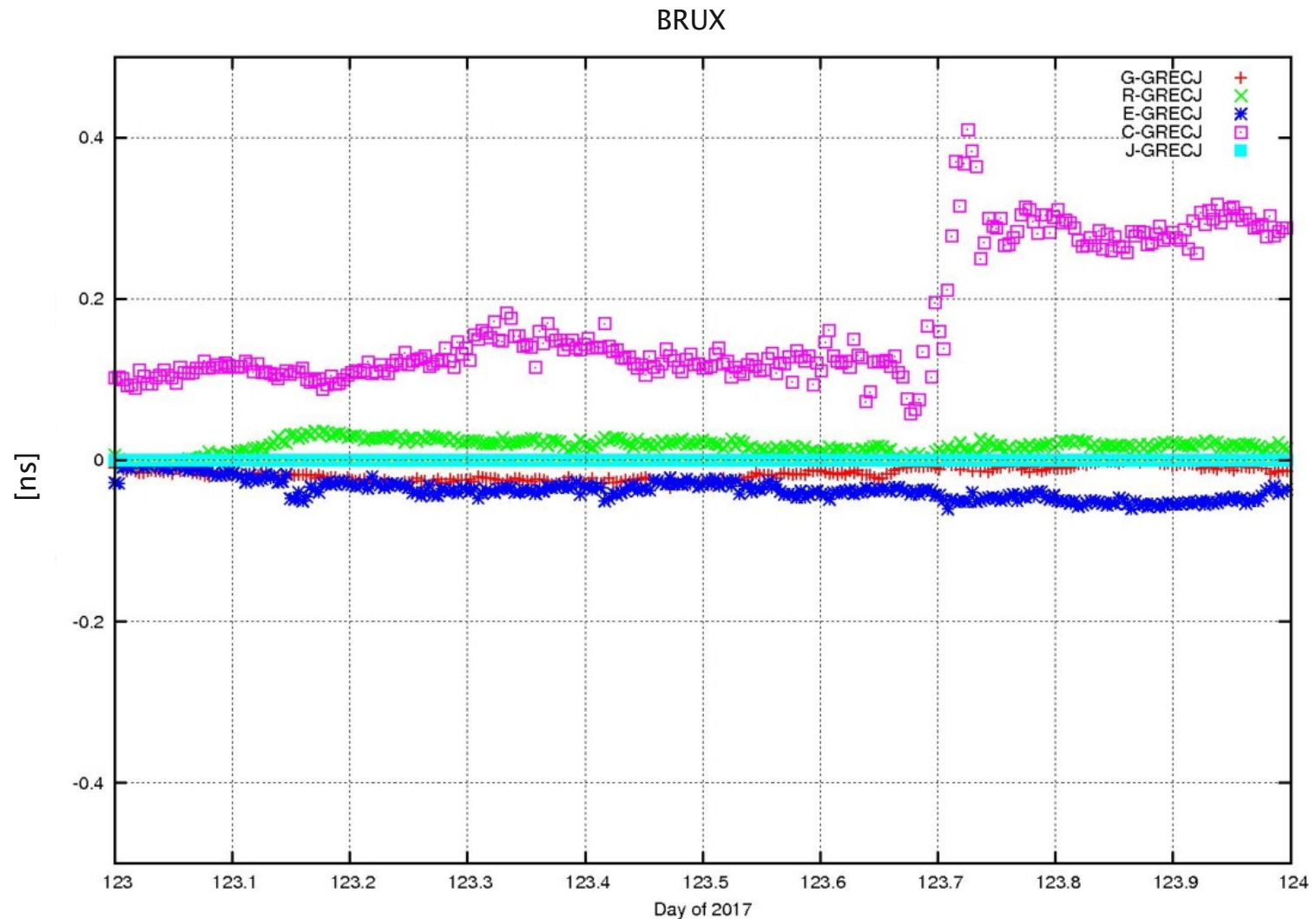
- PPP Clock test (5min, Station ZIM3)
- Offsets against multiday solution
- Repeatability of kinematic PPP solution
- MGEX2 Solution: before merging with C and J cluster
- CODE: Final clock product

Product	Sys	North		East		Up	
		[mm]		[mm]		[mm]	
MGEX	GRECJ	-0.09 +-	4.7	1.2 +-	5.05	0.2 +-	10.86
MGEX	GRE	0.03 +-	4.95	2.08 +-	5.24	-1.04 +-	11.17
MGEX	GR	0.01 +-	5.44	2.27 +-	5.63	0.58 +-	11.41
MGEX2	GRE	-0.46 +-	4.74	2.7 +-	4.2	-0.98 +-	9.96
MGEX2	GR	-0.56 +-	5.15	3.19 +-	3.19	0.38 +-	9.71
CODE	GR	-2.05 +-	5.26	-4.93 +-	4.4	0.48 +-	9.94

# GNSS-specific receiver clocks



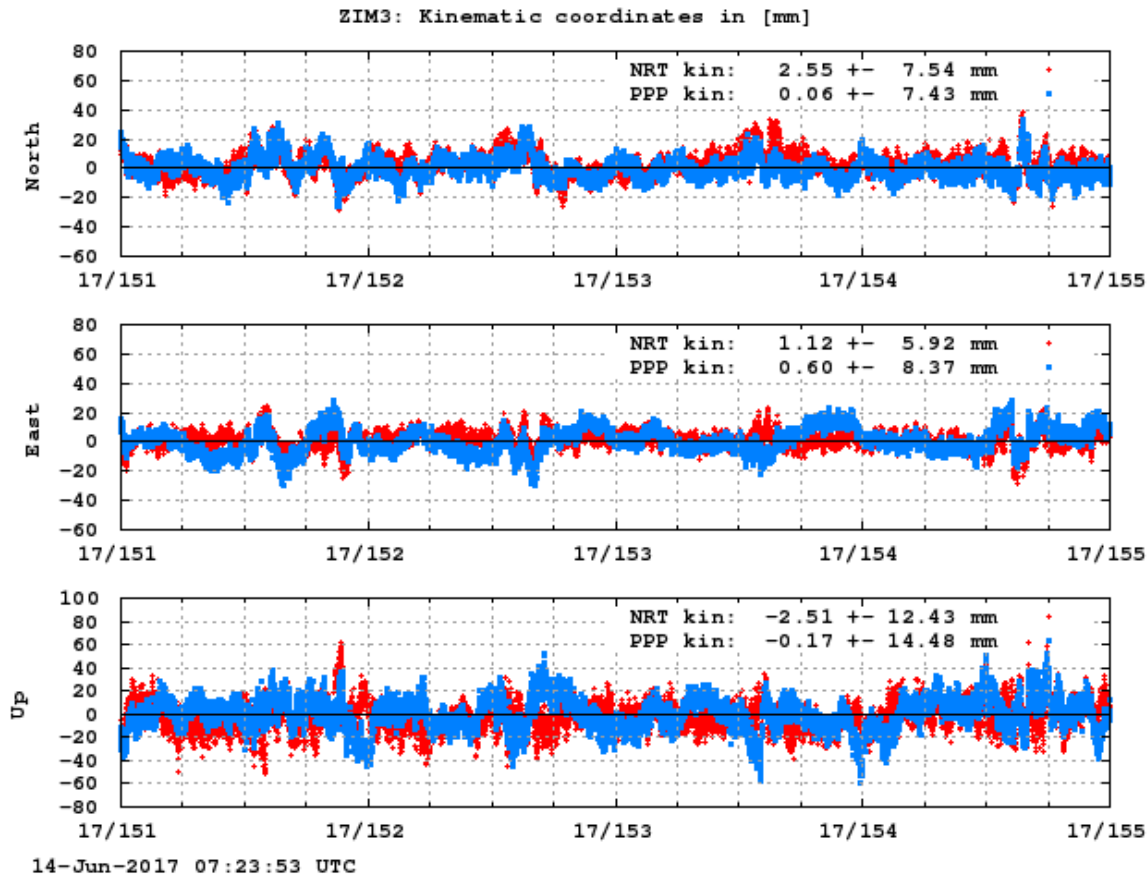
# GNSS-specific receiver clocks





# Highrate Clocks (30sec interpolation)

- MGEX 30 second interpolation for all GNSS (GRECJ)
- Phase-based interpolation between estimated 5min clocks



Solution using GRECJ; 30 Seconds  
NRT: Double-difference solution  
PPP: PPP solution

# Revision of MGEX bias handling

---

- **Generation of a 30 day MGEX bias set**
  - Active since 16 June 2017
  - Only from clock solution (IF)
  - Combination on normal equation level
- **Ionosphere estimation (prototype available)**
  - Ionosphere estimation using 5 systems (GRECJ)
  - Estimation of LC biases
- **Generation of a combined MGEX biases product**
  - Combination of biases on normal equation level
  - From clock and ionosphere analysis

# Conclusion

---

## IGS–Final Clocks:

- Full inversion of the satellite clocks without clustering
- Mathematically correct (compared to old three–cluster solution)
- Inversion of 6 hours bin (increase speed by a factor 3)
- Pre–elimination procedure delivers same results as full inversion

**CODE final clock product includes GPS and GLONASS 5 sec clocks since the switch from IGB08 to IGS14 based on more than 300 stations without clustering!**

## MGEX–Clocks:

- Clustering scheme under revision
- 30s clock interpolation is coming
- 30–day average MGEX code bias product