CODE's Update of the Clock Products

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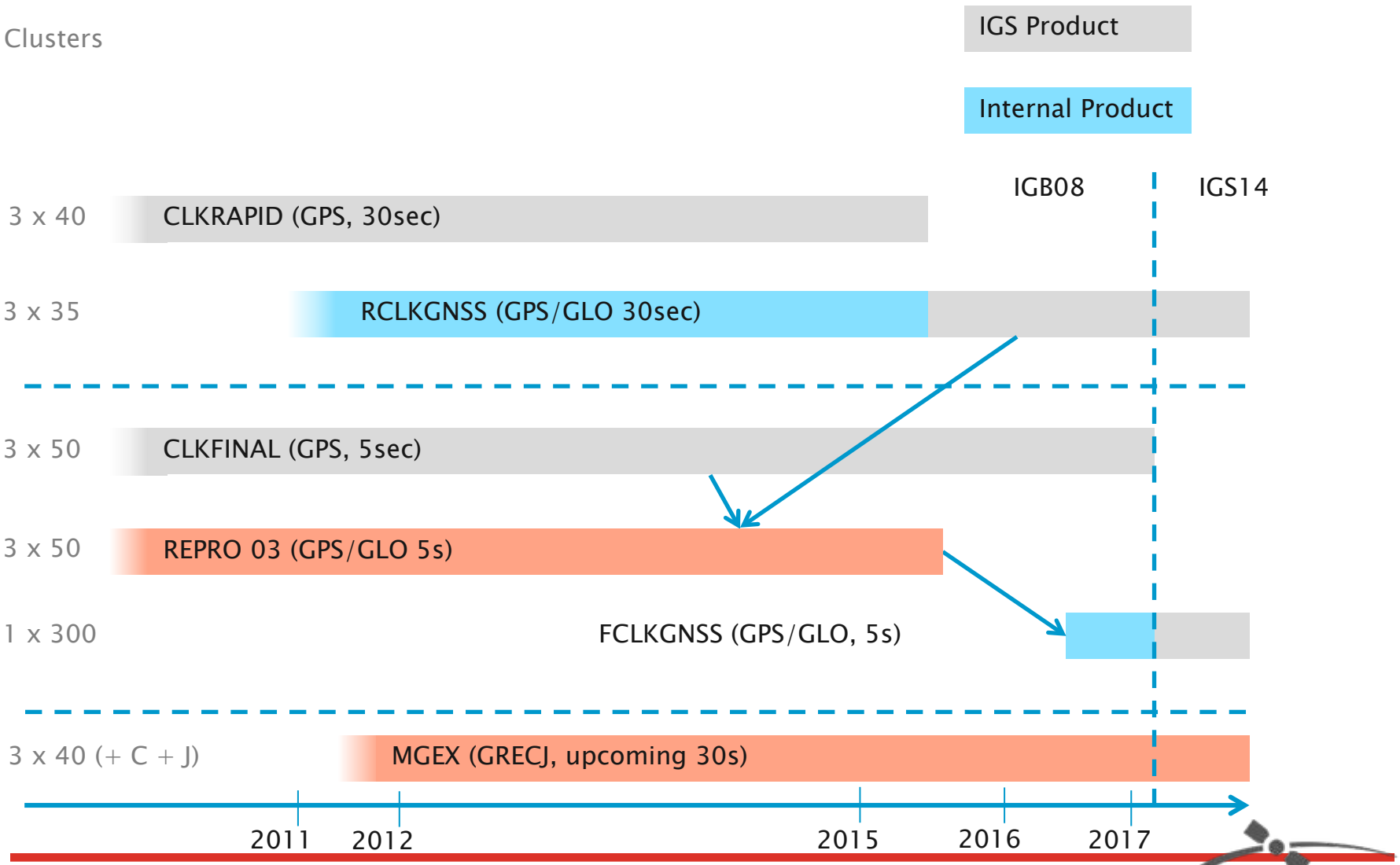
Evolution of CODE's Clock Products



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

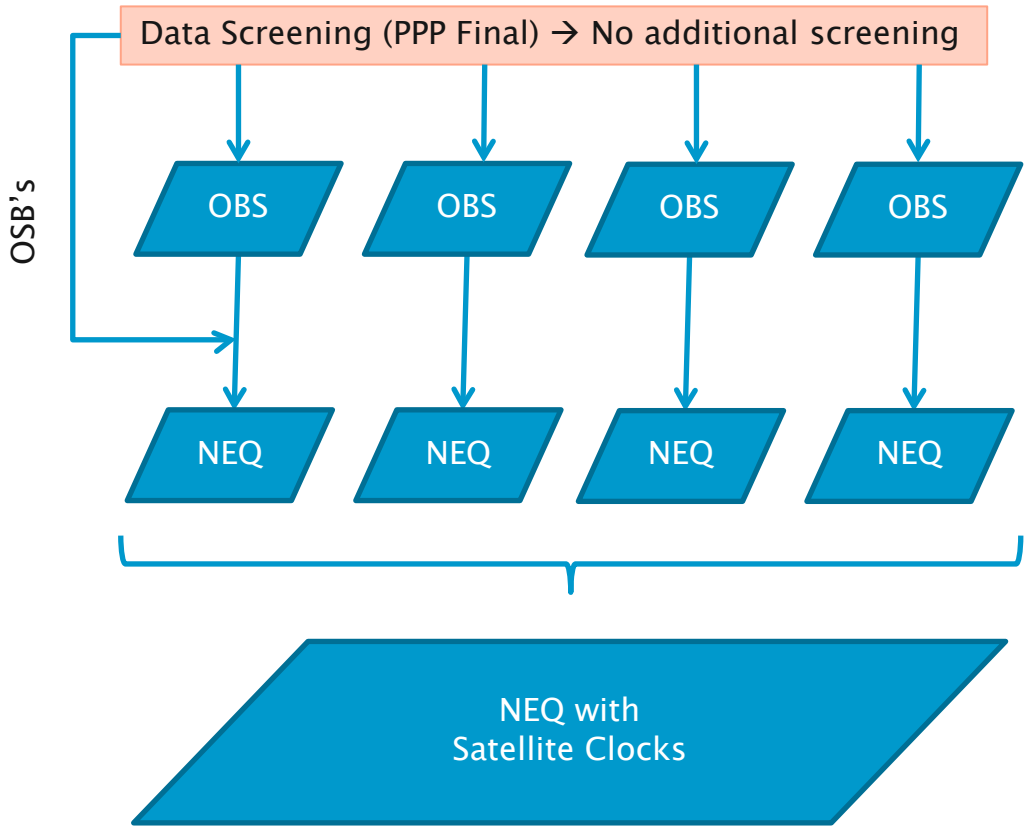
- From 150 to 300 processed stations
- Data screening based on PPP

- 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

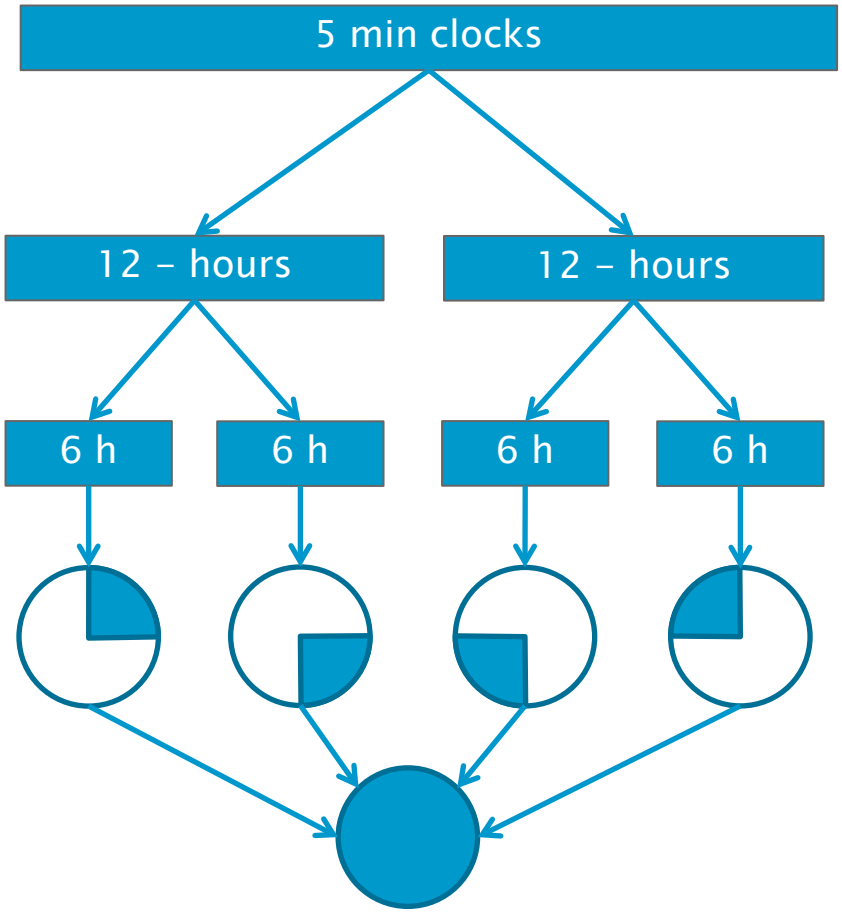
Station-wise clock setup
(Receiver clocks pre-eliminated)

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

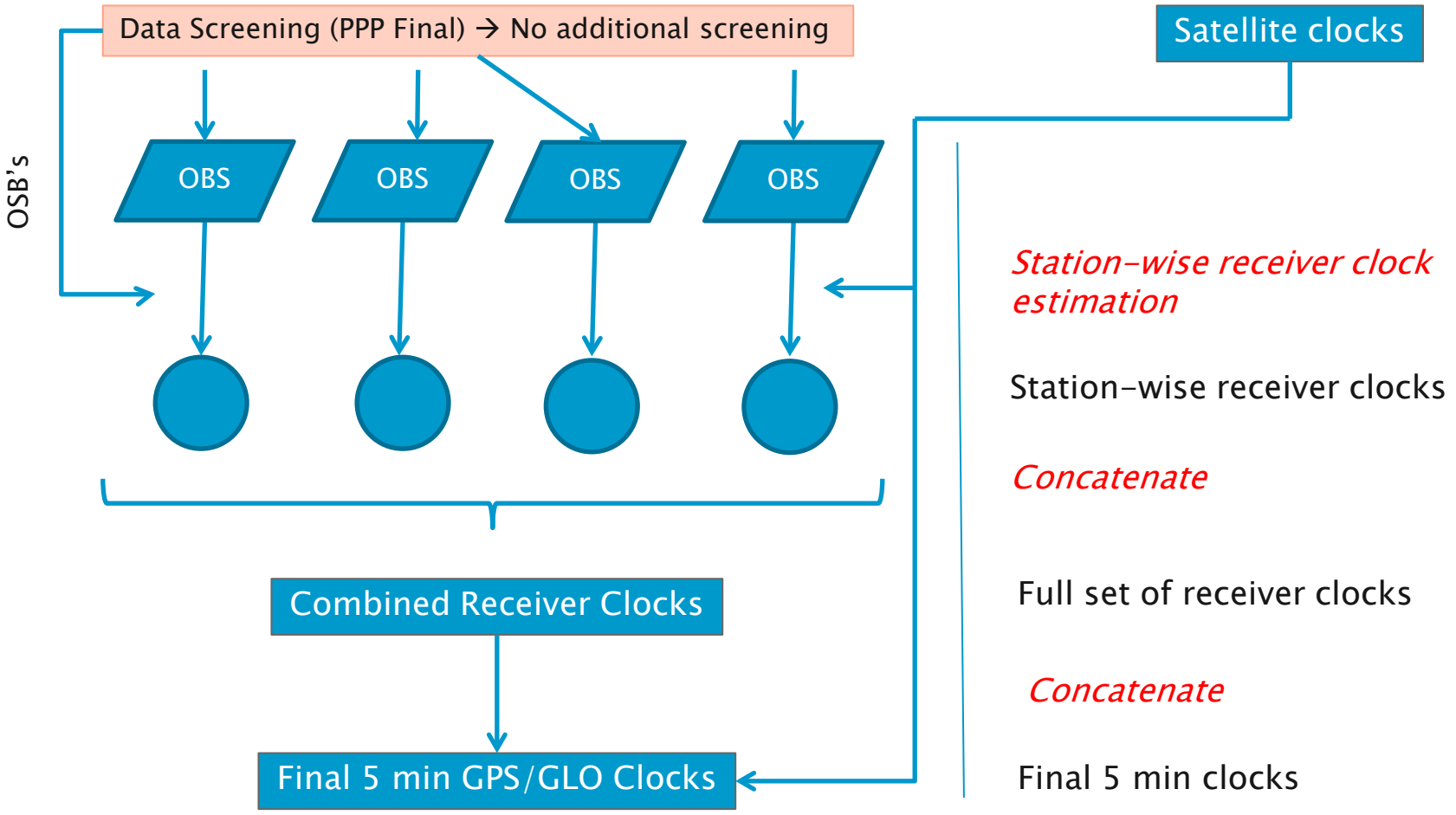
Inversion

6-hours clocks

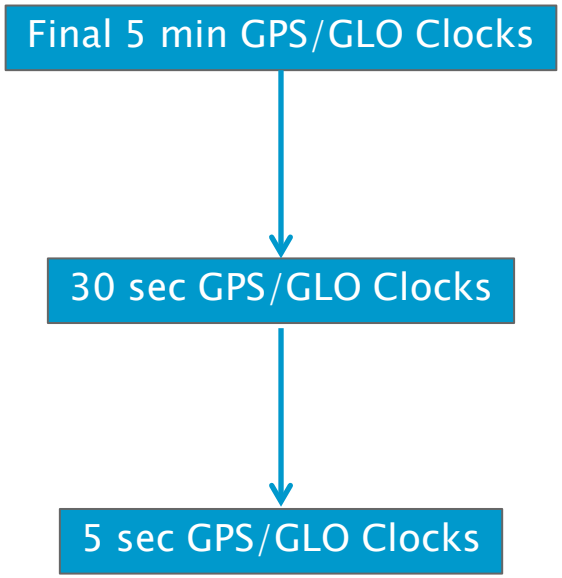
Concatenate

Full set of satellite clocks

Receiver Clock Estimation



Clock Densification



Station-wise receiver clocks

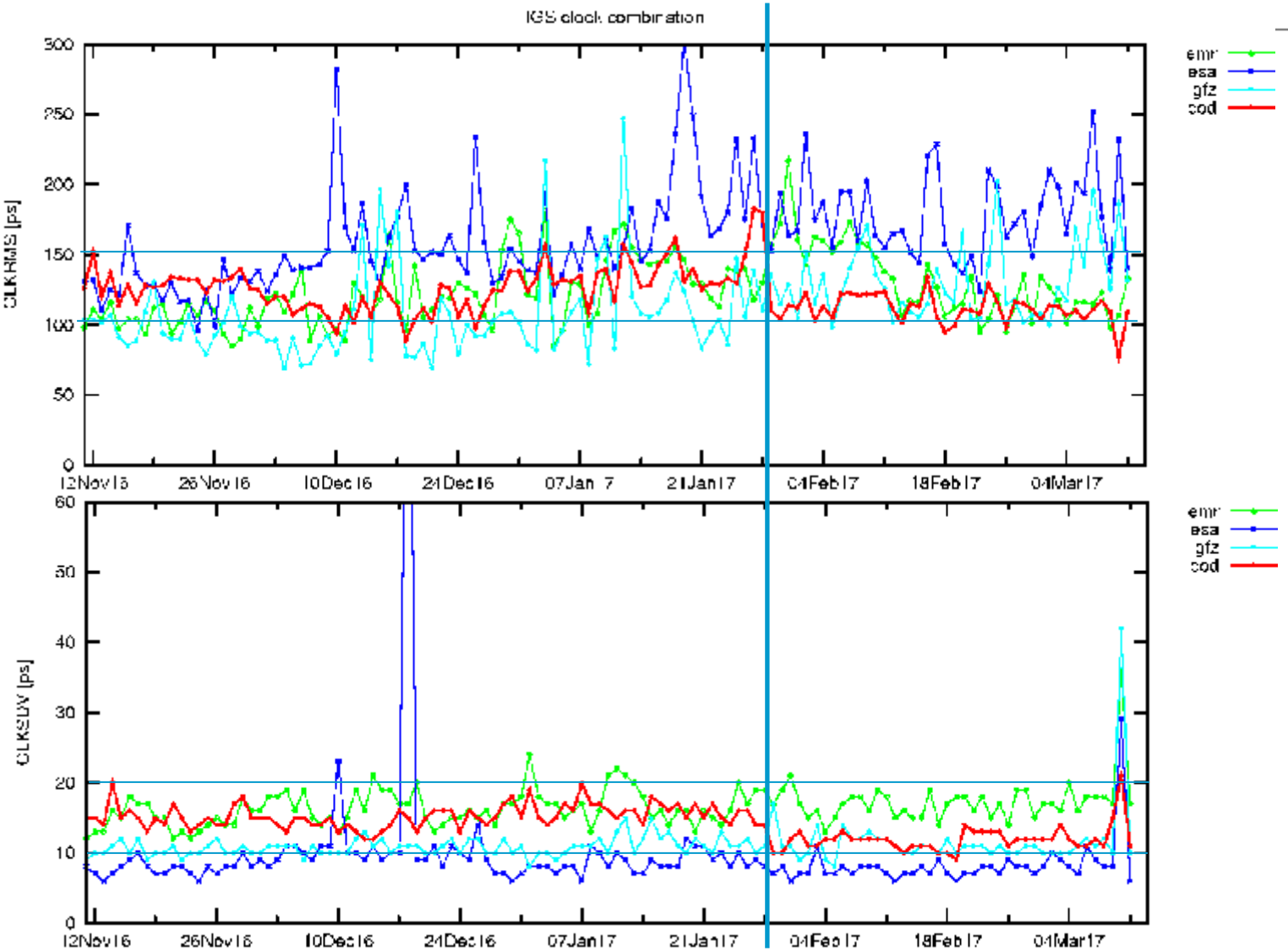
30 second densification

30-second clocks

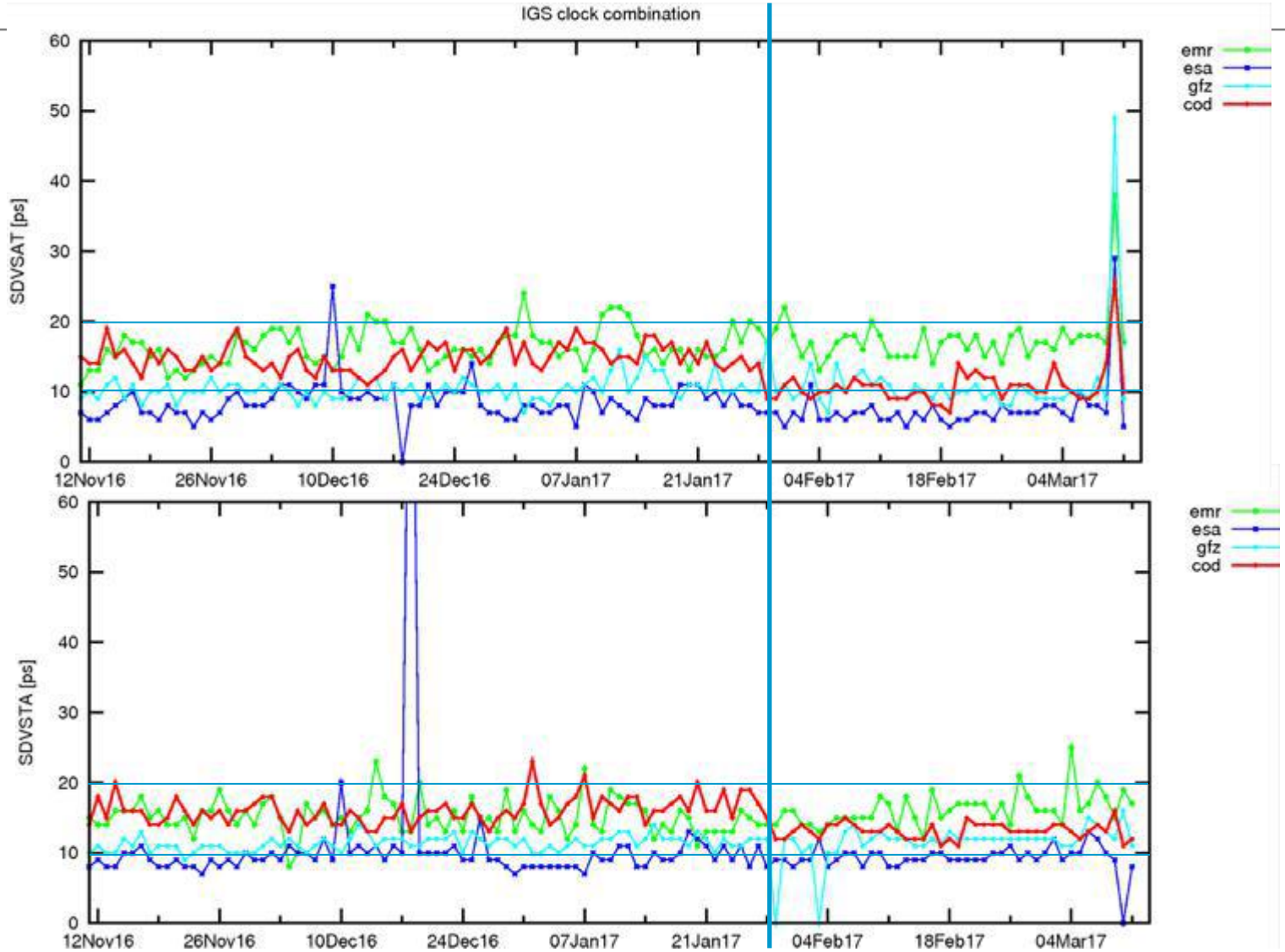
5 second densification

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

- Problem for the combination as receiver clocks are estimated for all clusters (and combined)

New approach (under development):

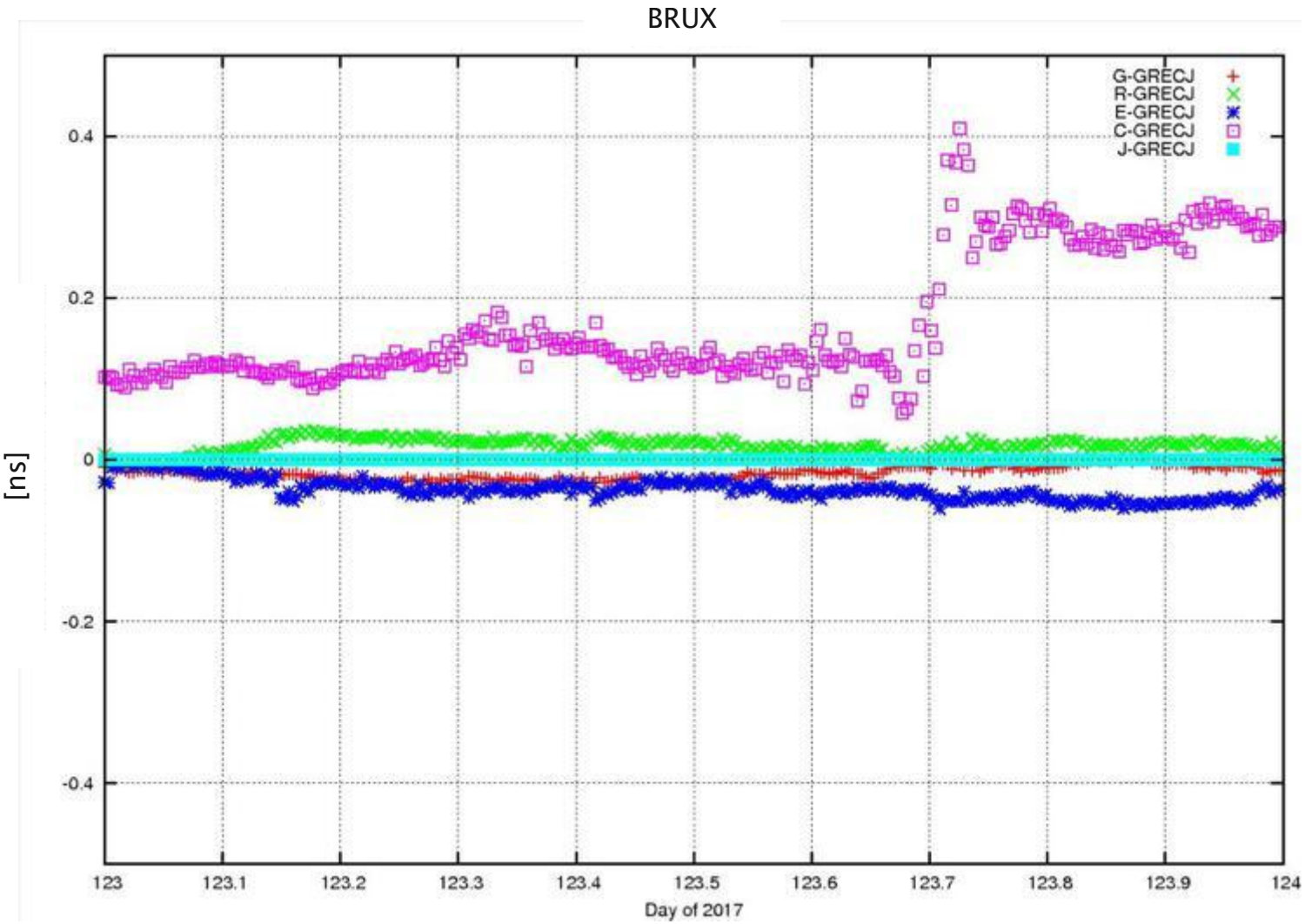
- Introduce receiver clocks from GRE estimation into the BeiDou and QZSS cluster
- Estimation of satellites clocks only (GPS satellites are omitted)
- Tests show better behavior in MGEX PPP solutions

PPP analysis of CODE's MGEX clocks

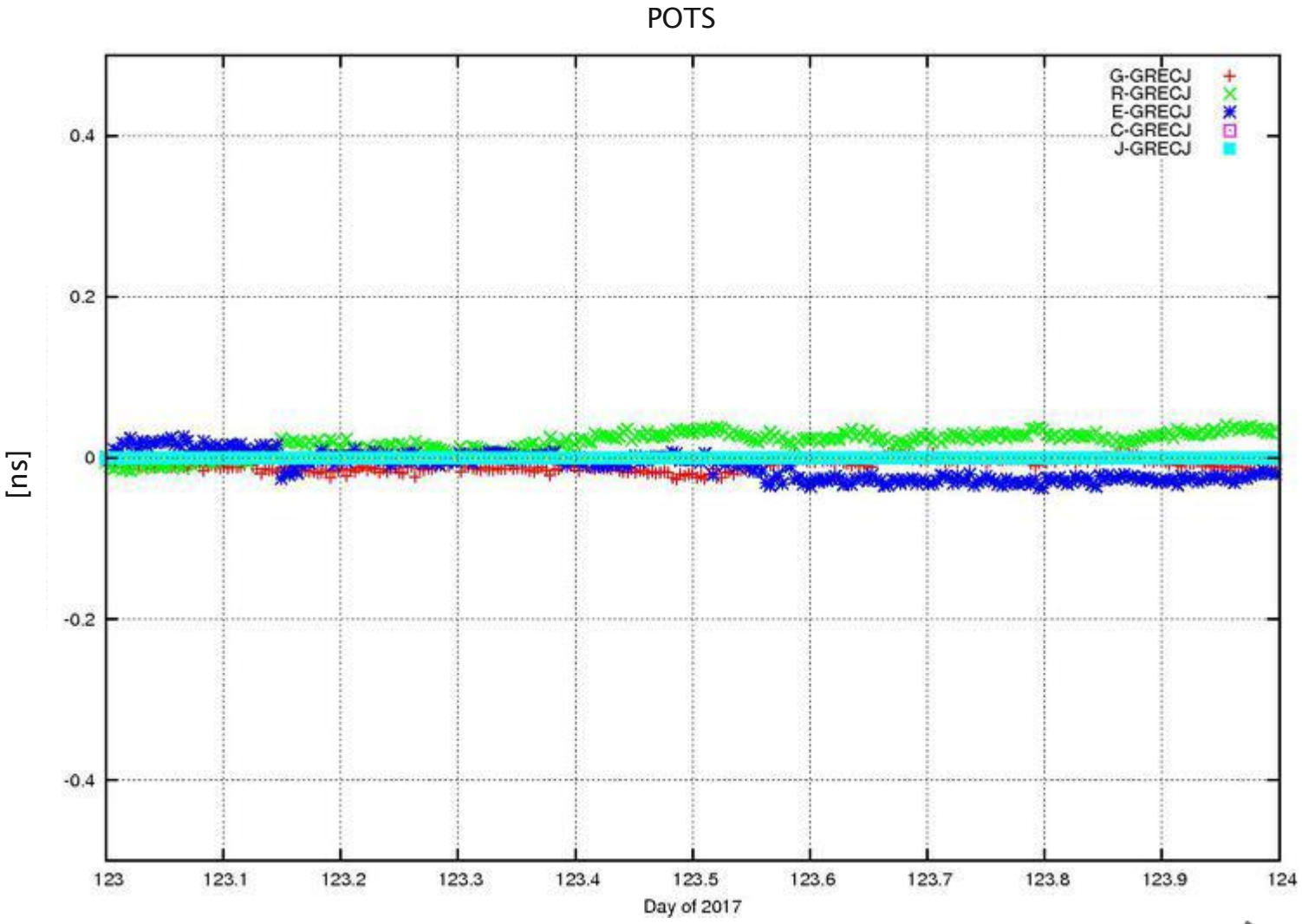
- PPP Clock test (5min, Station ZIM3)
- Offsets against multiday solution
- Repeatability of kinematic PPP solution
- MGEX2 Solution: before merging with C and J cluster
- CODE: Final clock product

Product	Sys	North [mm]	East [mm]	Up [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

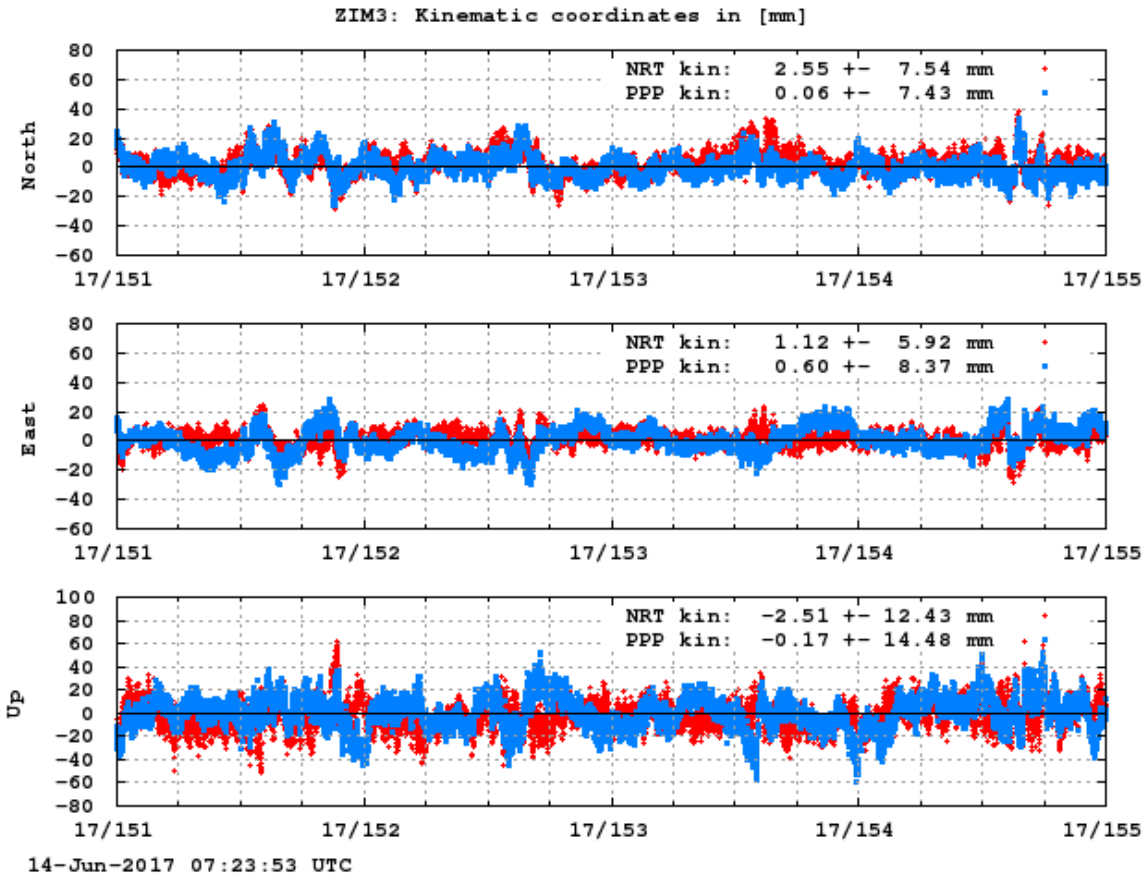


GNSS-specific receiver clocks



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
- Receiver-clocks only from GRE solution
- 30s clock interpolation is coming
- 30 day average MGEX code bias product is under development