CODE's Update of the Clock Products

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Content

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- 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

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Evolution of CODE's Clock Products

Clusters

IGS Product

Internal Product

IGB08   IGS14

3 x 40   CLKRAPID (GPS, 30sec)

3 x 35   RCLKGNSS (GPS/GLO 30sec)

3 x 50   CLKFINAL (GPS, 5sec)

3 x 50   REPRO 03 (GPS/GLO 5s)

1 x 300   FCLKGNSS (GPS/GLO, 5s)

3 x 40 (+ C + J)   MGEX (GRECJ, upcoming 30s)

2011   2012   2015   2016   2017

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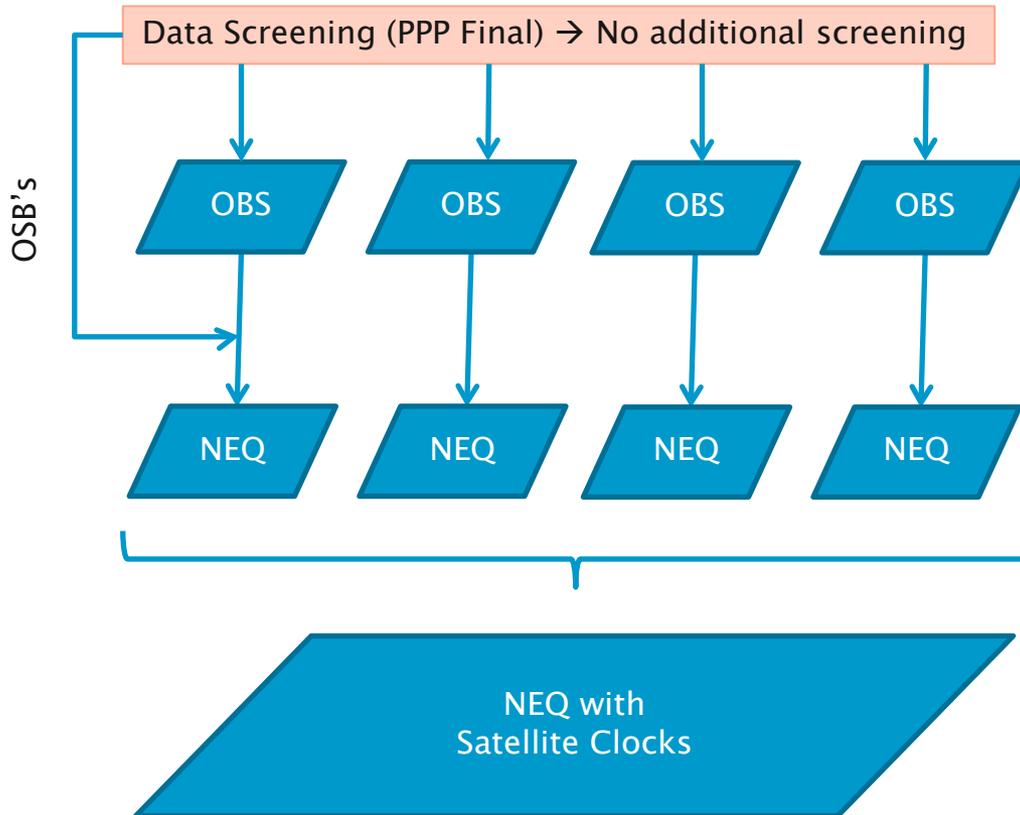
New IGS Final Clock Product

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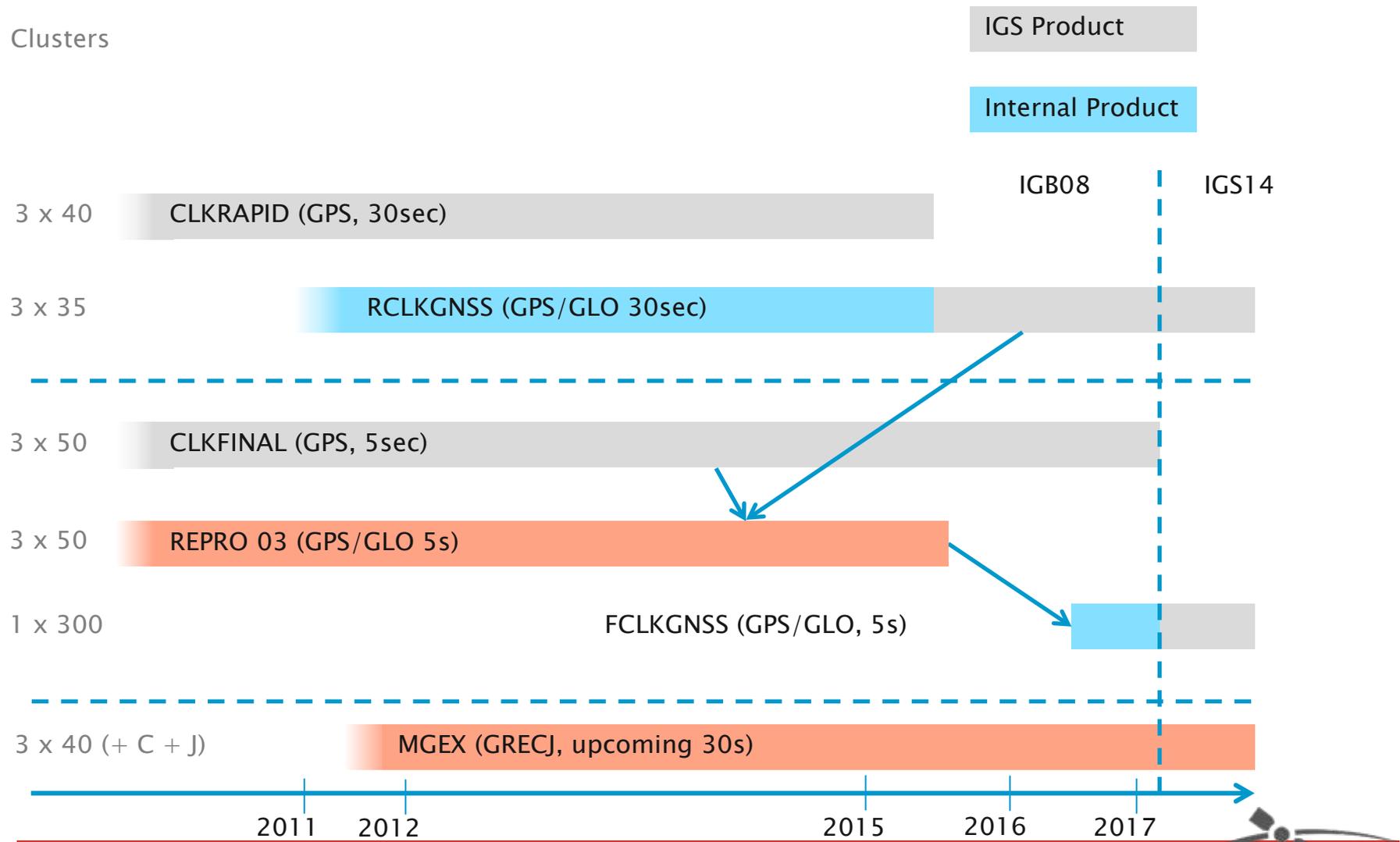
Updated IGS Final Clock Estimation

- **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

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New Clock Estimation Approach

Data Screening (PPP Final) → No additional screening

OSB's

OBS   OBS   OBS   OBS

NEQ   NEQ   NEQ   NEQ

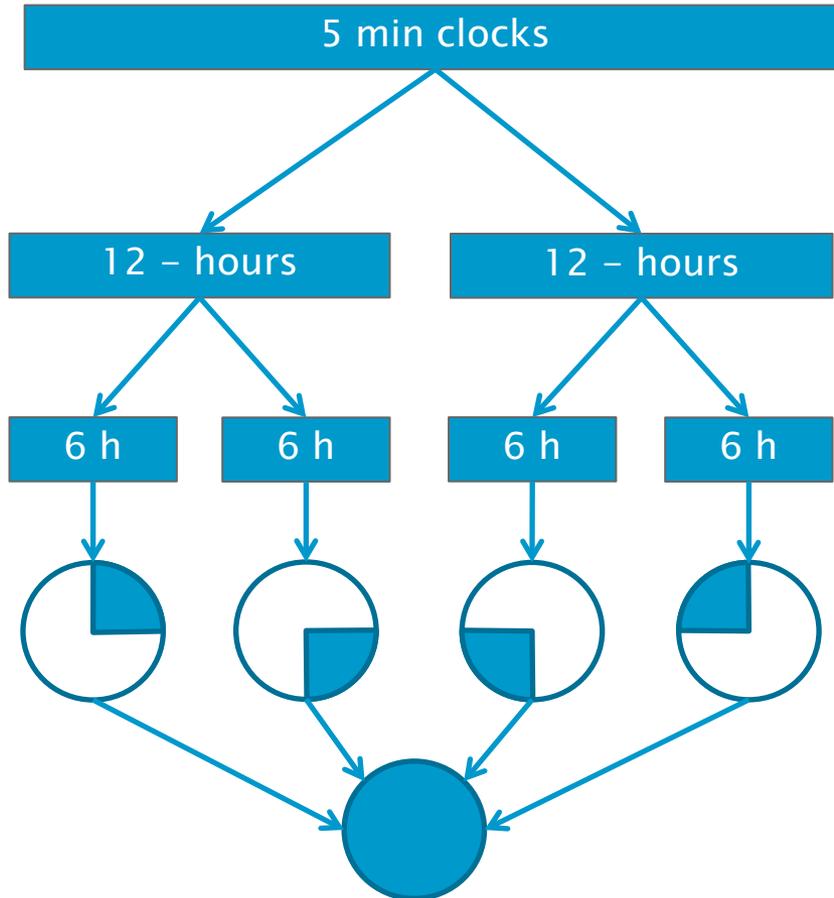NEQ with
Satellite Clocks

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

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Satellite Clock Estimation

5 min clocks

12 – hours   12 – hours

6 h   6 h   6 h   6 h

After 2 hours finished

Full Inversion: > 6 hours

Pre-elimination

12–hours NEQs

Pre-elimination

6–hours NEQs

Inversion

6–hours clocks
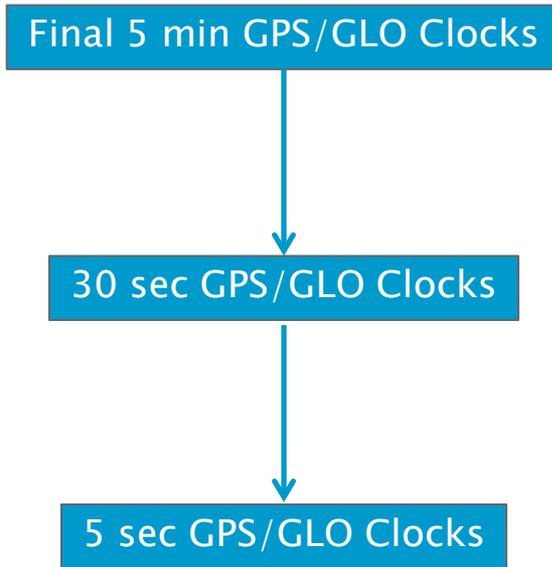
Concatenate

Full set of satellite clocks

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Receiver Clock Estimation

Data Screening (PPP Final) → No additional screening

Satellite clocks

OSB's

OBS OBS OBS OBS

Station-wise receiver clock estimation

Station-wise receiver clocks

Concatenate

Combined Receiver Clocks

Full set of receiver clocks

Concatenate

Final 5 min GPS/GLO Clocks

Final 5 min clocks

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Clock Densification

Final 5 min GPS/GLO Clocks

↓

30 sec GPS/GLO Clocks

↓

5 sec GPS/GLO Clocks

Station-wise receiver clocks

30 second densification

30-second clocks

5 second densification

Final 5 sec clocks

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IGS Combination Statistics

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IGS Combination Statistics

IGS clock combination

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Multi-GNSS Clock Product (MGEX)

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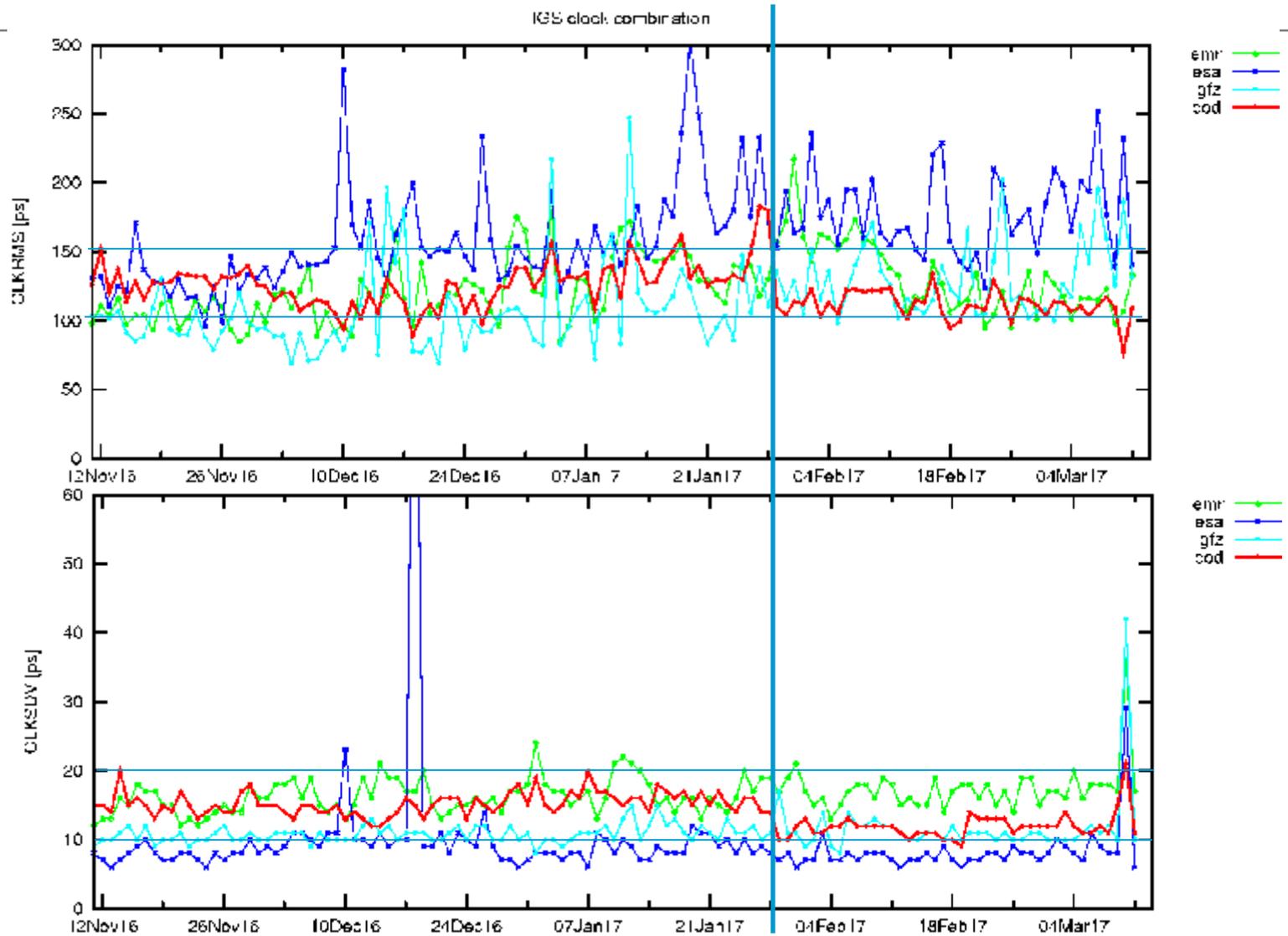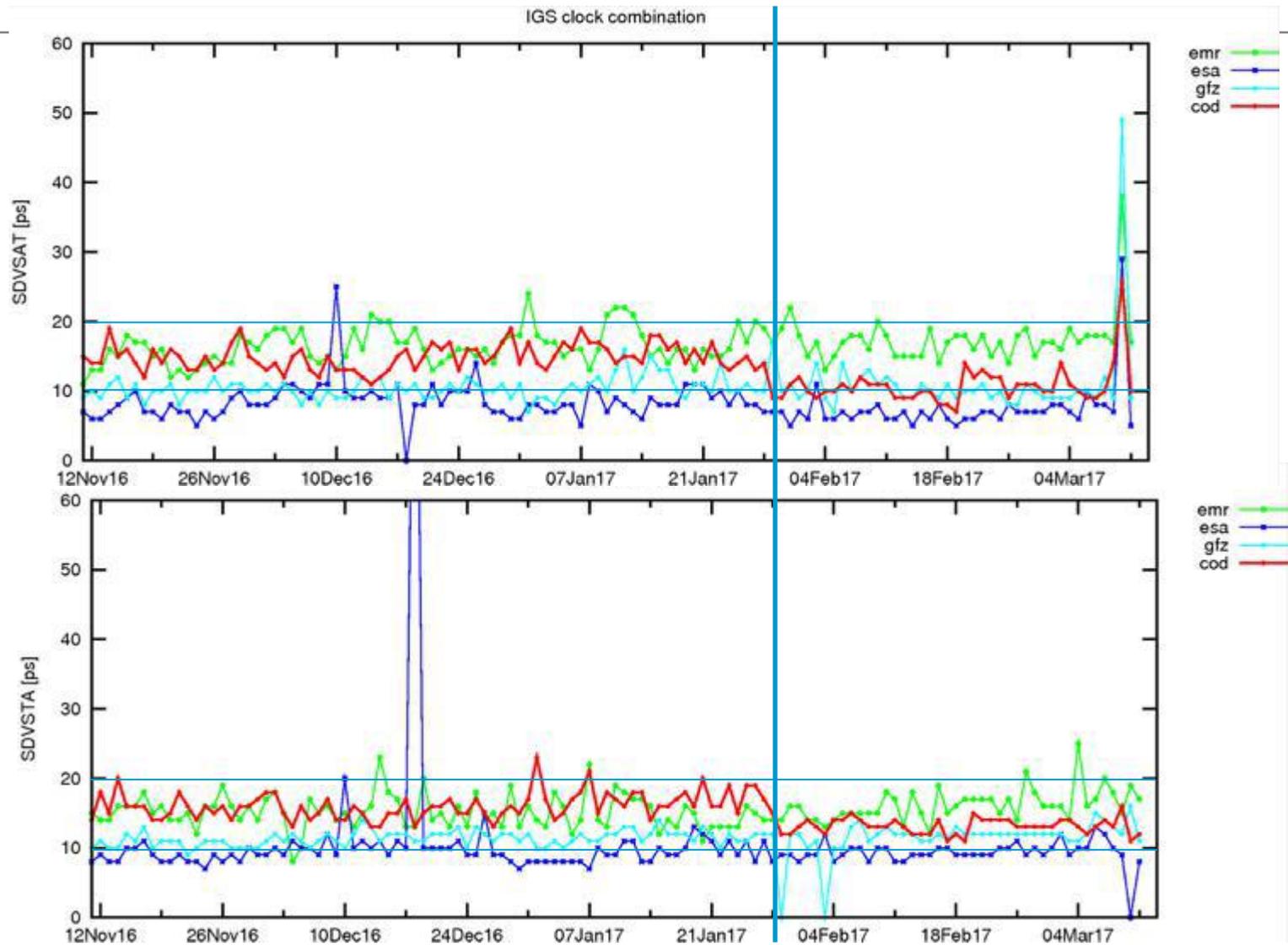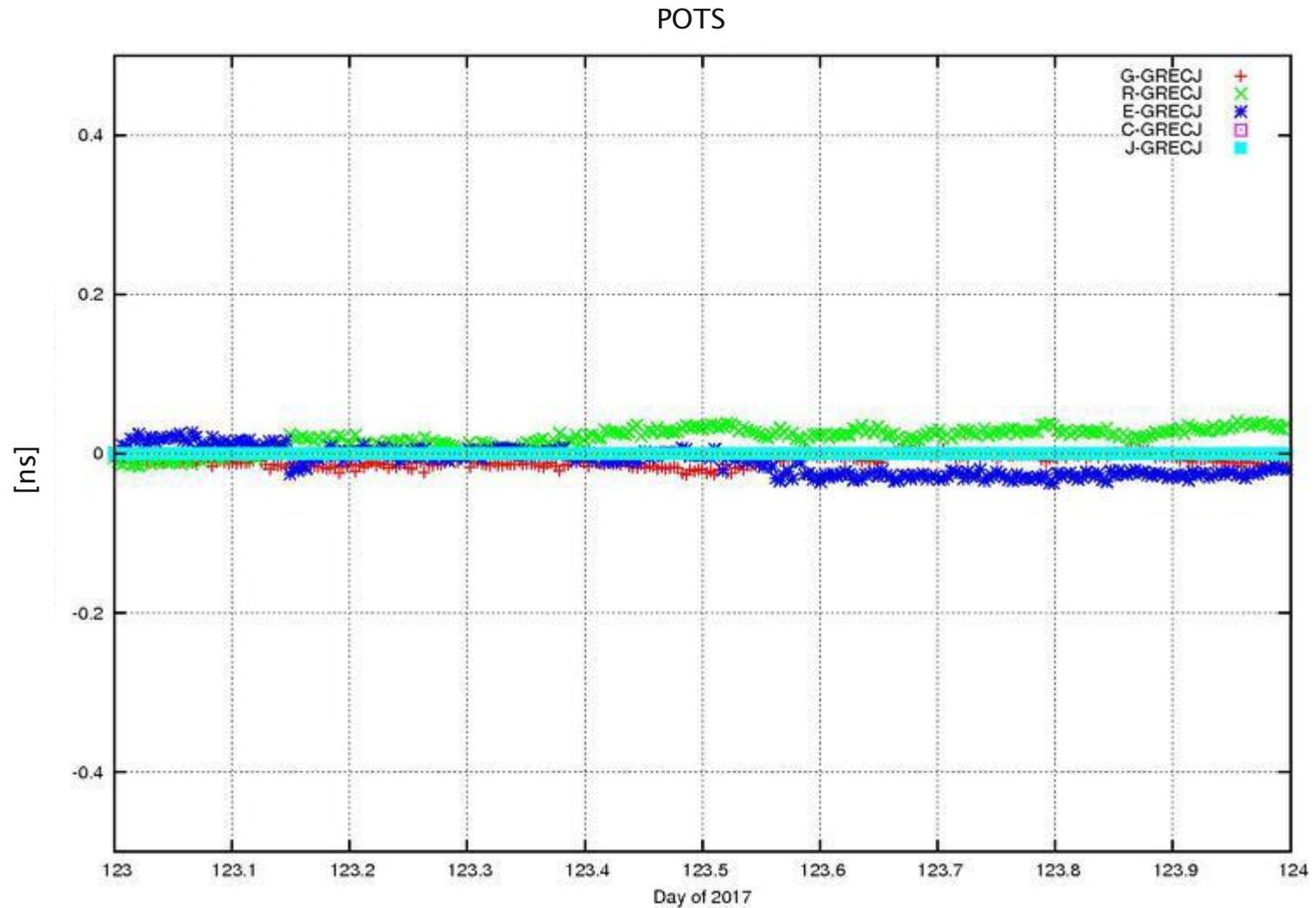
Revision of currently used cluster approach

- 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

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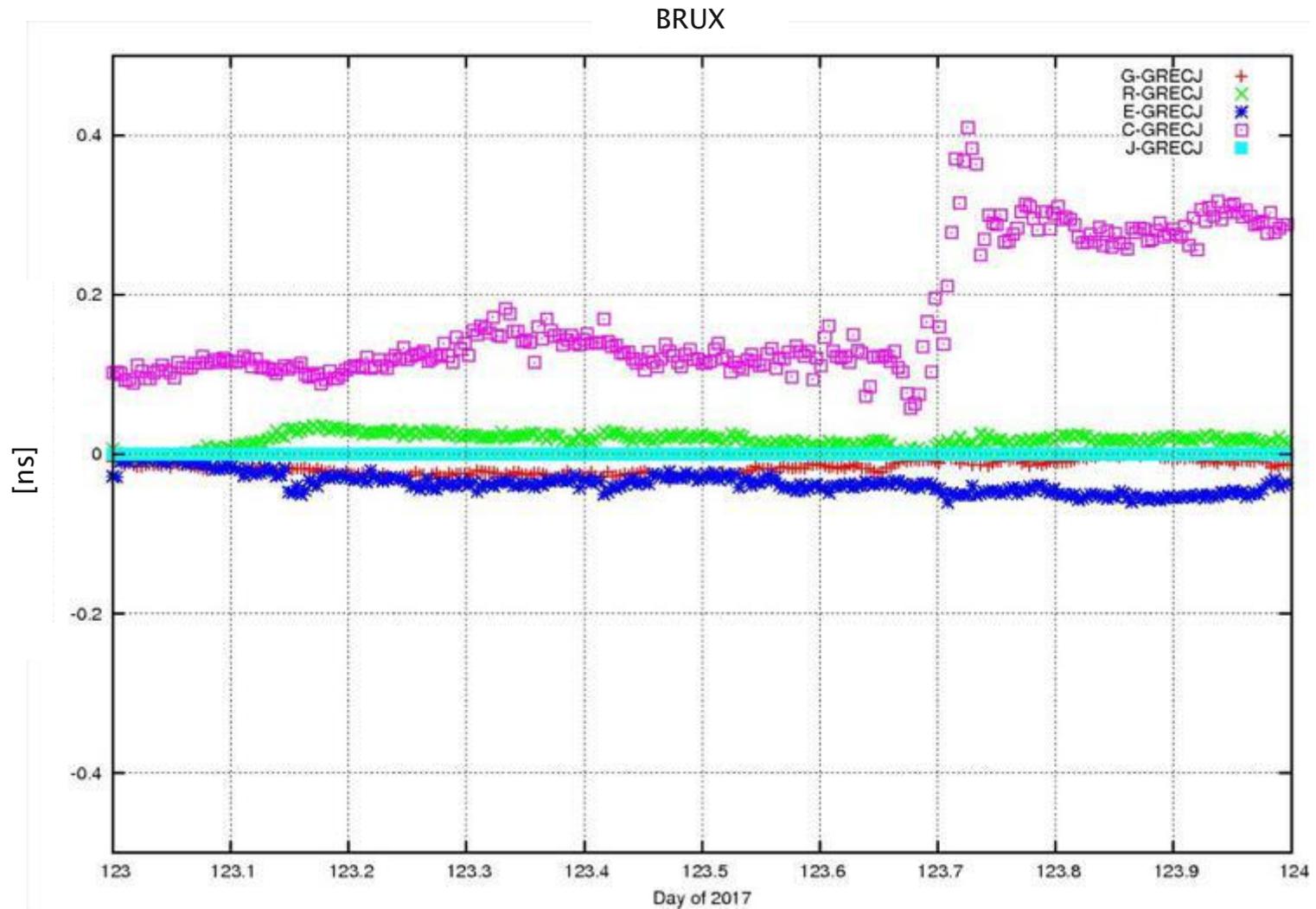AIUB CODE

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

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GNSS–specific receiver clocks

POTS

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GNSS–specific receiver clocks

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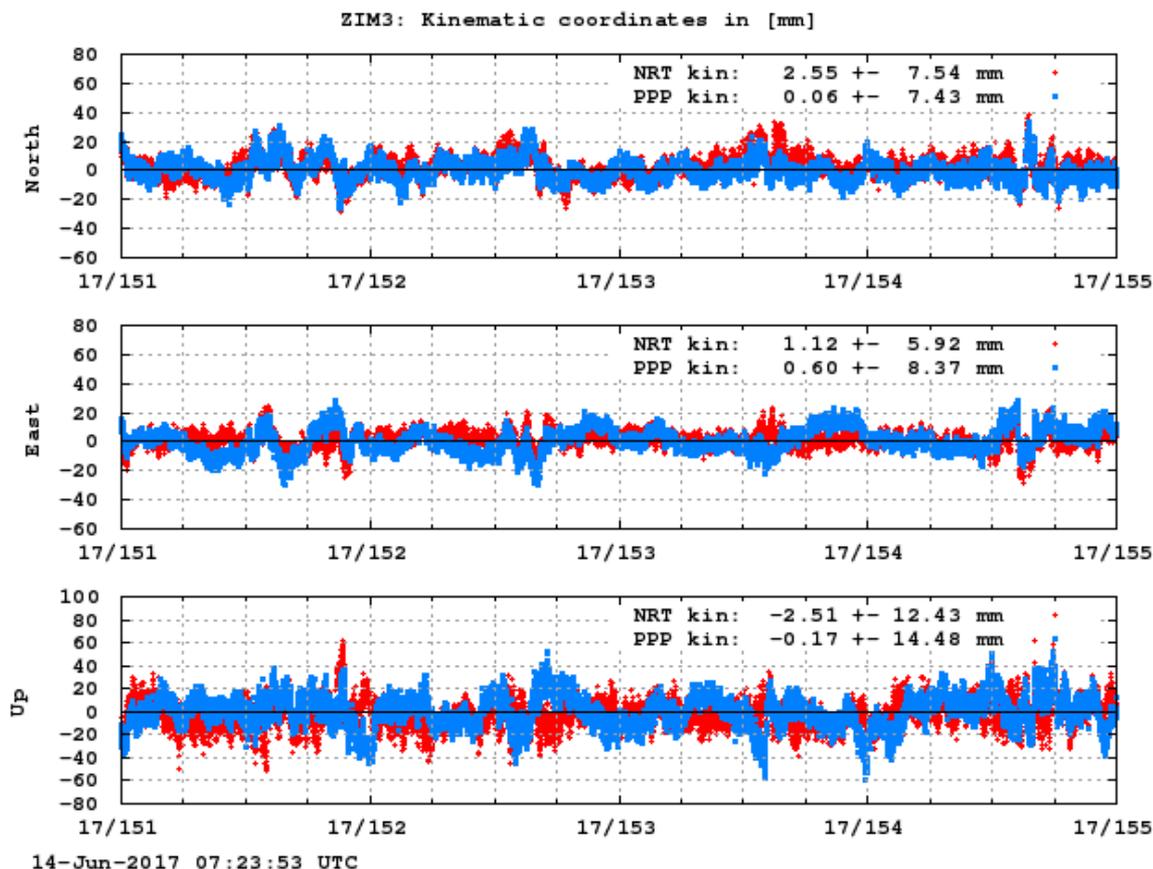
Highrate Clocks (30sec interpolation)

- 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

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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

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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

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