Testing real-time GPS orbit and clock product

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Outline

Goal:

⇒ test real-time orbit & clock product (CLCKx@BKG) using Bernese GPS software

Procedure:

- collect the product stream to a files
- convert the stream data into standard SP3 format
- design Bernese PCF for NRT Precise Point Positioning
- apply Bernese NRT PPP for CLCKx product
- validate the orbits & clocks in CLCKx product

CLCKx: real-time product @BKG

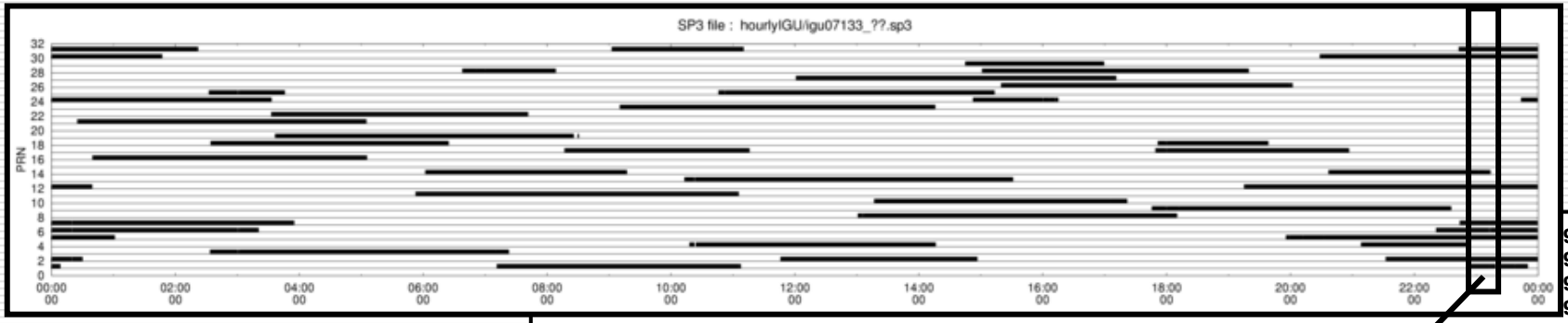
- SP3–like data stream (no header), 1Hz data
  - IGS ultra-rapid orbits provided as 1Hz samples
    (Earth-fixed orbits from polynomial representation)
  - clocks estimated by RTnet sw (regional solution)
    (GPS solutions Inc., developed by Ch. Rocken, L. Mervart etal.)

```
*  2007  2 25  9 18 24.00000000
PG03  13933.480693  -8006.625557  20914.814372     20.325223
PG07   9396.752569  24646.524176   3054.595031    403.587900
PG16  24638.084927    728.782455  10151.259507    125.005862
PG18  15489.772251  16446.040960  14354.379903   -253.421188
PG19   9633.285808 -17672.179881  17375.795677      9.567832
PG21   6109.667953  15012.819928  21059.975319     72.034574
PG22  23364.201665  11956.412407   4300.550719    170.582052
PG27  -4589.065957 -16323.602430  21027.226174     96.201418
*  2007  2 25  9 18 25.00000000
PG03  13934.383516  -8004.058513  20915.224581     20.325224
PG07   9396.499216  24646.960180   3051.503987    403.587783
PG16  24639.220026    729.400659  10148.449510    125.005461
PG18  15488.022232  16445.619105  14356.741594   -253.421400
PG19   9633.797795 -17670.040517  17377.707650      9.567905
PG21   6107.578492  15014.482372  21059.337411     72.034599
PG22  23363.602677  11956.509763   4303.642781    170.581732
PG27  -4587.241927 -16325.358991  21026.203780     96.201434
```

CLCKx: collecting RT stream into SP3 files

- **BKG Ntrip Client (BNC)**
  - get NTRIP stream (e.g. RT SP3-like data)
  - stores raw NTRIP stream in e.g. hourly batches
  - *but needs utility to convert to proper SP3 format*
- **NtripClientSP3 (in-home sw)**
  - get NTRIP stream (or read RT SP3-like data file)
  - validate SP3-like data records
  - complete the header and all missing epochs
  - stores in requested intervals or backward period
  - apply optional sampling

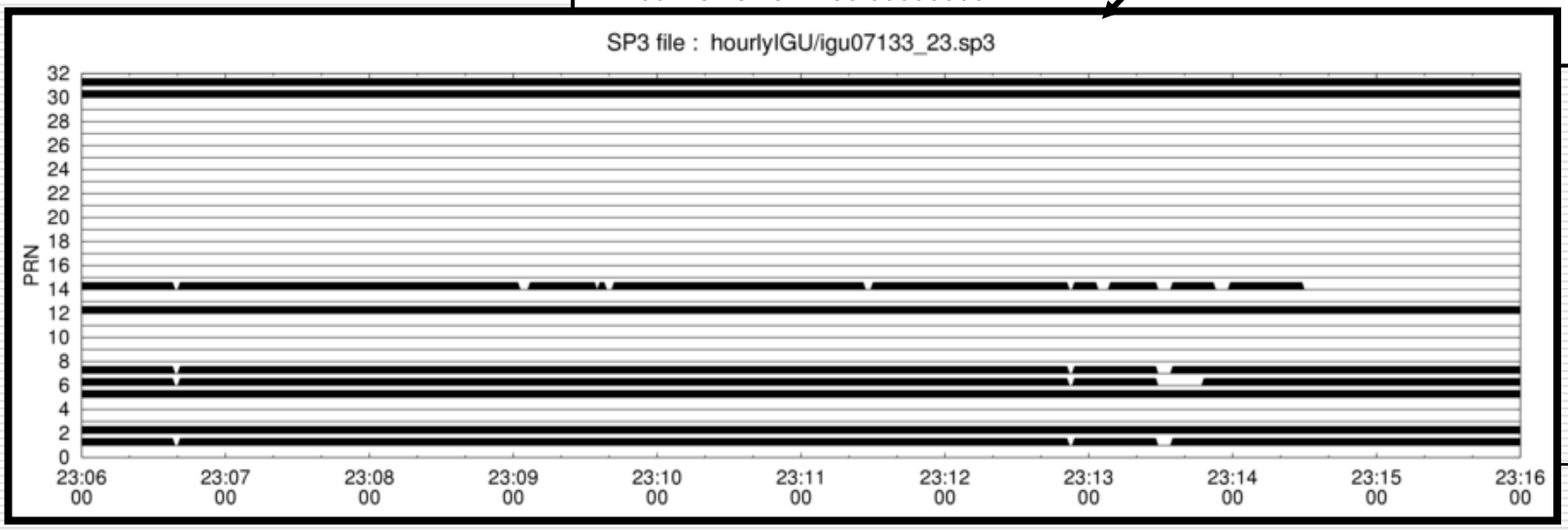
CLCKx: missing satellites, 1Hz stream



Satellite availability in RT stream = satell's for Europe

```
* 2007  5 13 15 21 40.00000000
* 2007  5 13 15 21 41.00000000  8713.485577 -20474.476861  13607.603517  -191.9933150
* 2007  5 13 15 21 42.00000000
* 2007  5 13 15 21 43.00000000  8713.903409 -20470.839808  13612.846880  -191.9933650
* 2007  5 13 15 21 44.00000000  8714.112499 -20469.020801  13615.423103  -191.9933920
* 2007  5 13 15 21 45.00000000
* 2007  5 13 15 21 46.00000000  8714.531027 -20465.381825  13620.574630  -191.9934280
* 2007  5 13 15 21 47.00000000  8714.740465 -20463.561857  13623.149935  -191.9934480
* 2007  5 13 15 21 48.00000000
* 2007  5 13 15 21 49.00000000  8715.159689 -20459.920959  13628.299627  -191.9934780
* 2007  5 13 15 21 50.00000000  8715.369475 -20458.100030  13630.874013  -191.9934970
* 2007  5 13 15 21 51.00000000  8715.579377 -20456.278781  13633.448093  -191.9935230
* 2007  5 13 15 21 52.00000000
* 2007  5 13 15 21 53.00000000
* 2007  5 13 15 21 54.00000000
* 2007  5 13 15 21 55.00000000  8716.420149 -20448.990583  13643.741351  -191.9936030
* 2007  5 13 15 21 56.00000000                                            -191.9936440
```

... Gaps in the stream



Precise point positioning in Bernese sw

Input: sat.orbits (IGS/IGR/Real-time)
sat.clocks (1s,30s,300s)
data: hourly RINEX (30s)

Variant setup: length of the processing window
24, 12, 6, 4, 3, 2, 1 (hours)
sampling interval: ***30, 300 (seconds)***
observables: ***code+phase, (phase only)***

Processing: windows for variants in one week

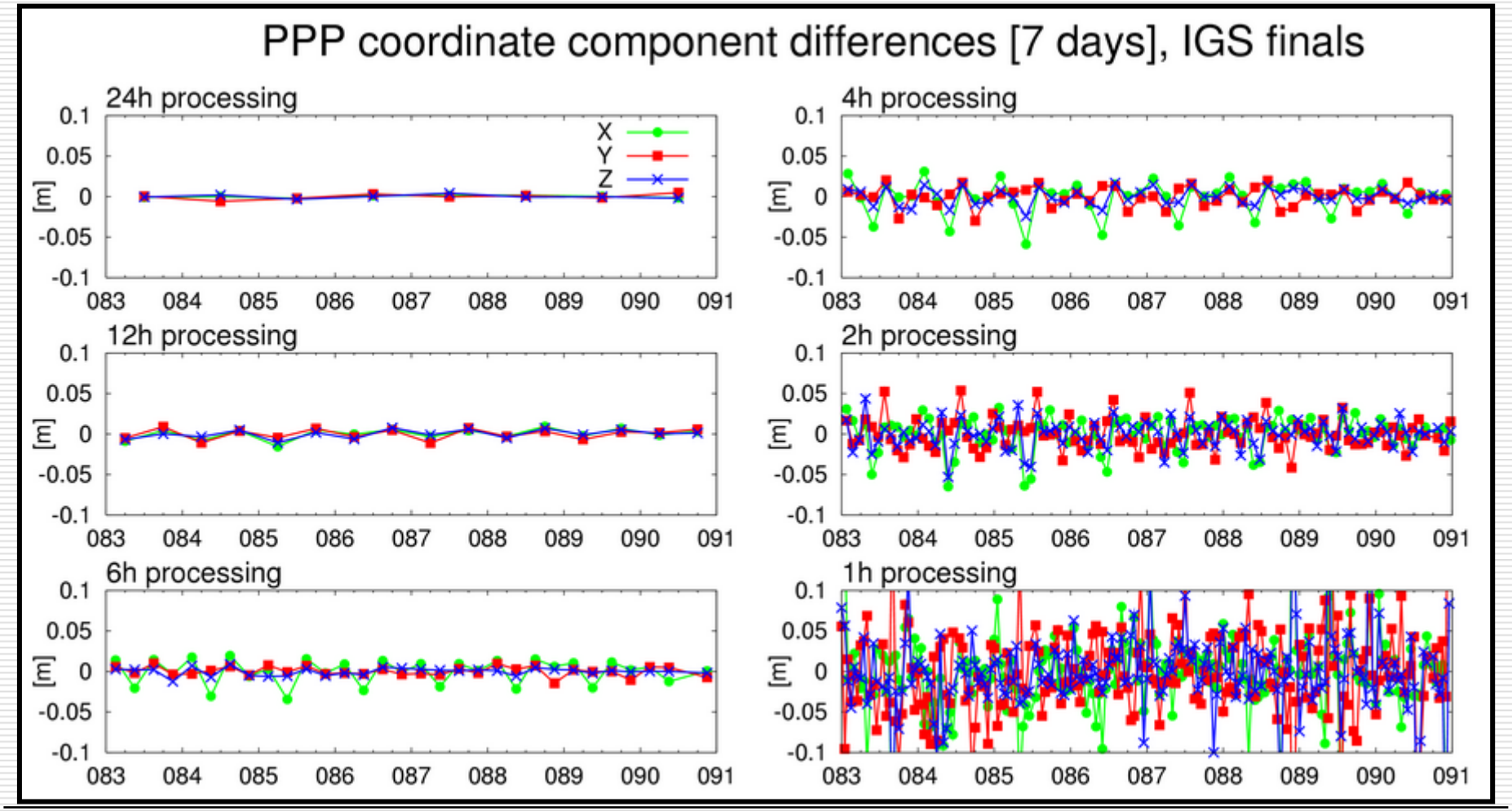
Estimates: coordinates, ZTDs, rec.clocks, ambiguities

Output: estimated parameters, all possible residuals
(CODSPP, GPSEST, ORBGEN)

Setting up Bernese PPP routine:

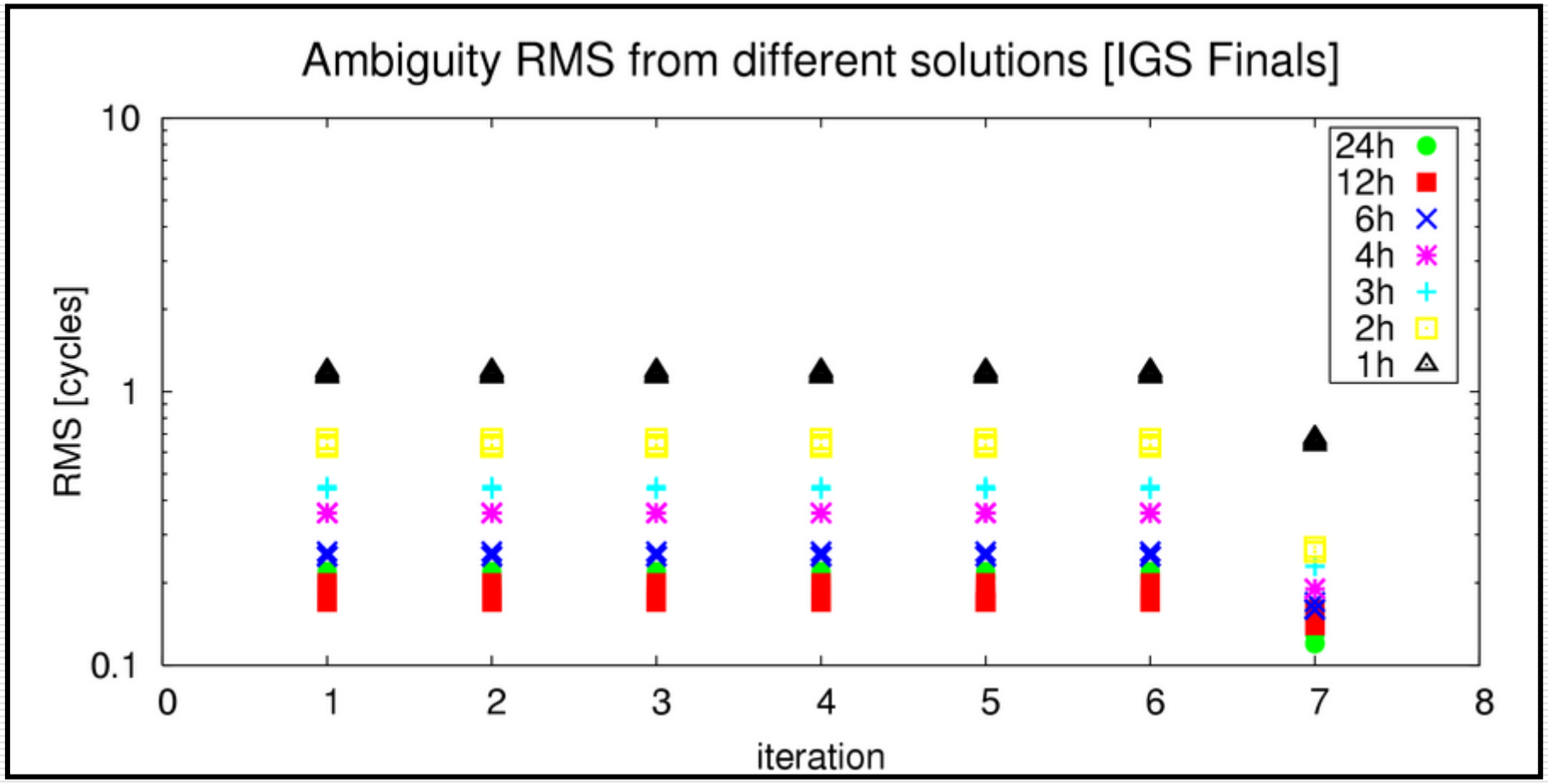
Setting up routine procedure for PPP in Bernese GPS sw.

Testing different processing interval using IGS Final orb+clk 300s.



Ambiguity RMS estimates

Ambiguity estimation depends on the processing interval.
(300s sampling, ambiguity RMS after iterative outlier rejection)



Final, Rapid and Real-time: 12h test

Coordinates repeatability

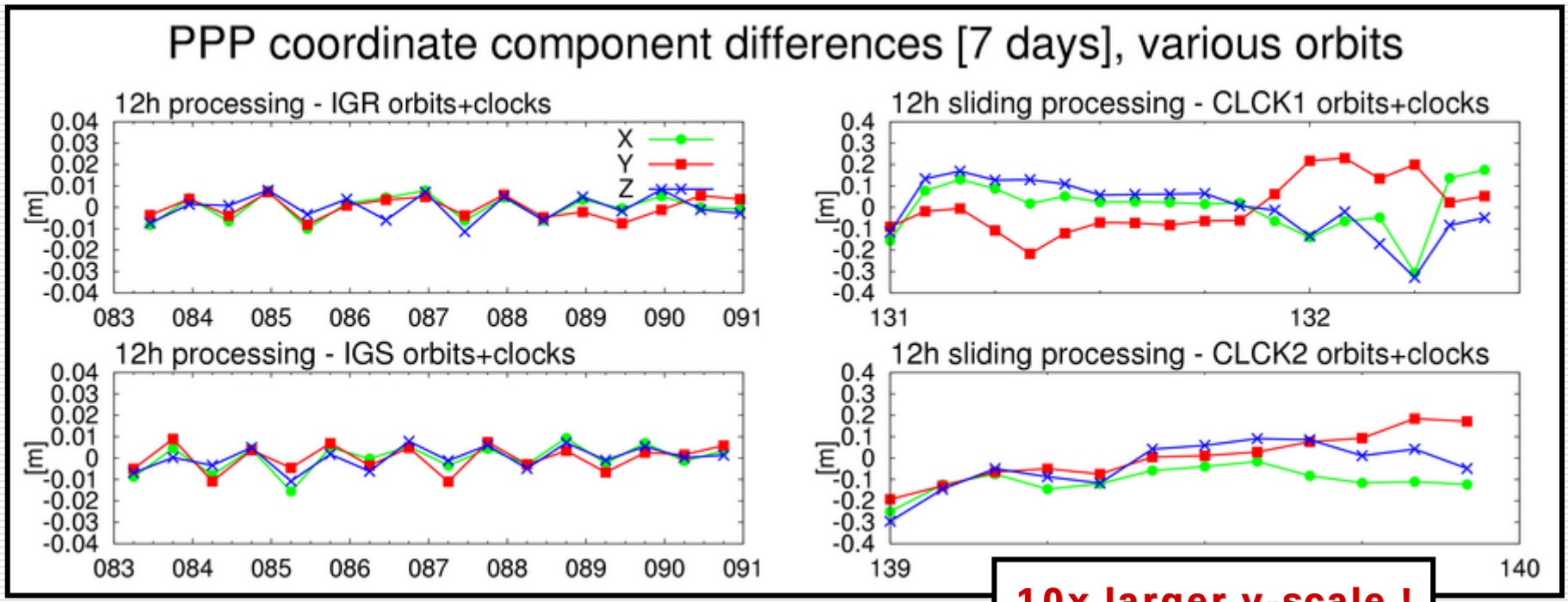
(phase+code observables)

IGR, IGS orb+clk

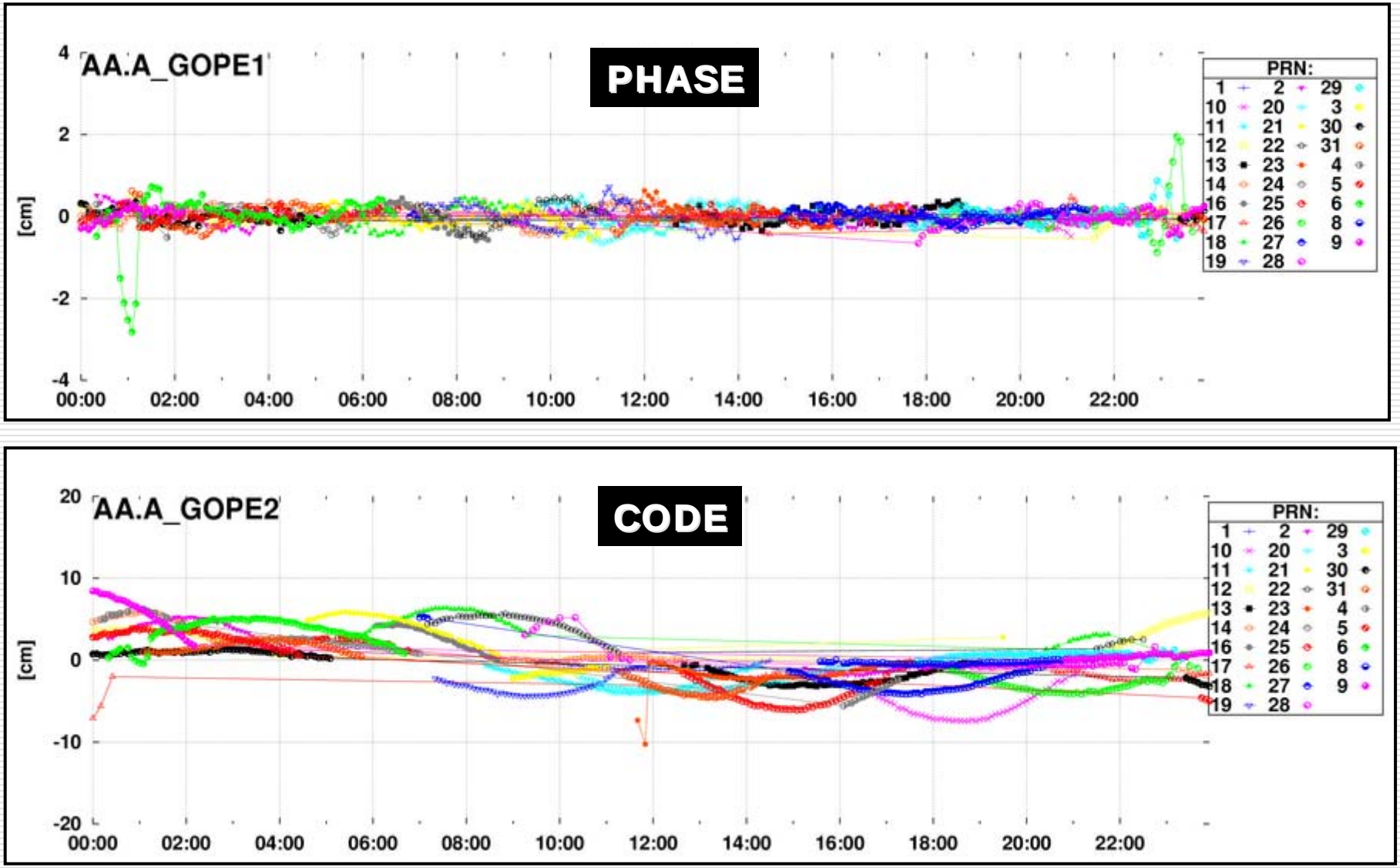
(12h processing)

CLCK1, CLCK2 orb+clk

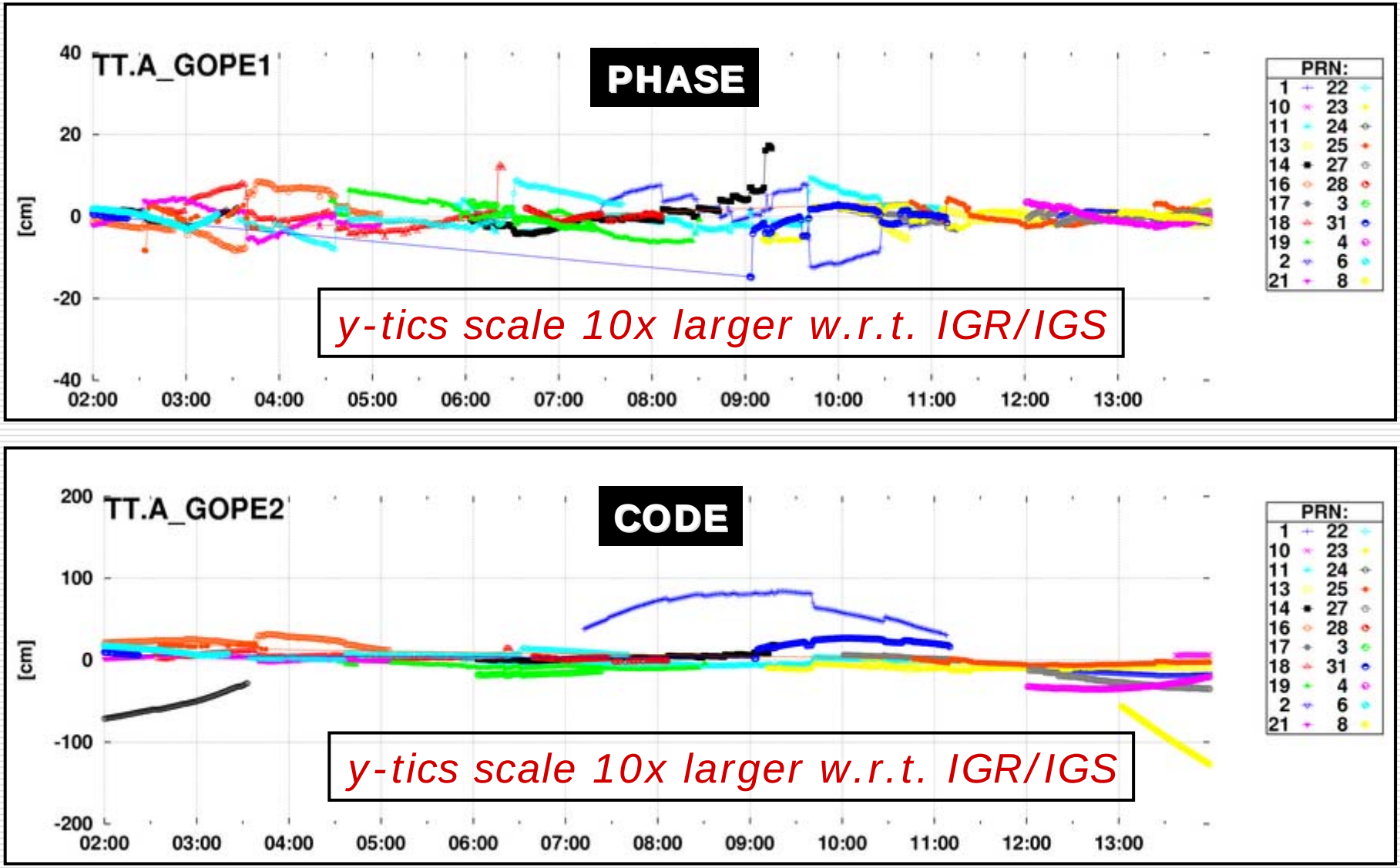
(12h sliding window)



IGS Finals – phase x code PPP residuals



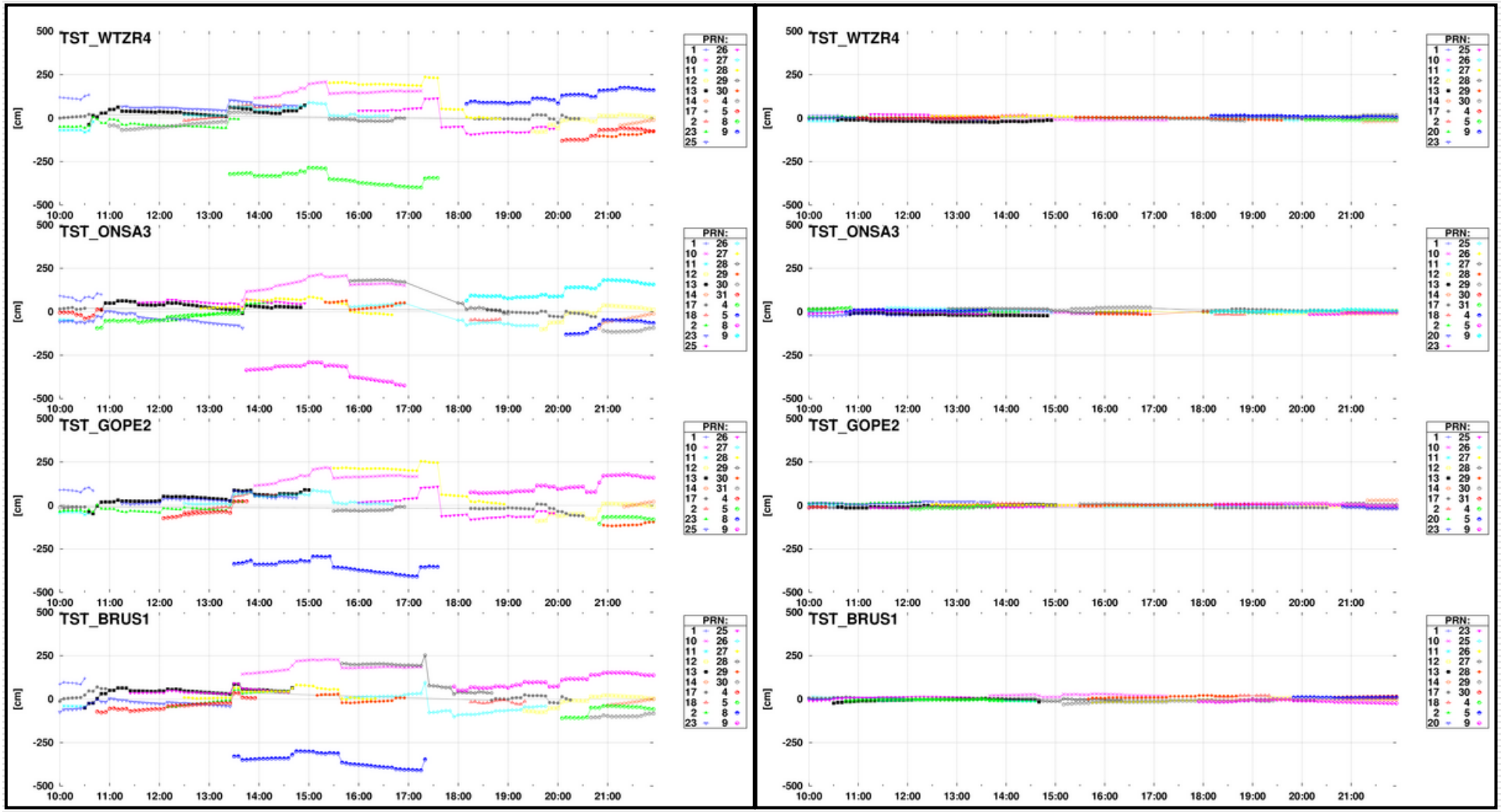
CLCKx – phase x code PPP residuals



Single point positioning - code residuals

CLCK2 real-time

IGS Rapid



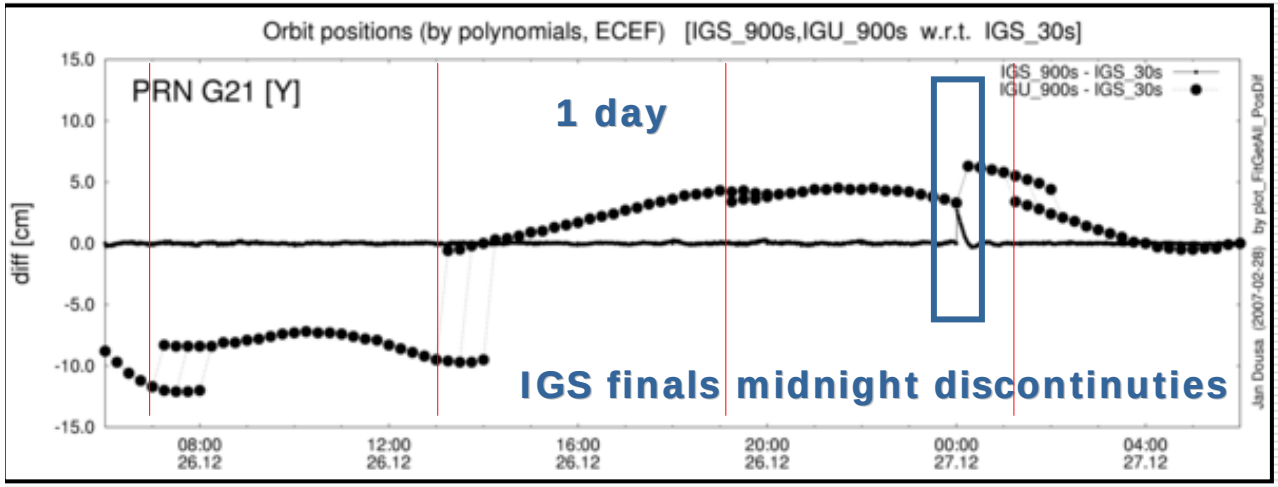
CLCKx - validation

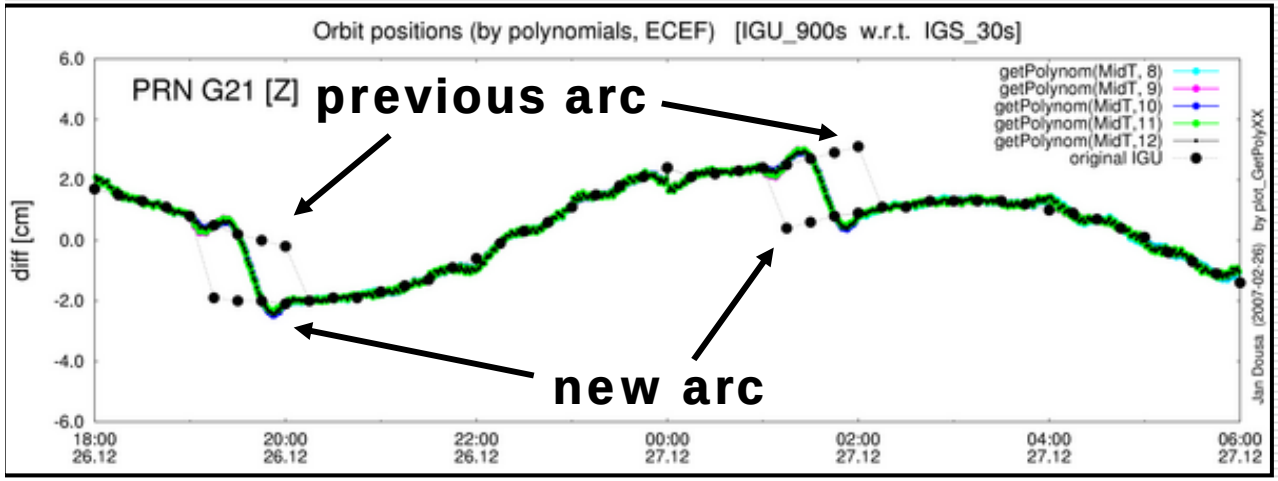
Validate separately:

- CLCKx orbits
- CLCKx clocks

- by substituting with precise IGS orbits/clocks
- by comparing to precise IGS orbits/clocks

CLCKx: orbits from IGS ultra-rapids ?





The orbit are represented using Lagrange interpolation (component by component)

IGU-00: @ 03h UTC
used: 04-10h
IGU-06: @ 09h UTC
used: 10-16h
IGU-12: @ 15h UTC
used: 16-22h
IGU-18: @ 21h UTC
used: 22-04h

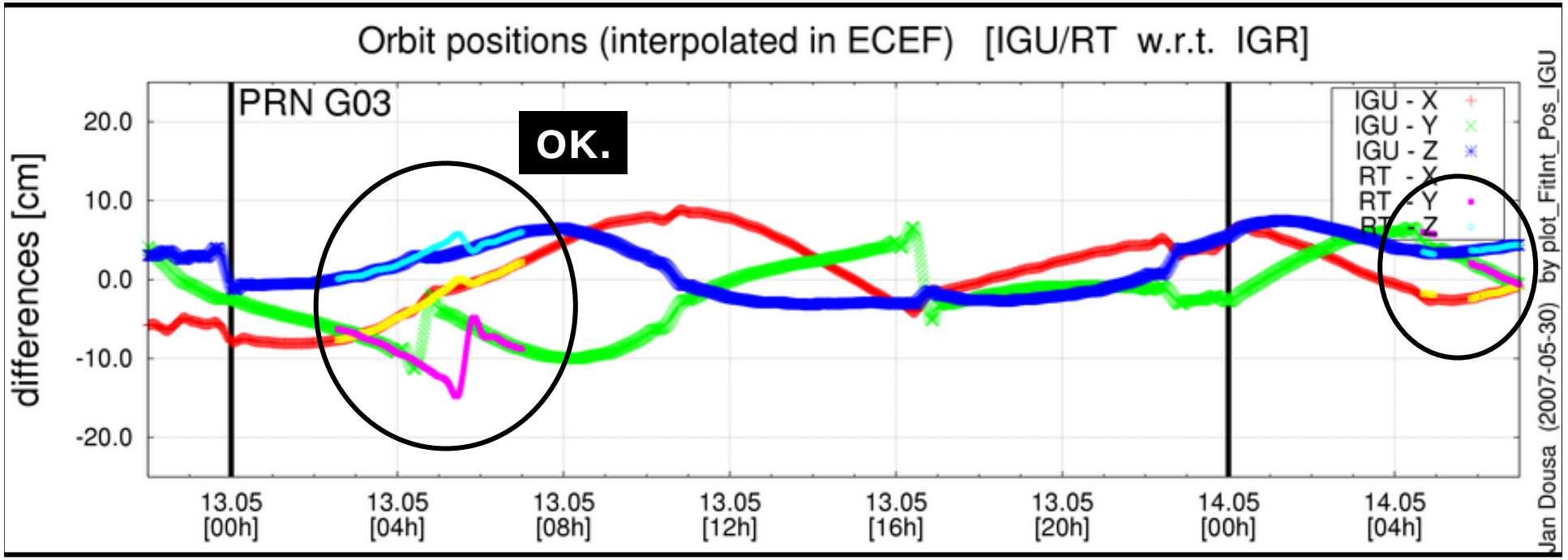
Real predictions: 4-10h

Comparisons:
(in ECEF system)

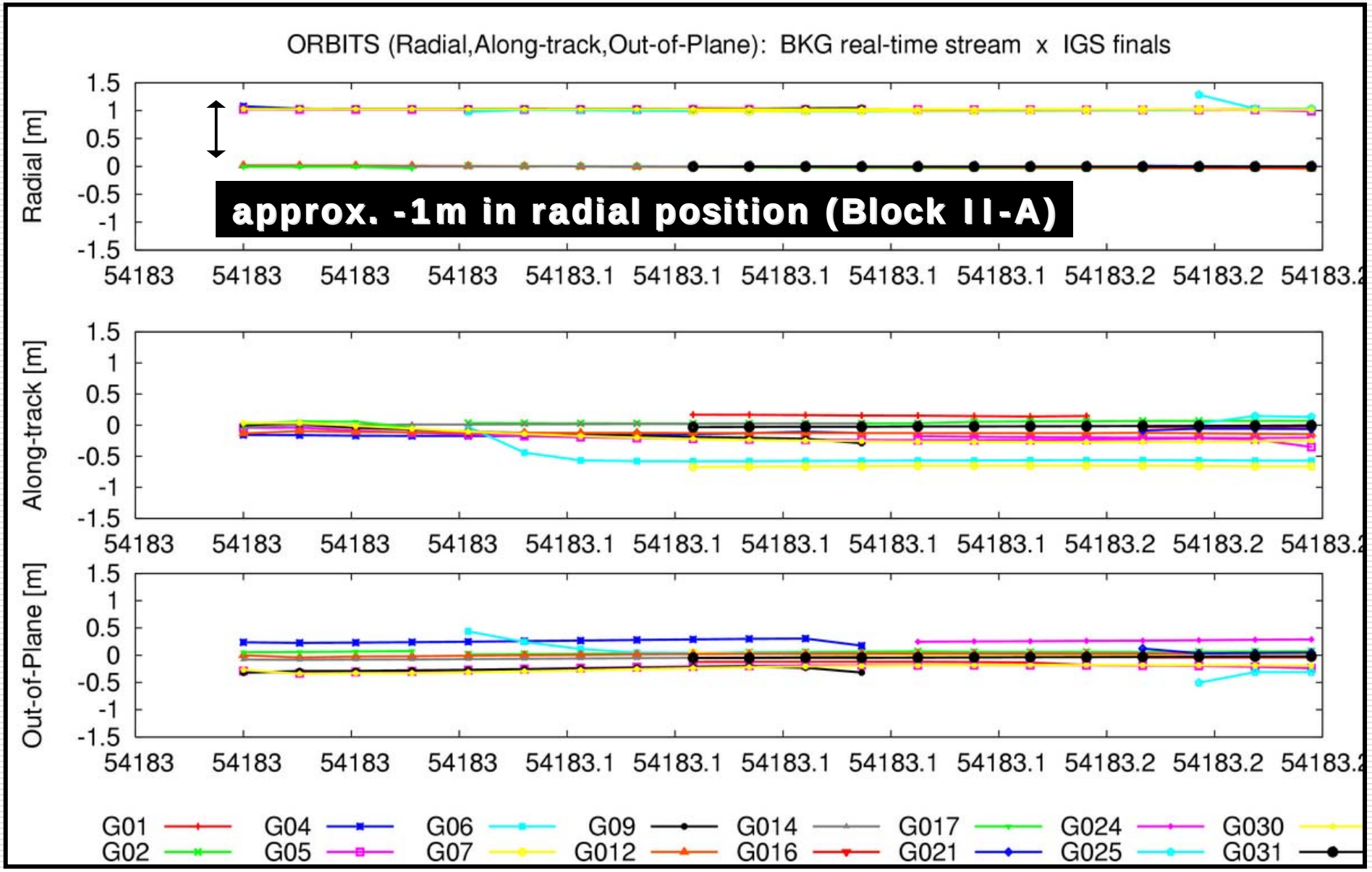
IGS
finals & ultra-rapids
in 15min SP3 std files
(interpolated in ECEF)
×
IGS finals in 30sec SP3
(modelled in inertial sys.)

CLCKx: rt stream orbits (1)

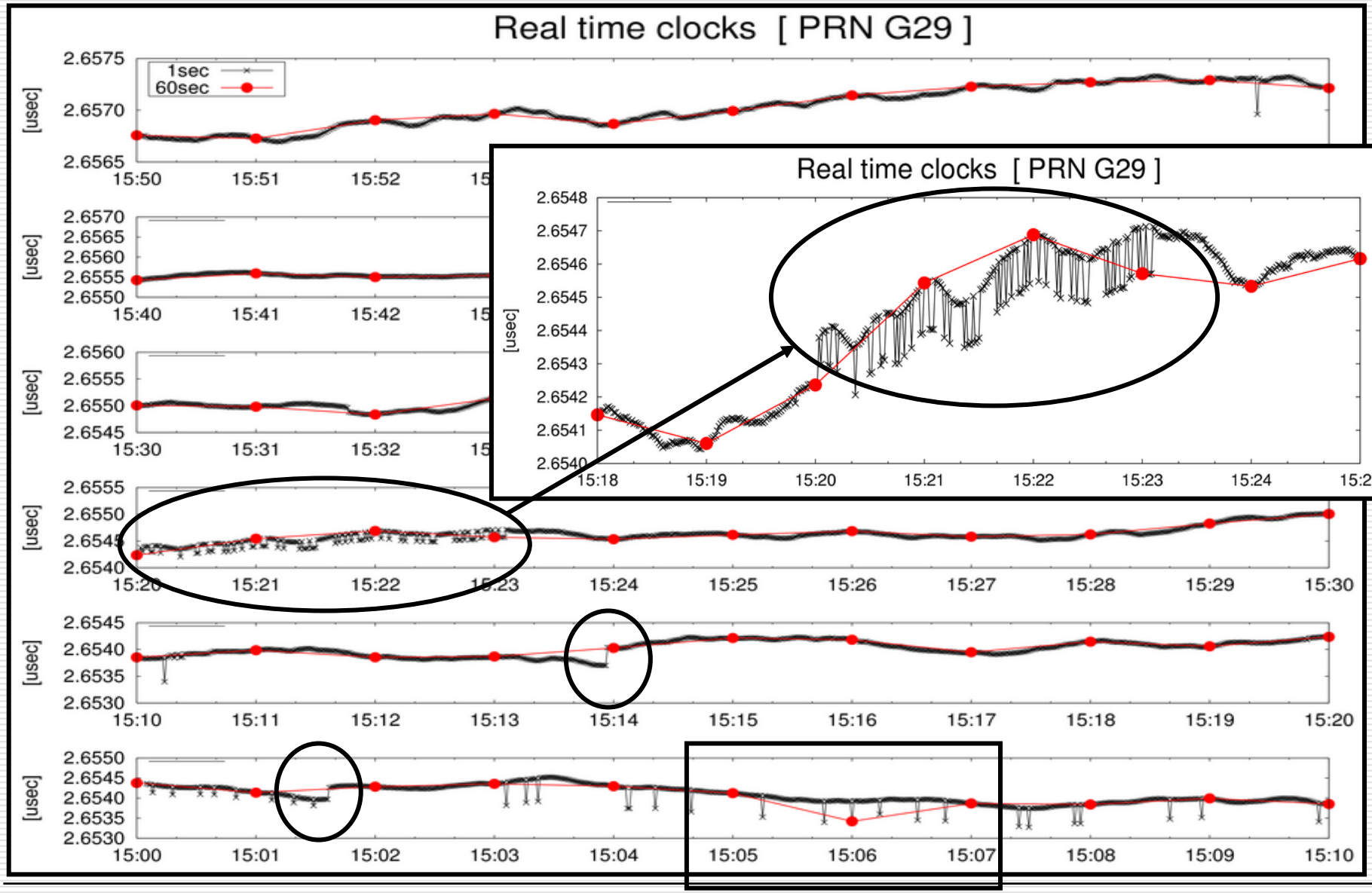
Evaluation of the CLCKx real-time orbits with respect to part accessible in real-time from IGS ultra-rapids



CLCKx: first orbit problem (2)



CLCKx: rt stream clocks



Clocks: code x phase

- **Phase observables model** (simplified)

$$L_k^i = \rho_k^i + c \cdot (\delta_k - \delta^i) + n_k^i \cdot \lambda$$

ρ_k^i .. geometrical distance (k=rec, i=sat)

δ_k .. receiver clock correction to GPStime

δ^i .. satellite clock correction to GPStime

c .. velocity of light

n_k^i .. initial phase ambiguity

one-to-one CORRELATED

Code observables model (simplified)

$$P_k^i = \rho_k^i + c. (\delta_k - \delta^i)$$

Using code: recv-satel clock correction differences are estimated

Using phase only: clock corrections estimated only in relative sense (between satellites, offsets are eated by initial ambiguities)

CLCKx: clock evaluation

- **clock difference:** evaluation w.r.t. reference (IGS)

$$\mathbf{dif}^{i}(t) = \delta^{i}(t) - \delta^{i}_{IGS}(t)$$ i ... satellite

- **clock-rate difference:**

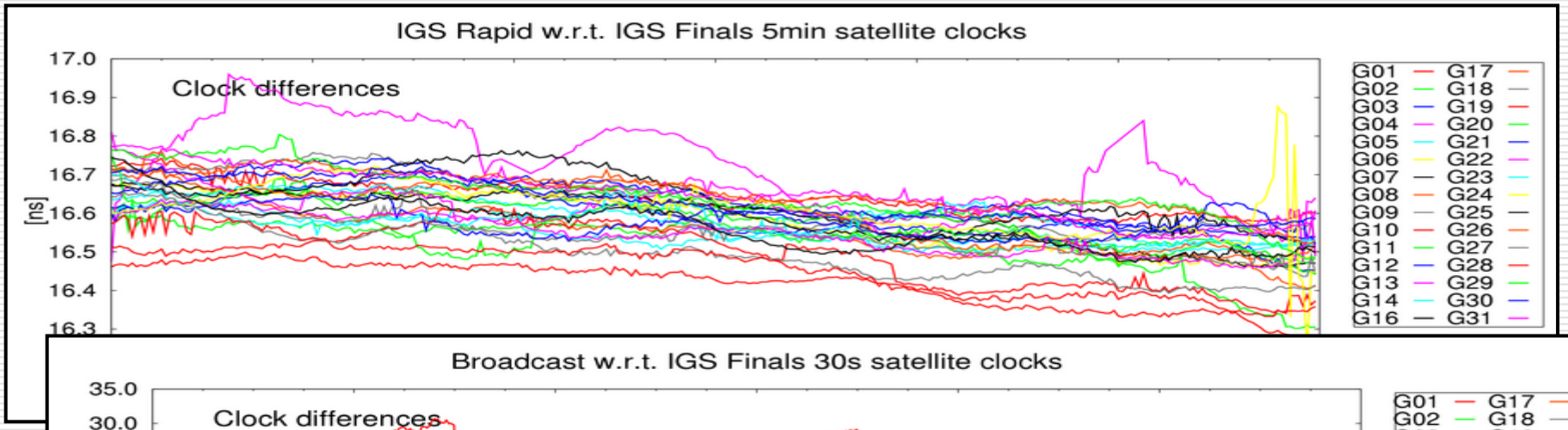
$$\mathbf{Rdif}^{i}(t_2) = \mathbf{dif}^{i}(t_2) - \mathbf{dif}^{i}(t_1)$$

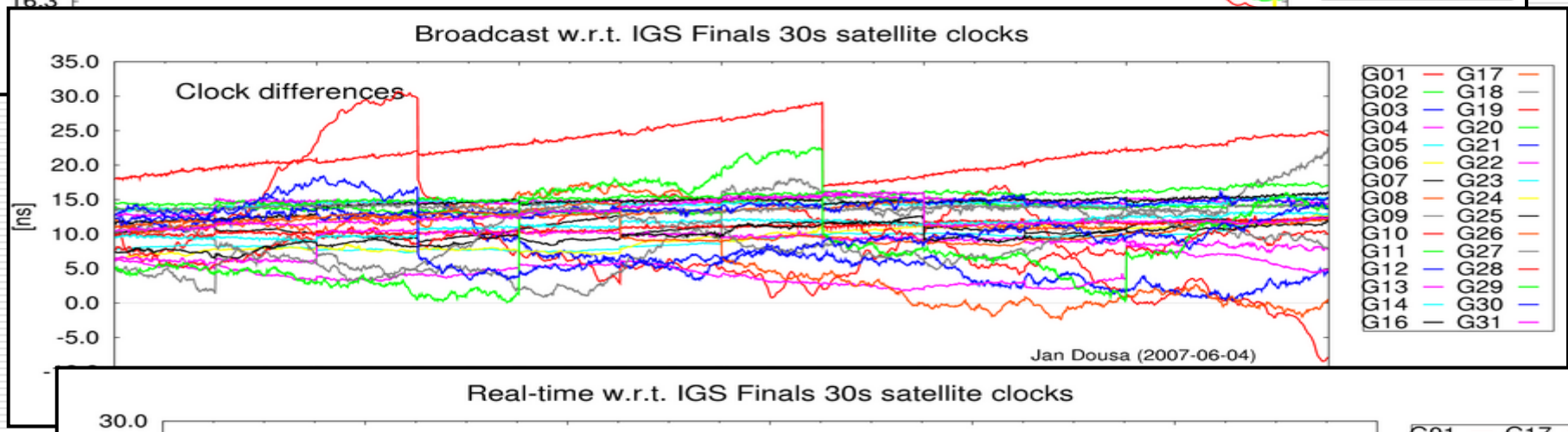
- **clock-rate differences w.r.t. reference satellite:**

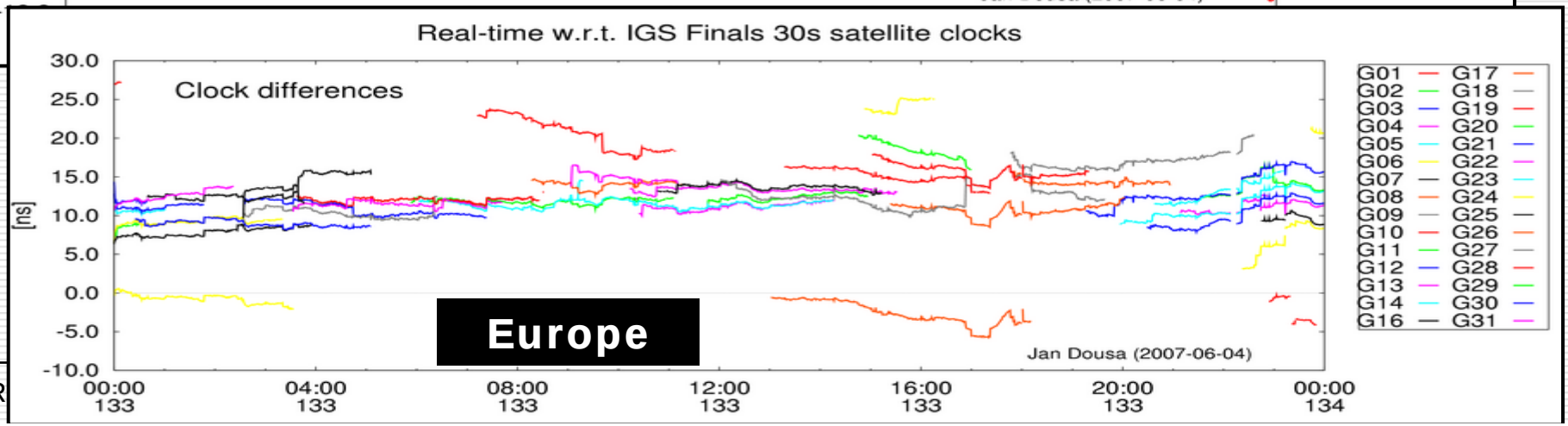
$$\mathbf{RSdif}^{i}(t) = \mathbf{Rdif}^{i}(t) - \mathbf{Rdif}^{REF}(t)$$

REF .. satellite actually in the highest elevation

CLCKx: clock evaluation (clock difference)

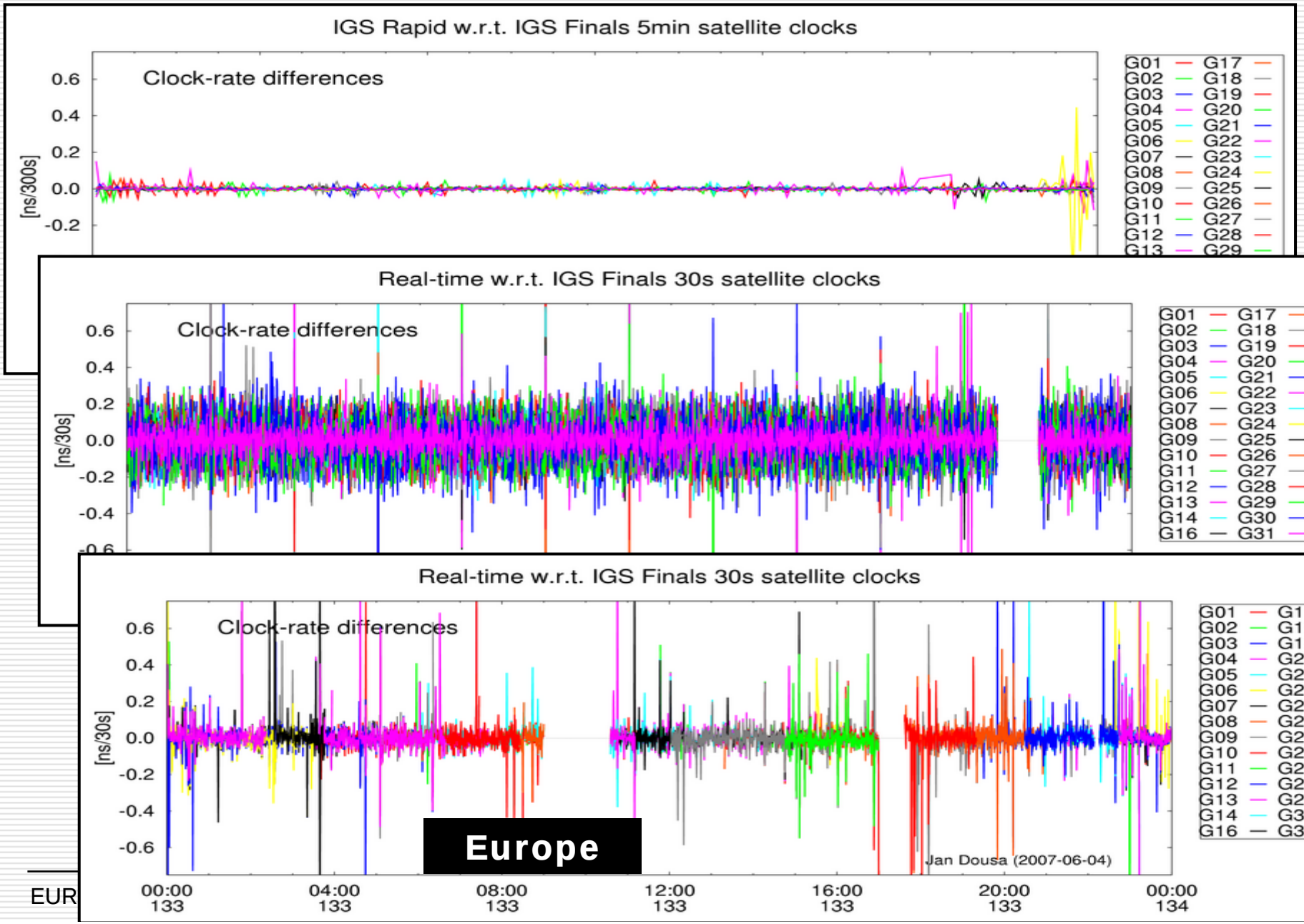






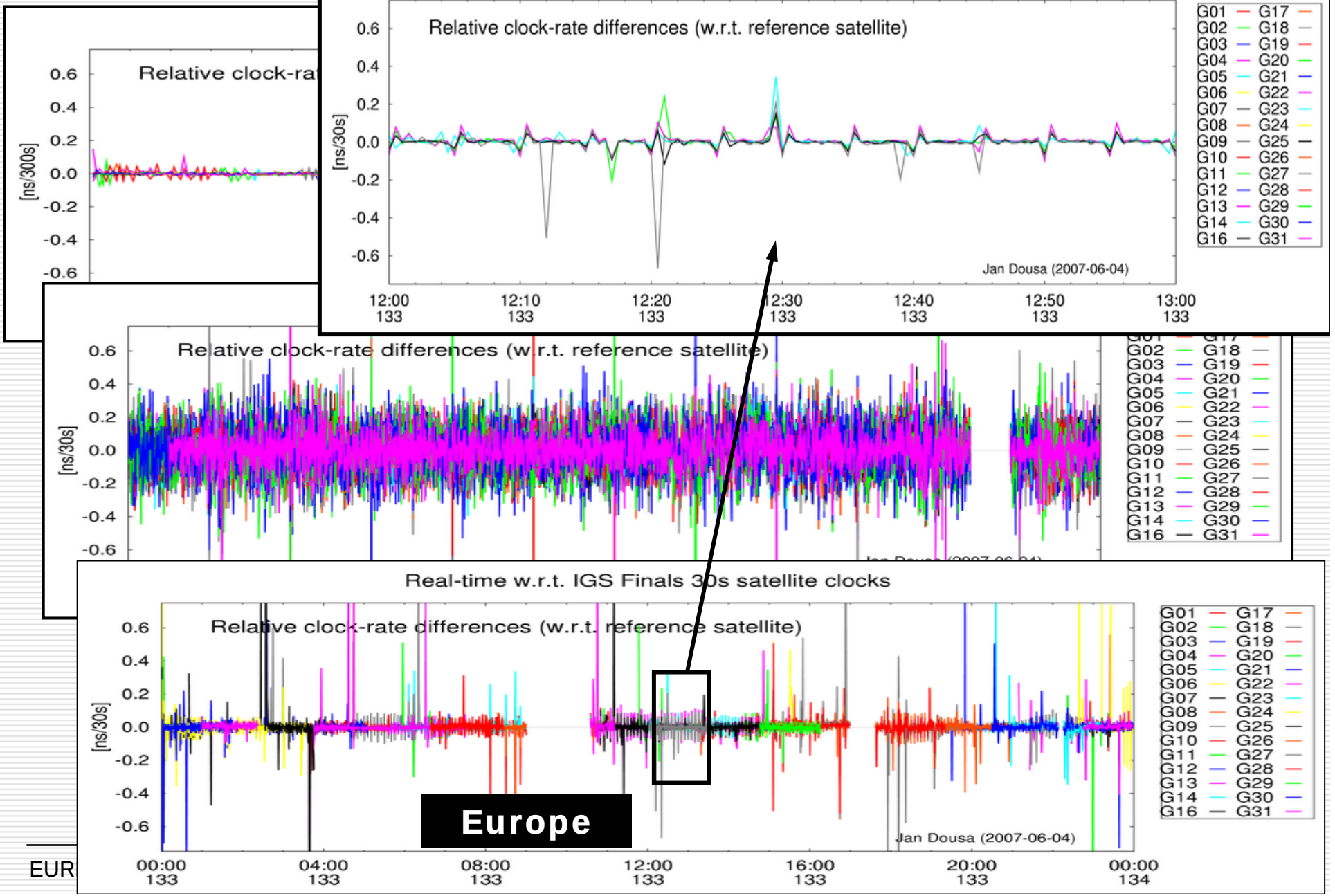
EUR

CLCKx: clock evaluation (clock-rate difference)

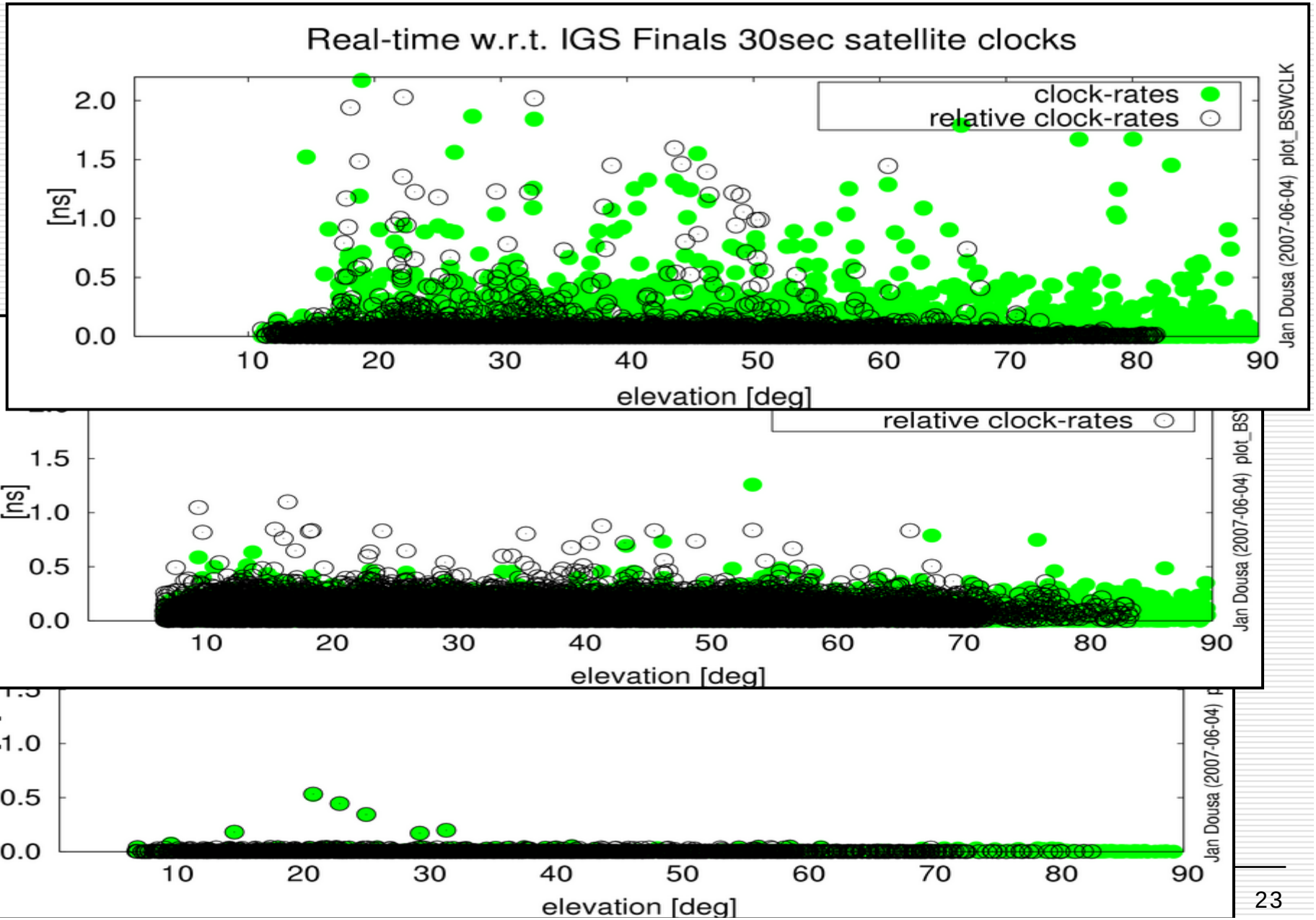


EUR

CLCKx: (relative clock-rate difference)



CLCKx: clock-rates w.r.t. satellite elevation



Summary

- we prepared the routine conversion of the rt CLCK-stream to the standard SP3 format. The conversion was evaluated.
- we didn't succeed to provide relevant results using Bernese PPP for "phase clock" rt product. The additional study is needed. Nevertheless, we setup and tested Bernese routine to use PPP e.g. for near real-time coordinate or ZTD monitoring.
- we evaluated real-time CLCK-x clocks and orbits individually.

Possible improvements of the real-time product:

- **Calibrate "phase clocks" with code observations**
- Clock estimated from global real-time network
  (to avoid problems with satellite rising/setting in regional network)
- Standard format for orbit and clock real-time streaming
  - functional representation for orbits rather than data sampling (ongoing activity within RTCM commission)
- Stability of the product