Near-real Time GPS Clock Generation at CODE

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- Background: IGS / CODE / AIUB
- Concept for the generation of NRT GPS clock corrections
- Example
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IGS / CODE / AIUB

- The Center for Orbit Determination in Europe (CODE) is one of the IGS analysis centers contributing to the IGS from the very beginning
- CODE is a joint venture of
  - Astronomical Institute, University of Bern, Switzerland (host)
  - Bundesamt für Landestopografie swisstopo, Wabern, Switzerland, and
  - Bundesamt für Kartographie und Geodäsie, Franfurt, Germany
- All CODE GNSS products are generated with a processing software developed at AIUB => Bernese GPS Software (BSW)

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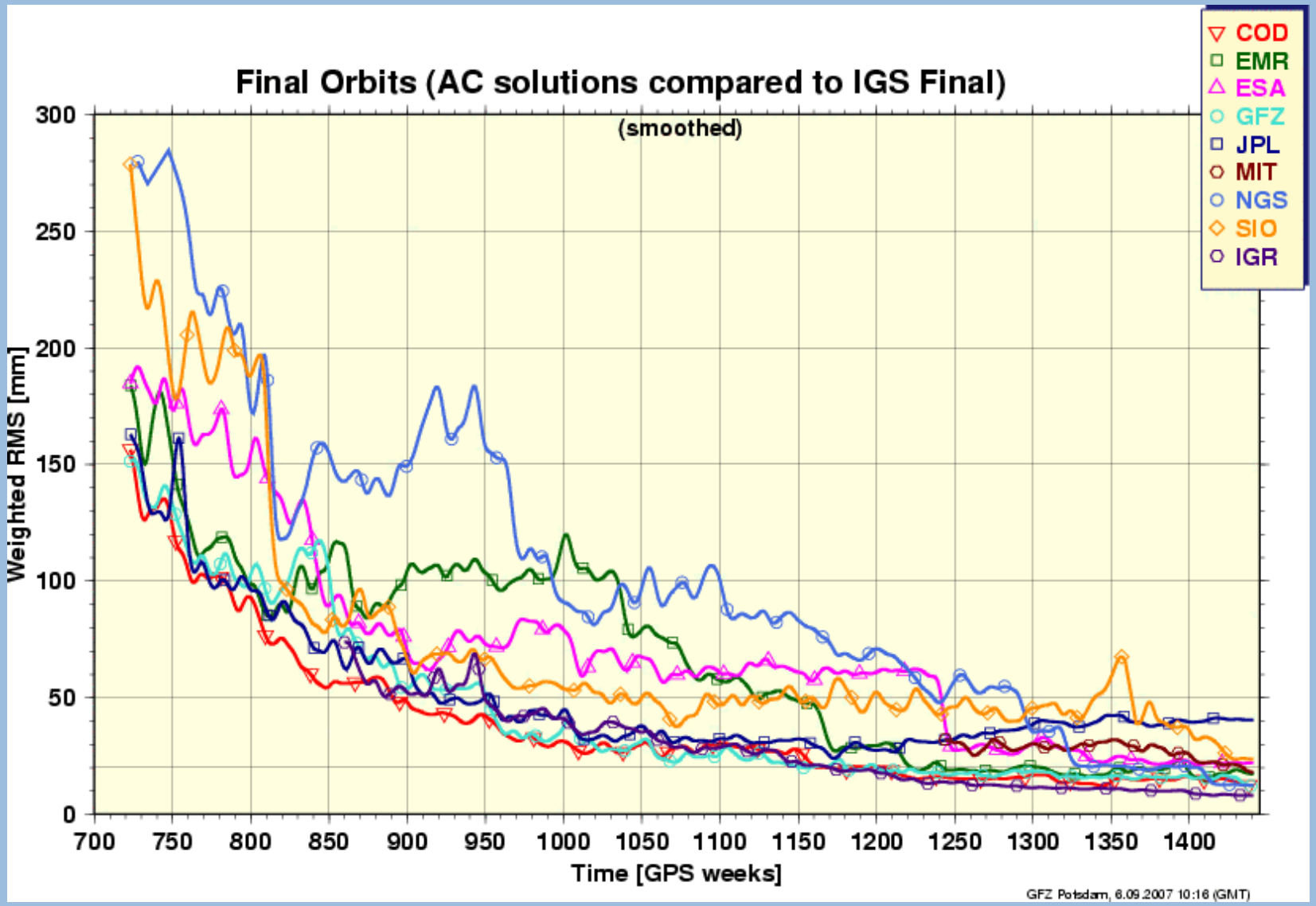

IGS => Products

		Accuracy	Latency	Updates	Sample Interval
Broadcast	orbits sat. clocks	~ 160 cm ~ 7 ns	real time	(every two hours)	
Ultra Rapid (predicted half)	orbits sat. clocks	~ 10 cm ~ 5 ns	real time	four times daily	15 min
Ultra Rapid (observed half)	orbits sat. clocks	< 5 cm ~ 0.2 ns	3 hours	four times daily	15 min
Rapid	orbits sat. clocks	< 5 cm 0.1 ns	17 hours	daily	15 min 5 min *
Final	orbits sat. clocks	< 5 cm < 0.1 ns	~ 13 days	weekly	15 min 5 min **

* CODE 30 seconds

** CODE, JPL and EMR 30 seconds

The CODE Analysis Center contributes to all of these IGS products.

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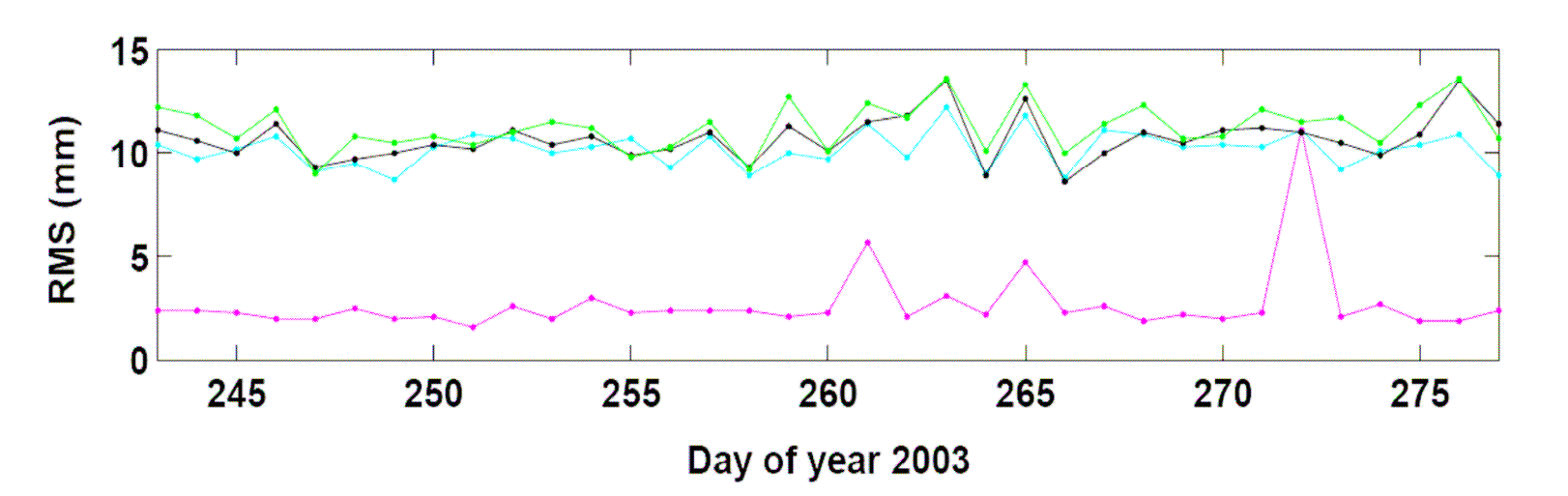
- The BSW is capable to do precise orbit determination for Low Earth Orbiters (LEOs):
  - Longer POD time series for CHAMP and GRACE satellites exist
  - Tests with other LEOs, e.g. COSMIC, SAC-C, MetOp
  - AIUB is responsible for the Precise Science Orbit of the GOCE satellite (member of the GOCE High-level Processing Facility)

GRACE K-band range RMS errors (**ZD**, **DD**, **DD comb**, **DD amb. fixed**)



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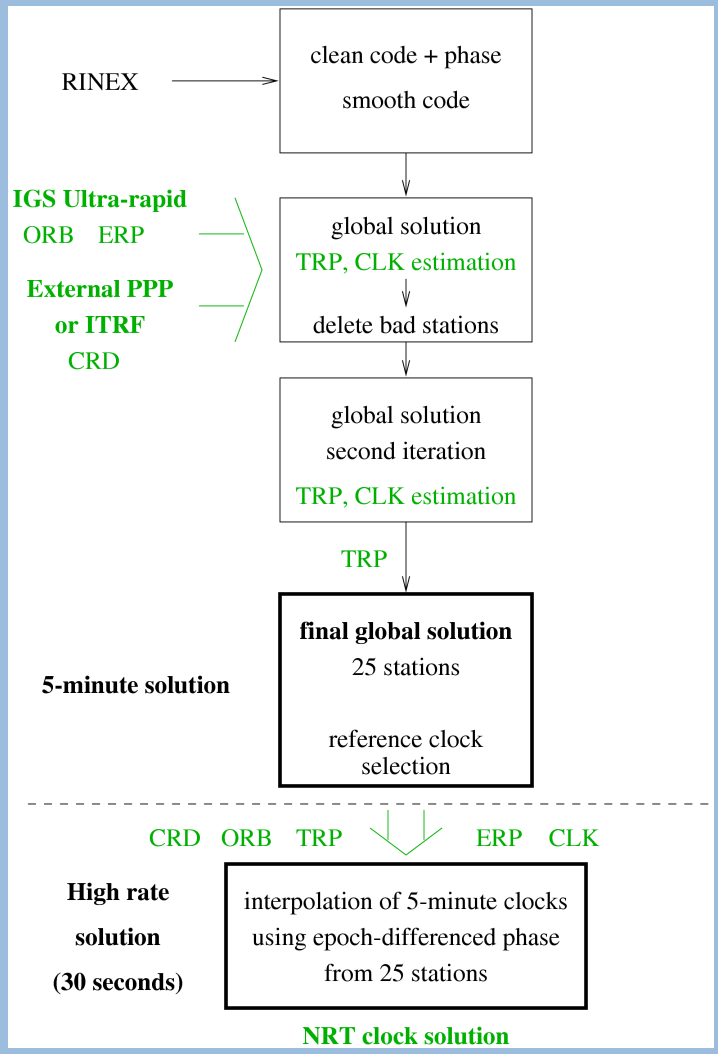
NRT GPS clock generation

Available NRT GPS products:

- IGS Ultra-rapid (predicted part) **IGUp**
  - ✓ free of charge
  - ✘ quality of clock corrections
- JPL Real-Time Generated **RT**
  - ✘ commercial
  - ✓ available within 1-2 minutes after observation
- Self generated NRT product **IGUp+c**
  - ➢ IGS Ultra-rapid orbits (predicted part) + generation of NRT GPS clock corrections based on a NRT station network
  - ✓ Consistency of orbits and clocks within the processing software which is also a big advantage for LEO POD

NRT GPS clock generation

- Zero-difference procedure is derived from the CODE rapid and final clock processing schemes
- 25 globally distributed stations
- Data cleaning and code smoothing
- IGS Ultra-rapid orbits and pole information introduced
- Two iterations for post-fit residual screening (troposphere delay estimation)
- Final global solution for clock estimation (5 minutes sampling, smoothed code, carrier phase)
- Interpolation to 30 seconds (epoch-differenced carrier phase)

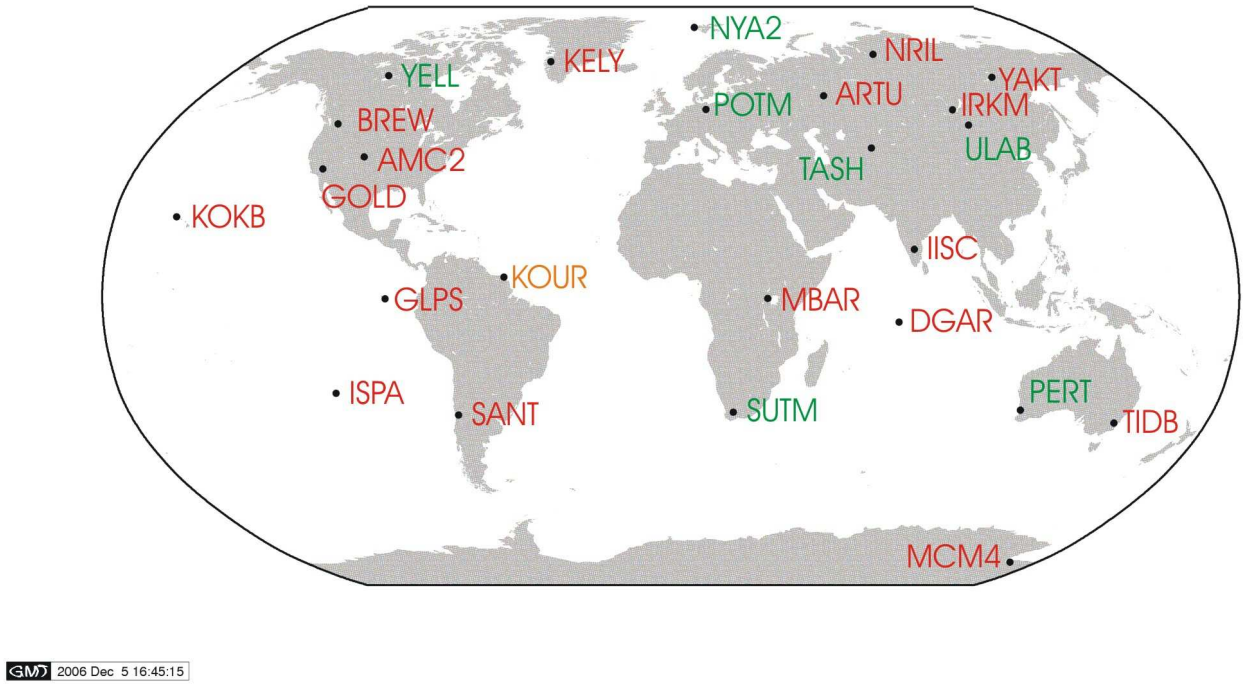


Example (7-9 October, 2006): Subnet of IGS 1Hz network

IGS 1 Hz network:
- 15 min data batches
- nominal latency < 5 min

- 25 stations (globally distributed)

- Latency of station data:
~ 70% > 60 min
=> Future alternative: real-time data stream



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Example: NRT processing scheme

Solution	Date	start time	end time	IGS Ultra Orbits
01	7 Oct. 2006	00:20:00	03:20:00	igu13956_00.sp3
02		02:00:00	05:00:00	igu13956_00.sp3
03		03:40:00	06:40:00	igu13956_00.sp3
04		05:20:00	08:20:00	igu13956_00.sp3
05		07:00:00	10:00:00	igu13956_06.sp3
06		08:40:00	11:40:00	igu13956_06.sp3
07		10:20:00	13:20:00	igu13956_06.sp3
08		12:00:00	15:00:00	igu13956_12.sp3
09		13:40:00	16:40:00	igu13956_12.sp3
...		...	...	...

- 43 solutions à 3 hours, updates every 100 minutes
- Most recent IGS Ultra-rapid orbit is used

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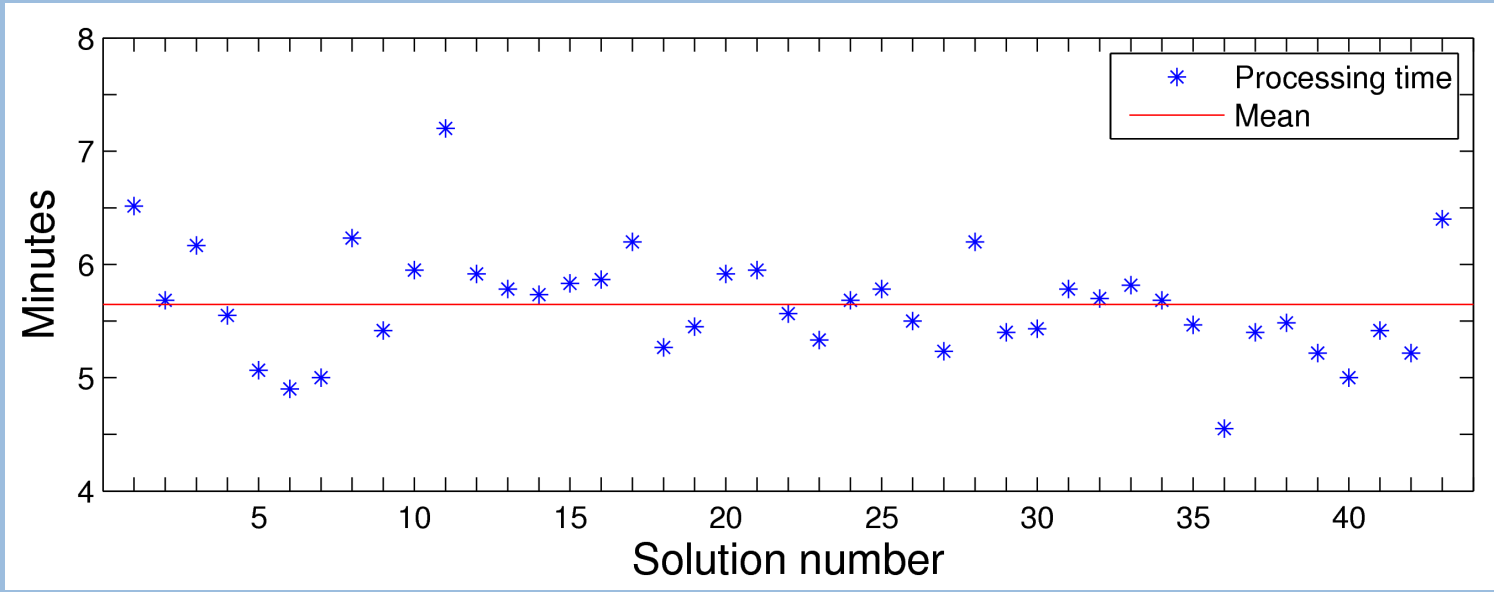
Example:
NRT clock generation, processing time



- Linux Cluster of the University (about 500 nodes)
- Parallel jobs if possible

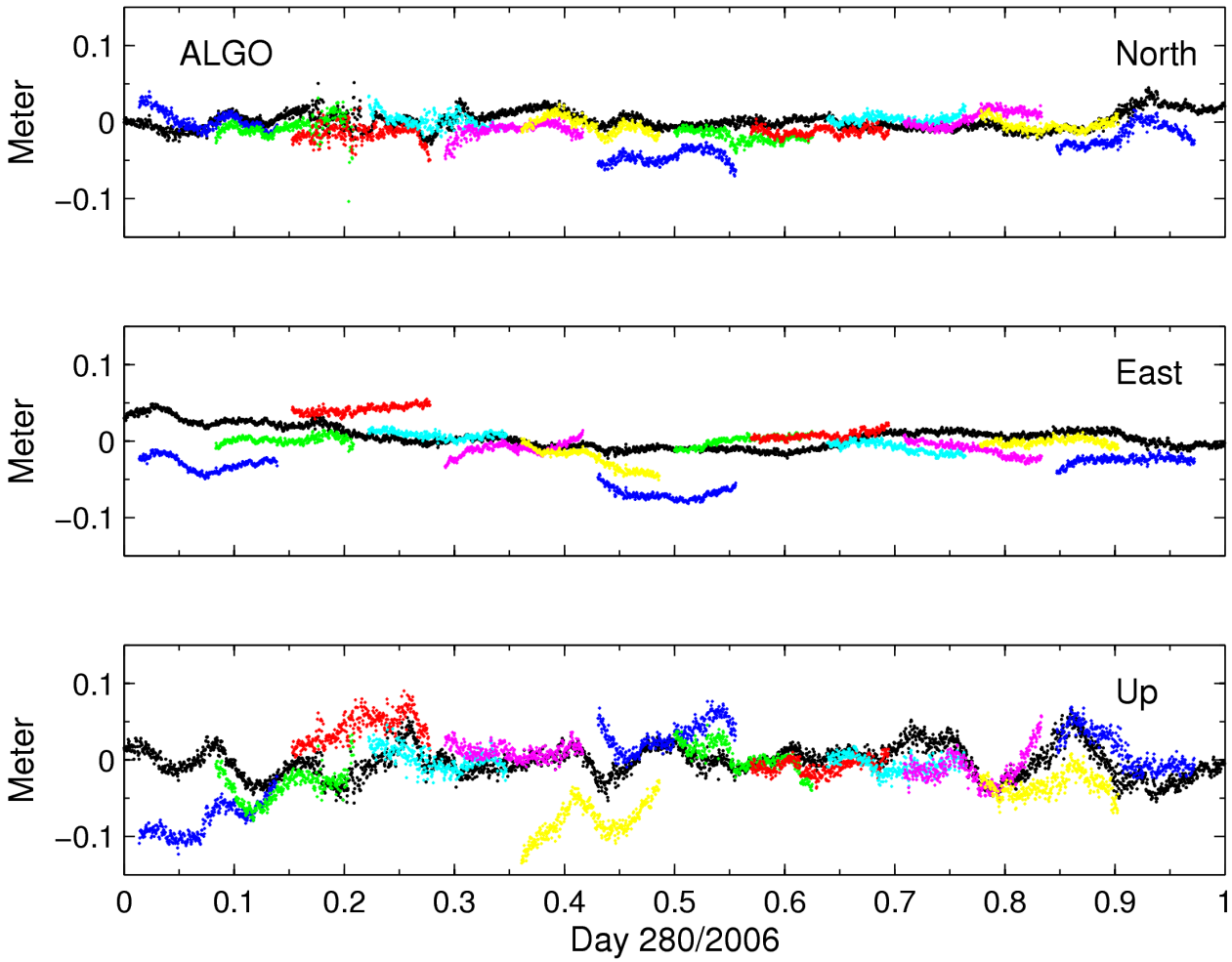
=> Processing time is non-critical for NRT applications

Validation of the NRT clocks

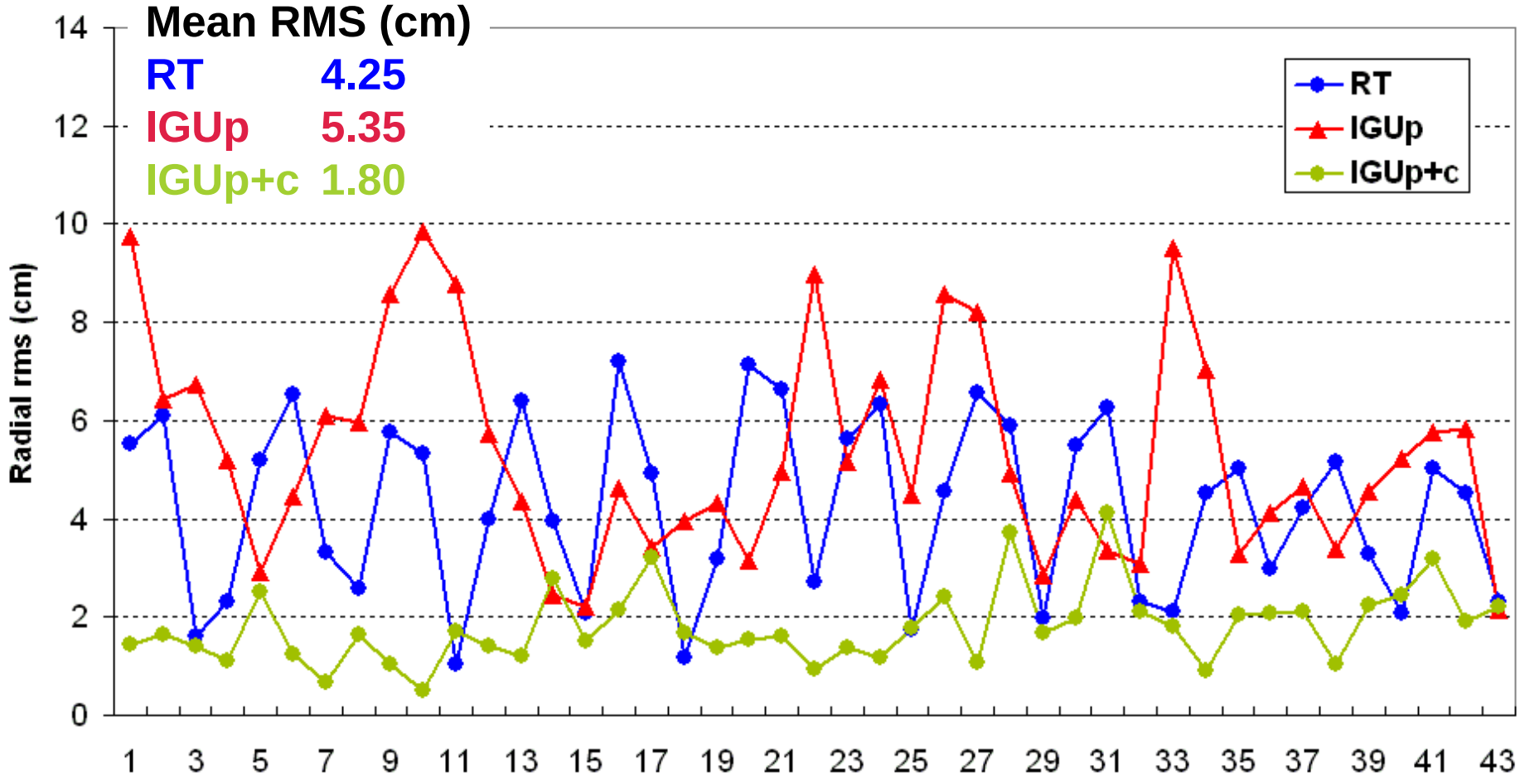
Kinematic precise point positioning of ground station:

- Black: reference solution, CODE final products used
- Other colors: IGS Ultra-rapid orbits and newly generated NRT clocks used

➢ agreement < 10 cm, even for the Up component ⇔ radial component of LEO

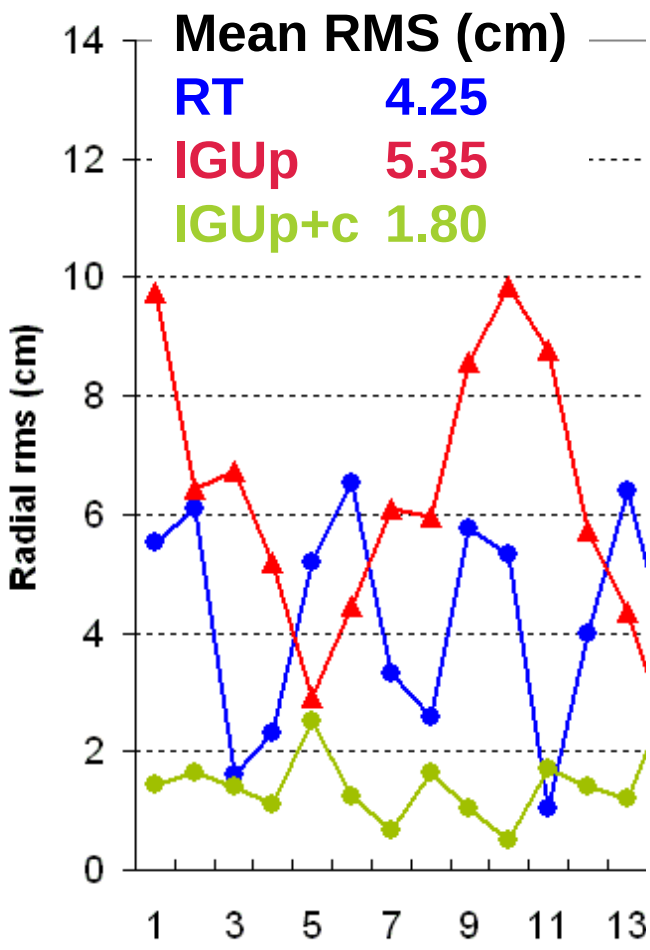


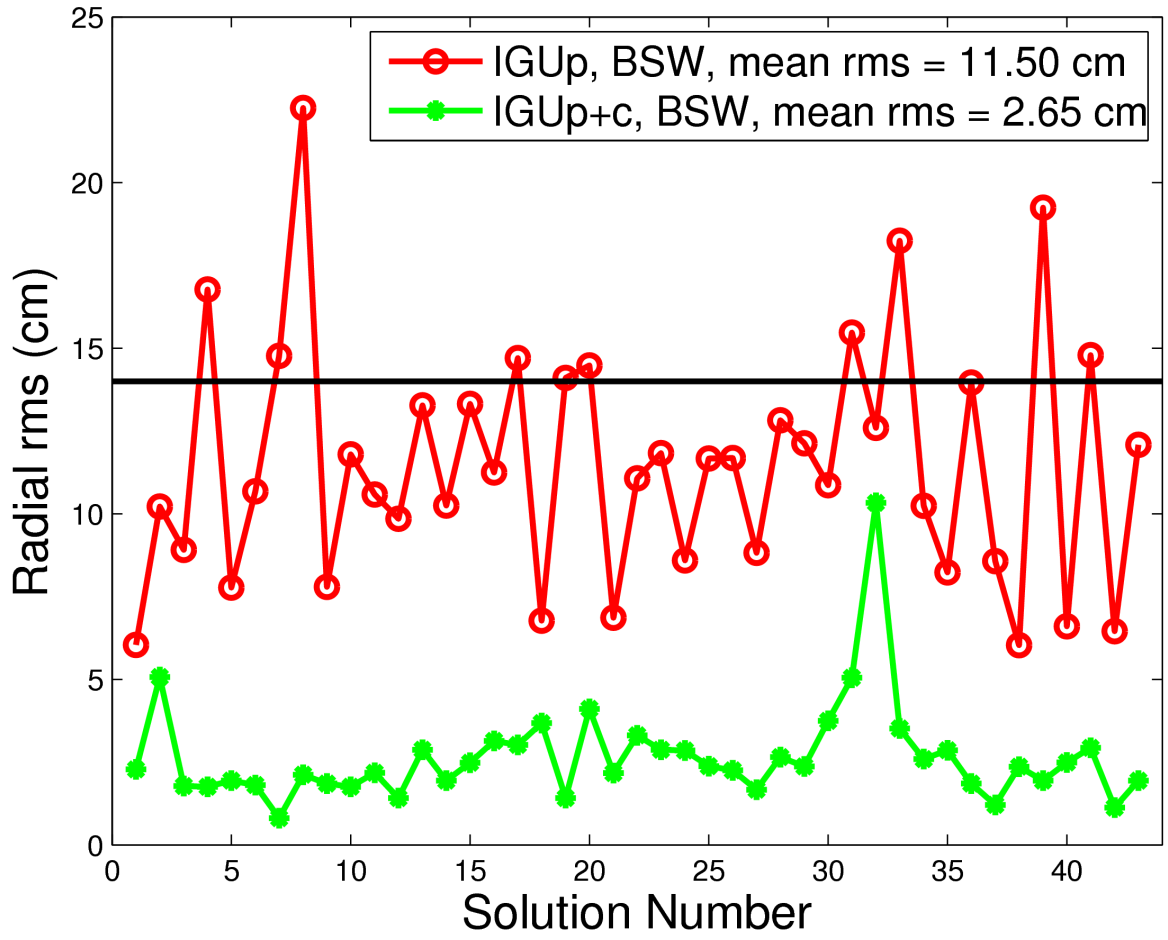
GRACE NRT POD (1)



GHOST software from DLR

GRACE NRT POD (1)





GHOST software from DLR

GRACE NRT POD (2)

- Different NRT GPS products are used for NRT POD of one GRACE satellite (GHOST software)
- The POD solutions using the new **IGUp+c** product show the best performance compared with the JPL Level 1 B orbit solution (mean radial rms: 1.8 cm)
- NRT POD solutions with the BSW (full consistency) show the same relative improvement when using **IGUp+c** instead of **IGUp**.
- Reduced-dynamic orbit solutions in BSW are less dynamic than in GHOST, i.e. they are closer to a kinematic solution.

Summary

- The AIUB is host of CODE, one of the IGS analysis centers.
- From the processing scheme in the framework of IGS a NRT GPS clock generation procedure has been developed.
- This procedure could be set up to support NRT POD for LEO missions.
- Tests with GRACE data (using the in-house and an independent GPS processing software) have shown an enormous improvement of the NRT POD results compared to currently available NRT GPS products.
- Based on the experience in the field of GNSS POD the AIUB is capable to perform LEO POD in a reduced-dynamic and fully kinematic mode using the Bernese GPS Software.