PTTI 2009

EVALUATION OF THE TIME AND FREQUENCY TRANSFER CAPABILITIES OF A NETWORK OF GNSS RECEIVERS LOCATED IN TIMING LABORATORIES

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SESSION XIII: RECEIVER BIASES

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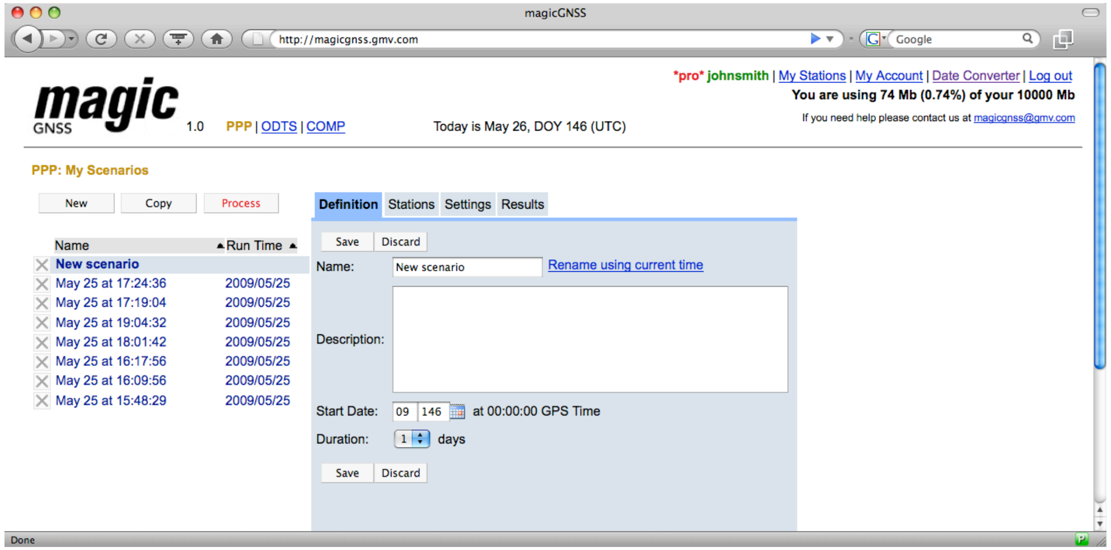
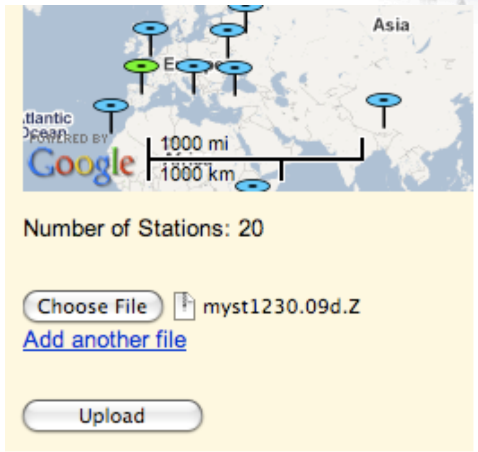
ABOUT *magicGNSS*

- *magicGNSS* is a web application for high-precision GNSS data processing
- The main application of *magicGNSS* is the calculation of GPS satellite **orbits** and **clocks**, and also of station **coordinates**, **tropo**spheric delay and **clock**
- You can upload your own station data (RINEX measurement files) or use data from a global network of pre-selected *core stations* from IGS (the *International GNSS Service*), or a combination of both





PPP AND ODTS

- Two algorithms to process station data in *magicGNSS*: **PPP** and **ODTS**
- PPP: *Precise Point Positioning*
- ODTS: *Orbit Determination & Time Synchronization*
- Both use un-differenced **dual-freq code and phase** station data
- ODTS requires a global station network; PPP requires just a single station, plus orbit and clock products from IGS
- The quality of ODTS and PPP **GPS** products is similar to **IGS** products

Product	ODTS	PPP	Format	Precision (RMS)
Report	✓	✓	pdf	N/A
Satellite orbits	✓	✗	sp3	~2/6/4 cm(*)
Satellite clocks	✓	✗	clk	~0.10 ns
Station clocks	✓	✓	clk	~0.10 ns
Station tropo	✓	✓	txt	~5 mm (zenith)
Station coords	✓	✓	snx	<1 cm

(*) In the Radial/Along/Normal directions

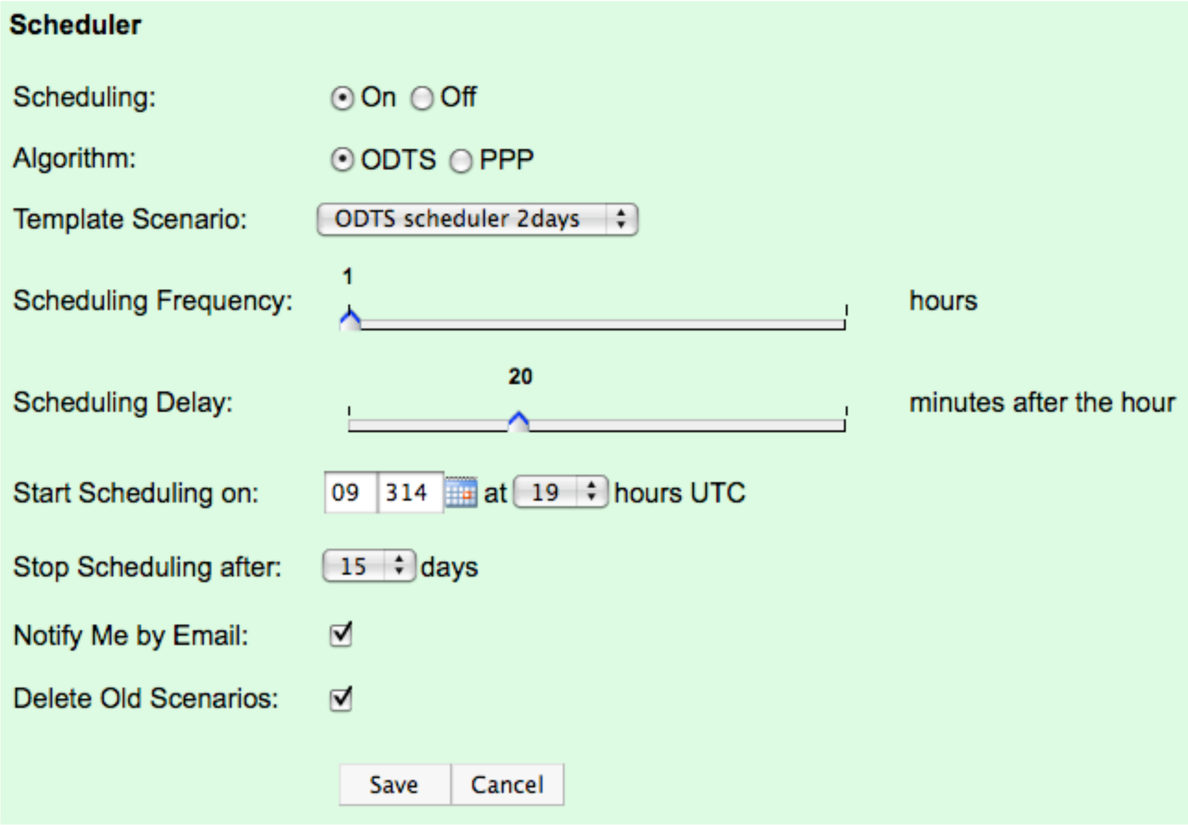
- **GLONASS** implementation nearly finished (testing ongoing)

HOW ODTS WORKS

- Input: station measurements and navigation messages; code and carrier-phase are used, in L1 and L2 frequencies
- If P1 code not available, C1 is automatically converted to P1 using "cc2noncc"
- A network of stations distributed worldwide is required; output quality depends on station density
- A set of *core stations* is provided to "fill the gaps"
- More stations = better quality, but longer computation time
- Unlike PPP, no other input "products" are required, ODTS is fully autonomous
- Based on a batch least-squares estimator, *not* on a filter
- "Everything" is estimated: orbits (state vector and 8 radiation parameters), satellite and station clocks, station coordinates, tropo delay, (float) ambiguities, Earth Rotation Parameters (optional)
- High-accuracy models: satellite and antenna phase center variations (ANTEX files from IGS), phase wind-up, relativity, ocean loading, etc
- Clocks are estimated "snapshot", no clock model used
- One station must be chosen as reference clock
- Clocks estimated at the same rate as the (decimated) input measurements: typically 5 minutes

AUTOMATION AND NEAR-REAL TIME

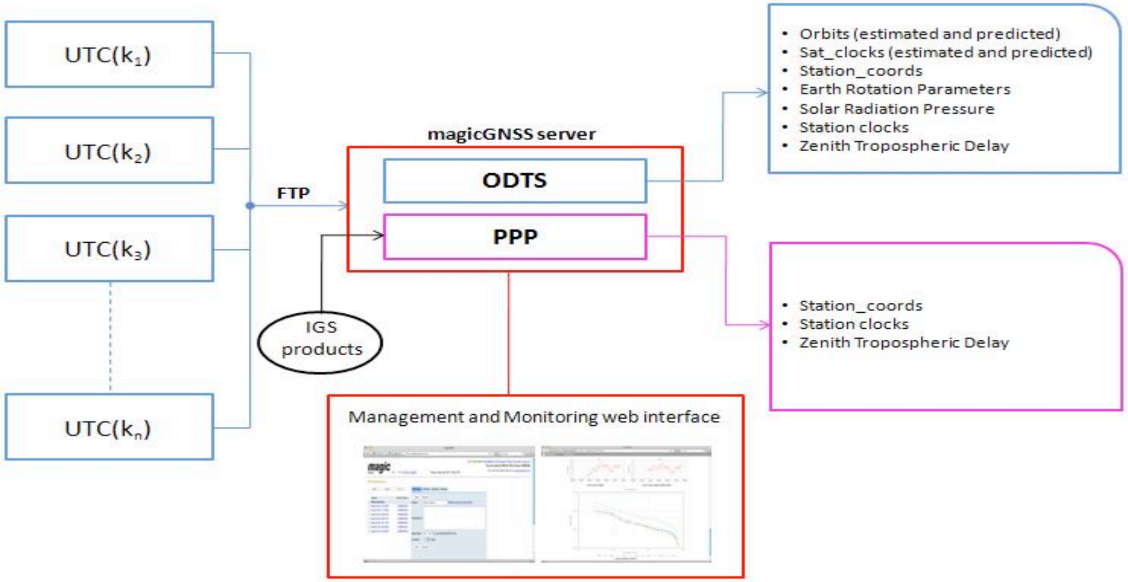
- RINEX upload via **ftp** allows automation of data input
- Support of daily, hourly, and **15-min** RINEX files
- Automatic download and processing of **NANUs**, do not worry about unhealthy GPS satellites
- A **Scheduler** is available to automate the data processing
- **Email** notifications supported
- **Results** from the Scheduler can be also downloaded by ftp



ODTS SETUP FOR EXPERIMENT (I)

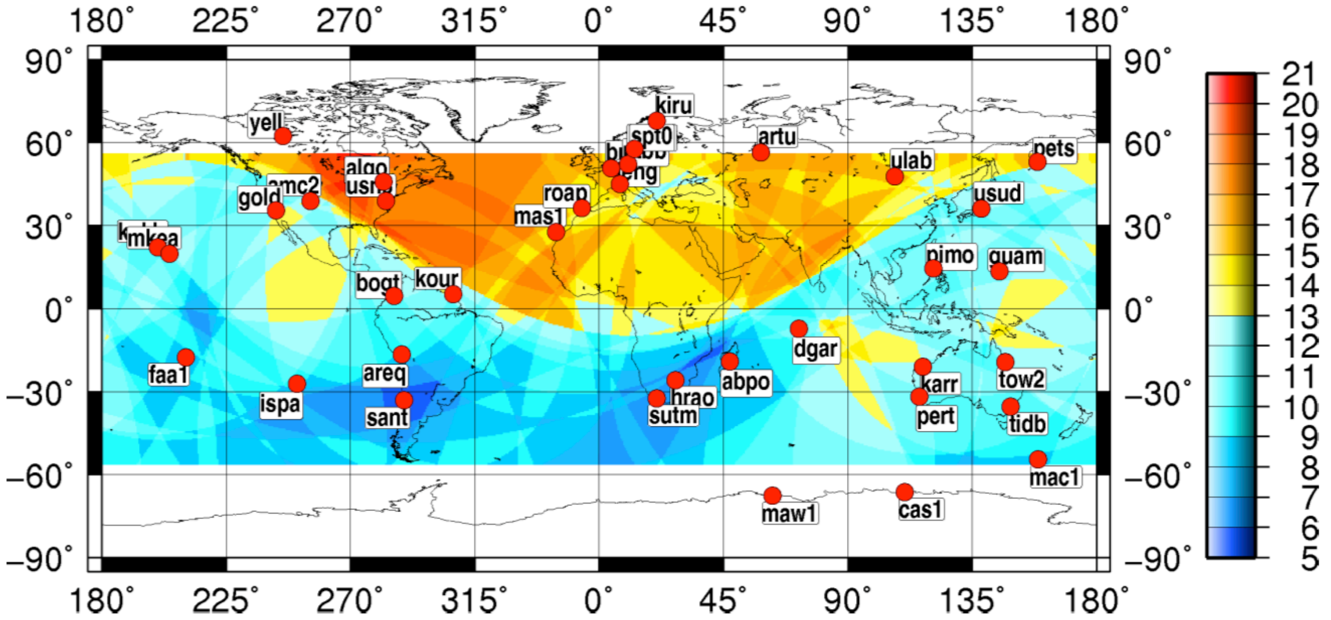
- Objective: time transfer in near-real time (30 minutes latency) among 6 timing labs (8 GPS stations)
- Experiment duration: 31 Oct – 19 Nov (DOY 304-323 ; MJD 55135 – 55154).

Laboratory	TAI code	Country	Station name	Receiver type	Reference
INRIM	IE	Italy	ieng	Ashtech Z-XII3T	UTC(IT)
ORB	OR	Belgium	brus	Ashtech Z-XII3T	UTC(ORB)
PTB	PT	Germany	ptbb	Ashtech Z-XII3T	UTC(PTB)
ROA	RO	Spain	roap	Septentrio PolaRx-3TR	UTC(ROA)
SP	SP	Sweden	sp01	Javad JPS GGD	UTC(SP)
SP	SP	Sweden	sp02	Javad JPS GGD	UTC(SP)
SP	SP	Sweden	spt0	Javad JPS GGD	External H-Maser
USNO	US	United States	usn3	Ashtech Z-XII3T	UTC(USNO)



ODTS SETUP FOR EXPERIMENT (II)

- **31** *core stations* from IGS and **8** timing labs *user stations* (39 stations in total)
- Station data (hourly files) are uploaded every hour onto a dedicated *magicGNSS* account and processed in ODTS automatically using the scheduler 20 minutes after the hour
- **ieng [UTC(IT)]** is used as reference clock in ODTS
- ODTS arc duration is **2 days**
- Clocks estimated every **5 minutes** (same as IGS *rapid* clocks for GPS)
- Live plots updated 30 minutes after the hour show the near-real time behavior of the 8 clocks

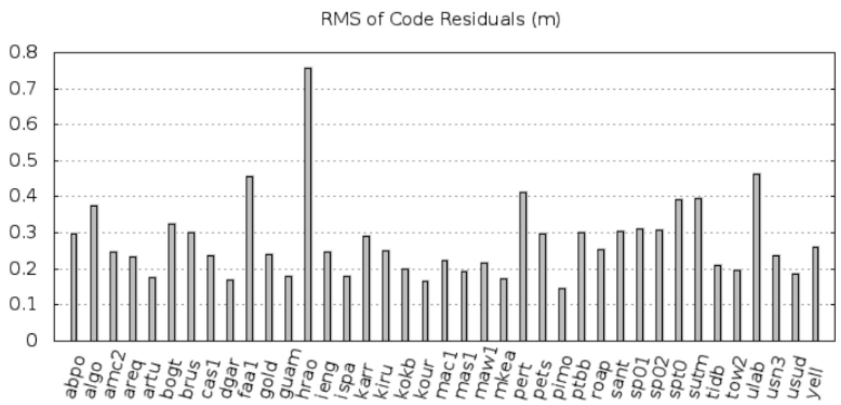


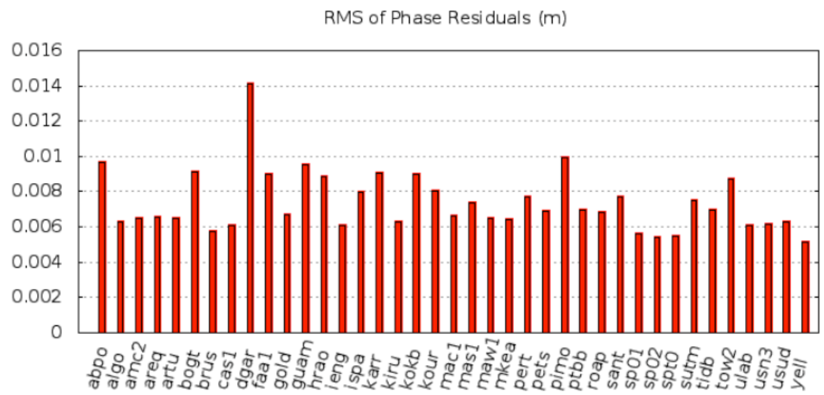
SOME ODTS INDICATORS

- Convergence

Iteration Number	RMS of Weighted Residuals	Delta RMS of Weighted Residuals	RMS of Code Residuals (m)	RMS of Phase Residuals (m)
0	946.004	-	94546.801	94654.299
1	4.596	941.408	0.293	0.038
2	1.346	3.250	0.287	0.008
3	1.290	0.056	0.286	0.008
4	1.280	0.010	0.285	0.008

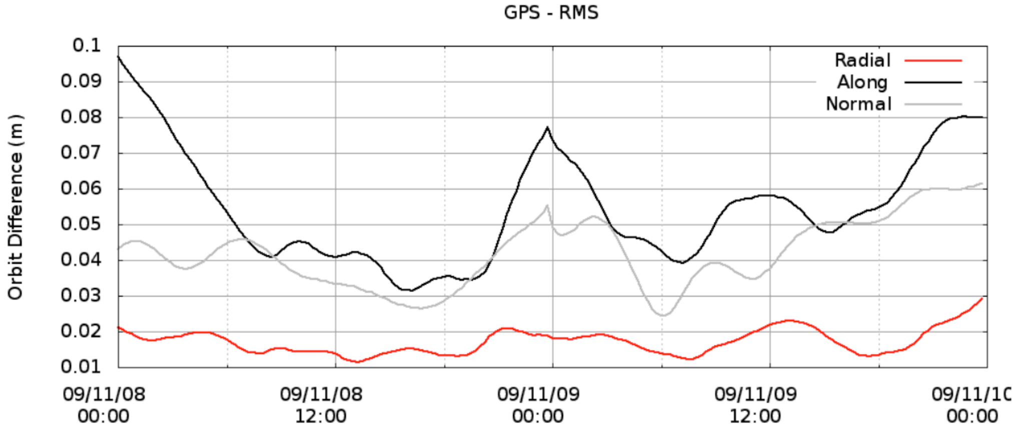
- Residuals



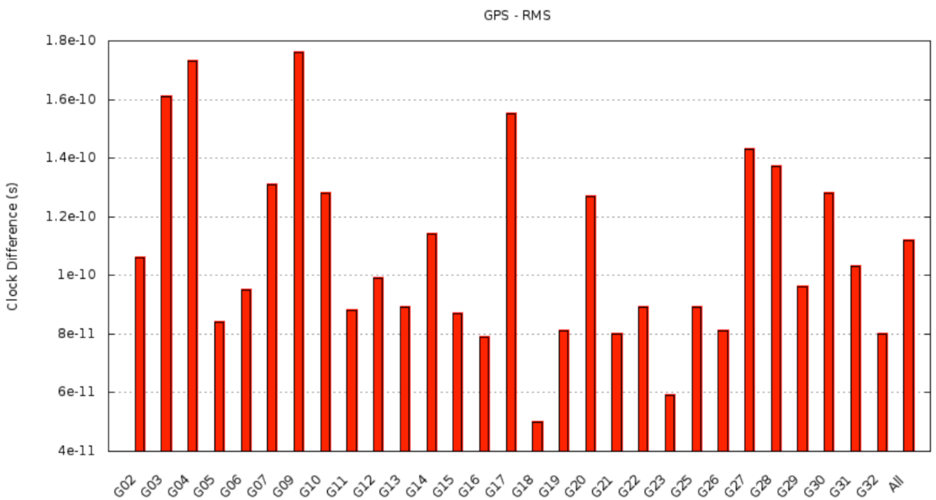


COMPARISON AGAINST IGS

- Satellite orbits: **5 cm** RMS

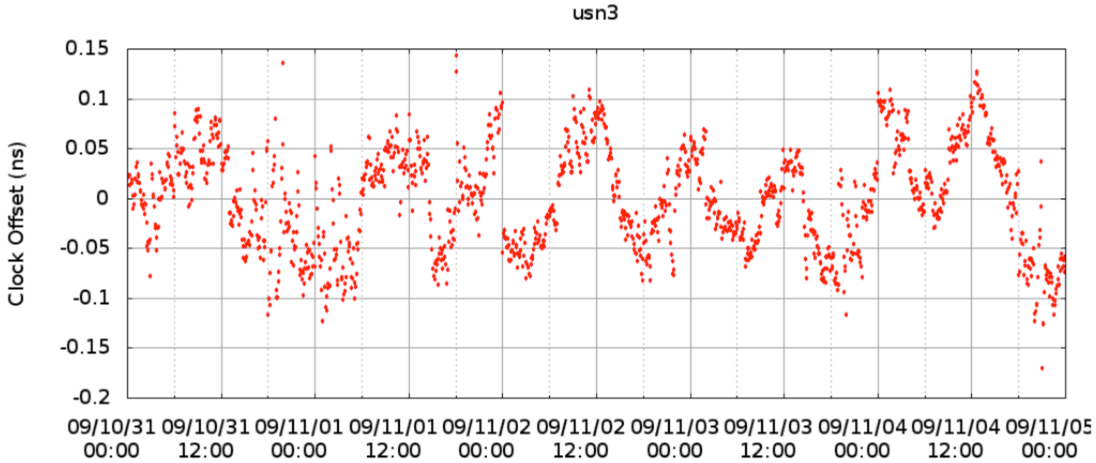


- Satellite clocks: **0.1 ns** RMS

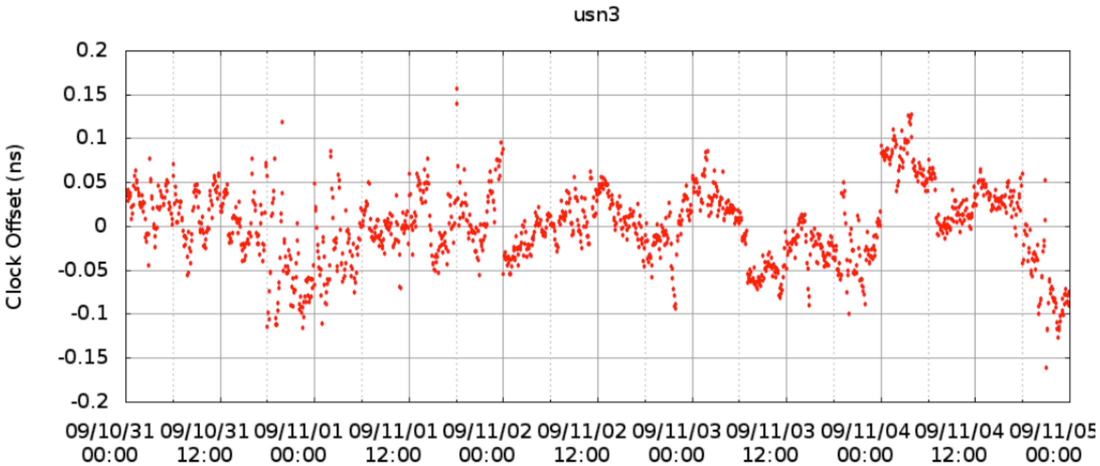


IMPORTANCE OF DETAILED MODELING

- usn3-IGRT, no ocean loading

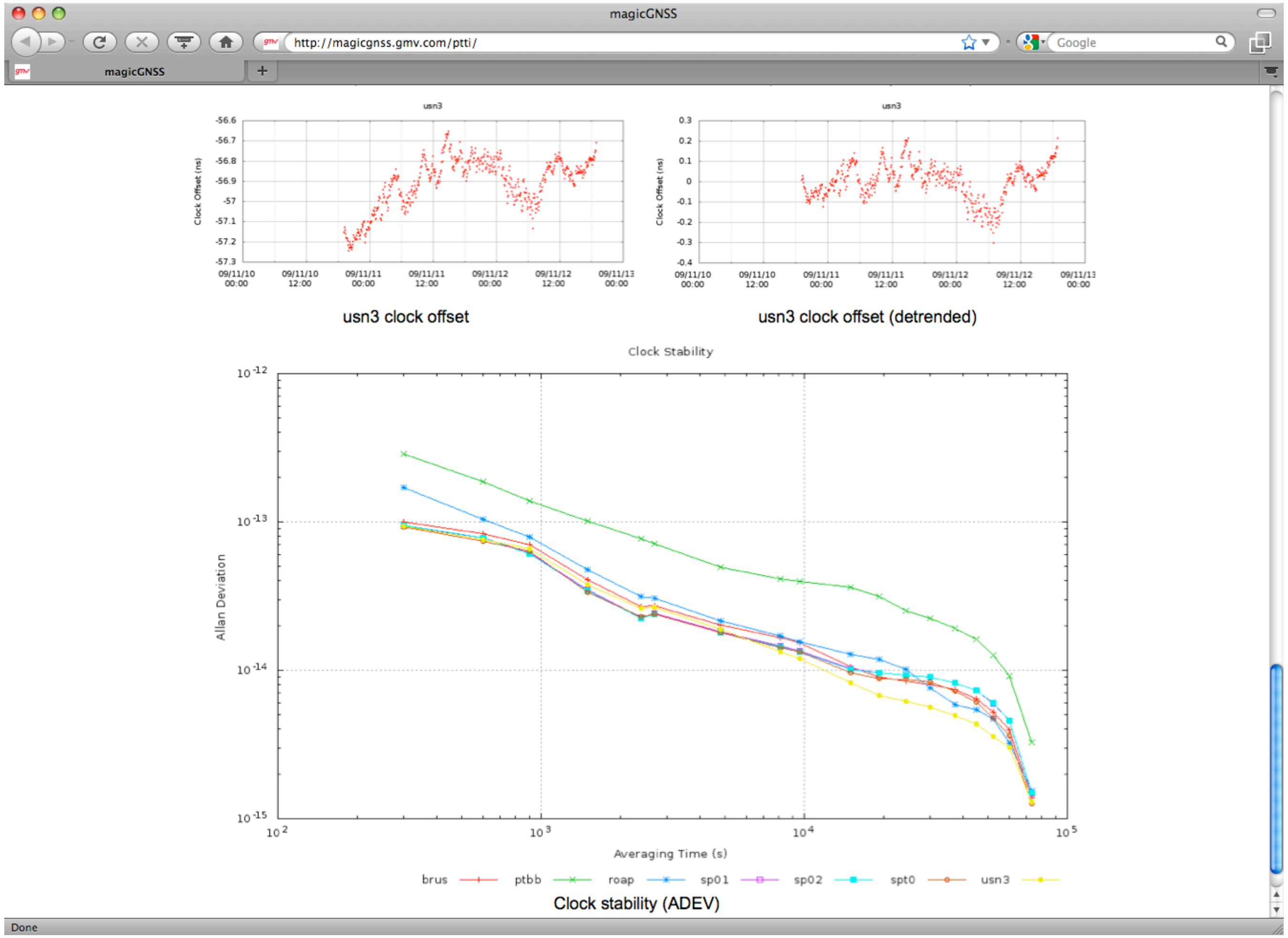


- usn3-IGRT, ocean loading (properly?) applied



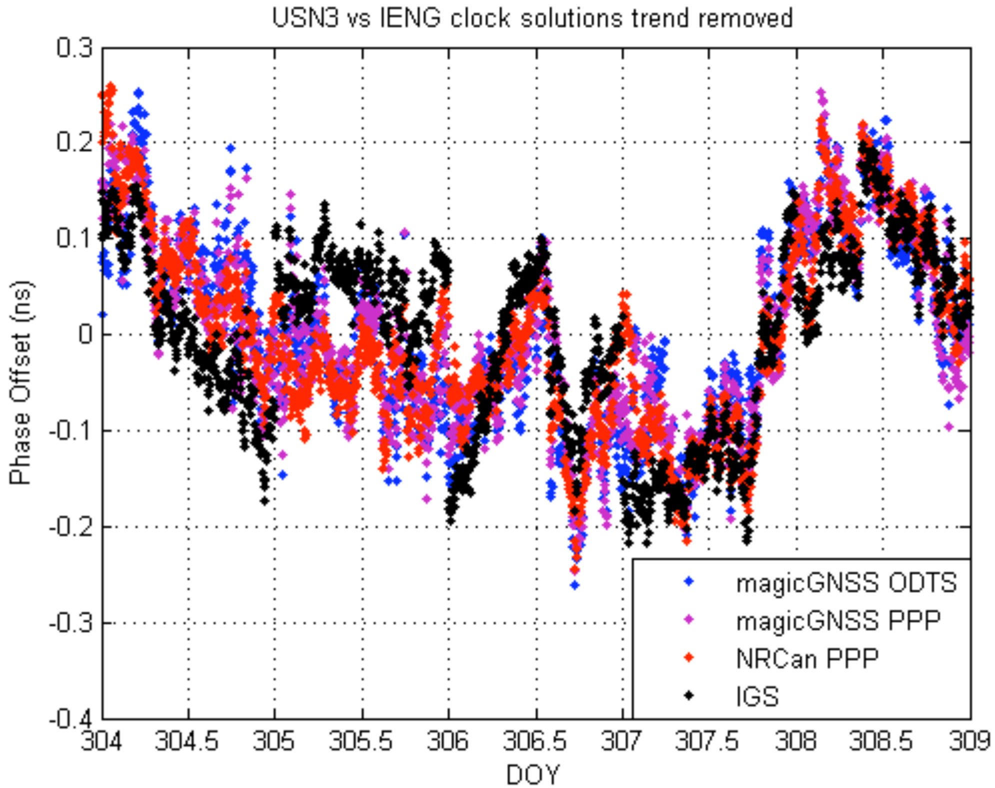
LIVE EXPERIMENT FOR PTTI '09

- **http://magicgnss.gmv.com/ptti**
- Updated every hour: 8 master clocks synchronized in near-real time



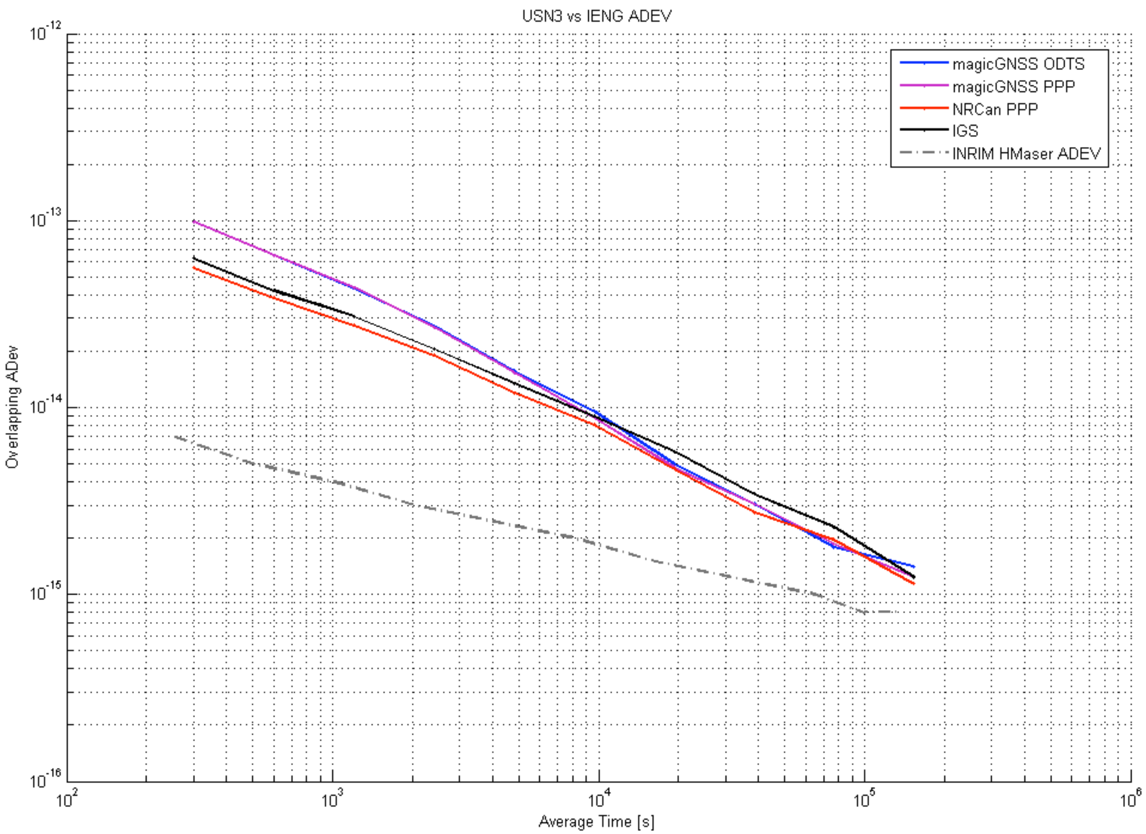
PERFORMANCE ASSESSMENT (I)

- ODTS real-time results are compared a posteriori with:
  - magicGNSS PPP (uses IGS *rapid* products)
  - NRCan PPP (uses IGS *rapid* products)
  - IGS clocks solutions



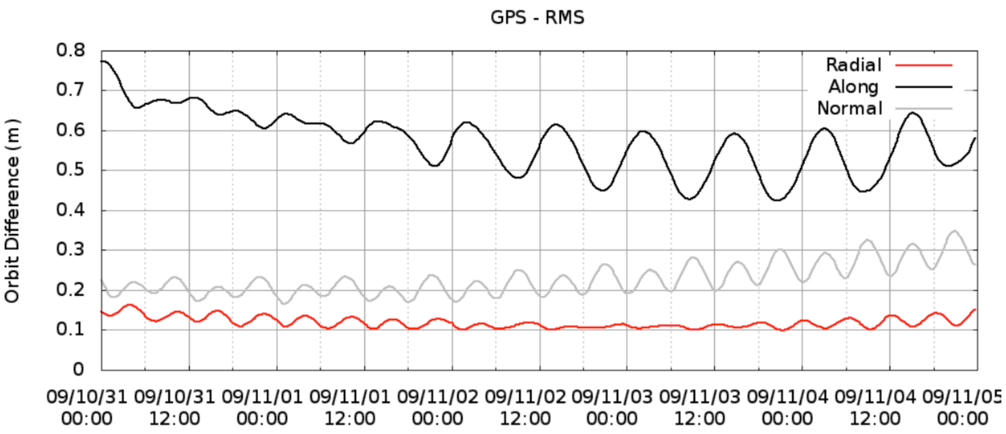
PERFORMANCE ASSESSMENT (II)

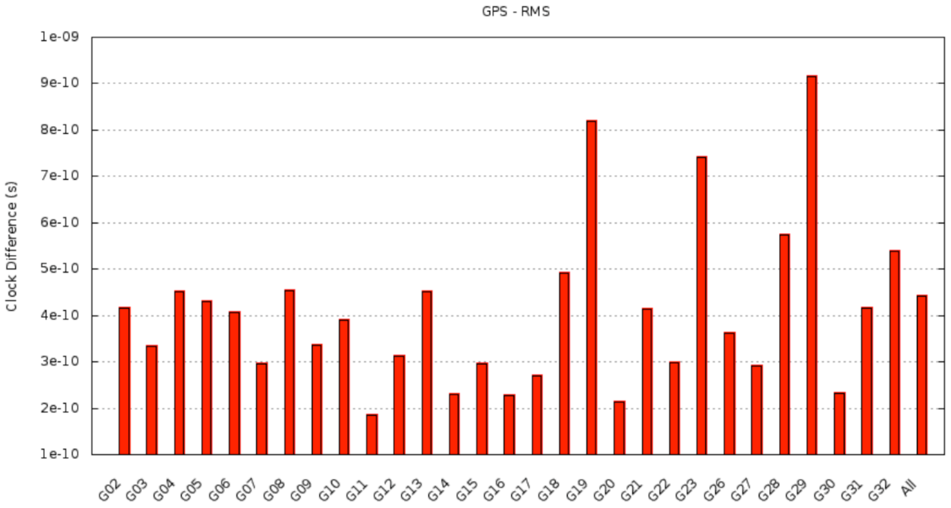
- Findings:
  - Overall good agreement among all techniques
  - magicGNSS ODTS and PPP show higher short-term noise (“snapshot” approach)
  - NRCan PPP and IGS show lower short-term noise (filter approach)



ODTS AND NETWORK SIZE (I)

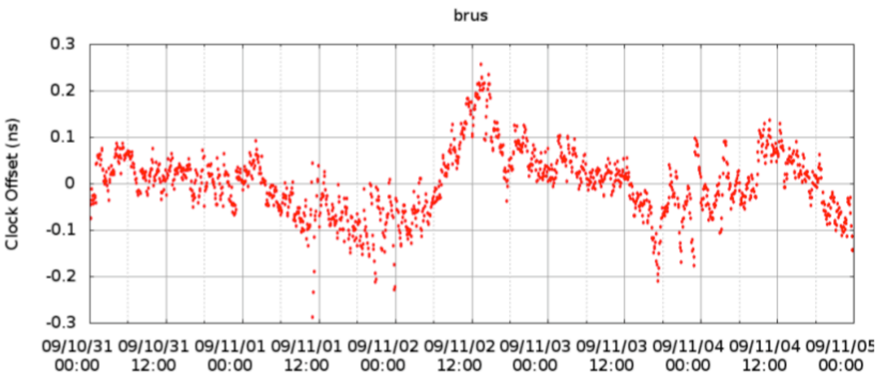
- What happens if we only use the **8** timing stations in ODTS?
  - GPS orbits and clocks degrade a lot (see comparison with IGS below)
  - However…

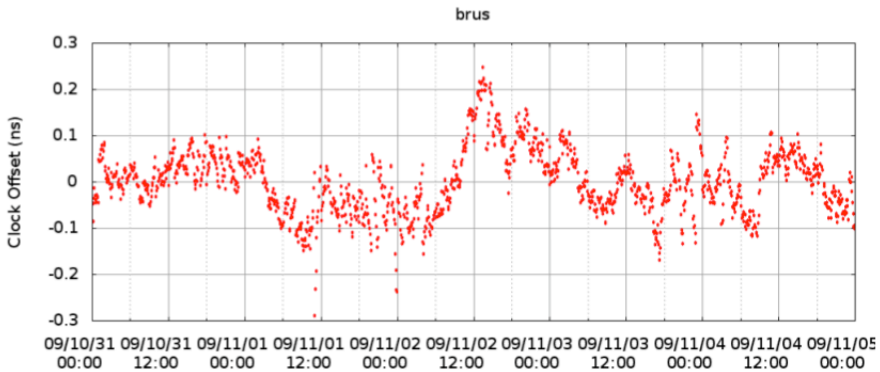


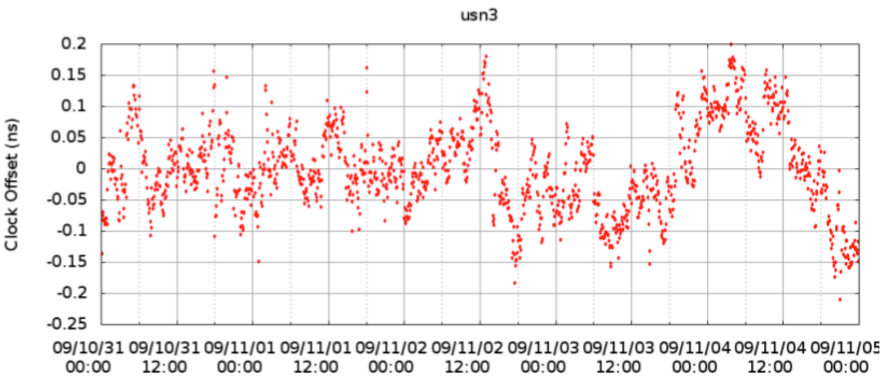


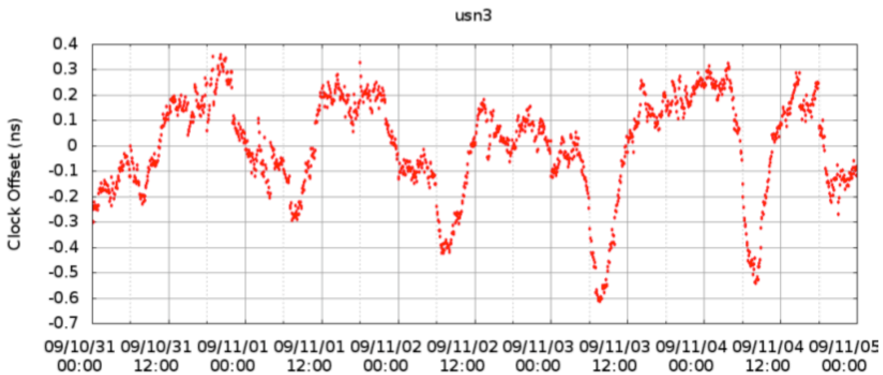
ODTS AND NETWORK SIZE (II)

- What happens if we only use the **8** timing stations in ODTS?
  - For short baselines (e.g. brus-ieng) the performance is nearly the same!
  - For long baselines (e.g. usn3-ieng) the performance degrades strongly







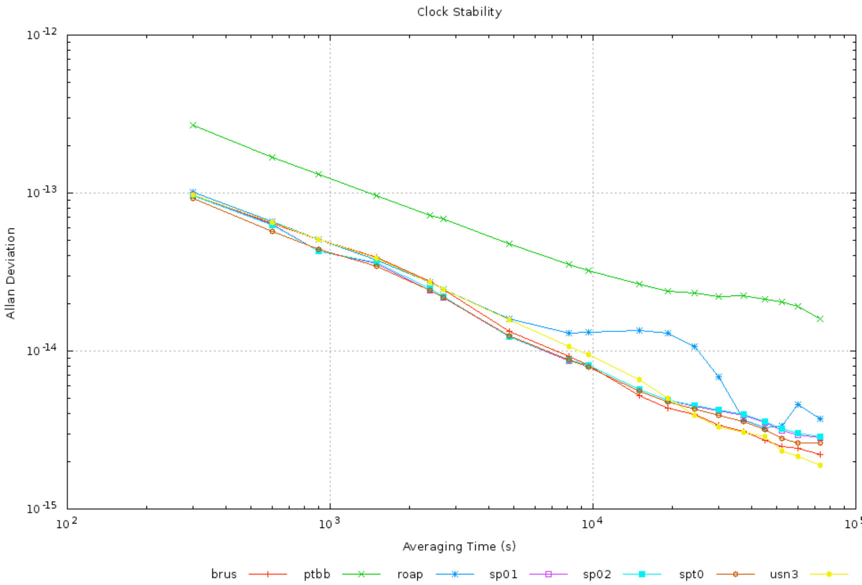


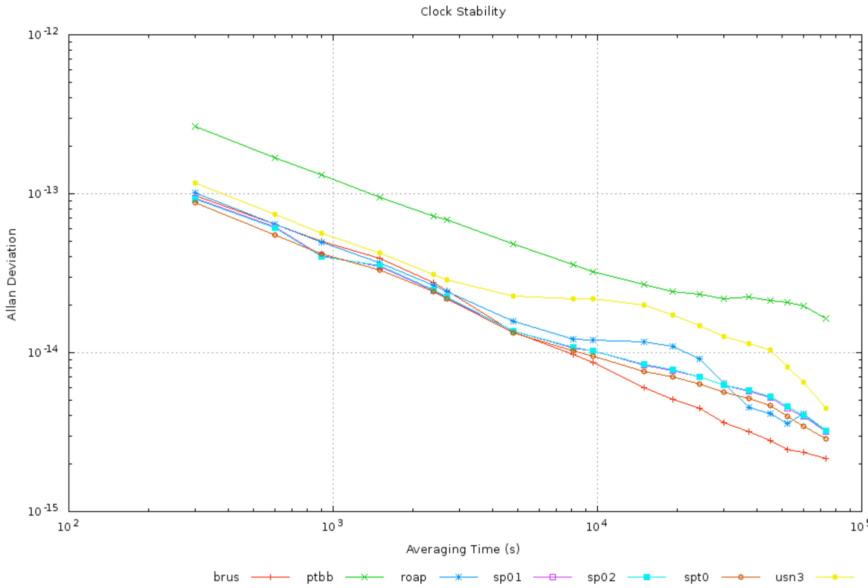
39 stations in ODTS

8 stations in ODTS

ODTS AND NETWORK SIZE (III)

- What happens if we only use the **8** timing stations in ODTS?





39 stations in ODTS

8 stations in ODTS

CONCLUSIONS AND FUTURE WORK

- ODTS allows autonomous time transfer among a network of GPS receivers in near-real time
- Typical latency of results: 30 minutes
- No input "products" required, just station measurements
- *magicGNSS* is very easy to use: just upload RINEX files and start processing
- Near-real-time clock results from ODTS are as good as a-posteriori PPP using IGS products
- Data processing automation is supported
- As little as 20-30 stations located worldwide are enough for good ODTS results: **international timing community can build up an autonomous time transfer system in near-real time with a low cost**
- With just a few regional stations (e.g. Europe) it is still possible to use ODTS autonomously for time transfer with good performances
- Some details still to be polished (ocean loading, short-term noise)

- Thanks to **ORB**, **PTB**, **ROA**, **SP**, and **USNO** for their kind contribution to this experiment
- If you are a timing lab and wish to participate in possible further experiments, please contact Giancarlo Cerretto (g.cerretto@inrim.it)

Thank you!

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