ION GNSS 2009

# ORBITS AND CLOCKS FOR GLONASS PPP

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SESSION E3: PPP AND NETWORK-BASED RTK 1

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INNOVATING SOLUTIONS

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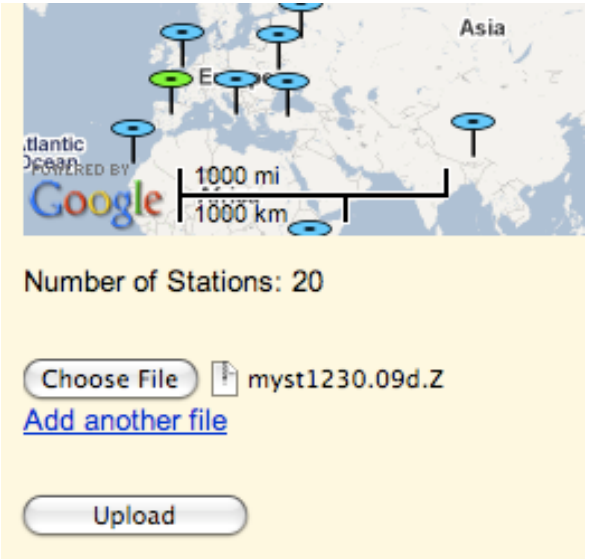
# ABOUT *magicGNSS*

- *magicGNSS* is a **web application** for GNSS data processing featuring **high-precision** and **integrity**
- The main application of *magicGNSS* is the calculation of GPS satellite **orbits** and **clocks**, and also of station/receiver **coordinates**, **tropo**spheric delay and **clock**
- You can **upload** and process your own dual-frequency station data (**RINEX** observation files)

# ODTS AND PPP

- The two main algorithms that process station data in *magicGNSS* are called **ODTS** (*Orbit Determination & Time Synchronization*) and **PPP** *(Precise Point Positioning*); both process **dual-freq iono-free** station data
- ODTS requires a global station network; PPP requires just a single station
- The quality of ODTS and PPP **GPS** products is similar to **IGS** products

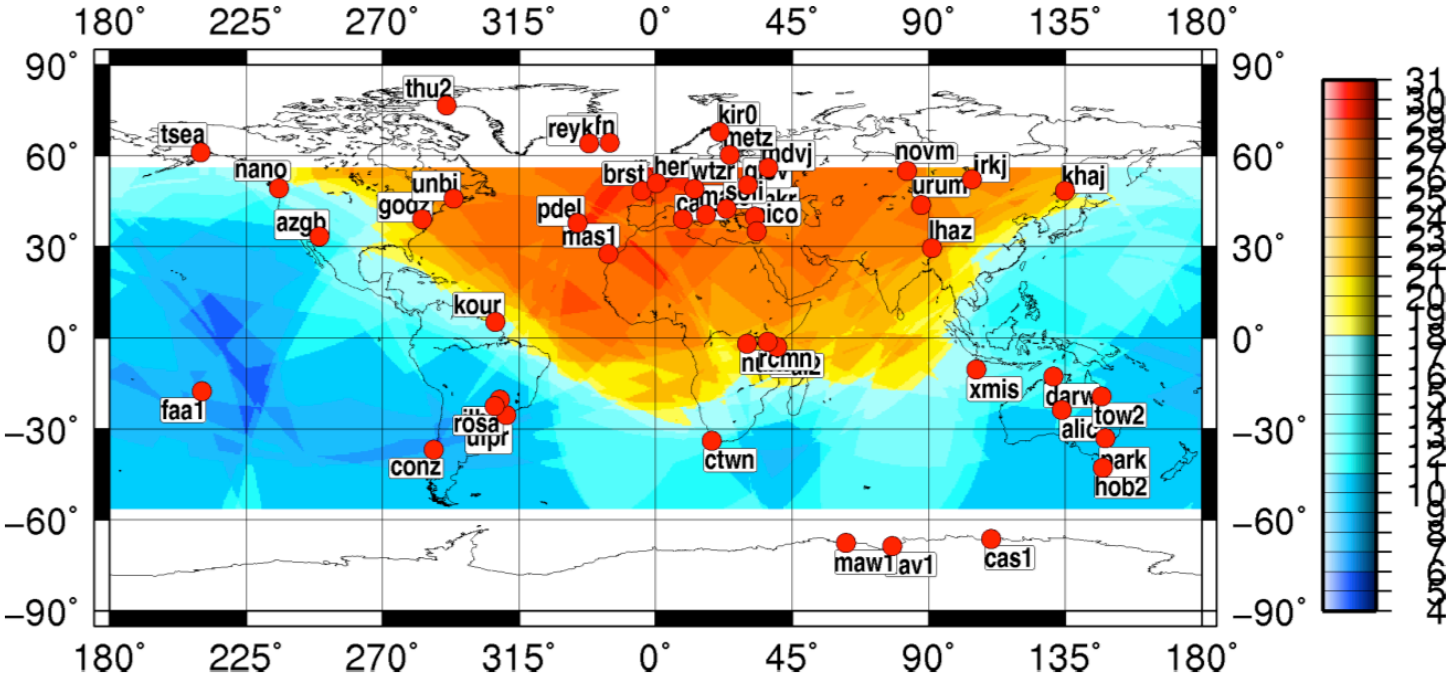
| Product | ODTS | PPP | Format | Accuracy (RMS) |
|---|---|---|---|---|
| Report | ✓ | ✓ | pdf | N/A |
| Satellite orbits | ✓ | ✗ | sp3 | ~2/6/4 cm(*) |
| Satellite clocks | ✓ | ✗ | clk | ~0.15 ns |
| Station clocks | ✓ | ✓ | clk | ~0.15 ns |
| Station tropo | ✓ | ✓ | txt | <1 cm (zenith) |
| Station coords | ✓ | ✓ | snx | <1 cm |

(*) In the Radial/Along/Normal directions

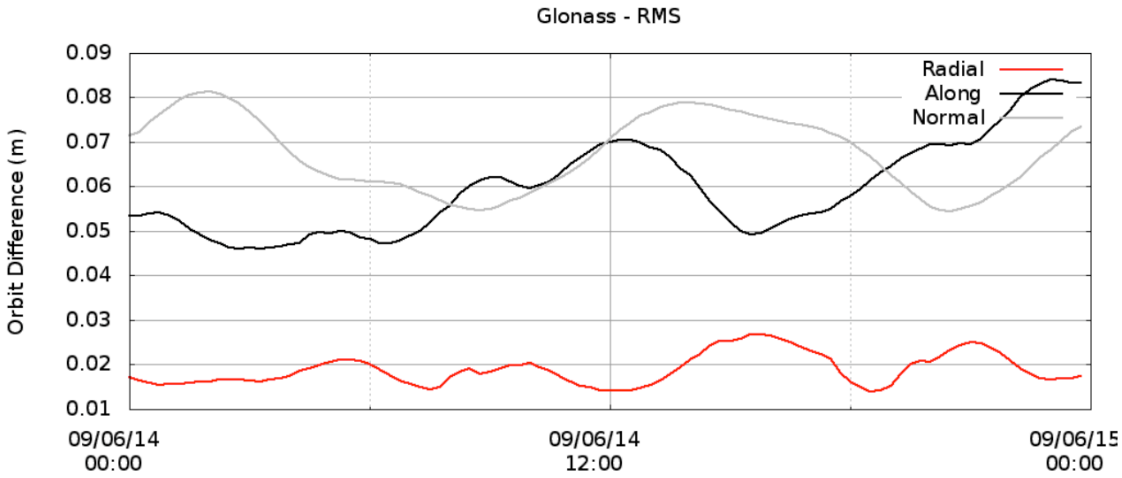
- For **GLONASS**, no clocks are published by IGS
- **Objective**: use ODTS to generate GLONASS orbits and clocks that can be combined with GPS products from IGS in GPS+GLONASS PPP

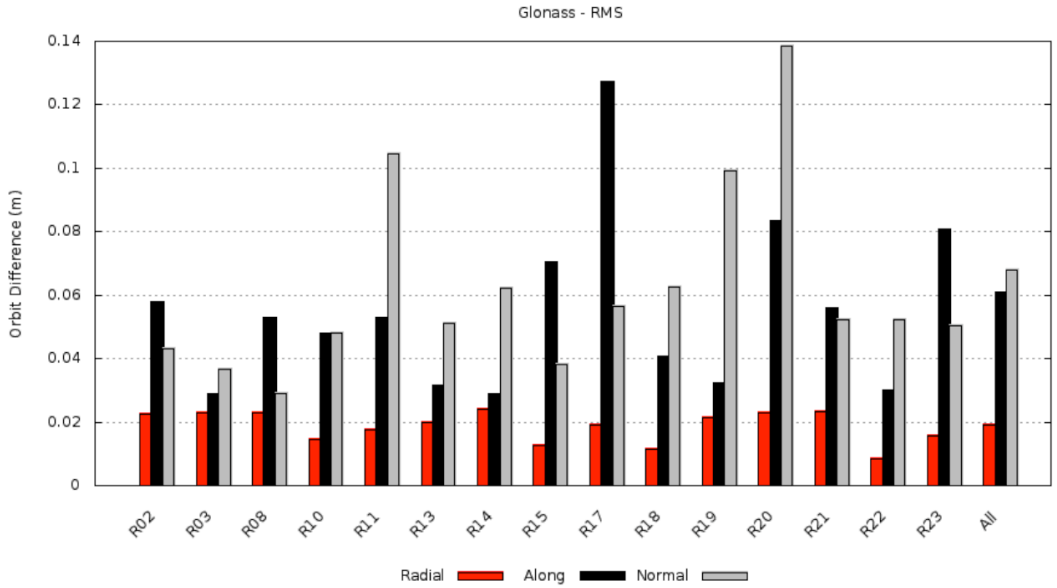
# ODTS SETUP FOR GLONASS

- Data processing period is **June 2009**
- **40+** usable **stations** from IGS with fairly good global coverage
- **MATE** is used as reference clock in ODTS
- A few **GLONASS** satellites discarded (**15 satellites** remaining)
- Sat clocks estimated every **5 minutes** (same as IGS *rapid* clocks for GPS)
- ODTS arc duration is **2 days**, only the **central day** is kept
- An **inter-channel bias** estimated per station-sat combination, constant per arc



# GLONASS ORBITS: ODTS VS IGS




Orbit accuracy similar to IGS for GLONASS:

- Radial: **2 cm** RMS
- Normal: **6 cm** RMS
- Along: **6 cm** RMS

# ALIGNING GLONASS CLOCKS TO IGST

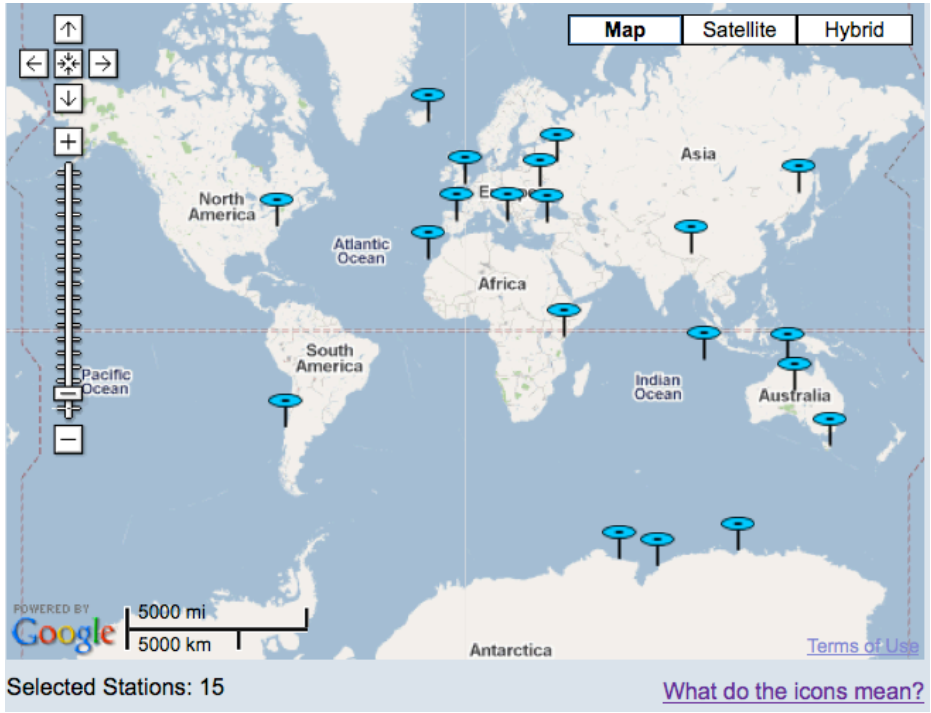
- The objective is to be able to combine GLONASS products (orbits and clocks) from ODTS and GPS products from IGS, in order to do GPS+GLONASS PPP
- Orbits are no problem since both ODTS and IGS work in the same terrestrial coordinate system (ITRF)
- IGS clocks are given w.r.t. the IGS Time Scale (**IGST**)
- GLONASS clocks from ODTS are given w.r.t. the reference station chosen (**MATE**)
- Solution: to use IGS station clock products to post-process ODTS clocks adding the MATE clock form IGS:

(**GLO_SAT_CLK** – ~~MATE_CLK~~) + (~~MATE_CLK~~ – **IGST**) = **GLO_SAT_CLK – IGST**

ODTS IGS

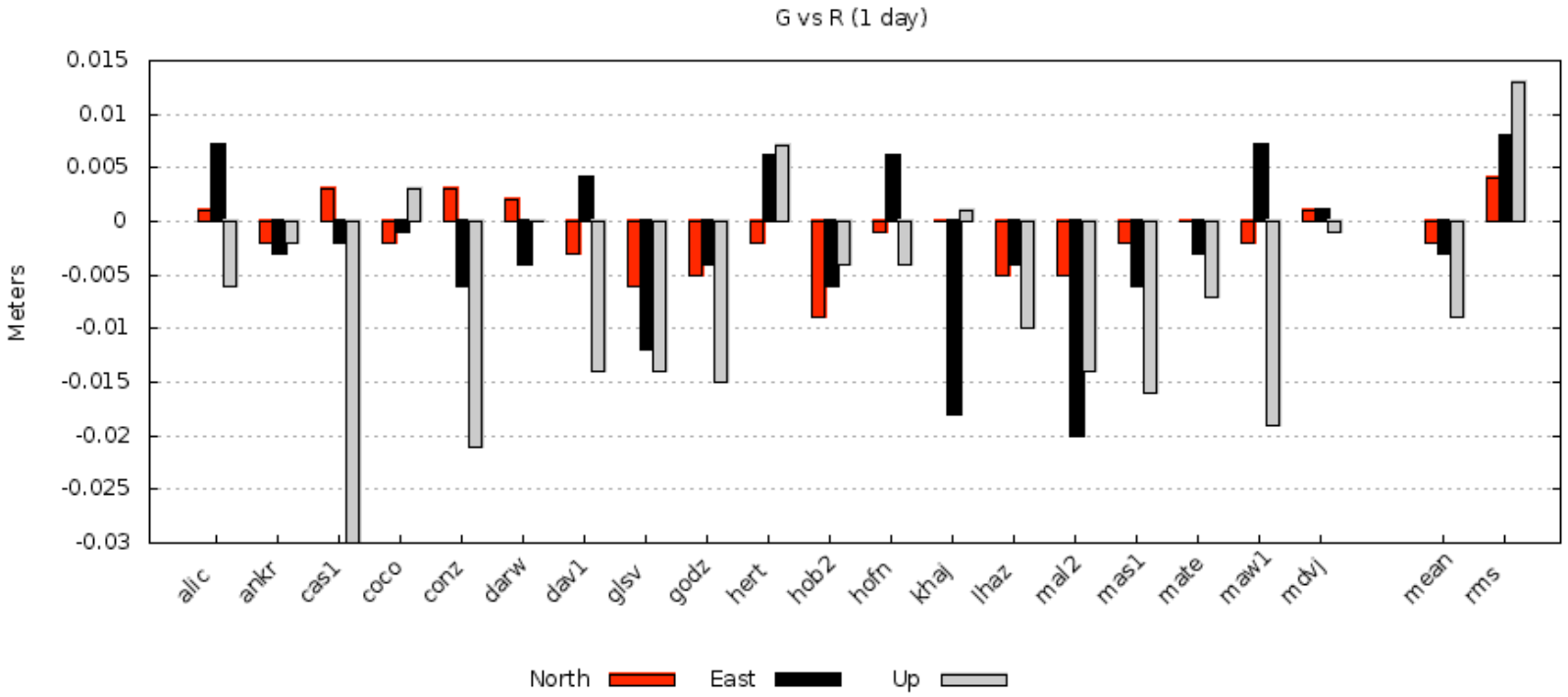
# STATIC PRECISE POINT POSITIONING (PPP)

- PPP is largely the same software as ODTS, but reading the satellite orbits and clocks from input files instead of estimating them
- Station parameters to be estimated: position, clock, tropo, float ambiguities
- Cycle slips are detected but not repaired (a new ambiguity is estimated)
- The station clock is calculated as "snapshot", at the same rate as the input measurements (typically 5 min)
- Several GPS+GLONASS *control stations* to test PPP



# PPP: ONE DAY OF STATION DATA (1)

- Using one day of data, GPS-only and GLONASS-only coordinates are consistent at **sub-cm** level
- In one day, GPS+GLONASS does not add much value with respect to GPS-only

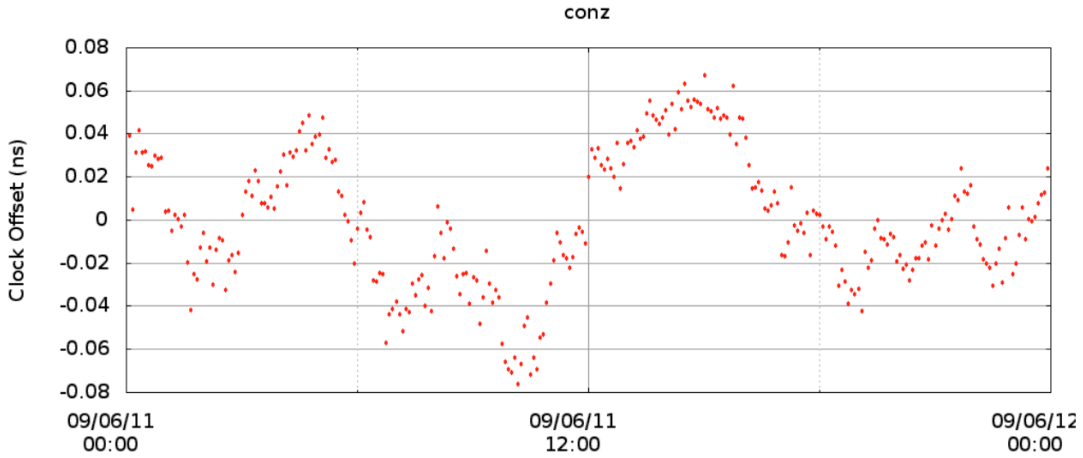



**GPS-only** vs **GLONASS-only** coordinates (1-day PPP)

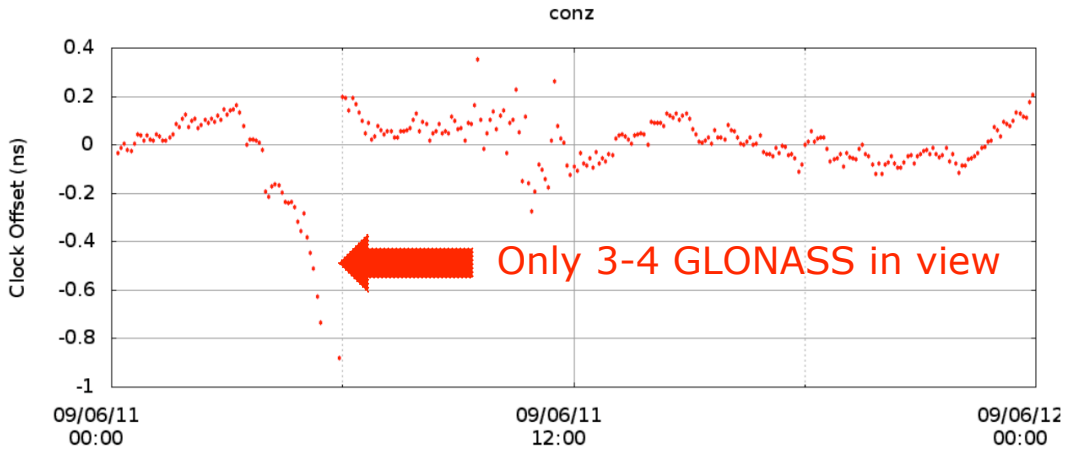
# PPP: ONE DAY OF STATION DATA (2)

- For **station clock**, GPS-only PPP is consistently accurate at the level of **50 ps**
- In **GLONASS-only** PPP one can observe "large" clock deviations sometimes, due to poor satellite availability -> difficult to characterize very stable ground clocks with GLONASS-only

The plots show the CONZ station clock estimated with PPP; a parabola has been removed to show the clock stochastic behavior

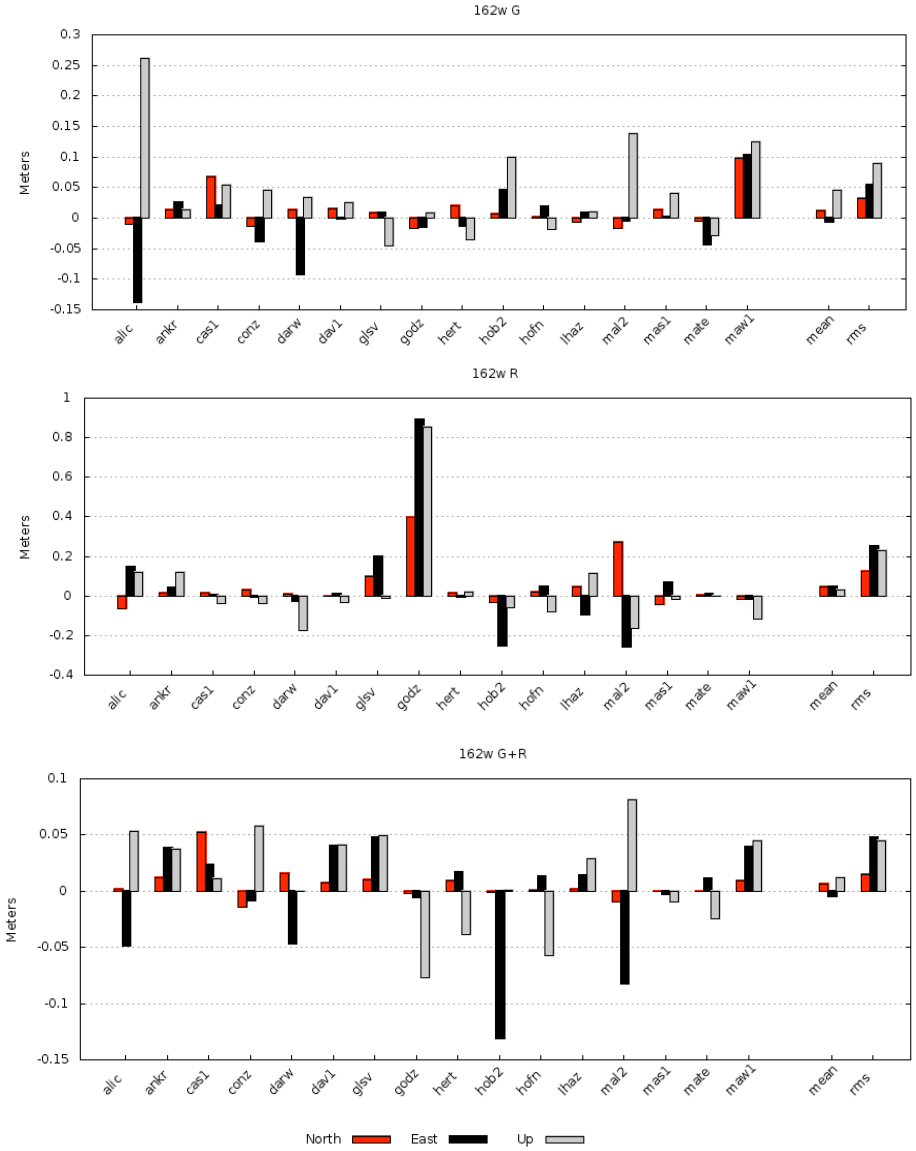



GPS-only




GLONASS-only

# PPP: ONE HOUR OF STATION DATA




**GPS-only**

**5-10 cm** RMS, some ***outliers***

**GLONASS-only**

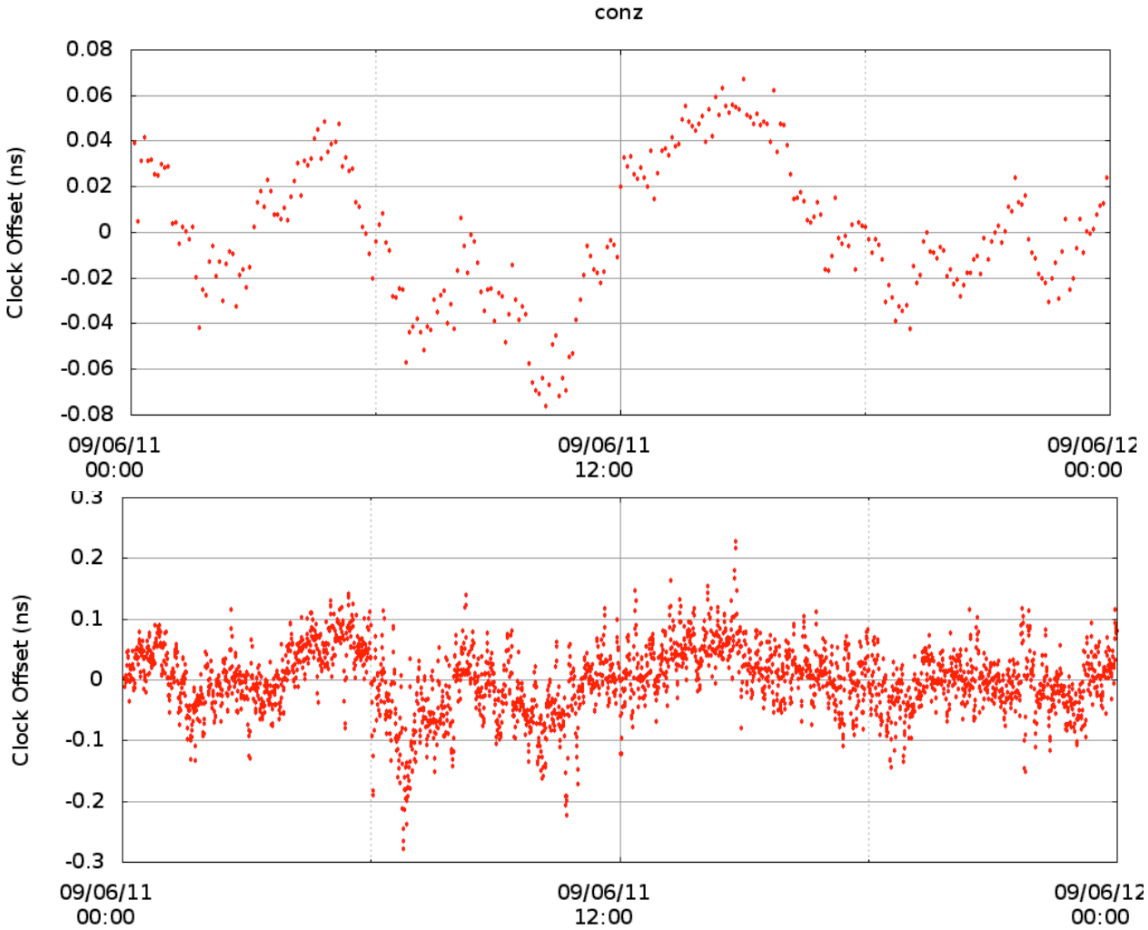
large **variablity**

**GPS+GLONASS**

~**5 cm** RMS, more **robust**

# CLOCK INTERPOLATION (1)

- GPS *rapid* clocks are published by IGS @ **5-min** rate; for PPP at higher data rate, satellite clocks must be interpolated
- Plots show a **GPS-only** PPP clock solution over **1 day** of station data (CONZ); a parabola has been removed to show the clock stochastic behavior




5-min data rate

(**no interpolation**)

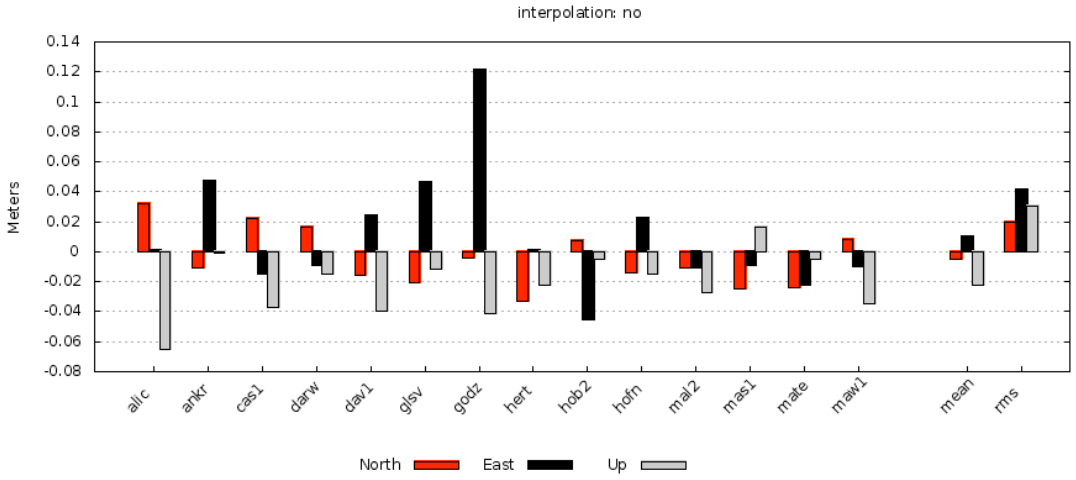
30-sec data rate

(**interpolation**)

added **noise**!

# CLOCK INTERPOLATION (2)

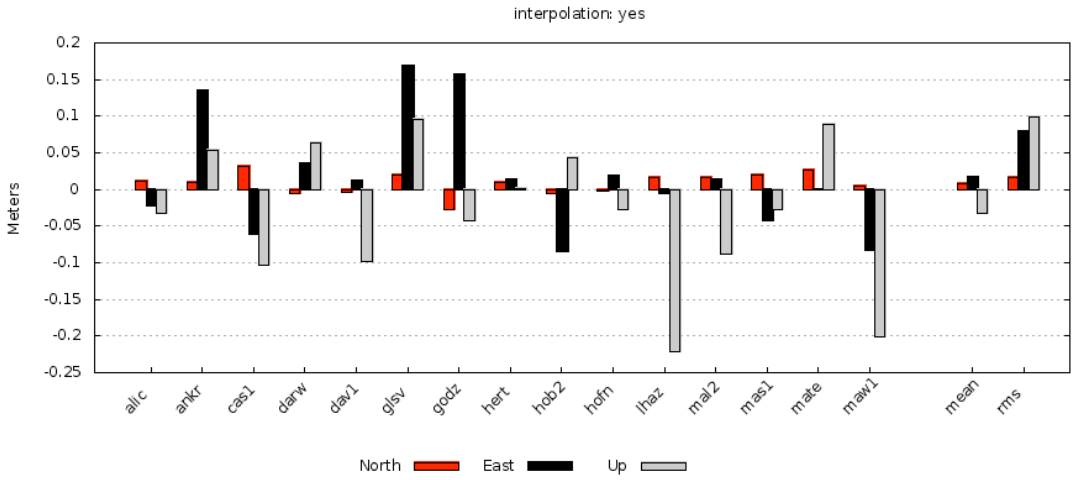
- The plots show a **GPS+GLONASS** solution using **one hour** of data
- A higher data rate results in less accurate coordinates!




5-min data rate

(**no interpolation**)

**~5 cm** RMS

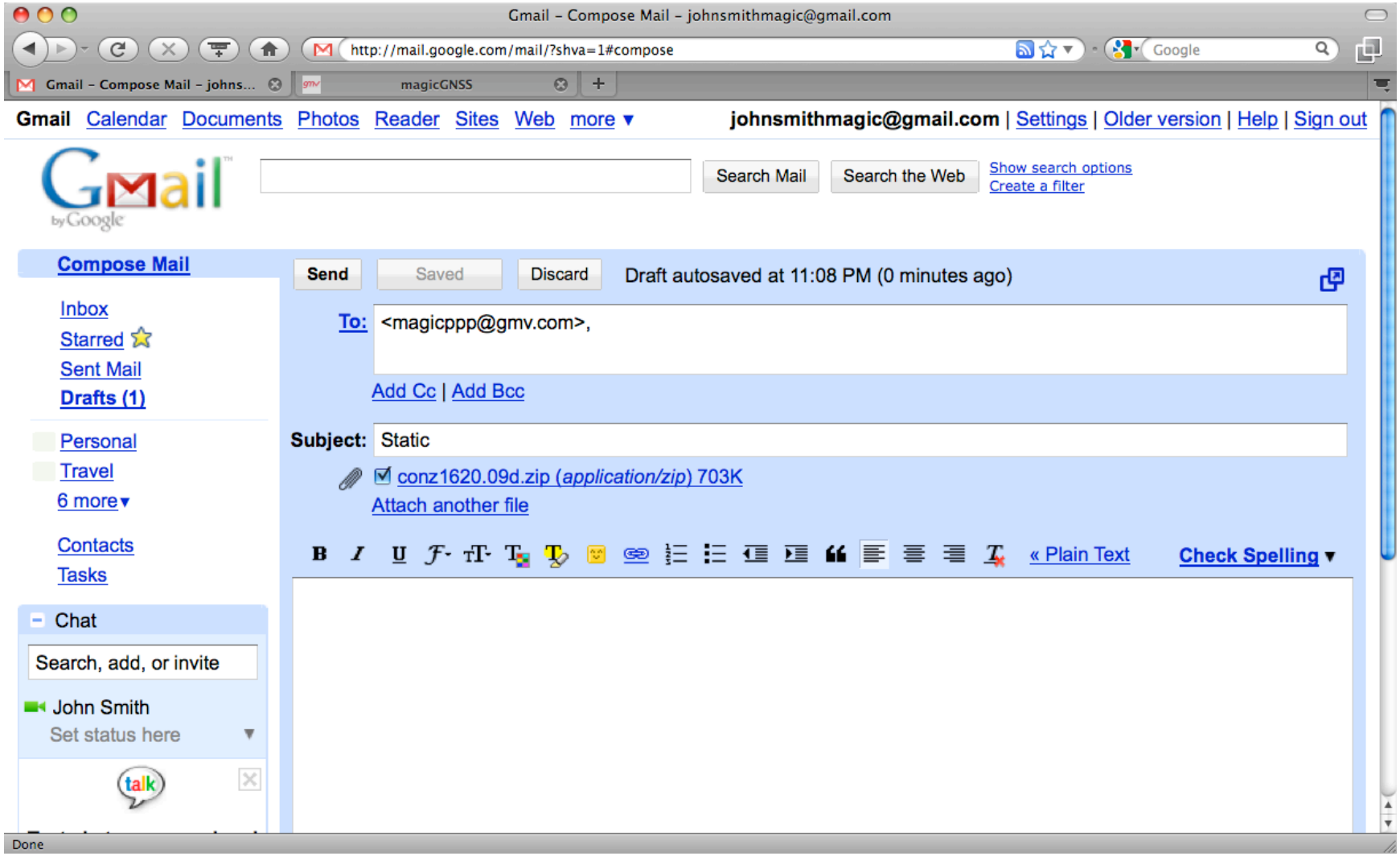



30-sec data rate

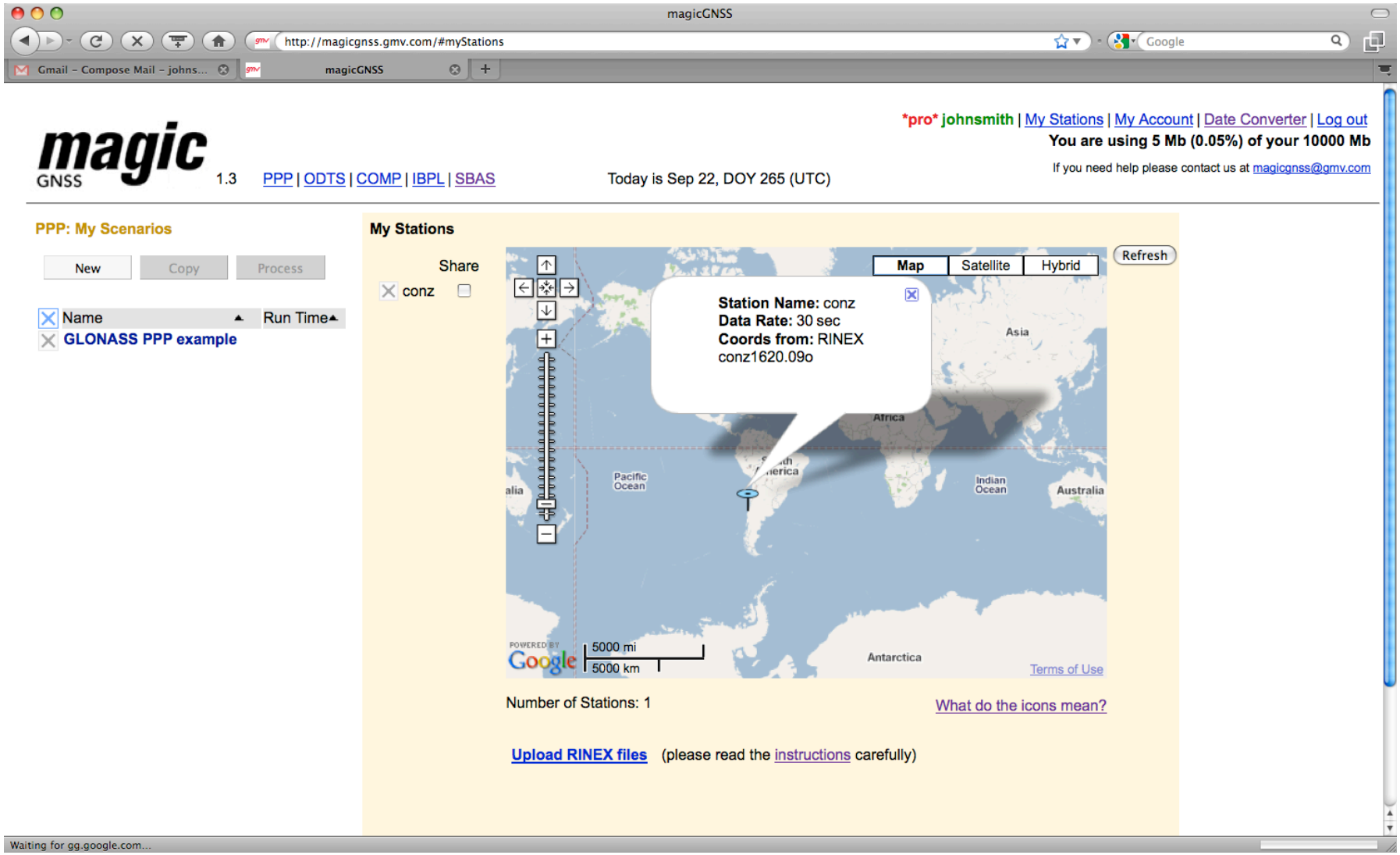
(**interpolation**)

**~10 cm** RMS

# LIVE DEMO: E-MAIL



# LIVE DEMO: WEB



# CONCLUSIONS

- PPP using **one day** of station data (@ 5-min rate):
  - **Position**: GPS-only and GLONASS-only coordinates agree at a **sub-cm** level
  - **Clock**: the GLONASS-only clock error is sometimes too large due to lack of satellites: it is difficult to characterize precise ground clocks with GLONASS-only PPP
  - GLONASS+GPS does not add much value w.r.t. GPS-only

- PPP using **one hour** of station data (@ 5-min rate):
  - PPP position accuracy depends a lot on satellite visibility, cycle slips
  - GLONASS-only position not very reliable
  - **GPS+GLONASS** position is **more robust and more accurate** than GPS-only (~**5 cm** RMS); increasing the data rate to **30 sec** does not improve the solution due to satellite clock interpolation

- PPP using **less than one hour** of station data: to be studied with higher-rate satellite clocks (GPS and GLONASS), avoiding clock interpolation


# Thank you!

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