MGEX Clock Determination at CODE

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Presentation Outline

- Overview of CODE MGEX orbit and clock solutions
- Bias handling in the clock estimation
- Inter-system biases stability
- Conclusions and outlook

CODE MGEX Orbit Solution

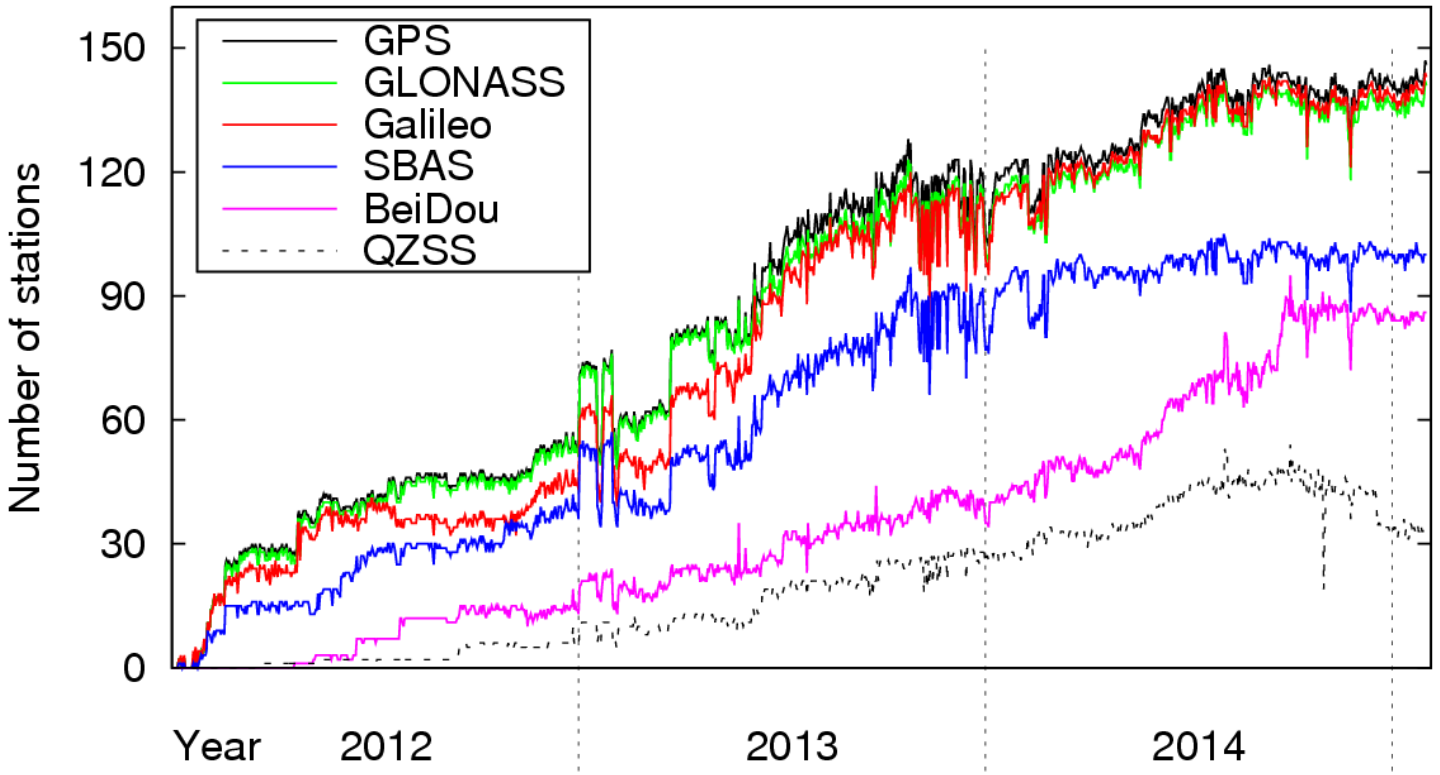
GNSS considered:	**GPS + GLONASS + Galileo + BeiDou** (MEO+IGSO) + **QZSS** (70 SV)
Processing mode:	post-processing / 2 weeks delay (since 2015)
Timespan covered:	GPS-weeks 1689 - today
Number of stations:	130 (GPS), 110 (GLONASS), 85 (Galileo); 55 (BeiDou); 20 (QZSS)
Processing scheme:	**double-difference** network processing (observable: phase double differences)
Signal frequencies:	L1+ L2 (GPS + GLO+ QZSS); E1 (L1) + E5a (L5) GAL; B1 (L1) + B2 (L7) BeiDou
Orbit characteristic:	3-day long arcs; RPR: ECOM / ECOM2 (since 2015)
Reference frame:	IGS08 (until week 1708); IGb08 (since week 1709)
IERS conventions:	IERS2003 (until 1705); IERS2010 (since 1706)
Product list:	daily orbits (SP3) and ERPs
Distribution:	ftp://cddis.gsfc.nasa.gov/gnss/products/mgex/
Designator:	comwwwwd.???.Z

CODE MGEX Clock Solution

GNSS considered:	**GPS + GLONASS + Galileo + BeiDou** + **QZSS** (70 SV)
Processing mode:	post-processing / 2 weeks delay (since 2015)
Timespan covered:	GPS-weeks 1710 - today
Number of stations:	130 (GPS), 35 (GLO), 45 (Galileo); 50 (BeiDou); 20 (QZSS)
Processing scheme:	**zero-difference** network processing (observable: code+phase undifferenced)
Signal frequencies:	L1+ L2 (GPS + GLO+ QZSS); E1 (L1) + E5a (L5) GAL; B1 (L1) + B2 (L7) BeiDou
A priori information:	orbits, ERPs, coordinates, and troposphere from CODE MGEX orbit solution introduced as known
Reference frame:	IGb08
IERS conventions:	IERS2010
Product list:	epoch-wise (300s) satellite and station clock corrections in daily clock RINEX files; daily inter-system biases for mixed stations in Bernese DCB and BIAS-SINEX (BIA) format
Distribution:	ftp://cddis.gsfc.nasa.gov/gnss/products/mgex/
Designator:	comwwwwd.???.Z

CODE MGEX solutions

- Stations providing RINEX3 included in CODE's data monitoring



Biases handling in the clock procedure

- Inter-system biases (ISB) are setup for each station and GNSS
- ISBs are the lumped sum of:
  - Systems time difference
  - DCBs
  - Inter-frequency biases (specific to GLONASS)
- Each GLONASS satellite is treated as an individual system
- ISBs are estimated session-wise (daily)
- For each GNSS, a zero-mean condition is applied over all tracking stations
- => Investigate the time variability of these ISBs

ISB reference unification

- ISB reference realized with a zero-mean condition each day for each system
- ISB daily references need therefore to be unified first
- Achieved by selecting a reference station for each GNSS and assume constant (zero) ISB over time
  - \+ Most stable station can be selected
  - \+ Not affected by less stable stations
  - – The selected station has to be available on each day
  - – Any artefact contained in the reference will be transfered to all others stations

    => may be necessary to select different references on sub-intervals

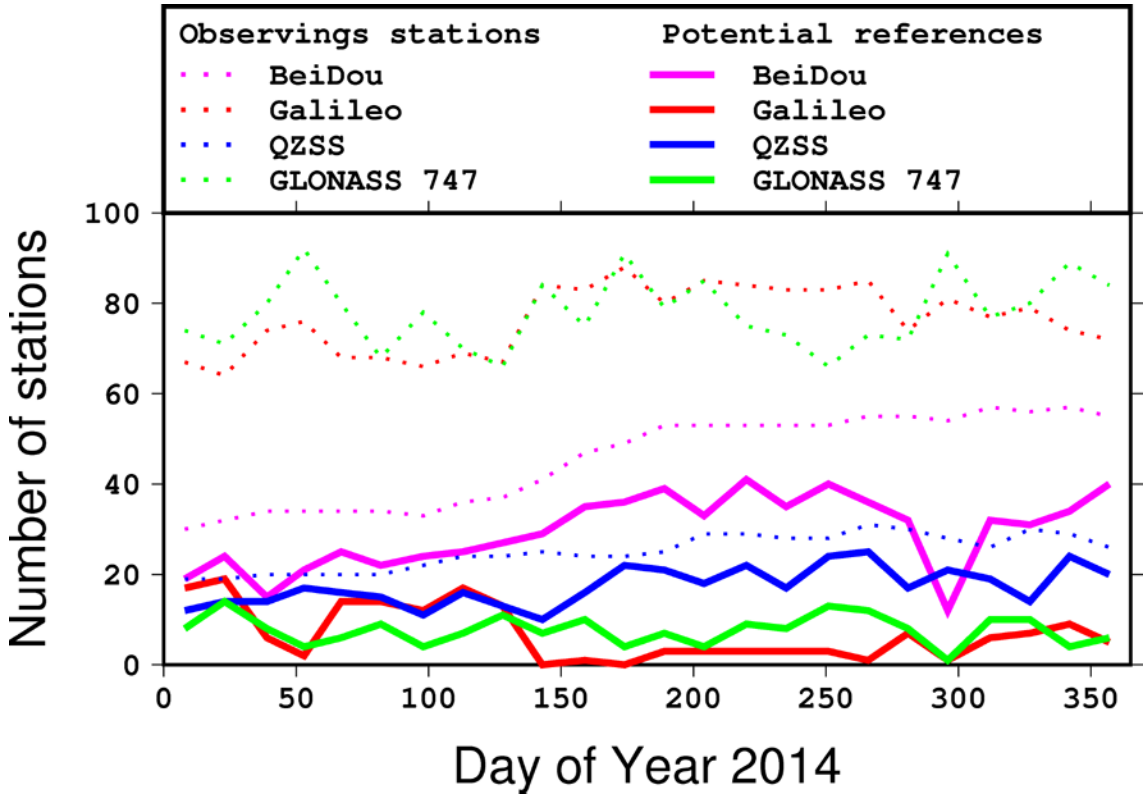
ISB reference unification

- But the high variability in of the sub-networks observing each GNSS prevented to identify acceptable reference ISB over long periods

  $\Rightarrow$ After some iterations, the full year was divided in 15-day periods over which a reference is chosen for each GNSS

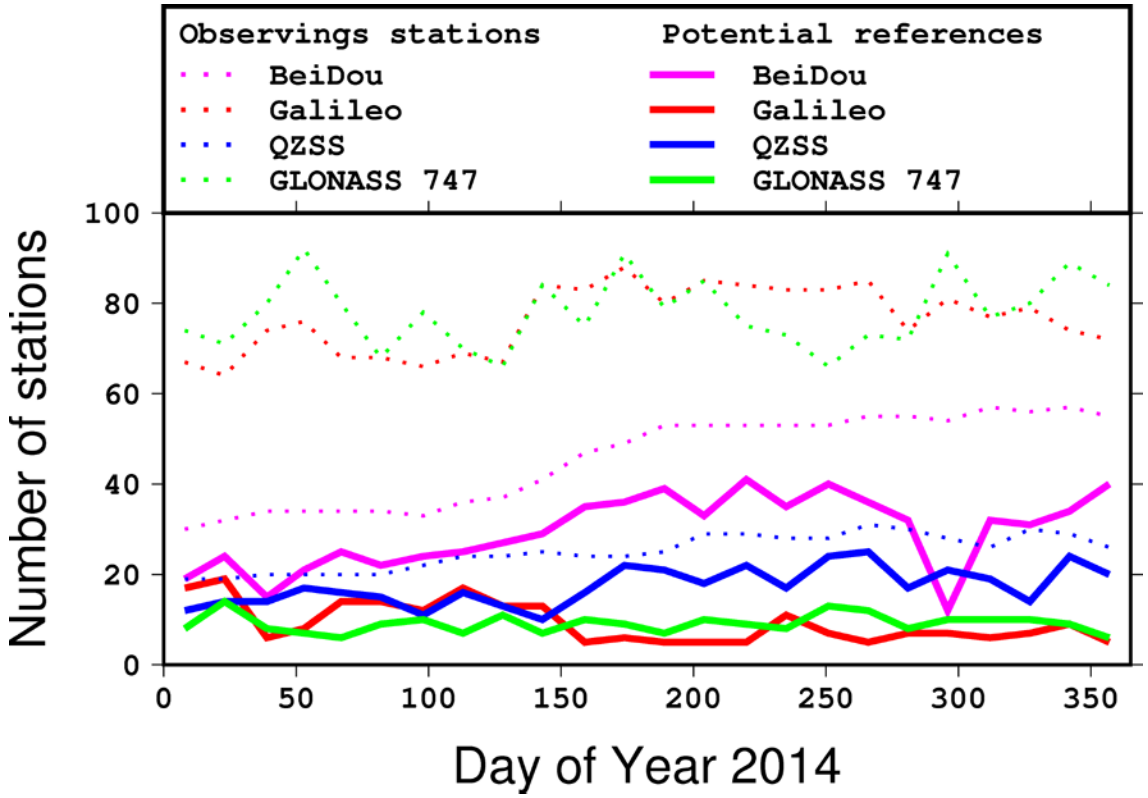
- Over each period the reference ISB site is chosen as the one that minimizes the sum of the RMS of the others.

ISB reference unification



- Even on 15-day periods, the situation is not always comfortable in terms of pool of potential reference sites

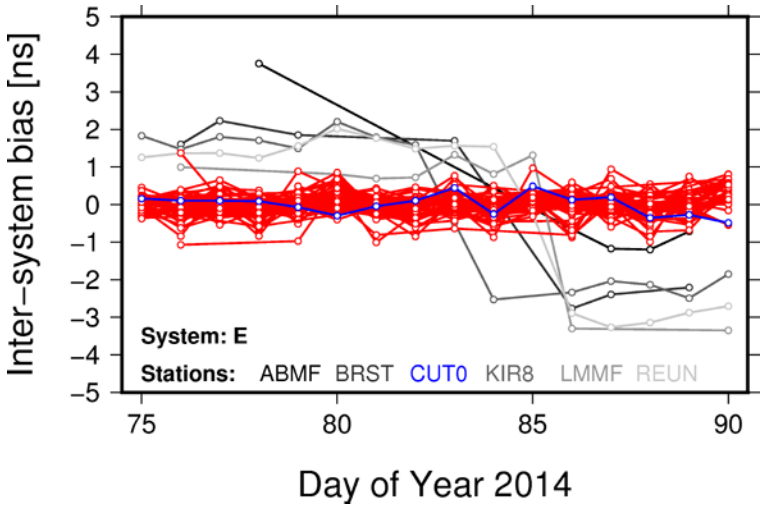
ISB reference unification



- To relax the system uncomplete references were added to have a least 5 potential references to chose from.

Events in ISB time series

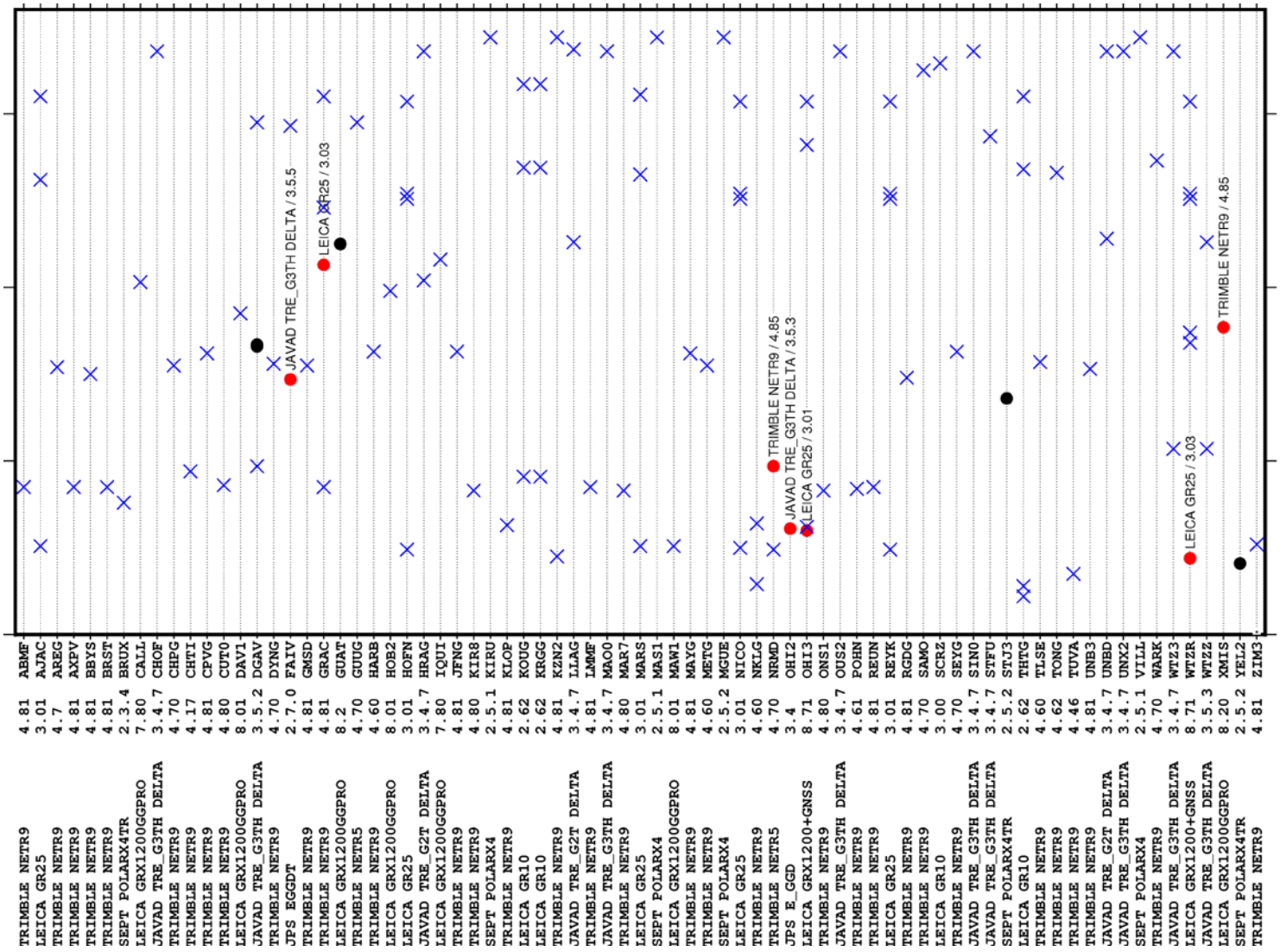
- Time series were splitted in case of receiver swap.
- Firmware upgrades (according to sitelogs) may impact the timeseries, but not systematically



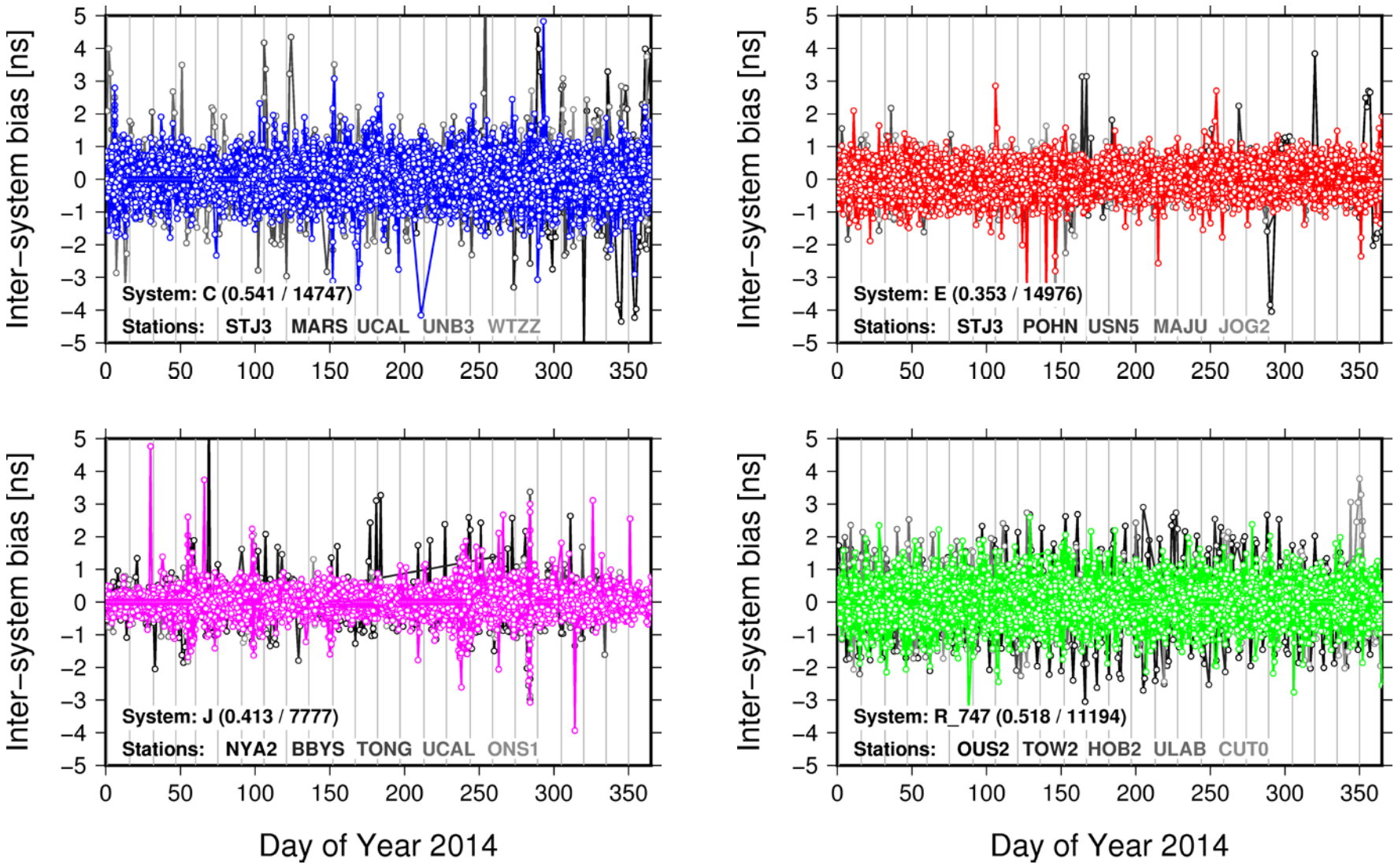
6 stations equipped with TRIMBLE NETR9 with same firmware upgrade from version 4.80 to 4.85.

- Since impractible to examine individually the time series, a generic screening was performed.
- Note that a jump only impacts the periods it belongs to.

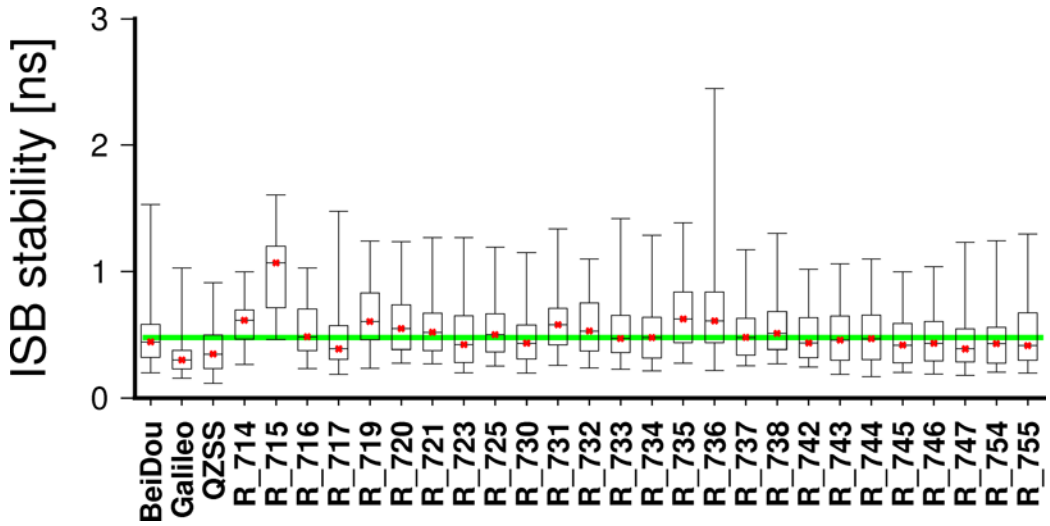
CODE MGEX Station with hardware/firmware changes in 2014



Stacked ISB time series

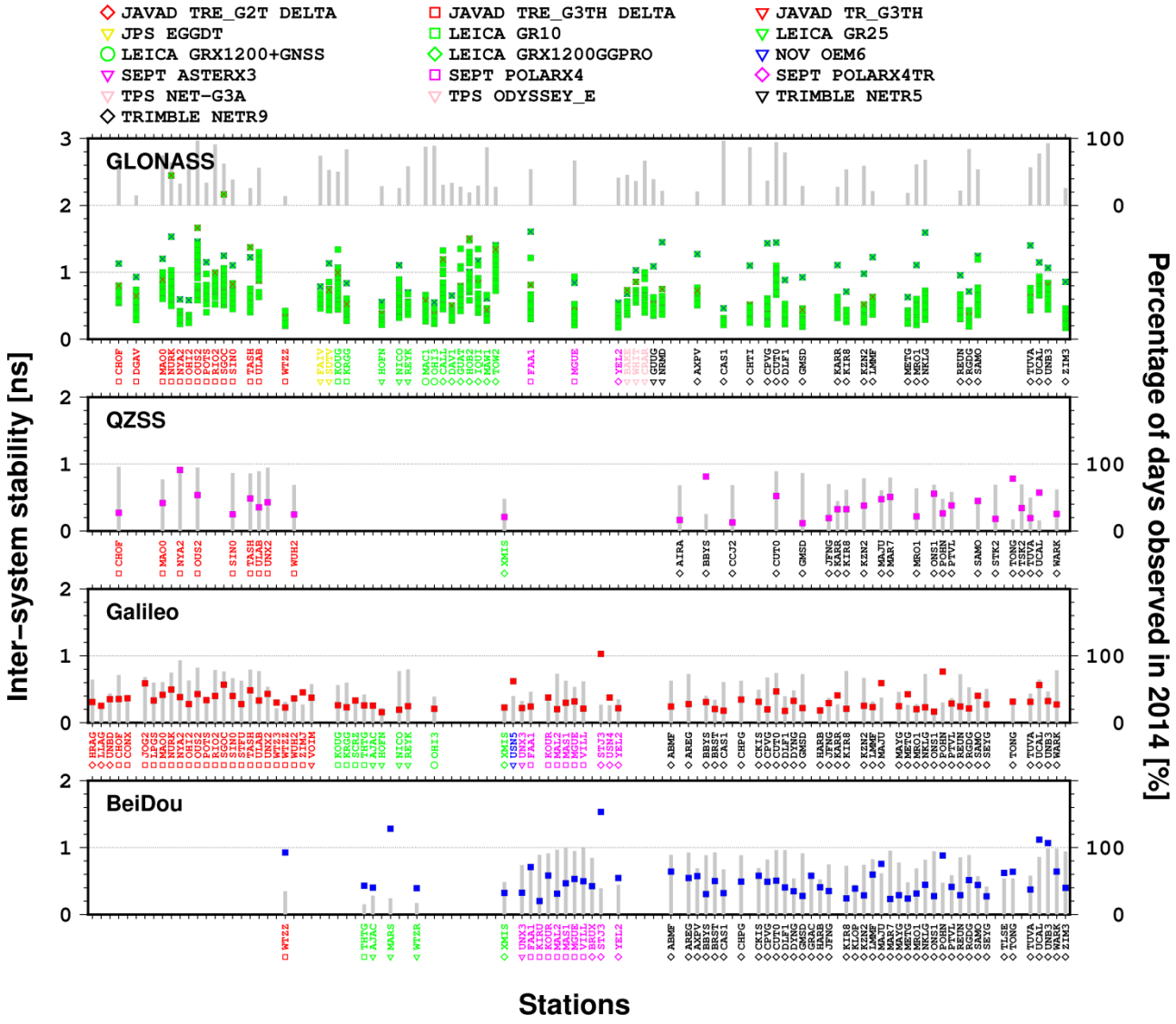


ISB stability: overview



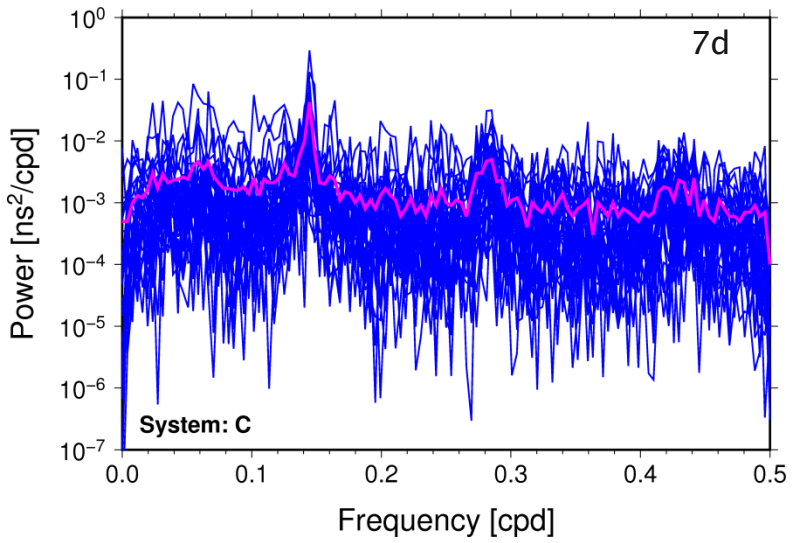
- Galileo & QZSS have 75 % of their stations below the overall median (0.476 ns).
- Apart from GLONASS R_715, all systems have their median value close to that of the overall median.
- Still apart R_715, the minimum values are similar over all systems.
- R_736 shows largest ISB stability spread.

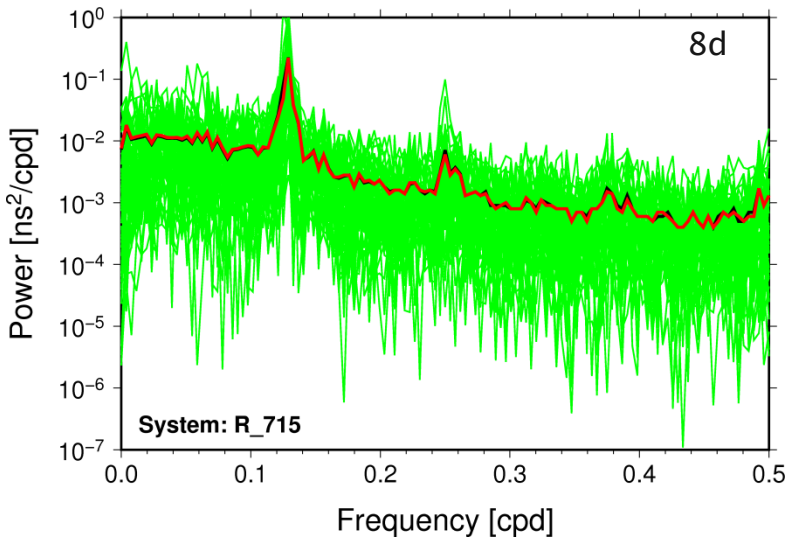
ISB stability over receiver types

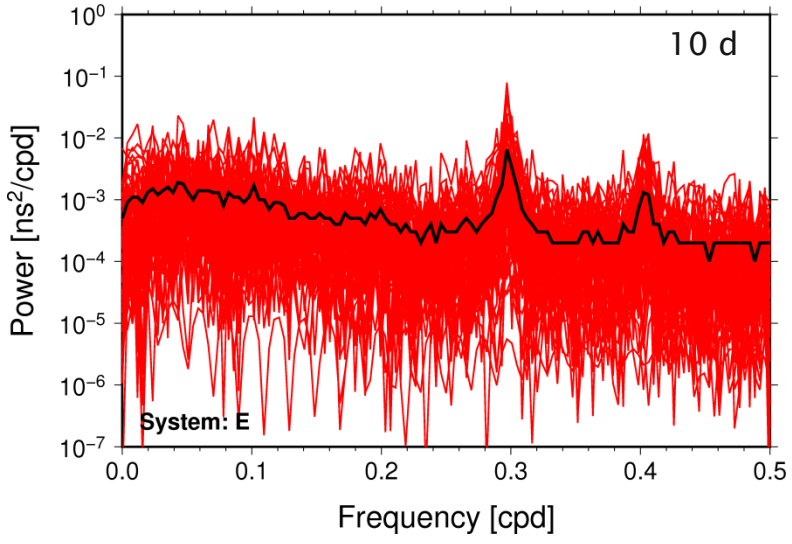


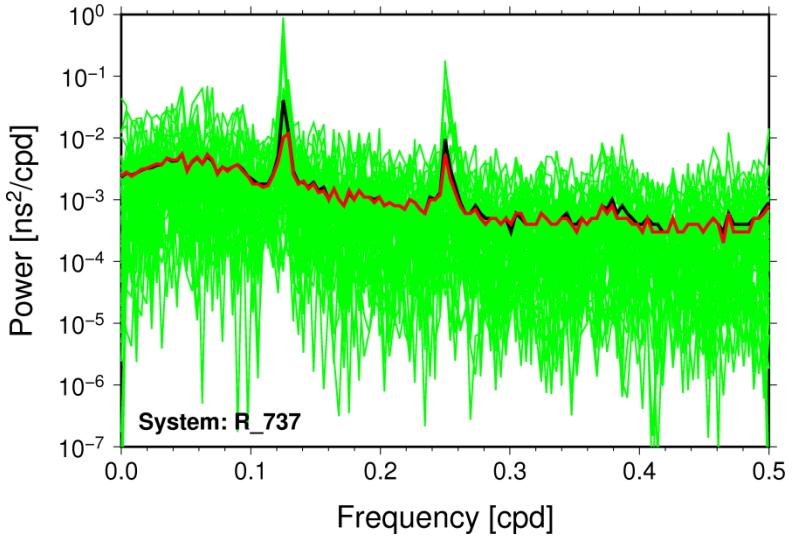
- ISB per brand and type
- No dependency observed
- No dependency either on time series length
- Some predominant receiver types
- R_715 and R_736 generally represent the least stable systems for GLONASS tracking stations

ISB periodicities









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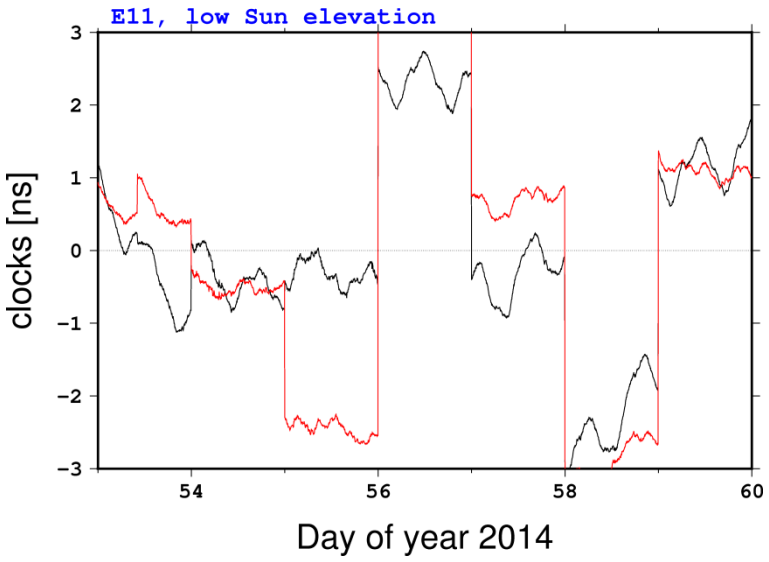
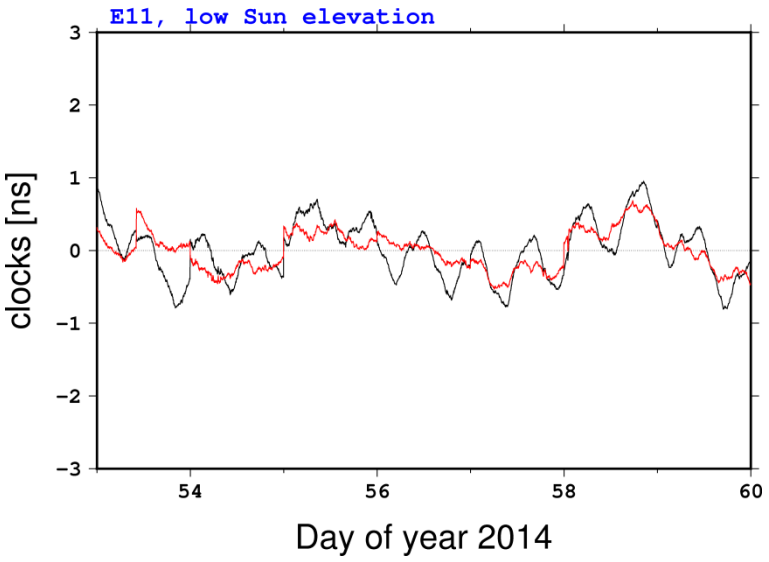
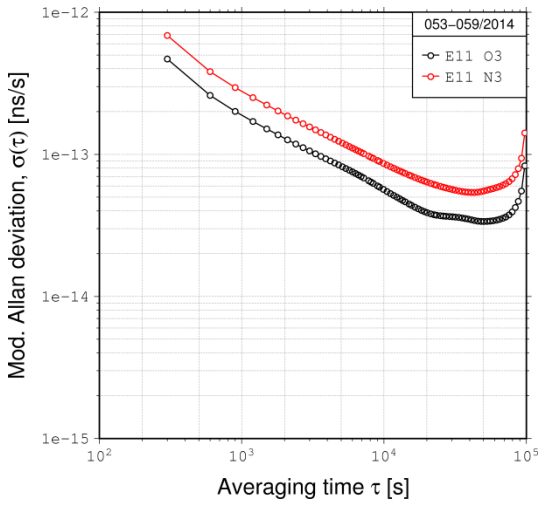
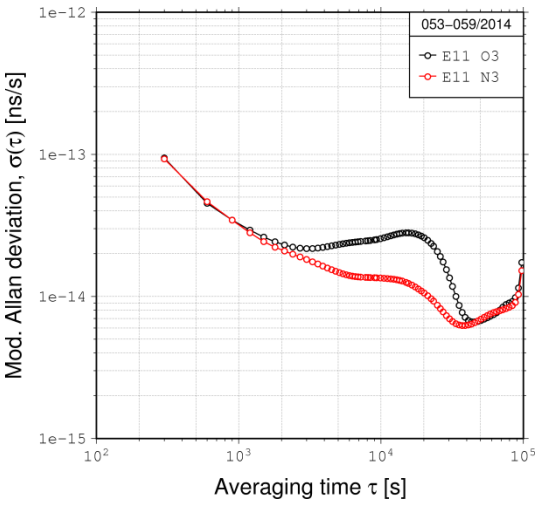
Building long clock time series: Galileo









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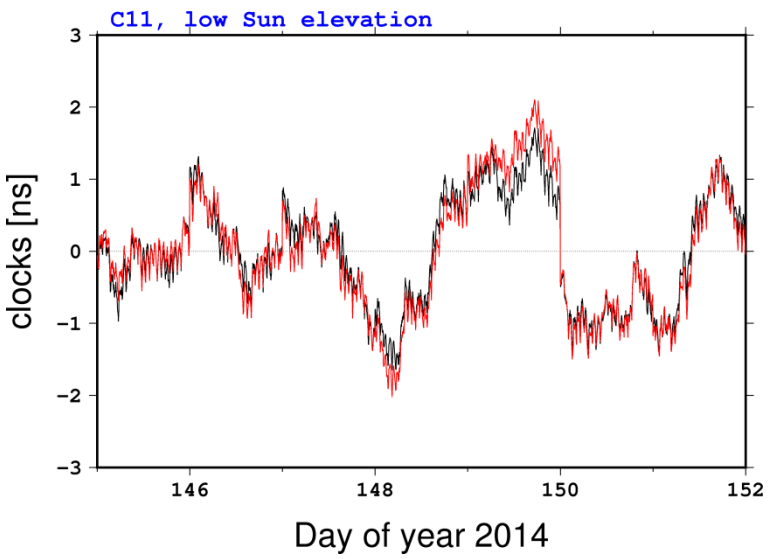
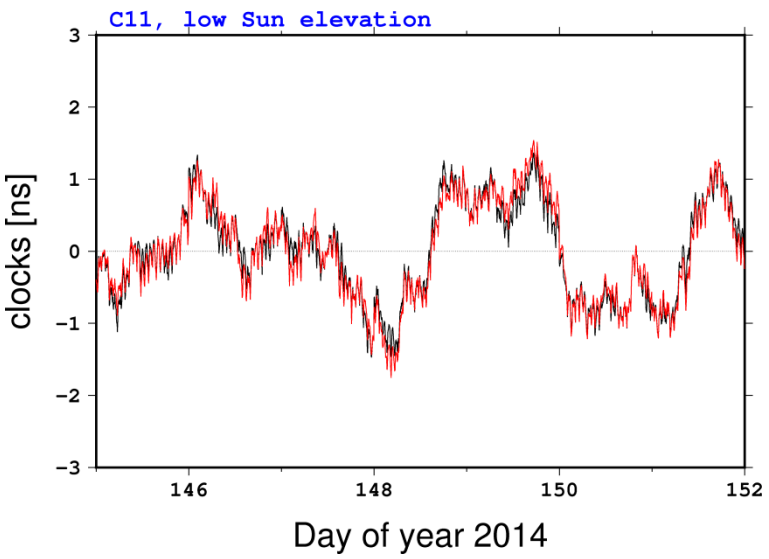
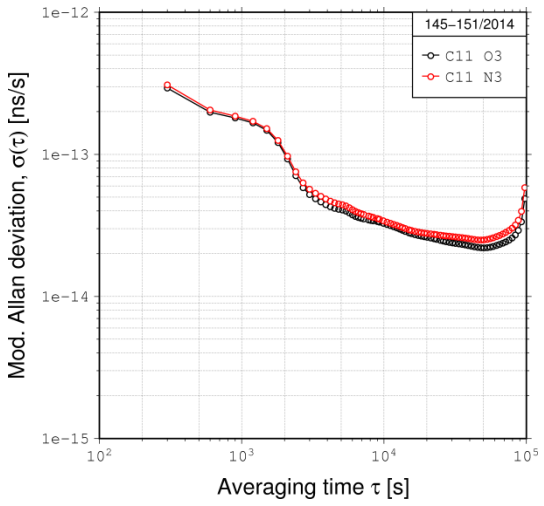
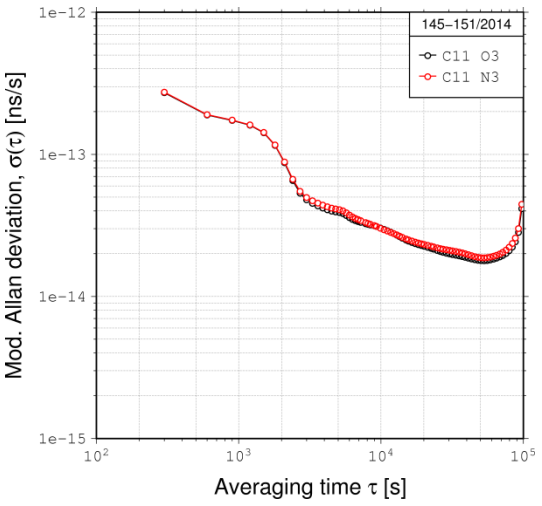
Building long clock time series: BeiDou

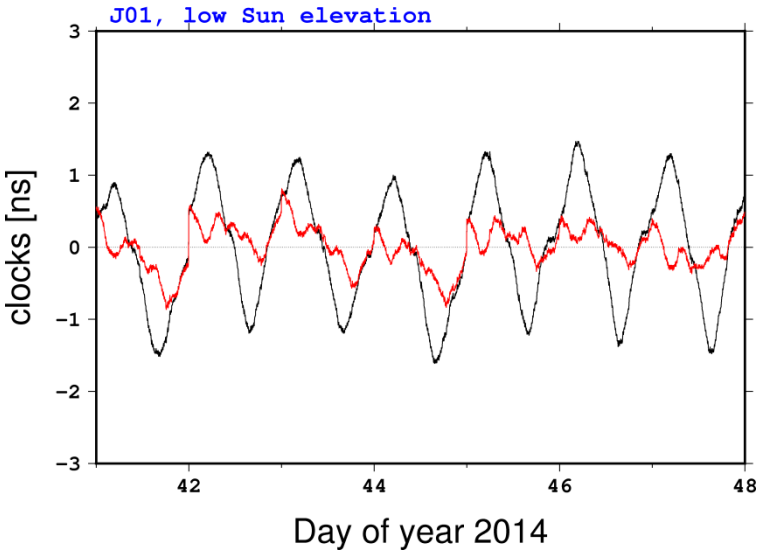


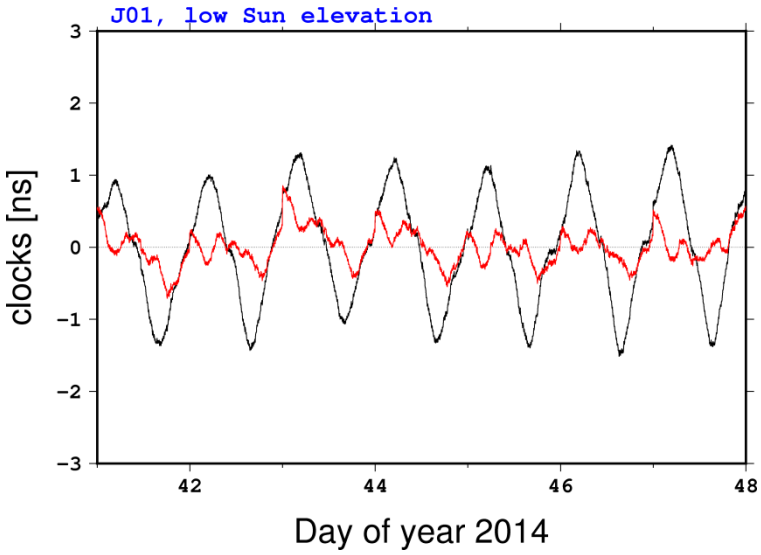


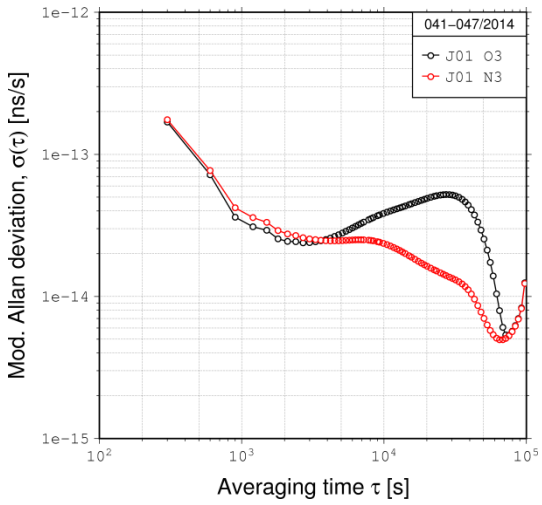


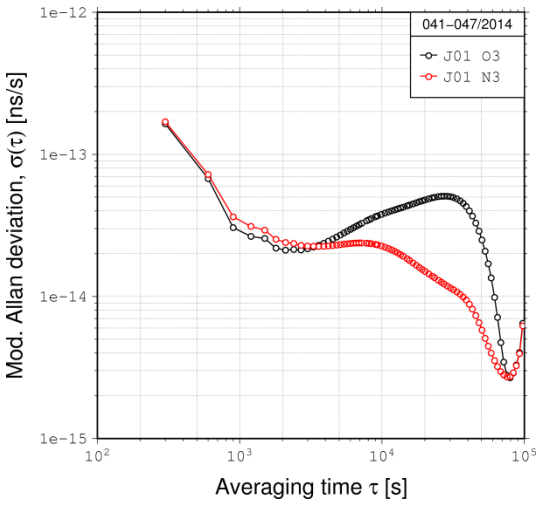


Building long clock time series: QZSS









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Conclusions and outlook

- The short-term variation of the ISBs was assessed for the four GNSSs considered on top of GPS
- Overall consistent performances over the systems, apart from R_715
- Periodic variations were found in the time series
- Jumps/outliers in time series remain to be understood

Thank you for your attention!