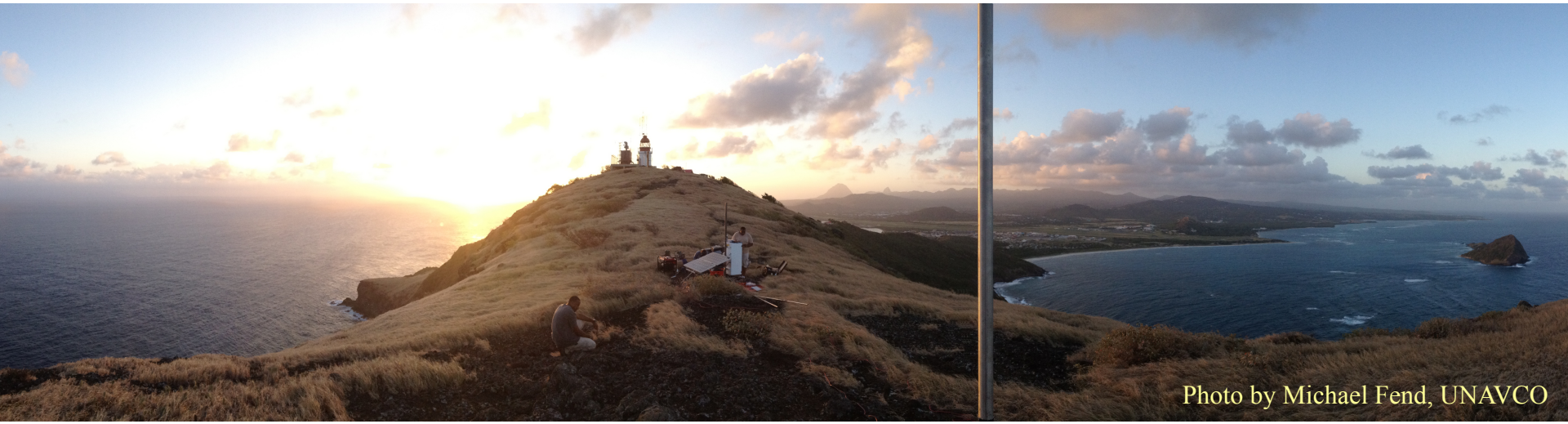
Impact of GNSS Clock Instability on Radio Occultation Retrievals for the COSMIC-2 Mission



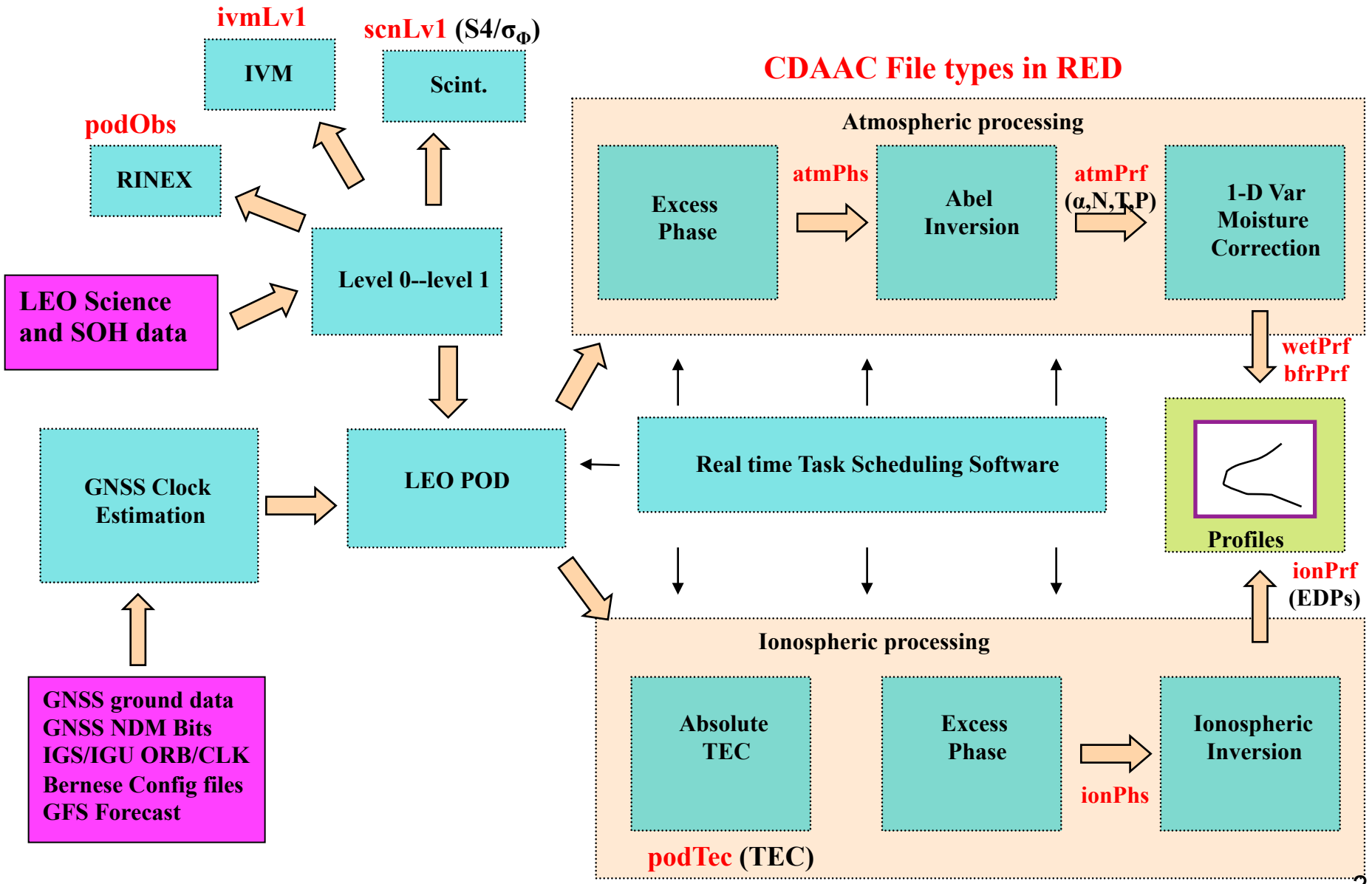
John J. Braun, Teresa Van Hove, B. Schreiner, S. Sokolovskiy, D. Hunt. J Lin, J. Weiss, J. Castilleja

COSMIC/UCAR

Acknowledgements: Research supported by NOAA and NSF

Data Acknowledgements: CODE, IGS, CDDIS

CDAAC Processing Flow



Impact of Clock on Bending Angle Noise

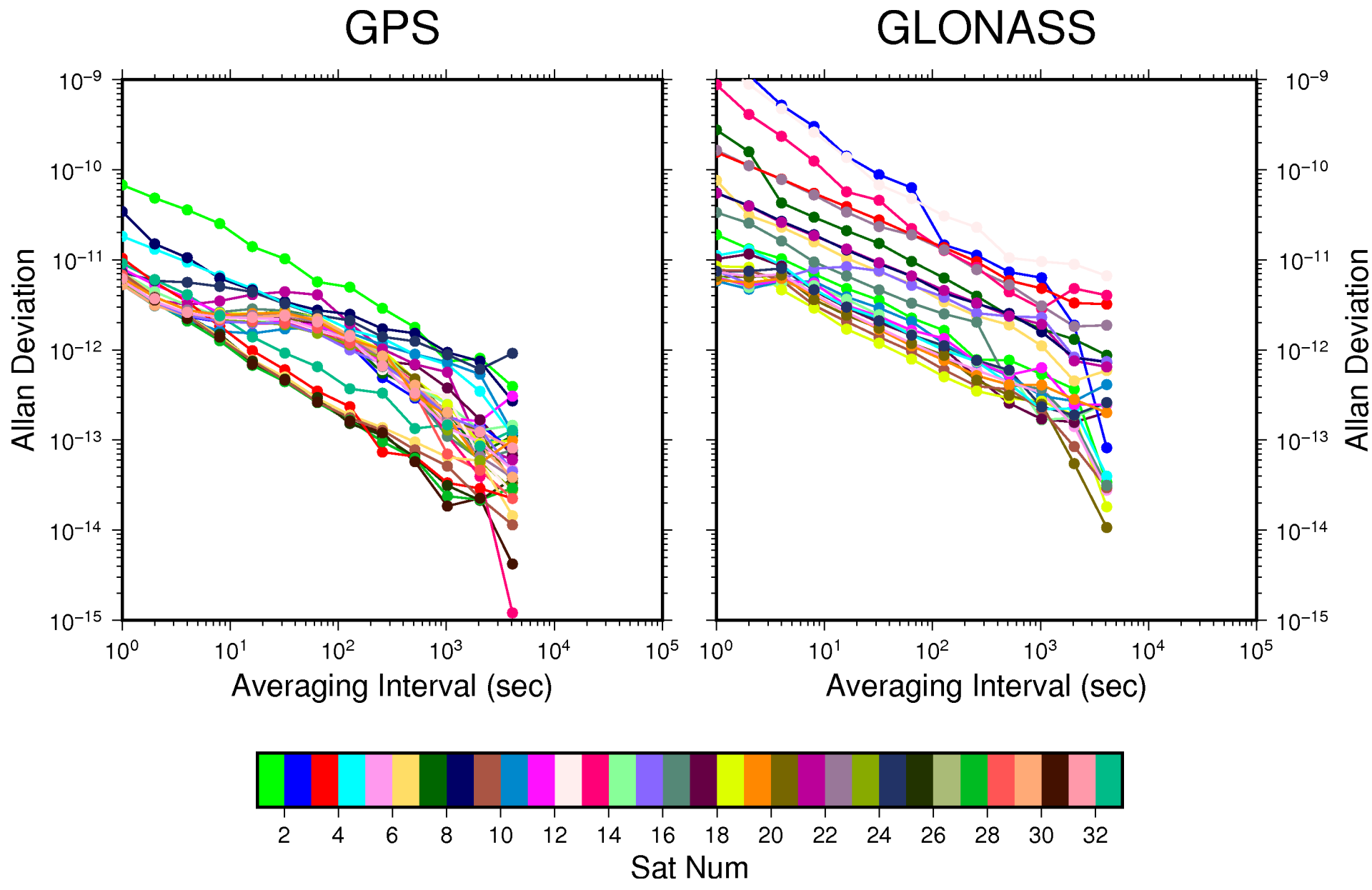
	Mean STDV (30sec SD)	Mean STDV (5sec SD)	Mean STDV (1sec SD)
GPS	1.52 x 10 -6	1.50 x 10 -6	1.47 x 10-6
GLONASS	????	????	????

- COSMIC-1 collocated soundings.
- Bending angle profiles between 60 – 80 km
- 5,596 co-located profiles between May 2-8, 2008
- Schreiner et al., GPS Solutions (2010)

$$STDV = C\sqrt{\sigma_{thermal}^2 + \sigma_{iono}^2 + \sigma_{clk}^2}$$

- Assumes clock, residual ionospheric, thermal, and other error sources are uncorrelated.

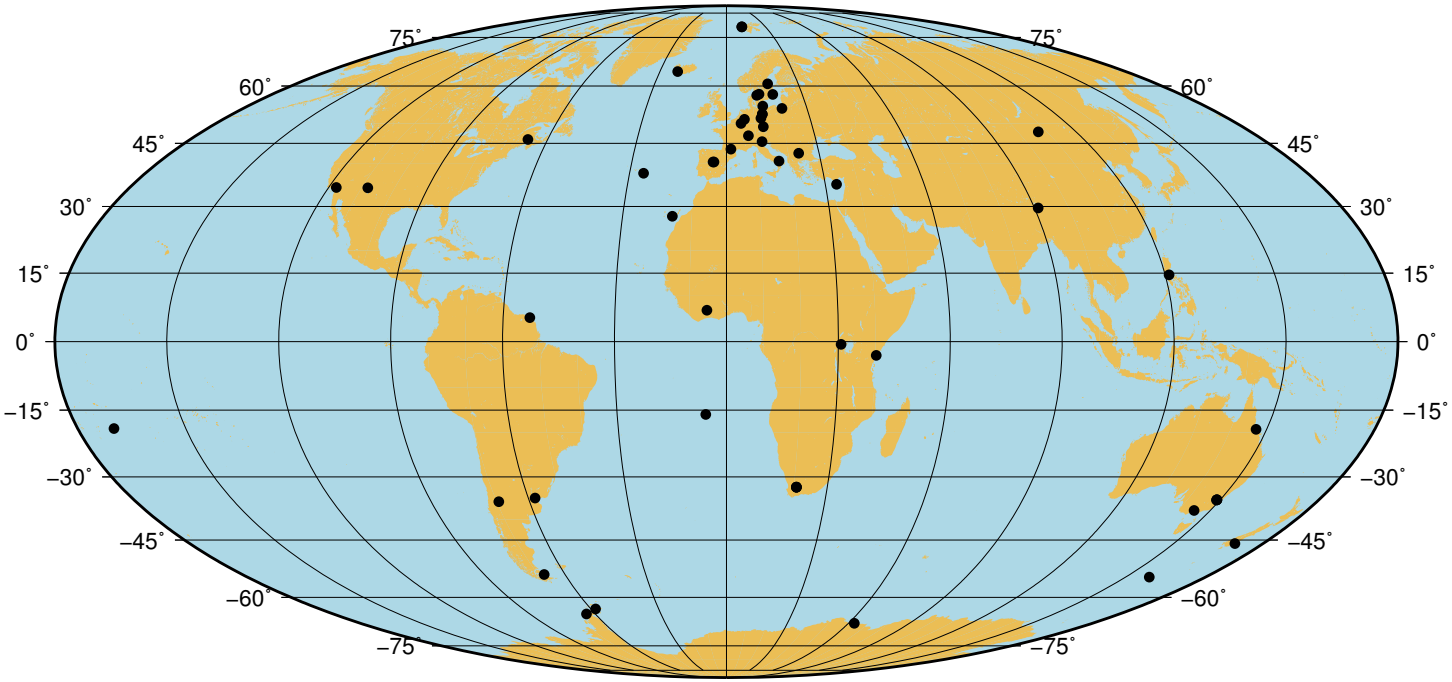
GNSS Allan Deviation



Motivation

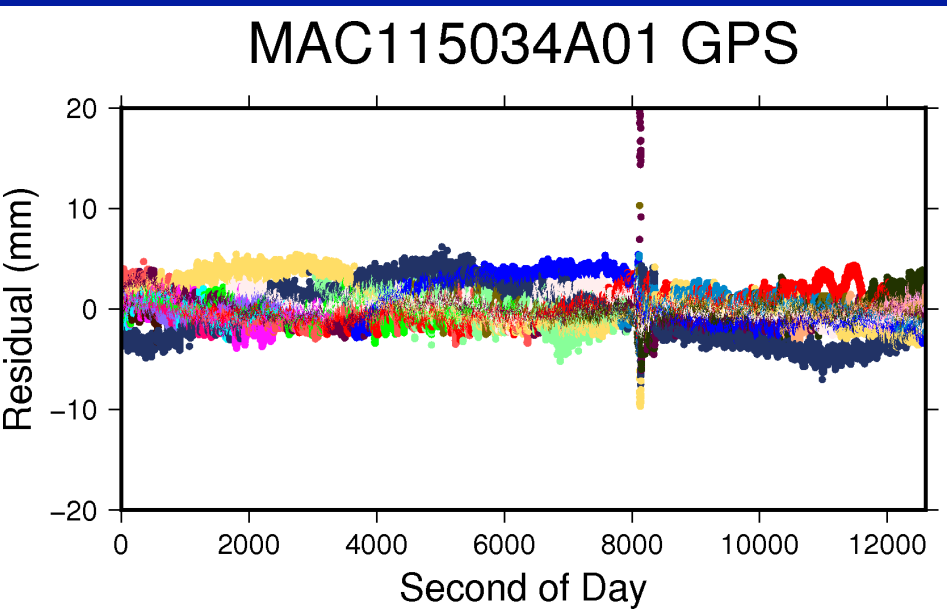
- GNSS clock stability directly impacts the precision of RO retrievals (see Schreiner et al., 2010).
- GLONASS clocks are known to have significantly higher variability than GPS over time periods important to RO (1-120) seconds.
- C-2 will be the first RO mission to utilize GLONASS observations.
- Currently CDAAC estimates clocks at 30 second intervals and interpolates to 50hz (100 Hz for C-2).
- Is it necessary to estimate satellite clocks at a higher rate for C-2 than is done operationally for C-1?

Experiment Design



- Use global network of ground GNSS stations with 1Hz data to to evaluate impact of clock interpolation on phase residuals.
- Decimate 1Hz clocks to: 2 sec, 5 sec, 10 sec, 15 sec, and 30 sec.
- Use a globally distributed network of ground GNSS stations with 1Hz data to evaluate the impact of clock interpolation on GNSS phase residuals.
- Estimate coordinates and troposphere parameters with GPS only, then reintroduce as a-priori values.

MAC1


MAC115034A01 GPS
Residual (mm)
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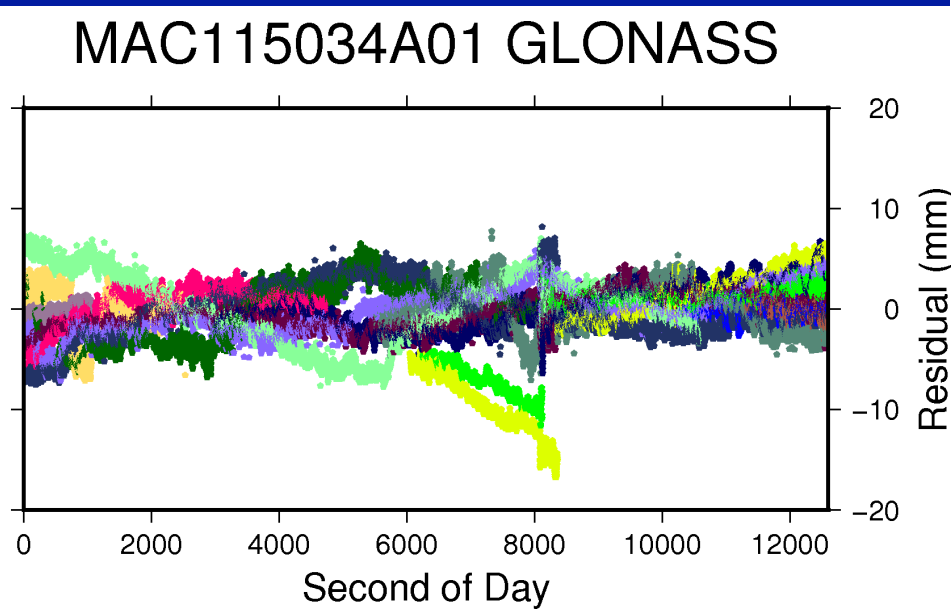
Second of Day


MAC115034A01 GLONASS
Residual (mm)
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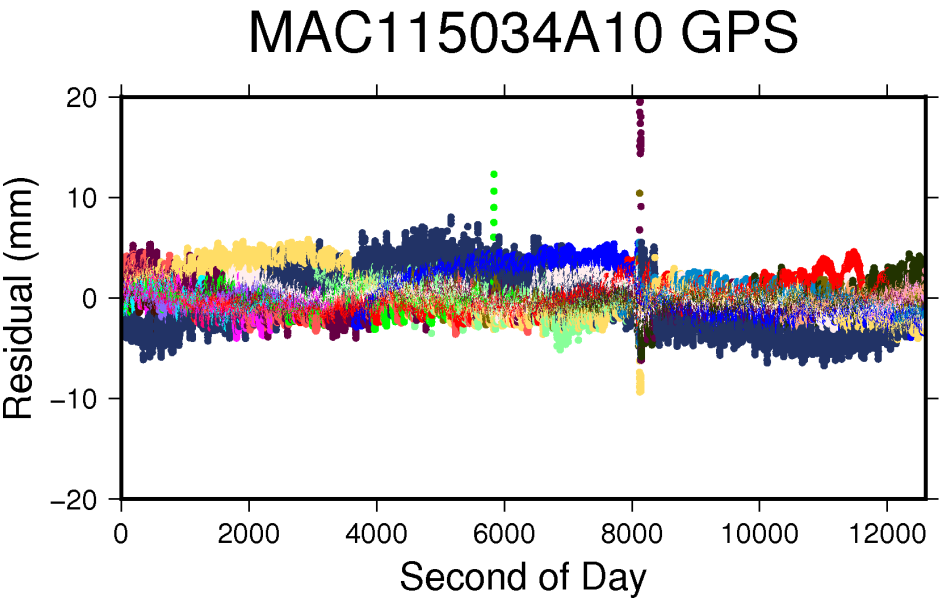
Second of Day


MAC115034A10 GPS
Residual (mm)
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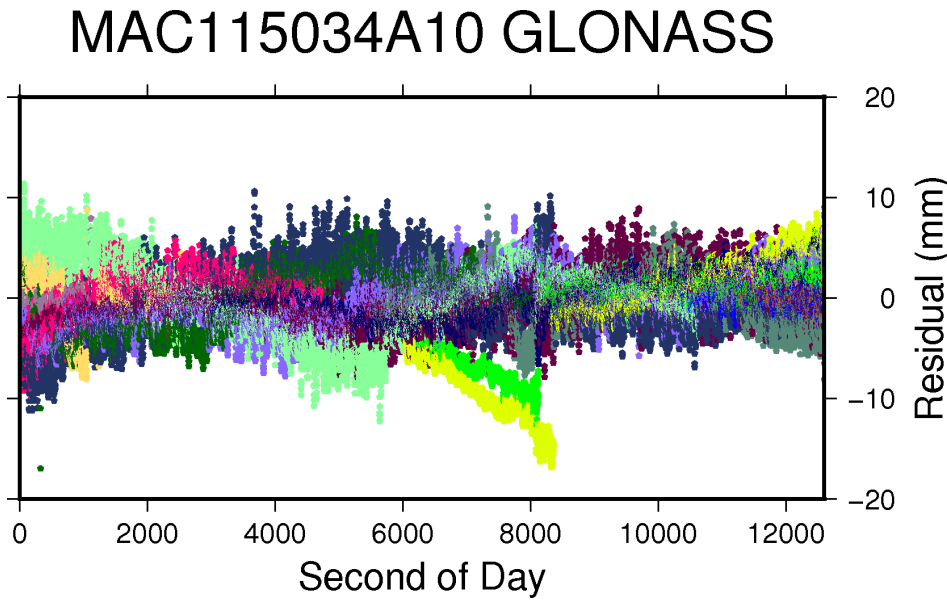
Second of Day


MAC115034A10 GLONASS
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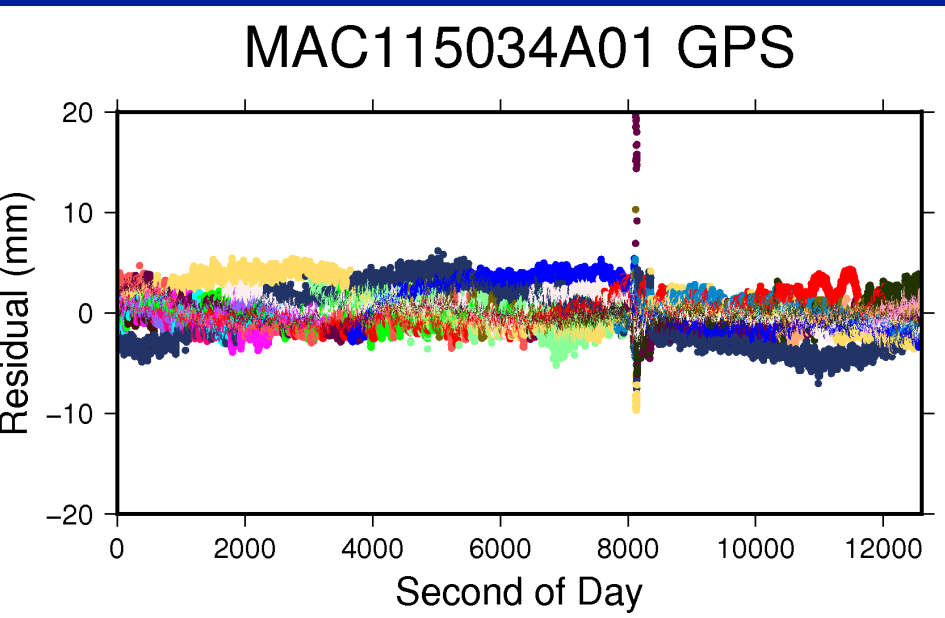
Second of Day

MAC1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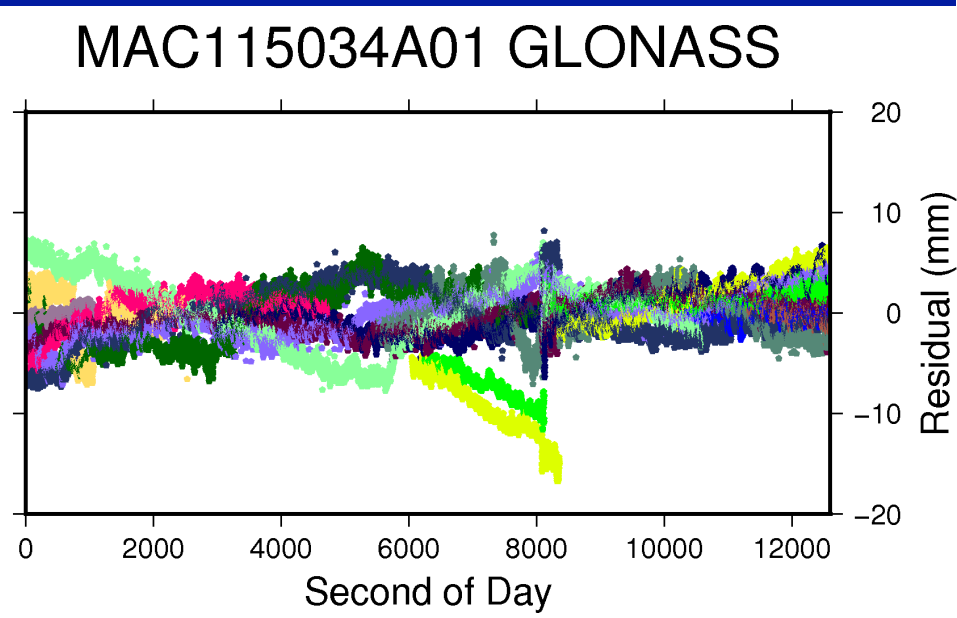
Second of Day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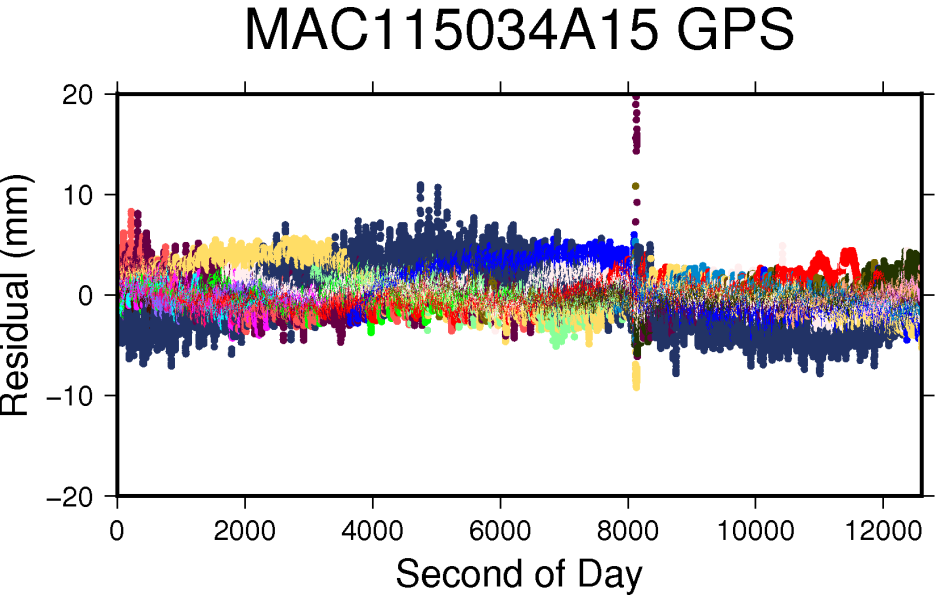
Second of Day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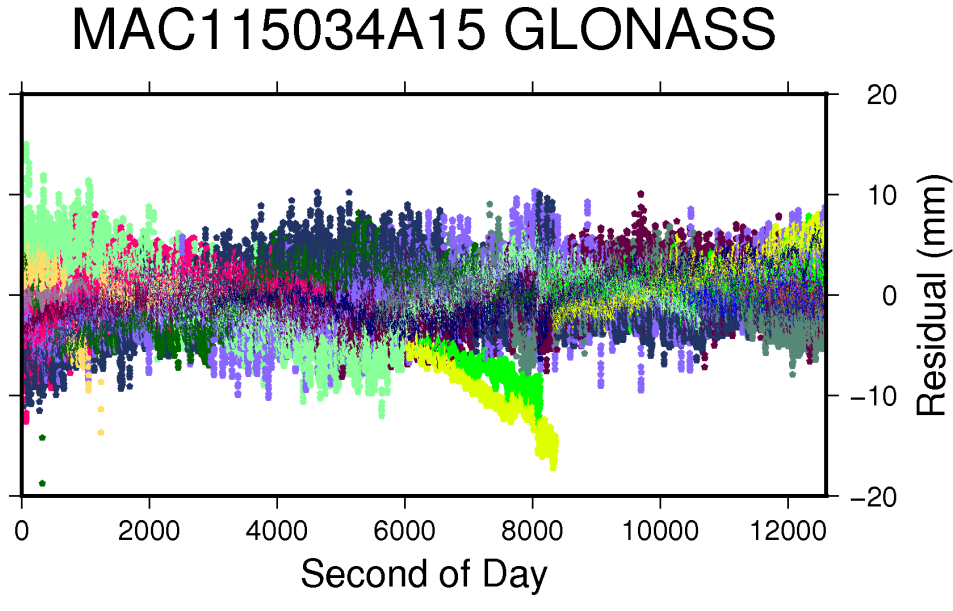
Second of Day


MAC115034A15 GLONASS
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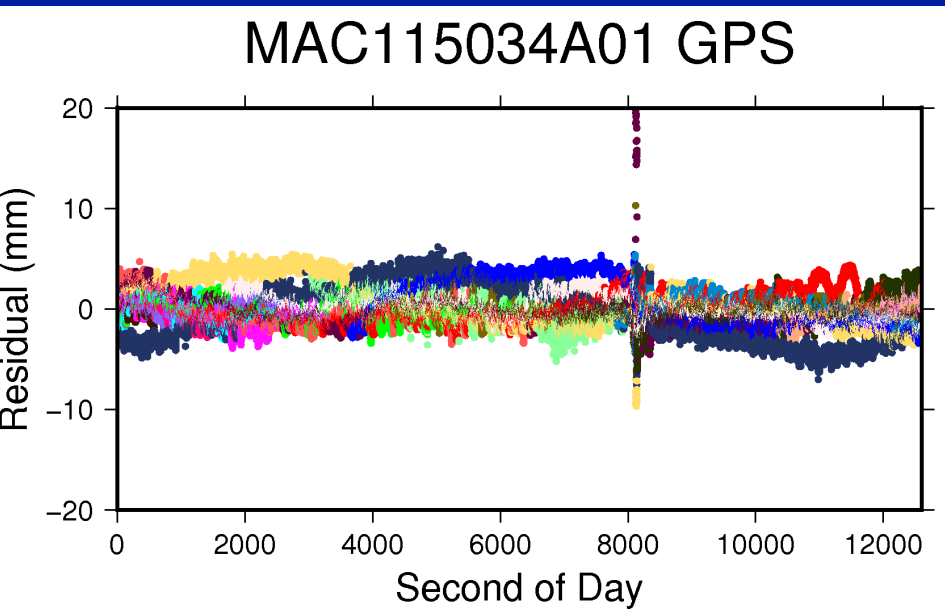
Second of Day

MAC1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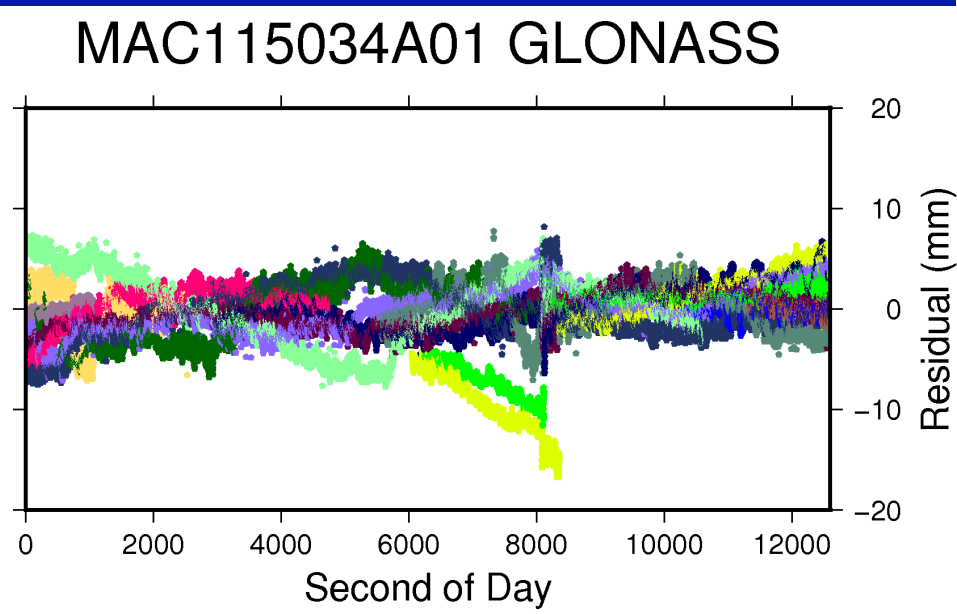
Second of Day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Residual (mm)
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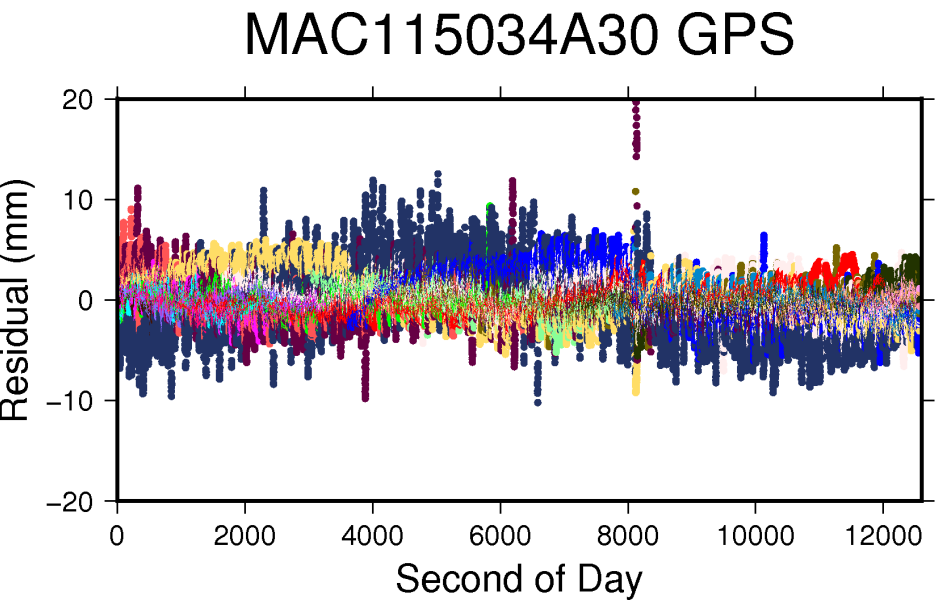
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Residual (mm)
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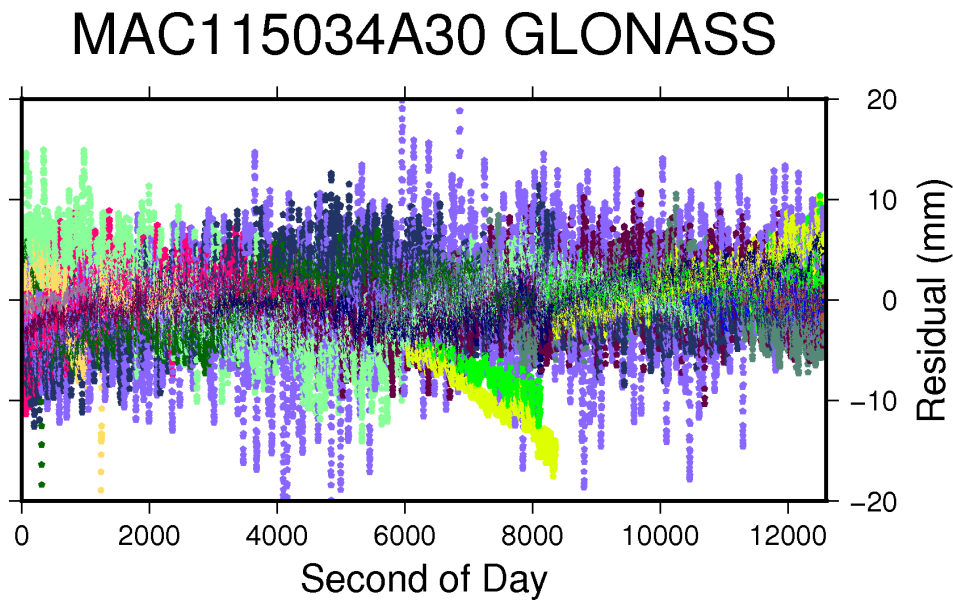
MAC115034A30 GLONASS
Residual (mm)
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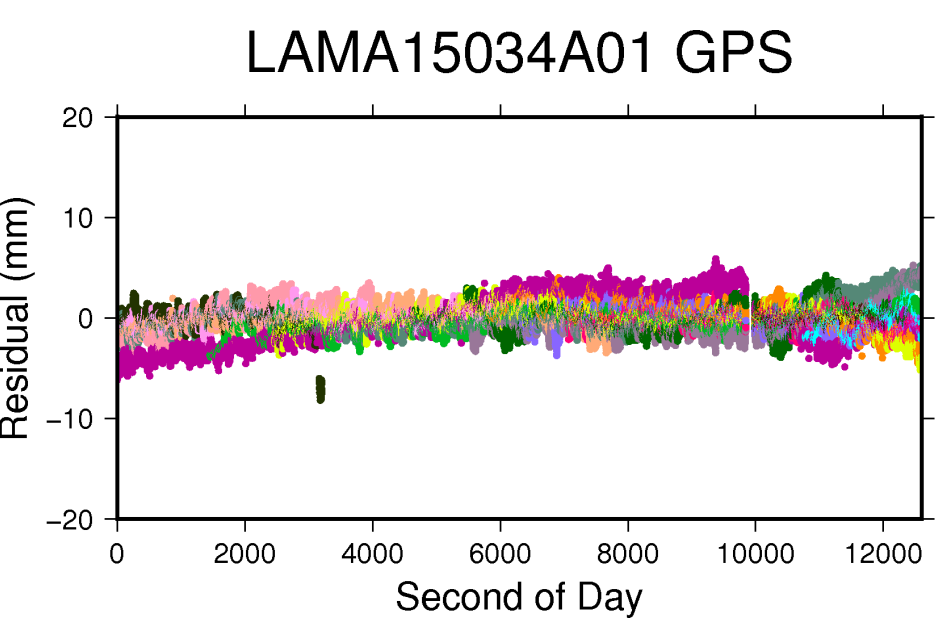
LAMA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Residual (mm)
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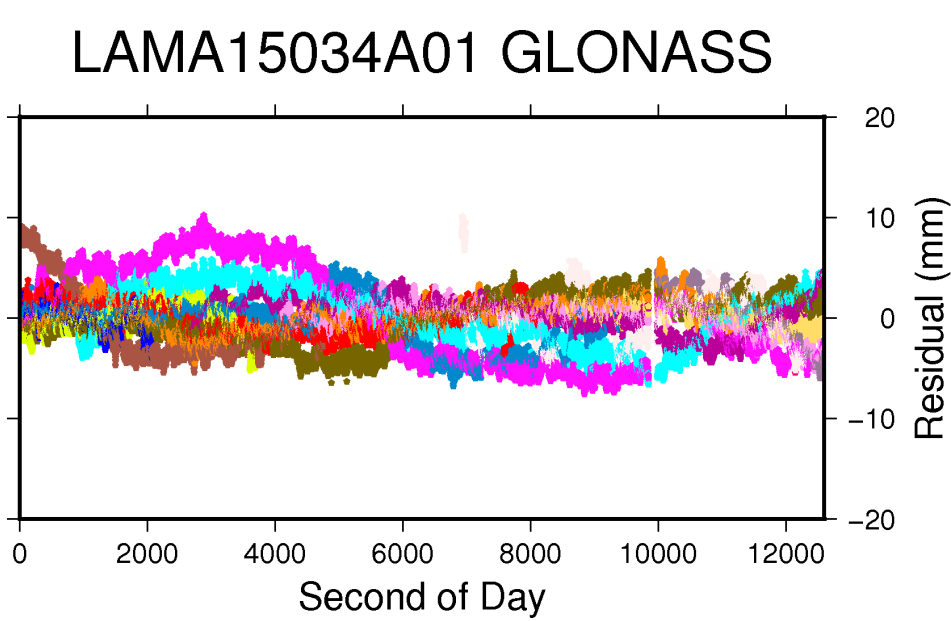
Second of Day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Residual (mm)
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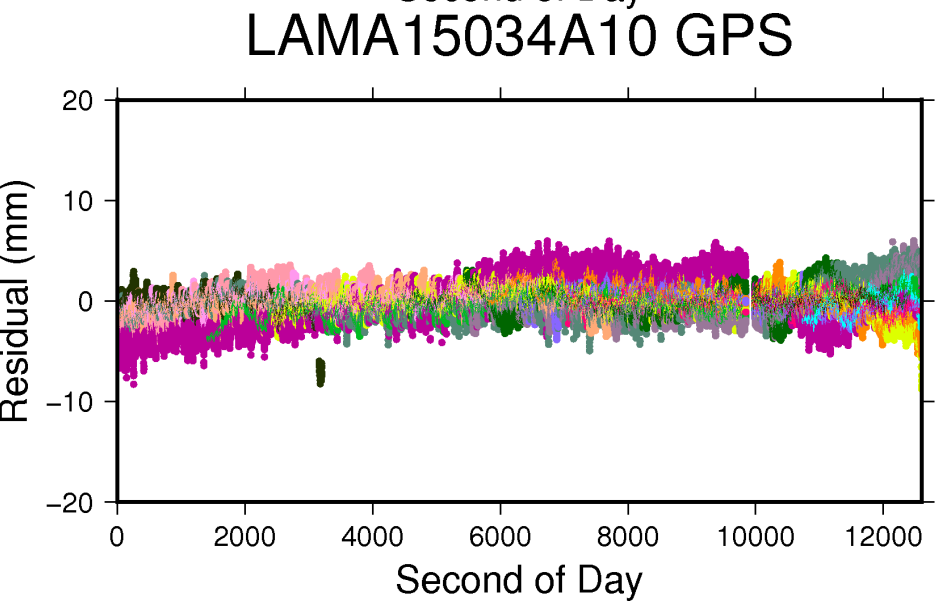
Second of Day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Residual (mm)
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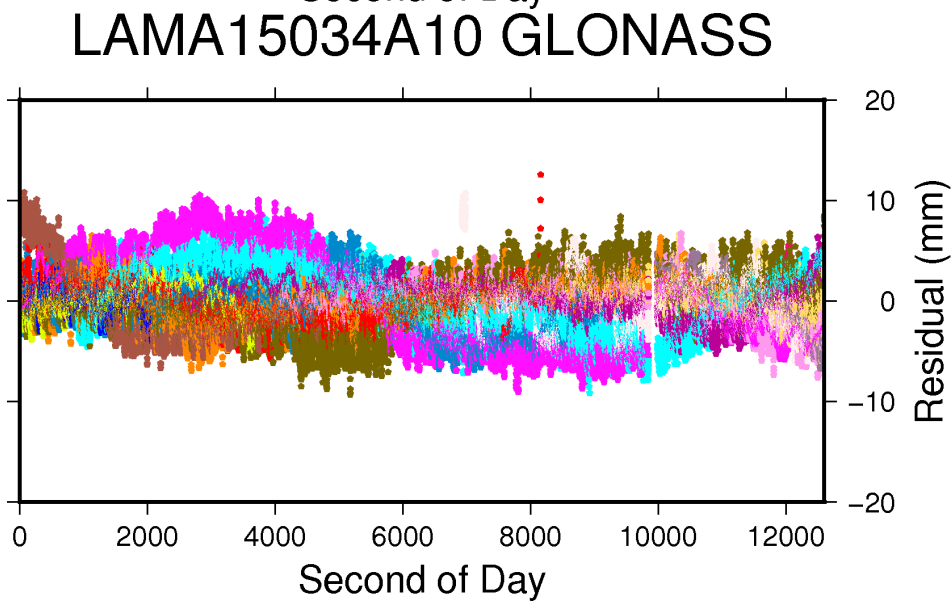
LAMA15034A10 GLONASS
Residual (mm)
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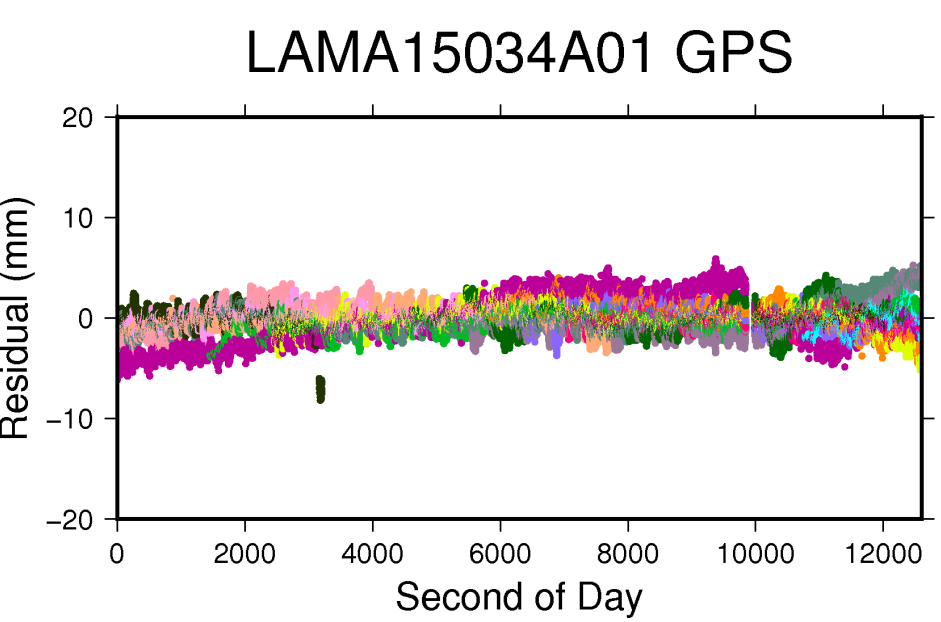
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Residual (mm)
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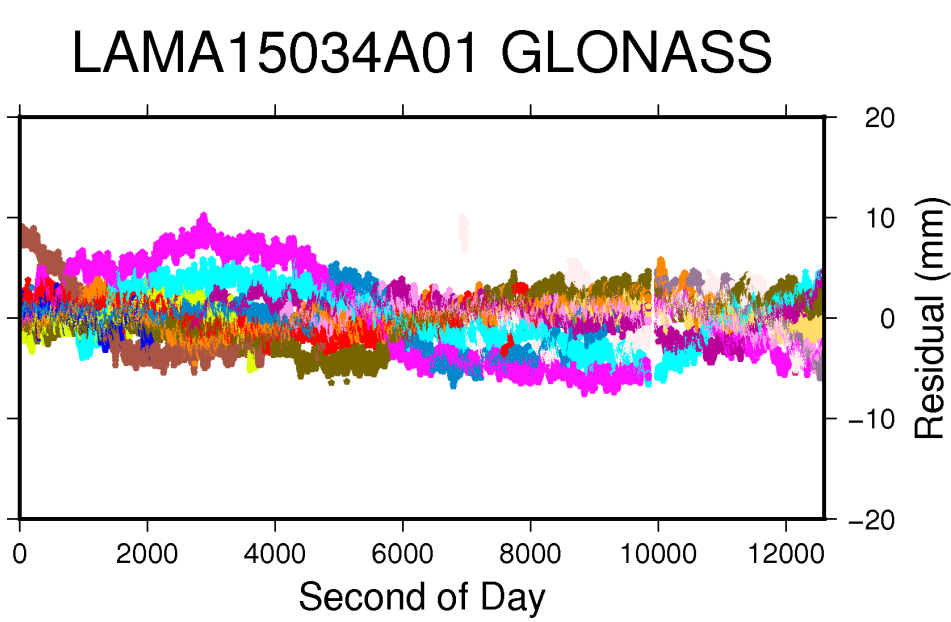
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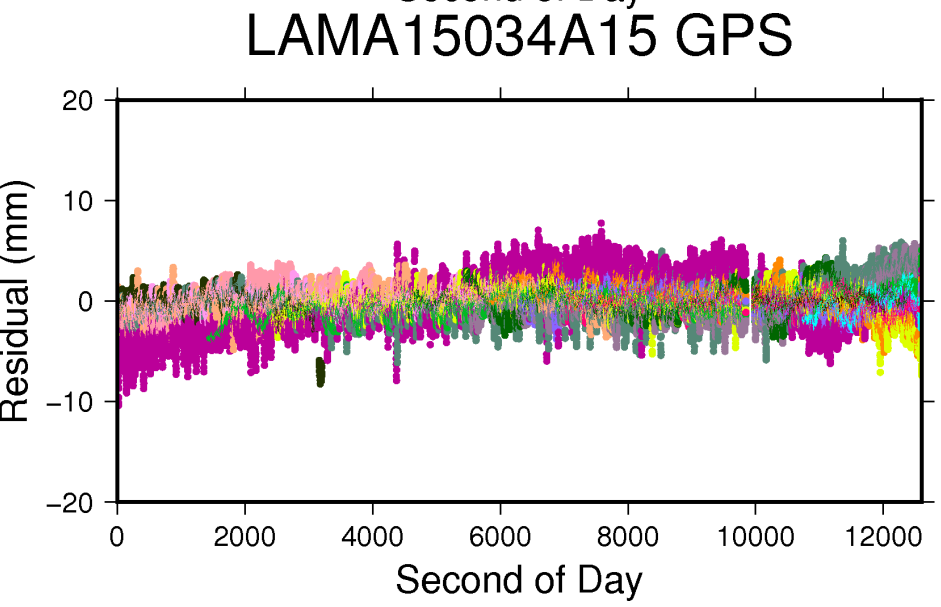
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Residual (mm)
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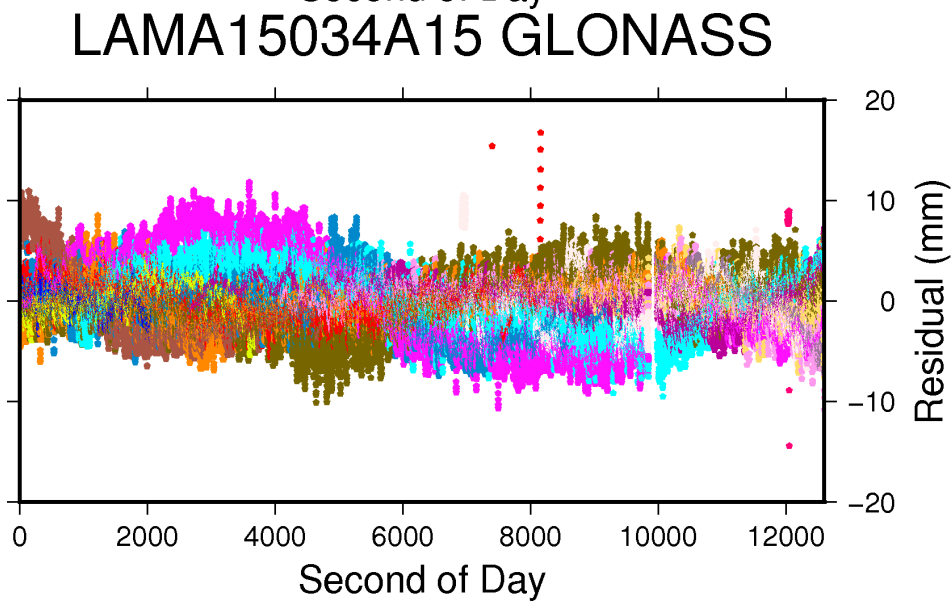
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Residual (mm)
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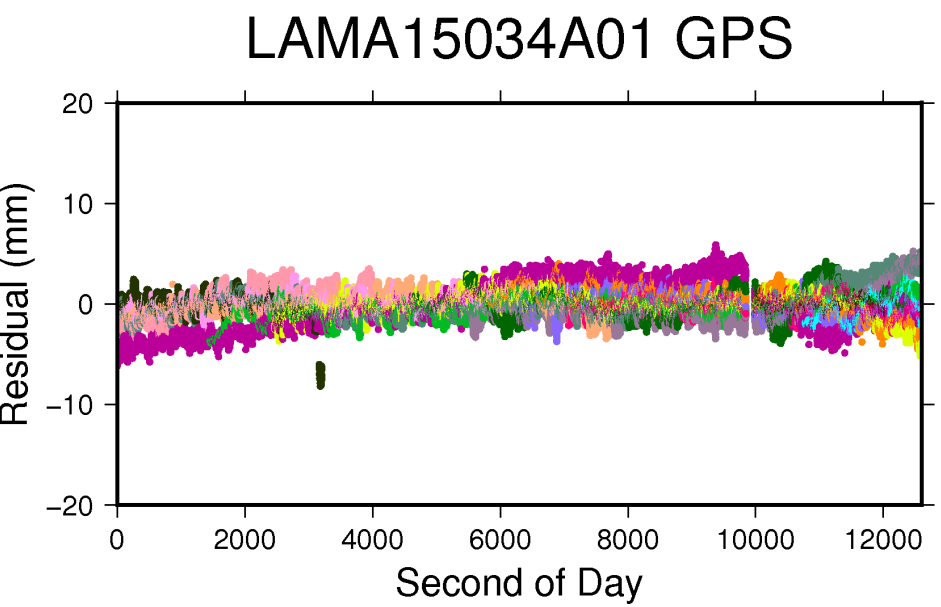
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Residual (mm)
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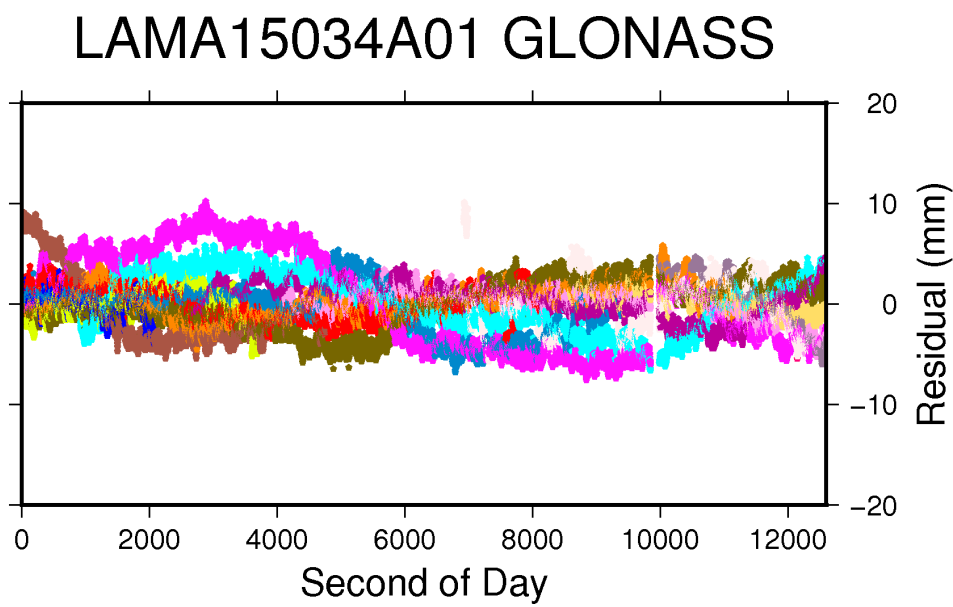
Second of Day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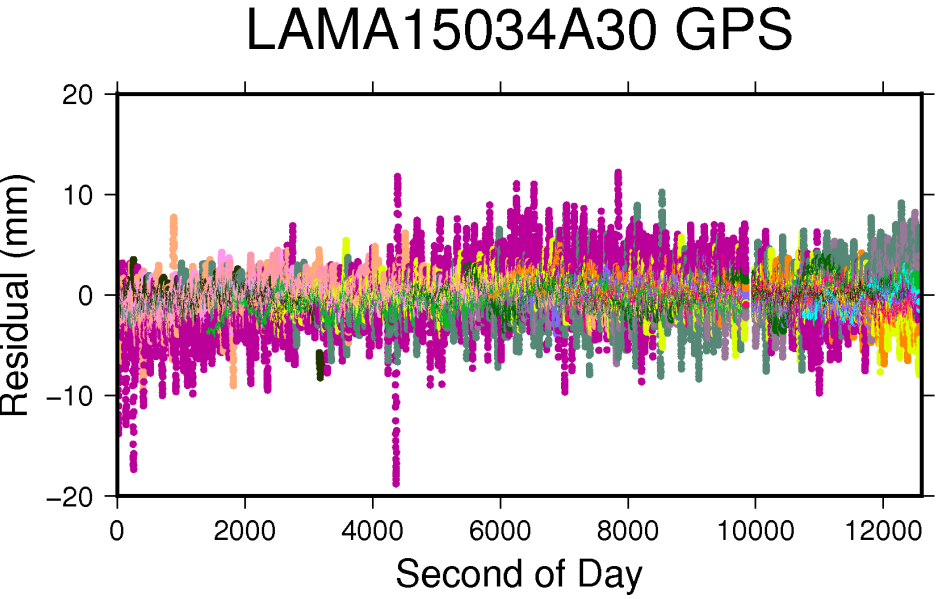
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Residual (mm)
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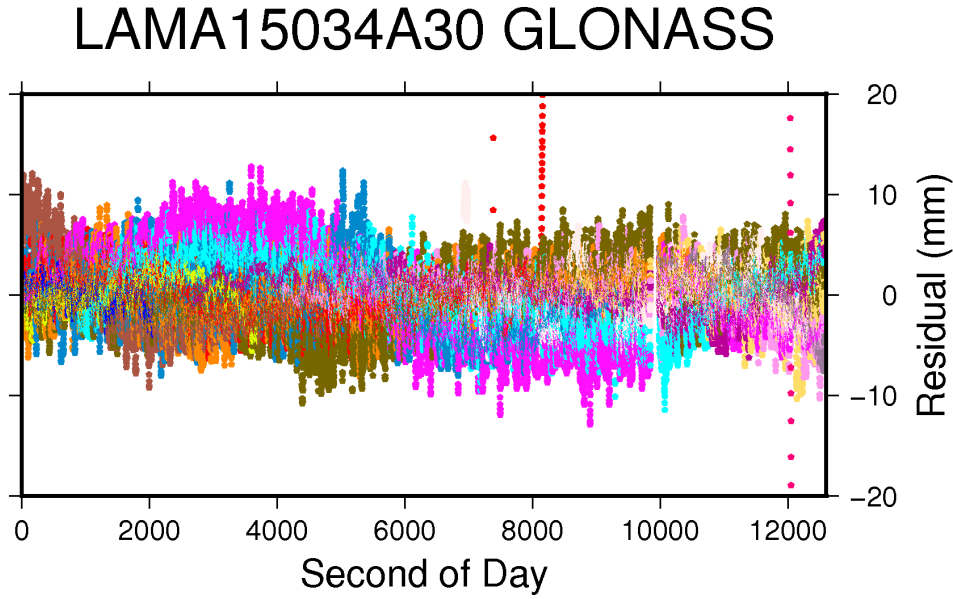
LAMA15034A30 GLONASS
Residual (mm)
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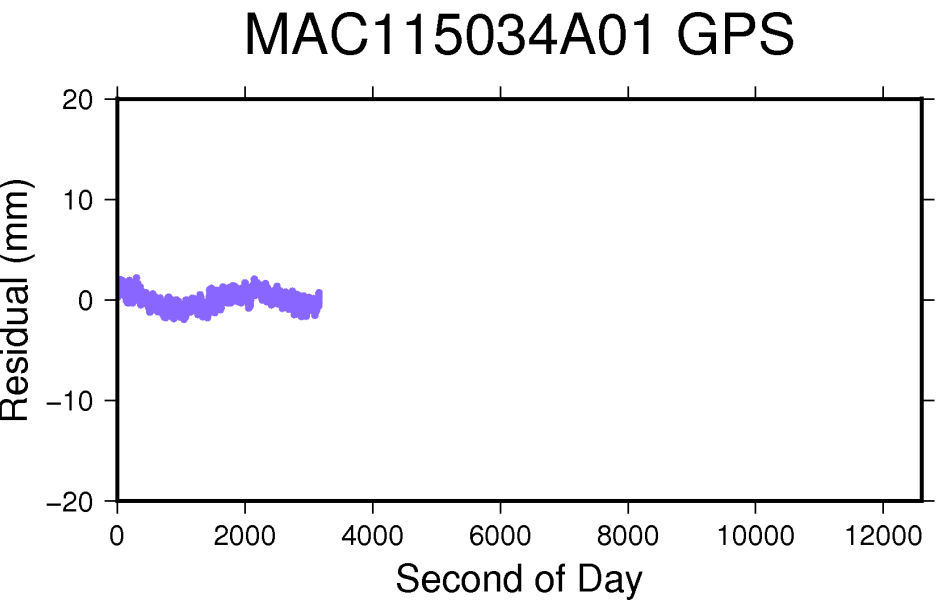
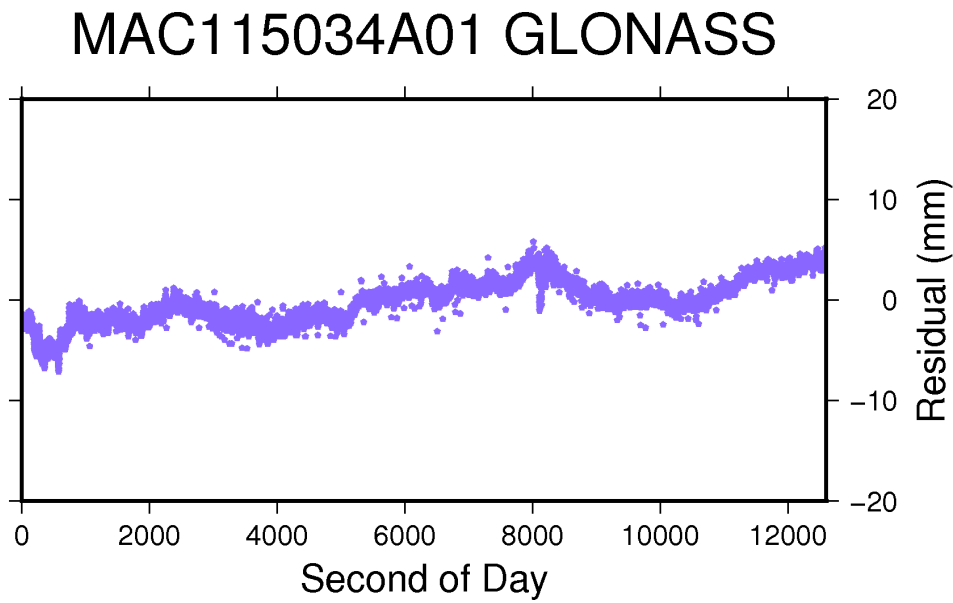
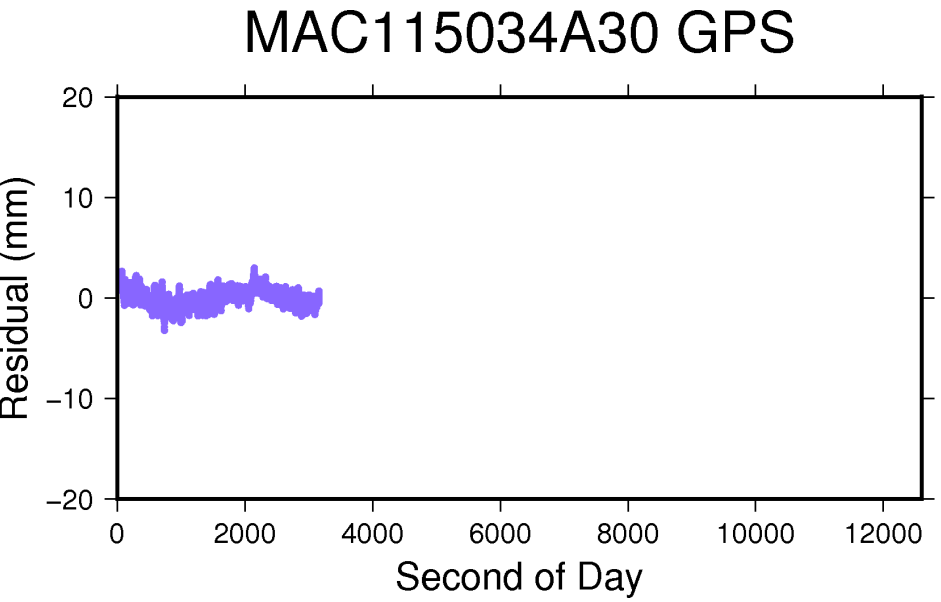
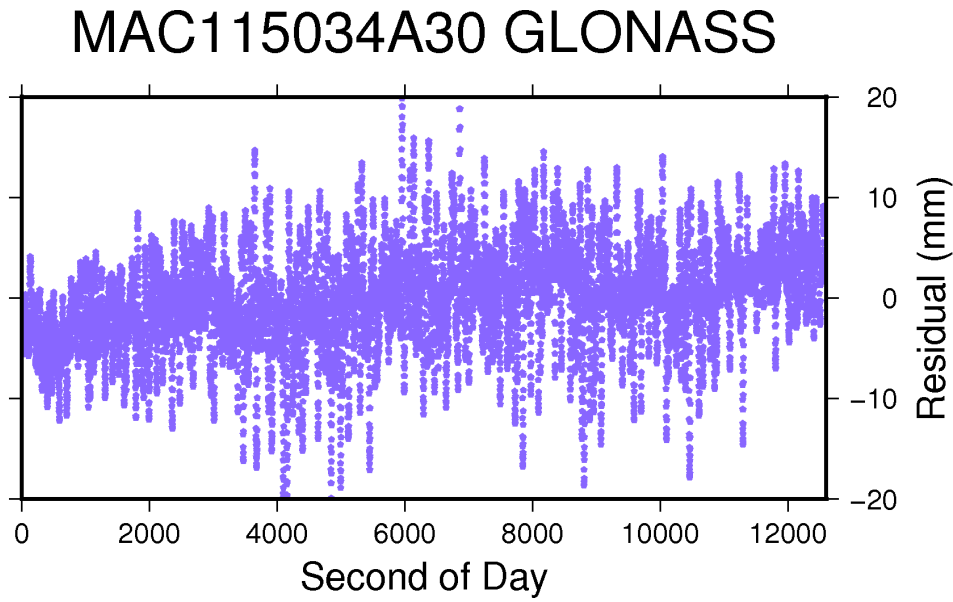
Second of Day

MAC1 – Individual Satellite Tracks (SV15)









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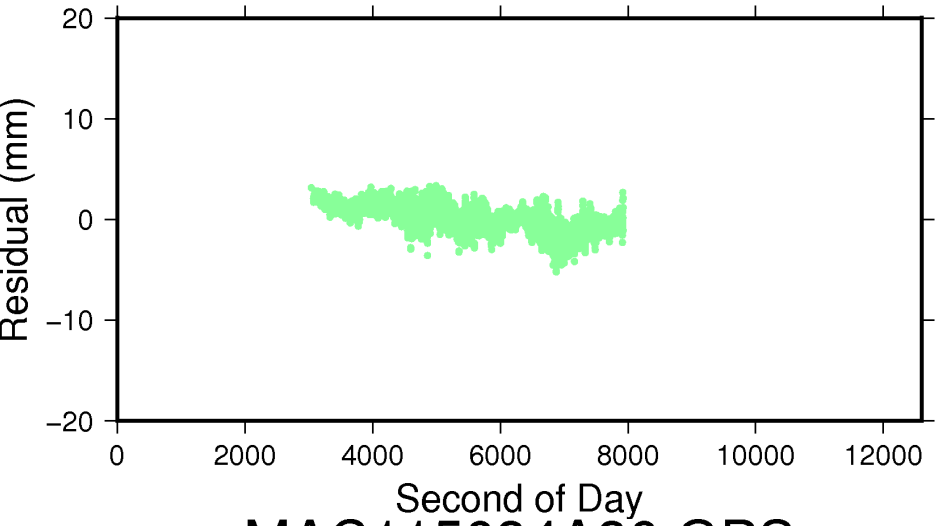
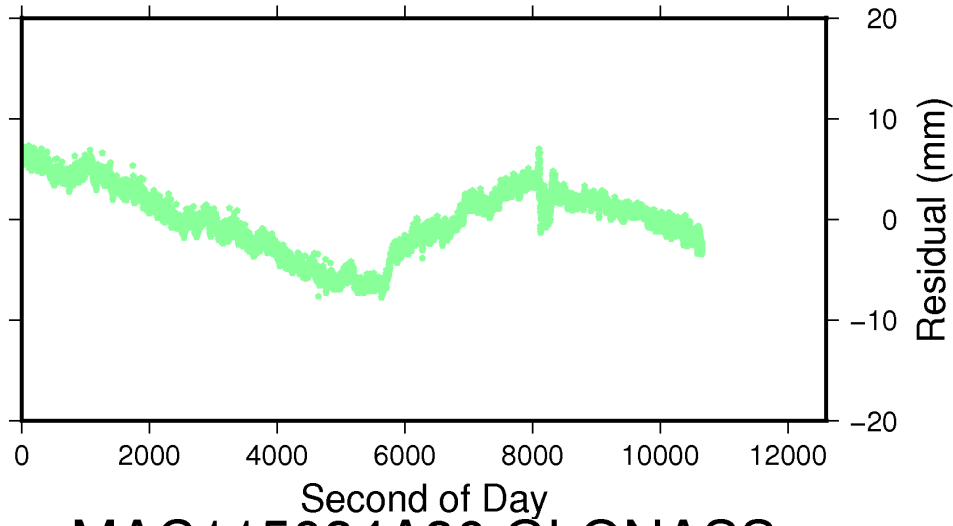
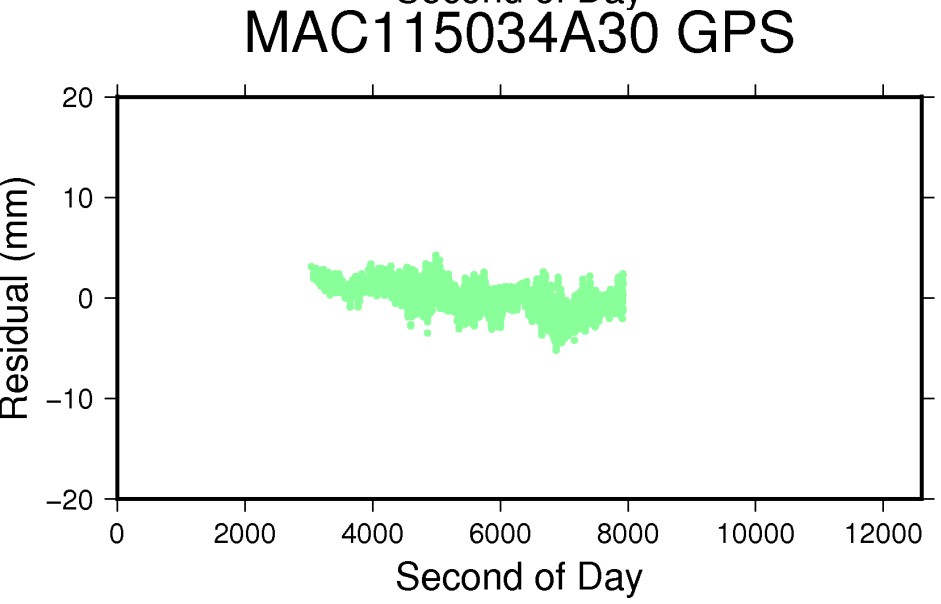
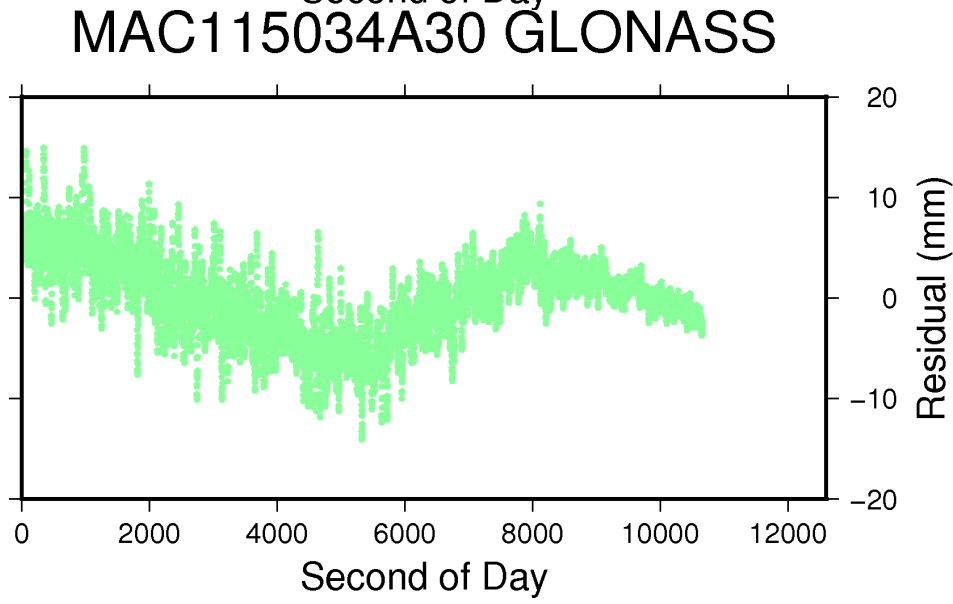
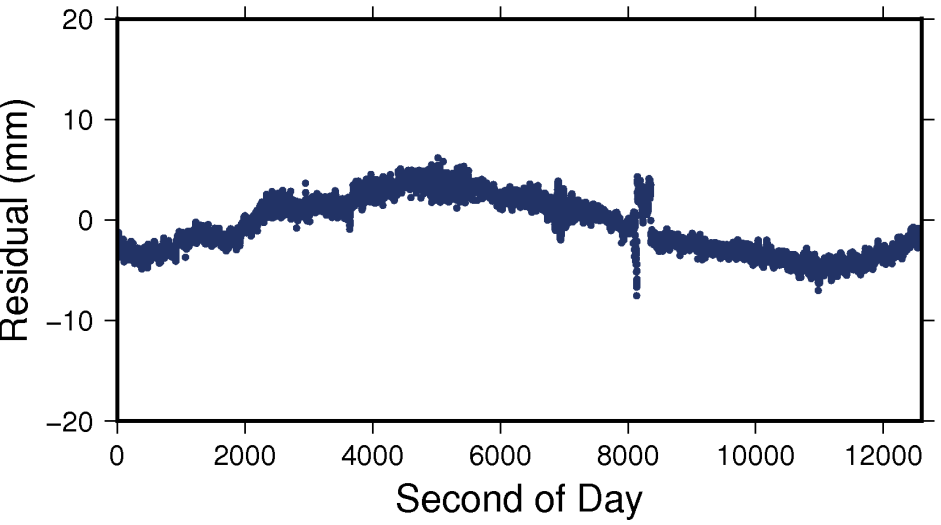


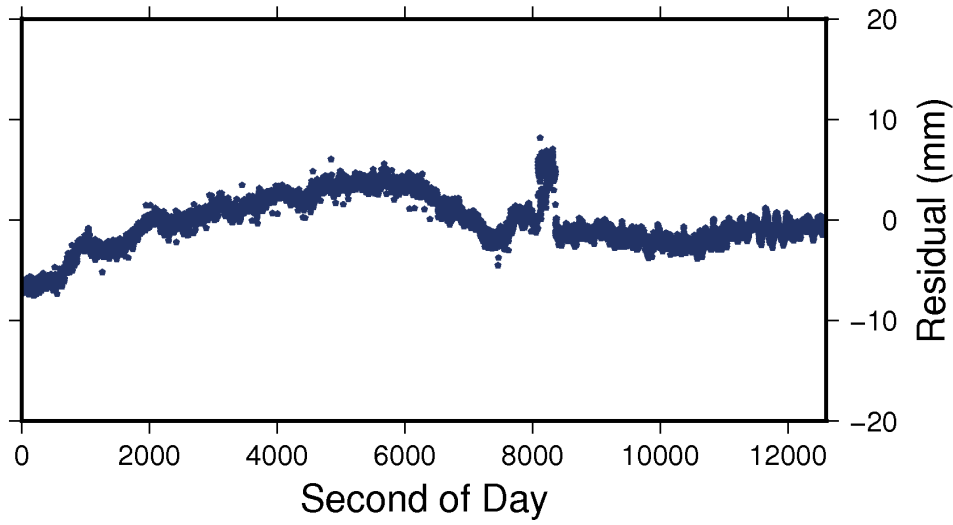


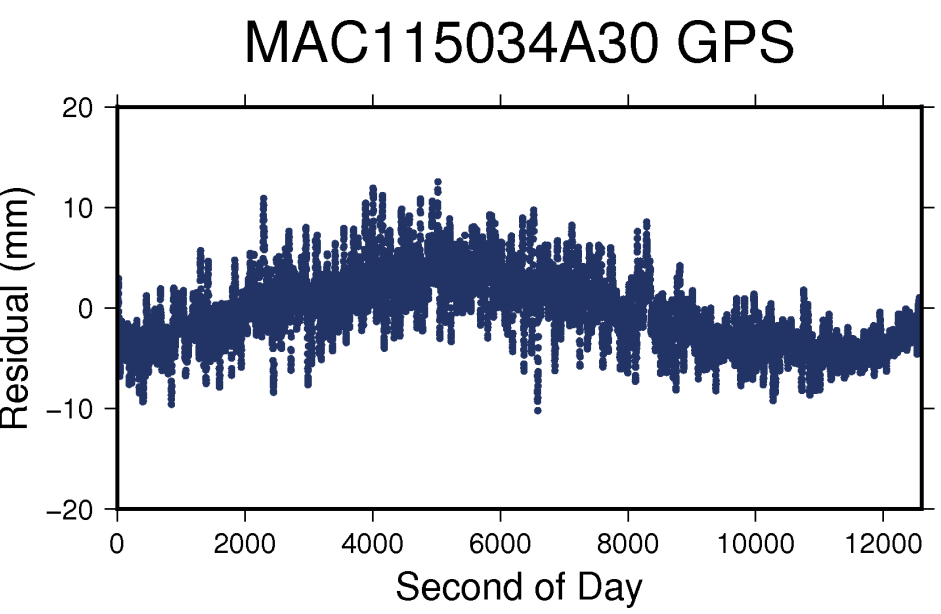


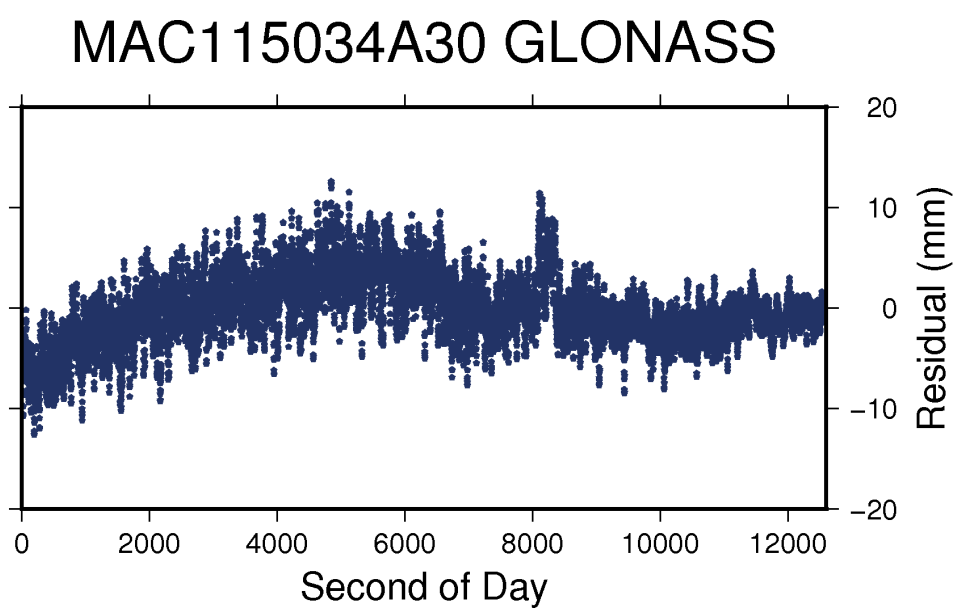


MAC1 – Individual Satellite Tracks (SV 24)

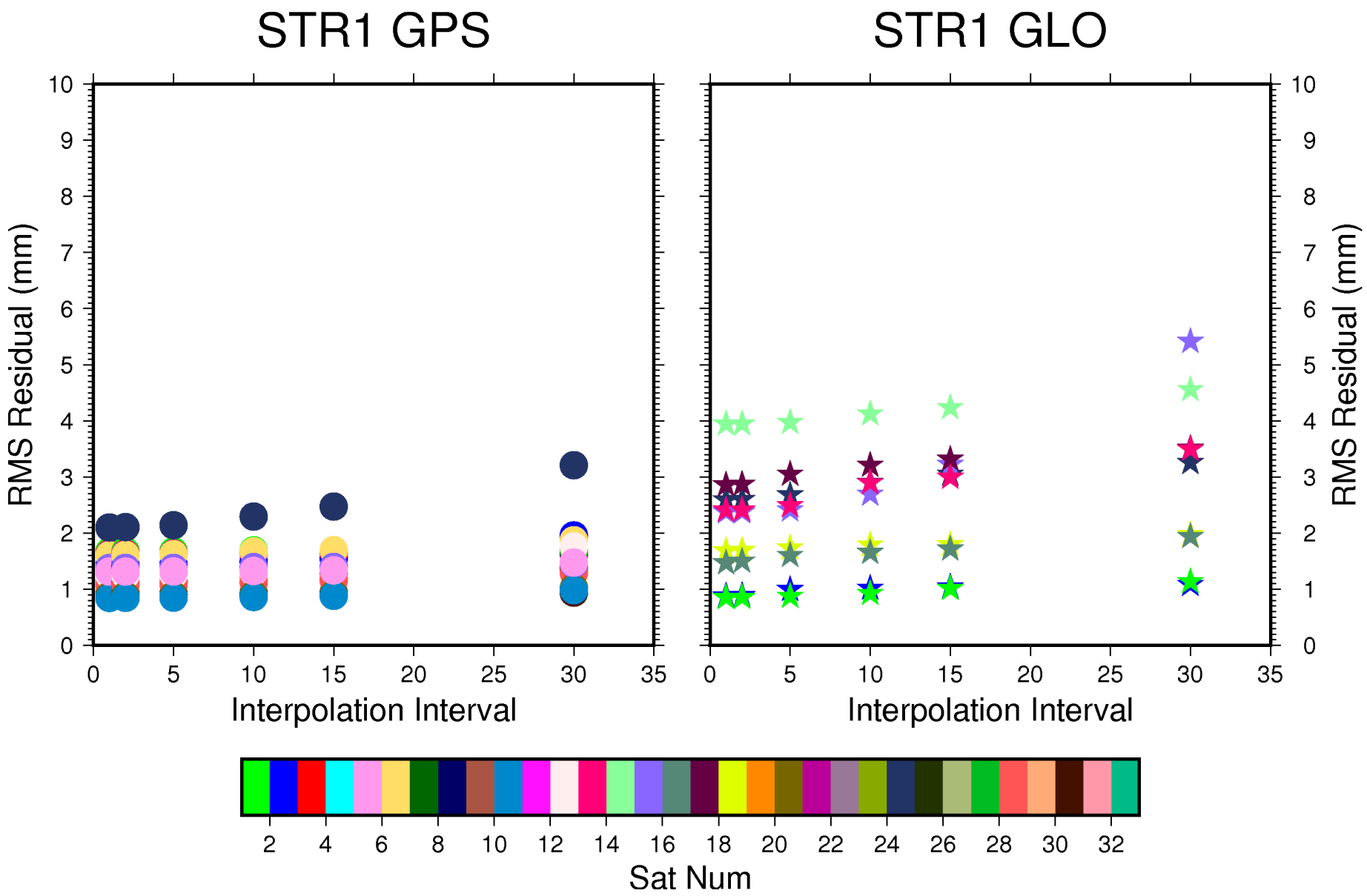




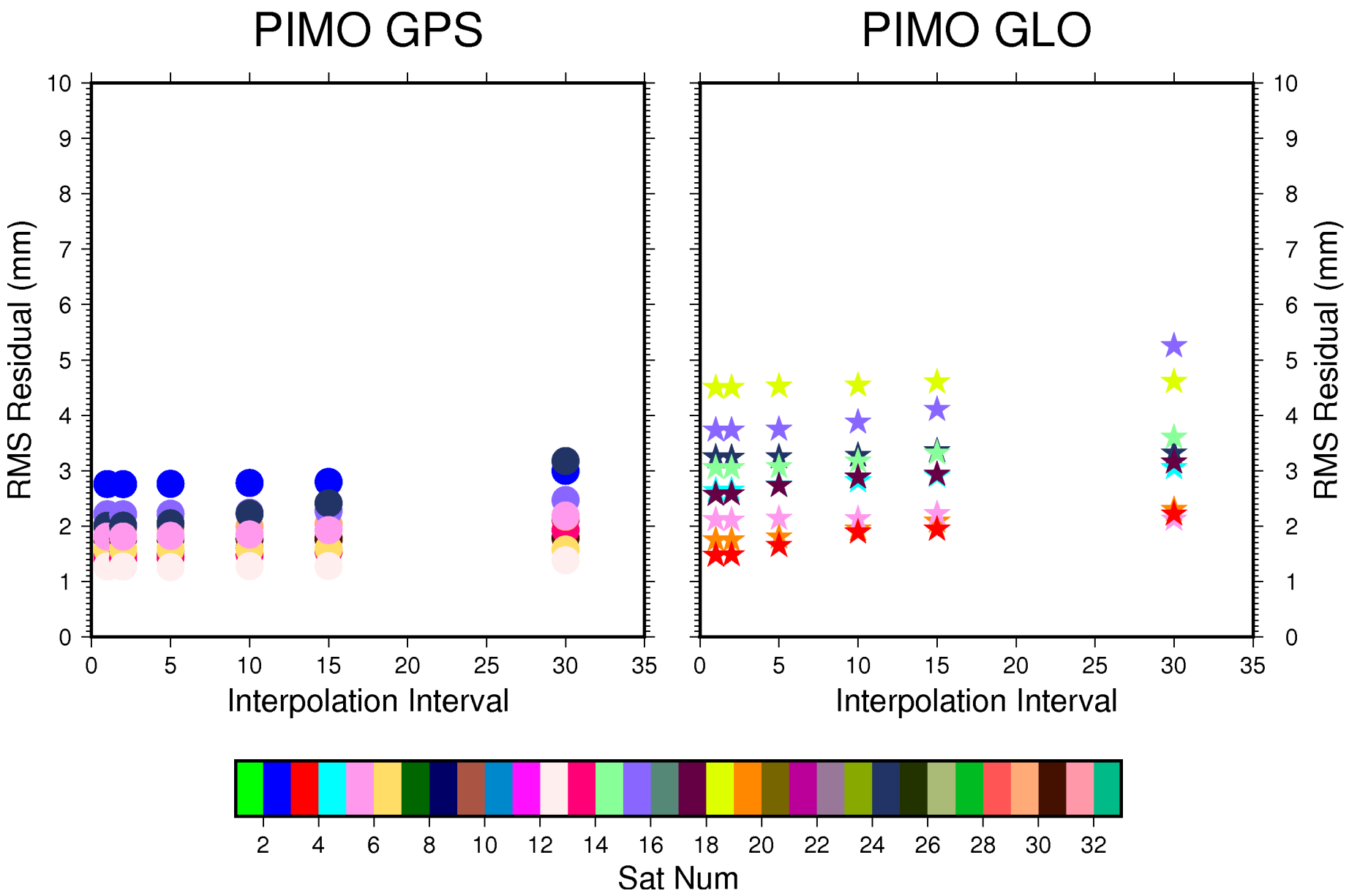




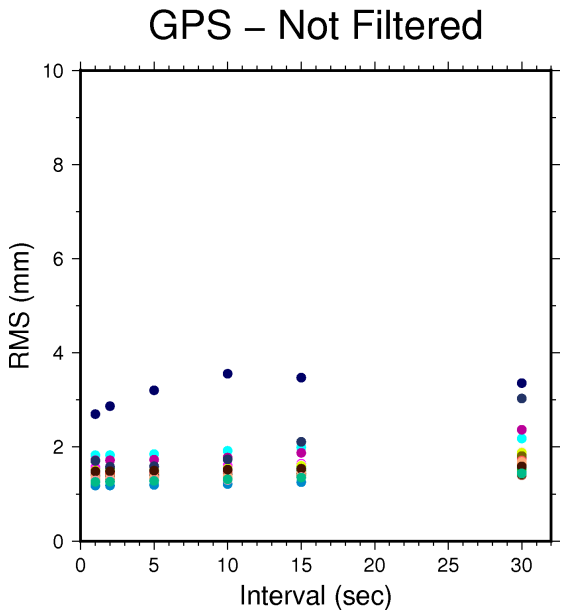
Residual RMS: Station STR1 (All Intervals)

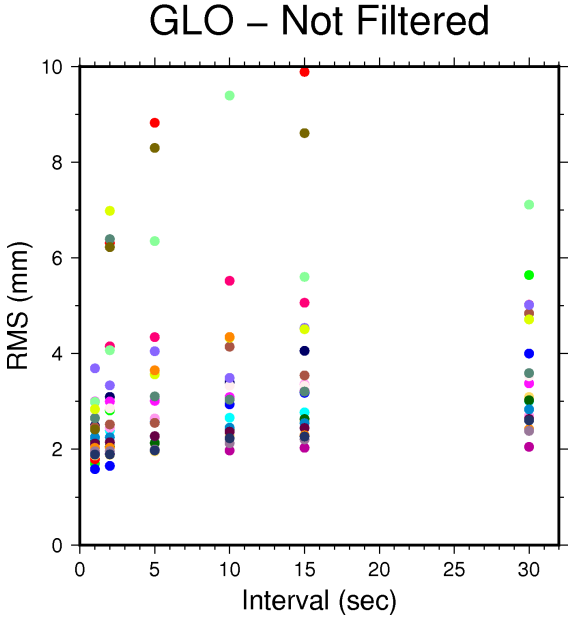


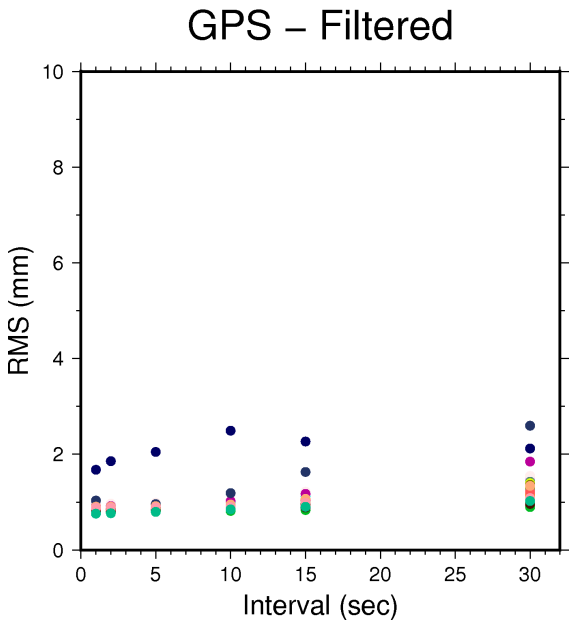
Residual RMS: Station PIMO (All Intervals)

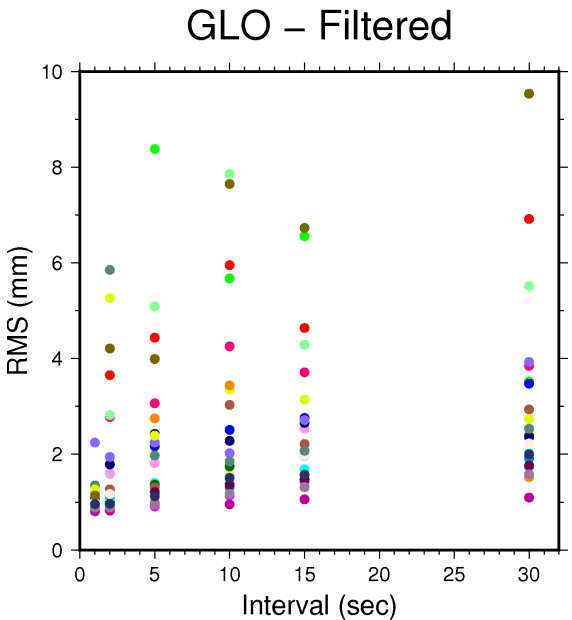


GPS and GLONASS Residual RMS by SAT





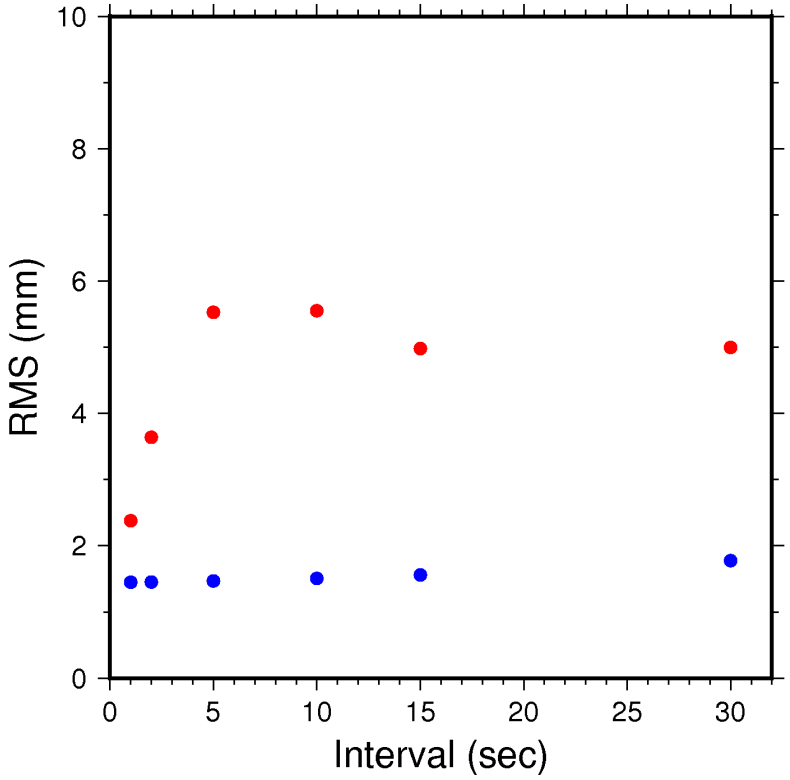




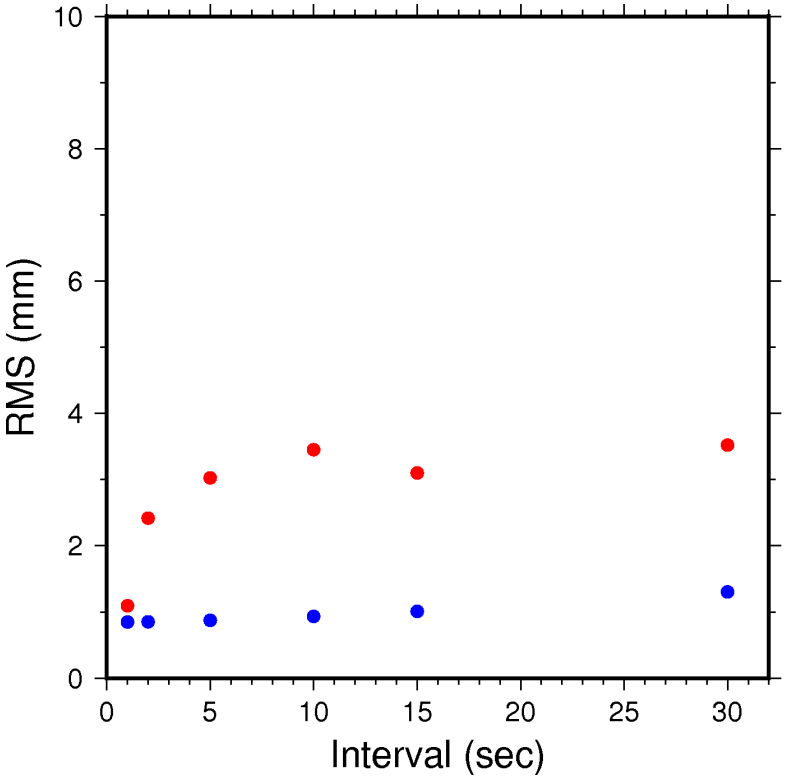
- All data filtered to remove structure with periods longer than 5 min.
- Addresses issues related to troposphere anisotropy, satellite orbit modeling, ground multipath, etc.
- Filtering reduces both GPS and GLO residual RMS.

Composite (GPS and GLONASS) Residual RMS

GPS (blue) – GLO (red) – Not Filtered



GPS (blue) – GLO (red) – Filtered



How does this translate to bending angle error?

Impact (GLONASS) of Clock on Bending Angle

	Mean STDV (30sec SD)	Mean STDV (5sec SD)	Mean STDV (1sec SD)
GPS	1.52 x 10-6	1.50 x 10 -6	1.47 x 10-6
GLONASS	2.03 x 10-6	2.03 X 10-6	1.52 x 10-6

$$STDV = C\sqrt{\sigma_{thermal}^2 + \sigma_{iono}^2 + \sigma_{clk}^2}$$

- Assumes clock, residual ionosphere, thermal, and other error sources are uncorrelated.
- COSMIC-2 will benefit from high-gain, beam steering occultation antenna, reducing thermal noise.
- No L2C tracking in 2008. Currently 16 GPS satellites now broadcast L2C and all GLONASS satellites broadcast L2. This will reduce residual ionosphere error.

Conclusions

- GLONASS clock instability is expected to slightly degrade RO precision when using 30 clocks (~1.5 -> 2.0 x10-6 radians)
- For COSMIC-2, improvements in antenna gain and tracking of L2C will counter the increase in noise due to clock instability.
- There is significant variability in clock stability within a system (ie GPS or GLONASS). This will map into variability of bending angle precision for individual satellites.
- To achieve RO precision from GLONASS that matches GPS, 1 second clock products are most likely necessary. It is not clear if this precision is necessary for real time applications or can be done in a post-processing mode.