Multi-technique capabilities in GipsyX

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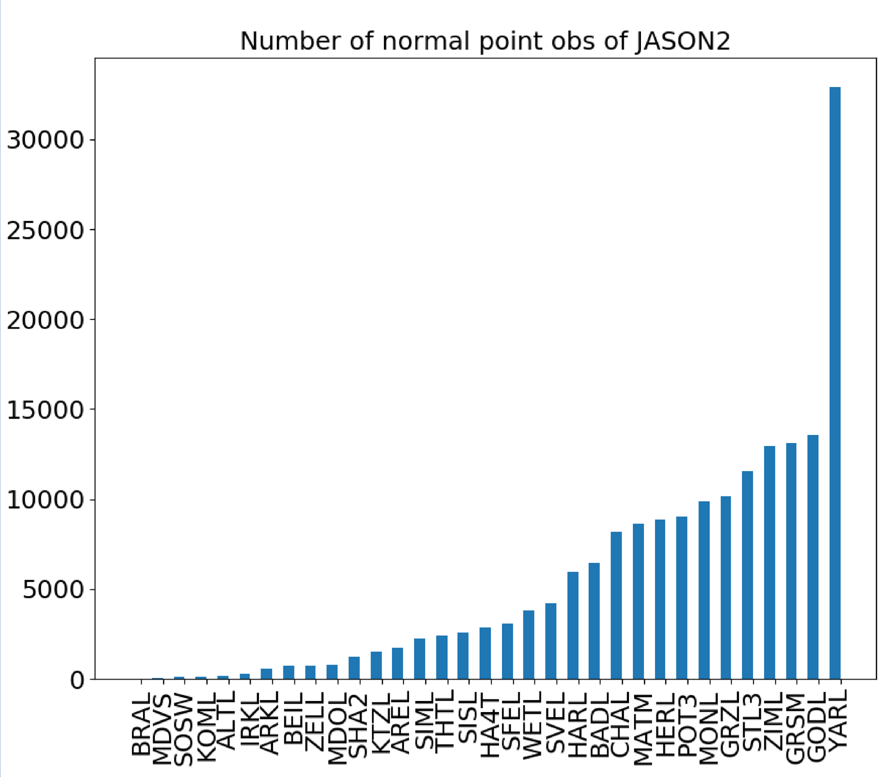
GipsyX Software

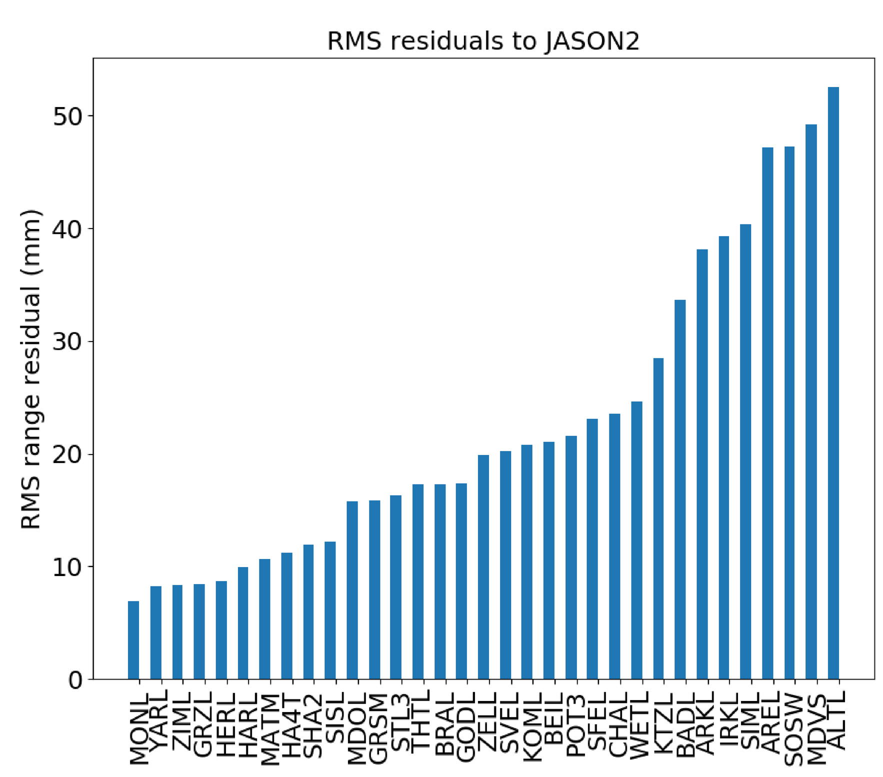
GipsyX is a clean-sheet rewrite of the venerable GIPSY-OASIS software, long-known for its capabilities to process GPS data. However, GIPSY-OASIS also had the ability to process SLR data. In fall of 2017, the capability to process SLR normal point data was initially added to GipsyX and several refinements to that capability have been added since. It is now possible to process GNSS and SLR measurements simultaneously in GipsyX, and capabilities for VLBI and DORIS are under development. All of the following are currently implemented for SLR processing in GipsyX:

- Convert normal point CRD files into GipsyX internal dataRecord format, retaining range and meteorological data
- Mendes-Pavlis 2004 troposphere model
- Database of all active SLR stations with ITRF 2014 solutions
- Convert CPF predicted orbits into native GipsyX posGoa format
- Full measurement model for twoWaySlr
- Support for az/el dependent calibrations
- Compute and apply station and satellite-dependent range biases (in progress)
- Solve for site positions or satellite antenna offsets

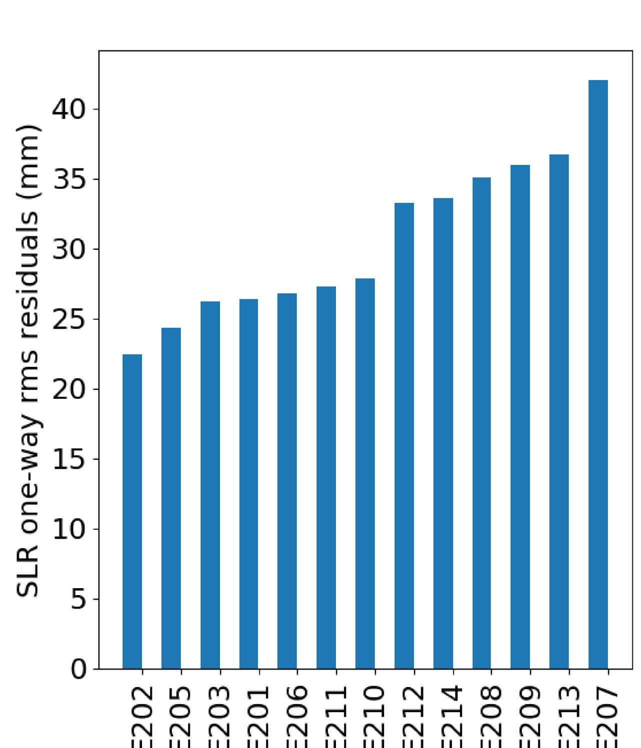
Jason-2 Residual Test

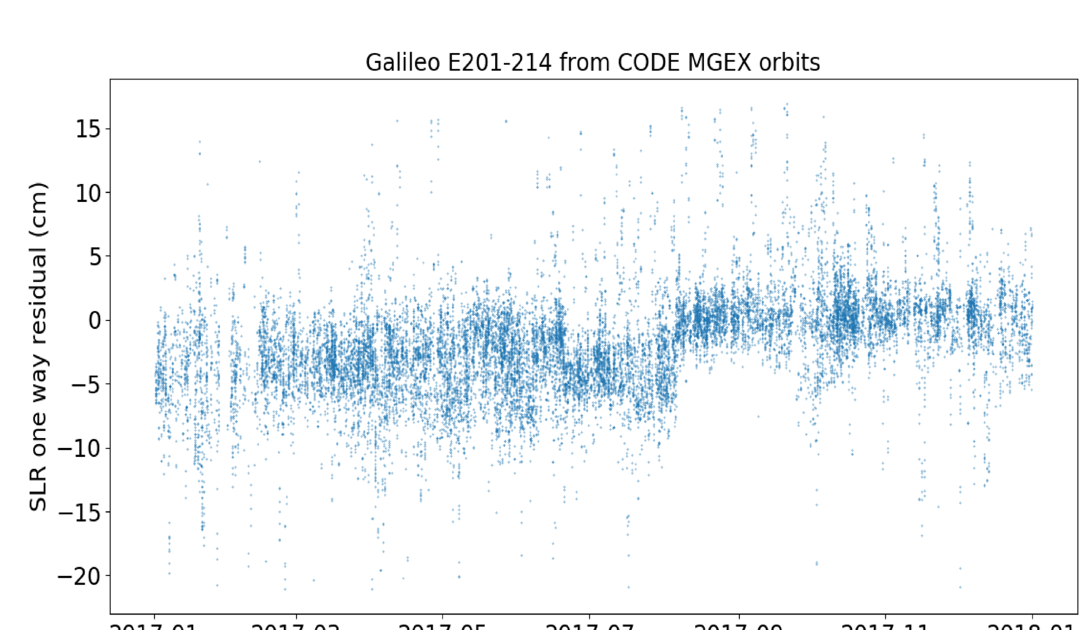
One way to verify our SLR implementation is to look at SLR residuals for a spacecraft with known orbits and quaternions. For this test, we processed all monthly normal point files for Jason-2 from 2015. For Jason-2's orbit, we used the rlse16 science orbits. For station positions, we used the ITRF14 solution and official ILRS site log eccentricities. For one non-ITRF station (IRKL) we used the position from the sitelog, and for another (SOSW), we used the sitelog position and the nearby WETL for velocity. We applied the official Jason-2 98 mm SLR two-way bias to all data, but did not apply any station biases. We also did 5-sigma editing on the entire data set to remove outliers. Several stations consistently have sub-cm residuals, large amounts of data, and small biases. We chose MONL, YARL, ZIML, GRZL, HERL, HARL, MATM, and HA4T as "good" sites for subsequent analysis.





Galileo Residual Test





GipsyX can also be used to calculate residuals to an entire constellation of GNSS satellites. Here we show SLR residuals from the "good" sites to the CODE MGEX orbits (Prange et al. 2015) for Galileo satellites E201 to E214. We observe that rms SLR residuals had a bias relative to the CODE orbits for the first 7 months of 2017 and that in the last five months of the year the RMS residuals vary by a factor of two between satellites.

Jason-2 Orbit Determination Tests

For another SLR verification, we performed various different types of orbit determination for Jason-2 using GipsyX for all of 2015. For the nominal orbits, we used the CNES predicted orbits from the previous day. We used the same station information as in the residual test. For all data types (GPS PC/LC and SLR), we allowed for iterative editing of the solution to remove outliers. We used SLR windows of 75 cm, 10 cm, and 5 cm. We used GPS data decimated to every 5 minutes, and all available SLR data. We used 30 hours of data on each day to allow for the computation of overlaps from the 6 hours shared between each day. For GPS processing, 30 hours is our standard because the length of our input GPS constellation orbit and clock products is also 30 hours. Values in tables are 50th percentile of daily results.

Overlaps in mm	Radial	Cross	Along
GPS Only	1.4	2.6	3.0
GPS+SLR (good)	3.0	4.0	6.5
GPS+SLR (all)	4.9	6.3	11.8
SLR (good)	13.4	8.1	31.3

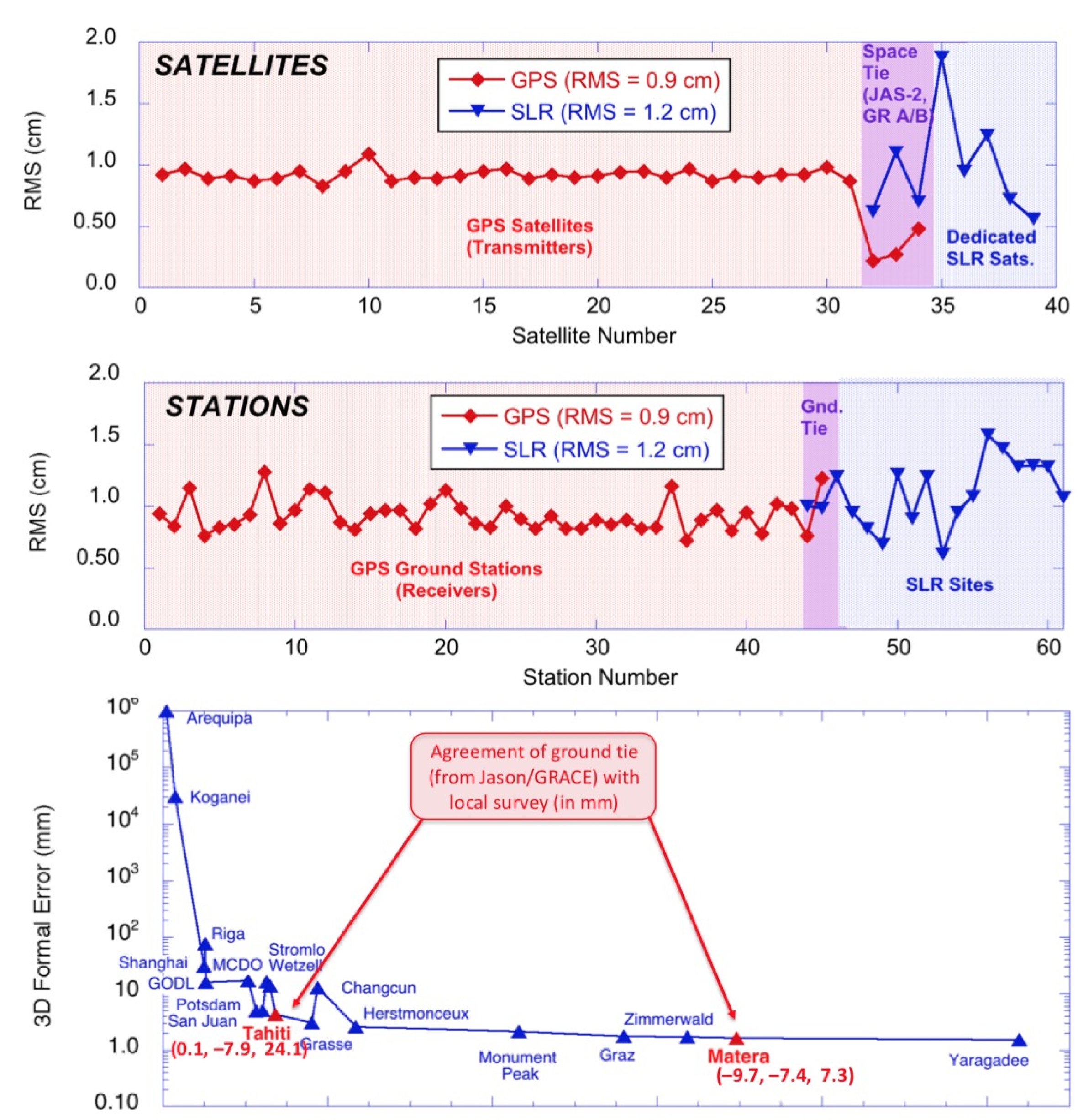
Rms diffs to rlse16 in mm	Radial	Cross	Along
Nominal orbit	442.9	2661.0	9209.0
GPS Only	2.5	4.7	4.4
GPS+SLR (good)	6.8	6.8	18.4
GPS+SLR (all)	9.6	11.0	29.3
SLR (good) only	31.2	44.1	112.5

The results are promising, but also show that we have some work remaining with SLR systematics. With a 30-hour arc (which is very short for SLR OD), we can get consistent overlaps and 12 cm accuracy just with SLR data (3cm radial). We still have work to do because adding SLR should improve the accuracy of our GPS orbits, but instead, it worsens it.

Diverse Network solutions

GipsyX provides great flexibility in data processing. Haines et al. (2018) used GipsyX to process 3.25 days of data from and solving for positions of 31 GPS satellites, 43 GPS ground stations, 3 GPS+SLR LEOs (Jason2+GRACE A/B), 5 SLR satellites (LAGEOS1+2, Ajasai, Starlette) and 17 SLR ground stations using GPS, SLR, and GRACE K-band ranging data.

The analysis resulted in, among other results, site ties for 2 SLR+GPS sites accurate to the cm level.



Future Work

The various analyses shown here demonstrate that GipsyX is readily capable of performing a diverse array of SLR calculations at the cm or better level. Future work involves further refinements to the analysis such as improving station and satellite bias estimates. We also intend the continue to expand our databases of SLR sites and retroreflector targets. Finally, we intend to remain actively involved in the SLR community to stay up to date with the best practices of the community.

References

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