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SLR station range bias and coordinate determination using independent multi-LEO DORIS- and GNSS-based precise orbits

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Satellite Laser Ranging (SLR) has become an invaluable core technique in numerous geodetic applications. SLR measurements to spherical geodetic satellites essentially contribute to the determination of geocenter coordinates and global scale in the ITRF realizations.

Precise orbits for active satellites in Low Earth Orbit (LEO) are, on the other hand, mainly determined with microwave observation techniques based on GNSS or DORIS. SLR measurements to such satellites are in most cases used for independent validation of orbit solutions. This allows for the analysis of systematic orbit errors not only in radial direction (key to satellite altimetry applications), but in three dimensions.

Major error source and an obstacle to reach mm accuracy and stability goals of 0.1 mm/year are unavoidable SLR station biases and coordinate errors. Among the International Laser Ranging Service (ILRS) stations a large diversity of calibration accuracies and measurement qualities exists, and the calibration of biases and offsets for all stations is key to further exploit SLR data for geodetic applications.

Using two orbit sets of independent altimeter and gravity missions we estimate SLR range biases for all involved tracking stations on a yearly basis. We find that for many of the stations independently estimated sets of biases agree on a few-mm level and that the inclusion of satellites from multiple missions allows rendering the bias estimation more robust and in particular less prone to geographically correlated orbit errors. Non-negligible station coordinate (CRD) corrections estimated in common with the range biases help to separate software-specific and reference frame-related (GNSS vs. DORIS) contributions from actual bias variations.

Contributions:

- AIUB (Software: Bernese GNSS Software)
  - GPS-only solutions for Sentinel-3A/B, Swarm-A/B/C, GRACE-FO C/D, Jason-3 (**only Phase III**)
- CNES (ZOOM)
  - DORIS-only or DORIS+GPS solutions for Sentinel-3A/B, CryoSat-2, Saral/AltiKa, Jason-2/3
- PosiTim (Napeos)
  - Combined Copernicus POD QWG solutions for Sentinel-3A/B (GPS-only, DORIS-only, GPS+DORIS)
- DLR (GHOST), starting in **Phase III**

Phase I: (concluded)

- Successful homogenization of SLR processing setups and comparison of measurement corrections
- Validation of range bias estimation from all groups for June 2017 for S-3A combined POD QWG solution

Phase II: (concluded)

- Yearly range bias (+ station coordinate) estimation based on respective orbit sets, different elevation cut-off angles, 2016-2019

Phase III: ongoing

- Orbit sets are based on different techniques (GPS, DORIS) => study impact of different techniques on frame of LEO orbits
- Range bias + station coordinate estimation based on AIUB orbit set; comparison between different s/w packages; need of additional parameters (LRA (laser reflector array) coordinates, LEO satellite orbital offsets) and impact of different constraining strategies (e.g., zero mean of station heights or of LEO orbit heights, no-net translation, rotation, scale) is investigated

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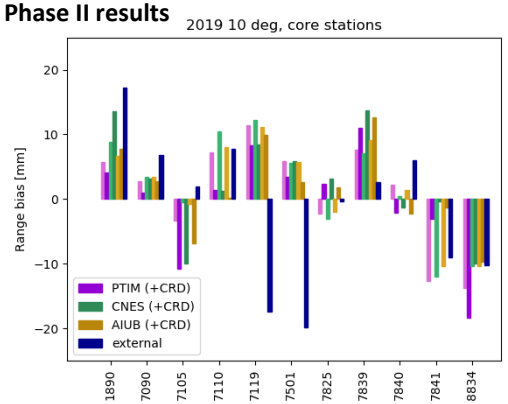
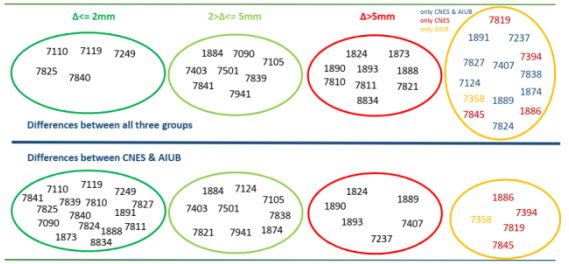
Phase II results



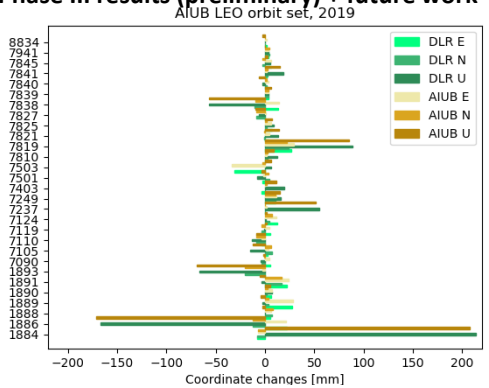
Estimated range biases for 2019 and all satellites. Light color: Only range bias estimated. Dark color: Range bias + coordinates estimated. External: Range biases from T.Otsubo

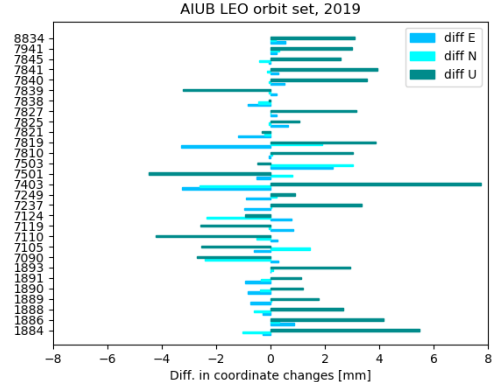


Cluster of stations with range bias estimate agreement on different Δ levels for 2019, all satellites, 10 deg cut-off.

AIUB and CNES agree for 16 stations within 2 mm (PosiTim estimates are based on S-3A/B only).

Phase III results (preliminary) + future work





- Full AIUB orbit set (8 satellites) processed by AIUB and DLR; range bias + coordinate estimation + LEO orbit offsets + Jason-3 LRA offset; zero mean constraint on orbit heights => differences in range bias estimates (not shown) < 1mm for 21 from 29 stations, station coordinate changes in Up > 5 cm !!! for several stations (left), agreement between AIUB+DLR estimates < few mm (right), some exceptions to be investigated
- **Future work:** Study impact of different constraining on results, comparison to coordinate estimates from DORIS-based orbit sets, understanding/interpretation of coordinate estimates, study impact on standard ILRS analyses