Ranging error determination using geodetic satellites in support of altimeter missions POD

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Introduction

Satellite Laser Ranging (SLR) data, made available by the International Laser Ranging Service (ILRS), is essential to validate and quantify the orbit precision of the altimeter satellites.

It is the only independent and non-ambiguous validation method that can provide the absolute radial orbit accuracy by means of high elevation passes in particular.

The SLR data are considered unbiased in the altimeter satellites' orbit validation process (i.e., range or time bias are not estimated). As a consequence, unknown or not communicated errors in the ranging data directly affect the validation results.

This study describes the current status of range biases encountered with Jason-2 Precise Orbit Determination (POD) validation at CNES.

Mean range bias assessment

At the time of the study an ILRS Pilot Project was in progress, which aimed at assessing station mean range biases and whose preliminary results for a limited number of Analysis Centers were available for Lageos-1 and -2 [1].

We started the study with similar calculations, though with different models and parameterization, as a benchmark of our setup. Our results being very well in agreement with those from the Pilot Project (not shown here, see the PowerPoint presentation), the lower orbiting geodetic satellites Starlette and Stella were added, as their orbit is closer to Jason-2's.

Computations:

- 5-day arcs
- Partials for station coordinates and 1 range bias (σ = 1 m) per station are computed -> normal equations
- Normal equations are stacked by month
- Station positions and range biases are solved simultaneously per month, per satellite

Background models:

Gravity potential	EIGEN GRGS RL03 (variable up to d/o 80)
Ocean tides	FES2014 with admittances
Atmospheric tides	ECMWF with Bode-Biancale model

Ocean pole tides	DESAI 2002
Solid Earth tides	IERS 2003
Ocean dealiasing	TUGO
Atmospheric dealiasing	3-hour ECMWF
Mean Pole	IERS 2010
Earth Orientation Parameters	IERS 0h
Tropospheric correction	Mendes
Drag	DTM 2013
Relativistic accelerations	Schwartzschild / Lense Thirring
Station coordinates	ITRF2014 with post-seismic relaxation coefficients
Station loading	Ocean and atmospheric loading
Data Handling	ILRS_Data_Handling_File + GRGS managed file (*range biases removed*), system dependent CoM corrections for LAG1/2

The following graph shows the mean range biases for the most prolific stations during the 4-year period 2005-2008. Station positions and range biases are adjusted simultaneously, and no range correction is applied. The reference frame is ITRF2014.

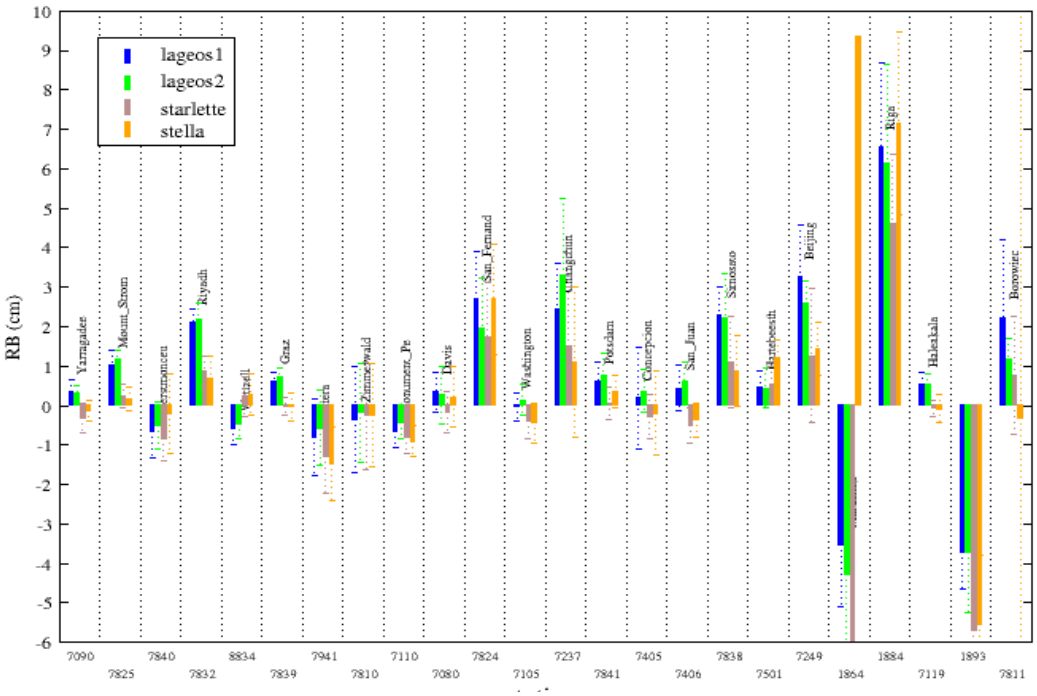

Figure 1: mean range biases for Lageos-1 and -2, Starlette and Stella on the 2005-2008 period

A large number of stations display systematic biases. The Starlette/Stella's range bias is generally several millimeters lower than Lageos. This is discussed in the following section.

Four stations have ILRS-provided range error corrections for this time period. As expected, applying the corrections only impacts those four stations (see below): Herstmonceux and Matera's biases nearly drop to zero, Beijing's bias decreases as well, Zimmerwald's increases.

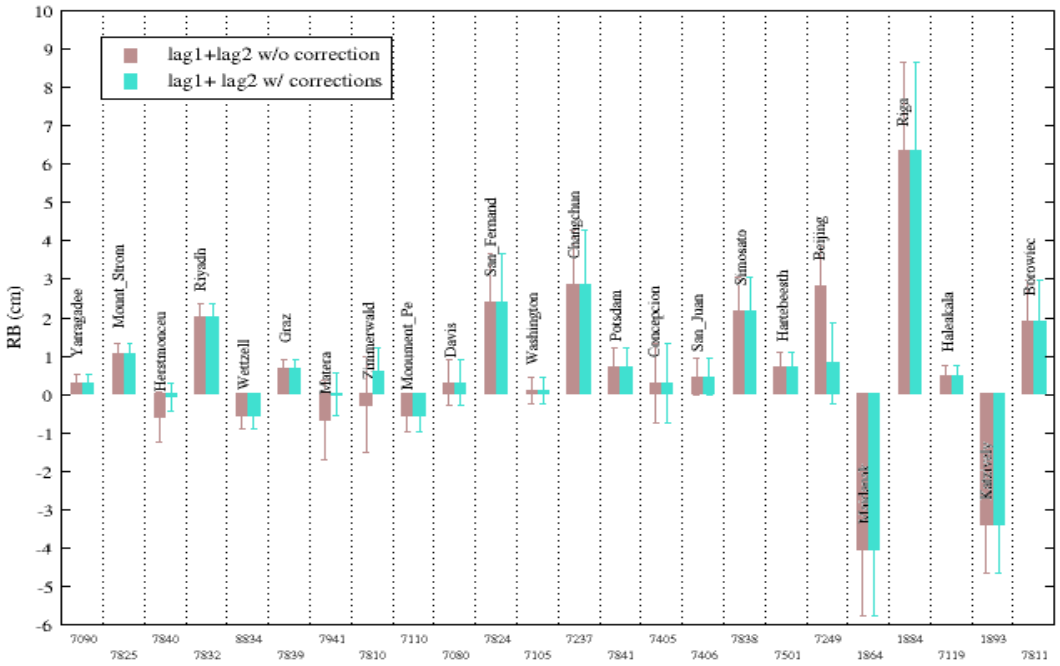

Figure 2: combined mean range biases for Lageos-1 and -2 on the 2005-2008 period, with and without known error corrections

Altimetry at CNES

Precision Orbit Determination for altimeter satellites is currently performed using Doris and GPS only. SLR is used for external validation, i.e. the orbits are not fitted to the SLR data. Only a reduced set of stations is used: Yarragadee (7090), Greenbelt (7105), Zimmerwald (7810), Graz (7839), Herstmonceux (7840), Matera (7941). Range bias corrections are applied: LPOD v19 (March 6, 2013) by John Ries [3]

In order to assess whether range biases are well corrected for Jason-2 POD, we studied the six core stations using the following setup with the 4 geodetic satellites (Lageos 1&2, Starlette, Stella):

- 5-day arcs
- Time frame : 2003-2016
- ITRF 2014
- Same background models as in first study
- No range error correction applied (the so-called CoM corrections are applied)
- Station positions are not adjusted, 1 range bias is adjusted per station/per arc

The range bias time series are then compared with the mean residuals for Jason-2.

Center of Mass corrections influence

ILRS currently provides so-called "Center of Mass corrections" for Lageos-1 & -2 and Etalon-1 & 2. Those corrections are satellite- and station-dependent range corrections. Those corrections are applied in our computations. An ILRS-provided constant value is used for Starlette/Stella.

The following graph shows the result for station Graz (7839). On the left side, the ILRS provided corrections are applied. On the right side, Starlette and Stella time series are shifted 7mm upwards, following conclusions from [2] : *« The result of STARLETTE indicates that the current standard value 75 mm is applicable only to single-photons systems and it is too small for the worldwide average ».* Graz is operating a CSPAD detector in Multi Photons mode.

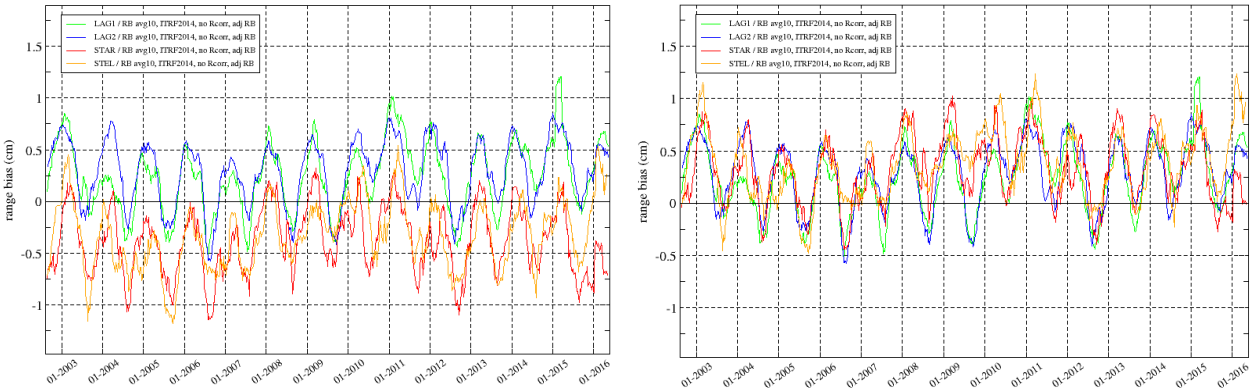

Figure 3: Graz station's adjusted range bias on the 2003-2016 period.
the Starlette and Stella plots are shifted by 7mm upwards on the 2nd graph

With this shift, all four geodetic satellites are fairly close to what is found with Jason-2:

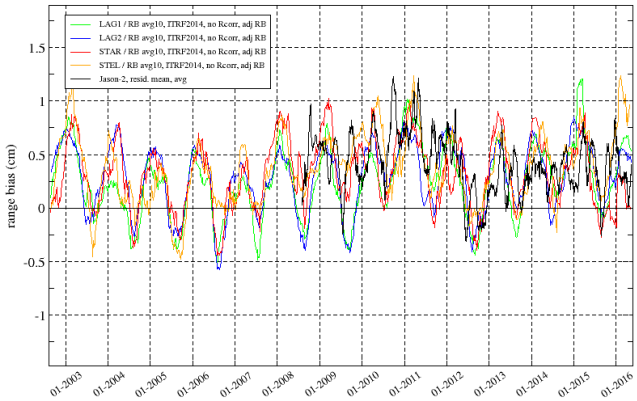

Figure 4: station Graz: geodetic satellites' adjusted RB, Jason-2 mean residuals

Reference Frame influence

The following graphs show station Yarragadee (7090). On the left side, the range bias is adjusted within the ITRF2014 reference frame. On the right side, the SLRF2008 frame is used, like with Jason-2 mean residual computation. On both graphs, the big change in July 2006 is explained in the station log as a "*significant laser upgrade*".

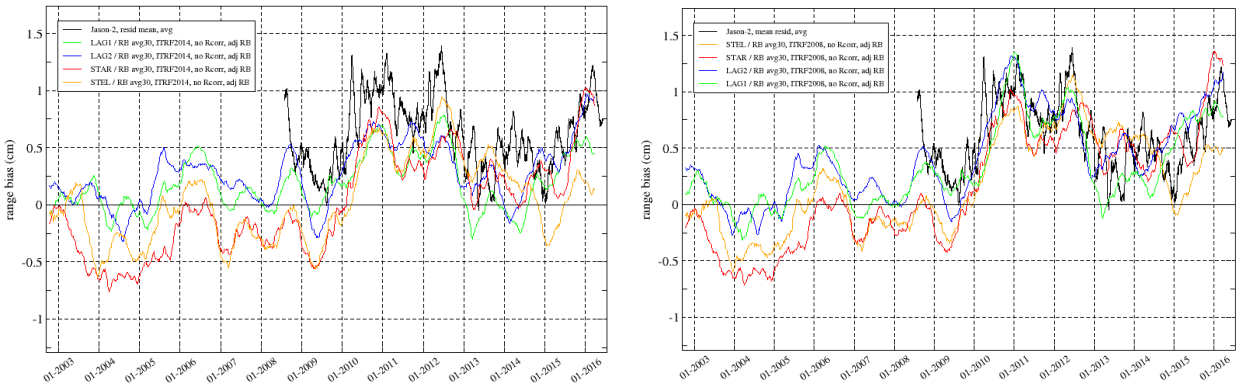

Figure 5: station Yarragadee: geodetic satellites' adjusted RB, Jason-2 mean residuals
The range bias is adjusted within the ITRF2014 (left) or SLRF2008 (right)

The reference frame has a clear influence. The match is better with SLRF2008, which can be explained by the fact that Jason-2 POD is done with ITRF2008.

Core stations summary

	STAR/STEL vs LAG1/LAG2	Jason-2
Graz (7839)	Good agreement, provided that the CoM correction be increased by several mm	Good agreement
Herstmonceux (7840)	Good agreement, slight degradation between 2010 and 2012	Good agreement
Greenbelt (7105)	Divergence after 2014, esp STAR	~ follows STAR
Yarragadee (7090)	Good agreement. Offset before 2010 ?	Good agreement
Matera (7941)	Good agreement	Good agreement
Zimmerwald (7810)	Good agreement	Good agreement

Other stations

Some other stations show a peculiar signal that could not be explained:

- station Greenbelt shows overall a good match between Jason-2 and the low-orbit satellites; it is worse with high-orbit satellites, especially after 2014. A drift of >1 cm over a period of a few years is clearly present and detected with all satellites. No correction is advertised by the ILRS. No bias is present before 2011, and the mean of the SLR residuals on Jason-2 is also centered on zero.
- station Monument Peak shows very similar biases for Lageos1/2 and the low-orbit satellite Starlette, but a different signature for Starlette's twin Stella before 2014. Opposite behavior in 2015-2016. There is a large offset for Jason-2.

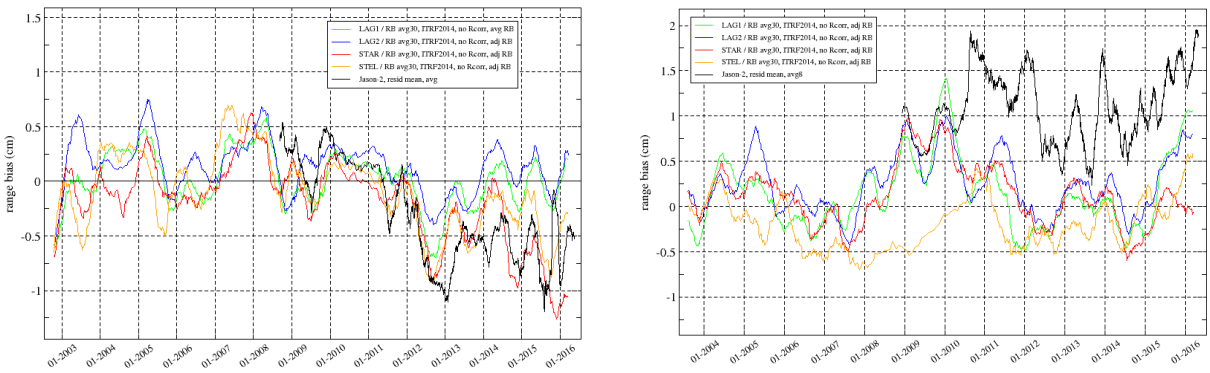

Figure 5: stations Greenbelt (left) and Monument Peak (right)

Conclusions

All four considered geodetic satellites generally show the same range bias, proving that this bias is station-dependent. However, the past effort of providing Center of Mass corrections for Lageos-1&2 must be extended to Starlette and Stella, especially for Multi-Photons systems.

The results obtained with the geodetic satellites are in good agreement with Jason-2: ILRS-provided range error corrections will be directly applicable in altimeter POD.

Range biases are not stable in time (and may even show a drift); a mere average over decades seems inadequate. An extensive study is required.

When the station coordinates are not adjusted at the same time as the range biases, a significant bias contribution lies in the reference frame. This is an important issue for the provision of system-dependent-only bias corrections.

References

1. ILRS Analysis Standing Committee pilot project on the determination of systematic errors in ILRS observations. First assessment of inter-AC consistency. [Appleby,G., Rodriguez, J., AC internal communication]

2. Center of Mass corrections of sub-cm precision targets, Starlette and Stella [Otsubo, T., Sherwood, R.A., Appleby, G.M. et al. J Geod (2015) 89: 303.]

3. LPOD2005: A recommendation for SLR coordinates for satellite orbit processing consistent with ITRF2005 [Ries, J] ftp://ftp.csr.utexas.edu/pub/slr/station_coordinates/LPOD2005_v19.doc