Enhanced ILRS analysis for ITRF2020

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Abstract

The time series of station positions and EOP provided by ILRS for the realization of the ITRF2020 was obtained as the combination of loosely constrained individual solutions from the seven ILRS Analysis Centers: ASI, BKG, DGFI, ESA, GFZ, JCET and NSGF. Everyone followed strict standards agreed within the ILRS Analysis Standing Committee (ASC) and used SLR data from LAGEOS, LAGEOS-2, Etalon-1 and Etalon-2. The ILRS ASC devised an innovative approach in handling systematic errors in the network, never before utilized. A series of long-term mean bias estimates for each station were generated during a pilot project including the time intervals of applicability and their statistics. They were obtained from freely adjusted station position and EOP solutions for the period 1993.0 to 2020.5, using the latest satellite CoM model. The simultaneous estimation of the station heights and measurement biases resulted in a self-consistent set of weekly bias estimates for each site and the utilized CoM model. Breaks and "jumps" were used to define the periods of applicability and to calculate the mean bias and its standard deviation. These mean biases were pre-applied in the re-analysis for ITRF2020, limiting the remaining jitter of the bias to negligible level. This approach strengthened the estimation process without a compromise of the final results' accuracy. As a result, the ILRS contribution to ITRF2020 minimized the scale difference between SLR and VLBI to roughly 1 mm (ITRF2014 ~9 mm). We present an overview of the procedures, models, and the improvement over previous ILRS products, focusing especially on the Core ILRS sites.

1. Introduction

The Satellite Laser Ranging (SLR) technique is one of the historical techniques contributing to the realization of the International Terrestrial Reference Frame (ITRF). SLR delivers time series of weekly station positions and daily Earth Orientation Parameters (EOPs) that define the origin of the frame and, along with the products from Very Long Baseline Interferometry (VLBI), the scale of the frame being the scale obtained by the average of the implicit scales of SLR and VLBI. The realization of ITRF2014 (Altamimi et al. 2017) revealed scale and scale rate differences between the two contributing techniques equal to 1.37 (± 0.10) ppb at epoch 2010.0 and 0.02 (± 0.02) ppb/yr; the techniques were thus asked to thoroughly investigate the issue.

The ILRS Analysis Standing Committee (ASC) considered the presence of station systematic errors as one of the major candidates and focused its efforts in that direction with the aim to find a better strategy. This effort led to an error characterization based on the direct estimation from the data, different from the initial approach based on the recovery of information from historical and engineering reports, site logs, communication with the stations etc. The strategy was applied in the realization of the ILRS contribution to ITRF2020.

2. Station Systematic Error Modeling (SSEM)

The official ILRS solutions are produced following the ASC guidelines. The SLR measurements are processed in intervals of 7 days to generate a loosely constrained solution for station coordinates and daily Earth Orientation Parameters (X-pole, Y-pole and excess Length-Of-Day). The weekly solutions, generated by all the ILRS Analysis Centers (AC), are then combined by the two ILRS Combination Centers (CC), thus delivering a unique combined weekly solution.

In 2015 ILRS launched a multi-year effort to address and resolve the SLR scale issue and established a pilot project called Station Systematic Error Modeling (SSEM PP) to check the reliability of the simultaneous estimation of station errors, namely range biases (R_B), and station positions. Within the Pilot Project, the ACs were asked to process LAGEOS and ETALON data and determine daily EOPs and weekly station coordinates, together with weekly range biases for all tracking stations; separate range biases for LAGEOS, a combined one for ETALON. The individual AC solutions were combined by the ILRS Combination Centers rigorously, including all of the estimated parameters, i.e. site coordinates, EOP and biases, for the generation of the official ILRS products.

Preliminary results over the period 1993-2017 for LAGEOS and LAGEOS-2 clearly showed that the majority of the estimated range biases were positive with the majority of the core sites having a long-term R_B within ±10 mm, as plotted in the figure below.

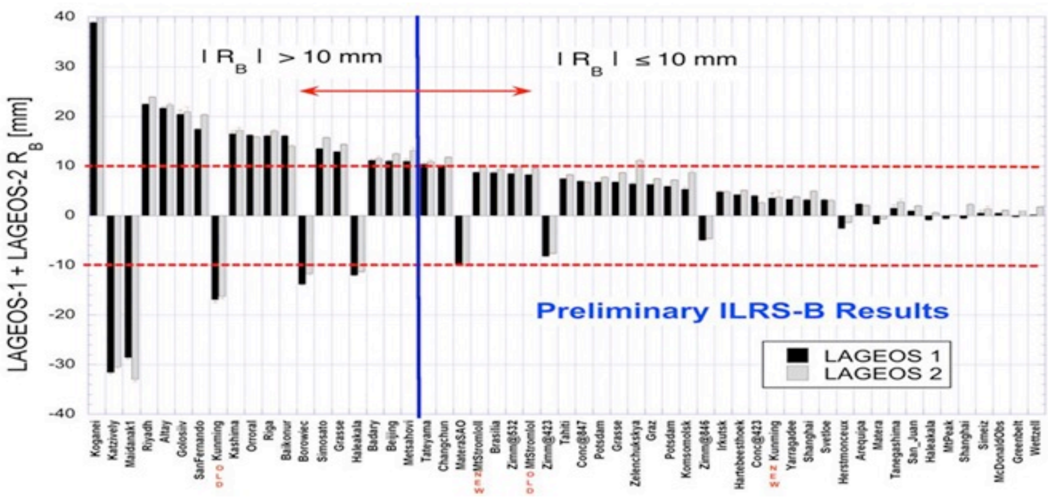

Figure 1: Long term mean range biases over 1993-2017

A common mismodeling source was identified in the satellite Center-of-Mass (CoM) correction model since inaccuracies in its value directly translate to ranging errors (with an opposite sign). Thanks to the work done by Rodriguez et al. (2018), an updated CoM model was delivered and the application of the revised model in a final reanalysis of the SSEM PP reduced the estimated R_Bs by several millimeters, with the majority of the core sites having a long-term R_B within ±5 mm (most of them much less). The updated model is absorbing a significant part of the systematic errors, but not entirely, and the residual systematic errors need to be modeled.

The figure below is an example of the R_B time series estimated in the final reanalysis by the ILRS ACs, the lines are running averages over the individual AC time series. It is worthwhile to underline that the individual estimates cannot reach the millimeter accuracy but such accuracy can be achieved in the mean value.

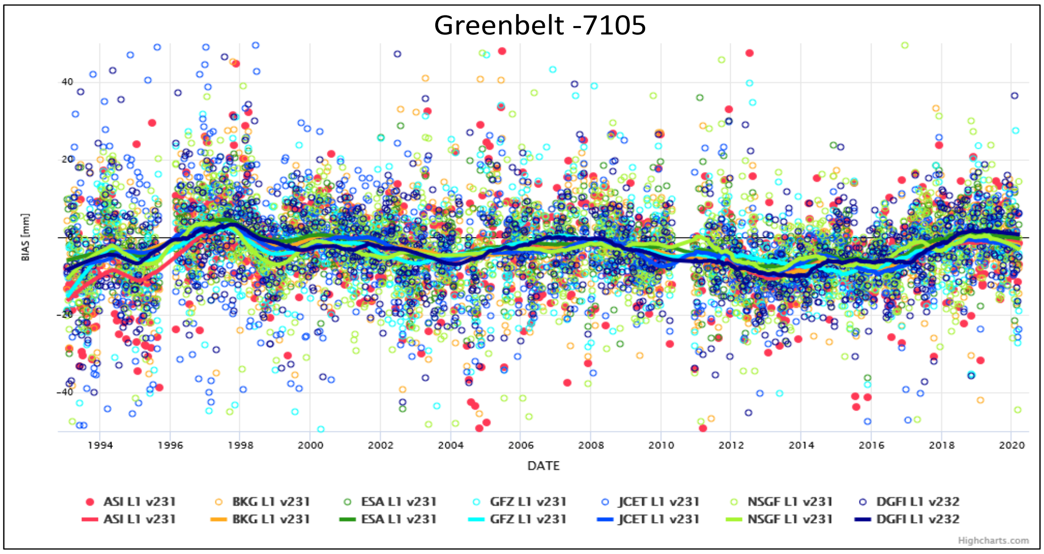

Figure 2: Individual AC range bias time series for Greenbelt

The results show that the agreement among the ACs is generally within the uncertainty of the estimates, except for a few cases. The comparison between estimated and well-known range biases confirmed that real biases can be recovered.

2.1 The Data Handling File

Since the interest is in detecting long-term biases, the R_B combined time series were analyzed to find the presence of biases that were stable over an extensive time span (months). Breaks and "jumps" were detected and a mean value, with its standard deviation, was computed over each identified interval. The dates of the breaks were compared with the dates of the major changes reported in the stations' site log and most of the time there was a clear correlation between a jump and a configuration change at the SLR station. The estimated mean biases were compared with the values reported in the archives (when available) and the stations were involved in the analysis whenever the values were different or not reported at all.

The figure below shows Greenbelt's combined range bias series for the two LAGEOS satellites, identifying jumps and intervals of persistent range bias. The significant mean values, 3 times higher than their standard deviation, were considered to be real biases and were added to the bias model for use in future reanalysis.

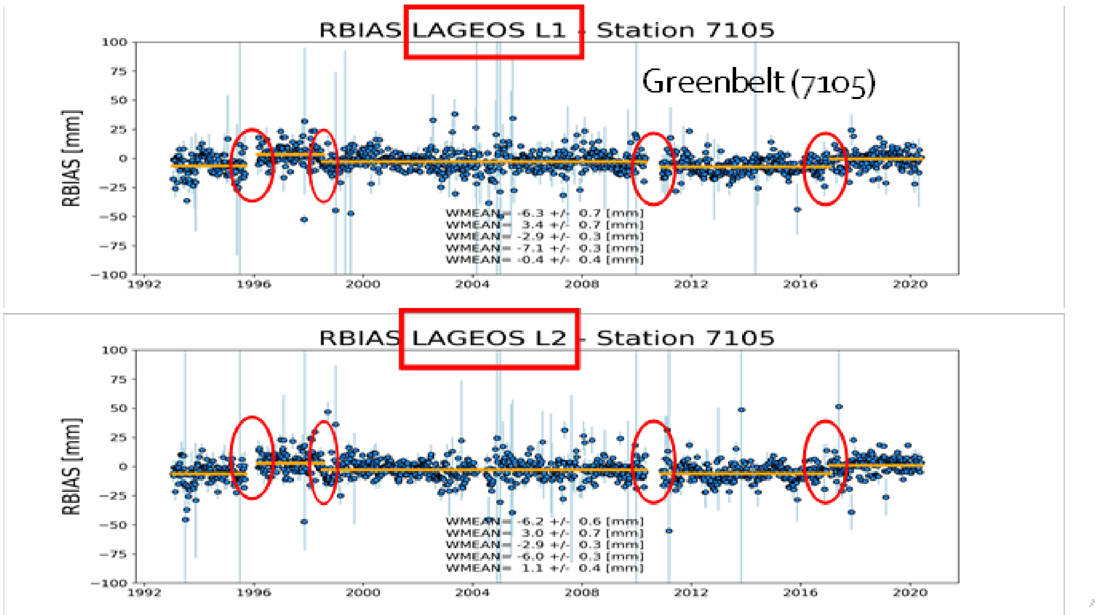

Figure 3: Combined range bias time series for Greenbelt

The same type of analysis was performed for all the stations and the corrections listed in a data handling file. The data handling file is complemented with additional information useful for a correct processing of SLR data:

- list of mandatory systematic errors to be applied on observations
- list of data to be deleted
- list of mandatory arc dependent biases to be estimated
- meteo data corrections
- time biases, including the T2L2 T_B and T_B-rate data records

The ILRS ASC is in charge of keeping the file up to date and thus maintain an ongoing estimation process into the future. It is very important to underline that the bias model is valid with the specific satellite CoM model used during its development because the values are anti-correlated.

The SSEM effort has been published in (Luceri et al., 2019) and was also presented to the community during the Unified Analysis Workshop 2022 (Luceri et al., 2022).

3. The ILRS contribution to ITRF2020

The innovative approach to handling systematic errors was used to realize the ITRF2020 ILRS contribution. All the corrections listed in the Data Handling File (DHF) were pre-applied to the data in the reanalysis, limiting the remaining jitter of the bias at a negligible level.

Together with the improvements of the underlying models, the ILRS reanalysis produced an enhanced contribution to ITRF2020. The major result is the impact on the reference frame. While the translations are not clearly different, the SLR scale with respect to the new ITRF2020 is by more than a full 1 ppb closer to the ITRF2020 overall scale than in previous TRFs. The plot hereafter shows the ILRS scale time series of the ILRS contribution to ITRF2014 and to ITRF2020, where the values are computed with respect to ITRF2014 and the significant information is the relative offset of 1.1ppb due to the innovative handling of the systematic errors.

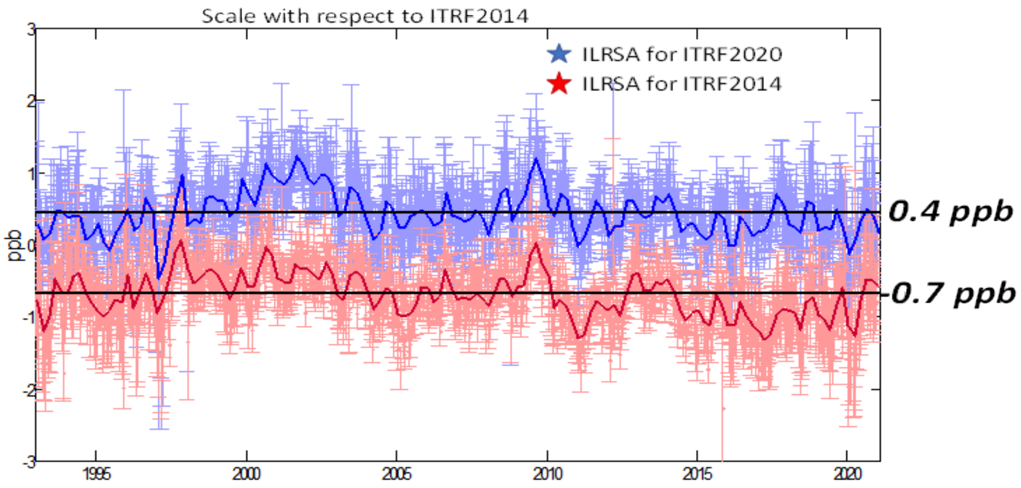

Figure 4: Comparison of the two ILRS contributions to ITRF2014 and to ITRF2020.

An initial presentation of this work was presented and discussed at the REFAG2022 (Pavlis, et al., 2022). At the same event, Altamimi et al. presented their results (Altamimi et al. 2022) stating that the ILRS scale with respect to ITRF2020 is -0.075±0.038 ppb at 2015.0, with a scale rate equal to 0.000±0.004 ppb/yr. The scale offset between SLR and VLBI is reduced to 0.15 ppb (1 mm at the equator).

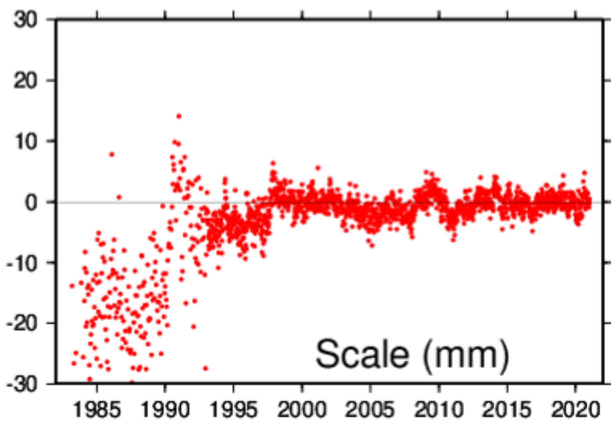

Figure 5: SLR scale with respect to ITRF2020, plot from https://itrf.ign.fr/images/solutions/itrf2020/slr-trf.png

4. Summary

The ILRS ASC stablished a new analysis approach for its contribution to ITRF2020 minimizing any potential error sources affecting the observations. This approach strengthened the estimation process and enhanced the quality of the SLR solution. As a result, the ILRS contribution to ITRF2020 minimized the scale difference between SLR and VLBI to 0.15ppb (1 mm at the equator).

The approach will be implemented in the ILRS operational series after the adoption of ITRF2020 (2023);

The complete SLR series for the 38-year period 1983 – 2022 will be reanalyzed;

The new bias model (SSEM-X) will be publicly available and maintained current over the coming years.

References

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