Improving ILRS products after an in-depth characterization of station biases

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ABSTRACT

The correction of station systematic errors is a non-trivial aspect of the SLR data analysis mostly due to the fact that many biases are not known nor reported by the stations. The ILRS Analysis Working Group has devoted a big effort in modelling the biases during the definition of the ILRS contribution to ITRF2008 with the establishment of guidelines to be followed by each analysis center for the individual solutions.

The in-depth characterization of the station biases has improved the quality of the latest ILRSA combined solution for ITRF2008 and some indicators will be presented.

The bias monitoring is an ongoing work to keep the ILRS routine product at a high quality standard. A few analysis centers are involved in this activity, in close contact with the site engineers, to estimate the biases whenever a field measured correction doesn't exist and keep the bias list updated.

1 SLR systematic errors

SLR is a clean, absolute ranging technique with the two possible kinds of systematic errors due to problems at the stations (e.g. calibration and/or synchronization issues, hardware malfunctioning): time biases and range biases. The range bias is the most critical, being highly correlated with height over short periods; the presence of intermittent biases can introduce jumps in the coordinate time series and a non homogeneous treatment of biases through the different Analysis Centers affects the combined product.

The ILRS Analysis Working Group (AWG) paid attention to the bias correction from the very beginning of its activities. Its main product is the weekly estimate of site coordinates and Earth Orientation parameters, using LAGEOS and ETALON tracking data, obtained from the combination of individual Analysis Centers (AC) solutions; the time series of weekly solutions is its fundamental contribution for the International Terrestrial Reference Frame (ITRF). The delivery of ITRF2005, the first reference frame obtained from the time series of solutions submitted by the various geodetic Services (ILRS, IVS, IGS and IDS), pointed out the problem of the jumps in the coordinates time series of some sites due to unmodelled errors and evidenced the necessity to make a deeper investigation on the systematic errors in the SLR data.

1.1 Error handling

The aim of the AWG was the establishment of guidelines to be followed by each analysis center for the individual solutions and the first important step was the recovery of information, above all for the historical data. Main sources of information were the engineering bias reports collected at the CDDIS database (technical report, station communication, ecc.) and the rapid, daily bias analysis report from the ILRS Analysis Centers. This information were not sufficient and, in order to compile a more complete list of biases in the data, a dedicated multi-year solution was made following the old fashioned way of doing global multi-year solutions: a wide data span back to 1983 was analysed to recover a single set of station coordinates and velocities, daily EOP and LOD, orbit parameters and time series of biases for all the stations of the worldwide network. This type of solution was chosen above all to obtain estimated biases de-correlated from the station height. The bias time series was a precious source of information to detect changes in the station configuration or unreported issues and was used, together with the information in the site logs, to define a mean correction to be applied whenever the presence of bias is clear and its value is not known. It is worthwhile to underline that this work was done in strict collaboration with the stations engineers and the resulting mean corrections followed the timeline of real changes made at the stations.

The result was the definition of the ILRS AWG data handling file containing: the corrections to be applied in the SLR data analysis, the biases to be estimated, the unrecoverable data to be deleted. The file is available on the ILRS website and is maintained by the ILRS AWG.

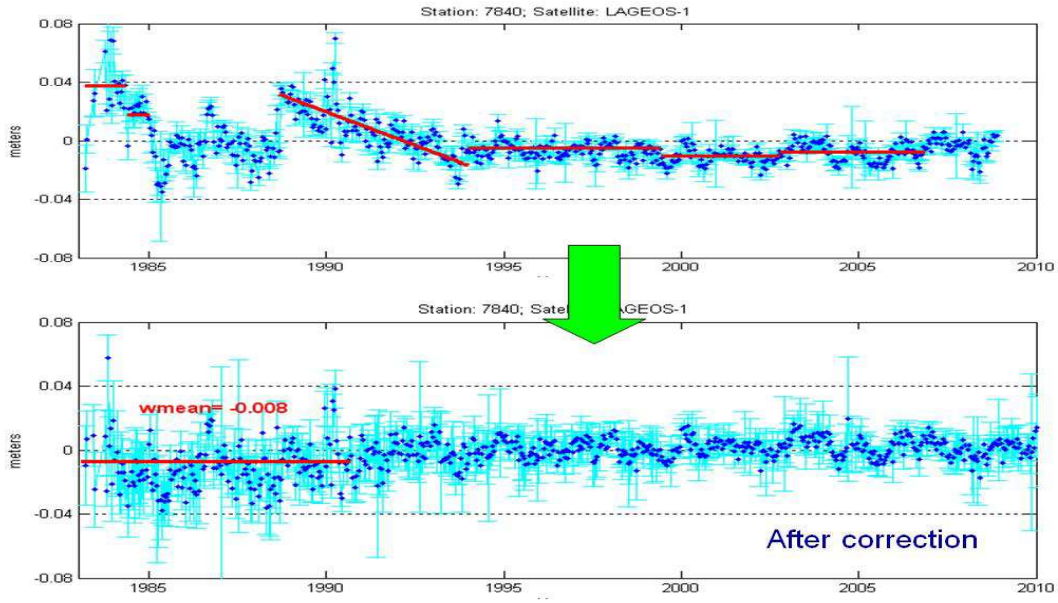

Figure 1 Herstmonceux systematic errors, before and after corrections

Figure 1 is an example of the LAGEOS range bias time series for Herstmonceux derived from the multi-year solution without any corrections (graph in the top) and after the application of the mean error correction shown as red segments in the graph at the top of the figure. Each single jump in the time series corresponds to a change in the station configuration: the last one is the replacement of the Stanford time interval counter. As easily seen, a refinement is needed for the data taken before 1991 because a small systematic error is still present.

The monitoring of the systematic correction is a continuous work. The AWG is providing feedback to the station whenever an error is visible in the data and is setting up an integrated alert system in order to support the stations 24 hours per day. One of the last cases is the range bias affecting Wettzell from the beginning of 2009 (see Figure 2), due to a calibration problem; the problem is now solved but the corrections are unrecoverable and the AWG will take care of that.

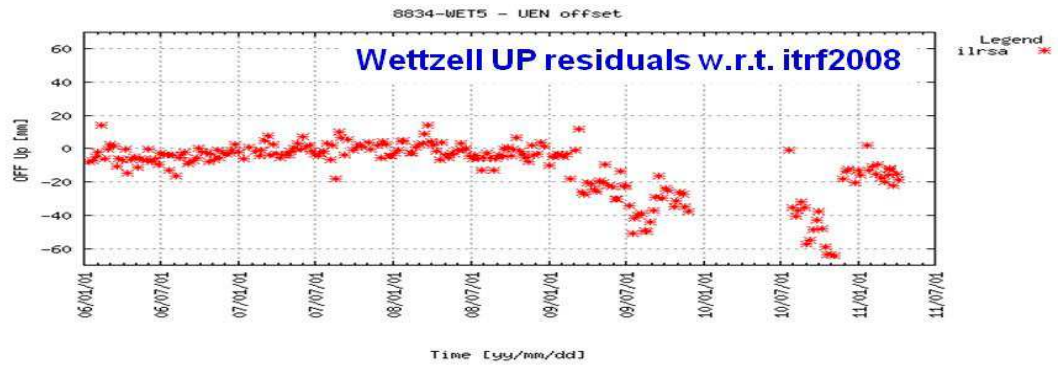

Figure 2 Wettzell systematic height time series

2 The ILRS contribution to ITRF2008

The realization of the last International Terrestrial Reference System, ITRF2008, follows the same strategy of ITRF2005 and is based on an inter-technique combination of geodetic solutions. The ILRS contribution to ITRF2008 is a time series of loose solutions containing SSC and EOP, from 1983.0 to 2009.0. Each weekly solution is obtained through the combination

of weekly solutions submitted by the official ILRS Analysis Centers (ASI, DGFI, GA, GFZ, GRGS, JCET and NSGF) and the AC solutions have strictly followed the ILRS/AWG guidelines, bias policy included.

The major upgrades, with respect to the previous submission for ITRF2005, are the larger time span (starting from 1983 instead of 1993) and the application of the error corrections as defined in the data handling file.

An immediate evidence of the benefit coming from the proper data error correction is the elimination of artifacts in the coordinate time series. As stated before, a range bias is correlated with the site height over short periods and the change of the bias value can introduce jumps in the coordinate time series not corresponding to a real site movement. The problem is obviously bigger when affecting stations with a valuable and extended data set as, for example, in the mentioned case of Herstmonceux. Figure 3 shows the plot of the Herstmonceux UP component, as computed in ITRF2005, and a discontinuity is clearly visible at the beginning of 2001 while there is no physical reason that can justify its presence; the artifact is not present anymore in ITRF2008.

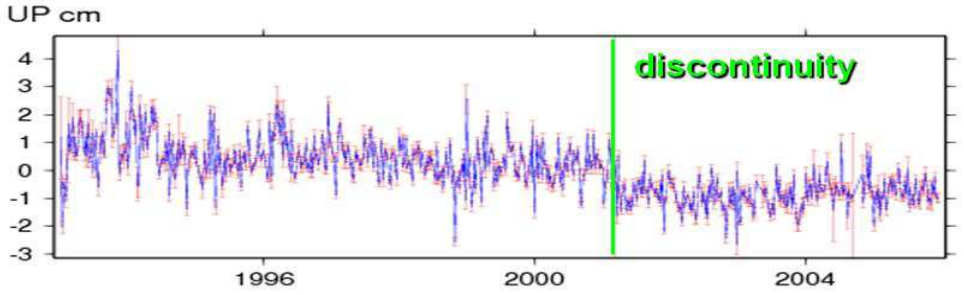

Figure 3 Herstmonceux height time series in ITRF2005 (plot from itrf.ensg.ign.fr)

The improvement in the estimate of the individual site coordinates has a direct impact in the reference frame datum. The ILRS SLR time series plays a fundamental role in the definition of the ITRF2008 origin (null translation parameters at epoch 2005.0 and null translation rates with respect to the ILRSA SLR time series) and a major role in the definition of the ITRF2008 scale (null scale and scale rate between ITRF2008 and the average of VLBI and SLR scales/rates).

2.1 Origin and scale

The time behavior of the ITRF origin and scale defines the stability of the reference frame: any non linearity or discontinuity is directly mapped into the geophysical results.

The translation and scale factors at epoch 2005.0 and their rates from the ILRS SLR solution to ITRF2008 are reported in the following table. The values have been estimated on the time span 1983-2009 according to the following formula

$$\mathbf{ITRF2008 = T + SF \cdot R \cdot AC}$$

where T is the translation vector, SF the scale factor, R the rotation matrix and AC the SLR solution

AC		Offset @ 2005.0 mm – *ppb*	Slope mm/y – *ppb/y*
ILRSA (core sites)	TX	0.09 ± 0.14	0.10 ± 0.02
	TY	-0.01 ± 0.12	0.05 ± 0.02
	TZ	-0.66 ± 0.25	-0.08 ± 0.05
	SF	*0.58 ± 0.02*	*0.04 ± 0.00*

The translations and their rates should be in principle equal to zero because the ITRF2008 origin is based on SLR and, generally, they are within the 3-sigma. A slope is present in the X translation and it can be explained by a 1 centimeter offset in the period 1982-1988 that will be investigated. All the parameters estimated considering the time range 1993-2009 are within 1-sigma.

Figure 4 shows a graphical representation of the linear fit of the scale estimated in the two time ranges.

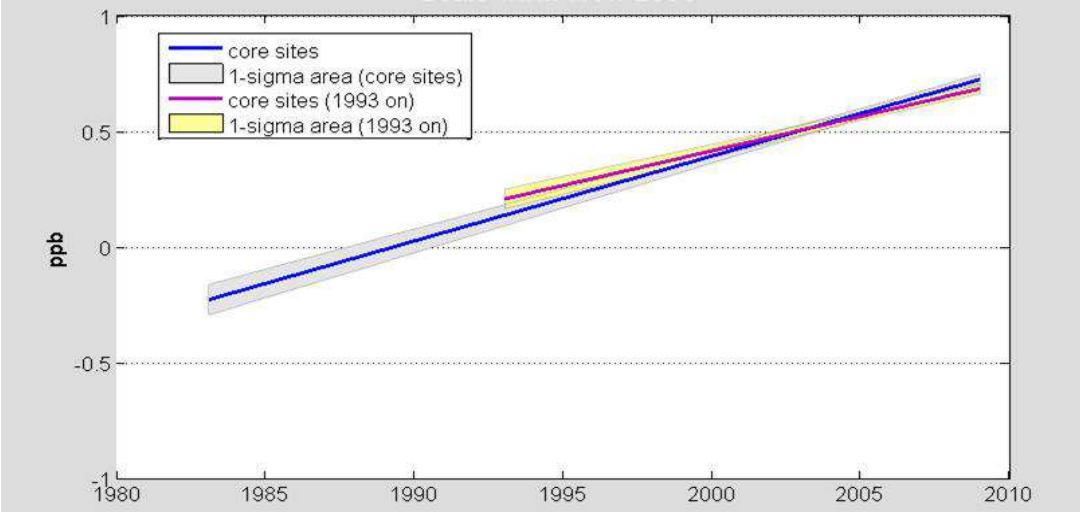

Figure 4 ILRSA scale offset and rate to ITRF2008

The realization of ITRF2005 showed a discontinuity in the SLR scale and a low level of agreement between the SLR and VLBI scales (Altamimi et al., 2009), 1.4 (±0.11) ppb at epoch 2005.0 and 0.08 (±0.01) ppb/yr for the scale and scale rate respectively. The effort spent in the improvement of the technique solutions for ITRF2008 brought an increase in the agreement level to 1.05 (±0.13) ppb at epoch 2005.0 for the scale and 0.049 (±0.010) ppb/yr for the scale rate. The SLR scale discontinuity is reduced within the error of the parameter.

3 Conclusion

The latest ILRS official product for ITRF2008 has adopted a common bias strategy for the single AC solutions (data handling SINEX file available). The effort devoted by the ILRS AWG has improved the quality of the SLR contribution to ITRF.

The bias monitoring is an ongoing work to keep the ILRS routine product to a high quality standard, in close contact with the site engineers.

References

Altamimi,Z., Collilieux,X., Métivier,L., 2011 (ITRF2008:an improved solution of the international terrestrial reference frame, J.Geod., doi:10.1007/s00190-011-0444-4)

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