The new SLR station in Yebes and the ILRS Associate Analysis Centre IGN-Yebes: recent analysis activities

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SUMMARY

The development of the Satellite Laser Ranging station in Yebes, YLARA (ERDF co-financed), is proceeding apace, with an estimated completion of the project in mid-2023. The station will be a modern system that will become part of the ground network of the International Laser Ranging Service (ILRS) and make of Yebes Observatory, together with its VLBI antennas and GNSS receivers, a fundamental geodetic station. In parallel to the operational running of the station, and its development in different areas of interest, the Observatory counts since 2020 with an Associate Analysis Centre of the ILRS, IGN-Yebes. This analysis centre has worked in collaboration with NSGF (UK), an official ILRS AC, for the reanalysis of SLR data towards the ILRS contribution to the recently released ITRF2020. Additionally, IGN-Yebes is responsible for the computation of the satellite centre of mass corrections for the targets employed by the ILRS in its reanalyses and routine solutions. We present a brief update on the status of the YLARA project, and focus on the discussion of the analysis activities of IGN-Yebes.

KEY WORDS

SLR, ILRS, Yebes, centre of mass

INTRODUCTION

The Observatory of Yebes (Guadalajara, Spain) is a radiostronomical and space geodesy observatory. It currently hosts a 40 m radiotelescope employed both for radioastronomy and geodetic observations, a new generation 13 m VGOS radiotelescope, and two GNSS receivers, all contributing to the observational effort required to materialise the global reference frame through their respective networks and services. A major upgrade to the observing capabilities of the observatory has been in the works for the last years, in what will be a change of status to a fundamental geodetic station: the construction of a new Satellite Laser Ranging station. This will be a modern site that will contribute to the densification of the ILRS network in Europe, providing an invaluable additional co-location with two VLBI instruments with presence in the ITRF. Its main activity will be to support the ILRS targets and objectives, although it is also planned to perform other kinds of observations, such as space debris. The project, co-financed with European Regional Development Funds, is in the last stages of completion, with first light expected at some point in 2023. This is a major commitment to upgrade the existing geodetic infrastructure in Spain, and it takes place within the context of the Spanish-Portuguese RAEGE project, whereby several sites in mainland Spain and both Spanish and Portuguese islands will see the installation of VGOS receivers, GNSS, and SLR. From the Spanish side, these projects are led by the National Geographic Institute of Spain (IGN) and the National Centre of Geographic Information (CNIG). In parallel to the effort of building new infrastructure, IGN is committed to the exploitation of the data generated. In fact, IGN counts with analysis centres in the space geodetic techniques of GNSS, VLBI, and SLR. The latter is the most recent addition to the analysis capabilities of IGN. Here we provide a brief description of the future SLR station at Yebes and summarise the activities of this analysis centre.

YLARA STATION

Yebes Observatory is one of the Singular Scientific and Technological Infrastructures (ICTS) in Spain. These

Figure 1: SLR station at Yebes Observatory.

are unique facilities in its kind, in the national territory, dedicated to cutting edge research and development. The Observatory has secured funds for the development of additional infrastructures and laboratory activities for space geodesy (YDALGO project), part of which entails the construction of a new SLR site in the grounds of the observatory. The station has been commissioned to the Spanish and German companies TTI and DiGOS, and its nearing completion. In terms of hardware, the station will be a modern site equipped with a high-repetition, kHz grade laser, which ensures a high level of productivity and fast target switching times. This will be able to operate at two wavelengths: the typical frequency-doubled 532 nm seen in most stations of the ILRS network, and at the fundamental 1064 nm in the infrared. In the receiver side, a single-photon sensitive detectors will be used to operate in the so-called single-photon mode, therefore minimising potential systematic errors that can arise from time-walk effects and the inevitable changing conditions during operations (e.g. atmospheric transparency). The system is designed to be modular and flexible, opening up the possibility of easy upgrade paths to add new applications and kinds of observations. Some of the key technical characteristics of the station are given in Table 1, and a picture of the current status of the station is shown in Figure 1.

Table 1: YLARA SLR station at Yebes. Key parameters.

Parameter	Value
Receive telescope diameter	0.75 m
Blind pointing accuracy	5 arcsec RMS
Transmitting telescope	10 cm
Az/El slew rate	12 deg/s
Laser firing rate	1000 Hz
Laser energy/pulse	350/500 uJ
Pulse length	8 ps
Detector 532 nm	Compensated SPAD
Detector 1064 nm	SPAD

Among the plans for the near future is the automation of the station operations. Other than lowering the running costs in terms of personnel, automatic operations ensure very high data yields as the observing time is maximised, only dependent on weather conditions. The path towards this upgrade involves providing additional redundancy in some key subsystems (in particular safety-related ones) and the software changes required to handle the station in an autonomous way.

IGN-YEBES ANALYSIS CENTRE

In 2020, an analysis centre of SLR data, based in Yebes, was accepted by the ILRS as an Associated Analysis Centre (AAC). These are not required to submit routine global geodetic solutions, unlike the so-called official analysis centres of the ILRS. AACs commit to specific tasks that may be related to quality control of the data, specialised analysis, analysis of targets not included in the official ILRS products, research & development, etc. The AAC at Yebes has focused in two main activities, to date: a) the reanalysis of historical data for the computation of TRF2020, in collaboration with NSGF AC (UK); b) the computation of centre of mass corrections for spherical geodetic satellites.

ITRF2020 reanalysis with NSGF

NSGF (NERC Space Geodesy Facility, UK) is an official analysis centre of the ILRS, based in the south of England, in Herstmonceux, where a prolific and long-standing SLR station is located. NSGF and IGN-Yebes collaborate on a number of tasks related to the analysis of SLR data. The software employed by both centres, originally created within the Royal Greenwich Observatory, of which the Herstmonceux station was part, is currently co-developed by NSGF and IGN-Yebes. Much of the work required to perform a new reanalysis of the historical data for TRF realisations are indeed tasks related to the development of the software, in order to implement the new conventions and models, format changes, and quality checks agreed upon within the respective analysis standing committees of each service.

For the latest realisation of the TRF, the following changes have been implemented in the various ILRS solutions, including that from NSGF/IGN-Yebes:

- New handling of systematic errors
- New set of centre of mass corrections
- SINEX format updates to detail the corrections used in each solutions
- High-frequency Earth Orientation Parameters
- IERS secular linear pole model
- Updated GRACE-based models and dealiasing products
- Various SW-specific updates and fixes

The reanalysis comprised observations from the ILRS network in the 1983–2019 period, with contributions from over 100 stations. The number of observations employed was about 2 million for LAGEOS, 1.7 million LAGEOS-2, and 150K for each of the Etalon satellites. These were used to solve for 15-day arcs (pre-1993) and 7-day arcs, estimating station coordinates and Earth Rotation Parameters (every 3 days for pre-1993, and daily afterwards). The post-fit RMS achieved by the NSGF/IGN-Yebes solution was ~7.5 mm for LAGEOS-1/2, and ~10 mm for Etalon-1/2 (see Figure 2). A total of 6 submissions from independent analysis centres of the ILRS were combined by the Combination Centres (ASI and JCET) to create the ILRS contribution to ITRF2020.

Centre of mass corrections of geodetic spherical satellites

The other main activity of IGN-Yebes ILRS AAC is the computation of the centre of mass corrections of spherical geodetic satellites. The SLR observable is the time of flight of laser pulses from the ground stations to the internal surfaces of the cube corner retroreflectors (and back). For the purposes of orbit determination, the variable required is the distance to the centre of mass of the satellites observed, as opposed to the retroreflector arrays. Therefore it is required to know the vectors relating the position of the latter to the former, with sufficient accuracy so as not to compromise the products derived from the orbital solutions. The most accurate centre of mass corrections for the satellites employed by the ILRS for their official products are based on the work by the Rodríguez et al (Rodríguez et al, 2019). Beyond the theoretical basis for these models, their application and updating to the ever changing landscape of ILRS ground network is a time consuming task, currently done at IGN-Yebes. Interested readers can refer to the reference given here and others therein for the details involved in the computation of these quantities. For the present discussion suffice it to say that from the physical characteristics of the retroreflector arrays, an

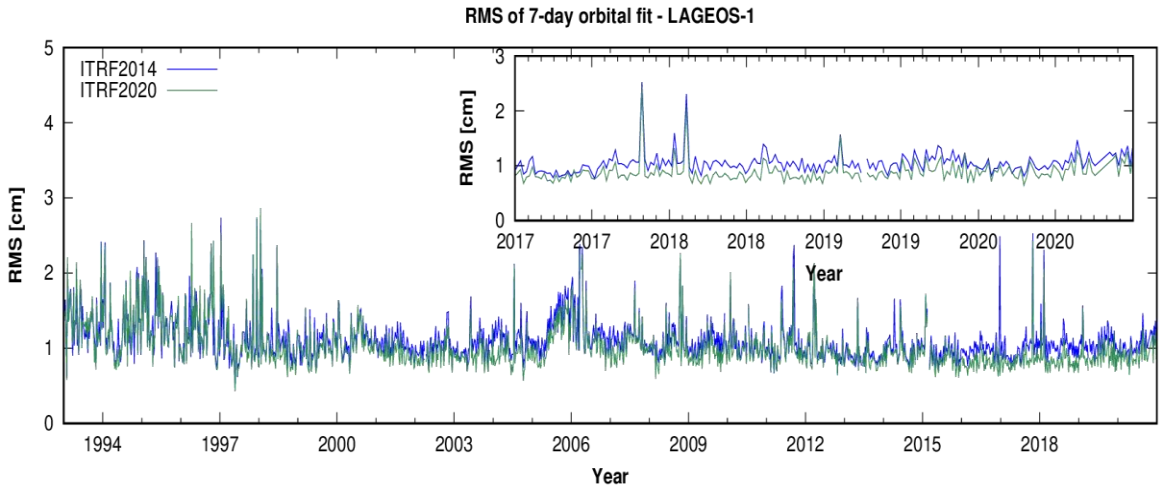

Figure 2: Post-fit RMS of NSGF/IGN-Yebes solutions, provided for the ILRS contribution to ITRF2020.

optical response function for the satellite is derived, which is then used to compute the expected distribution of laser returns for specific station hardware and mode of operation, taking into account what relevant parameters required for the computation are known from the ILRS site logs.

The current centre of mass values are satellite- and site-specific, and are publicly available from IGN-Yebes at https://icts-yebes.oan.es/slr , where the tables of corrections, example software, and supporting documentation are provided. The use of these values has proved to reduce, on average, the magnitude of the systematic errors estimated for the ILRS network, to half the observed difference in mean range bias between the satellites LAGEOS and LAGEOS-2, and most importantly, to reduce the difference between the scales of the technique-specific frames of VLBI and SLR. This, in addition with the new ILRS strategy to handle systematic errors, has explained almost entirely said scale difference, therefore resulting in a much improved result for this key parameter of the ITRF.

CONCLUSIONS

The Observatory of Yebes will soon have the status of a fundamental geodetic stations, by virtue of the new SLR station currently being finalised. The station will be a modern setup to provide high quality data and support the goals of the ILRS. Beyond increasing its geodetic infrastructure, the National Geographic Institute of Spain seeks to exploit the data it produces, through the analysis centres for the various space geodetic techniques it funds. The ILRS associate analysis centre IGN-Yebes provides a key product for the SLR analysis community, the centre of mass corrections of the satellites used by the ILRS in the computation of its official products. In a separate area of activity, IGN-Yebes collaborates with the analysis centre NSGF (UK) in various tasks, most notably the recent reanalysis of historical SLR data for the ILRS contribution to ITRF2020.

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