EARTH ORIENTATION PARAMETERS FROM SATELLITE LASER RANGING

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Abstract

We present the new re-analysis of Satellite Laser Ranging (SLR) data to LAGEOS 1/2 and ETALON 1/2 for the definition of the Terrestrial Reference Frame (TRF) and its crust-fixed orientation (Earth Orientation Parameters –EOP). The TRF plays an important role in the multi-technique monitoring of temporal variations in the gravitational field and its very low degree and order components. This area is becoming extremely important with the launch of recent and future geopotential mapping missions for the referencing and calibration of the data and products from these missions. Satellite laser ranging (SLR) has for a long time monitored the continuous redistribution of mass within the Earth system through concomitant changes in the Stokes coefficients of the terrestrial gravity field. Seasonal changes in these coefficients have also been closely correlated with mass transfer in the atmosphere and oceans. The hydrological cycle contributions however are the most difficult to measure accurately so far. This latest analysis of the 1993-present SLR data set from SLR data for the International Earth Rotation Service (IERS) TRF (ITRF) development includes the weekly monitoring of such compound changes in the low degree and order harmonics. Along with the static parameters of the TRF we have determined a time series of variations of its origin with respect to the center of mass of the Earth system (geocenter) and the orientation parameters (pole coordinates and length of day) of the TRF, at daily intervals. The data were obtained by the ILRS global tracking network and they were reduced using NASA Goddard's GEODYN/SOLVE II software, resulting in a final RMS error of ~8 mm – close to the data noise level. We will discuss our solution, compare it to EOP series inferred from other techniques, and examine their spectrum.

Introduction

The analysis of Satellite Laser Ranging (SLR) data to LAGEOS, LAGEOS 2 and in recent years, the two ETALON satellites results in a SLR-based realization of the Terrestrial Reference Frame (TRF), complete, with a consistent series of Earth's Orientation Parameters (EOP) at daily intervals. We present here the new re-analysis of this data for the definition of the TRF and its crust-fixed orientation. This analysis of the 1993-present SLR data set for the International Earth Rotation and Reference Systems Service (IERS) TRF (ITRF), includes the weekly monitoring of weekly changes in the low degree and order harmonics (up to degree two). Along with the static parameters of the TRF we determine a time series of variations of its origin with respect to the center of mass of the Earth system (geocenter) and the orientation parameters (pole coordinates and length of day) of the TRF, at daily intervals. The data were obtained by the ILRS global tracking network and they were reduced using NASA Goddard's GEODYN and SOLVE II software, resulting in a final RMS error of ~8 mm – close to the data noise level. For a detailed discussion of the products from this analysis, see [Pavlis, these proceedings; and Pavlis, 2002]. In the following sections we will discuss our EOP results, compare them to EOP series inferred from other techniques, and examine their spectrum.

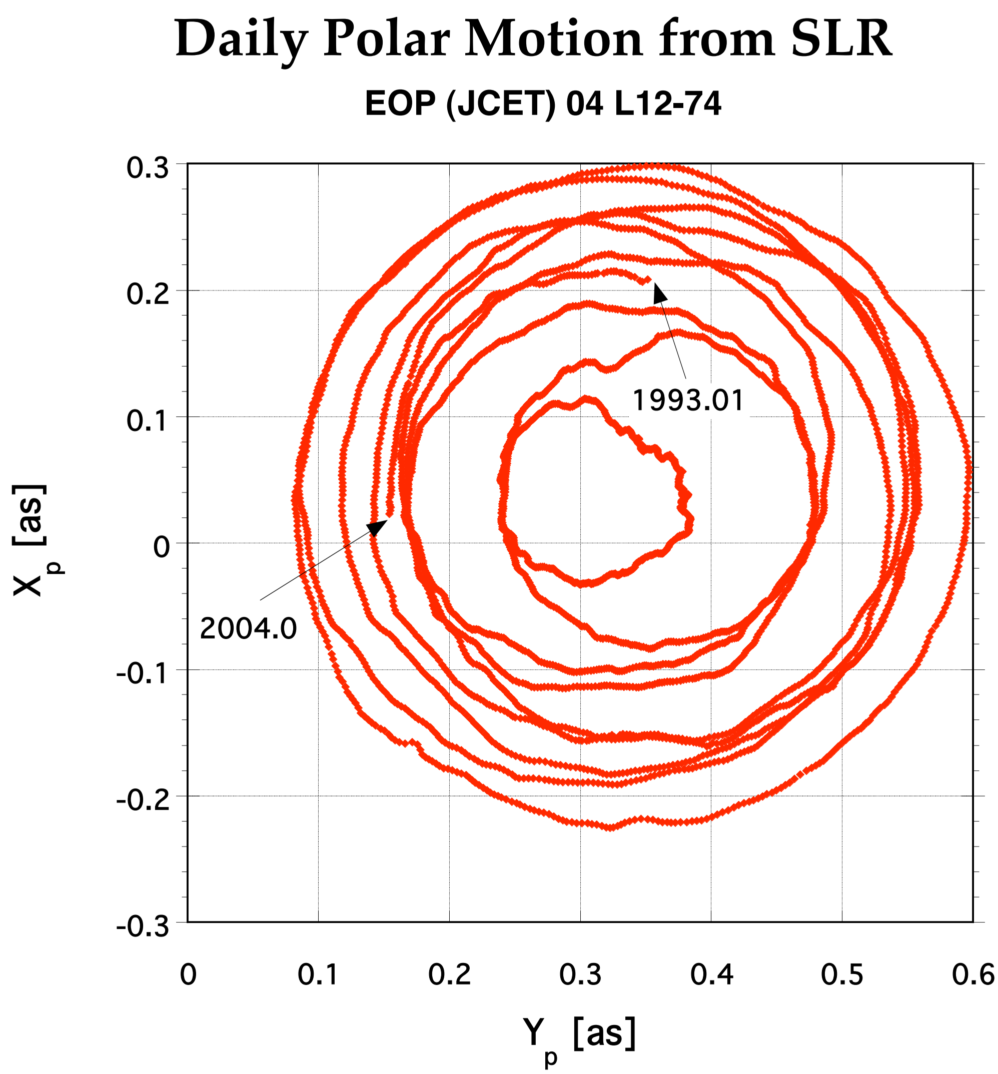

Figure 1. The daily resolution path of the pole from 1993 to 2004, EOP (JCET) L 2004.

The JCET/GSFC 2004 Solution

JCET/GSFC contributes weekly to the newly established ILRS Combination Project, for a SLR-technique optimally combined product, to be generated and submitted to the IERS. Since many years now, JCET has generated these weekly solutions for station positions

EOP and long-wavelength gravitational harmonics, and generated annually a multi-year TRF realization on the basis of these weekly normal equations.

The weekly updates of the annual solution are generated by sequential addition of the normal equations generated from the last weekly solution, and they are subsequently solved using minimal constraints that assure the solution is aligned in a fixed manner with the chosen TRF definition, in this case ITRF2000 [Altamimi et al., 2002]. This approach has the advantage of being referenced to the same datum throughout the time, as opposed to the approach involving the estimation of the EOP from a single, stand-alone weekly set of equations, in a datum-free mode. The EOP that we produce out of our analysis exhibit datum continuity and are free from biases, trends, etc. from one week to the next. The "polhode", the trajectory of the instantaneous rotational axis projected on the equatorial plane is shown in Figure 1.

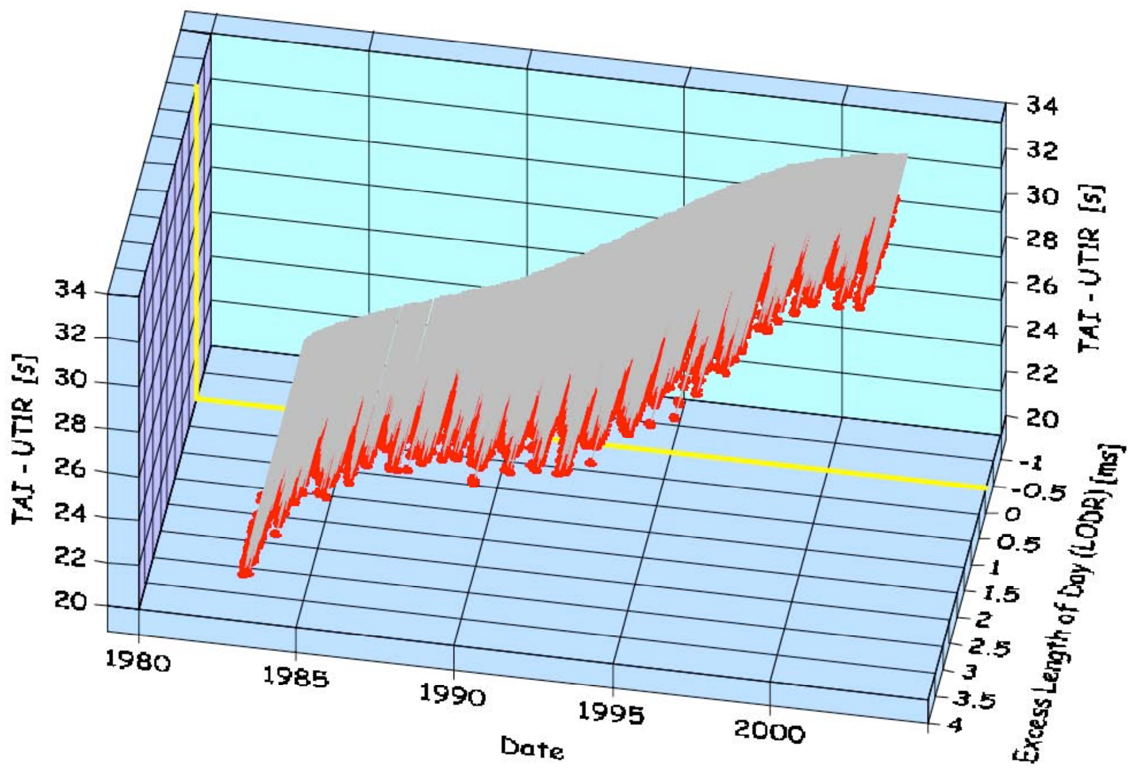

Figure 2. LOD variations at daily intervals, and integrated effect, EOP (JCET) L 2004.

Along with polar motion, satellite techniques are sensitive in variations in the orientation of Earth under the "quasi-inertial" frame realized by the dynamics of the orbit. Thus, although we are not sensitive to Earth Rotation in the absolute sense (UT1), we can observe its derivative, the Excess Length of Day (LOD). To do this we adopt an initial orientation based on Very Long Baseline Interferometry (VLBI), which is sensitive and does observe UT1 directly. By integration of the SLR-derived LOD, we can thus produce a UT1-like series also, although it should be recognized that it is not an independent product, since the long-wavelength evolution of these series is governed by the VLBI benchmark values adopted every week. Figure 2 shows the surface produced by plotting the difference of these series from TAI (Int. Atomic Time) versus time (grey surface), and on that, the variations in LOD (red dots) at daily intervals. For a clearer picture of LOD that reveals the seasonal and decadal variations, you can see Figure 3.

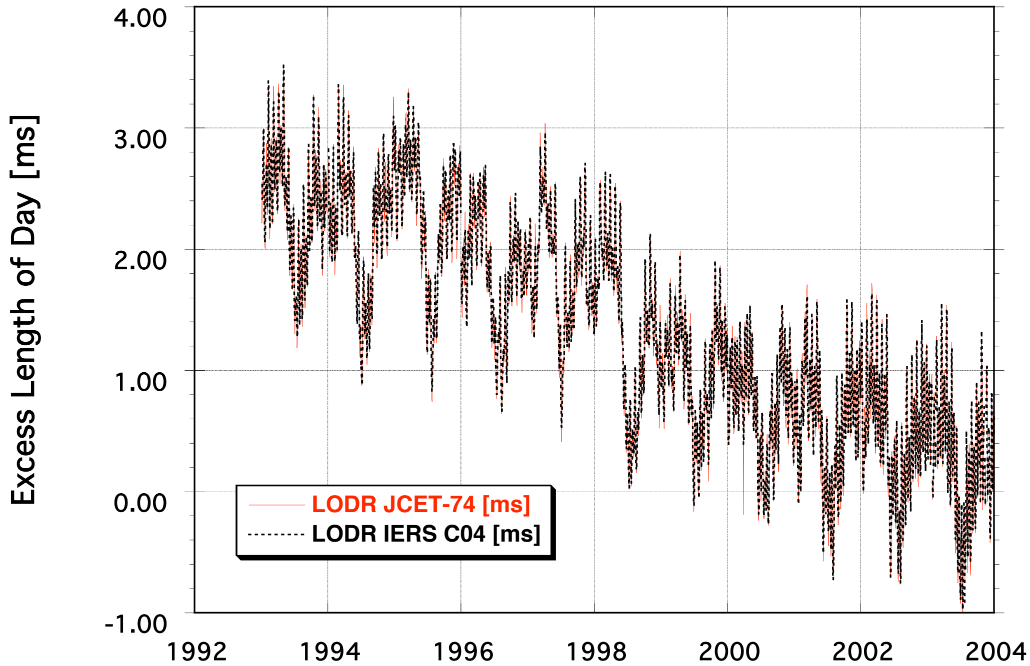

Figure 3. LOD from EOP (JCET) L 2004 and the a priori series, IERS C04.

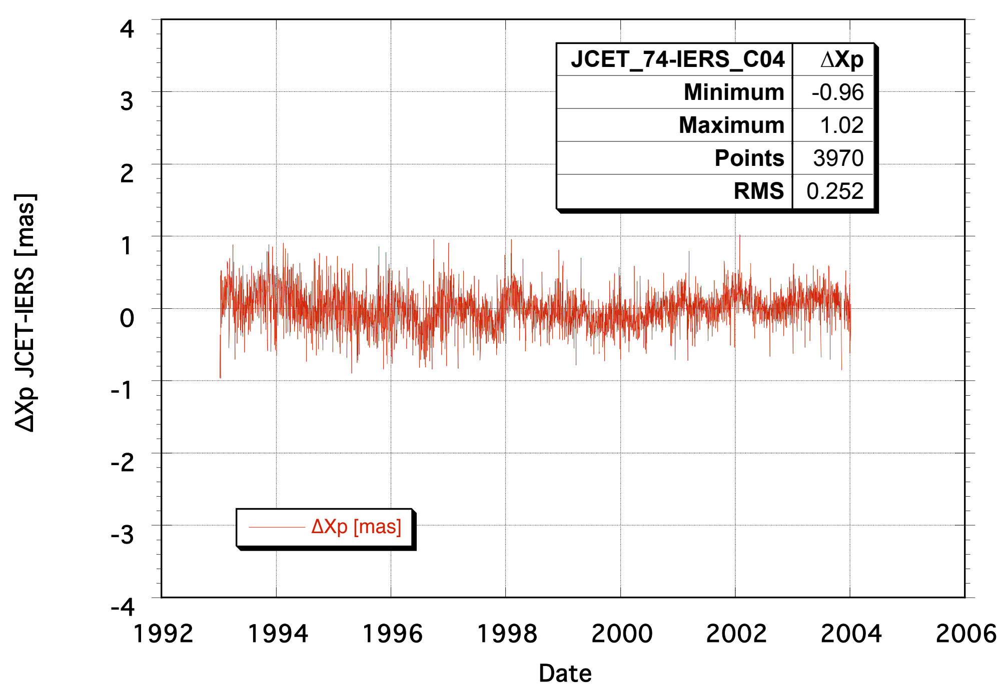

Figure 4. X-pole daily differences between IERS C04 and EOP (JCET) L 2004.

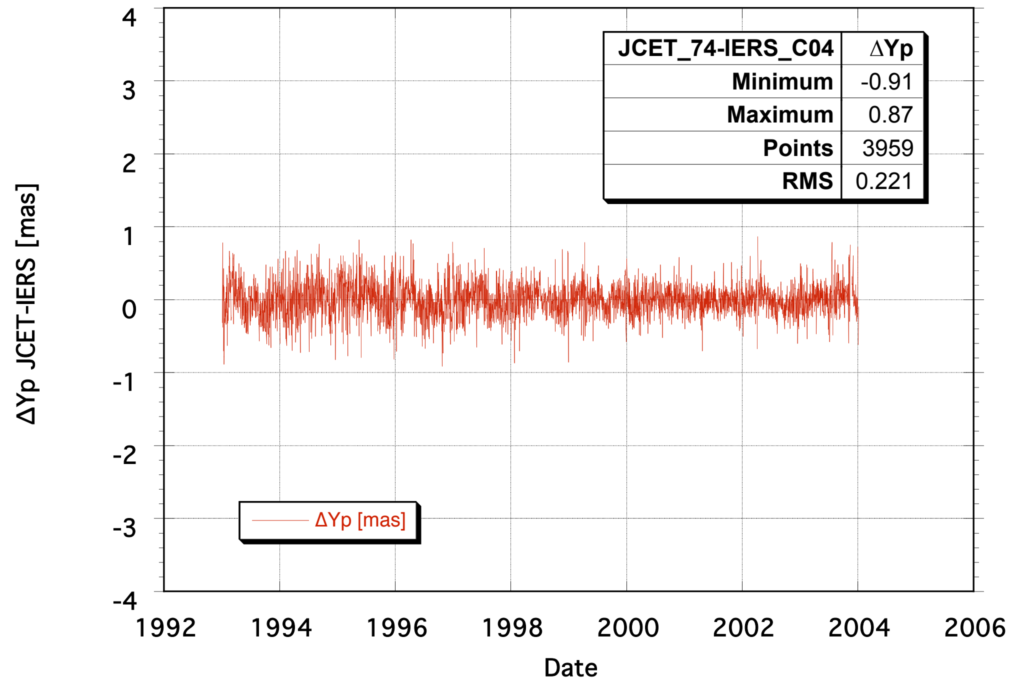

Figure 5. Y-pole daily differences between IERS C04 and EOP (JCET) L 2004.

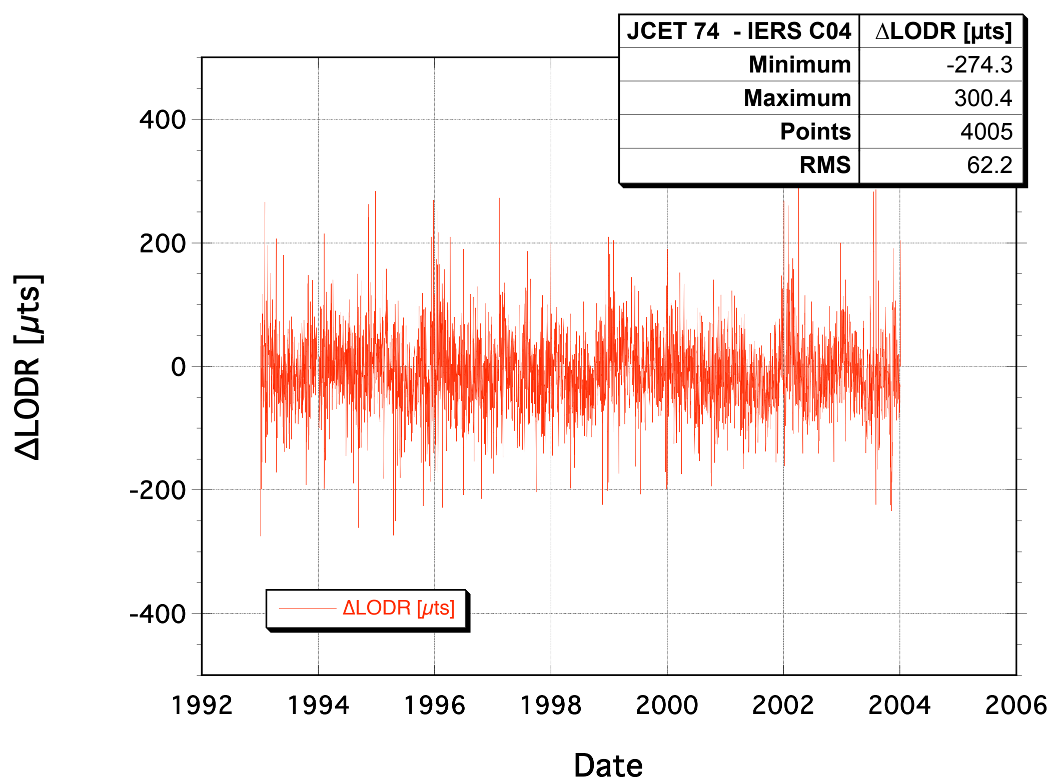

Figure 6. LOD daily differences between IERS C04 and EOP (JCET) L 2004.

The datum on which IERS C04 is based is different from that of ITRF2000, and that manifests itself as a bias and trend when comparing EOP series derived with ITRF2000 as the underlying TRF, versus the IERS C04 series. Once these biases and trends are removed though, the differences of the two series can be used to gauge the quality of the SLR products, since IERS C04 is heavily dependent on GPS and to a lesser extent, VLBI input. The time series of the differences in polar motion and LOD are displayed in Figures 4 through 6. It should be noted that the majority of the observed noise originates in the SLR series, as IERS C04 is a smooth series, albeit only very mildly so.

The EOP differences and associated statistics are based on an editing process that removed all points whose differences are larger than 4σ of the population. This is an insignificant percentage of the total and these outliers are primarily due to poor tracking on certain days, especially near the end-of-year period and Christmas. The results indicate that the accuracy of the SLR-derived Polar Motion is of the order of 0.25 mas and the LOD is at the 62 μs level. These are about 2-3 times higher than the internal precision of the results, and are primarily due to poor distribution of the tracking data, network asymmetries (north-south and east-west hemispheric distribution of tracking sites), and to a lesser extent, geophysical signals, primarily originating in the atmosphere, that are not yet modeled in our analysis.

Operational Series

For operational purposes, EOP users require a series that is precisely and consistently referenced to the currently adopted TRF, presently ITRF2000. JCET generates a parallel series along with the one discussed above, which is based on a TRF with all its sites fixed to the ITRF2000 positions. These series differs insignificantly from the nominal series, however it tracks very closely the rapid service series from NEOS, the primary user of such operational solutions (http://maia.usno.navy.mil/).

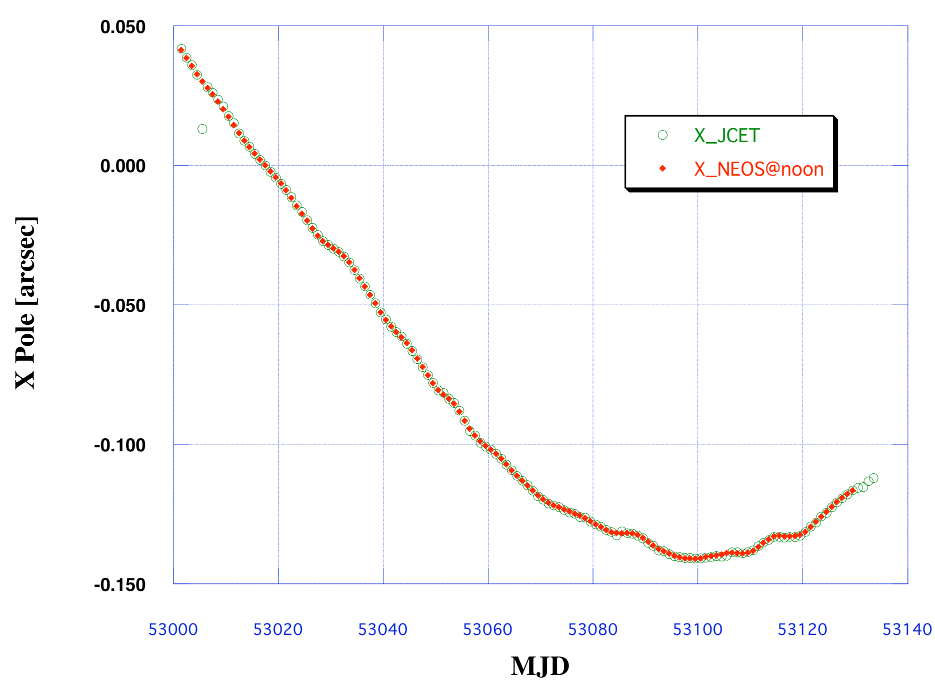

Figure 7. Comparison of X-pole from EOP (JCET) L 2004 and NEOS.

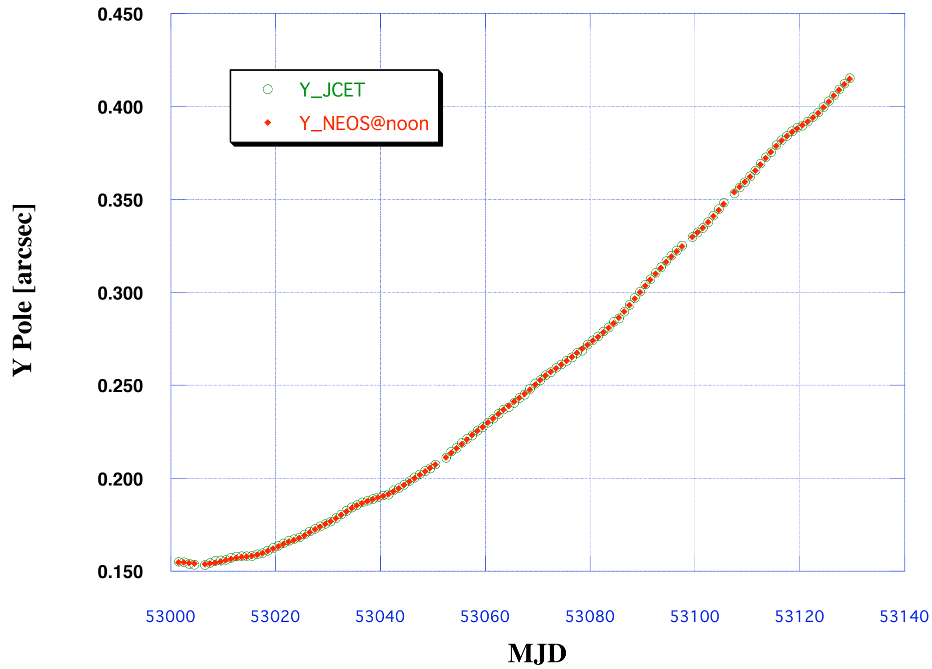

Figure 8. Comparison of Y-pole from EOP (JCET) L 2004 and NEOS.

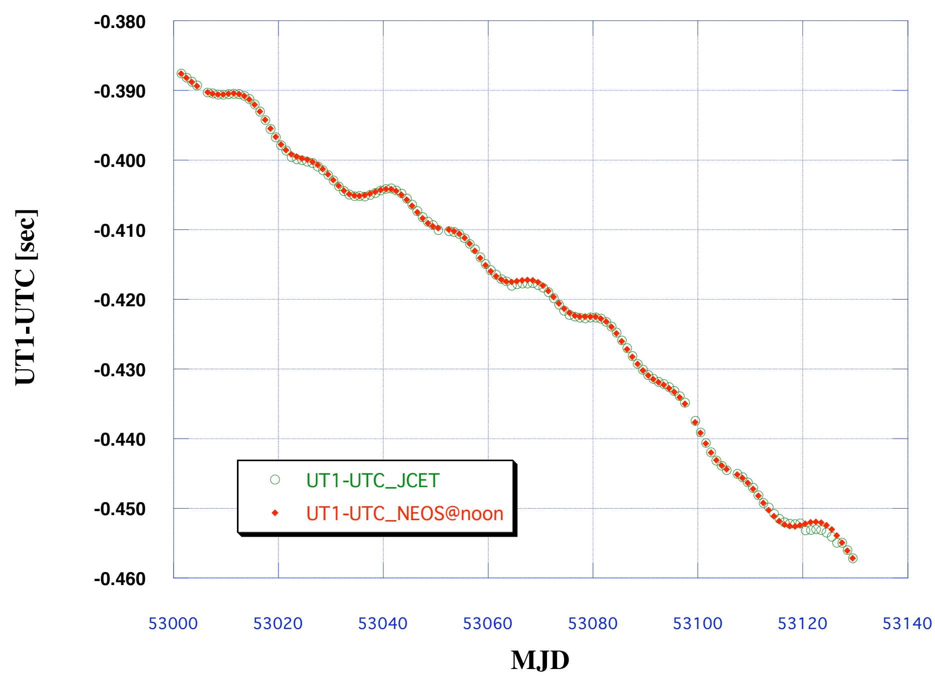

Figure 9. Comparison of UT1-UTC from EOP (JCET) L 2004 and NEOS series.

Figures 7 through 9 display a comparison of the strictly ITRF2000-based JCET/GSFC EOP series with the operational rapid service NEOS series. It is obvious that the two series are describing the same phenomenon in the long- and intermediate wavelength band, although there are events and shorter period variations that are not common to both. Because of the operational nature, the SLR results will sometimes show variable quality due to lack of tracking on certain days, station drop-outs, weather problems, etc. This can be alleviated in the future with a more uniformly distributed network, a greater availability of suitable targets (as opposed to only two LAGEOS), and improved, automated design of future systems.

Summary

The maintenance of the Terrestrial Reference Frame requires that we continuously monitor its evolution, and in particular its orientation with respect to inertial space, as well as with respect to the crust on which our tracking stations are located. Satellite Laser Ranging is one of the very first precise space geodetic techniques to contribute to this effort. In addition to contributing to the definition and the development of the TRF, it delivers in a routine fashion over many decades now, the daily motion of the pole and the daily variations in the Length of Day. In this presentation we examined one series of SLR contributions of EOP and compared them to those published by IERS, in their definitive IERS C04 series. We conclude from these comparisons, that the accuracy of SLR polar motion series is in the order of 0.25 mas, while the LOD series is accurate at the 60 μs level, both for daily resolution. Long, uniform quality series as those obtained from SLR, help extend the applicability of the current TRF in the past, and allow us to analyze data that were taken many decades ago, once again, with better models and better station positions, not available at the time of the data collection. This is the last SLR series produced on the basis of the old IERS Conventions 1996, the upcoming analysis uses the newly adopted IERS Standards and Conventions 2003 [McCarthy and Petit, 2004], which will be the basis for future TRF development and EOP reference.

References

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