The JCET/GSFC Satellite Laser Ranging TRF and EOP Series

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We present here the re-analysis of Satellite Laser Ranging (SLR) data to LAGEOS and LAGEOS 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. Secular changes in J_2 due to post-glacial relaxation have been observed since many years and similar changes in J_3, J_4 J_5, etc. are attributed to changes in the ice sheets of Greenland and Antarctica. 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 LAGEOS and LAGEOS 2 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 centre of mass of the Earth system (geocentre). These estimates provide a measure of the total motion due to all sources of mass transport within the Earth system and can be used to either complement the estimates from the future missions or to validate them through comparisons with their estimates for the same quantities. The data 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 for the GM, the geocentre (degree one terms), and the $C_{2,1}$, $S_{2,1}$, $C_{2,2}$, $S_{2,2}$ time series, compare them to variations inferred from geophysical processes, and examine their spectrum.

A miniature version of the presented poster is attached. For a more detailed discussion of the solution and results can be found in the recently published proceedings of the 2001 IAG Scientific Assembly: *Vistas for Geodesy in the New Millennium*, in [Pavlis, 2002].

Reference:

Pavlis, E. C. Dynamical Determination of Origin and Scale in the Earth System from Satellite Laser Ranging, in *Vistas for Geodesy in the New Millennium*, proceedings of the 2001 International Association of Geodesy Scientific Assembly, Budapest, Hungary, September 2-7, 2001, J. Adam and K.-P. Schwarz (eds.), Springer-Verlag, New York, 2002.

Poster Presentation

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Abstract

We present the new re-analysis of Satellite Laser Ranging (SLR) data to LAGEOS and LAGEOS 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. Secular changes in J_2 due to post-glacial relaxation have been observed since many years and similar changes in J_3, J_4, J_5, etc. are attributed to changes in the ice sheets of Greenland and Antarctica. 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 LAGEOS and LAGEOS 2 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). These estimates provide a measure of the total motion due to all sources of mass transport within the Earth system and can be used to either complement the estimates from the future missions or to validate them through comparisons with their estimates for the same quantities. The data 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 for the GM, the geocenter (degree one terms), and the $C_{2,1}$, $S_{2,1}$, $C_{2,2}$, $S_{2,2}$ time series, compare them to variations inferred from geophysical processes, and examine their spectrum.

MODELING STANDARDS:

- § IERS Conventions 1996 as close as possible
- § Identify and quantify the effect of exceptions
- § Use state-of-the-art force and s/c models
- § A priori Reference Frame: **ITRF2000**
- § Use the latest data releases from CDDIS

FORCE & MEASUREMENT *A PRIORI* MODELS:

Gravity from *EGM-96* and *GOT99.2* ocean tides
Extended ocean tides' model from hydrodynamics
Secular rates for $C_{2,0}$, $C_{2,1}$, $S_{2,1}$ and rotational deformation
Solar Pressure and Thermal Drag with LAGEOS' spin axes modeled by Vokrouhlicky's models
Earth Albedo (Knocke-Rubincam)
J2000 and 1996 Nutation Reference frame (DE403)
EOP from **IERS C04**
Ocean loading from **Scherneck** and **GOT99.2** tides
"Center-of-mass" and EOP tide-induced variations (**IERS**)
Adopt ILRS-info on calibrated measurement biases

DATA ANALYSIS:

Data analyzed in 7 ^{day} arcs (473 total), ***930103 - 020127***
State-vector estimated for each arc
Constant and 1 *cpr* along-track accelerations (per 2^d)
Cross-track 1 *cpr* accelerations (per 2^d)
Data biases estimated in combination (L-1 & 2)
Polar motion, UT1-UTC, Pole Rates and LOD estimated daily
Site positions and velocities estimated from 9 year span

TRF CONSTRAINTS APPLIED:

TRF 2001 Solution:

POSITIONS & VELOCITIES:

Minimum Constraints:

Latitude, Longitude & rates on **GGAO** (Greenbelt, MD) and,
Latitude & its rate for **Haleakala** (Hawaii)

EOP and EOP Rates:

Loose constraints on X_P,Y_P, X_P-rate, Y_P-rate, and LOD
UT1-UTC: One value per arc constrained to IERS C04

SUMMARY

§ The combined analysis of **SLR** data from **LAGEOS 1 & 2** produces accurate, high resolution determination of Earth kinematics (**EOP**) with **daily resolution**, and provides an independent source of EOP information (**x, y, LOD, xdot, ydot**) to IERS.

§ Comparisons to other **SLR** solutions and independent techniques indicate that the TRF **scale** uncertainty is at **< 1 ppb** and the weighted RMS difference in **position** and **velocity** is about **3 mm** and **1 mm/y** respectively. Weekly "geocenter" variations have a precision of **~1 mm** for X and Y , and **~2 mm** for Z. The estimated value of GM consistent with these results, is: **398600.4418 ± 0.0001 [10^9 m^3/s^2]**

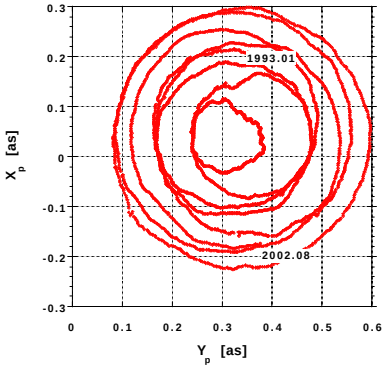
§ EOP series of daily averages have internal precision of **~120 µas** in Pole **x** and **y**, and the newly derived products of **x and y rates**, have an internal precision of **~200 µas/d**. The corresponding number for **LOD** is **90 µs**.

§ External comparisons to **IERS C 04** and **SPACE2001*** series, indicate that the accuracy of these estimates is **~0.5 mas** for **x** and **y**, **~170 µs** for **LOD**, and **~1 mas/d** for **xdot** and **ydot**.

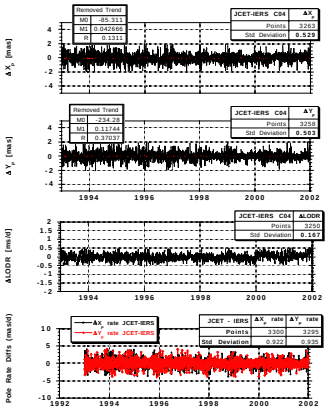
*Thanks to Richard Gross for this test. Special SPACE2001 series without SLR contributions.

Daily Polar Motion from SLR

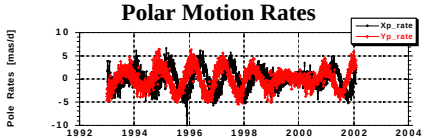
EOP (JCET) 02 L12



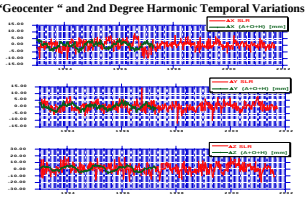
Differences from IERS C 04



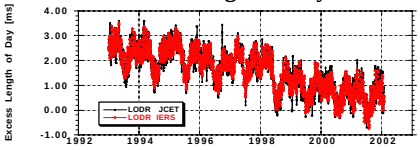
Polar Motion Rates

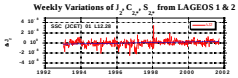


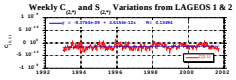
"Geocenter " and 2nd Degree Harmonic Temporal Variations

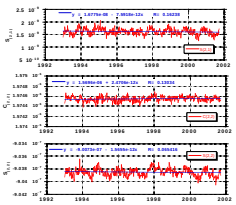


Excess Length of Day









Seven Parameter Helmert Transformation Results for (JCET) L 02 vs. ITRF2000

Parameters	T_X mm	T_Y mm	T_Z mm	D_S ppb	R_X mas	R_Y mas	R_Z mas
(JCET) L 02	-2.80	-3.91	-3.27	0.03	-0.06	-0.11	+0.15
σ	*4.68*	*4.57*	*4.21*	*0.66*	*0.18*	*0.19*	*0.15*

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