Improvements in SLR Data Modelling and Reduction for POD

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Abstract

The ILRS Analysis Working Group has recently revised some of the models that are used for the reduction of SLR data for its operational products. Some of the changes are due to the implementation of the new IERS 2010 Conventions and others are coming from improved models specific to the SLR technique. The benefits for Precision Orbit Determination (POD) of SLR-tracked missions can be significant. The main areas of improvement since our ITRF2008 contribution are the careful evaluation and remedy of tracking station systematic errors, the improvement of the target signature models, and the evaluation and implementation of environmental models that affect the measurements and the description of the forces acting on the satellite. A new re-analysis of the cannonball satellite data that extends from 1983 to present will serve as a validation period for these improvements, and will eventually be contributed to the next ITRF development effort. An evaluation of the commission error from the past, present and future ITRF on the mean sea level rate indicates a very significant improvement, although we are still far from reaching the accuracy levels required by GGOS. The ILRS has implemented a number of online "live documents" to keep track of each station's performance and a history of systematic errors, in order to achieve the highest accuracy possible. ILRS requires that all stations track the two LAGEOS satellites in order to be able to precisely calibrate them over time at the few millimeter level. The systematic errors that are thus obtained should be applied by all users of SLR data, to all tracking data from each site for the specified period, unless stated otherwise in the data base. The AWG ACs that contribute to the daily quality control (QC) of all SLR data, are now issuing standardized reports which are delivered electronically and should be consulted for very detailed characterization of each station's performance by the data users. We expect that the new models and the accompanying ancillary data will contribute significantly towards the improved POD for missions with very stringent accuracy requirements such as those monitoring long-term sea-level change.

NEW MODELING STANDARDS:

- **IERS Conventions 2003** (except gravity model)
- **GRACE RL04-based** gravity model
- Use state-of-the-art force and s/c models
- A priori Reference Frame: **ITRF2008S (SLRF2008)**
- Use the latest data releases from CDDIS

FORCE & MEASUREMENT *A PRIORI* MODELS:

Gravity from *GRACE* and *GOT4.7* ocean tides

Extended ocean tides' model from hydrodynamics, atmospheric tides included

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 LOSSAM models

Earth Albedo (Knocke-Rubincam)

J2000 Reference frame (DE403)

EOP (*a priori*) from **IERS C04**

Ocean loading from **GOT4.7** tides (*R. Ray/GSFC)*)

"Geocenter" and EOP tide-induced variations (**IERS--Ray model**)

Improved Atmospheric Refraction zenith delay and mapping function (**Mendes & Pavlis, 2004)**

Adopted ILRS-info on calibrated measurement biases (*a priori*)

ETALON 1 & ETALON 2

DATA ANALYSIS:

Analyze 7 day arcs in ***930103 - end of 2009***

State-vector estimated for each arc

Constant and 1 *cpr* along-track accelerations (per 3.5d)

Cross-track 1 *cpr* accelerations (per 3.5d)

Data biases estimated in combination (L-1 & 2, no E1&2)

Polar motion, [UT1-UTC], and **LOD** estimated **daily**

Site positions and velocities estimated from the entire data span

TRF CONSTRAINTS APPLIED:

TRF Solution:

POSITIONS & VELOCITIES:

Minimum Constraints:

Latitude, Longitude & their rates for **GGAO** (Greenbelt, MD) and,

Latitude & its rate for **Haleakala** (Hawaii)

EOP and EOP Rates:

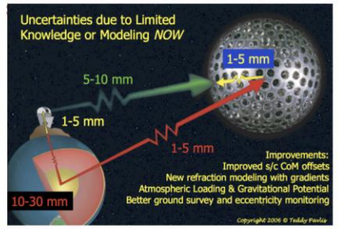
Loose constraints on X_P, Y_P, and LOD (practically free)

UT1-UTC: Estimated to avoid implicit "fixing" of the LOD to *a priori*

LAGEOS & LAGEOS 2

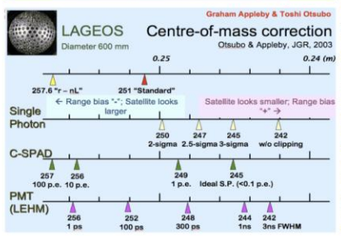
We gratefully acknowledge the support of the ILRS and their network for making their SLR tracking data available to us for this study, as well as the GRACE Mission Project for the release of GSM results.

SLR MEASUREMENT ERROR BUDGET ESTIMATES



Stn pad ID	Name	Pulse length (ps)	Detector	Regime (single, few, multi)	Editing Level (+/-)	Calib. St. error (mm)	LAGEOS St. error (mm)	LAGEOS CoM range (mm)	LAGEOS CoM ADOPTED (mm)
1873	Simeiz	350	PMT	No CNTL	2.0	60	70	248-344	248
1884	Riga	130	PMT	CNTLD s-mm	2.0	10	15	252-348	252
7090	McDonald	200	MCP	CNTLD s-mm	3.0	8.5	13	250-346	248
7090	Yarragadee	200	MCP	CNTLD 1-mm	3.0	4.5	10	250-346	249
7105	Greenbelt	200	MCP	CNTLD 1-mm	3.0	5	10	250-346	249
7110	Mon. Peak	200	MCP	CNTLD 1-mm	3.0	5	10	250-346	249
7124	Tahiti	200	MCP	CNTLD 1-mm	3.0	5	10	250-346	249
7237	Changchung	200	CSPAD	CNTLD s-mm	2.5	10	15	250-245	248
7249	Beijing	200	CSPAD	No CNTL, m	2.5	10	15	250-245	248
7356	Urumqui	30	CSPAD	No CNTL	2.5	15	20	248-247	251
7405	Concepton	200	CSPAD	CNTLD s-mm	2.5	10	15	250-244	248
7501	Harteb.	200	PMT	CNTLD 1-mm	3.0	5	10	250-344	247
7808	Metsahovi	50	PMT	CNTLD s-mm	2.5	15	20	252-348	252
7810	Zimmerwald	350	CSPAD	CNTLD s-mm	2.5	10	15	248-344	251
7811	Borowiec	40	PMT	No CNTL, m	2.5	15	20	252-348	252
7824	San Fernando	100	CSPAD	No CNTL, s-mm	2.5	30	35	252-348	252
7825	Stromlo	35	PMT	CNTLD s-mm	2.5	4	10	252-348	252
7838	Simosato	100	MCP	CNTLD s-mm	3.0	20	40	252-348	252
7839	Graz kHz	10	CSPAD	No CNTL, m	2.2	3	9	252-348	252
7839	Graz kHz	10	CSPAD	No CNTL s-mf	2.2	3	9	252-348	252
7840	Herstmonceux	100	CSPAD	CNTLD s	3.0	6	10	248-344	248
7840	Hx kHz	10	CSPAD	CNTLD s	-1.5 +2.5	3	9	248-344	248
7841	Potsdam 3	50	PMT	CNTLD s-mf	2.5	10	18	254-348	251
7941	Matera	40	MCP	CNTLD m	3.0	1	3	252-348	250
8834	Wettzell	80	MCP	No CNTL 1-mm	2.5	10	20	248-348	250

SLR's EQUIVALENT TO GNSS' ANTENNA PHASE CENTER

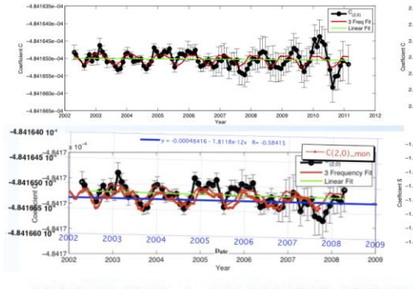


Stn pad ID	Name	Pulse length (ps)	Detector	Regime (single, few, multi)	Editing Level (+/-)	Calib. St. error (mm)	ETALON CoM range (mm)	ETALON CoM ADOPTED (mm)
1873	Simeiz	350	PMT	No CNTL	2.0	60	580-680	596
1879	Altay	150	PMT	No CNTL	2.5	20	600-610	605
1884	Riga	130	PMT	CNTLD s-mm	2.0	10	602-612	607
7090	McDonald	200	MCP	CNTLD s-mm	3.0	8.5	598-608	603
7090	Yarragadee	200	MCP	CNTLD 1-mm	3.0	4.5	598-608	603
7105	Greenbelt	200	MCP	CNTLD 1-mm	3.0	5	598-608	603
7110	Mon. Peak	200	MCP	CNTLD 1-mm	3.0	5	598-608	603
7119	Holeakala	200	MCP	CNTLD 1-mm	3	4.5	598-608	603
7124	Tahiti	200	MCP	CNTLD 1-mm	3.0	6	598-608	603
7237	Changchung	200	CSPAD	CNTLD s-mm	2.5	10	570-580	575
7249	Beijing	200	CSPAD	No CNTL, m	2.5	10	570-580	575
7355	Urumqui	30	CSPAD	No CNTL	2.5	15	576-586	581
7356	Tanegashima	80	MCP	No CNTL	3	3	602-612	607
7405	Concepton	200	CSPAD	CNTLD s	2.5	15	573-577	575
7406	San Juan	40	CSPAD	No CNTL	2.5	6	576-586	581
7501	Harteb.	200	PMT	CNTLD 1-mm	3.0	5	598-608	603
7808	Metsahovi	50	PMT	CNTLD s-mm	2.5	15	602-612	607
7810	Zimmerwald	350	CSPAD	CNTLD s-mf	2.5	20	570-574	572
7811	Borowiec	40	PMT	No CNTL f	2.5	18	602-612	607
7824	San Fernando	100	CSPAD	No CNTL s-mm	2.5	30	573-583	578
7825	Stromlo	10	CSPAD	CNTLD s-mm	2.5	4	578-586	581
7838	Riyadh	100	CSPAD	CNTLD s-mm	2.5	10	573-583	578
7839	Grasse	50	CSPAD	CNTLD s-mm	2.5	6	604-613	609
7839	Potsdam	35	PMT	CNTLD s-mm	2.5	10	604-613	609
7839	Simosato	100	MCP	CNTLD s-mm	3.0	20	602-612	607
7839	Graz	35	CSPAD	No CNTL, m	2.2	3	580-579	574
7839	Graz kHz	10	CSPAD	No CNTL s-mf	2.2	3	571-577	574
7840	Herstmonceux	100	CSPAD	CNTLD s	3.0	6	583-587	585
7840	Hx kHz	10	CSPAD	CNTLD s	-1.5 +2.5	3	583-587	585
7841	Potsdam 3	50	PMT	CNTLD s-mf	2.5	10	606-612	609
7941	Matera	40	MCP	CNTLD m	3.0	1	607-613	610
8834	Wettzell	80	MCP	No CNTL 1-mm	2.5	10	603-613	608

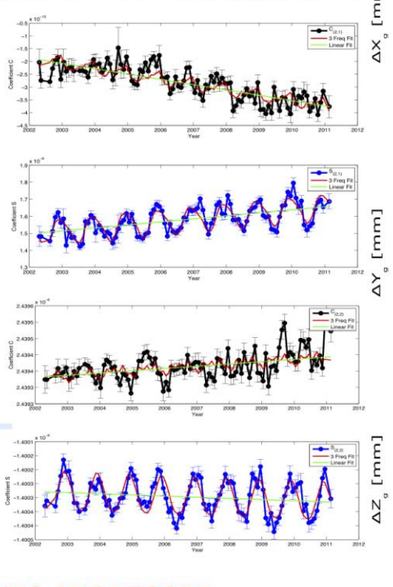
GRACE CSR/RL04 Monthly Gravity Models

We used the nine-year monthly series from CSR's release RL04 available from April 2002 up to early 2011, along with the associated de-aliasing product and estimated a set of mean coefficients at epoch 2000.0, secular linear trends and annual, semi-annual and seasonal terms for the entire 60 x 60 field.

GRACE CSR/RL04 J2 vs. SLR-derived J2



GRACE 2nd DEGREE HARMONICS



Atmospheric Loading Tests with LAGEOS SLR Data and ECMWF Grids

Difference in the RMS of fit of weekly arcs of LAGEOS SLR for 2001 & 200

and four Atmospheric loading treatments (one being NO loading)

Variable	Points	Mean	Median	RMS	Std Deviatio
ΔRMS v0-NO	52	3.4	2.7	4.45	2.87
ΔRMS v1-NO	104	2.9	2.1	4.31	3.16
ΔRMS v2-NO	52	2.7	1.7	4.09	3.08
ΔRMS v1-v0	52	0.4	0.0	0.92	0.82
ΔRMS v2-v1	52	1.7	1.4	2.58	1.96

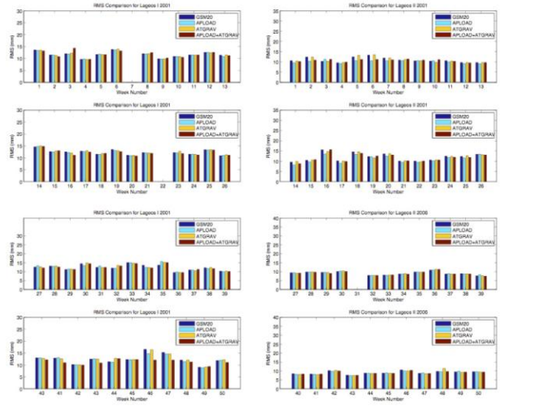
"v0": 1970/01 - 2002/08: ECMWF Reanalysis (ERA40), with a spatial resolution of 1.125 degrees

"v1": 2000/12 - 2006/12: ECMWF Operational, with a spatial resolution of about 0.350 degrees

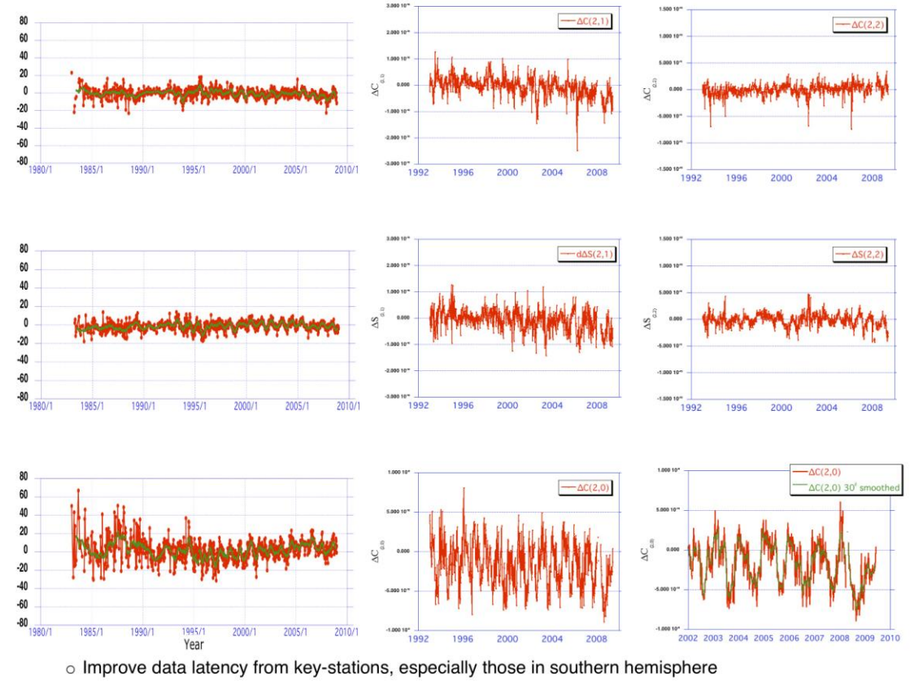
"v2": 2005/10 - now: ECMWF Operational, with a spatial resolution of about 0.250 degrees

NCEP Reanalysis
- 3-D displacements:
  http://gemini.gsfc.nasa.gov/aplo/ (SLR, GPS, VLBI & Doris stations)
- Time-variable gravity field:
  http://gemini.gsfc.nasa.gov/agra/
  From Petrov & Boy, J. Geophys. Res., 2004.

ECMWF ERA40 (and soon ERA-interim) and operational models
- 3-D displacements (Atmosphere):
  ftp://ftp-eost.u-strasbg.fr/jpboy/APLO/ (SLR, VLBI & Doris stations)
- Time-variable gravity field:
  ftp://ftp-eost.u-strasbg.fr/jpboy/AGRA/ (Atmosphere)
  ftp://ftp-eost.u-strasbg.fr/jpboy/HGRA/ (Hydrology)



SLR(JCET) WEEKLY SERIES FOR ORIGIN OFFSETS & 2nd DEGREE HARMONICS



MODELING & ANALYSIS ISSUES ADDRESSED:

- **Historical biases in older data and their correct handling in new analyses is ILRS' top priority at present, with significant improvements since last ITRF**
- Ensuring the consistent modeling across ACs at all levels and for all products
- Improve data latency from key-stations, especially those in southern hemisphere
- Use state-of-the-art force and s/c models appropriate for each tracking station
- Including temporally varying geophysical signals (atmosphere, ocean, GIA, etc.)
- Use improved modeling to allow LEO's to contribute to official products

2011 Ocean Surface Topography Science Team Meeting
19-21 October 2011
San Diego,CA, USA