SLRF2008: The ILRS Reference Frame for SLR POD Contributed to ITRF2008

E. C. Pavlis

Joint Center for Earth Systems Technology - JCET and NASA Goddard, USA epavlis@umbc.edu

Abstract

Since over two decades, Satellite Laser Ranging (SLR) data contribute to the definition of the Terrestrial Reference Frame (TRF). The development of ITRF2005 ushered a new era with the use of weekly contributions, allowing greater flexibility in the relative weighting and the combination of information from various techniques. Moreover, the need of a unique, official, representative solution for each Technique Service, based on the rigorous combination of the various Analysis Centers' contributions, gave the opportunity to all techniques to verify, as a first step, the intra-technique solution consistency and, immediately after, to engage in discussions and comparison of the internal procedures, leading to a harmonization and validation of these internal procedures. In many occasions, the time series approach joint with the intra- and inter-technique comparison steps also highlighted differences that previously went unnoticed, and corrected incompatibilities. During the past year we worked on the ILRS contribution to a second TRF developed in this way, the ITRF2008. The ILRS approach is based strictly on the current IERS Conventions 2003 and our internal standards. The Unified Analysis Workshop in 2007 stressed a number of areas where each technique needed to focus more attention in future analyses. In the case of SLR, the primary areas of concern were tracking station biases, extending the data span used in the analysis, and target characteristics. The present re-analysis extends from 1983 to 2009, covering a 25-year period, the longest for any of the contributing techniques; although the network and data quality for the 1983-1993 period are significantly poorer than for the latter years, the overall SLR contribution will reinforce the stability of the datum definition, especially in terms of origin and scale. Engineers and analysts have also worked closely over the past two years to determine station biases, rationalize them through correlation with engineering events at the stations, and validate them through analysis. A separate effort focused on developing accurate satellite target signatures for the primary targets contributing to the ITRF product (primarily LAGEOS 1 & 2). As a companion to the release of the new TRF, a number of data bases document biases that need to be applied to specific stations' SLR data over prescribed time intervals, in order to achieve the highest accuracy possible. ILRS requires that the stations track the two LAGEOS satellites in order to be able to precisely calibrate them over time at the few millimeter level. The biases that are thus obtained should be applied to all tracking data from these sites for the specified period, unless stated otherwise in the data base. The new TRF 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.

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: **ITRF2005S (SLRF2005)**
- 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

LAGEOS & LAGEOS 2

DATA ANALYSIS:

Analyzed 7 day arcs in **1993 - end of 2008** and 15 day arcs in **1983 - 1992**
State-vector estimated for each arc
Data biases estimated according to ILRS AWG rules (L-1 & 2, no E1&2)
Polar motion and **LOD** estimated **daily** in **1993 – 2008** and every **3 days** in **1983 – 1992.**
Site positions estimated for the middle of each arc
Loose constraints (**> 1 m**) applied on coordinates, X_P, Y_P, and LOD only
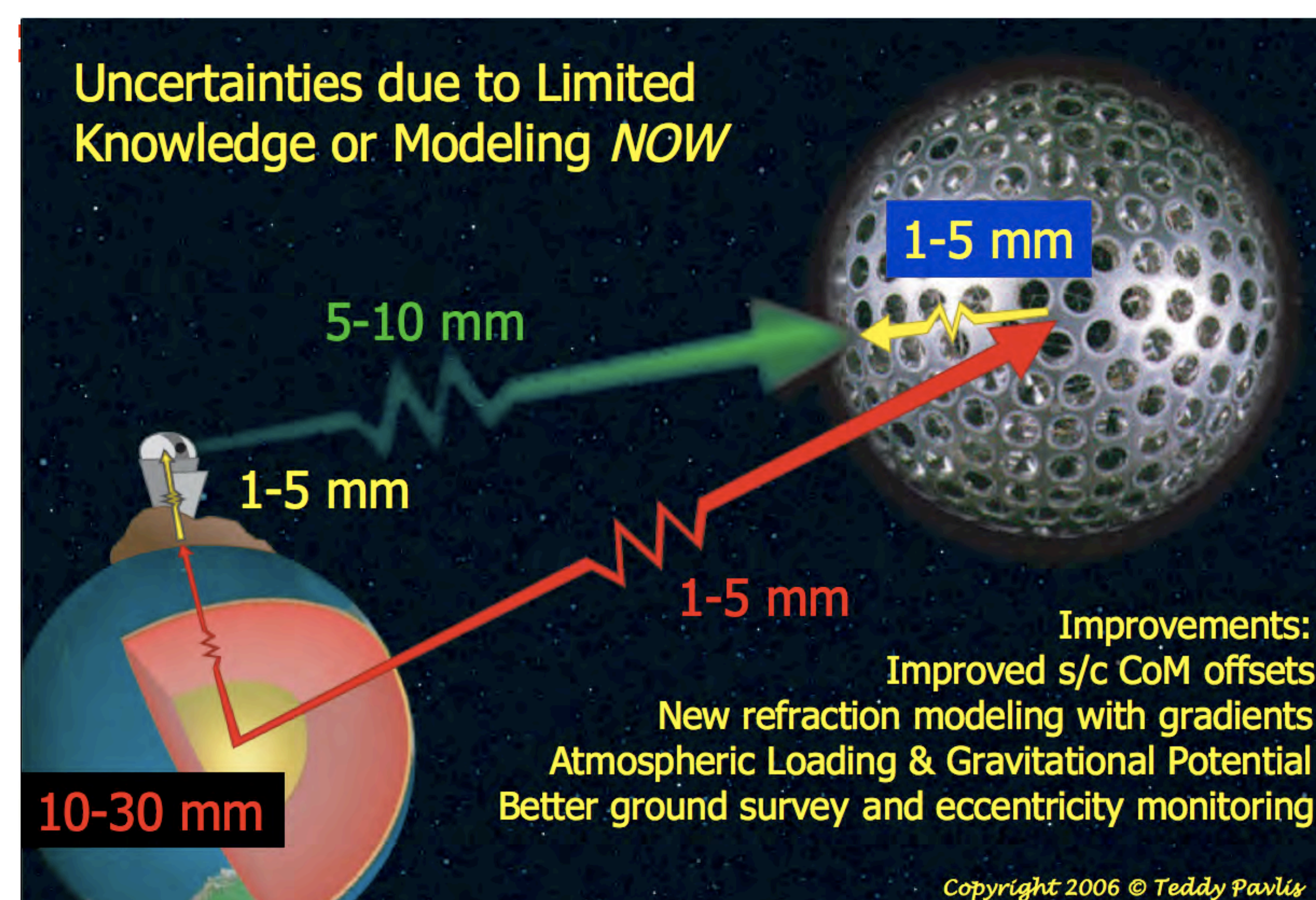
CONTRIBUTING ANALYSIS CENTERS :

1983 – 1993: ASI, DGFI, GA, GFZ, GRGS, JCET and NSGF

1993 – 2009: ASI, DGFI, GA, GFZ, JCET and NSGF

COMBINATIONS (INDEPENDENT) BY: ASI & DGFI

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**
- **Biases that was not possible to obtain from engineering logs were estimated from multi-year solutions and applied a priori by all ACs**
- Ensuring the consistent modeling across ACs at all levels and for all products (not a simple task as it turns out!)
- Uniform data weighting, using ILRS AWG adopted standards for the core sites versus infrequent contributors (associate sites)
- Use state-of-the-art force and s/c models appropriate for each tracking station (now applied only to Herstmonceux, 7840)
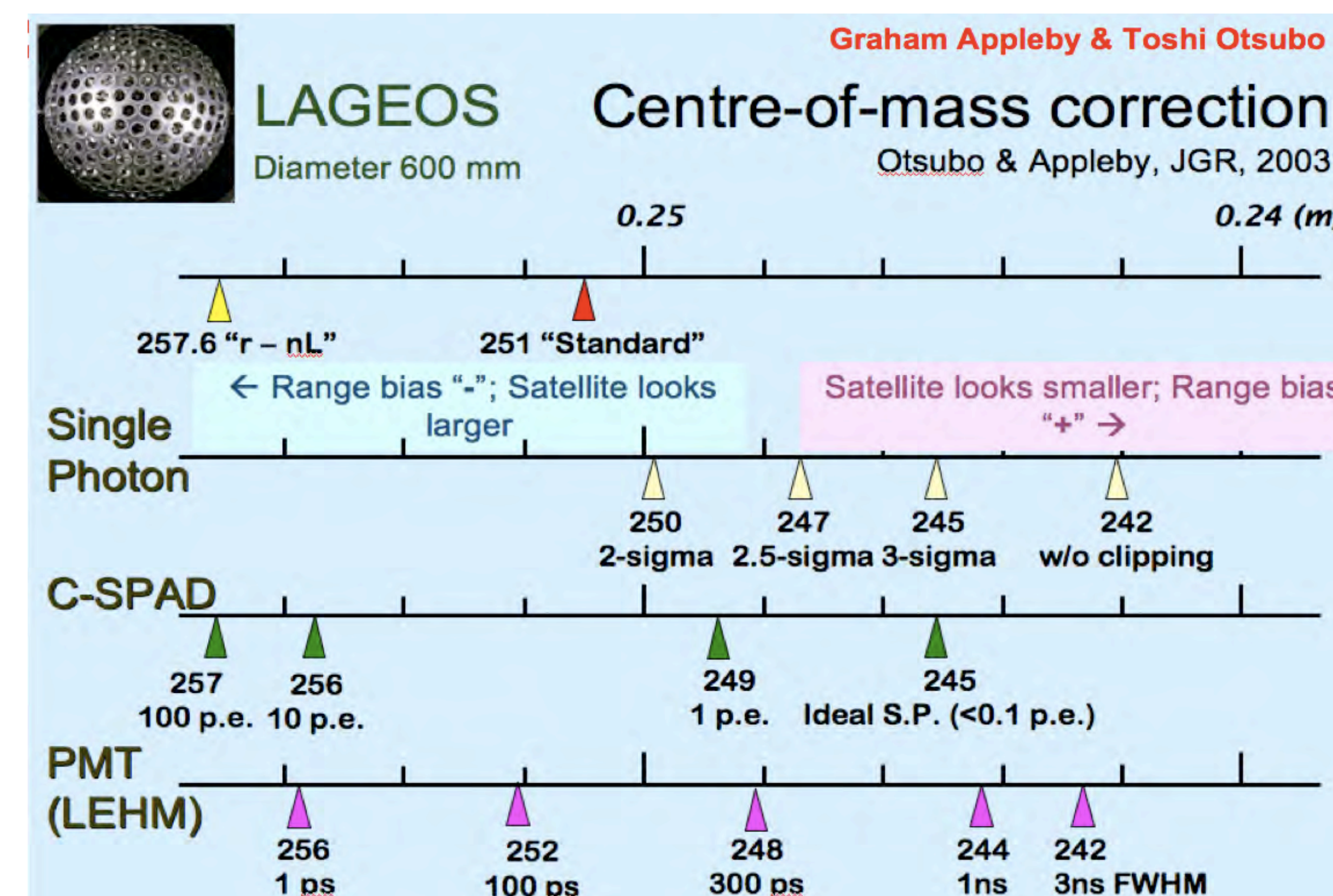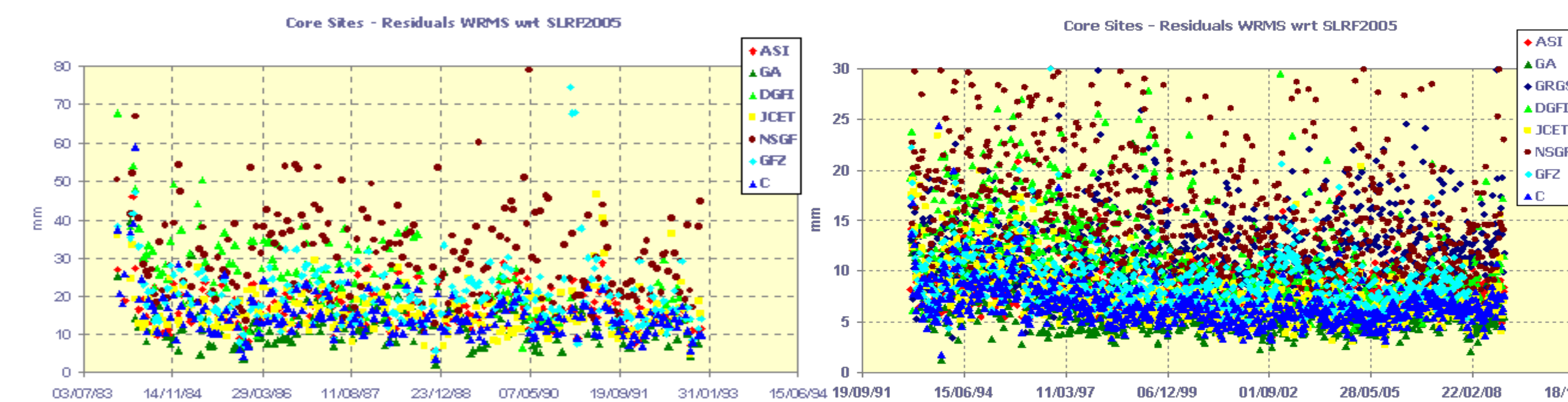
SLR MEASUREMENT ERROR BUDGET ESTIMATES

Uncertainties due to Limited Knowledge or Modeling *NOW*
1-5 mm
5-10 mm
1-5 mm
1-5 mm
10-30 mm
Improvements:
Improved s/c CoM offsets
New refraction modeling with gradients
Atmospheric Loading & Gravitational Potential
Better ground survey and eccentricity monitoring
Copyright 2006 © Teddy Pavlis

TARGET SIGNATURE:

SLR's EQUIVALENT TO GPS' ANTENNA PHASE CENTER UNCERTAINTY

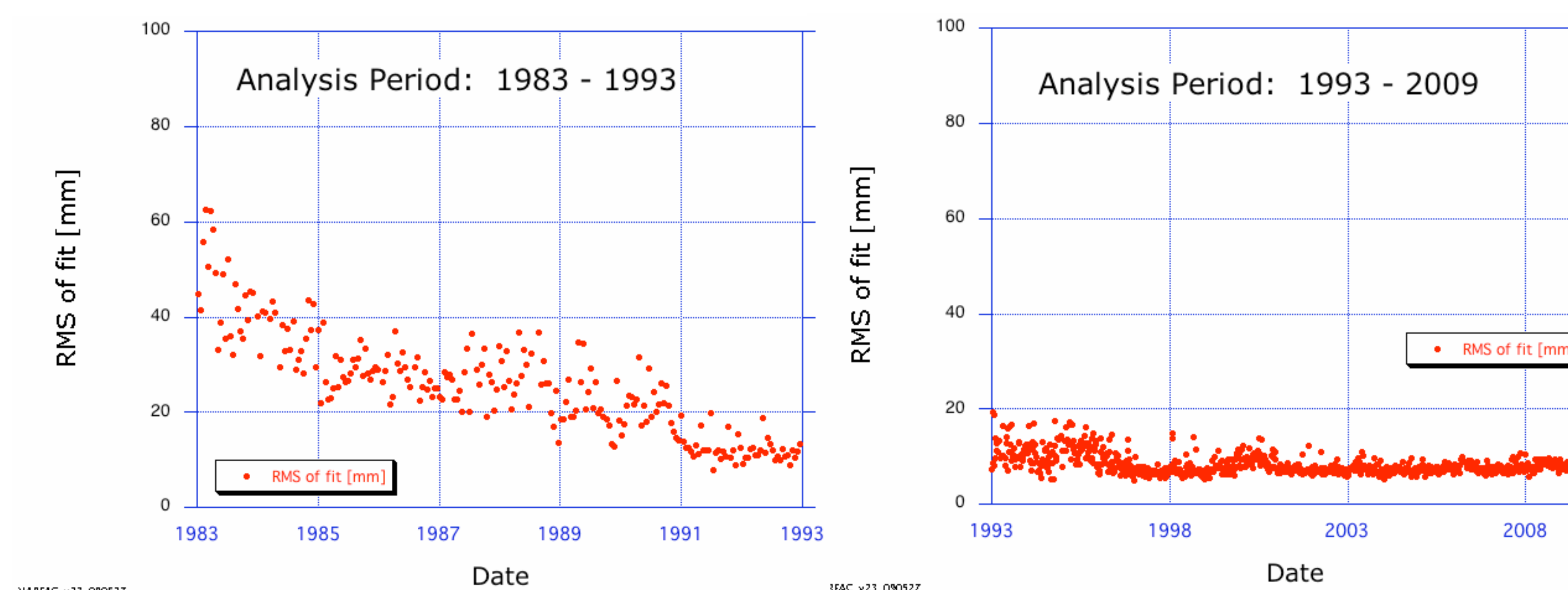**Correction depends on satellite geometry as well as station's mode of operation !!!**

Graham Appleby & Toshi Otsubo

LAGEOS Centre-of-mass correction
Diameter 600 mm Otsubo & Appleby, JGR, 2003
0.25 0.24 (m)
257.6 "r – nL" 251 "Standard"
← Range bias "-"; Satellite looks larger
Satellite looks smaller; Range bias "+" →

Single Photon: 250 2-sigma, 247 2.5-sigma, 245 3-sigma, 242 w/o clipping
C-SPAD: 257 100 p.e., 256 10 p.e., 249 1 p.e., 245 Ideal S.P. (<0.1 p.e.)
PMT (LEHM): 256 1 ps, 252 100 ps, 248 300 ps, 244 1ns, 242 3ns FWHM

INDIVIDUAL CORE SITE WRMS vs SLRF2005

Core Sites - Residuals WRMS wrt SLRF2005

HELMERT PARAMETERS Tx, Ty, Tz & SCALE WITH RESPECT TO A PRIORI (SLRF2005)

ILRSA - Weekly Helmert Parameters
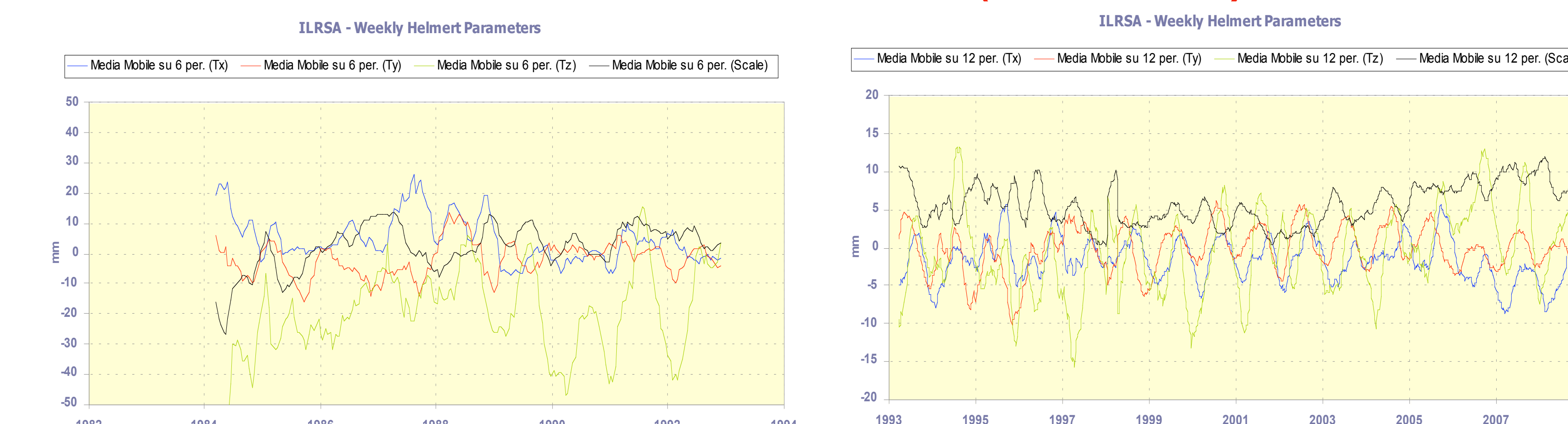
SLR DATA QUALITY OVER THE PERIOD 1983 - 2009

Analysis Period: 1983 - 1993
Analysis Period: 1993 - 2009
RMS of fit [mm]
Date

SUMMARY

- The ILRS developed a consistent reanalysis product of SLR data from **LAGEOS 1 & 2** and **ETALON 1 & 2** for the period 1983 to 2009, as our official contribution to ITRF2008.
- Preliminary evaluation of this analysis indicates a product that is superior to what was contributed to ITRF2005, primarily due to improved handling of instrument biases.
- Once the individual components are finalized, they will be used to develop an SLR-only frame (SLRF2008), which will be referenced to the same datum as ITRF2008, for use by SLR analysts and POD of SLR targets.
- The difference between SLRF2008 and ITRF2008 will be that the former will be maintained on a regular basis to include new sites as they become available and to correct for any errors, biases, etc. that may occur after the finalization of ITRF2008.
- For the highest possible accuracy in POD (typical LAGEOS weekly fits at 6-7 mm), the frame should be used together with its associated "geocenter" series, which will be made available upon its release and extended by means of the official ILRS weekly products.

Ocean Surface Topography From Space

International Laser Ranging Service

OSTM JASON-2