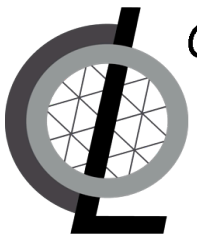
GEODYN & Multitechnique Processing for the Reference Frame

F.G. Lemoine, D.D. Rowlands, D.E. Pavlis,
S.B. Luthcke, J.J. McCarthy, N.P. Zelensky,
D.S. Chinn, D.S. Macmillan, K. Le Bail



Combination at the Observation Level

IERS Working Group

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What is GEODYN?

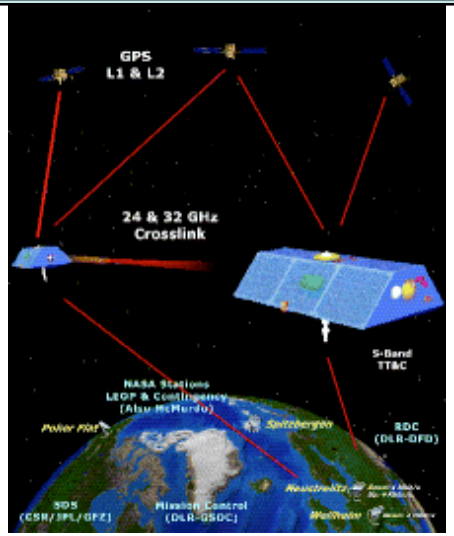
An Orbit Determination and Geodetic Parameter Estimation Software.

Better Way to Look at it :

GEODYN is a software which models the range and range rate between points:

Point 1	Point 2
Satellite	Fixed Earth tracking station
Satellite	Location of radar or laser altimeter surface return
Satellite	A second satellite

GEODYN models the widest range of tracking data types including interplanetary and altimetry. ***It can take advantage of multiple data types in integrated solutions. Tracking data can be complex linear combinations of the previous range types.***



SOLVE is part of GEODYN too …

SOLVE

Manipulates sets of normal equations generated by GEODYN…

Writes constraint equations…

Inverts large normal equations…

- **Provides parameter solutions**
- **Provides co-variances**

$$[A^T \bullet W \bullet A + W_p] \bullet \Delta X = A^T \bullet W \bullet R + W_p \bullet R_p$$

A BRIEF HISTORY OF GEODYN DEVELOPMENT

GEODYN dates back to the early 70s.

- Completely redesigned in early 80s to exploit "modern" mainframes.

Mainstay for Analysis of Satellite Tracking Data & Determination of Geophysical Parameters (Tracking stations, EOP, Gravity Field & Tidal parameters …)

- GEML2, GEMT1 GEMT3, JGM1-2, EGM96 Gravity solutions.
- GRACE KBRR data processing for time-variable gravity recovery.
- Tidal solutions using Starlette …. and GRACE.
- Orbit Determination for SLR targets (Lageos1/2, Starlette, Stella..)
- DORIS (1-w rrate grnd-> s/c) added before launch of T/P.
- Altimetry Satellites POD (TOPEX/Poseidon, Jason-1, Jason-2, GFO).

GPS, laser altimetry capability added in late 90s and early 2000s

- GPS capability added and used to compute "1cm" JASON orbits.
- Laser altimetry capability makes GEODYN the only OD software able to calibrate pointing on satellite laser altimeters.
- ICEsat mission relies on Goddard for pointing calibration.

SUMMARY OF "*RECENT (≥ 2003)*" UPGRADES (1)

- **IERS 2003 standards**

  Earth tides, Ocean tides, IAU 2000 Precession/nutation.

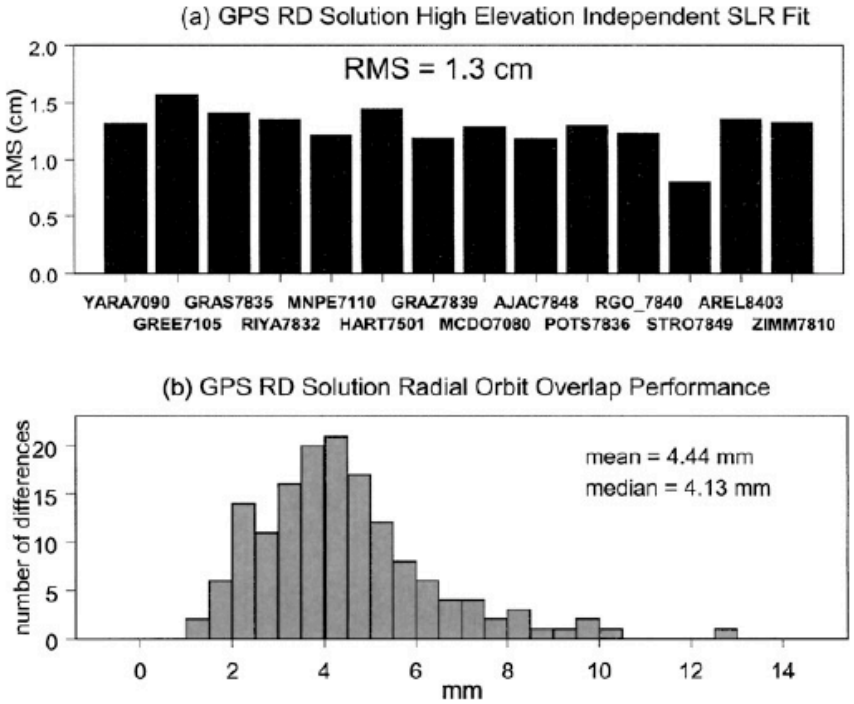
- **Accelerometry (CHAMP & GRACE)**
- **Satellite-to-satellite tracking (KBRR data) for GRACE.**
- **Ocean pole tide.**
- **Atmospheric loading.**
- **Arc parameter Constraint equations (exponential decay + process noise sigma) … Drag, Empirical Accelerations, Troposphere, Solar radiation.**
- **Force modelling: Satellite-specific models (UCL for Jason-1 & ENVISAT); Self-shadowing (applied to MRO & Odyssey).**
- **Laser altimetry processing for geolocation (includes attitude determination) (ICESAT, LRO, DESDyNI, LiveX).**

SUMMARY OF "*RECENT (≥ 2003)*" UPGRADES (2)

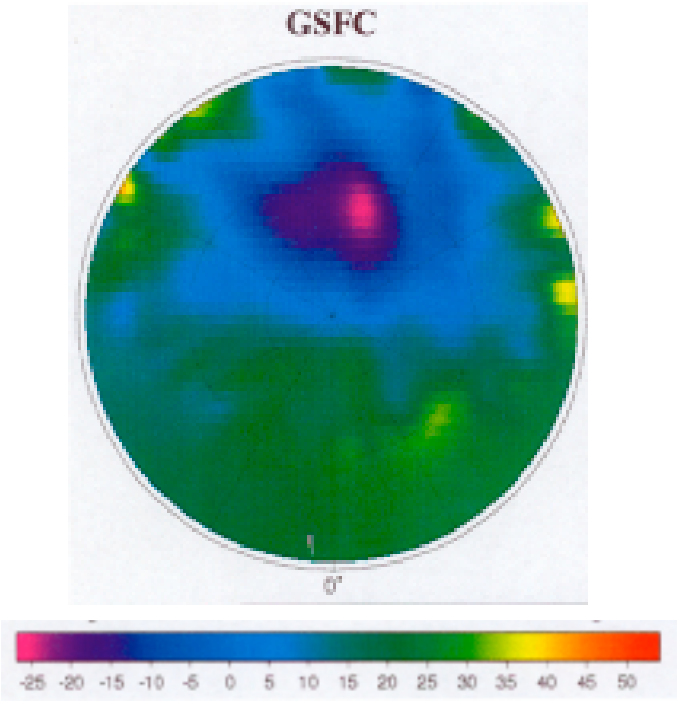
GEODYN VLBI Capability

- **VLBI code has been implemented to allow estimation of VLBI parameters (site positions, EOP, clocks, wet zenith troposphere, gradients, and radio source positions).**
- **Comparison of theoretical VLBI time delays computed in GEODYN agree with VLBI Calc/SOLVE with an rms diff of 1.8 psec.**
- **Average scaled (by parameter sigma) difference between parameter values estimated in Geodyn and Calc/Solve solutions for each 24 hour VLBI experiment session is 1/10.**
- **Capability was used to simulate reference frame error of the VLBI+SLR component of a next generation geodetic network for NASA (*Pavlis & Kuzmicz-Cieslak, 2008*).**
- **Poster at AGU on SLR+VLBI results.**

Example: GPS/SLR Processing with Jason-1



Top: **SLR High-Elev (> 60º) fit for GPS red-dynamic orbits, RMS 1.3 cm**. Bottom: **Radial orbit overlaps, median, 0.44 cm. (Jason-1 cycles 8-24)**

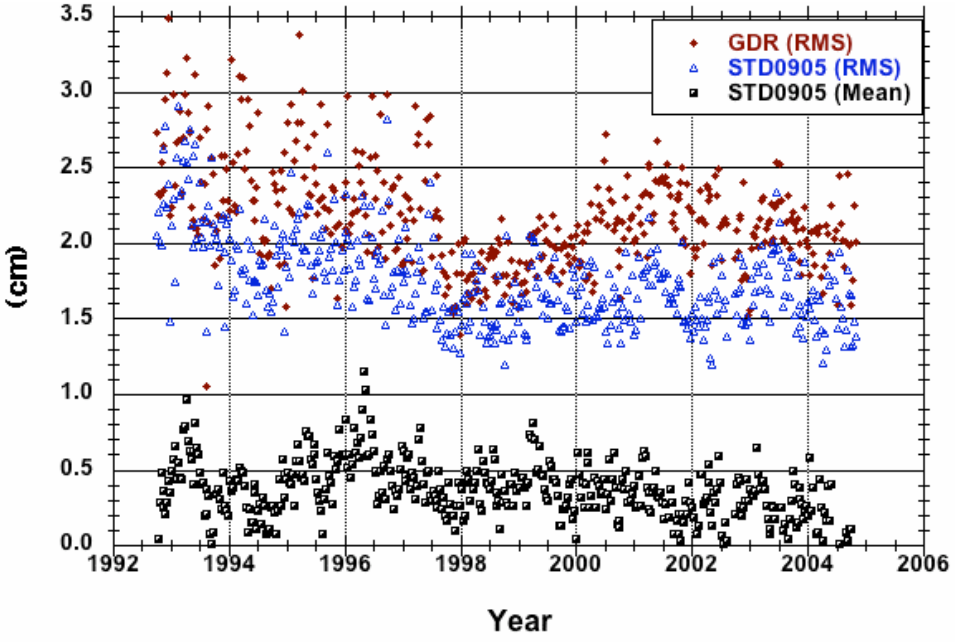


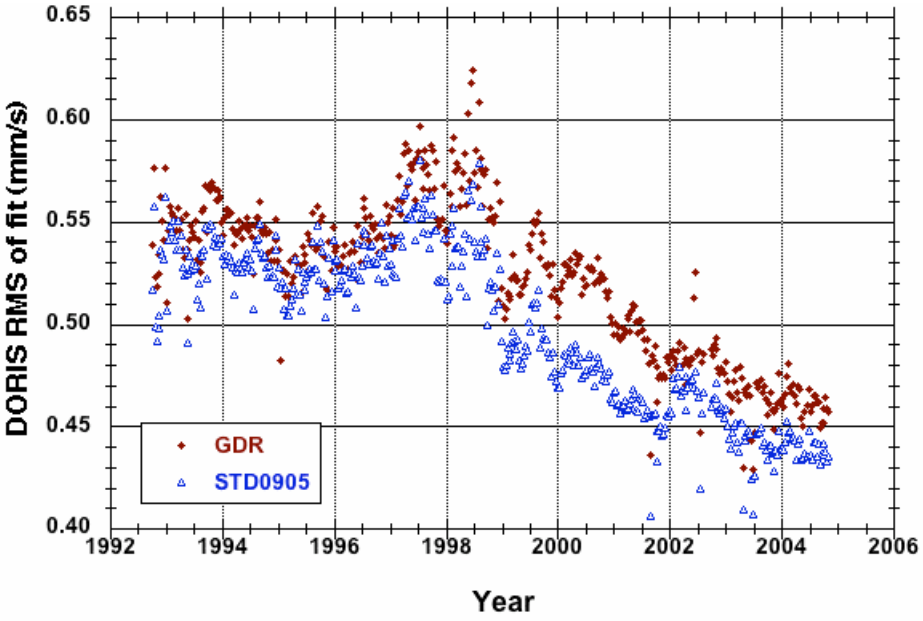
Empirically derived GPS phase map for Jason-1 (units mm)

Luthcke, S.B., Zelensky, N.P., Rowlands, D.D., et al., "The 1-cm orbit: Jason-1 precision orbit determination using GPS, SLR, DORIS, and altimeter data", *Marine Geodesy, 26(3-4),* 261-284, 2003

Example: SLR & DORIS Processing (TOPEX/Poseidon)

T/P SLR & DORIS RMS of fit, 1992-2004: GDR vs. STD0905 Processing (Sept. 2009)

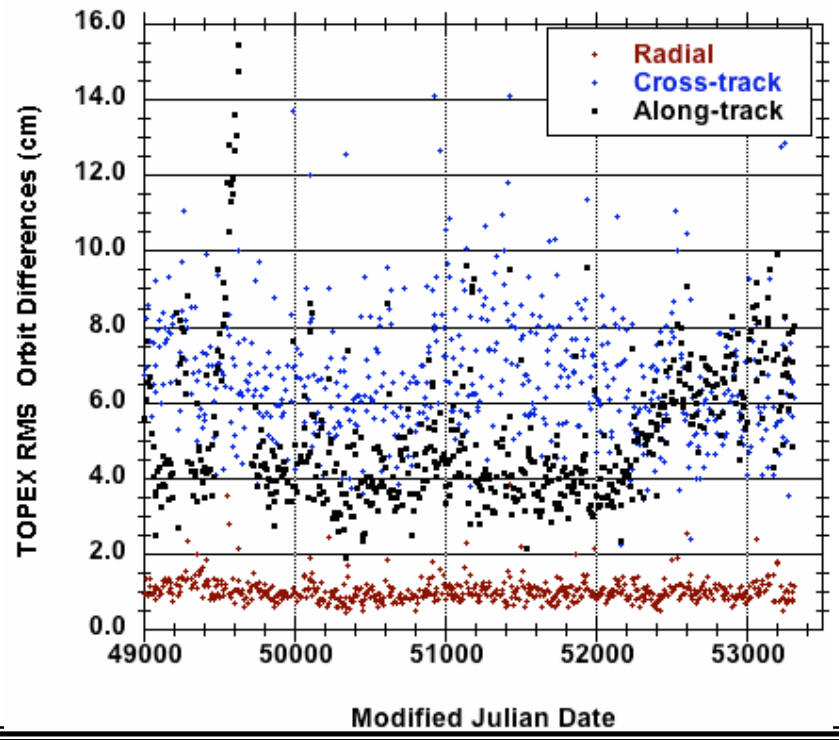


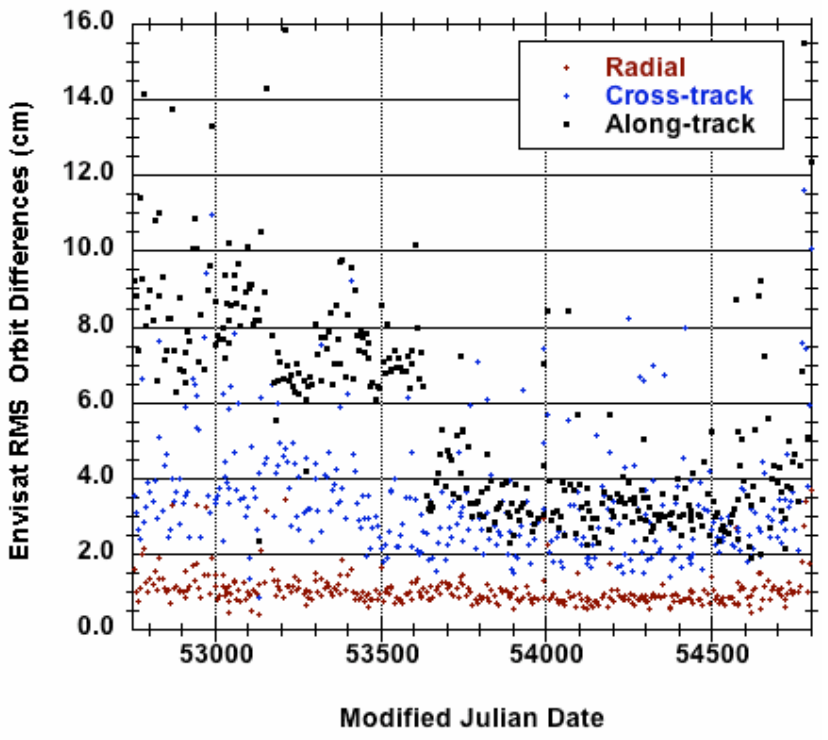


Lemoine et al., "Towards Development of a Consistent Orbit Series for TOPEX/Poseidon, Jason-1, and Jason-2" , *Adv. Space Res., DORIS special issue,* submitted, 2009.

Example: SLR & DORIS Processing
(TOPEX/Poseidon & Envisat)

Orbit Differences: DORIS-only vs. SLR+DORIS



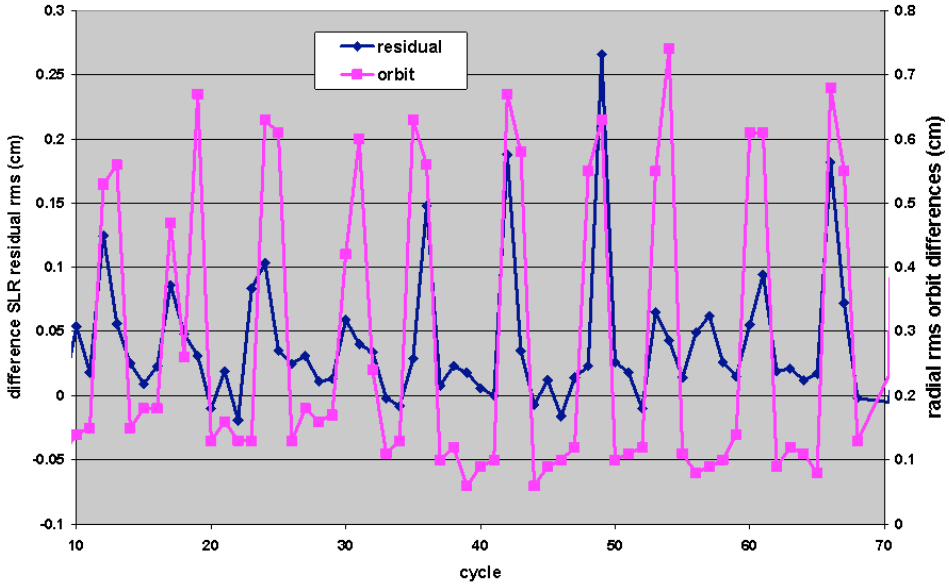


Le Bail K., Lemoine F.G., Chinn, D.S., "GSFC DORIS Contribution to ITRF2008" , *Adv. Space Res., DORIS special issue,* submitted, 2009.

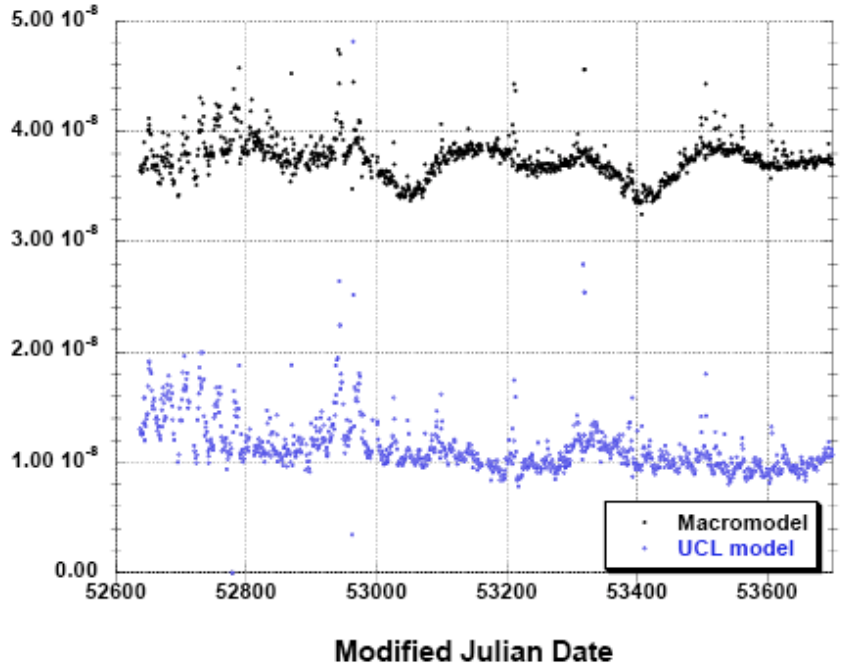
Example: Jason-1 & Envisat Model Improvement

Radiation pressure mismodelling induces error in TRF parameters, esp. TZ at draconitic periods. (annual for DORIS sats: (SPOTs, Envisat); 118 days for T/P).
See Gobinddass,M.L. et al. (2009, Adv. Space Research) & Herring, T. (2009, EGU presentation)

Figure 4. **J1 SRP UCL -vs- Panel model**
(+ means UCL improvement in residuals)
Jason-1 (panel-ucl) differences



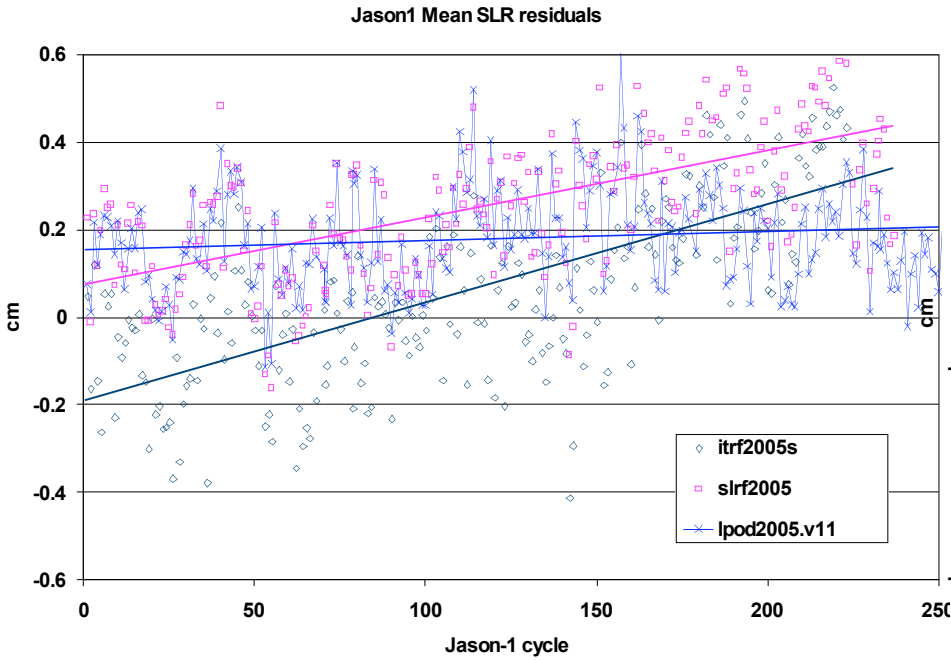
Envisat daily Along-track OPR amplitude

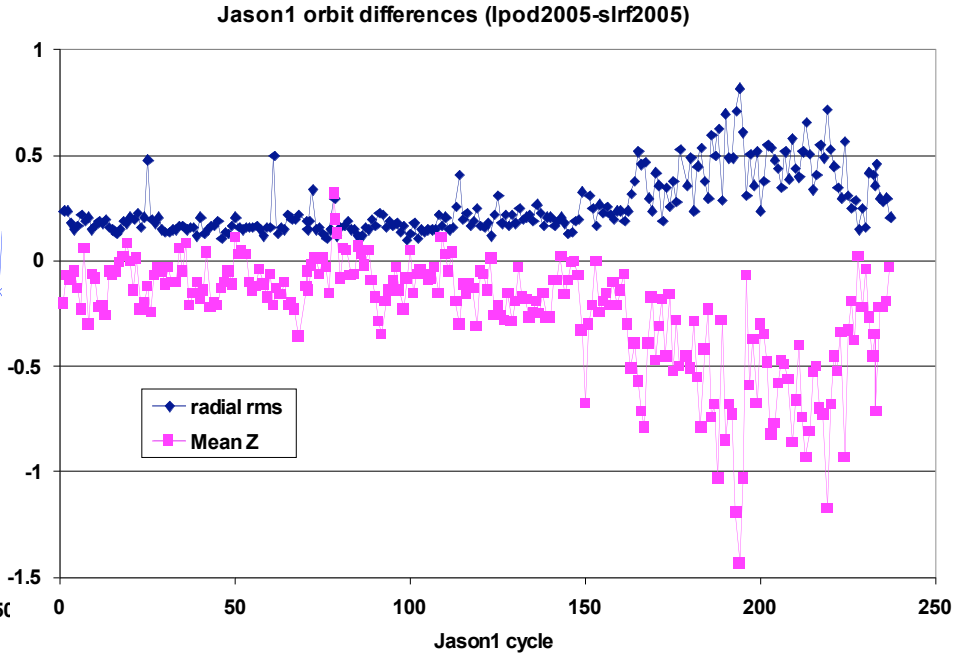


Zelensky N.P.., Lemoine F.G., Chinn, D.S., "DORIS/SLR POD Modeling Improvements for Jason-1 & Jason-2" , *Adv. Space Res., DORIS special issue,* submitted, 2009.

Le Bail K., Lemoine F.G., Chinn, D.S., "GSFC DORIS Contribution to ITRF2008" , *Adv. Space Res., DORIS special issue,* submitted, 2009.

Example: Jason-1 POD

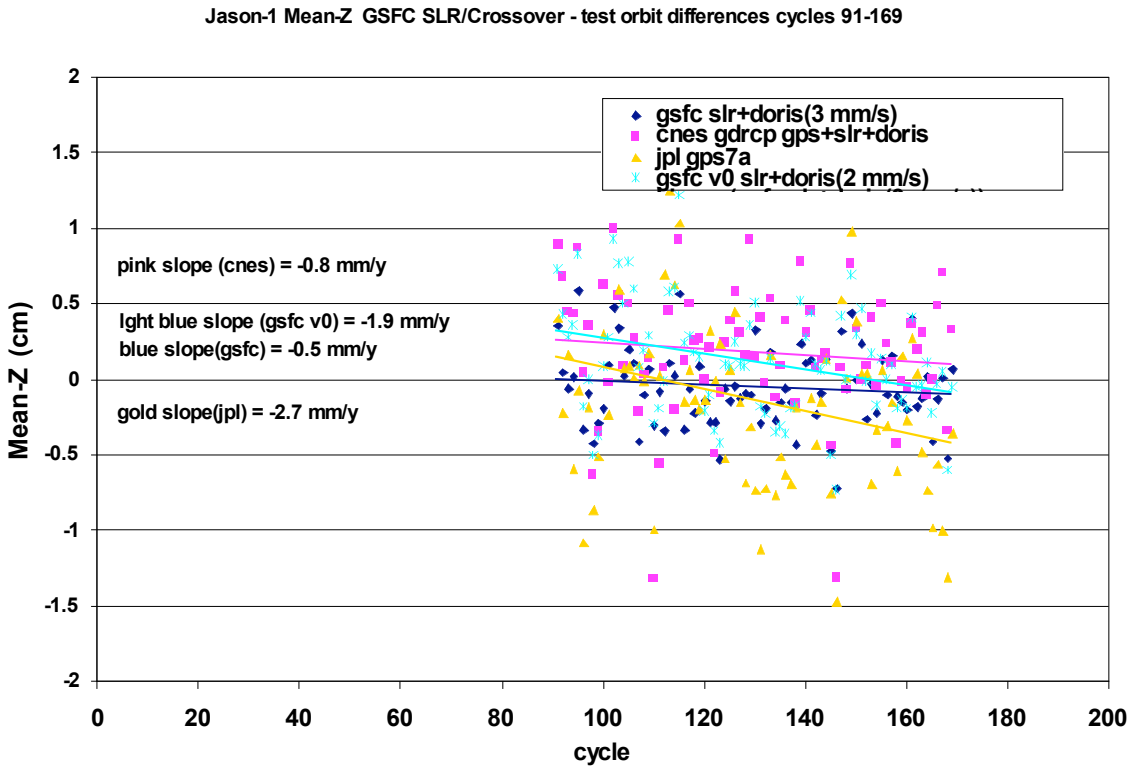




Errors in coordinates of just three SLR stations (Zimmerwald, Herstmonceux, and Riyadh) cause increase in mean residuals on Jason-1, and large radial orbit errors on Jason-1.

Lemoine et al., "Towards Development of a Consistent Orbit Series for TOPEX/Poseidon, Jason-1, and Jason-2" , *Adv. Space Res., DORIS special issue,* submitted, 2009.

Example: Jason-1 Orbit Comparison: SLR/Xover vs. Test Orbits



SLR/Xover, SLR/DORIS, & GPS orbits not consistent in Mean-Z orbit evolution

Lemoine et al., "Towards Development of a Consistent Orbit Series for TOPEX/Poseidon, Jason-1, and Jason-2" , *Adv. Space Res., DORIS special issue,* submitted, 2009.

Objectives

- Develop an improved reference frame for MSL applications, using combined processing of all the geodetic techniques.
- Concentrate in beginning on 2003-2006 for GPS+SLR processing (since this is period when GPS data are available on Jason-1).
- We are interested in consistency between techniques, & in improved vertical rates at tide gauge sites.