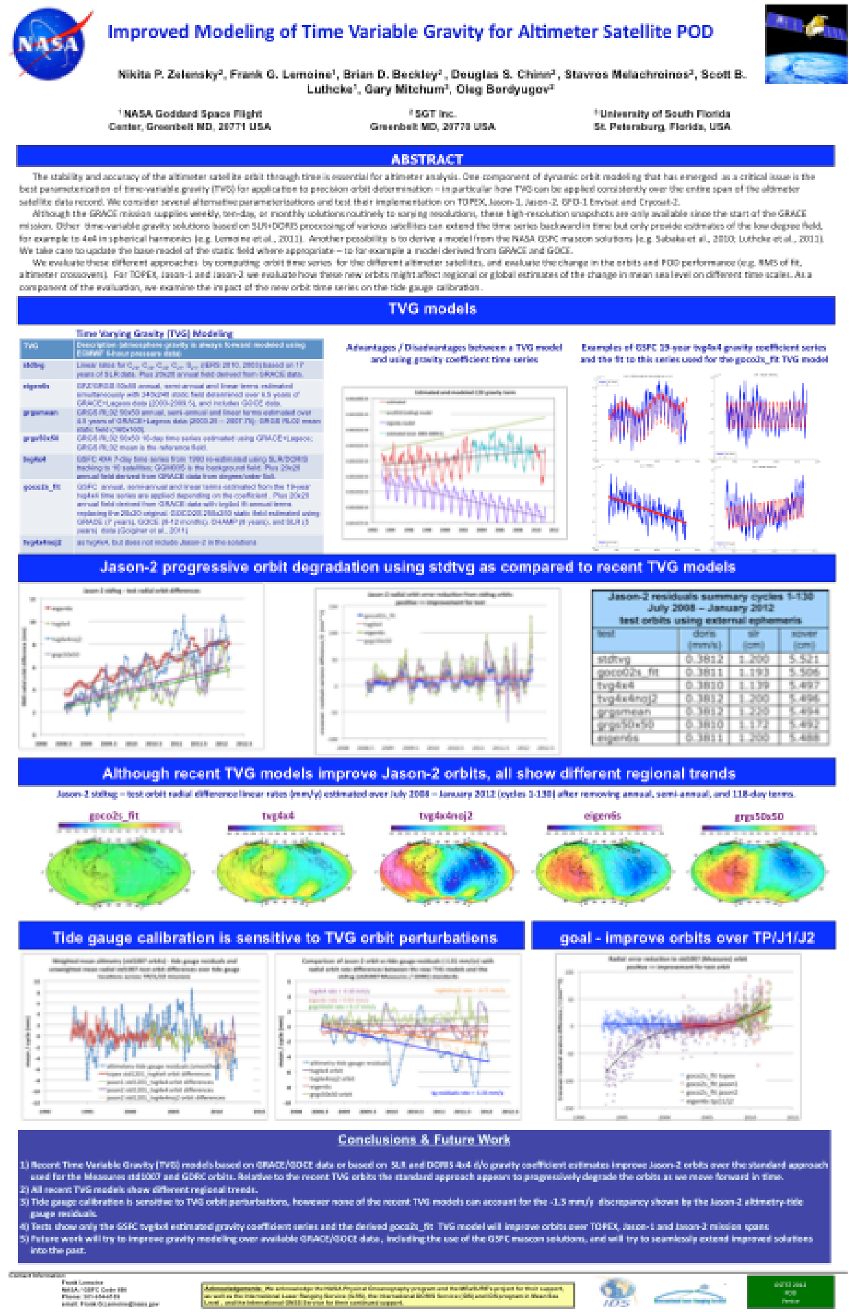
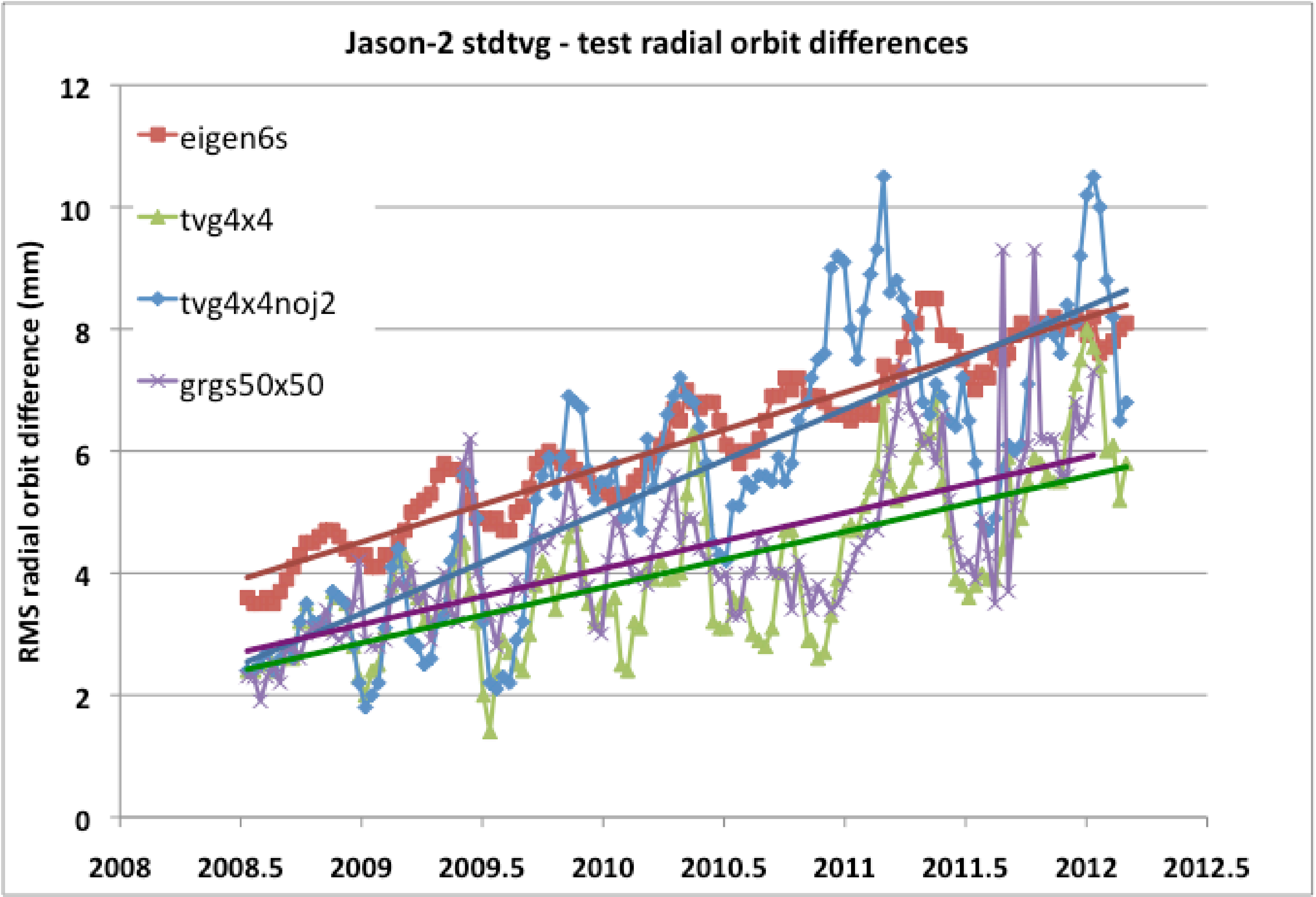
OSTST 2012
POD SPLINTER

Venice, Italy, September 28, 2012

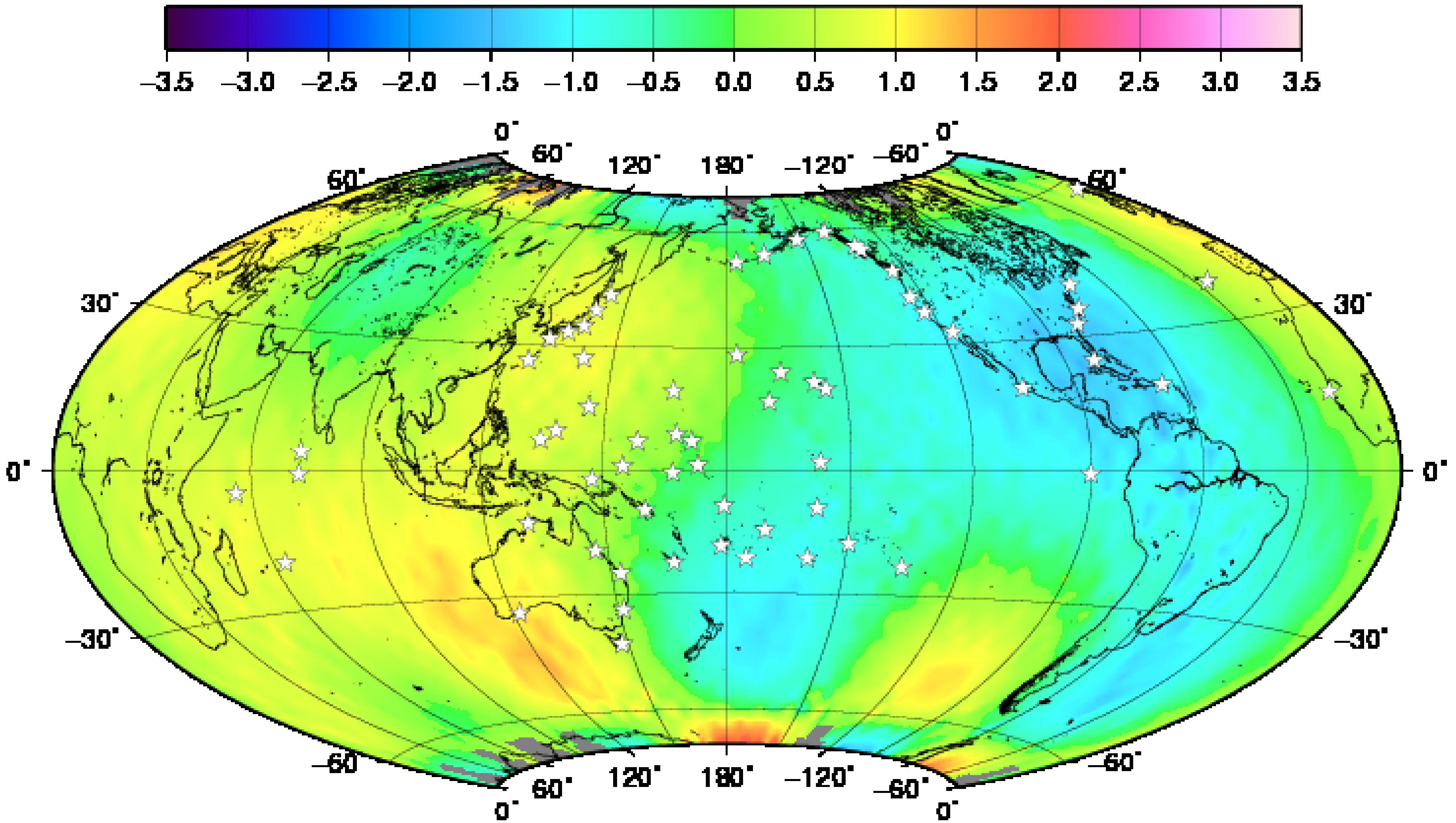
Improved Modeling of Time Variable Gravity for Altimeter Satellite POD



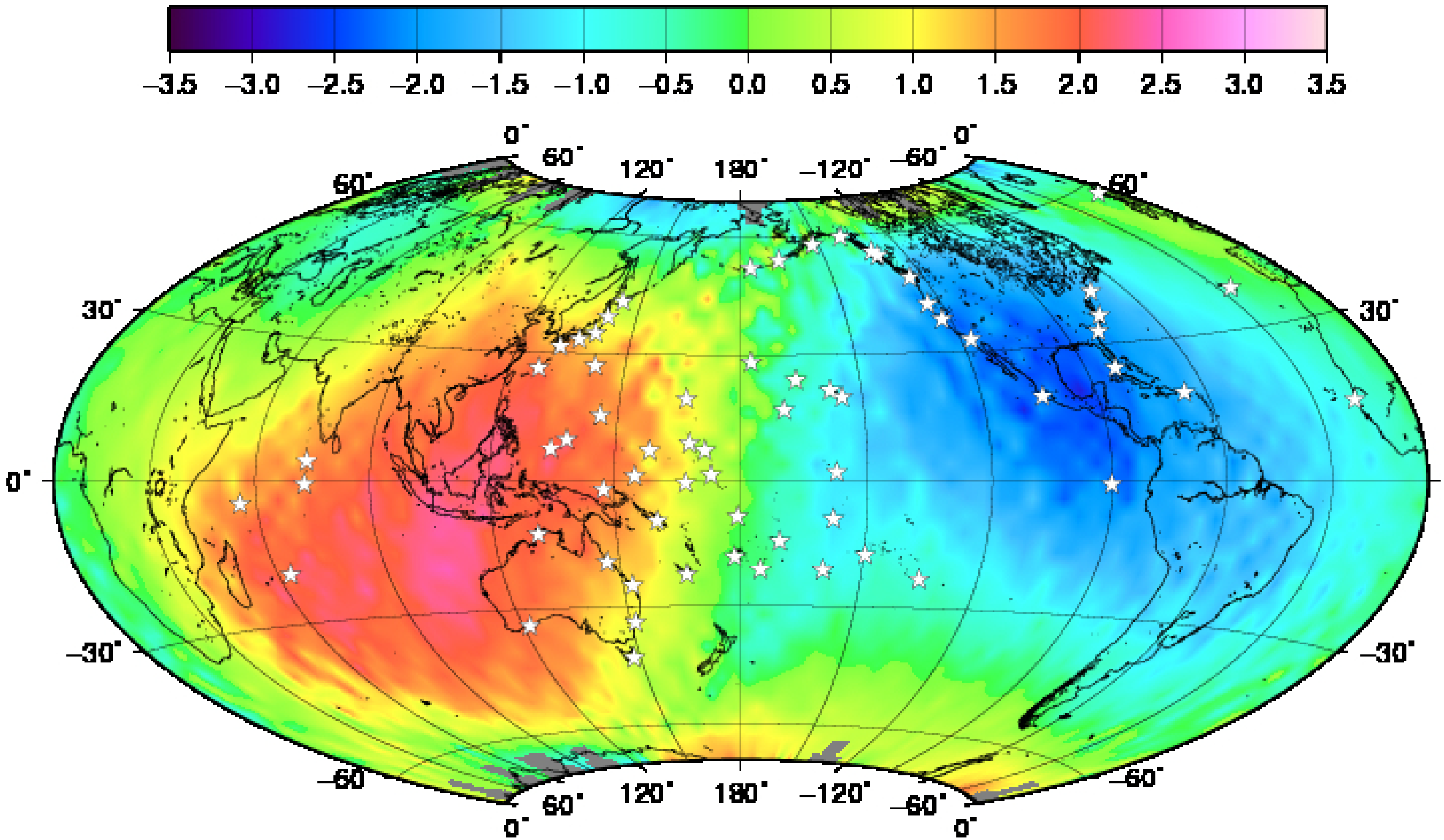


Jason-2 stdtvg - test radial orbit differences
eigen6s
tvg4x4
tvg4x4noj2
grgs50x50
RMS radial orbit difference (mm)
0
2
4
6
8
10
12
2008
2008.5
2009
2009.5
2010
2010.5
2011
2011.5
2012
2012.5

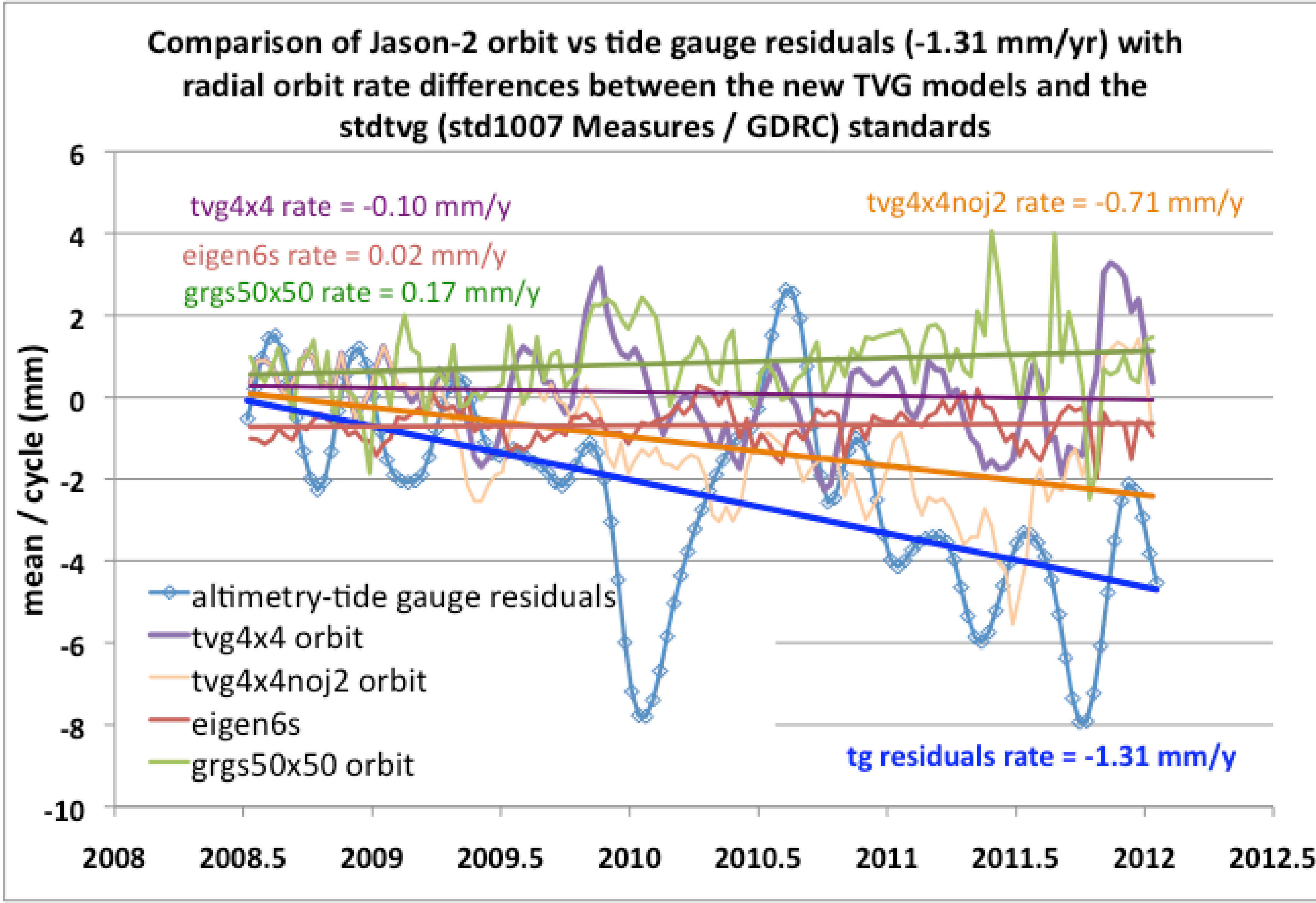
Jason-2 stdtvg – tvg4x4 orbit radial difference linear rates (mm/y)



Jason-2 stdtvg – grgs50x50 orbit radial difference linear rates (mm/y)



Altimeter tide gauge calibration sensitive to TVG orbit perturbations



Recent results in LEO GPS ambiguity fixing at CNES : HY2A and Jason 2

F. Mercier, L. Cerri, S. Houry, A. Couhert CNES, Toulouse, France

Introduction

GPS ambiguity fixing was recently performed successfully on the HY2A data, using the GRG (CNES/CLS) IGS products for the constellation orbits and clocks. The fixed ambiguities improve the observability of the orbit determination process, which allows to significantly reduce the dynamic constraint of the solutions.
These new orbits were computed at the beginning of the mission and compare well to the official products (GPS/Doris/SLR).

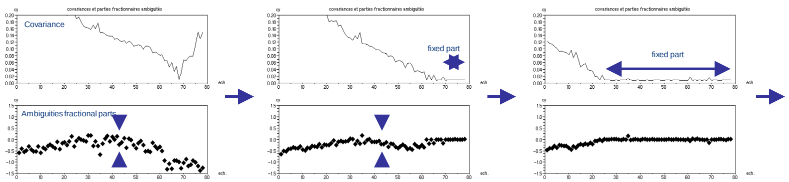
For Jason 2, due to the simultaneous half cycles slips occurring at some epochs, the standard processing must be improved to avoid such errors, and also, the ambiguity fixing process must be changed in order to be able to fix half cycles.
A new processing for GPS Jason 2 has been developed, and the ambiguity fixing can now be efficient, with fixing rates comparable to HY2A.
Daily orbits have been computed from january to june 2012. These orbits have been compared with the current GDRD POE product.

HY2 GPS ambiguity fixing results

Daily 1s sampling Rinex files, with C1,P1,P2,L1,L2
Detection of cycles slips, construction of the widelane ambiguity
Widelane ambiguity fixing using CNES/CLS IGS analysis centre grg solution widelane biases

Down sampling to 30 s, use of igs 30 s clock data aligned on grg 300 s clock data.
Final ambiguity fixing in zero difference mode (10.7 cm wavelength) at 30 s sampling

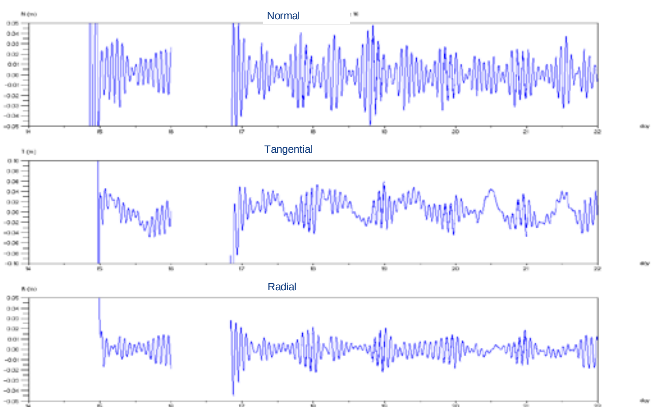
Bootstrap method using short overlapping arcs (~two orbits), more than 99 % of the passes are fixed



Initial (floating) 30 ambiguities fixed 77 ambiguities fixed

History of covariance and ambiguities fixing for one elementary arc (5 hours)
Remark the ambiguities fractional part dispersion change between first and second case

Comparison of one day arcs (30 s sampling) using increased parameterization (1/rev every 6 hours) and initial configuration
Excellent overlaps (arcs from j-1, 20 h to j 24 h)
Some systematic behavior to be investigated : Normal 12h effect, Along track (partly due to the 1/rev 24 hours in the reference)



References : *Integer Ambiguity Resolution on Undifferenced GPS Phase Measurements and Its Application to PPP and Satellite Precise Orbit Determination*. Laurichesse D. et al. Navigation, Journal of the Institute Of Navigation, pp 135-149, Vol. 56 N° 2, 2009

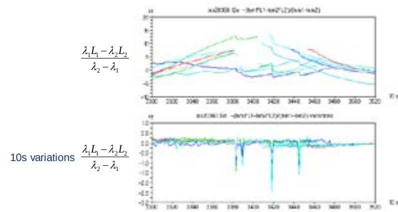
Zero-Difference Ambiguity Fixing - Properties of satellite/receiver widelane biases. Toulouse Space Show'08, European Navigation Conference ENC-GNSS. Toulouse, France, April 22-25, 2008

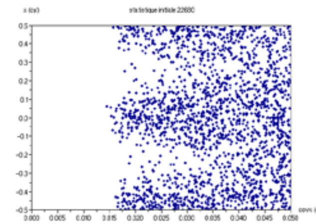
Zero-difference GPS ambiguity resolution at CNES/CLS IGS Analysis Center. Loyer S. et al. Journal of Geodesy. Springer

Jason 2 GPS processing improvements

10 s rinex mesurements : construction of passes without L2-L1 cycles slips, and with widelane ambiguity fixed.

Computation at 30 s sampling using grg IGS solution for clocks and orbits (clocks reconstructed from 300 s grg clocks and 30 s igs clocks)
Reconstruction of all 0.5 cycle slips using the standard POE orbit.





Observed simultaneous cycle slips on the iono combination
Normalised to lam2-lam1 (no widelane cycle slip)

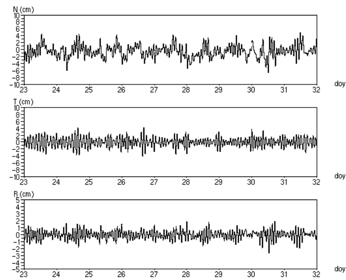
Some half cycle slips (~2.5 cm on lam2*L2-lam2*L1), sometimes distributed on more than two successive 10 s samples.

Initial differences of floating ambiguities (before bootstrap)

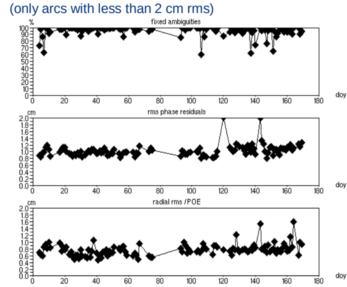
The two families are clearly observed (0.0 cy and 0.5 cy ambiguities)

New orbits : 32 hours arcs, with 4h 1/rev in N,T and bias in T, ambiguities fixed, 30 s sampling, grg IGS solution

Example : comparison with POE in N,T,R



Comparison with POE, residuals, daily radial rms on all arcs
(only arcs with less than 2 cm rms)



The new processing (reconstruction of half cycle slips) works well : more measurements and less passes
it can also be implemented in standard POE processing (but needs 30 s GPS clocks processing)

The ambiguity fixing success rate is very high (often more than 90 %)
The new orbits are ~0.8 cm rms from the current POE.

There are still some problems to solve
- the phase rms residuals are much higher than the corresponding floating values.
- some days have important anomalies (too much differences with POE, very high residuals rms values)
- the ambiguity fixing process may fail, implement a more robust procedure
- the GRG solution has significant biases in N/S (now corrected after week 1701), to be corrected before a complete validation

The complete performances will be studied in the future (parameterization, SLR residuals, altimeter crossovers)

Conclusion

The short duration of the passes on LEO satellites makes the use of zero difference ambiguity fixing a very attractive technique to improve the accuracy of POD solutions. This is shown here using the grg solution (CNES/CLS analysis centre).

For HY2A, a method using short overlapping arcs has been developed. The ambiguity fixing success rate is very good, but the method must be simplified to be able to produce systematic solutions. The method used for Jason2 will also be tested on HY2A in the future.

For Jason2, it was first necessary to solve the problem of the half cycle slips. Even after that, a significant number of half cycle ambiguities remained. Thanks to the high quality of the models (satellite dynamics and measurements) the process is precise enough to achieve excellent fixing rates, even with half-integer ambiguities. These results are very promising, nevertheless further work is needed to completely validate the accuracy of the ambiguity fixing process, which is made difficult by the short wavelength (~5 cm). We will now focus on making the overall process more robust and assessing the outmost performance of these new orbit solutions.

Evaluation of new precise orbits of Envisat, ERS-1 and ERS-2 using altimetry

D. Dettmering[1], S. Rudenko[2], and W. Bosch[1]
[1] Deutsches Geodätisches Forschungsinstitut (DGFI), München, Germany
[2] Helmholtz Centre Potsdam GFZ German Research Centre for Geosciences, Oberpfaffenhofen, Germany
dettmering@dgfi.badw.de

Motivation

Precise orbits of altimetry satellites are a prerequisite for a range of altimetry applications, such as sea level anomalies computations, global and regional sea level change studies and others. New precise orbits of altimetry satellites Envisat, ERS-1 and ERS-2 were recently computed within the ESA funded Sea Level Project of the ESA Climate Change Initiative (SLCCI). The first version of these orbits computed with the EIGEN-GL04S geopotential model is evaluated using a dedicated cross-calibration between all altimeter missions operating contemporaneously.

GFZ SLCCI Orbits

New precise orbits of altimetry satellites ERS-1, ERS-2, and Envisat were derived at GFZ within the Sea Level project of the European Space Agency (ESA) Climate Change Initiative (SLCCI).

The orbits were computed in the same (ITRF2008) terrestrial reference frame for all satellites using common, most precise models and standards as listed in Tab. 1.
The ERS-1 orbit is computed using SLR and altimeter crossover data, while the ERS-2 orbit is derived using additionally PRARE measurements. The Envisat orbit is based on DORIS and SLR observations.

The orbit files are available via ftp at ftp://slcci:slcci@ftp.esa-sealevel-cci.org/Data/WP2200

Tab. 1: List of the main models used to compute the GFZ SLCCI orbits.

Terrestrial Reference Frame	ITRF2008; SLRF2008 and DPOD2008 are used for stations missing in ITRF2008
Polar motion and UT1	IERS EOP 08 C04 (IAU2000A) series with IERS daily and sub-daily corrections
Precession and Nutation model	IERS Conventions (2010)
Gravity field (static)	EIGEN-GL04S-ANNUAL
Gravity field (time varying)	Annual and semi annual variation up to degree and order 50 from EIGEN-GL04S-ANNUAL gravity field model
Solid Earth tides	IERS Conventions (2010)
Pole tide	IERS Conventions (2010)
Ocean tides	EOT10a, all constituents up to degree and order 50
Atmospheric tides	Biancale and Bode (2006)
Atmospheric gravity	ECMWF 6-hourly fields up to degree and order 50
Third bodies	Sun, Moon, Mercury, Venus, Mars, Jupiter, Saturn, Uranus, Neptune and Pluto (DE-421)

Multi-Mission Crossover Analysis (MMXO)

Method:

- Computation of single and dual-satellite crossover sea surface height differences Δx_{jk} in all combinations between passes j and k (max. time interval = 2 days)
- Minimizing both, Δx_{jk} and $\delta x_i = x_{i+1} - x_i$, i.e. consecutive differences of radial errors for time step i for each mission; allows to estimate the radial errors x_i at all crossovers

Output: Time series of relative radial errors for each mission (w.r.t. a reference mission, generally TOPEX or Jason-1), which are used to derive

- Empirical auto-covariance functions (EACF) of the radial errors
- Geographically correlated errors (GCE)
- Mean range bias Δr (per 10 day cycles and per mission lifetime)
- Mean differences in the center-of-origin realization $\Delta x, \Delta y, \Delta z$ (10 day sampling)

Stochastic properties of Radial Errors

Fig. 1 shows the empirical auto-covariance functions (EACF) of the radial errors. They provide useful information on possible systematics within the radial errors. All EACF have relative maxima after the orbital revolution, i.e. correlations between measurements on neighboring ground tracks – an early indication of GCE. ERS-1 also shows longer periods (> some days).

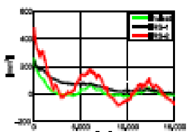


Fig. 1: Empirical Auto-Covariance functions of the radial errors for Envisat (green), ERS-1 (black), and ERS-2 (red)

The orbital period is more distinct in SLCCI orbits than in REAPER (see Fig. 2). The differences in orbital height between SLCCI and REAPER/GDR-C orbits clearly show a 6036 sec period with amplitudes of about 2 cm (for all three missions, without Fig.).

Fig. 2: Power spectrum of ERS-1 radial errors (Cyc. 91) for SLCCI- (red) and REAPER-orbits (grey).

Scatter of Radial Errors

The standard deviation sd of the radial errors serves as an indicator for the data quality. The scatter is highest in times with high solar activity (see Fig. 3).
The mean sd for the whole mission life-time reaches 19.8 mm for ERS-1, 25.8 mm for ERS-2, and 18.1 mm for Envisat.
For ERS, the scatter is slightly lower when using REAPER orbits (18.7/23.6 mm). For Envisat GDR-C orbit it reaches 18.5 mm.

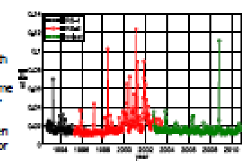


Fig. 3: Standard deviation of radial errors for SLCCI orbits

Range Biases and Center-of-Origin Realization

For each mission relative range bias w.r.t. TOPEX (M-GDR with GSFC std0809 orbit) are computed as well as center-of-origin shifts. This post-processing is performed per 10-day cycle by means of a least squares adjustment based on the following model:

$$x_i + v_{x_i} = \Delta r + \Delta x \cos\varphi_i \cos\lambda_i + \Delta y \cos\varphi_i \sin\lambda_i + \Delta z \sin\varphi_i$$

Whereas the range biases Δr are mainly due to instrumental effects, the origin shifts ($\Delta x, \Delta y, \Delta z$) are mainly caused by the orbit realization.

	Δr	Δx	Δy	Δz
ERS-1	442.0 ± 7.6	0.9 ± 3.2	0.7 ± 2.7	-2.3 ± 5.1
ERS-2	71.1 ± 6.7	0.0 ± 6.4	1.4 ± 5.0	-3.4 ± 7.4
Envisat	449.8 ± 6.8	-0.2 ± 3.5	-4.2 ± 5.2	0.1 ± 5.3

Tab. 2: Global mean range bias (Δr) and center-of-origin shifts relative to TOPEX (GSFC std0809 orbit) based on GFZ SLCCI EIGEN-GL04S orbits; in [mm]

Table 2 shows the mean values for each mission. None of the shifts is mathematically significant.

However, the Δy component of Envisat shows a clear systematic trend with time (see Fig. 4), which might be caused by long-term variations of the gravity field which were not taken into account in the EIGEN-GL04S version of GFZ SLCCI orbits (in contrast to GDR-D ones).

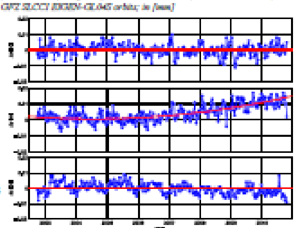


Fig. 4: Center-of-origin realization of Envisat GFZ SLCCI EIGEN-GL04S orbit; differences to Jason-1 (GDR-C orbit)

Geographically Correlated Errors (GCE)

Error components having the same sign for ascending and descending passes are called geographically correlated errors (GCE). The MMXO is able to reveal GCE from the estimated radial errors for each of the involved missions. GCE mainly represent problems in precise orbit determination (POD), e.g. reference frame differences, but also include other geographically correlated effects.

Fig. 5 shows the GCE for ERS-1, ERS-2, and Envisat based on the GFZ SLCCI orbits:

- All SLCCI GCE show large scale pattern with moderate amplitudes.
- The GCE for all three missions do not exceed 1 cm (except for a few outliers).
- The RMS is 3.0 mm for ERS-1, 3.8 mm for ERS-2, and 3.2 mm for Envisat.
- These values are slightly higher than the corresponding GCE for the REAPER combined orbits, reaching 2.8 mm (ERS-1) and 3.7 mm (ERS-2), resp. The pattern is similar to the REAPER GCE. The RMS for Envisat GDR-C orbit is 3.1 mm.
- With respect to early DEOS DGM-E04 orbits (RMS of 7.7 mm for ERS-1 and 9.5 mm for ERS-2), SLCCI solutions show significant improvements.

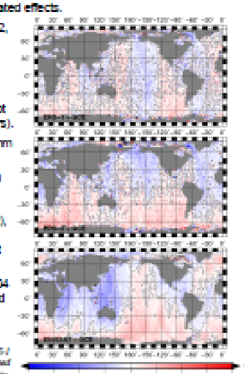


Fig. 5: Geographically correlated error for ERS-1 (top), ERS-2 (middle), and Envisat (bottom) based on GFZ SLCCI EIGEN-GL04S orbits.

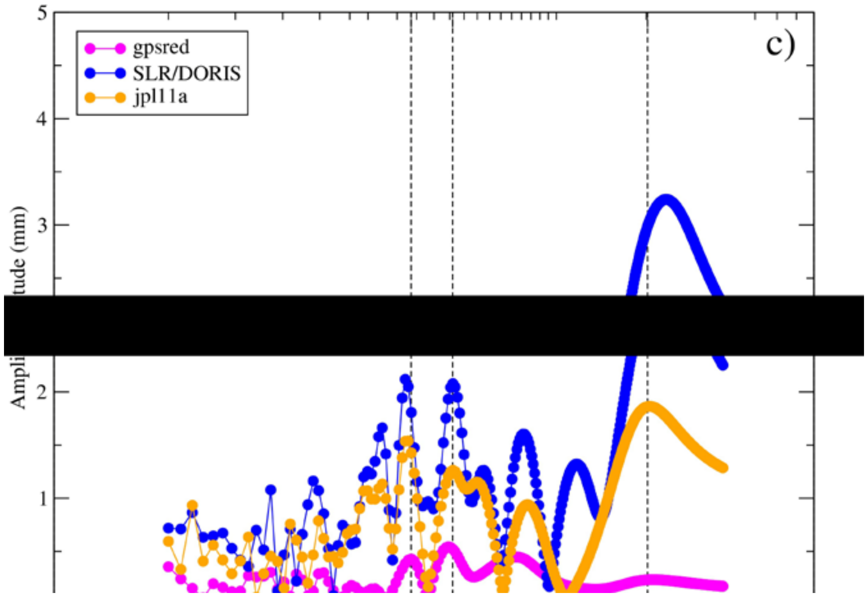
Conclusions

GFZ SLCCI orbits for ERS and Envisat show GCE smaller than 1 cm and no significant differences in the center-of-origin realization. However, a systematic trend in the Δy-component between Envisat and Jason is found. That might be caused by the non-consideration of long-term drifts of the gravity field. For ERS, the comparison to REAPER combined orbits reveals small systematics with the orbital period as well as slightly increased scatter of radial errors. In order to exploit the advantages of a combined orbit solution (such as REAPER), a reprocessing of ERS orbits in ITRF2008 (or newer) with the use of latest standards and the participation of a few orbit groups is advisable.

References:
Dettmering D., Bosch W.: Multi-Mission Crossover Analysis: Merging 20 years of data into one consistent long-term data record. Poster OSTST and 20yrs, 2012
Rudenko, S. et al. Computation and evaluation of new consistent orbits of Envisat, ERS-1 and ERS-2 in the ITRF2008 reference frame. EGU2012-5894-1, 2012
Rudenko, S. et al. New improved orbit solutions for the ERS-1 and ERS-2 satellites. Advances in Space Research, 49(8), 2012

The effect of geocenter motion on Jason-2 orbits and the mean sea level

Stavros A MELACHROINOS, Brian D BECKLEY, Dr Frank G LEMOINE et al.

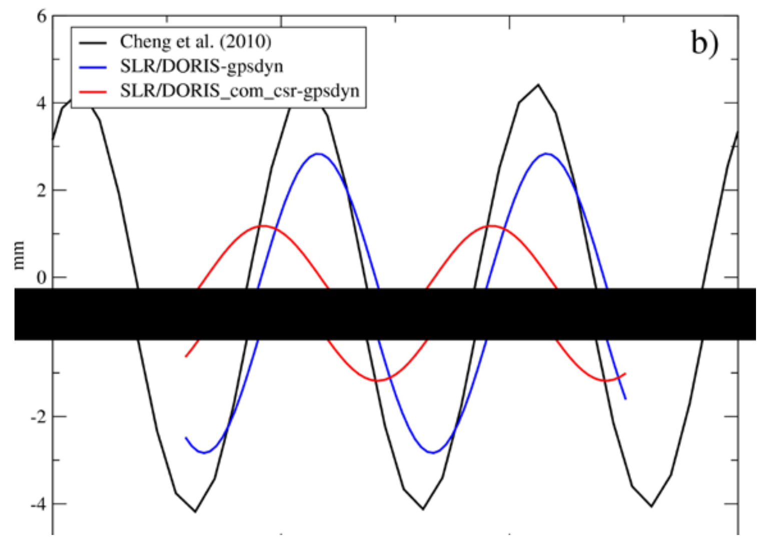


Our GPS orbits closely follow the CM consistent with the conservative force modeling

Our SLR/DORIS orbits are centered closer to the origin of the ITRF, which is the CF for sub-secular scales

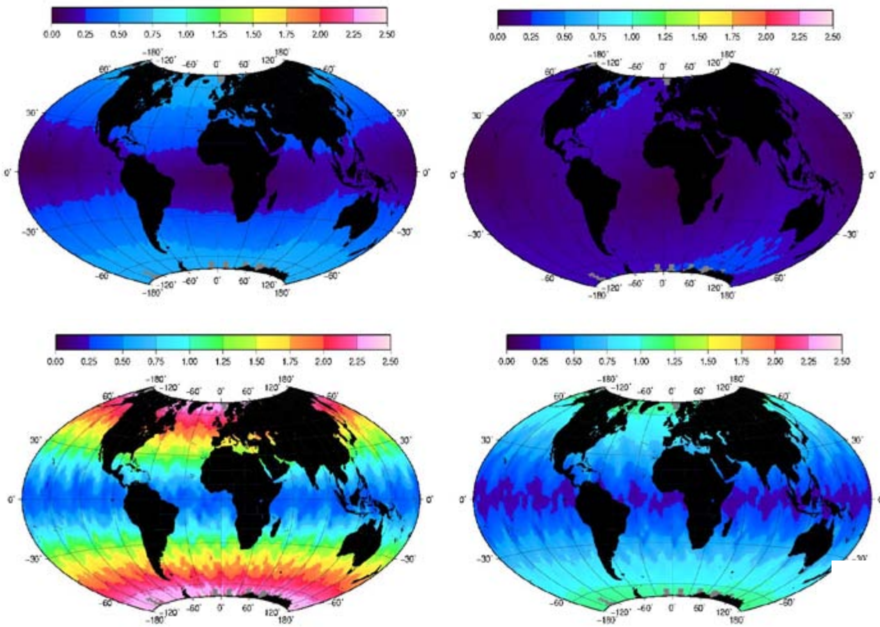
The 118-day signal is dominant in the X and Y components

In the Z-component the annual signature has the largest amplitude

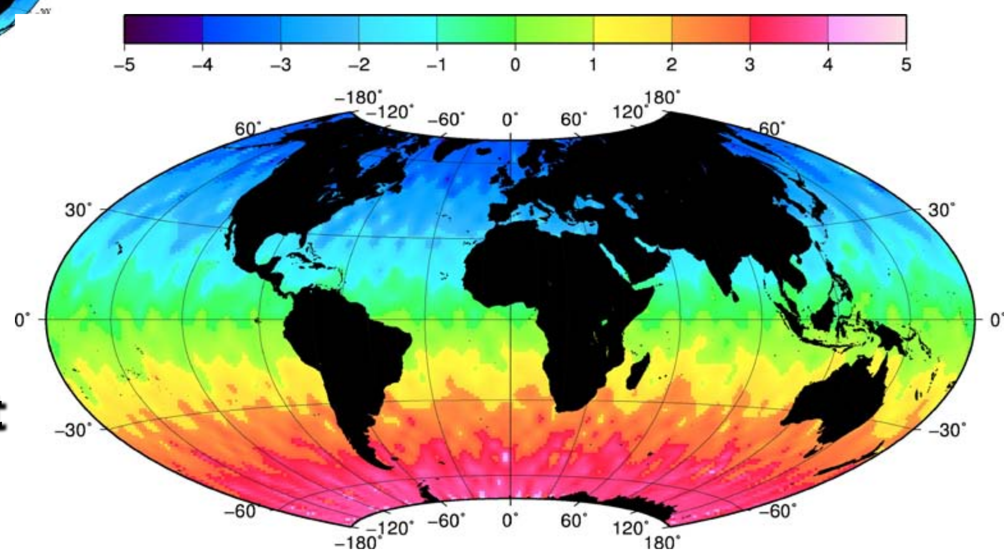


The effect of geocenter motion on Jason-2 orbits and the mean sea level

Stavros A MELACHROINOS, Brian D BECKLEY, Dr Frank G LEMOINE et al.



The systematic error from the modeled geocenter motion affects more the SLR/DORIS orbits. Propagates with the same transfer function in the GPS and SLR/DORIS orbits.

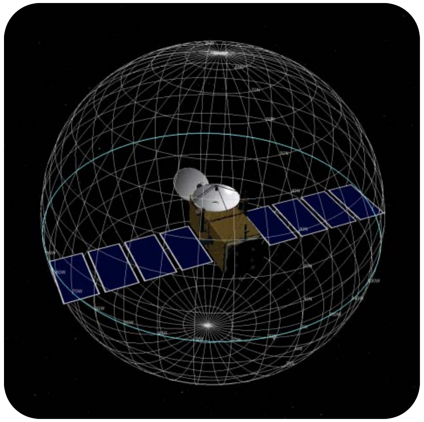


The observed geographical MSL error (in mm) resulting from the geocenter motion on the SLR/DORIS orbits can reach ~5 mm with an apparent drift of > 0.1 mm/yr in 2 years.

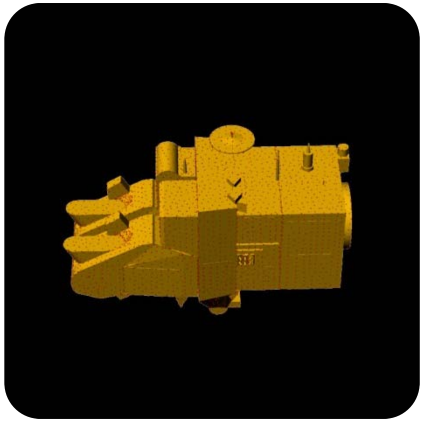
Plans and status for UCL non-conservative force models for precise orbit determination in altimetry missions.

M Ziebart, S Grey, S Allgeier

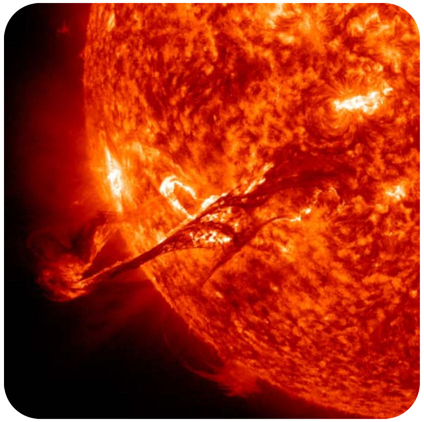
University College London



Force Modelling

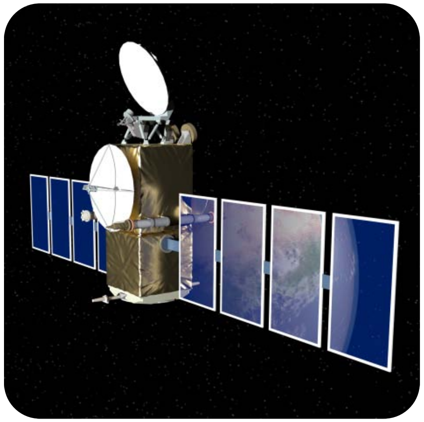


Target Missions

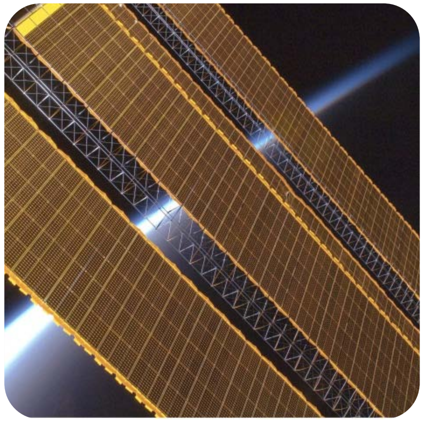


Solar Radiation Pressure

Planetary Radiation Pressure



Ray Tracing



Solar Panel Thermal Forces

Atmospheric Drag

UCL

On the proper use of the EIGEN-6 models for altimetric orbit computation over decades

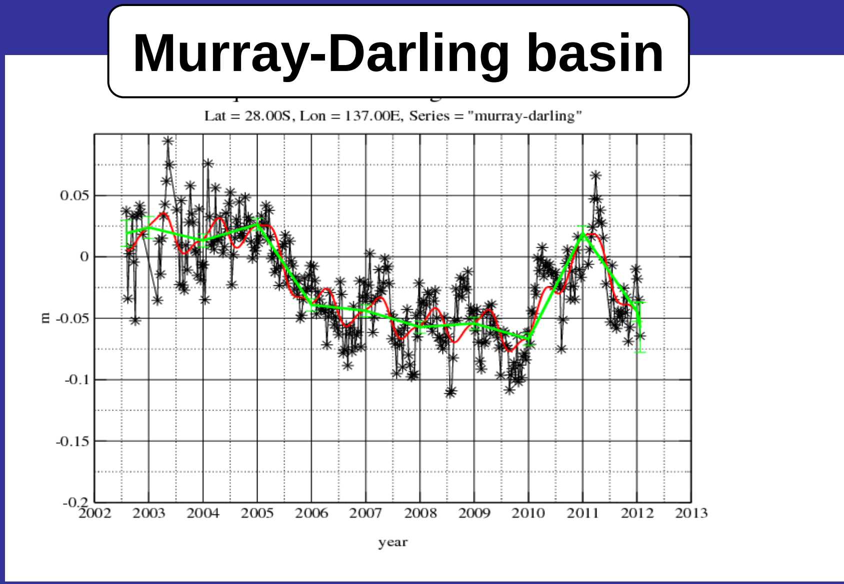
R. Biancale [(1)], J.-M. Lemoine [(1)], S. Bourgogne[(2)], S. Bruinsma [(1)], F. Reinquin [(1)]

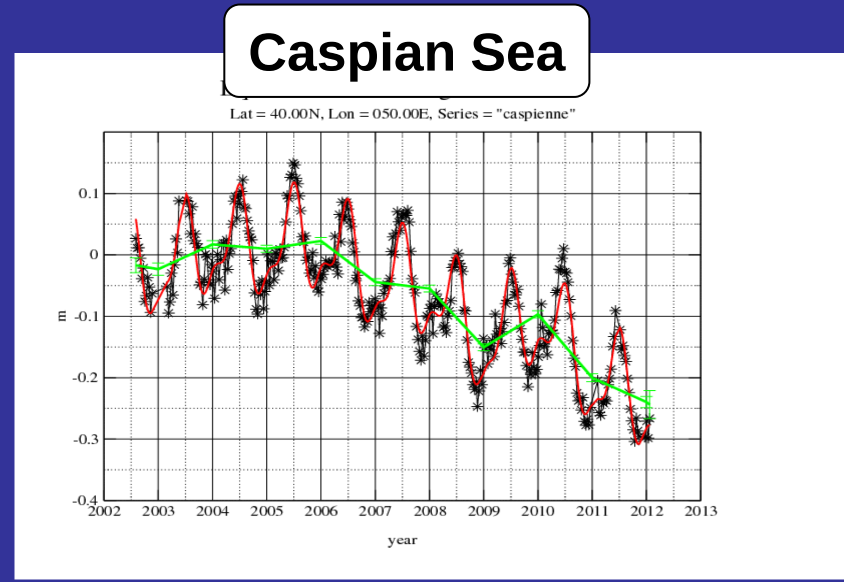
(1) Groupe de Recherche de Géodésie Spatiale, Toulouse, France (e-mail: richard.biancale@cnes.fr)
(2) Noveltis, Ramonville Saint Agne, France

Summary

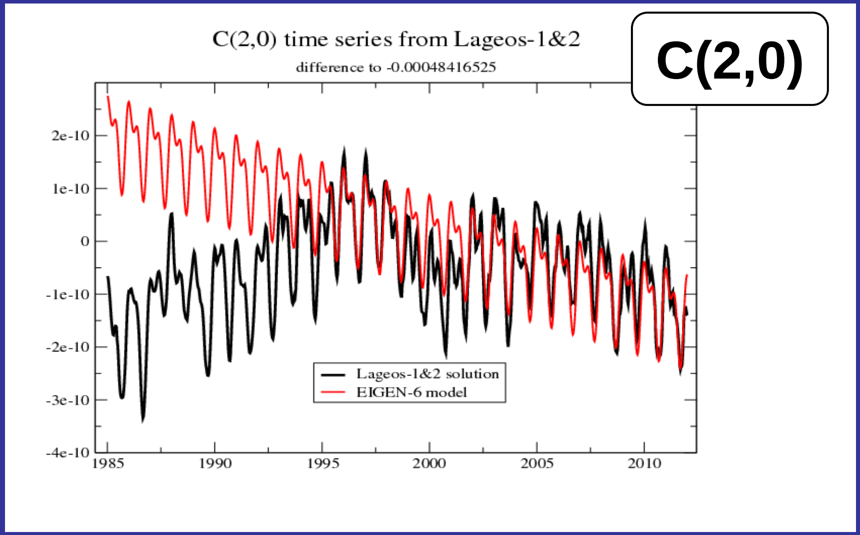
The **EIGEN-6S or -6C** Earth gravity models are commonly used for altimetric orbit computation. These models are mainly based on GRACE KBR data, with a participation of Lageos-1 and -2 SLR data for the lower spherical harmonics. They are complete to degree and order 160 and **contain time variable coefficients** for the spherical harmonics up to degree 50 : bias, drift, once and twice per year terms. These terms have been **modeled globally over the GRACE period** (2002-2012)..
However **extrapolating** these time variable terms in the past until the beginning of altimetric missions or even in the near future can generate some degradation of the orbital precision which can **lead to noticeable radial discrepancies**. Furthermore, the 10-year long time series of gravity field solutions we have today shows that a simple bias + drift + periodic terms mean model adjusted over the full data span is not sufficient to optimally represent the non regular features observed in the time series.
This is why **we propose a more refined parameterization** for the mean model which would at the same time allows **to better express the long-term evolution** of the first degrees of the gravity field beyond the GRACE **era, thanks to information provided by SLR satellites**, **and to more closely follow the time evolution of the 10-day gravity field series** within the GRACE era

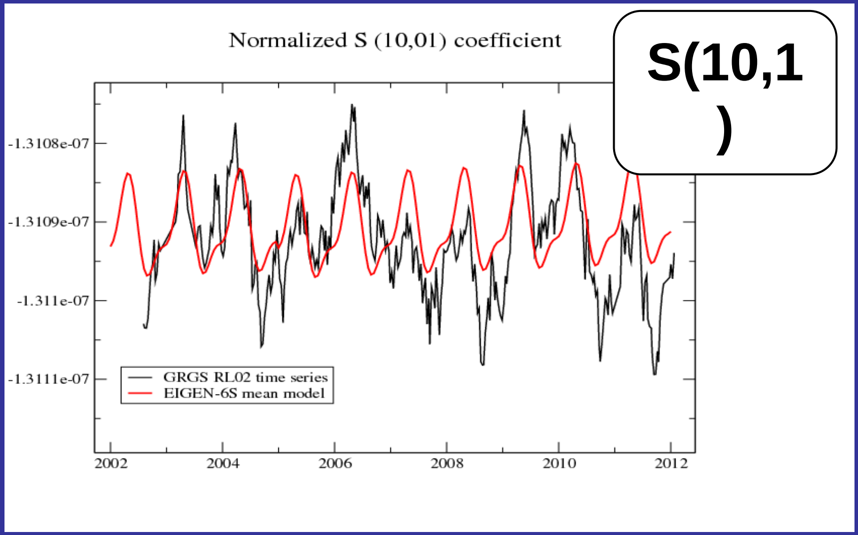
Gravity changes are not steady over time





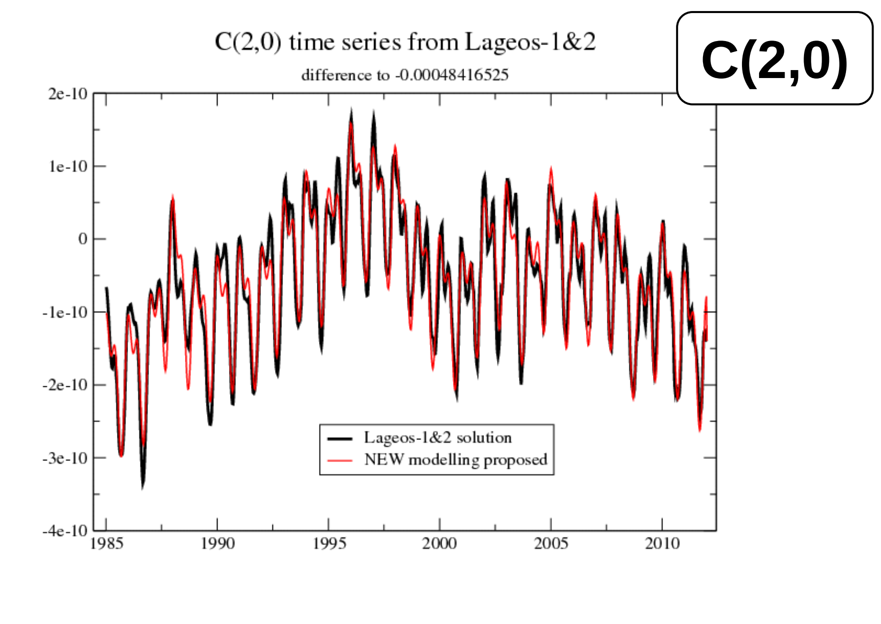
Present mean modeling for orbit computation is too regular, does not account for interannual changes nor before GRACE

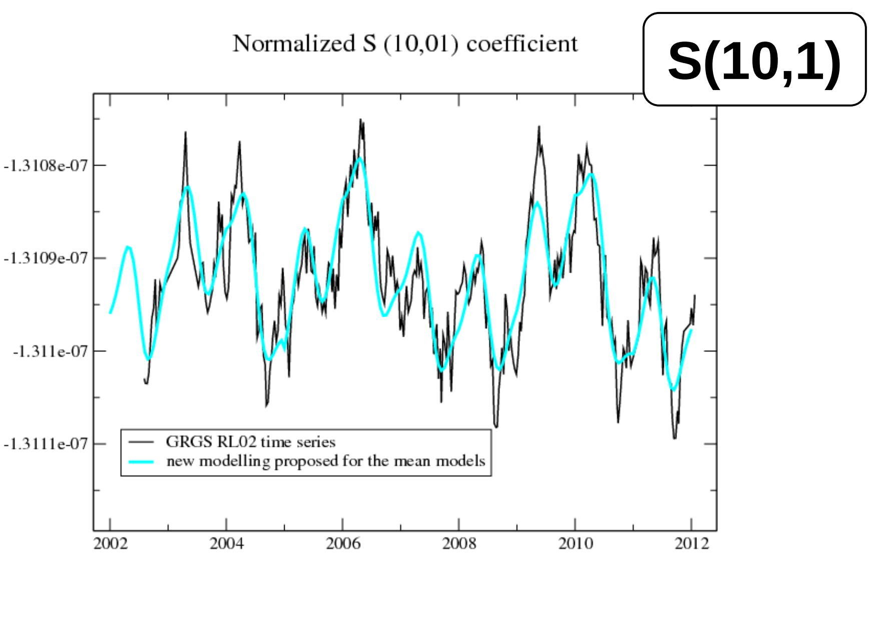




New modeling:

- keeping annual and semi-annual terms constant
- introducing annual biases and drifts in piece-wise linear mode

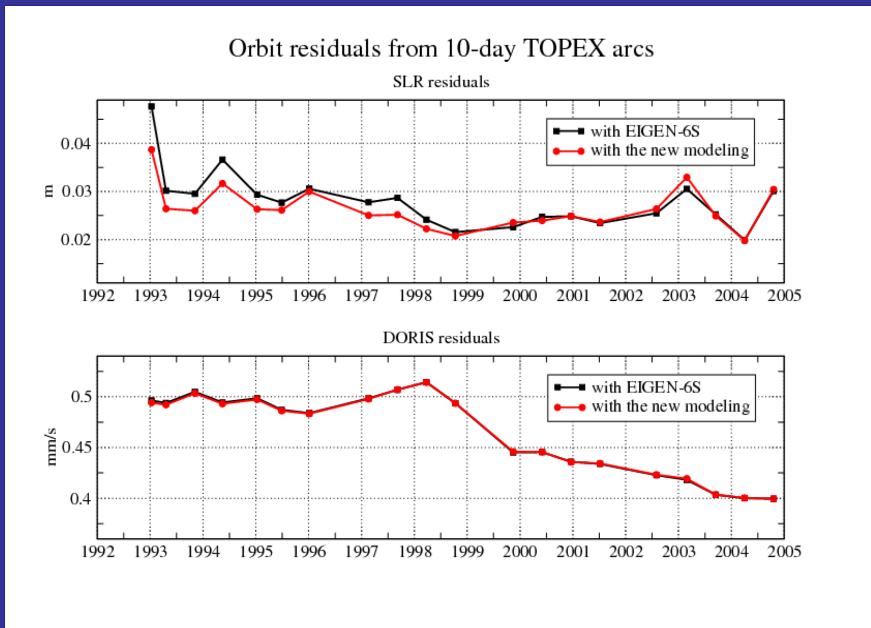


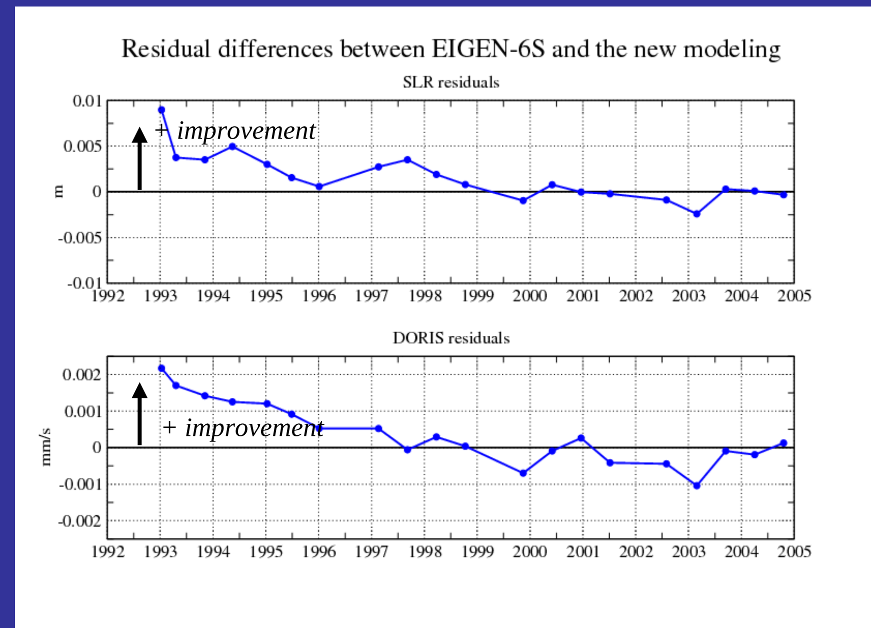


Allow to:

- better express th long term evolution given by SLR satellites
- more closely follow the time evolution of the 10-day models

Improvements are noticeable on TOPEX SLR and DORIS residuals





A new format (explained on the poster) of gravity field coefficients will be given for the next GRGS RL03 iteration (Spring 2013)

Example of proposed format

G_BIAS	2	0	-.484165479521E-03	0.000000000000E+00	0.1392E-10	0.0000E+00	19500101.0000	19850109.1751
GDRIFT	2	0	0.104634158251E-11	0.000000000000E+00	0.5603E-12	0.0000E+00	19500101.0000	19850109.1751
G_BIAS	2	0	-.484165356094E-03	0.000000000000E+00	0.7295E-11	0.0000E+00	19900101.0000	19910101.0000
GDRIFT	2	0	0.162048658823E-10	0.000000000000E+00	0.1449E-10	0.0000E+00	19900101.0000	19910101.0000
GCOS1A	2	0	0.386222759789E-10	0.000000000000E+00	0.3748E-11	0.0000E+00	19500101.0000	20500101.0000
GSIN1A	2	0	0.542428904167E-10	0.000000000000E+00	0.3404E-11	0.0000E+00	19500101.0000	20500101.0000
GCOS2A	2	0	0.379017840266E-10	0.000000000000E+00	0.3617E-11	0.0000E+00	19500101.0000	20500101.0000
GSIN2A	2	0	-.163073508081E-10	0.000000000000E+00	0.3494E-11	0.0000E+00	19500101.0000	20500101.0000