Improved Modeling of Time Variable Gravity for Altimeter Satellite POD

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ABSTRACT

The stability and accuracy of the altimeter satellite orbit through time is essential for altimeter analysis. One component of dynamic orbit modeling that has emerged as a critical issue is the best parameterization of time-variable gravity (TVG) for application to precision orbit determination – in particular how TVG can be applied consistently over the entire span of the altimeter satellite data record. We consider several alternative parameterizations and test their implementation on TOPEX, Jason-1, Jason-2, GFO-1 Envisat and Cryosat-2.

Although the GRACE mission supplies weekly, ten-day, or monthly solutions routinely to varying resolutions, these high-resolution snapshots are only available since the start of the GRACE mission. Other time-variable gravity solutions based on SLR+DORIS processing of various satellites can extend the time series backward in time but only provide estimates of the low degree field, for example to 4x4 in spherical harmonics (e.g. Lemoine et al., 2011). Another possibility is to derive a model from the NASA GSFC mascon solutions (e.g. Sabaka et al., 2010; Luthcke et al., 2011). We take care to update the base model of the static field where appropriate – to for example a model derived from GRACE and GOCE.

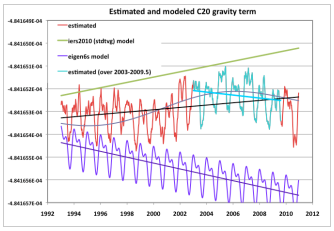
We evaluate these different approaches by computing orbit time series for the different altimeter satellites, and evaluate the change in the orbits and POD performance (e.g. RMS of fit, altimeter crossovers). For TOPEX, Jason-1 and Jason-2 we evaluate how these new orbits might affect regional or global estimates of the change in mean sea level on different time scales. As a component of the evaluation, we examine the impact of the new orbit time series on the tide gauge calibration.

TVG models

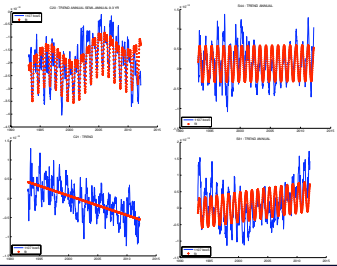
Time Varying Gravity (TVG) Modeling

TVG	Description (atmosphere gravity is always forward modeled using ECMWF 6-hour pressure data)
stdtvg	Linear rates for C_{20}, C_{30}, C_{40}, C_{21}, S_{21}, (IERS 2010, 2003) based on 17 years of SLR data. Plus 20x20 annual field derived from GRACE data.
eigen6s	GFZ/GRGS 50x50 annual, semi-annual and linear terms estimated simultaneously with 240x240 static field determined over 6.5 years of GRACE+Lageos data (2003-2009.5), and includes GOCE data.
grgsmean	GRGS RL02 50x50 annual, semi-annual and linear terms estimated over 4.5 years of GRACE+Lageos data (2003.25 – 2007.75); GRGS RL02 mean static field (160x160).
grgs50x50	GRGS RL02 50x50 10-day time series estimated using GRACE+Lageos; GRGS RL02 mean is the reference field.
tvg4x4	GSFC 4X4 7-day time series from 1993 re-estimated using SLR/DORIS tracking to 10 satellites; GGM03S is the background field. Plus 20x20 annual field derived from GRACE data from degree/order 5x5.
goco2s_fit	GSFC annual, semi-annual and linear terms estimated from the 19-year tvg4x4 time series are applied depending on the coefficient . Plus 20x20 annual field derived from GRACE data with tvg4x4 fit annual terms replacing the 20x20 original. GOCO2S 250x250 static field estimated using GRACE (7 years), GOCE (8-12 months), CHAMP (8 years), and SLR (5 years) data (Goiginer et al., 2011)
tvg4x4noj2	as tvg4x4, but does not include Jason-2 in the solutions

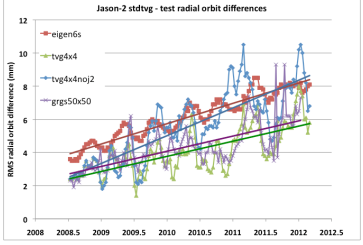
Advantages / Disadvantages between a TVG model and using gravity coefficient time series

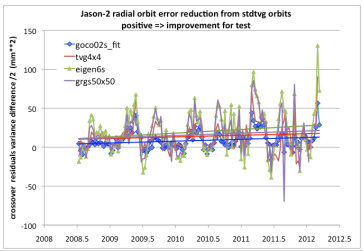


Examples of GSFC 19-year tvg4x4 gravity coefficient series and the fit to this series used for the goco2s_fit TVG model



Jason-2 progressive orbit degradation using stdtvg as compared to recent TVG models





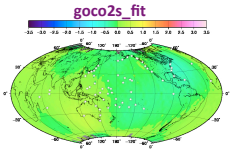
Jason-2 residuals summary cycles 1-130 July 2008 – January 2012 test orbits using external ephemeris

test	doris (mm/s)	slr (cm)	xover (cm)
stdtvg	0.3812	1.200	5.521
goco02s_fit	0.3811	1.193	5.506
tvg4x4	0.3810	1.139	5.497
tvg4x4noj2	0.3812	1.200	5.496
grgsmean	0.3812	1.220	5.494
grgs50x50	0.3810	1.172	5.492
eigen6s	0.3811	1.200	5.488

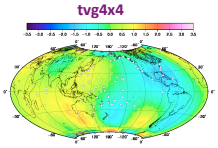
Although recent TVG models improve Jason-2 orbits, all show different regional trends

Jason-2 stdtvg – test orbit radial difference linear rates (mm/y) estimated over July 2008 – January 2012 (cycles 1-130) after removing annual, semi-annual, and 118-day terms.

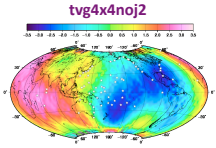
goco2s_fit



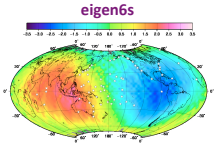
tvg4x4



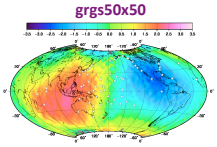
tvg4x4noj2



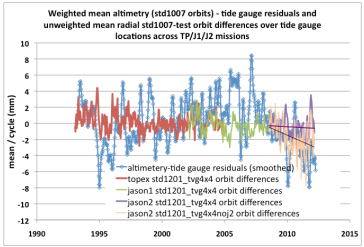
eigen6s

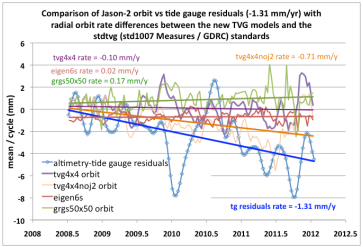


grgs50x50

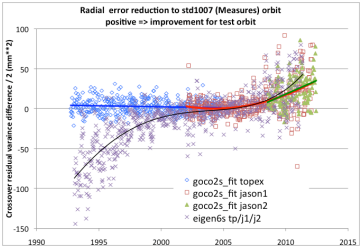


Tide gauge calibration is sensitive to TVG orbit perturbations





goal - improve orbits over TP/J1/J2



Conclusions & Future Work

1) Recent Time Variable Gravity (TVG) models based on GRACE/GOCE data or based on SLR and DORIS 4x4 d/o gravity coefficient estimates improve Jason-2 orbits over the standard approach used for the Measures std1007 and GDRC orbits. Relative to the recent TVG orbits the standard approach appears to progressively degrade the orbits as we move forward in time.
2) All recent TVG models show different regional trends.
3) Tide gauge calibration is sensitive to TVG orbit perturbations, however none of the recent TVG models can account for the -1.3 mm/y discrepancy shown by the Jason-2 altimetry-tide gauge residuals.
4) Tests show only the GSFC tvg4x4 estimated gravity coefficient series and the derived goco2s_fit TVG model will improve orbits over TOPEX, Jason-1 and Jason-2 mission spans
5) Future work will try to improve gravity modeling over available GRACE/GOCE data , including the use of the GSFC mascon solutions, and will try to seamlessly extend improved solutions into the past.

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IDS

International Laser Ranging Service

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