



# Orbit error due to time variable gravity and impact on mean sea level trend estimates and tide gauge calibration

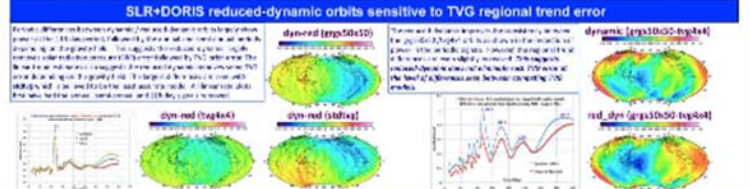
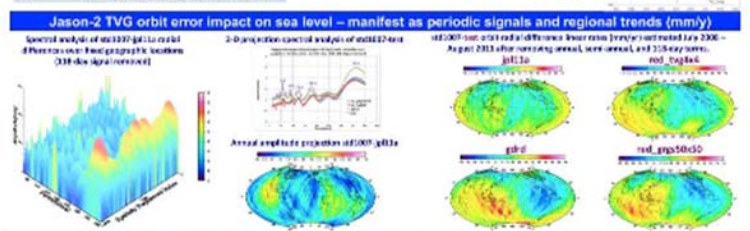
**NASA** Orbit error due to time variable gravity and impact on mean sea level trend estimates and tide gauge calibration  
 Nikita P. Zolenskiy<sup>1</sup>, Frank G. Lemoine<sup>1</sup>, Stavros Melachroinou<sup>1</sup>, Brian D. Beckley<sup>1</sup>, Douglas S. Chinn<sup>1</sup>, Scott B. Luthcke<sup>1</sup>, Gary Mitchum<sup>2</sup>, Oleg Borisyukov<sup>3</sup>

<sup>1</sup>NASA Goddard Space Flight Center, Greenbelt MD, 20771 USA      <sup>2</sup>AGU Inc, Greenbelt MD, 20771 USA      <sup>3</sup>University of South Florida, St. Petersburg, Florida, USA

**ABSTRACT**  
 The orbit error due to time variable gravity (TVG) is a significant factor in the accuracy of satellite altimetry. This paper presents a new approach to TVG modeling, which is based on the use of Proper Orthogonal Decomposition (POD) to reduce the dimensionality of the TVG data. The results show that the TVG error can be significantly reduced by using the TVG models derived from the POD analysis. The TVG models are used to calibrate the tide gauges and to estimate the mean sea level (MSL) trend. The results show that the TVG error can be significantly reduced by using the TVG models derived from the POD analysis. The TVG models are used to calibrate the tide gauges and to estimate the MSL trend. The results show that the TVG error can be significantly reduced by using the TVG models derived from the POD analysis.

**TVG models and POD performance**

Model	POD Rank	POD Error (mm)	POD Error (mm)	POD Error (mm)
TVG-1	1	0.00	0.00	0.00
TVG-2	2	0.00	0.00	0.00
TVG-3	3	0.00	0.00	0.00
TVG-4	4	0.00	0.00	0.00
TVG-5	5	0.00	0.00	0.00
TVG-6	6	0.00	0.00	0.00
TVG-7	7	0.00	0.00	0.00
TVG-8	8	0.00	0.00	0.00
TVG-9	9	0.00	0.00	0.00
TVG-10	10	0.00	0.00	0.00

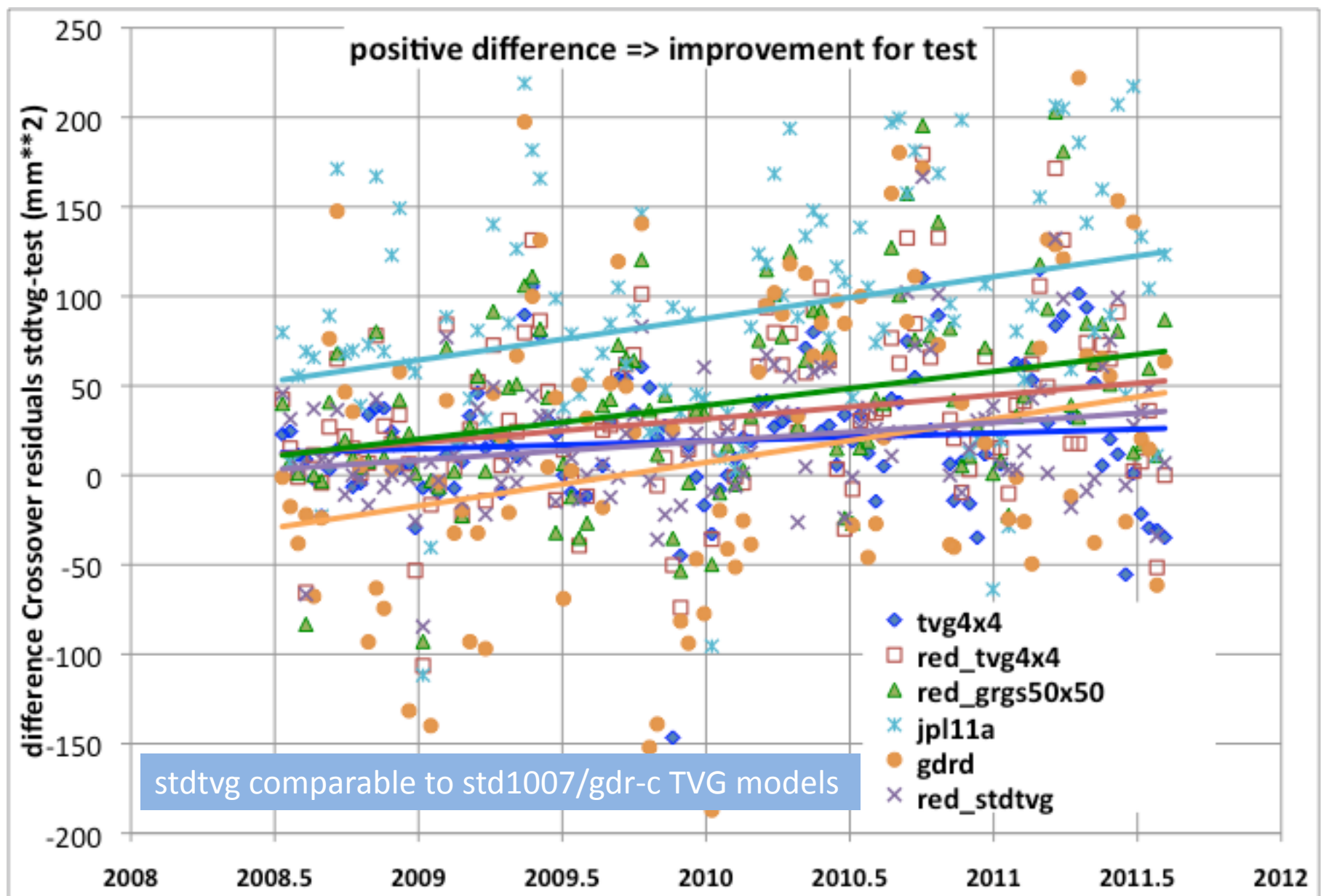


**Conclusions**  
 1) TVG error may be large as an annual signal in regional trends. All these TVG models show different regional trends.  
 2) The gauge calibration is sensitive to TVG regional trend error, however, the gauge data comparably, not so directly sensitive to TVG model.  
 3) The gauge calibration is sensitive to TVG regional trend error, however, the gauge data comparably, not so directly sensitive to TVG model.  
 4) The gauge calibration is sensitive to TVG regional trend error, however, the gauge data comparably, not so directly sensitive to TVG model.  
 5) The gauge calibration is sensitive to TVG regional trend error, however, the gauge data comparably, not so directly sensitive to TVG model.

- introduce 4 Items from poster:
- 1) TVG important to POD, with several recent competing models
  - 1) impact TVG error on MSL
  - 1) impact TVG error on calibration
  - 1) SLR+DORIS reduced dynamic orbit sensitivity to TVG error



# 1) Orbit accuracy using the old TVG model (stdtv) progressively degrades compared to 6 orbits with recent TVG modeling

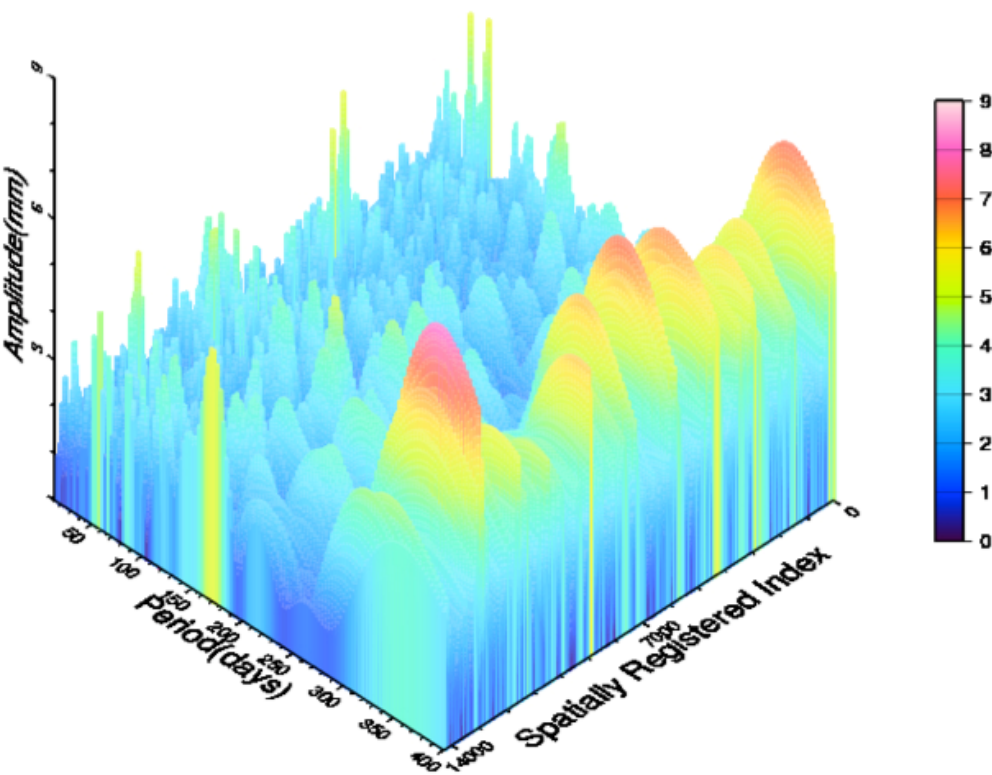




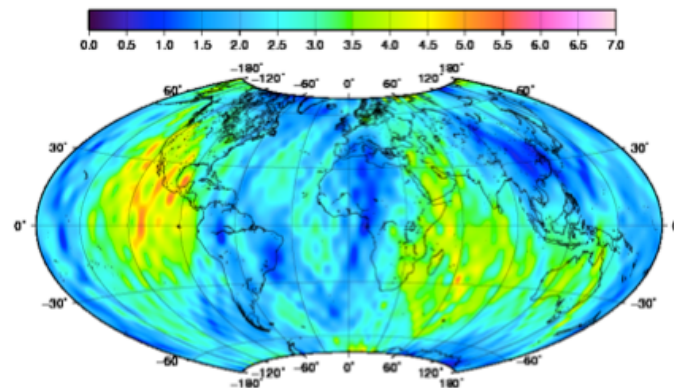
# 2) Jason-2 TVG orbit error impact on sea level – manifest as periodic signals and regional trends

## periodic signals

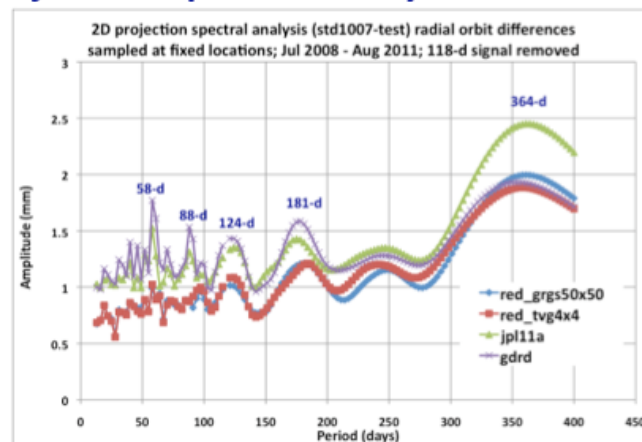
Spectral analysis of std1007-jpl11a radial differences over fixed geographic locations (118-day signal removed)



Annual amplitude projection std1007-jpl11a



2-D projection spectral analysis of std1007-test

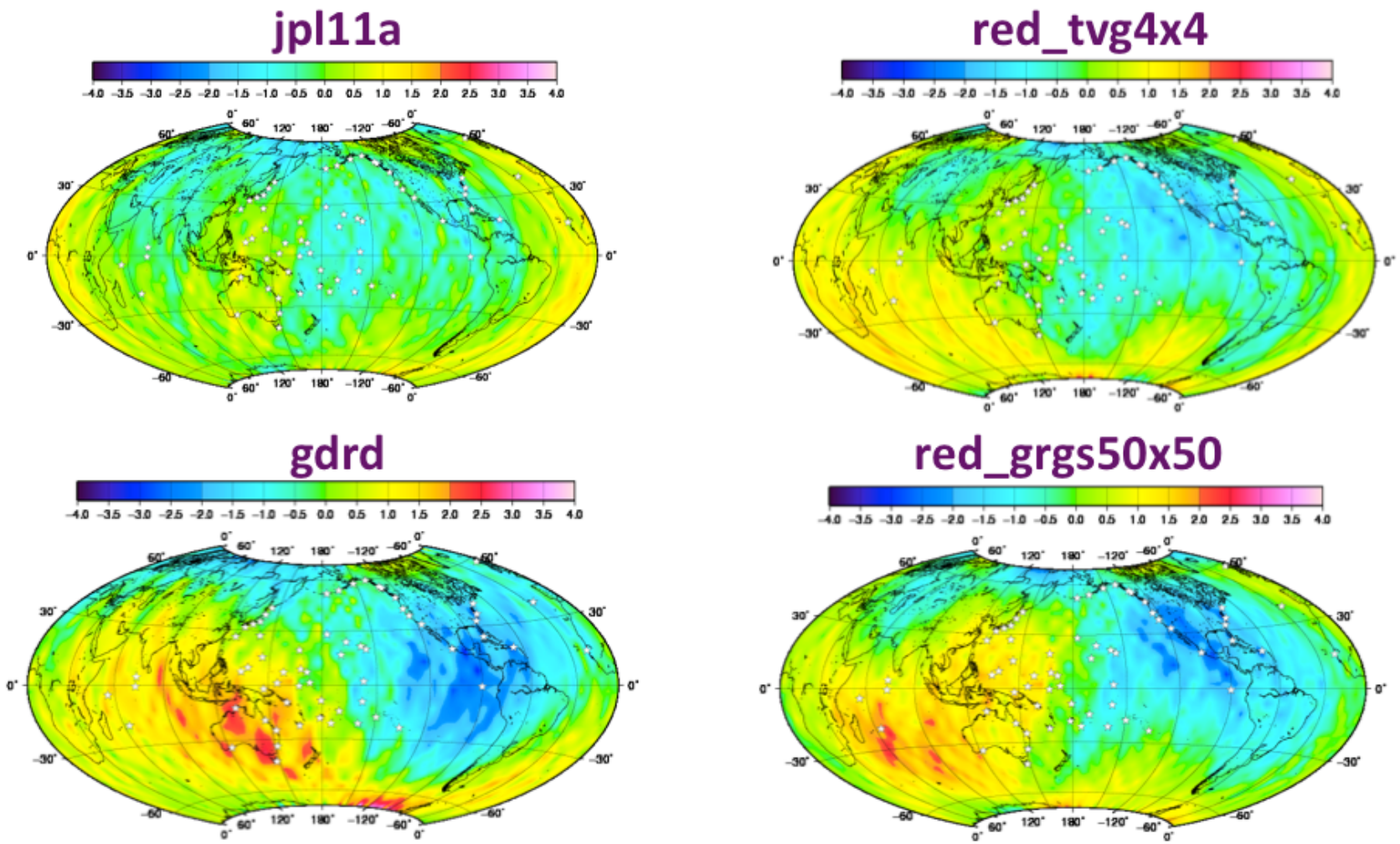




# 2) Jason-2 TVG orbit error impact on sea level – manifest as periodic signals and regional trends

## regional trends (mm/yr)

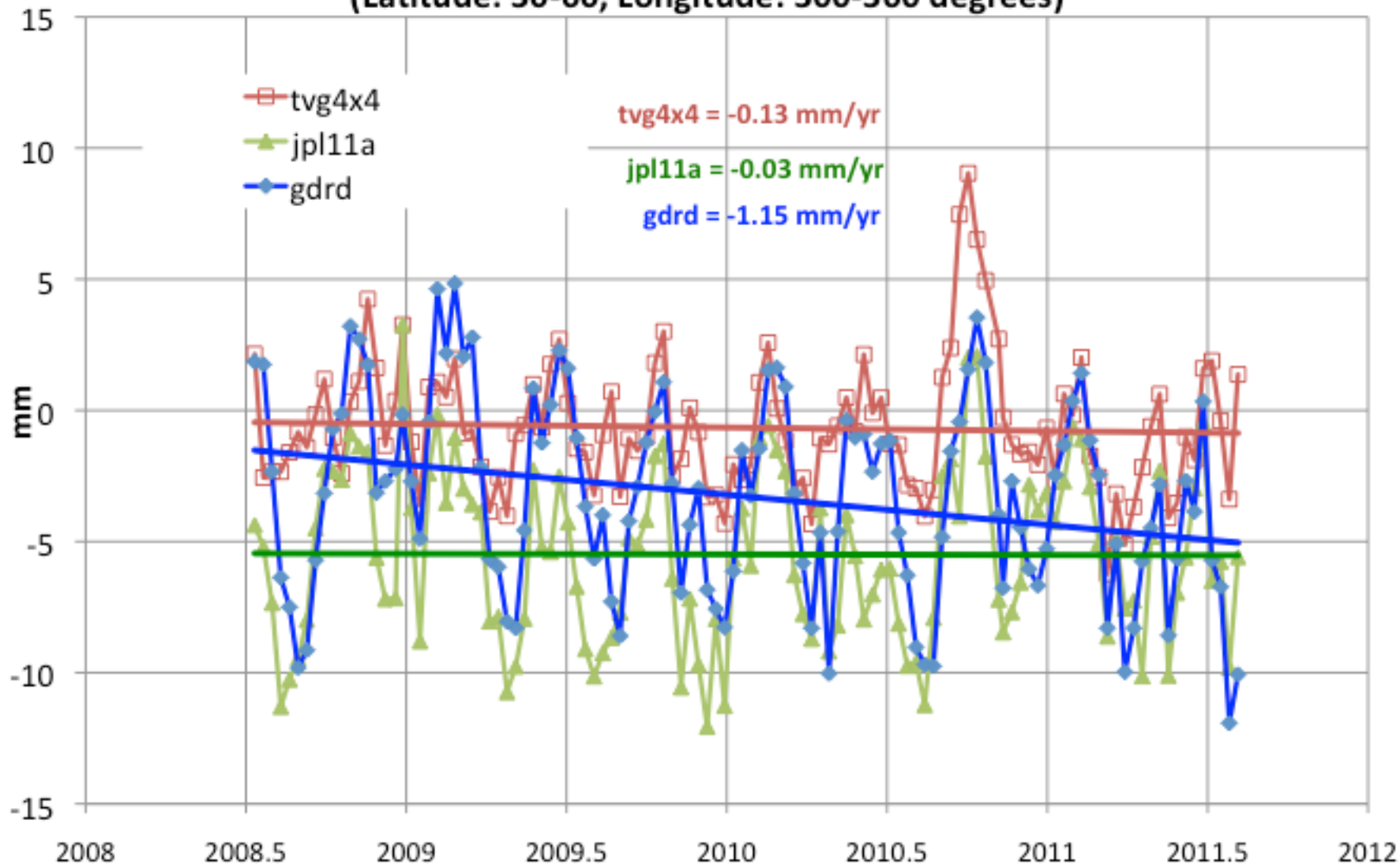
std1007-test orbit radial difference linear rates (mm/yr) estimated July 2008 – August 2011 after removing annual, semi-annual, and 118-day terms.





## 2) example of TVG orbit error potential impact on regional sea level trend analysis (mm/yr)

Mean radial (std1007-test) orbit differences over N. Atlantic  
(Latitude: 30-60, Longitude: 300-360 degrees)





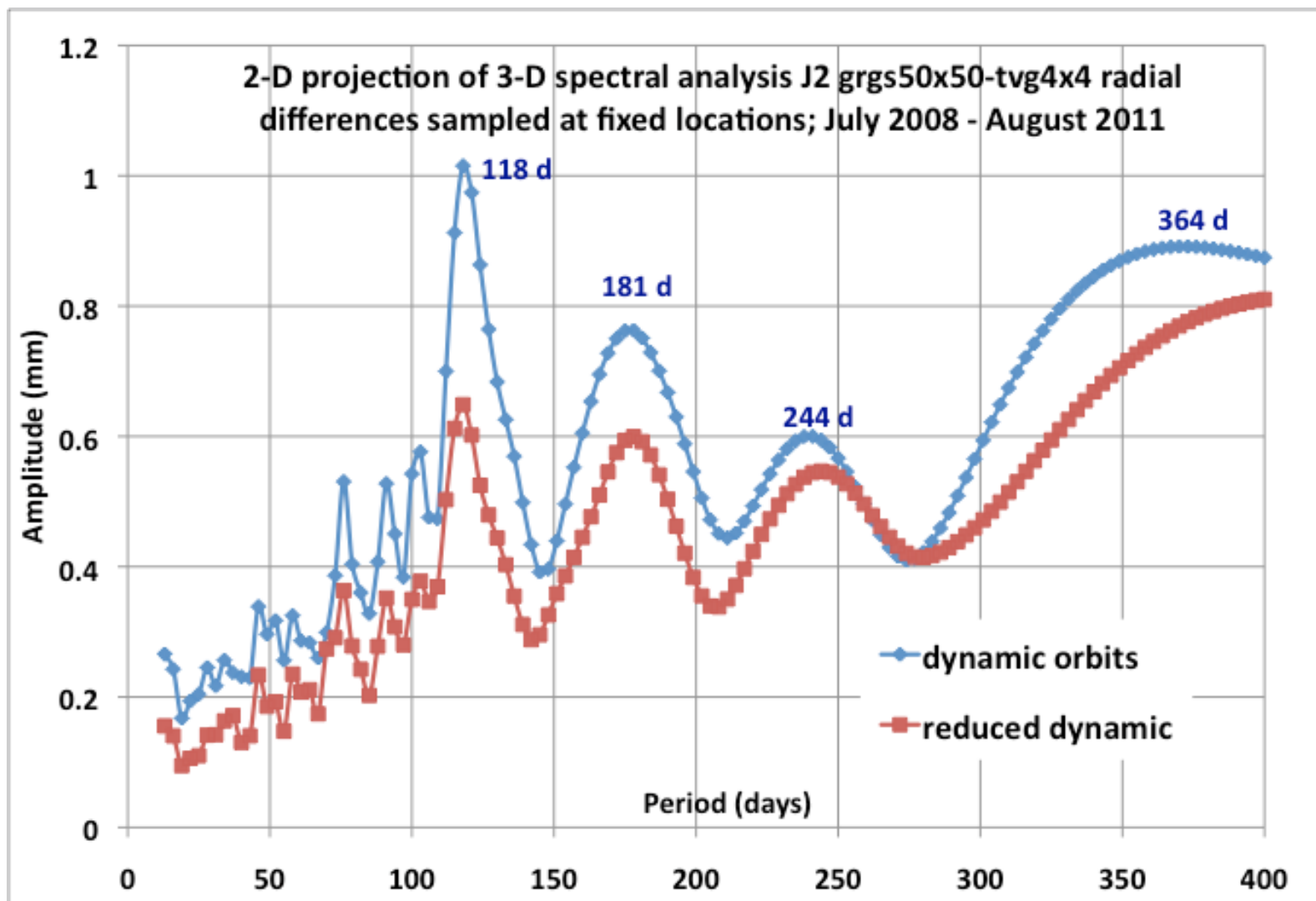
### 3) Tide gauge calibration sensitive to Jason-2 TVG regional trend orbit error

Altimetry-Tide Gauge Calibration Sensitivity to Jason-2 orbits cycles 1-114 (Jul 2008 – Aug 2011)						
Estimated linear rate (mm/y)	Orbit					
	std1007	tv4x4	red_tv4x4	grgs50x50	gdrd	jpl11a
<b>weighted</b> altimetry-tide gauge calibration estimate over 64 tide gauge sites (see Note below)	-1.00	-----	-----	-----	-----	-----
<b>un-weighted</b> mean orbit differences over 64 tide gauge sites (test-std1007)	0.00	0.33	0.48	-0.24	0.03	0.12
<b>un-weighted</b> altimetry-tide gauge calibration approximation	-1.00	-0.67	-0.52	-1.24	-0.97	-0.88

Note. Gary Mitchum's latest **weighted** altimetry-tide gauge residuals mean for the std1007 orbits Jason-2 cycles 1-182 (see Beckley et al., 2013 poster, Global CAL-VAL session).

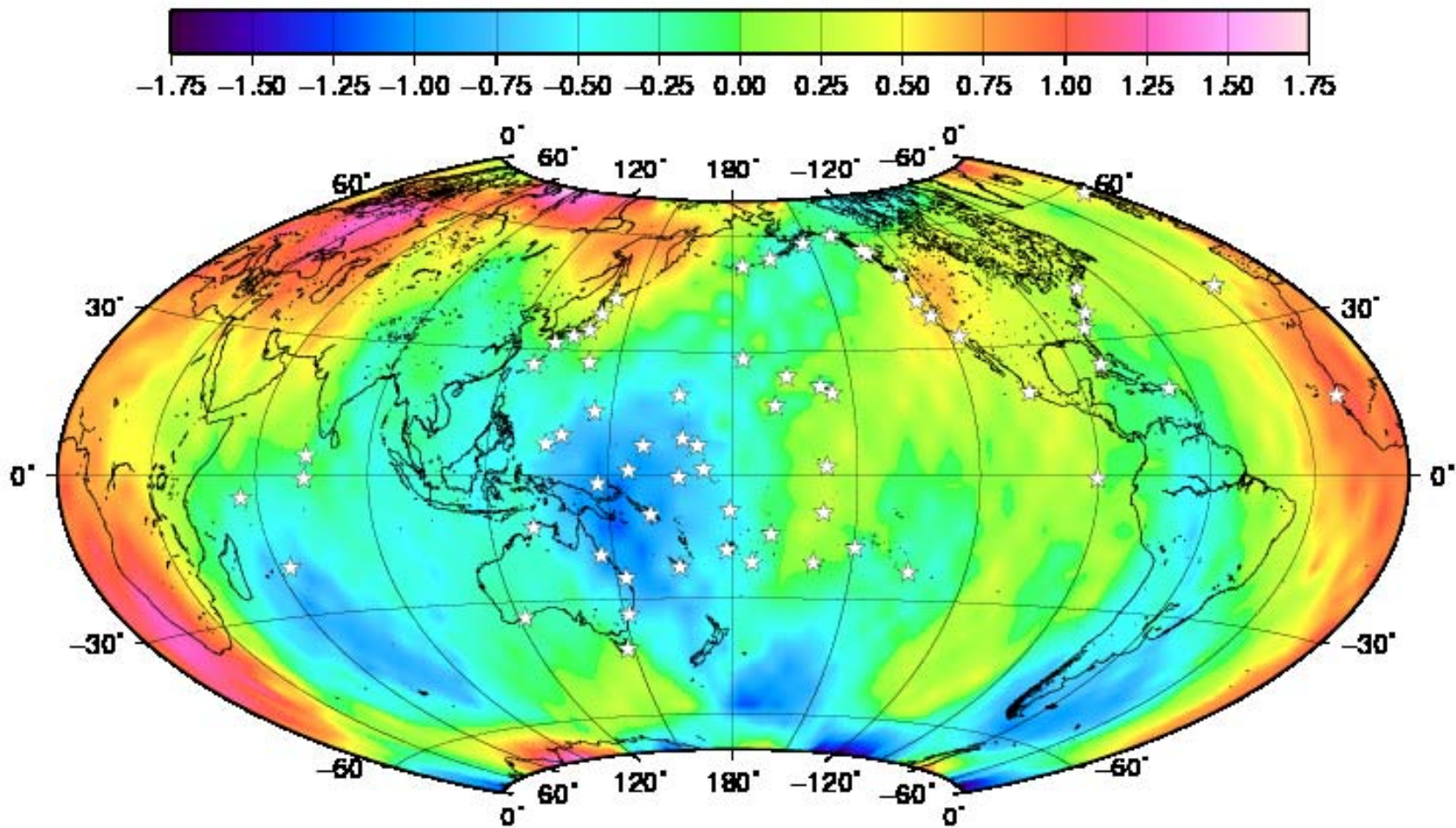


4) The SLR+DORIS reduced-dynamic improves consistency between the grgs50x50 / tvg4x4 orbits as shown in the reduction of power for the periodic signals. However ...





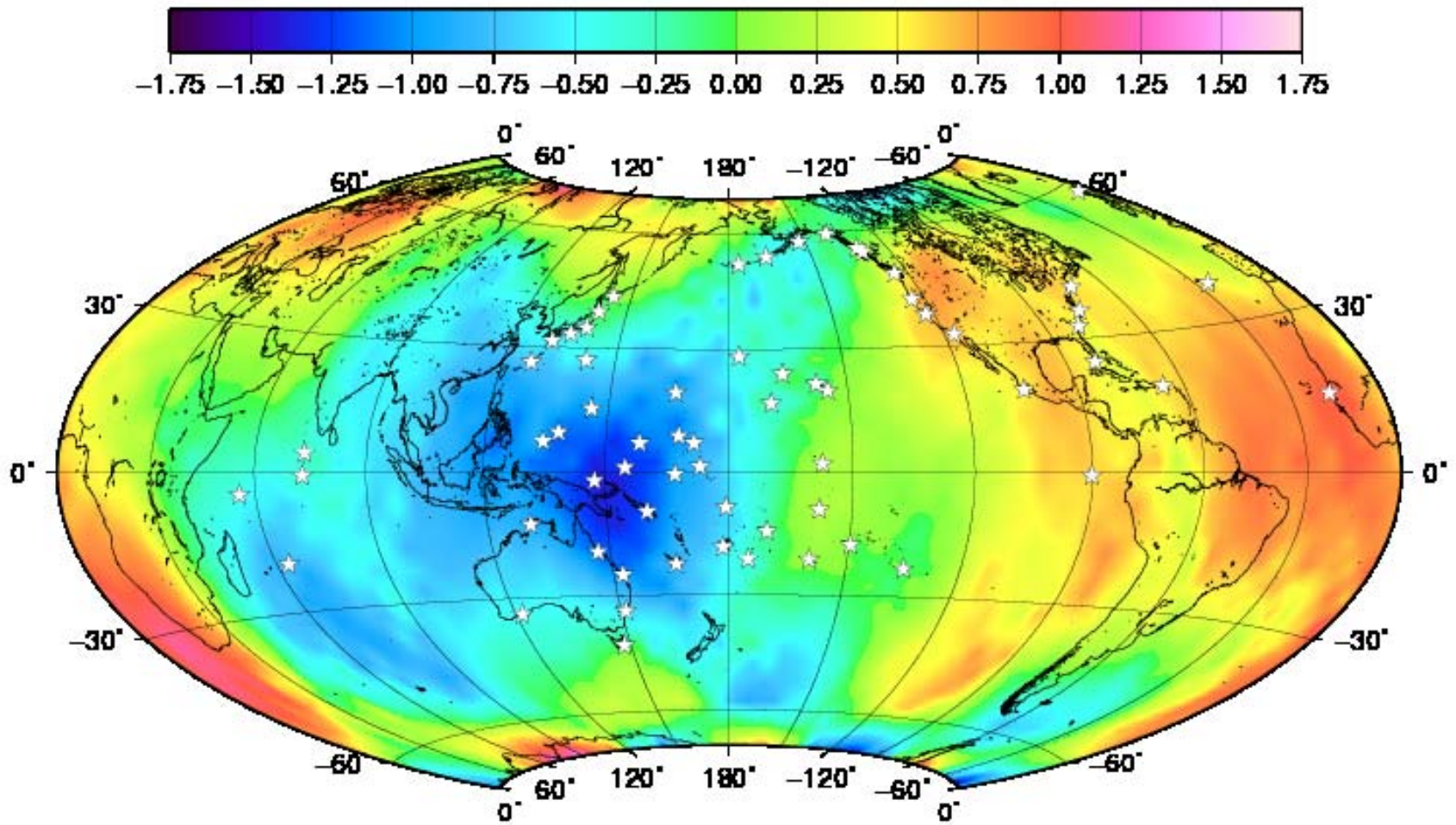
**J2 dynamic orbit (grgs50x50-tvg4x4) radial difference linear rates (mm/yr) estimated July 2008 – August 2011 after removing annual, semi-annual, and 118-day terms.**







**J2 reduced-dynamic orbit (grgs50x50-tvg4x4) radial difference linear rates (mm/yr) estimated July 2008 – August 2011 after removing annual, semi-annual, and 118-day terms.**





## Conclusions

- 1) Recent TVG models progressively improve Jason-2 orbits over the standard approach used for the previous Measures std1007 and GDRC orbits.**
- 2) TVG orbit error manifests largely as an annual signal and in regional trends. All recent TVG models show significantly different regional trends.**
- 3) Tide gauge calibration is sensitive to TVG regional trend orbit error, however tide gauge data can probably not be directly used to evaluate TVG models.**
- 4) SLR+DORIS reduced-dynamic approach does not eliminate TVG regional trend error at the level of differences seen between competing TVG models.**