OSTST 2014 POD Splinter

# Long-term Analysis of Possible Remaining Sources of Orbit Error

A. Couhert, F. Mercier, E. Jalabert, J. Moyard, S. Houry

October 29, 2014

Lake Constance, Germany

# GDR-D Orbit Error Budget

| Error Source | Time Scale | Global | Regional | Rationale |
|---|---|---|---|---|
| Tracking Data Residual Consistency | seasonal | | 3–8 mm | SLR v. GPS/DORIS orbits |
| | interannual | | 3 mm/y | |
| | decadal | | 2 mm/y | |
| Reference Frame | seasonal | | 8 mm | GPS v. SLR+DORIS, ITRF08 v. 05 |
| | interannual | 0.03 mm/y | 1 mm/y | |
| | decadal | 0.05 mm/y | 0.3 mm/y | |
| Time Variable Gravity | seasonal | | 4 mm | Mean field v. 10-day series and external orbits |
| | interannual | 0.1 mm | 2 mm/y | |
| | decadal | 0.1 mm/y | 1.5 mm/y | |

An estimated **radial orbit error budget** for the Jason series GDR-D solutions is given in Jason POD Team paper *Towards the 1 mm/y Stability of the Radial Orbit Error at Regional Scales*, (Adv. Space Res.)

## Non-tidal displacement corrections

# Tested Loading Models

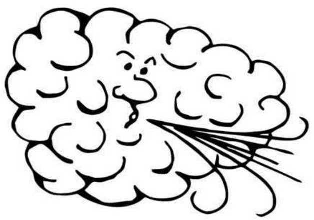
## Context

- Significant annual signals in the mean SLR residuals of the core-network stations (Yarragadee, Greenbelt, Graz) on the Jason-2 GPS-derived orbits

- A degradation of residuals on the best performing SLR stations of the network was noticed last year:
  - Between mid 2010 and mid 2012 for Yarragadee
  - From 2011 for Greenbelt

⇒ Un-modeled effects in the station position are investigated

⇒http://loading.u-strasbg.fr

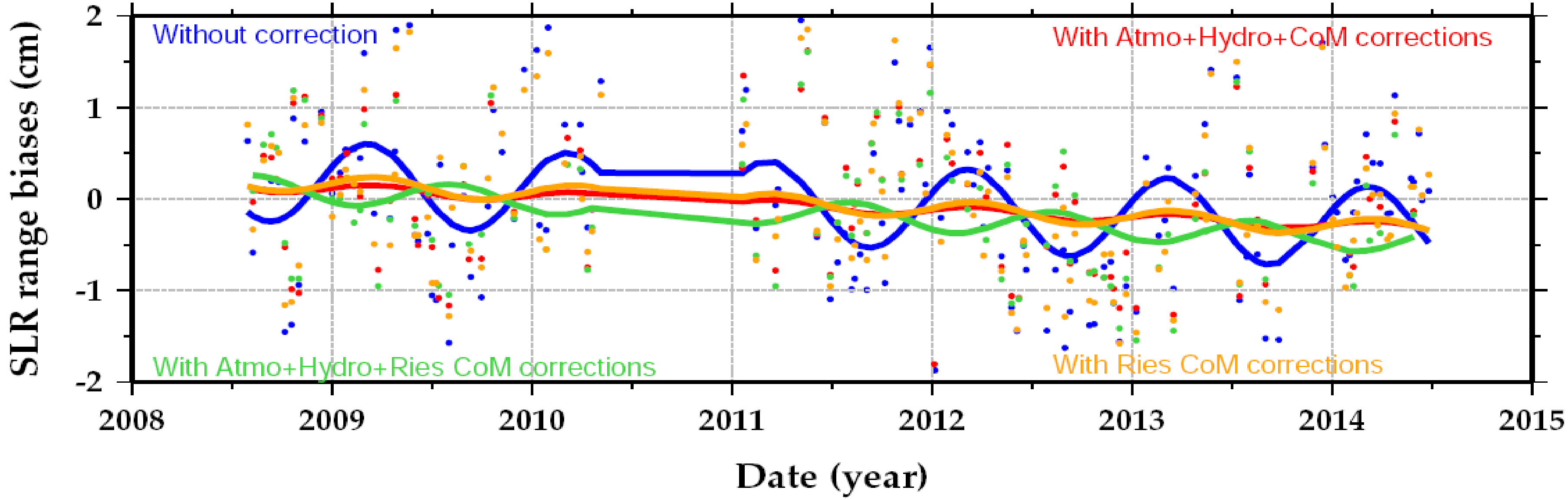


Atmospheric loading (ECMWF/IB)

\+

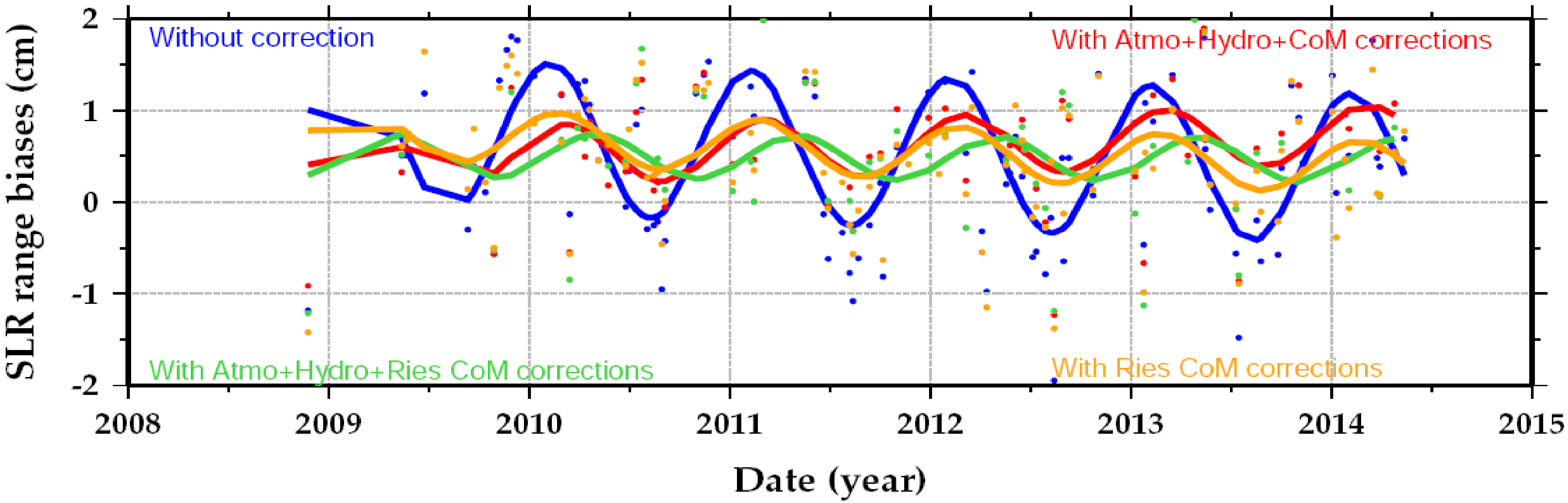
Hydrological loading (GLDAS/Noah)

# Greenbelt



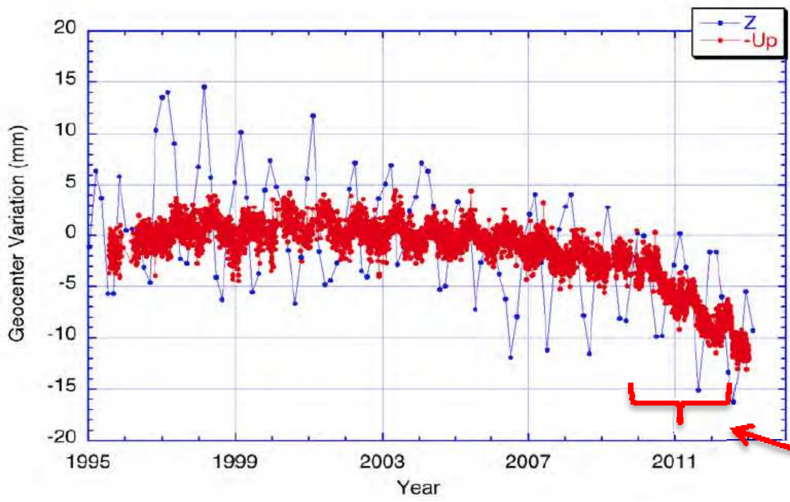
Without correction
With Atmo+Hydro+CoM corrections
With Atmo+Hydro+Ries CoM corrections
With Ries CoM corrections
SLR range biases (cm)
2
1
0
-1
-2
2008
2009
2010
2011
2012
2013
2014
2015
Date (year)

# Matera

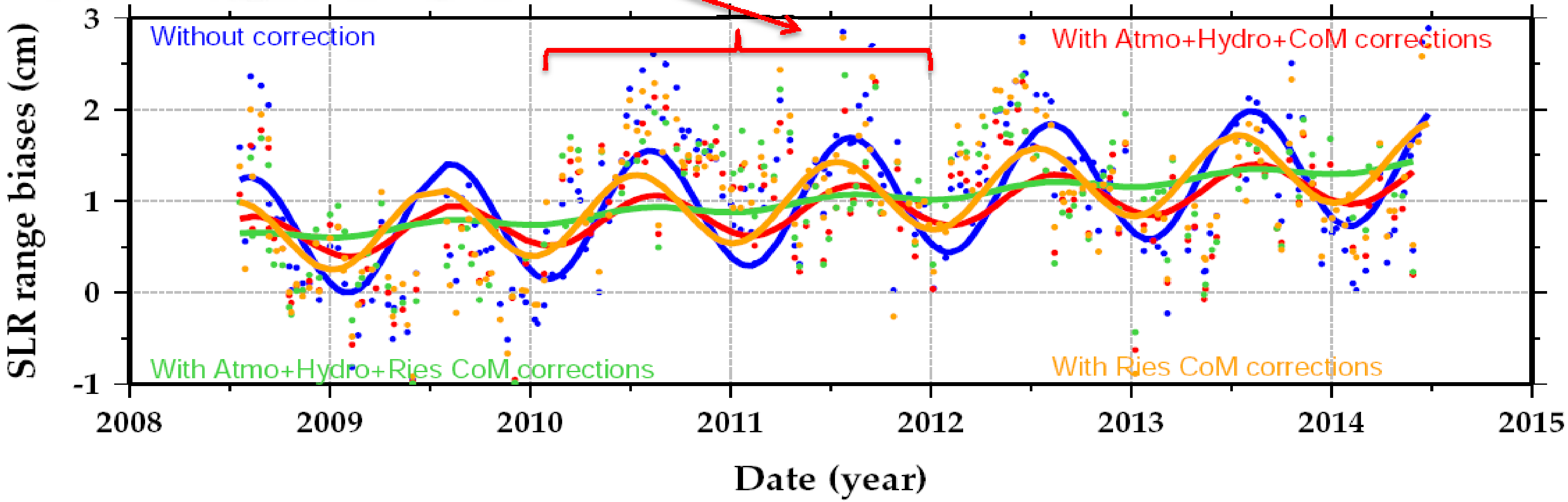


Without correction
With Atmo+Hydro+CoM corrections
With Atmo+Hydro+Ries CoM corrections
With Ries CoM corrections
SLR range biases (cm)
2
1
0
-1
-2
2008
2009
2010
2011
2012
2013
2014
2015
Date (year)

# Yarragadee




Courtesy of
J. Ries




Combining atmospheric, hydrology loading and seasonal non-tidal geocenter corrections significantly reduces the amplitudes of annual signals in the residuals. The positive bias of ~1 cm is not reduced by the non-tidal loading models: deficiencies in the loading models (local motions)? Acceleration in geocenter motion (due to present-day accelerated ice mass loss)?

cnes

# Non-tidal time-variable gravity effects

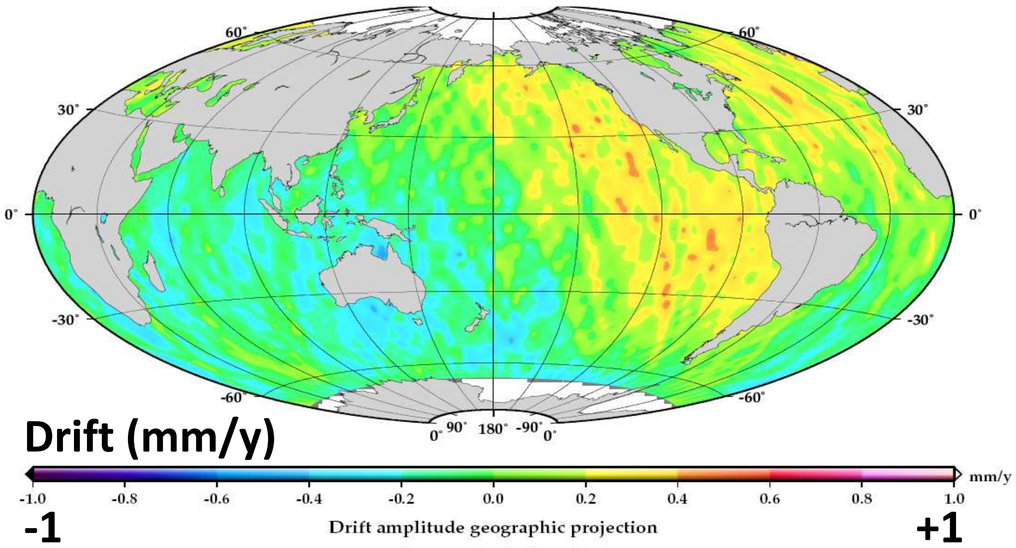
# Test of the GRACE Monthly Gravity Field Solutions

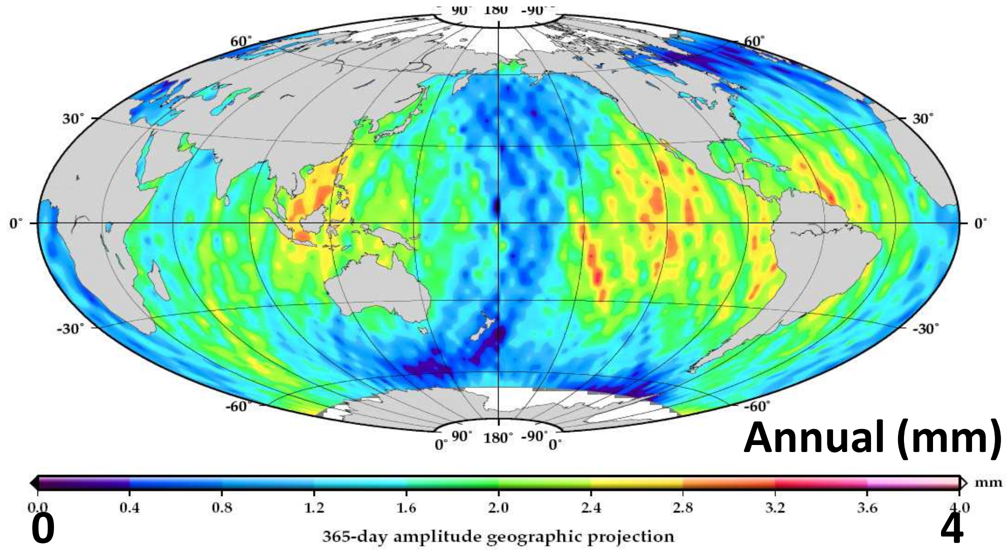
## Background

- GRACE RL05 time-series of monthly time-variable gravity field estimates from JPL, CSR, GFZ, and GRACE solutions RL03 from CNES/GRGS.
- The C20 values were replaced within the RL05 monthly gravity field solutions with the values from the TN07 SLR-derived estimates.
- Jason-2 GDR-D like dynamic orbits were reprocessed using the different GRACE monthly solutions (instead of the mean gravity field model) and compared to reduced dynamic orbits to assess their accuracy.
  - » GDR-E preliminary GPS+DORIS solution (*abandoned first order Gauss-Markov process to enable the stochastic empirical accelerations to absorb potential bias errors in the models*): along-track constant every 30 min + 1/rev along and cross-track per revolution.
  - » JPL RLSE 14A GPS-based solution

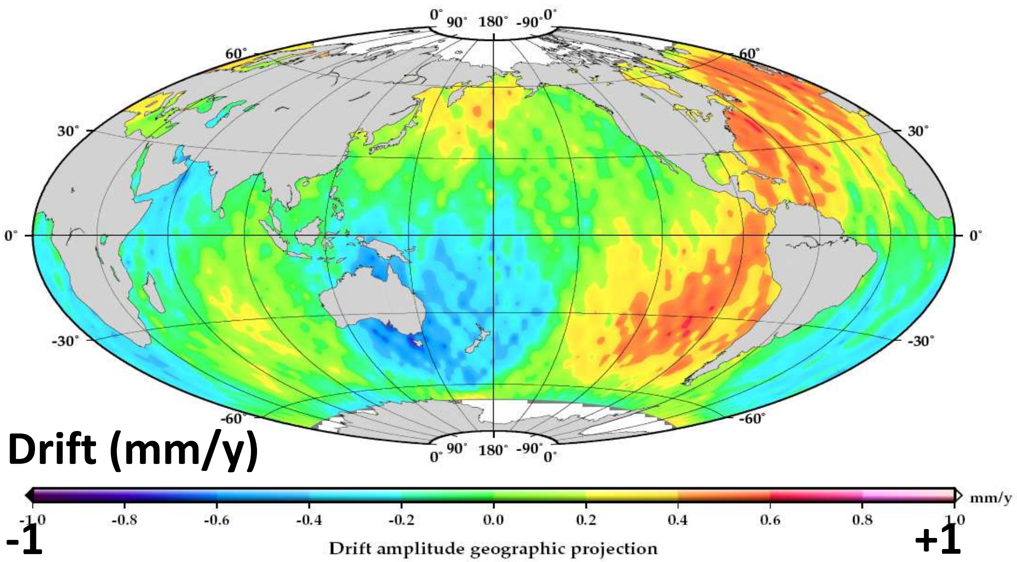
# Test of the GRACE Monthly Gravity Field Solutions

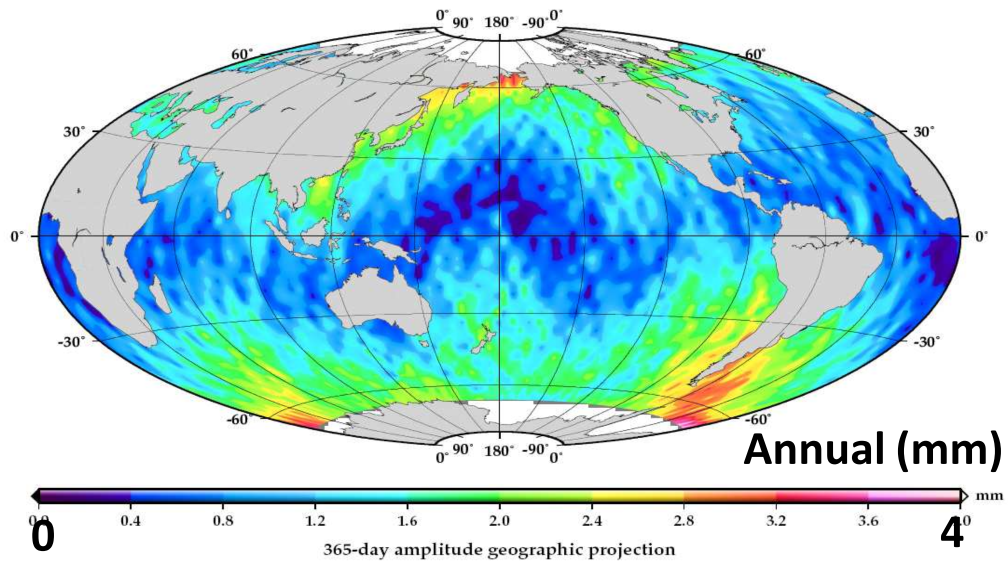
## J2 (GDR-D + CSR TVG) – (JPL14A red. dyn.)




## J2 (GDR-D + CSR TVG) – (GDR-E preliminary red. dyn.)

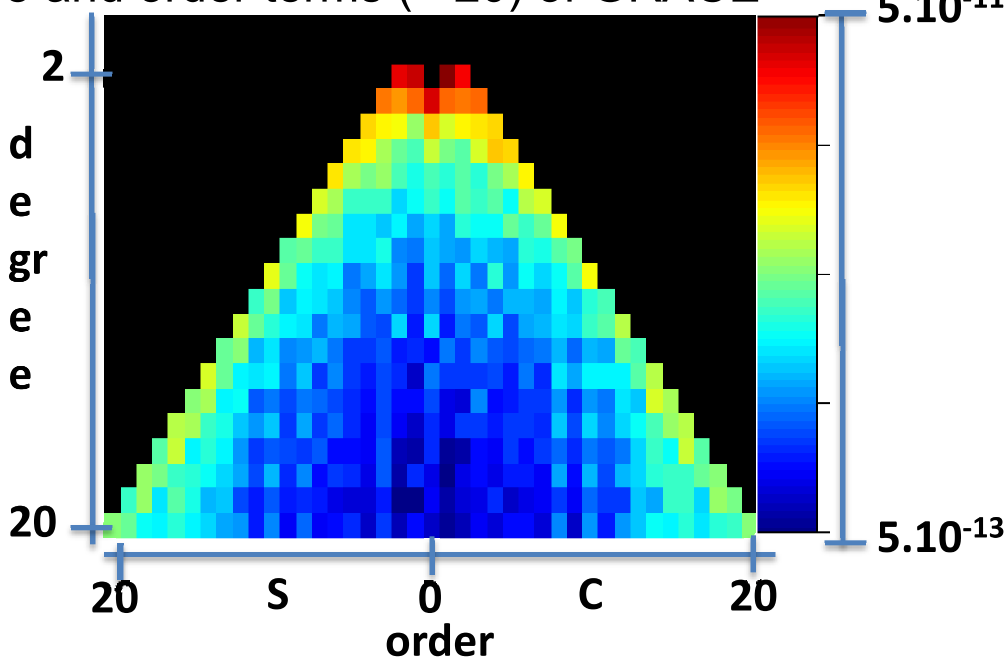


# Satellite Orbit Sensitivity Analysis

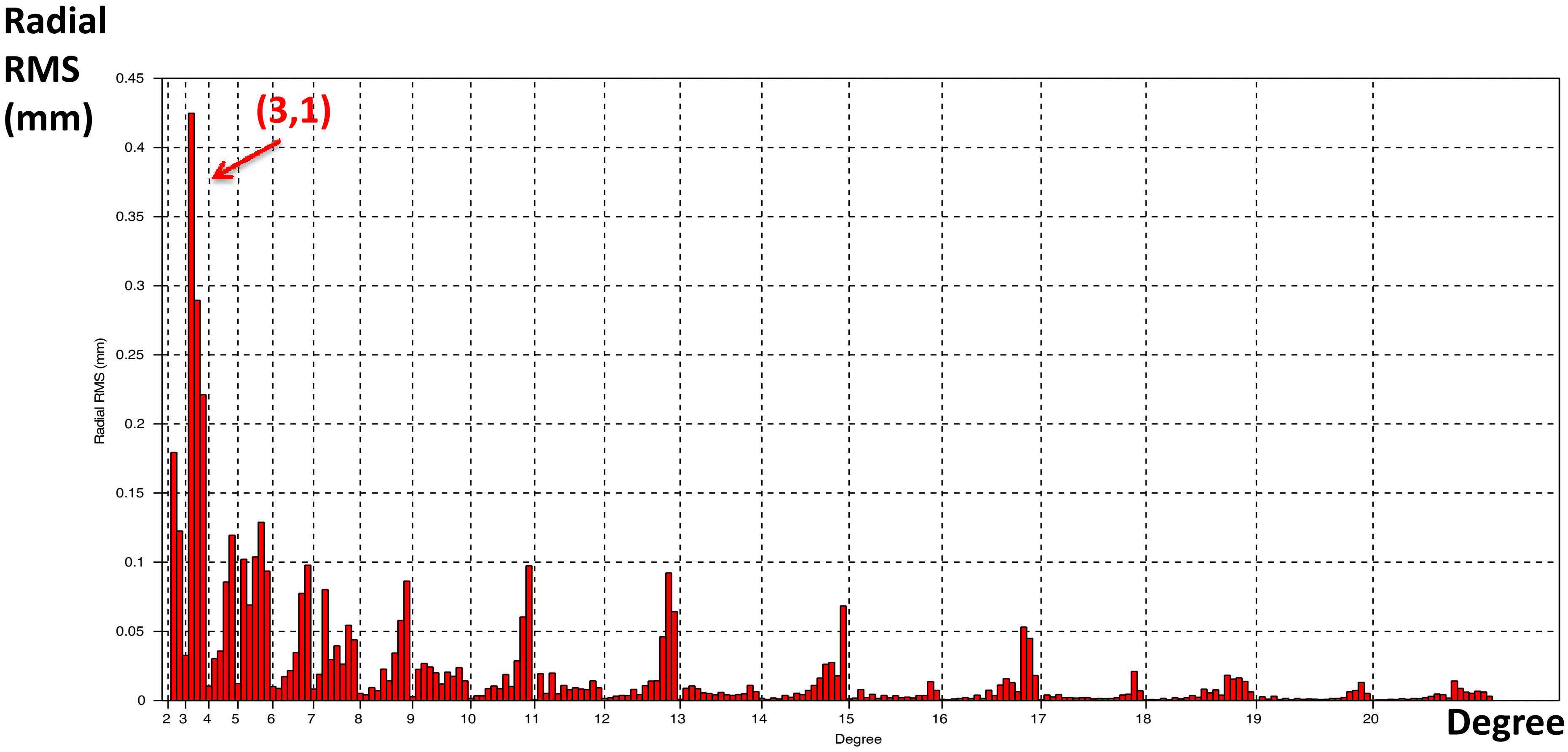
## Goal

- The differences between the low degree and order terms (< 20) of GRACE monthly gravity field solutions from the four processing centers (CSR, GFZ, JPL and GRGS) was analyzed to gauge their "internal" error.




- The radial orbit sensitivity of the four currently flying altimeter missions to individual variations in spherical harmonics corresponding to the standard deviation values previously obtained was then computed.

# Jason-2

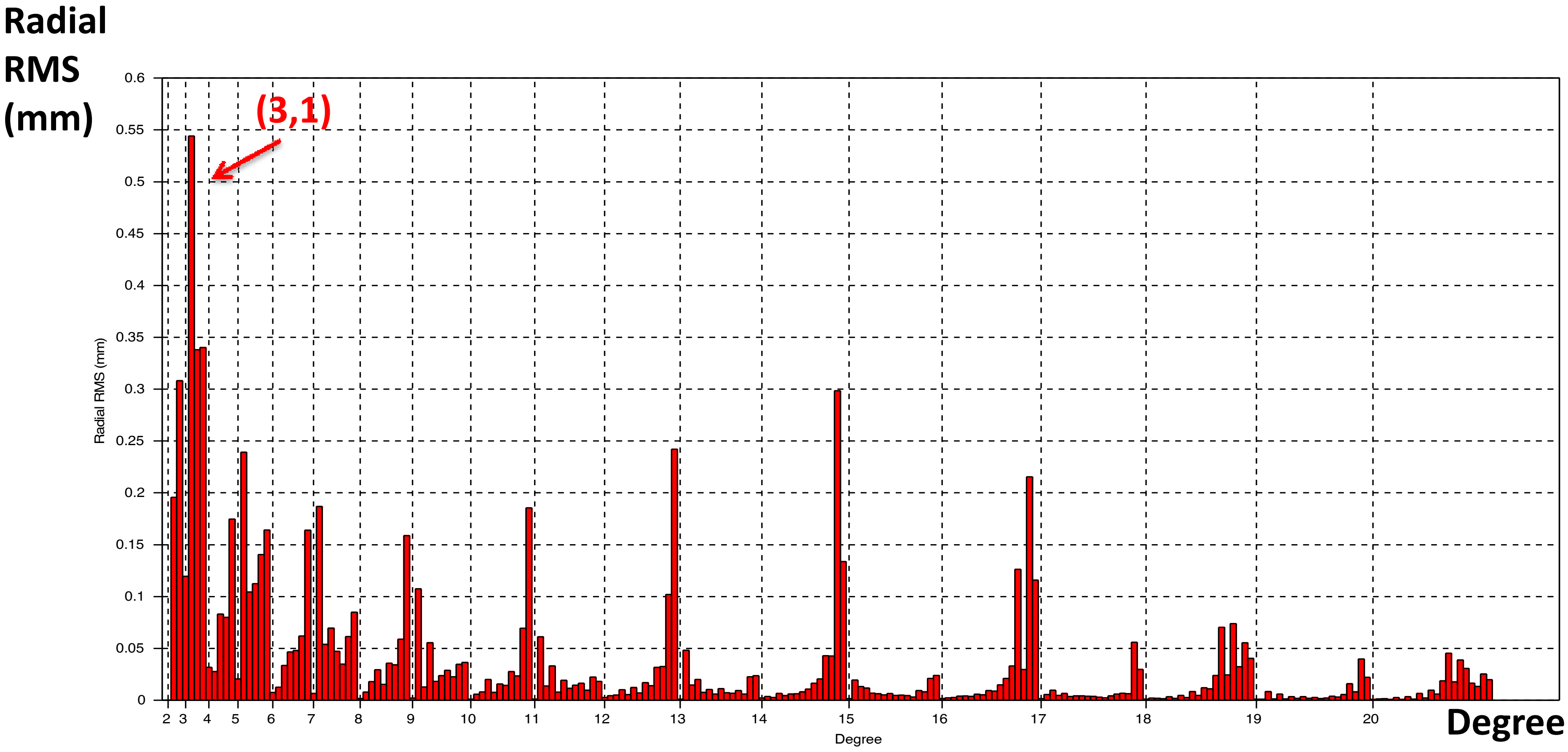


Radial RMS (mm)
(3,1)
Degree
Radial RMS (mm)
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Degree



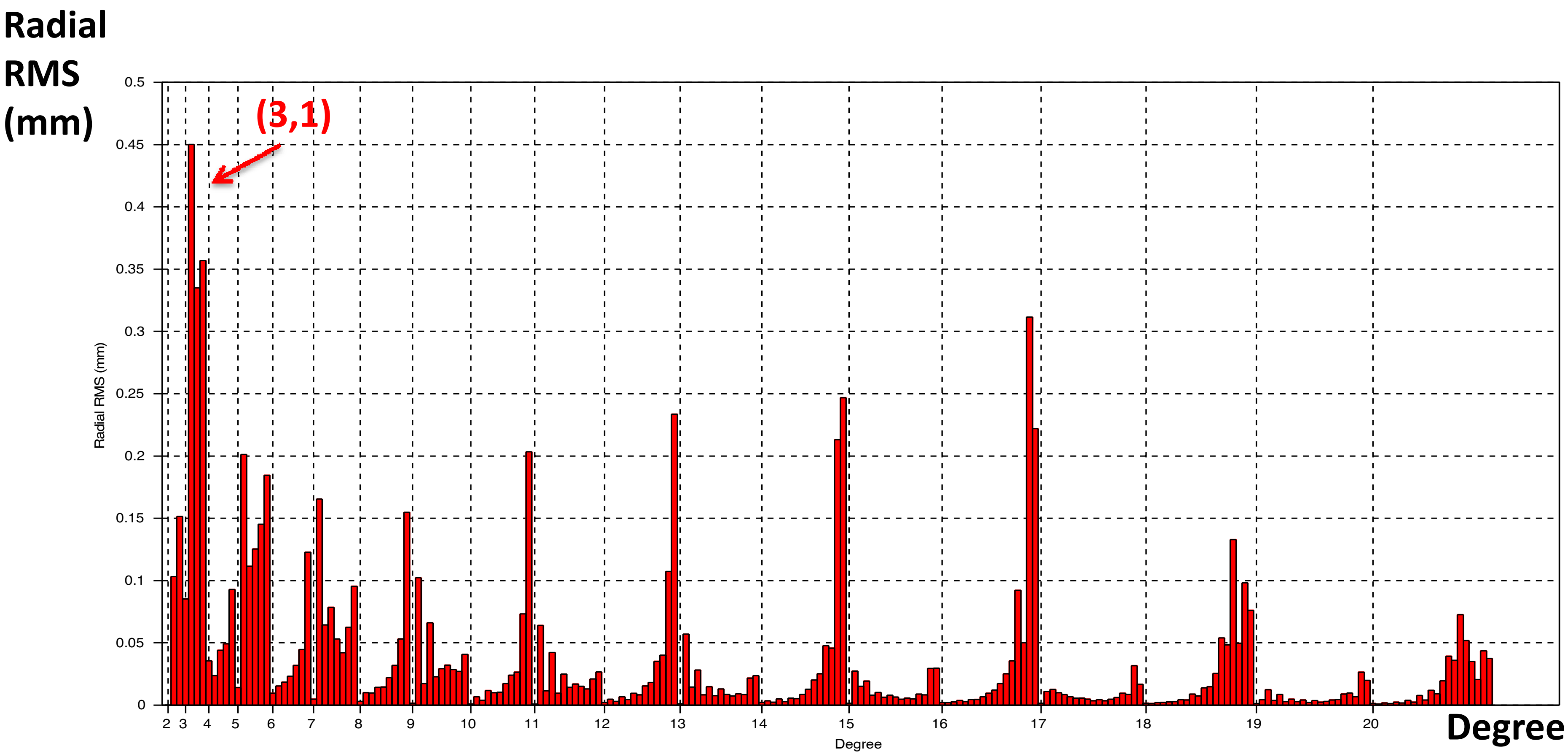

cnes

# HY-2A



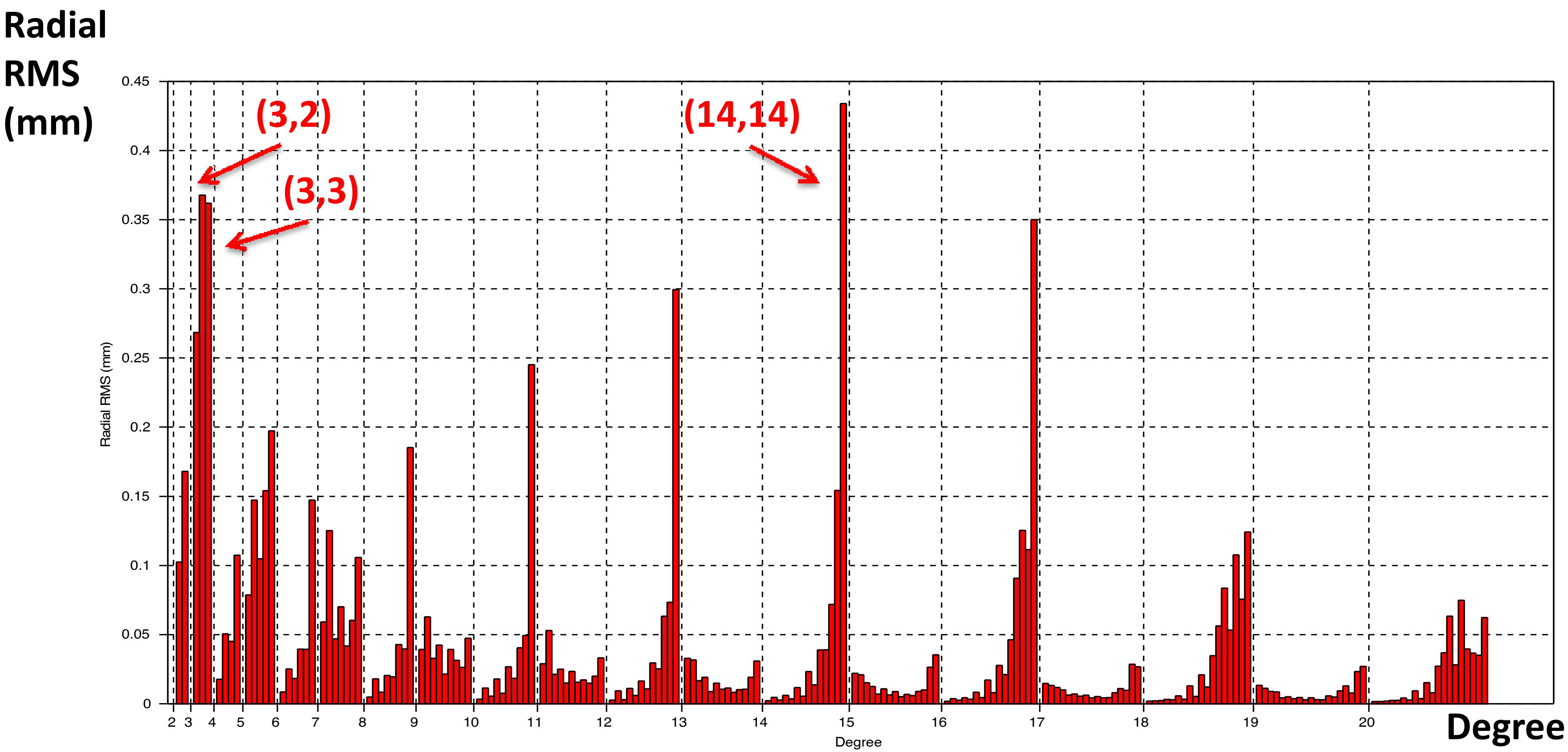
Radial
RMS
(mm)
(3,1)
Radial RMS (mm)
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Degree
Degree

# Saral



Radial RMS (mm)
(3,1)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Radial RMS (mm)
2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Degree
Degree

# CryoSat-2

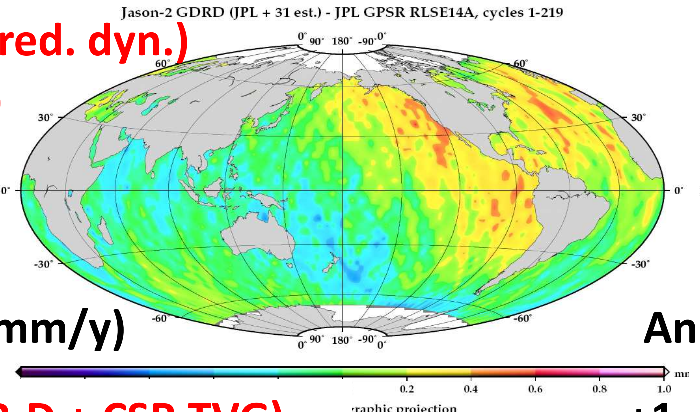



Error analysis shows that the Jason-2, HY-2A and Saral satellites are most sensitive to TVG error in the degree 3 order 1 present in the GRACE time series, and in the degree 14 order 14 and degree 3 order 2, 3 for CryoSat-2.

# Satellite Tracking Data Use to Absorb Such Residual Errors in the TVG Models

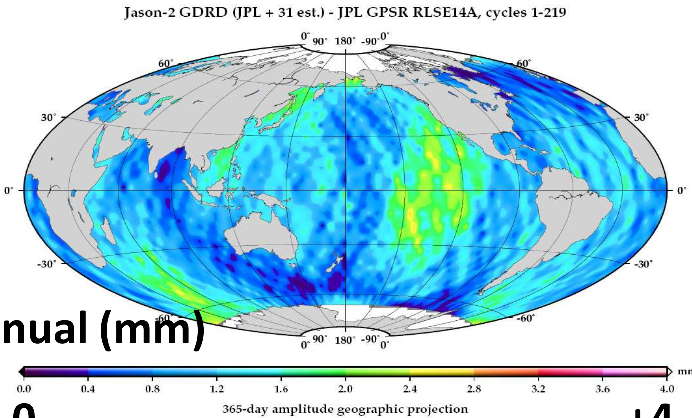
**J2 (GDR-D + JPL TVG) – (JPL14A red. dyn.)**

**J2 (GDR-D + JPL TVG + 31 est.) – (JPL14A red. dyn.)**




Drift (mm/y)

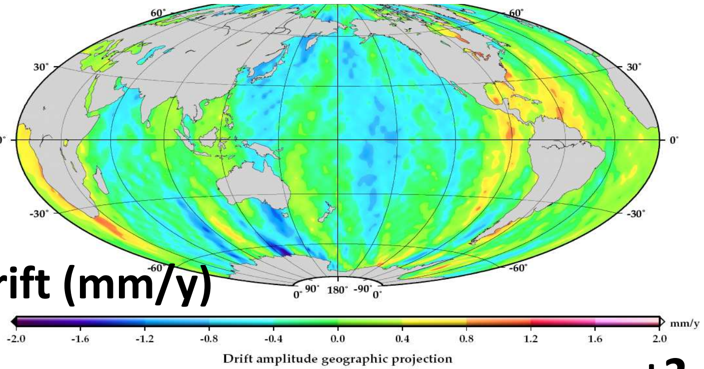
+1




Annual (mm)

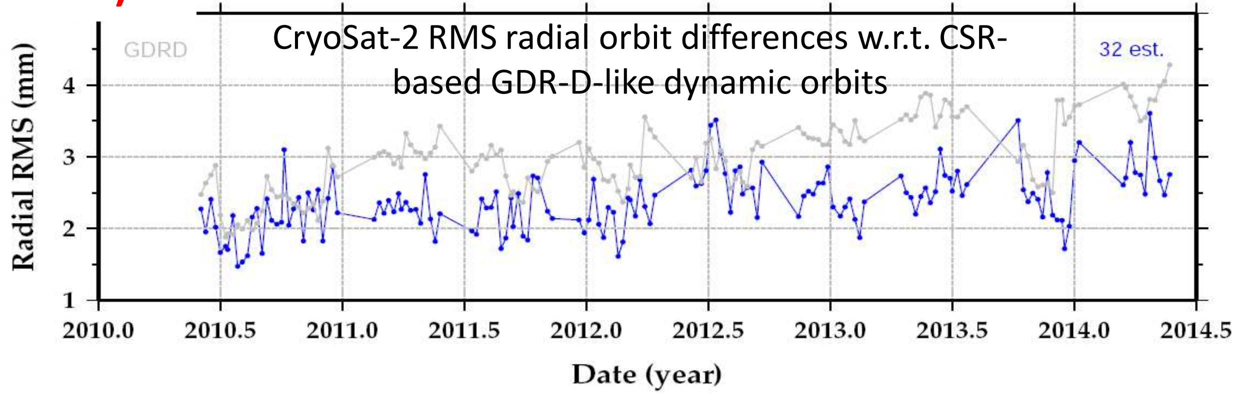
0 +4

**HY-2A (GDR-D + 31 est.) – (GDR-D + CSR TVG)**

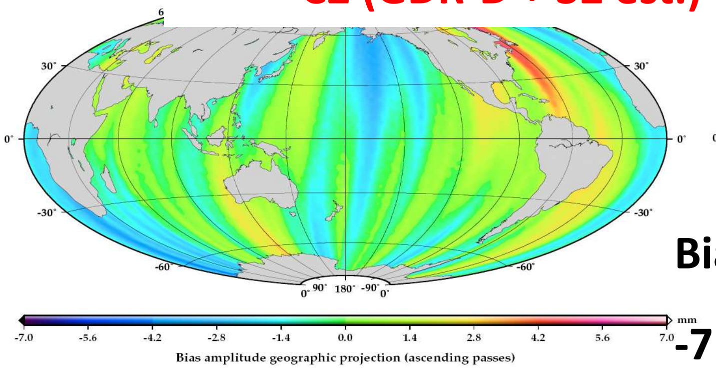


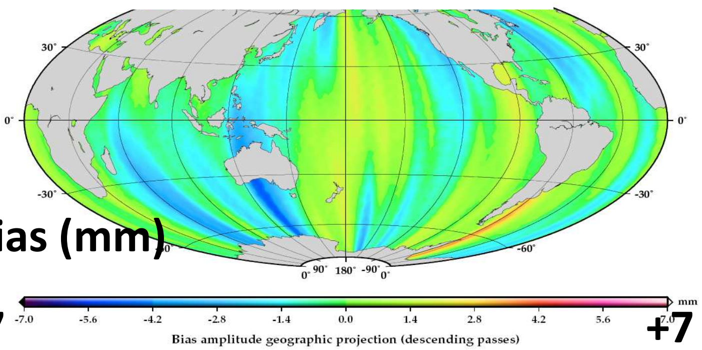

Drift (mm/y)

-2 +2




**C2 (GDR-D + 32 est.) – (GDR-D + CSR TVG)**



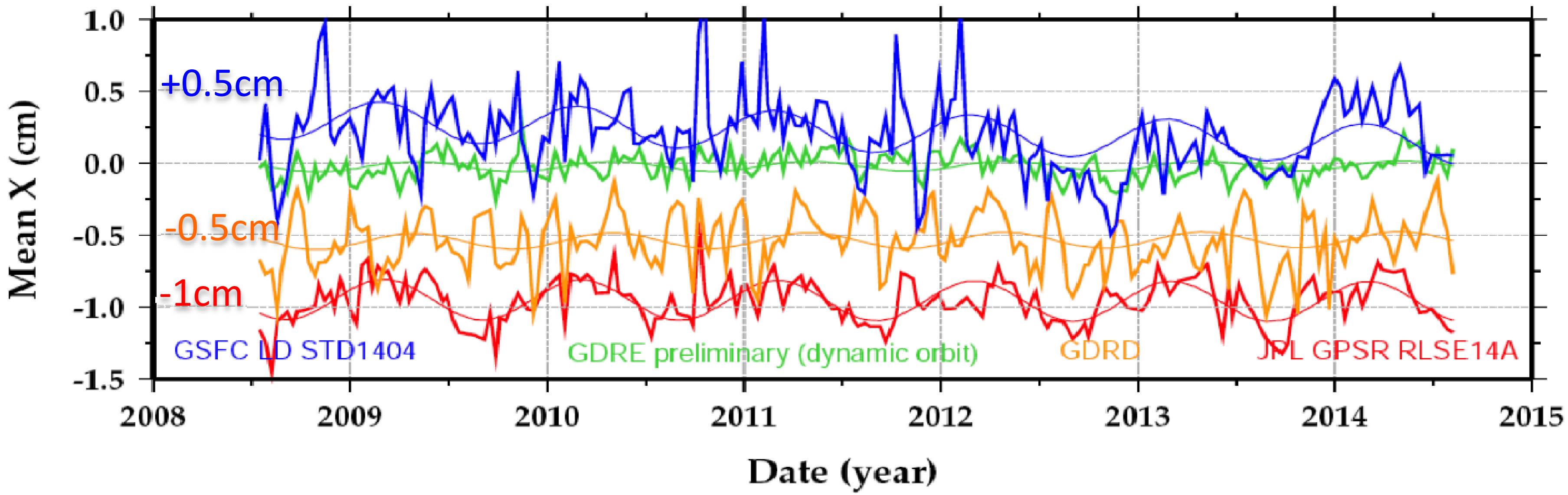

Bias (mm)

-7 +7

# Annual geocenter correction

# Relative Orbit Centering Stability Between POD Centers

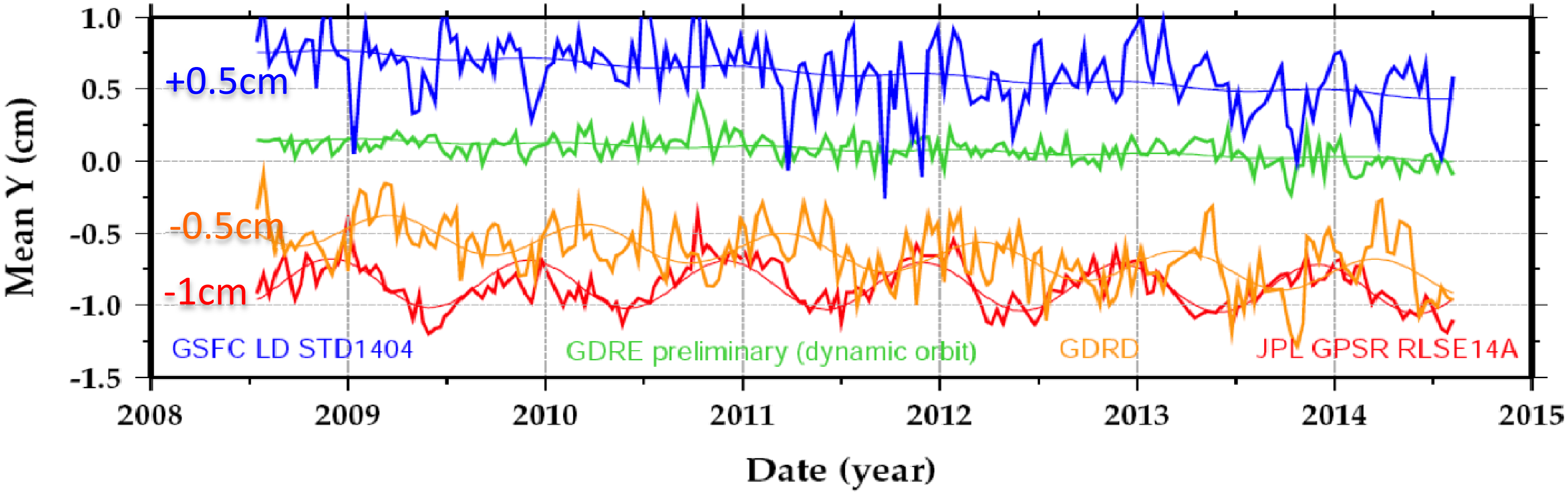
Mean X orbit differences with respect to the GDR-E preliminary reduced-dynamic solution




**X bias of 2-3 mm** (and drift?) w.r.t. GSFC,
X annual signal at the mm level w.r.t. GSFC and JPL

# Relative Orbit Centering Stability Between POD Centers

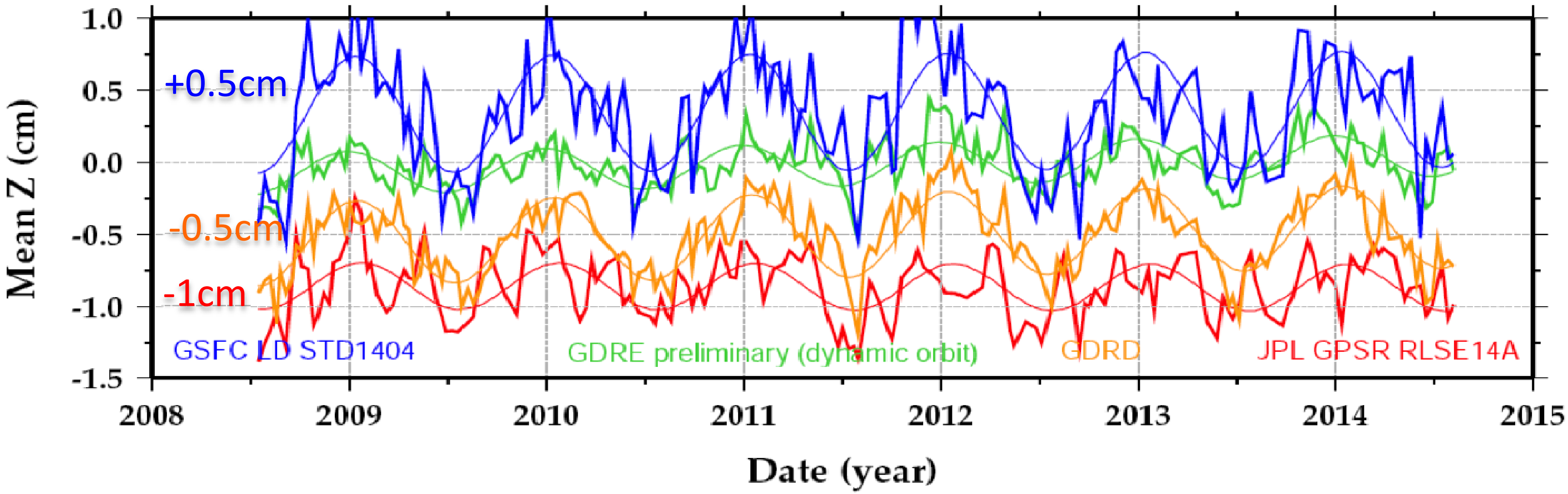
Mean Y orbit differences with respect to the GDR-E preliminary reduced-dynamic solution




Y bias of 1-2 mm w.r.t. GSFC and GDR-D,
**Y drift of ~0.5 mm/y** w.r.t. GSFC and GDR-D,
Y annual signal at the mm level w.r.t. GDR-D and JPL

# Relative Orbit Centering Stability Between POD Centers

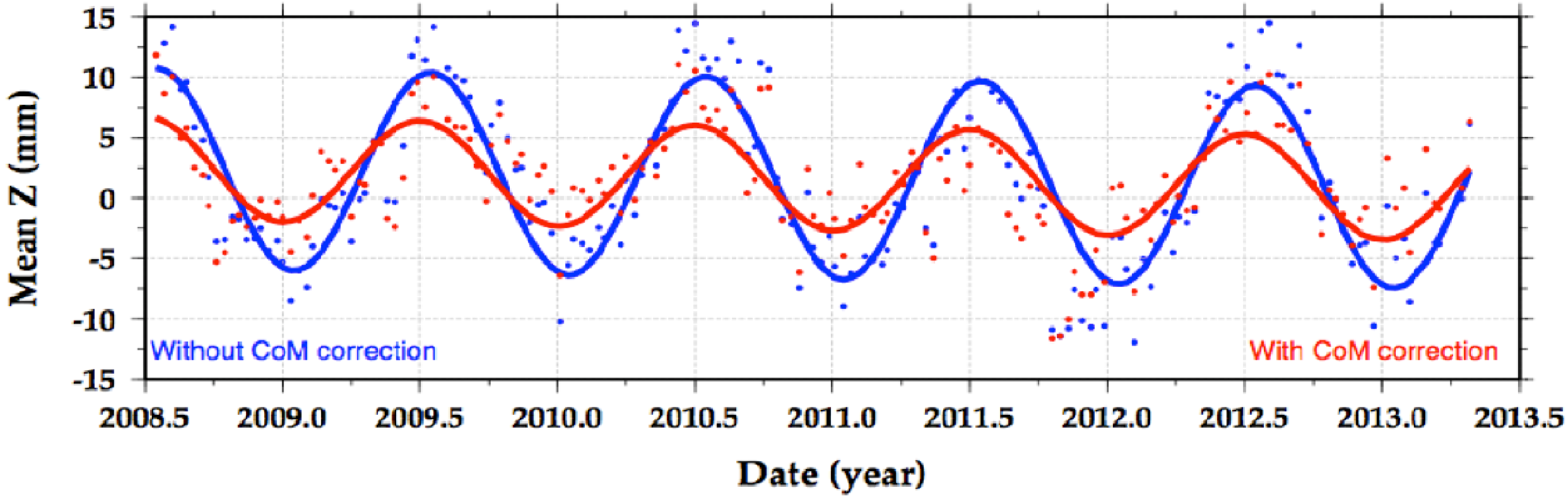
Mean Z orbit differences with respect to the GDR-E preliminary reduced-dynamic solution




Z bias of 1-2 mm (opposite sign) w.r.t. GSFC and JPL,
**Z annual signal from 1 to 4 mm** between all orbits

# Annual Geocenter Correction

Jason-2 mean Z orbit differences between GPS-derived and DORIS-only GDR-D dynamic orbits

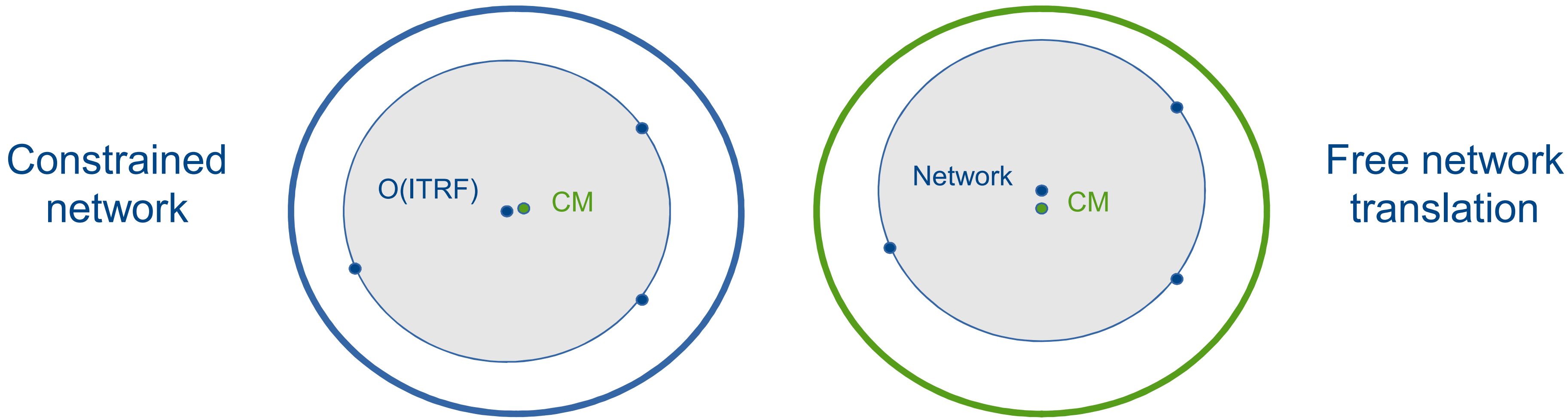



The use of a **seasonal non-tidal geocenter correction** ("Climatological model" SLR-only; from J. Ries) **improves** DORIS-only (and DORIS+SLR) solutions **consistency** with GPS-based orbits, **but half of the signal (~4 mm) is still left…**

# Estimation of the “Geocenter Motion” as Seen by DORIS

## « Dynamical » approach

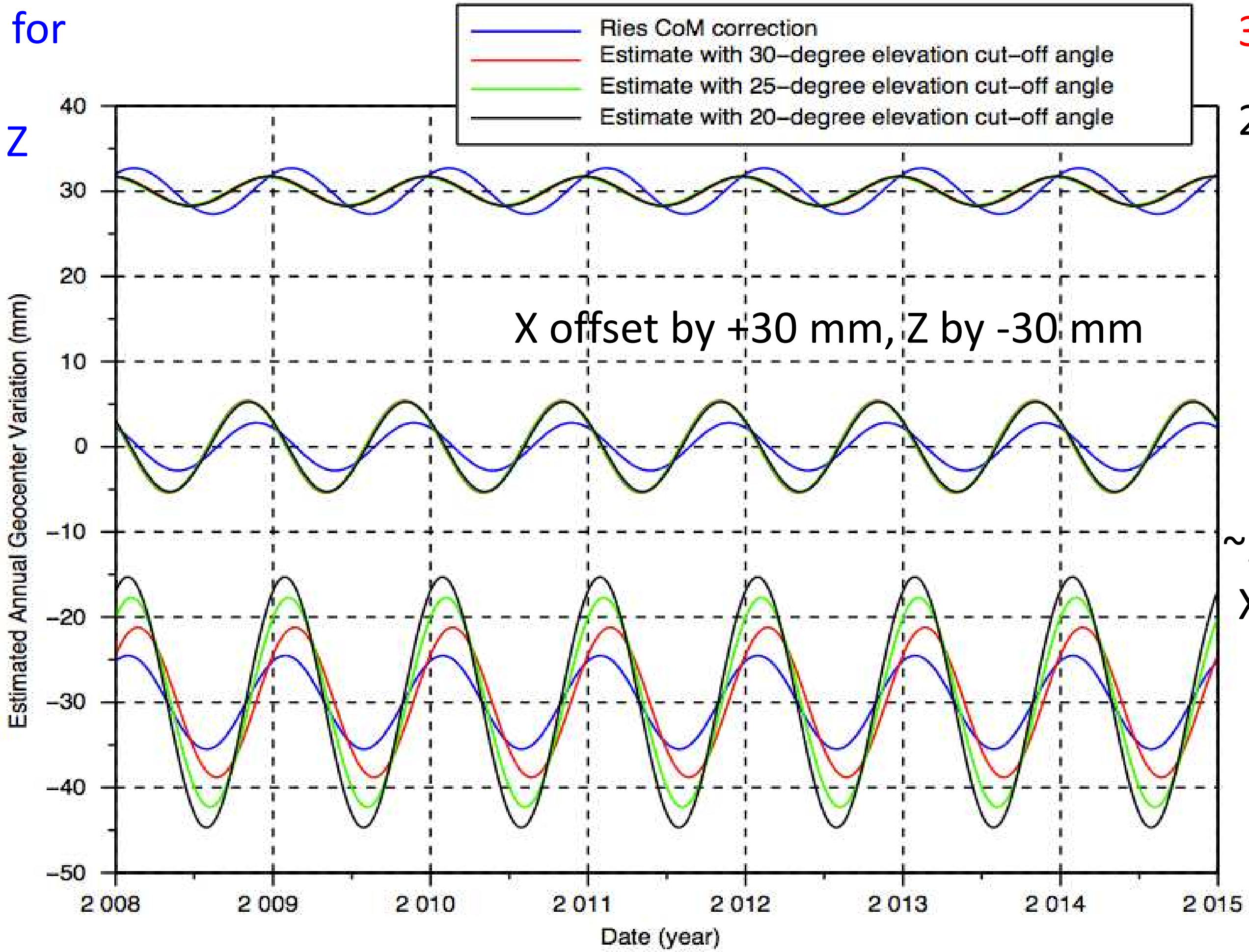
- A global translation vector for the network is determined simultaneously with the Jason-2 orbit (one per 10-day cycle).




- The time evolution of the estimated translation vector is well characterized by a simple annual sinusoid.

# Estimation of the “Geocenter Motion” as Seen by DORIS

<u>Ries CoM correction:</u>
~3 mm amplitude for X and Y, and 5-6 mm for Z




30 deg. Elev.
25 deg. Elev.
20 deg. Elev.

<u>DORIS estimate:</u>
~2 mm amplitude for X, ~3 mm for Y, and 9-15 mm for Z, depending on the elevation cut-off angle

Stable and consistent X and Y components but Z is affected by the elevation cut-off angle (tropospheric delay modeling error?)

# Estimation of the “Geocenter Motion” as Seen by DORIS

## Prospects

- The reason for the odd behavior of the Z component estimates remains to be determined.
  - ✦ Test if any improvement with other altimeter satellites (Saral, CryoSat-2, HY-2A).

- Inclusion of SLR stations with DORIS+SLR orbits may help reducing this instability.

- Apply the same process with the GPS constellation (instead of the DORIS stations) and see if the gap in the North/South centering between DORIS-only and GPS-based orbits can be reduced.