Ocean Surface Topography Science Team Meeting
Precision Orbit Determination Splinter

Status of GDR orbits for ocean topography missions and prospects for future improvements

L. Cerri, A. Couhert, S. Houry, F. Mercier(1)

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(1) CNES POD Team, Toulouse, France

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- Evaluation of EIGEN6S2
- Improved processing strategies for Jason POD : TEST2013 orbits
- First SARAL POD results

❑ Evaluation of EIGEN6S2

- ❑ Improved processing strategies for Jason POD : TEST2013 orbits
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EIGEN6S2

- Progressive improvements in geopotential models and reference frame drive 10 year of changes in POD standards
- **EIGEN6S2: GRACE data <=2012 and inter-annual TVG**

GDR-A (Jan 2002)	GDR-B (Oct 2005)	GDR-C (Aug 2008)	GDR-D (Jan 2012)
GRIM5-S1 (1999)	EIGEN3-C0 (2005)	EIGEN-GL04S-ANNUAL (2008)	EIGEN-GRGS_RL02bis_MEAN-FIELD (2011)
Non-tidal TVG : drifts in degree 2,3,4 zonal coeffs	Non-tidal TVG : drifts in degree 2,3,4 zonal coeffs	Non-tidal TVG : drifts in degree 2,3,4 zonal coeffs, C21/S21; Annual and semi-annual terms up to deg/ord 50	Non-tidal TVG : Annual, Semi-annual, and drifts up to deg/ord 50
Solid Earth Tides: from IERS1996 conventions	Solid Earth Tides: from IERS2003 conventions	Solid Earth Tides: from IERS2003 conventions	Solid Earth Tides: from IERS2003 conventions
Ocean tides FES952	Ocean tides FES2004	Ocean tides FES2004	Ocean tides FES2004
	Atmospheric gravity : only tides from Horwitz-Cowley model	Atmospheric gravity : 6hr NCEP pressure fields + tides from Horwitz-Cowley model	Atmospheric gravity : 6hr NCEP pressure fields + tides from Biancale-Bode model
	Pole Tide: solid Earth from from IERS2003 conventions	Pole Tide: solid Earth and ocean from IERS2003 conventions	Pole Tide: solid Earth and ocean from IERS2010 conventions
Third bodies: Sun, Moon, Venus, Mars and Jupiter	Third bodies: Sun, Moon, Venus, Mars and Jupiter	Third bodies: Sun, Moon, Venus, Mars and Jupiter	Third bodies: Sun, Moon, Venus, Mars and Jupiter
ITRF2000	ITRF2000	ITRF2005	ITRF2008

Next GDR (2014 ?)

EIGEN6-S2 (2013; proposed field for ITRF 2013)

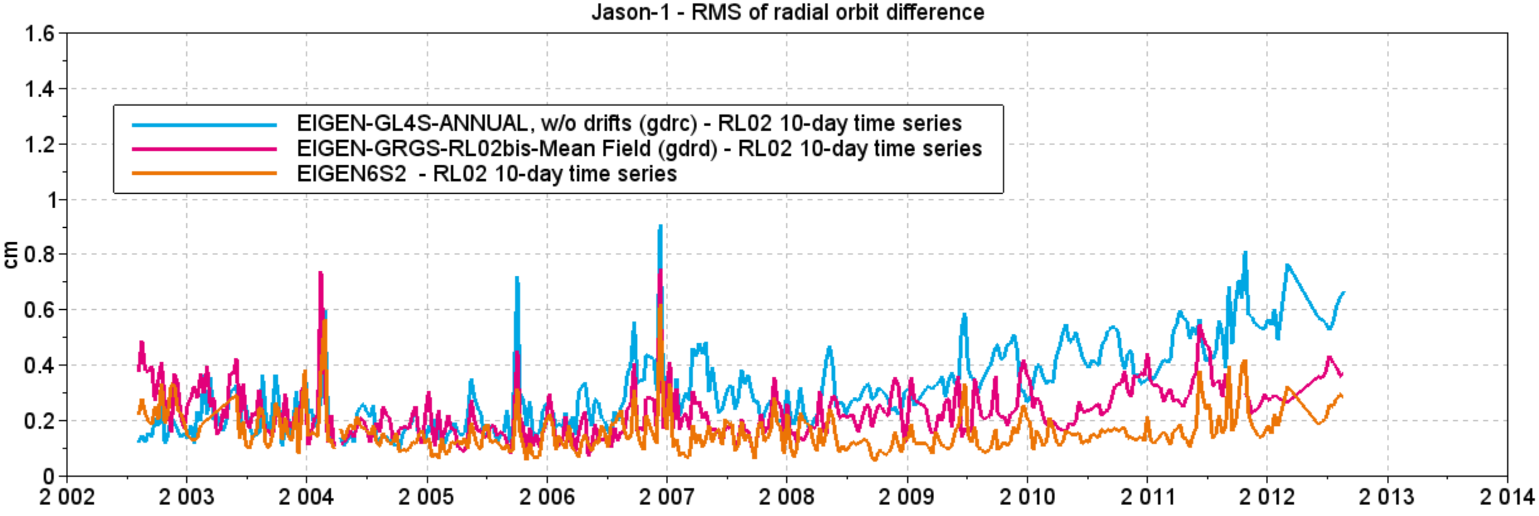
Besides the periodic annual and seasonal components, this new field accounts for non-linear interannual variability with a piecewise linear model: bias and drift per year

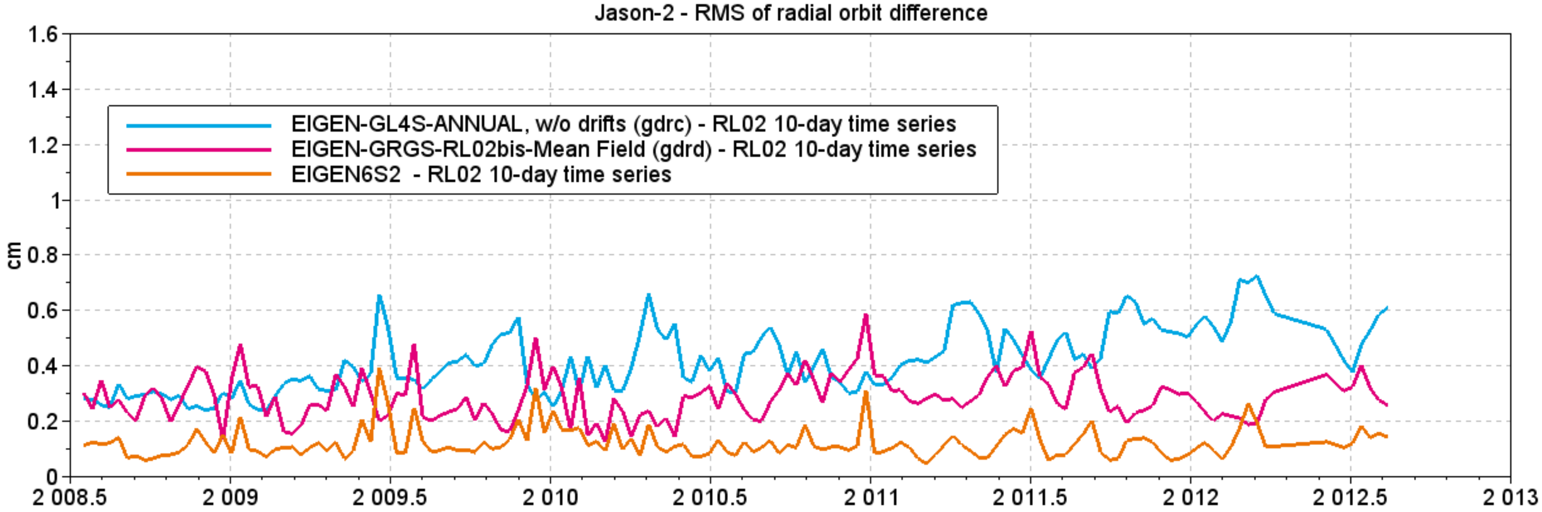
Zero-drift extrapolation beyond 2012

EIGEN fields : result from cooperation between GFZ (GeoForschungsZentrum, Potsdam) and CNES/GRGS (Toulouse)
http://grgs.obs-mip.fr/grace

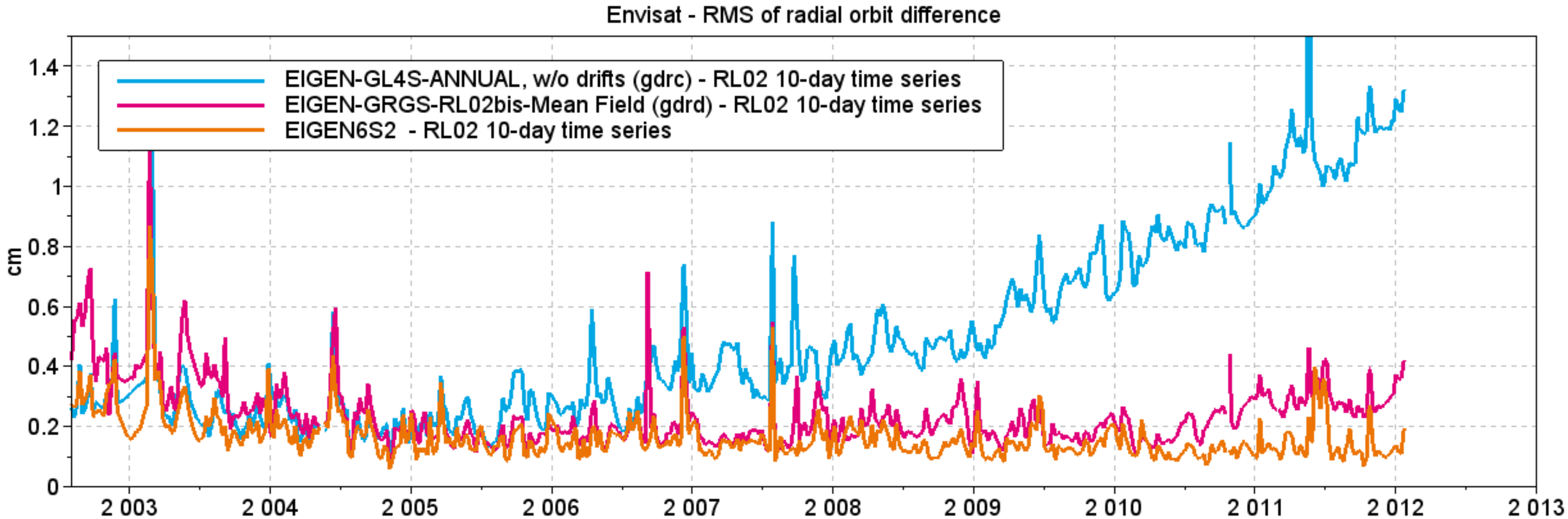
ITRF2013

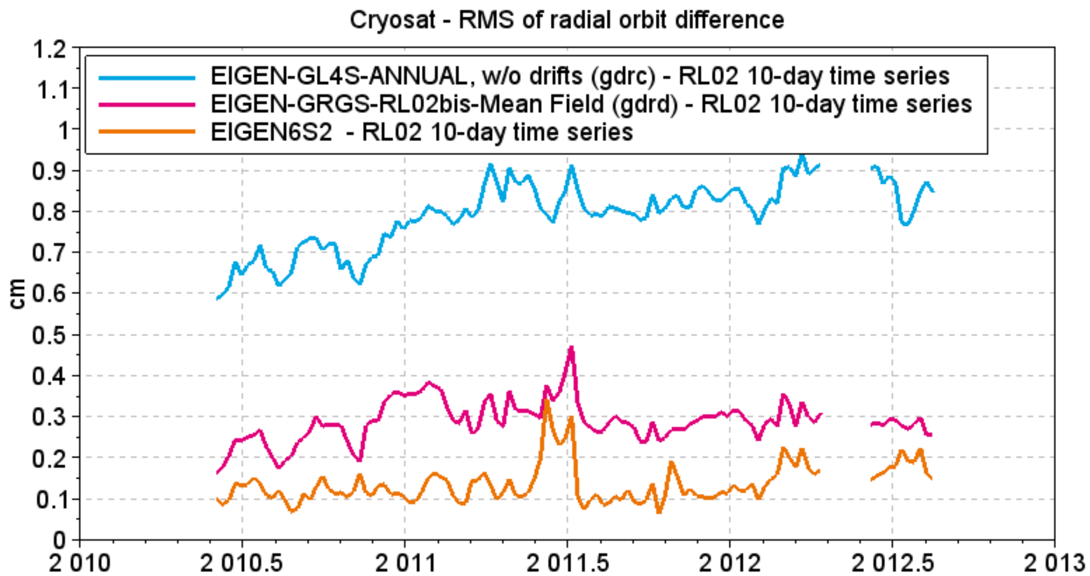
EIGEN6S2 – Comparison to GRACE time-series



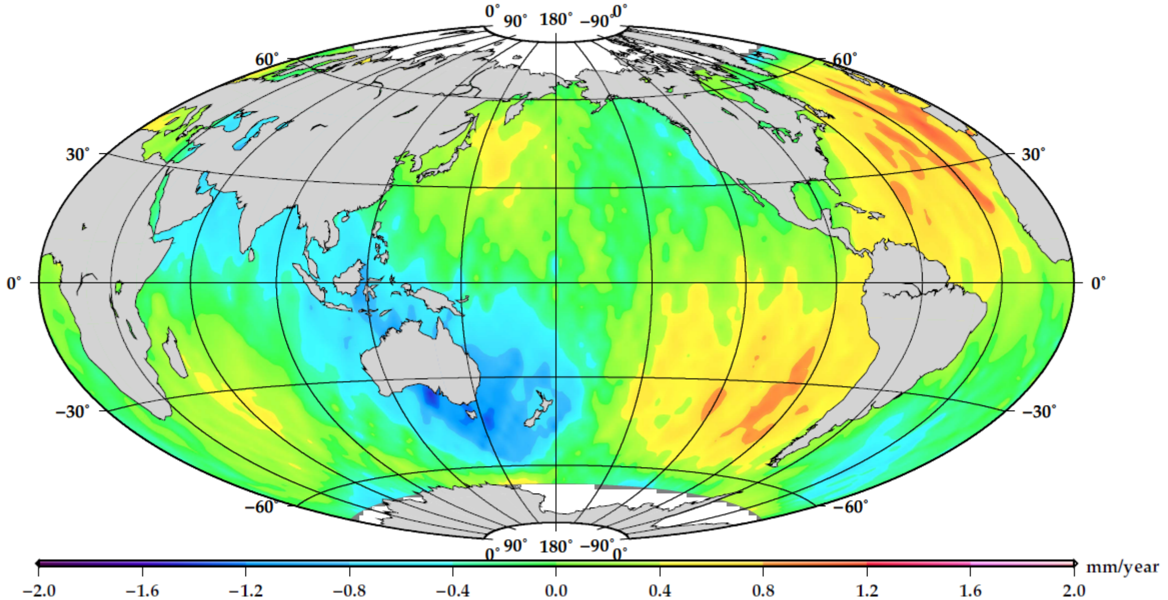


EIGEN6S2 – Comparison to GRACE time-series



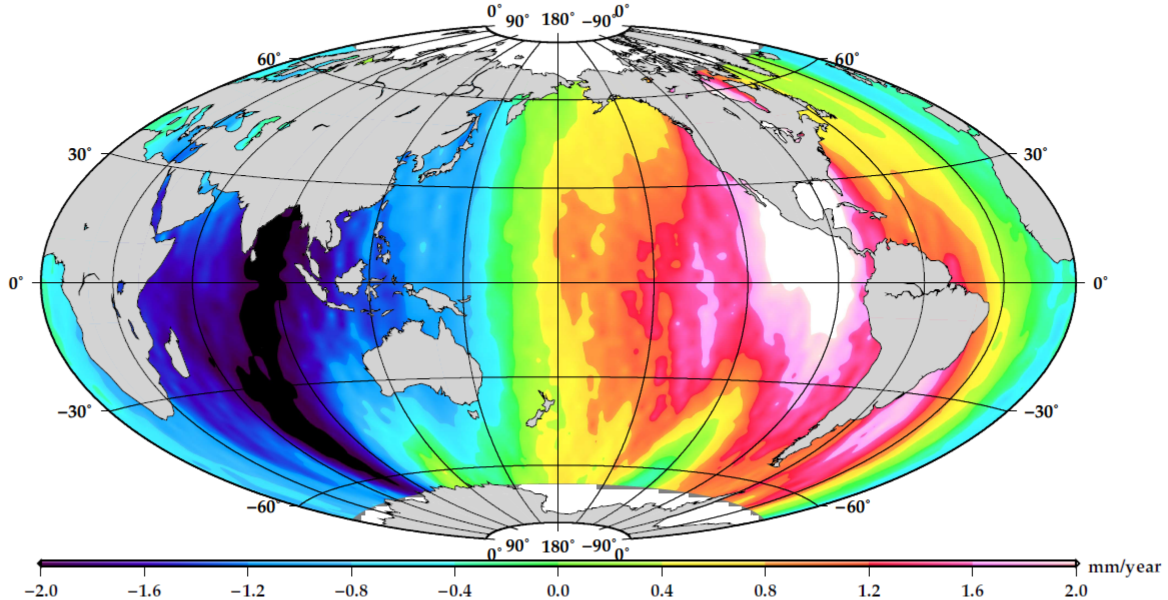


EIGEN6S2 – Impact on the rate of radial differences (GDRD - EIGEN6S2)



- JASON-2 (2009-2012)

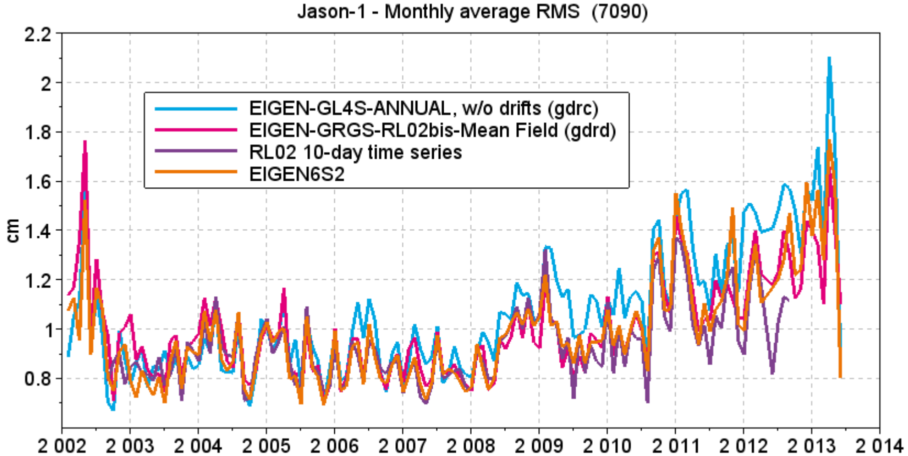
Differences below 1 mm/year – impact is small, not sufficient to completely explain differences with respect to other groups

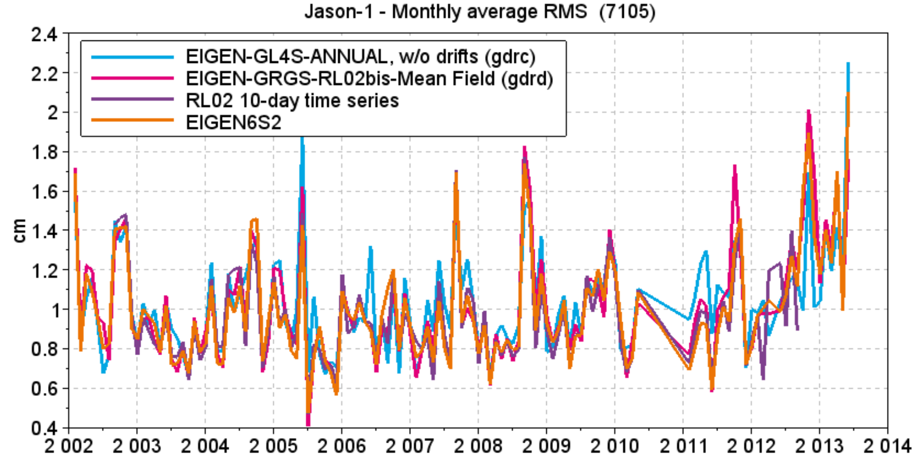


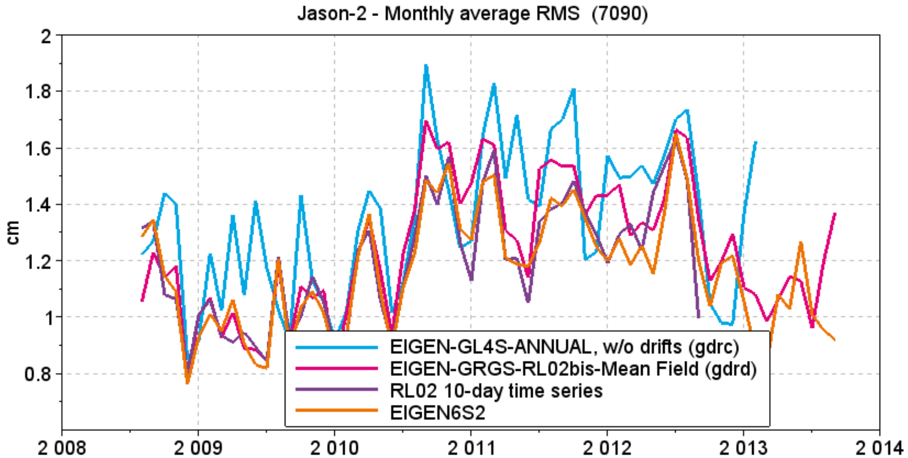
- ENVISAT (2009-2012)

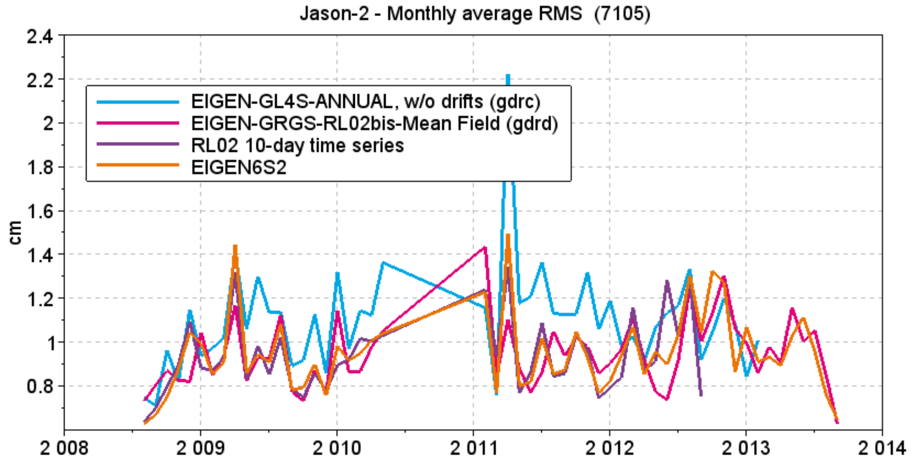
Differences exceed 2 mm/year close to the end of the mission

EIGEN6S2 – POE Post-fit SLR residuals

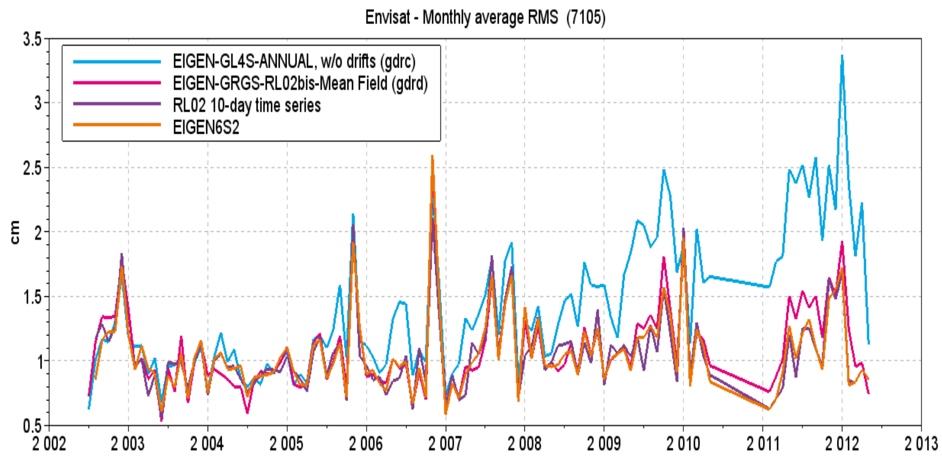


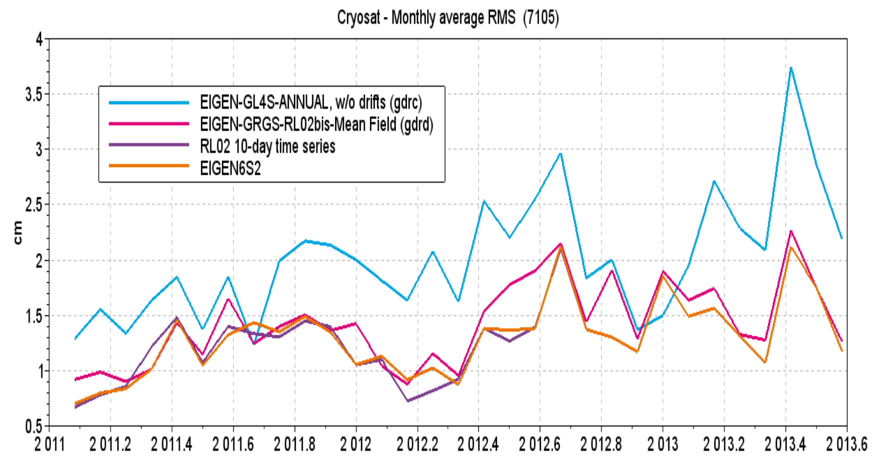


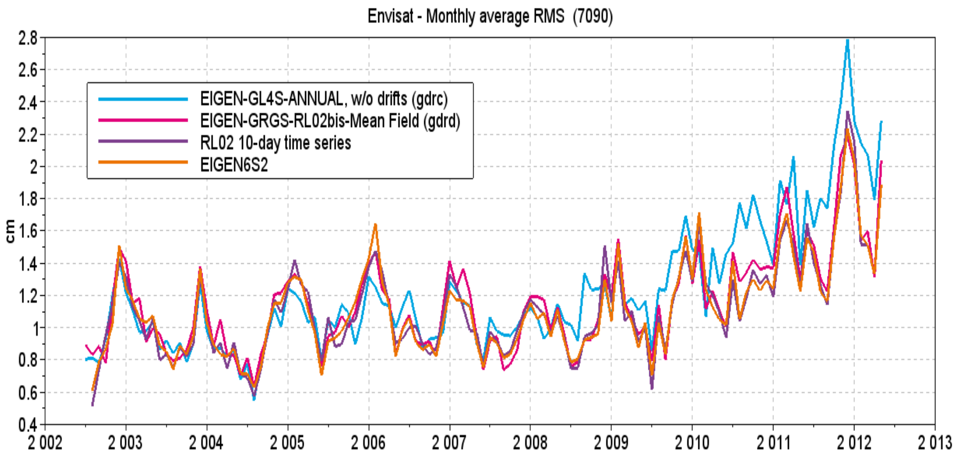


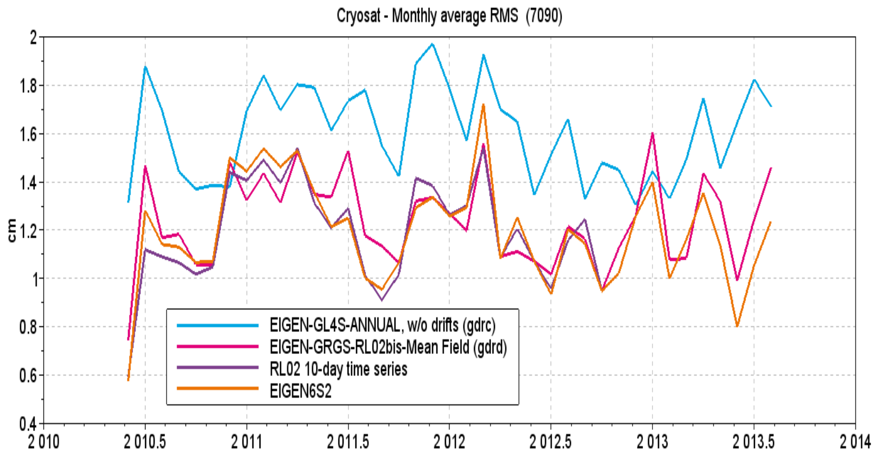


EIGEN6S2 – POE Post-fit SLR residuals









EIGEN6S2 - Conclusion

- EIGEN6-S2 allows a small improvement over the previous model (GDRD) ; better SLR fits and makes dynamic orbits closer to reduced dynamic orbits (see backups)

- Usually 2-3 years between successive POD standard definitions (mean model update) : next GDR orbit release foreseen in 2014 (ITRF2013)

- If we can't wait … observed errors induced on Jason are < 2 mm/yr on regional MSL trends and < 0.2 mm/year on global MSL trends, over 3 years (see also Couhert et al.). To mitigate this error
  - **Dynamic orbits** : need a time series of Grace derived fields compatible with the latency of altimeter GDR products – Recommendation to GFO?
  - **Reduced dynamic orbits** : several options exists. At CNES we tried combining different approaches (Mascon for LEOs , C31/S31 for Jason, GPS based RD orbits) . However, for better than 1 mm/year stability over <= 5 years time-span, using only tracking data from Jason, GPS-tracking seems necessary (is it sufficient ?)

cnes

- Evaluation of EIGEN6S2

- **Improved processing strategies for Jason POD : TEST2013 orbits**

- First SARAL POD results

CNES TEST 2013 : improved processing strategies

- Need for **a more stringent preprocessing of GPS measurements** (see previous splinter summaries) → **30 sec processing** → reduced arc-length to avoid cumbersome calculations
  - **36-hour arcs every day (12 hours overlap)**

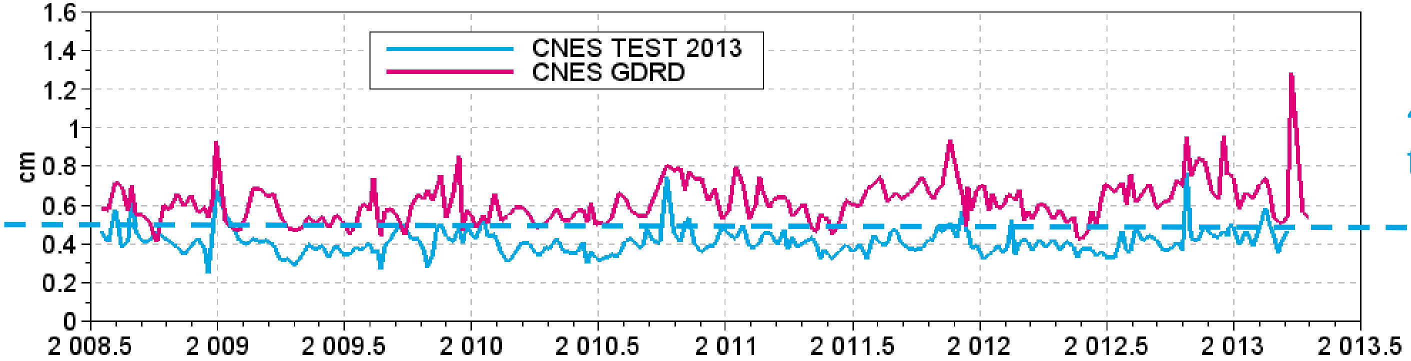
- “Dynamic” step for DORIS, GPS and D+G : 1/rev Al. and Cross track per arc, 1 along-track constant every 6 hours

- **Final “TEST2013” orbit**: Dynamic D+G step, **C31/S31 free to adjust**, with 3-axis **1st order Markov process** (sigma 1e-9 m/s^2 , time constant : 900 s)

- Improved underlying models : **EIGEN6S2** , Atmospheric gravity from 3Hr ECMWF + full ocean response from T-UGOm2D , FES2012, **Calibrated Semi-Empirical SRP model** (Mercier and Cerri, OSTST 2013)

Closer to reference solutions of other groups

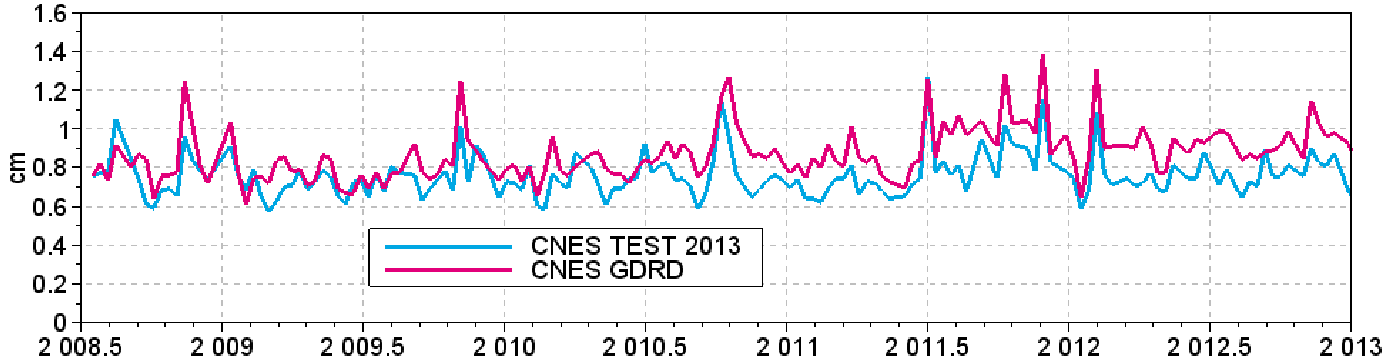
Jason-2 RMS of radial orbit difference with respect to JPL13A



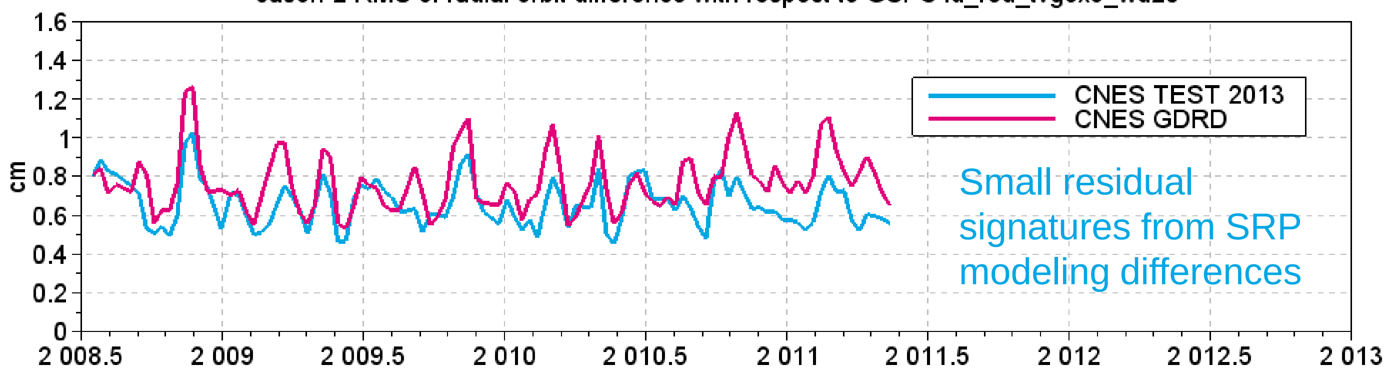
5 mm

4 mm RMS wrt to JPL13A

Jason-2 RMS of radial orbit difference with respect to GSFC ja2_poe_ld_std1204



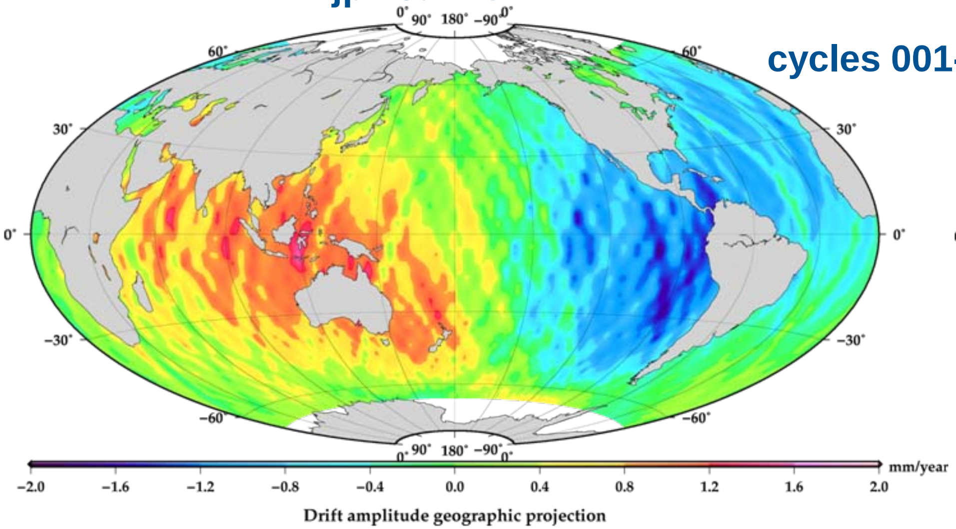
Jason-2 RMS of radial orbit difference with respect to GSFC ld_red_tvg5x5_wd20



Small residual signatures from SRP modeling differences

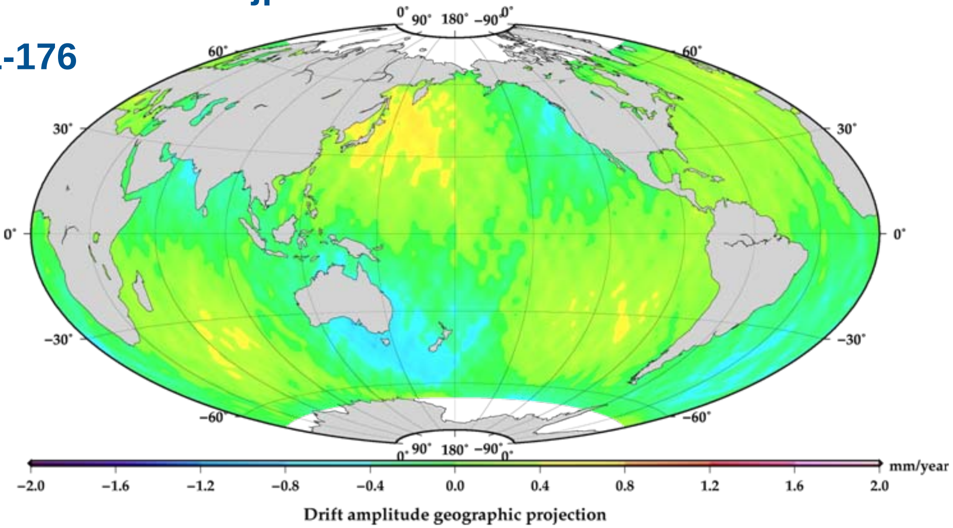
Closer to reference solutions of other groups

jpl13a – GDRD

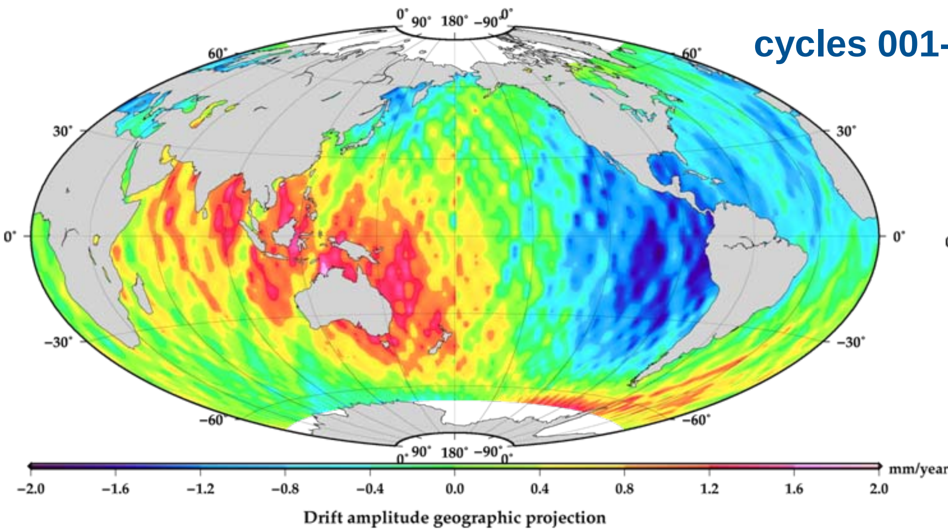


cycles 001-176

jpl13a – CNESTEST2013

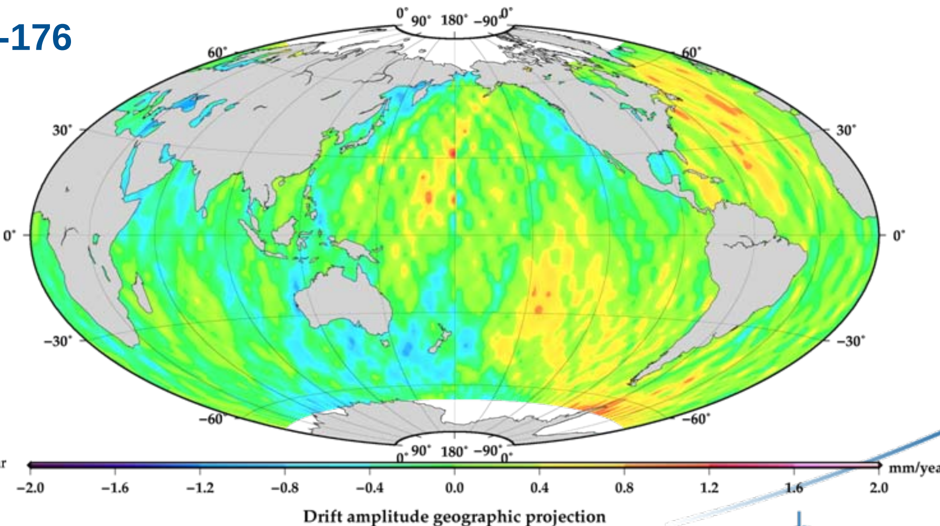


GSFC gsfc_ja2_poe_ld_std1204 – GDRD

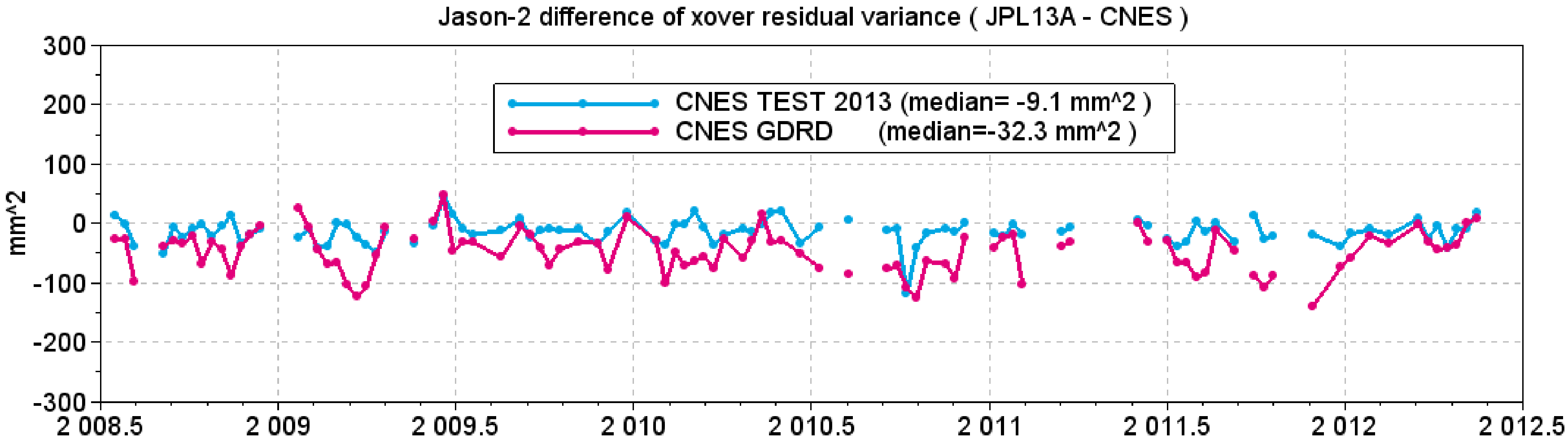


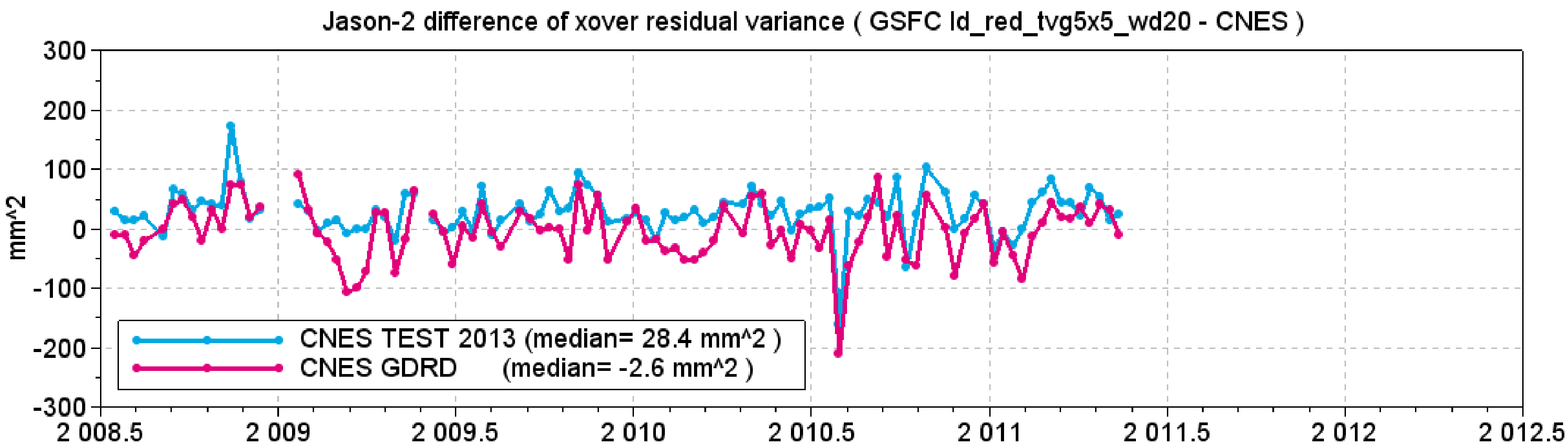
cycles 001-176

GSFC gsfc_ja2_poe_ld_std1204– CNESTEST2013



Improved metrics: crossover variance

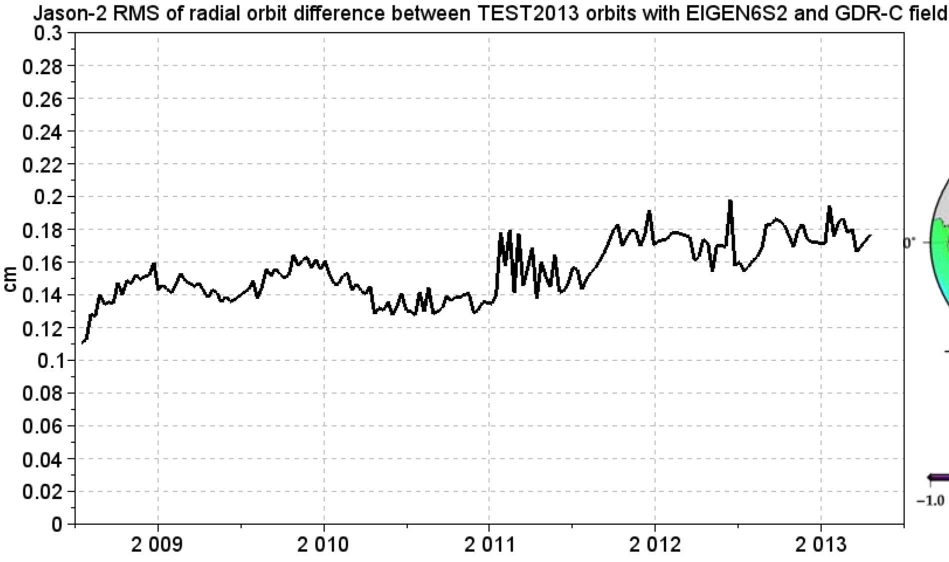


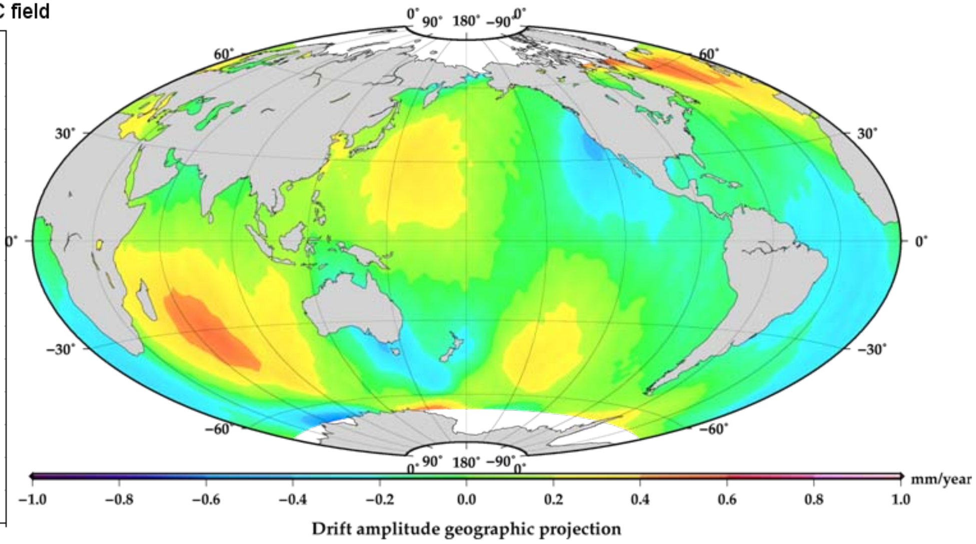


Each comparison is performed using common crossover points per cycle, only when nr points > 2800

Sensitivity of TEST2013 orbits to changes in gravity field

- Reduced dynamic approach: when TEST2013 orbits are computed with GDR-C gravity field (no drifts at all) instead of EIGEN6S2, impact on the orbit is negligible (RMS< 2mm, <0.5 mm/year).





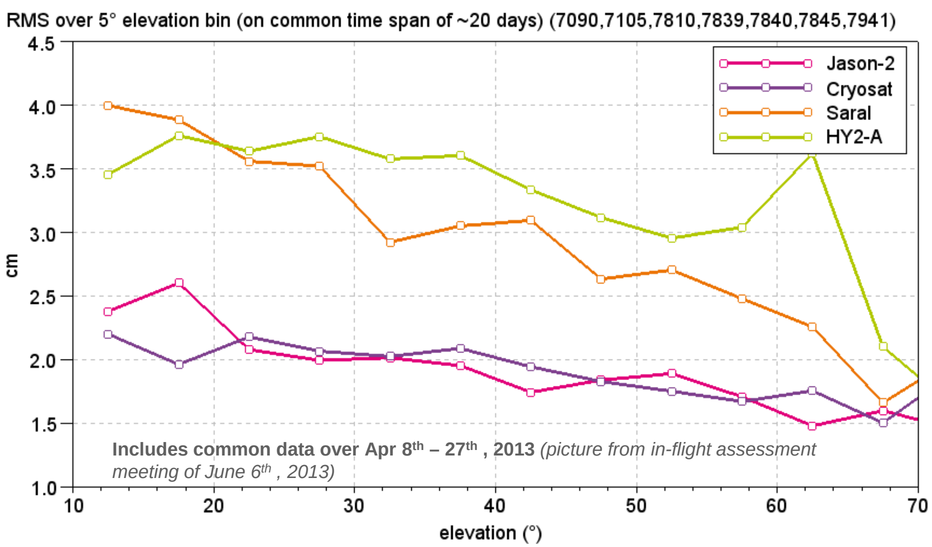
TEST2013 orbits: conclusion

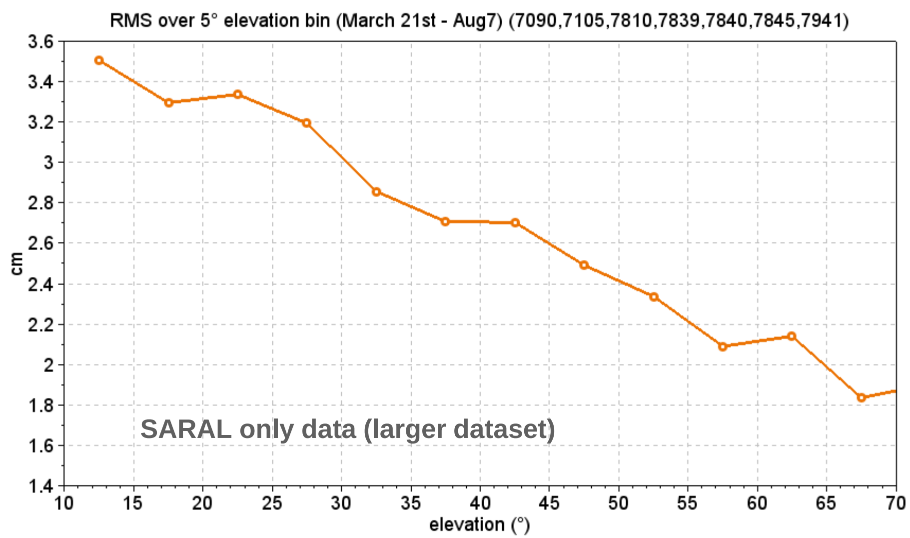
- TEST2013 reduced dynamic orbits are very close to JPL13a orbits
  - Both driven by GPS tracking
  - Average radial RMS ~ 4 mm
  - geographically correlated rate of radial difference < 0.5 mm/year
- Orbit accuracy measured by crossover residuals is better on TEST2013 orbits than GDR-D (variance reduction of more than 20 mm^2)
- The dependency on the gravity field model underlying TEST2013 orbits is negligible
- However differences between dynamic orbits (either DORIS or GPS-based) are still significant …

- Evaluation of EIGEN6S2
- Improved processing strategies for Jason POD : TEST2013 orbits
- **First SARAL POD results**

SARAL POE: SLR RESIDUALS ON DORIS-ONLY ORBITS

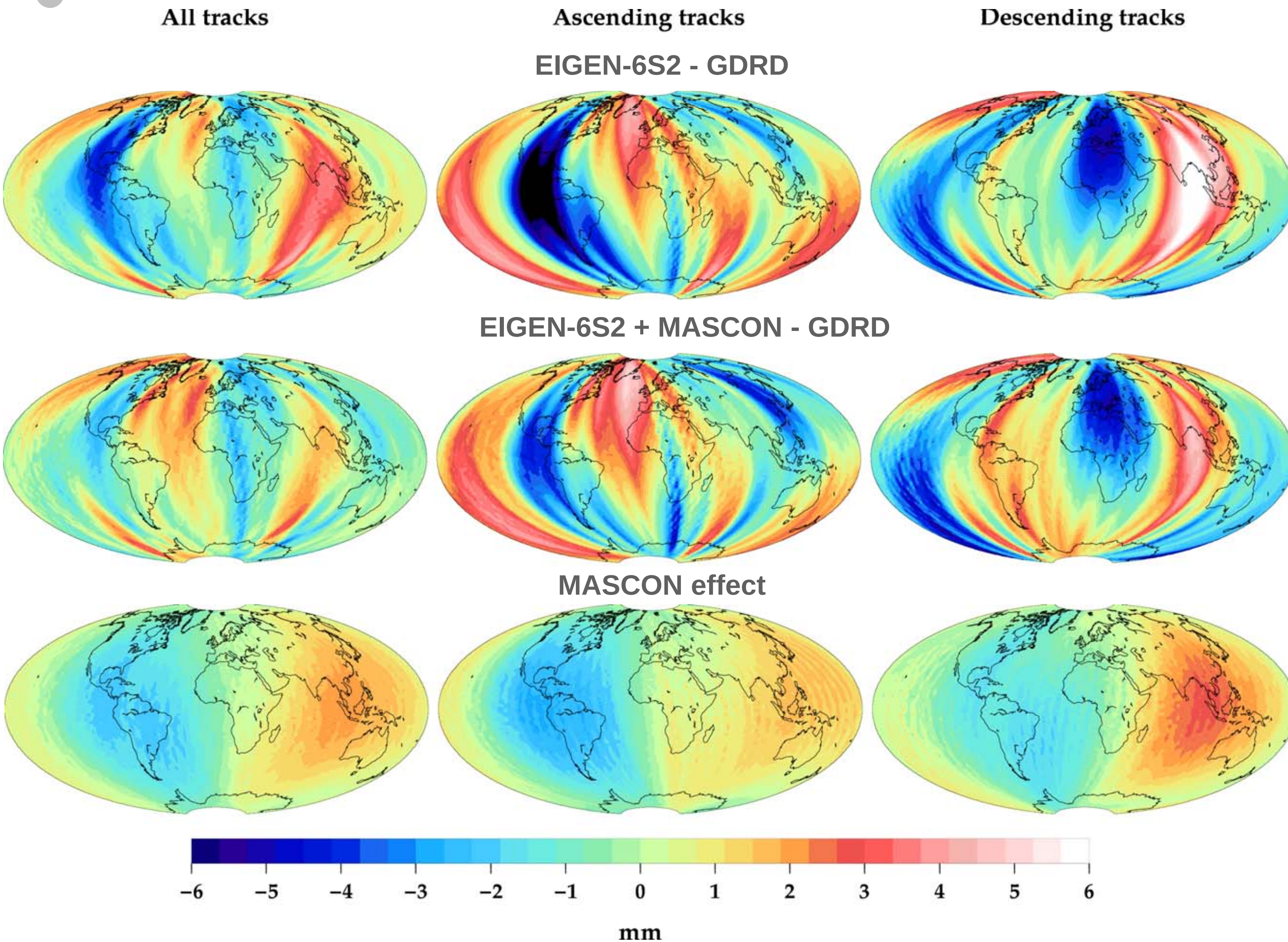
- **Radial accuracy** of DORIS-only orbits **better than 2 cm RMS** (SLR residuals > 70°) – Similar to other DGXX-based missions
- Significant error is observed in the horizontal plane (low elevation residuals)





- Cross-track bias of the orbits of about 5 cm ; effect is common to Doris-only or SLR-only orbits : either a mismodeled cross-track force or CoM correction
- This effect is likely too large for SRP/TRR mismodeling only, given the satellite surface towards the sun
- No impact on the altimeter mission , but relevant for the IDS analysts

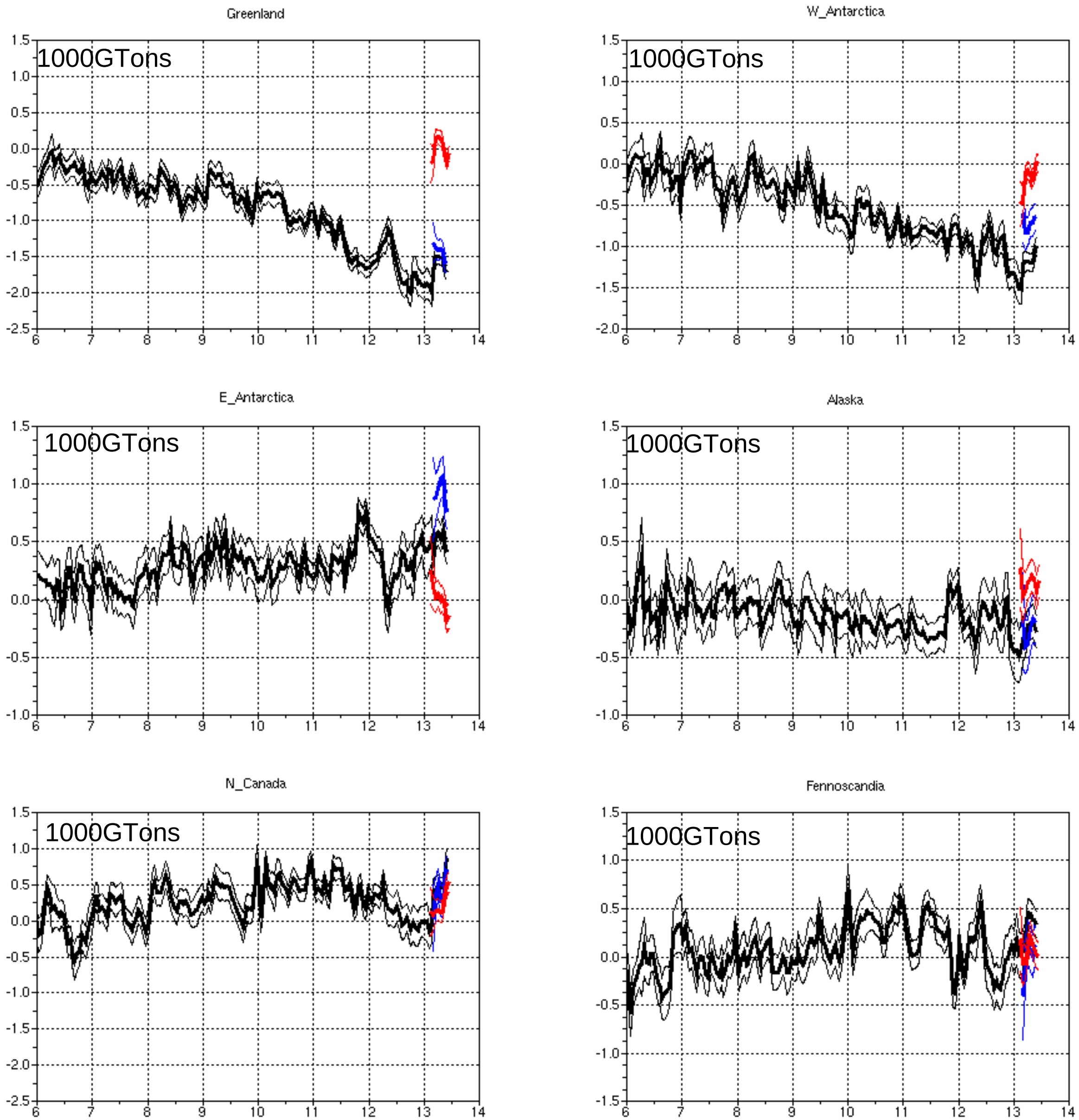
SARAL POE: SENSITIVITY TO GRAVITY FIELD ERRORS



SARAL POE: SENSITIVITY TO GRAVITY FIELD ERRORS

- DORIS allows to solve for local mass anomalies (mascons) to correct a given field.

(Cerri et al. doi: 10.1016/j.asr.2013.03.023)



Mascons wrt to GDRD , drifts removed (Envisat, Cryosat)

Mascons wrt to GDRD , drifts removed (Saral)

Mascons wrt to EIGEN6S2, drifts removed (Saral+Cryosat)

SARAL POD conclusions

- The radial accuracy of SARAL precise orbits is comparable to that of other DORIS-based altimeter missions.

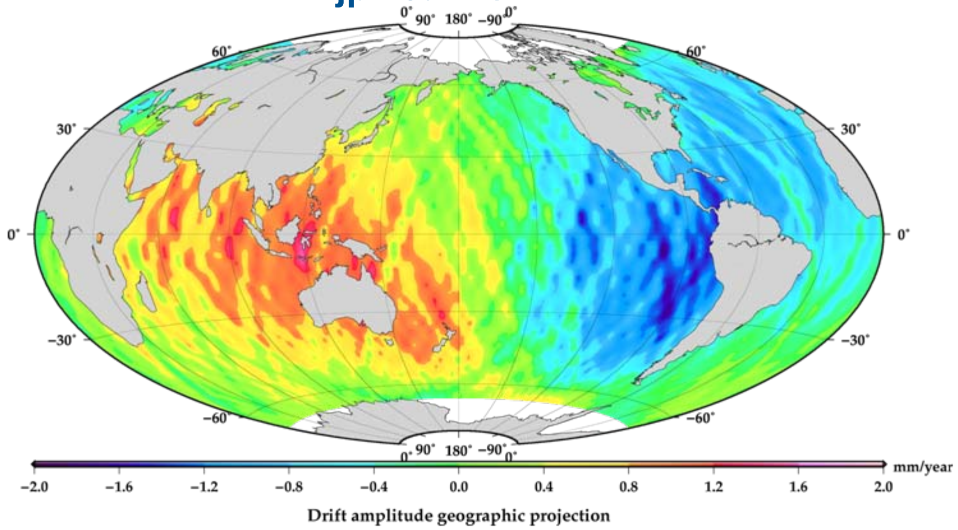
- **The current estimate of the radial accuracy is better than 2 cm RMS**, as measured by the core network SLR residuals at high elevations on DORIS only orbits

- The most significant contributor to the geographically correlated error is to the time varying gravity field; its contribution does not exceed 5 mm on average over the time interval covered by this analysis – TBC when GRACE time series become available

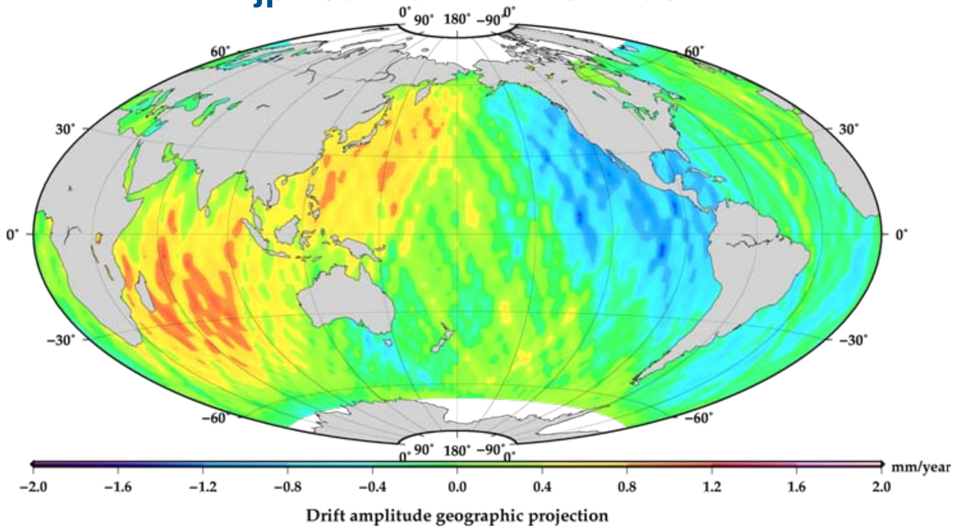
- A **significant cross-track error is observed using either DORIS or SLR data**. This could be due to an error along Z in a surface force model or in the center of mass Z-coordinate, or both. Given the amplitude of this error, it is unlikely that the cause is a surface force alone. **No impact expected on altimeter data analysis** – relevant issue for IDS

Backups

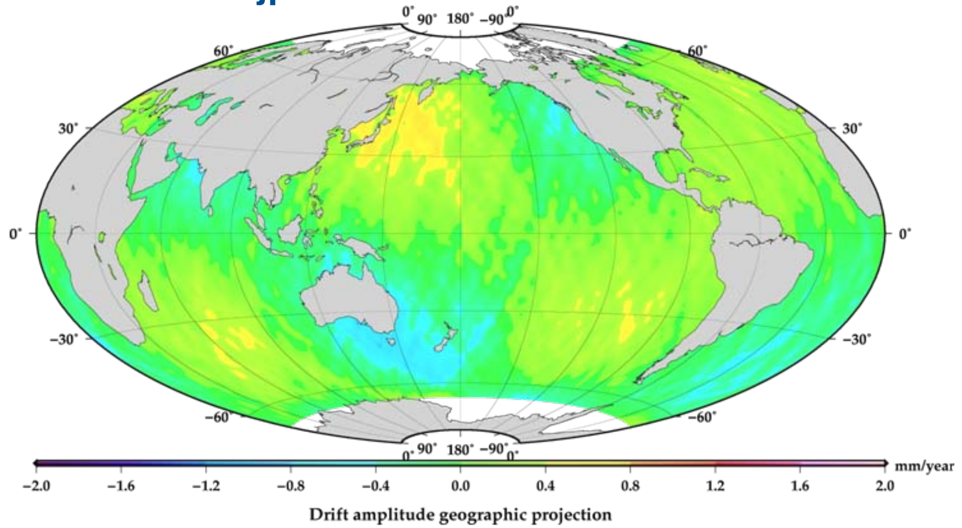
jpl13a – GDRD



jpl13a – GDRD EIGEN6S2



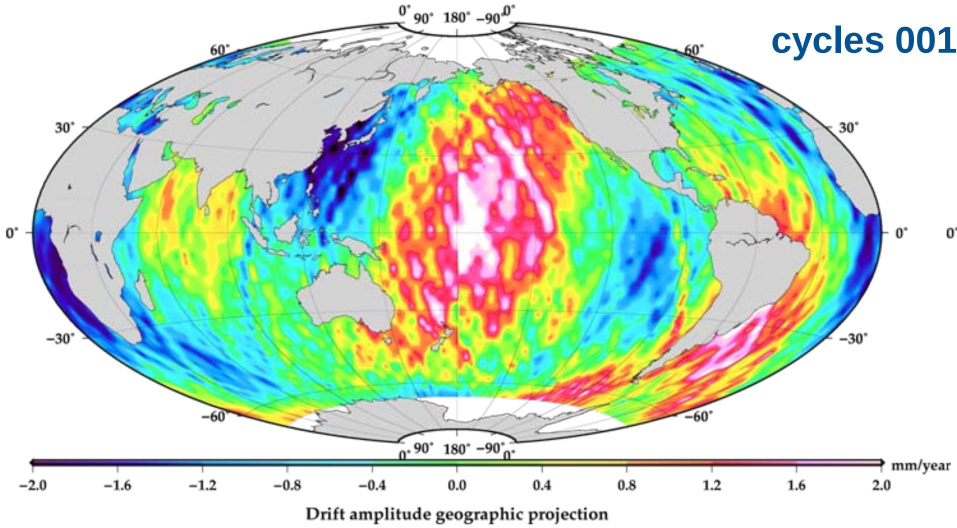
jpl13a – CNESTEST2013

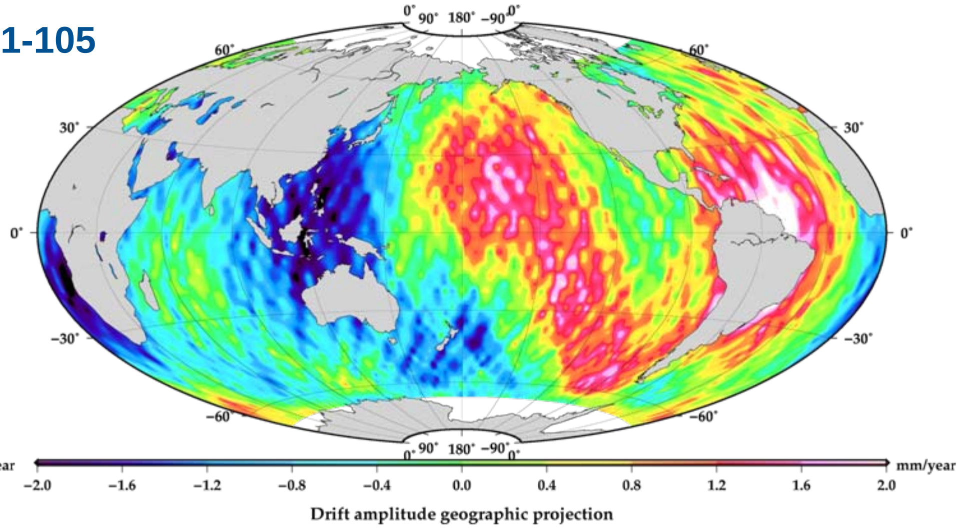


gsfc_ld_red_tvg5x5_wd20 – GDRD

gsfc_ld_red_tvg5x5_wd20 – CNESTEST2013

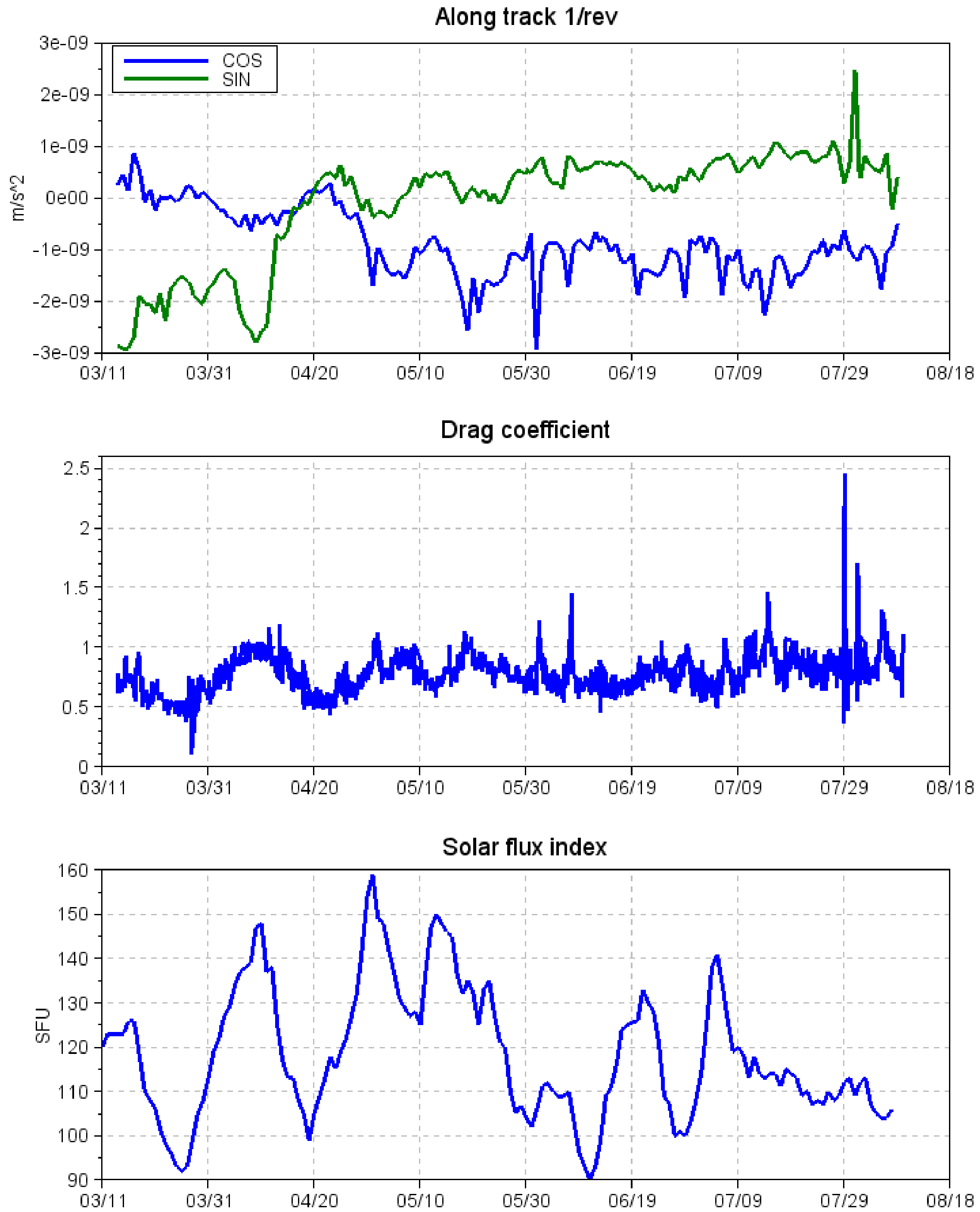
cycles 001-105





SARAL POE: estimated empirical parameters

- Solar radiation pressure acts mostly as a bias perpendicular to the orbit plane
- In this configuration, atmospheric drag mismodelling errors significantly affect the along-track 1/rev empirical (noticeable signature of the ~25-day sun-rotation cycle)
- A different behavior is observed before April 2013. Did anything change in the satellite configuration?



SARAL POE: estimated empirical parameters

- The systematic component in the 1/rev empiricals (constant + f(beta))– could be removed by calibration if a complete beta prime cycle (1 year) is available in stable configuration

- In conclusion, estimated empirical forces are small and comparable in amplitude to those of other missions