Is CryoSat-2 orbit accuracy affected by space weather?

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Overview of talk

• TU Delft involvement: validation/calibration within the CryoSat-2 community
  – DORIS tracking data, 59 beacons from the IDS, 10s Doppler data
  – SLR Tracking data: ~10 stations from the ILRS, Independent sparse laser data
  – Do quality checks, internal, external, forcing, residuals

• Latest developments
  – Extend orbits up to 1-Aug-2016
  – Investigate DORIS residuals and investigate whether we can see anything related to Space Weather / South Atlantic Anomaly
Models, tools etc

• GEODYN software from NASA/GSFC plus own tools.
• Station coordinates and Earth rotation parameters:
  – DORIS and SLR station coordinates in DPOD2008/SLRF2008
  – IERS data, polar motion, length of day from Bulletin B
• Satellite Dynamics
  – EIGEN5c gravity model, third body gravity etc
  – Temporal gravity from GRACE to degree and order 20
  – FES2004 ocean load tides
  – Frequency offsets and tropospheric biases estimated by pass
• Spacecraft specific models
  – Panel model, antenna offsets, LRA offsets, from IDS
  – Satellite attitude reconstructed from star camera quaternions
  – ftp://dutlru2.lr.tudelft.nl/pub/ejo/cryosat2/quaternion/
  – Empirical accelerations (6h), Drag (3h), SRP model calibration
SLR: residual of fit consistent at 1.27 cm rms (median). Low weight wrt DORIS, independently it yields ≈4 cm orbits radially,
Daily mean SLR CS2 orbits

rms 1.27 cm (median)
96.4% used

SLR station statistics

DORIS station statistics

average rms: 0.397 [mm/s]
Solar flux at F10.7

$10^{-22} \text{ W} / (\text{m}^2 \text{ Hz})$

Year

Empiricals 6 hour intervals, Drag: 3 hours

Along track cos term acceleration amprms=3.565488 rms=3.198777 mean=1.573088

Along track sin term acceleration amprms=3.565489 rms=2.006278 mean=-0.035513

3.19 nm/s²

2.01 nm/s²
As far as possible: annual maps of the evolution of the DORIS tracking residual anomalies, April 2010 To Aug-2016
External orbit comparison

• We compare to CNES products
  – Real time navigator orbits, computed within the receiver real time
  – Rapid science orbits, produced within approximately one or two days (discussion on predicted satellite maneuvers)
  – Delayed final solutions, converged product after a month, i.e. when IERS bulletin B products have converged.
Conclusions 1

- SLR: median of SLR residuals at 1.26 cm
- DORIS: consistent fits at 0.39 mm/s based on 10 s data
- The south atlantic anomaly area is visible in the CryoSat-2 residuals, shows up in the EOFs.
- There are systematic differences that can not be explained in the current parameterization with:
  - Frequency biases that we solve for by beacon
  - Tropospheric biases that we solve for by pass
  - Empirical acceleration modelling (6 hours) or drag (3 hours)
- The median of the residuals varies by ±0.1 mm/s in the South Atlantic Anomaly, effect is visible in median of annual or longer time scale binned residuals
Conclusions

• Empirical accelerations vary around 2 to 3 nm/s$^2$ in the along track direction for CryoSat-2.

• We compare against Navigator orbits, rapid sciences CNES MOE and the final solution POE orbits

• Radial consistency between 1.51 cm wrt POE, 1.63 cm wrt to the MOE

• The real-time DIODE Navigator data has been improved, since 2012.6 we see a radial consistency 3.45 cm, before that time it was 8.95 cm