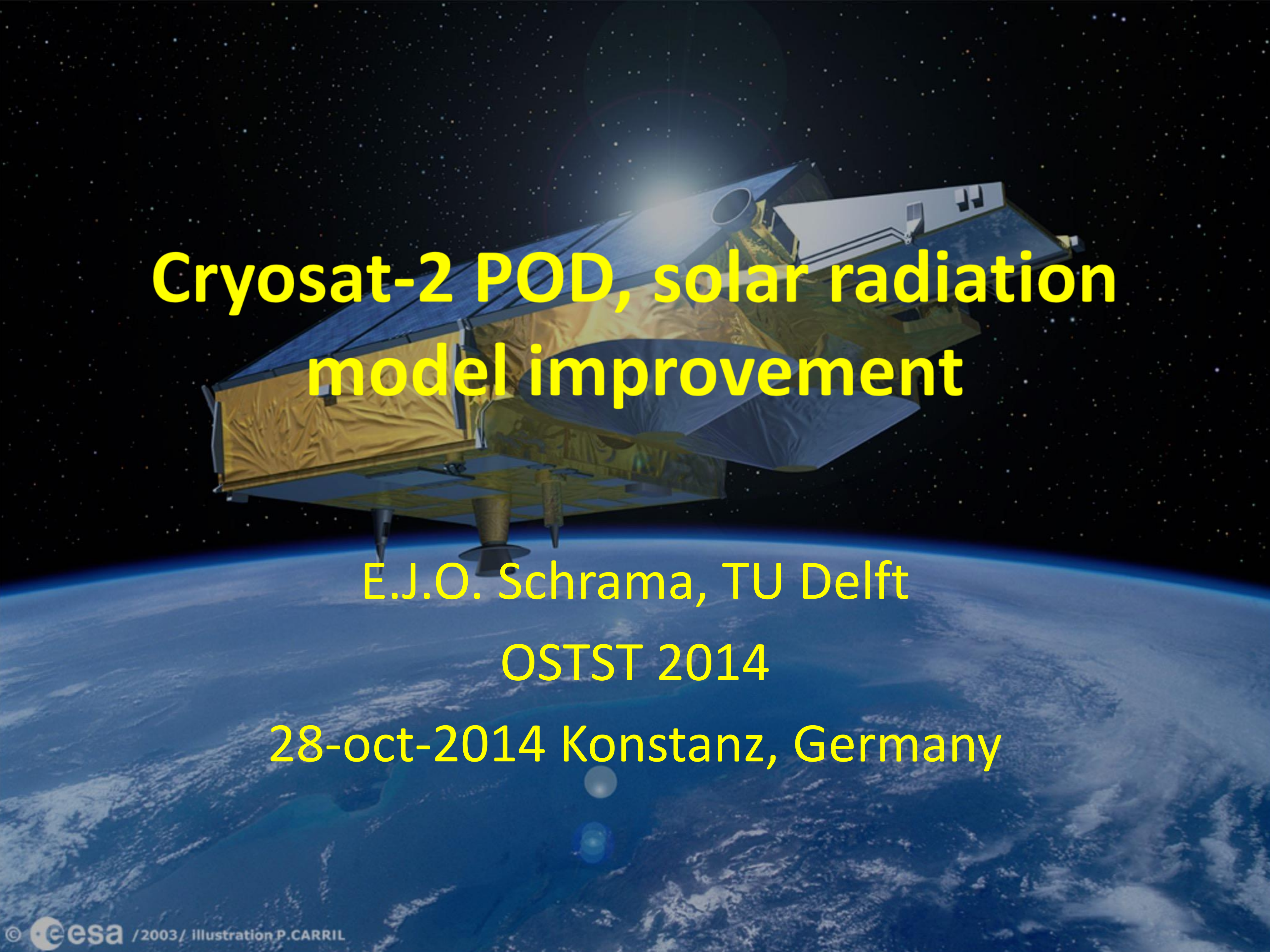

Cryosat-2 POD, solar radiation model improvement

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Overview of talk

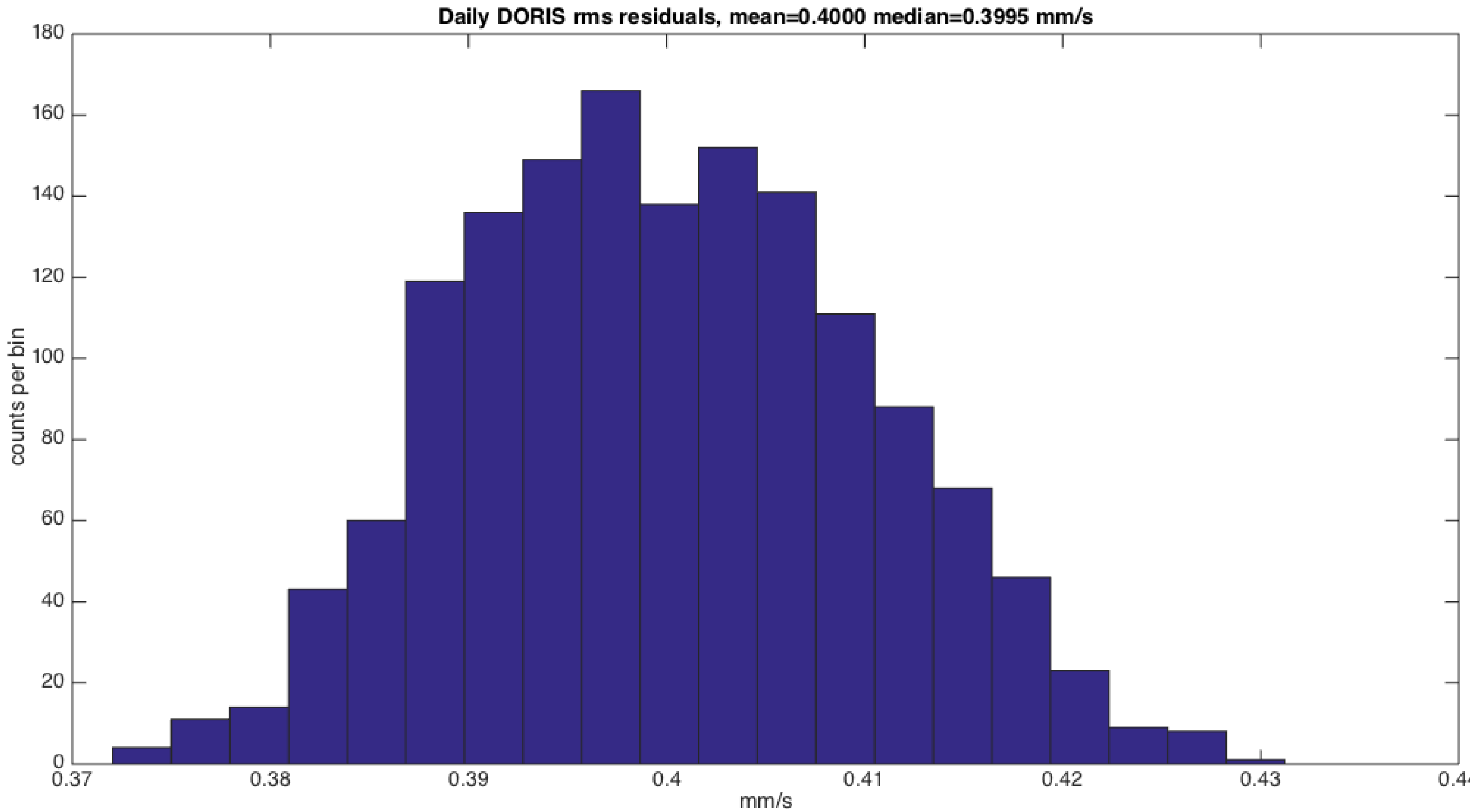
- TUD involvement: validation/calibration within the CryoSat-2 community
  - DORIS tracking data, ~50 beacons from the IDS, 10s doppler data
  - SLR Tracking data: ~10 stations from the ILRS, Independent sparse laser data
  - Do quality checks, internal, external, forcing
- Latest developments
  - Explain the empirical accelerations and link them to a SRP model

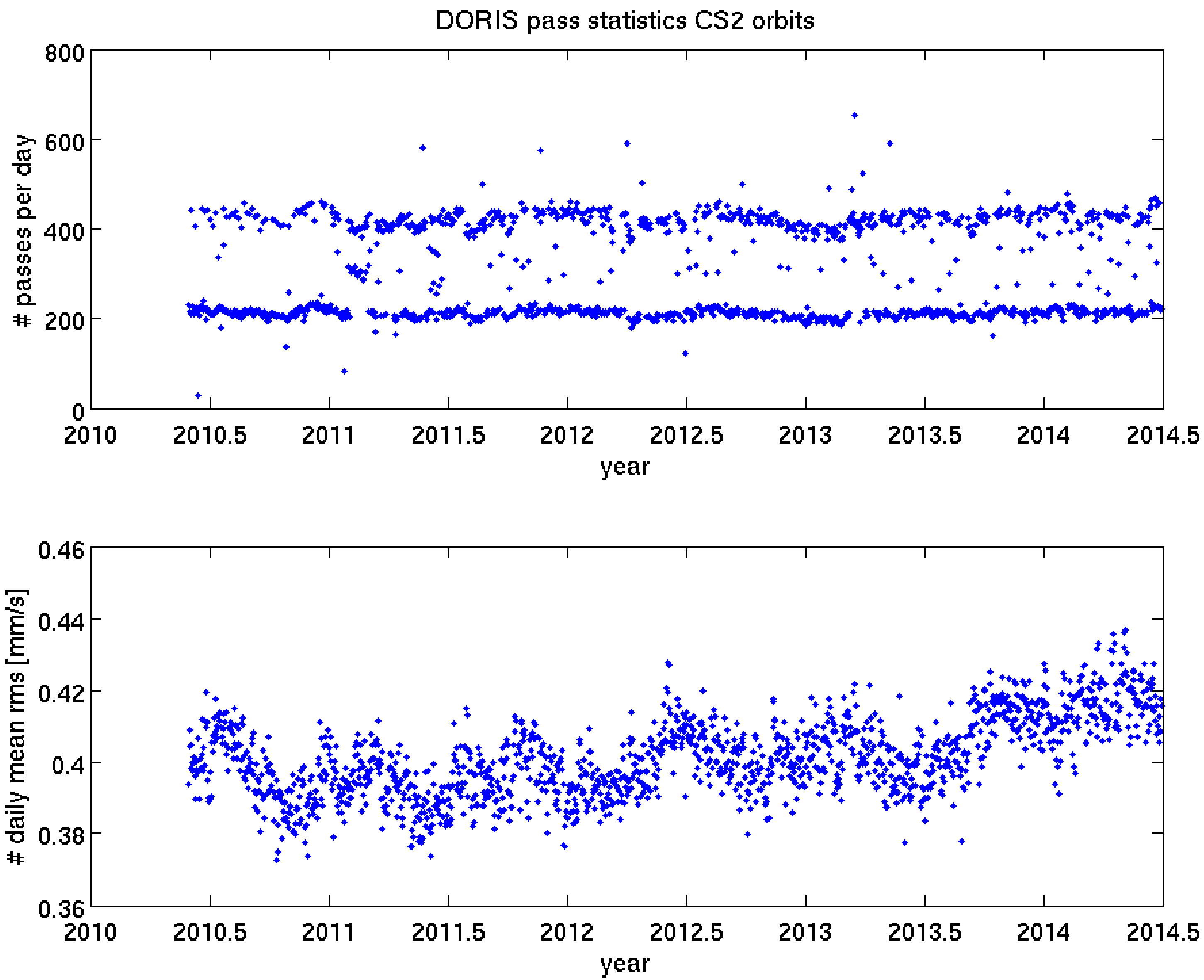
Models, tools etc

- 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
  - Temporal gravity from GRACE to degree and order 20
  - FES2004 ocean load tides
- Spacecraft specific models
  - Panel model, DORIS antenna offsets, LRA offsets, from ESA
  - Satellite attitude reconstructed from star camera quaternions
  - ftp://dutlru2.lr.tudelft.nl/pub/ejo/cryosat2/quaternion/

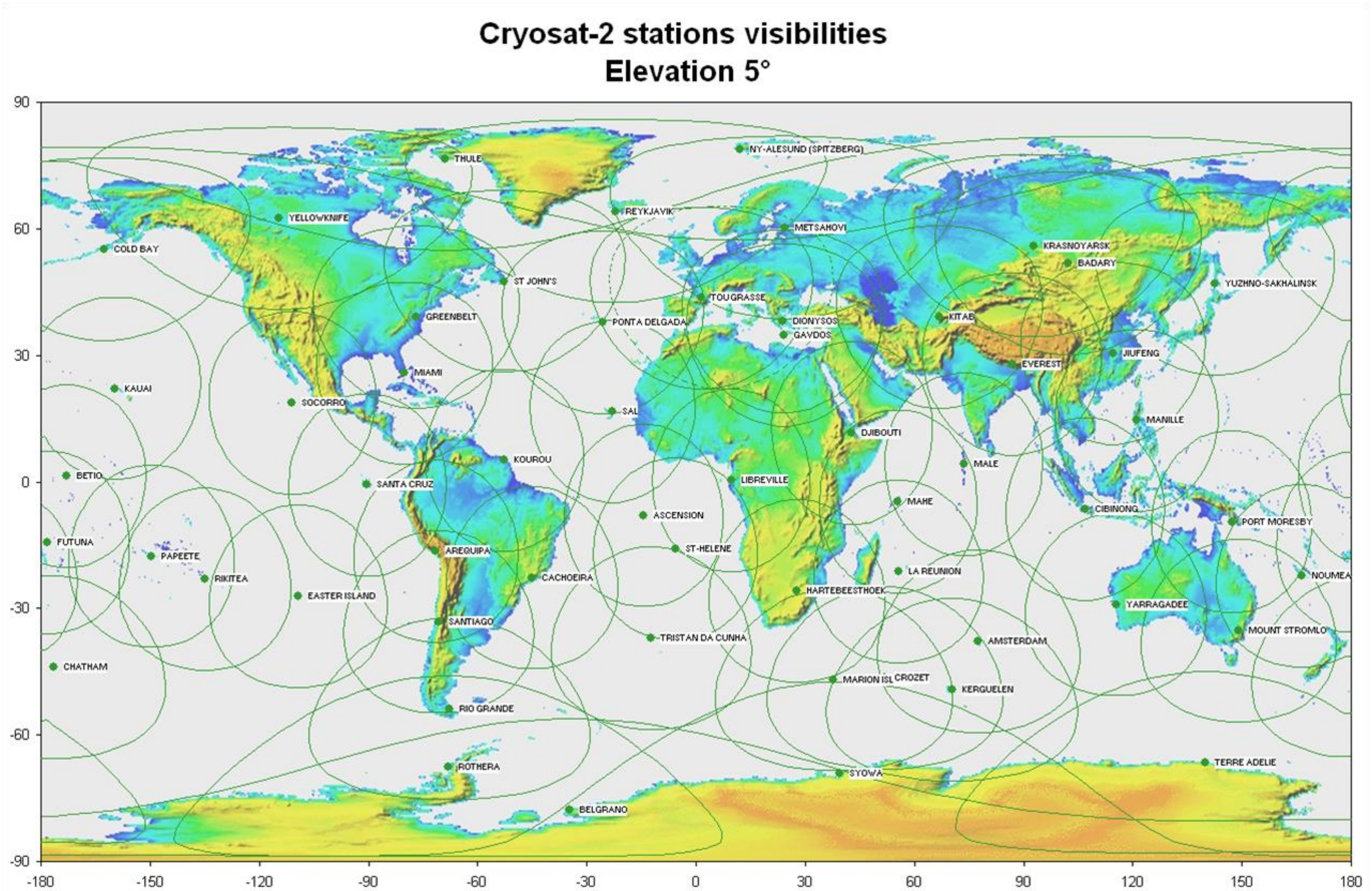
DORIS 10s residuals

Median or mean
0.40 mm/s



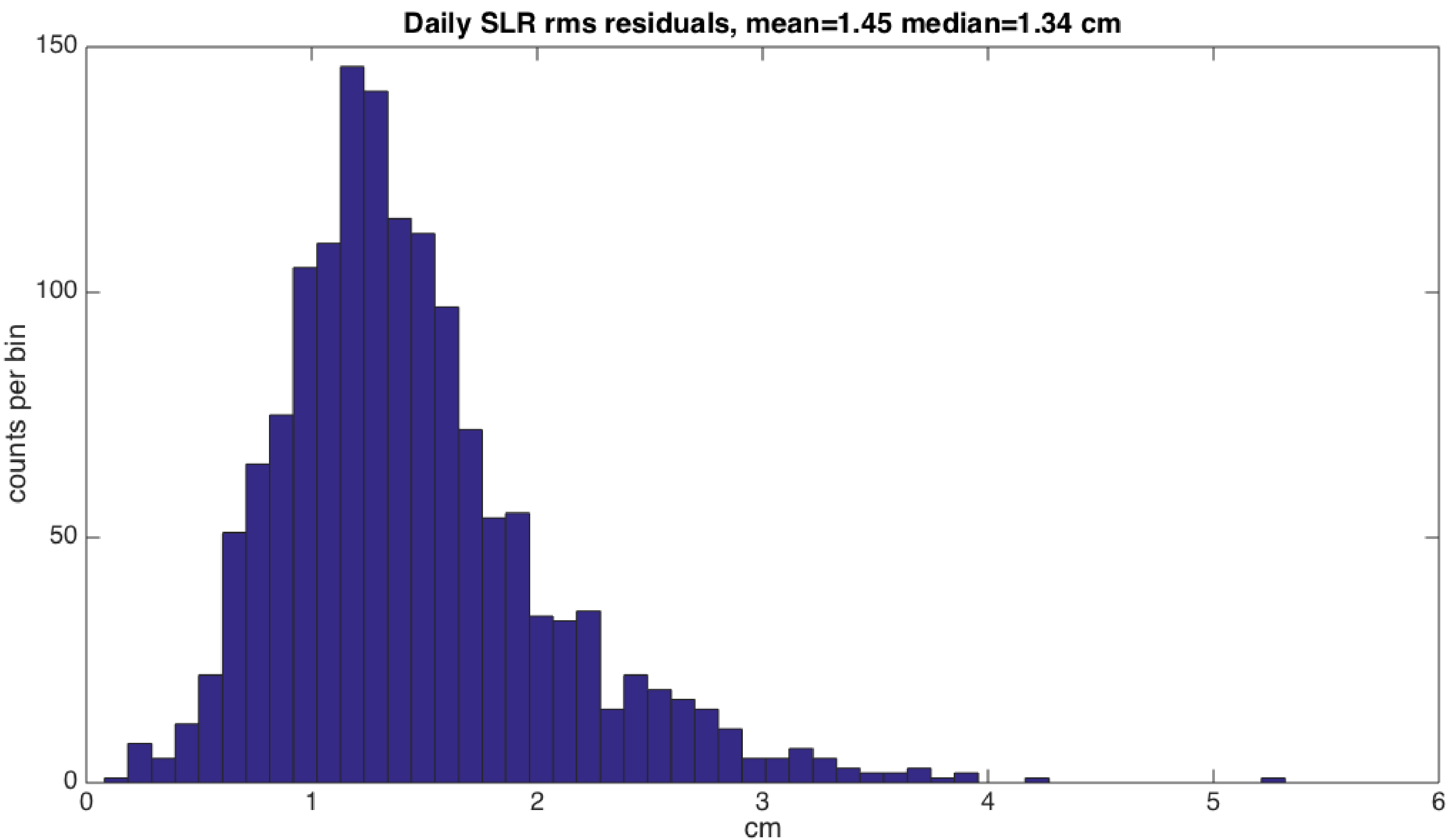

DORIS pass statistics CS2 orbits
passes per day
800
600
400
200
0
2010
2010.5
2011
2011.5
2012
2012.5
2013
2013.5
2014
2014.5
year
daily mean rms [mm/s]
0.46
0.44
0.42
0.4
0.38
0.36
2010
2010.5
2011
2011.5
2012
2012.5
2013
2013.5
2014
2014.5
year

DORIS network

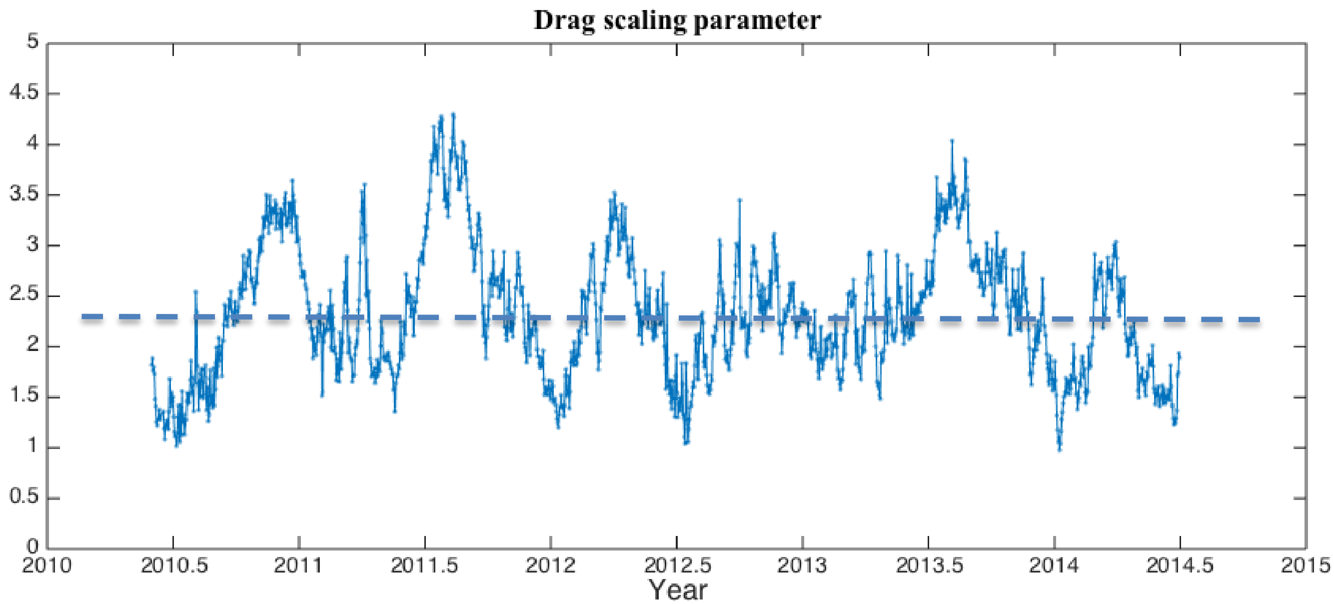


SLR daily residuals

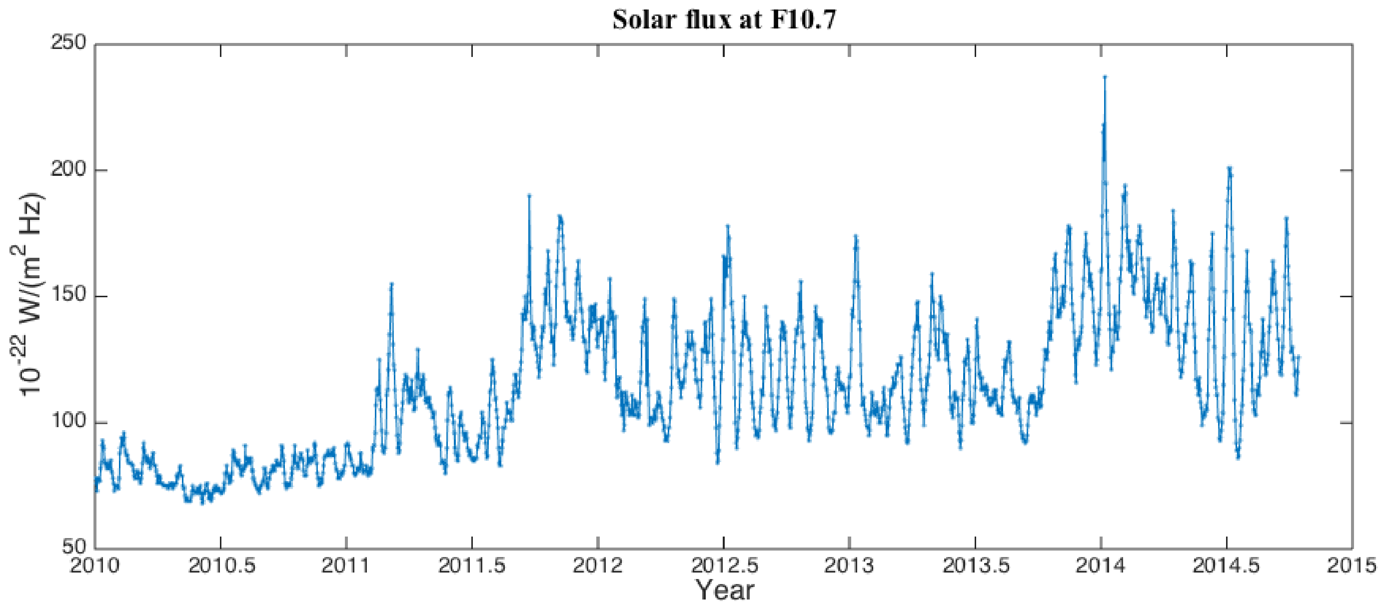
Median 1.34 cm
Mean 1.45 cm




SLR metrics CS2 orbits
passes per day
year
daily mean rms [cm]
year
0
10
20
30
40
50
60
70
0
1
2
3
4
5
6
2010
2010.5
2011
2011.5
2012
2012.5
2013
2013.5
2014
2014.5



Drag

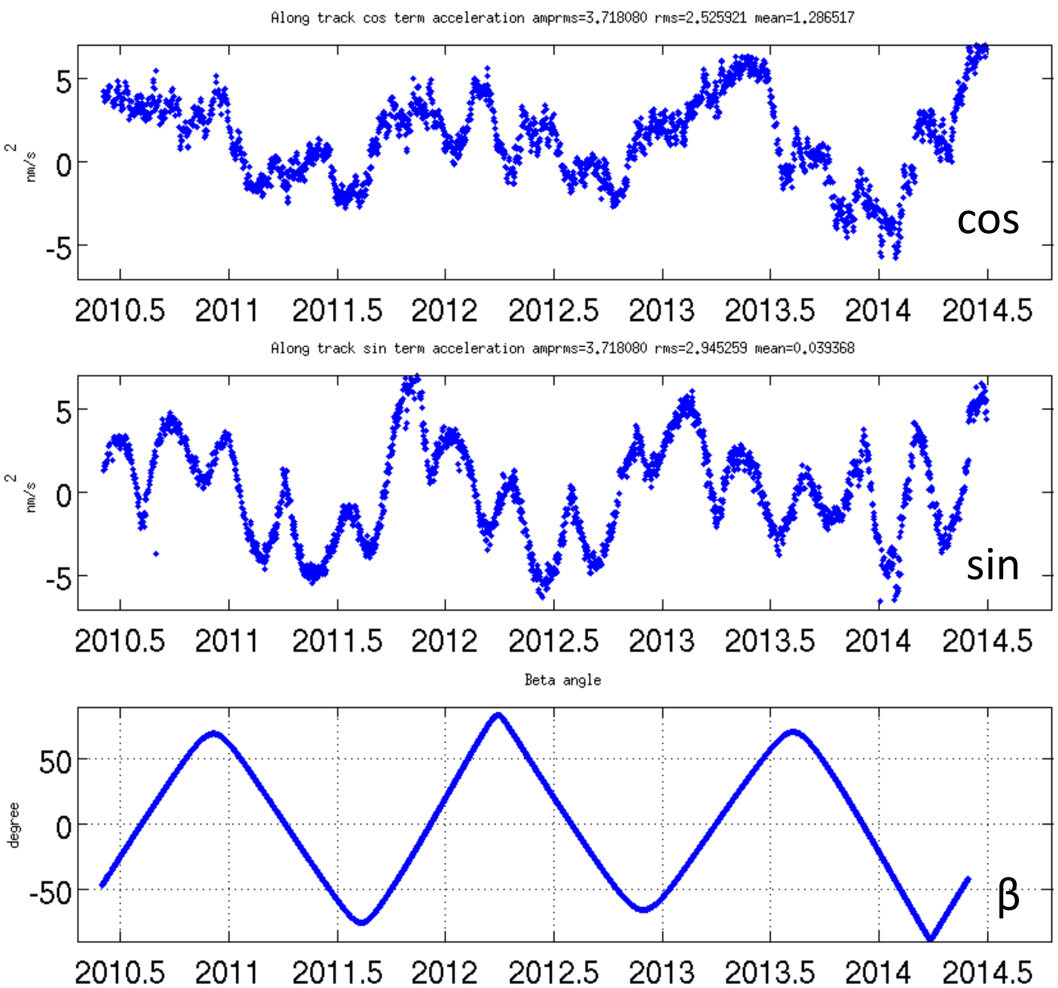


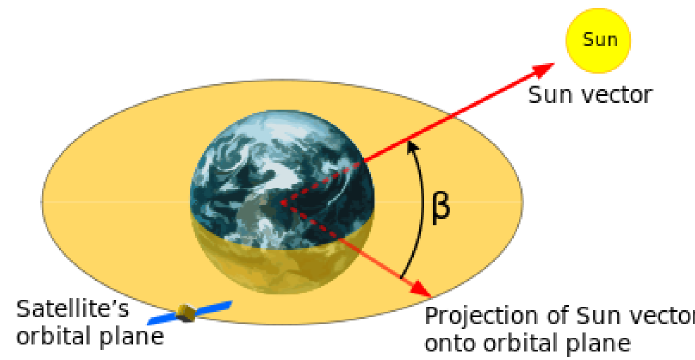
F10.7

Adjusted every 3 hours
Consecutive constraints

Forcing Parameters vs beta angle

24h intervals





Solar radiation pressure model

- SRP parameters for panels in a satellite model
- Simplest approach, assume a cannonball model and adjust the scaling constant, C_r
- ESA model: six panels
- ESA micro model: many panels
- EADS micro model: many panels
- Effort by UCL (Stuart Grey): convert the micro models into acceleration profiles depending on the position of the Sun relative to the spacecraft

ESA CryoSat-2 wire frame model

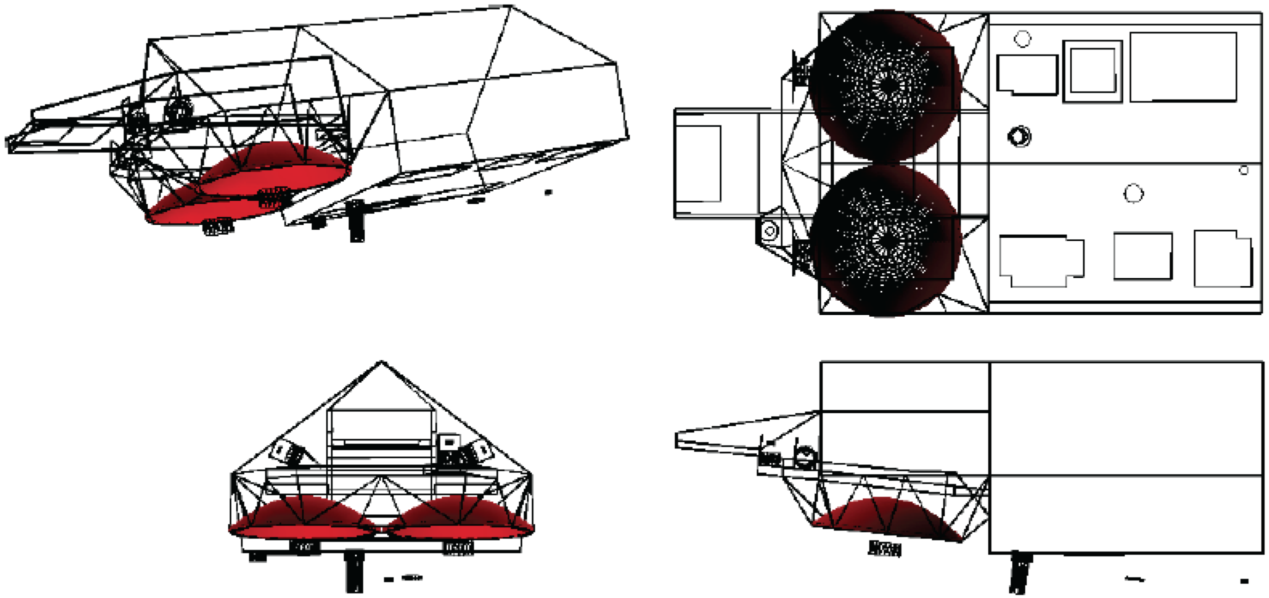


Figure 5.4: *Wire-frame of the first micro model of Cryosat-2. All the elements that are not polygons, cylinders or parabola are missing. Top left: 3D view, top right: top view, bottom left: front view and bottom right: side view.*

Thesis Bart Root

EADS CryoSat-2 model

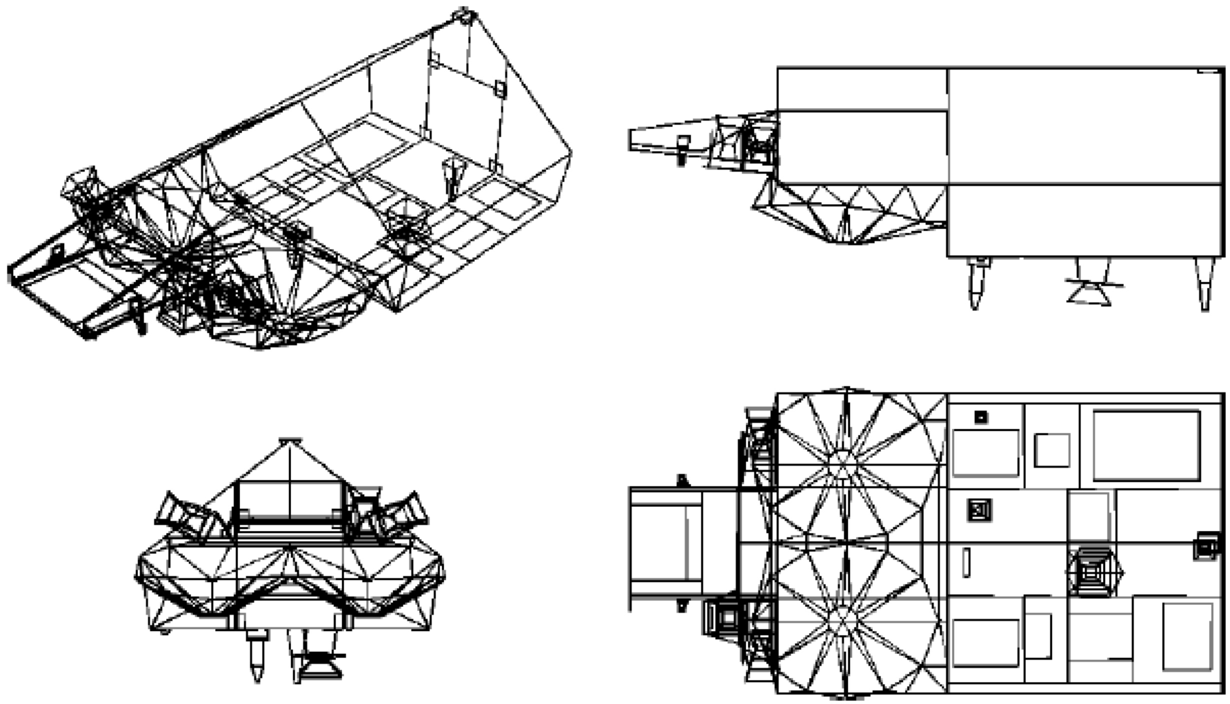
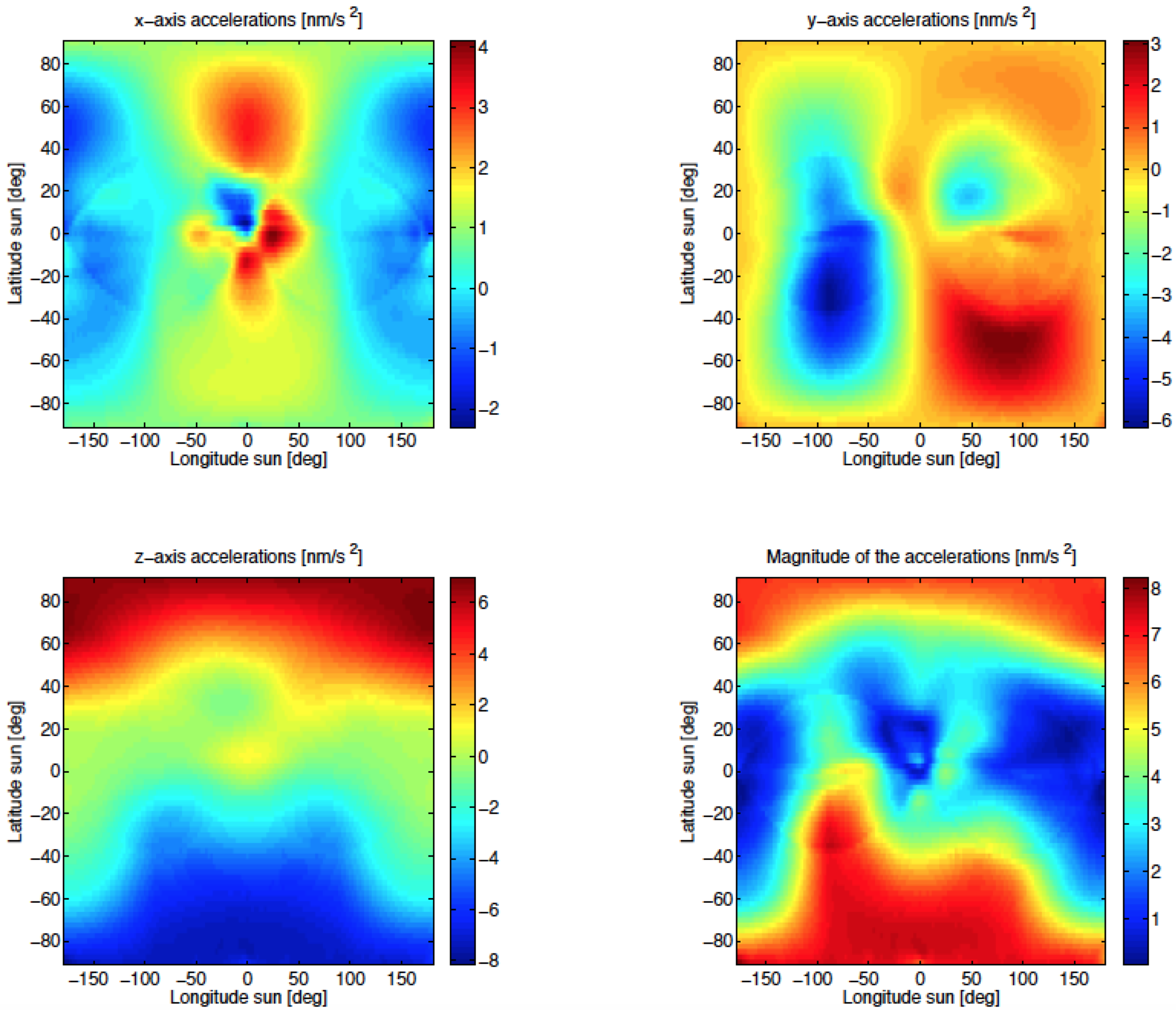


Figure 5.5: *Wire-frame of the EADS micro model of Cryosat-2. This is the second model that will be used. Top left: 3D view, top right: top view, bottom left: front view and bottom right: side view.*

Thesis Bart Root



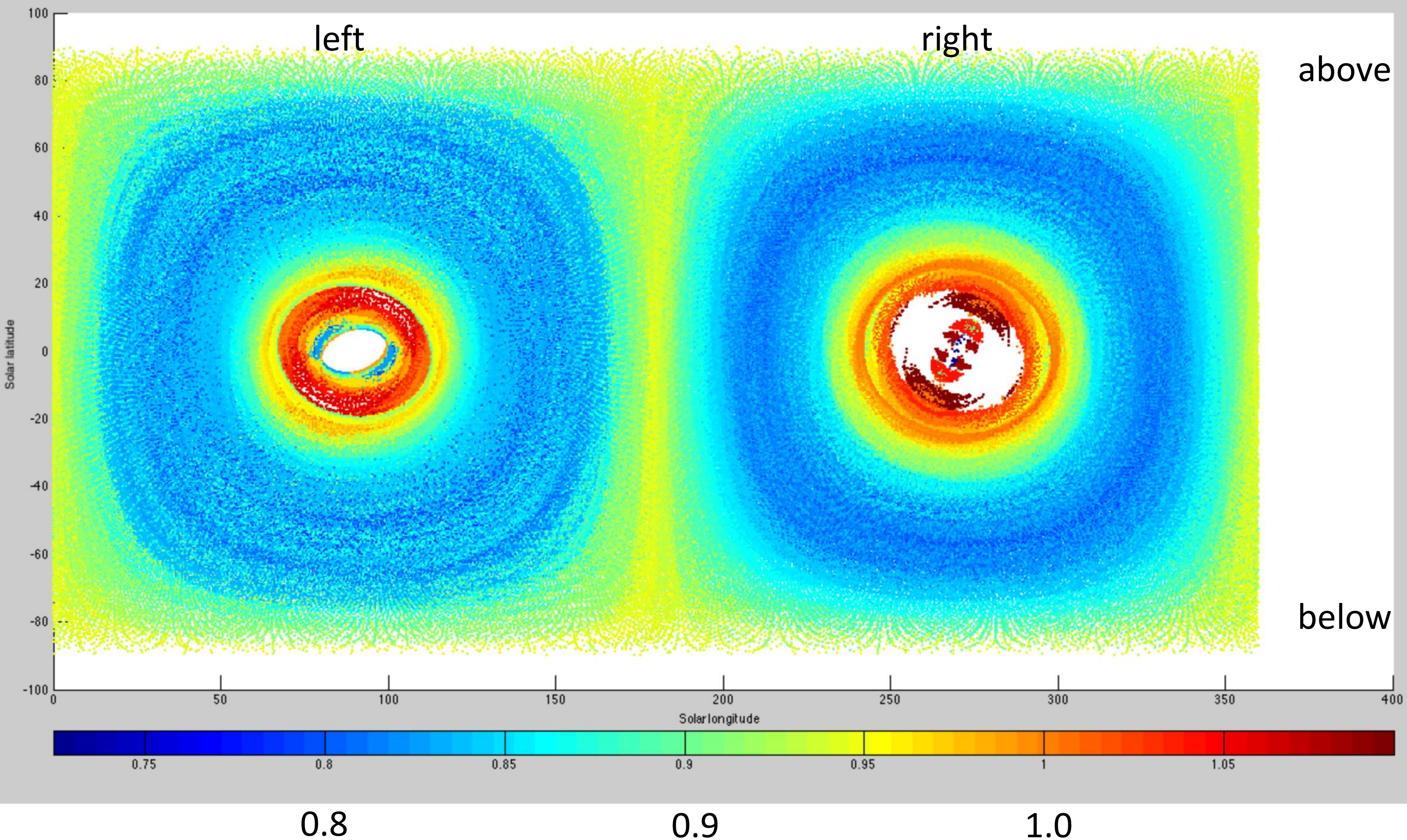
5 nm/s^2

Figure 5.22: *The latitude and longitude plot of the difference between the two different micro models. The results are generated by computing the difference by ESA model (setup D) minus the EADS model (setup E).*

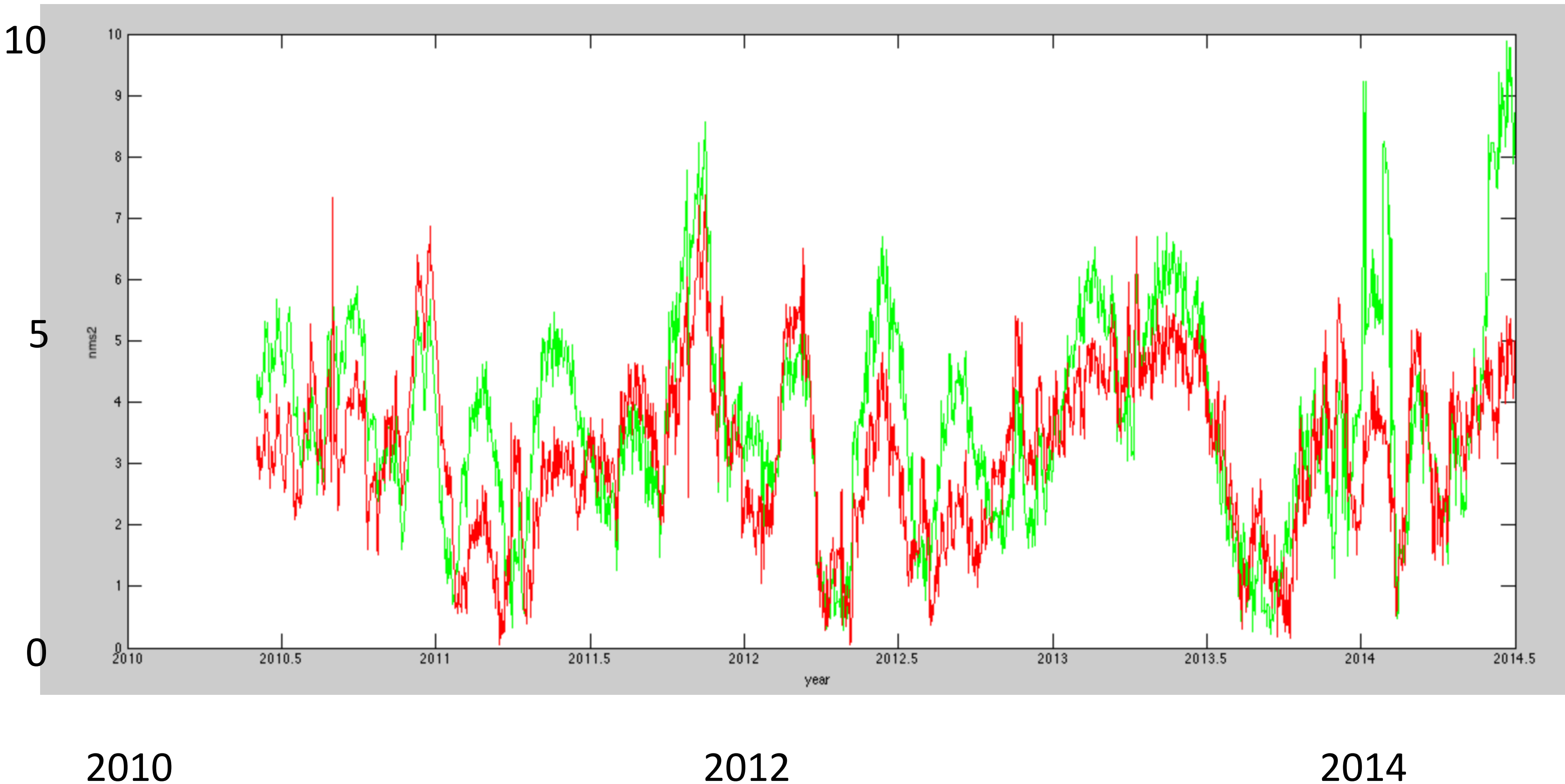
SRP Calibration procedure

- Return to the box model to see what happens with C_r during a full **β** cycle
- First turn off all options in GEODYN that estimate parameters related to general acceleration modeling, normally we estimate once per orbit cos/sin empirical accelerations parameters once per day
- Estimate a radiation model scaling parameter C_r for 6 days arcs for at least a full **β** cycle
- Map C_r in solar latitude and longitude in the local satellite coordinate frame
- Adjust C_r once and rerun with generalized acceleration models

Scan of C_r in the satellite frame

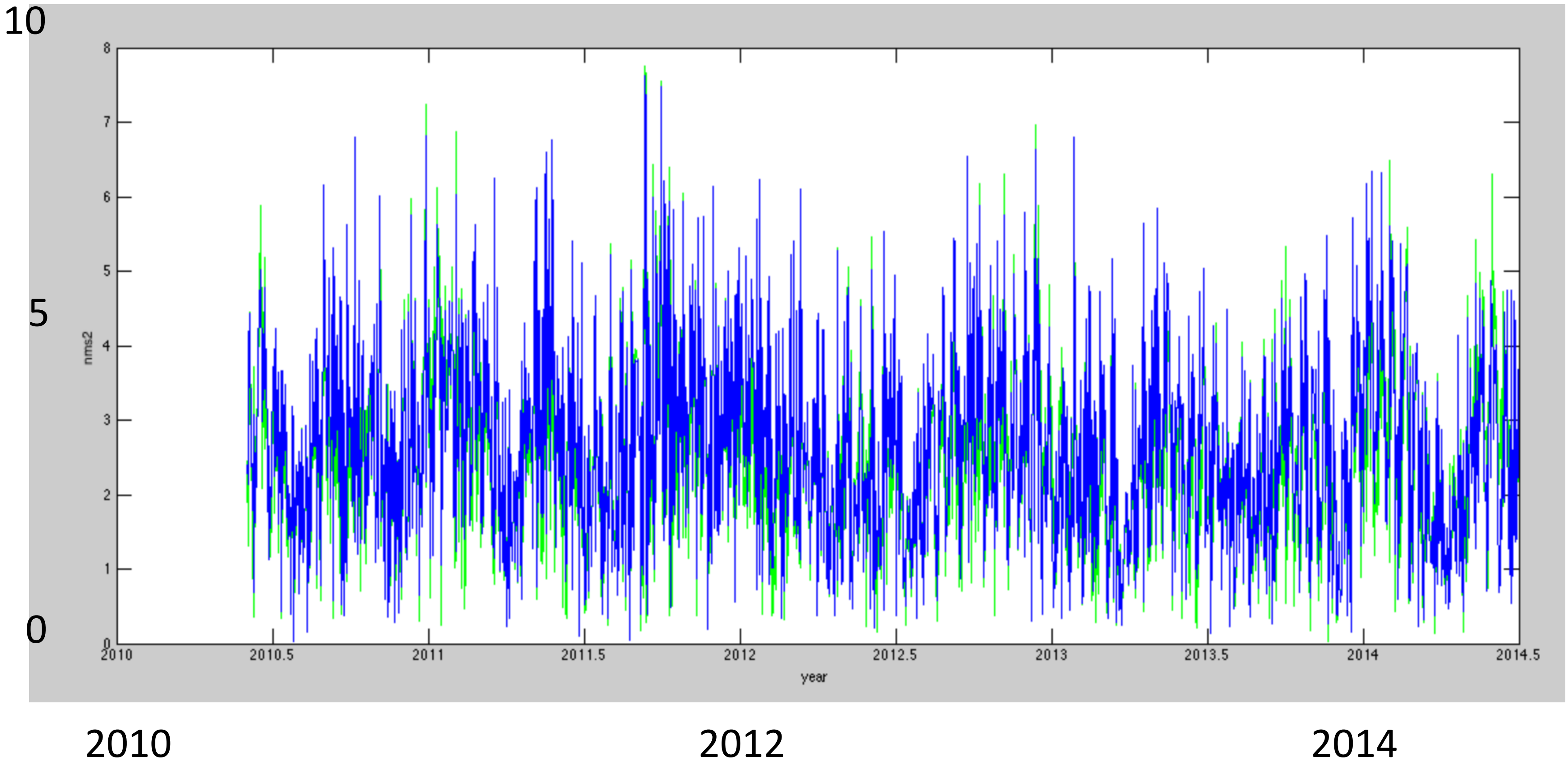


C_r=0.87, empirical along track acc. level in nm/s^2



Improvement: 1.6840 nm/s^2 goes down to 1.3364 nm/s^2

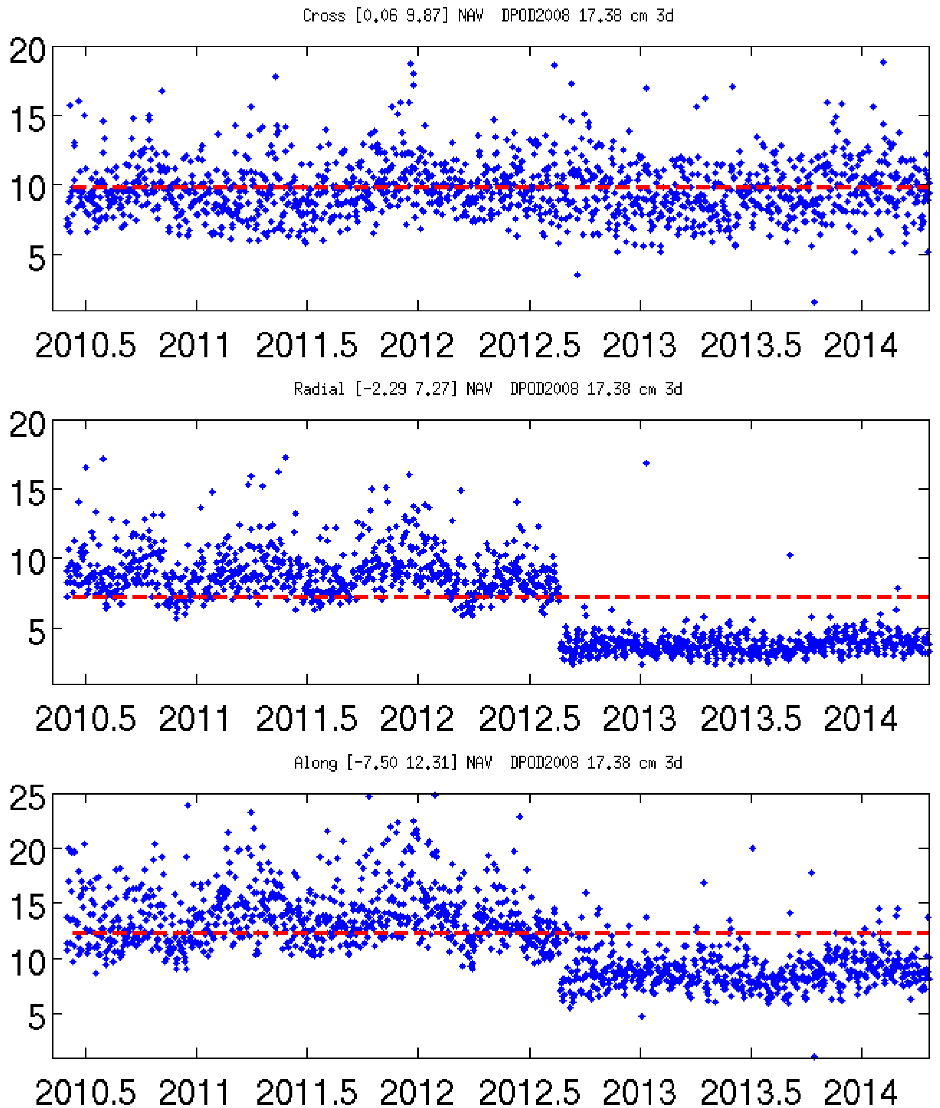
C_r=0.87, empirical <u>crosstrack</u> acc level in nm/s^2



Actually: no improvement here

External orbit comparison

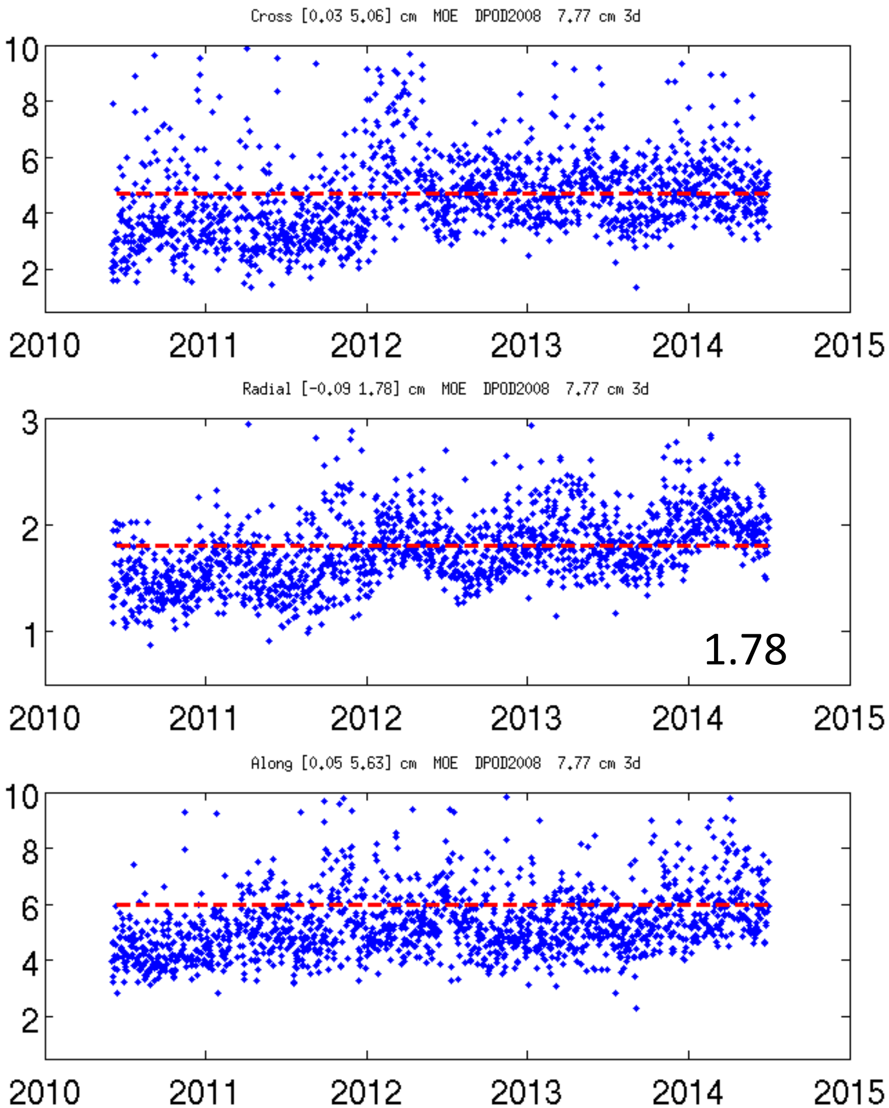
- We compare to CNES products
  - Real time navigator orbits, computed within the receiver real time
  - Rapid science orbits, produced within approximately one or two days (discussion on predicted satellite maneuvers)
  - Delayed final solutions, converged product after a month, ie. when IERS bulletin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



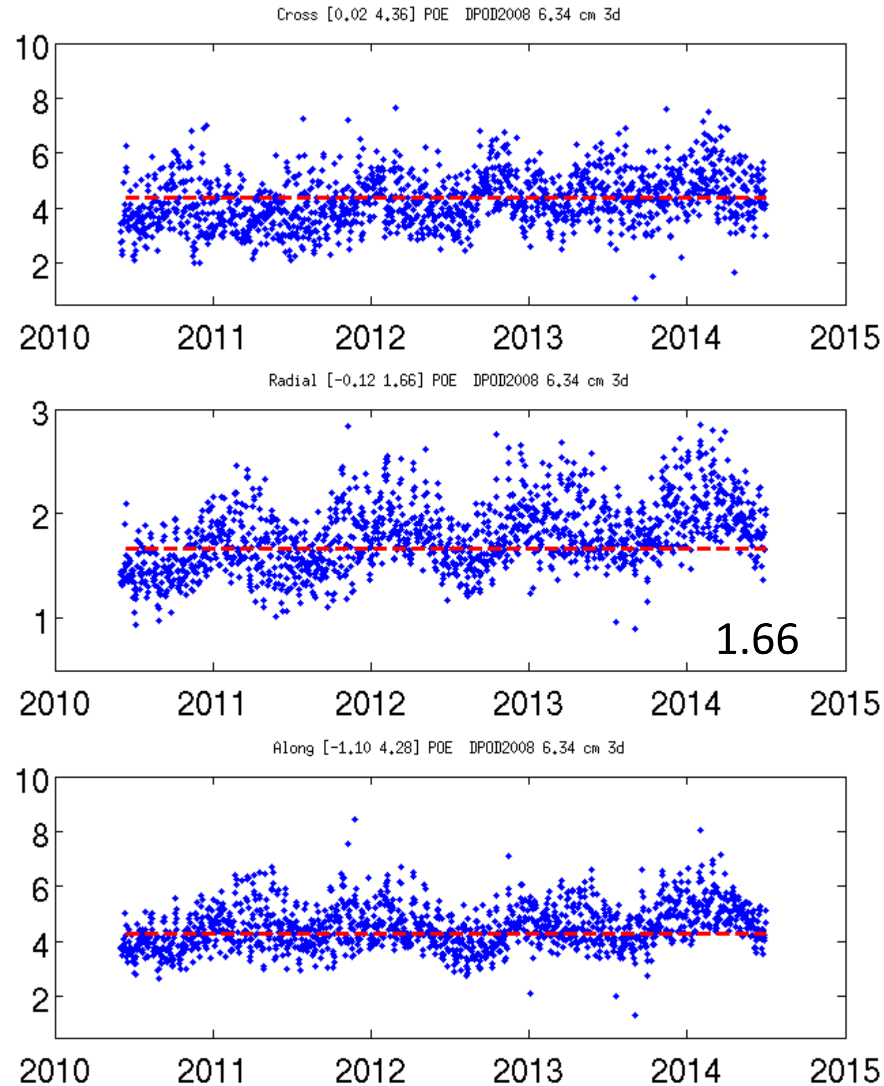
Navigator

9cm -> 3.5cm

MOE orbit



POE orbit



Summary (1)

- SLR: independently it yields ≈4 cm orbits radially, residual of fit consistent at ≈1.34 cm (median). Low weight wrt DORIS
- DORIS: consistent fits at 0.40 mm/s based on 10 second data, CNES: Rinex data, ours: 10s Doppler counts
- We compare against Navigator orbits, rapid sciences CNES MOE and the final solution POE orbits
- Radial consistency between 1.5 to 2.0 cm wrt POE, average **1.66 cm** between two independent procedures, **1.17 cm** if we say the orbit products are uncorrelated.
- The real-time DIODE Navigator data has been improved, since 2012 we see a radial consistency < 5 cm

Summary (2)

- EADS vs ESA micro model -> acceleration differences 5 nm/s^2 (or 5% or the total SRP effect)
- ESA 6 panel model for SRP modelling
  - Shows an anisotopic response, it wants to see an more diffuse rather than specular S/C
  - Optimal scale factor C_r = 0.87 for SRP
  - Reduces 1.68 to 1.34 nm/s^2
  - A rescaled C_r does not really improve orbit residuals or an external orbit comparisons