
Cryosat-2 Precise Orbit Determination
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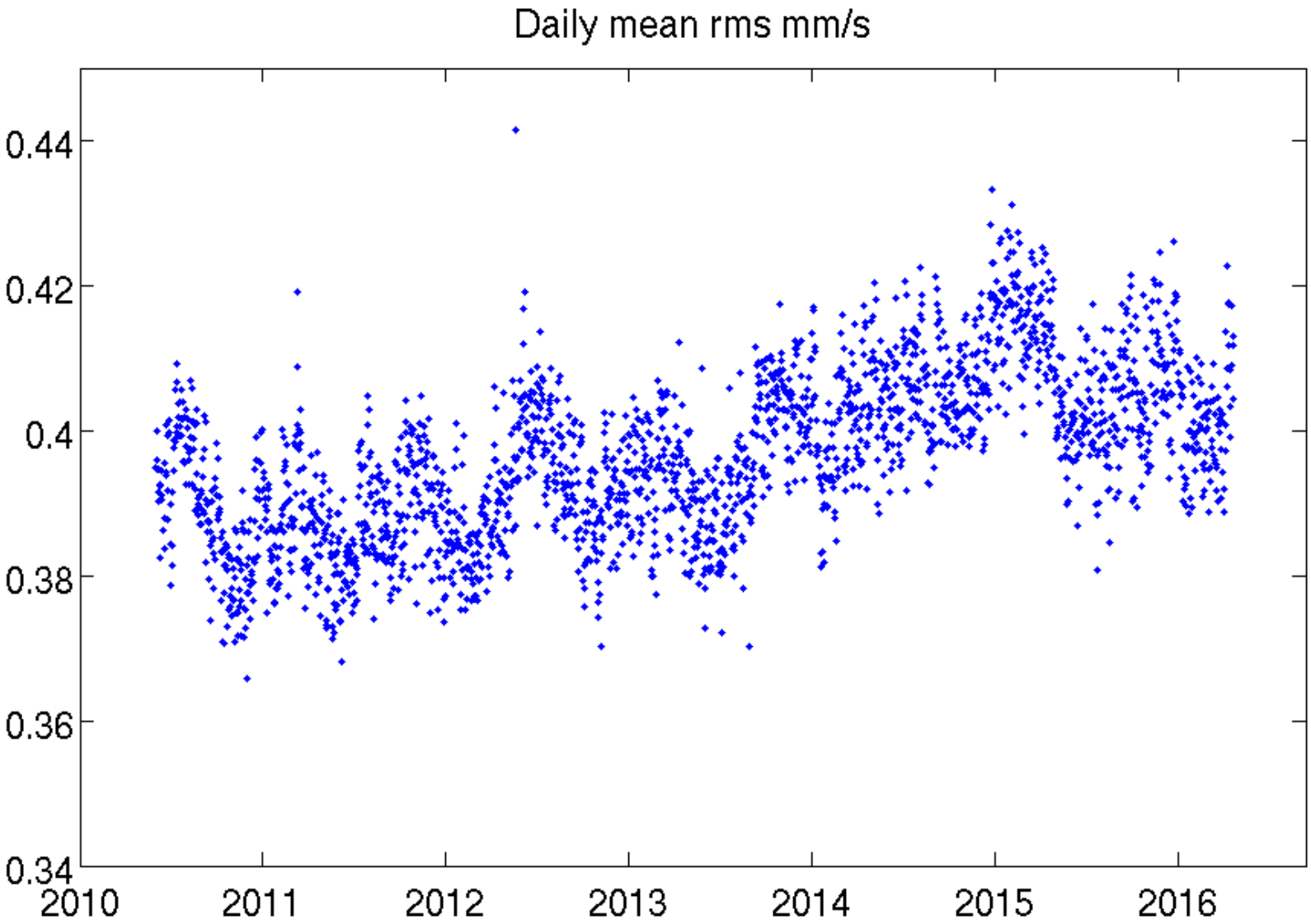
Overview of talk

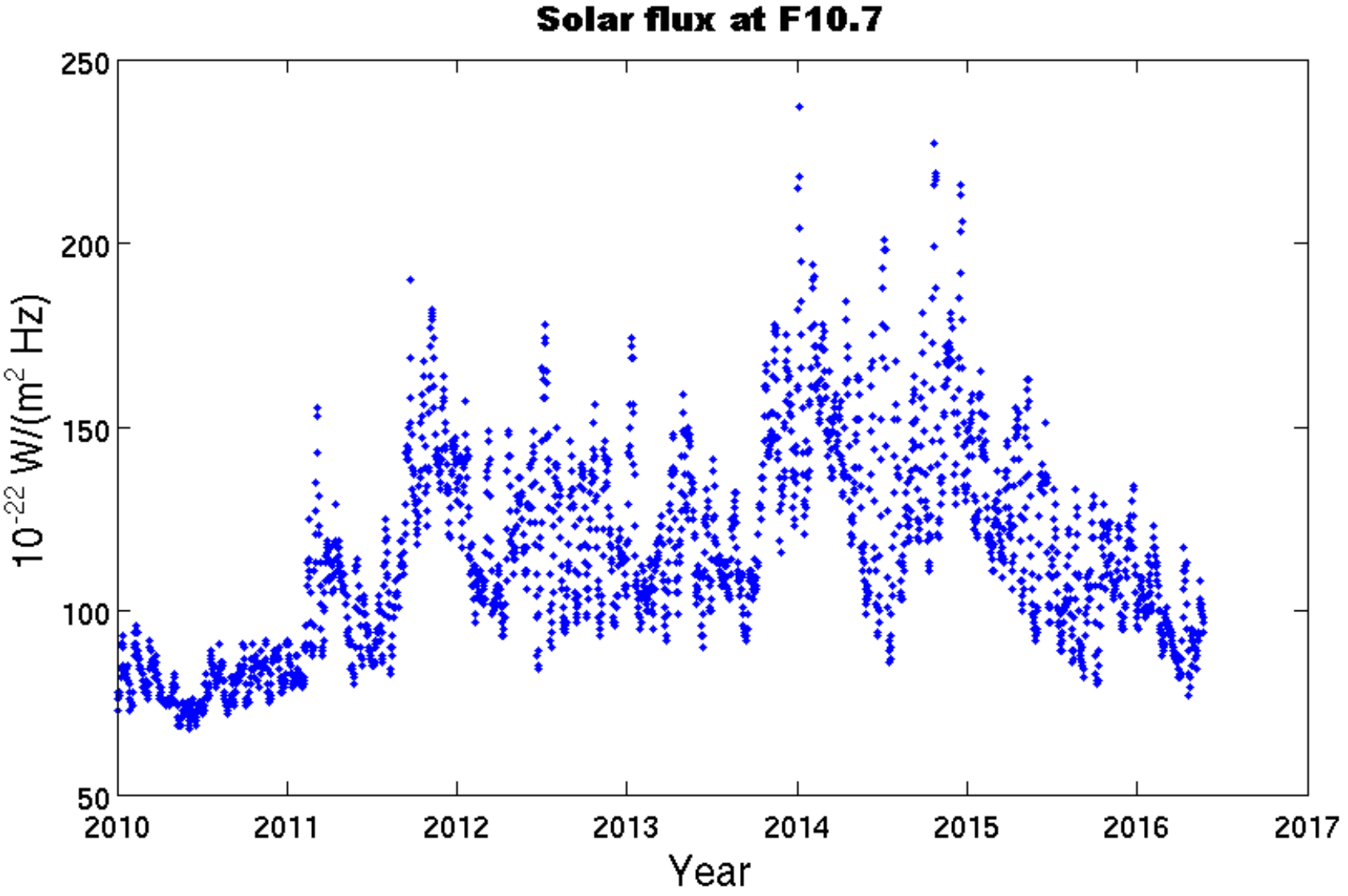
- TUD involvement: validation/calibration within the CryoSat-2 community
  - DORIS tracking data, 59 beacons from the IDS, 10s doppler data
  - SLR Tracking data: ~10 stations from the ILRS, Independent sparse laser data
  - Do quality checks, internal, external, forcing
- Latest developments
  - SRP model from the CNES
  - More aggressive empirical acceleration model, parameterization

Models, tools etc

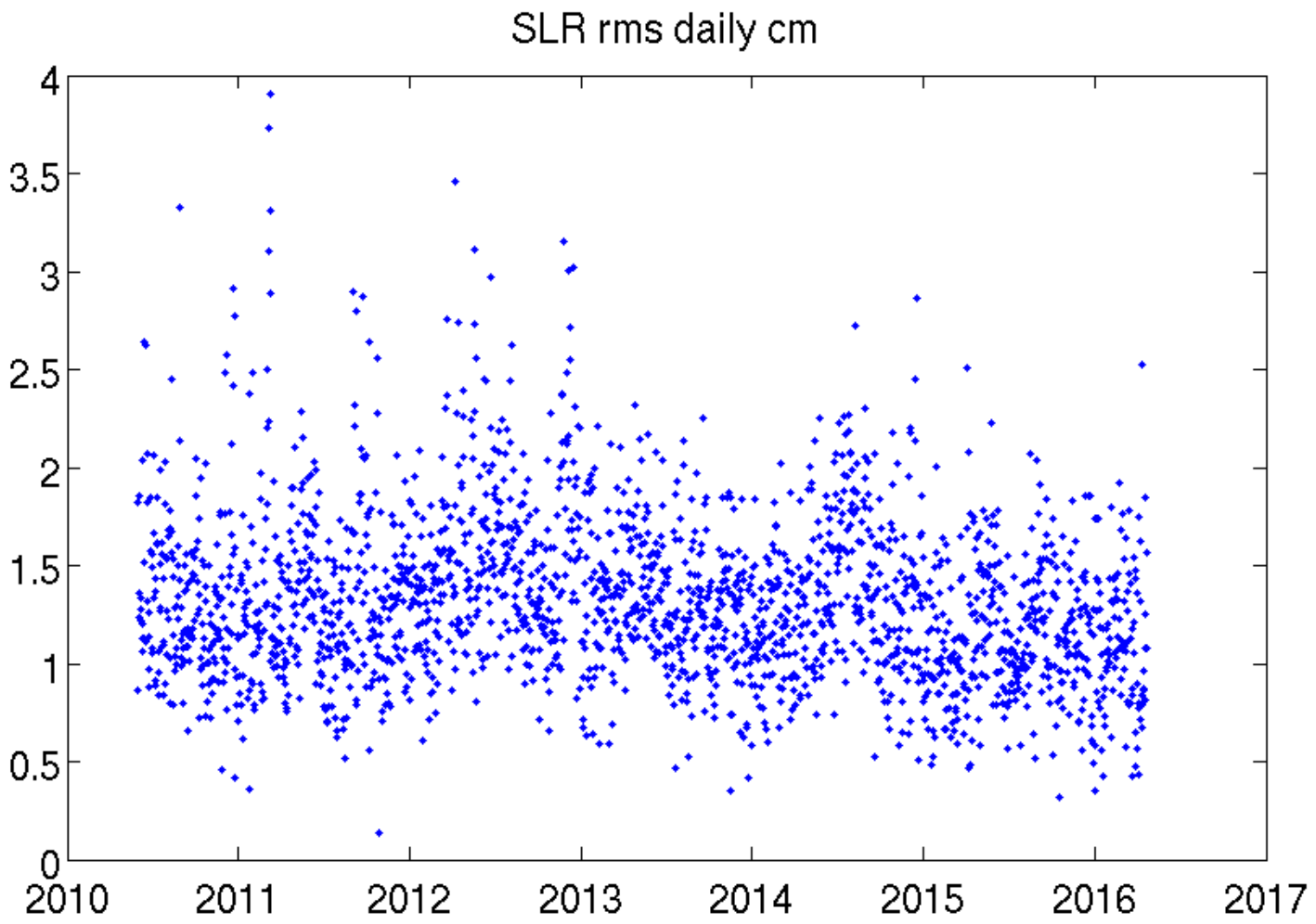
- GEODYN software from NASA/GSFC plus own tools.
- Station coordinates and Earth rotation parameters:
  - DORIS and SLR station coordinates in DPOD2008/SLRF2008
  - IERS data, polar motion, length of day from Bulletin B
- Satellite Dynamics
  - EIGEN5c gravity model
  - Temporal gravity from GRACE to degree and order 20
  - FES2004 ocean load tides
  - Frequency offset and troposphere estimate 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/
  - Emprical accelerations, Drag, SRP model calibration

0.39 mm/s

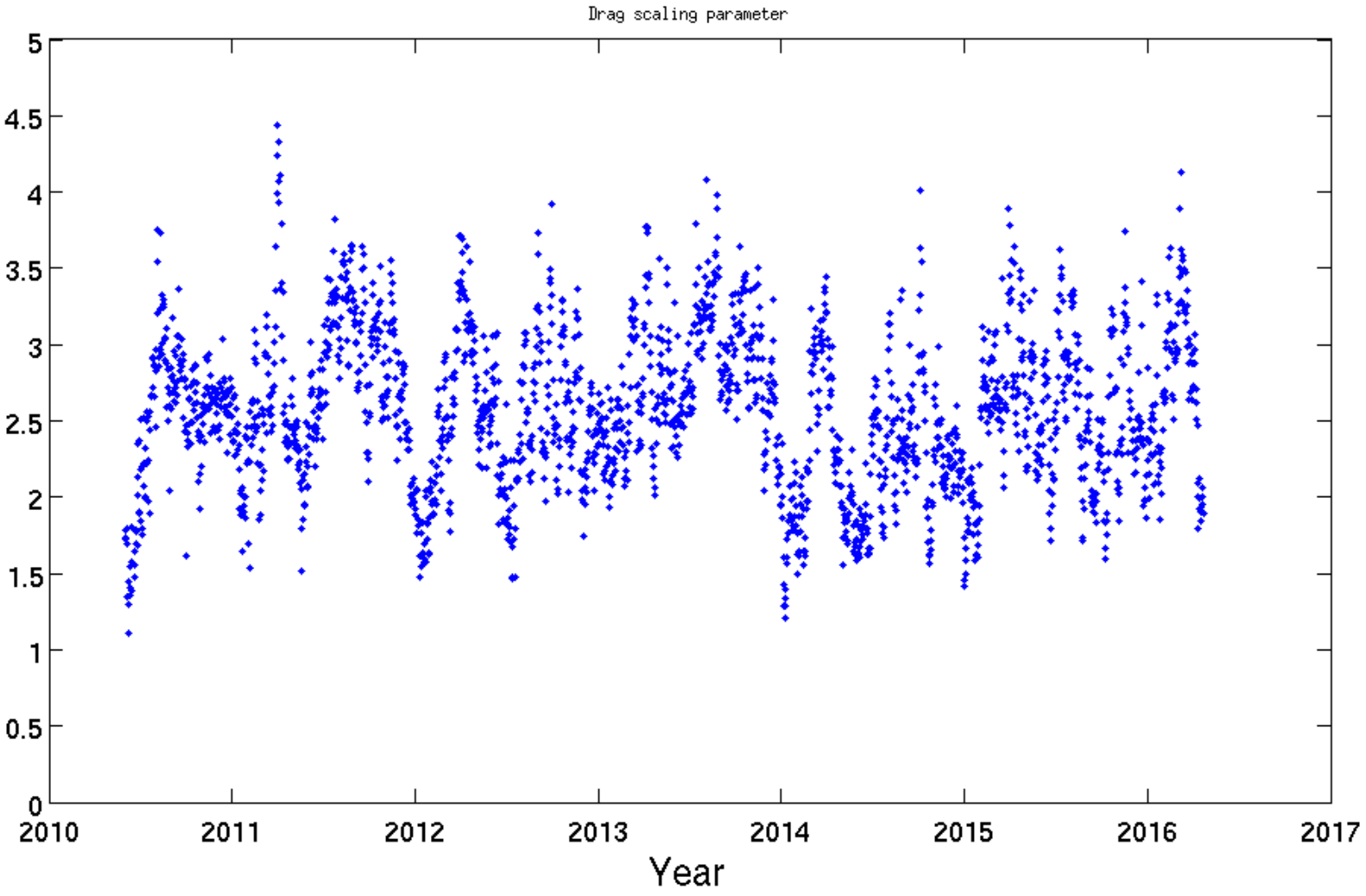

Daily mean rms mm/s
0.44
0.42
0.4
0.38
0.36
0.34
2010
2011
2012
2013
2014
2015
2016


Solar flux at F10.7
250
200
150
100
50
10^{-22} W/(m^2 Hz)
2010
2011
2012
2013
2014
2015
2016
2017
Year

1.41cm



SLR: residual of fit consistent at 1.41 cm rms. Low weight wrt DORIS, independently it yields ≈4 cm orbits radially,

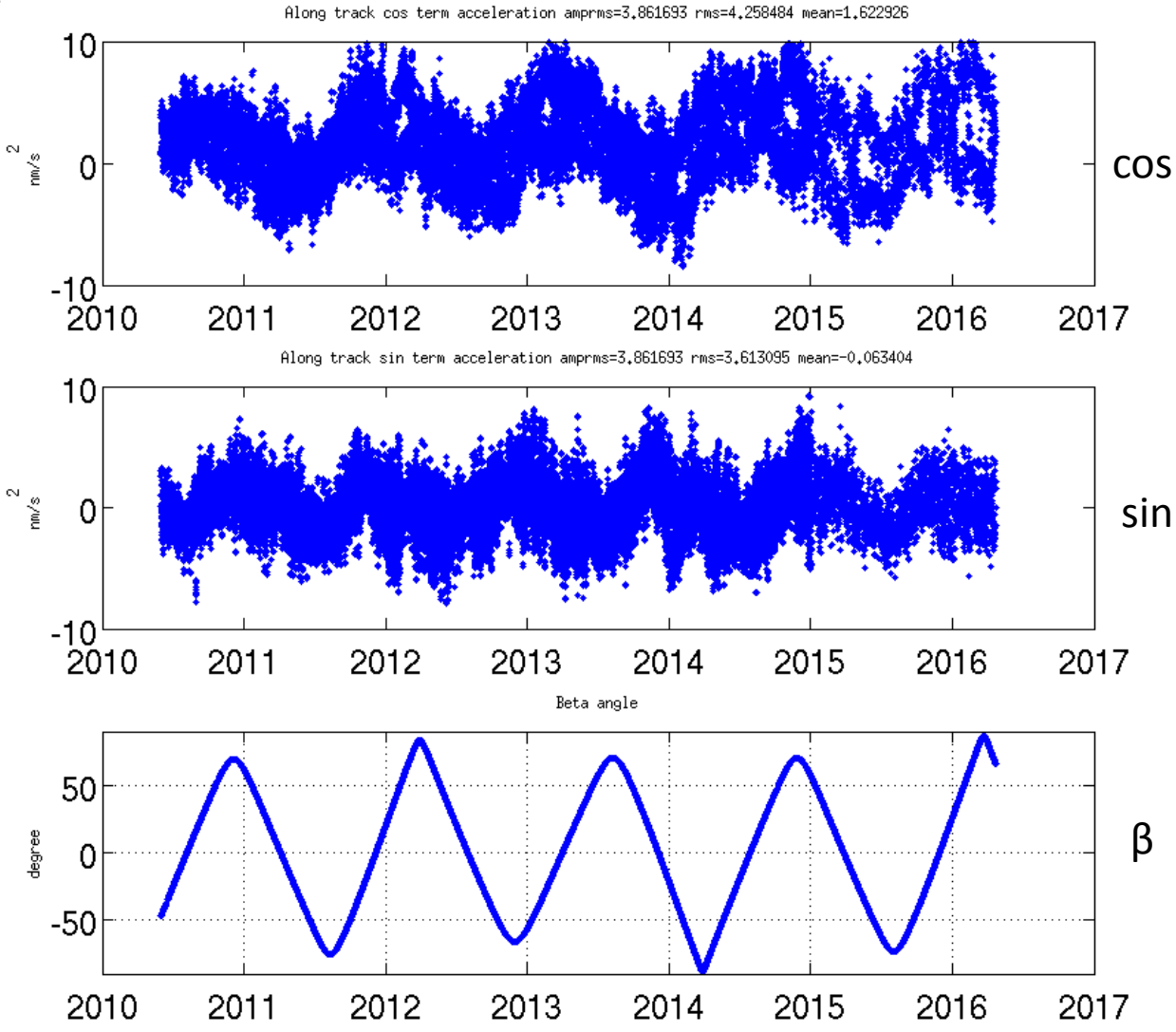

Drag scaling parameter
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
2010
2011
2012
2013
2014
2015
2016
2017
Year

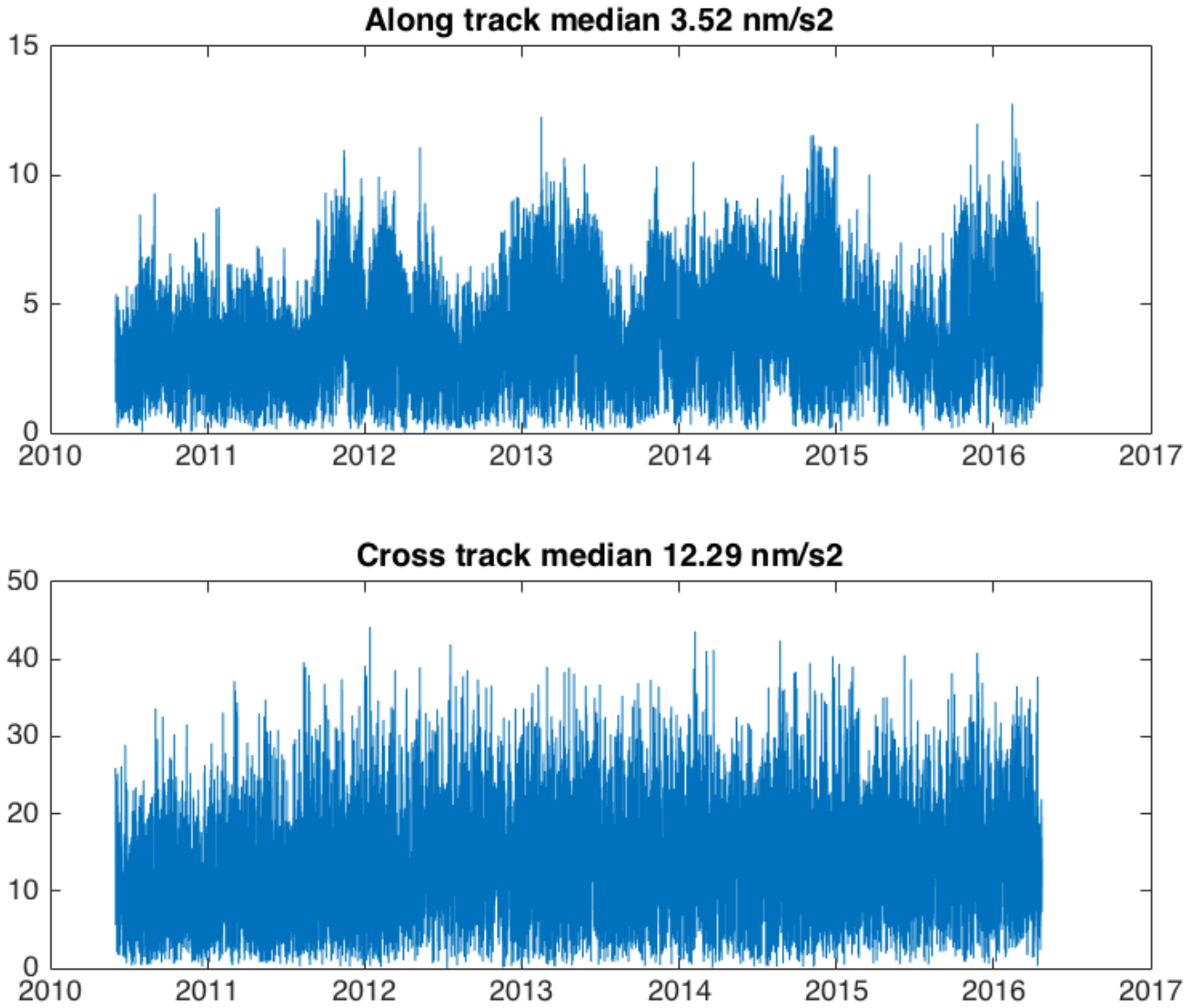
Empirical: 12h intervals up to 2015, 6 hour intervals since

Drag: 3 hours

Noise level: 3.52 nm/s^2

Along trackForcing Parameters vs beta angle




Along track median 3.52 nm/s2
15
10
5
0
2010
2011
2012
2013
2014
2015
2016
2017
Cross track median 12.29 nm/s2
50
40
30
20
10
0
2010
2011
2012
2013
2014
2015
2016
2017

Crossover tests

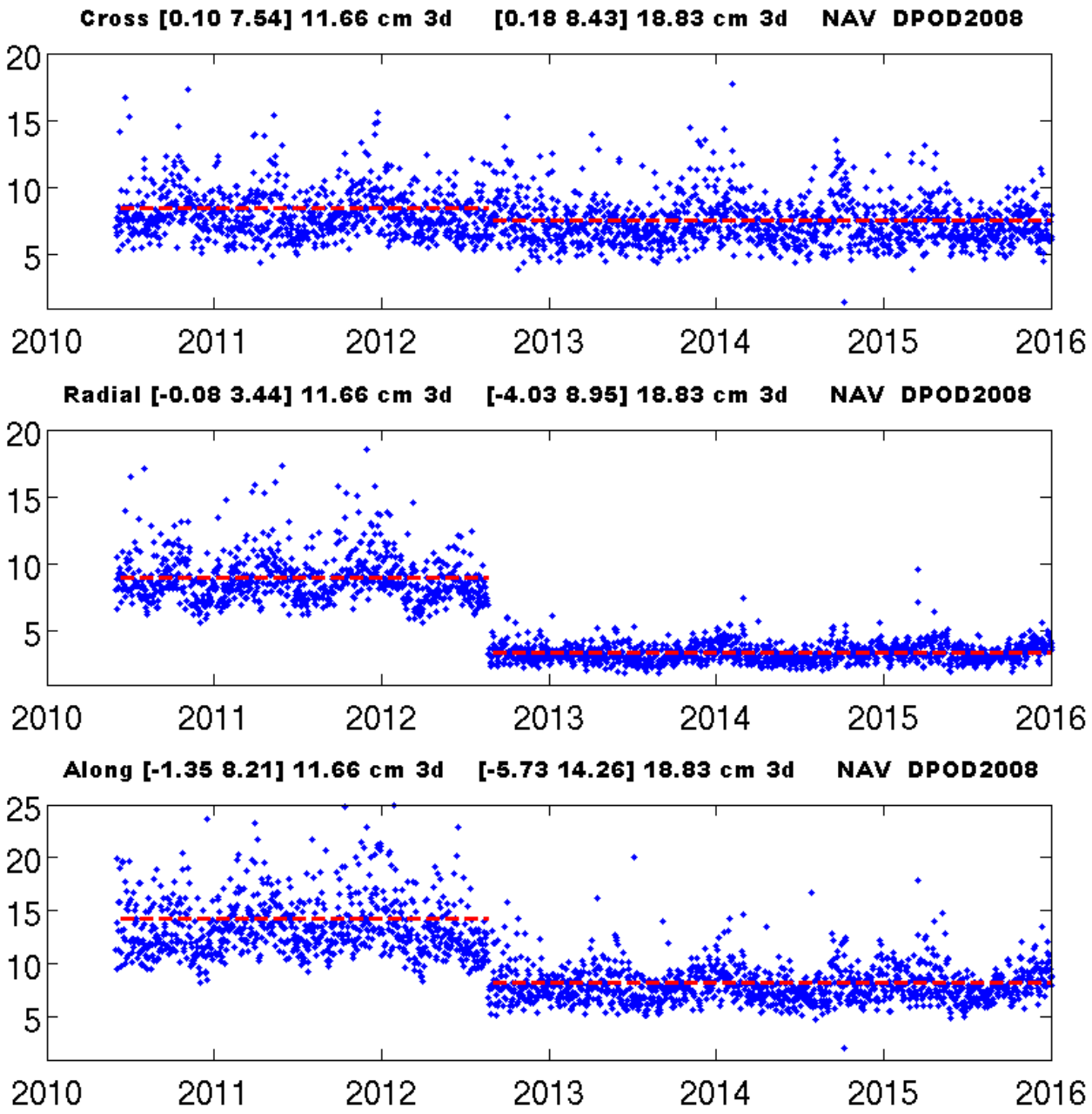
	Our	NAV	MOE	POE
Bias	-0.2327	0.0927	0.0951	0.2875
St.Dev.	4.4050	7.3127	4.4794	4.3309

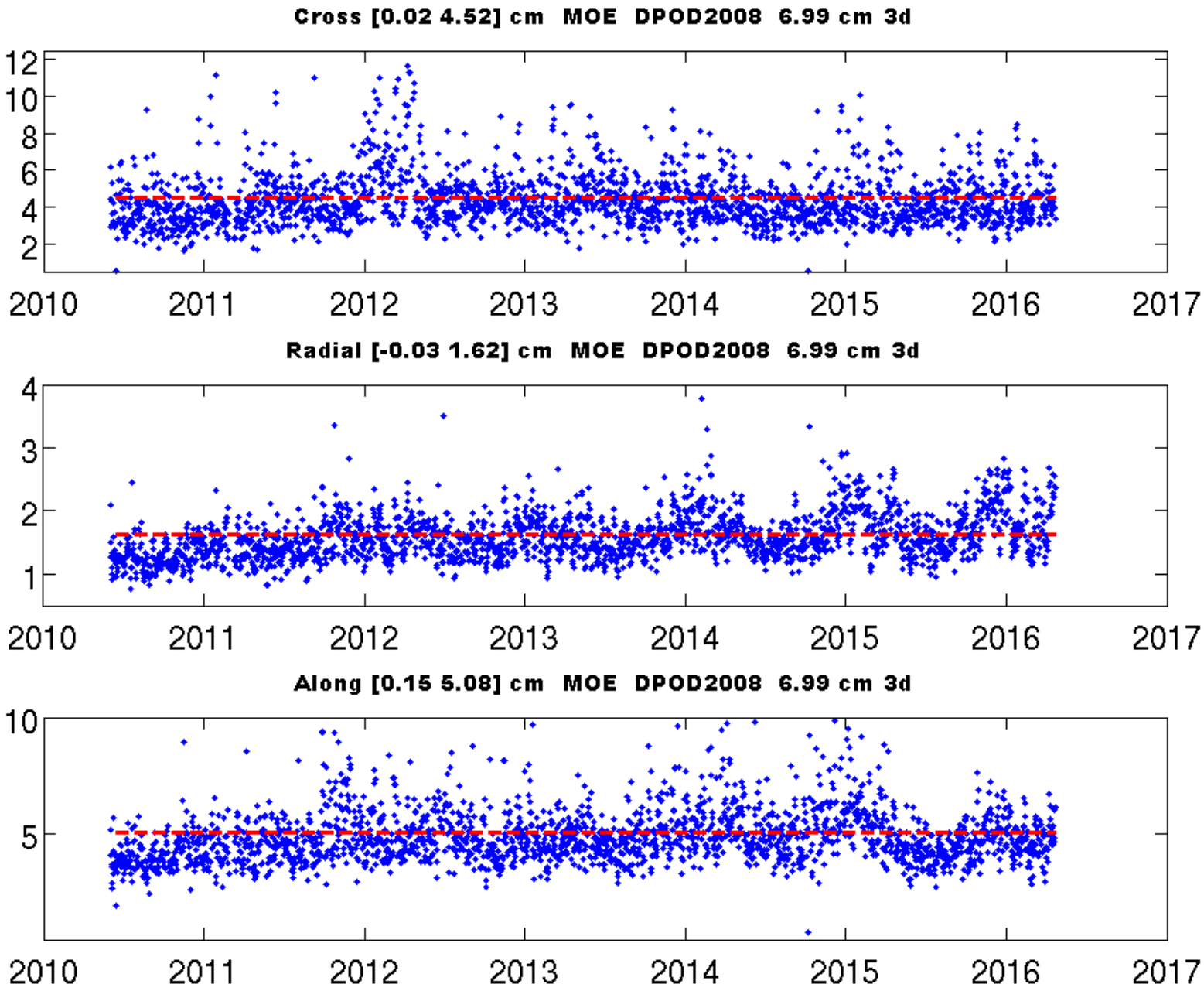
Crossover statistics for all involved orbits in this study. The maximum allowed time difference at the crossing point locations is 15 days, the editing limit (absolute maximum sea level anomaly difference) was set at 9cm, and the latitude is between 65N and 65S. The first row shows the bias in cm, the second row shows the standard deviation in cm.

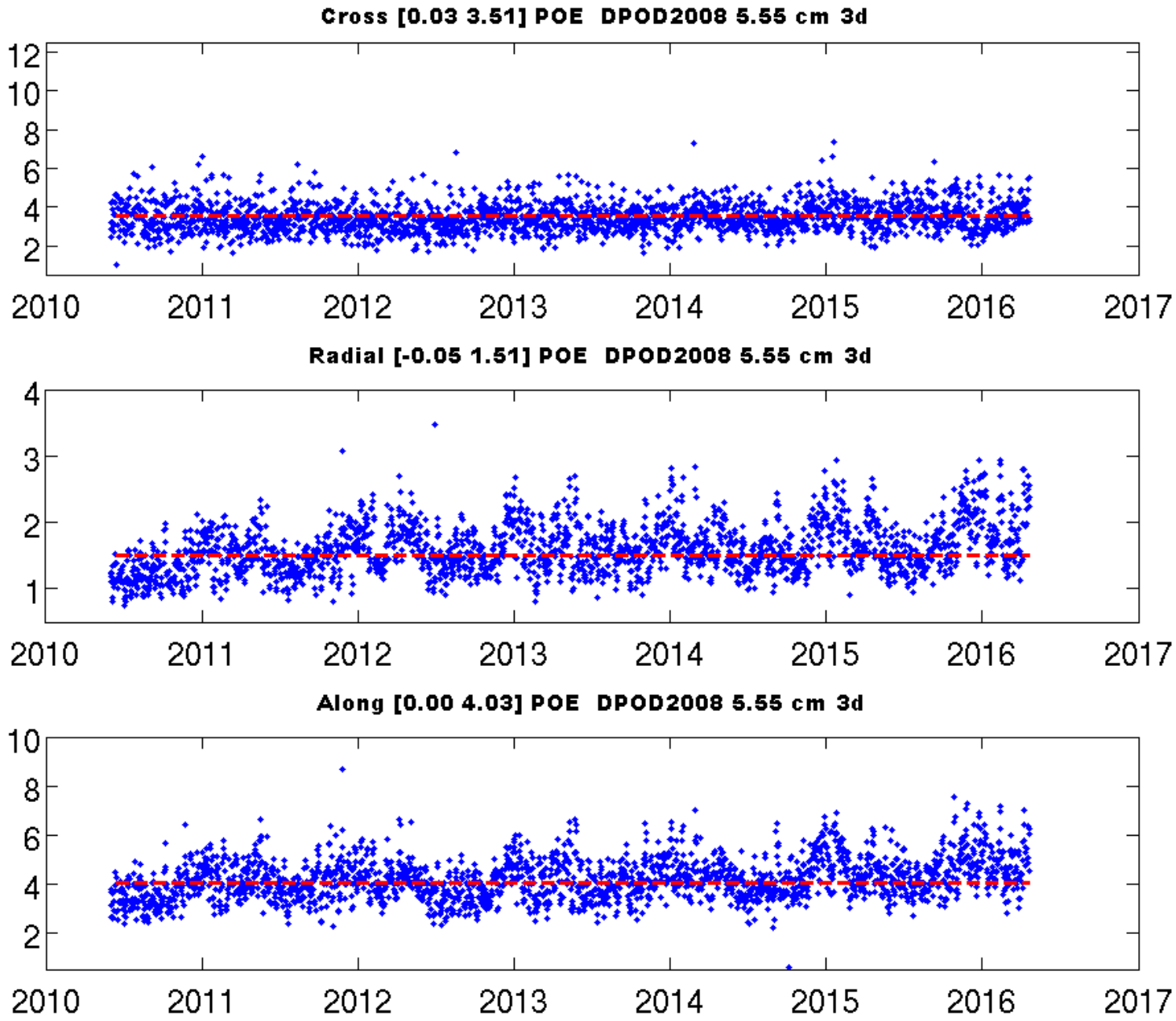
Editing criteria are not trivial, all crossovers need to be the same for four different orbits

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.


Cross [0.10 7.54] 11.66 cm 3d [0.18 8.43] 18.83 cm 3d NAV DPOD2008
20
15
10
5
2010
2011
2012
2013
2014
2015
2016
Radial [-0.08 3.44] 11.66 cm 3d [-4.03 8.95] 18.83 cm 3d NAV DPOD2008
20
15
10
5
2010
2011
2012
2013
2014
2015
2016
Along [-1.35 8.21] 11.66 cm 3d [-5.73 14.26] 18.83 cm 3d NAV DPOD2008
25
20
15
10
5
2010
2011
2012
2013
2014
2015
2016


Cross [0.02 4.52] cm MOE DPOD2008 6.99 cm 3d
12
10
8
6
4
2
2010
2011
2012
2013
2014
2015
2016
2017
Radial [-0.03 1.62] cm MOE DPOD2008 6.99 cm 3d
4
3
2
1
2010
2011
2012
2013
2014
2015
2016
2017
Along [0.15 5.08] cm MOE DPOD2008 6.99 cm 3d
10
5
2010
2011
2012
2013
2014
2015
2016
2017


Cross [0.03 3.51] POE DPOD2008 5.55 cm 3d
12
10
8
6
4
2
2010
2011
2012
2013
2014
2015
2016
2017
Radial [-0.05 1.51] POE DPOD2008 5.55 cm 3d
4
3
2
1
2010
2011
2012
2013
2014
2015
2016
2017
Along [0.00 4.03] POE DPOD2008 5.55 cm 3d
10
8
6
4
2
2010
2011
2012
2013
2014
2015
2016
2017

Summary

- DORIS: consistent fits at 0.40 mm/s based on 10 s data
- Empirical accelerations computed, still relatively high levels are found for CryoSat.
- We compare against Navigator orbits, rapid sciences CNES MOE and the final solution POE orbits
- Radial consistency between 1.51 cm wrt POE, 1.62 cm wrt to the MOE
- The real-time DIODE Navigator data has been improved, since 2012.6 we see a radial consistency 3.44 cm, before that time it was 8.95 cm

Outlook

- Switch to new ITRF
  - STCD files from CB
- Short arc solution
  - 3 daily arcs
    - Improves everything
    - Forcing more difficult to interpret
- Better editing?