Improvements CryoSat-2 POD

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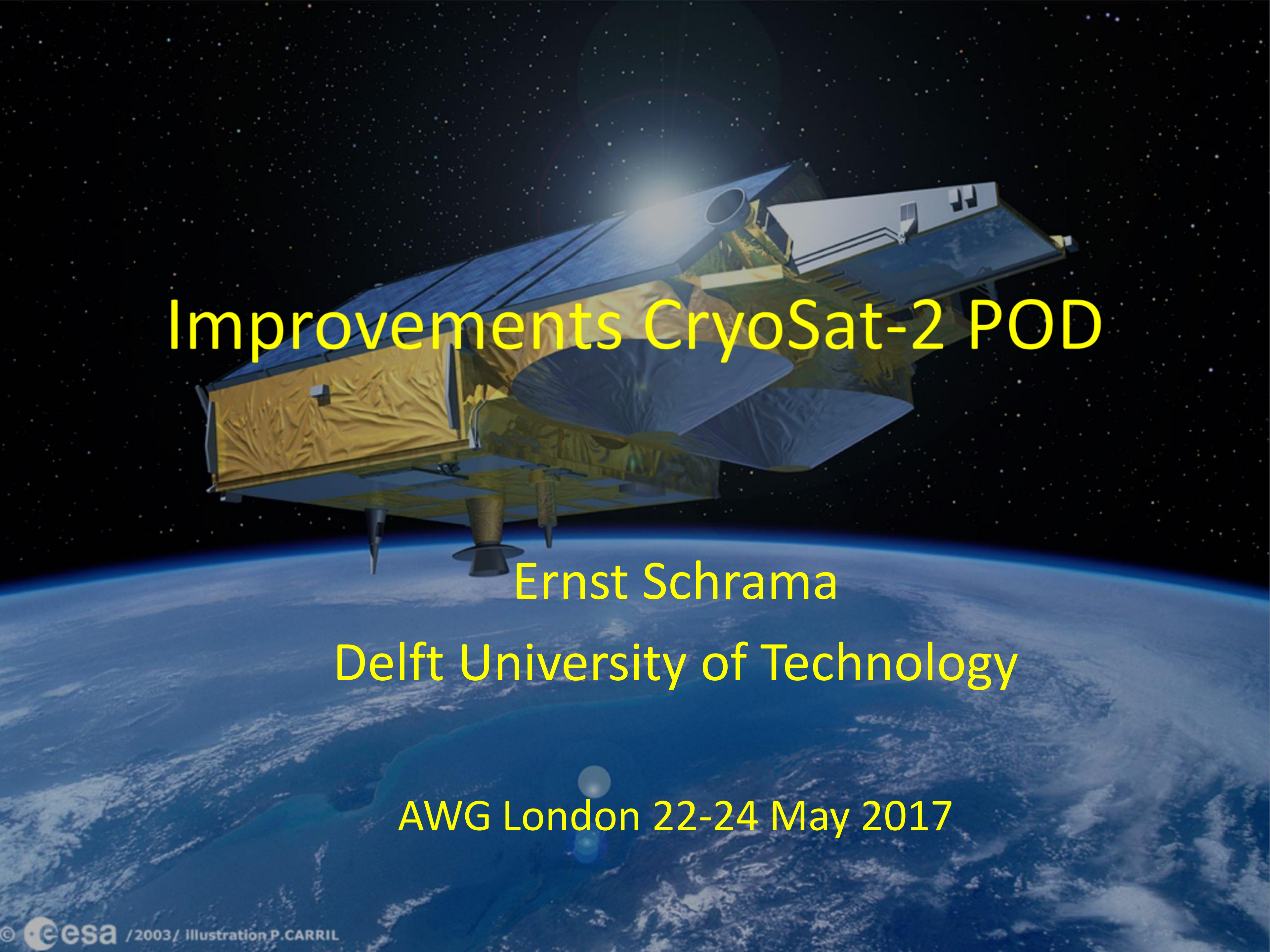
AWG London 22-24 May 2017



Outline

- ESA/ESRIN contract: 4000112740
- Independent POD and PAD
- Tracking data residuals
- Empirical accelerations
- External trajectory
  - Comparison
  - POE, MOE and NAV
- Altimeter crossover statistics (RADS)

POD set-up (1)

- Precision orbit determination
  - DORIS: 10 second Doppler data V2.2
  - ILRS Tracking data
  - 6 day arcs, ±24h overlap, avoid orbit maneuvers, cut at attitude maneuvers
  - Window: Jun-2010 up to Feb-2017
- Spacecraft attitude
  - Reconstructed from S/C star trackers (3)
  - Attitude events are recognized

POD set-up (2)

- ITRF2014 (new)
  - DORIS beacon coordinates, velocities, PSD
  - SLR stations coordinates, velocities, ECC, PSD
  - Formerly: DPOD2008/SLRF2008
- Gravity
  - Static: EIGEN5C
  - Time variable: GRACE + GAC + GAD (new)
  - Formerly GRACE mascons for ice and hydrology
- Tides
  - Solid Earth tides (Love numbers)
  - Ocean load tides, latest FES (new)
  - Ocean tide dynamics

POD set-up (3)

- Fixed
  - SRP model from CNES (IDS website)
  - Offsets SLR and DORIS receiver (IDS website)
  - EOP parameters from IERS
- Estimated:
  - Initial state vector (by arc)
  - Drag model (3 hourly)
  - Empirical acceleration model (6 hourly)
  - Beacon frequency offsets (by pass)
  - Tropospheric parameters (by pass)
  - Depending on run: some station coordinates (by arc)
  - SLR offset in satellite frame
- The rest is “as recommended by IAU etc”

Solution overview

V	IDS	SLR	Along	Cross	NAV	MOE	POE	SLR	GRV	ADJ	REF
	mm/s	cm	nm/s^2	nm/s^2	cm	cm	cm				
41	0.3975	1.334	3.56	12.77	3.45	1.63	1.65	Yes	ICE	No	2008
42	0.3893	0.959	2.78	10.58	3.27	1.35	1.28	Yes	ALL	No	2014
43	0.3936	0.959	2.77	10.13	3.27	1.33	1.25	Yes	ALL	Yes	2014
44	0.3950		2.77	10.65	3.26	1.33	1.25	No	ALL	Yes	2014
45	0.3972	1.015	3.63	12.89	3.49	1.66	1.68	Yes	ICE	No	2014

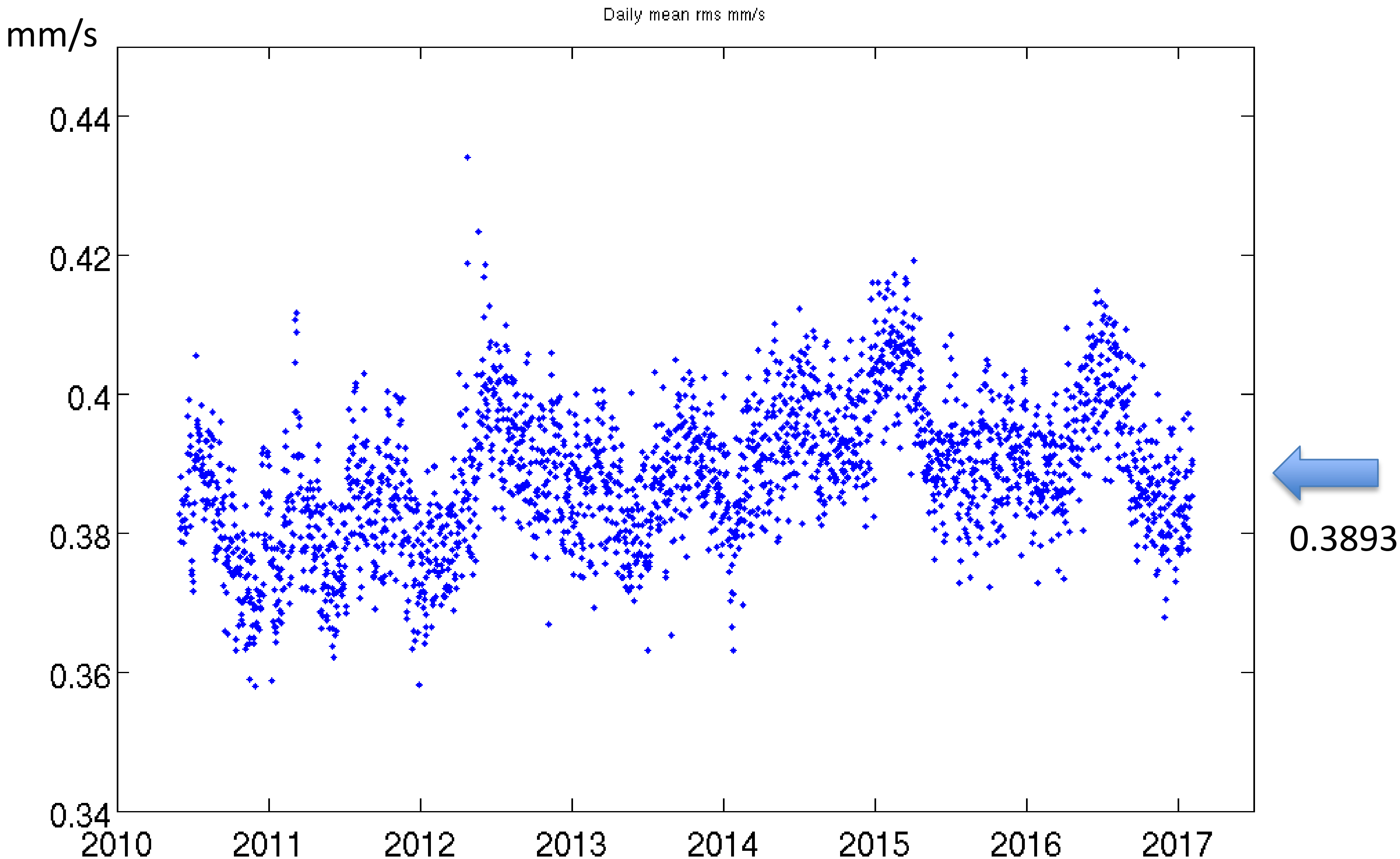
Table 1: Solution characteristics, DORIS and SLR fits, level of empirical accelerations in along track and cross-track direction, differences of our solution compared to navigator, MOE an pPOE orbits provided by the CNES. The NAV, POE and MOE statistics concern only the radial component, also, for the NAV orbits we ignored the part up to 2012.6 because of an improvement in the DIODE processor. Switch fields are included to clarify the solution strategy

Five solutions

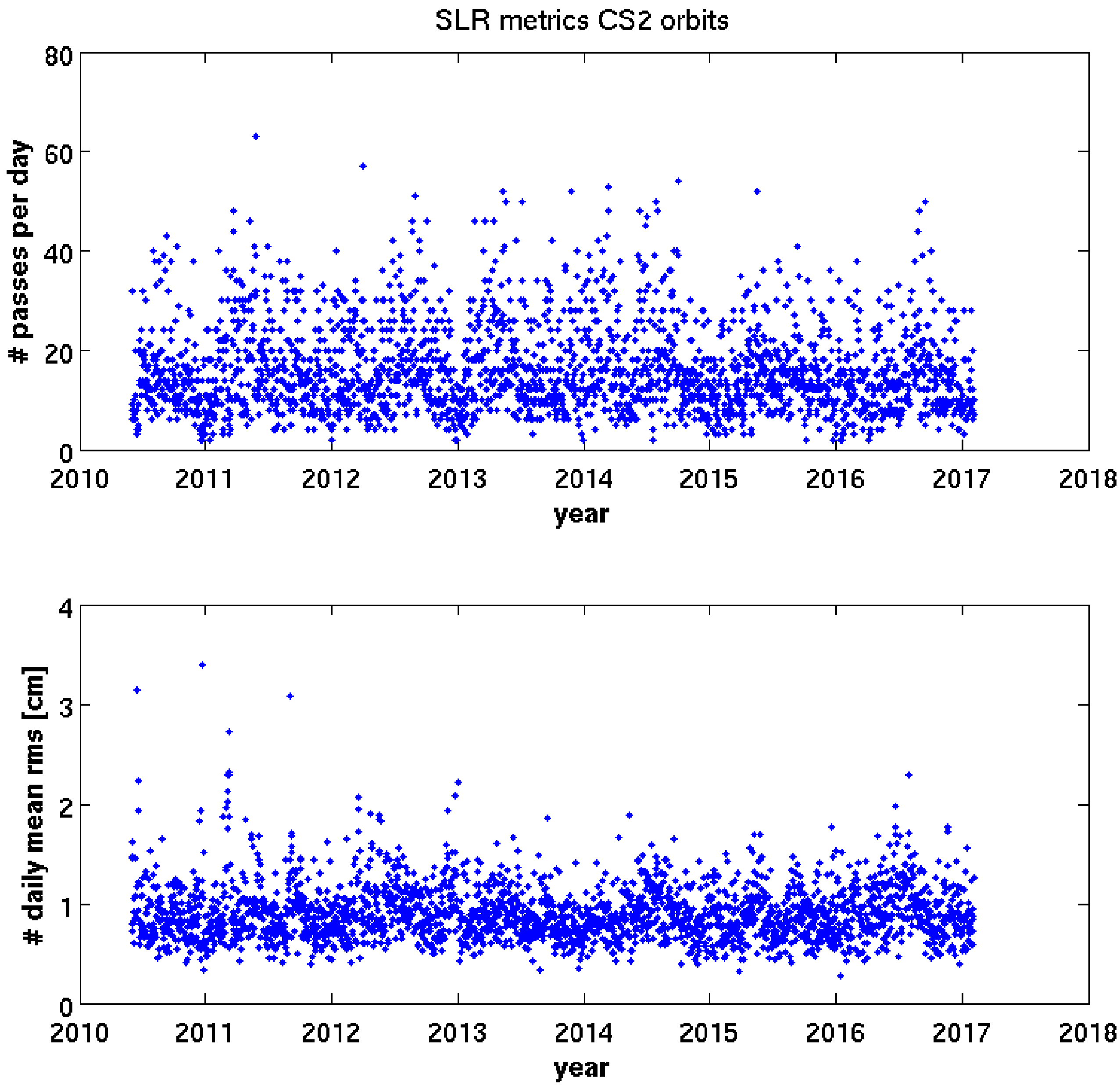
- V41 is the former processing scheme based on DPOD2008/SLRF2008 and our previous temporal gravity model
- V42 is the new processing scheme, ITRF2014 for both IDS and SLR, and an updated temporal gravity model
- V43 is similar to V42, but now we adjust the IDS beacons that are not in ITRF2014, SLR station positions that are not in ITRF2014 are ignored.
- V44 is like V43, without SLR tracking data.
- V45 is like V42, assuming DPOD2008/SLRF2008

DORIS 10s residuals

V42

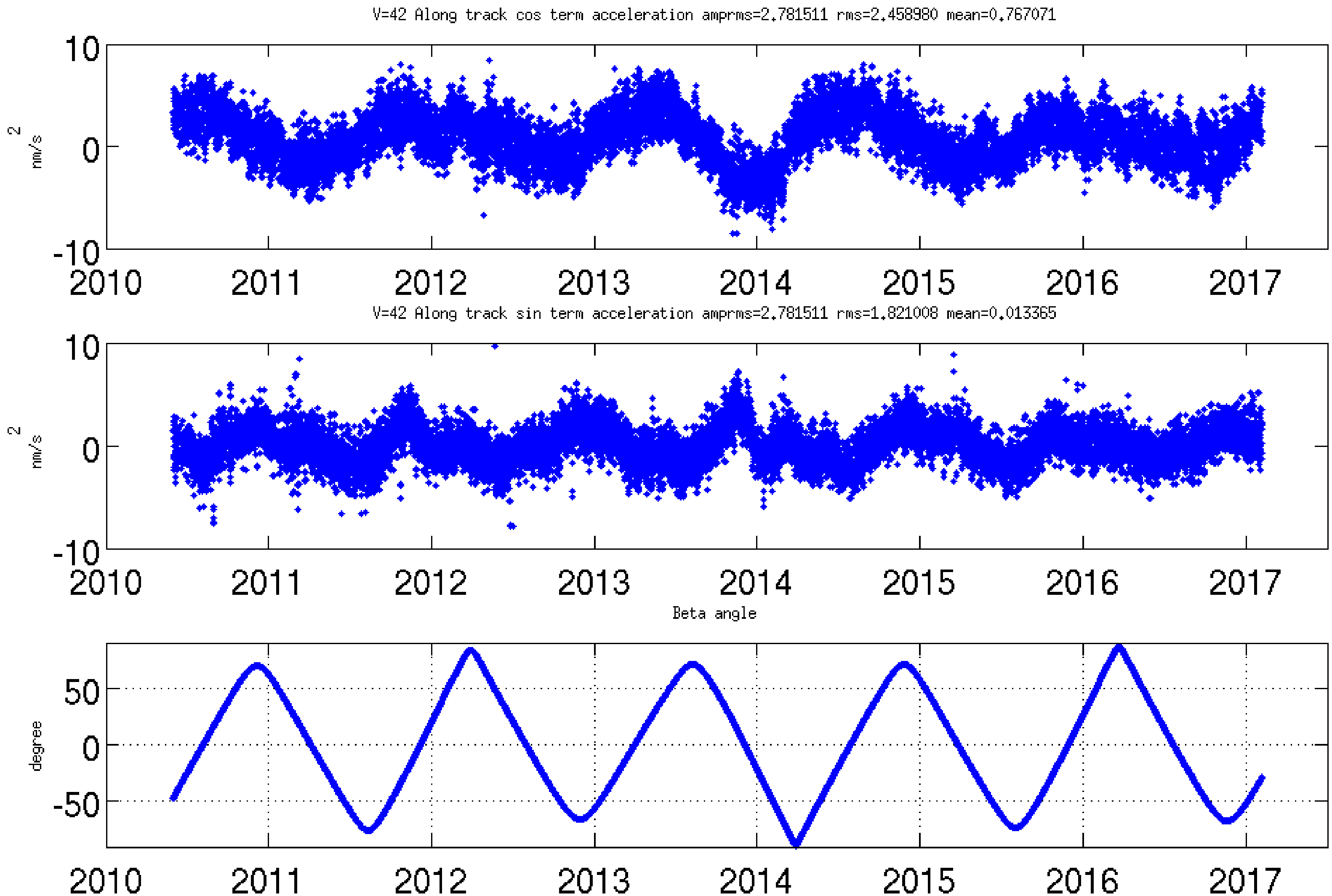


V42


SLR metrics CS2 orbits
passes per day
0
20
40
60
80
2010
2011
2012
2013
2014
2015
2016
2017
2018
year
daily mean rms [cm]
0
1
2
3
4
2010
2011
2012
2013
2014
2015
2016
2017
2018
year

0.96

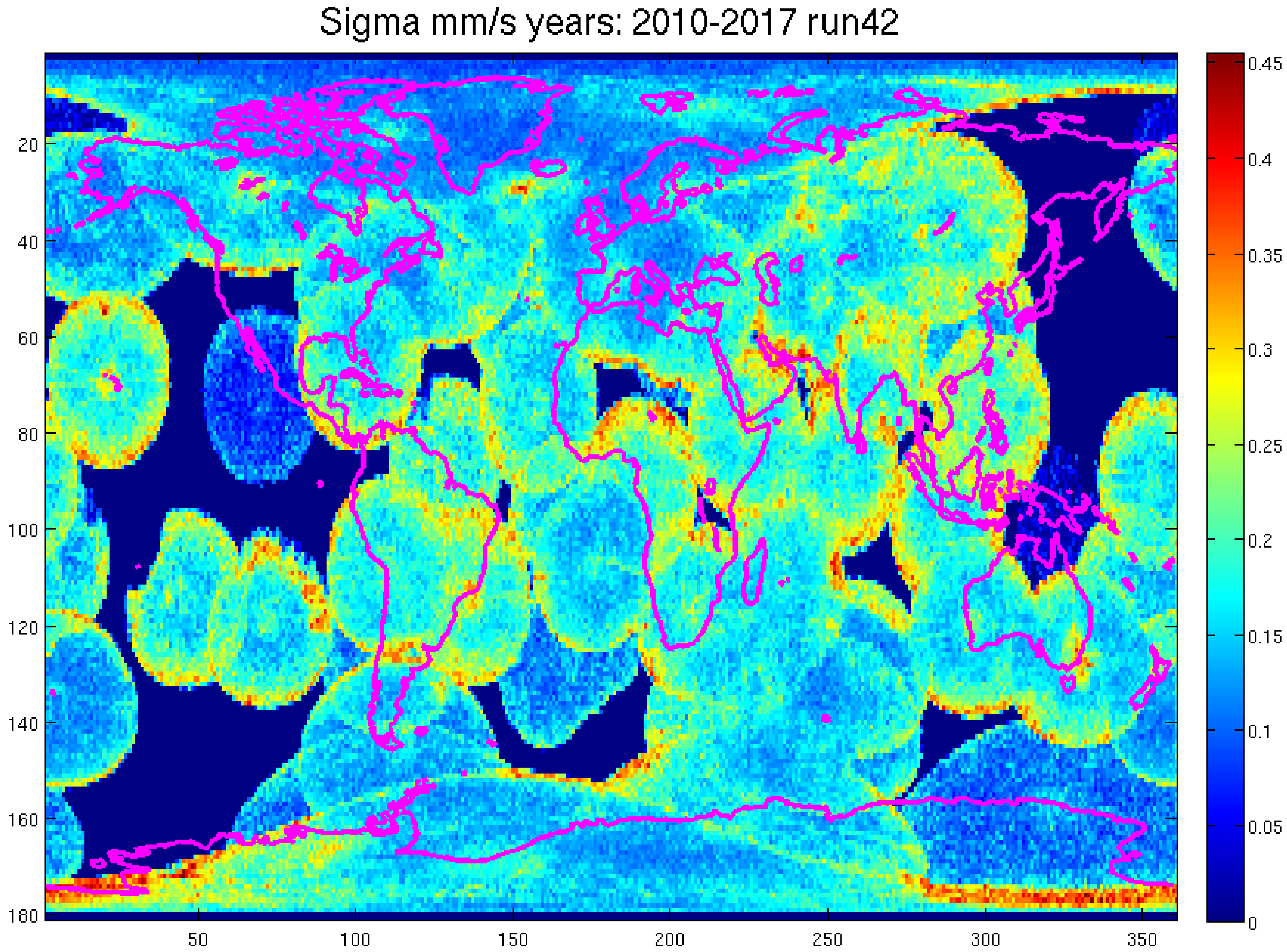
Level of empirical accelerations, along cos 2.46 nm/s^2 and along sin 1.82 nm/s^2 V42



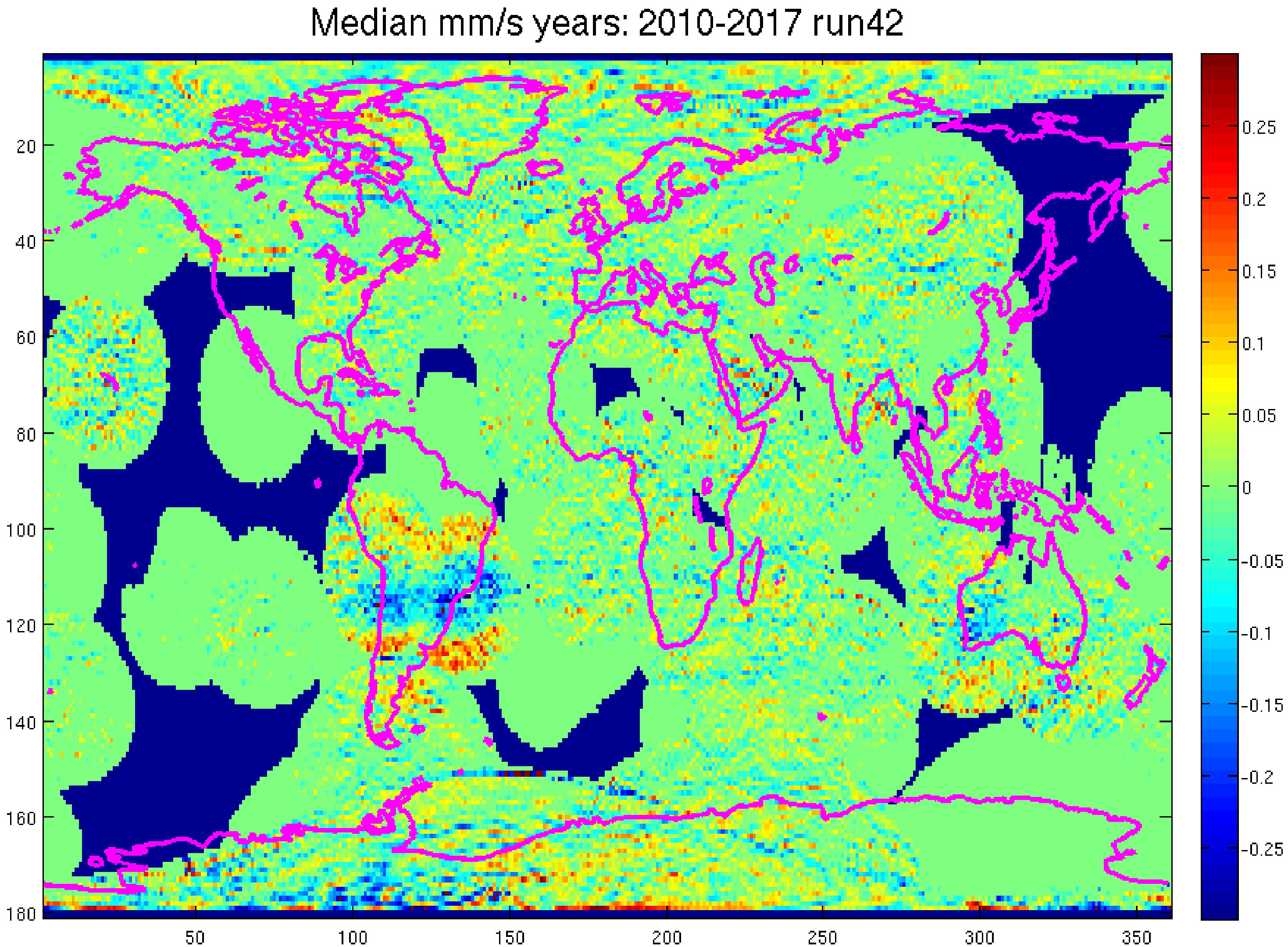
Crossover statistics

- CryoSat-2 as in RADS, 10 cm threshold at the crossovers, up to 65 degree latitude, by cycle and for adjacent cycles, cycle numbers 5 to 83.
  - V42 : 4.60 cm rms
  - NAV: 7.29 cm rms
  - MOE: 4.71 cm rms
  - POE: 4.55 cm rms
- Matching crossover set was used, of course the NAV orbits stand out but otherwise it is difficult to get anything meaningful out of this comparison

Residual mapping analysis (V42)



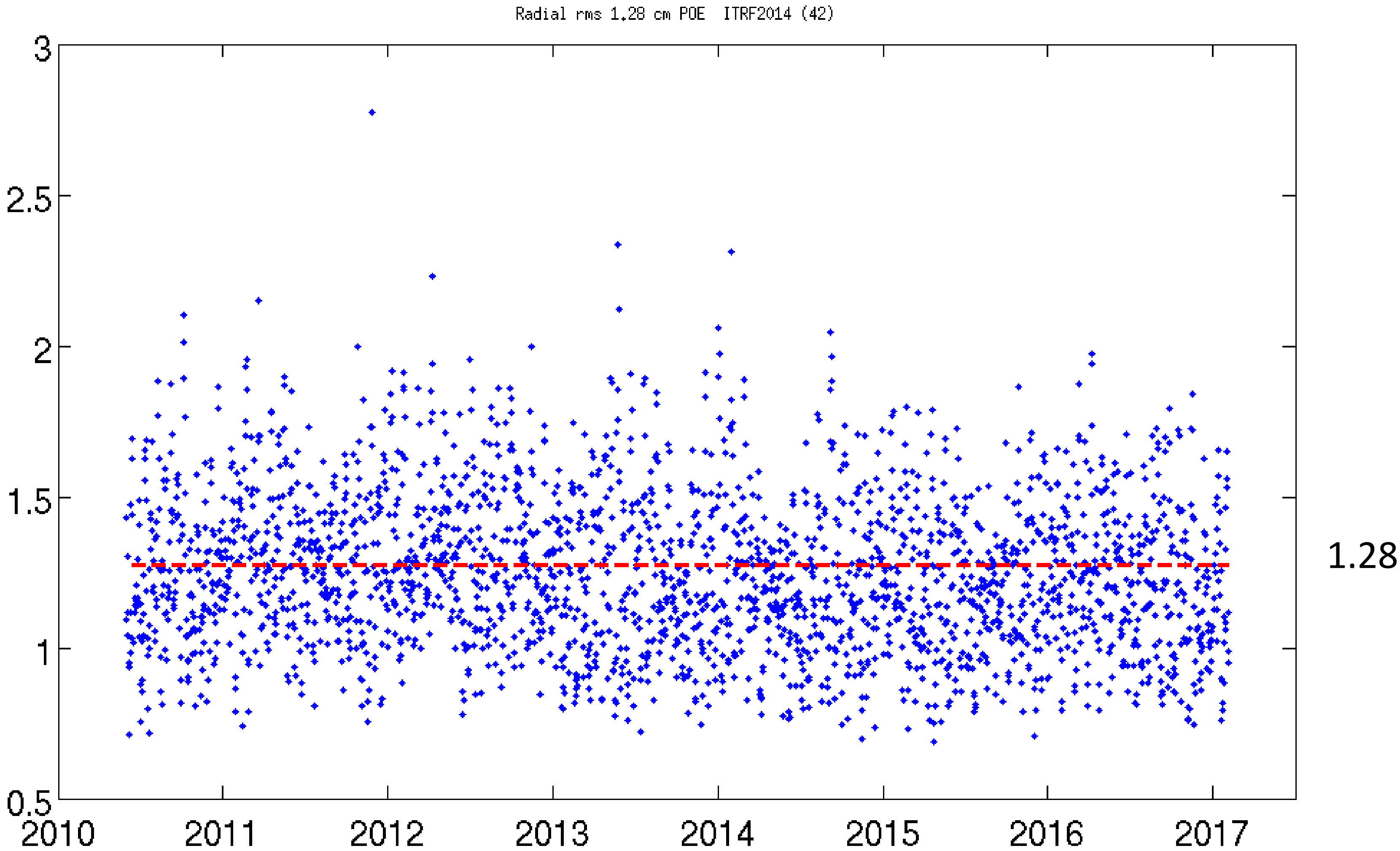
Residual mapping analysis (V42)



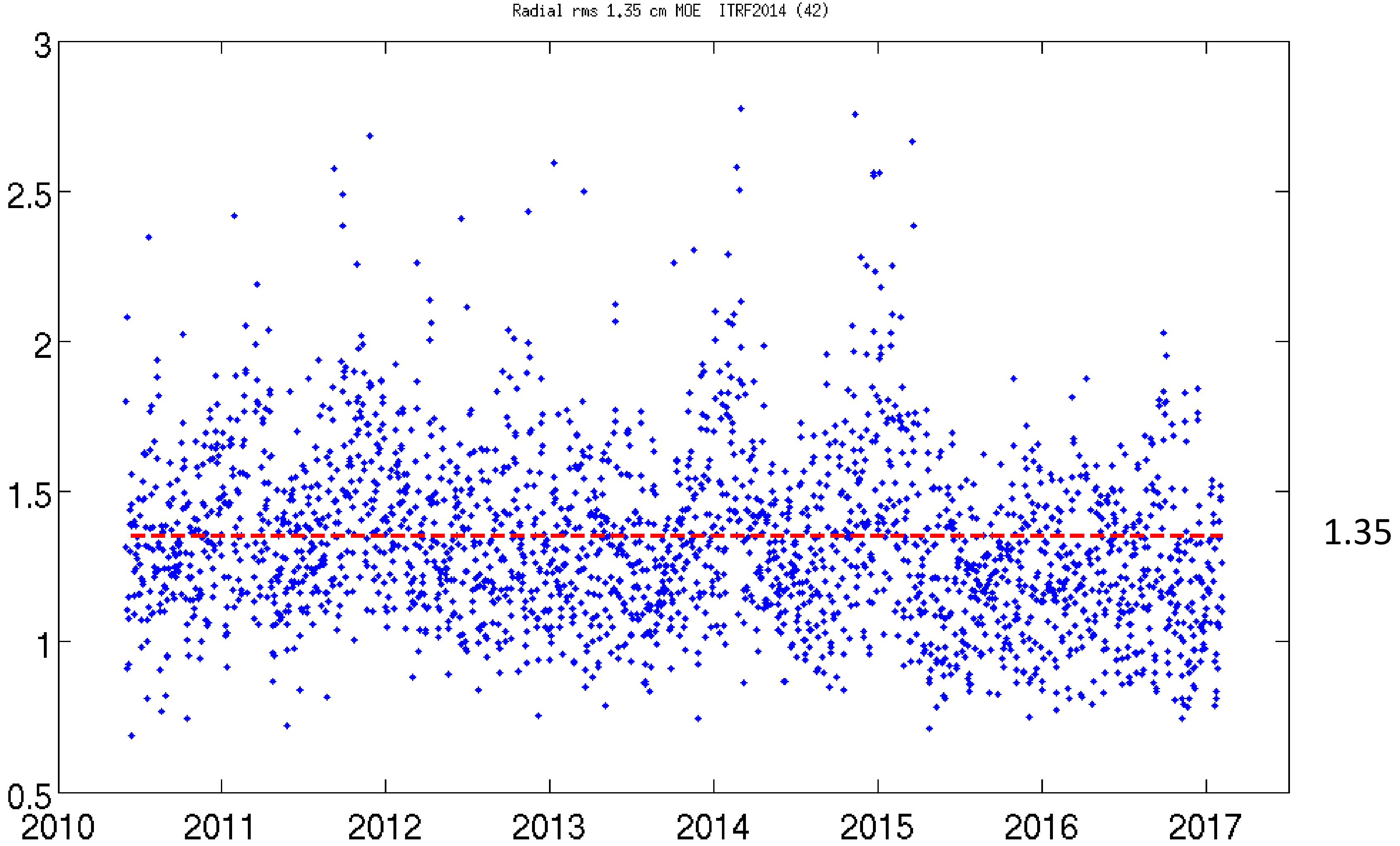
External orbit comparison

- We compare to NAV, MOE and POE products
  - Real time navigator orbits, computed within the receiver real time
  - Rapid science orbits, produced within approximately one or two days (satellite maneuvers may cause confusion, anomalies)
  - Delayed final solutions, consolidated product after a month, ie. when IERS bulletin B products have converged.

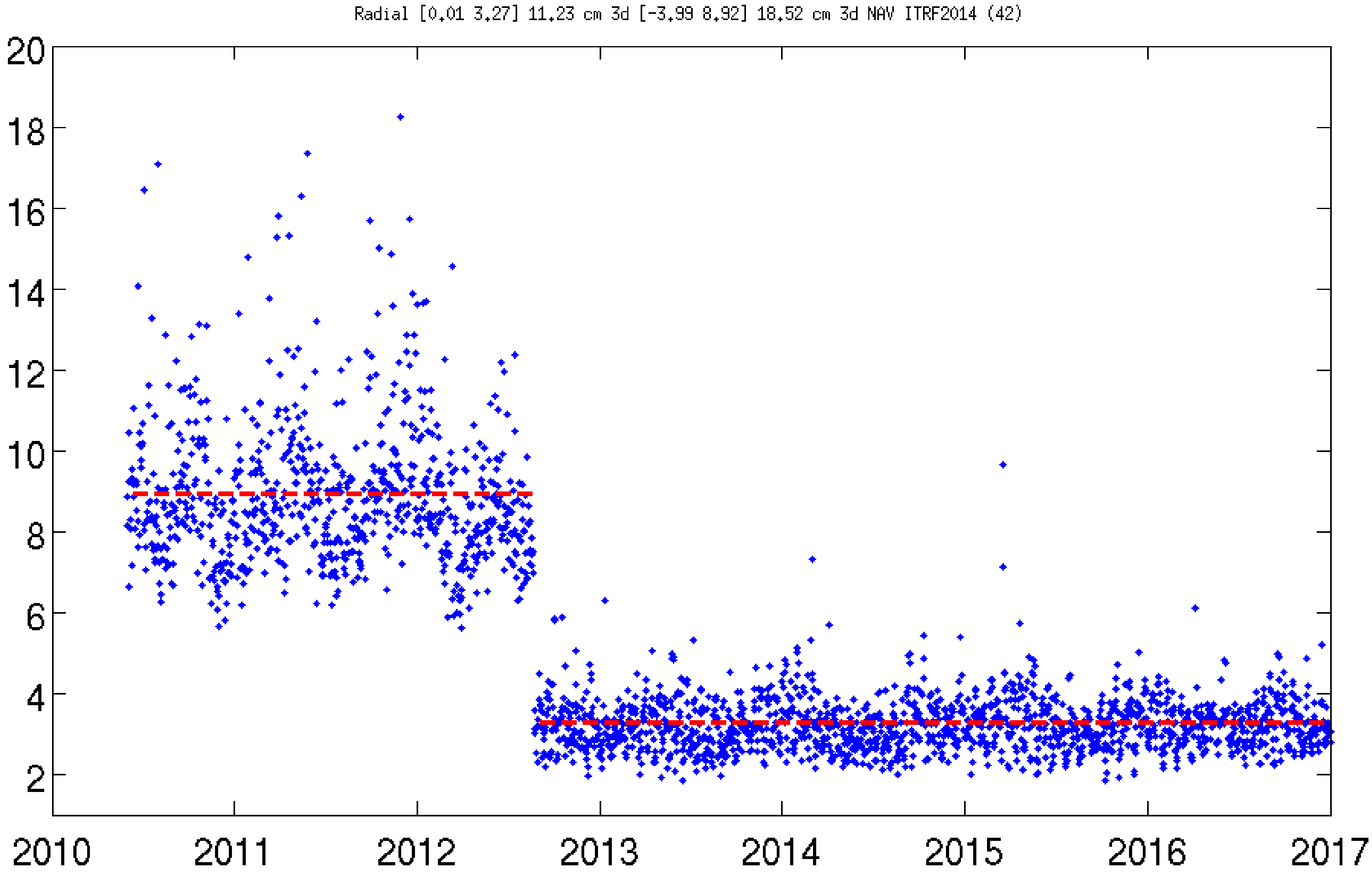
Consolidated POE orbit



Rapid science MOE orbit



NAV



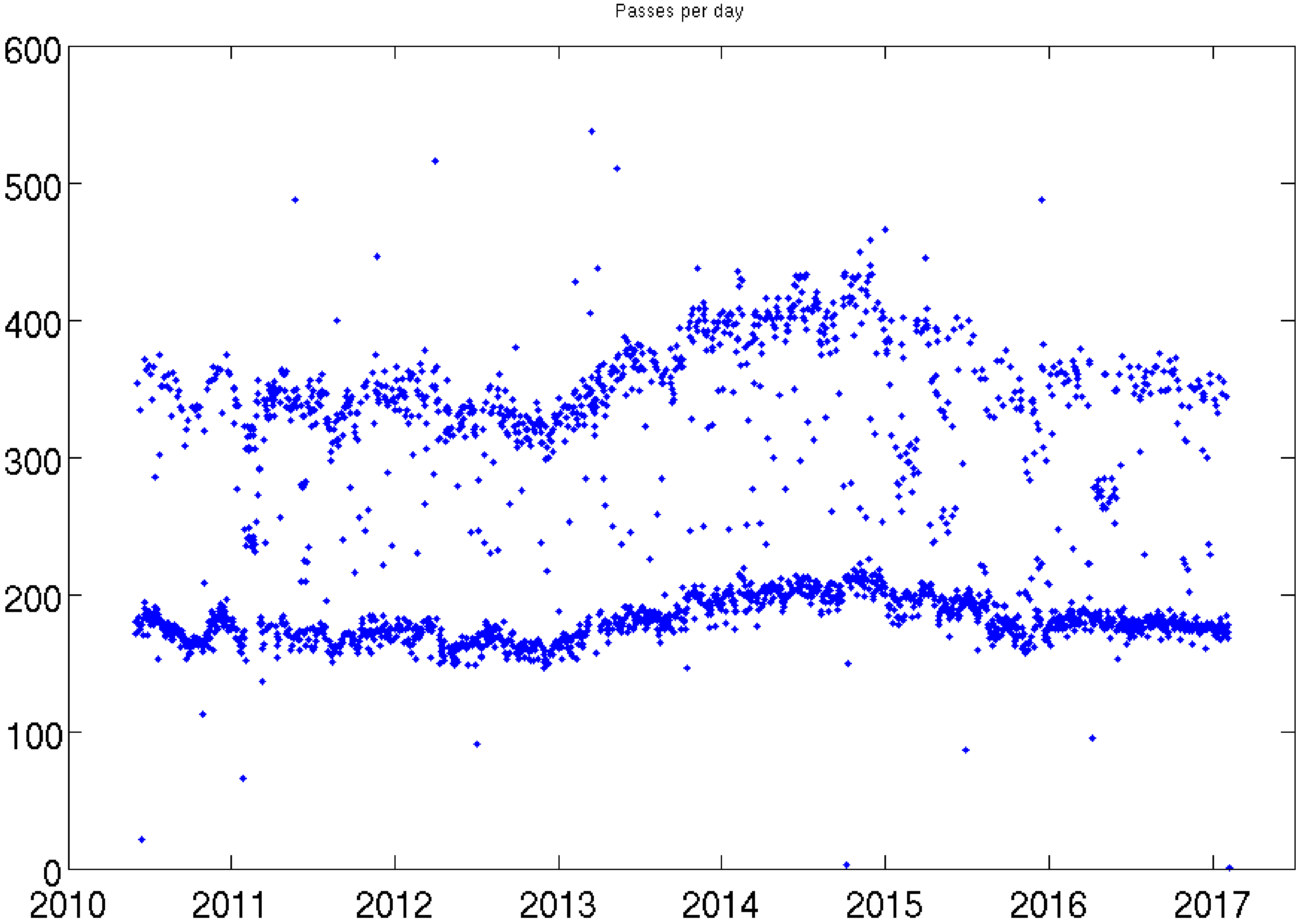
Radial [0.01 3.27] 11.23 cm 3d [-3.99 8.92] 18.52 cm 3d NAV ITRF2014 (42)
20
18
16
14
12
10
8
6
4
2
2010
2011
2012
2013
2014
2015
2016
2017

Conclusions

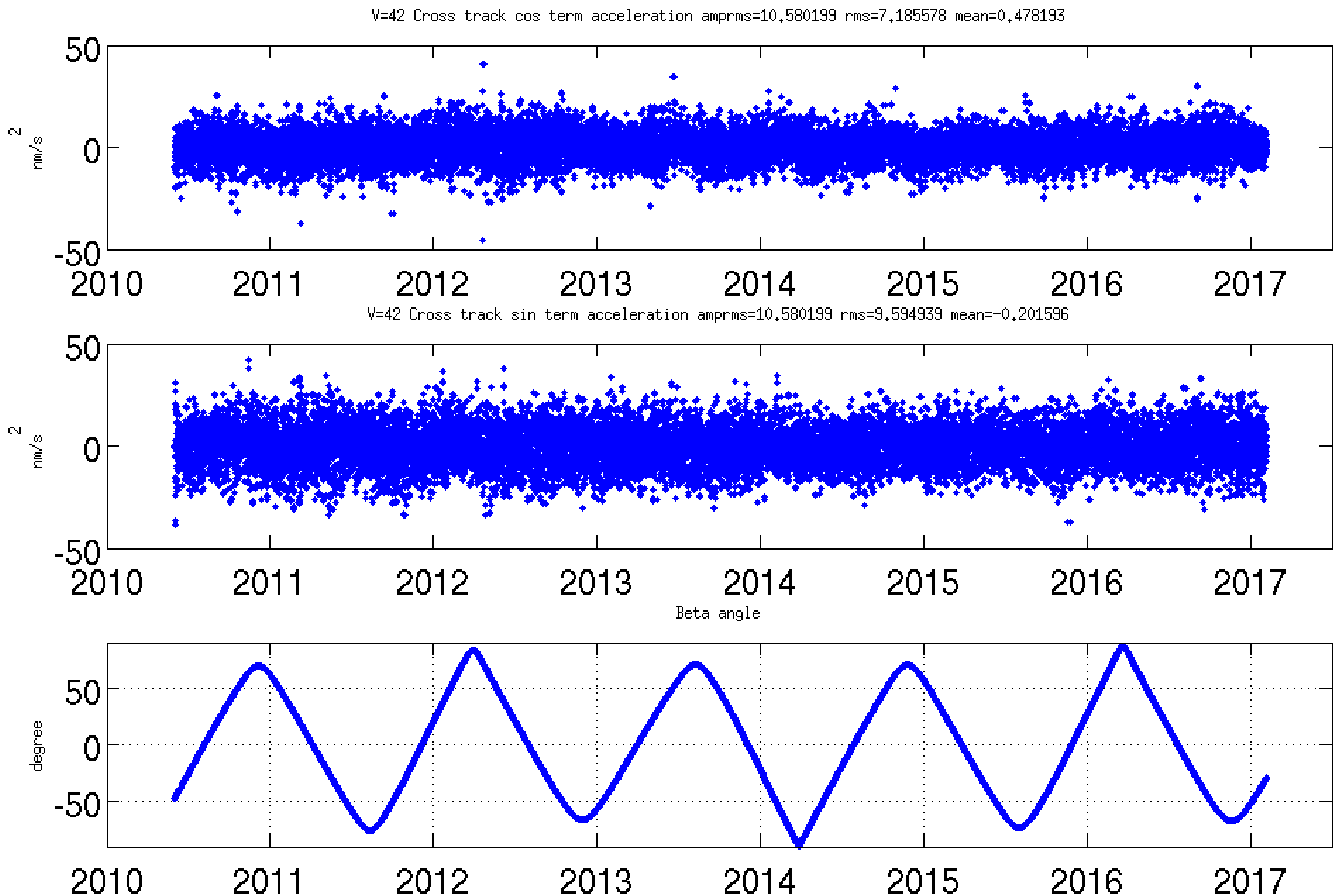
- Implementation of ITRF2014 causes more work for the user than DPOD2008/SLRF2008 because of the PSD an the ECC sinex files
- Station coordinates in ITRF2014 are more consistent
- A DPOD2014 solution will probably outperform the ITRF2014 approach, no opportunity yet not to test it
- We improved more by updating our temporal gravity model, you need GRACE + atmosphere + ocean
- Geographic features of DORIS residuals suggests an SA effect which shouldn't be there. This is not affected by the choice of switching to ITRF2014

Backup

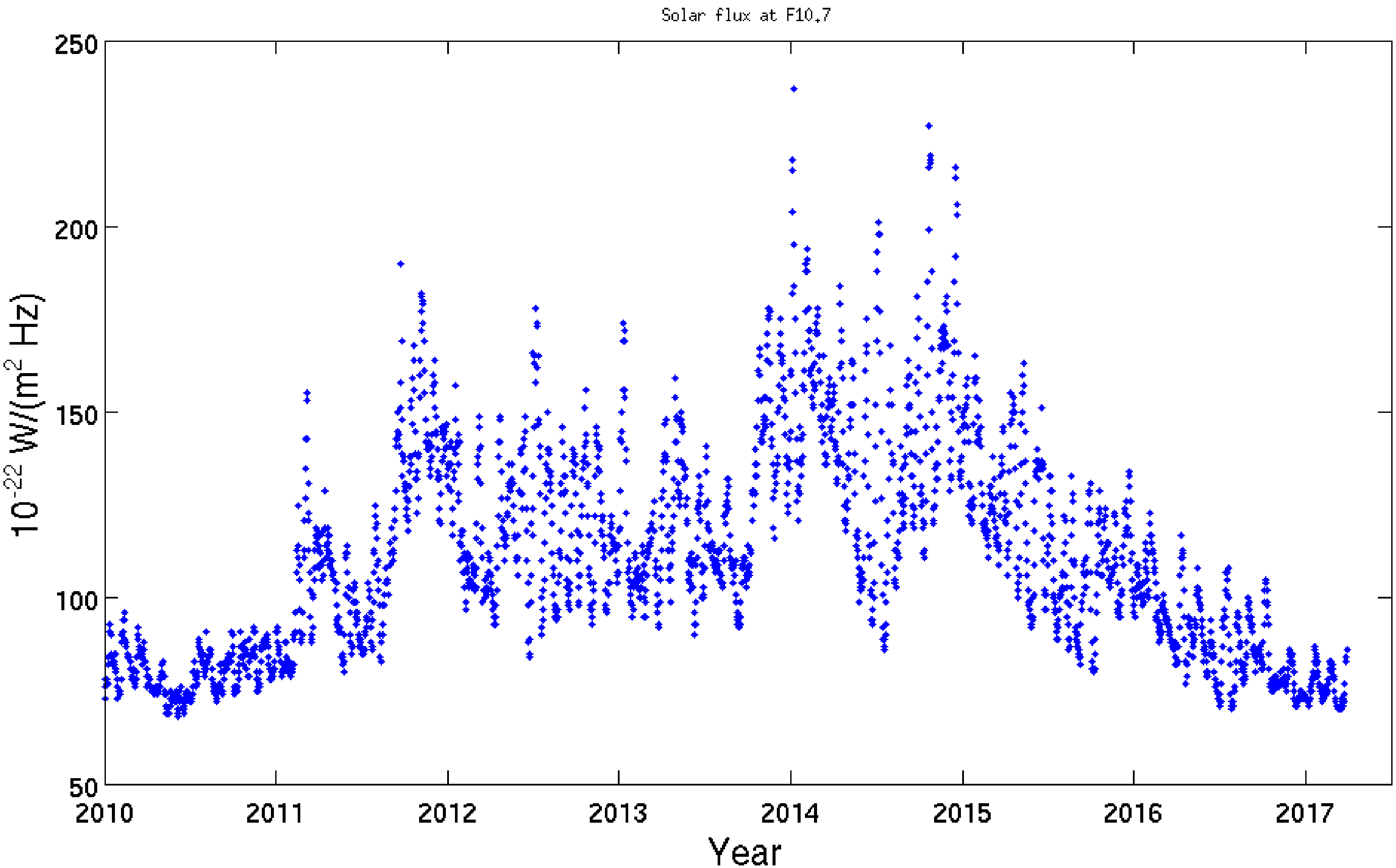
IDS passes per day



Level of empirical accelerations, cross-track cos 7.19 nm/s^2 and along sin 9.59 nm/s^2

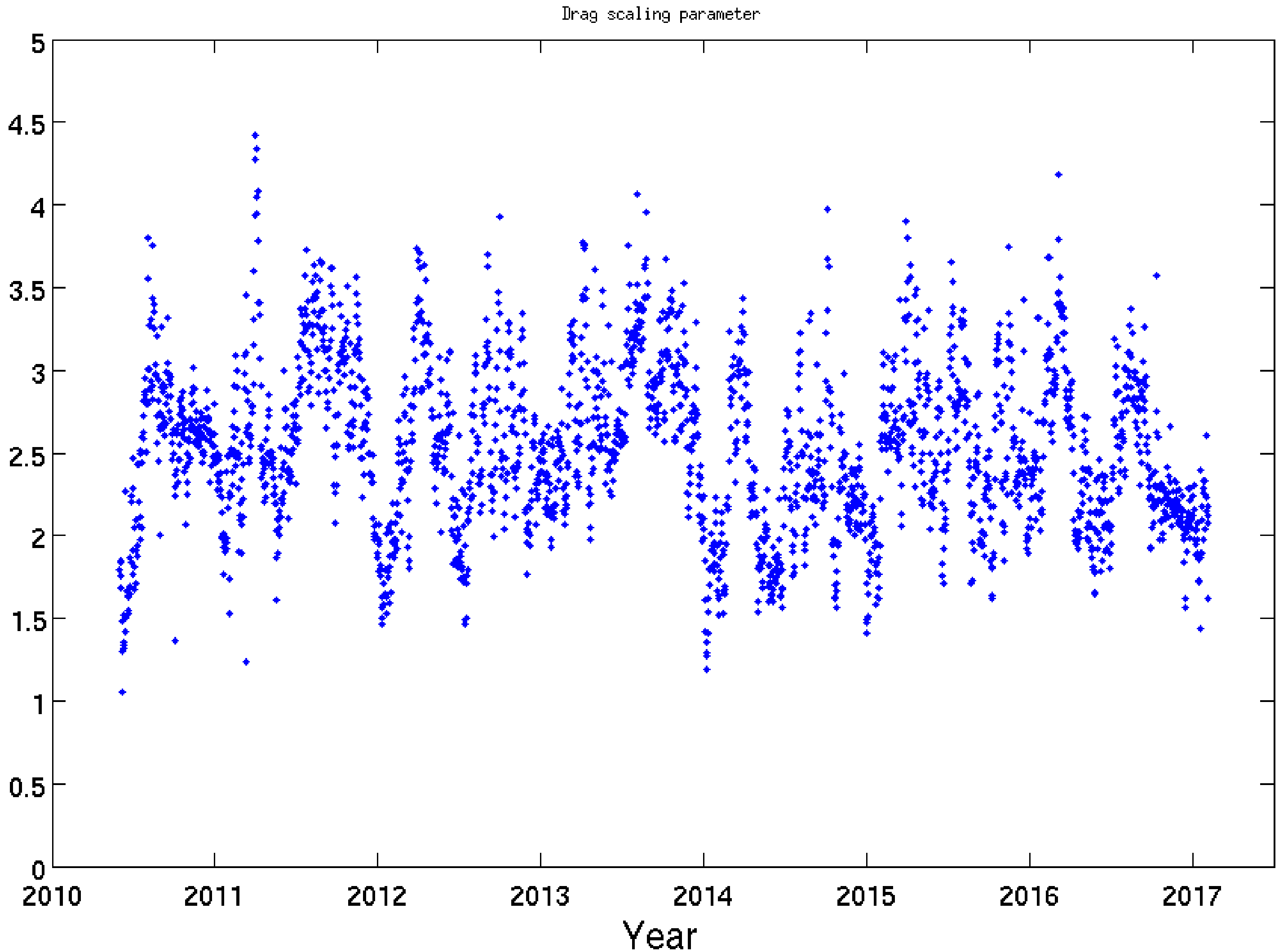


FLUX



Solar flux at F10.7
250
200
150
100
50
10-22 W/(m2 Hz)
2010
2011
2012
2013
2014
2015
2016
2017
Year

DRAG



Adjusted every 3 hours
Consecutive constraints

What to distribute from this activity

- TU Delft quaternion solutions, flat ascii
- Converted navigator orbits, flat ascii
- POD solutions based on the latest SRP model, either internal flat ascii format, or within SP3