Cryosat-2 precision orbit determination validation activity

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IDS Analysis Working Group

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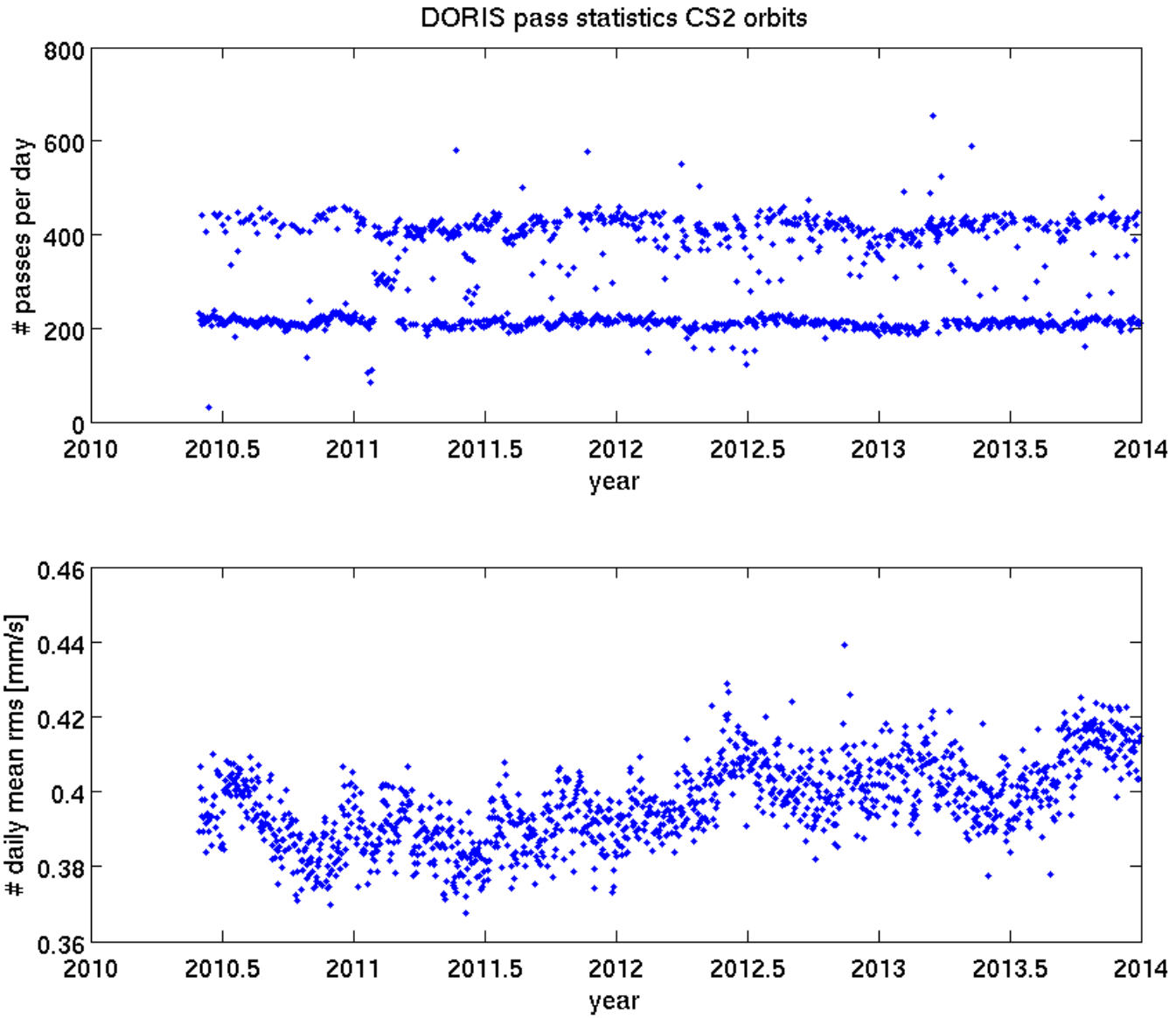
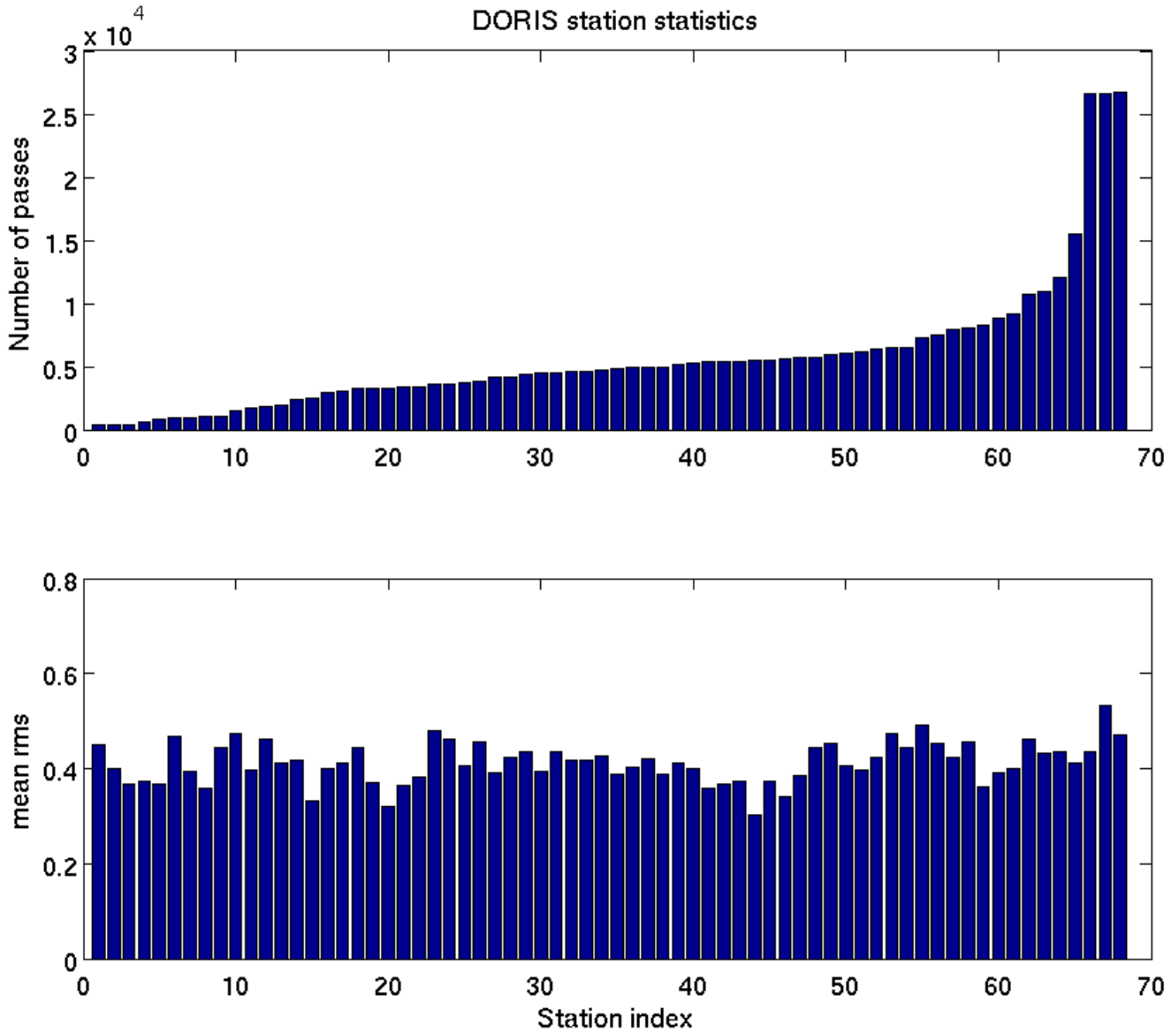
Precision Orbit Determination

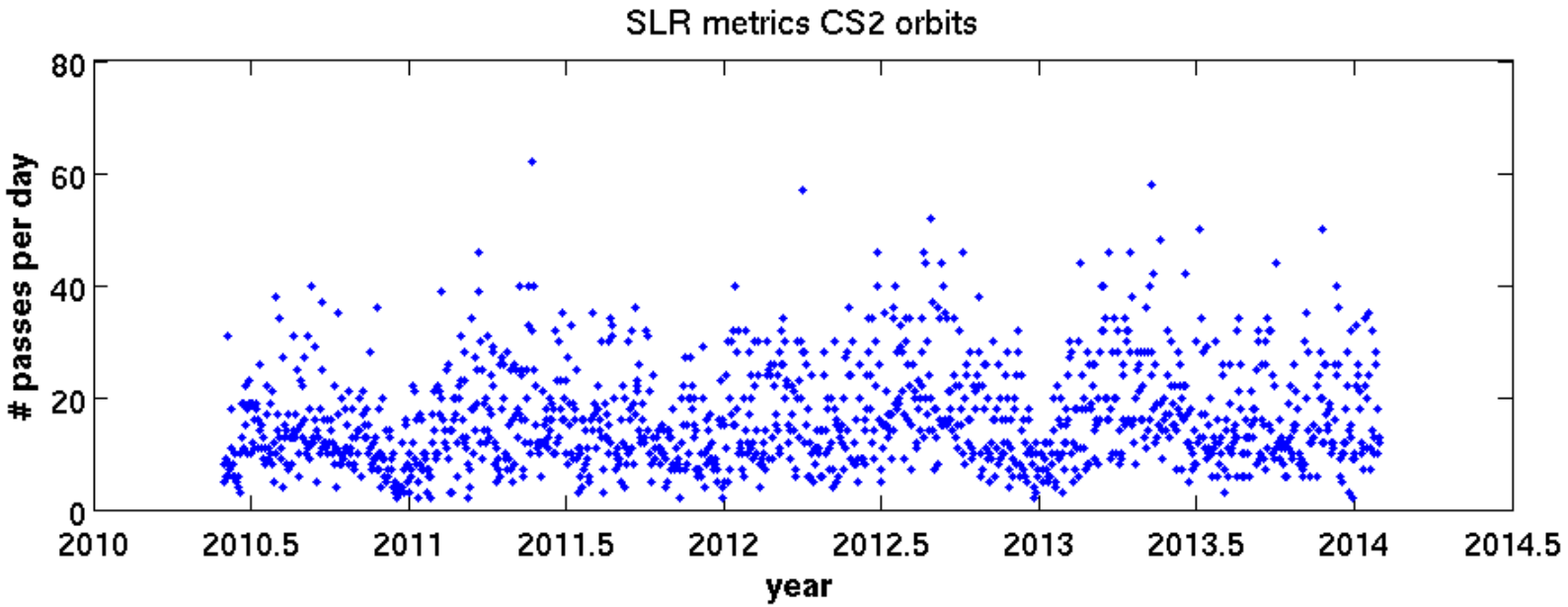
- For our 6-day arcs we have:
  - ~50 beacons from the IDS, 10s doppler data
  - ~10 stations from the ILRS
- Inspect internal quality:
  - Evaluate DORIS + SLR tracking residuals
  - Inspect the dynamic parameters that we solve for
  - Compare to external trajectories from the CNES
- New options where we solve for:
  - IDS coordinates, keep SLR fixed
  - Helmert parameters between different solutions

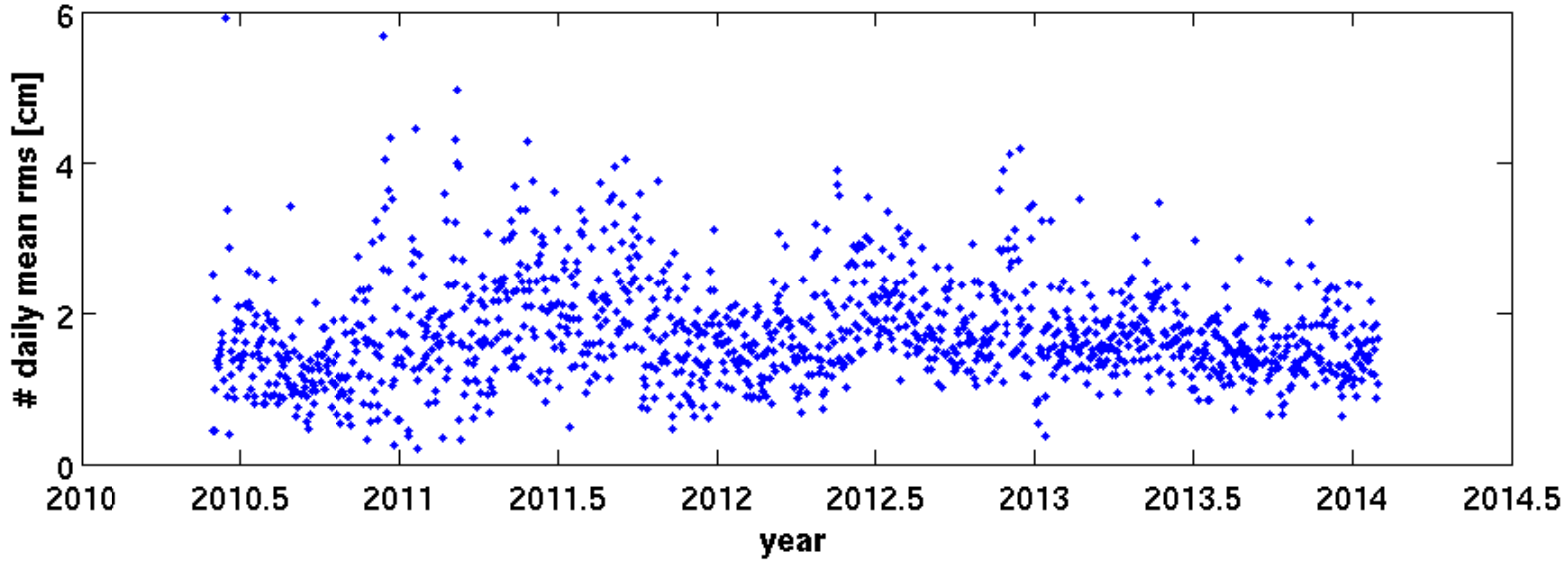
Models, tools etc

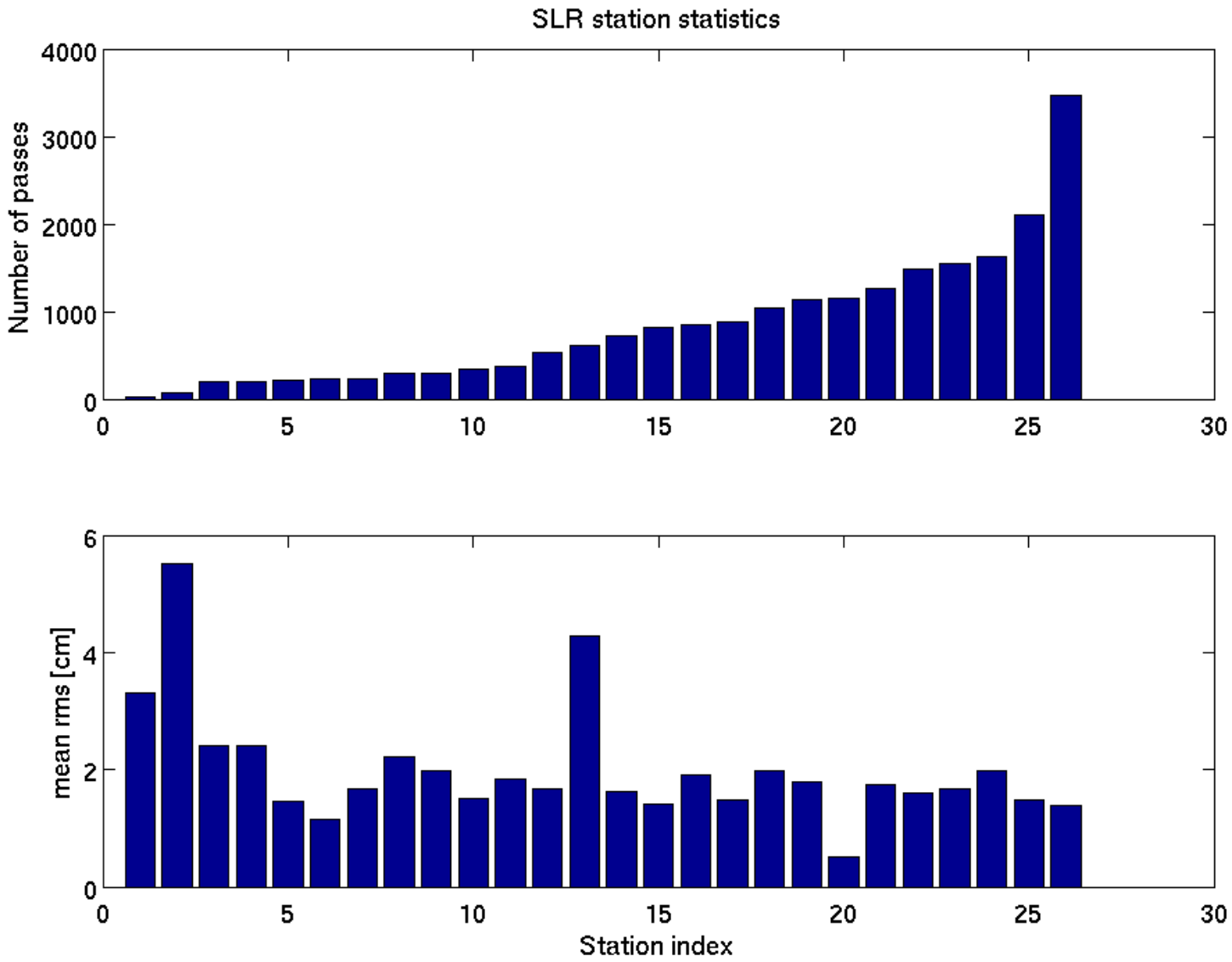
- GEODYN software from NASA GSFC plus own tools.
- Station coordinates and Earth rotation parameters:
  - DORIS and SLR station coordinates in DPOD2008/SLRF2008
  - IERS standards implemented
- Dynamics
  - EIGEN5c gravity model
  - Temporal gravity from GRACE to degree and order 20
  - FES2004 ocean load tides
- Spacecraft specific models
  - Panel model, antenna offsets, LRA offsets, provided by ESA
  - Satellite attitude reconstructed from star camera quaternions
  - ftp://dutlru2.lr.tudelft.nl/pub/ejo/cryosat2/quaternion/


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
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
year

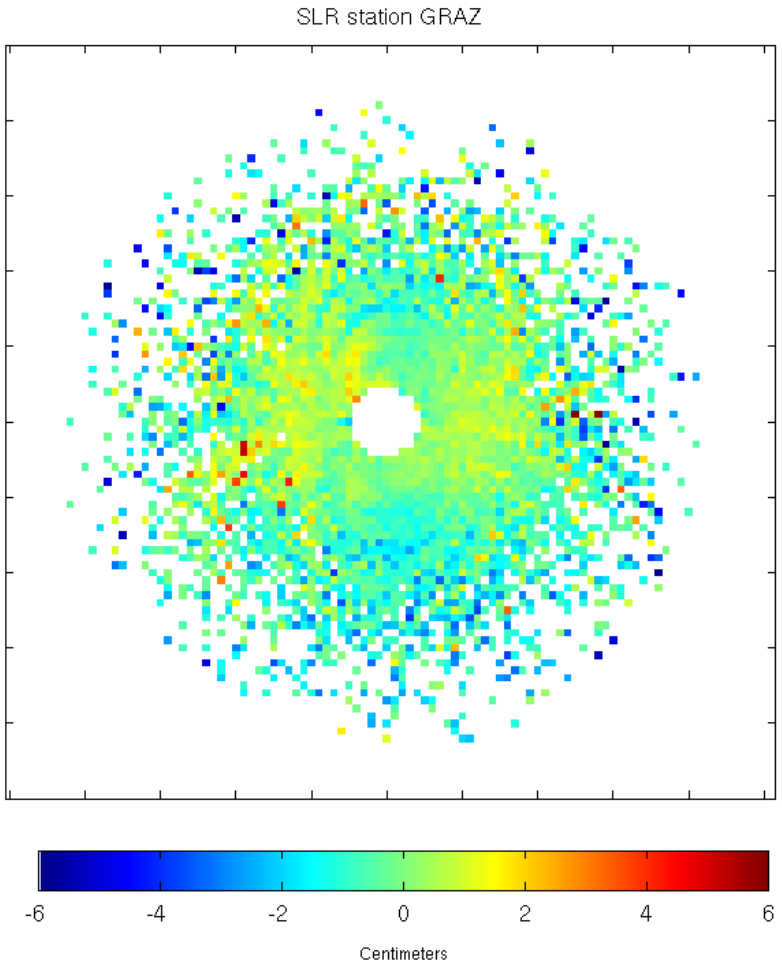

DORIS station statistics
x 10^4
Number of passes
mean rms
Station index
0
0.5
1
1.5
2
2.5
3
0.2
0.4
0.6
0.8
10
20
30
40
50
60
70

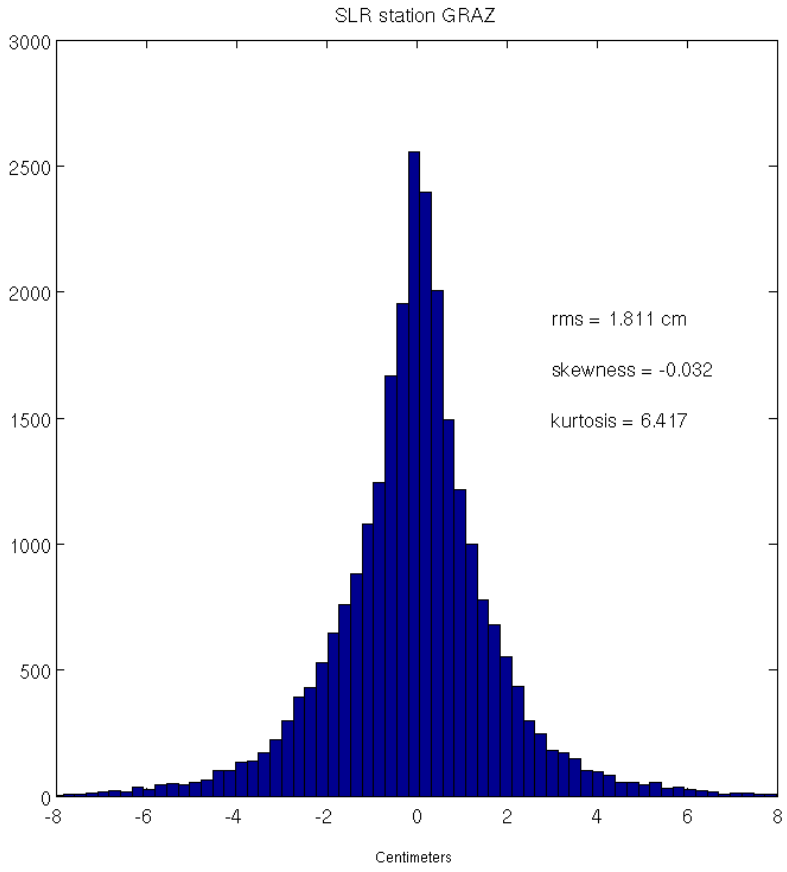

SLR metrics CS2 orbits
passes per day
0
20
40
60
80
2010
2010.5
2011
2011.5
2012
2012.5
2013
2013.5
2014
2014.5
year

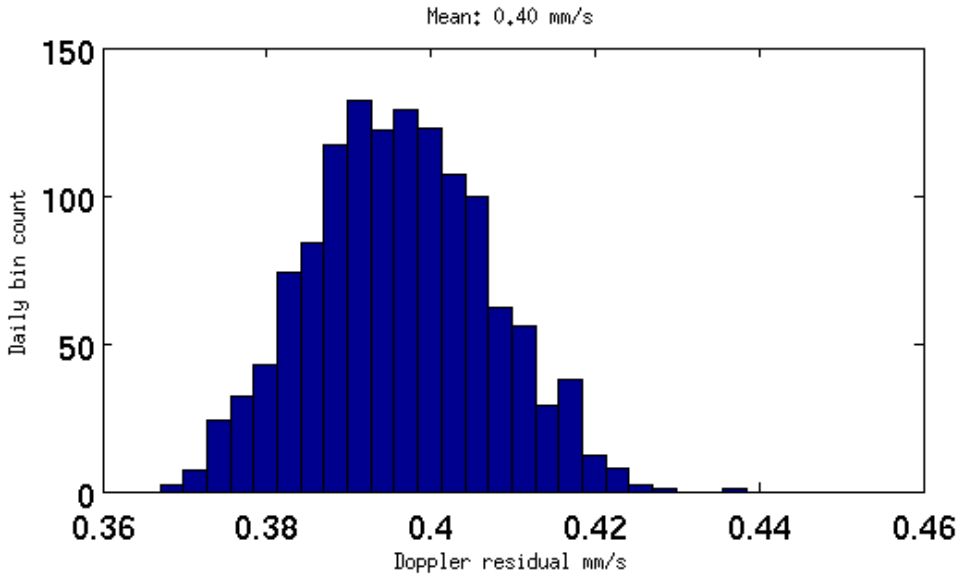

daily mean rms [cm]
0
2
4
6
2010
2010.5
2011
2011.5
2012
2012.5
2013
2013.5
2014
2014.5
year


SLR station statistics
Number of passes
4000
3000
2000
1000
0
0
5
10
15
20
25
30
mean rms [cm]
6
4
2
0
0
5
10
15
20
25
30
Station index

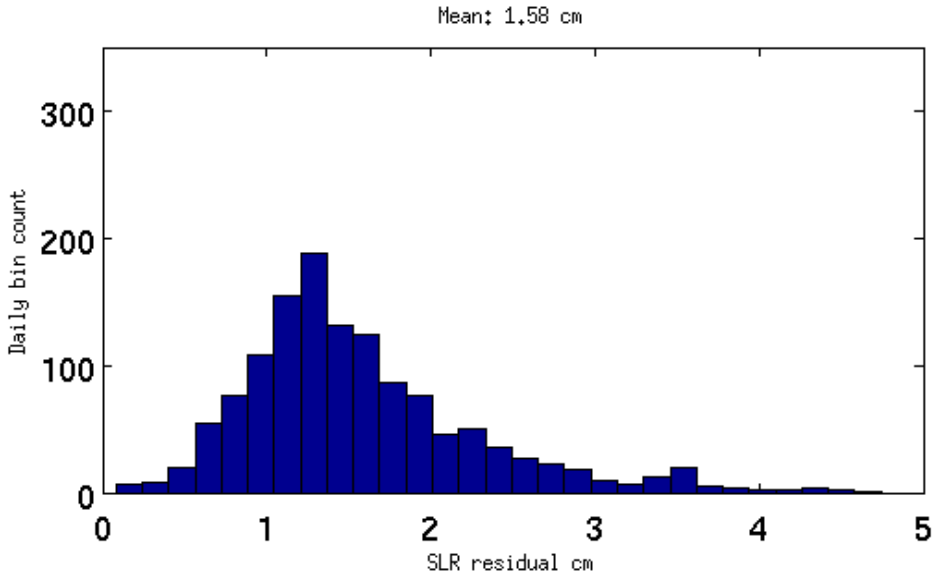
Graz


SLR station GRAZ
-6
-4
-2
0
2
4
6
Centimeters


SLR station GRAZ
3000
2500
2000
1500
1000
500
0
-8
-6
-4
-2
0
2
4
6
8
rms = 1.811 cm
skewness = -0.032
kurtosis = 6.417
Centimeters



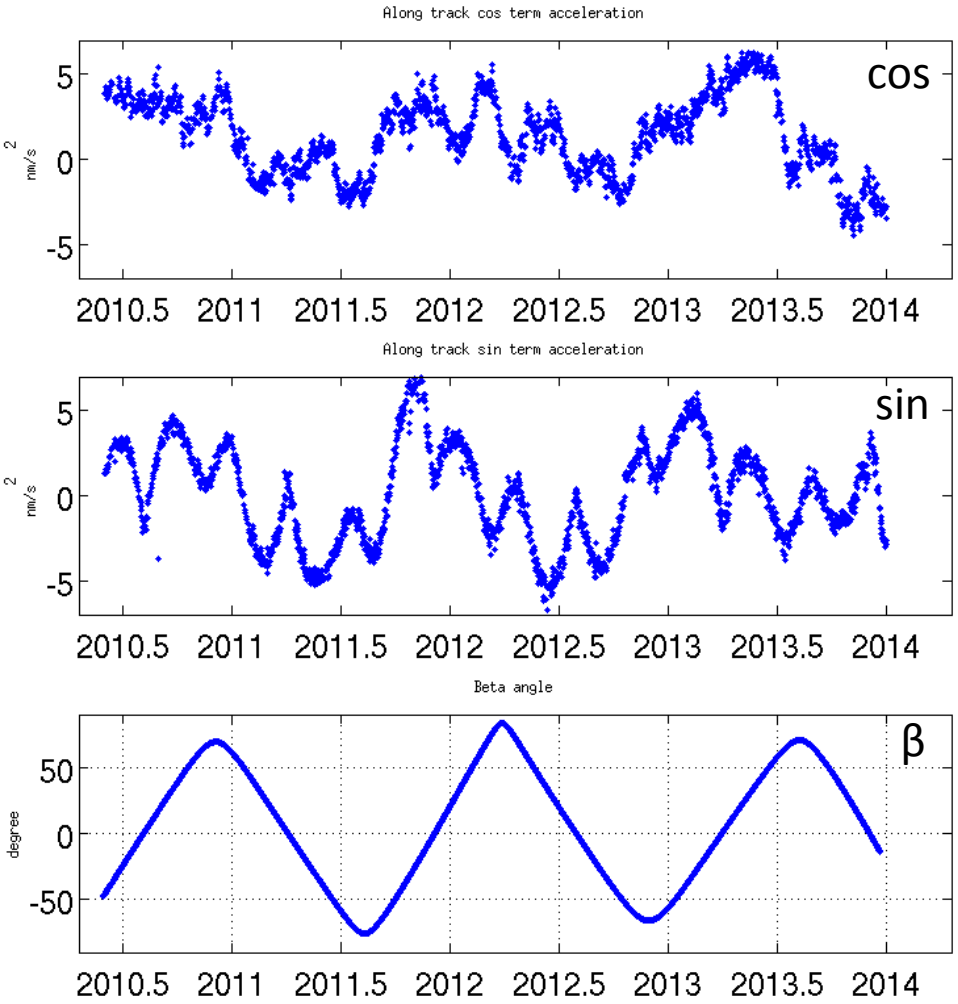
0.40 mm/s

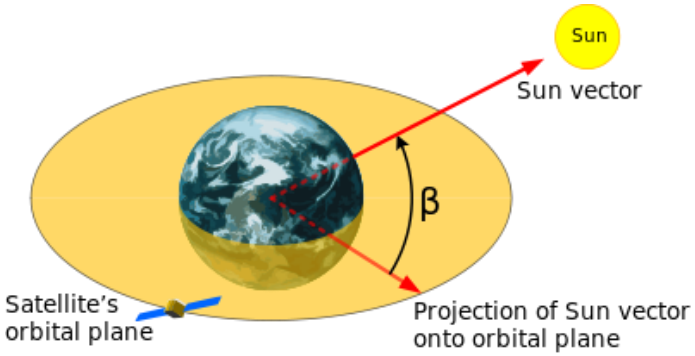


1.58 cm

24h intervals

Forcing Parameters vs beta angle





Actions:

- There is work to do here
- Adjust emissivity of panels
- No UCL solution worked yet

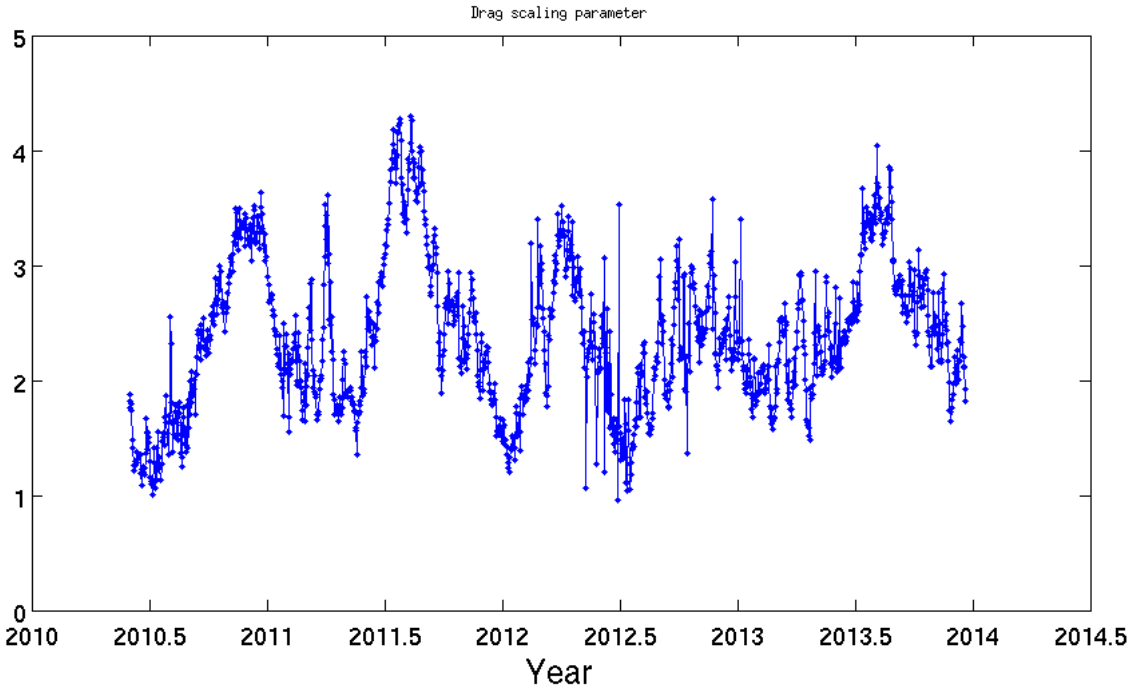
Tidal aliasing

- The periodicity of the β angle is 485 days (or 243 days from node to node)
- If we assume that the orbital period of week 5-dec-2013 is maintained in a 443 day 'repeat' then:

Tide	Aliasing (days)
M_2	2612
S_2	2481
O_1	3343
K_1	1465

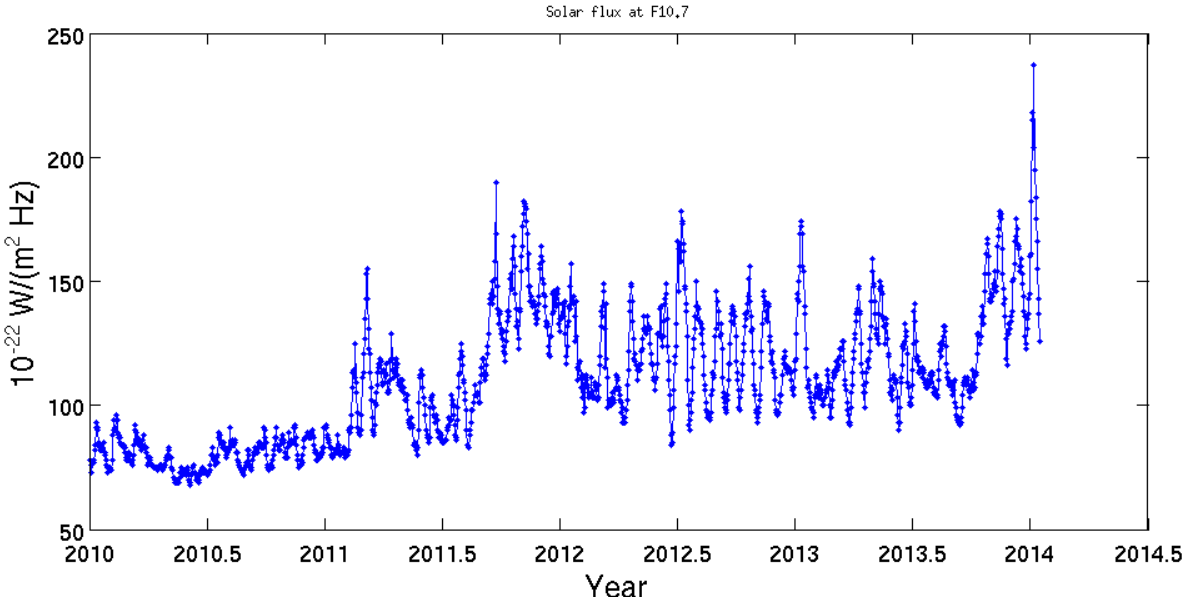
Drag parameters:

- scale factor
- MSIS86 model
- satellite properties
- 3 hourly estimates

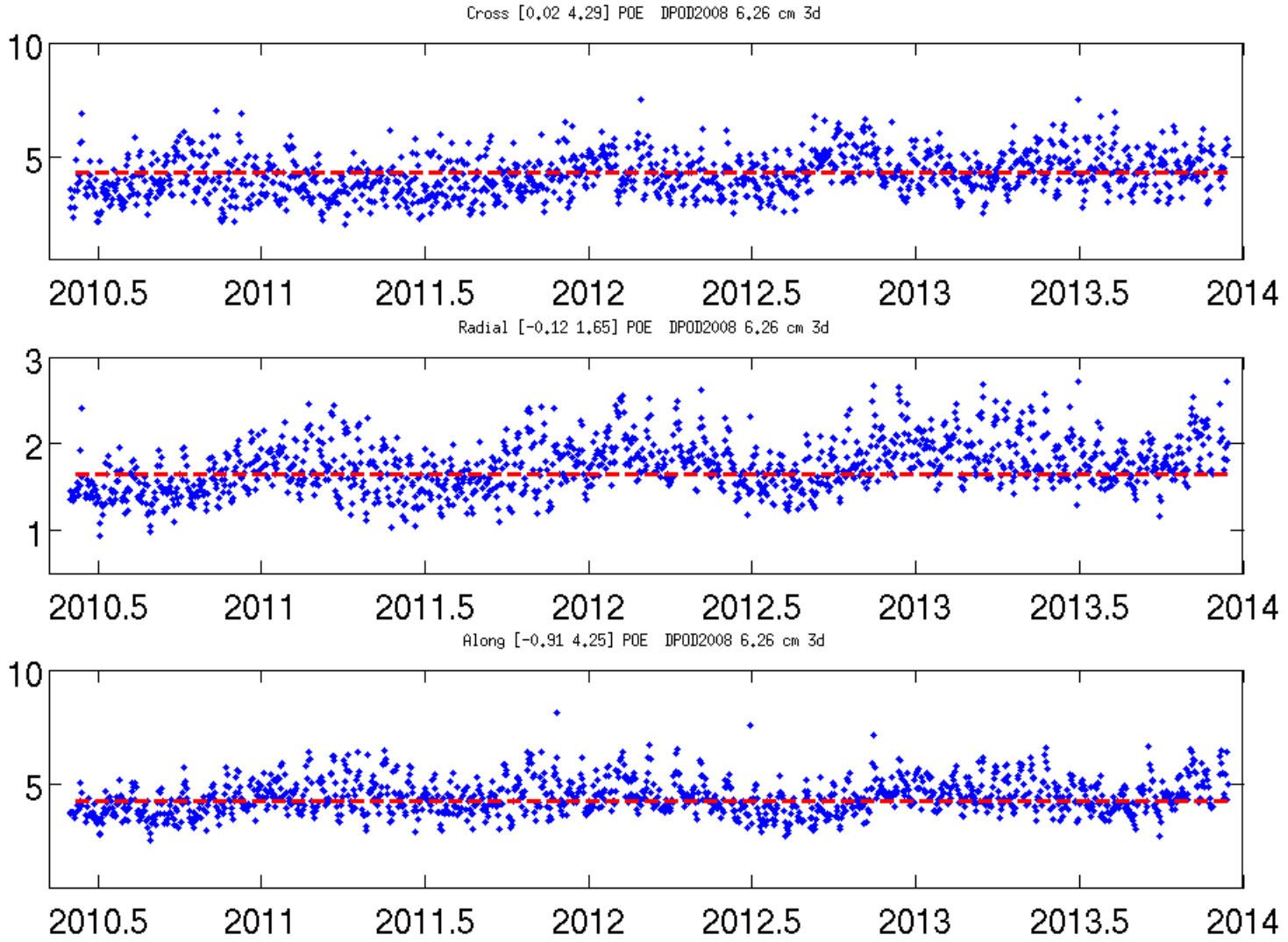


Solar flux (F10.7)

- proxy par.



POE orbit



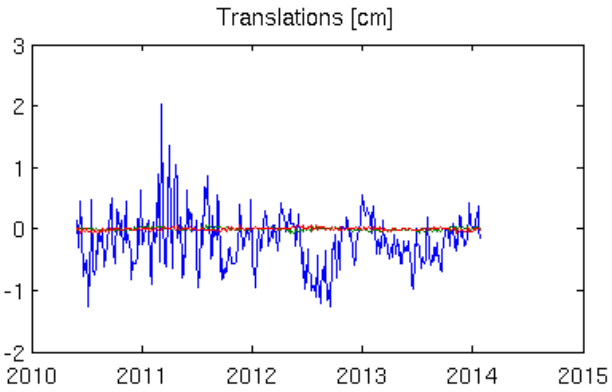
4.29cm

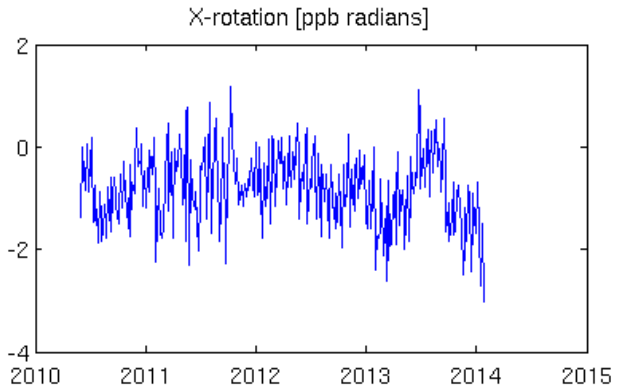
1.65cm

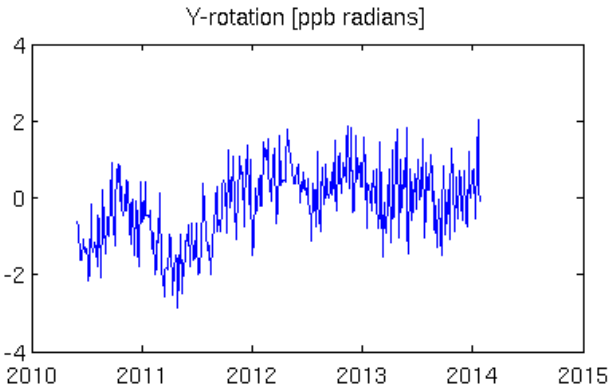
4.25cm

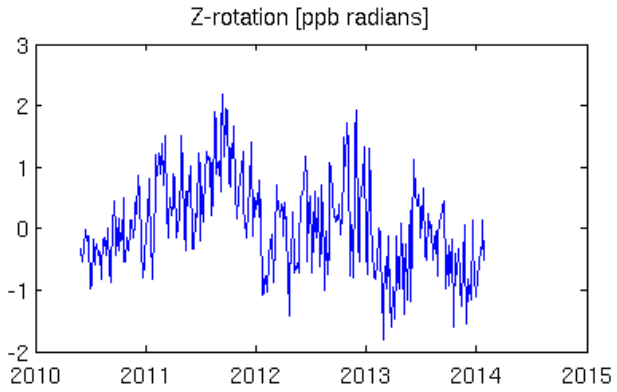
IDS beacon coordinates

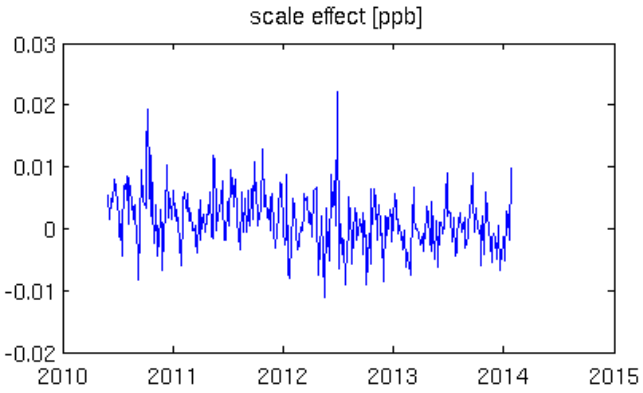
- Allow beacon coordinates to ‘freely’ adjust while we keep the ILRS stations fixed in SLRF2008
- This procedure results in a new orbit solution which van be compared to the DPOD2008/SLRF2008 solution we had computed earlier
- Inspect the Helmert parameters between both trajectories.
- Initially developed as a screening tool, it is an option in the current processing scheme

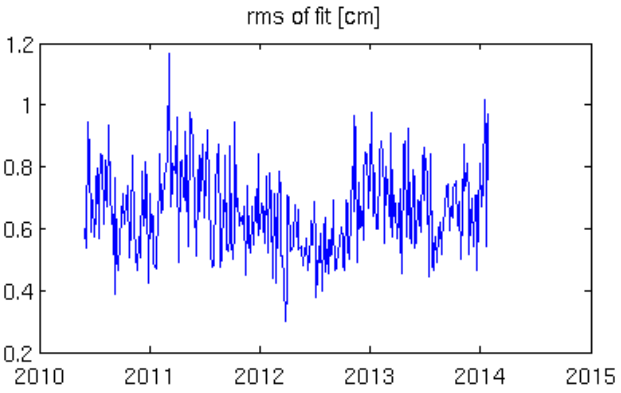

Translations [cm]
3
2
1
0
-1
-2
2010
2011
2012
2013
2014
2015


X-rotation [ppb radians]
2
0
-2
-4
2010
2011
2012
2013
2014
2015


Y-rotation [ppb radians]
4
2
0
-2
-4
2010
2011
2012
2013
2014
2015


Z-rotation [ppb radians]
3
2
1
0
-1
-2
2010
2011
2012
2013
2014
2015


scale effect [ppb]
0.03
0.02
0.01
0
-0.01
-0.02
2010
2011
2012
2013
2014
2015


rms of fit [cm]
1.2
1
0.8
0.6
0.4
0.2
2010
2011
2012
2013
2014
2015

Helmert transformations

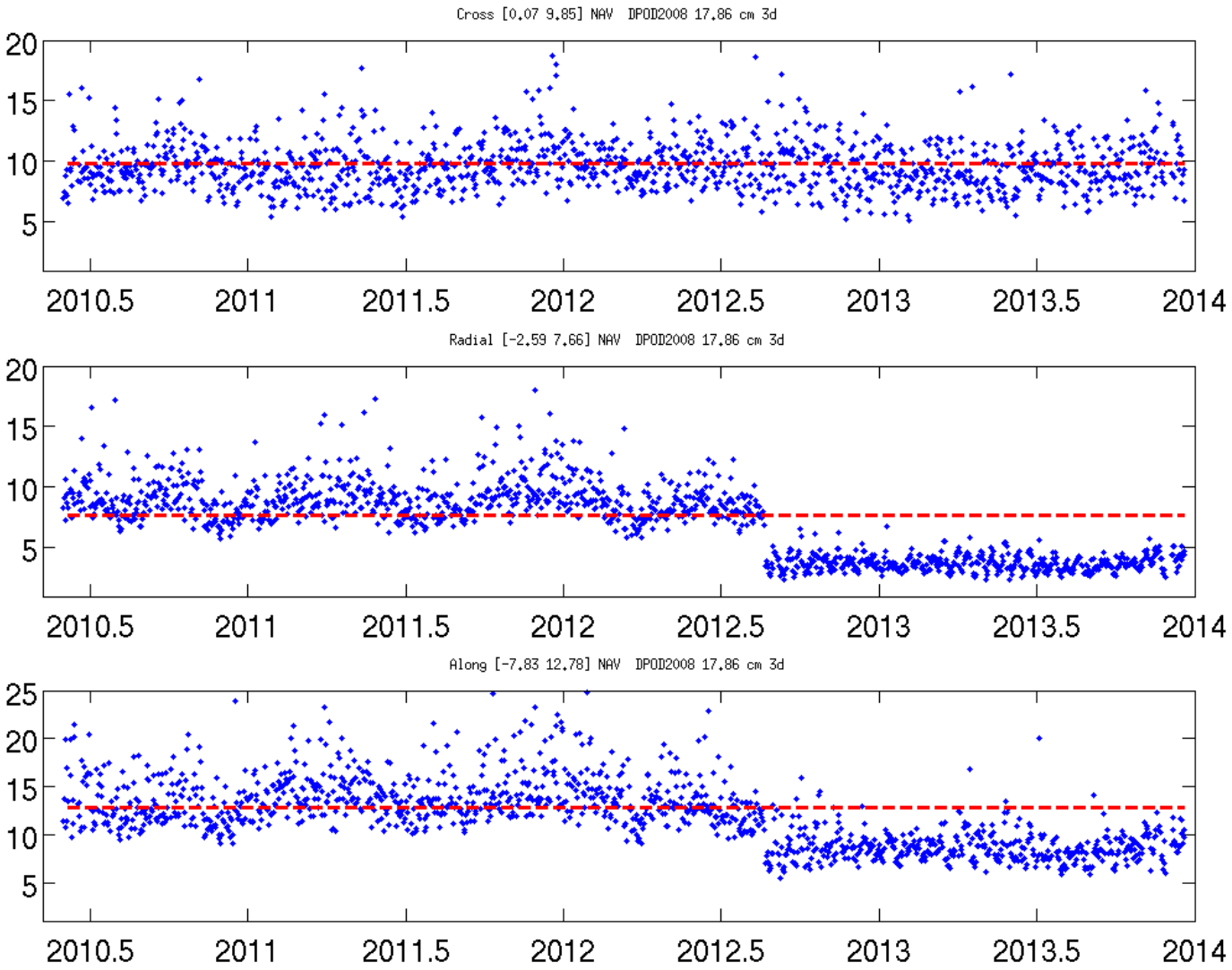
- Translations: the only significant effect goes along the z-axis, signal: 10 mm
- Rotations: both trajectory solutions are compatible at the 1 ppb level, trend signal at 1 ppb/3.5 year, or 2.8e-10 radians/year
- Scale: no significant differences are noted
- 3d rms after fit: around 7 mm.
- MSL error = -0.16 * dz according to Morel and Willis (2005), the reference frame effect on the MSL is therefore 1e-9/3.5*0.16 = 0.3 mm/yr

Conclusions

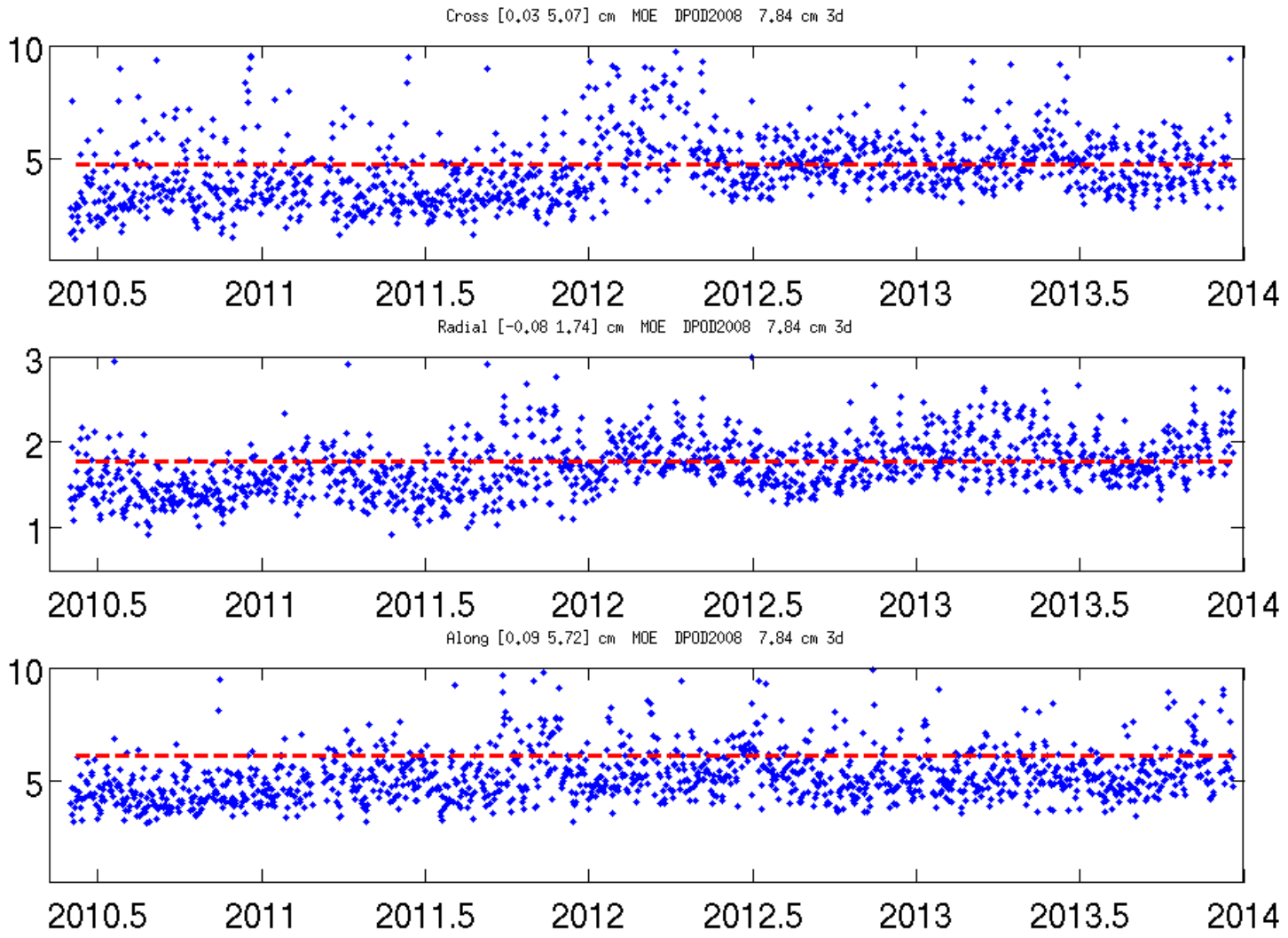
- Cryosat-2 is unique in the sense that it does not carry a GPS tracking receiver, all tracking by DORIS and SLR
- SLR:
  - Fall back option, independently it yields ≈4 cm orbits radially
  - SLR fits consistent at the ≈1.5 cm level
  - Low weight relative to DORIS
  - Allows us to check the reference frame effect
- POD scheme differs from the CNES
  - CNES: rinex data, Ours: 10s Doppler counts
  - MOE and POE orbits are compared to ours
  - Radial consistency at the 1.5 to 2.0 cm level
- The real time DIODE Navigator data has been improved, since the summer of 2012 we see a radial consistency below the 5 cm level
- Reference frame: IDS to ILRS seems to be consistent at the 1e-9 level for rotations and 10 mm for dz, MSL effect estimated at 0.3 mm/yr

Backup slides

navigator

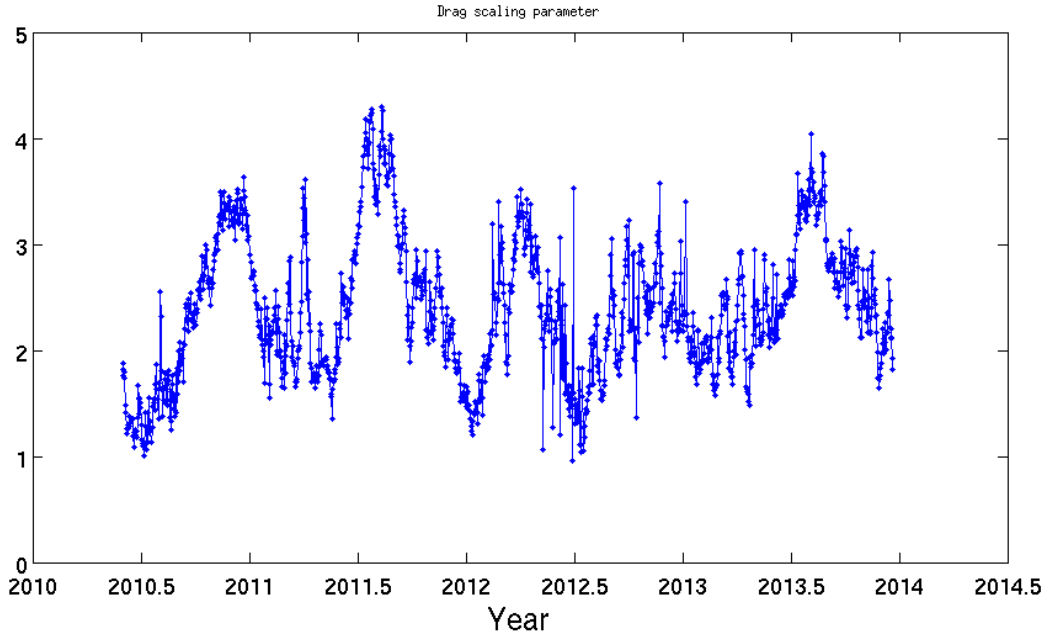

Cross [0.07 9.85] NAV DPOD2008 17.86 cm 3d
20
15
10
5
2010.5
2011
2011.5
2012
2012.5
2013
2013.5
2014
Radial [-2.59 7.66] NAV DPOD2008 17.86 cm 3d
20
15
10
5
2010.5
2011
2011.5
2012
2012.5
2013
2013.5
2014
Along [-7.83 12.78] NAV DPOD2008 17.86 cm 3d
25
20
15
10
5
2010.5
2011
2011.5
2012
2012.5
2013
2013.5
2014

MOE orbit


Cross [0.03 5.07] cm MOE DPOD2008 7.84 cm 3d
10
5
2010.5
2011
2011.5
2012
2012.5
2013
2013.5
2014
Radial [-0.08 1.74] cm MOE DPOD2008 7.84 cm 3d
3
2
1
2010.5
2011
2011.5
2012
2012.5
2013
2013.5
2014
Along [0.09 5.72] cm MOE DPOD2008 7.84 cm 3d
10
5
2010.5
2011
2011.5
2012
2012.5
2013
2013.5
2014

Drag parameters:

- scale factor
- MSIS86 model
- satellite properties
- 3 hourly estimates



KP3 index

- proxy par.