GOCE reduced-dynamic orbits - inter-agency comparisons

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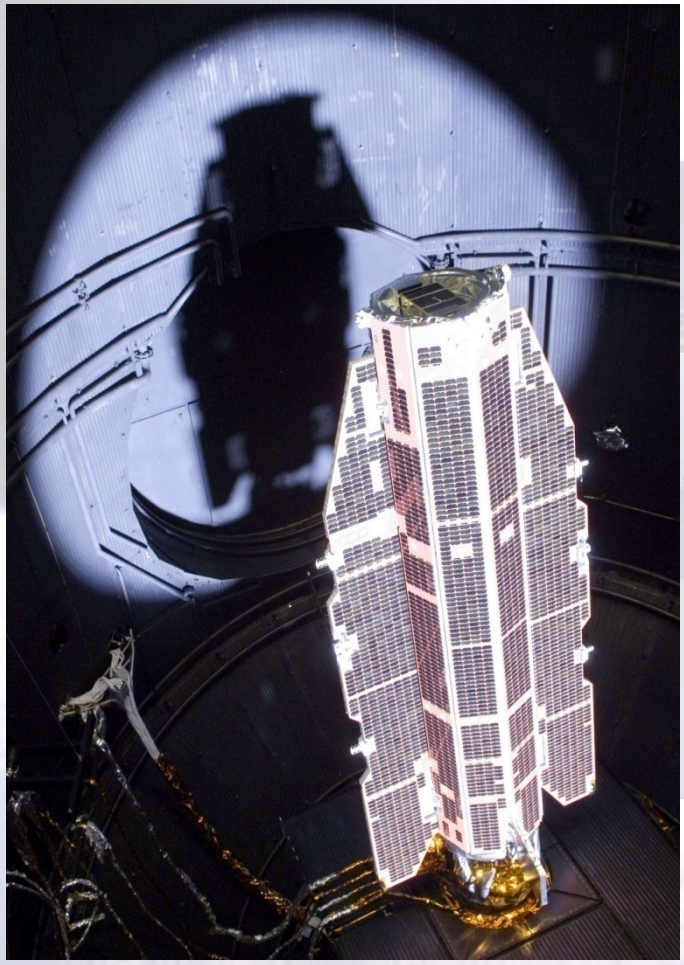
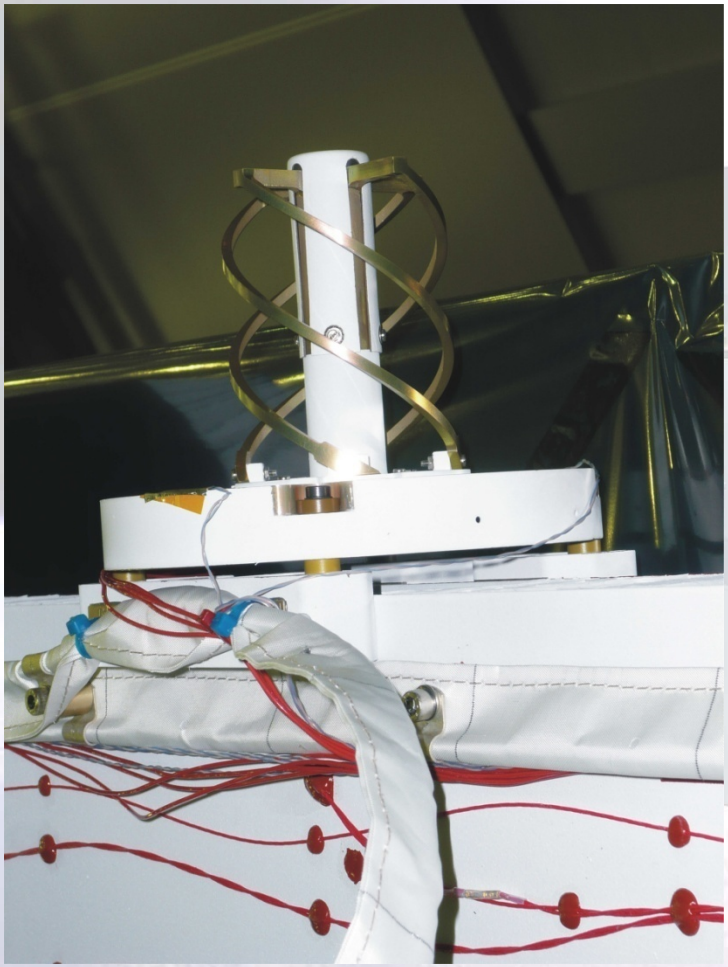
GOCE satellite mission



Courtesy:ESA

- Gravity and steady-state Ocean Circulation Explorer
- First Earth Explorer of the Living Planet Program of the European Space Agency
- Launch: **17 March 2009** from Plesetsk, Russia
- Sun-synchronous orbit with inclination of 96.5^{o}
- Altitude: 254.9 km
- 12-channel dual frequency GPS receiver
- Special characteristics: drag-free flight

Motivation and background



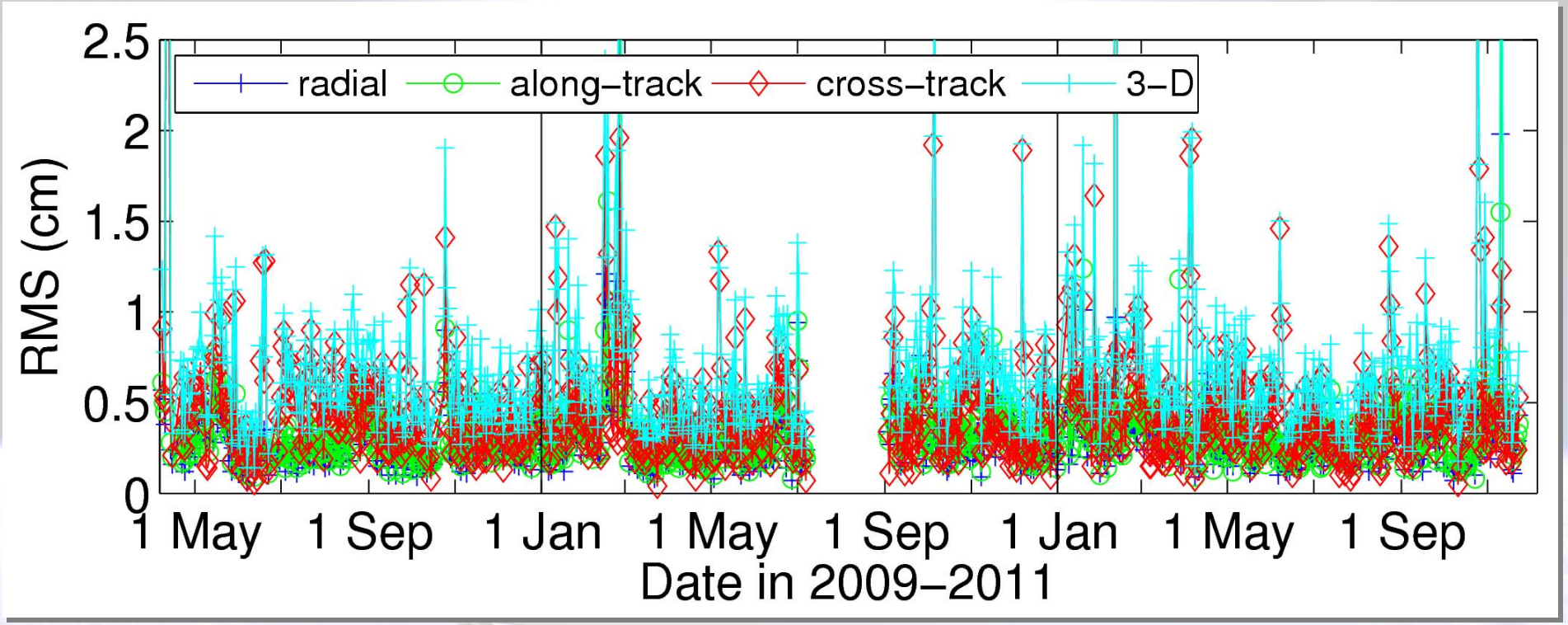
Courtesy:ESA

- Official GOCE orbit solutions are provided by DEOS (RSO) and AIUB (PSO)
- External SLR validation confirms a very good quality of the orbits
- Nevertheless we would like to compare with other reduced-dynamic orbit solutions, which are computed at different agencies with different software packages
- The different dynamical orbit modeling may reveal systematics and/or inadequateness in the orbit modeling

Orbit generation from different agencies

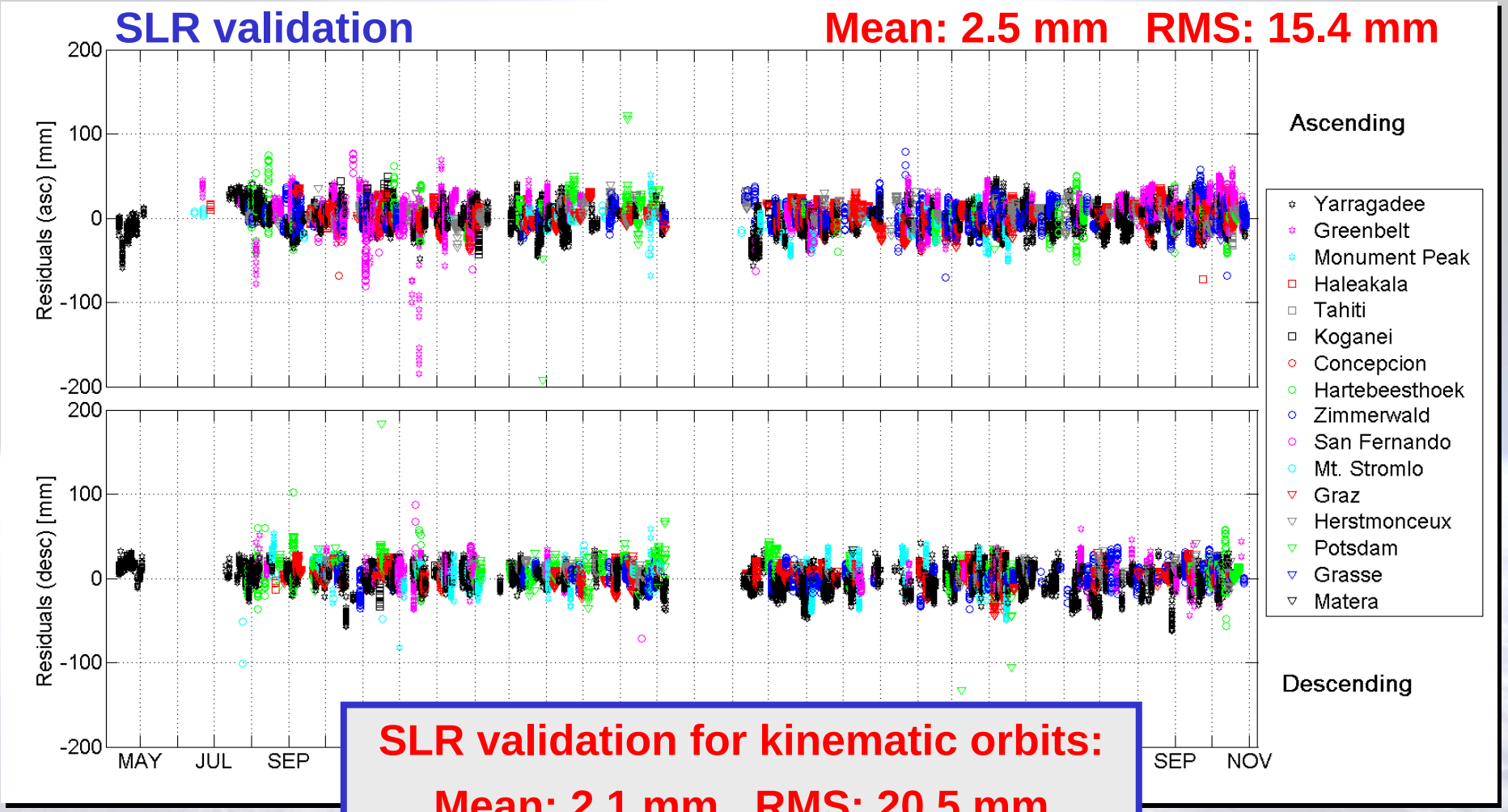
	Software	GPS Observ	GPS		Data	Dynamical Parameters
			Official GOCE orbit solutions			
RSO	GEODYN	triple-diff	IGS rapid	10 sec	30 h	15-min piece-wise constant accelerations
PSO	BERNESE	zero-diff	CODE final	10 sec	30 h	3 constant, 6-min piece-wise constant accelerations
DLR	GHOST	zero-diff	CODE final	10 sec	24 h	cannon-ball drag and SRP, 10-min piece-wise constant accelerations
DFT	GEODYN	triple-diff	IGS final	10 sec	30 h	20-min piece-wise constant accelerations

GOCE PSO quality – reduced-dynamic orbit



5 h overlaps of the reduced-dynamic orbits
mean 3D-RMS 0.89 cm

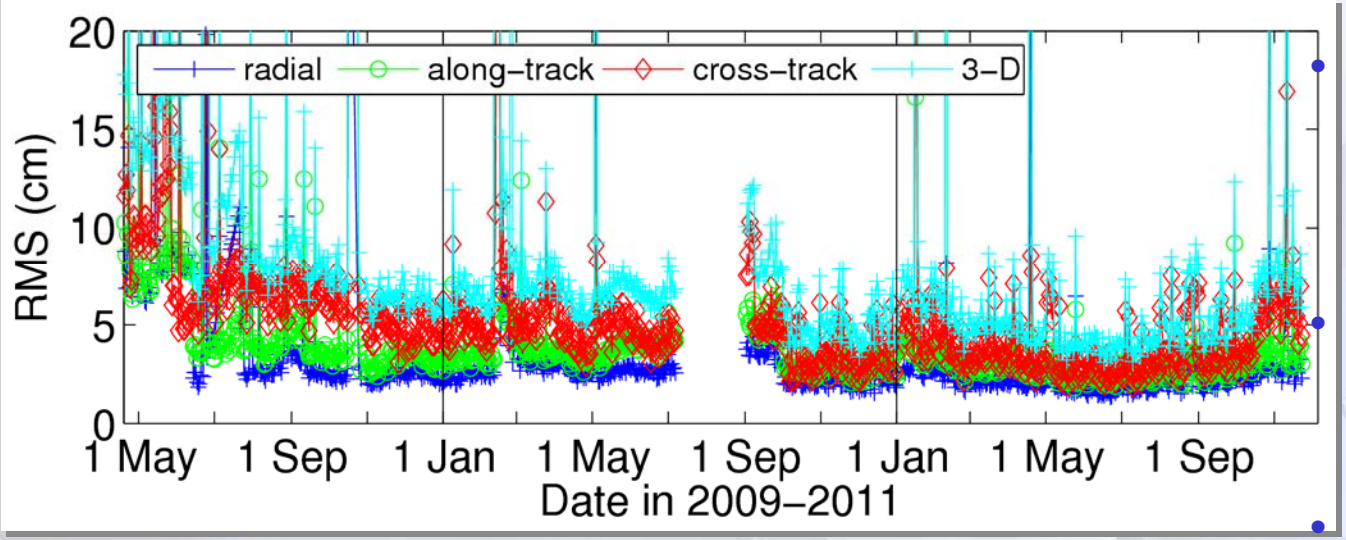
GOCE PSO quality – reduced-dynamic orbit

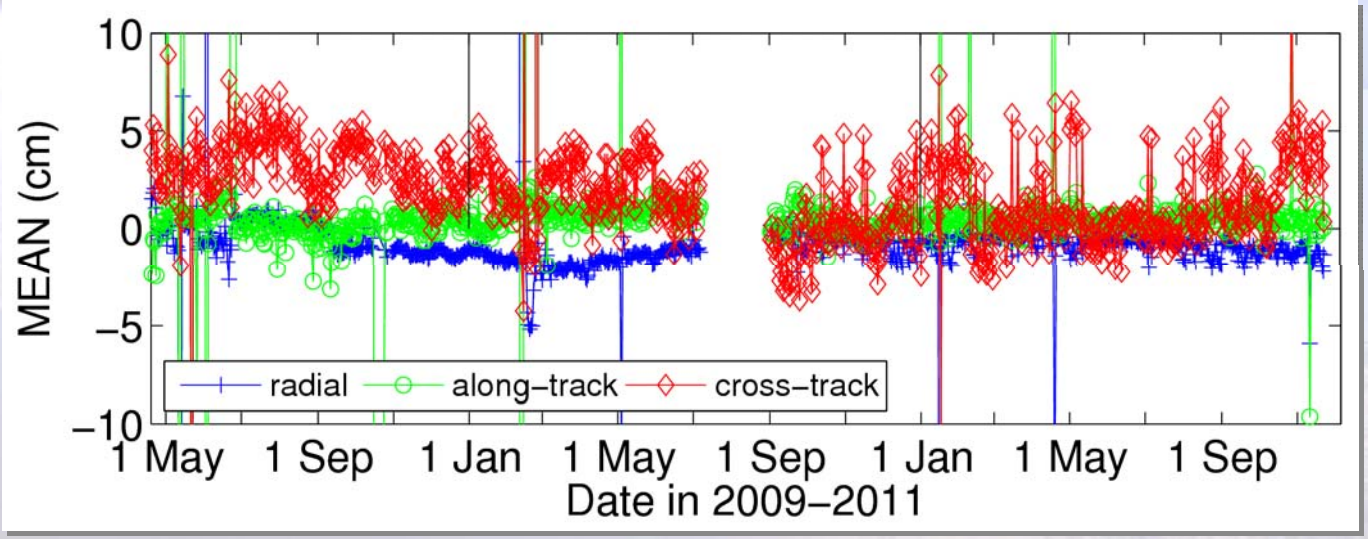


SLR validation for kinematic orbits:

Mean: 2.1 mm RMS: 20.5 mm

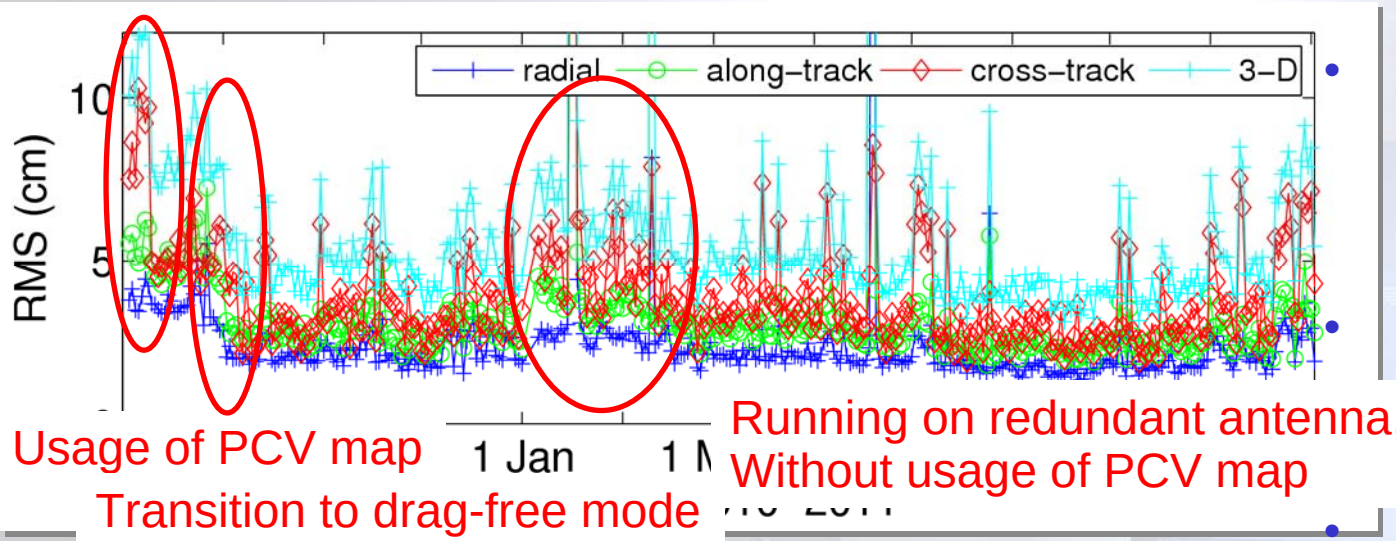
Comparison PSO ⇔ RSO





- Consistency of RSO to PSO is better than 10 cm
- Several improvements are visible
- Quality sometimes suffers from late GOCE GPS data delivery => missing data

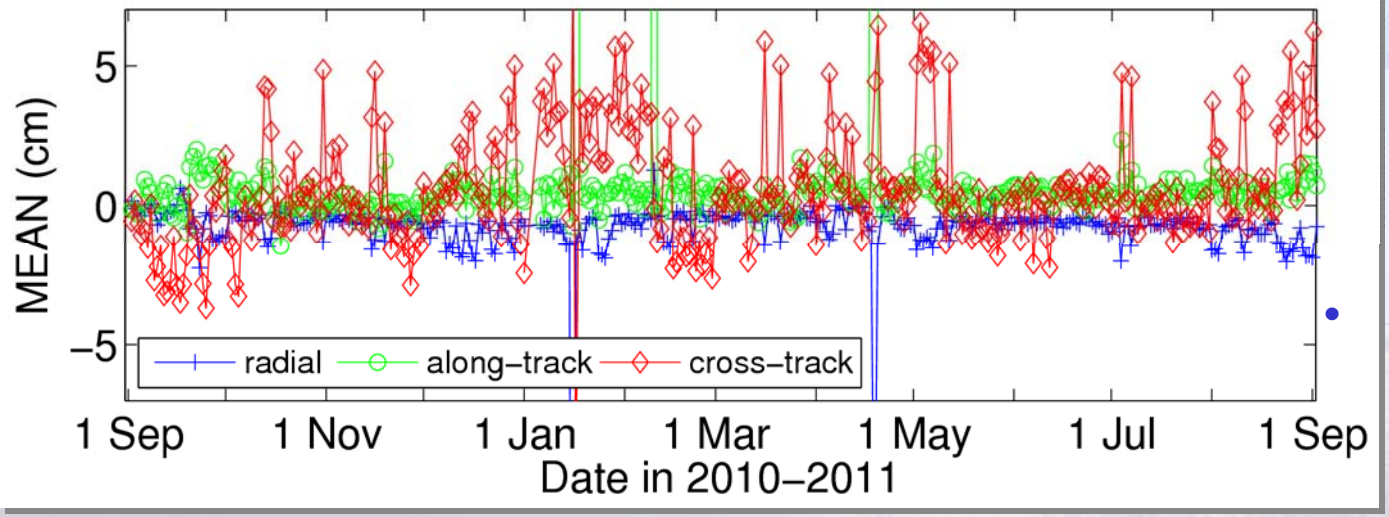
Comparison PSO ⇔ RSO



Usage of PCV map

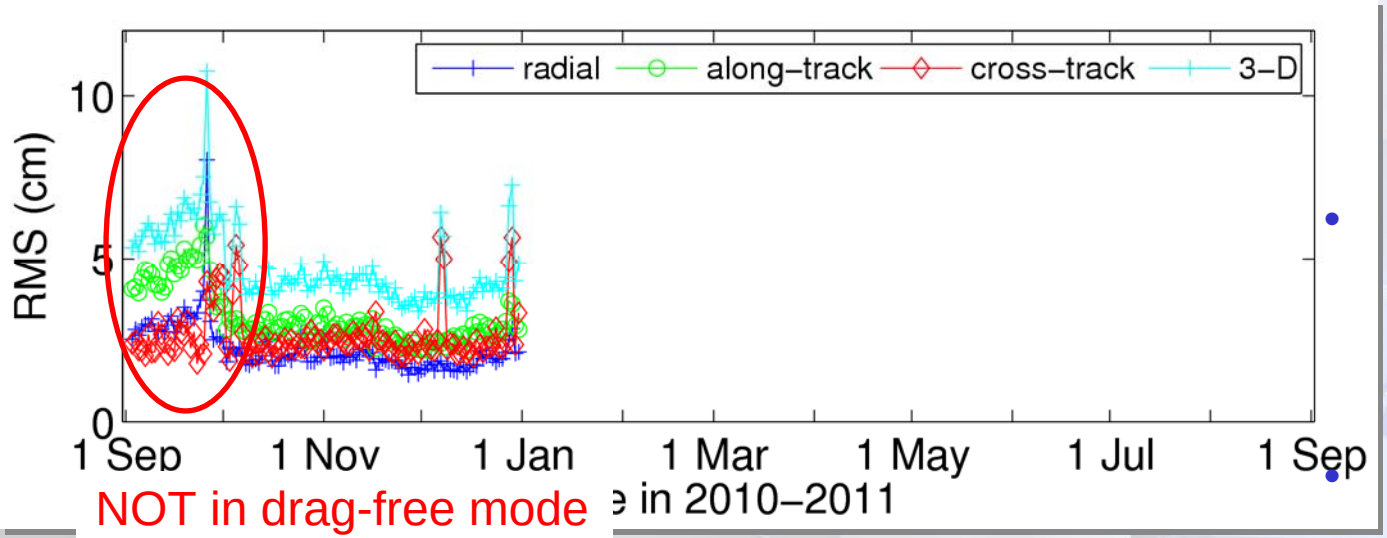
Transition to drag-free mode

Running on redundant antenna, Without usage of PCV map

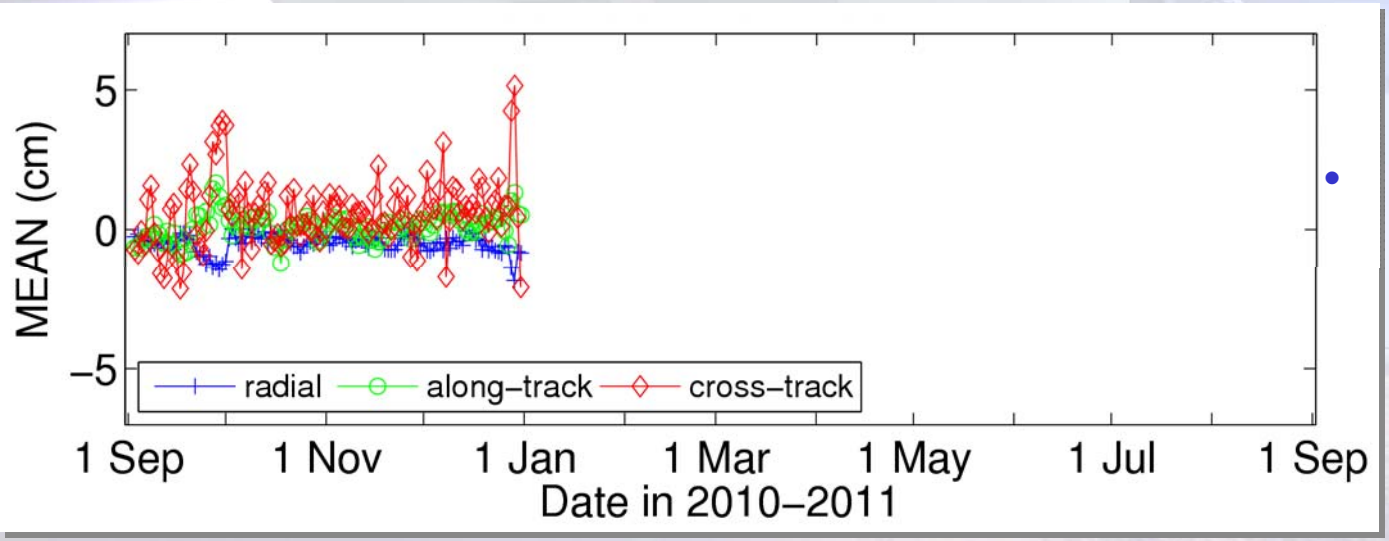


- Consistency of RSO to PSO is better than 10 cm
- Several improvements are visible
- Quality sometimes suffers from late GOCE GPS data delivery => missing data
- Mean 3D RMS 7.75 cm

Comparison PSO ⇔ DFT

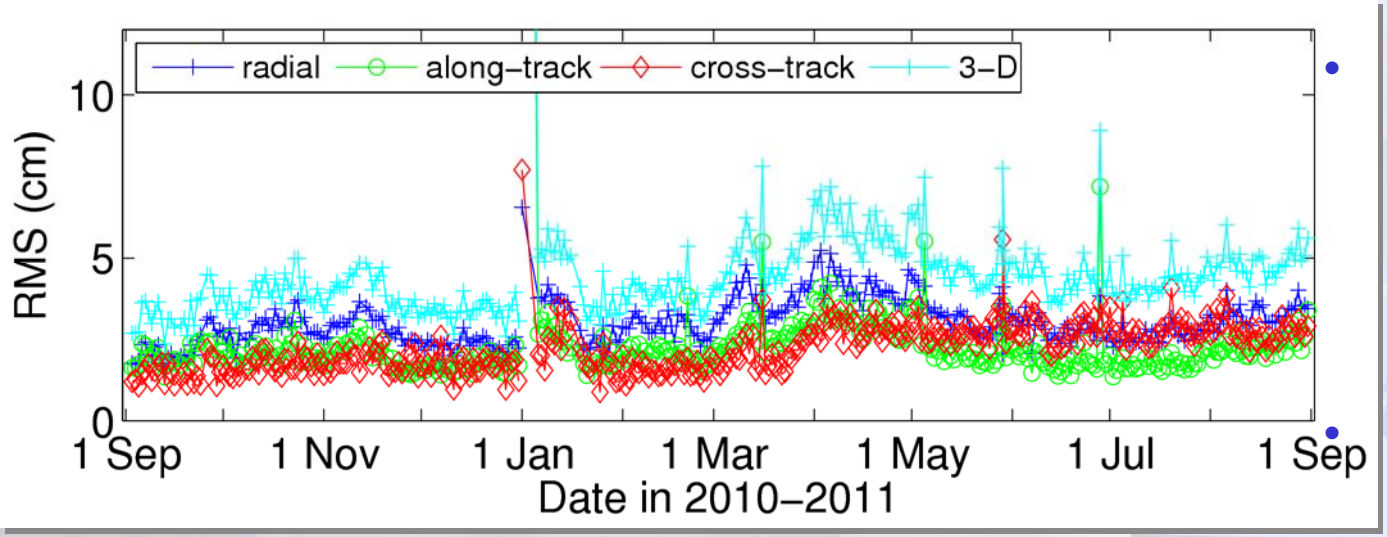


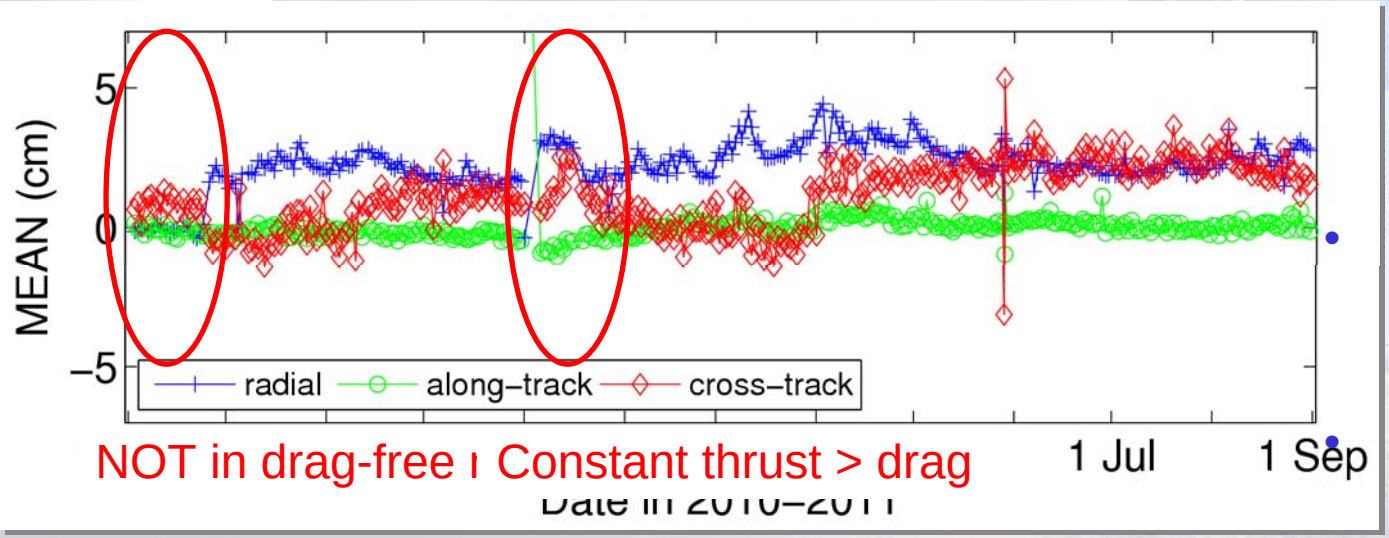
NOT in drag-free mode



- Consistency of DFT solution to PSO is better than RSO
- Difficulties with orbit modeling in non drag-free periods
- Mean 3D RMS 4.48 cm

Comparison PSO ⇔ DLR A

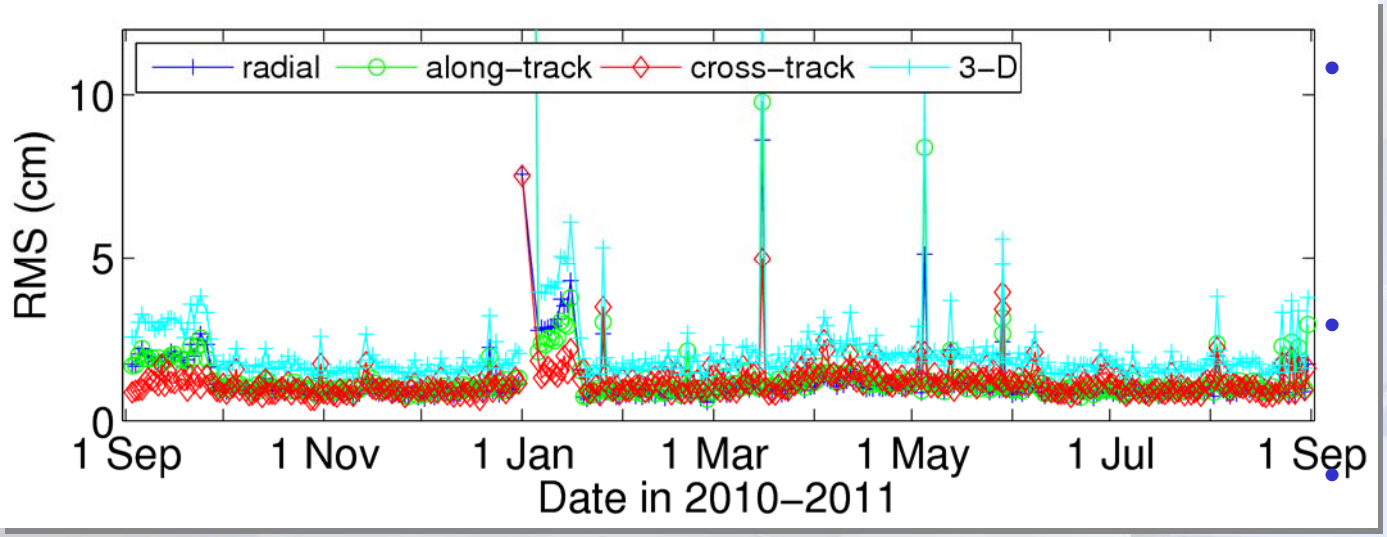




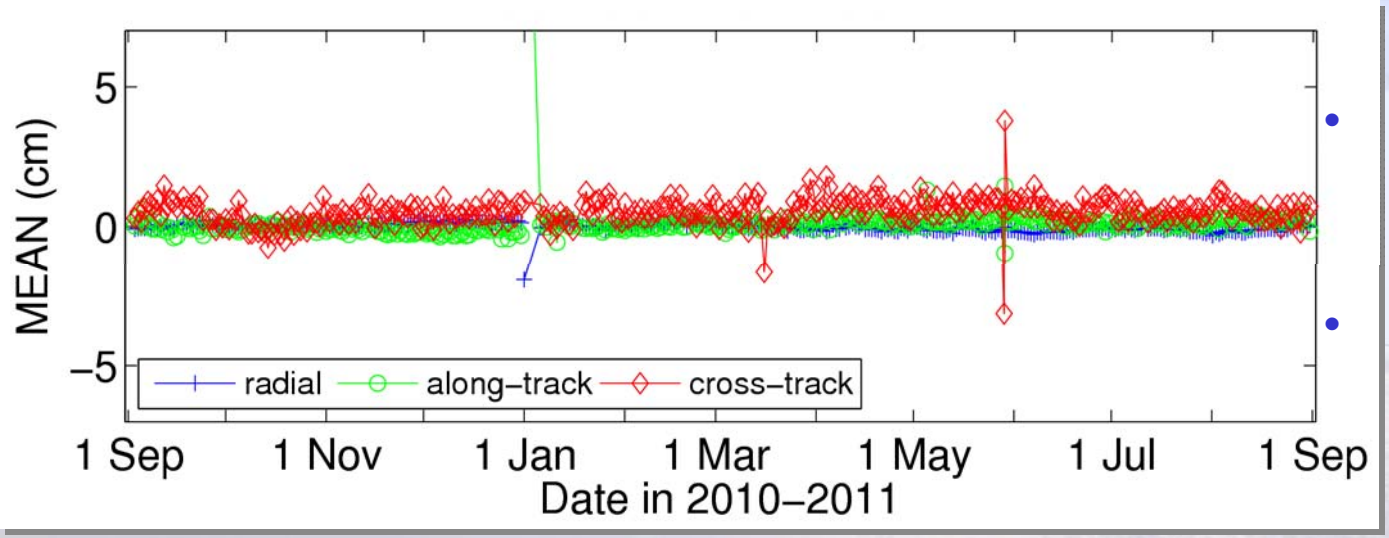
NOT in drag-free ı Constant thrust > drag

- DLR A solution is more dynamic than PSO solution (radial component has very tight constraints)
- Compared to PSO no radial offset in non drag-free period, but significant offset during drag-free flight
- Cross-track offset during eclipse periods
- Mean 3D RMS 3.64 cm

Comparison PSO ⇔ DLR B

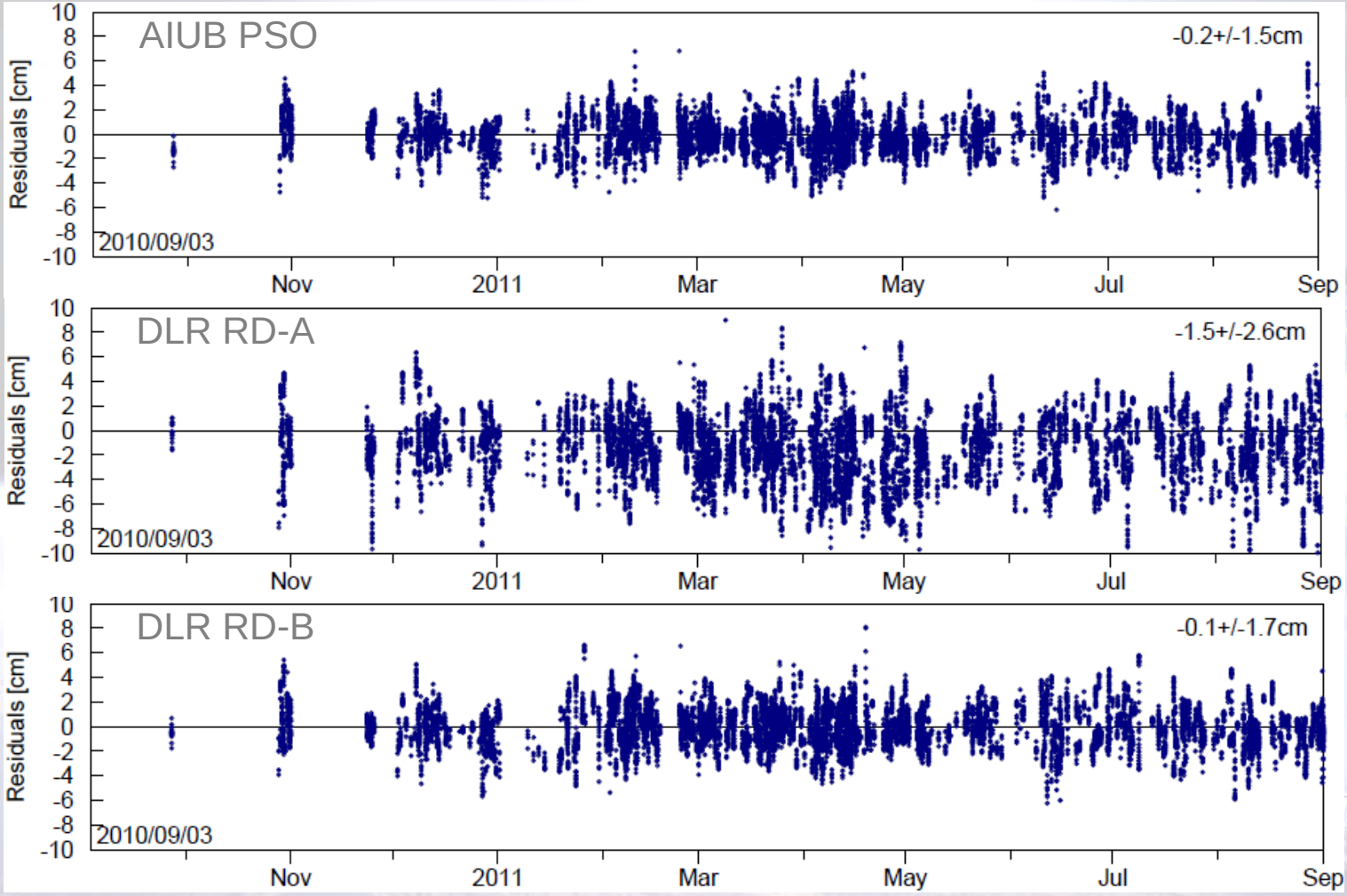


- DLR B: loosly constrained solution => similar to PSO
- No radial offset
- Cross-track offset significantly reduced

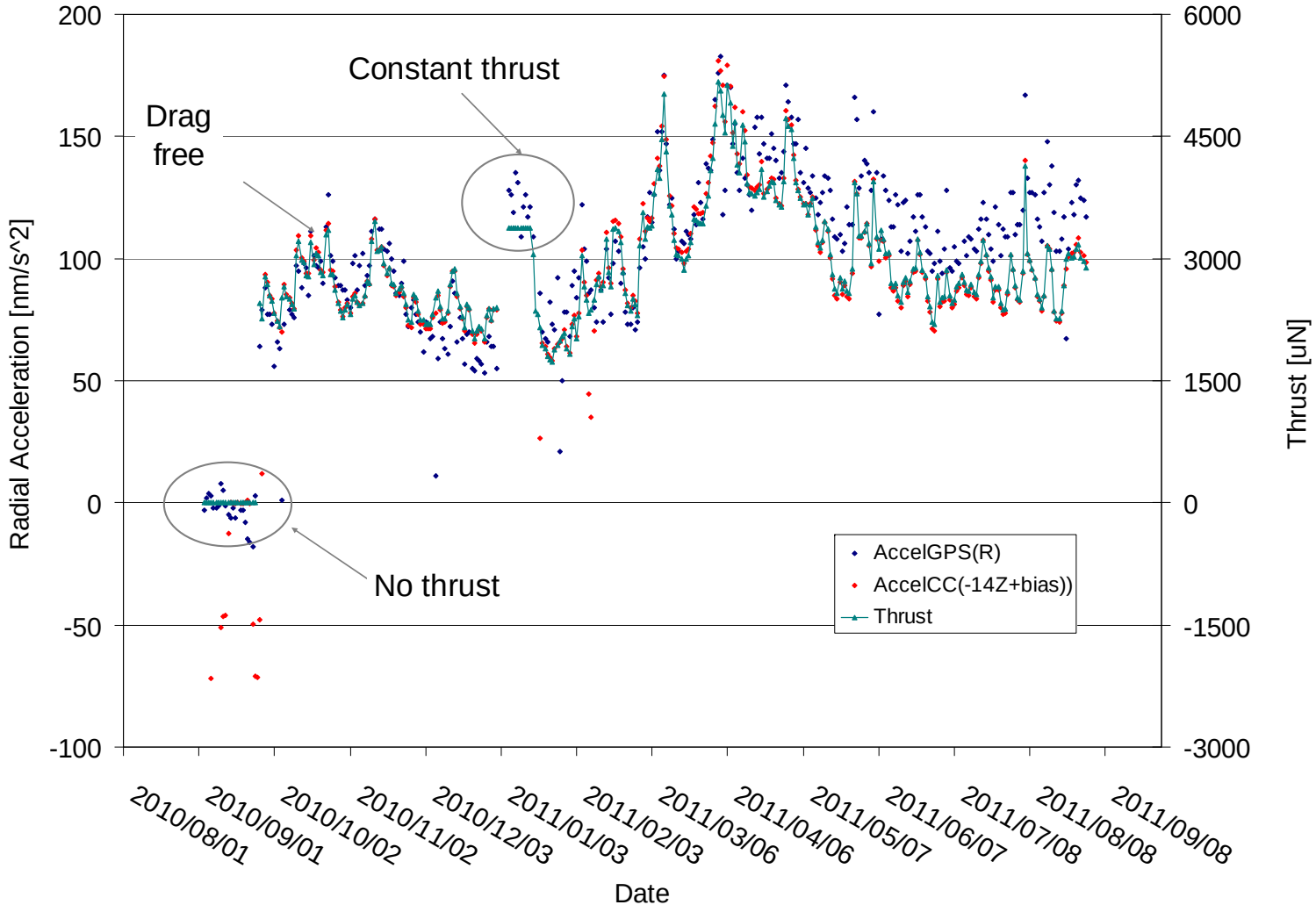


- Very good consistency to PSO
- Mean 3D RMS 1.96 cm

SLR validation and results

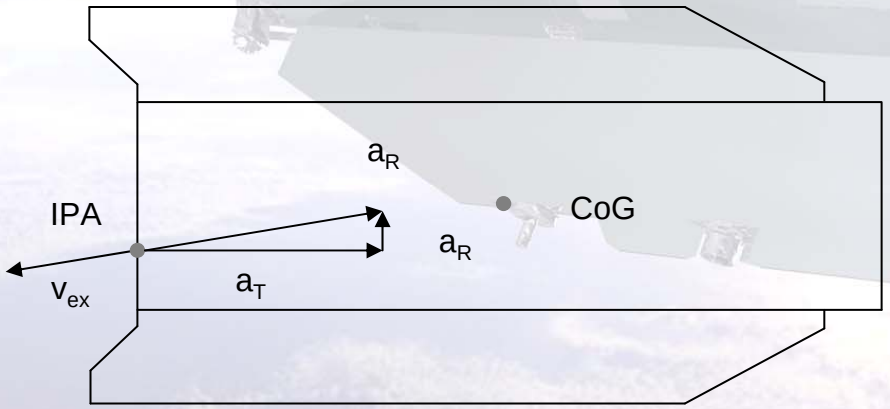


Radial acceleration (DLR B) versus thrust vector



Radial acceleration versus thrust vector

- 3.4..3.7% radial cross-coupling with the thrust vector has been found
- this implies 2.0..2.1° tilt angle of thrust vector (corresponds to real cant angle of IPA)



Edwards et al. 2004

Summary

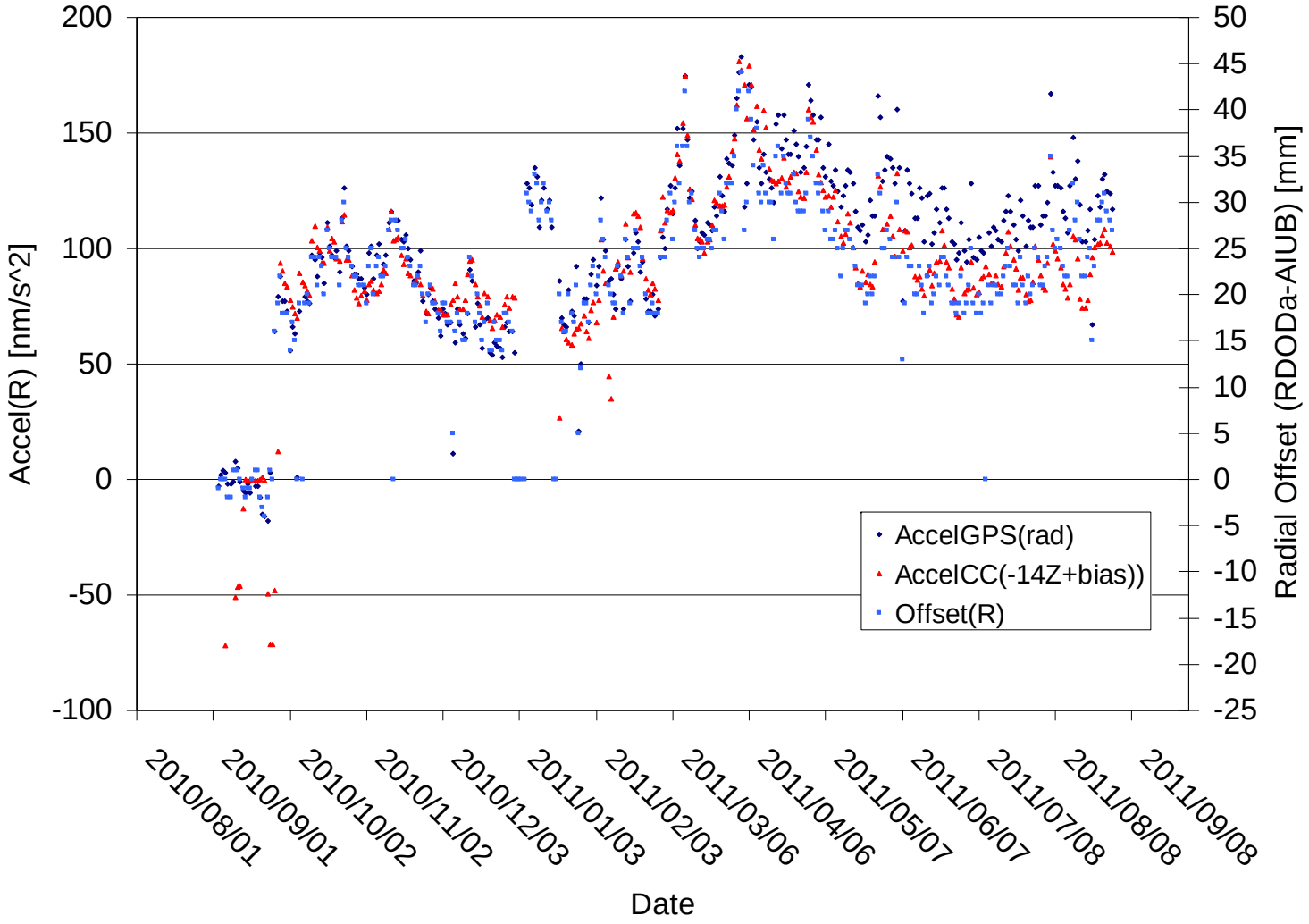
- Inter-agency comparison of reduced-dynamic orbits for GOCE has been performed

- Orbit solutions from AIUB, DEOS and DLR are compared

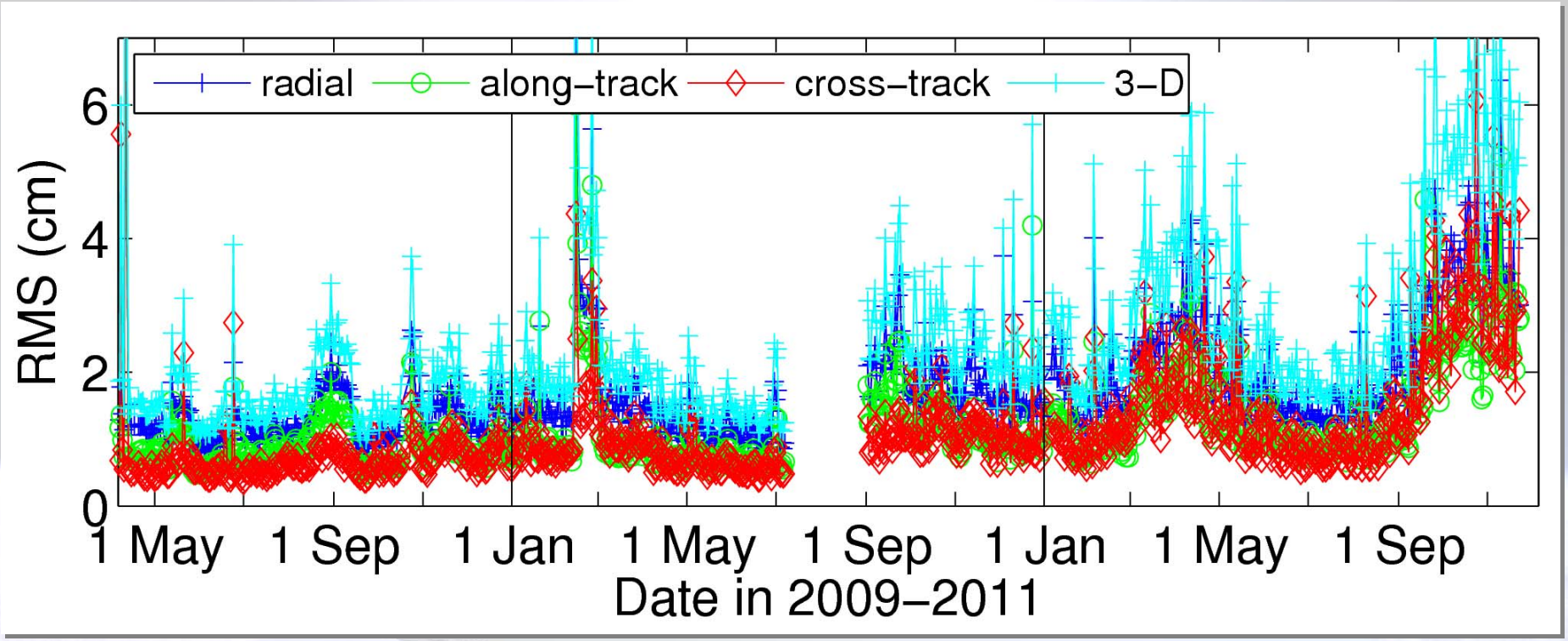
- GOCE PSO validated through inter-agency comparison (2 cm 3D RMS) and SLR analysis (1.5 cm RMS)

- Dynamical GOCE POD needs to account for radial acceleration implied by IPA (cross-coupling approx. 3.4..3.7%)

Radial offset (DLR A) versus radial acceleration (DLR B)

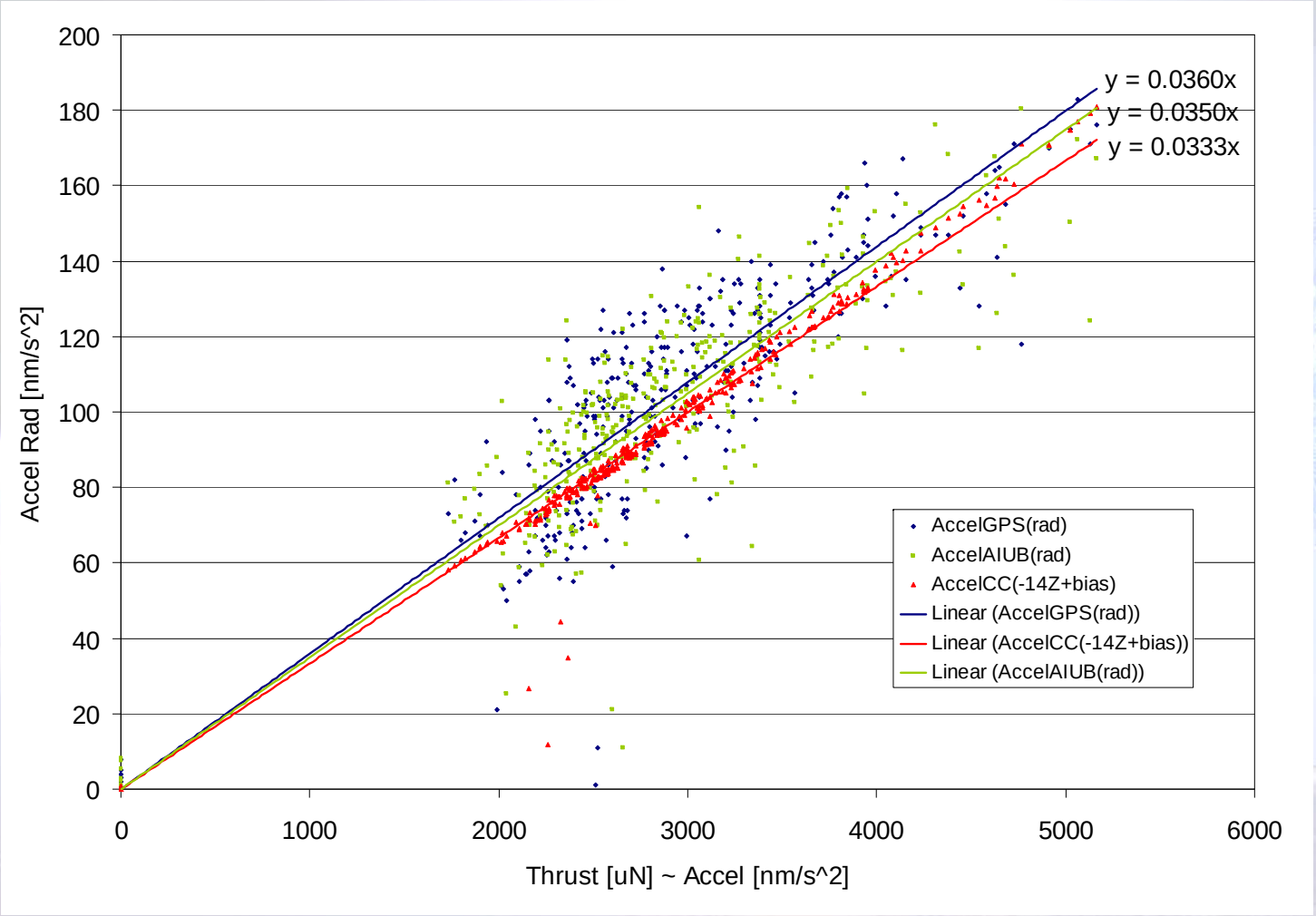


GOCE PSO quality – reduced-dynamic orbit



Differences between reduced-dynamic and kinematic orbits

Radial acceleration versus thrust



F=1000 μN @ 1035 kg yields a_T=966 nm/s^2

a_R=33.3..36.0 nm/s^2 at a_T=966 nm/s^2 implies 3.45..3.66% cross-coupling, i.e. 1.97°..2.10° tilt

Possible quadratic trend in accelerometer data?