Rapid and Precise Orbit Determination for the GOCE Satellite

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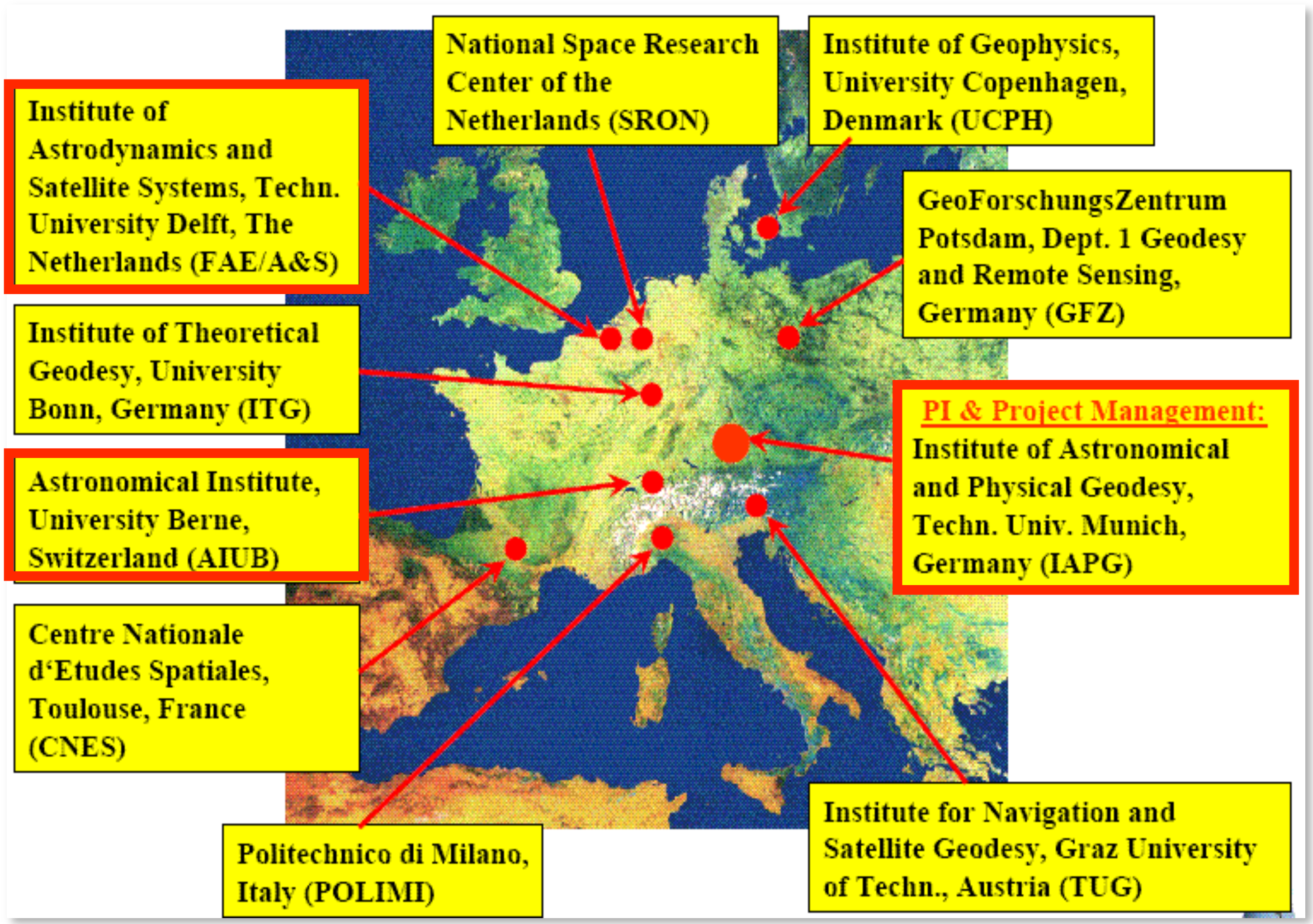
Outline

- Introduction
- Instruments
- Tracking performance
- Orbit determination products
- Quality

GOCE-HPF: Orbit groups



Responsibilities:

- DEOS => RSO
(Rapid Science Orbit)

- AIUB => PSO
(Precise Science Orbit)

- IAPG => Validation

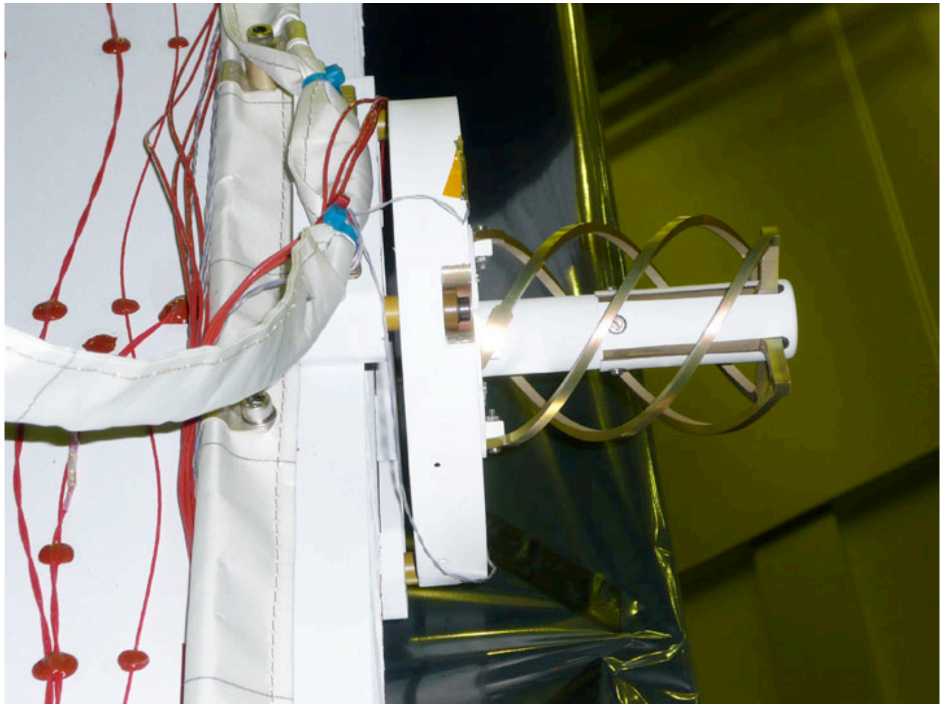
GOCE Orbit Determination

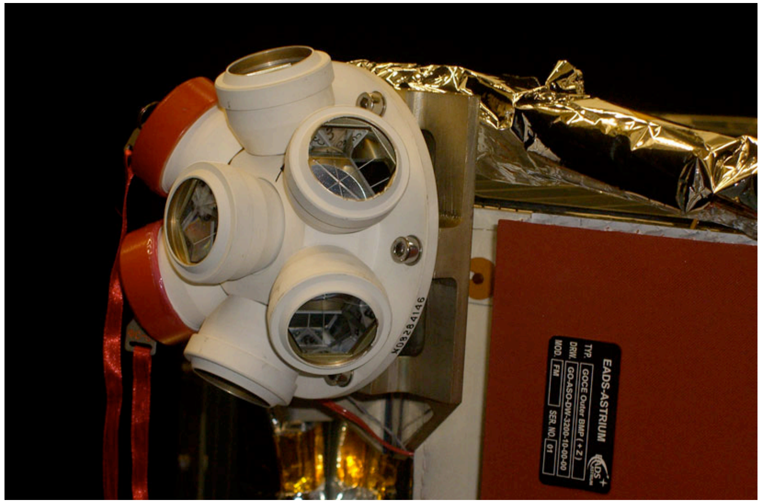
- Support to operations (RSO):
  - Format checks (RINEX)
  - Check of quality of GPS observations
  - Check of gradiometer (common-mode)
  - Geo-location of gravity gradients
  - Pseudo observations for quick-look gravity field determination

- Support to gravity field determination (PSO):
  - Final geo-location of gravity gradients
  - Pseudo observations for final gravity field determination

- Spin-off (PSO):
  - Orbit prediction for ILRS

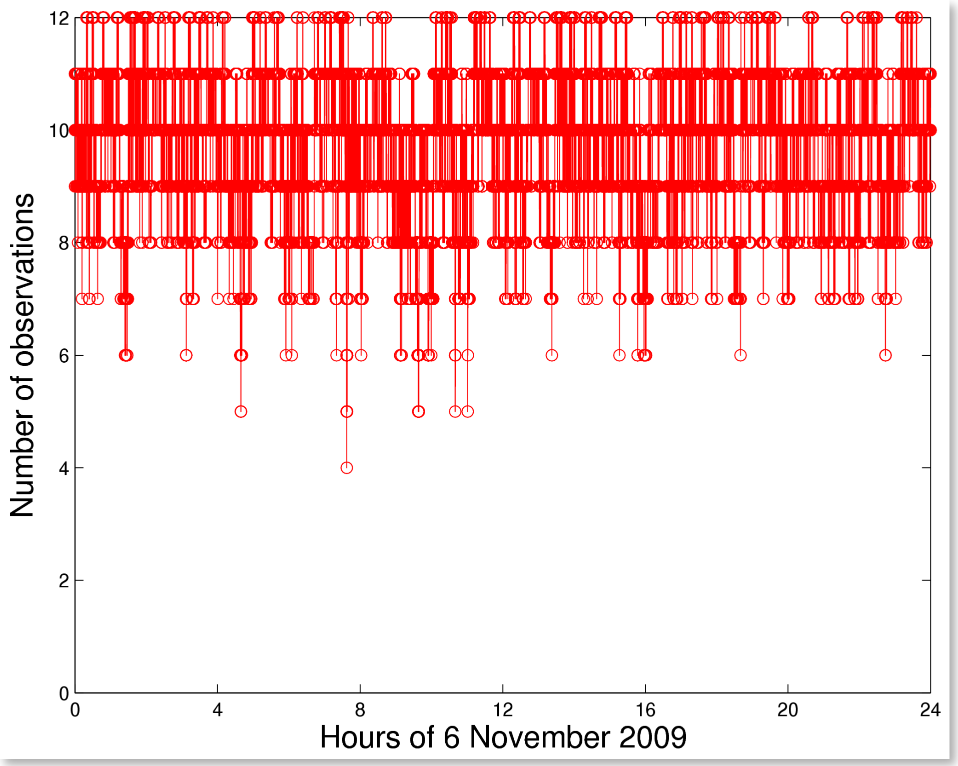
Instruments for POD: GPS and SLR

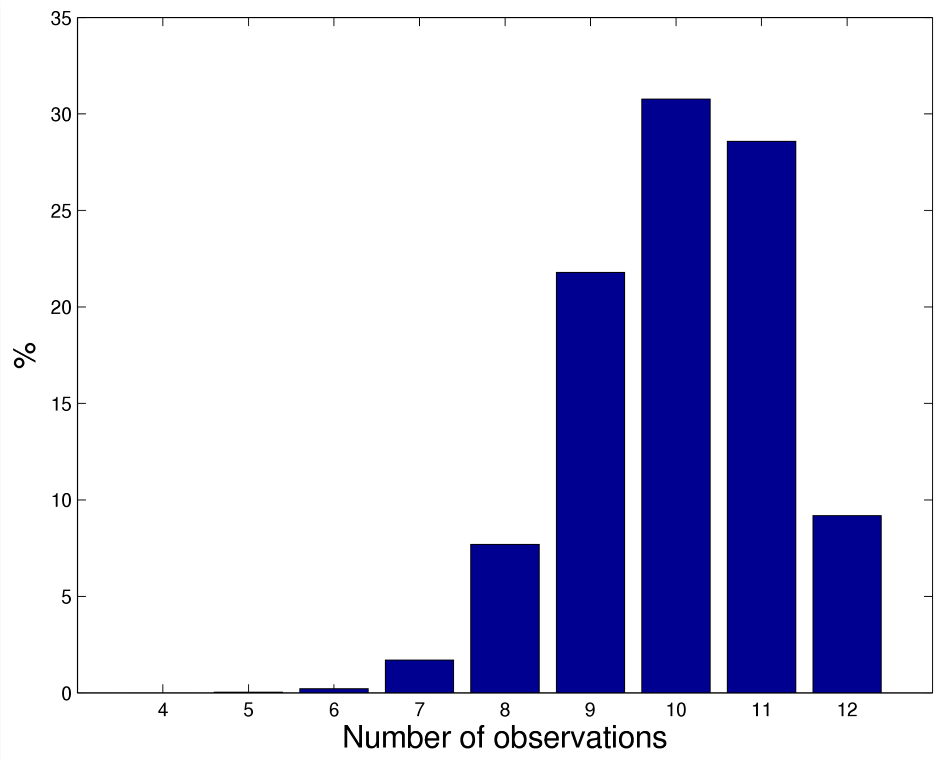




NB: star trackers required for center-of-mass offset computation

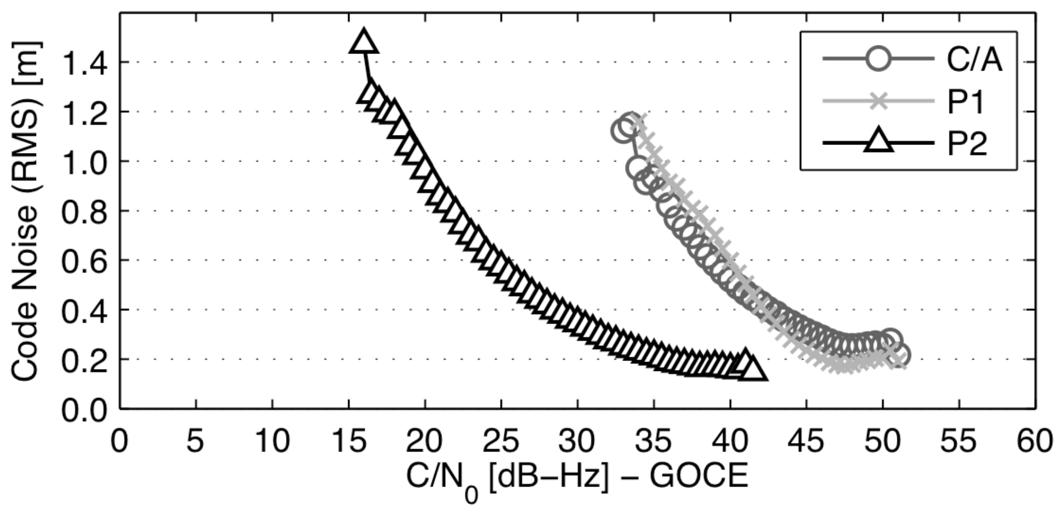
GOCE GPS data: used for POD

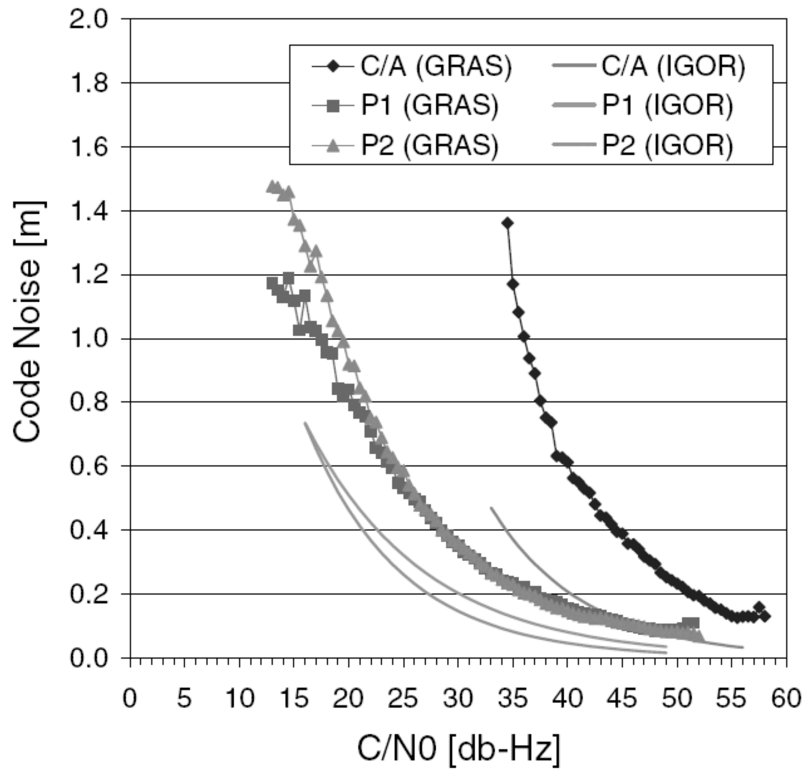




- GPS receiver with 12 channels
- 1 Hz data
- hardly any data gaps

GOCE GPS Lagrange and MetOp GRAS Receiver performance

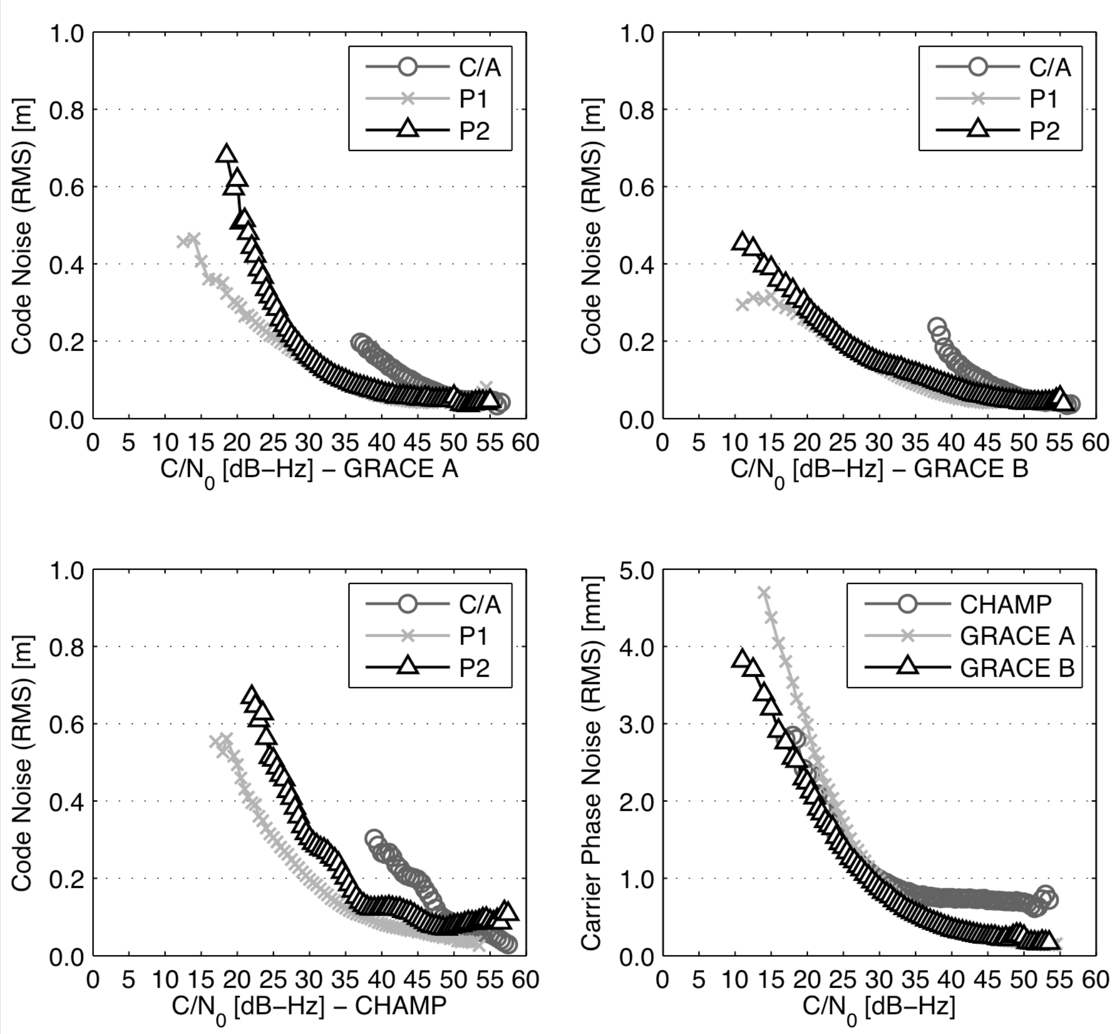




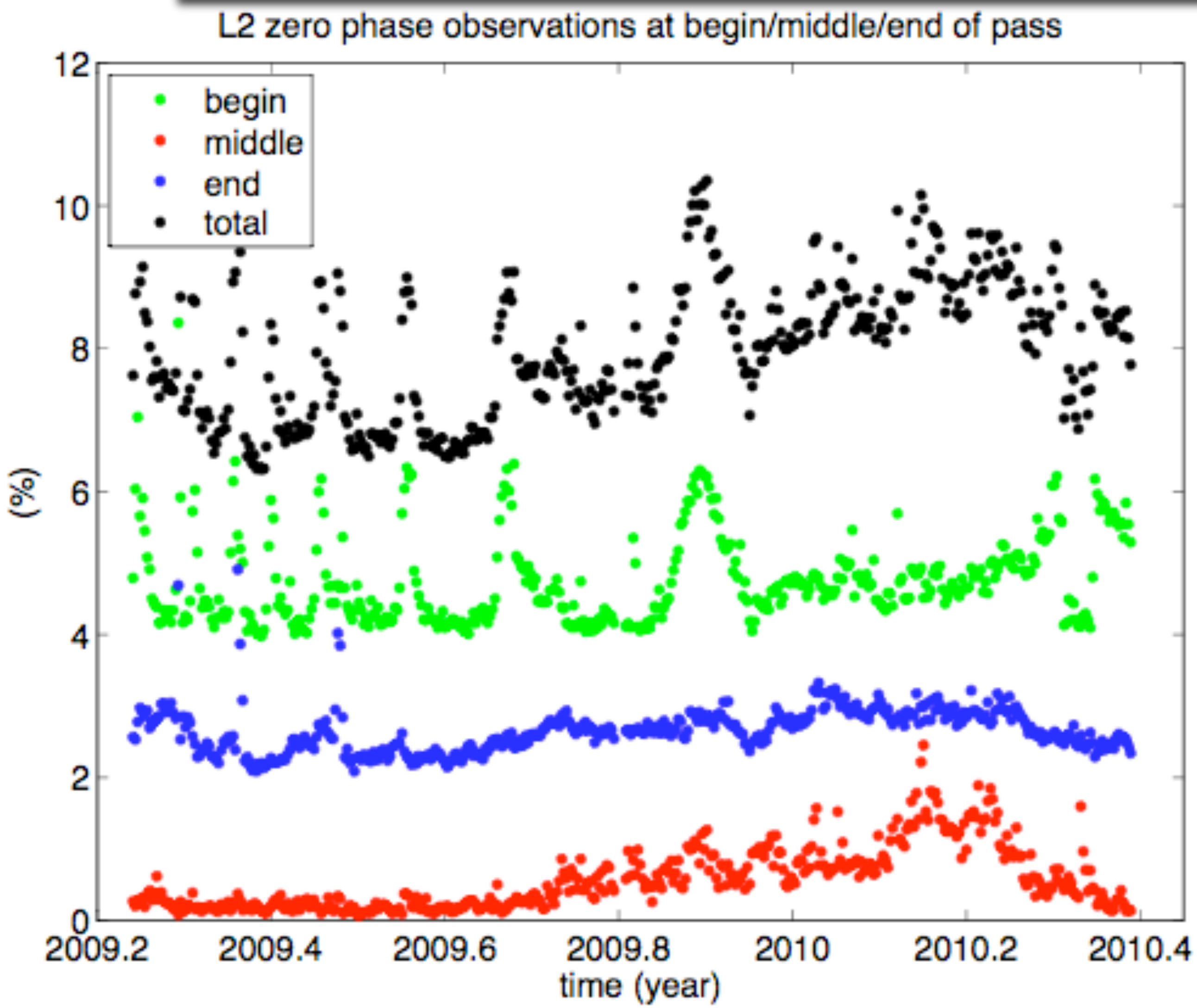
Receiver	RMS phase (mm)
Lagrange	5.6/7.7 (Antex/No)
GRAS	7.5 (no Antex)

GPS BlackJack Receiver performance (CHAMP and GRACE)

Receiver	RMS phase (mm)
CHAMP	no kin.
GRACE-A	5.0 (Antex)



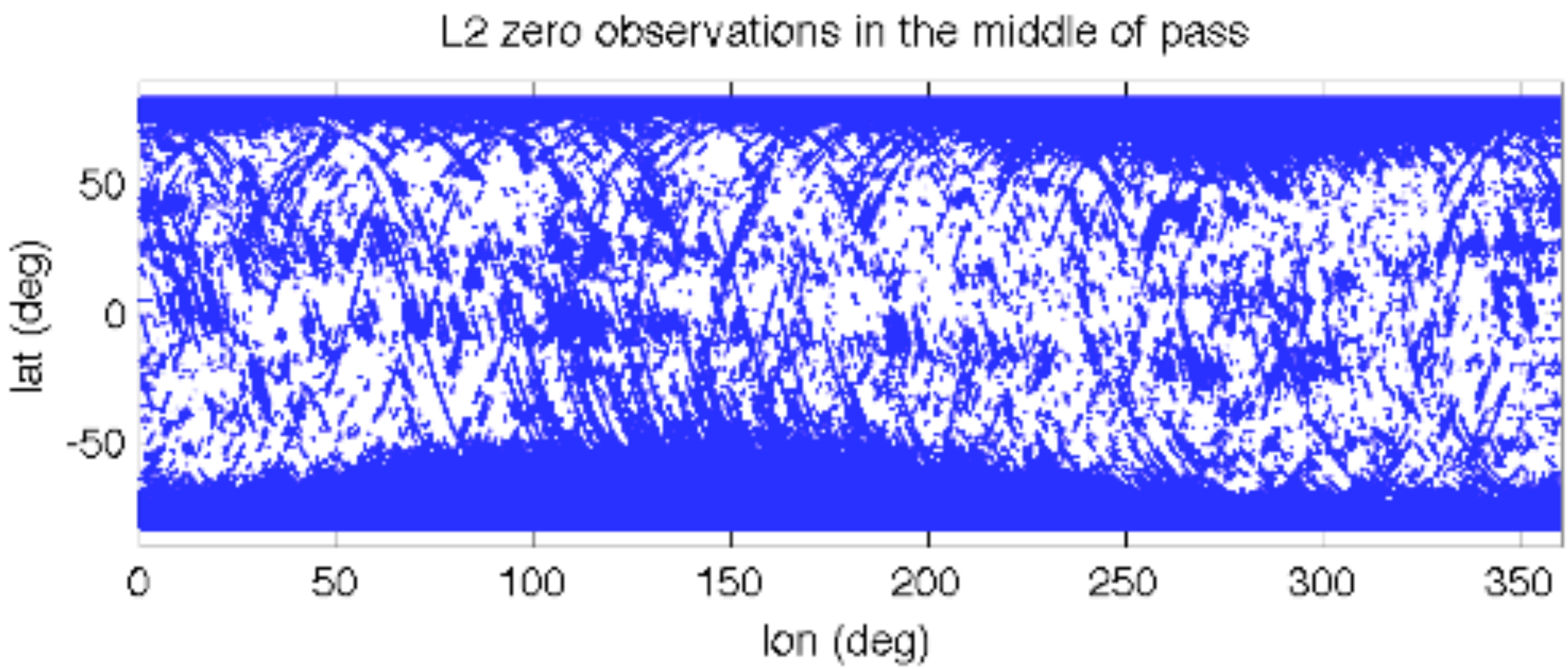
GOCE GPS data: zero L2 observations



Currently the % of zero L2 observations during the middle of a pass is small again

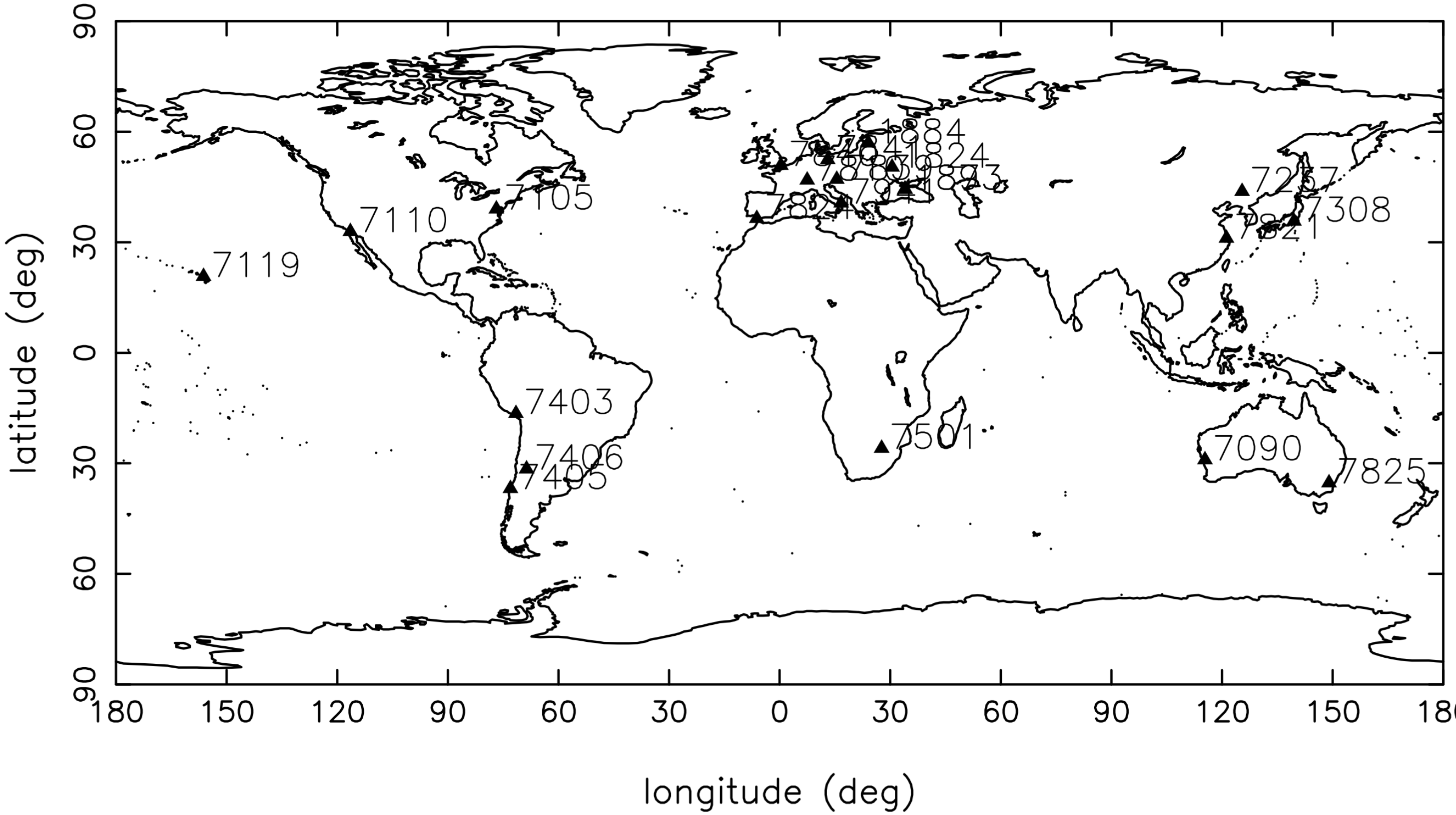
NB: more than sufficient high-quality observations remaining!

GOCE GPS data : zero L2 observations Cont'd



Zero L2 observations during middle of a pass mostly occur at geomagnetic poles as well as on both sides of the geomagnetic equator

GOCE SLR data: used for validation

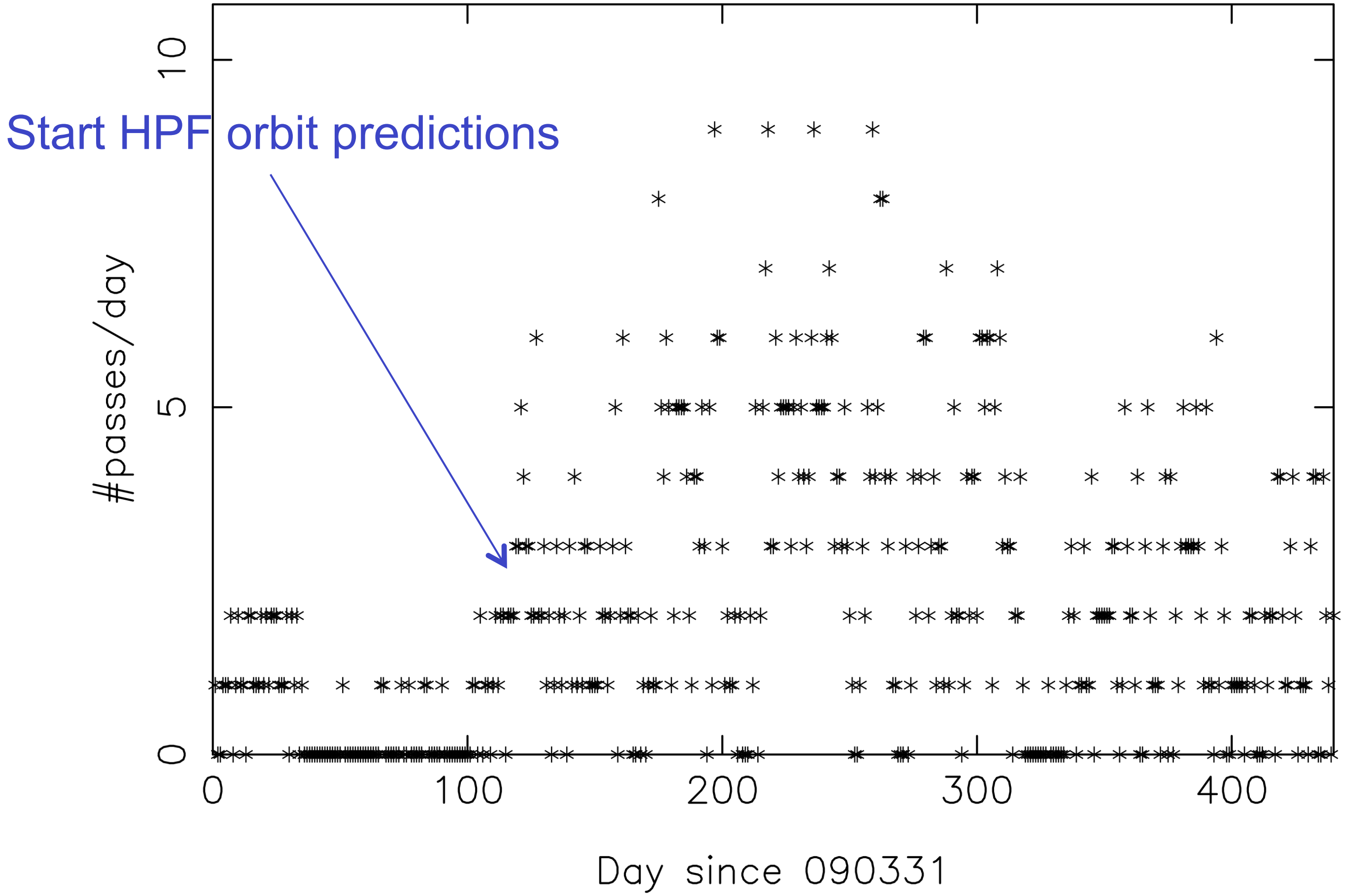


5.4 passes and 95 normal points/day (31 March 2009 – 13 June 2010)

GOCE SLR data

Tracking period	Station	#passes	#obs	
090331 21:42:33 - 100613 11:20:01	7090	286	6333	Yarragadee, Australia
090821 08:56:08 - 100605 09:13:32	7237	114	1265	Changchun, China
090828 05:58:13 - 100611 06:10:42	7839	85	2092	Graz, Austria
090621 22:05:58 - 100428 22:25:55	7105	64	1508	Greenbelt, Maryland
090729 17:14:28 - 100609 06:19:23	7810	51	1078	Zimmerwald, Switzerland
090730 17:15:18 - 100613 17:38:33	7840	47	562	Herstmonceux, United Kingdom
090615 08:17:52 - 100604 08:58:11	7825	38	144	Mt Stromlo, Australia
090924 18:43:08 - 100201 06:43:44	7824	33	540	San Fernando, Spain
090824 06:08:29 - 100606 16:39:56	7841	29	604	Potsdam, Germany
090817 14:01:44 - 100601 14:26:01	7110	25	316	Monument Peak, California
090430 23:06:51 - 100523 23:19:47	7406	24	392	San Juan, Argentina
091013 15:52:18 - 100126 04:06:59	1893	18	208	Katzively, Ukraine
091006 16:26:04 - 100123 15:58:30	1884	15	151	Riga, Latvia
090729 04:26:09 - 100202 03:54:38	7501	14	153	Hartebeesthoek, South Africa
091007 16:18:24 - 100407 16:28:12	7941	10	61	Matera, Italy
090907 10:11:52 - 091125 10:28:37	7405	8	77	Concepcion, Chile
091013 08:21:55 - 100204 09:02:54	7308	7	68	Koganei, Japan
090628 04:02:09 - 100205 04:25:58	7119	7	42	Haleakala, Hawaii
100323 10:42:38 - 100610 10:59:35	7403	6	33	Arequipa, Peru
091122 09:52:28 - 100104 09:46:21	7821	5	64	Shanghai, China
100119 16:14:01 - 100119 16:14:37	1824	1	7	Golosiiv, Ukraine
091201 15:15:55 - 091201 15:18:31	1873	1	5	Simeiz, Ukraine

GOCE SLR data



GOCE orbit generation

	Orbit solution	Software	GPS Observ.	GPS products	Sampling	Data batches	Latency
RSO	reduced-dynamic	GEODYN	triple-diff	IGS rapid	10 sec	24 h	1 day
	kinematic	GHOST	zero-diff	CODE rapid	1 sec	24 h	1 day
PSO	reduced-dynamic	BERNESE	zero-diff	CODE final	10 sec	30 h	7-10 days
	kinematic	BERNESE	zero-diff	CODE final	1 sec	30 h	7-10 days

Precision requirement:
50 cm

Precision requirement:
2 cm

GOCE orbit products

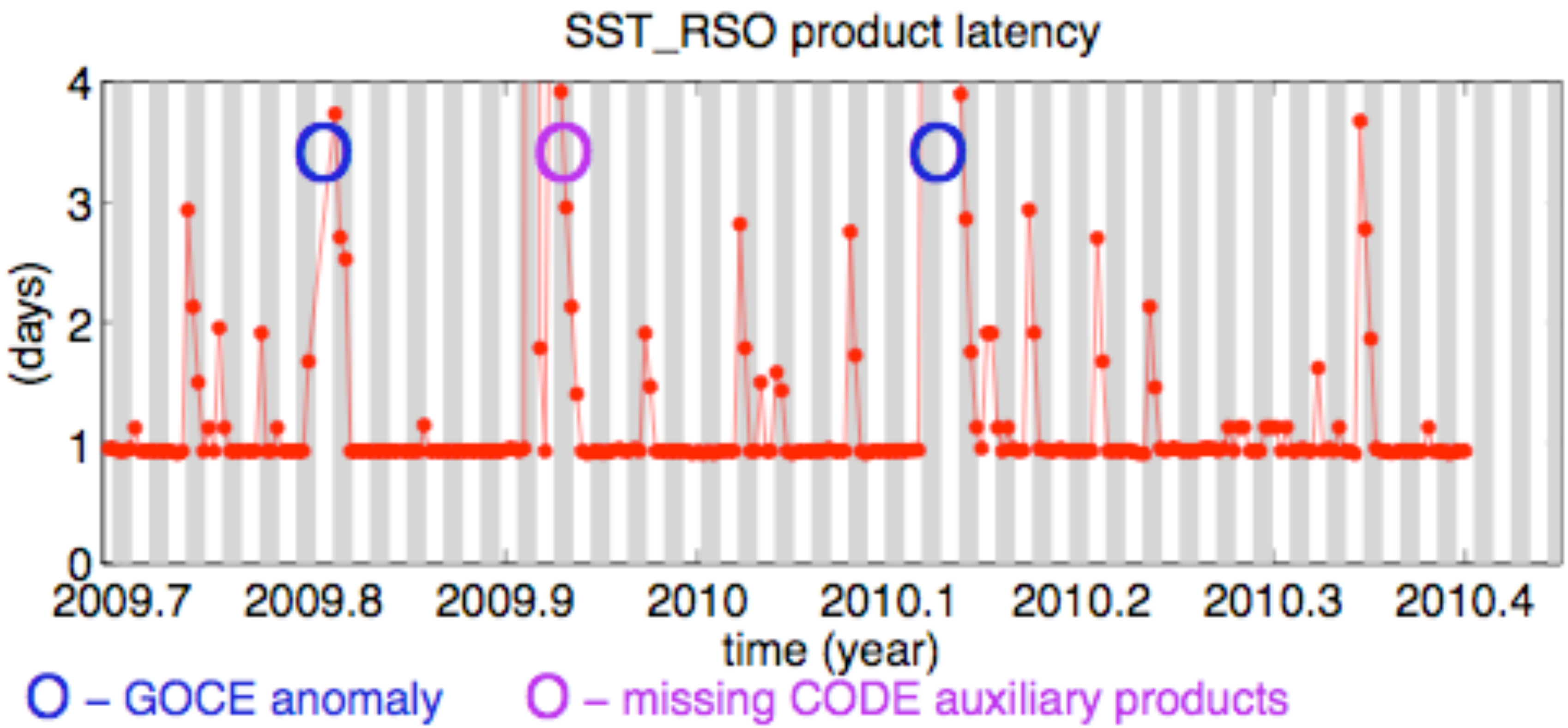
Rapid Science Orbit product (1-day latency):

- Reduced-dynamic orbit solution:
  - SP3 file (position + velocity @ 0.1 Hz) & Observation residuals
- Kinematic orbit solution:
  - SP3 file (position @ 1 Hz) & Observation residuals
- Rotation matrices (J2000 ⟷ ECF)
- Quality Report

Precise Science Orbit product (1-2 weeks latency):

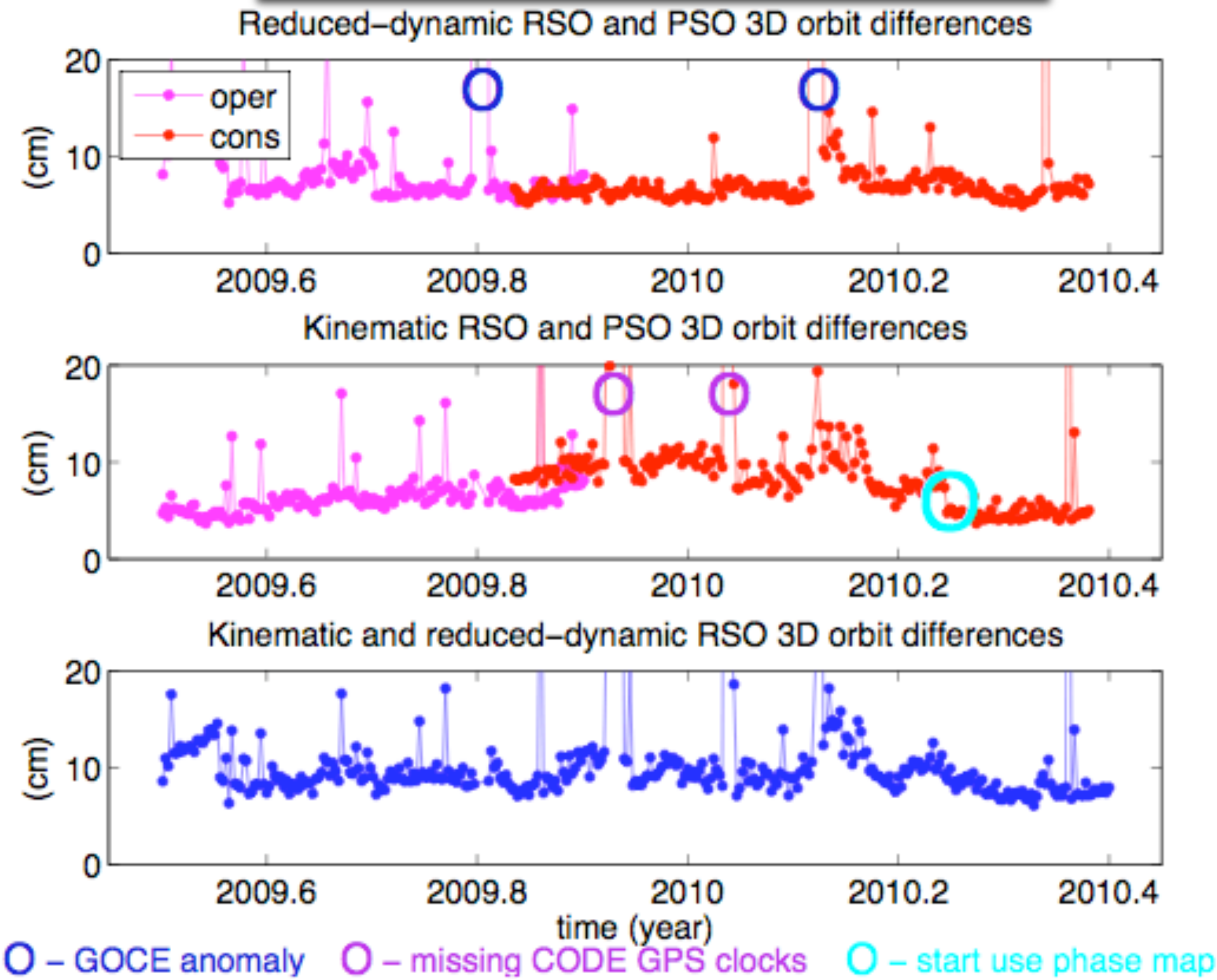
- Reduced-dynamic orbit solution:
  - SP3 file (position + velocity @ 0.1 Hz) & Observation residuals
- Kinematic orbit solution:
  - SP3 file (position @ 1 Hz) & Observation residuals & variance/covariance matrix
- Rotation matrices (J2000 ⟷ ECF)
- Quality Report

RSO latency



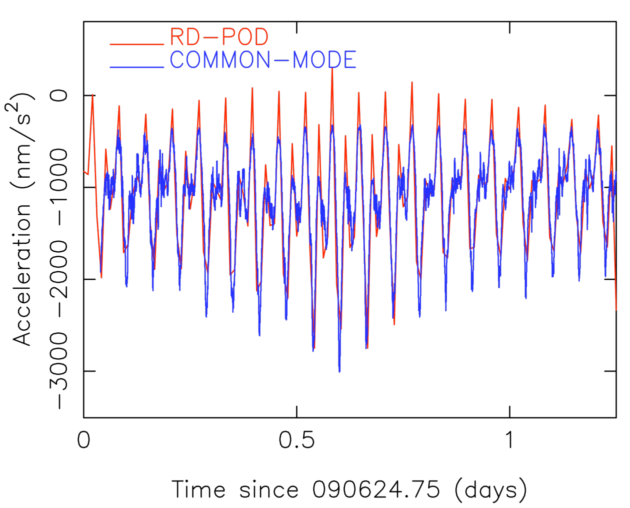
SST_RSO product latency
(days)
0
1
2
3
4
2009.7
2009.8
2009.9
2010
2010.1
2010.2
2010.3
2010.4
time (year)
O – GOCE anomaly
O – missing CODE auxiliary products

Overview RSO performance

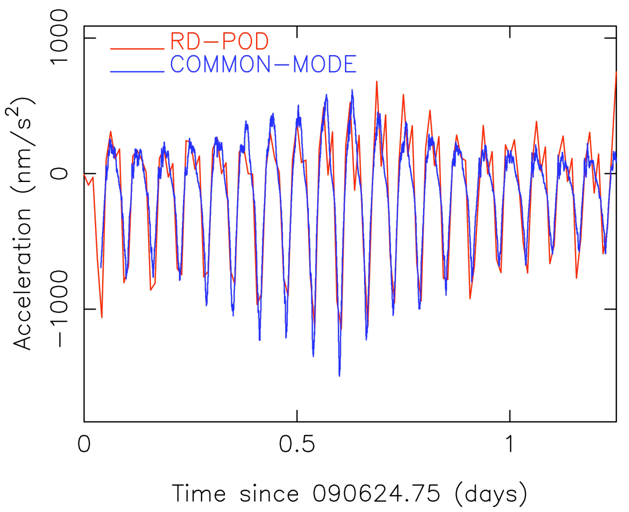


Currently consistency between RSO and PSO is nominally below 1 dm

Spin-off RSO: common-mode vs. accelerations from reduced-dynamic POD (DFC off)

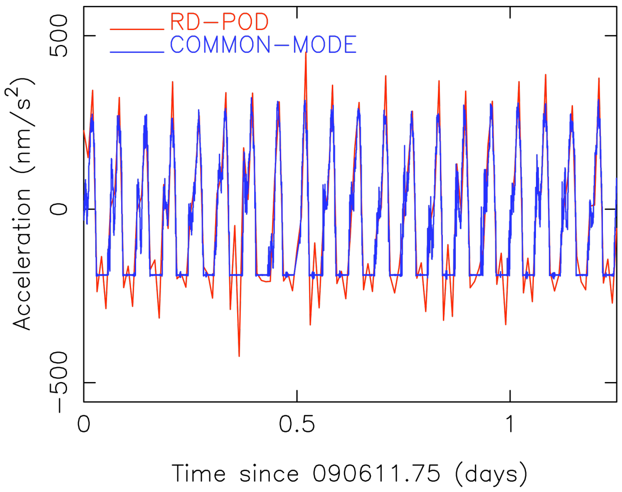


Along-track

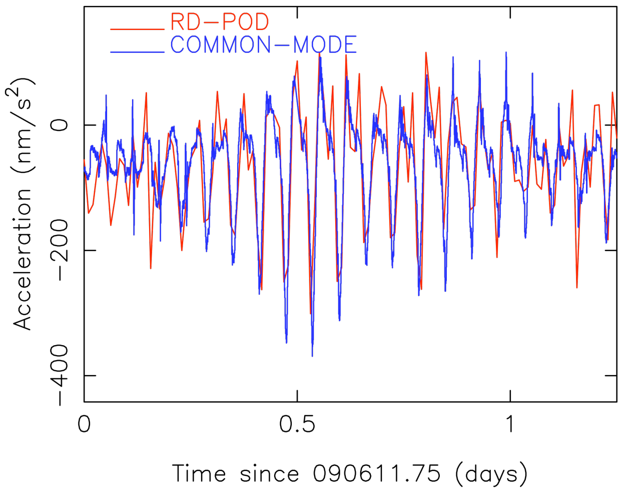


Cross-track

Spin-off RSO: common-mode vs. accelerations from reduced-dynamic POD (DFC on)

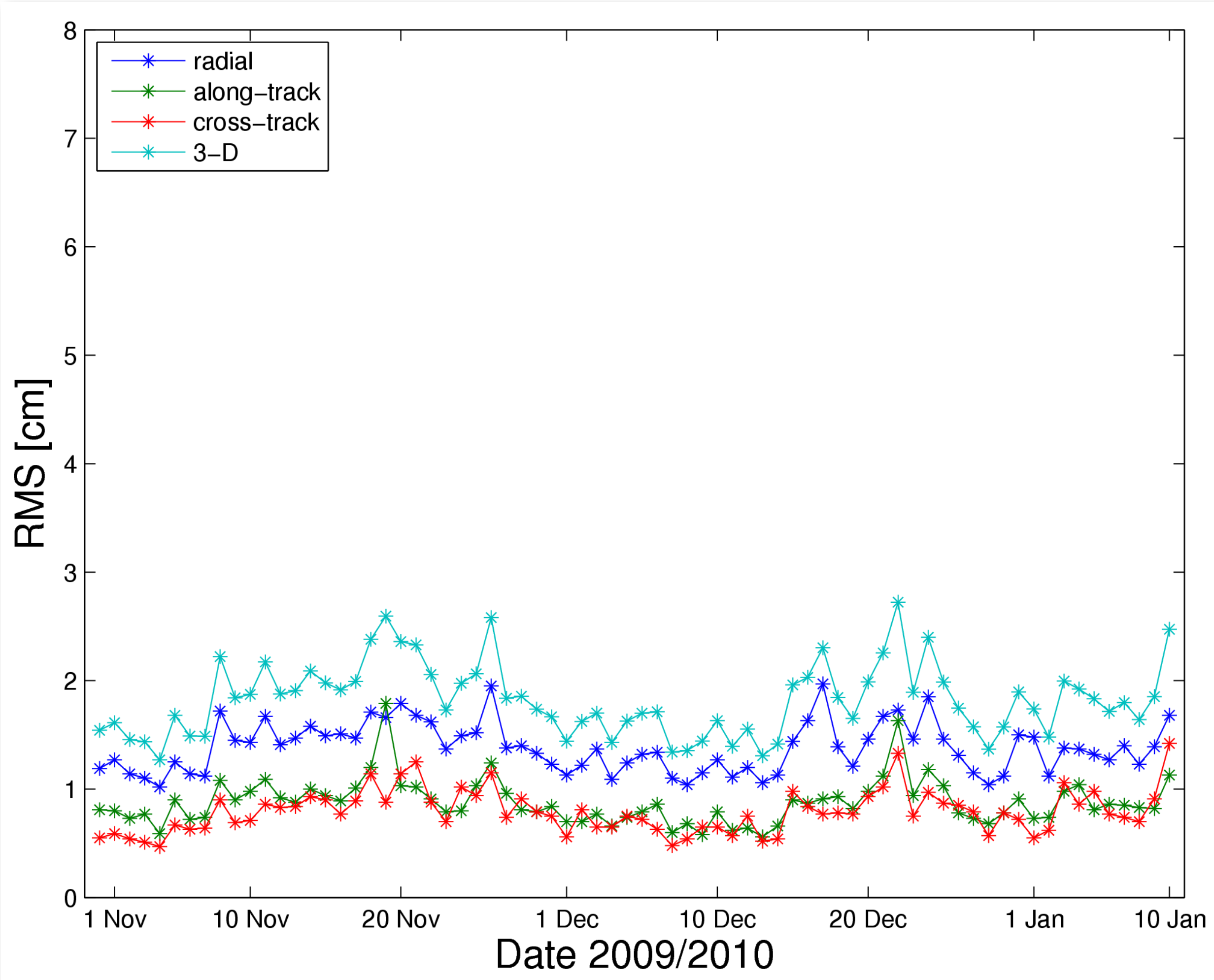


Along-track



Cross-track

PSO: Comparison reduced-dynamic ⇔ kinematic orbits



Consistency between reduced-dynamic and kinematic PSO is at 2 cm

Validation with SLR

	Orbit solution	Mean [cm]	RMS [cm]
RSO	reduced-dynamic	1.29	4.10
	kinematic	0.53	7.14
PSO	reduced-dynamic	0.88	2.05
	kinematic	0.88	2.23

Summary

- Lagrange GPS receiver is state-of-the-art space-borne dual-frequency receiver

- Decent amount of SLR tracking supported by HPF orbit predictions

- Latency and precision requirements are fulfilled:
    - Low latency orbits (RSO): < 10 cm @ 1-day delay
    - Post-processed orbits (PSO): 2 cm @ 1-2 weeks delay

More details

1. Precise Science Orbits for the GOCE Satellite: Aiming at cm-Level Precision, Bock et al., Session 2.3.4 - GOCE: Level 2 data processing and products II, Tuesday, 29 June 2010 - Room 3

2. GOCE Rapid Science Orbits: Achieving Sub-Dm Orbit Precision with Minimal Latency, van den IJssel et al., Poster Session – GOCE, Wednesday, 30 June 2010, 17:40-19:00