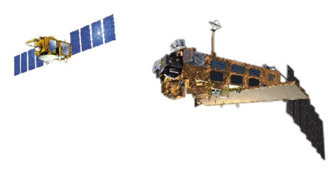
Precise Orbit Determination using SLR and DORIS data for Jason-1 and Envisat

Eelco Doornbos (eelco@deos.tudelft.nl) and Remko Scharroo (remko.scharroo@noaa.gov)
Delft Institute for Earth-Oriented Space Research (DEOS), Delft University of Technology, the Netherlands



Abstract

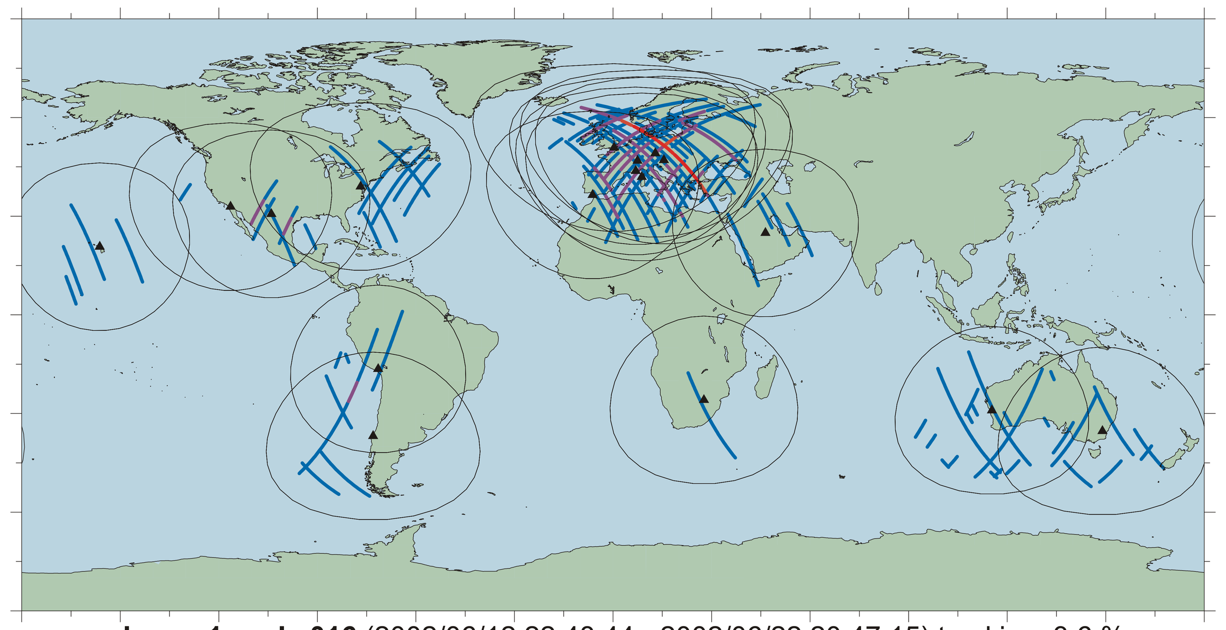
The Jason-1 and Envisat satellites are both equipped with a DORIS receiver and SLR retroreflector, providing highly accurate tracking measurements. The altimeter instruments on both satellites and the GPS receiver on Jason-1 provide independent data for the verification of the orbits. An assessment has been made of the tracking data, force models, measurement models, and of course the orbits themselves. This is done by examining the tracking data and residuals, the force model parameters, comparing orbits, and by testing several models and parameterization strategies. The orbit quality indicators and model parameters suggest that the orbits for both satellites seem to be of the same precision or better than their predecessors, TOPEX/Poseidon and ERS-2.

Models, parameters and data weights

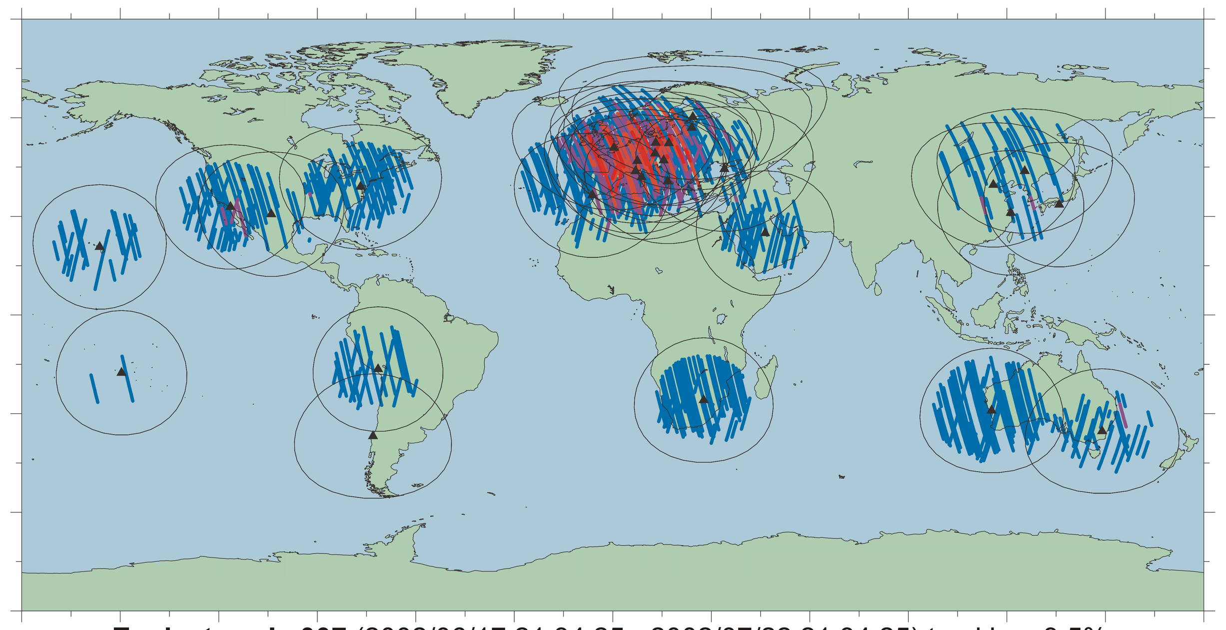
Gravity	Jason-1: JGM-3/GRIM5-C1 Envisat: GRIM5-C1
Atmospheric density	MSIS-86
Satellite surfaces	Jason-1: CNES box-wing; Envisat: ANGARA
Attitude	nominal attitude algorithms*
1-CPR accelerations	four parameters estimated per day (along/cross)
Drag parameters	Jason-1: three per day, Envisat: four per day
Station coordinates	ITRF-2000 with IGN and CSR updates **
DORIS weighting	Jason-1: 0.45 mm/s; Envisat: 0.55 mm/s
SLR weighting	3 cm + station noise

* Attitude algorithms are the same as for TOPEX/Poseidon and ERS-1/2
** ITRF-2000 updates provided by John Ries

SLR tracking data coverage



Jason-1 cycle 016 (2002/06/12 22:48:44 - 2002/06/22 20:47:15) tracking: 3.6 %



Envisat cycle 007 (2002/06/17 21:34:25 - 2002/07/22 21:34:25) tracking: 3.5%

Figures 1 and 2: Ground track plots of SLR tracking for a 10-day repeat cycle of Jason-1 and a 35-day repeat cycle of Envisat. Visibility circles are plotted for each station for altitudes 800 km (Envisat) and 1336 km (Jason-1) and at an elevation of 10°.
Availability of SLR tracking is largely dependent on clear weather conditions at the stations. Because of its higher altitude, Jason-1 passes are longer than Envisat passes. Envisat is more routinely tracked by the Chinese stations.

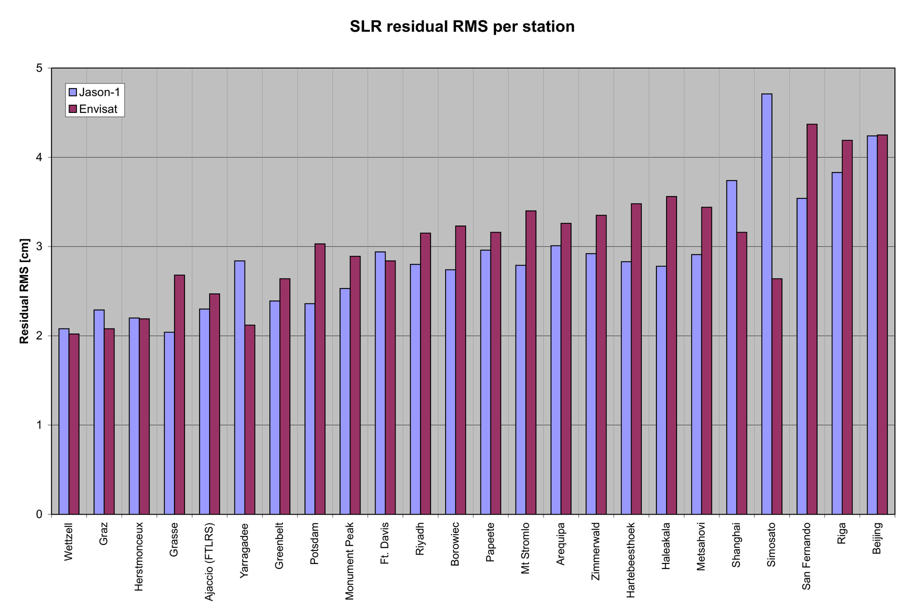
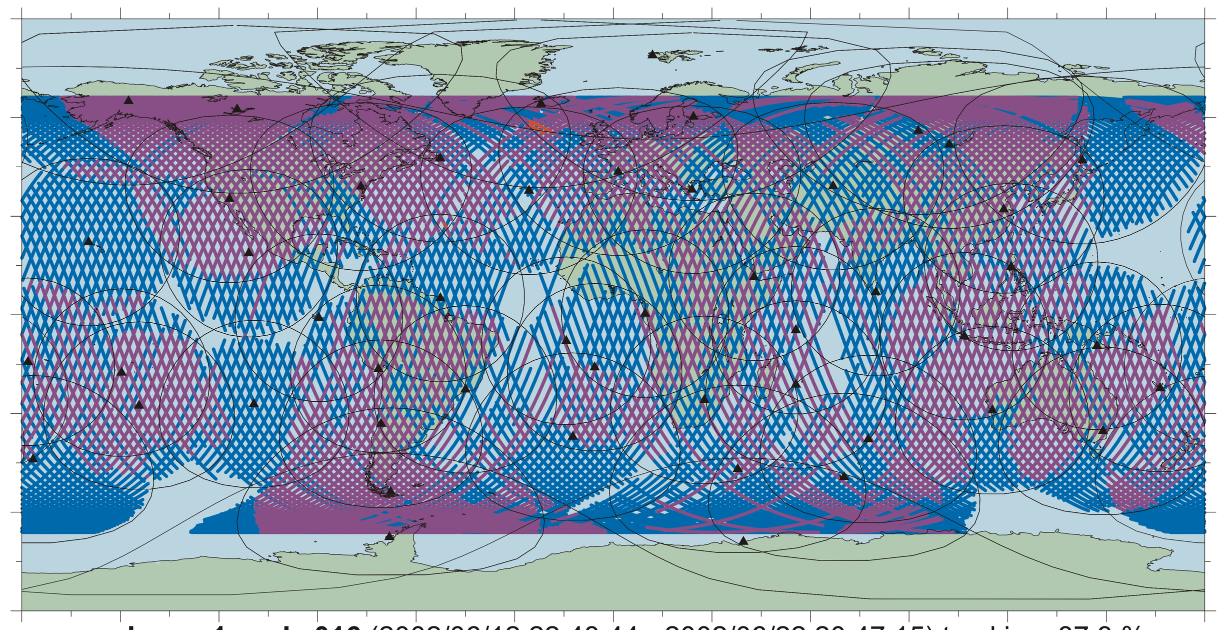
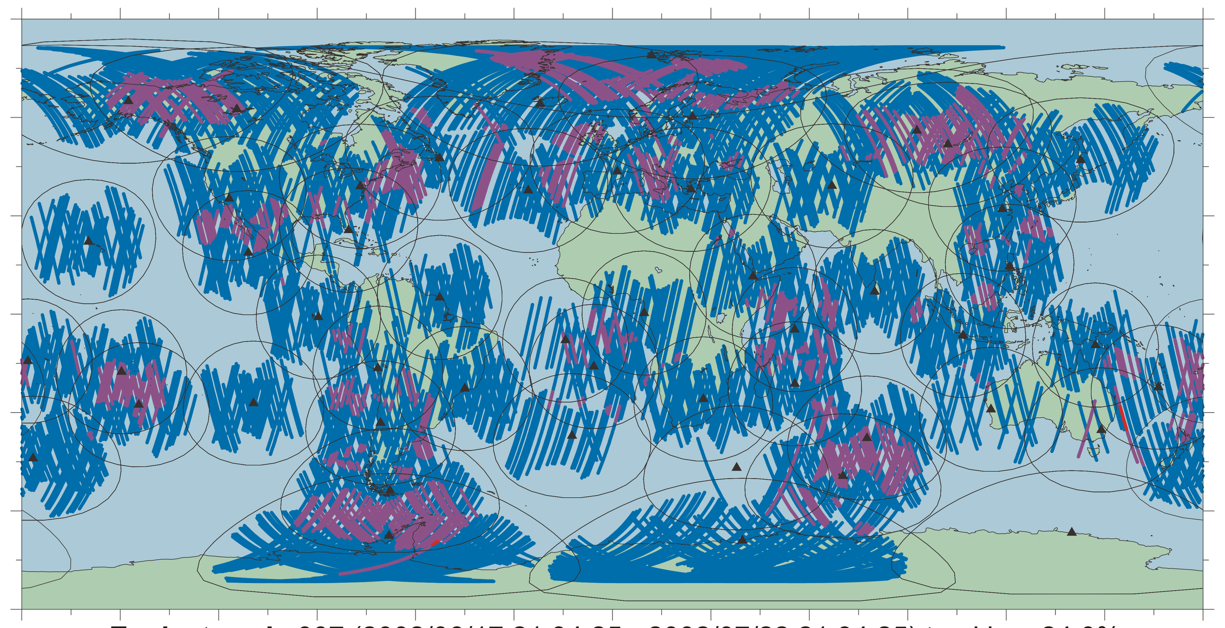


Figure 5: Residual RMS per SLR station. With a few exceptions, Jason-1 fits are a few mm better than Envisat fits. For the most reliable and accurate stations, Jason-1 residuals are at 2.0-3.0 cm, Envisat at 2.0-3.5 cm.

DORIS tracking data coverage



Jason-1 cycle 016 (2002/06/12 22:48:44 - 2002/06/22 20:47:15) tracking: 87.3 %



Envisat cycle 007 (2002/06/17 21:34:25 - 2002/07/22 21:34:25) tracking: 24.0%

Figures 3 and 4: Ground track plots of DORIS tracking for Jason-1 and Envisat. Jason-1 is receiving tracking data nearly 90% of the time by one or two beacons. DORIS on Envisat is not yet at its optimal performance level, in terms of data quantity. This is mainly caused by problems in the Envisat ground segment, which prevent continuous data delivery. The map for Envisat also shows that coverage is limited compared to Jason-1 because of the lower satellite altitude and that high-elevation passes are much shorter than they should be.

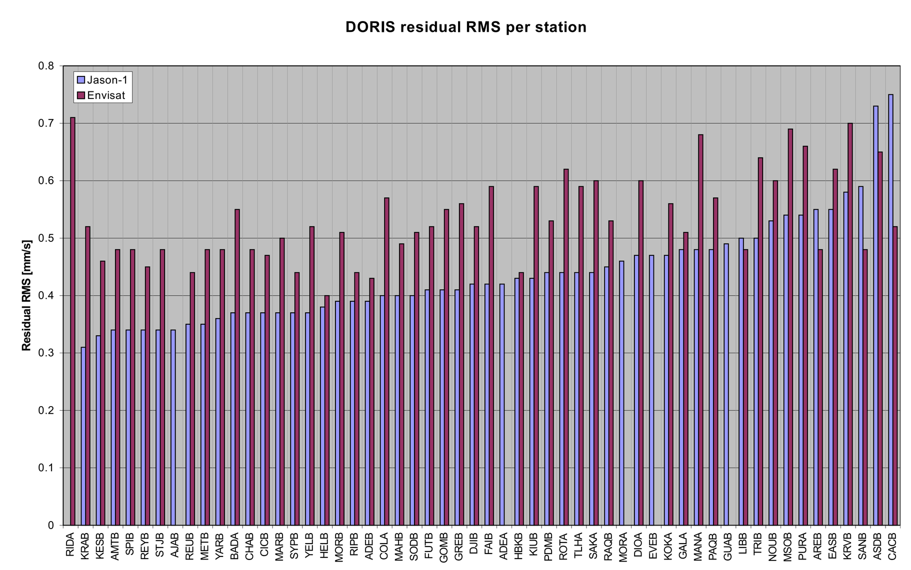
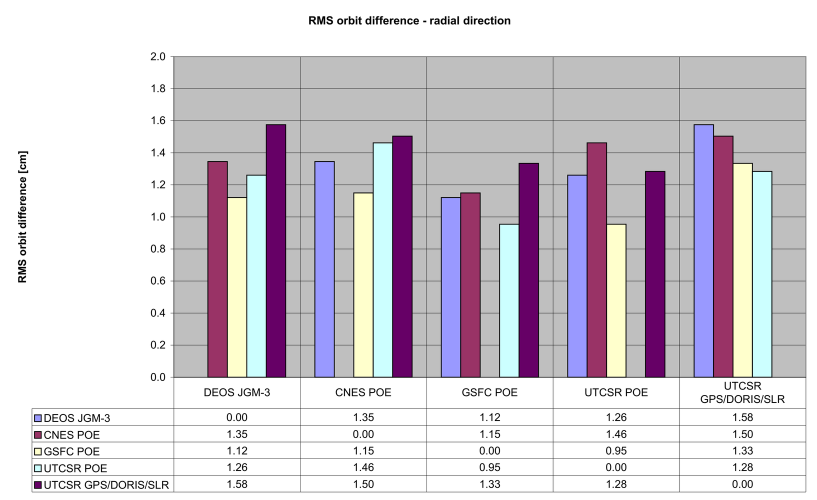
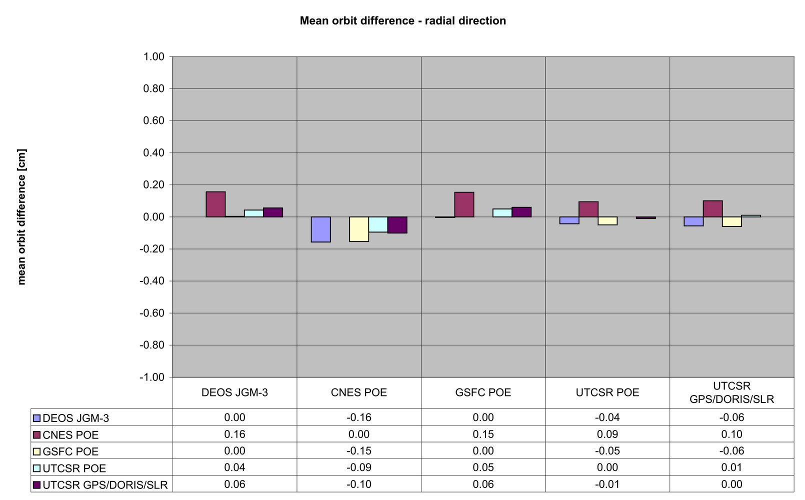


Figure 6: Residual RMS per DORIS station. Stations are sorted from left to right by their RMS fit on Jason-1. Therefore, the South-Atlantic Anomaly stations are all on the right side of the plot. Envisat does not seem to suffer from the same problem, but there are some indications that station coordinates can be improved with Envisat tracking.

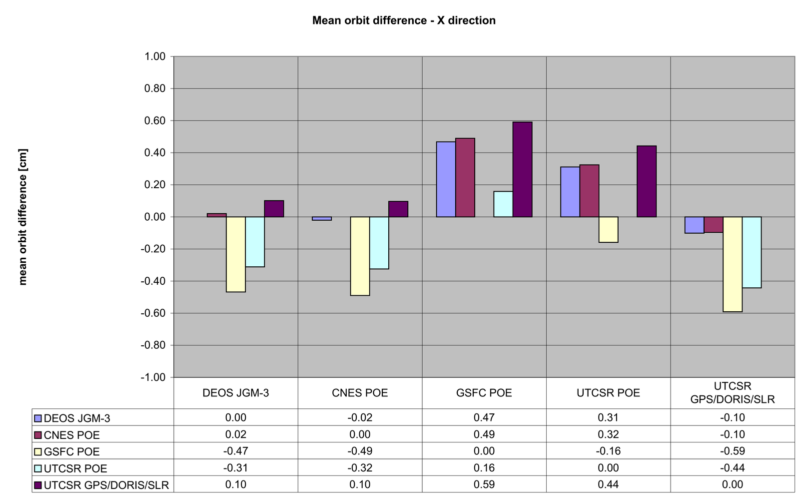
Orbit comparisons: Jason-1 cycle 016

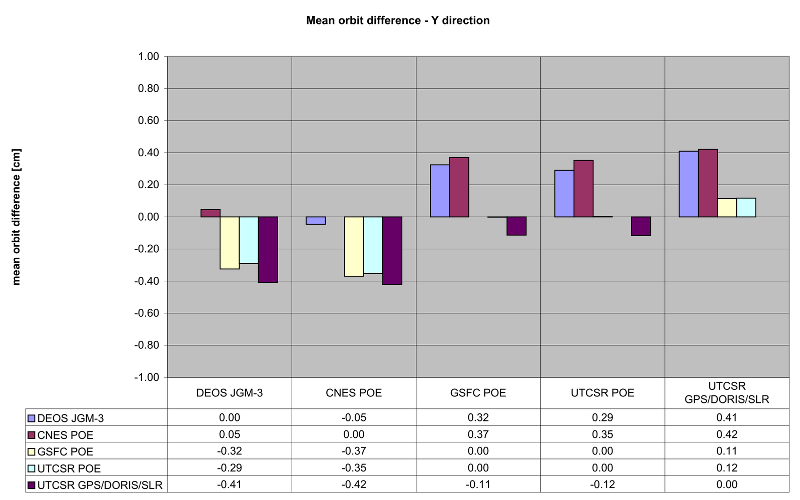


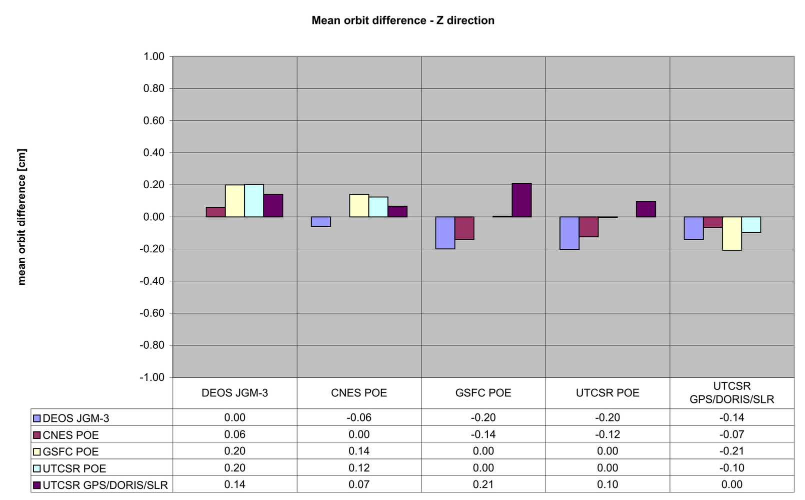


Institute / solution	Crossover stats #	Mean	RMS
DEOS JGM-3	3365	-0.27	6.36
CNES POE	3383	-0.74	6.23
GSFC	3324	0.14	6.26
UTCSR DORIS/SLR	3362	0.50	6.17
UTCSR GPS/DORIS/SLR	3380	0.55	6.14

Table 1: Crossover statistics for the period 2002/06/13 00:00:00 - 2002/06/21 00:00:00







Figures 7-11: These orbit comparison statistics show that the solutions agree to within 1.6 cm RMS in the radial direction. The X, Y and Z mean values are at the level of a few mm's. The crossover statistics in Table 1 show that the CSR solution with GPS data included performs better than the SLR/DORIS solutions. When compared to the other institutes, there should be some room for improvement for the DEOS Jason-1 solutions.

Parameters, weights, models: Jason-1 cycle 016

DORIS weight	Residual RMS SLR	DORIS	Crossover stats #	Mean	RMS
Double	3.0	0.435	5262	-0.51	6.94
Nominal	2.5	0.437	5264	-0.32	6.88
Half	1.7	0.440	5288	-0.15	6.87
Downweight SAA	2.2	0.438	5285	-0.51	6.85

Table 2: Changes in measurement data weights, estimated parameters and models only have a limited influence on the orbits. Downweighting all the DORIS data, or just the stations that are affected by the SAA radiation problem, results in only a slight improvement.

Drag parameter	Residual RMS SLR	DORIS	Crossover stats #	Mean	RMS
4 hours	2.2	0.436	5368	-0.29	6.87
6 hours	2.3	0.436	5368	-0.30	6.87
8 hours	2.5	0.437	5368	-0.25	6.88
12 hours	2.6	0.441	5368	-0.10	6.90

Table 3: Differences in the statistics for different drag parameter estimation periods are even smaller. Shortening the estimation interval seems to have a limited positive effect, but it remains to be investigated if this is also true for low solar activity.

Gravity model	Residual RMS SLR	DORIS	Crossover stats #	Mean	RMS
JGM-3	2.5	0.437	5253	-0.26	6.88
GRIM5-C1	2.2	0.438	5253	-0.33	6.83
TEG4	2.5	0.437	5253	-0.11	6.89
EIGEN-1S	2.3	0.439	5253	-0.06	6.84

Table 4: The GRIM5-C1 and EIGEN-1S gravity models show a slight improvement over JGM-3.

Orbit comparisons: Envisat cycle 7 arc 2

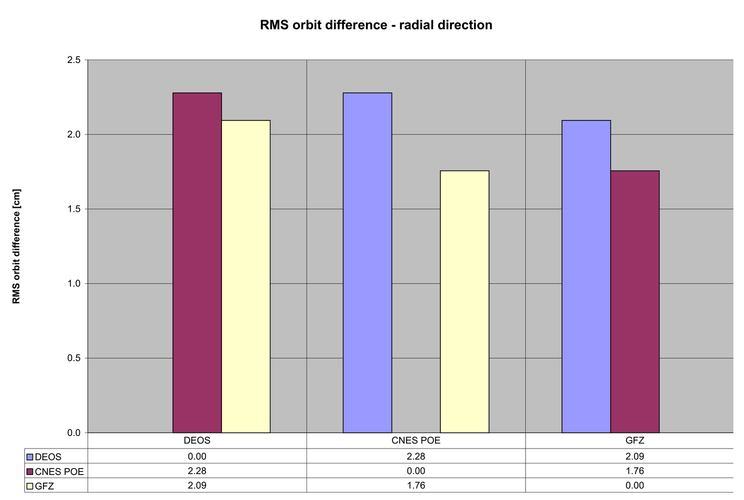


Figure 12: At the time of writing, three orbit solutions were made available for comparison: CNES, GFZ and DEOS. Radial orbit difference RMS for these solutions is generally at the level of 1.5 to 2.5 cm. Altimetry data and more orbit solutions are required for a more detailed analysis.

Models: Envisat cycle 7

Gravity model	Residual RMS SLR	DORIS
DGM-E04	4.2	0.540
GRIM5-C1	2.8	0.528
TEG4	3.1	0.530
EIGEN-1S	3.2	0.534

Table 5: The GRIM5-C1 gravity model clearly gives the lowest residuals for Envisat. Whether this also reflects the best radial orbit accuracy remains to be seen when the orbits are applied to Envisat altimeter data. Tests on ERS-2 indicate that DGM-E04 orbits still result in the lowest crossover RMS.

DEOS 5.5-day arcs

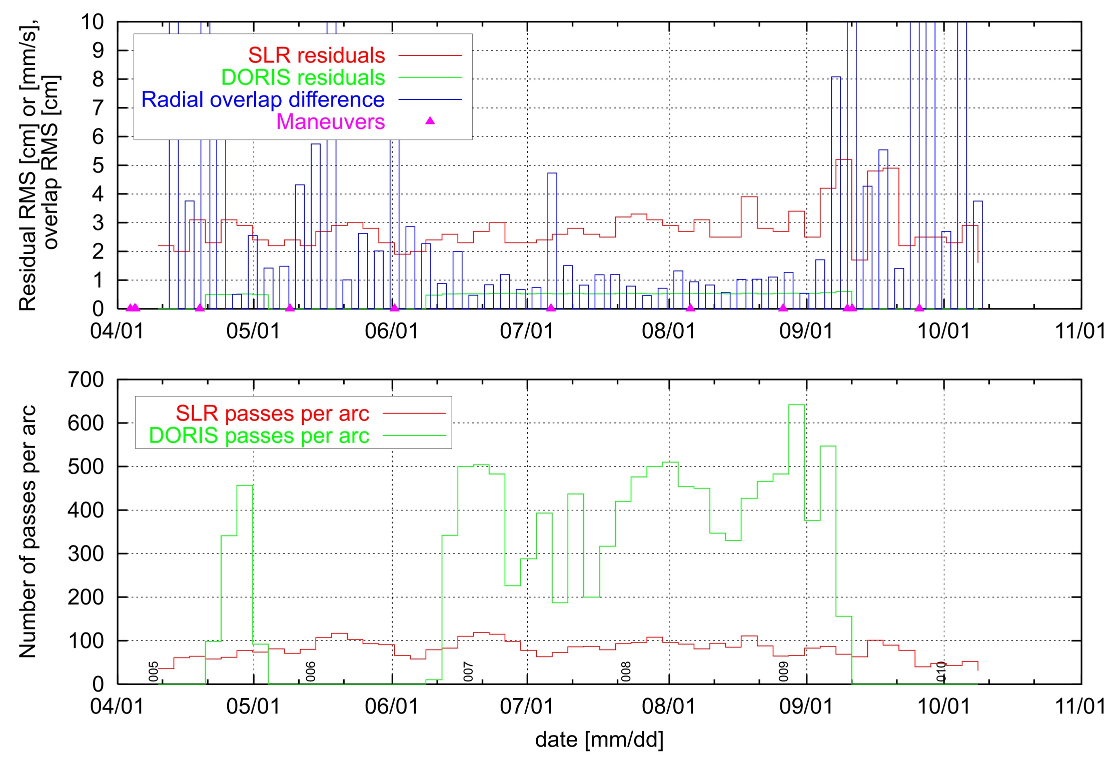


Figure 13: For the past ten years, DEOS has been computing ERS orbits in 5.5-day arcs. This tradition is continued with Envisat. This Figure shows the initial results. These orbits are based on SLR data, and DORIS data where available. On the SLR-only orbits, both the radial overlap RMS and SLR residual RMS per arc surpass those figures for ERS-2. It is clear from this plot that for the periods where DORIS data was available, the radial overlap RMS is significantly lower than for the SLR-only arcs. The 'outliers' in the radial overlaps can all be related to periods with maneuvers or sparse SLR tracking.

Conclusions and outlook

Despite known problems in Envisat's ground segment and on Jason-1's DORIS receiver over the South-Atlantic Anomaly, the initial orbit determination results for these satellites look quite encouraging. In fact, these orbits seem to be already at the same quality level or better than their predecessors, ERS-2 and TOPEX/Poseidon. However, much work needs to be done, especially for Envisat. Because of its low-altitude orbit, additional gains can certainly be expected during its lifetime from advances in force modelling.