DORIS-related activities at GFZ

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Recent activities in Altimeter Satellite Orbit Modeling and Determination

- Detailed tests on using 7 tropospheric refraction models (Yionoulis and Hopfield, Hopfield, Saastamoinen, Davis, Niell, Global Mapping Function (GMF), Vienna Mapping Function 1) for the correction of DORIS observations for Envisat (2002 - 2012), TOPEX/Poseidon (1992-2005) and Jason-1 (2002-2013) precise orbit determination were performed.
- Detailed tests on using GFZ Atmosphere and Ocean De-aliasing Level 1B (AOD1B) RL05 product (maximum degree and order 100) instead of RL04 one (maximum degree and order 50) and no atmospheric gravity data at all for ERS-1 (1991-1996), ERS-2 (1995-2006), TOPEX/Poseidon (1992-2005), Envisat (2002-2012) and Jason-1 (2002-2012) precise orbit determination were done.
- A new orbit solution was computed for Envisat by using, additionally to SLR, also DORIS data and denser parameterization from 12.04.2012 till 12.06.2012.
- A new geopotential model EIGEN-6S2.extended.v2 was tested for Envisat and Jason-1.
- New orbits of Envisat, TOPEX/Poseidon, Jason-1 and Jason-2 have been computed and analyzed.

Precise orbits of Jason-1 (2002-2013) computed at GFZ

- CCI01 orbit based on using EIGEN-GL04S geopotential model
- CCI02 orbit based on using EIGEN-6S2 geopotential model
- Seven CCI02_DOR01-DOR07 orbits derived using seven tropospheric refraction models for the correction of DORIS observations
- CCI06 orbit derived using DORIS data corrected for the South Atlantic Anomaly (SAA)
- CCI09 orbit derived using AOD1B RL05 product instead of RL04 one
- CCI10 orbit computed using

  - EIGEN-6S2 geopotential model (until 2012.0)

  and EIGEN-6S2.extended.v2 geopotential model (after 2012.0),

  - SAA corrected DORIS data used until January 7, 2012,

  - Vienna Mapping Function 1 (VMF1) as a tropospheric refraction model

  for the correction of DORIS observations,

  - AOD1B RL05 product,

  - improved parameterization at some orbital arcs.
- CCI11 orbit: the same as CCI10 orbit, but SAA-corrected DORIS data used over the whole mission

The main models used for precise orbit determination

Parameter	SLCCI phase 2 project (VER08 orbits)	SLCCI phase 1 project (VER06 orbits)
Terrestrial Reference Frame	ITRF2008	ITRF2008
Polar motion and UT1	IERS EOP 08 C04 (IAU2000A)	IERS EOP 08 C04 (IAU2000A)
Precession and nutation model	IERS Conventions 2010	IERS Conventions 2010
Gravity field model (static)	EIGEN-6S2.extended.v2	EIGEN-6S2
Gravity field model (time varying)	EIGEN-6S2.extended.v2	EIGEN-6S2
Tropospheric correction for DORIS observations	Vienna Mapping Function 1	Hopfield model
Solid Earth and pole tide	IERS Conventions 2010	IERS Conventions 2010
Ocean tides	EOT10A	EOT10A
Atmospheric tides	Biancale and Bode (2006)	Biancale and Bode (2006)
Atmospheric gravity	GFZ AOD1B RL05 based on ECMWF 6-hourly fields up to degree and order 100	GFZ AOD1B RL04 based on ECMWF 6-hourly fields up to degree and order 50
Third bodies	Sun, Moon, all 8 major planets (DE-421)	Sun, Moon, all 8 major planets (DE-421)

The main parameters of the geopotential models used

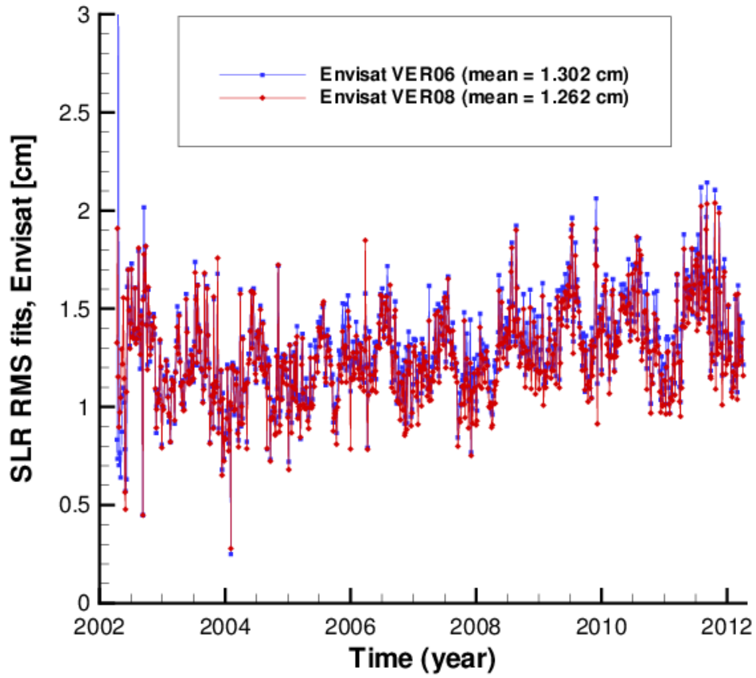
Parameter		EIGEN-6S2 (VER6)	EIGEN-6S2. extended.v2 (VER8)
Maximal degree and order		260	260
Truncation level		90	90
Reference epoch		Coefficient specific	Coefficient specific
$C_{2,0}$		Time dependant	Time dependant
$C_{2,0}$dot (1950.0-1985.0)		0.0	0.0
$C_{2,0}$dot (1985.0-2012.0)		A yearly time series	A yearly time series
$C_{2,0}$dot (2012.0-2014.0)		0.0	A yearly time series
$C_{2,0}$dot (2014.0-2050.0)		0.0	0.0
$C_{3,0}$dot - $S_{50,50}$dot (1950.0-2003.0)		0.0	0.0
$C_{3,0}$dot - $S_{50,50}$dot (2003.0-2012.0)		A yearly time series	A yearly time series
$C_{3,0}$dot - $S_{50,50}$dot (2012.0-2014.0)		0.0	A yearly time series
$C_{3,0}$dot - $S_{50,50}$dot (2014.0-2050.0)		0.0	0.0

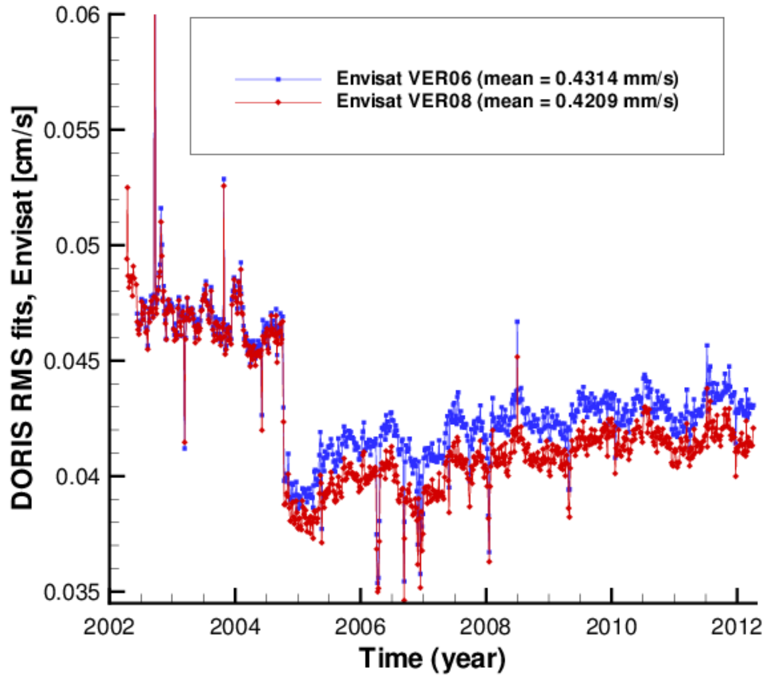
The main differences of the VER08 orbits w.r.t. VER06 orbits

The differences (improvements)	ERS-1	ERS-2	Envisat	TOPEX	Jason-1
AOD1B RL04 → RL05	Yes	Yes	Yes	Yes	Yes
AOD1B truncation level: 50 → 100	Yes	Yes	Yes	Yes	Yes
Improvement of parametrization at some orbital arcs	Yes	Yes	Yes	Yes	Yes
Use of VMF1 instead of Hopfield model for DORIS troposp. correction	-		Yes	Yes	Yes
Use of the EIGEN-6S2.extended.V2 geopotential model (after 2012.0)	-	–	Yes	–	Yes
Use additionally DORIS data at some time spans (Envisat, Apr.-Jun. 2002)	-	–	Yes	–	–
Correction of DORIS data for the South Atlantic Anomaly	–	–	–	–	Yes

Results of precise orbit determination for Envisat

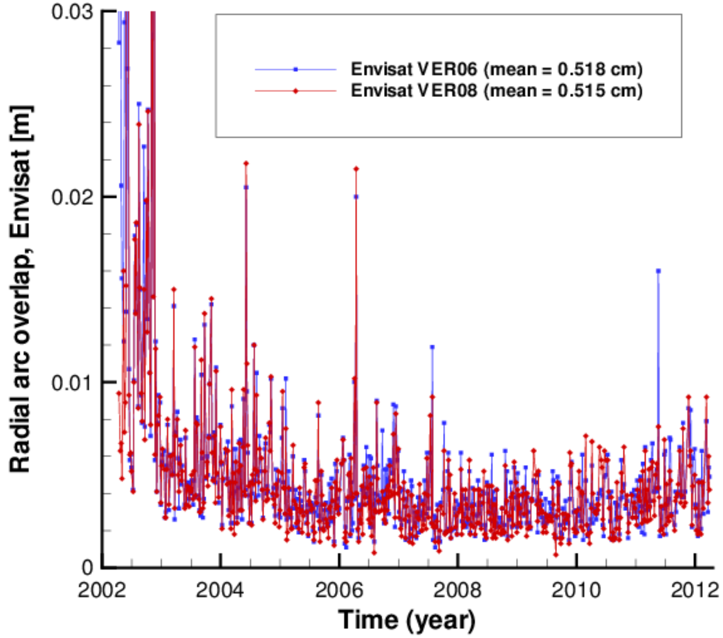
Improvement of RMS fits of observations for Envisat (April 2002 – April 2012): CCI33 (VER08) orbit versus CCI14 (VER06) orbit

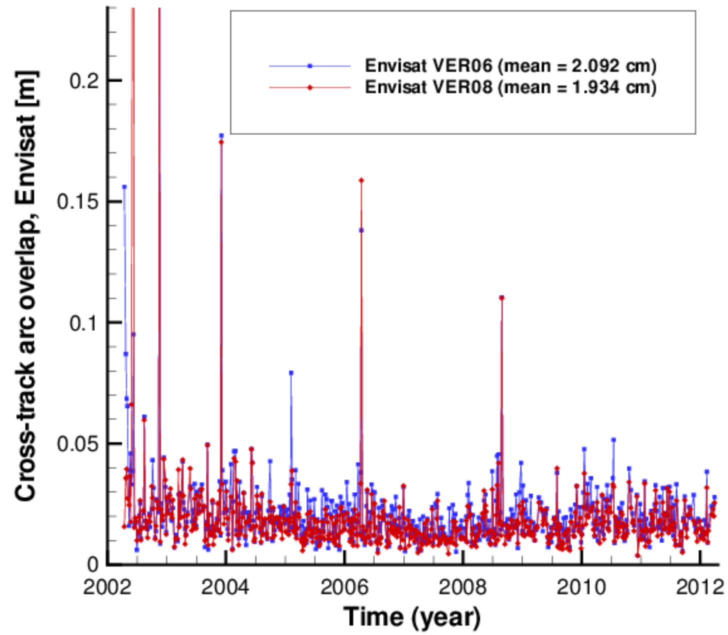


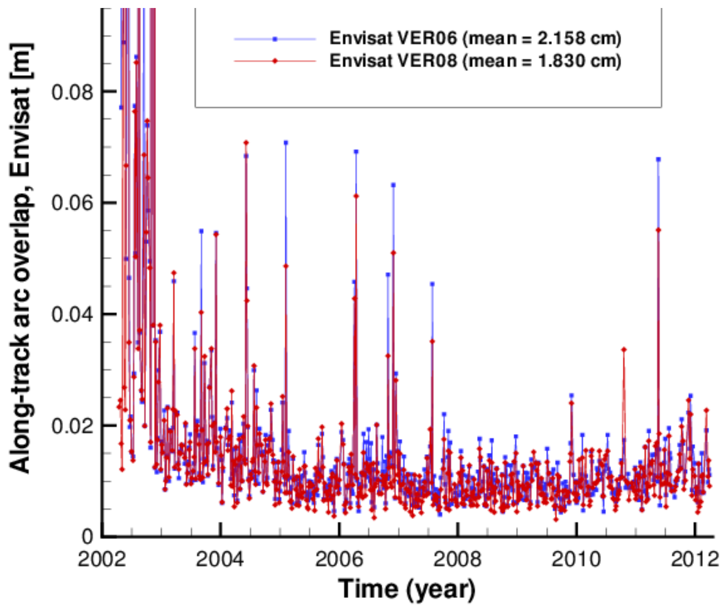


- The mean value of the SLR RMS fits reduced from 1.302 to 1.262 cm, i.e. by 0.04 cm (about 3.1%) for the VER08 orbit, as compared to the VER06 orbit;
- The mean value of the DORIS RMS fits reduced from 0.4314 mm/s to 0.4209 mm/s, i.e. by 0.0105 mm/s (about 2.4%) for the VER08 orbit, as compared to the VER06 orbit.

Two-day arc overlaps for Envisat: VER08 orbit versus VER06 orbit







Reduction of the mean values
of the arc overlap of VER08 orbit,
as compared to VER06 orbit:
Radial – from 0.518 to 0.515 cm,
i.e. by 0.003 cm (about 0.6%),
Cross-track – from 2.092 to 1.934 cm,
i.e. by 0.158 cm (about 7.6%),
Along-track – from 2.158 to 1.830 cm,
i.e. by 0.328 cm (about 15.2%)

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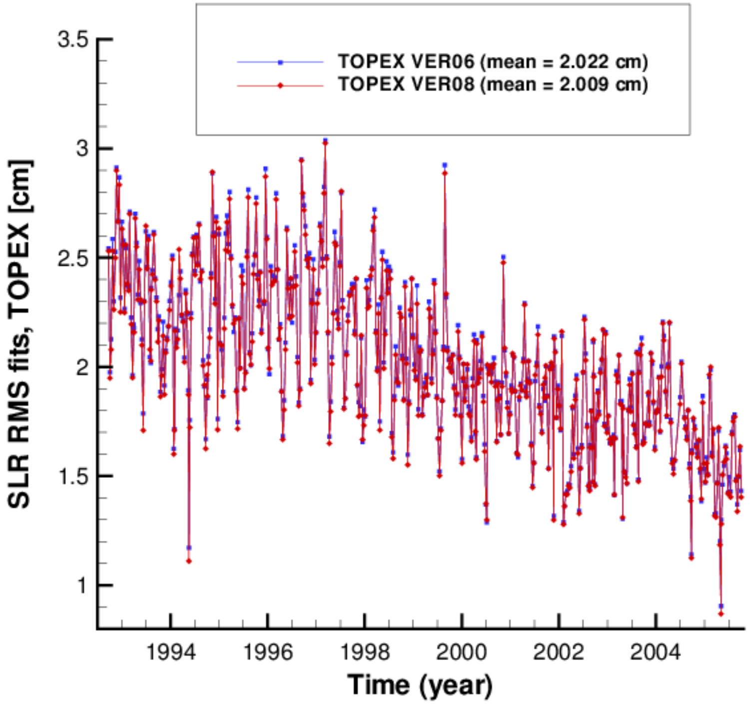
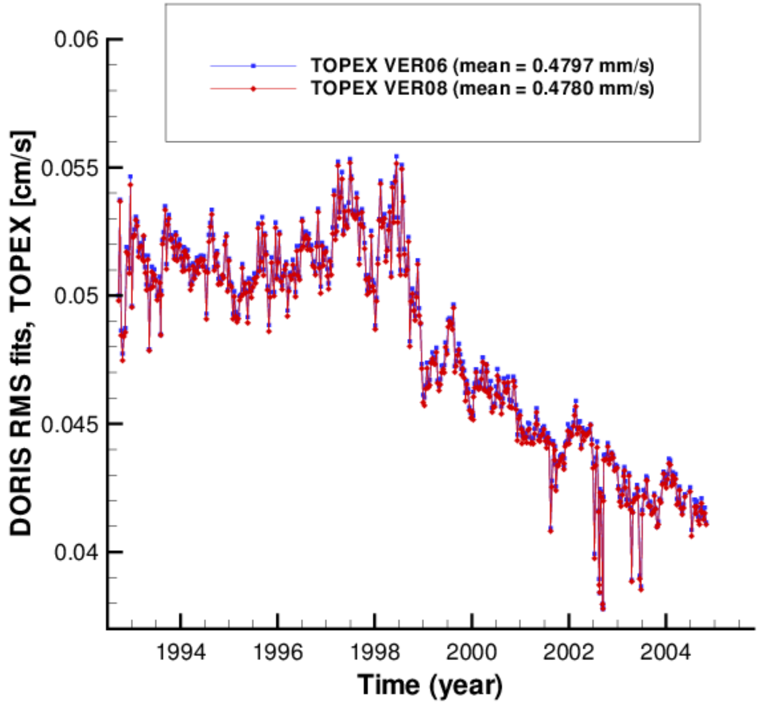
Results of precise orbit determination for TOPEX/Poseidon

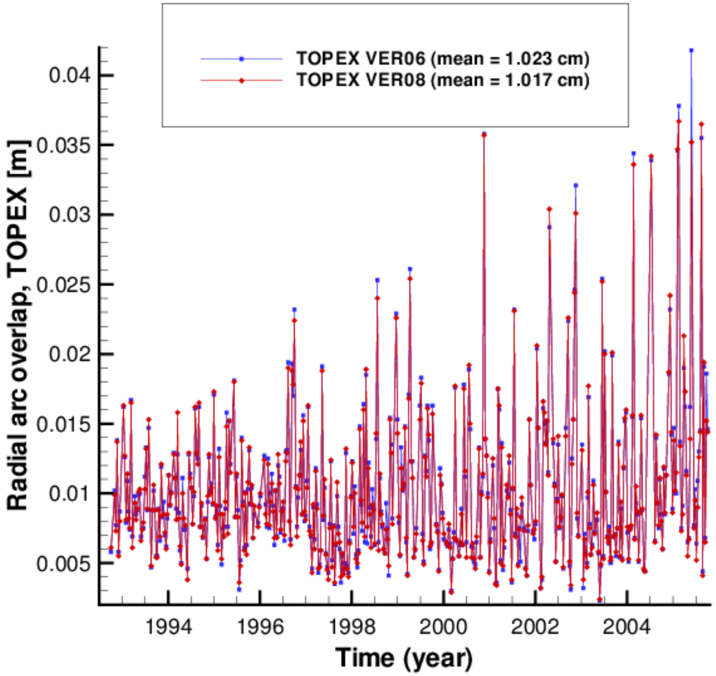
Improvement of RMS fits of observations for TOPEX/Poseidon (September 1992 – October 2005): CCI10 (VER08) orbit versus CCI05 (VER06) orbit

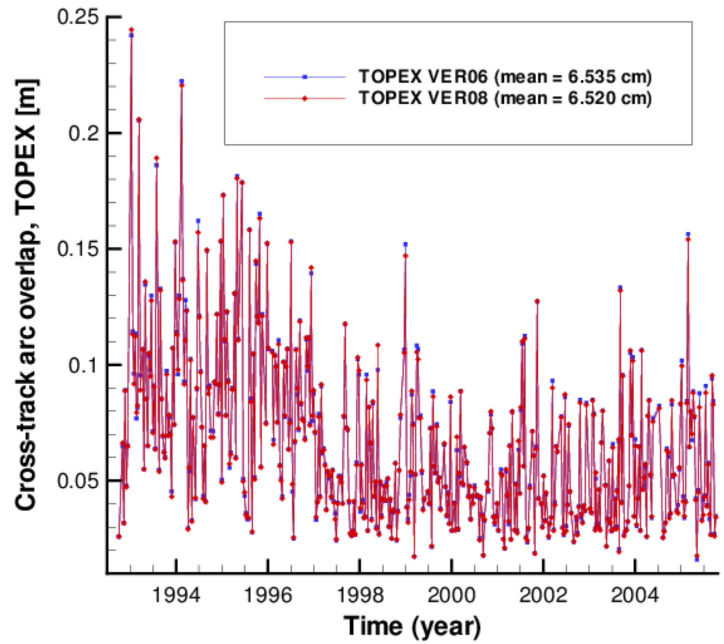


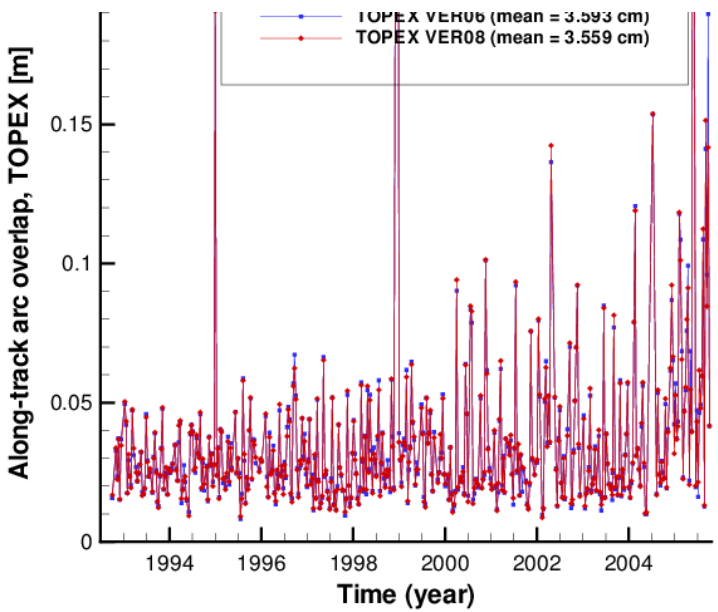


- The mean value of the SLR RMS fits reduced from 2.022 to 2.009 cm, i.e. by 0.013 cm (about 0.6%) for the VER08 orbit, as compared to the VER06 orbit;
- The mean value of the DORIS RMS fits reduced from 0.4797 mm/s to 0.4780 mm/s, i.e. by 0.0017 mm/s (about 0.4%) for the VER08 orbit, as compared to the VER06 orbit.

Two-day arc overlaps for TOPEX: VER08 orbit versus VER06 orbit



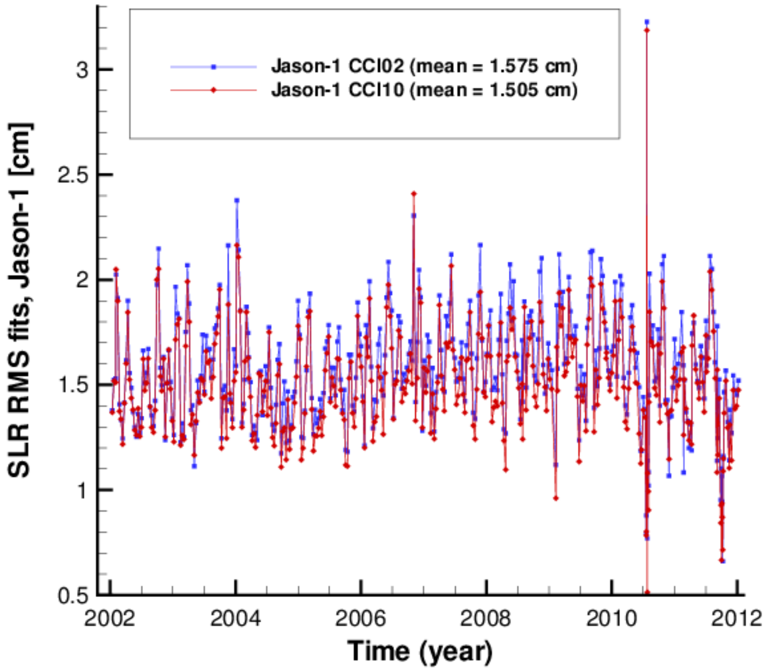


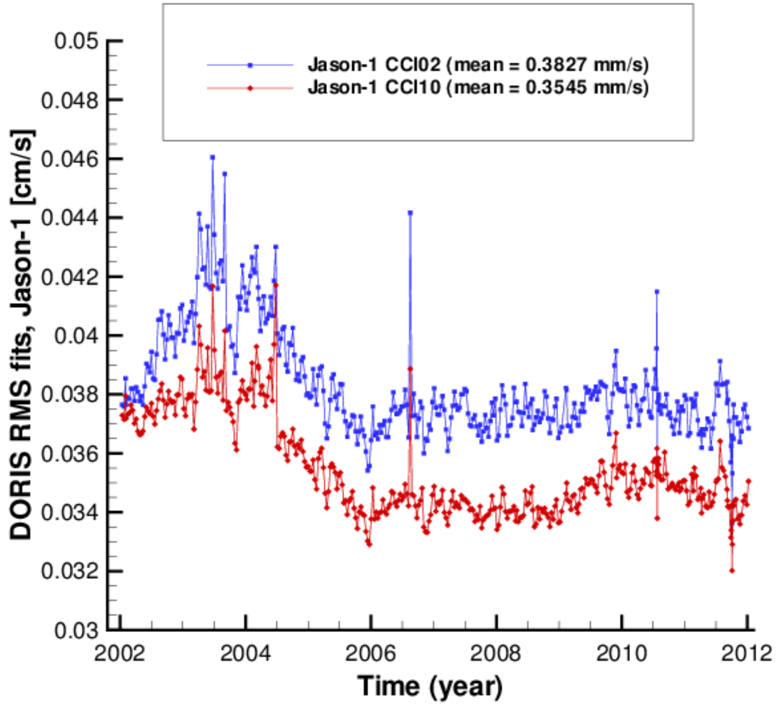


Reduction of the mean values
of the arc overlap of VER08 orbit,
as compared to VER06 orbit:
Radial – from 1.023 to 1.017 cm,
i.e. by 0.006 cm (about 0.6%),
Cross-track – from 6.535 to 6.520 cm,
i.e. by 0.015 cm (about 0.2%),
Along-track – from 3.593 to 3.559 cm,
i.e. by 0.034 cm (about 0.9%)

Results of precise orbit determination for Jason-1

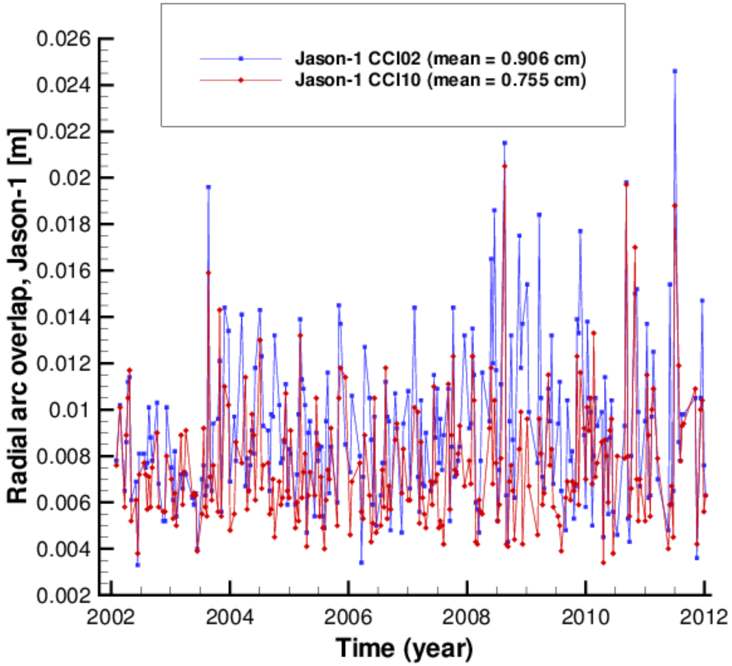
Improvement of RMS fits of observations for Jason-1 (13 January 2002 – 18 January 2012): CCI10 (VER08) orbit versus CCI02 orbit

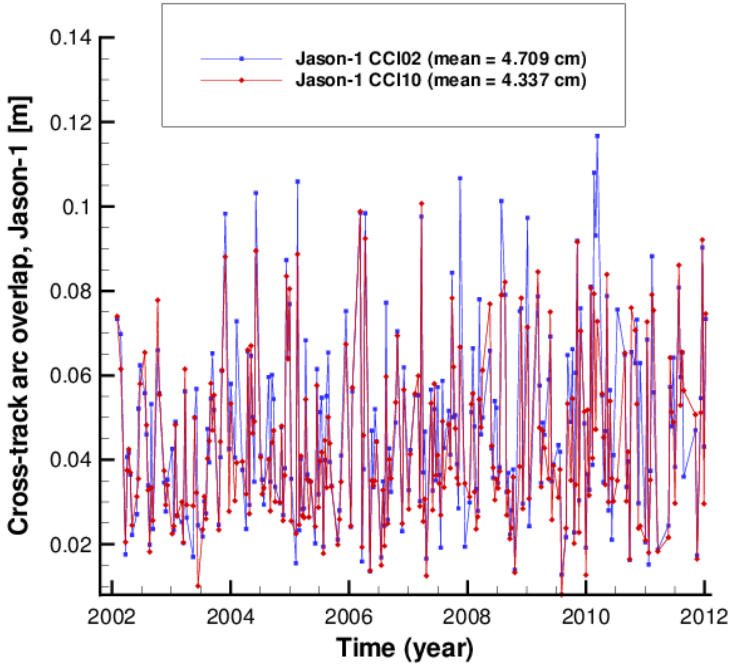


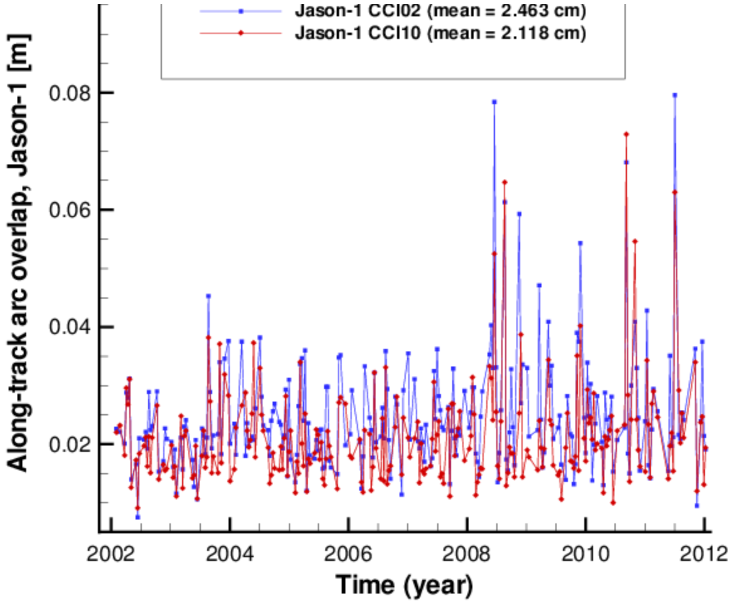


- The mean value of the SLR RMS fits reduced from 1.575 to 1.505 cm, i.e. by 0.070 cm (about 4.4%) for the CCI10 orbit, as compared to the CCI02 orbit;
- The mean value of the DORIS RMS fits reduced from 0.3827 mm/s to 0.3545 mm/s, i.e. by 0.0282 mm/s (about 7.4%) for the CCI10 orbit, as compared to the CCI02 orbit.

Two-day arc overlaps for Jason-1 (2002-2012): CCI10 versus CCI02

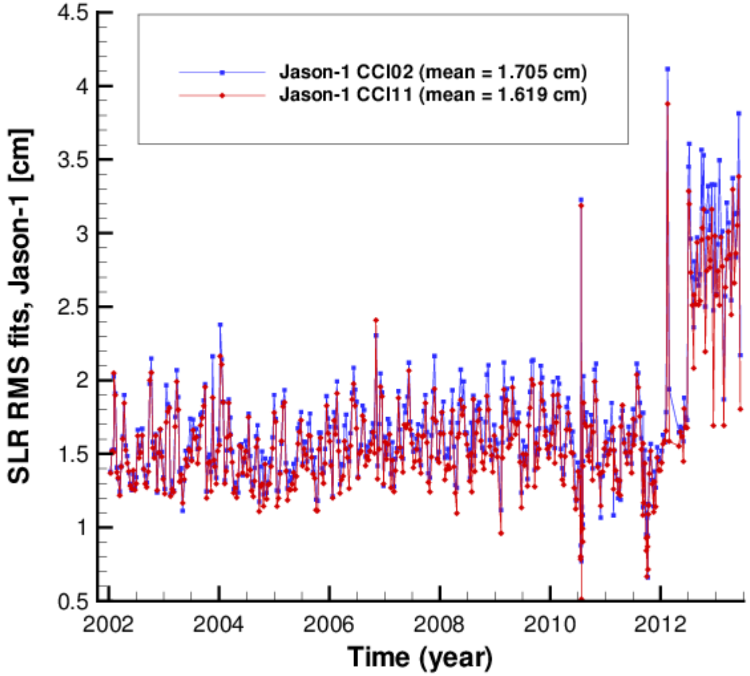


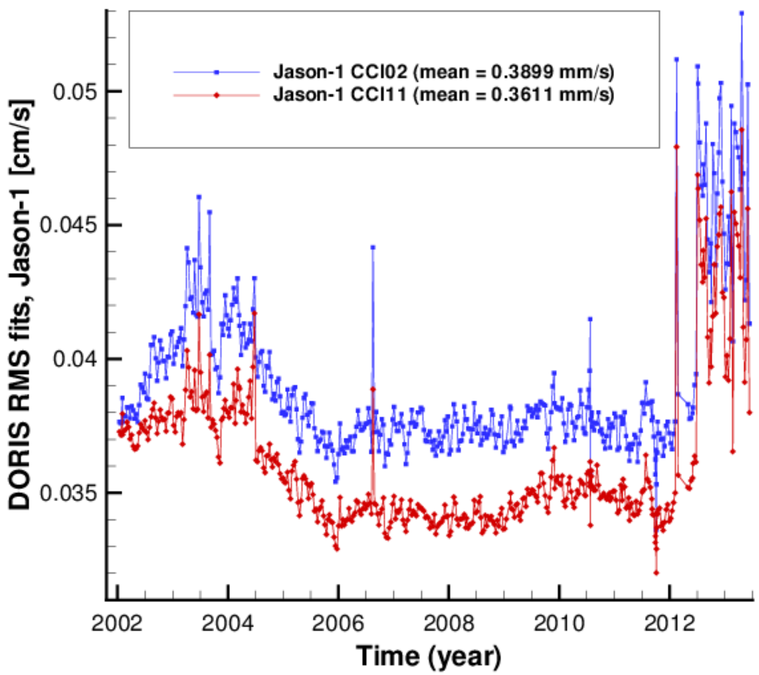




Reduction of the mean values
of the arc overlap of CCI10 orbit,
as compared to CCI02 orbit:
Radial – from 0.906 to 0.755 cm,
i.e. by 0.151 cm (about 16.7%),
Cross-track – from 4.709 to 4.337 cm,
i.e. by 0.372 cm (about 7.9%),
Along-track – from 2.463 to 2.118 cm,
i.e. by 0.345 cm (about 14.0%)

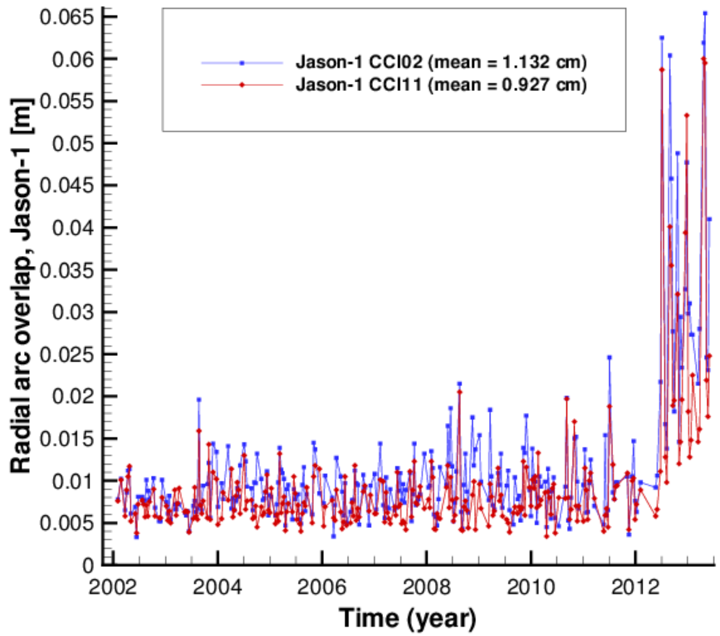
Improvement of RMS fits of observations for Jason-1 (January 2002 – July 2013): CCI11 orbit versus CCI02 orbit

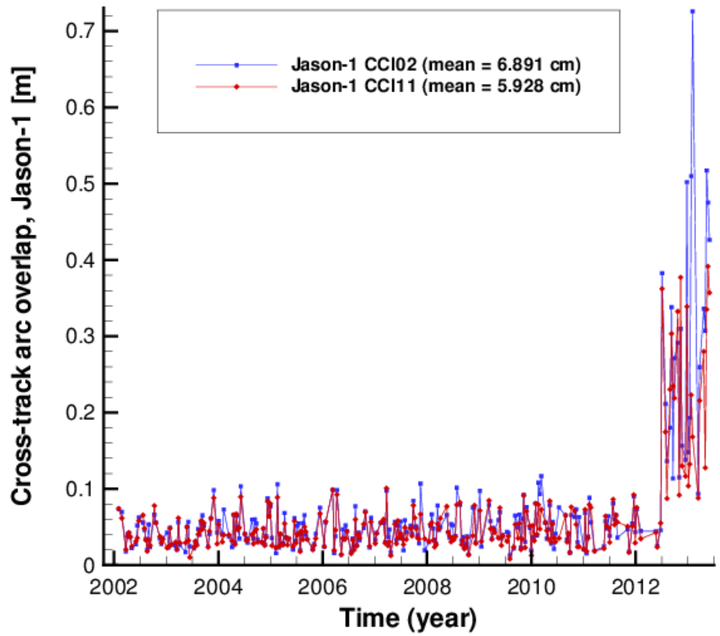


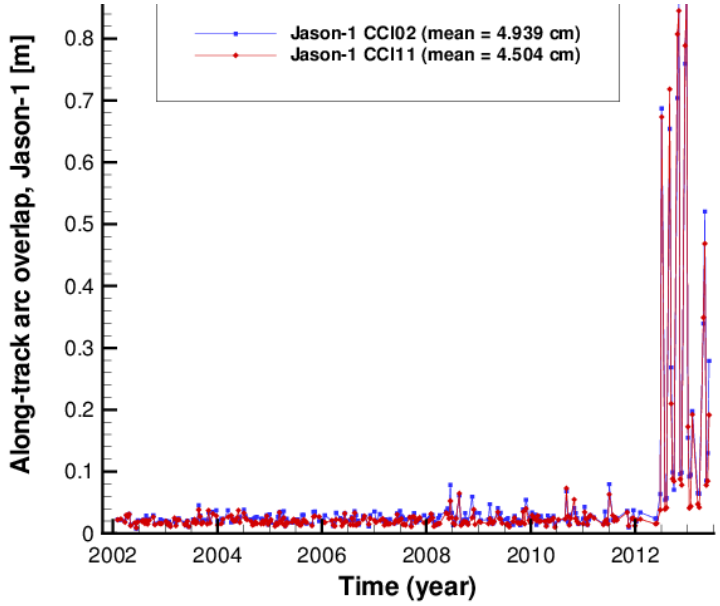


- The mean value of the SLR RMS fits reduced from 1.705 to 1.619 cm, i.e. by 0.086 cm (about 5.0%) for the CCI11 orbit, as compared to the CCI02 orbit;
- The mean value of the DORIS RMS fits reduced from 0.3899 mm/s to 0.3611 mm/s, i.e. by 0.0288 mm/s (about 7.4%) for the CCI11 orbit, as compared to the CCI02 orbit.
- Both SLR and DORIS RMS fits show higher values after July 5, 2012.

Two-day arc overlaps for Jason-1: CCI11 orbit versus CCI02 orbit



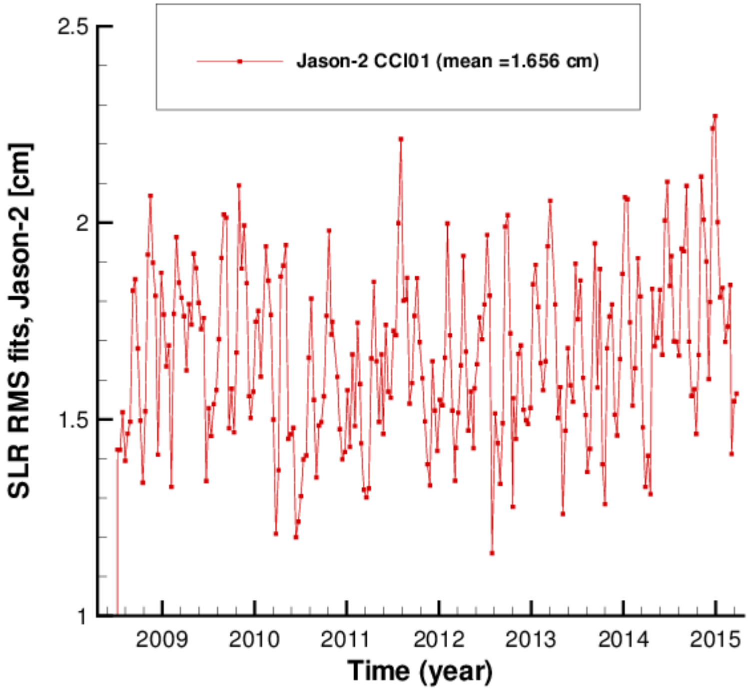


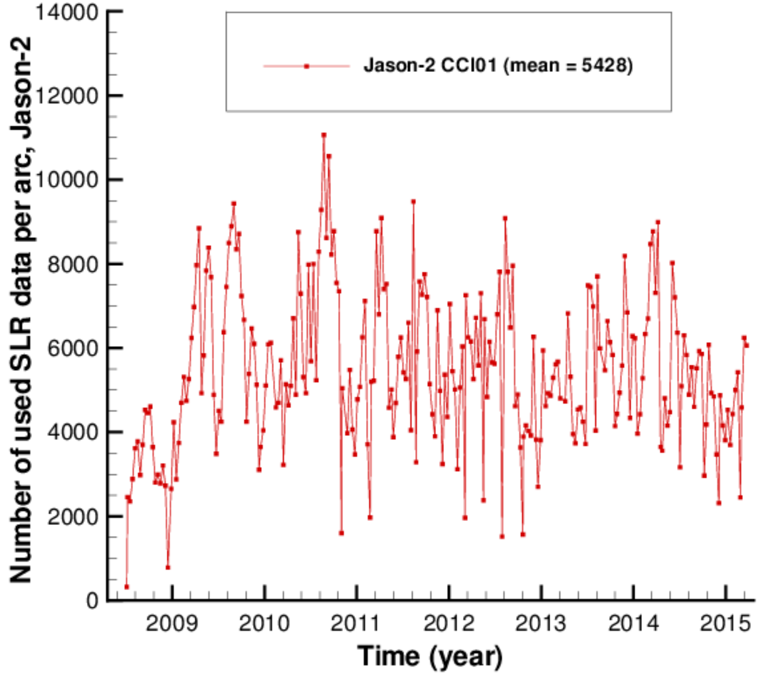


Reduction of the mean values of the arc overlap of CCI10 orbit, as compared to CCI02 orbit:
Radial – from 1.132 to 0.927 cm,
i.e. by 0.205 cm (about 18.1%),
Cross-track – from 6.891 to 5.928 cm,
i.e. by 0.963 cm (about 14.0%),
Along-track – from 4.939 to 4.504 cm,
i.e. by 0.435 cm (about 8.8%).
However, larger values after July 5, 2012.

Some preliminary results of precise orbit determination for Jason-2

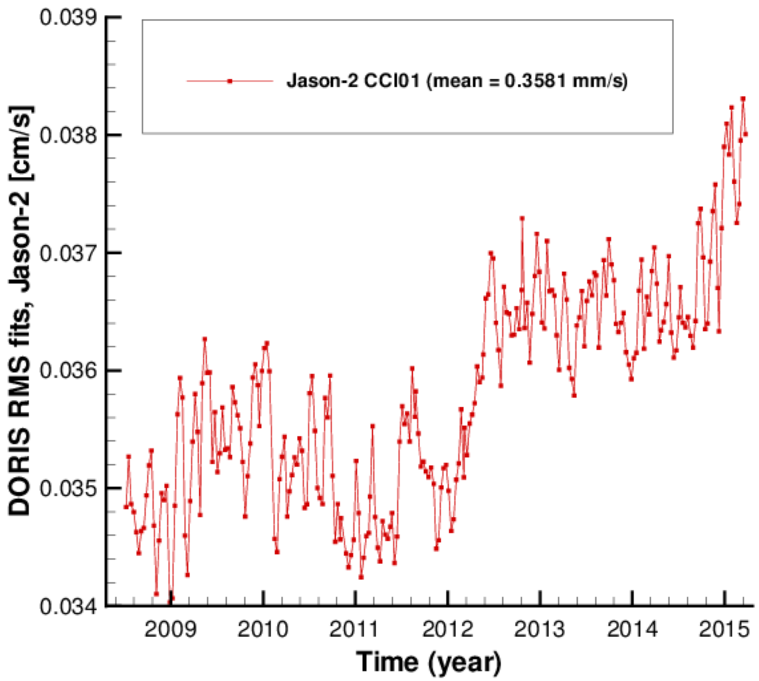
A preliminary CCI01 orbit of Jason-2 (5 July 2008 – 5 April 2015): Statistics on SLR observations

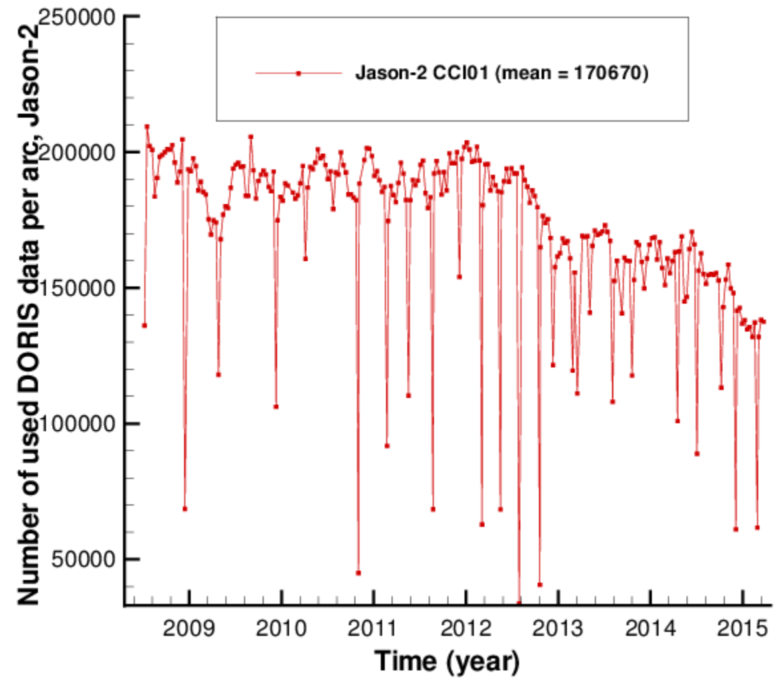




- The mean value of the SLR RMS fits is 1.66 cm.
- The mean value of the number of used SLR observation per 12-day orbital arc is 5428.

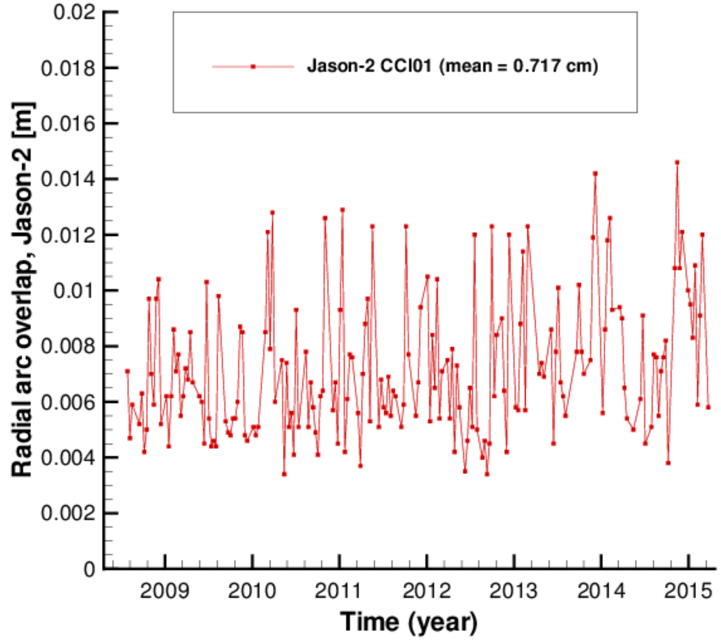
A preliminary CCI01 orbit of Jason-2 (5 July 2008 – 5 April 2015): Statistics on DORIS observations

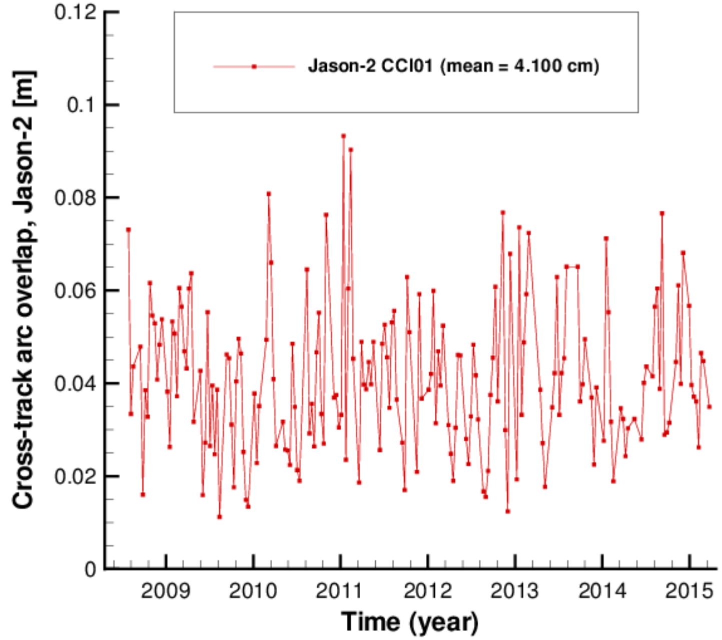


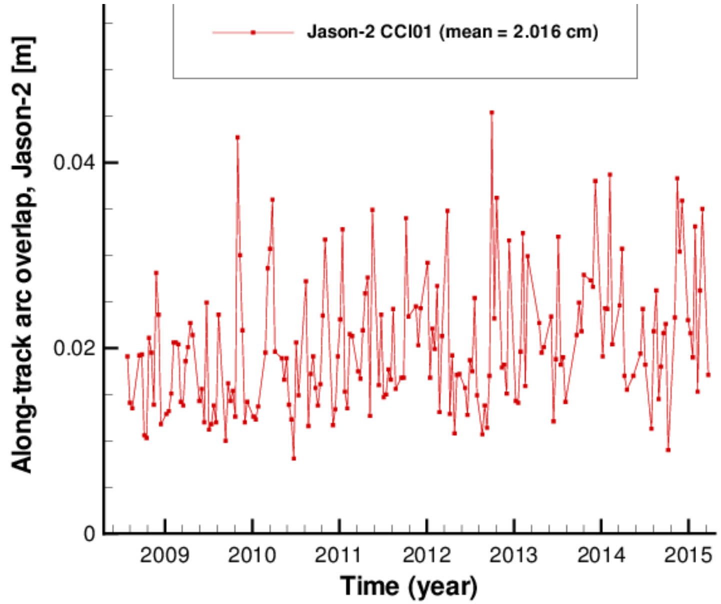


- The mean value of the DORIS RMS fits is 0.3581 mm/s.
- The mean value of the number of used SLR observation per 12-day orbital arc is 170,670.
- The increase of DORIS RMS after April 2012 seems to correlate with the decrease of the number of used DORIS data. However, it is not (!) an indication of a degradation of DORIS data. New stations appeared after April 2012 were not included in our station file. It will be corrected very soon.

Internal consistency of Jason-2 CCI01 preliminary orbit







The internal consistency of Jason-2 CCI01 preliminary orbit, as based on 2-day orbital arc overlaps:
Radial direction – 0.717 cm,
Cross-track – 4.100 cm,
Along-track – 2.016 cm.
These values are a bit better than those of GFZ CCI10 orbit.

Conclusions and Oulook

- New orbits of TOPEX/Poseidon (1992-2005), Envisat (2002-2012), Jason-1 (2002-2013) and Jason-2 (2008-2015) were computed at GFZ in the same ITRF realization (ITRF2008) using DORIS and SLR observations and consistent, improved models for precise orbit determination for all four missions.
- The analysis of these orbits performed at GFZ shows improved orbit quality of the new (VER08) orbits computed within the phase 2 of the ESA Sea Level project of the Climate Change Initiative, as compared to the previous (VER06) orbits derived within the phase 1 of this project.
- Thus, the mean values of the RMS fits of observations and orbital arc overlaps reduced by 0.6% for VER08 orbits, as compared to VER06 orbits, for TOPEX/Poseidon. The improvement for Envisat is even more significant: 3.1% improvement of SLR and 2.4% improvement of DORIS RMS fits and 0.6, 7.6 and 15.2% improvement of the radial, cross-track and along-track overlaps, accordingly.
- Further improvement of these orbits is expected, especially, for Jason-2.
- A reason of the degradation of Jason-1 orbit quality in 2012-2013 must be found.

Acknowledgements

- SLR and DORIS data available from the ILRS and IDS were used in this research
- This investigation was supported by Deutsche Forschungsgemeinschaft (DFG) within the project “Consistent estimate of ultra-high resolution Earth surface gravity data (UHR-GravDat)” and by the European Space Agency (ESA) within the Climate Change Initiative Sea Level Phase 2 Project

Thank you for your attention!