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Status of precise orbit determination of altimetry satellites at DGFI-TUM

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Introduction

Precise orbits of altimetry satellites are a prerequisite for altimetry investigations since they provide positions of altimetry satellites in a well defined reference frame. Since decades SLR data of spherical satellites have been processed at DGFI-TUM for reference frame determination and Earth rotation investigations. In the recent years macro-models and satellite specific information of non-spherical satellites Jason-1, Jason-2 and Jason-3 have been implemented in DGFI Orbit and Geodetic parameter estimation Software (DOGS) used for precise orbit determination (POD). In 2018 the processing of DORIS observations in the IDS 2.2 format was implemented in this software. To reach a better orbit quality, processing of observation-based attitude data in the quaternion form for satellite main body and solar panel angles has been implemented and tested.

This poster presents the POD status for the altimetry satellites Jason-1, Jason-2 and Jason-3 using SLR and DORIS data with the DOGS-OC software. We show, in particular, the impact of the recent ITRS realizations, using observation-based attitude instead of nominal one and thermosphere density models and horizontal wind model HWM14 on the satellite orbits.

The main models used for precise orbit determination

Station models	Description
A priori station coordinates and velocities	SLRF2014 and DPOD2014
A priori EOP values	IERS EOP 14 C04
Precession and nutation	IAU2000A/IAU2006 model up to degree 10
Solid Earth tidal displacement	Anelastic model (IERS Conventions 2010)
Permanent tide	Conventional model (IERS Conventions 2010)
Ocean tidal displacement	EOT11a (Savchenko and Bosch, 2012)
Atmospheric tidal displacement	S1/S2 tidal model (Ray and Ponte, 2003)

Force models	Description
Earth gravity field	EIGEN-6S (Förste et al., 2011, static up to degree/order 120, time variable up to d/o 50)
Third body gravity effect	DE-421: Sun, Moon and 5 major planets
Solid Earth tides and pole tide	IERS Conventions 2010
Ocean and atmospheric tides	EOT11a up to d/o 30, Biancale and Bode, 2006 and 62 admittance waves (IERS Conventions)
Ocean pole tide	Desai, 2002
Solar radiation pressure	Constant radiation with eclipse modelled
Earth radiation pressure	Albedo and infrared (Knocke et al., 1988)

Table 1: List of the main station and force models used in this study.

Estimated parameters: Keplerian elements, solar radiation pressure scaling coefficient, Earth albedo scaling coefficient, along-track and normal empirical accelerations (one-per-revolution terms), atmospheric drag scaling coefficients (every 12 h), and station frequency biases (for DORIS data, 1 per path).

Satellites used and data processed

Satellite name	Time span processed	SLR data-based orbit	DORIS data-based orbit
Jason-1	13 Jan. 2002 – 30 Jun. 2013	Yes	Yes
Jason-2	20 Jul. 2008 – 9 Jan. 2019	Yes	Yes
Jason-3	17 Feb. 2016 – 9 Jan. 2019	Yes	Not yet

Table 2: Time intervals and satellite observation types processed in this study.

Impact of ITRS realizations on Jason-2 SLR observation residuals

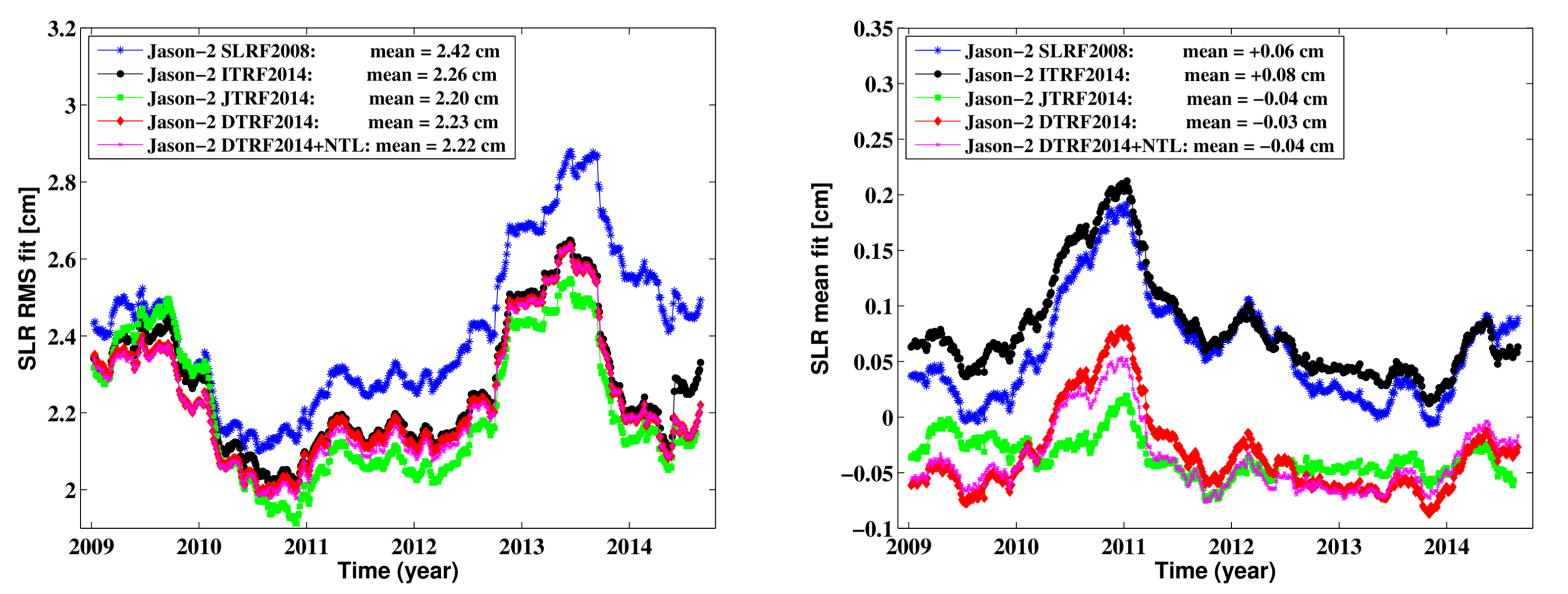

Figure 1: 50-week running averages of the RMS (left) and mean (right) fits of SLR observations for Jason-2 orbits derived using SLRF2008, ITRF2014, JTRF2014, DTRF2014 linear and DTRF2014+NTL reference frame realizations (Rudenko et al., 2018)

Acknowledgements: SLR and DORIS data of Jason satellites made available by ILRS and IDS, respectively, were used in this work.

Impact of the observation-based attitude on RMS fits of SLR and DORIS measurements

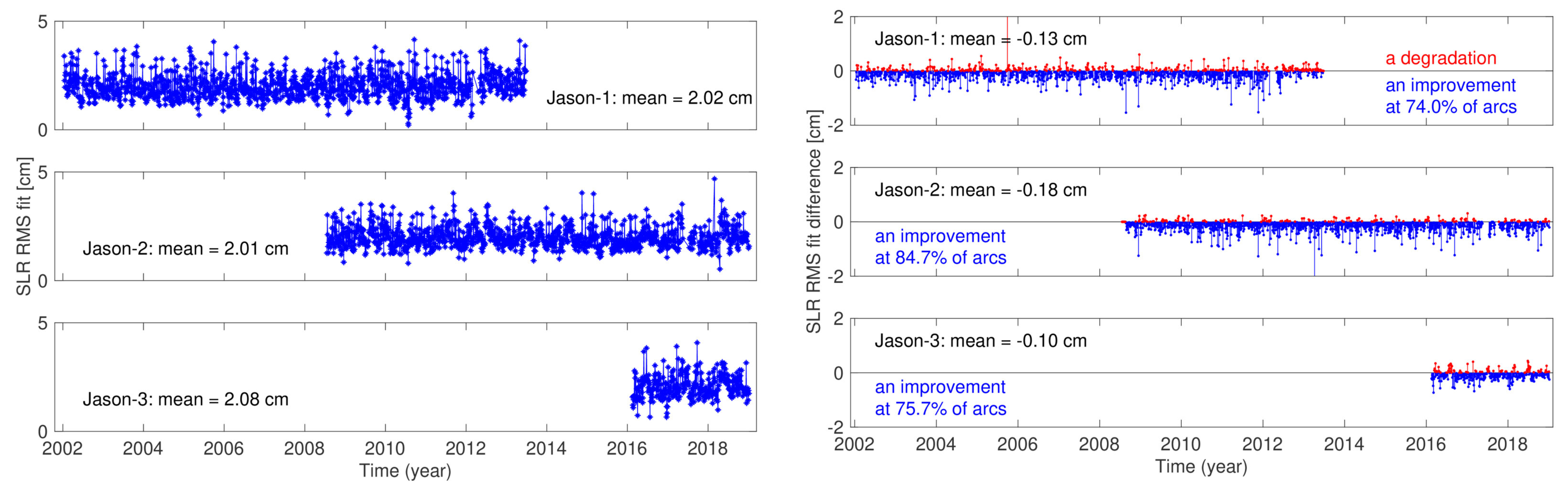

Figure 2: RMS fits of SLR observations for Jason-1 (top), Jason-2 (middle) and Jason-3 (bottom) computed using observation-based attitude data (left) and the differences of these RMS fits and those obtained using satellite nominal attitude model (right)

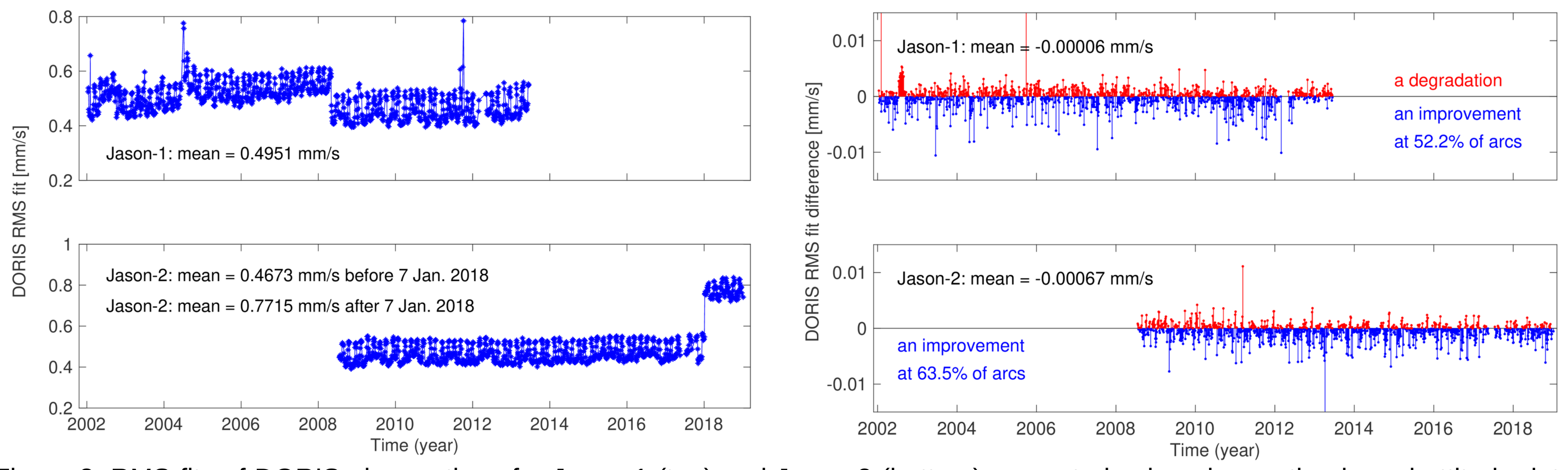

Figure 3: RMS fits of DORIS observations for Jason-1 (top) and Jason-2 (bottom) computed using observation-based attitude data (left) and the differences of these RMS fits and those obtained using satellite nominal attitude model (right)

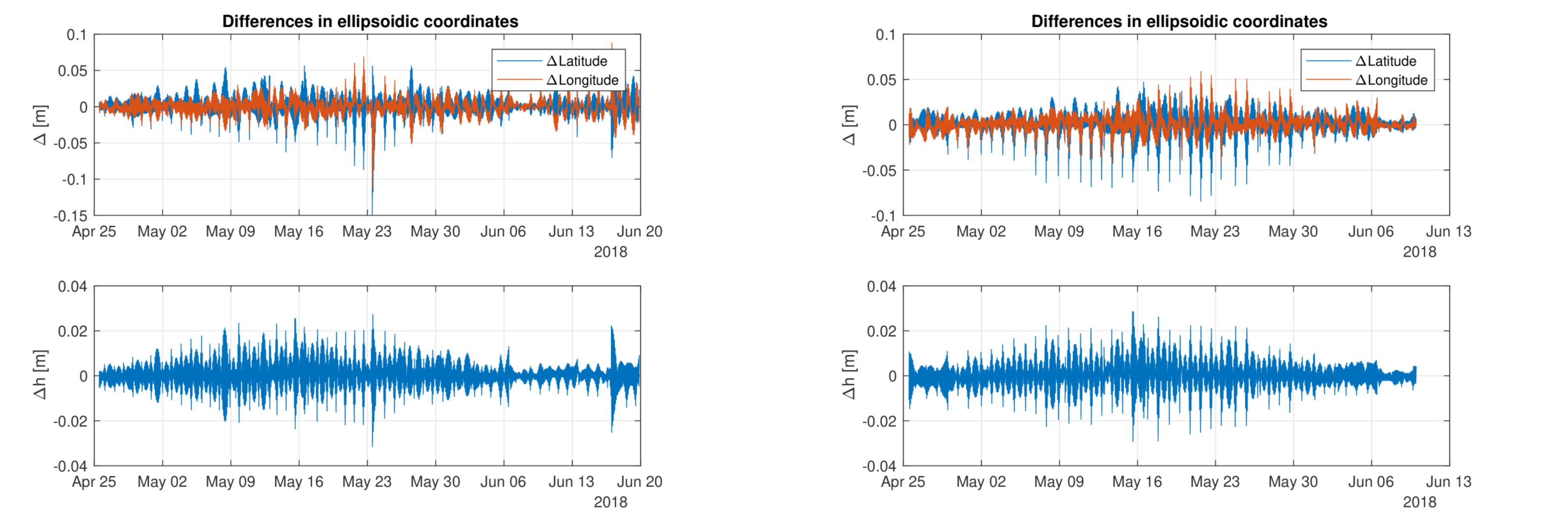

Figure 4: Differences of satellite positions in the latitude, longitude (top) and height (bottom) directions for Jason-2 SLR-only (left) and DORIS-only (right) orbits computed using observation-based and nominal satellite attitude.

Impact of thermosphere density models on DORIS and SLR data based orbits of Jason-2

Data used: Jason-2 DORIS and SLR observations (1 Jan. 2014 – 7 Jan. 2015, period of high solar activity). DORIS-only and SLR-only orbits are computed. Thermosphere density models used: CIRA86, NRLMSISE00 and JB2008. For each model, additionally an impact of the Horizontal Wind Model 2014 (HWM14, Drob et al. 2015) is tested.

Model name	SLR RMS fit (cm)	DORIS RMS fit (mm/s)	Atmosphere drag scaling factor (—)	Solar radiation scaling factor (—)	Cosine term of empirical along-track acceleration (10^{-10} m/s²)	Cosine term of empirical normal acceleration (10^{-10} m/s²)
CIRA86	1.993	0.455671	1.445	0.9909	2.61	1.42
CIRA86-HWM14	1.988	0.455639	1.442	0.9907	2.63	1.46
NRLMSISE00	1.959	0.455524	1.447	0.9913	2.46	1.77
NRLMSISE00-HWM14	1.954	0.455490	1.444	0.9910	2.47	1.82
JB2008	1.971	0.455383	1.383	0.9931	2.29	2.67
JB2008-HWM14	1.970	0.455381	1.378	0.9927	2.30	2.66

Table 3: RMS fits of SLR and DORIS observations and average values of dynamical parameters obtained using three different thermosphere density models and HWM14 for Jason-2.

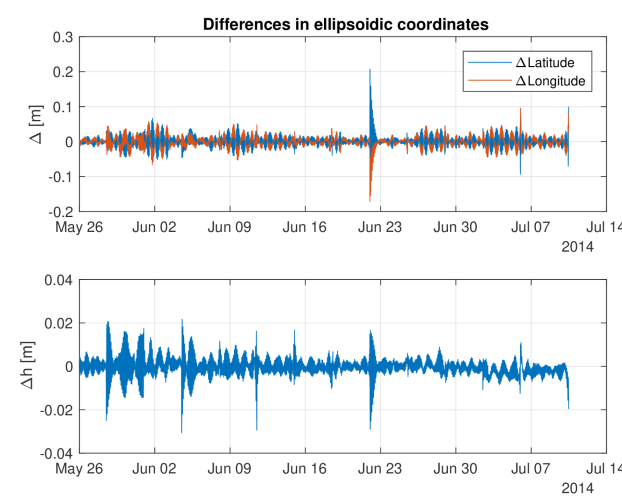

Figure 5: Differences of satellite positions computed using JB2008-HWM14 and CIRA86-HWM14 thermosphere density models for Jason-2 DORIS data orbits

Conclusions

- DOGS-OC is capable to process **SLR and DORIS observations** (presently in the IDS 2.2 format) of non-spherical satellites Jason-1, Jason-2 and Jason-3.
- Totally about 25 years of Jason-1, Jason-2 and Jason-3 SLR observations have been processed. The average **RMS fits of SLR observations** are about 2.0-2.1 cm.
- Totally about 22 years of Jason-1 and Jason-2 DORIS observations have been processed. The average **RMS fits of DORIS observations** are 0.495 mm/s for Jason-1, 0.467 mm/s for Jason-2 before 7 January 2018 and 0.772 mm/s after 7 January 2018.
- Using **observation-based attitude data** (instead of nominal ones) reduces SLR RMS fits by 1.0-1.8 mm (5-8%) and causes 6-7 mm RMS differences of satellite height for Jasons.
- NRLMSISE00 and JB2008 **thermosphere density models** reduce SLR RMS fits by 1.1-1.7% compared to CIRA86 for Jason-2 at the period of high solar activity and cause about 3.0 mm RMS height differences. **Horizontal wind model HWM14** additionally reduces SLR RMS fits by 0.1-0.2% and causes 0.4 mm scatter in the height differences.

References

- Bloßfeld et al. Observation-based attitude control for accurate Jason satellite orbits (in preparation)
- Rudenko et al. (2018) Evaluation of DTRF2014, ITRF2014, and JTRF2014 by Precise Orbit Determination of SLR Satellites. IEEE Transactions on Geoscience and Remote Sensing, 56(6), 3148 - 3158, DOI: 10.1109/TGRS.2018.2793358.

Ocean Surface Topography Science Team Meeting (OSTST) 2019, 21-25 October 2019, Chicago, Illinois, United States of America