Status of the IDS data processing at DGFI-TUM

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DORIS Analysis Working Group (AWG) meeting of the International DORIS Service,
June 11, 2018, Toulouse, France

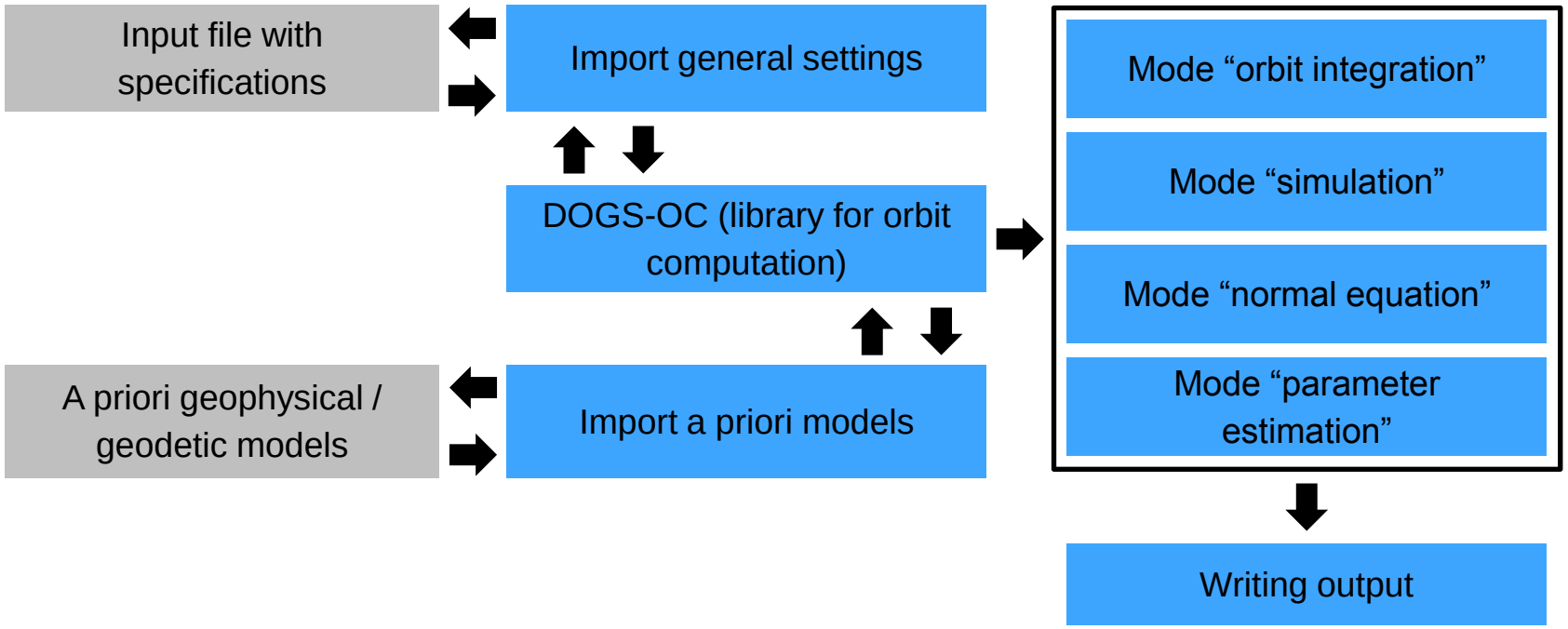
Outline

- ⇨ DGFI Orbit and Geodetic parameter estimation Software (DOGS)
- ⇨ DGFI-TUM contribution to ILRS
- ⇨ Recent improvements in Jason-2 satellite modelling at DGFI-TUM
- ⇨ DORIS data processing
- ⇨ Some results of processing of SLR and DORIS data of Jason-2
- ⇨ Conclusions and outlook

DGFI Orbit and Geodetic parameter estimation Software (DOGS)

The DGFI-TUM software for the analysis and combination of space geodetic techniques comprises three main software libraries:

- ⇨ DOGS-CS: combination and solution of equation systems
- ⇨ DOGS-RI: analysis of radio interferometry data (VLBI)
- ⇨ DOGS-OC: precise orbit determination, parameter estimation, etc. for the satellite techniques SLR and DORIS



DGFI-TUM contribution to ILRS

DGFI-TUM operates the EDC (Eurolas Data Center) as an ILRS-OC (Operation Center)

⇨ The main task of the EDC is to guarantee the necessary ILRS data flow

⇨ The main task of the OC is the format checking of all incoming SLR observations such as

Normal Points, Full-Rate (CRD),

Predictions (CPF),

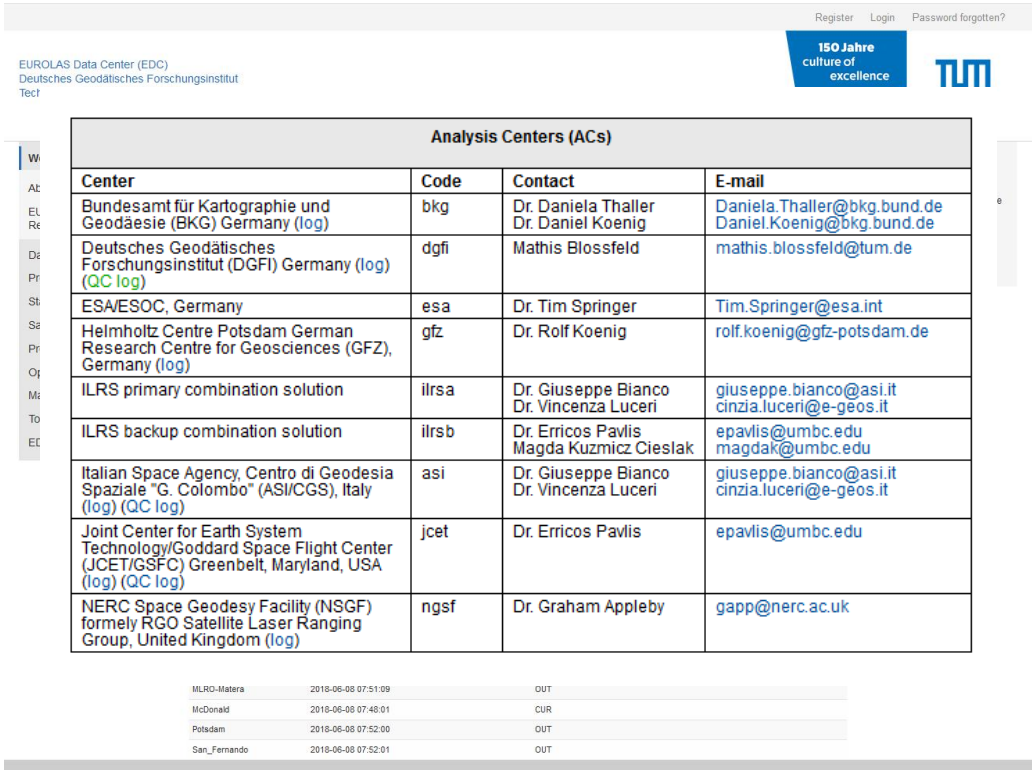
Normal Points (CSTG),

Full-Rate (MERIT-II).

Beside the EDC, DGFI-TUM is also an ILRS Analysis Center

⇨ Routine delivery of operational products (daily/weekly)

⇨ participation in all ILRS pilot projects



Analysis Centers (ACs)

Center	Code	Contact	E-mail
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Italian Space Agency, Centro di Geodesia Spaziale "G. Colombo" (ASI/CGS), Italy (log) (QC log)	asi	Dr. Giuseppe Bianco Dr. Vincenza Luceri	giuseppe.bianco@asi.it cinzia.luceri@e-geos.it
Joint Center for Earth System Technology/Goddard Space Flight Center (JCET/GSFC) Greenbelt, Maryland, USA (log) (QC log)	jcet	Dr. Erricos Pavlis	epavlis@umbc.edu
NERC Space Geodesy Facility (NSGF) formely RGO Satellite Laser Ranging Group, United Kingdom (log)	ngsf	Dr. Graham Appleby	gapp@nerc.ac.uk

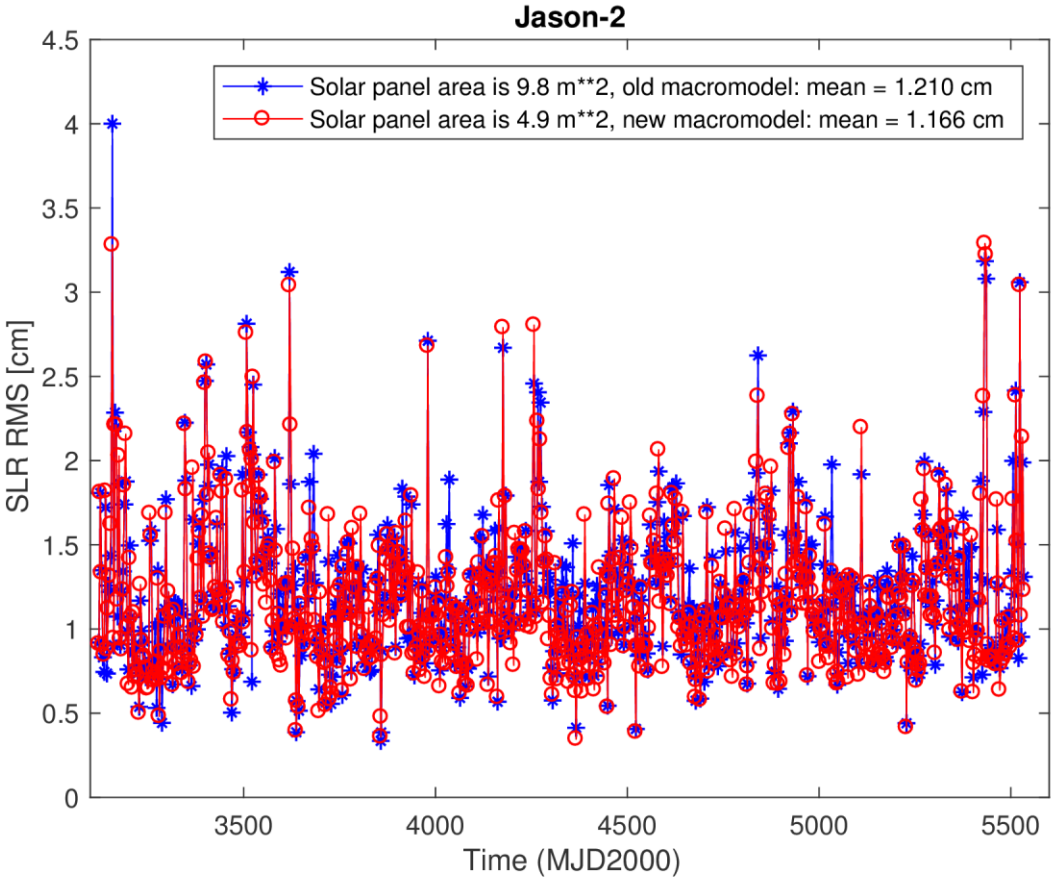
Updates in the Jason-2 satellite macromodel (29.09.2016)

A new Jason-2 macromodel implemented according to ftp://ftp.ids-doris.org/pub/ids/satellites/DORISSatelliteModels.pdf (box areas and the reflectance coefficients changed)

The individual solar panel area was changed from 9.8 to 4.9 m^2, previously twice as large as it should have been.

=> As a result, the mean value of SLR RMS fits over 704 orbital arcs covering the time span from July 20, 2008 till February 25, 2015 reduced from 1.21 to 1.17 cm (by 3.6%).

=> Solar radiation pressure scaling factor changed from 0.53 (using the old macromodel) to 0.96-1.00 (using the new macromodel) – more realistic.



Realization of the Jason-2 SLR-DORIS space tie

- Implementation of Jason-2 in DOGS-OC originally done for SLR only:
- Jason-2 mass and center of mass (CoM) coordinates history in the SRF for the whole spacecraft, including the solar panels

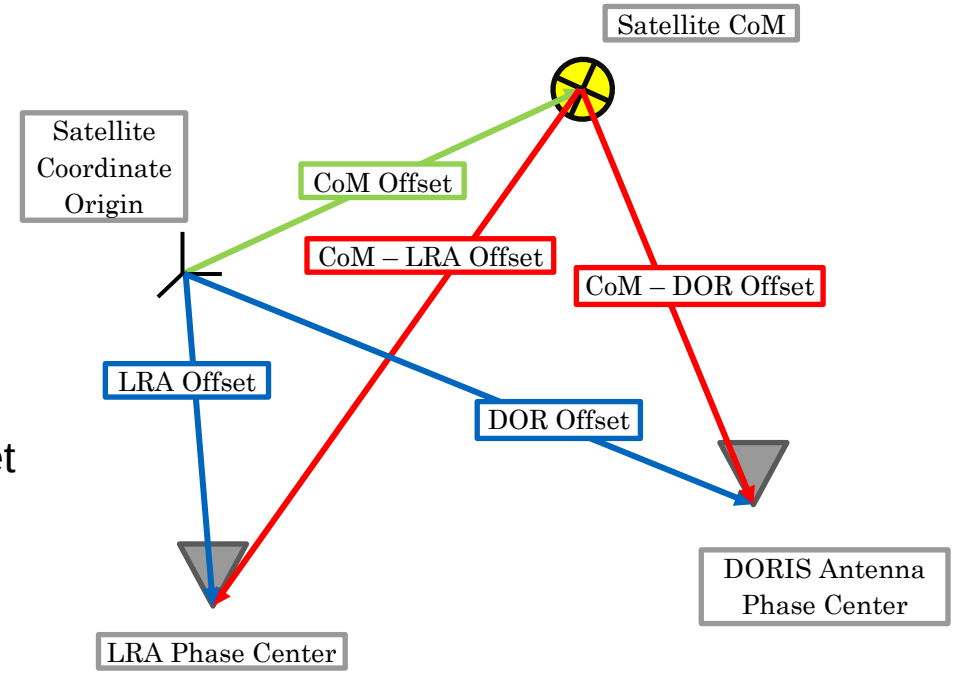
Mass (kg)	X_{CoM} (m)	Y_{CoM} (m)	Z_{CoM} (m)
505.9	0.9768	0.0001	0.0011

- Jason-2 LRA optical center

X_{LRA} (mm)	Y_{LRA} (mm)	Z_{LRA} (mm)
+1194.0	+598.0	+684.0

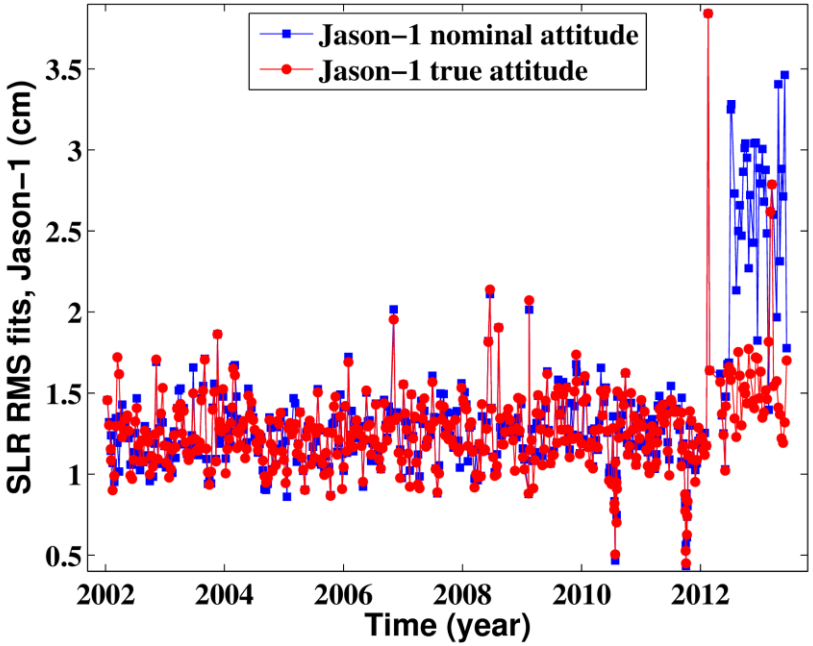
- Additional correction for phase center offset
- Jason-2 DORIS antenna phase center

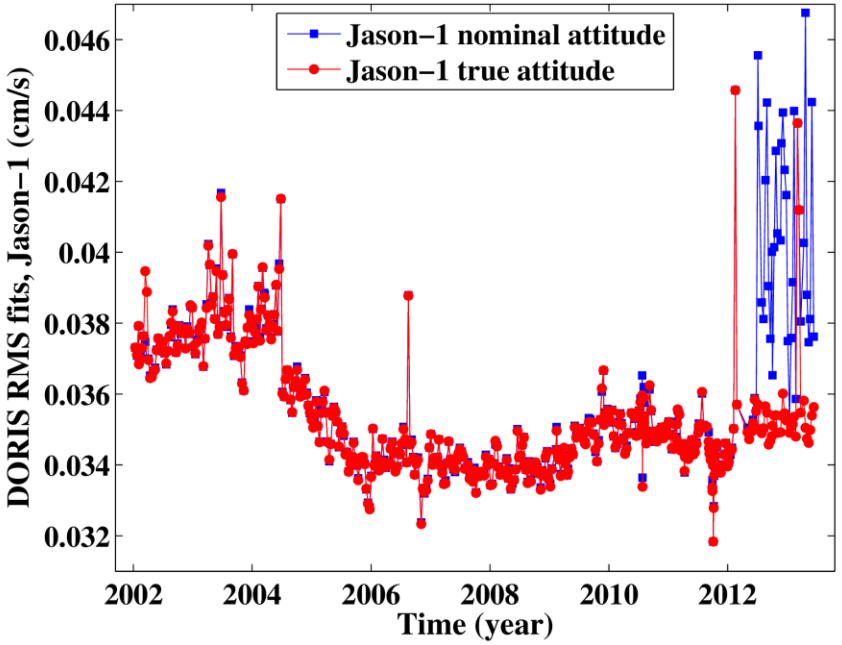
X_{DOR} (mm)	Y_{DOR} (mm)	Z_{DOR} (mm)
+1194.0	-598.0	1022.0



- Attitude control is of crucial importance for drag modelling and geometry!!!

Importance of using true attitude instead of nominal (Jason-1, from 5 July 2012 to 5 July 2013)





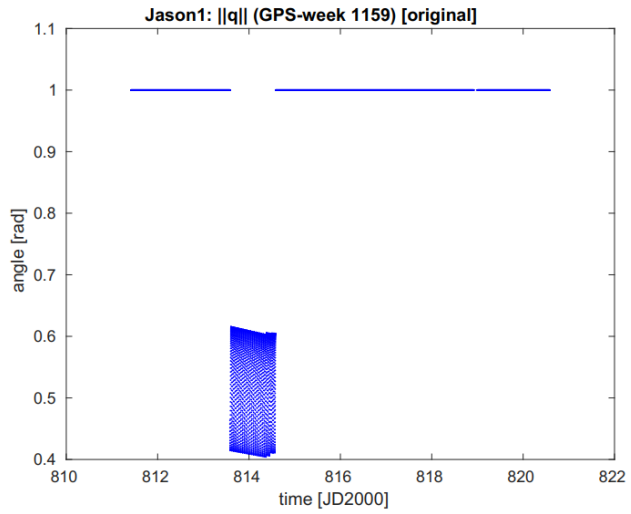
Attitude	SLR RMS (cm)	DORIS RMS (mm/s)	Radial overlap (cm)	Cross-track overlap (cm)	Along-track overlap (cm)
nominal	2.67	0.4046	2.80	24.40	33.57
true	1.57 (-41.1%)	0.3561 (-12%)	1.69 (-39.7%)	7.27 (-70.2%)	7.95 (-76.3%)

(Rudenko et al., 2017)

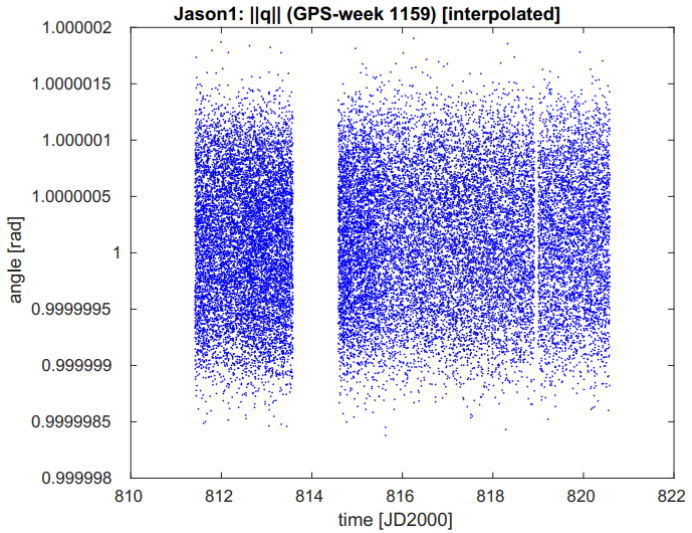
Challenges at attitude data handling and interpolation

- ⇨ Inconsistency in original data files:
  - Header with varying number of lines (standard: 6 lines)
  - Only header available
  - Only zero measurements for parameters (single / all parameters)
  - Column for epochs filled with strings
  - Incomplete lines
  - Incorrect file names

- ⇨ Sum of quaternions at some time spans is not equal to 1 (e.g. March 23, 2002 for Jason-1):

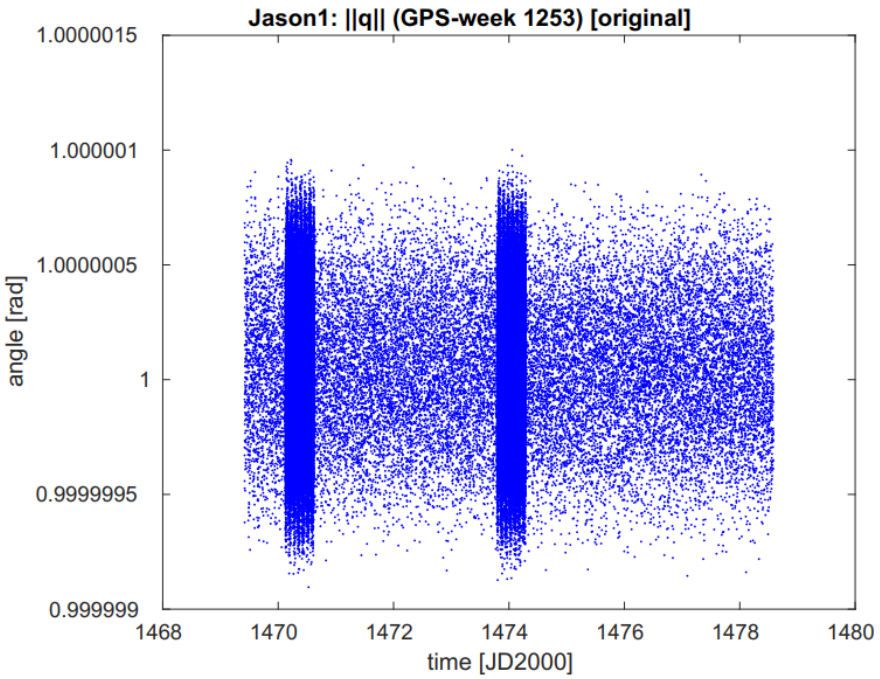


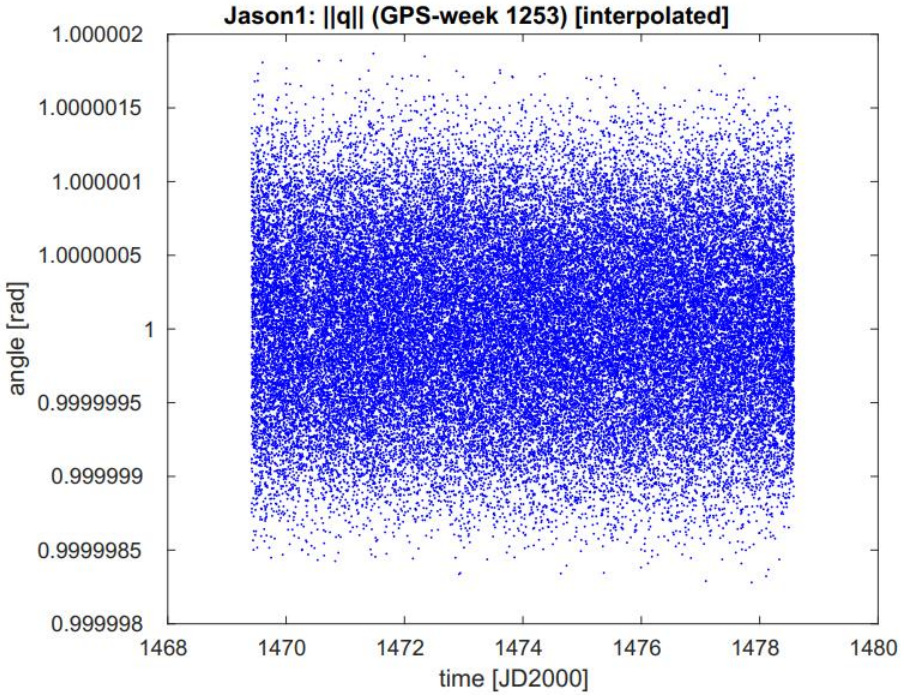
these time spans have to be deleted



Challenges at attitude data handling and interpolation (continue)

⇨ Too high frequency of data

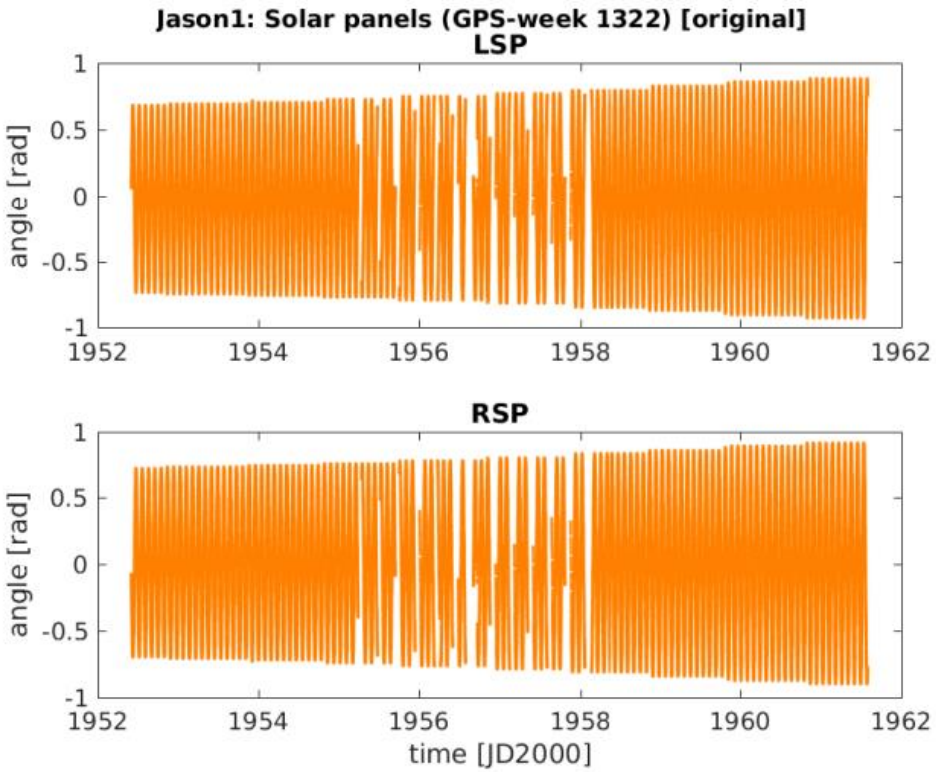


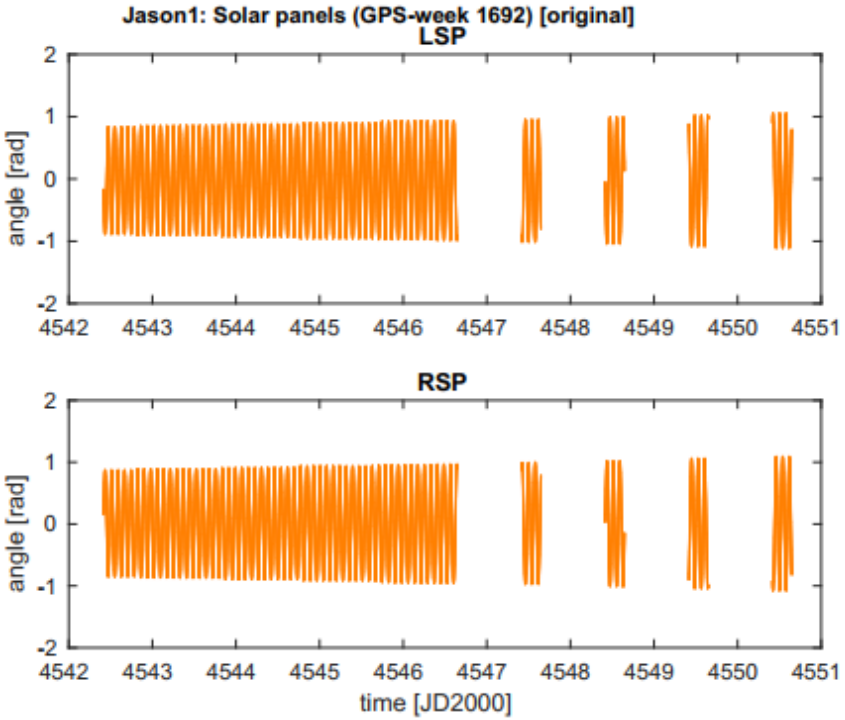


Challenges at attitude data handling and interpolation (continue)

⇨ Irregular epochs, gaps in data (left)

Only hourly data available (right)

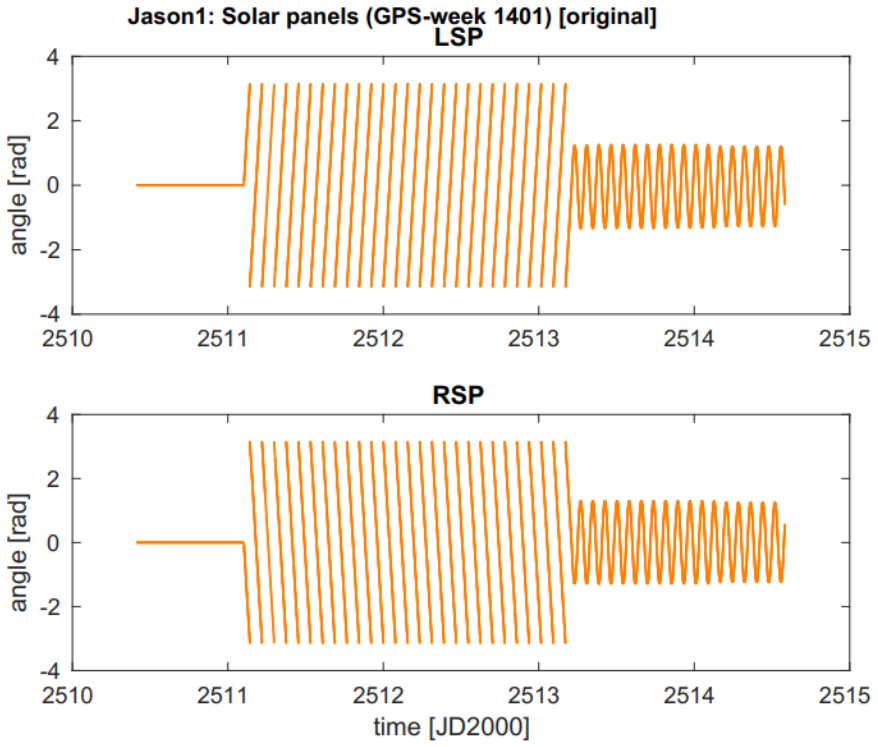


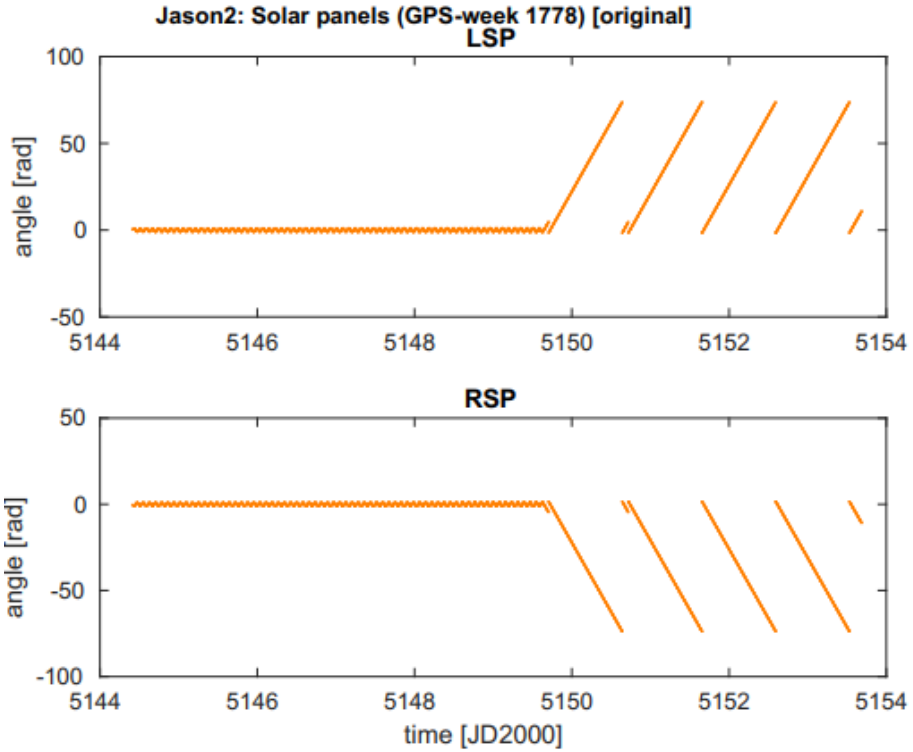


Challenges at attitude data handling and interpolation (continue)

⇨ Differing behavior of solar panels angles
Epochs with 0 values
No data available (left)

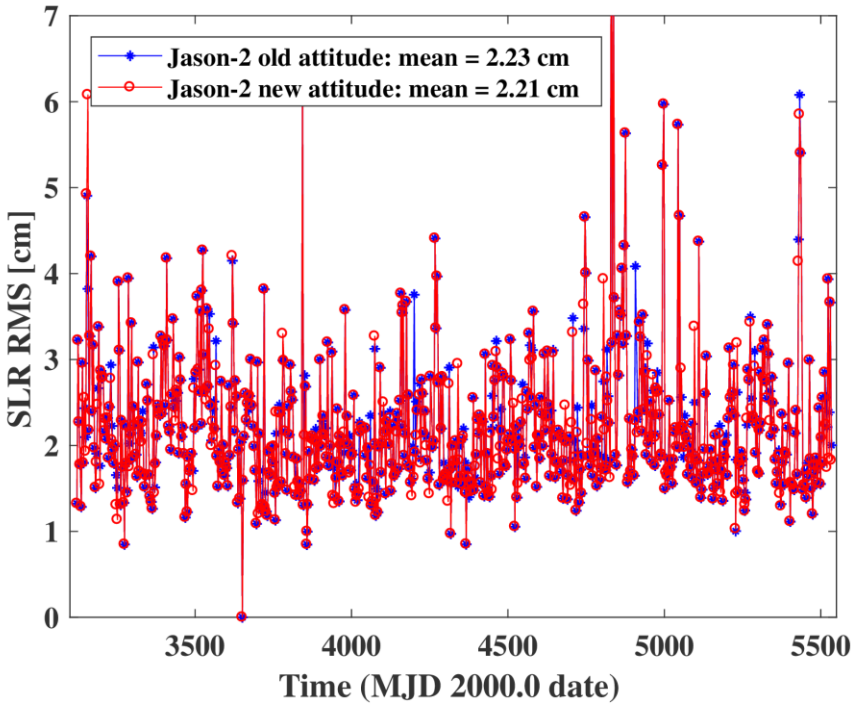
Huge linear effects of solar panels angles (Jason-2 & Jason-3) (right)

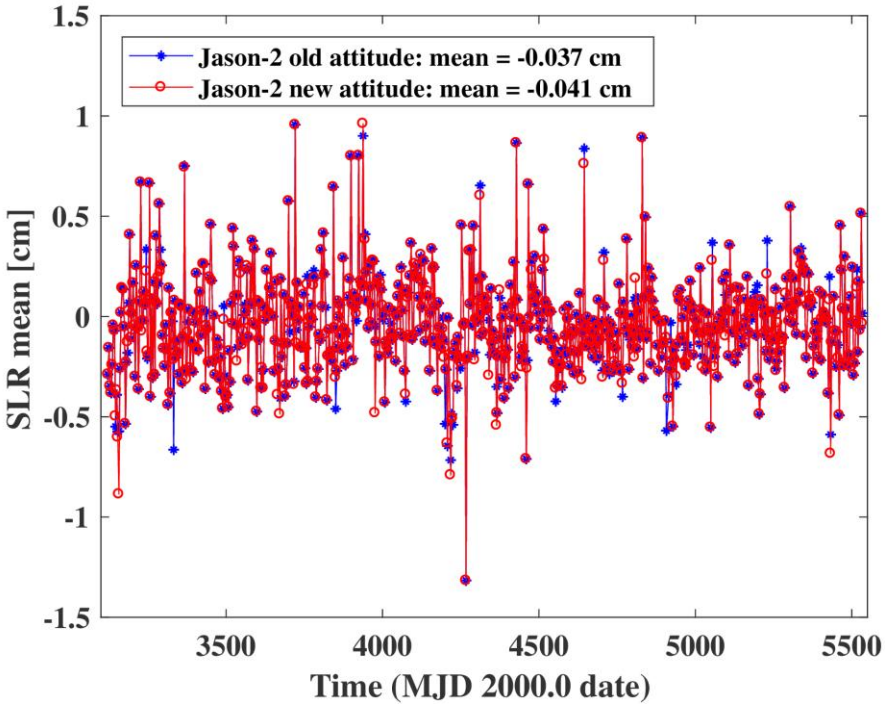




Refined satellite attitude handling

SLR RMS (left) and mean (right) fits of Jason-2 orbit computed using “old” and interpolated, cleaned and preprocessed attitude data





The mean value of SLR RMS fits reduced by 0.02 cm from 2.23 to 2.21 cm. However, the absolute mean fits slightly increased by 0.004 cm from 0.037 to 0.041 cm.

DORIS-related models implemented in DOGS-OC

- ⇨ Treatment of DORIS data in GINS and IDS 2.2 format
- ⇨ Jason-2 and TOPEX/Poseidon macromodels according to ftp://ftp.ids-doris.org/pub/ids/satellites/DORISSatelliteModels.pdf
- ⇨ Estimation of the correction to the wet part of the tropospheric zenith delay
- ⇨ Estimation of the pass-wise frequency bias
- ⇨ Station-dependent phase center offsets in the measurement direction

- ⇨ Corrections to DORIS measurements:
  -> center of Mass correction of the instrument at the satellite,
  -> phase center correction of the emitter (beacon),
  -> tropospheric refraction (different models available),
  -> relativistic contraction (according to model of Moyer),
  -> frequency bias and frequency-drift.

- ⇨ Computation of the partial derivatives of the theoretical observation w.r.t. the included free parameter, i.e. dynamic parameter, Center of Mass correction, pole coordinates, time parameter (UT1, LOD), and the station parameter together with biases.

DORIS-related models implemented in DOGS-OC (continue)

- Computation of the partial derivatives of the theoretical observation w.r.t. the included free parameter, i.e.
  - dynamic parameter (e.g. gravity field coefficients),
  - Center-of-Mass correction,
  - pole coordinates,
  - time parameter (UT1, LOD),
  - the station parameter (coordinates),
  - station frequency biases, tropospheric (wet) scaling factors

- Troposphere distance correction models implemented:
  - refined model of Hopfield using the algorithm of Yionoulis,
  - simplified model of Hopfield,
  - simplified model of Saastamoinen,
  - model of Davis,
  - tropospheric delay: Collins (1999), mapping functions (dry, wet) by Neill.

DORIS-related models to be implemented in DOGS-OC

- ⇨ Treatment of DORIS data in RINEX format
- ⇨ Corrective models for DORIS observations due to South Atlantic Anomaly (Jason-1 and Jason-2) or use of corrected observations
- ⇨ Estimation of station frequency drift
- ⇨ Troposphere correction models based on
  - Global mapping function,
  - Vienna mapping function 1
- ⇨ Some other

Some results of processing of SLR and DORIS data of Jason-2

- ⇨ Test arc: 1-day/3.5-days/7-days in GPS week 1830 (01-08 Feb 2015)
- ⇨ tested arcs: SLR-only, DORIS-only, SLR-/DORIS-combined

- ⇨ Parameterization:
  - Keplerian elements (initial elements)
  - pass-wise frequency biases
  - one scaling factor of the (wet) troposphere per station
  - 6-hourly scaling factors for the atmospheric density
  - empirical accelerations in along-track and cross-track direction (once-per-rev sine-/cosine-term)
  - **station coordinates/EOP are fixed for POD comparisons!**

Some results of processing of SLR and DORIS data of Jason-2

⇨ 1-day DORIS-only arc to test partials (the estimated parameters are marked with X):

DORIS orbit fit [mm/sec]	(initial) Keplerian elements	Station coordinates	EOP (pole/UT1)	pass-wise frequency biases	station-wise tropospheric scaling factors	6-hourly therm. density scaling factors, empirical acc.
7.42E+03	X	-	-	-	-	-
1.74	X	-	-	X	-	-
1.76	X	-	-	X	X	-
1.75	X	-	-	X	X	X
17.18	X	X	X	X	X	X

⇨ 3.5-day SLR-only orbit fit: 1.03 cm; 7-day SLR-only: 3.33 cm ← **already problems here?**

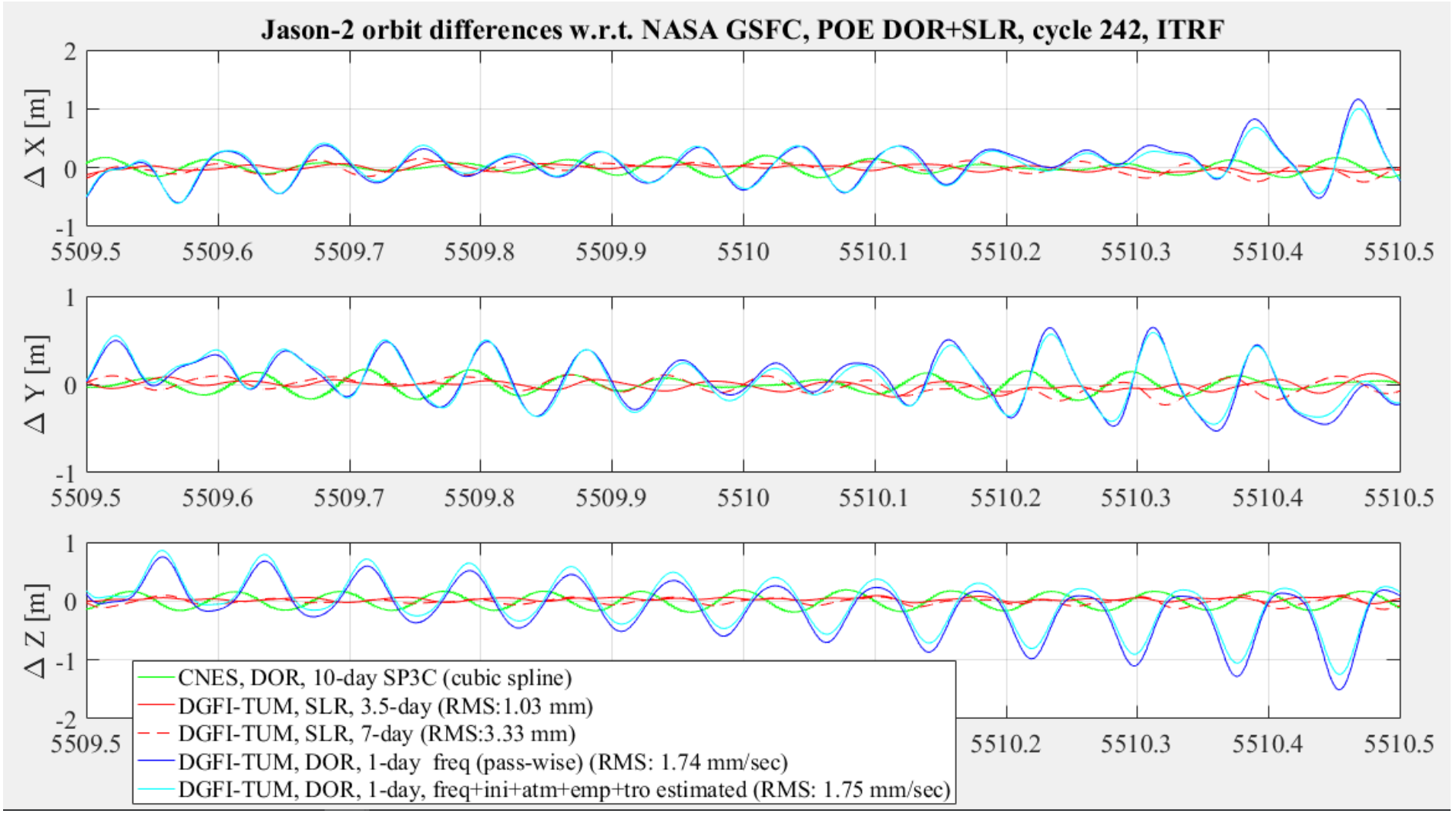
⇨ 3.5-day DORIS-only orbit fit (no coordinates/EOP estimated): 1.60 mm/sec

⇨ Estimated frequency biases are reasonable and comparable to GSFC estimates

⇨ From this analysis, it seems that some partials are not OK!

⇨ Up to now, the target accuracy is not yet reached!

Some results of processing of SLR and DORIS data of Jason-2



Conclusions and outlook

- ⇨ DOGS-OC is, in principle, able to process DORIS (IDS 2.2 format) observations
- ⇨ Up to now, a factor of 4-5 in the accuracy (RMS fits of DORIS observations) is still missing
- ⇨ Impact of troposphere is not the main problem; analysis showed that variation of troposhere models do not affect the solution significantly

- ⇨ Further analysis of partial derivatives (maybe collaboration with an IDS AC)
- ⇨ Implementation of GPT, VMF1, VMF3
- ⇨ Implementation of nominal frequency shift models (only for some stations necessary)
- ⇨ Estimation of time bias between SLR and DORIS in combined POD
- ⇨ Extension of empirical accelerations (currently sine-/cosine-terms can be only estimated once-per-arc)

References

- Rudenko, S., Neumayer, K., Dettmering, D., Esselborn, S., Schöne, T., Raimondo, J. (2017): Improvements in precise orbits of altimetry satellites and their impact on mean sea level monitoring. IEEE Transactions on Geoscience and Remote Sensing, 55, 6, pp. 3382-3395, DOI: http://doi.org/10.1109/TGRS.2017.2670061.

Acknowledgments

- The first author is also thankful to Nikita P. Zelensky (SGT Inc., Greenbelt, USA), Dave Roland (NASA GSFC), Leonid Petrov (NASA GSFC) and many other people from NASA GSFC

- The authors are grateful to Julian Zeitlhöfler for providing some results on the challenges at attitude data handling and interpolation.

- This work was partly supported by the German Research Foundation through the project „Consistent dynamic satellite reference frames and terrestrial geodetic datum parameters”.