On the Effect of Non-tidal Atmospheric Loading on Altimetry Orbits

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Outline

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- Missions and data analyzed
- Precise Orbit Determination (POD)
- Effects of NTA&NTO loading on POD
- Summary

Motivation

- Situation
  - Precise orbits of altimetry missions are available
  - A number of NTA & NTO loading models are available
  - Models of NTA loading improved orbital fits of geodetic satellites
- Objective here
  - Use NTA & NTO in agreement with the usage of the GRACE AOD mass variations
  - What is the effect of NTA & NTO loading on altimetry orbits?

The Missions

(Courtesy ESA, 2018)

(Courtesy CNES, JPL, 2018)

Mission	Altitude (km)	Eccentricity	Inclination (deg)
ENVISAT	796	0.001	98.4
JASON-1	1325	0.001	66.0
JASON-2	1335	0.001	66.0

The Models for Atmospheric and Oceanic Loading

- GFZ model
  - provided by GFZ as associated product center by order of the International Earth Rotation and Reference System Service (IERS)
  - based on European Centre for Medium Weather Forecasts (ECMWF) operational Numerical Weather Model (NWM) data
  - long-term harmonized with re-analysis data
  - compatible with GRACE AOD RL06
  - here adopted are the 3 hourly 0.5°x0.5° global grids in the Center of Figure (CF) frame for NTA and NTO separately as netCDF
  - comes with a software and a land-water mask to interpolate for any station on Earth‘s surface
  - so the NTA and NTO grids need to be interpolated and combined

The Models for Atmospheric and Oceanic Loading

- IMLS model
  - provided as International Mass Loading Service (IMLS), in person L. Petrov
  - based on Modern-Era Retrospective analysis for Research and Applications (MERRA) NWM data
  - here adopted are 6-hourly pre-computed displacements of ~1200 stations for A and O
  - so the displacements are added component-wise for each available station
  - in the end we miss 9 stations out of 121 which were not found in the pre-computed displacements

Precise Orbit Determination

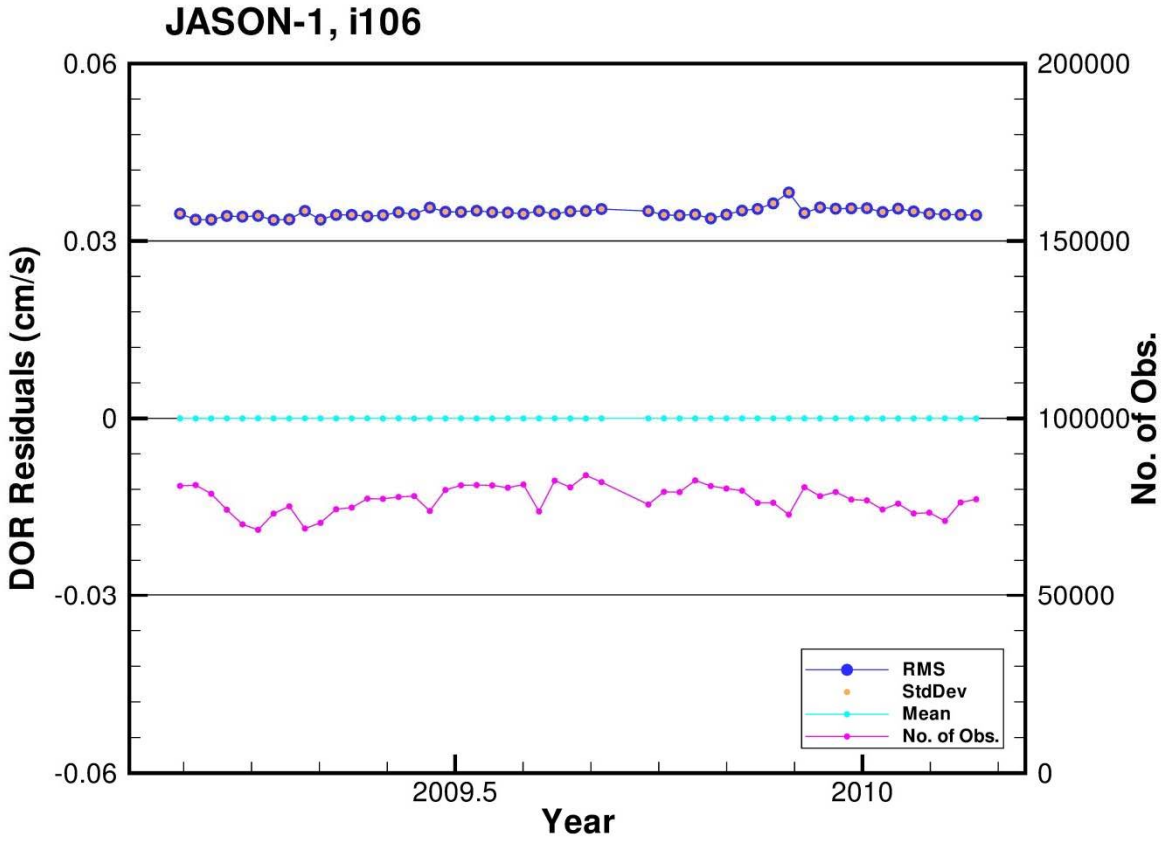
- Dynamic models
  - Gravity: EIGEN-6C up to degree/order 90 with linear trends up to degree/order 50
  - Ocean tides: EOT11A
  - Atmospheric tides: Bode&Biancale 2003
  - NTA and NTO mass variations: GRACE AOD RL06
- Geometric models
  - Tidal ocean loading: ocean loading provider service at Chalmers University by H.G. Scherneck based on FES2004
  - Tidal atmospheric loading not available
  - NTA & NTO loading either from GFZ or from IMLS

Precise Orbit Determination

- Solved-for parameters:
  - Initial orbits elements: 1 set per arc
  - Scaling factor for solar radiation pressure: 1 per arc
  - Atmospheric drag scaling factors:
    - ENVISAT: 8 per day
    - JASON1 and JASON2: 5 per day
  - Empirical accelerations:
    - ENVISAT: 1 per day
    - JASON1 and JASON2: 2 per day
  - DORIS time biases: 1 per arc
  - DORIS frequency biases: 1 per pass
  - DORIS tropospheric scaling: 1 per pass
  - SLR range biases: 1 per station per arc

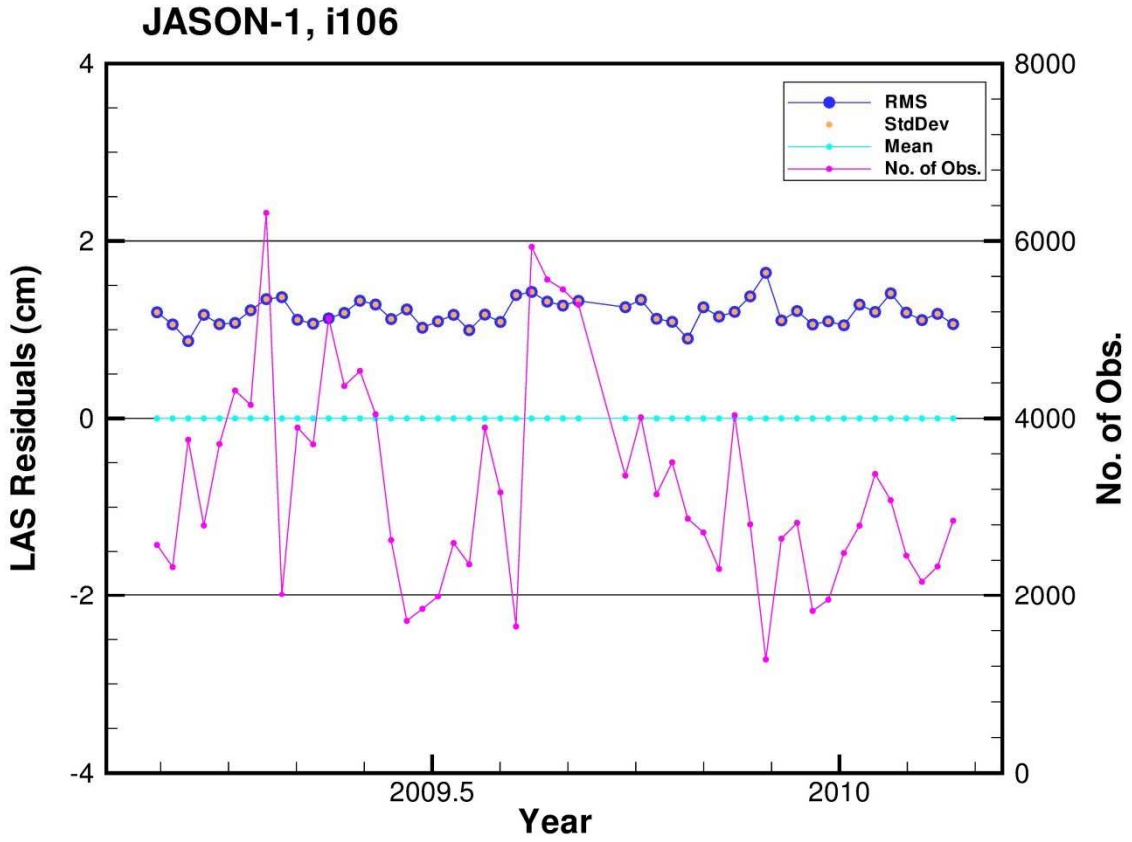
Precise Orbit Determination

- Orbital fits:
  - DORIS



Precise Orbit Determination

- Orbital fits:
  - SLR



Precise Orbit Determination

- SLR orbital fits in cm

Mission	No. Obs.	Initial	+ AOD	+ AOD + NTA&NTO
ENVISAT	82,491	1.3271	1.2598	1.2576 GFZ 1.2560 IMLS
JASON-1	162,454	1.1869	1.1541	1.1538 GFZ 1.1510 IMLS
JASON-2	193,776	1.2044	1.1703	1.1696 GFZ 1.1666 IMLS

Precise Orbit Determination

- DORIS orbital fits in cm/s

Mission	No. Obs.	Initial	+ AOD	+ AOD + NTA&NTO
ENVISAT	3,035,841	0.041599	0.041569	0.041571 GFZ 0.041567 IMLS
JASON-1	3,860,228	0.034774	0.034767	0.034769 GFZ 0.034769 IMLS
JASON-2	5,662,279	0.034805	0.034799	0.034800 GFZ 0.034798 IMLS

Precise Orbit Determination

- Orbit differences for 987,889 **ENVISAT** states, RMS in mm

Direction	AOD - Initial	NTAO – AOD GFZ	NTAO – AOD IMLS
Radial	4.4	0.3	0.9
Cross-track	10.9	0.9	1.4
Along-track	14.7	1.4	2.3

Precise Orbit Determination

- Orbit differences for 1,008,050 **JASON-1** states, RMS in mm

Direction	AOD - Initial	NTAO – AOD GFZ	NTAO – AOD IMLS
Radial	3.7	0.4	1.1
Cross-track	7.6	1.3	2.0
Along-track	9.7	1.0	2.3

Precise Orbit Determination

- Orbit differences for 1,048,372 **JASON-2** states, RMS in mm

Direction	AOD - Initial	NTAO – AOD GFZ	NTAO – AOD IMLS
Radial	3.6	0.4	1.0
Cross-track	7.2	1.0	1.7
Along-track	9.4	0.9	2.2

Summary

- The most benefit in terms of orbital fits comes from the dynamical effect of short-term mass variations provided by the GRACE AOD products: 0.6 mm
- AOD affects the orbit also the most: radial ~4 mm
- The orbital fit improves by NTAO loading effects by 0.2 mm in case of GFZ, 0.4 mm in case of IMLS
- NTAO loading affects the orbit radially: 0.4 mm in case of GFZ, 1.1 mm in case of IMLS

Next Steps

- Check effect of consolidated models
- Extend analysis period
- Analyze long-period orbit differences in space and time
- Expose orbits to altimeter data analysis

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