# A Review of IDS Processing for ITRF2008 and Avenues for Future Improvements

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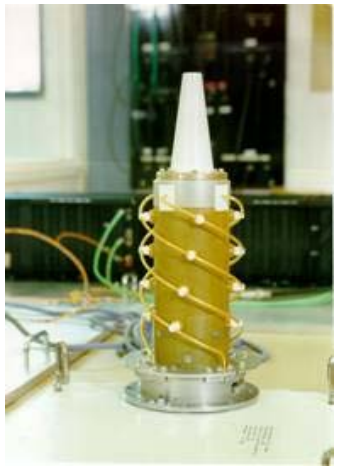
International DORIS Service

Outline

I. Introduction
II. Overview of AC's.
III. Significant improvements for ITRF2008
    • SRP; • Grace gravity models; • Drag parameterization.
IV. Processing Standards
V. Orbit comparisons
VI. Design of Combinations.
VII. Results.
VIII. Lessons learned & Issues
    • SPOT-5 SAA; DORIS Time-bias;
IX. Future work. Analysis campaigns.



# DORIS Ground Network


Colocations: GPS (~37); SLR(9); VLBI(7); Tide gauges (~23)

Ground ties (< 3 mm): GPS-DORIS, ~25; DORIS-DORIS; ~45

# IDS Analysis Centers Participating in ITRF2008

| Analysis Center | Acron. | Contact & Reference | Software |
|---|---|---|---|
| **ESA/ESOC**, Germany<br>European Space Agency/European Space Operations Center | ESA | *Michiel Otten*<br>*Otten et al. (2010)* | NAPEOS |
| **Geoscience Australia**<br>Canberra, Australia | GAU | *Ramesh Govind*<br>*Govind et al. (2010)* | GEODYN |
| **Geodetic Observatory Pecny**,<br>Czech Republic | GOP | *Petr Stepanek*<br>*Stepanek et al. (2010)* | BERNESE 5.0 |
| **NASA Goddard Space Flight Center**,<br>(GSFC), USA | GSC | *Karine Le Bail*<br>*Douglas Chinn*<br>*Frank Lemoine*<br>*Le Bail et al. (2010)* | GEODYN |
| **IGN/IPGP**, France<br>Institut Géographique National (IGN)/<br>Institut de Physique du Globe de Paris (IPGP) | IGN | *Pascal Willis*<br>*Marie-Line Gobinddass*<br>*Gobinddass et al. (2009a;2009b)* | GIPSY/OASIS 5.0 |
| **INASAN**, Institute of Astronomy, Russian Academy of Sciences, Russia | INA | *Sergey Kuzin*<br>*Suriya Tatevian*<br>*Kuzin et al. (2010)* | GIPSY/OASIS 4.03 |
| **CLS/CNES**, France<br>Centre National d'Etudes Spatiales<br>Laboratoire d'Etudes en Géophysique et Océanographie Spatiale Collecte Localisation Satellites | LCA | *Laurent Soudarin* | GINS/DYNAMO |

**IDS AC's Included in ITRF2005**

# Preparations and Improvements Implemented for IDS ITRF2008 Processing (1)

**Needed new *a priori* for ITRF2008 processing**

DPOD2005 (*Willis et al., Adv. Space Res., 44, 535-544, 2009)*

- Extend ITRF2005 for POD/Altimetry applications.
- Fix anomalies: e.g. Arequipa.
- Specify periods when data should be deleted (station anomalies).
- Test on TOPEX/Poseidon & Jason 1.
- Verify with available GPS & DORIS data.

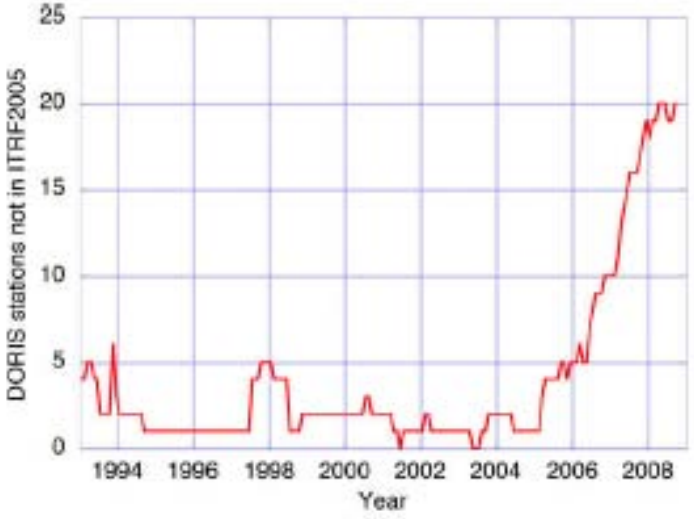



Fig. 2. Number of DORIS observing tracking stations not in the origi ITRF2005 solution (per month).

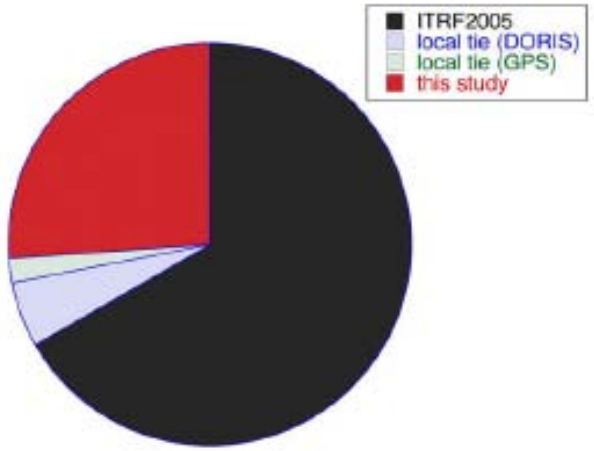


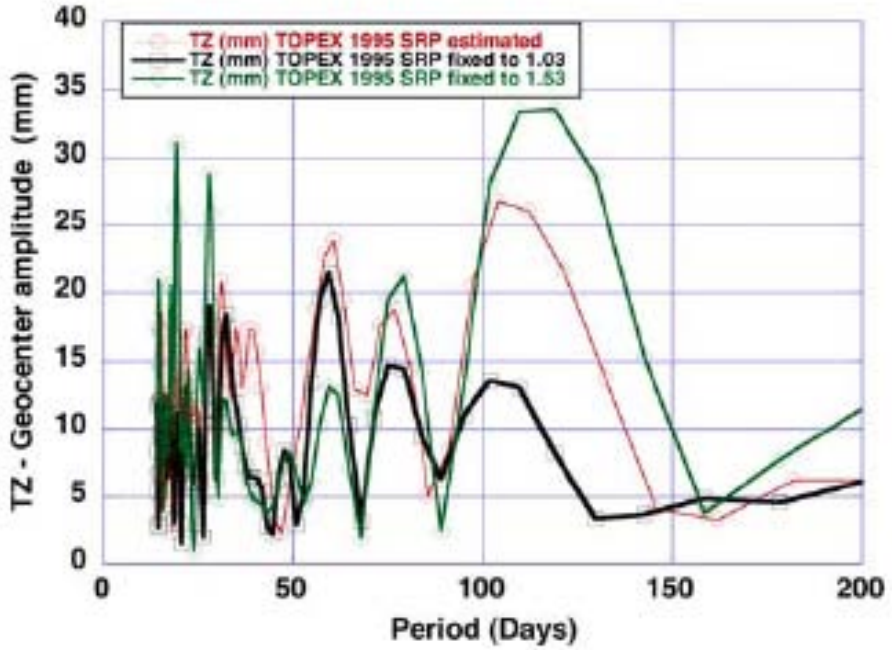

Fig. 6. Origin of DPOD2005 coordinates (statistics).

# Preparations and Improvements Implemented for IDS ITRF2008 Processing (2)

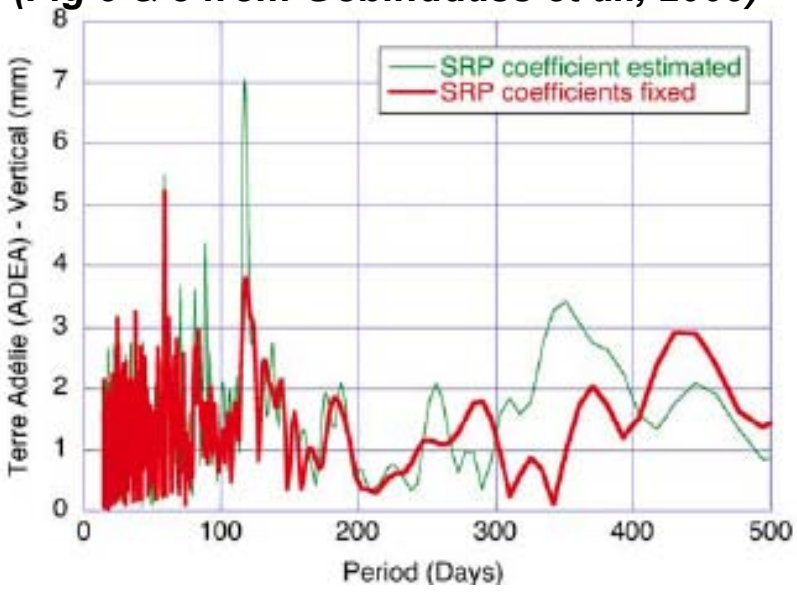
**Solar Radiation Pressure Modelling Improvements**
(*Gobinddass et al., J. Geodesy, 83, 849-855, 2009)*

- **SRP Mismodelling impacts particularly TZ geocenter at beta-prime (draconitic) period (~120 days TP; ~annual for SPOT/Envisat).**
- **Mismodelling generates "extraneous" signal in station coordinates at those frequencies.**
- **Solution: Tune Cr (Reflectivity Coefficient) & Hold Fixed.**

- **Alternate solution:** *(Le Bail et al., Adv. Space Res., 2010).* **Tune specific parameters of macromodel.**




*(Fig 5 & 8 from Gobinddass et al., 2009)*



# Preparations and Improvements Implemented for IDS ITRF2008 Processing (3)

**Drag Modelling Parameterization**
(*Gobinddass et al., Adv. Space Res., in press, 2010*)

- **Low-altitude DORIS satellite affected by atmospheric drag (esp. SPOT, Envisat, ~800 km).**
- **Drag errors can bias pole determination and worsen station coordinate estimation.**
- **DORIS data density are sufficient to adjust Cd more frequently ( 1/hr or 1/2hr) … & this reduces error.**

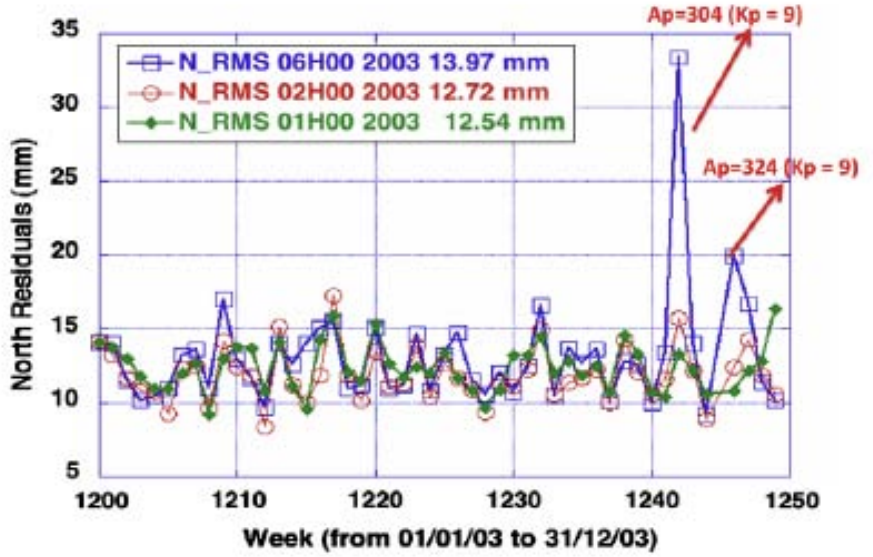



Fig. 7. Weekly DORIS station precision in the North component when using different strategies to reset the drag parameter.

# Processing Standards Summary (1)

| AC | Gravity | Atmos. Gravity | Ocean Tides | Troposphere + Met Data + Mapping Function | Elev. Cutoff (Deg) |
|---|---|---|---|---|---|
| ESOC | EIGEN-GL05C (120x120) | NCEP | FES2004 | GMF+GPT + GMF | 10° |
| GAU | GGM02C | NCEP | GOT4.7 | Hopfield + GPT+ Niell | 12° |
| GOP | EIGEN-GL04S (100x100) | ECMWF | CSR3 | GMF+ GPT + GMF | 10° |
| GSC | EIGEN-GL04S1 (120x120) | ECMWF | GOT4.7 | Hopfield + GPT+ Niell | 10° |
| IGN | GGM03S (120x120) | - | FES2004 | GMF+ formula +GMF | 10° |
| INA | GGM01C (120x120) | - | CSR3 | Lanyi+ formula+ Lanyi | 15° |
| LCA | EIGEN-GL04S | ECMWF | FES2004 | (1) | 12° |

(1) After 2002. Dry and Wet Interpolated from ECMWF grids; Before 2002, use DORIS Met. Data. Mapping function Guo and Langley (2003).

**Table 3a, Valette et al., 2010.**

# Processing Standards Summary (2)
## (Nonconservative force models)

| AC | Solar Radiation Pressure Modelling | Atmosphere Density Model | Drag Coefficient Estimation | Planetary Radiation Pressure |
|---|---|---|---|---|
| ESOC | Envisat : ANGARA Doornbos et al. (2002) T/P & SPOT's : Box-wing | MSIS90 | Cd/2.4 hrs | Knocke et al. (1988) |
| GAU | T/P, SP2, SP3 : GSFC(1) box-wing (untuned) SP4, SP5, Envisat : CNES box-wing (untuned) (2) | MSIS86 | SPOT's & Envisat : Cd/6 hrs T/P : Cd/8hrs | Knocke et al. (1988) |
| GOP | N/A (3) | N/A (3) | (3) | N/A (3) |
| GSC | T/P, SP2, SP3 : GSFC (tuned) (1) SP4, SP5 : CNES (tuned) (2) Envisat : UCL, Sibthorpe (2006) | MSIS86 | SPOT's & Envisat : Cd/2hrs. Cd/1hr 2001-2002 T/P : Cd/8 hrs | Knocke et al. (1988) |
| IGN | CNES box-wing (tuned) Gobinddass et al. (2009) | DTM94 | SPOT's & Envisat : Cd/1hr T/P :Cd/day | Knocke et al. (1988) |
| INA | CNES box-wing (untuned) (2) | DTM94 | SPOT's & Envisat : Cd/6hrs T/P : Cd/day | Not Applied |
| LCA | CNES box-wing (untuned) (2) | DTM94 | T/P: Cd/12 hrs SPOT's & Envisat: Cd/4 hrs Cd/1 hr 2001-2002 | Albedo & IR values from 6-hr ECMWF grids |

(1). See Le Bail et al. (2010) for GSFC macromodel summaries.
(2). CNES macromodels available from the IDS data centers.
(3). No exact models for non-conservative forces. Empirical constant and harmonic parameters in Sun and y-directions ; Stochastic parameters along-track every 15 minutes (Stepanek et al., 2006)

008 …"

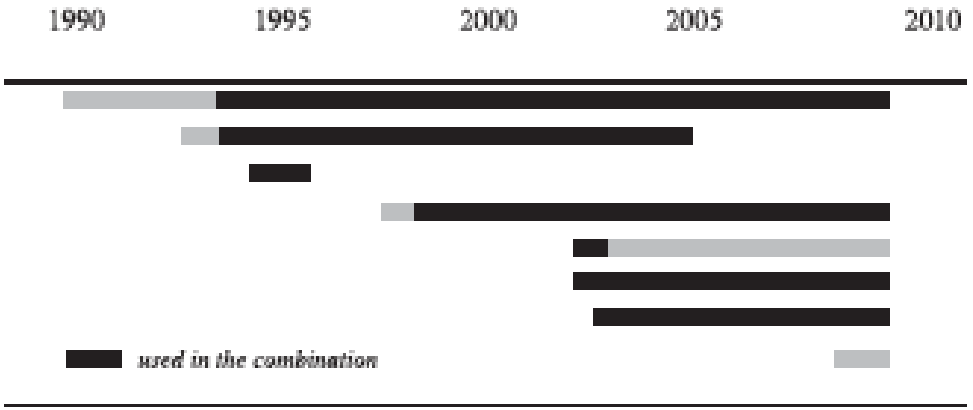
# Analysis Center Orbit Comparison & Validation Summary

(SPOT5 example for 2005)

| Series Compared (*RMS orbit diffs., cm*) | Radial | Cross-tr. | Along-tr. | N |
|---|---|---|---|---|
| AUS5 vs GSFC-base. | 0.36 | 2.20 | 1.26 | 48 |
| AUS5 vs GOP | 1.54 | 4.60 | 5.44 | 27 |
| AUS5 vs IGN3 | 1.25 | 4.33 | 3.59 | 328 |
| GOP vs GSFC-10dg | 1.51 | 4.68 | 5.37 | 30 |
| IGN3 vs GSFC-base. | 1.29 | 4.33 | 4.38 | 356 |
| GOP vs IGN3 | 1.69 | 4.44 | 5.44 | 28 |
| IGN3 vs GSFC-base. | 1.26 | 3.77 | 4.47 | 359 |
| IGN3 vs INA2 | 0.93 | 2.04 | 1.89 | 285 |
| IGN3 vs LCA | 1.23 | 3.62 | 3.20 | 312 |
| INA2 vs GSFC-10dg | 1.39 | 4.13 | 4.57 | 287 |

# DORIS data used in ITRF2008

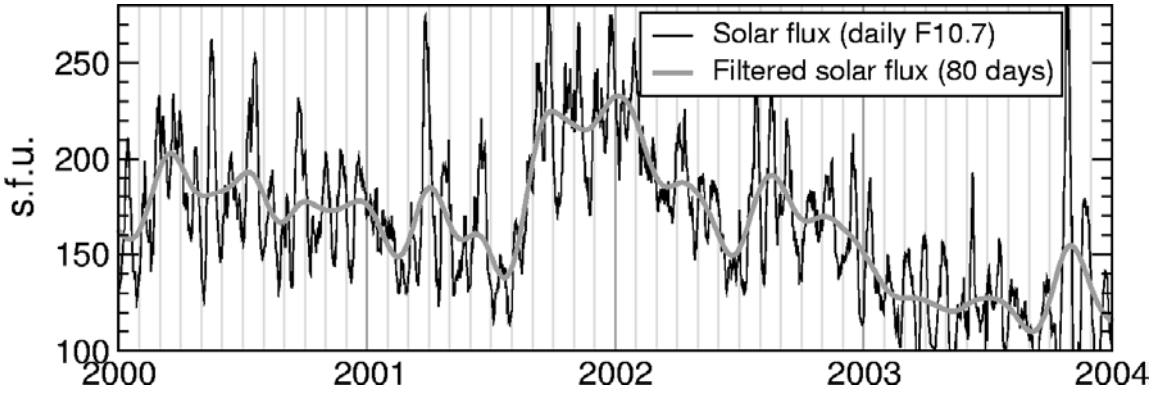
| Satellite | DORIS receiver |
|---|---|
| SPOT 2 | 1G |
| TOPEX | 1G |
| SPOT 3 | 1G |
| SPOT 4 | 1G |
| JASON 1 | 2GM |
| SPOT 5 | 2GM |
| ENVISAT | 2G |
| JASON 2 | DGXX |



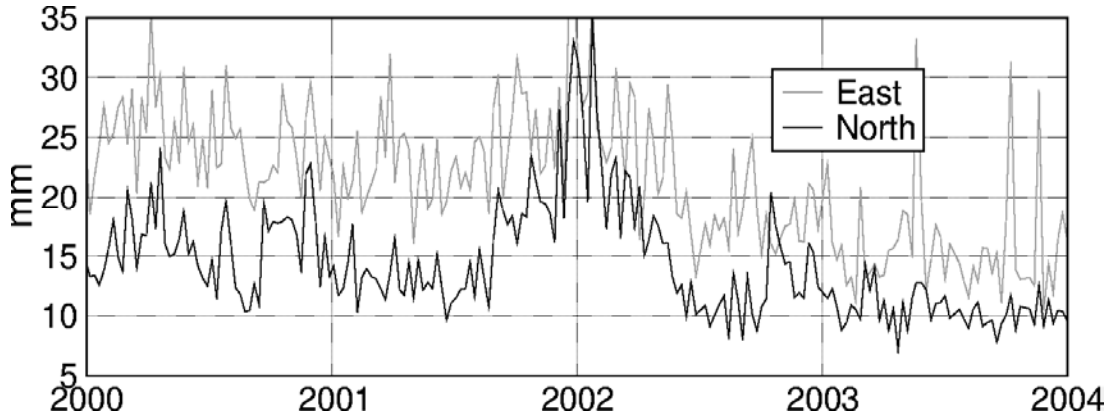

- 1993 to end of 2008.
- TOPEX, SPOT2, SPOT3, SPOT4, SPOT5, Envisat.
- Only 1 yr of Jason 1 (one AC) due to Instability of Jason-1 DORIS USO.
- No Jason-2 (Launched in June 2008) since POD modelling was not validated before submissions had to be completed.

# ITRF2008 results (1)

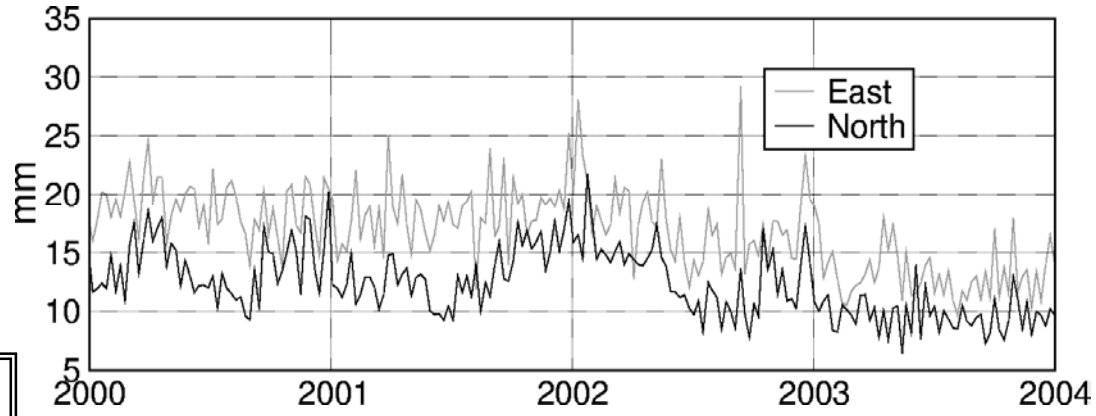
Solar Flux




IDS-1
Horizontal Residuals



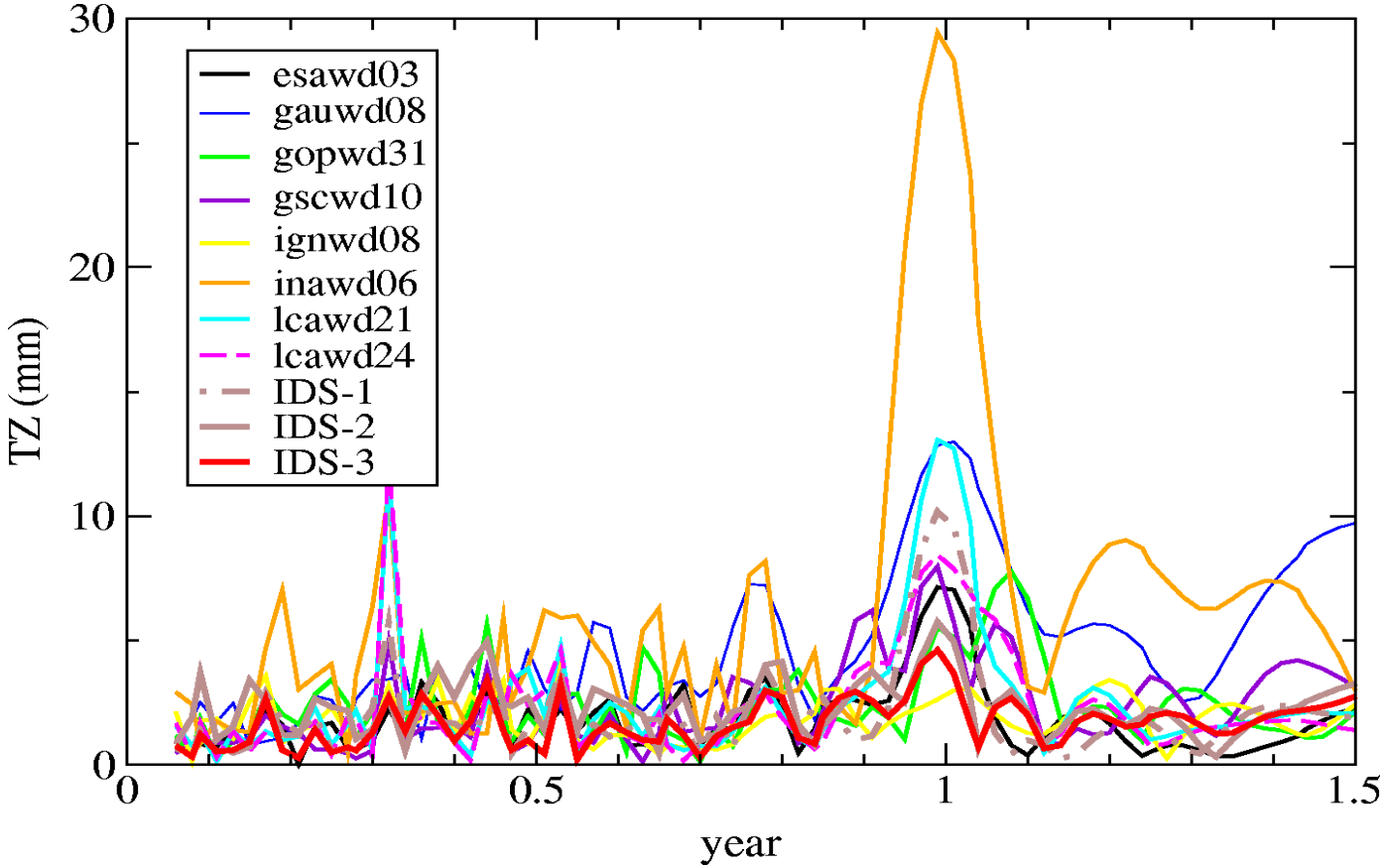

IDS-3
Horizontal Residuals




*After 2 AC's reprocessed data with more frequent cd parameterization*

Valette et al., 2010.

# Definition of the IDS Combination

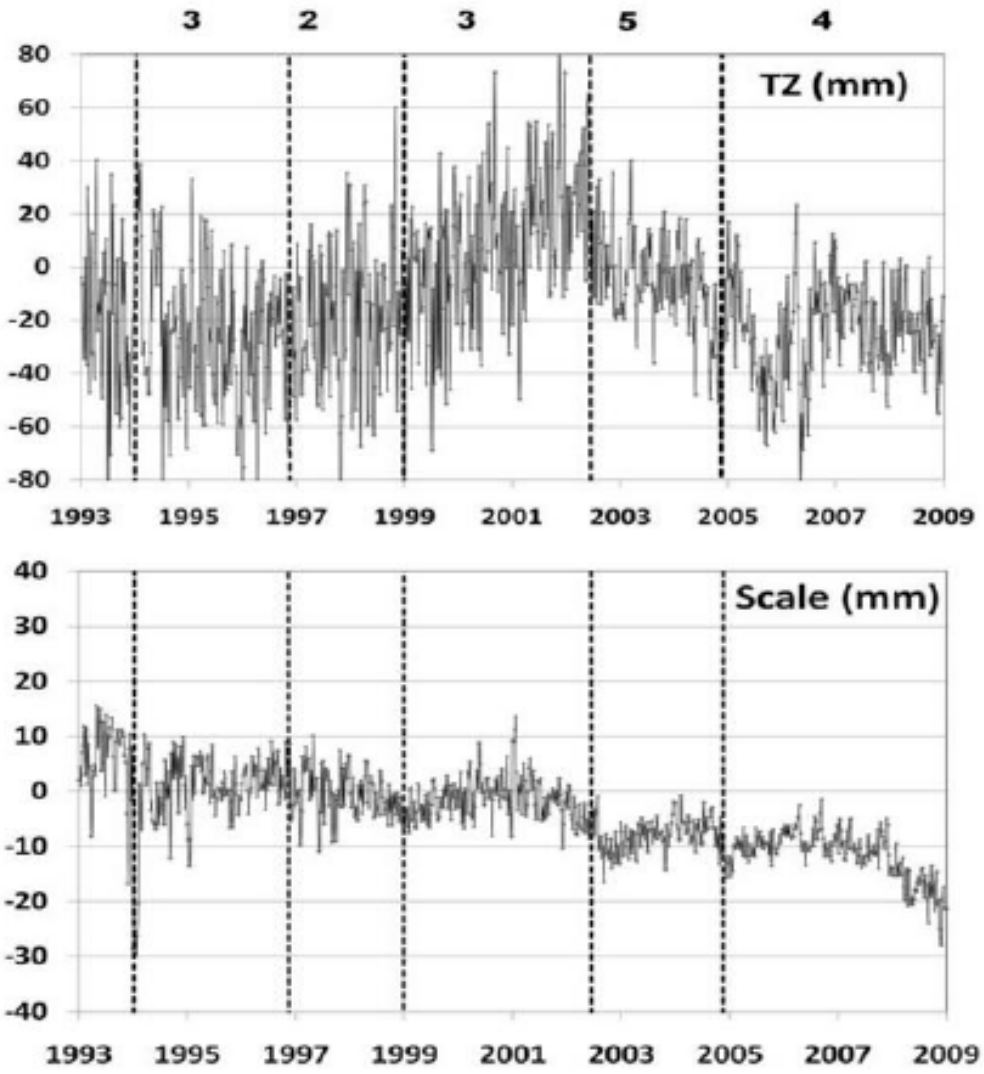



Valette et al., 2010

- Gobinddass et al. (2009) improved geocenter modelling by tuning & fixing Cr coefficient for each satellite.
- Analyzed the geocenter & scale time series of each AC contribution and looked at the 365-day and 118-day signals.
- This information used to define which AC's contribute to Combination geocenter & scale.

# IDS-3 Geocenter & Scale

*(wrt ITRF2005)*




Solar cycle signal?

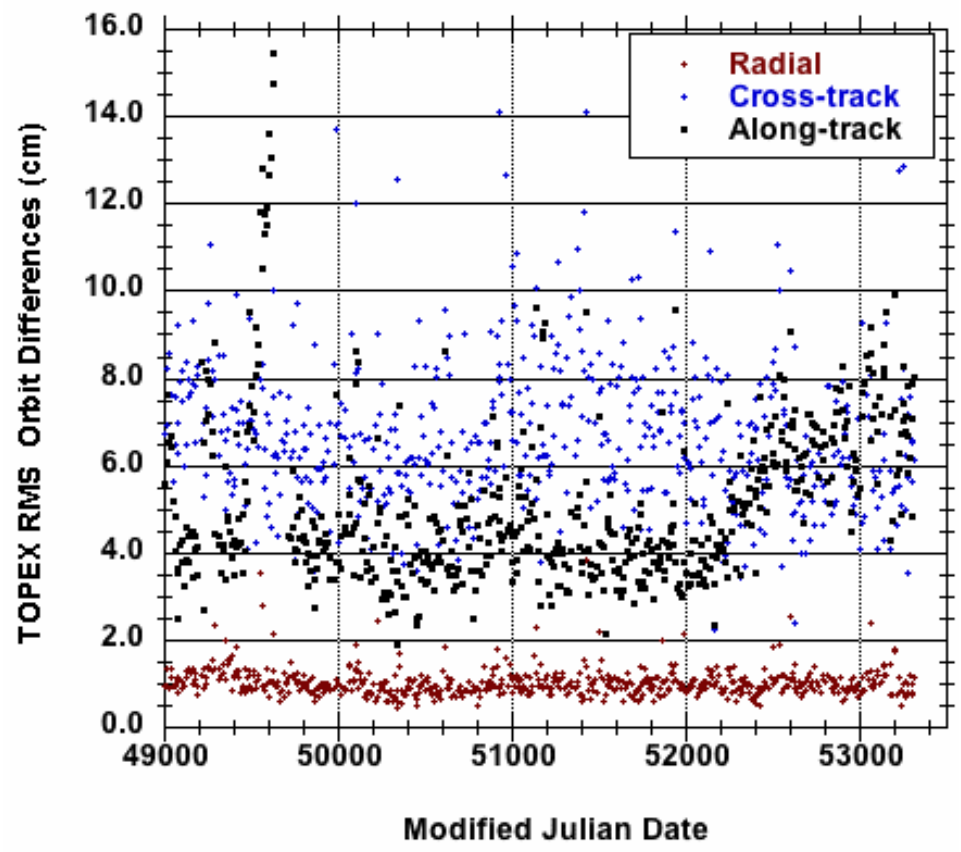
Discontinuities in scale related to satellites entering or leaving solution?

Valette et al., 2010

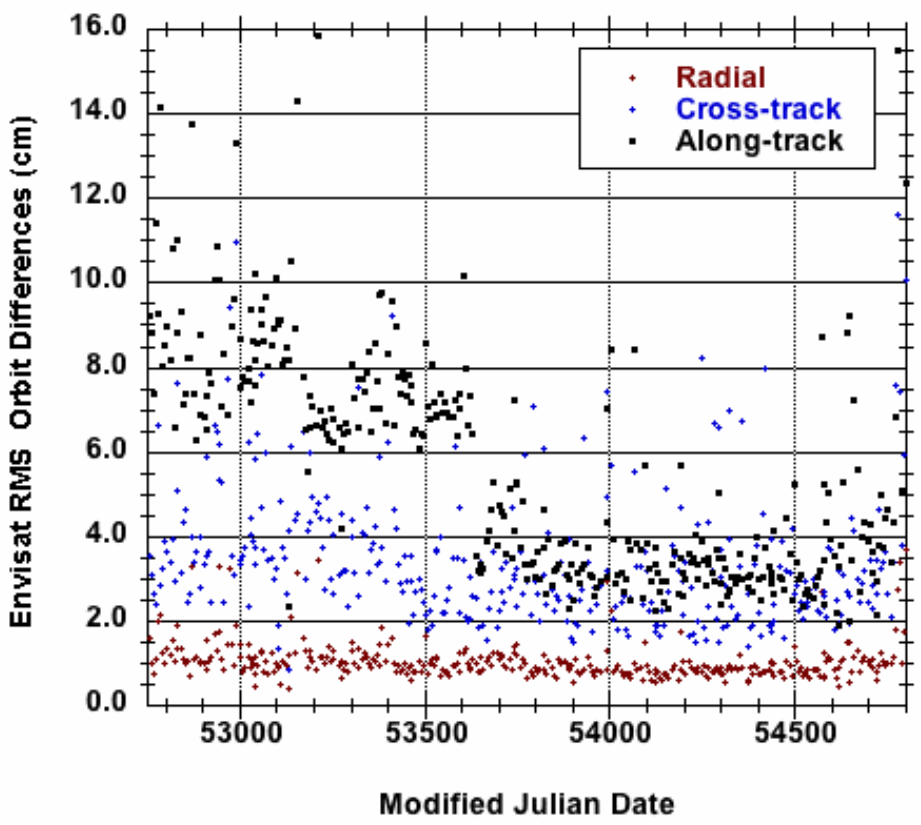
# DORIS system time-bias (wrt. SLR)

(SLR/DORIS vs DORIS-only Orbit Differences)

## TOPEX



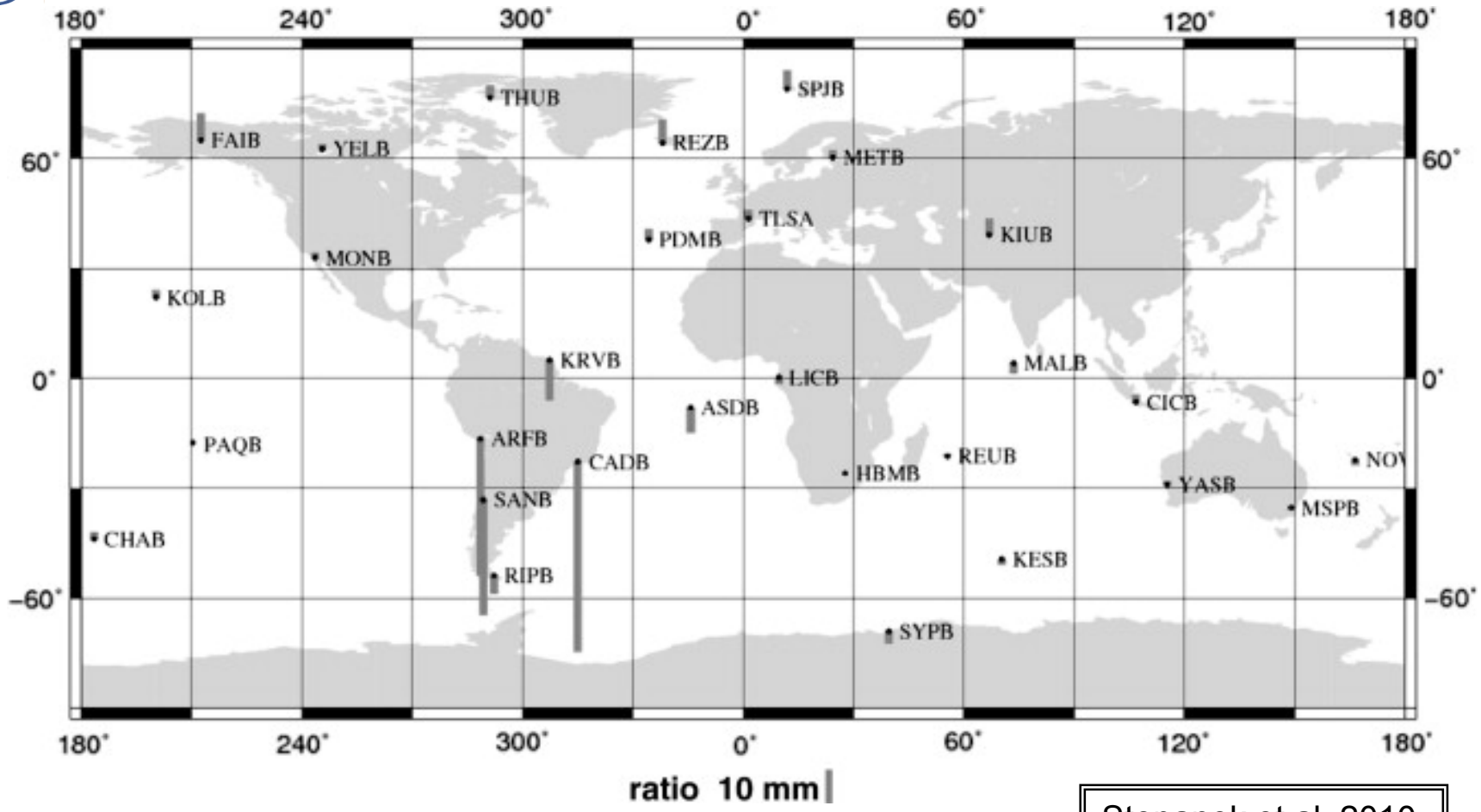

## Envisat




Le Bail et al. 2010.

**But what to do for the SPOT satellites?**

# SPOT-5 Anomaly?



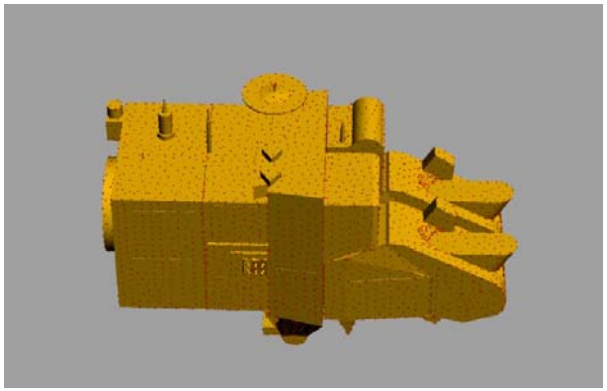

Stepanek et al. 2010.

ZTD DORIS-GNSS "Double differences"($\Delta ZTD_2$) between average value of the SPOT-2,4, Envisat individual solutions and the SPOT-5 solution.

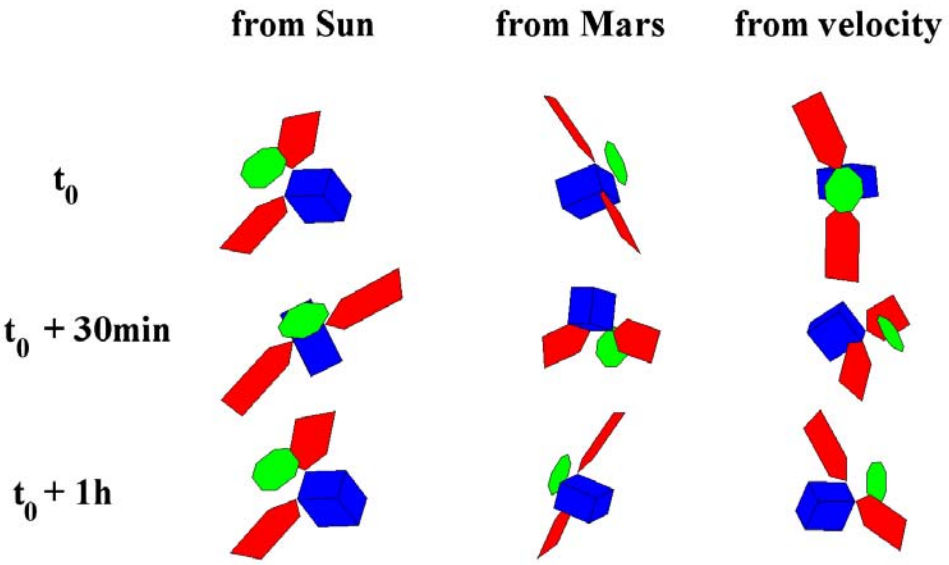
# Nonconservative Force Model Improvements?

All AC's used DTM94 or MSIS86. Use newer atmosphere models? (e.g. GRACE-derived; or JB2006, Bowman et al., 2008-J. Atmos. Sp. Physics)

UCL models for SPOT's & Cryosat-2?



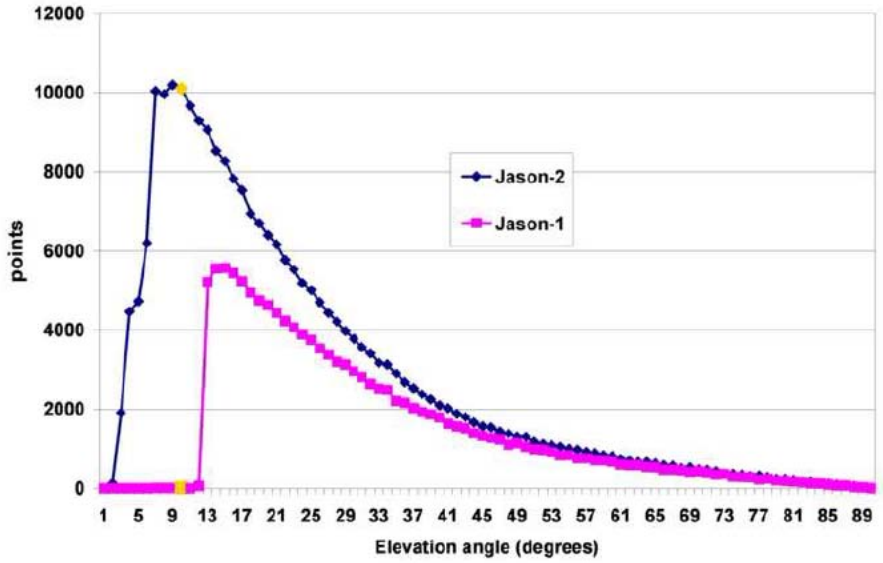
Self-shadowing as in *Mazarico et al., 2009, J. Spacecraft Rockets,* for MRO?




**Spacecraft attitude at three different orbital positions - view from different directions.**

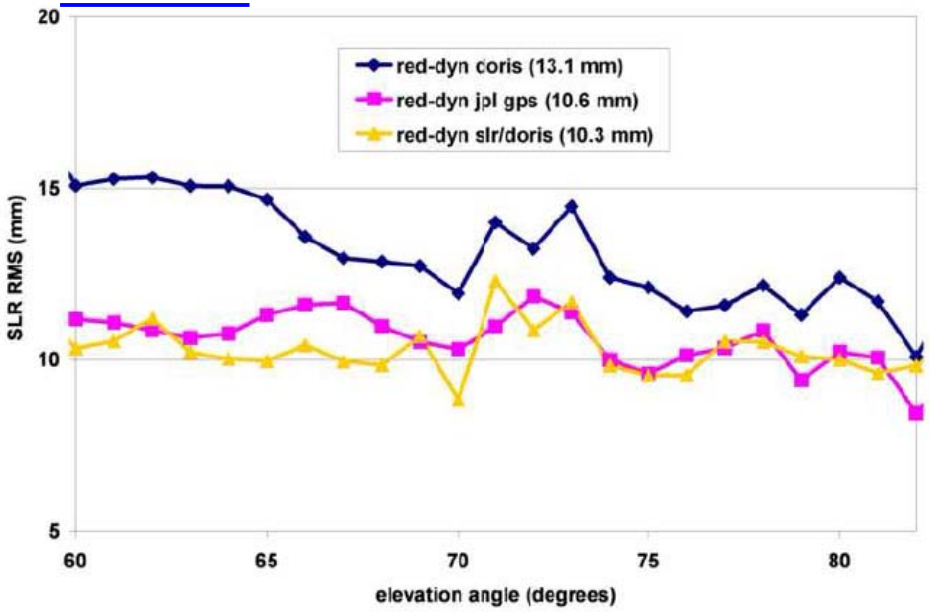
# Recent Jason-2 POD Results

## DORIS data vs. Elevation



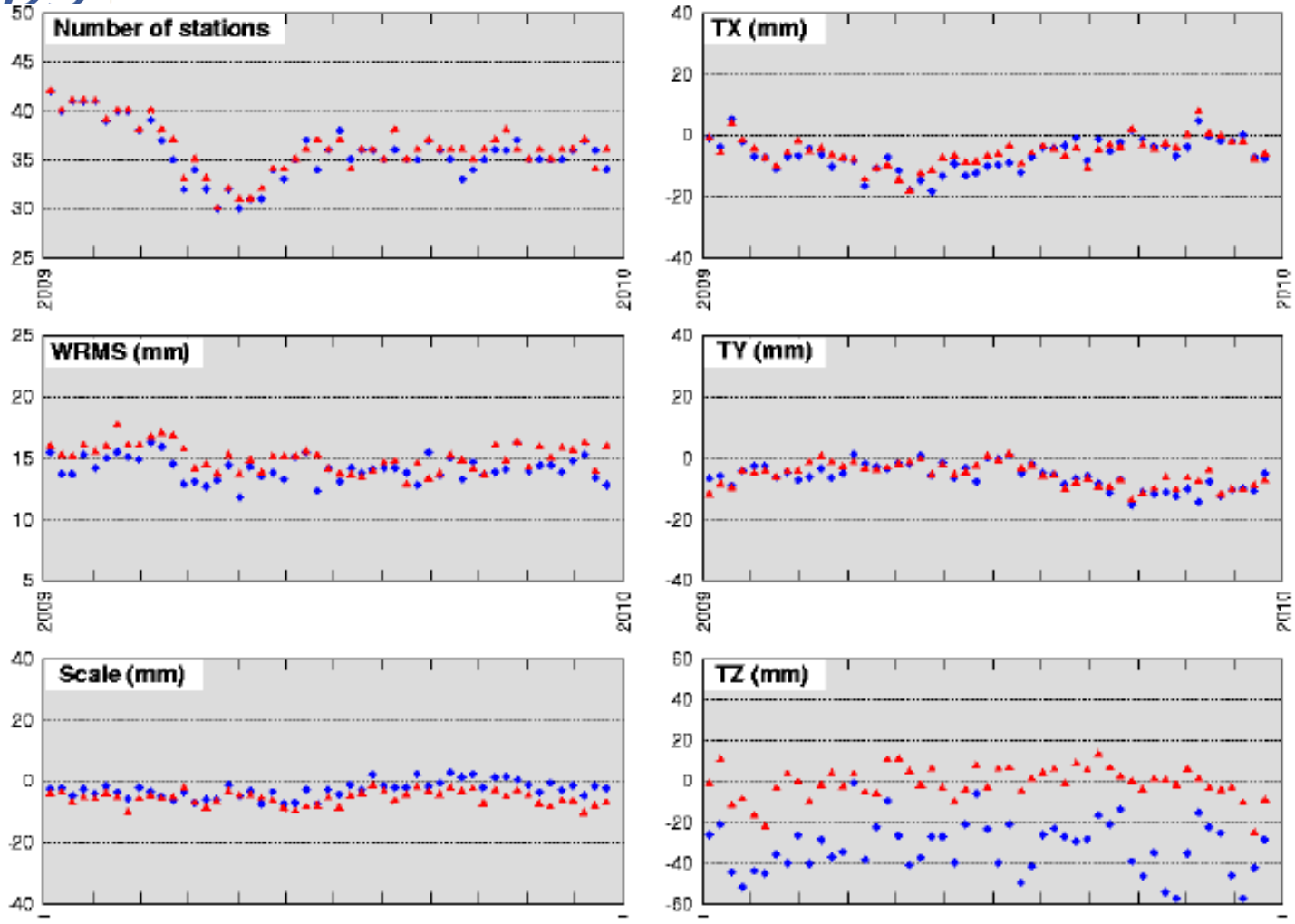

**New Jason-2 DGXX Receiver delivers at least 2X data of previous receivers.**

## High-elevation SLR Residuals for different orbits




Zelensky et al. 2010.

# Preliminary combinations with (esa04) & without (esa03) Jason2




Higher stability & better centering of TZ

esa03
esa04

Valette & Moreaux, IDS AWG Darmstadt, May 2010.

# Summary

1. The IDS for the first time constructed an technique-level combination based on analysis by seven independent analysis centers (5 separate software packages).
2. Our goals in the near future are - integrating new satellites into the solutions (Jason2 & Cryosat2) - and developing a routine weekly combination.
3. Issues that need to be investigated: (1) time biases on DORIS data; (2) improved non-conservative force modelling for DORIS satellites; (3) better troposphere modelling including mapping functions; (4) SPOT-5 Anomaly.

4. DORIS workshop is scheduled in Lisbon, Portugal in conjunction with Jason SWT meeting (October 18-22, 2010).
5. For more details see DORIS special issue in Adv. Space Research, 2010 (two volumes).

6. **For more information see URL http://ids-doris.org**

# (some) References


**Willis, P., Fagard, H., Ferrage, P., Lemoine, F.G., Noll, C.E; et al., (2010). The International DORIS Service, Toward maturity, *Adv. Space Research, 45(12),*1408-1420, DOI: 10.1016/j.asr.2009.11.018. <====== NEW IDS CITATION.**

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# Satellite Status & Future Missions

| | | |
|---|---|---|
| **CRYOSAT-2 (ESA)** | **717 km, 92°** | **DGXX+SLR** |
| (*launched April 2010. Data now available from IDS data centers).* | | |
| **ENVISAT (ESA)** | **800 km, 98.5°** | **D2G +SLR** |
| *(17 km orbit reduction planned in Oct. 2010).* | | |
| **SARAL/ALTIKA (ISRO/CNES)** | **880 km, 98.5°** | **DGXX+SLR** |
| *(Launch: January 2011)* | | |
| **HY2A (CNSA)** | **963 km, 99.3°** | **DGXX+SLR+GPS** |
| *(Launch: June 2011; Then HY2B, HY2C ….)* | | |
| **SENTINAL 3A (GMES)** | **814 km, 98.6°** | **DGXX+SLR+GPS** |
| *(Launch: April 2013)* | | |
| **JASON-3** | **1336 km, 66°** | **DGXX+SLR+GPS** |
| **(NOAA/EUMETSAT/CNES/NASA)** | | |
| *(Summer 2013; Follow-on to TOPEX, Jason-1, Jason-2)* | | |
| **SWOT (NASA/CNES)** | **970 km, 78°** | **DGXX+SLR+GPS** |
| *(Surface Water Ocean Topography; Launch 2018)* | | |