

# Altimeter satellite POD Status in the context of ITRF2013

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### Outline

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- II. Satellite-specific force modeling
- III. Measurement offsets.
- IV. Empirical Parameter Parameterization & Results
- V. DORIS system time biases
- VI. RMS of fit
- VII. SLR-DORIS vs DORIS-only orbit comparisons

VIII.External Ephemeris comparisons (Saral only)













### **Motivation: Processing for ITRF2013**





- 1. SLR data processed systematically to validate orbit processing for altimeter satellites.
- 2. Especially during initial processing, SLR data helped to validate implementation of attitude model & use of quaternions.
- 3. SARAL not part of processing for ITRF2013 but analyzed separately.



## General Model Summary (wd25)



| Change                  |  |
|-------------------------|--|
| Static gravity model    | GOCO2s (L > 5)   |
| Time-variable gravity   | (L<5). GSFC-derived SLR-DORIS time series.                     |
| Troposphere             | GMF/Saastmoinen; Adjust wet-only.                              |
| Solid Earth tides       | Formulation per IERS2003.                                      |
| Ocean Tides             | GOT4.8 (20x20)   |
| Ocean pole tide         | Applied.   |
| Station coordinates     | DPOD2008v1.12 & SLRF2008 (w. modifications for SLR biases)     |
| Ocean loading           | GOT4.8   |
| Atmospheric Gravity     | ECMWF-6hr  |
| Pole modeling           | IERS2010 standards (Petit and Luzum, 2010; Table 7.7, pp. 115) |
| Atmospheric density     | MSIS86   |
| Planetary Radiation Pr. | Knocke & Ries (1988)   |





# Non-conservative force models summary (wd25)

| Satellite | Model Applied & Source  | Attitude                               |
|-----------|---|--|
| Envisat   | SRP. UCL. Cr=1.00417 ( <i>sibthorpe, 2006</i> ). Drag & PRP. Macromodel.    | Model                                  |
| Jason-1   | SRP. UCL. Cr=1.00. ( <i>Ziebart et al., 2005</i> ). DRAG & PRP. Macromodel. | quaternions                            |
| Jason-2   | CNES-derived macromodel. Cr=0.945.  | quaternions                            |
| Cryosat-2 | CNES, 7-plate macromodel. Untuned.  | quaternions (EJO<br>Schrama, TU Delft) |
| HY2A      | CNES macromodel. GSFC-tuned.  | Model                                  |
| SARAL     | CNES macromodel.  | Model                                  |





### Measurement Offsets (wd25)

| Satellite | SLR              | DORIS                   |
|-----------|------------------|-------------------------|
| Envisat   | ILRS (nominal)   | nominal (CNES document) |
| Jason-1   | Tuned (GSFC)     | nominal (CNES document) |
| Jason-2   | Tuned (GSFC)     | nominal (CNES document) |
| Cryosat-2 | Tuned (GSFC)     | nominal (CNES document) |
| HY2A      | ILRS (corrected) | nominal (CNES document) |
| SARAL     | Tuned (GSFC) ¶   | nominal (CNES document) |

¶ For details IDS Poster on SARAL orbit determination by N. Zelensky

wd25: Tracking Point correction is computed in GEODYN with attitude model or quaternions (J1, J2, C2).
wd20: Tracking Point correction is computed with attitude model or quaternions (J1, J2, C2) only for SLR data; For DORIS, the data-supplied corrections were applied.





### SARAL Center-of-Mass & Offset Adjustment

| 2) Correct SARAL CM and re-estimate DORIS/SLR antenna offsets  |                        |              |         |              |  |  |
|--|------------------------|--------------|---------|--------------|--|--|
| SARAL SLR / DORIS antenna offset re-tuning<br>over 130317-131222 data. (CM corrected<br>using mean of tune1 SLR+DORIS Z estimates) |                        | Offset (m)   |         |              |  |  |
|  |                        | X<br>(nadir) | Z       |              |  |  |
| CM (Contor of Mass)  | CNES a-priori          | -0.0112      | -0.0067 | -0.6583      |  |  |
| CM (Center of Mass)  | Corrected              | -0.0112      | -0.0067 | -0.6152      |  |  |
|  |                        |              |         |              |  |  |
| LRA antenna offset<br>re-tune  | a-priori               | 0.4735       | 0.0000  | -0.9400      |  |  |
|  | correction to a-priori | 0.0157       |         | -0.0025      |  |  |
|  | estimate sigma         | ±0.0016      |         | $\pm 0.0014$ |  |  |
| DODIC antonna offact   | a-priori               | 0.8050       | -0.3040 | -1.1290      |  |  |
| re-tune  | correction to a-priori | 0.003        |         | 0.002        |  |  |
|  | estimate sigma         | ±0.001       |         | ±0.002       |  |  |
| Note. LRA OBSCOR = -0. 03748 m (Arnold); DORIS phase map correction  |                        |              |         |              |  |  |

#### +4.43 cm correction in Z (cross-track) for SARAL Center-of-mass (COM)



### wd25 Empirical OPR Summary (over time span of data)



| Satellite | Along-track Amplitude<br>(nm/s**2) |        | Cross-trac<br>(nm | n      |      |
|-----------|------------------------------------|--------|-------------------|--------|------|
|           | Mean                               | Median | Mean              | Median |      |
| TOPEX     | 0.91                               | 0.50   | 2.30              | 1.40   | 4324 |
| Envisat   | 1.40                               | 1.30   | 1.47              | 1.32   | 3519 |
| Jason-1   | 1.52                               | 1.27   | 1.71              | 1.57   | 1243 |
| Jason-2   | 1.37                               | 1.23   | 2.70              | 2.89   | 2110 |
| Cryosat-2 | 2.45                               | 2.38   | 2.27              | 2.16   | 1490 |
| HY2A      | 3.04                               | 2.80   | 2.74              | 2.48   | 906  |
| Saral     | 1.59                               | 1.42   | 1.49              | 1.35   | 157  |

OPR parameterization: along-track, cross-track cosine & sine term per-day. For HY2A. Along-track constant acceleration per day is also adjusted.



## Envisat: empirical OPR's (wd25, 2002-2012)





Modified Julian Date



### HY-2A: empirical OPR's (wd25, 2011-2014)





Lemoine et al., 2014; Altimeter Satellite POD Status, OSTST, Konstanz, Germany



### HY-2A: constant along-track Accel. (wd20 & wd25, 2011-2014)







### Cryosat-2: empirical OPR's. (wd25, 2010-2014)





Lemoine et al., 2014; Altimeter Satellite POD Status, OSTST, Konstanz, Germany



Lemoine et al., 2014; Altimeter Satellite POD Status, OSTST, Konstanz, Germany



### DORIS system time bias from SLR+DORIS POD (wd25), I



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wd25 Slr/Dor Timing Bias 8 en c2 6 hy sa Δ 2 microsec 0 -6 -8 2000 2005 2010 2015



### DORIS system time bias from SLR+DORIS POD (wd25), II





Lemoine et al., 2014; Altimeter Satellite POD Status, OSTST, Konstanz, Germany



## **POD RMS of fit Summary**

(over time span of data)



#### (cm for SLR, mm/s for DORIS)

| Satellite & Data | wd20  | wd25         |
|------------------|-------|--------------|
| Envisat (SLR)    | 1.126 | 1.039        |
| (DORIS)          | 0.491 | <b>0.491</b> |
| TOPEX (SLR)      | 1.668 | 1.701        |
| (DORIS)          | 0.513 | 0.512        |
| Jason2 (SLR)     | 1.172 | 1.118        |
| (DORIS)          | 0.379 | 0.379        |
| Cryosat-2 (SLR)  | 1.304 | 1.134        |
| (DORIS)          | 0.402 | 0.400        |
| HY-2A (SLR)      | 1.506 | 1.335        |
| (DORIS)          | 0.411 | 0.409        |
| SARAL (SLR)      | 1.621 | 1.405        |
| (DORIS)          | 0.399 | 0.392        |



Orbit Comparison Summary: Avg RMS orbit differences per arc, over time span of available data (gscwd25, SLR+DORIS vs. DORIS; cm)



| Satellite | Radial | Cross-track | Along-track |
|-----------|--------|-------------|-------------|
| Cryosat2  | 0.20   | 1.24        | 3.81        |
| Envisat   | 0.30   | 2.14        | 1.70        |
| HY-2A     | 0.19   | 1.92        | 1.79        |
| Saral     | 0.19   | 1.02        | 1.47        |
| TOPEX     | 0.86   | 6.84        | 3.60        |
| Jason-1   | 0.55   | 3.32        | 3.34        |
| Jason-2   | 0.35   | 2.05        | 1.77        |



Aug 2014)

std1404 - gdrd

External Orbit Comparison: Saral (1) (std1404 vs. CNES GDR-D)



| SLR+DORIS ORBI<br>(external                    | T SARAL cycles 1-15<br>March 14 2013 – August 10 2014 |                                |          |       |       |       |       |       |      |
|--|---|--------------------------------|----------|-------|-------|-------|-------|-------|------|
| ephemeris                                      | DORIS   |                                | SLR (cm) |       |       |       | Xover |       |      |
| residuals)                                     | (mr   | (mm/s)                         |          | lean  | RMS   |       |       | (cm)  |      |
| std1404  | 0.4   | 261                            | +(       | ).123 |       | 1.378 |       | 5.    | .782 |
| gdrd   | 0.4   | 0.4149                         |          | ).290 | 1.581 |       |       | 5.837 |      |
| orbit difference<br>cycles 1-15<br>(Mar 2013 – | RMS   | RMS Inertial (mm) Mean ECF (mm |          |       |       |       | (mm)  |       |      |
|  | radial  | cros                           | 55-      | along | -     | Х     | Y     | (     | Z    |

Lemoine et al., 2014; Altimeter Satellite POD Status, OSTST, Konstanz, Germany

23.5

9.7

track

track

35.2

-0.9

-5.4

1.8



External Orbit Comparison: Saral (2) (std1404 vs. CNES GDR-D, cyc. 1-15)



### std1404-gdrd (mm) cycles 1-15





### Summary & Future work



- As part of the work for ITRF2013, we have processed SLR+DORIS data for the entire constellation of current and past altimetry satellites (Envisat Saral, HY-2A, Cryosat-2 in addition to TP, Jason-1, Jason-2) using the standards set for the ITRF2013 processing.
- 2. Carry out detailed orbit inter-comparisons for other satellites, using orbits provided by other analyis centers (completed only for SARAL at present, 1 cm radial orbit agreement with CNES/GDRD)
- 3. Continue work on improving non-conservative force models for the DORIS satellites.