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

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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.
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

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

**IDS AC’s Included in ITRF2005**
Preparations and Improvements
Implemented for IDS ITRF2008 Processing (1)

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


(Fig 5 & 8 from Gobinddass et al., 2009)
Preparations and Improvements Implemented for IDS ITRF2008 Processing (3)

**Drag Modelling Parameterization**

- 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 $C_d$ 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)

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


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**Table 3a, Valette et al., 2010.**
## Processing Standards Summary (2)
(Nonconservative force models)

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

(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)
## Analysis Center Orbit Comparison & Validation Summary
(SPOT5 example for 2005)

<table>
<thead>
<tr>
<th>Series Compared (RMS orbit diffs., cm)</th>
<th>Radial</th>
<th>Cross-tr.</th>
<th>Along-tr.</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>AUS5 vs GSFC-base.</td>
<td>0.36</td>
<td>2.20</td>
<td>1.26</td>
<td>48</td>
</tr>
<tr>
<td>AUS5 vs GOP</td>
<td>1.54</td>
<td>4.60</td>
<td>5.44</td>
<td>27</td>
</tr>
<tr>
<td>AUS5 vs IGN3</td>
<td>1.25</td>
<td>4.33</td>
<td>3.59</td>
<td>328</td>
</tr>
<tr>
<td>GOP vs GSFC-10dg</td>
<td>1.51</td>
<td>4.68</td>
<td>5.37</td>
<td>30</td>
</tr>
<tr>
<td>IGN3 vs GSFC-base.</td>
<td>1.29</td>
<td>4.33</td>
<td>4.38</td>
<td>356</td>
</tr>
<tr>
<td>GOP vs IGN3</td>
<td>1.69</td>
<td>4.44</td>
<td>5.44</td>
<td>28</td>
</tr>
<tr>
<td>IGN3 vs GSFC-base.</td>
<td>1.26</td>
<td>3.77</td>
<td>4.47</td>
<td>359</td>
</tr>
<tr>
<td>IGN3 vs INA2</td>
<td>0.93</td>
<td>2.04</td>
<td>1.89</td>
<td>285</td>
</tr>
<tr>
<td>IGN3 vs LCA</td>
<td>1.23</td>
<td>3.62</td>
<td>3.20</td>
<td>312</td>
</tr>
<tr>
<td>INA2 vs GSFC-10dg</td>
<td>1.39</td>
<td>4.13</td>
<td>4.57</td>
<td>287</td>
</tr>
</tbody>
</table>
DORIS data used in ITRF2008

- 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

- 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.

Valette et al., 2010
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

But what to do for the SPOT satellites?

Le Bail 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.

Stepanek et al. 2010.
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**

**High-elevation SLR Residuals for different orbits**

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

Zelensky et al. 2010.
Preliminary combinations with (esa04) & without (esa03) Jason2

Higher stability & better centering of TZ

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](http://ids-doris.org)
(some) References


## Satellite Status & Future Missions

<table>
<thead>
<tr>
<th>Satellite</th>
<th>Height</th>
<th>Inclination</th>
<th>DGXX/SLR/GPS</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ENVISAT (ESA)</strong></td>
<td>800 km</td>
<td>98.5°</td>
<td>D2G +SLR</td>
<td>(17 km orbit reduction planned in Oct. 2010).</td>
</tr>
<tr>
<td><strong>SARAL/ALTIKA (ISRO/CNES)</strong></td>
<td>880 km</td>
<td>98.5°</td>
<td>DGXX+SLR</td>
<td>(Launch: January 2011)</td>
</tr>
<tr>
<td><strong>HY2A (CNSA)</strong></td>
<td>963 km</td>
<td>99.3°</td>
<td>DGXX+SLR+GPS</td>
<td>(Launch: June 2011; Then HY2B, HY2C ....)</td>
</tr>
<tr>
<td><strong>SENTINAL 3A (GMES)</strong></td>
<td>814 km</td>
<td>98.6°</td>
<td>DGXX+SLR+GPS</td>
<td>(Launch: April 2013)</td>
</tr>
<tr>
<td><strong>JASON-3</strong></td>
<td>1336 km</td>
<td>66°</td>
<td>DGXX+SLR+GPS</td>
<td>(NOAA/EUMETSAT/CNES/NASA) (Summer 2013; Follow-on to TOPEX, Jason-1, Jason-2)</td>
</tr>
<tr>
<td><strong>SWOT (NASA/CNES)</strong></td>
<td>970 km</td>
<td>78°</td>
<td>DGXX+SLR+GPS</td>
<td>(Surface Water Ocean Topography; Launch 2018)</td>
</tr>
</tbody>
</table>