DORIS results on Precise Orbit Determination and on geocenter and scale solutions from CNES/CLS IDS Analysis Center contribution to the ITRF2020

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Outline

- Models and Standards Update
- Processing Strategy update
- POD results
  - OPR and DORIS RMS of fit
- Status of POD for DORIS satellites used for altimetry
  - DORIS RMS of fit
  - Comparison to external orbits
- Impact on the multi-satellite solution
- Ongoing and future work
## Models/Standards update

- **Models and standards recommended by IERS**

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<thead>
<tr>
<th>Models/Standards</th>
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<th>NEW</th>
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</thead>
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<td><strong>Earth rotation</strong></td>
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<tr>
<td>Mean pole</td>
<td>IERS2010</td>
<td>Linear mean pole from updated IERS conventions</td>
</tr>
<tr>
<td>Subdaily pole model</td>
<td>Previous IERS convention</td>
<td>Desai &amp; Sibois from updated IERS conventions</td>
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<tr>
<td><strong>Gravity model</strong></td>
<td></td>
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<tr>
<td>Time variable gravity field</td>
<td>EIGEN-GRGS.RL03</td>
<td>EIGEN-GRGS.RL04</td>
</tr>
<tr>
<td>Oceanic/Atmospheric gravity</td>
<td>No</td>
<td>AOD 1B RL06 (GFZ)</td>
</tr>
<tr>
<td>Dealiasing Products</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Ocean tides</strong></td>
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</tr>
<tr>
<td>Station displacements (ocean loading)</td>
<td>FES2012</td>
<td>FES2014b</td>
</tr>
<tr>
<td>Gravitational attraction</td>
<td>FES2012</td>
<td>FES2014b</td>
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<tr>
<td><strong>Phase Law</strong></td>
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<tr>
<td></td>
<td>Alcatel, STAREC-B/C</td>
<td>New Alcatel, STAREC-B/C</td>
</tr>
</tbody>
</table>
## Processing strategy update

### Processing strategy (GINS/DYNAMO software)

<table>
<thead>
<tr>
<th>Theme</th>
<th>OLD</th>
<th>NEW</th>
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<tbody>
<tr>
<td><strong>Attitude modelling</strong> (Spacecraft + Solar array)</td>
<td>Attitude model for all satellites</td>
<td>Quaternions for Jason-1, Jason-2 and Jason-3</td>
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<tr>
<td>Coefficient Solar Radiation pressure Cr</td>
<td>Satellite dependent estimated and fixed</td>
<td>Satellite and time dependent adjusted per arc (Not done for ITRF2020 but planned)</td>
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<tr>
<td>Estimated measurement parameters</td>
<td>One frequency bias per pass</td>
<td>One frequency bias and drift for SAA stations per pass (for Jason-1, Jason-2 and Jason-3)</td>
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<tr>
<td>Elevation cut-off and data downweighting</td>
<td>Cut-off 12° downweighting: elev²/400 for elev &lt; 20°</td>
<td>Cut-off 10°</td>
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<tr>
<td>Integration Step Size</td>
<td>60 sec</td>
<td>30 sec</td>
</tr>
<tr>
<td>SAA mitigation</td>
<td>Corrected data for Jason-1 and SPOT-5 Using SAA data from the most affected satellites only for POD (only for Jason-1)</td>
<td>Corrected data for Jason-1 and SPOT-5 Using SAA data from the most affected satellites only for POD (for Jason-1, Jason-2&amp;3, Sentinel-3A&amp;B)</td>
</tr>
</tbody>
</table>
Available DORIS data have been processed from 1993/01 to 2020/12 to contribute to the realization of the ITRF2020.

ITRF2020 = ITRF2014 + new missions (Jason-3, Sentinel-3A, Sentinel-3B)
For the two directions, Along-track and Cross-track, the mean amplitudes are lower than $4 \times 10^{-9}$ m/s$^2$, reflecting a satisfying level in the modeling of the satellite macromodels and the attitude law.
Status of POD for DORIS satellites used for altimetry

- **DORIS RMS of fit**

  - **TOPEX**  
    (from Jan. 1993 to Jul. 2002)  
    Avg. = 0.477 mm/s

  - **Jason-1**  
    (from Nov. 2004 to Jul. 2008)  
    Avg. = 0.316 mm/s

- For TOPEX satellite, there are 2 level of DORIS RMS residuals respectively for the 2 DORIS USO (change from Nominal DORIS instrument to Backup in Dec. 1998).
- There is a ~59 days periodic signal for both satellites (draconitic period, β’ angle).
Status of POD for DORIS satellites used for altimetry

- **DORIS RMS of fit**

  **ENVISAT**
  (from Jul. 2002 to Mar. 2012)

  Avg.=0.398 mm/s

  ![Graph showing ENVISAT data](image)

  **Cryosat-2**
  (from Jun. 2010 to Dec. 2020)

  Avg.=0.354 mm/s

  ![Graph showing Cryosat-2 data](image)

- For **ENVISAT**, there are 2 levels of DORIS RMS residuals reflecting the change from DORIS nominal chain to DORIS redundant chain in Jun. 2004.
- For **Cryosat-2**, there is a ~240 days periodic signal (draconitic period).
For both satellites, there is an annual periodic signal (draconitic period).
A similar signature for both satellites which could be linked to solar activity.
Status of POD for DORIS satellites used for altimetry

- **DORIS RMS of fit**

  - **Jason-2**
    - (from Jul. 2008 to Sep. 2019)
    - Avg. = 0.326 mm/s
  - **Jason-3**
    - (from Feb. 2016 to Dec. 2020)
    - Avg. = 0.362 mm/s

- For Jason-3, the level of DORIS RMS residuals is slightly higher compared to Jason-2, explained by its higher sensitivity to the South Atlantic Anomaly (SAA).
- There is a ~59 days periodic signal for both satellites (draconitic period).
Status of POD for DORIS satellites used for altimetry

- **DORIS RMS of fit**

**Sentinel-3A**
(from Mar. 2016 to Dec. 2020)

Avg. = 0.372 mm/s

**Sentinel-3B**
(from May. 2018 to Dec. 2020)

Avg. = 0.387 mm/s

- The level of DORIS RMS residuals is slightly higher for Sentinel-3B which could be explained by its higher sensitivity to the SAA.
- There is a ~40 days periodic signal for both satellites.
Status of POD for DORIS satellites used for altimetry

- Comparison to CNES (POE-F) orbit
  - RMS and Avg. Radial orbit differences (in cm)
  - ENVISAT
    - (from Jan. 2006 to Jun. 2008)
    - Avg. = 0.5 cm
    - Reference orbit = GRG orbit
  - Cryosat-2
    - (from Jan. 2019 to Dec. 2020)
    - Avg. = 0.6 cm

- There is a good agreement between GRG orbit and external orbit CNES-POE-F (< 1 cm RMS).
- For ENVISAT, there is a semi-annual periodic signal.
- For Cryosat-2, there is a ~240 days periodic signal (draconitic period).
Status of POD for DORIS satellites used for altimetry

- Comparison to CNES (POE-F) orbit

<table>
<thead>
<tr>
<th>Satellite</th>
<th>RMS and Avg. Radial orbit differences (in cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HY-2A</td>
<td>Reference orbit = GRG orbit &lt; 1 cm RMS</td>
</tr>
<tr>
<td>SARAL</td>
<td>Avg. = 0.7 cm</td>
</tr>
</tbody>
</table>

- There is a good agreement between GRG orbit and external orbit CNES-POE-F (< 1 cm RMS).
- For SARAL, there is an annual periodic signal.
Status of POD for DORIS satellites used for altimetry

- Comparison to CNES (POE-F) orbit

RMS and Avg. Radial orbit differences (in cm)

<table>
<thead>
<tr>
<th>Jason-2</th>
<th>Jason-3</th>
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</table>

Reference orbit = GRG orbit

- There is a good agreement between GRG orbit and external orbit CNES-POE-F (~0.8 cm RMS).
- There is a 59 days periodic signal in the radial component and small bias (~0.1 cm).
Status of POD for DORIS satellites used for altimetry

- Comparison to CNES (POE-F) orbit

**RMS and Avg. Radial orbit differences (in cm)**

**Sentinel-3A**
(from Jan. 2019 to Dec. 2020)

- Reference orbit = GRG orbit

**Sentinel-3B**
(from Jan. 2019 to Dec. 2020)

There is a good agreement between GRG orbit and CNES-POE-F (< 1 cm RMS).
There is a small bias (~0.04 cm) and a semi-annual periodic signal.
Impact on the multisatellite solution

- SAA strategy is also applied for Sentinel-3A&B satellites
  SAA strategy: not using SAA data from the most affected satellites on the station positioning

  - Single satellites solutions differences:
    Sentinel-3B - Saral
    WRMS of weekly differences on East component

  - Multisatellite solution when SAA strategy is applied for Sentinel-3A&B
    Impact on Arequipa station

  - Improvement in East component.

- Sentinel-3B single satellite SAA stations impacted.
Impact on the multisatellite solution when SPOT-5 does not contribute to the scale

Green = Blue - Red

\[ \text{GRG SPOT-5 Scale (black curve)} \]

\[ \text{Sawtooth pattern for SPOT-5 scale} \]

\[ \text{Multisatellite Scale} \]

\[ \text{Multisatellite solution when SPOT-5 does not contribute to the scale (in red)} \]

- Improvement of the multisatellite scale when SPOT-5 does not contribute to the scale estimation.
Impact on the multisatellite solution

- GRG multisatellite solution (weekly) compared to DPOD2014v5

GRG ITRF2014 like (in red) vs GRG ITRF2020 (in blue)

Improvement in East and North component.

See also presentation of Moreaux & al: The IDS Contribution to the ITRF2020: Realization and Evaluation (EGU21-2315)
Ongoing and future work

**Ongoing work**
- Continue discussions with other ACs to improve the IDS solutions (comparison of single satellite solutions)
- Continue to evaluate GRG orbits:
  - by comparisons to GRG orbits with GNSS
  - by comparison to other external orbits
  - by Independent SLR RMS of fit
  - by Altimeter crossover Cycles
- Implement HY-2C and Sentinel-6 in our processing chain

**Future work**
- Write a paper on the ITRF2020 reprocessing
- Improve satellite macromodels from analyzing ITRF2020 reprocessing
- Use quaternions for Sentinel-3A&B and Cryosat-2
- ...