Precision Orbit Determination for Jason-2 with GPS

Willy Bertiger, Shailen Desai, Angie Dorsey, Bruce Haines, Felix Landerer, David Wiese, Dah-Ning Yuan

Jet Propulsion Laboratory, Calif. Inst. of Tech., Pasadena CA USA
JASON-2 GPS Receiver Performance

**Daily Data Loss:** Median = 13 min

**Mean Track Length:** Median = 29 min

**Average GPS Satellites Tracked:** Median = 8.2
Focus

- POD with GPS
- Time Variable Gravity
  - EIGEN6S
  - JPLRL05M
  - Atmospheric/Ocean de-aliasing
    - GRACE RL05 (6-Hr Time Series)
    - 3-Hr ITRF2013 AOD (till Dec. 2012)
- GPS Antenna Calibrations
  - IGS has decided to change the standard for the GPS satellites
    - Only affects low Earth orbiters
    - Goal is to maintain consistency with IGS
  - Previous releases of JASON-2 antenna maps were consistent with the previous IGS Maps (with JPL extensions).
  - What are the effects of the change?
IGS has released extensions to GPS transmitter antenna PCV calibrations for boresight angles of 15-17 degrees, as follows:

- Block I: No change
- Block II/IIA: Constant PCV using value at 14 degrees.
  - Becomes arbitrary reference for PCVs of other blocks.
- Blocks IIR and IIF: Based on analysis of LEO data by CODE, using Block II/IIA constraint.
  - Used Jason-2, GRACE-A, GRACE-B, GOCE, MetOp-A.
- No change to PCV calibrations from 0-14 degrees
  - Previously JPL used linear extrapolation > 14 degrees
GPS Satellite PCV: New vs. Old

Block II (GPS13)

Block IIR-A (GPS41)

Block IIR-B/AI (GPS47)

Block IIF (GPS62)
Impact of New Antenna Standards on Jason-2 POD: Old (RLSE11a) vs New (RLSE13a) approach

- Impact of new pairing (GPS satellite PCV + Jason-2 PCV) is small (0.4 mm RMS)
- Old pairing is fine, as long as consistency is maintained.
Impact of New Antenna Standards on Jason-2 POD: Worst Case

- Use new IGS GPS Calibrations, but:
- Fail to update prior release (i.e. RLSE11A) of Jason-2 calibrations

![Graph showing Mean and RMS values for Radial, Cross Track, and Along Track differences over years from 2008.5 to 2013.5.](image)

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>RMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radial</td>
<td>−0.2</td>
<td>1.9</td>
</tr>
<tr>
<td>Cross Track</td>
<td>0.0</td>
<td>1.2</td>
</tr>
<tr>
<td>Along Track</td>
<td>0.0</td>
<td>4.2</td>
</tr>
</tbody>
</table>
Antenna Test Summary

- Failure to change antenna calibrations on Jason-2 while using the new IGS antenna calibrations => errors ~2 mm RMS
- Update Jason-2 or, for now, stay consistent and use previous GPS antenna calibrations
  - Updating is simpler, if you want to use IGS Calibrations, given unknown future launches
• RSLE13a = RLSE11a + TVG(JPL) + New Antenna Cals
  – Bias Fixed, reduced dynamic
• Time Variable Gravity
  – EIGEN6S
    • Lageos (6.5 years), GRACE Data 2003 – June 2009; GOCE data from first 6.7 months (until June 2010).
  – JPLRL05M
    • GRACE(2003-2012) fit to Surface Mass Concentrations
    • Fit Drift, Annual, Semi-annual to monthly mass concentrations + background GIF48 field
  – Atmospheric/Ocean de-aliasing
    • 3-Hr ITRF2013 AOD – through Dec. 2012
RLSE13a □ RLSE11a Radial Orbit Differences
(JPLRL05 time variable gravity vs. GGM02C static gravity)

Mean GCE RMS: 1.0 mm

Ascending GCE RMS: 1.1 mm

Descending GCE RMS: 1.3 mm
AMPLITUDE OF ANNUAL DIFFERENCES

RATE DIFFERENCES

Amplitude of Annual Differences Highlights Amazon

Annually varying surface mass from GRACE (Wahr et al., 2004)
Impact of Different TVG Models on GPS Reduced Dynamic Orbit

(JPLRL05 vs. EIGEN6S)

JPLRL05 chosen on basis of crossover performance (slight advantage) and improved dynamic POD

Mean GCE RMS: 0.7mm

Ascending GCE RMS: 0.7mm
GDR-D POE – JPL RLSE13a Radial Orbit Differences

RMS: 2.3 mm

RMS: 2.5 mm

RMS: 2.9 mm

JASON2 GDRD - JPL Rlse13a
Mean: -1.1 mm RMS: 6.2 mm
Crossover Variance Reduction
Relative to GDR-D POE
Crossover Variance Reduction, Relative to RLSE11a

Variance Reduction RLSE11a – X, < 0 improvement

- EIGEN6S-RLSE11a, Av: -3.0 Median: -3.1
- REL13a-RLSE11a, Av: -3.8 Median: -4.1
Summary

- Excellent GPS Receiver Performance – stable for last two years
- New IGS GPS transmit antenna calibrations do not have big impact.
  - Recommend Jason-2 update to be consistent
- Time Variable Gravity
  - ~ 2 mm (RMS) impact on reduced-dynamic GPS orbits (i.e., RLSE13a vs. RLSE11a)
  - Competing TVG models (EIGEN6S vs. JPLRL05M) yield similar reduced dynamic orbits
    - EIGEN6S dynamic performance poorer than JPLRL05M
  - Annual Amplitude JPLRL05M(tvg) – GGM02C(static) largest over the Amazon: 3.7 mm
- Differences of GDR-D POE and latest GPS-based (RLSE13a) orbit:
  - 6 mm RMS (1 min. sampling, cycles 1-185)
  - RMS ~2-3 mm when averaged over 6°x 6° bins
  - Global Drift over mission: -0.15 mm/yr.
  - Crossover variation reduction of ~45 mm² for RLSE13a.
BACKUPS
Jason-2 Radial Orbit Differences
GDR-D POE — JPL GPS

Ascending Passes

Descending Passes

Mean (mm)

Rate (mm/yr)
Recalibrated JASON2 GPS Code Center
New - Old

Dual-Freq. Code biased by -276 mm
Re-calibrated Phase Center Map

New - Old

biased by -11 mm
Radial Diff. Comparison With Independent Data
GSFC Reduced Dynamic SLR/DORIS Cycles 1-107

JPL RLSE13a - GSFC Reduced Dynamic SLR/DORIS Cycles 1-107 RMS: 2.4 Mean: -0.5 (mm)

JPL RLSE13a - GSFC Reduced Dynamic SLR/DORIS Ascending Cycles 1-107 RMS: 3.2 Mean: -2.0 Min: -9.1 (mm)

RLSE13a GSFC Reduced Dynamic SLR/DORIS Cycle Mean Radial
Bias: -0.4 mm Drift: 0.03 mm/yr Annual Amp: 0.2 mm

Cycle Mean Radial Difference/Fit (mm)

Years Past 2008-07-12

57.7 days

Cycles per Year
Comparison With Independent Data (Cont.)
GSFC Reduced Dynamic SLR/DORIS Cycles 1-107

Max: 3.7 Min: 0.07 RMS: 1.7 Avq: 1.5 (mm)

JPL RLSE13a - GSFC Red. Dyn. SLR/DORIS Drift
Max: 2.4 Min: -2.6 RMS: 1.1 Avq: 0.02 (mm/yr)

JPL RLSE13a - GSFC Id red tyr5x5 wd20
Mean: -0.3 RMS: 0.5 mm

Years Past 12-JUL-2008
Cycles 1-107
Cross-Over Variance Reduction
Cycles 1-185; Mean: -45 Median: -41 mm²

Cross-Over Means
GDRD:  +1.6 ± 0.3 mm
RLSE13a: +0.5 ± 0.3 mm
GDRD – JPL RLSE13a Ascending/Descending Drift (mm/yr)