Absolute Calibration of TOPEX/Poseidon, Jason-1 and Jason-2 Altimeters in Corsica

Results of Jason-1 and Jason-2 Formation Flight Phase

P. Bonnefond\textsuperscript{(1)}, P. Exertier\textsuperscript{(1)}, O. Laurain\textsuperscript{(1)}, F. Pierron\textsuperscript{(1)} and G. Jan\textsuperscript{(2)}

\textsuperscript{(1)}OCA/GeoSciences Azur, Grasse, France
\textsuperscript{(2)}NOVELTIS, Ramonville, France

OSTST Meeting
Seattle, 22-24 June 2009
The absolute calibration site in Corsica is based on a double configuration:

- A geodetic site at Ajaccio: FTLRS has been settled in 2002, 2005 and 2008.
- An in-situ site at Senetosa cape under the track N°85

The Senetosa site allows to perform altimeter calibration from tide gauges as well as from a GPS buoy. All geodetic measurements have been redone in 2009 and confirm 1999 ones at the mm level.

Definition of altimeter bias calibration:

\[ \text{Sea height bias} = \text{altimeter sea height} - \text{in situ sea height} \]

- **Sea height bias < 0** meaning the altimetric sea height being too low (or the altimeter measuring too long)
- **Sea height bias > 0** meaning the altimetric sea height being too high (or the altimeter measuring too short)

Products used for the study:

- Jason-1: IGDR-C, GDR-C
- Jason-2: IGDR-C, GDR-C
- T/P: MGDR+ (TMR & orbit), and retracked products
The observed jump in summer 2008 (OSTST Nice 2008) was due to error in the tide gauge data reduction (calibration coefficient, meteorological data). The whole tide gauges time series have been rebuilt using Figari airport weather station (25km east Senetosa): outside the summer 2008 period the whole series are equivalent (mean=3mm / StD=13mm).

Products used:
- T/P: MGDR + TMR replacement products + TVG ITRF05-rescaled orbits
- Jason-1: GDR-C (cycle 1 to 259)
- Jason-2: GDR-C (cycle 0 to 26)

The relatively high slope of Jason-1 (+3 mm/yr) is due to last data since Jason-2 launch: when this period is excluded the slope is not statistically significant (+1 ±1 mm/yr).
Main impact, using LSE:

- the T/P (ALT-B) bias is increased by 35 mm (from negative to positive value)
- the standard deviation is increased by 23 mm (square root)
- the slope isn't negligible $+5 \text{ mm/yr}$
Orbit minus Range (OMR) a little higher than global analysis from JPL (+77mm): Very good agreement of bias differences and OMR: 3 mm (correction impact) Very small impact on the bias if using other POEs (CNES, GSFC, JPL)
Main contribution comes from **Wet tropospheric** (~6 mm) and **Ionospheric** (~+8 mm) corrections

Recalibrated **JMR** (cycle 228 to 259) has **no significant impact** (mean=-1mm / StD=2mm)

Better agreement between GPS and Coastal path delays from **AMR** (2 mm)

Other environmental parameters:
- **SWH:** Mean = -1 cm StD = 23 cm
- **Wind Speed:** Mean = +0.6 m/s StD = 0.6 m/s
Calibration from Corsica

Absolute bias 18 four common overflights:
- Jason-2: +183 mm (174 from Harvest)
- Jason-1: +102 mm (92 from Harvest)

Relative bias from 18 common overflights:
- Jason-2 - Jason-1: +87 mm (82 from Harvest) (84 mm from orbit-range)
  In good agreement JPL global analysis (77 mm)

Corrections:
- Wet tropo. from radiometers show a bias of -6 mm (JMR dryer)
- GPS shows that both AMR and JMR are dryer
- No significant drift detected from JMR/GPS comparisons.
- Recalibrated JMR (cycle 228 to 259) has no significant impact
- Better agreement between GPS and coastal path delays from AMR (2 mm)
  => Jason-2 bias increases by ~10mm
- Dual Ionospheric corrections exhibit a bias of +8 mm (Jason-2 - Jason-1).
  Compared to GIM biases are respectively -5 mm and -13 mm for Jason-2 and Jason-1

T/P MGDR+:
- 10 mm decrease of the T/P ALT-B bias compared to MGDR (-3 mm from TMR and -7 mm from orbit)
  Jason-1 (GDR-C) - T/P (ALT-B, MGDR+): +85 mm (11 common overflights)
  (78 from Harvest)

Using LSE retracked products increases T/P ALT-B bias by 35 mm
and induces a slope of 5 mm/yr
Calibration over Inland waters

CAL/VAL activities on rivers and lakes enable to avoid the contributions of the Sea Surface Bias (SSB) and liquid tides in the range calibration and to address other problems such as the performance of the various tracking/retracking algorithms and more globally assess the quality of the geophysical corrections.
Jason's overflights over lake Issyk-kul on August, 5th

JASON-2 POSEIDON-3 - Cycle : 3 - Pass : 131

NO SSB APPLIED: Jason-1 bias = 17 mm / Jason-2 bias = 70 mm
Jason-1&2 relative calibration from lake Issyk-Kul

Jason-1&2 altimeter calibration
ISSYK-Kul pass 131 (surf_5): Orbit - Range

Jason-2 - Jason-1 cycle
Jason-2 - Jason-1: mean=106mm, StD=38mm
bias from GPS: 53 mm
Jason-1 (GDR-B/MLE4) and T/P (RGDR/LSE) SSB

T/P and Jason-1 SSB
Senetosa Cape: pass 085 / Formation Flight Phase

TOPEX/Poseidon and Jason-1 Altimeter Calibration
Senetosa Cape: pass 085 / Formation Flight Phase
Jason-1&2 Wet Tropospheric Path Delay (corrections)

Jason-1&2 Corrections
Senetosa pass 85: Wet Troposphere

Jason-2 cycle
Jason-1 Wet Tropospheric Path Delay (corrections)

Jason-1 Corrections (JMR vs GPS)
Senetosa pass 85: wet troposphere

Slope: +1 ±1 mm/yr
Jason-2 Wet Tropospheric Path Delay (corrections)

Jason-2 Corrections (AMR vs GPS)

Senetosa pass 85: wet troposphere

Better agreement between GPS and AMR coastal

AMR-GPS: mean=+13mm / StD=11mm
AMR (coastal)-GPS: mean=+2mm / StD=9mm
Jason-1 & T/P Wet Tropospheric Path Delay (corrections)

JMR and TMR over 4 years
AMR over less than 1 year (cycle 0 to 26)
Jason-1, Jason-2 & T/P Wet Tropospheric Path Delay

[Images of graphs and charts showing data analysis]
Jason-1&2 Corrections
Senetosa pass 85: Ionosphere

- dual (JS1)
- dual (JS2)
- GIM (JS1)
- GIM (JS2)

Jason-2 - Jason-1 (mm)

- dual: mean=+7.6mm / StD=23.6mm
Jason-1&2 Sea State Bias

Statistics are for common cycles and include cycle 2 (sigma bloom)

Jason-1&2 Corrections
Senetosa pass 85: SSB

JS2-JS1: mean=-2.7mm / StD=5.8mm
Jason-1&2 MOE orbit validation by the laser-based Short-Arc Technique

Radial orbit errors estimation over Europe

Radial Short-Arc Corrections for JASON-1 (Med Area • JASON-1 (MOE) orbits) correlated with Radial Short-Arc Corrections for JASON-2 (Med Area • JASON-2 (MOE) orbits)

Correlation results
- Correlation Coefficient: 0.377
- Slope: 0.268, Constant: 0.037
- Standard deviation: 1.101

Smoothed data:
- Mean: 0.9
- Std: 1.3

Raw data:
- Mean: 1.0
- Std: 3.2

Smoothed data:
- Mean: 0.6
- Std: 1.3

Raw data:
- Mean: 0.5
- Std: 2.6

Jason-1:
Mean=+10mm StD=32mm

Jason-2:
Mean=+5mm StD=26mm

Smoothing Parameters
- Beginning position: 21356.98
- Ending position: 21711.91
- Window step: 1.00
- Window width: 10.00
Jason-1 & 2 MOE orbit validation by the laser-based Short-Arc Technique

Radial orbit errors estimation over USA

Radial Short-Arc Corrections for JASON-1 (USA Area - JASON-1 (MOE) orbits) correlated with Radial Short-Arc Corrections for JASON-2 (USA Area - JASON-2 (MOE) orbits)

Correlation results
- Correlation Coefficient: 0.262
- Slope: 0.170, Constant: 0.0152
- Standard deviation: 1.848

Smoothing Parameters
- Beginning position: 21360.16
- Ending position: 21713.18
- Window step: 1.06
- Window width: 10.00

Jason-1:
- Mean = +9 mm
- StD = 29 mm

Jason-2:
- Mean = +3 mm
- StD = 19 mm
Jason-1&2 POE orbit validation by the laser-based Short-Arc Technique

Radial orbit errors estimation over Europe

Radial Short-Arc Corrections for JASON-1 (Med Area - JASON-1 (POE) orbits) correlated with Radial Short-Arc Corrections for JASON-2 (Med Area - JASON-2 (POE) orbits)

Correlation results
- Correlation Coefficient: 0.988
- Slope: 0.399 - Constant: 0.184
- Standard deviation: 0.988

Smoothing Parameters
- Beginning position: 240.00
- Ending position: 267.00
- Window step: 1.00
- Window width: 3.00

Jason-1:
- Mean=+11mm StD=14mm
- Smoothed data:
  - Mean: 1.1
  - Std: 0.7
- Raw data:
  - Mean: 3.1
  - Std: 1.4

Jason-2:
- Mean=+8mm StD=13mm
- Smoothed data:
  - Mean: 0.9
  - Std: 0.5
- Raw data:
  - Mean: 0.8
  - Std: 1.3
Jason-1&2 POE orbit validation by the laser-based Short-Arc Technique

Radial orbit errors estimation over USA

Radial Short-Arc Corrections for JASON-1 (USA Area - JASON-1 (POE) orbits)
correlated with
Radial Short-Arc Corrections for JASON-2 (USA Area - JASON-2 (POE) orbits)

Correlation results
Correlation Coefficient: 0.911
Slope: 0.296  Constant: 0.164
Standard deviation: 0.196

Jason-1:
Mean=+11mm Std=11mm

Jason-2:
Mean=+5mm Std=9mm

Smoothing Parameters
Beginning position: 240.00
Ending position: 267.30
Window step: 1.06
Window width: 3.00
Jason-2 absolute bias from different POEs

Small impact (mm) on the absolute value except for the reduced dynamic from GSFC.
Jason-1 & Jason-2 absolute bias from Harvest and Corsica

Jason-1 & Jason-2 Altimeter calibration
Harvest & Corsica sites

- Jason-1 (Harvest): +94 +/- 2 mm
- Jason-2 (Harvest): +174 +/- 5 mm
- Jason-1 (Corsica): +63 +/- 3 mm
- Jason-2 (Corsica): +183 +/- 8 mm
Methodology

JASON-1 POSEIDON-2 - Cycle: 4 - Pass: 85

Applied correction:
- Center of mass
- Dry
- Vaitrop radiometer
- Ionosphere
- Ionospheric loading
- Solid and pole Tides

Point of Closest Measurement:
- Rh: M4
  - Lat: 41.946
  - Lon: 8.566
  - Distance: 5.308 km
  - Time: 01:19:46 (UTC)

Point of Closest Approach:
- Rh: M4
  - Lat: 41.258
  - Lon: 8.566
  - Distance: 0.05 km
  - Time: 01:19:46 (UTC)

Along track distance PCI-M-PCA:
- 5.308 km

Along track distance PCI-M-Coast:
- 5.344 km
Corsica Sea Level Tide Gauges Records

Senetosa Cape, Macinaggio, Capraia & Ajaccio

Corsica extension

Jason-1, T/P
- Envisat, ERS 1&2
- GFO

MACINAGGIO:
- 1 Tide gauge

AJACCIO:
- FTLRS
  (not permanent)
- ICE GPS receiver
- DORIS
  (not permanent)
- 1 Tide gauge

SENETOSA CAPE:
- GPS receiver
- Weather station
- 4 Tide gauges

CAPRAIA:
- Tide gauge
EnviSat RA2 Altimeter Calibration
Ajaccio site, pass 130

Table 1. RA2 altimeter bias at Ajaccio using different ionospheric corrections

<table>
<thead>
<tr>
<th>Iono. Correction used</th>
<th>Bias (mm)</th>
<th>Number of data</th>
<th>Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dual frequency</td>
<td>425 ±5</td>
<td>33</td>
<td>cycle 16 to 65</td>
</tr>
<tr>
<td>DORIS</td>
<td>432 ±6</td>
<td>44</td>
<td>cycle 16 to 76</td>
</tr>
<tr>
<td>Model (GIM+IRI95)</td>
<td>446 ±8</td>
<td>38</td>
<td>cycle 38 to 76</td>
</tr>
</tbody>
</table>