SCOOP Science Review Meeting

WP7000 – Wet Troposphere Model
**Objectives**

- To develop methods and techniques to produce an enhanced WTC for Sentinel-3 (S3), compared to the S3 baseline correction, over the open and coastal ocean:
  - based on the combined use of third-party data;
  - evaluated at the S3 orbit space-time sampling.

- While S3 data are not available, Envisat data will be used for test purposes (e.g., algorithm development).

- In addition, the WTC will be computed for the selected CryoSat-2 (CS-2) regions of interest (ROI).
• **WP7100 – Data set specification**

• **CS-2 data (time and location) for the project ROI.**

• **Envisat and S3-A/B MWR data.**

• **Wet path delays from third-party data sets:**
  - derived at GNSS coastal and island stations,
  - computed from water vapour products from SI-MWR,
  - computed from atmospheric model (ECMWF Operational model).
• WP7200 – Data set generation

1) Data pre-processing, analysis and inter-calibration.

2) Algorithm implementation (GPD+ tuning to S3).

3) WTC (and associated error) computation:
   - WTC provided for:
     - all selected CS-2 ROI;
     - S3 ground-tracks.

4) Set of recommendations (out of SOW scope) about the correct approaches to compute the DTC to avoid height dependent errors in coastal regions.
Recent developments

Algorithm update: GNSS-derived Path Delay Plus (GPD+) methodology

GPD+ combines previous GPD and DComb algorithms
- Data combination method using space-time objective analysis.

Additional data from
- scanning imaging radiometers (SI-MWR) on board various remote sensing satellites, improving the WTC retrieval for the most recent altimetric missions.

All MWR data sets calibrated w.r.t. SSM/I and SSM/IS.

Improved detection of invalid on-board MWR values:
- land and ice contamination; definition of statistical criteria based on MWR and model values in the vicinity of the point; tuning the criteria to each mission, based on a careful inspection of the baseline MWR.
• **MWR calibration**

**Step 0 – Comparison between each SI-MWR and ERA Interim**

• Differences between each SI-MWR-derived WTC and ERA-derived WTC, collocated in space and time with each SI-MWR measurement point, were analyzed.

• Identified SI-MWR instability periods:
  - Rejection of F15 data;
  - MTA used only after 2008;
  - N15, N16 and N17 used only after 2005.2.
• All radiometer data sets have been calibrated using the set of SSM/I and SSM/IS, on board the DMSP satellite series (FXX), as reference;

• Calibration improves consistency and long term stability.
Differences in WTC (cm) from SI-MWR sensors (SSM/I-SSM/IS, TMI, AMSR-E, AMSR-2 and WindSat) and ERA Interim.

Differences in WTC (cm) from SSM/I, SSM/IS and ERA Interim.

Differences in WTC (cm) from AMSU-A and ERA Interim.
– The calibration was performed in 3 steps:
  
  • Step 1 – TP, J1, J2 → FXX
  • Step 2 – 35-day missions → TP, J1, J2
  • Step 3 – remaining SI-MWR → TP, J1, J2

– Adjustment model uses Offset \( a \), scale factor \( b \) and trend \( c \)

\[
Y = a + bX + c(T - T_0), \quad T_0 = 1992
\]

Satellite altimetry reference missions calibrated against the contemporary DMSP missions (all data from FXX satellites in the common T/P, J1 or J2 periods were used).
Step 1 – Calibration between TP, J1, J2 and SSM/I & SSM/IS

- Matching points between SSM/I and SSM/IS sensors and MWR on board reference altimetric mission (TP, J1, J2) were identified:
  - Only points with $\Delta T < 45$ min and $\Delta D < 50$ km were considered.

- WTC from each reference altimetric mission was adjusted to WTC from SSM/I and SMM/IS set of sensors.

### Calibration parameters

<table>
<thead>
<tr>
<th>Mission</th>
<th>Offset (mm)</th>
<th>Scale factor</th>
<th>Trend (mm/y)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TP</td>
<td>-8.1882</td>
<td>0.97720</td>
<td>0.1542</td>
</tr>
<tr>
<td>J1</td>
<td>-4.3642</td>
<td>0.98428</td>
<td>-0.1399</td>
</tr>
<tr>
<td>J2</td>
<td>-5.6329</td>
<td>0.97704</td>
<td>-0.2288</td>
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</tbody>
</table>
Differences in WTC (cm) from SSM/I, SSM/IS and T/P, J1 and J2 radiometers, before and after calibration.
Differences in WTC (cm) from ERA Interim and T/P, J1 and J2 MWR, before and after calibration.
Step 2 – Calibration between 35-day missions and TP, J1, J2

• Crossovers (matching points) between each sun-synchronous 35-day altimetric mission (E1, E2, EN, SA) and the altimetry reference missions (TP, J1, J2) were identified.
  – Only points with a ΔT < 180 min were considered.

• WTC from 35-day missions were calibrated against the WTC from reference missions using a crossover adjustment.

<table>
<thead>
<tr>
<th>Mission</th>
<th>Offset (mm)</th>
<th>Scale factor</th>
<th>Trend (mm/y)</th>
</tr>
</thead>
<tbody>
<tr>
<td>E1</td>
<td>-12.1711</td>
<td>0.96279</td>
<td>0.1724</td>
</tr>
<tr>
<td>E2</td>
<td>-12.7178</td>
<td>0.95680</td>
<td>0.0970</td>
</tr>
<tr>
<td>EN</td>
<td>-12.2356</td>
<td>0.95462</td>
<td>-0.0809</td>
</tr>
<tr>
<td>SA</td>
<td>6.1130</td>
<td>1.00681</td>
<td>-</td>
</tr>
</tbody>
</table>
Step 3 – Calibration between other SI-MWR and TP, J1, J2

- WTC from all remaining SI-MWR (except the FXX series) sensors were adjusted to the WTC from altimetric reference missions.

<table>
<thead>
<tr>
<th>Mission</th>
<th>Offset (mm)</th>
<th>Scale factor</th>
<th>Trend (mm/y)</th>
</tr>
</thead>
<tbody>
<tr>
<td>COR</td>
<td>-0.4262</td>
<td>0.98909</td>
<td>-0.0581</td>
</tr>
<tr>
<td>N15</td>
<td>-4.7925</td>
<td>1.01624</td>
<td>-0.0760</td>
</tr>
<tr>
<td>N16</td>
<td>-5.2776</td>
<td>1.01222</td>
<td>-0.0737</td>
</tr>
<tr>
<td>N17</td>
<td>-11.6989</td>
<td>0.98413</td>
<td>0.2560</td>
</tr>
<tr>
<td>N18</td>
<td>-2.5803</td>
<td>1.00950</td>
<td>-0.1422</td>
</tr>
<tr>
<td>N19</td>
<td>-2.8430</td>
<td>1.00711</td>
<td>-0.1673</td>
</tr>
<tr>
<td>AQU</td>
<td>-0.5598</td>
<td>0.99023</td>
<td>0.0134</td>
</tr>
<tr>
<td>TRM</td>
<td>0.1653</td>
<td>0.99514</td>
<td>-0.0327</td>
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<tr>
<td>MTA</td>
<td>-2.5543</td>
<td>0.99882</td>
<td>-0.2594</td>
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<tr>
<td>MTB</td>
<td>-5.4636</td>
<td>0.99673</td>
<td>-0.1872</td>
</tr>
<tr>
<td>GCW</td>
<td>-0.6326</td>
<td>0.98857</td>
<td>-0.0414</td>
</tr>
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Differences in WTC (cm) derived from MWR on board altimetric reference missions and from AMSU-A.

Differences in WTC (cm) derived from MWR on board altimetric reference missions and from AMSR-E (AQU), AMSR-2 (GCW), TMI (TRM) and WindSat (COR).

Before calibration

After calibration

**GPD+ performance in coastal regions**

- The next slides show, for various missions, the RMS difference between various WTC and the WTC derived at the nearby coastal GNSS stations.
- A set of over 700 stations has been used.
- Only points up to 100 km from the station are considered.
- Differences are binned function of distance from coast.
- For each bin, the RMS is presented.

- **Black dots**: GPD+ WTC
- **Blue dots**: Baseline MWR valid according to all criteria
- **Red dots**: Baseline MWR valid according to all criteria except the maximum distance from coast (D_{max})
Jason-2

$D_{\text{max}} = 15 \text{ km}$
Envisat

$D_{\text{max}} = 30 \text{ km}$
SARAL

$D_{\text{max}} = 15 \text{ km}$
• **Summary**

  - GPD+ implemented for 8 mission in the scope of the SL-cci project.
  
  - For most missions, the new WTC reduce sea level anomaly variance w.r.t. previous non-calibrated versions.
  
  - Coastal improvements are also illustrated through the reduction of the RMS differences between GNSS-derived wet path delays at coastal stations and the WTC at the nearby altimeter points, function of the distance from coast.

• **GPD+ will be tuned for S3 in the scope of the project.**
• WP7300 – Data set validation

• The WTC will be evaluated through an independent validation, within WP5000 and WP6000.

• WTC will be validated in this task by means of a set of statistical analyses of sea level anomaly (SLA) variance (along-track, at crossovers, function of distance from coast and function of latitude).
• Outline of deliverables

• Product Validation Plan D2.4 (Feb. 9, 2016)

• Product Validation Report D2.5 (Oct. 9, 2016, Updated Jul. 9, 2017)

• WTC Output Products D2.9 (Jul. 9, 2017)