On the performance of CryoSat-2 SAR and LRM mode over inland water bodies
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Abstract
To determine realistic lake water level variations, corrupted CryoSat-2 LRM and SAR mode waveforms need to be retracted. We retracted full-waveforms to correct water level variations and assessed the performance of LRM and SAR mode of CryoSat-2 against other satellite altimetry missions over inland water bodies. We analyzed different retracking algorithms using waveforms of both modes, i.e., LRM and SAR mode, and evaluated the performance of each retracker.

CryoSat-2 mission
Launch: 8 April 2010
Mission duration: 3 years
Orbit height: 717 km
Inclination: 92°

<table>
<thead>
<tr>
<th>Mode</th>
<th>Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>LRM</td>
<td>Ocean and land</td>
</tr>
<tr>
<td>SAR</td>
<td>Coastal zone and sea ice</td>
</tr>
<tr>
<td>SAR In</td>
<td>Ice-sheet slope</td>
</tr>
</tbody>
</table>

Retracking
LRM and SAR waveforms were retracted by following retracker algorithms:
- OCOG (Offset Center Of Gravity of the waveform)
- Threshold with different threshold values
- 5-β parameter
- SAMOSA3 single look (Only for SAR mode)

\[ \Delta R_{\text{retracking}} = (G_{i} - G_{0}) \frac{c}{2 \tau} \]

\( G_{i} \): Retracted gate
\( G_{0} \): Nominal retracking gate
\( c \): Light velocity
\( \tau \): Pulse duration

Retracted water level
Water level anomaly estimation:
- Defining water level time series from median values of water level for each satellite pass
- Rejecting outliers from the long time series by fitting the following model:

\[ h(t) = a + bt + ct^{2} + d \sin \left( \frac{2 \pi t}{T} \right) + e \cos \left( \frac{2 \pi t}{T} \right) \]

\( a, b, c, d, e \): Unknown parameters
\( T \): Annual period
\( h \): Retracted water height
- Validation in front of other satellite altimetry mission data

Data and area of studying
Data: LRM and SAR mode L1B, L2I and L2 (Oct 2010 – 2014)
Area: Qinghai lake and Caspian sea

Along track waveform variations

<table>
<thead>
<tr>
<th>Mode</th>
<th>Retracker</th>
<th>RMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>LRM</td>
<td>ESA</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>OCOG</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Threshold 10%</td>
<td>101</td>
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<tr>
<td></td>
<td>Threshold 20%</td>
<td>86</td>
</tr>
<tr>
<td></td>
<td>Threshold 50%</td>
<td>82</td>
</tr>
<tr>
<td></td>
<td>5-β parameter</td>
<td>16</td>
</tr>
<tr>
<td>SAR</td>
<td>ESA</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>OCOG</td>
<td>34</td>
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<tr>
<td></td>
<td>Threshold 10%</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>Threshold 20%</td>
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</tr>
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<td></td>
<td>5-β parameter</td>
<td>34</td>
</tr>
</tbody>
</table>

Qinghai lake

Caspian sea

Conclusion and discussion
- SAR and LRM have same performance over Caspian sea with L2 data
- In SAR mode almost all retrackers have the same performance but SAMOSA3 is a bit better
- In LRM mode 5-β has the best performance, may be due to the fact that Qinghai lake is an ice cover lake in the cold seasons
- Why L2 and L2I level of data need to be investigated, why L2 is more precise than L2I?

Acknowledgment
We would like to thank Salvatore Dinardo from ESA and Jain Mauli in DTU for guidance in the SAR mode data processing. Also we thank ESA and DCFI for providing altimetry data.

References
- ESA-Erin, CryoSat-2 product handbook, 2013
- ESA-Erin, Development of SAR Altimetry Mode Studies and Application over ocean, coastal zones and inland water, No. 20698/07/1-LG, 2013