CryoSat-2 SARIn mode success to determine lake level variations
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Abstract
To determine realistic lake water level variations, corrupted SARIn waveforms need to be corrected. We use different retracking algorithms to retrack the waveforms and to correct water level variations. We assessed the performance of SARIn mode of CryoSat-2 against external data, e.g. in-situ gauge. In this study we use SARIn level 1 and 2I data from October 2010 to 2014 over Nasser lake, located in Southern Egypt. We analyzed different retracking scenarios over full and sub-waveforms and based on external validation the performance of each retracker was evaluated.

Introduction
CryoSat-2 mission was originally designed to study the ice fluctuation in continental ice sheet and ice covered marine of the Earth, especially in Arctic region. But nowadays it is being used to measure water level changes even over inland water bodies. CryoSat-2 is equipped with the SIRAL radar altimeter that collects measurements from the Earth surface in three modes. Over the open ocean, flat ice sheets and land it plays the role of pulse limited altimeters, LRM mode. SIRAL is running in SAR mode over sea-ice, coastal zone and some inland water bodies. Generally, the mission operates in SARIn mode over continental sloped ice sheets but it also makes observations over other areas such as lakes and coastal zones. In this mode of observation instead of a pulse, a burst of pulses is emitted from the radar therefore we have more samples during a given echo, 512 samples. Even though SARIn mode footprint size is small, some of the reflected signal back to the radar (waveform) can be contaminated by land and vegetation effects.

Retracking
SARIn waveforms were retracted by following retracker algorithms:
▶ OCOG (Offset Center Of Gravity)
▶ Threshold with different threshold values
▶ 5-β parameter
▶ Brown model
\[ \Delta R_{\text{retracking}} = (G_r - G_0) \times \frac{c}{2T} \]
G_r: Retracted gate
G_0: Nominal retraction gate
C: Light velocity
T: Pulse duration

Retracked 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:
\[ h(t) = a + bt + \epsilon t^2 + d \sin \left( \frac{2\pi}{T} t \right) + e \cos \left( \frac{2\pi}{T} t \right) \]
\( a, b, c, d, e \): Unknown parameters
\( T \): Annual period
\( h \): Retracked water height
▶ Validation in front of available in-situ gauge data

Data and area of studying
Data: SARIn mode level 1B and 2I (Oct 2010 – 2014) Area: Nasser lake

Conclusion
▶ Obviously waveform retracking techniques can improve the quality of altimetry data over inland water bodies.
▶ The quality of water level is dependent on the waveform retracking techniques.
▶ Backscatter coefficients are changed too much over the lake surface which leads to variety of waveform variations.
▶ Full-waveform retracking: ESA retracker provides the minimum RMS.
▶ Sub-waveform retracking: First sub-waveform retracted by 5-β parameter is the best scenario.

Along track waveform variations

RMS (cm) of different retracking scenarios respect to the in-situ gauge data

<table>
<thead>
<tr>
<th>retracker</th>
<th>full-waveform mean-all</th>
<th>first mean-all</th>
<th>min-residual</th>
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<td>ESA</td>
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<td>OCOG</td>
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<td>Brown</td>
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</tbody>
</table>

Retracking result

Performance of different retrackers

Water level anomaly from CS-2 SARIn mode and in-situ gauge measurements