Lake level variations from satellite radar altimetry with retracking of multi-leading edge

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Why waveform retracking?

- Improve the quality of water level measurements
- Increase the number of reliable observations particularly in the shoreline and shallow water

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RADAR principle

http://www.altimetry.info

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How can we have more precise water level measurements?

- Increasing precision of range measurements
  - Use more precise range correction, e.g. corrections included in GDRs
  - *waveform retracking, i.e. calculate another range correction from SGDRs*

\[
\Delta R_{\text{retracking}} = (G_r - G_0) \times \frac{c}{2\tau}
\]

- \(G_r\): retracked gate, \(G_0\): nominal retracking gate, \(c\): light velocity, \(\tau\): pulse duration
Waveform retracking techniques

- Conventional retrackers
  - Onboard retracker (Ice-1/2 and Sea-ice)
  - Offset Center Of Gravity (OCOG)
  - Threshold
  - $\beta$- parameters

- Unconventional retrackers
  - Multi-leading edge
  - Modified waveform
Data and area of study

RA2 Geophysical and Sensor Data Records, i.e. RA2 GDRs and RA2 SGDRs of Envisat satellite altimetry from cycle 6 to cycle 113

Envisat satellite ground tracks from cycle 92
Conventional retrackers

- Onboard retrackers:
  Water level from RA2 GDRs data using median values of water level in each satellite over pass in Ice-1 retracker algorithm

\[ h(t_i) = a + bt_i + ct_i^2 + d \sin \left( \frac{2\pi}{T} t_i \right) + e \cos \left( \frac{2\pi}{T} t_i \right) \]

\(a, b, c, d\) and \(e\) are unknown parameters to be estimated. \(T\) is the annual period and \(h\) is the observed water height.
Conventional retrackers

- **OCOG**

- **Threshold**

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Unconventional retrackers

- Multi-leading edge
Unconventional retrackers

- Multi-leading edge

Water level time series from combined ascending and descending tracks

<table>
<thead>
<tr>
<th>Year</th>
<th>Water Level [m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>1270</td>
</tr>
<tr>
<td>2003</td>
<td>1270.5</td>
</tr>
<tr>
<td>2004</td>
<td>1271</td>
</tr>
<tr>
<td>2005</td>
<td>1271.5</td>
</tr>
<tr>
<td>2006</td>
<td>1272</td>
</tr>
<tr>
<td>2007</td>
<td>1272.5</td>
</tr>
<tr>
<td>2008</td>
<td>1273</td>
</tr>
<tr>
<td>2009</td>
<td>1273.5</td>
</tr>
<tr>
<td>2010</td>
<td>1274</td>
</tr>
</tbody>
</table>

Residual = 14 cm
Comparing different retrackers

- **Onboard retracker**

  Water level time series and fitting the trend to the all values

  ![Ascending tracks](image1)
  ![Descending tracks](image2)

  Residual = 42 cm

- **Other retrackers**

  Water level time series based on Threshold 10 % retracker

  ![Ascending track](image3)
  ![Descending track](image4)

  Residual = 59 cm

  ![Ascending track](image5)
  ![Descending track](image6)

  Residual = 74 cm

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Comparing different retrackers

<table>
<thead>
<tr>
<th>retracker</th>
<th>standard deviation (cm)</th>
<th>improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ice-1</td>
<td>27</td>
<td>–</td>
</tr>
<tr>
<td>OCOG</td>
<td>27</td>
<td>0 %</td>
</tr>
<tr>
<td>Threshold 10</td>
<td>18</td>
<td>33 %</td>
</tr>
<tr>
<td>Threshold 20</td>
<td>15</td>
<td>44 %</td>
</tr>
<tr>
<td>Threshold 50</td>
<td>17</td>
<td>37 %</td>
</tr>
<tr>
<td>Multi-leading edge</td>
<td>14</td>
<td>48 %</td>
</tr>
</tbody>
</table>

\[
\text{Improvement} = \frac{\sigma_{\text{Ice-1}} - \sigma_{\text{Ret}}}{\sigma_{\text{Ice-1}}} \times 100 \%
\]
Along track waveform variations

First ascending pass - Jun 2002

Last ascending pass - Sep 2010

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Validation

▶ OCOG

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▶ Threshold
Validation

- Multi-leading edge

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Conclusion

- Obviously waveform retracking techniques can improve the quality of altimetry data.
- Due to the land and environmental effects on the return echoes to the altimeter particularly in the shoreline the waveform retracking is necessary.
- The quality of water level is dependent on the waveform retracking techniques.
- According to the result of data processing using both RA2 GDR and RA2 MWS (SGDRs) of Envisat, multi-leading edge and threshold 20 % retrackers outperform the other retackers to determine water level variations of Urmia lake.
Works under way

- Continuing waveform retracking using:
  - $\beta$–parameter
  - Modified waveform
Thank you for your attention