A new Arctic 25-year Altimetric Sea-level Record (1992-2016) and Initial look at Arctic Sea Level Budget Closure

Ole B. Andersen, S. K. Rose

M. Passaro (TUM),
J. Benveniste (ESA)

Contribution to ESA SL_CCI+SLBC projects
Outline

• Arctic Ocean

• 25 years Arctic Sea Level Products
  – DTU (reprocessed but largely un-retracked)
  – DTU/TUM (ALES+ retracked, REAPER and in house processed)

Linear Arctic Sea level change.

Preliminary Arctic sea level budget closure

Conclusion
Arctic Ocean challenges:
Seasonal to permanent ice cover
Radiometer+altimeter observations are affected by ice
Ocean tide models less accurate (sun-synchronous ERS/ENVISAT/C2/S3)
Retracking is challenging
Residual orbit errors
General Timeline for Satellite Radar Altimeters with Short Repeat Periods

- 1985: ERS-1 (ESA)
- 1991: ERS-2 (ESA)
- 1998: ENVISAT (ESA)
- 2000: SARAL (ISRO/CNES)
- 2014: Sentinel-3 (ESA)
- 2015: Cryosat-2
Two Arctic Sea level products

**DTU sea level product**

Covers Arctic Ocean (68N-82N -> 1991-2016)
Gridded: Spatial res: 0.5 degree, Temporal: 3 Days/1 month.
NO RETRACKING of ERS/ENVISAT (Brown/Haines retracked).
In stead: Tailored Arctic reprocessing of RADS data.
Retracking of Cryosat-2 Baseline B/C SAR data (DTU-LARS).
Data available from [ftp.space.dtu.dk/pub/ARCTIC_SEALEVEL](ftp.space.dtu.dk/pub/ARCTIC_SEALEVEL)
Pros: consistent data, Cons: Not adequate data.

**DTU/TUM product**

ALES+ RETRACKING of ERS-2 and ENVISAT.
Retracking of Cryosat-2 Baseline B/C SAR data (DTU-LARS).
REAPER retracking of ERS-1.
Gridded: Spatial res: 0.5 degree, Temporal: 3 Days/1 month.
Pros: More data & inverse barometer signal (comp to tidegauge)
DTU Sea Level Product – reprocessed (ESA-SLcci_ECV V2)

RADS available default data
Relative to DTU13 MSS

DTU - Reprocessed data allowing for low SWH+few 20Hz obs and using model corrections (wet) relative to DTU13 MSS

Western Arctic/Beaufort: average data increases of 383%.
(74N-80.5N, 130W-180W) on average data increase of 130%
DTU/TUM Sea level product:
ALES+ : ALES extension to peaky waveforms

ALES (non-peaky waveforms):
1. Leading Edge Detection
2. First retracking (leading edge only)
3. Subwaveform extension
4. Second retracking of the extended subwaveform

ALES (peaky waveforms):
1. Leading Edge Detection
1a*: External estimation of trailing edge slope
2. First retracking (leading edge only)
3. Subwaveform extension
4. Second retracking of the extended subwaveform

*1a: Brown-Hayne simplified model with trailing edge slope as 4th unknown

Retracking ENVISAT + ERS2
Considerably increases number of retrieved SLA valuable to complete time series.

DTU Space
National Space Institute

-Zoom on an 8x oversampled peaky waveform
23 year Arctic Sea Level trend (68° N – 82° N)

Average linear trend 2.2 mm/year. Large inter-annual variations (AO driven)
Updating the time series to 2018 incl S-3 and SARAL
Beaufort Gyre

- Average 0.8 cm sea level increase over the 25 years.

- Recently
Initial Arctic regional sealevel budget.

The sea level budget may be expressed as height changes using the main components of sea level change:

$$\Delta SSH = \Delta SH + \Delta OM$$

$SSH =$ sea surface height, $SH =$ steric height, $OM =$ ocean mass from GRACE (JPL-MASCONS)

No ARGO data available
### Closing the Arctic Sea Level budget (2005-2015 -> “first attempt”)

<table>
<thead>
<tr>
<th>Components</th>
<th>Linear trend (2005 – 2015) [mm/y]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sea level (Altimetry)</td>
<td>4.34 ± 2.44</td>
</tr>
<tr>
<td>Mass (GRACE)</td>
<td>3.85 ± 0.87</td>
</tr>
<tr>
<td>Total steric (NOAA)</td>
<td>0.09 ± 0.36</td>
</tr>
<tr>
<td>Thermosteric</td>
<td>0.33 ± 0.32</td>
</tr>
<tr>
<td>Halosteric</td>
<td>-0.24 ± 0.14</td>
</tr>
<tr>
<td>GRACE + steric</td>
<td>3.94 ± 0.94</td>
</tr>
</tbody>
</table>

Sea level budget closure within 0.5 mm/year (68N-82N)

During 2005-2010 large halosteric component found (0.9 mm/year).
Summary and availability.

- The DTU and DTU/TUM sea level product available at [ftp.space.dtu.dk/pub/ARCTIC_SEALEVEL](ftp.space.dtu.dk/pub/ARCTIC_SEALEVEL)

- The Annual signal is heavily influenced by atmospheric pressure

- The linear sea level trend has large inter-annual variations (AO driven).

- First attempt to close Arctic Sea level budget closes at < 0.5 mm/year