The Zone of Influence
Matching along-track coastal altimetry data with high-frequent tide gauge observations for vertical land motion estimation

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Outline

• Introduction - Vertical land motions
• Approach: Improving comparability of altimetry and tide gauges
• The Zone of Influence
• Results – Validation with GPS
• Conclusion
Absolute SL Trends vs. Vertical Land Motion


1 https://openadb.dgfi.tum.de/
Absolute SL Trends vs. Vertical Land Motion

Absolute Sea Level Trends (1993 – 2017)\(^1\) + Vertical Land Motion Trends (GPS)\(^2\)

\(^1\) https://openadb.dgfi.tum.de/
\(^2\) SONEL
Absolute SL Trends vs. Vertical Land Motion

Absolute Sea Level Trends (1993 – 2017)\(^1\) + Vertical Land Motion Trends (GPS)\(^2\)

We need more vertical land motion trend estimates!
Observing Vertical Land Motion

- **GNSS (GPS):**
  Most precise technique, limited global coverage

- **Altimetry and tide gauge difference**
  - Higher uncertainties than GNSS measurements
  - Enhances global coverage

Vertical land motion = relative – absolute sea level change

(modified from Wöppelmann and Marcos, 2016)
Observing Vertical Land Motion

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Aim: Improving the methodology

GPS stations near tide-gauges (<1km)

Tide-gauges (>15 years of data)

\(^3\) Data from GESLA and SONEL
Improving VLM estimates by satellite altimetry and tide gauge difference

Challenges and Motivation

previous studies (e.g. Cazenave et al., 1999; Wöppelmann and Marcos, 2016; Kleinherenbrink et al., 2018) show that **Performance** of ALT-TG VLM trend estimates **depends on**

- **Data** (altimetry product and resolution, performance in coastal zones ...)
- **Selection scheme** of sea level anomalies around the tide-gauge (closest, area-average or highest correlated SLAs ...)

→ **Improve coastal performance of altimetry and comparability with tide-gauges**
Data and Methods

- Improve **coastal performance of altimetry**
  - Coast-dedicated multimission along-track altimetry (1Hz)
    ALES + corrections

- and **comparability** with tide-gauges
  - High-frequent tide gauge observations from GESLA between 1995-2015 (Woodworth et al. 2016)
  - Redefined coupling procedure of altimetry and tide gauges

Comparison with:
- Gridded data (AVISO, 0.25° resolution) (best selection\(^1\))
- Monthly tide gauge data from PSMSL
- 250km-radius-averages of SLAs

set-ups: ALES-GESLA AVISO-PSMSL

\(^1\)Wöppelmann and Marcos, 2016
Data and Methods

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\(^1\)Wöppelmann and Marcos, 2016
Matching altimetry and tide gauges: The Zone of Influence

Which SLAs to select?

South-western Australia
North-western America
Japan (Chichijima)
Matching altimetry and tide gauges: The Zone of Influence

Derive point-wise statistics of comparability between SLAs and tide gauges records (correlation, rms …)
Matching altimetry and tide gauges: The Zone of Influence

Derive point-wise statistics of comparability between SLAs and tide gauges records (correlation, rms …)

Select sub-set of best-performing SLAs using relative thresholds in a 300km radius

20% highest correlated data
Matching altimetry and tide gauges: The Zone of Influence

Derive point-wise statistics of comparability between SLAs and tide gauges records (correlation, rms ...)

Select sub-set of best-performing SLAs using relative thresholds in a 300km radius

Zone of Influence represents coherent zones of coastal, high-frequent sea level variability
Validation of SAT-TG trend estimates

- Combine all SLA within a Zone of Influence for various relative thresholds
  \[ \rightarrow \text{derive } VLM_{\text{SAT-TG}} \text{ time series} \]

- Compute $VLM_{\text{SAT-TG}}$ trends and formal uncertainties
  (using the Hector Software from Bos et al. 2013)

- Validate against ULR6-GPS trend estimates (from SONEL) at 72 common stations (i.e. within a 1km distance)
Results: ALES-GESLA

- Validation with respect to
  - RMS of $VLM_{\text{SAT-TG}}$ minus $VLM_{\text{GPS}}$
  - Median uncertainties of $VLM_{\text{SAT-TG}}$ trends

- Optimal Zone of Influence is comprised of 20% of best performing SLAs
Results: ALES-GESLA vs. AVISO-PSMSL

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  - $\text{RMS of } VLM_{\text{SAT-TG}} \text{ minus } VLM_{\text{GPS}}$
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<thead>
<tr>
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<th>AVISO PSMSL</th>
<th>ALES GESLA</th>
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<tbody>
<tr>
<td><strong>RMS [mm/yr]</strong></td>
<td>1.55</td>
<td>1.25</td>
</tr>
<tr>
<td><strong>Trend Uncertainties [mm/yr]</strong></td>
<td>0.82</td>
<td>0.61</td>
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- Optimal Zone of Influence is comprised of 20% of best performing SLAs
Results: ALES-GESLA vs. AVISO-PSMSL

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  - RMS of \( \text{VLM}_{\text{SAT-TG}} \) minus \( \text{VLM}_{\text{GPS}} \)
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<table>
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<th>AVISO PSMSL</th>
<th>ALES GESLA</th>
<th>ALES GESLA – local optima</th>
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<tbody>
<tr>
<td>RMS [mm/yr]</td>
<td>1.55</td>
<td>1.25</td>
<td>0.86</td>
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<td>Trend Uncertainties [mm/yr]</td>
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</tr>
</tbody>
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- Optimal Zone of Influence is comprised of 20% of best performing SLAs
Conclusion

- Using the Zone of Influence improves $VLM_{\text{SAT-TG}}$ trend estimates (RMS: -20%, trend uncertainties: -25%, w.r.t. gridded alimetry)

- Zone of Influence captures small-scale, coherent coastal SL variability:
  - Facilitated by high coastal performance and spatio/temporal resolution (ALES + GESLA)
  - Offshore and non-representative SL dynamics can induce large uncertainties of $VLM_{\text{SAT-TG}}$ trends

Outlook:
- Advanced adaption of the Zone of Influence to further features of coastal sea level dynamics!
Thank You!

Tide Gauge data from GESLA and PSMSL: [https://gesla.org](https://gesla.org); [https://www.psmsl.org/](https://www.psmsl.org/)

GPS-solution from SONEL: [https://www.sonel.org/](https://www.sonel.org/)

DGFI-TUM altimetry data are available on OpenADB at: [https://openadb.dgfi.tum.de](https://openadb.dgfi.tum.de)

Matching altimetry and tide gauges: The Zone of Influence

Zone of Influence reduces noise of SAT-TG differences and thus trend uncertainties!
(a) RMS for different criteria

(b) Distribution of local optimal thresholds

(c) Uncertainties - criteria

(d) Mean distance to coast
<table>
<thead>
<tr>
<th>Category</th>
<th>Method</th>
<th>Reference</th>
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<tr>
<td>Range and Sea State Bias</td>
<td>ALES</td>
<td>Passaro et al., 2014</td>
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<td>Carrere et al., 2016, Carrere and Lyard, 2003</td>
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<td>Fernandes et al., 2015</td>
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<td>Petit and Luzum, 2010</td>
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<td></td>
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Dependency of RMS of $(VLM_{SAT-TG} - VLM_{GPS})$ and trend uncertainties on time series length
High-frequent (GESLA) vs. monthly tide gauges (PSMSL)

RMS of trend differences

SAT-TG trend uncertainties
Dependency of $VLM_{\text{SAT-TG}}$ and trend uncertainties on level of comparability of altimetry and tide gauges:

Trend and uncertainties are computed for correlation-dependent level ranges (0-20%, 20%-40%, 40%-60% ...).
Comparison: AVISO-PSMSL vs. ALES-GESLA (+ Zone of Influence)

- RMS: AVISO-PSMSL 1.55 vs. ALES-GESLA 1.25
- Trend uncertainties: AVISO-PSMSL 0.82 vs. ALES-GESLA 0.61
Matching altimetry and tide gauges: The Zone of Influence

Median corr.: 0.91  0.77  0.84

20% highest correlated data
Along-shore coherence and frequency dependencies

frequencies $T = [4.4-5.8]$  

frequencies $T = [9.2-11]$  

Kurapov et al., 2017
Matching altimetry and tide gauges: The Zone of Influence

Zone of Influence reduces noise of SAT-TG differences and thus trend uncertainties!