

# Geocentric mean sea level fields at the German North Sea and Baltic coast

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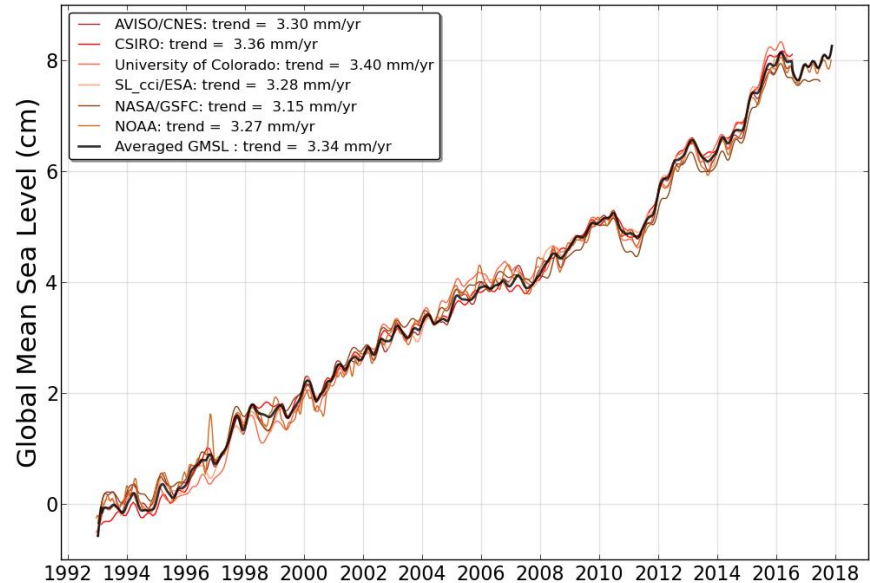
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# Introduction

## Global

- Global Mean Sea level (GMSL) trend since 1993: ca. 3.3 mm/yr
- Constant acceleration of GMSL since 1993
- Cause: increasing contributions from ice sheets and especially Greenland!



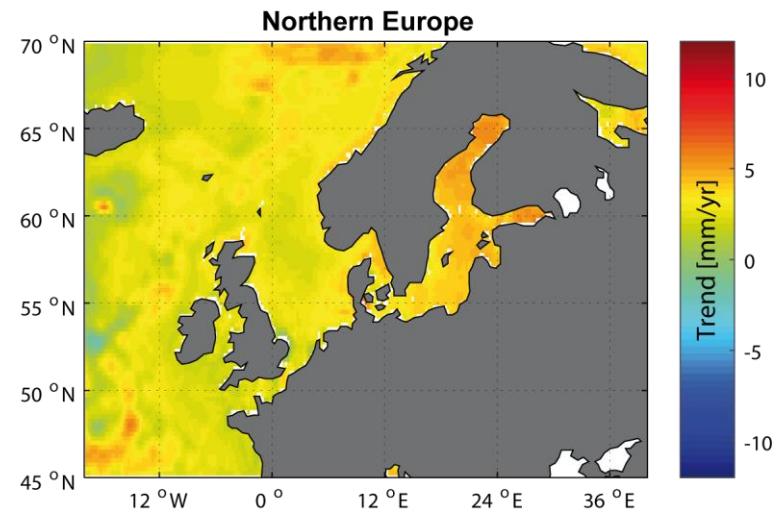
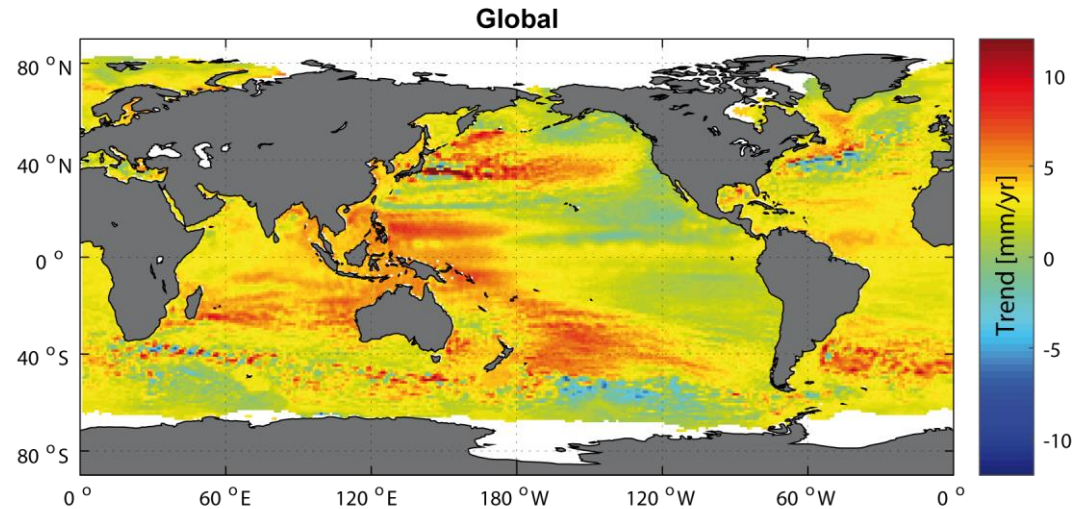
WCRP GMSL Budget, 2018

# Introduction

## Regional

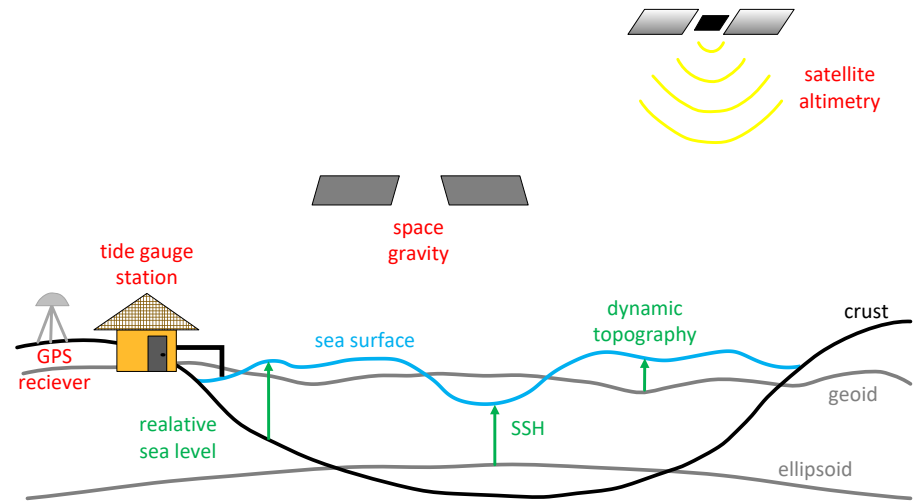
- Regional MSL trends can vary significantly from the global average
- Complex regional structures, resulting especially from mass redistribution
- North Sea and Baltic Sea show significant regional differences in the linear Trends (ca. 3 to 6 mm/yr)

There is need for long (temporal) and high resolution (spatial) MSL Information!

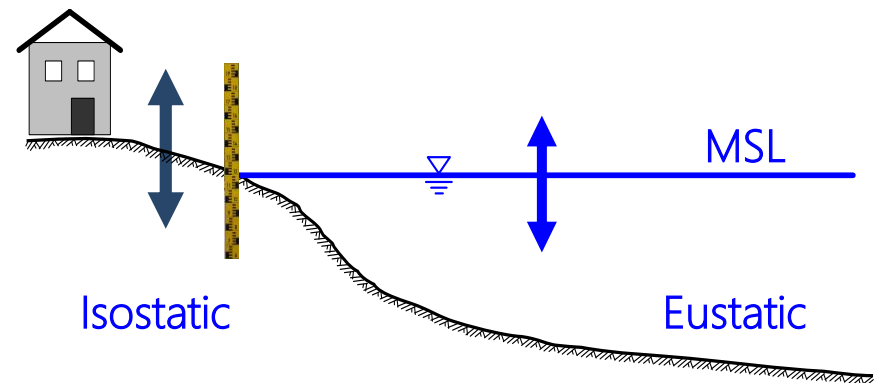


# Data

- Satellites measure the **absolute** sea level relativ to the reference ellipsoid → no vertical land movements and no ocean basin deformations are measured
- Tide gauges measure Sea level **relativ** to the land surface → only source for the detection of global volume changes

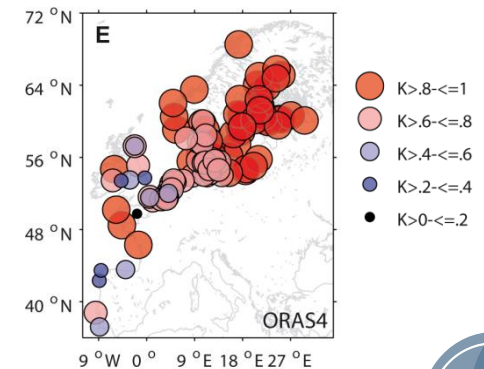
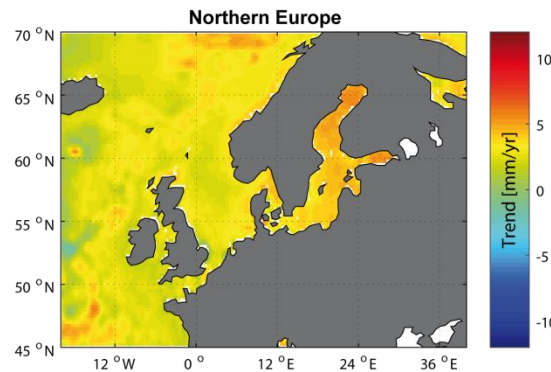
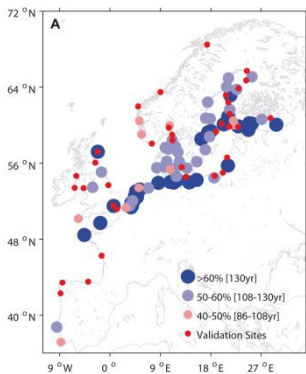


Tamisea et al. 2014



# Data

Tide gauges	Satellite Altimetry	Ocean reanalysis
Novel dataset: > 130 MSL records 1799-2013	AVISO ESA CCIv1 ESA CCIv2	SODA ORAS4
<ul style="list-style-type: none"> <li>✓ Long temporal informations</li> </ul>	<ul style="list-style-type: none"> <li>✓ High spatial resolution</li> <li>✓ ASL (no VLM contamination)</li> </ul>	<ul style="list-style-type: none"> <li>✓ High spatial and temporal resolution</li> <li>✓ ASL (no VLM contamination)</li> </ul>
<ul style="list-style-type: none"> <li>✗ Pointwise information</li> <li>✗ „Contaminated“ by VLM</li> </ul>	<ul style="list-style-type: none"> <li>✗ Limited temporal information 1993-2016</li> </ul>	<ul style="list-style-type: none"> <li>✗ A model cannot capture all processes</li> </ul>



# Goal

- Combining the advantages of different measurement types
- Calculate geocentric sea level fields along the entire German North and Baltic Sea coastline having the same **spatial resolution as satellite altimetry** and/or ocean reanalysis and the **same temporal information as TGs**

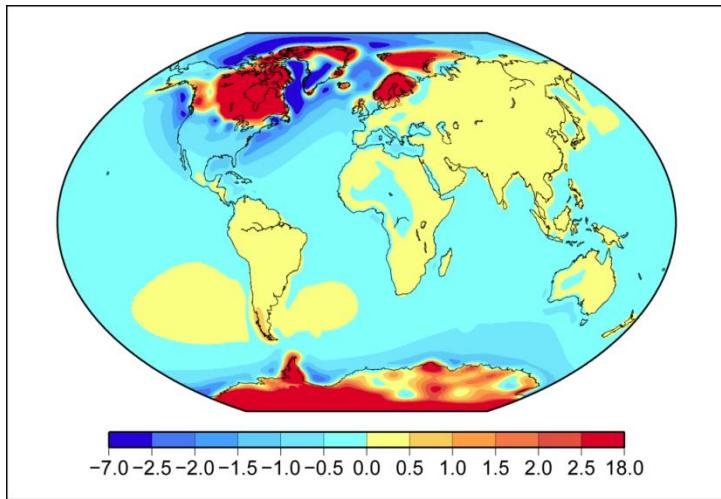
**BUT:** VLM correction of TGs is necessary!

Challenge 1: VLM correction  
Challenge 2: ASL Reconstruction

# Vertical land movements (VLM)

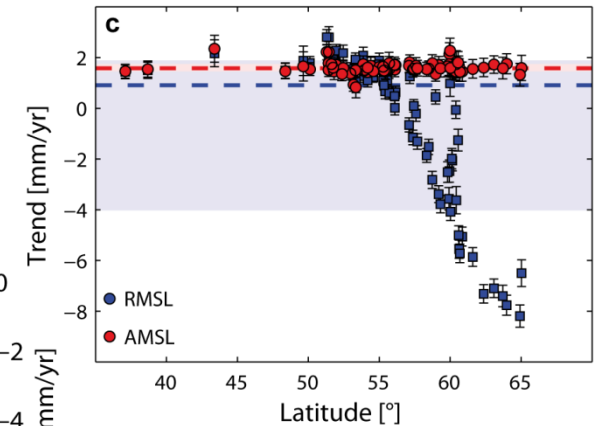
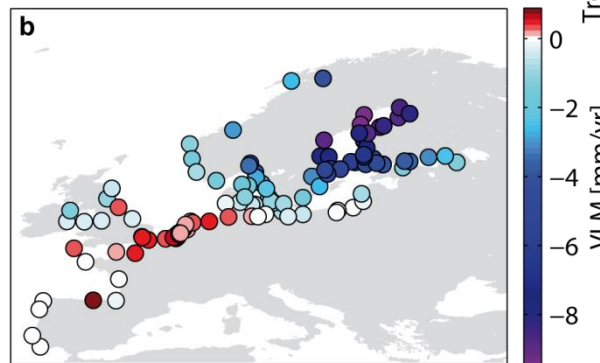
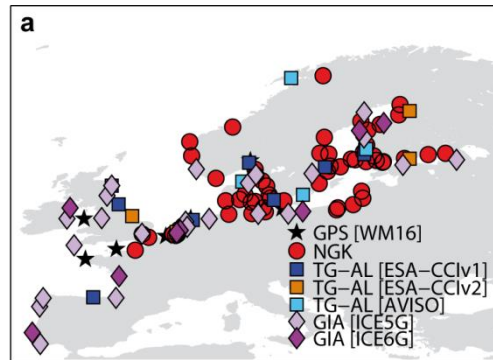
Causes of VLM:

- Glacial isostatic adjustment (GIA)
- Current mass changes due to glaciers, ice sheets and terrestrial water reservoirs
- Local effects (groundwater / gas extraction, earthquakes, etc.)



# Vertical land movements (VLM)

- VLM estimates from different data sources are carefully evaluated at each TG using a novel algorithm
- Assuming: majority of the trend differences between individual locations is indeed driven by VLM
- Searching for the combination of VLM estimates, which minimizes the spatial RSL trend variability over all stations

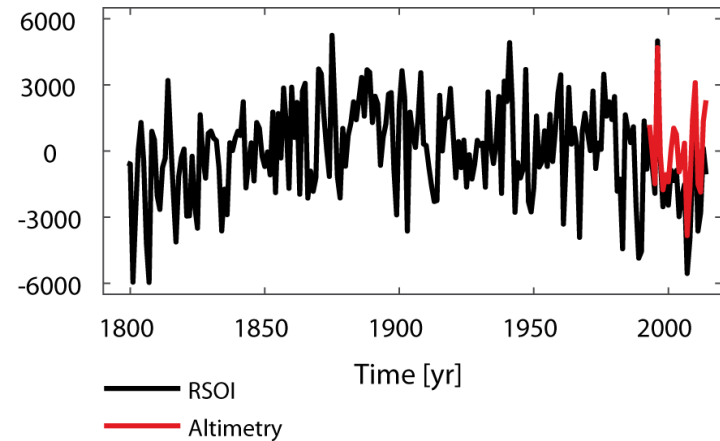
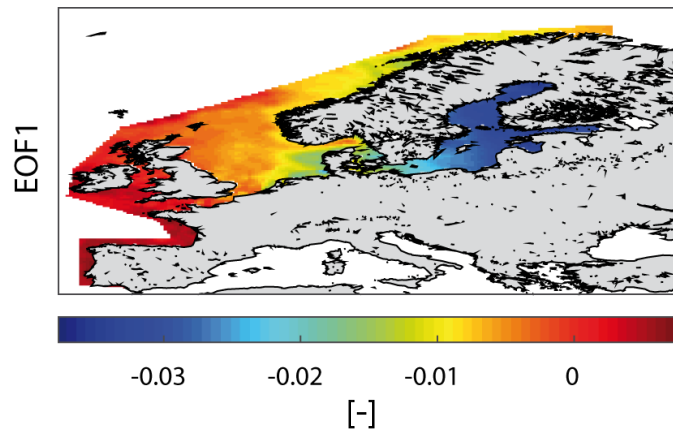




# Spatial and temporal ASL reconstruction

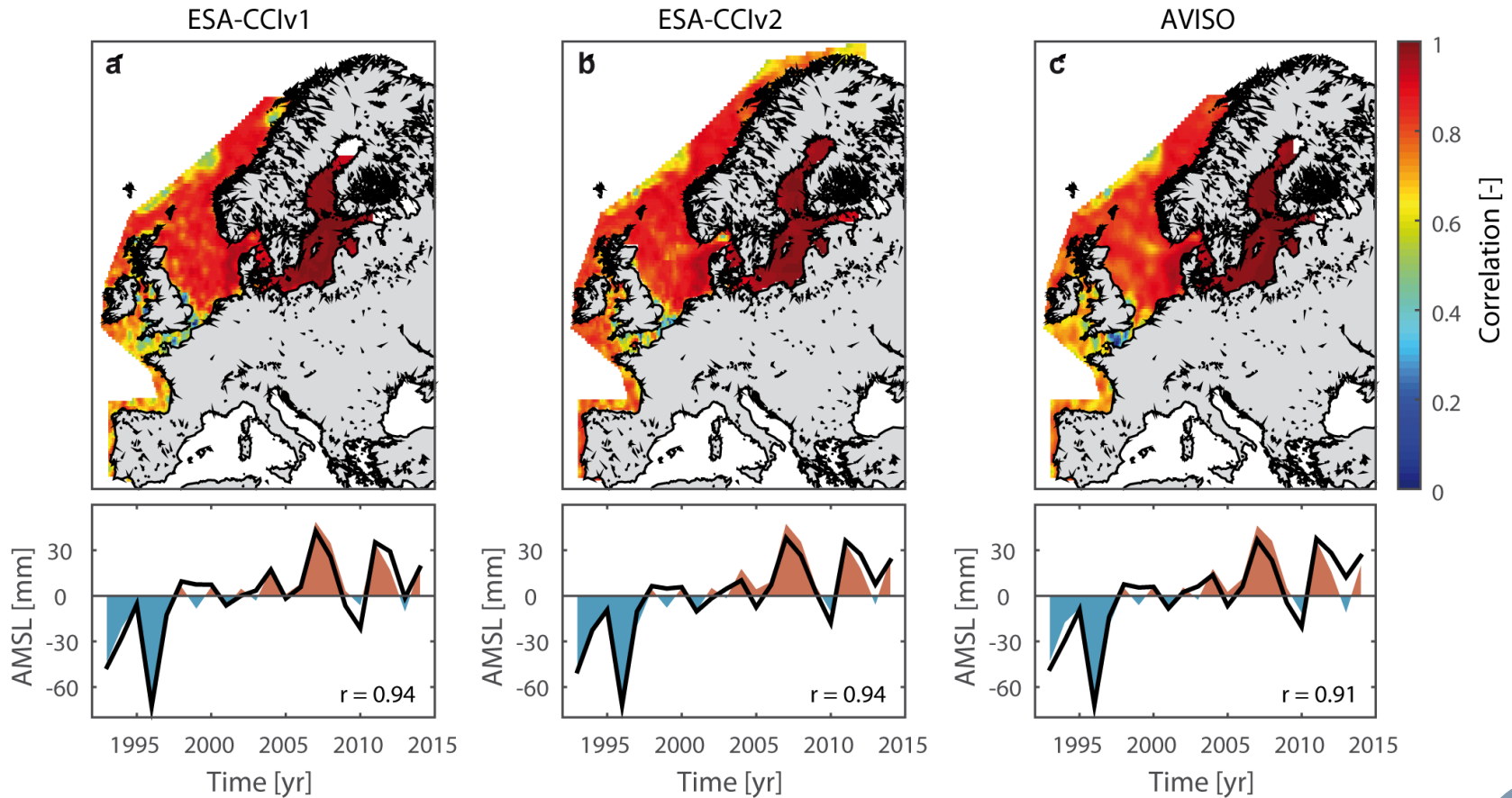
## Empirical orthogonal functions (EOF's)

- Decomposition of satellite altimetry/ocean reanalysis data into spatial modes and their temporal amplitudes
- Temporal reconstruction of the amplitudes with tide gauge measurements in a least squares sense



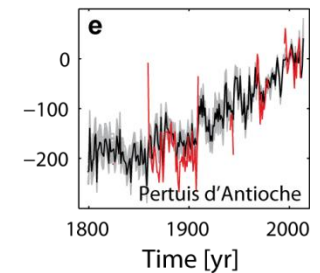
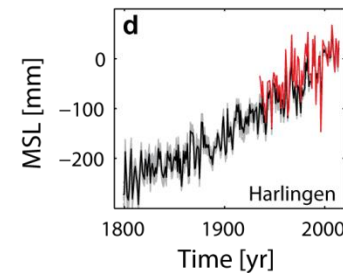
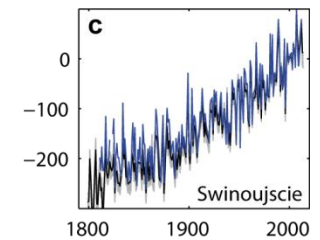
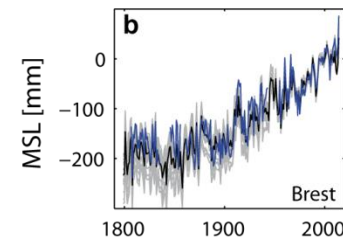
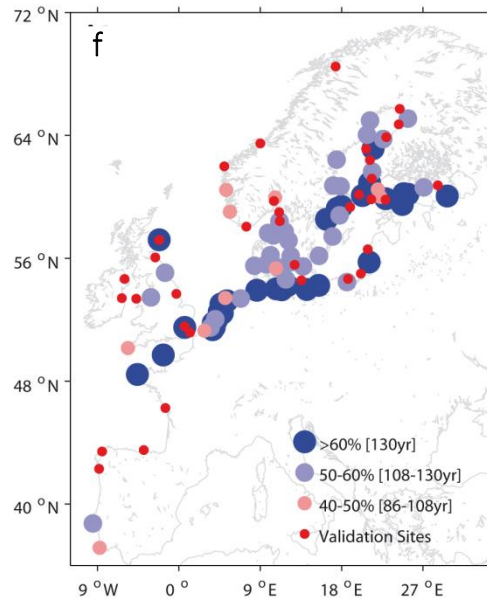
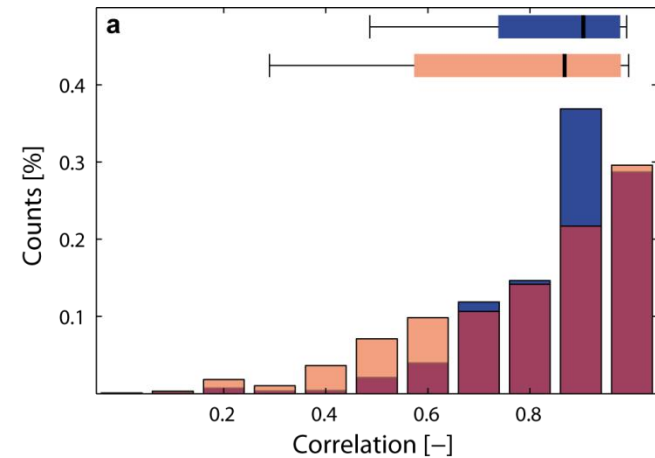
# Spatial and temporal ASL reconstruction

- EOF: good agreement between satellite measurements and reconstruction from TGs



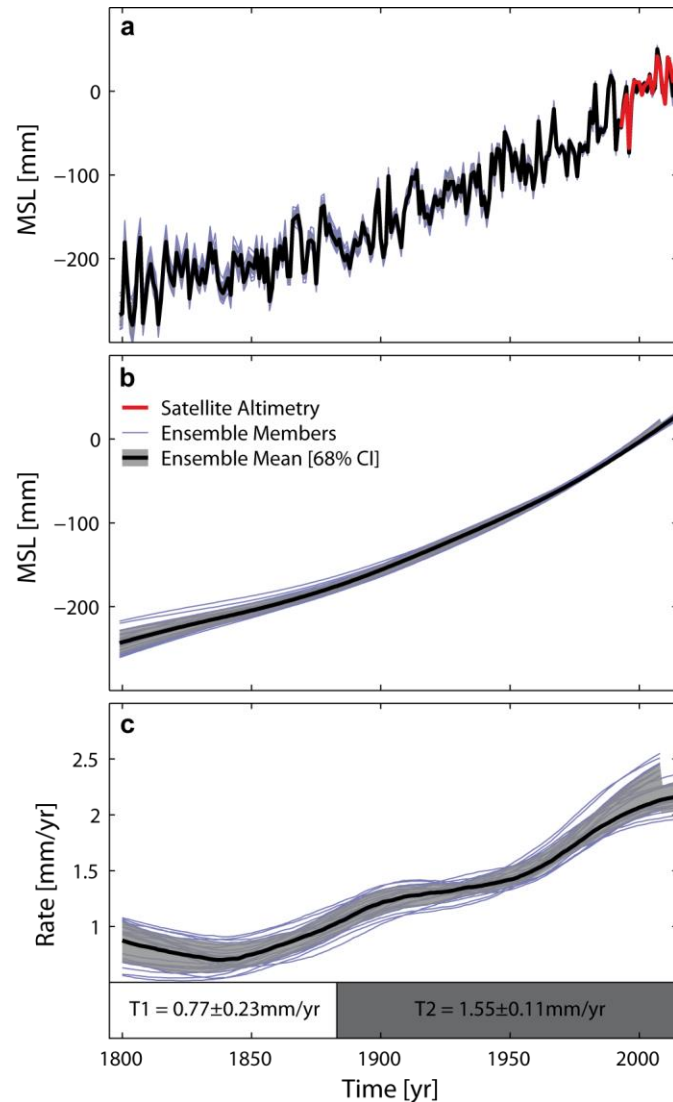
# Spatial and temporal ASL reconstruction

- Testing the reconstructed ASL fields at TG stations (blue = considered in reconstruction; red = unconsidered)
- Good performance at most TGs, just a few outliers

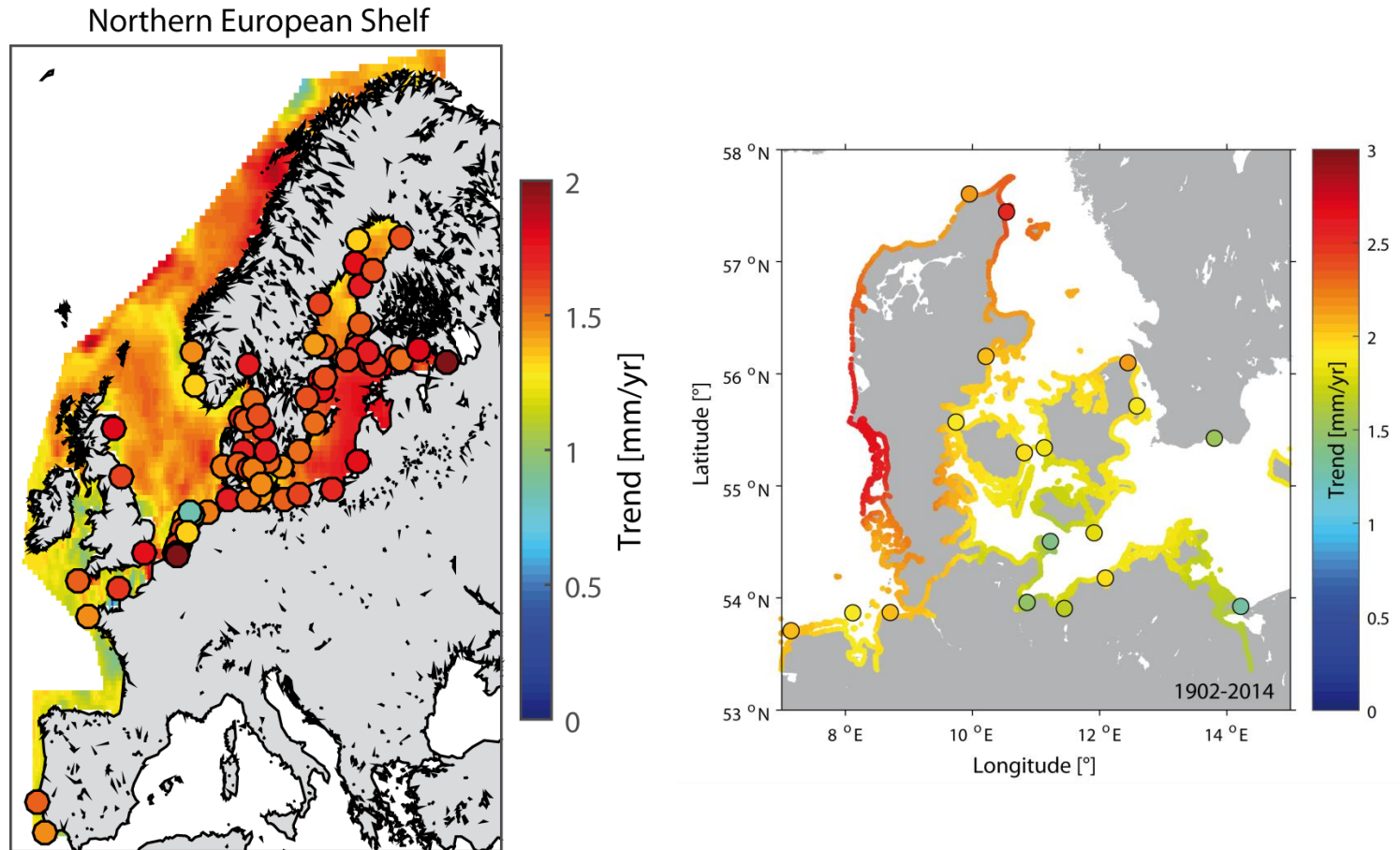


# Spatial and temporal ASL reconstruction

- Northern european shelf: mean of 24 ensemble reconstructions (different combinations of input data)
- All reconstructions show a very good agreement
- Non-linear trends show a significant acceleration over the entire period



# Spatial and temporal ASL reconstruction



# Conclusions

- Reconstruction methods (EOF) as a tool to generate high resolution data-driven MSL reconstructions of **similar spatial coverage as satellite or model data** and the **same temporal availability as TGs**.
- As a result, **geocentric sea level fields** along the entire German North and Baltic Sea coastline with a high spatial and temporal resolution are provided.
- These can be used to put recent satellite altimetry measurements in a historical context and track potential long-term changes and accelerations along the entire coastline in order to inform planners, policy makers and the general public as well.

Thank you for your attention!

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