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Coherent modes of coastal sea level variability from altimetry and tide gauge observations

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Motivation

Previous research[1] has shown that sea level dynamics in the coastal zone can differ significantly from that in the open ocean. The presence of the continental slope, shallow waters and the coastlines give rise to a variety of processes that mediate the response of coastal sea level to open-ocean changes and produce distinct spatiotemporal sea level patterns. Yet how exactly this interplay occurs and, more importantly, the extent to what coastal sea level variations differ from open-ocean variability remain poorly understood.

Objectives

Here, we use coastal altimetry observations in combination with tide gauge data to determine patterns of coherent coastal sea level variations and the degree of decoupling between such variations and open-ocean changes. We seek to answer the following questions:

- **What are the regions of coherent coastal sea level variability?**
- **What are the cross- and along shore correlation length scales of coastal sea level variability?**

Conclusions

- We provide a **systematic assessment of cluster of coastal sea level variations** and their **length-scales**
- Results are in line with many previous studies showing that coastal sea level variations can be regionally highly coherent
- Along-shore correlation length scales of several thousands of km might be caused by processes as coastally trapped waves
- Across-shelf length scales under **decoupling** of monthly coastal and open ocean sea level variability

Outlook

- The study should motivate investigations to identify:
  - the **mechanisms** causing these coherent variations (i.e., river runoff, coastally trapped waves, …)
  - the time-scale dependencies of correlation length scales
  - new gridding strategies taking into account across-shelf correlation length scales

Cluster of coherent coastal sea level variability

Identification of tide gauge cluster using Bayesian mixture models:

$$Y_{t,n} = \sum_{k=1}^{K} p_k(\mu_{t,k} + e_{t,k}),\ n = 1, \dots, N$$

with

$Y_{t,n}$: detrended, monthly SLAs at location n and time t (from PSMSL[2])
$\mu_{t,k} = AR(2)_{t,k}$: time series of cluster k
$e_{t,k} \overset{iid}{\sim} N(0, \sigma_k^2)$: i.i.d. normal random observation errors
N: number of tide gauges
p_k :mixture proportion coefficient
K: number of coherent regions
$p_k \sim Dirichlet(a)$;$\sum p_k = 1$
$\Pr(TG_n \in k) = \frac{p_k N(Y_n|\mu_k, \sigma_k^2)}{A}$: posterior probability that the tide gauge n belongs to the mixture component k

- Mean correlation with tide gauges: **0.77**
- Cluster explain about **60%** of the total variance

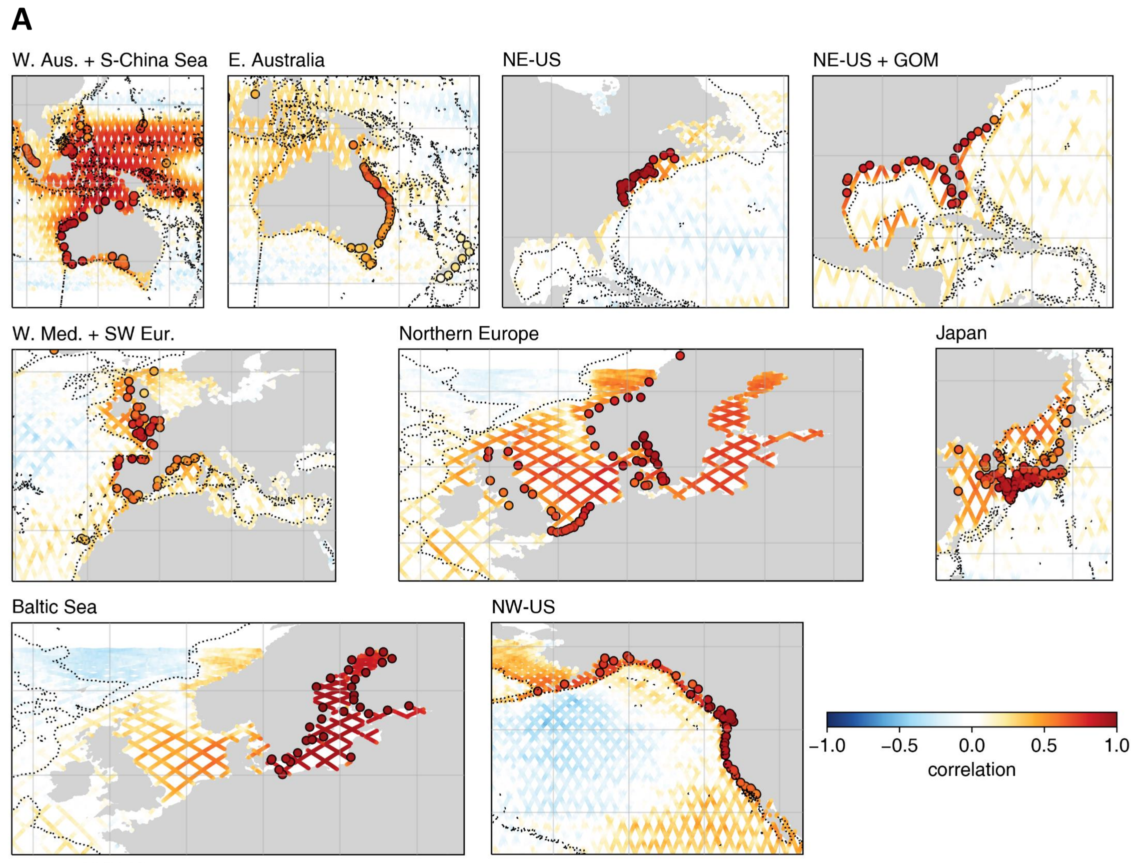


Figure 1: A) Correlations of cluster time series with tide gauges and along-track altimetry data[3].

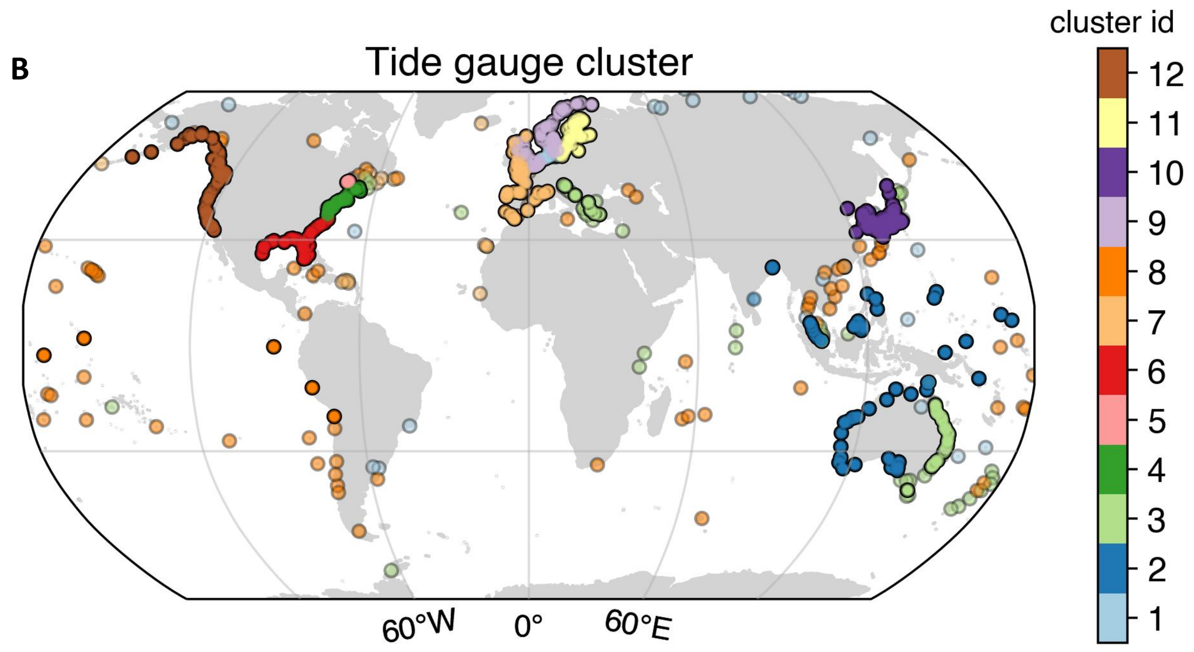


Figure 1: B) Clusters based monthly tide gauge observations as derived by the Bayesian Mixture Model approach described. Tide gauges with correlation below 0.5 (w.r.t. the associated cluster time series) are shown as transparent colors.

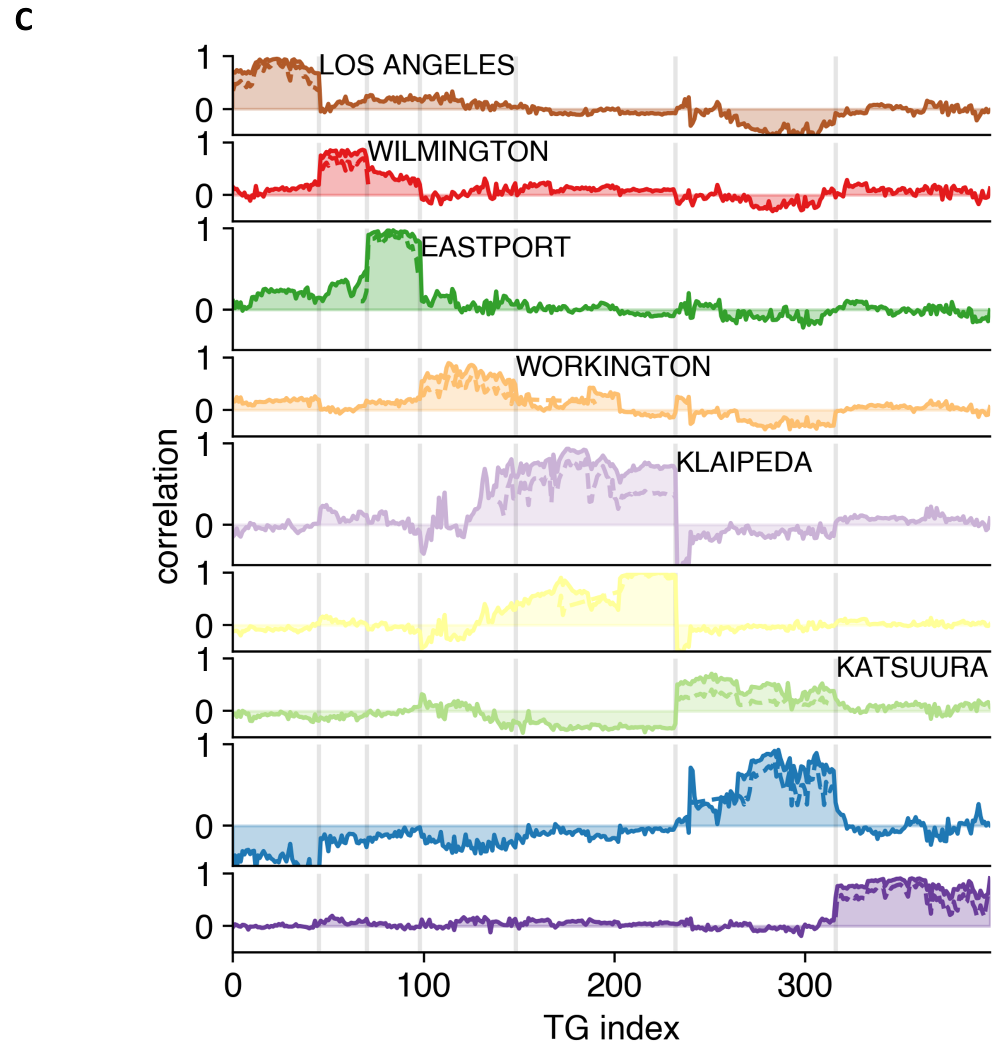


Figure 1: C) Correlations (solid line) and explained variance (dashed line) of cluster time series with every tide gauge time series.

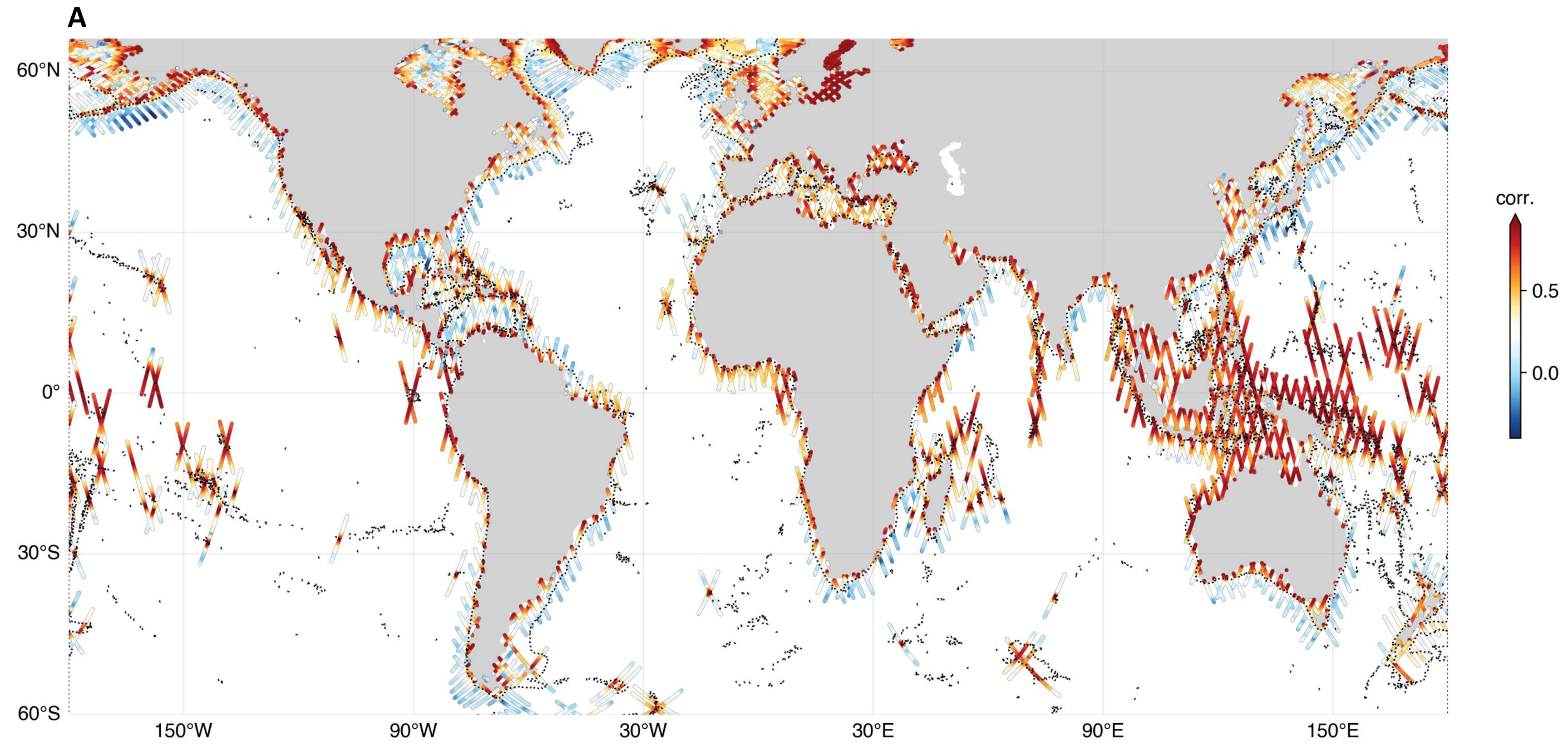
Across-shelf correlation length scales

- Across-shelf correlation length scales are computed based on coastal altimetry data (Jason 1 – Jason 3) over 2002-2020 using coastal retracking (ALES)[3].
- Correlation length scale λ is computed based on correlation between all time series on the track and a coastal average (0-15 km) of the data on the same track:

$$corr(d) = ae^{-d/\lambda},$$

with d = distance to coast, and a = scaling coefficient.

- Latitude/depth dependency of across-shelf correlation scales, which are approximately proportional to the Rossby radius
- Pronounced influence of shelf-width on correlation length scales in the extratropics → strong decoupling of coastal and open ocean sea level variability on monthly time scales
- Limitations of gridded products in resolving the observed correlation length scales[5] → commonly applied along-track filter length scales are larger than the estimated length scales λ



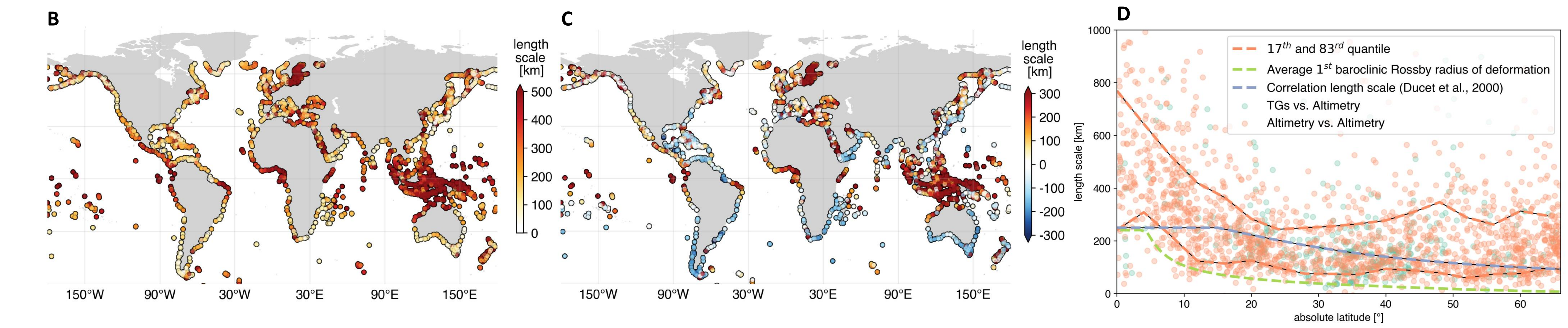


Figure 2: A) Correlations between the point-wise along-track data and the average of the same data within 15-km to the coast. B) Across-track correlation length scales λ based on along-track altimetry data. C) Difference between correlation length scale λ and along-track filter length-scale from Ducet et al., 2000 (previously applied in gridded sea level data). D) Correlation length scales based on altimetry data only (orange) and tide gauge vs. along-track alimtetry (green). Dashed orange lines show 17th and 83rd percentiles of correlation length scales (based on altimetry), green dashed line shows the zonally averaged 1st baroclinic Rossby radius of deformation[4], blue dashed line shows the along-track filter length scales as described by Ducet et al., 2000[5].

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