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How much decadal, coastal sea level variability can we describe by climate modes?

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Attributing global sea level rise to its component parts

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erc

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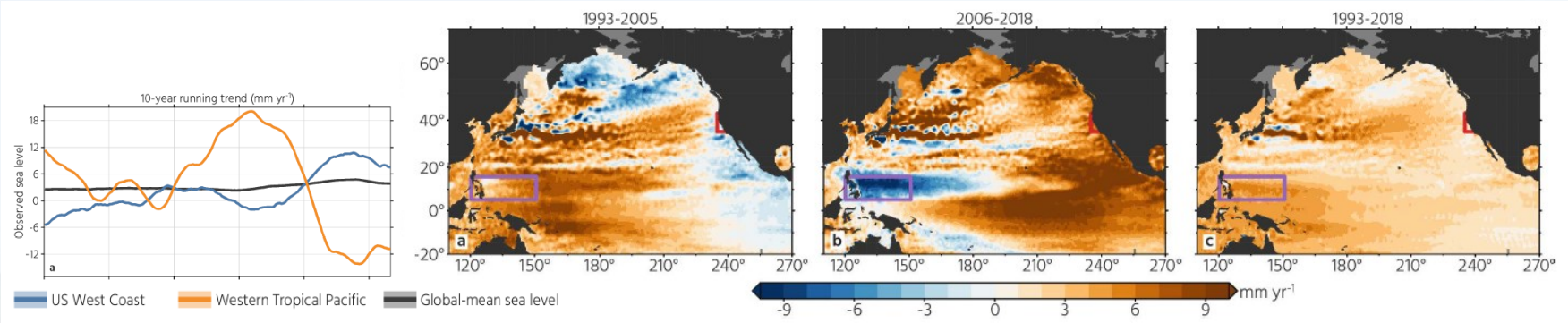
It is well known that key climatic variability like the El Niño Southern Oscillation and Pacific Decadal Oscillation dominate steric sea-level variability in the Pacific Ocean and that this variability influences global- and regional-mean sea-level time series. Reducing the known internal variability from these time series reduces trend errors and can elucidate other factors including anthropogenic influence and sea-level acceleration, as has been demonstrated for the open ocean. Here we discuss the influence of key climate modes on coastal, decadal sea-level variability. For coastal stakeholders and managers it is important to understand the decadal-scale and local changes in the rate of sea-level rise in the context of internal variability in order to inform management decisions in the short- to medium-term. We use a 53-year run of a high-resolution NEMO ocean model run, forced by the DRAKKAR reanalysis atmospheric data set and with the global-mean sea level at each timestep removed, to investigate modes of decadal sea-level variability at the coast, in different basins and from different sea-level components. At more than 51% of Pacific Ocean coastal locations, greater than 50% of the decadal sea-level change can be explained by a regression of the leading principal component mode with key climate indices; ENSO in the Pacific Ocean. In different ocean basins, 23.0% to 68.8% of coastal locations have more than 33% of decadal sea-level variance explained by our climate index reconstructions. These areas include coastal regions lacking long-duration or good quality tide gauges for long-term observations such as the North-West Africa coastline. Because of the shallow depth of continental shelves, steric sea-level change propagates onto the shelf as a manometric (mass) sea-level signal. We use a set of tide gauge locations to demonstrate the internal, decadal sea-level change observed at many coasts has a substantial contribution from local, manometric signal that is driven by climate variability.

Sea level varies on decadal scale by internal variability

Pacific dominant, ENSO-related changes in the open ocean.

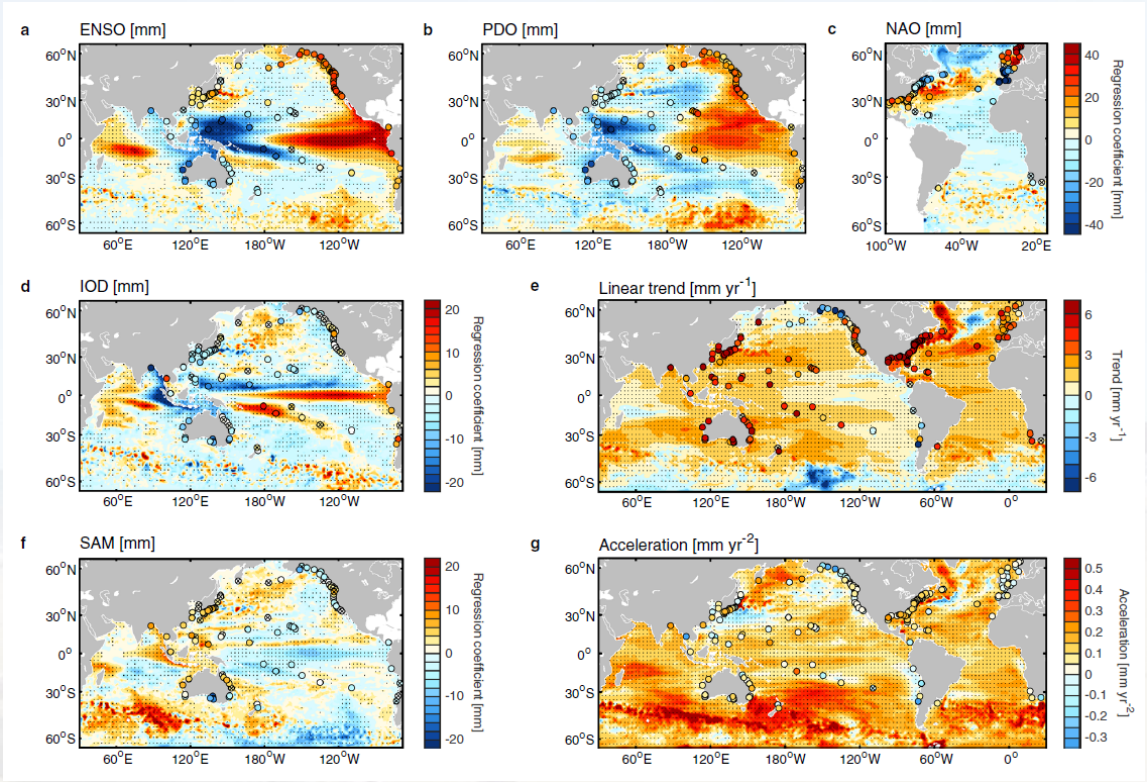


Hamlington et al (2021)

Sea level varies on decadal scale by internal variability

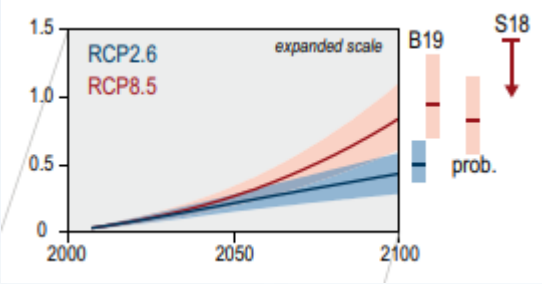
Wang et al 2021 (Nat. Comms.)

These studies aim to ‘reduce’ variability in sea level observations to reduce uncertainties in trend and acceleration estimates



Sea level varies on decadal scale by internal variability

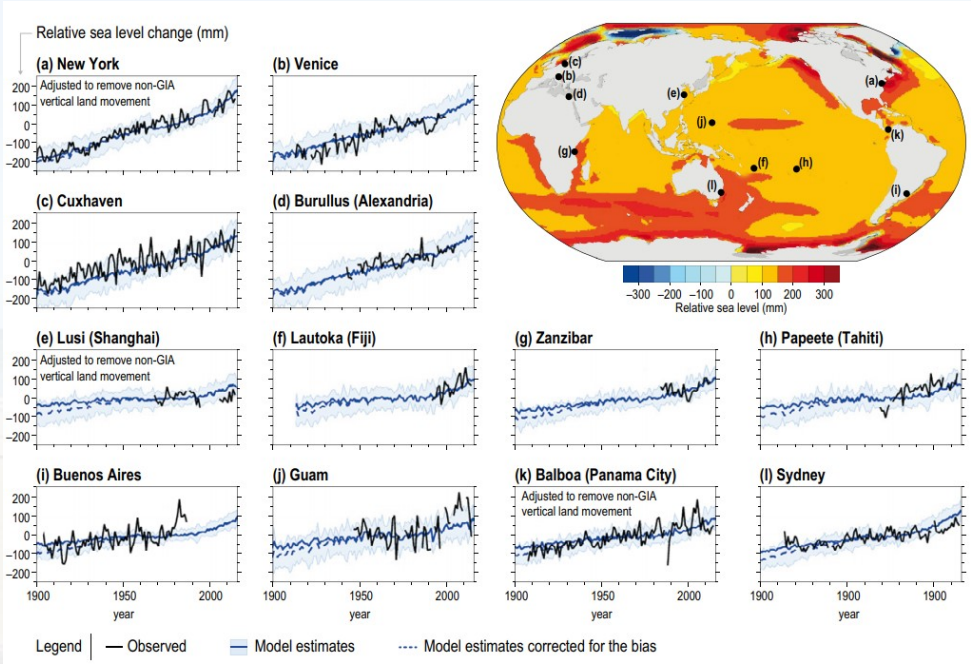
Sea level rise is not globally uniform and varies regionally. Thermal expansion, ocean dynamics and land ice loss contributions will generate regional departures of about ±30% around the GMSL rise.



IPCC SROCC (2020)

Projections include model spread + scenario uncertainty. CMIP are mostly coarse models, smaller internal variability than observed, so ensemble model spread might not capture real magnitude.

Deviations from global-mean important for planning and mitigation – need local projections

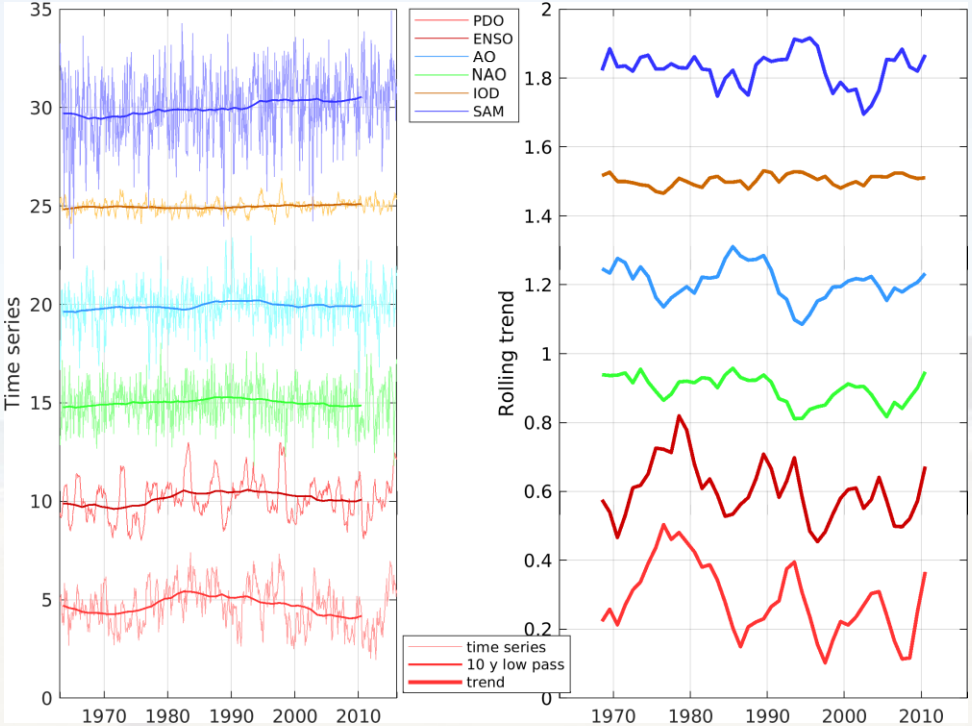


IPCC SROCC (2020) adapted from Meyssignac et al (2017)

Aim: How much decadal, coastal sea level variability can we describe by climate modes?

Method:

- NEMO 1/12° model forced by Drakkar atm. (1963-2016.0), global mean is removed at each time step
- SSHA = model bottom pressure + model steric sea level + GRD (GRD from Frederikse 2020,*Nature*)
- Low-pass filter and rolling trends
- Principal component analysis (PCA) on coastal (<25 km to coast) points
- Linear regression with climate index (PDO, ENSO, SAM, IOD, AO, NAO)



Method

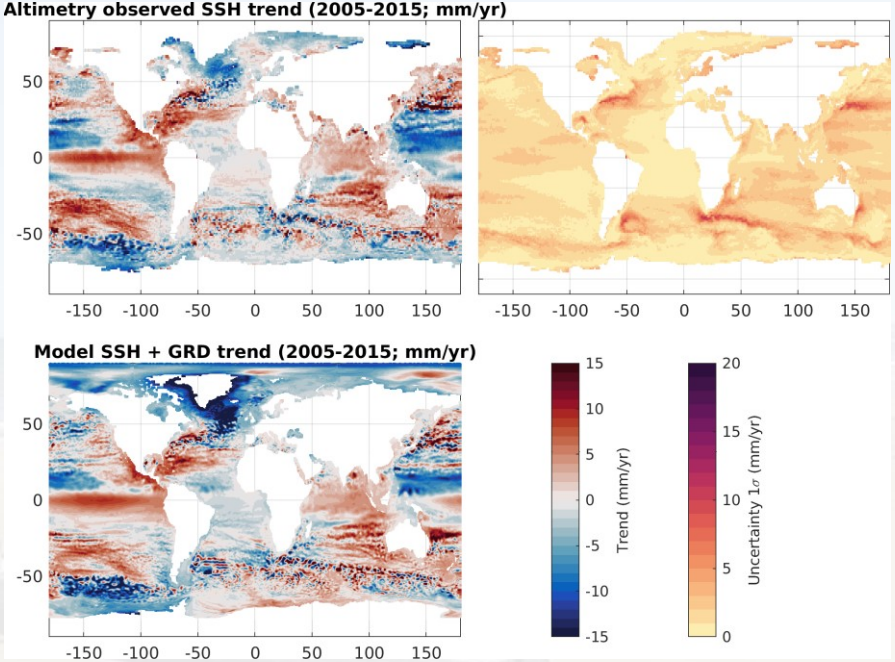
Model has good match to regional trends observed by altimetry

Altimetry –

global mean

NEMO –

global mean

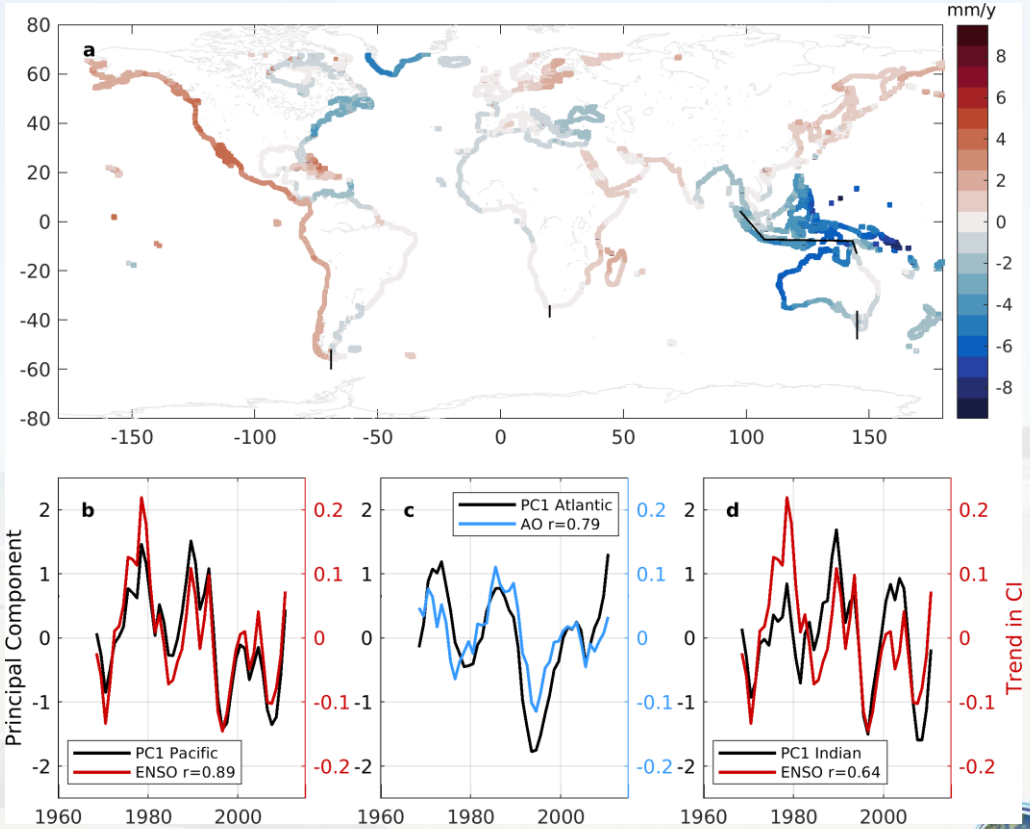


Climate index regression on PCs

(deviation from
global mean)

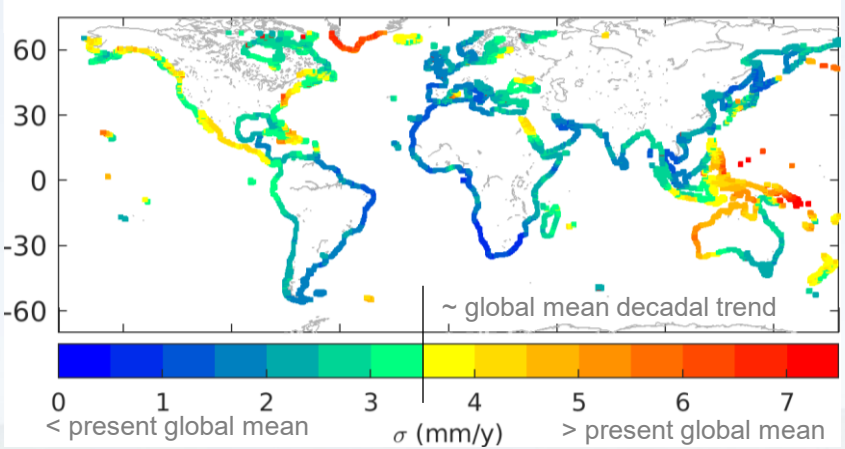
Obtain highest correlation:

- Rolling trends
- PCA separate basins

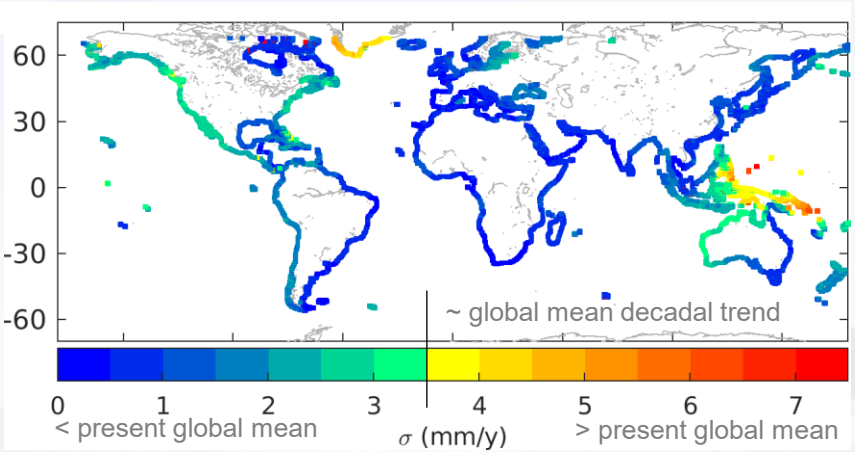


Magnitude of decadal, coastal sea level variability

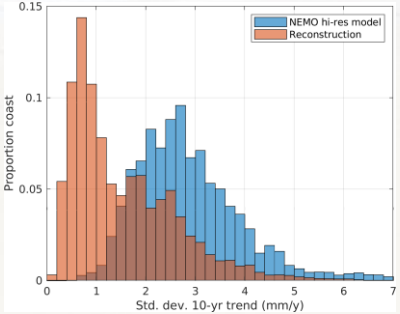
Hi-Res Model:



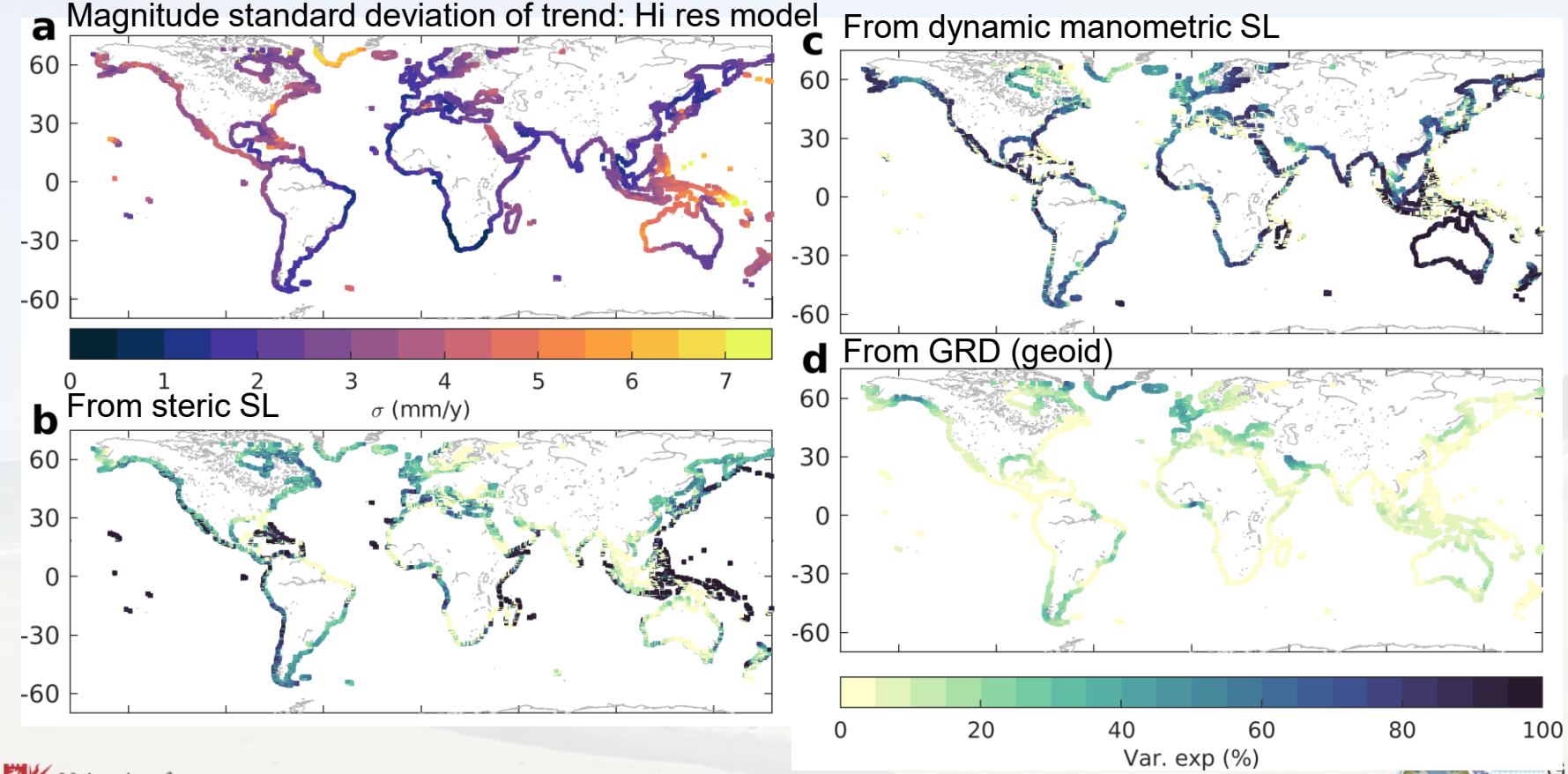
Reconstructed from climate index:



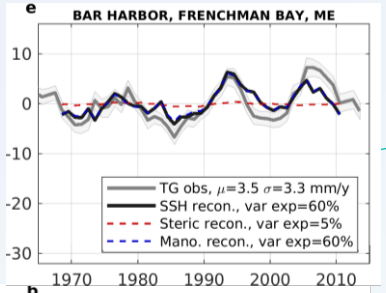
σ rolling trend (mm/y)	Median	95%ile
NEMO (high-resolution model)	2.7	4.9
Climate index reconstruction	1.2	3.6

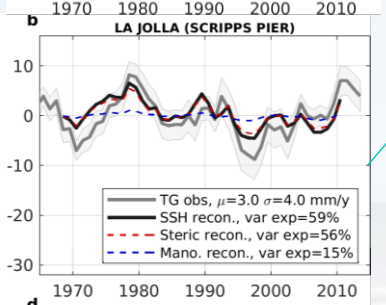


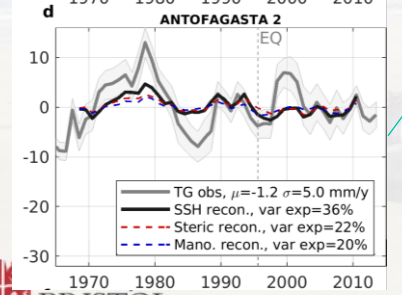
Components of decadal, coastal sea level variability

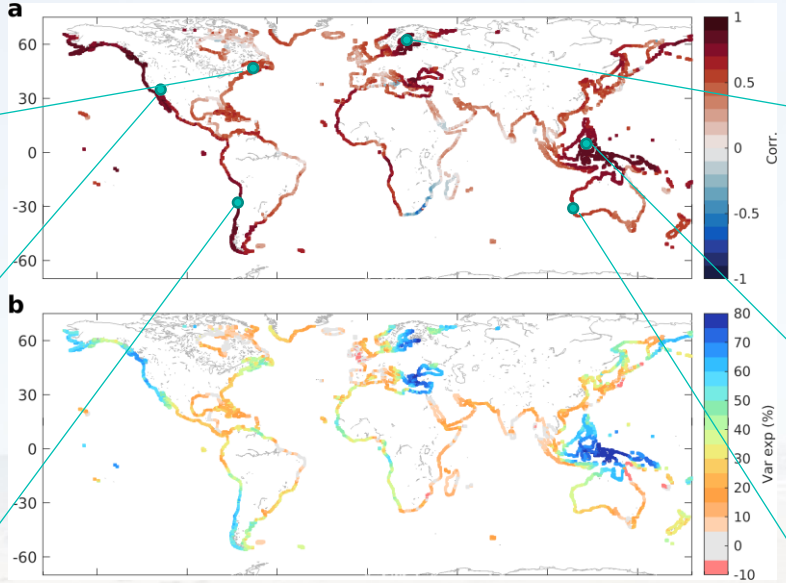


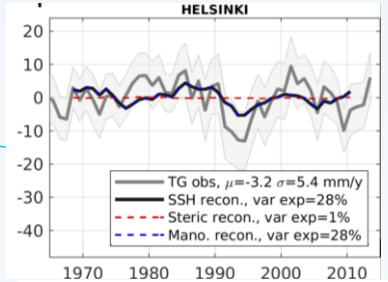
How much decadal, coastal sea level variability can we describe by climate modes?

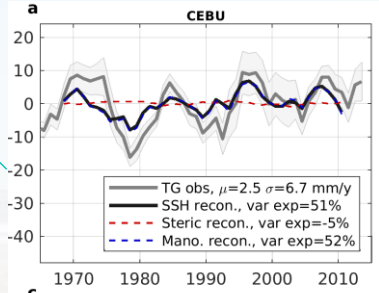


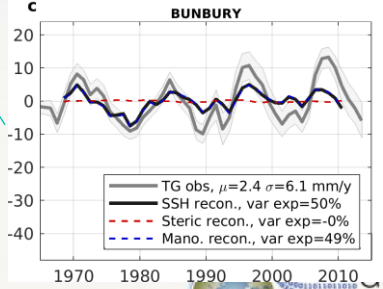












Proportion of coast locations	50%	25%	5%
σ^2 explained rolling trend (%) by climate index reconstruction against NEMO model	28.3	53.3	73.7

How much decadal, coastal sea level variability can we describe by climate modes?

- Obtain highest correlation with rolling trends and PCA applied to separate basins

σ rolling trend (mm/y)	**Median**	**95%ile**
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Proportion of coast locations	**50%**	**25%**	**5%**
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- For decadal sea level studies :
  - account for internal variability by basin or region (not globally) and by sea level component
  - ensure GRD effects are included, especially decadal-scale variability from hydrology
  - make allowance for underprediction of internal variability in coarse-resolution climate models