Relationship of local and regional variability in a coupled climate model

Igor Kröner, Torben Kunz, and Thomas Laepple (igor.kroener@awi.de)

Alfred-Wegener-Institute, Helmholtz Centre for Polar and Marine Research, Potsdam, Germany

ALFRED-WEGENER-INSTITUT HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

Introduction

Comparing in-situ observations or palaeoclimate proxy data to model simulations includes the issue of comparing different spatial scales. While coupled climate models typically have grid cells spanning several hundred kilometres proxy records sample local points. A straight forward comparison would assume that proxy records are representative for a larger region while neglecting possible small-scale variability.

In addition, only specific locations are suitable to retrieve high-resolution palaeoclimate records. Marine sediments, for instance, are often taken close to shores due to a beneficial high sediment rate. This could cause sampling biases of local variance estimates making them non-representative of regional variability in general.

Within this study we focus on three . . .

. . . **Research objectives**

1. **How does climate vary on small spatial scales?** We estimate **spatial degrees of freedom** with respect to local-to-regional scales to examine a spatial structure of variability
2. **How does correlation decay in space with respect to different time scales?** We estimate isotropic **decorrelation lengths** as the distance where correlation drops below $1/e$ for different time scales and filter strategies
3. **With respect to sedimentation rate, are there spatial sampling biases?** Within a sensitivity study we investigate potential **spatial sampling biases** in spectral domain for different regions.

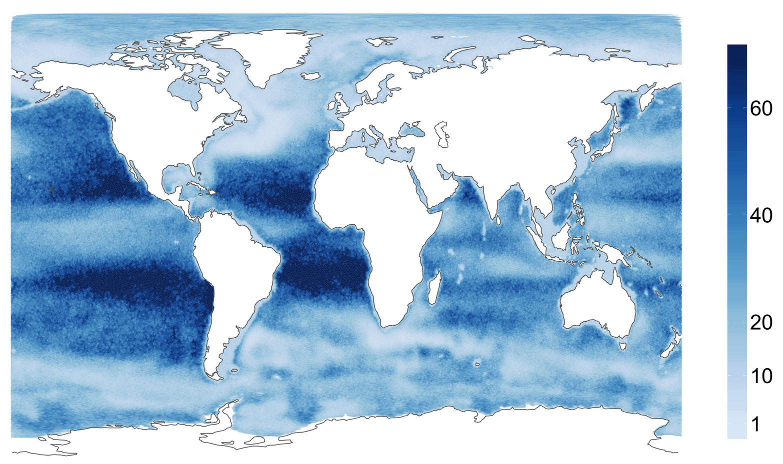
Conclusions

1. **Spatial Degrees Of Freedom**
   - high regional degrees of freedom are obtained at regions of surface currents and up-welling.
   - atmospheric temperature variability additionally varies at elevated regions
   - higher ocean resolution leads in principle to an increased potential spatial variability, but does not necessarily have impact on the difference of oceanic and atmospheric degrees of freedom
   - atmosphere-ocean difference of local to regional variance ratio is nearly constant with temporal scales (yearly, 5-15 years band pass filtered, 15-25 years band pass filtered (not shown))
2. **Decorrelation Length**
   - Complex correlation structures in a constantly forced control simulation at larger time scales
3. **Spatial Sampling Biases**
   - sampling biases with respect to low and high sediment accumulation rate can be seen at small scale variable regions
   - in Northern Atlantic variance estimates can be larger a factor of 2 in preferred core regions
   - Large differences can be seen when comparing distributions of coastal (land/ocean) grid points

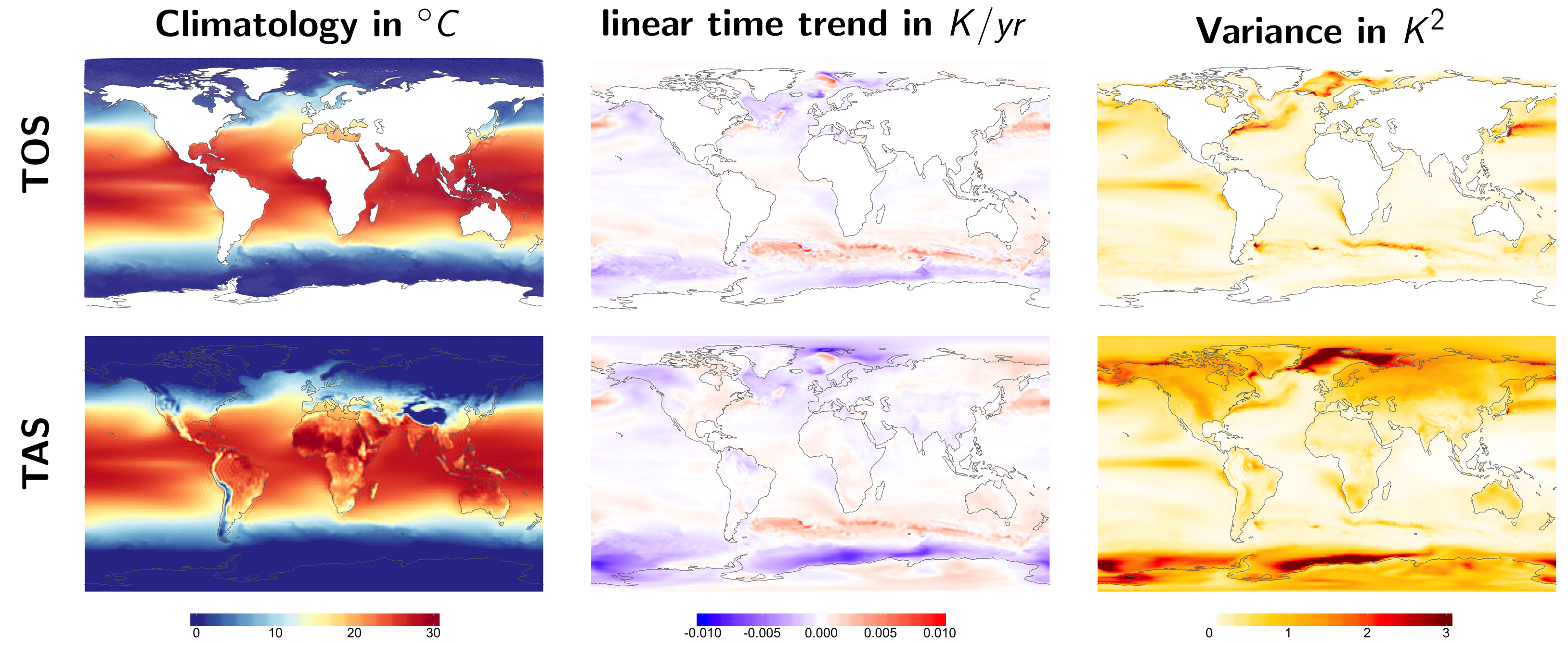
Data

- **AWI Climate Model** (e.g. Sidorenko et al., 2015; Rackow et al., 2016)
  - Unstructured mesh with 830000 surface nodes in ocean component **FESOM1.4**
  - coupled with T127L47 atmosphere **ECHAM6**
- 300 years of yearly averages
- ocean surface (**TOS**) and 2m atmospheric temperature (**TAS**)
- constant forcing with pre-industrial conditions
  - → model output is de-trended linearly in time

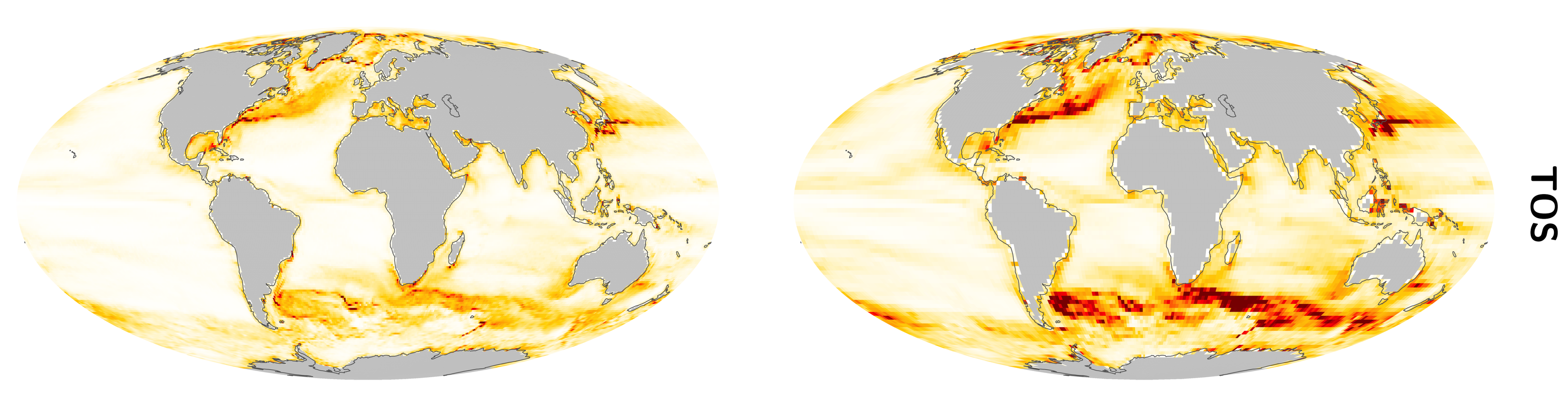
Ocean Resolution in km

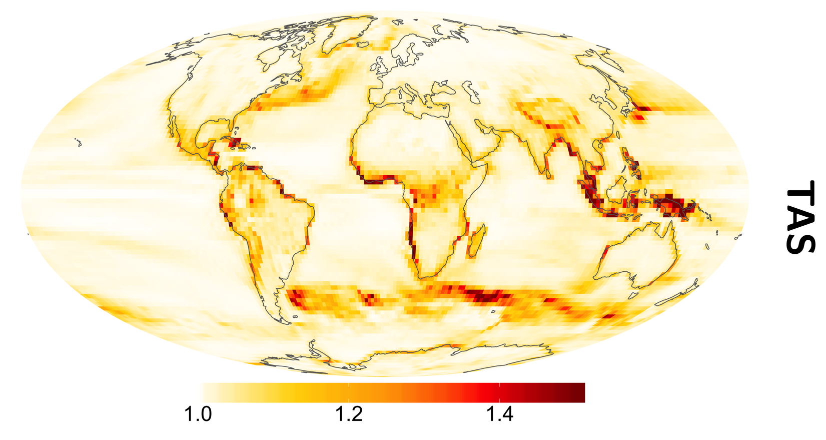


General model output description:



1. Spatial Degrees of Freedom – ,,What is hidden in small scales?"



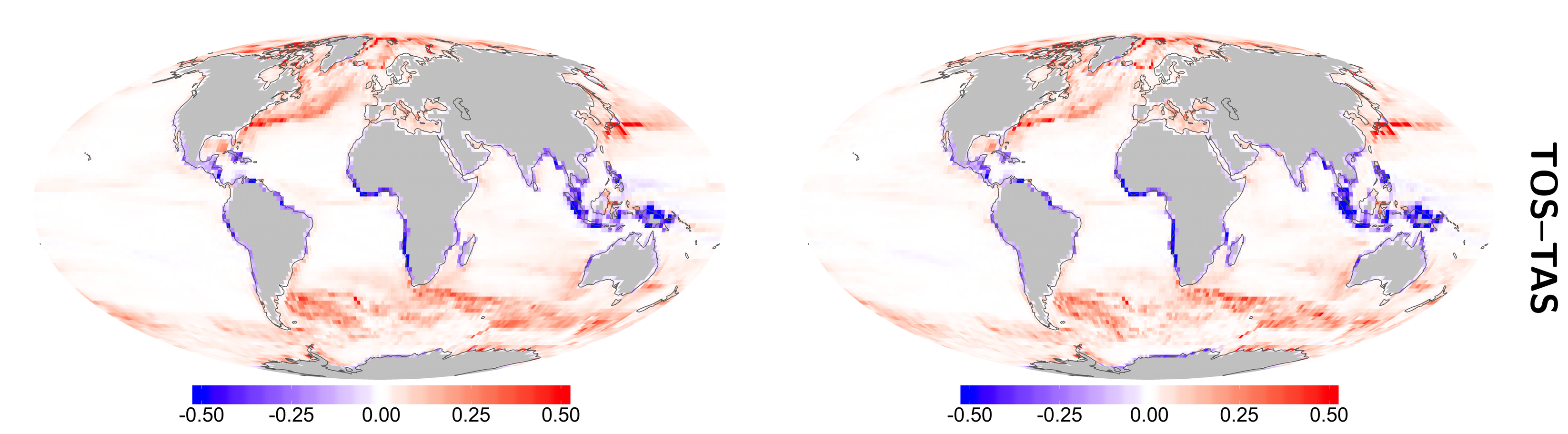


top and middle row:

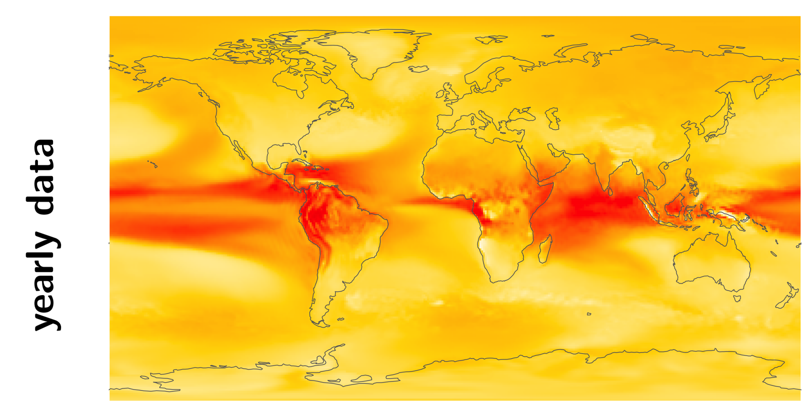
- Quotient of mean, local variance and variance of the regional mean ($\frac{\sigma(X_l)}{\sigma(X_r)}$, Jones et al., 1997)

Difference plots:

- Difference of spatial degrees of freedom in temperature of ocean surface (**TOS**) and 2m atmosphere temperature (**TAS**)

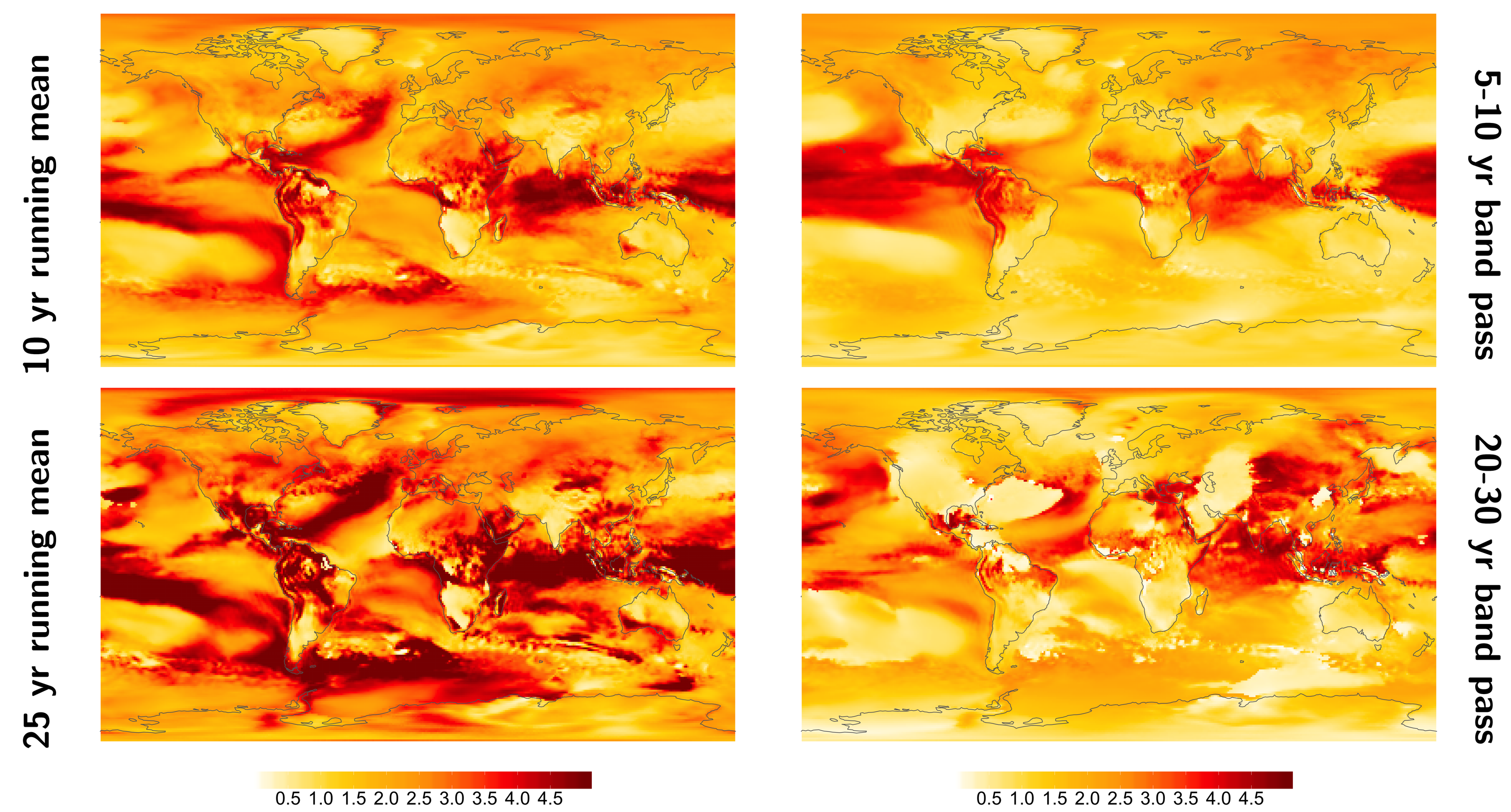


2. Decorrelation Length – ,,How representative are local points?"



Decorrelation length in $10^6\,m$

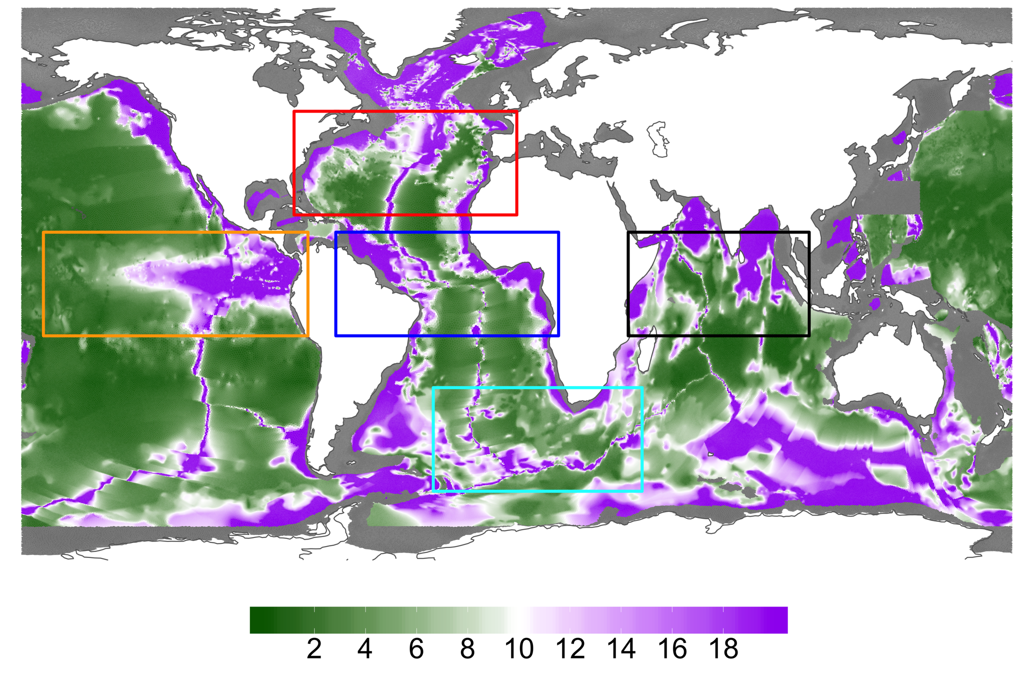
An exponential decay has been fitted individually for each grid point with correlation to all resuming grid points as predictand and their distance as predictor. Decorrelation length is here the distance where the statistical model drops the $1/e$ level (Briffa and P. Jones, 1993)

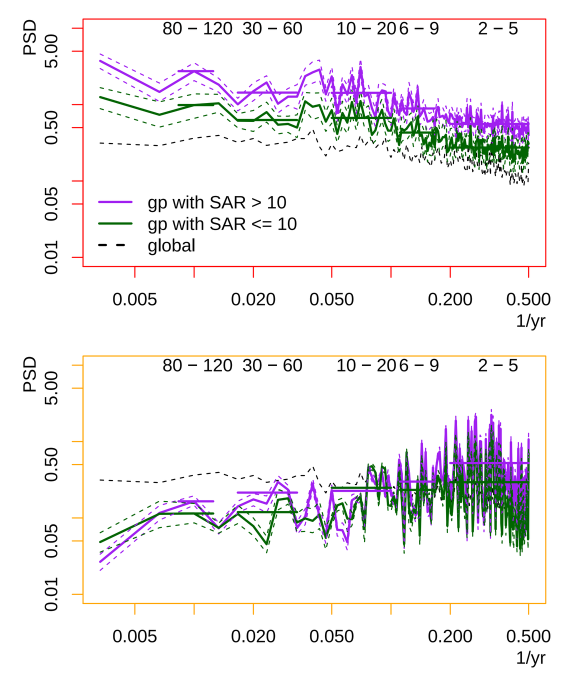


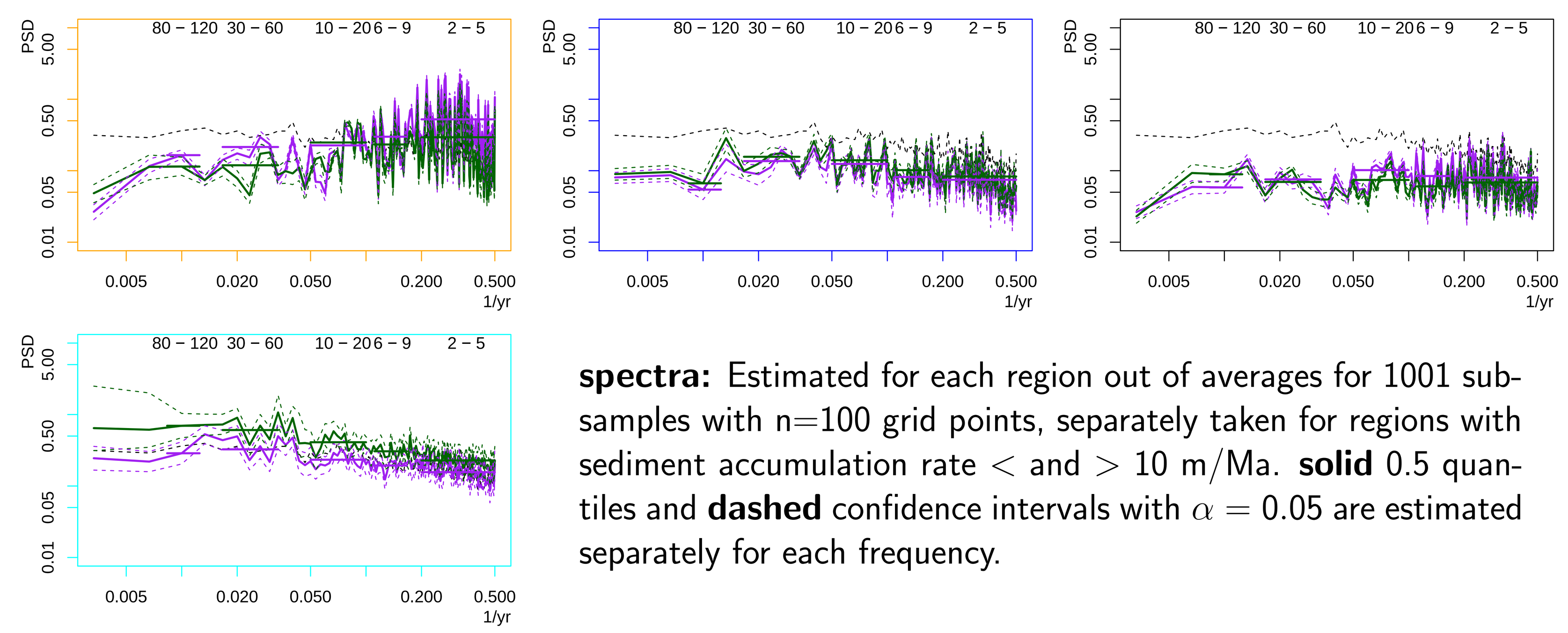
3. Spatial Sampling Biases – ,,Does location matter?"

A sensitivity study with respect to local sampling biases in the model world gives a first estimate of the potential magnitude of local sampling biases

right: Global time average ocean sediment accumulation rate in m/Ma as a ratio of ocean sediment thickness and age of the ocean crust (modified of Olson et al., 2016, Fig. 2a)

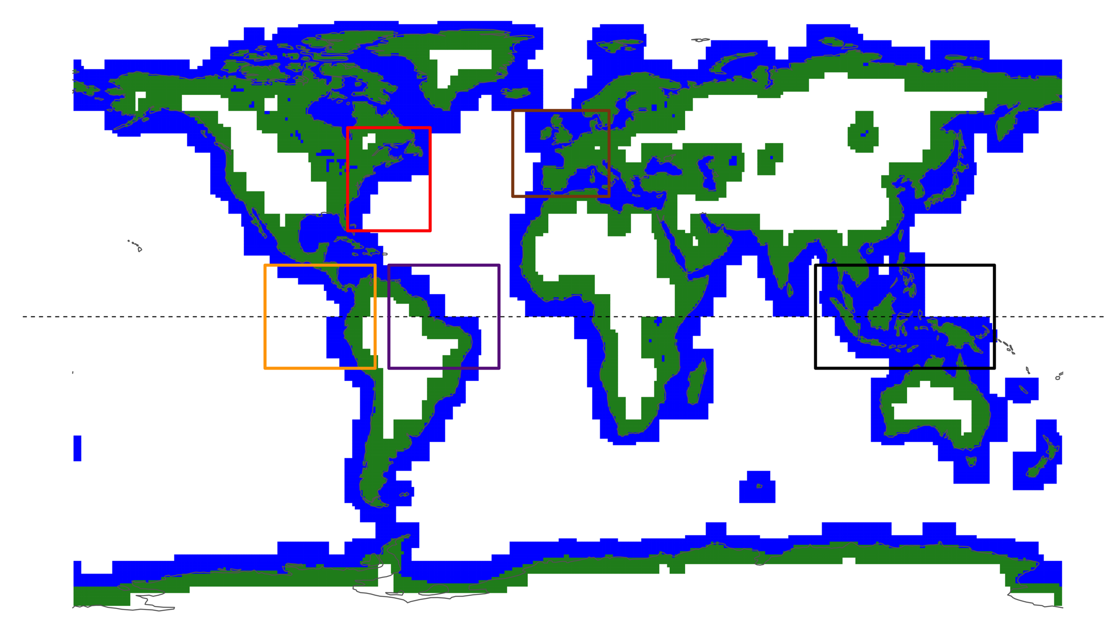




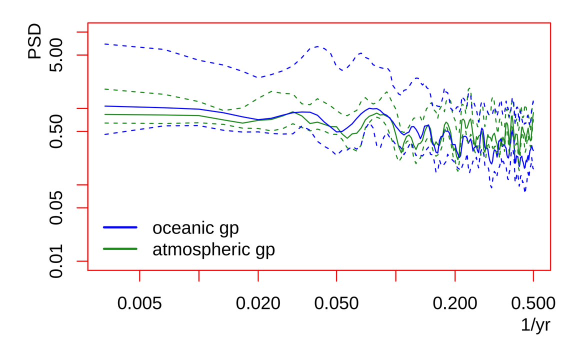


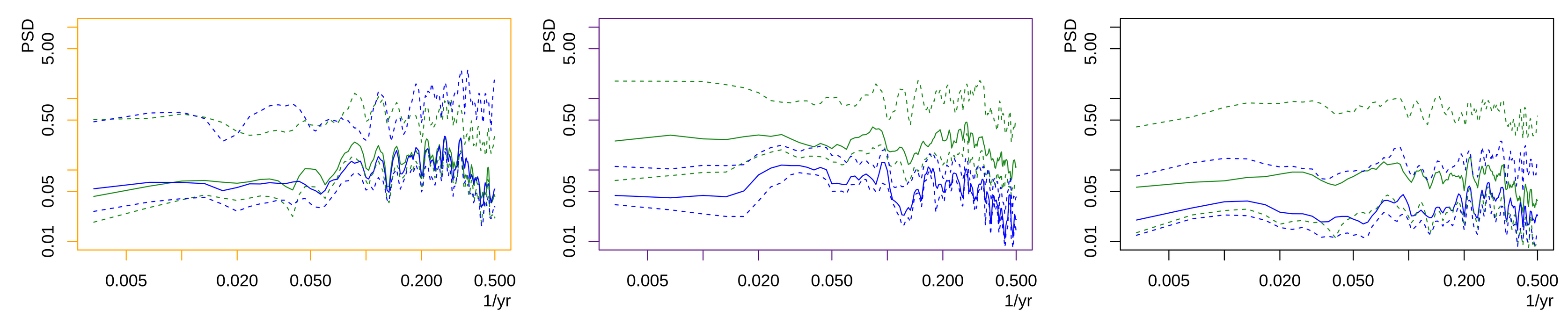
spectra: Estimated for each region out of averages for 1001 subsamples with n=100 grid points, separately taken for regions with sediment accumulation rate < and > 10 m/Ma. **solid** 0.5 quantiles and **dashed** confidence intervals with $\alpha = 0.05$ are estimated separately for each frequency.

Now focusing on coastal regions:

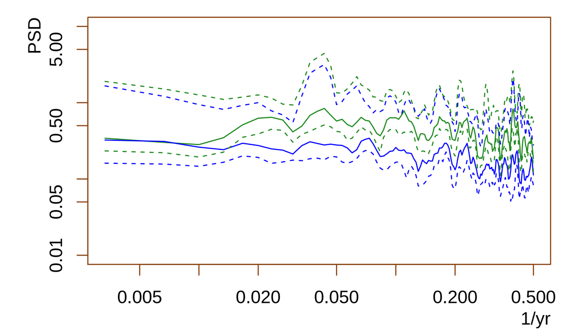


left: Coastal mask, with grid points over land marked **green** and over ocean **blue**. Coloured points are used for the estimation of the spectra shown below.





spectra: Median, and 0.025 and 0.975 quantiles are estimated out of the spectra of all coastal grid points either over land **darkgreen** or ocean **blue** for each frequency separately



Briffa, K.R. and P.D. Jones (1993). ''Global surface air temperature variations during the twentieth century: Part 2 , implications for large-scale high-frequency palaeoclimatic studies''. In: *The Holocene* 3.1, pp. 77{88.
Jones et al. (1997). ''Estimating Sampling Errors in Large-Scale Temperature Averages''. In: *Journal of Climate* 10.10, pp. 2548{2568.
Olson, Peter et al. (2016). ''Variation of ocean sediment thickness with crustal age''. In: *Geochemistry, Geophysics, Geosystems* 17.4, pp. 1349{1369.
Rackow, T. et al. (2016). ''Towards multi-resolution global climate modeling with ECHAM6-FESOM. Part II: climate variability''. In: *Climate Dynamics*.
Sidorenko, D. et al. (2015). ''Towards multi-resolution global climate modeling with ECHAM6--FESOM. Part I: model formulation and mean climate''. In: *Climate Dynamics* 44.3, pp. 757{780.

This work was funded by the Helmholtz Climate Initiative REKLIM (Regional Climate Change) a joint research project of the Helmholtz Association of German Research Centres (HGF). The contribution was financially supported by Geo.X, the Research Network for Geosciences in Berlin and Potsdam (SO_087_GeoX).

Geo.X REKLIM Helmholtz-Verbund Regionale Klimaänderungen ALFRED-WEGENER-INSTITUT HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG HELMHOLTZ RESEARCH FOR GRAND CHALLENGES