

Is there a break in scaling on centennial time scale in Holocene temperature records?

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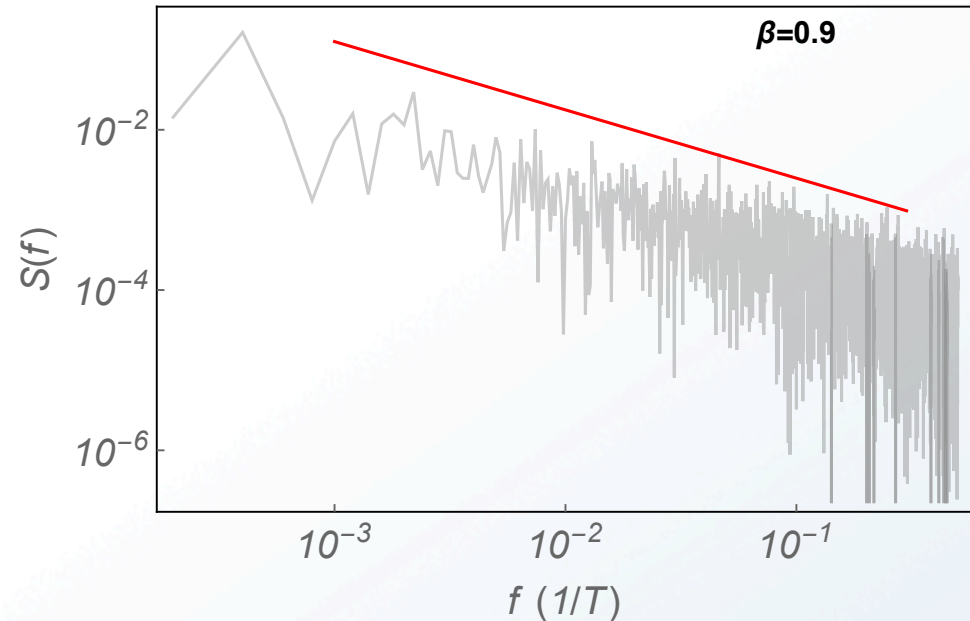
Introduction

Persistent scaling:

The power spectral density (PSD)
follows a power law:

$$\lim_{f \rightarrow 0} S(f) \propto f^{-\beta}$$

where $0 < \beta < 3$.



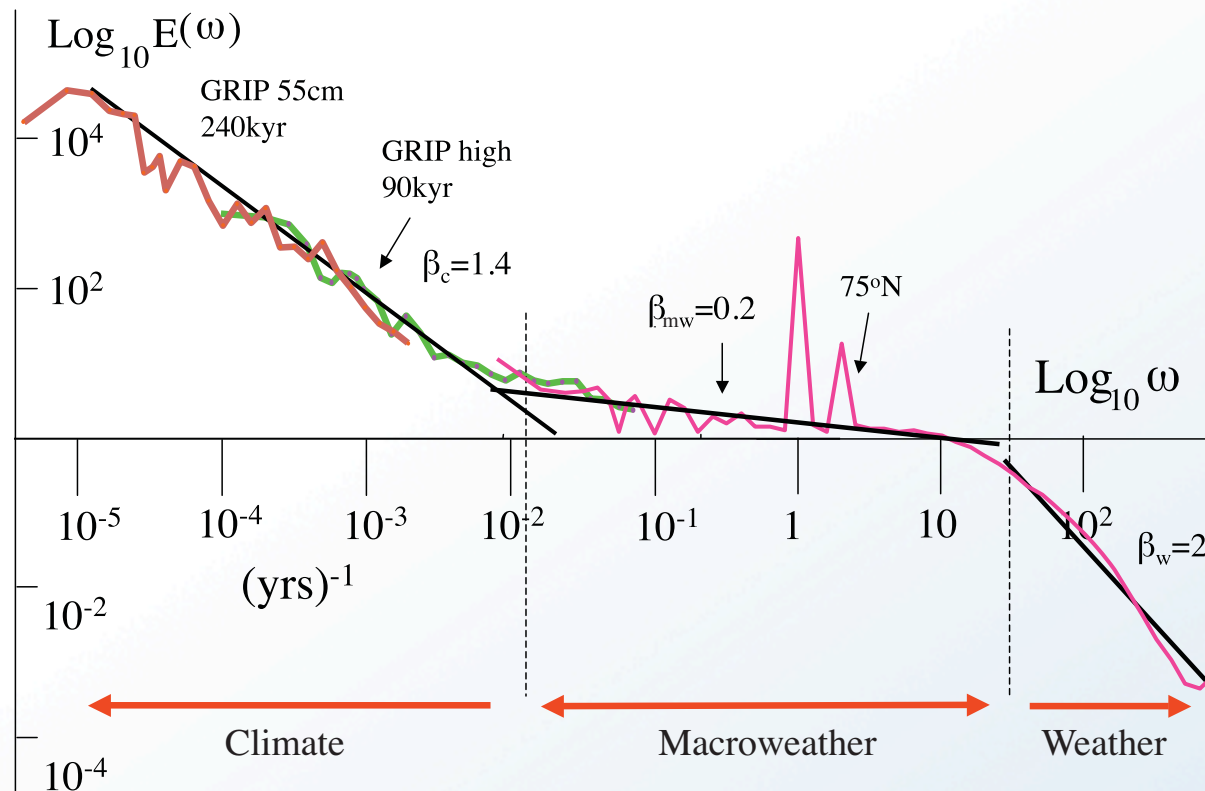
The power-law behavior of the PSD indicates the absence of a characteristic scale in the time record; the record is scale-invariant, or just *scaling*.

Introduction

Lovejoy et al., (2013), *Earth Syst. Dyn.*, **4**, 439.

Lovejoy & Schertzer, (2012), *Extreme Events and Natural Hazards: The Complexity Perspective*, AGU monographs, **196**, 4.

Huybers & Curry, (2006), *Nature*, **441**, 329.



Alternative model

LRM processes can be generated as LRM-response to a white-noise forcing.

A convolution integral for generating a fractional Gaussian noise:

$$T_{\text{fGn}}(t) = \underbrace{\sigma \int_0^t (t-s)^{\beta/2-1} dB(s)}_{\text{fGn}}$$

The kernel $G(t-s) = \exp^{-\gamma(t-s)}$ yields an Ornstein-Uhlenbeck (AR(1)) red-noise.

Stochastic-dynamic response model

$$F_{\text{tot}}(t) \rightarrow \underbrace{F(t)}_{\text{deterministic}} + \underbrace{\sigma dB(t)}_{\text{stochastic}}$$

$$T(t) = \underbrace{\mu \left[\int_0^t (t-s)^{\beta/2-1} F(s) ds \right]}_{\text{deterministic}} + \underbrace{\sigma \int_0^t (t-s)^{\beta/2-1} dB(s)}_{\text{stochastic}}$$

The unknown parameters μ , β , σ are estimated using the MLE method

M. Rypdal & K. Rypdal, *J. Climate*, **27**, 5240 (2014).

Evidence for Holocene scale break?

Nilsen et al. (2016): Are there multiple scaling regimes in Holocene temperature records? *Earth Sys. Dyn.*, 7, 419-439.

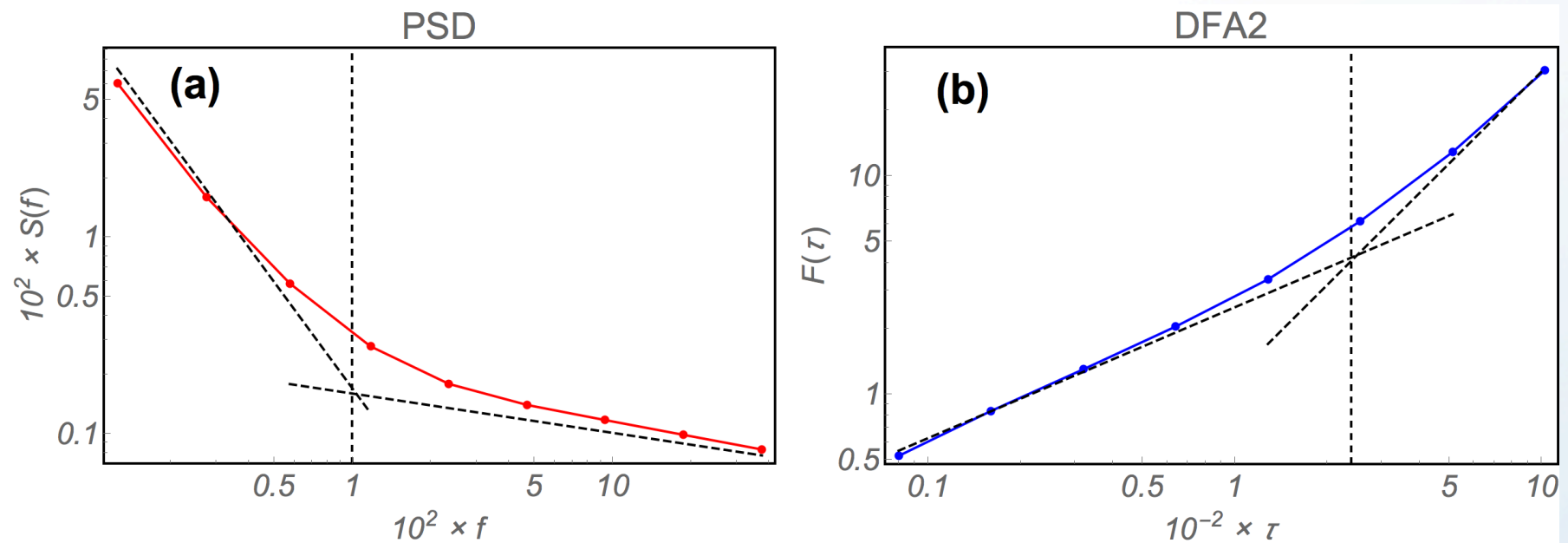
- Is the scale-break around centennial time scales universal?
- If the scale break can be removed by detrending, what does this mean?
- Which dynamics separate the two scaling regimes?

Data and methods

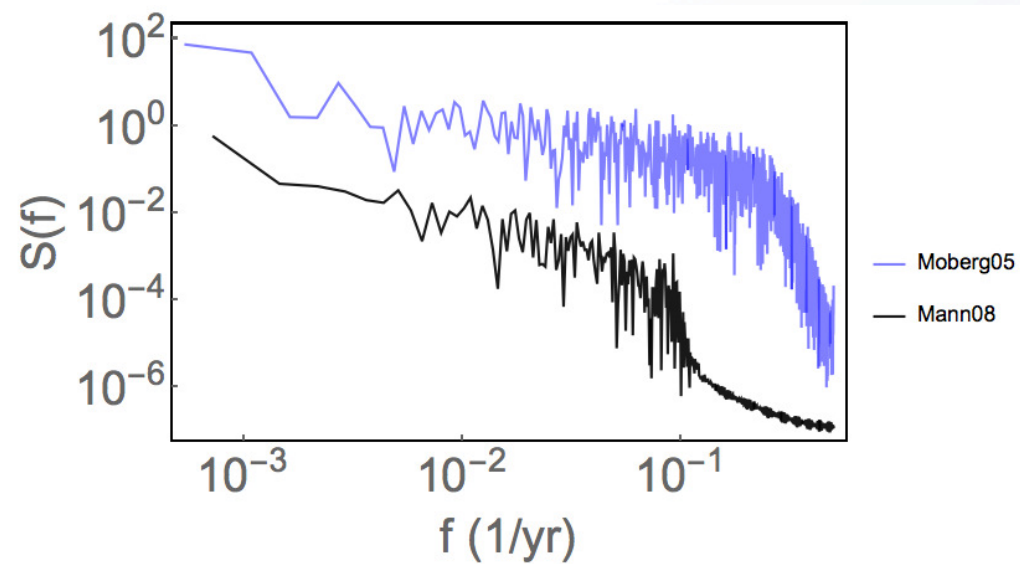
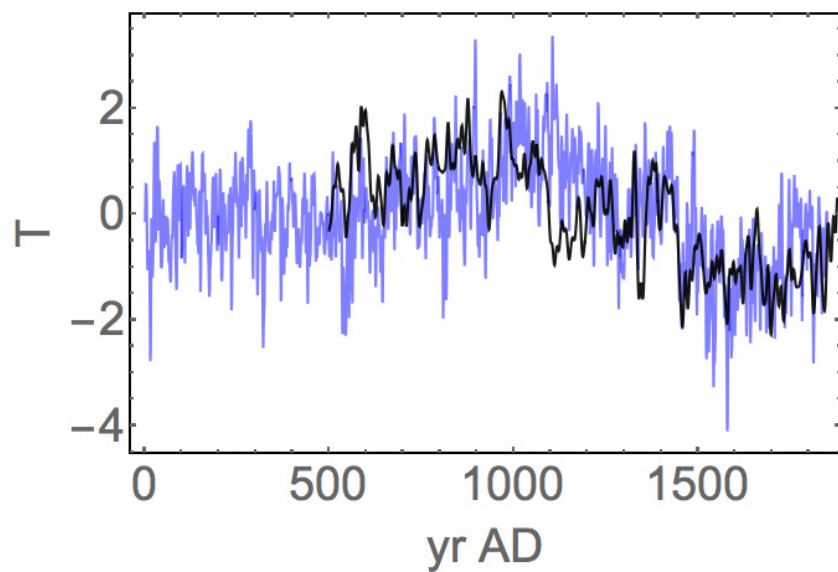
- 7 proxy/multiproxy temperature reconstructions for the late Holocene.
- 1 temperature reconstruction for the entire Holocene
- 6 stable isotope ratio time series from Greenland and Antarctic ice cores.
- Periodogram
- Wavelet scalogram
- Structure/scaling function
- Haar fluctuation function

PSD vs DFA2

Signal: Superposition of fGn ($\beta = 0.2$), and an fBm ($\beta = 0.8$)



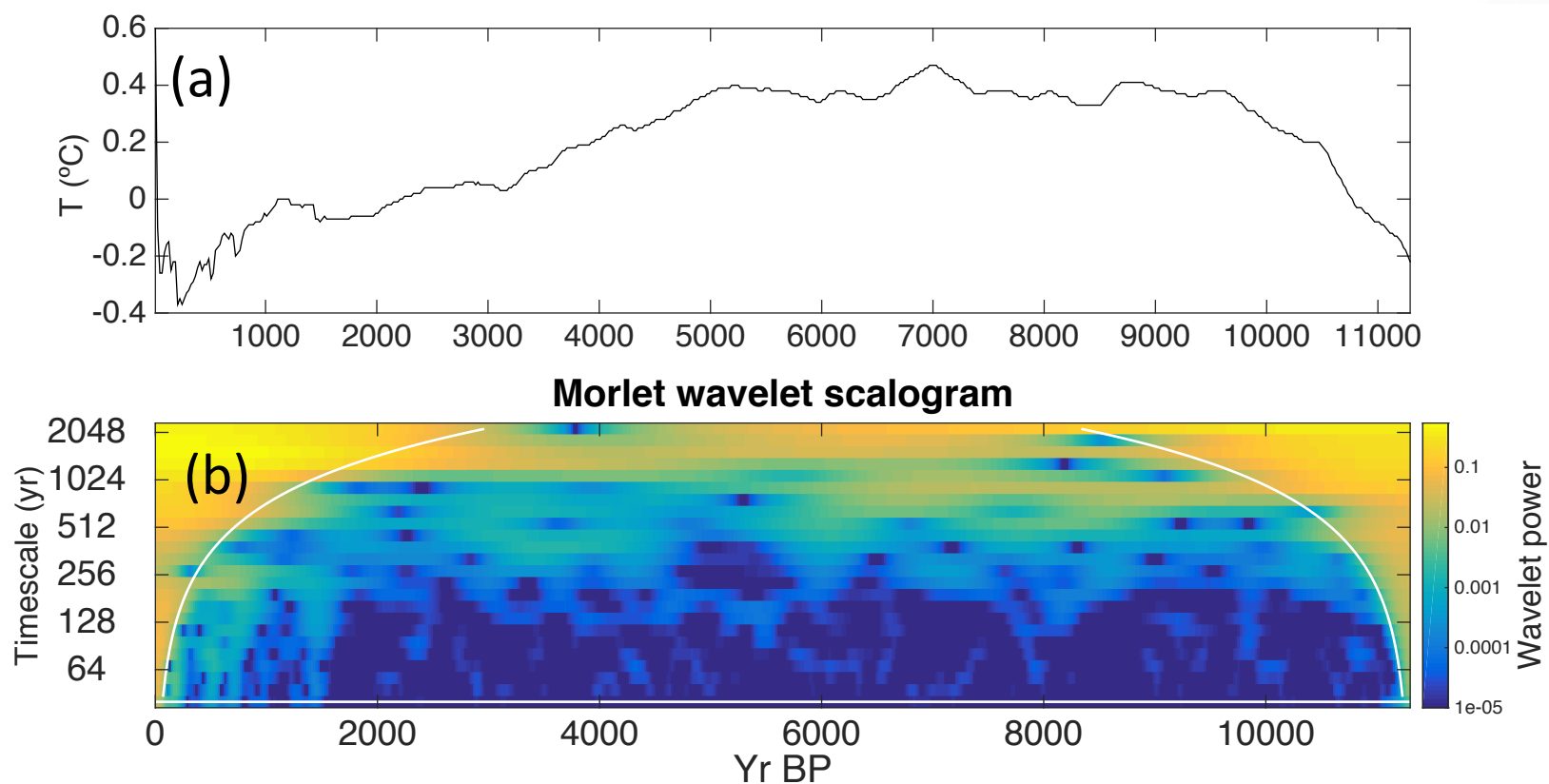
Examples



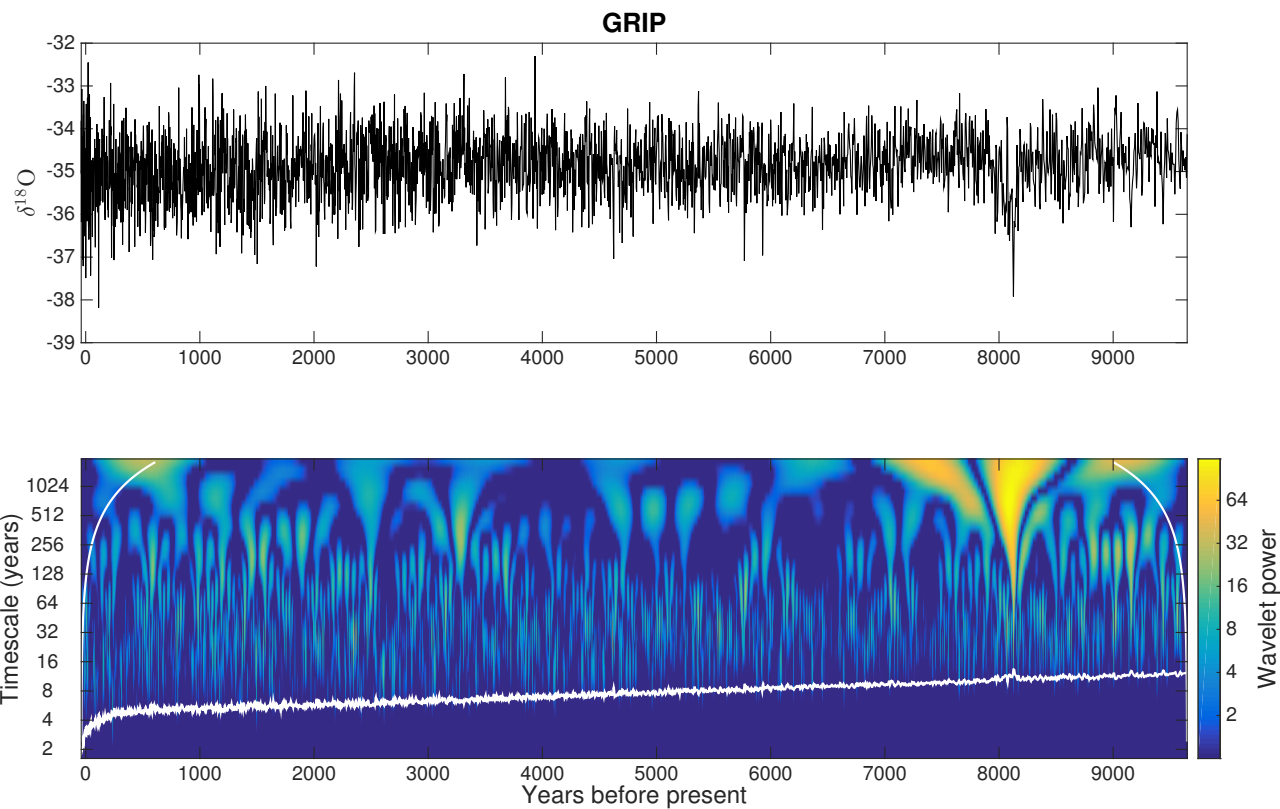
Moberg et al. (2005), *Nature*, **433**,

Mann et al. (2008), *P. Natl. Acad. Sci. USA*, **105**

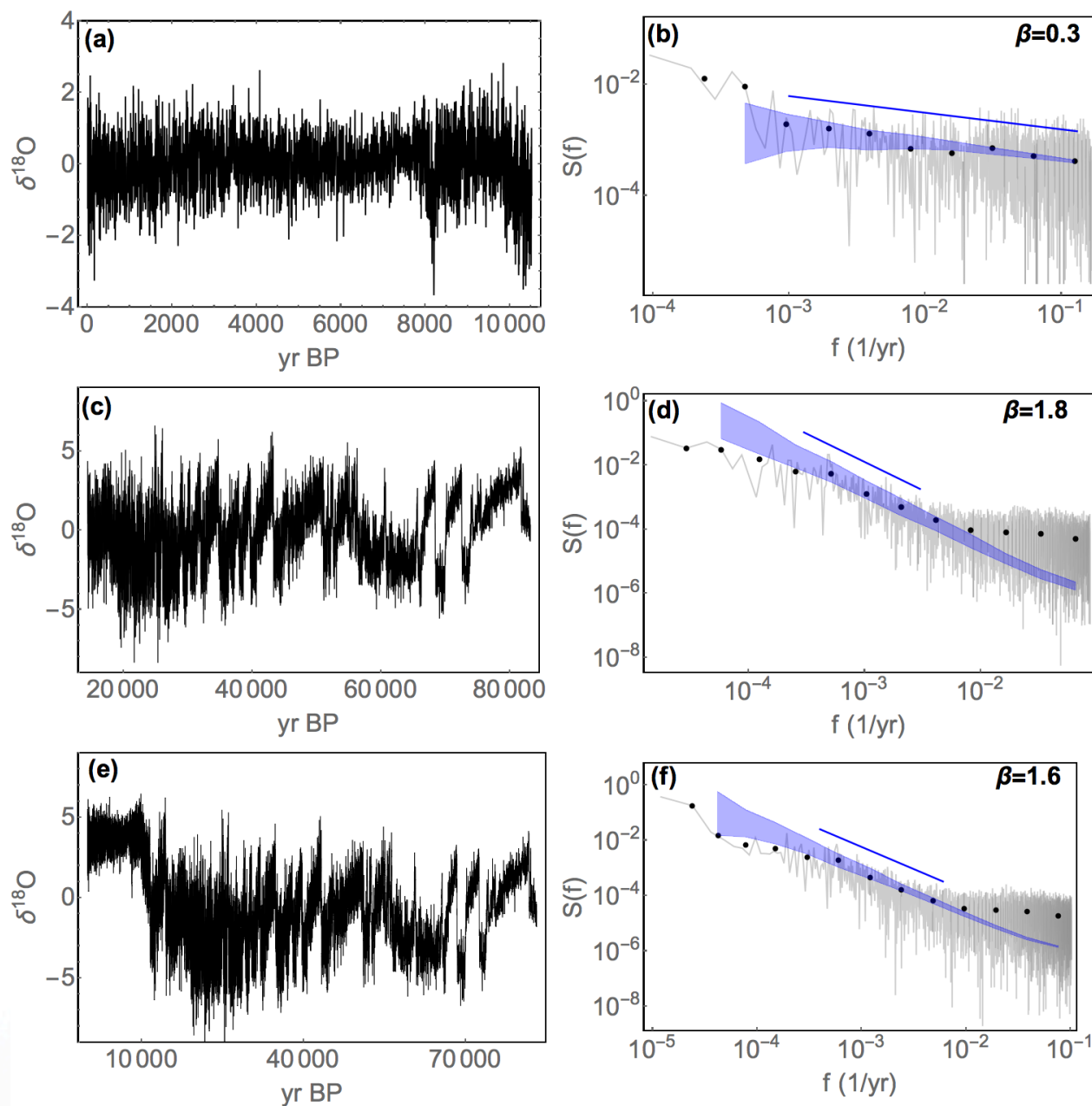
Examples



Greenland ice core data - Holocene



GRIP ice core data



Conclusion

- A mono-scaling LRM process cannot be rejected as a model for the temperature variability for the Holocene.
- Trends and individual events can explain changes in the spectral exponent, using this information gives a more precise model than multiple scaling regimes.
- There seems to be a significant scale-break associated with the glacial climate. However, the use of scaling analysis on records with time-dependent statistical properties is problematic.