Quantification of terrestrial regional climate variability from a large database of pollen-based reconstructions and implications for future projections

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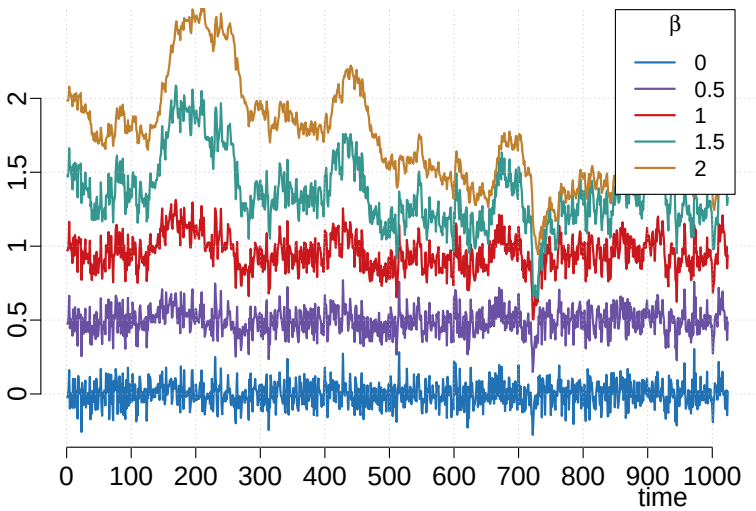
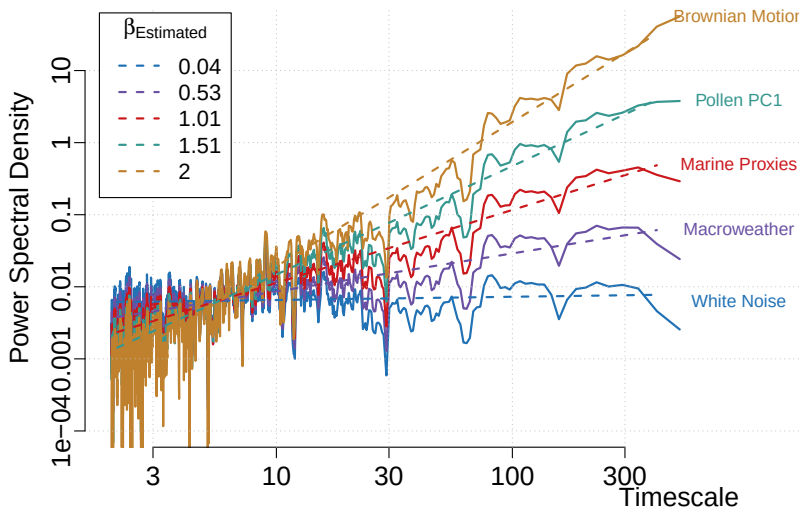
Premise



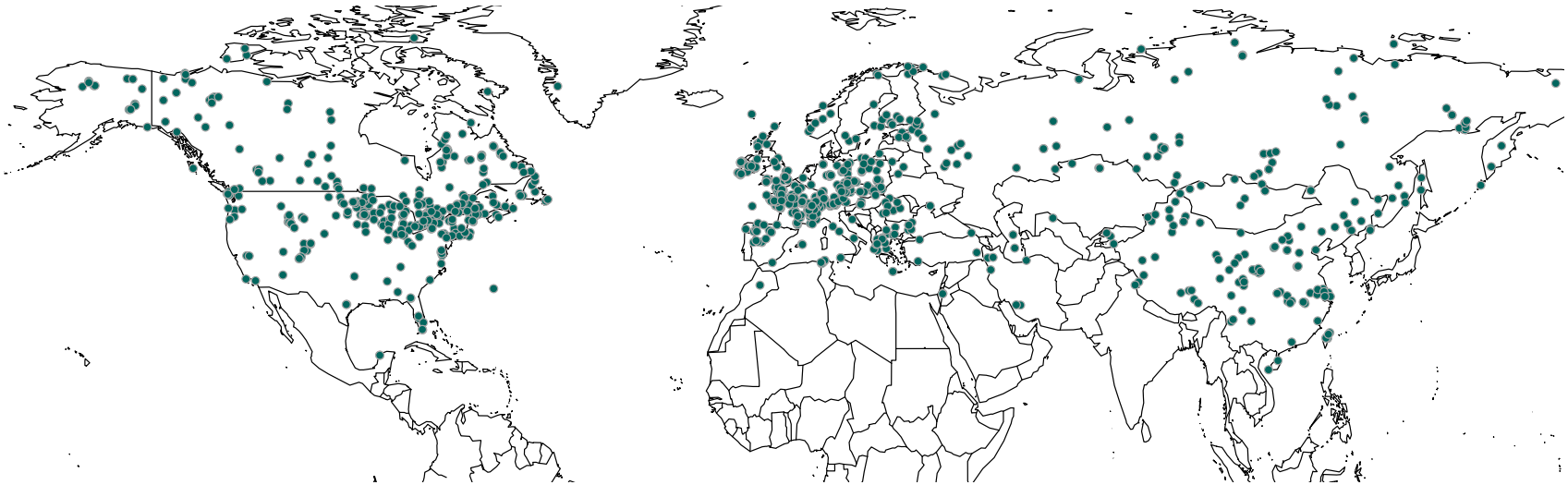


Climate variability can be characterized using a power-law relationship such that:

$$S(\Delta t) \propto \Delta t^{\beta}$$

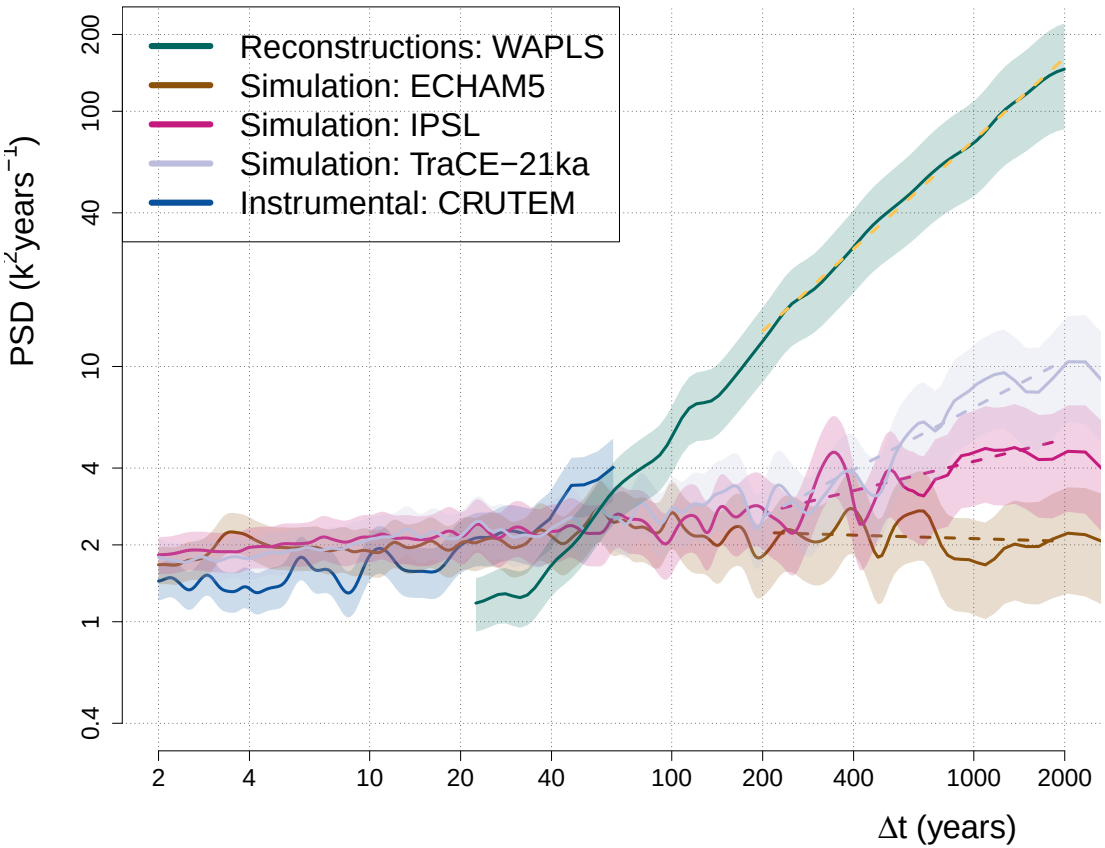
where S(t) is the power spectral density (PSD), Δt is a given timescale and β is the scaling exponent.
PSD was computed using Thomson's Multitaper technique.

Pollen Database



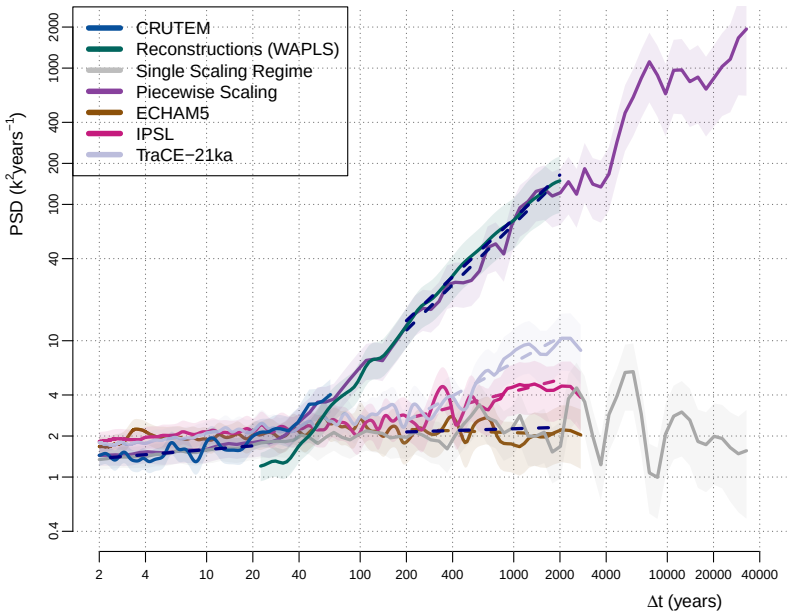
Large database of pollen assemblages, taxonomically harmonized, spanning the Holocene.
We compare to transient climate model runs: ECHAM5, IPSL and TraCE-21ka, in both vegetation and climate spaces.

Average Spectra of July Temperature

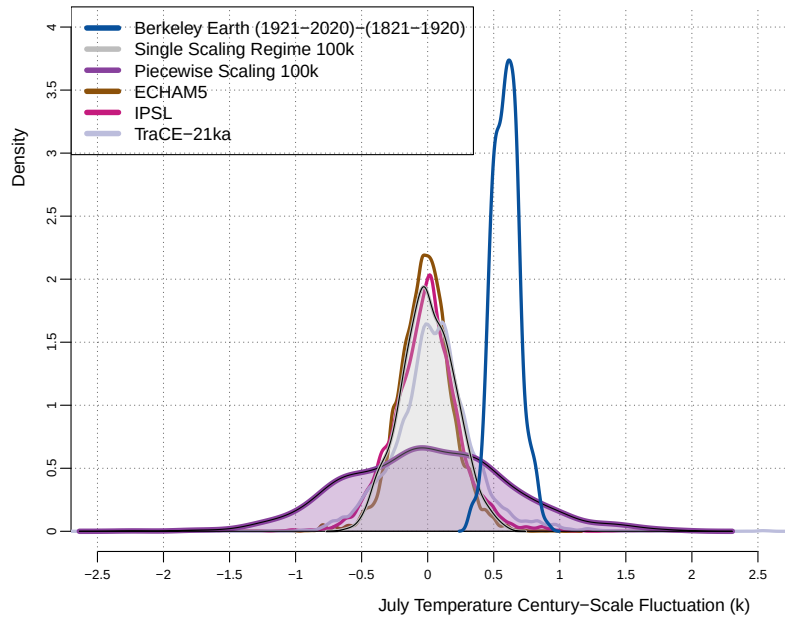


- Variance breaks off from the small β background around 20-100 years.
- Reconstructions show steep increase of variability $\beta \approx 1.2$ up to the 2000-year timescale.
- TraCE-21ka and IPSL show increase variability from 200-year timescale ($\beta \approx 0.7$, and $\beta \approx 0.3$).

Implications of a Piecewise Spectra of Climate Variability



The picture of climate variability supported by the data (Reconstructions + Instrumental) of July temperature suggests a piecewise scaling spectrum from $\beta \approx 0.1$ below 30 years, $\beta \approx 1.0$ above. We generated surrogate data using this model and compared with a single regime model with $\beta = 0.1$ consistent with model simulations.



If we compare the Century-Scale fluctuations in July temperature (difference in average between consecutive centuries), we find much wider fluctuations for the piecewise scaling model ($\sigma = 0.6$) compared to the single scaling model and GCMs ($\sigma \approx 0.2$). Also shown is the Century-Scale increase in temperature between the last century and the previous (0.6 ± 0.1).

Key Findings

- Model simulations produce vegetation variability of realistic amplitude given their climate variability.
- Pollen-based reconstructions reveal high-levels of natural climate variability in the Holocene, coherent with a piecewise scaling from $\beta = 0.1$ to $\beta = 1.0$ from $\Delta t = 30$ *years*.
- Expected regional natural fluctuations under the piecewise scaling null model could further amplify or significanty offset a large amount of the expected anthropogenic warming.
- Variance mismatch between reconstructions and simulations is 8 times greater at lower latitudes (30^o)compared to the higher latitudes 70^o.