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Frequency Dependence of Tree-Ring Climate Reconstructions

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Motivation

Can tree-ring reconstructions of past climate variability be complemented by the use of forest models?

Method

Apply standard tree-ring reconstruction methods to tree-ring data simulated with a forest model that is forced with a sinusoidal temperature variation.

Forest Simulations

- Forest model FORLAND [1]
- Site Sils Maria: E[Tann.] = 1.9°C, E[Precip. ann.] = 1048mm
- Single species forest, 1.3ha, e.g. *Larix decidua* or *Pinus cembra*
- Simulation from year 800 to 5000, starting from bare ground
- Control experiment: constant climate (baseline 1976-2003)
- Perturbation experiments: sinusoidal variation of E[Tann.] after year 1990. Amplitudes: 0.5K, 1K, 2K; frequencies: 1/500a, 1/250a, 1/100a
- Output: annual tree diameter increments (TDI)

Climate Reconstruction

- Target variable: annual mean temperature (Tann.)
- Input: annual TDI for simulated trees born after year 2500
- Arstan tree ring standardization software [2]
- Regional Curve Standardization (RCS) method [3]

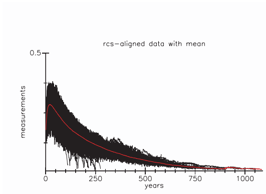

Fig.1: Aligned tree-ring time-series and resulting RCS curve. *Larix decidua*, 1/100a, amplitude 1K.

Results

For amplitudes above 1K, the obtained tree-ring chronologies reproduce well the frequencies of the temperature perturbation (Fig. 2, below).

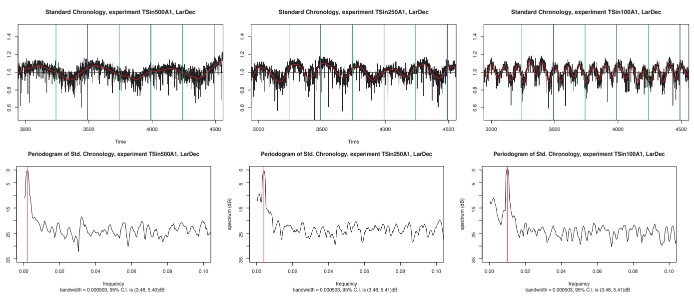

Fig.2: Tree-ring chronology (top) and smoothed periodograms (bottom) for *Larix decidua* at Sils Maria, for temperature perturbation of frequency 1/500y (left), 1/250y (middle), and 1/100y (right), and amplitude 1K. Bottom: vertical red line at frequencies 1/500a, 1/250a, and 1/100a resp.

However, for a climate forcing of amplitude 0.5K, the amplitude of the reconstructed signal is of the same order of magnitude as the fluctuations of the control reconstruction (Fig. 3, right).
The reconstructed amplitude depends on the species: *Larix decidua* gives the better signal, while another dominant species, *Pinus cembra,* yields chronologies of weaker signal, thus poorly representing the forcing.

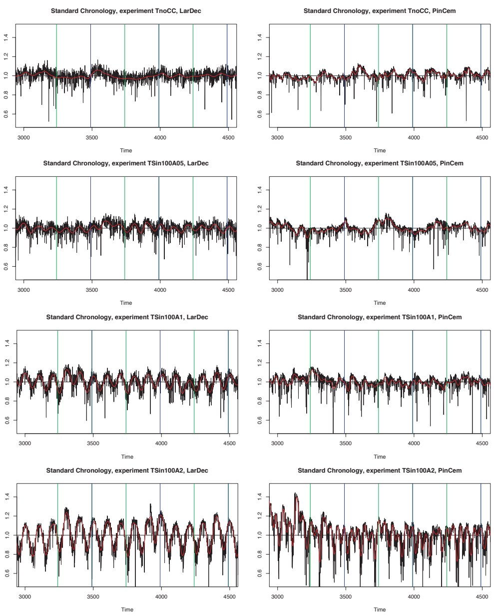

Fig. 3: Tree-ring chronology for *Larix decidua* (left) and *Pinus cembra* (right) for the control (top), and for perturbations of 0.5K, 1K, and 2K at Sils Maria.

Conclusions

We *can* reconstruct the annual mean temperature variations that force a forest model from the simulated tree-ring time series, especially for amplitudes above 0.5K.

Signal to noise ratio of tree-ring chronologies depends on species, with *Larix decidua* giving the better results.

Possible Applications

Climate reconstructions: Using forest models with our approach may (i) lead to more robust reconstructions, (ii) help determine the adequacy of sites and species, and (iii) offer new insights in the statistical properties of tree-ring samples.

Forest modeling: Using forest models in this way may provide new approaches to model validation.

References

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[4] Cook, E.R.et al., 1995: The 'segment length curse' in long tree- ring chronology development for palaeoclimatic studies, *The Holocene*, **5**, 229-237.
[5] von Storch, H., 2004: Reconstructing past climate from noisy data, *Science*, **306**, 679-682.

Acknowledgments

We are indebted to David Frank for his valuable advice and his help with Arstan. This research has been funded by ETH Zurich and NCCR.