On the Climatic Frequency Response of Forests

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The response to low-frequency climate variations is essential to the understanding of the behavior of forest (C) carbon pools and other forest properties under transient climate change.

To address this issue we studied the response of the FORLAND forest patch model [1, 2] to periodic variations in driving climate variables. FORLAND is a spatially explicit successor of the forest gap model FORCLIM [3, 4], built according to principles of structured modeling, which incorporates many submodels such as a submodel for decomposition and soil C [5, 6], and which supports a physically consistent simulation of fully transient changes in climate.

Simulations were carried out for 12 representative Swiss sites [7] over 10'000 years. We considered sinusoidal, annually uniform fluctuations in the expected values of monthly mean temperature and/or precipitation that were superposed on the average present-day climate after the model had reached steady state (simulation year 1'200). We evaluated for each site and climate forcing the average response from n = 200 simulations representing possible alternative monthly weather conditions associated with the respective climate. The system was forced in this manner for temperature only, precipitation only, and a combination of both at various frequencies and amplitudes. For comparison, a control experiment was carried out without climate oscillation over the entire integration period.

First results for the central alpine site of Davos (1590 m a.s.l.) imply that subalpine forests behave as a "low-pass filter" with regard to temperature oscillations: At low frequencies the estimated expected value of total above-ground biomass was found to follow a 1°C temperature signal (Fig. 1a) with little or no phase lag (analyses not shown), whereas high frequency temperature oscillations showed a much smaller effect (Fig. 1b). All perturbed simulations showed a decrease in long-term mean biomass as compared to the control simulation, with a tendency for greater mean biomass losses (up to 10%) at combined high frequency and amplitude (Fig. 2a). The variability of the simulated mean biomass was larger than in the control run in all perturbed simulations, and it depended systematically on the temperature signal; a "resonance frequency" in the order of 10^{-3} to $5 \cdot 10^{-2}$ y^{-1} was detected for signal amplitudes above 1°C (Fig. 2b).

Our preliminary results are in line with theoretical expectations. However, to our knowledge, this is the first study to assess the frequency response of selected forest characteristics in such a systematic and quantitative manner. Our simulations suggest that under increased variability in temperature mortality effects may outweigh temporarily improved growth conditions, and that biomass response (and thus also C sequestration potential) shows maximum sensitivity to climate perturbations at periodicities of 500-1000 y.

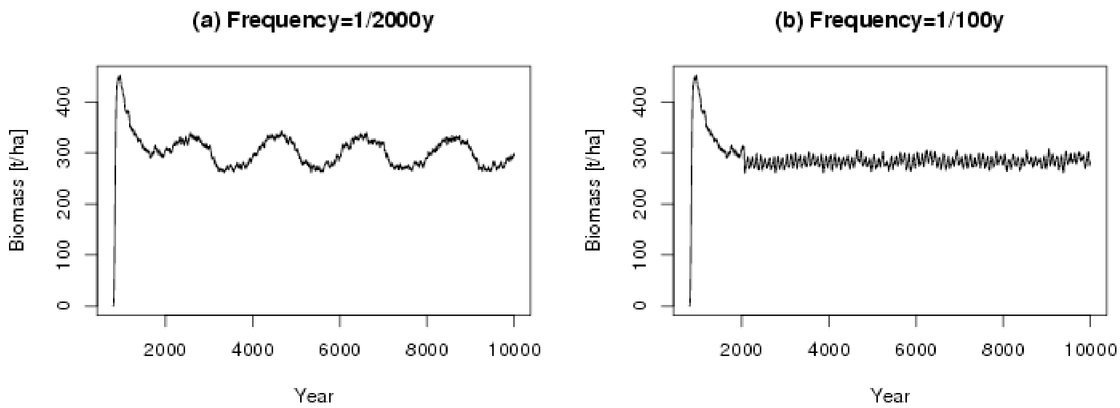

Fig.1: Total simulated above-ground biomass for Site Davos (1590 m a.s.l.) under a sinusoidal temperature signal of amplitude 1°C and frequencies (a) 1/2000y, and (b) 1/100y.

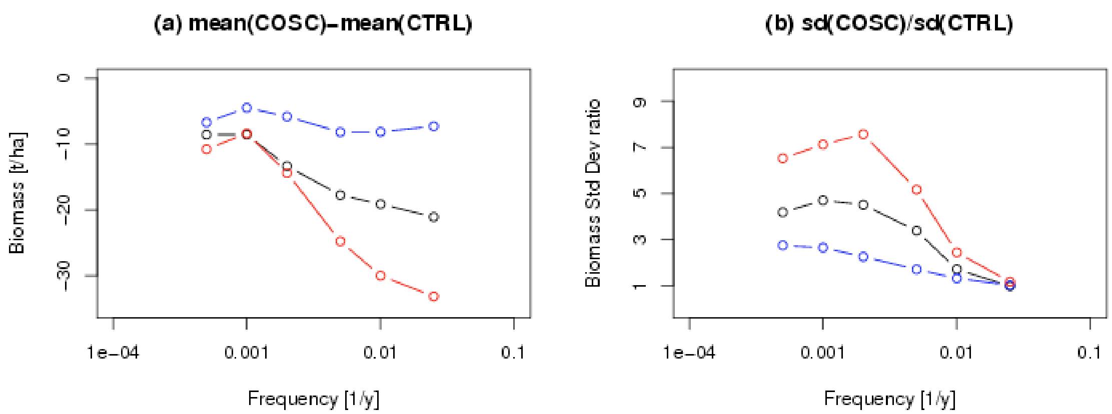

Fig.2: (a) Difference in mean biomass and (b) ratio of biomass standard deviation (sd), between Climate Oscillation (COSC) and Control (CTRL) simulations at site Davos (1590 m a.s.l.) as a function of the frequency of a sinusoidal temperature signal. Colors blue, black, and red denote signal amplitudes of 0.5, 1, and 2°C, respectively.

References

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