Impacts of the summer 2003 heat wave on forests as assessed by simulation models

Andreas Fischlin[*], Dimitrios Gyalistras[*], Sophie Fukutome[*], and Claude Theato[*]

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Abstract

The exceptional summer heat wave of 2003 had surprisingly a relative small impact on simulated forests located in Central Europe. We used a state-of-the-art forest patch model and simulated forest responses for the instrumental period (1864-2005), which included several drought spells. The simulations showed comparatively stronger impacts on forests for 1921 than for 2003, which comes only 3rd most impacted. A similar signal was also found in tree rings as well as by our model simulated and reconstructed tree rings, indicating that our findings are not mere model artefacts.

Contents

[*]Systems Ecology, Department of Environmental Sciences, ETH Zurich (Swiss Federal Institute of Technology Zurich), Universitätsstr. 16, 8092 Zurich, Switzerland. http://www.sysecol.ethz.ch/

1 Introduction

Summer heat wave in much of Europe was exceptional (Schär *et al.*, 2004; Schar & Jendritzky, 2004; Beniston & Diaz, 2004; Rebetez, 2004), probably hottest since 1500 (Luterbacher *et al.*, 2004), yet might be similar to what can be expected in the future towards the end of this century (Schär *et al.*, 2004; Beniston, 2004; Meehl & Tebaldi, 2004) if human emissions continue to grow (Stott *et al.*, 2004; Nakicenovic *et al.*, 2000; Carter *et al.*, 2000). It is generally assumed that ecosystems such as forests are strongly impacted by such heat spells, not only because of the temperature effect, but also because of the exceptional precipitation pattern together with the positive feedbacks leading to drought (Beniston & Diaz, 2004). Such drought may not only cause tree mortality, but alse reduces growth (Leuzinger *et al.*, 2005) and can alter the net ecosystem productivity (NEP) as has been reported by Ciais *et al.* (2005) and Reichstein *et al.* (2005). This may even scale up to significant biotic feedbacks potentially affecting the climate system (Nepstad *et al.*, 2004). This causes trees not only to produce less wood, leading to narrower tree rings, but also more susceptible to factors potentially causing mortality due to an increased susceptibility to disease and insects (Poumadere *et al.*, 2005). Finally, drought may also lead to more or more intense forest fires as this was the case in Europe in 2003 (Barbosa *et al.*, 2003; Trigo *et al.*, 2005), wich is not only costly (De Bono *et al.*, 2004), but again may have a potentially signifcant feedback effects onto the climate system or at least have long-lasting effect onto the landscape (Vazquez & Moreno, 2001; Salvador *et al.*, 2005).

However, some authors have reported conflicting evidence on those effects (Jolly *et al.*, 2005). While some findings indicated full recovery (Gobron *et al.*, 2005), others reported longer lasting and possibly delayed impacts (Fischer, 2005). Drought effects are also considered to be quite complex also, because forests are not only composed of many tree species, each with its species-specific drought tolerance, but it has also been found that there is also a genetically determined large within-species variability to drought tolerance (Atzmon *et al.*, 2004) as well as a remarkable inter-individual variability (Cavender-Bares & Bazzaz, 2000).

We tried to simulate all these effects by forcing a state-of-the-art forest patch model (Fischlin & Gyalistras, 2005, in prep.; Gyalistras & Fischlin, 2005, in prep.) with a particularly long temperature and precipitation series (Begert *et al.*, 2005) from central European sites at varying altitudes to test, whether the expected impacts of such heat waves do actually show up as drought stress as perceived by trees, and whether they would lead to reduced growth also measurable in tree ring widths and possibly also in increased mortality.

2 Material and Methods

Homogenized temperature and precipitation records for twelve Swiss sites covering the period from 1864 to 2000 (Begert *et al.*, 2005) were extended by recent records up to 2005 (Bantle, 1989) to force the forest patch model ForLand (Fischlin & Gyalistras, 2005, in prep.; Gyalistras & Fischlin, 2005, in prep.).

The tree ring data used in this study consist of ring-width measurements for 20 trees in Eponde (Switzerland, 7.18°E, 46.13°N, altitude 880m) over the period 1826-1979 (Felix Kienast, WSL Birmensdorf, WSL Dendro Database, Switzerland. www.wsl.ch/dendro).

Annual tree-ring chronologies were then computed with the Arstan software on the basis of these measurements, using the Regional Curve Standardization (RCS) method (e.g., Esper *et al.*, 2003).

3 Results

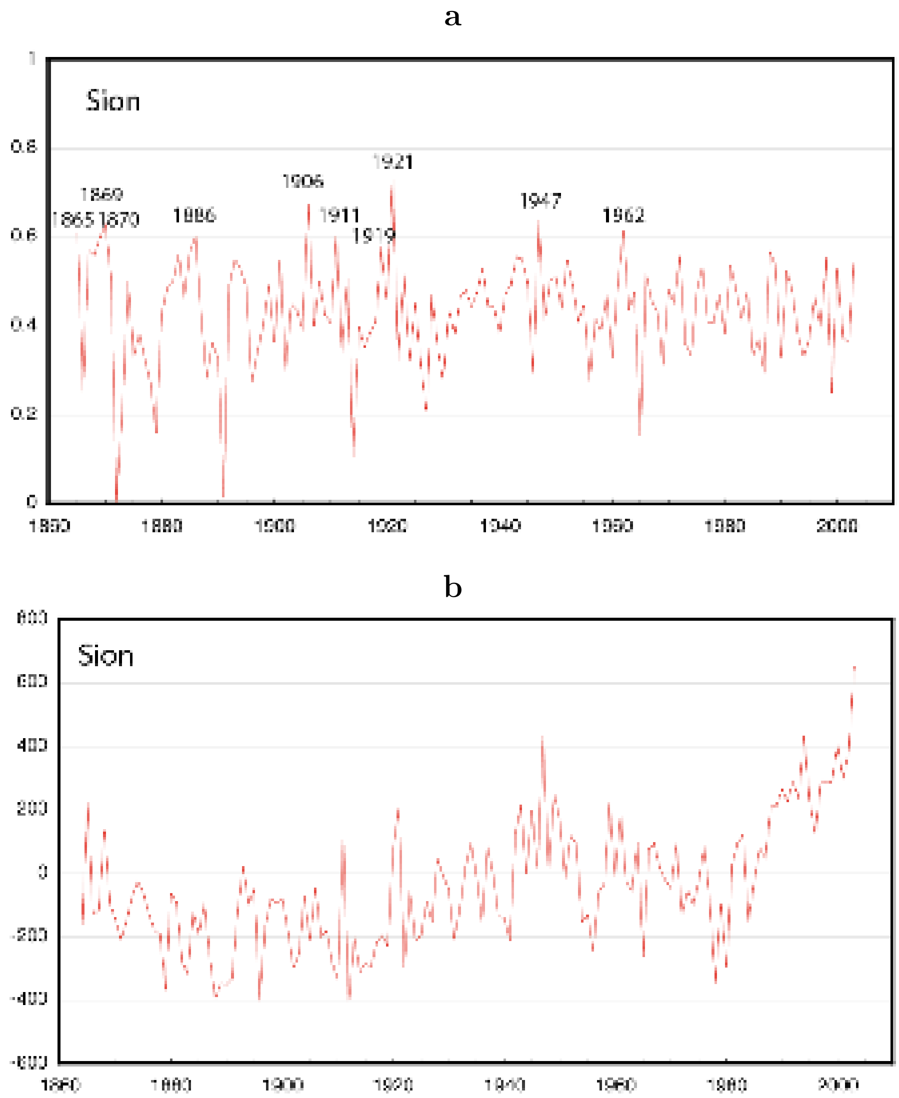

Figure 1: Drought stress (**a**) and degree days (**b**) simulated by state-of-the-art forest patch model ForLand (Fischlin & Gyalistras, 2005, in prep.; Gyalistras & Fischlin, 2005, in prep.) forced by the historical weather from 1864 till 2003 at a site in Central Europe. Note, that the drought stress was smaller in 2003 than in e.g. in 1921, but that 2003 is characterized by a unique temperature sum.

4 Discussion

Summer temperature signal not visible in tree rings of Nothofagus menziesii (Hook, f.) Oerst in New Zealand Cullen, 2001, Cu14

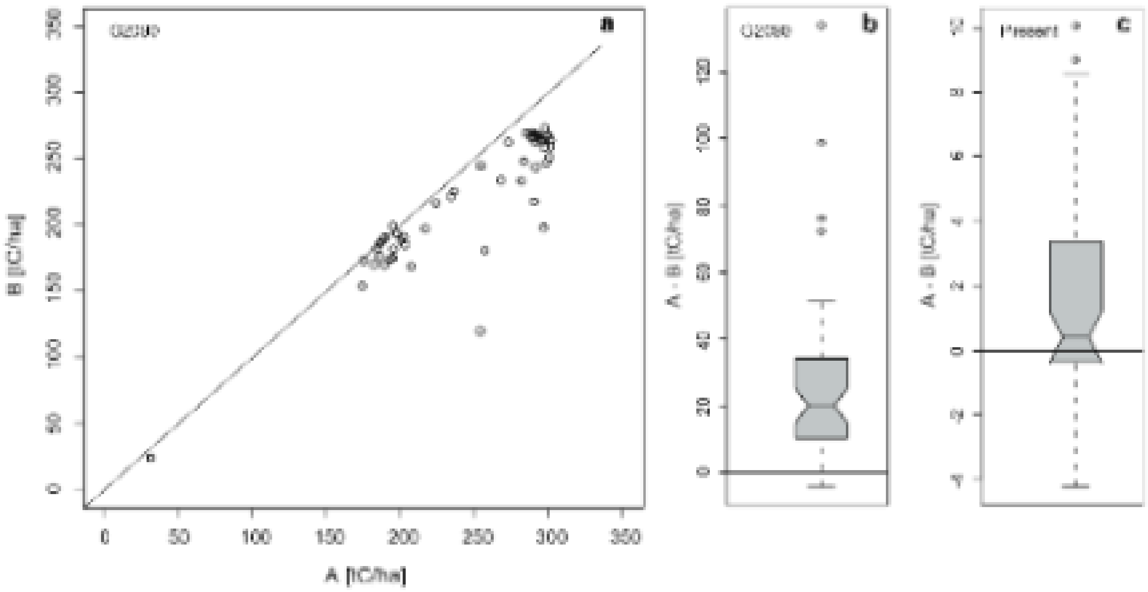

Figure 2: Steady state carbon stocks in the Dischma valley (1x1 km grid point simulations) under assumption (i) A (abscissa) with a species pool consisting of all central European species vs. assumption (ii) B (ordinate) with only those species which are currently present in the valley. The climate change scenario were downscaled from a transient HDCM2 GCM run 2090 (no sulfate aerosols). The two assumptions (i) and (ii) represent two extremes and any future development will in reality be somewhere between. Boxplots in the panels b (future climate) and c (present climate) show that the differences between A and B values are significantly affected by the climate change and that climate change may bring the risk of reduced carbon stocks.

5 Conclusions

From this study we concluded:

Model validation

Forest sensitivity Forests appear to be sensitive to any warming equal or greater than 1°C.

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A Appendix - Derivation of forcing signal

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