CONTRASTING RESPONSE IN CARBON UPTAKE OF TWO BEECH FORESTS TO EUROPEAN DROUGHT 2003

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ABSTRACT
Here we use the severe heat and drought event in Europe from summer 2003 as a natural experiment to study the impact of a climatic extreme event on ecosystem physiology and its feedback to the atmosphere. The combination of continuous eddy covariance and tree growth measurements at two nearby located deciduous forests showed a large reduction in carbon uptake during the drought (-30%) and a strong carry-over effect into the next year. Both forests, however, responded differently, although climatic forcing was almost identical. Species composition and site condition of the ecosystems seemed to play a major role in the ecosystems response to the drought.

INTRODUCTION
Extreme climate events are expected to increase in intensity and frequency [*Meehl and Tebaldi*, 2004]. It remains unclear how such events will impact terrestrial ecosystems in their physiological functions and their capability to remove carbon from the atmosphere [*Easterling et al.*, 2000]. Based on in-situ measurements of CO_2 fluxes, meteorological drivers and tree stem growth as well as remote sensing at two near-by located deciduous beech forests in Central Germany, we want to investigate (a) how forests that are typically not exposed to severe drought responded to the drought in Europe 2003, (b) if drought leads to carry-over effects in the year after the drought, and (c) if two nearby-located beech forests respond similarly to the drought.

METHODS
Measurements using the eddy covariance technique were performed since September 1999 and since April 2002, respectively at two deciduous forests: an uneven-aged and unmanaged mixed beech forest at the Hainich site and an even-aged managed pure beech forest at the Leinefelde site, both located in Thuringia/Germany [*Anthoni et al.*, 2004]. Since the fetch at the Leinefelde site was limited to the wind sectors 200º to 360º we only used data with wind from these directions. To be able to compare both sites we restricted data analysis at the Hainich site to the same wind directions. As a consequence, annual carbon uptake differed from previously published data [*Anthoni et al.*, 2004].

RESULTS AND DISCUSSION
The Hainich and Leinefelde sites showed very similar environmental forcing in terms of temperature, radiation and moisture in the years 2002 to 2004. During the year of the drought, 2003, precipitation was much lower (-32%), radiation and air temperature higher than previous years resulting in very low soil moisture (<15 vol%).

In 2002, net ecosystem carbon uptake was very similar at both sites (Fig. 1a and 1b) In 2003, carbon uptake was very large in early summer as a consequence of high radiation and sufficient soil water availability and then strongly declined during the drought when soil water became limited (Fig. 1a). The decline, however, was stronger at the Hainich site resulting in a reduction of annual uptake by 10%

compared to 2002 (Fig. 1b). At the Leinefelde site the response to drought was less pronounced and combined with an elongated growing season resulted in an increase by 10% in annual carbon uptake. These differences are likely to be related to the unequal response of different tree species. The mixed beech forest at the Hainich site consists of about 25% ash trees which show a strong decline in stem growth during the drought (Fig. 1c). Beech trees seem to be less affected by the drought than ash trees which might explain that the reduction in carbon uptake was less pronounced in the pure beech stand at the Leinefelde site. In 2004, carbon uptake was strongly reduced during the entire year compared to 2002 with much smaller carbon uptake rates at Leinefelde (annual sum = -335 g C m^{-2} y^{-1}) than at Hainich (-447 g C m^{-2} y^{-1}) (Fig. 1b). In the year after drought, ash tree growth showed similar behavior than in the year before drought, while beech stem growth was delayed and strongly reduced (by 45%).

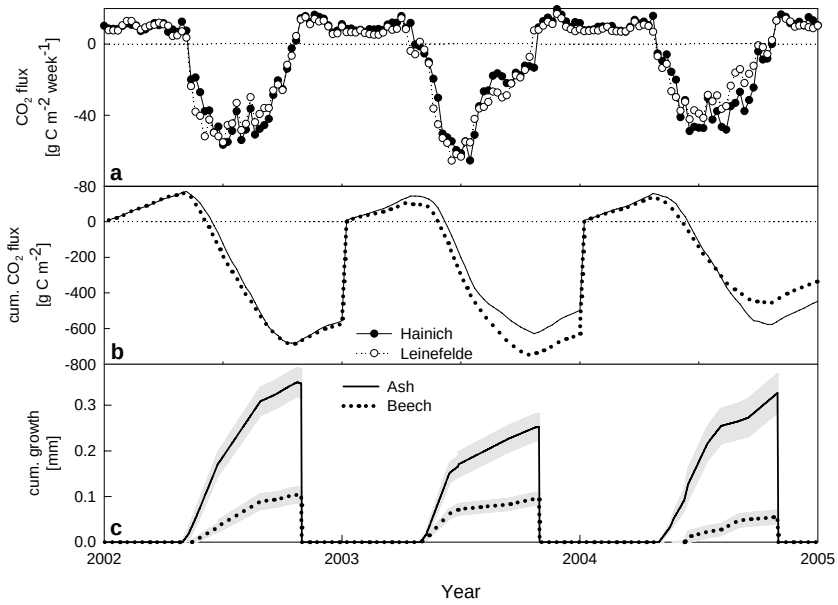

Fig. 1 (a) Net CO_2 flux, (b) cumulative net CO_2 flux, and (c) tree stem growth (with standard error) from 2002 to 2004

Remote sensing data and albedo measurements indicated that leaf area index was reduced in 2004. Also, a high insect infestation was reported for beech in 2004. This suggests that the drought not only affected carbon fluxes directly during drought, but also resulted in an indirect carry-over effect into the next year. Possible mechanisms for this carry-over effect are a weakening of beech trees leading to the observed insect infestation or a lack of carbohydrate productions during the drought limiting leaf and stem growth in the following spring. Species composition and site conditions are reflected at the ecosystem scale and seem to play a major role in the ecosystems response to the drought.

ACKNOWLEDGEMENT

This project was financed by the EU as part of CARBOEUROFLUX under Contract N° EVK2-CT-1999-00032 and by the Max Planck Institute for Biogeochemistry, Jena. AK is currently funded by the EU with a Marie Curie fellowship under Contract N° MOIF-CT-2004-002543.

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