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Isoprene emissions from boreal peatland microcosms; effects of elevated ozone concentration in an open field experiment

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Abstract

Boreal *Sphagnum*-dominated peatlands are known to emit isoprene in amounts comparable to emissions from boreal *Picea abies*-dominated forests. Due to its high reactivity, isoprene can affect the local climate. Increases in isoprene emission under elevated ozone concentration have been detected in a few plant species, but the effects at the ecosystem level are largely unknown. We investigated the isoprene emission from microcosms representing a boreal *Sphagnum* fen under long-term realistically elevated ozone concentration in open-field conditions. The vegetation of the microcosms was dominated by *Sphagnum papillosum* Lindb. moss with dense *Eriophorum vaginatum* L. growth. The mean standardised emissions of isoprene under ambient and elevated ozone concentrations in the growing season of 2005 were on average $1.016\,\mathrm{mg\,m^{-2}\,h^{-1}}$, and $1.308\,\mathrm{mg\,m^{-2}\,h^{-1}}$, respectively. In August 2004, they were $0.434\,\mathrm{mg\,m^{-2}\,h^{-1}}$ under ambient, and $0.509\,\mathrm{mg\,m^{-2}\,h^{-1}}$ under elevated ozone concentration. Elevated ozone concentration had no statistically significant overall effects on the isoprene emission, although isoprene emissions tended to vary more and were slightly higher under ozone exposure during the warmest weather conditions. The results are in accordance with earlier observations of substantial isoprene emissions from boreal peatlands. As isoprene emissions from peatlands can be increased by ozone during warm periods, further research addressing this issue is needed.

Keywords: Peatland; Isoprene; *Sphagnum*; *Eriophorum*; Tropospheric ozone

1. Introduction

Isoprene (2-methyl-1,3-butadiene) is the dominant volatile organic compound (VOC) emitted by vegetation into the atmosphere. Isoprene emissions from vegetation exceed anthropogenic sources (Lamb et al., 1987; Singh and Zimmermann, 1992) and they can reach significant quantities, even though only approximately 30% of plant species are reported as isoprene emitters (Kesselmeier et al., 2002). The modelled estimate of the global isoprene emission is $440-660\,\mathrm{Tg\,C\,a^{-1}}$ (Guenther et al., 2006). This amount of carbon re-emitted to the atmosphere can affect the carbon sequestration in

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the biosphere, and therefore it has to be accounted for in the global and regional models for carbon fluxes (Guenther, 2002; Kesselmeier et al., 2002). However, reliable estimations of this carbon loss are unavailable (Kesselmeier et al., 2002).

The biogenic emission of isoprene has been of interest in the past decades because of its significant but complex role in the atmospheric chemistry (Fuentes et al., 2000; Atkinson and Arey, 2003). Isoprene takes part in the pollution-dependent production–destruction processes of ozone, and it affects the oxidation capacity of the atmosphere extending the lifetime of methane (Bell et al., 2003), an important determinant of the radiative balance of the atmosphere. In addition, the oxidation of isoprene can lead to substantial atmospheric formation of secondary organic aerosols (Claeys et al., 2004a,b).

At the level of plants and ecosystems the emission of isoprene can form a substantial fraction of the assimilated carbon. Therefore, the reason why plants invest in these emissions is puzzling and still unclear. Many environmental factors, such as temperature and light, affect the emission (Kesselmeier and Staudt, 1999). It has been assumed that isoprene protects the photosynthetic apparatus against abiotic stresses such as high temperature, atmospheric pollution (Peñuelas and Llusià, 2003) and limited CO_2 supply (Magel et al., 2006). Isoprene can react with membrane bilayers increasing the stability of the layers at high temperatures (Sharkey and Singsaas, 1995) or under oxidative stress caused for example by ozone (Loreto and Velikova, 2001). The quenching ability of isoprene against ozone and other reactive oxygen compounds has also been demonstrated (Loreto et al., 2001; Velikova et al., 2005a). Another hypothesis suggests that isoprene and other VOCs are inevitably released by plants because of the high volatility of the compounds, and this release serves to dissipate extra energy or carbon under various stresses (Peñuelas and Llusià, 2004).

Tropospheric ozone is a secondary air pollutant, photochemical production of which involves NO_x compounds, carbon monoxide, oxygen and VOCs, such as isoprene (Finlayson-Pitts and Pitts Jr., 1997). Since the preindustrial times the average background concentrations of ozone in the northern hemisphere have approximately doubled (Vingarzan, 2004) mainly due to combustion processes of fossil fuels. Therefore the increase in ozone levels can be considered as a part of the global climate change. Ozone is a regional pollutant as even remote areas can be exposed to elevated levels due to long-distance transport of precursors and biogenic emissions of NO_x and VOCs (Biesenthal et al., 1998; Fowler et al., 1998; Collins et al., 2000). Phytotoxic ozone can cause severe damage to cultivated and natural plant species leading to foliar injury, yield reduction (Ashmore, 2002) and altered secondary metabolism (Kangasjärvi et al., 1994; Long and Naidu, 2002).

Effects of ozone on isoprene emission have been inconsistent. A significant increase in isoprene emission after exposure to a high ozone concentration (300 ppb) has been detected in common reed (*Phragmites australis)* (Velikova et al., 2005a), whereas in downy oak (*Quercus pubescens*) the emission decreased immediately after the exposure but increased after several days (Velikova et al., 2005b). Fares et al. (2006) observed that ozone exposure of 150 ppb reduced isoprene emission from white poplar (*Populus alba*) leaves developed before the exposure but increased the emission from leaves that developed under the exposure. Effects of ozone on isoprene emission from natural plant communities have not been demonstrated so far.

Peatlands are a typical ecosystem type in the boreal and arctic landscape. They are also known for their ability to store carbon in the waterlogged subsurface (Clymo et al., 1998). Therefore, fluxes of methane and carbon dioxide in peatlands of the boreal zone have been intensively studied, while isoprene research has concentrated on forests and trees (e.g. Hakola et al., 1998, 2003). However, it is also common for moss species to emit isoprene (Hanson et al., 1999). Indeed, *Sphagnum* peatlands have been shown to be a significant source of isoprene (Janson and De Serves, 1998; Janson et al., 1999), emissions reaching over $2.5\,mg\,m^{-2}\,h^{-1}$ (Janson and De Serves, 1998). Janson et al. (1999) concluded that isoprene emissions from wetlands are in quantities comparable to those from *Picea abies*-dominated forest sites in the boreal zone. Therefore isoprene emissions from peatlands might significantly affect the local climate by the mechanisms mentioned.

A recent growth chamber experiment focusing on non-isoprene VOCs showed that elevated ozone concentration increases the emissions of other VOCs from microcosms representing a boreal *Sphagnum* peatland (Rinnan et al., 2005). Elevated ozone concentrations are suggested to affect typical peatland vegetation, mosses, since their one