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Short communication

Woody stem methane emission in mature wetland alder trees

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ABSTRACT

Methane (CH_4) is an important greenhouse gas that is predominantly emitted to the atmosphere from anoxic wetland ecosystems. Understanding the sources and emissions of CH_4 is crucially important for climate change predictions; however, there are significant discrepancies between CH_4 source estimates derived via so-called bottom-up and top-down methods. Here we report CH_4 emission from the stems of mature wetland alder (*Alnus glutinosa*) trees in the UK, a common tree of northern hemisphere floodplains and wetlands. The alder stems most likely behave as conduits for soil-produced CH_4 either in the gaseous or aqueous phase, and may, therefore, help to reconcile methodological differences in the way the wetland CH_4 source is estimated.

Alder tree stems emitted average peak CH_4 fluxes of 101 μg CH_4 m^{-2} h^{-1} (on a stem area basis) in early October, a rate that is similar to that obtained from mature Japanese ash (*Fraxinus mandshurica* var. *japonica*) in Japan and amounting to approximately 20% of the measured CH_4 flux from the soil surface. The finding suggests that trees, which occupy 60% of Earth's wetlands and are normally excluded from the measurement programmes that form the basis for bottom-up estimates of the global wetland source, could be important contributors to overall terrestrial ecosystem CH_4 flux.

1. Introduction

Wetlands form the largest source of methane (CH_4) to the atmosphere, a powerful greenhouse gas that is thought to have contributed approximately 50% of the enhanced greenhouse effect of CO_2 since 1850 (Hansen et al., 2000). Great importance is therefore placed on characterizing the various CH_4 sources and emission pathways to enable changes observed in atmospheric growth rate to be better understood. Methane has received considerable recent attention as satellite and airborne measurements have yielded an unexpected spatial distribution of sources with strong emission plumes identified over tropical forests, many of which are seasonally flooded (Frankenberg et al., 2005; Miller et al., 2007). In many such regions, there continues to be a discrepancy between bottom-up emissions-based estimates and top-down inverse or satellite-based estimates of the CH_4 source (Frankenberg et al., 2008).

The recent reporting of novel aerobic CH_4 production pathways in plants (Keppler et al., 2006) has been invoked as a potential explanation for discrepancies between low, bottom-up and high, top-down satellite-based or inverse method derived estimates of CH_4 sources. However, the large size estimates initially made for this hypothesized source (up to ~240 Tg CH_4 yr^{-1} (Keppler et al., 2006)) have since been revised down to between zero and 85 Tg CH_4 (e.g. Houweling et al., 2006; Dueck et al., 2007). Here we provide evidence for a more straightforward and almost completely overlooked pathway for CH_4 emissions from anaerobic soils and sediments that may account for at least part of the discrepancy in the way CH_4 sources and balances are estimated.

Emission of CH_4 produced in anaerobic soils to the atmosphere is the largest individual source of CH_4. Fluxes are thought to be controlled by three transport mechanisms: diffusion, ebullition and vascular transport in herbaceous plants, all of which are measurable using established small-scale enclosure methods. In peatlands, aerenchyma in sedges and certain other vascular plants allows CH_4 to bypass an oxic 'acrotelm' layer at the top of the peat column (Joabsson et al., 1999). Without this escape route, methanotrophic bacteria in the acrotelm would consume a large proportion of produced CH_4. Aerenchyma tissue provides a diffusion pathway for oxygen, enabling sedges and other herbaceous wetland plants to maintain active roots in anoxic environments (Armstrong and Boatman, 1967). Similarly, flood-tolerant trees growing in soil with a high water table or exposed to periodically flooded conditions develop important adaptations that collectively facilitate oxygen supply to roots, thus preventing hypoxia (Kozlowski, 1997).

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Such features are classically evident in trees such as mangrove and swamp cypress where morphological adaptations, principally aerial roots and pneumatophores, facilitate gaseous exchange, and from which CH_4 emission has been measured (Vann and Megonigal, 2003; Purvaja et al., 2004). However, many other tree species also grow under flooded conditions without overtly exhibiting such morphological adaptations. The trees prevent hypoxia via the formation of aerenchyma in root tissue and hypertrophied lenticels on tree stems and submerged roots (Kozlowski, 1997).

A relatively unexplored pathway of CH_4 flux from such wetland trees is the transfer of anaerobically-produced CH_4 from soils into roots via the aqueous phase, and emission to the atmosphere via transpiration. This mechanism is similar to that described for N_2O transport in *Fagus sylvatica*, (e.g. Pihlatie et al., 2005) and, like N_2O, there are no physical or chemical barriers to the entry of apolar dissolved CH_4 into roots during uptake of soil water. The CH_4-bearing water can be transported through xylem tissue, ultimately releasing CH_4 to the troposphere via leaf stomata or lenticels. This emission pathway may be an important mechanism for mediating CH_4 flux from wetland- or fine-textured soils where moisture levels allow for the existence of anaerobic microsites (Teh et al., 2005).

The only previous report of CH_4 flux from mature, non-pneumatophore-forming trees was made for Japanese ash (*Fraxinus mandshurica* var. *japonica* (Terazawa et al., 2007)). Other species have not been investigated in mature trees, despite the morphological features thought to be responsible for CH_4 emission being reported for a wide range of tree species (e.g. Kozlowski, 1997).

Here we report findings from a study to examine the potential for a new family of mature freshwater wetland trees to serve as a conduit for trace gas transport to the atmosphere. Common or Black Alder (*Alnus glutinosa*) are the most common tree species in riparian forests and are found throughout Europe, Russia and Siberia and are also commonly found in the Northeast USA and Eastern Canada. Taken together with the work of Terazawa et al. (2007), our study is designed to examine the potential for a wide variety of wetland trees to collectively serve as a significant source of CH_4 to the atmosphere.

2. Methods

We examined CH_4 emission from *A. glutinosa* trees at Flitwick Moor nature reserve in Bedfordshire, United Kingdom (52°00′ N, 00°28′ W). Three mature trees having diameters of 10–30 cm at a height of 30 cm above the forest floor were selected for the study. The site consists of a peat soil which is spring fed which allows the water table to remain consistently at or just above the soil surface. Three site visits were made from May to October 2006 to monitor changes in headspace CH_4 concentration with time in temporary gas-exchange chambers that enclosed the entire stem section 30 cm above the forest floor for 3 h. The chambers were constructed from four clear acrylic walls, each having dimensions of 500 × 350 × 6 mm (Fig. 1). The headspace was defined by enclosing the volume with transparent sheets of gas-impermeable FEP film (Adtech Ltd.) to form the top and bottom of the enclosure. Strips of closed cell foam (3-cm wide) were attached to the stem 35 cm apart, providing an effective seal with the tree on which the FEP film could be attached. Measurements were initiated at approximately midday, and headspace samples (3 × 20 ml) were drawn via a septum into 3 gas-tight syringes fitted with 3-way valves at $t = 0$, 60, 120, 180 min. The samples were transported to the lab within 48 h for analysis using a Cambridge AI gas chromatograph (GC) equipped with a flame ionisation detector (FID) with a measured $[CH_4]$ standard error of 23 ppbv. The minimum measurable flux using our approach was 2.4 μg CH_4 m^{-2} h^{-1}. Soil CH_4 fluxes were measured during the October sampling from 3 chambers positioned on the ground surface using established methods (Gauci et al., 2002). Fluxes were estimated using linear regression analysis of the change in headspace methane concentration with time. The phenological status of the sampled trees was also recorded at each site visit. During the May site visit, alder tree leaves had yet to emerge on sampled trees. In June leaves had fully emerged and in October the trees remained in full leaf.

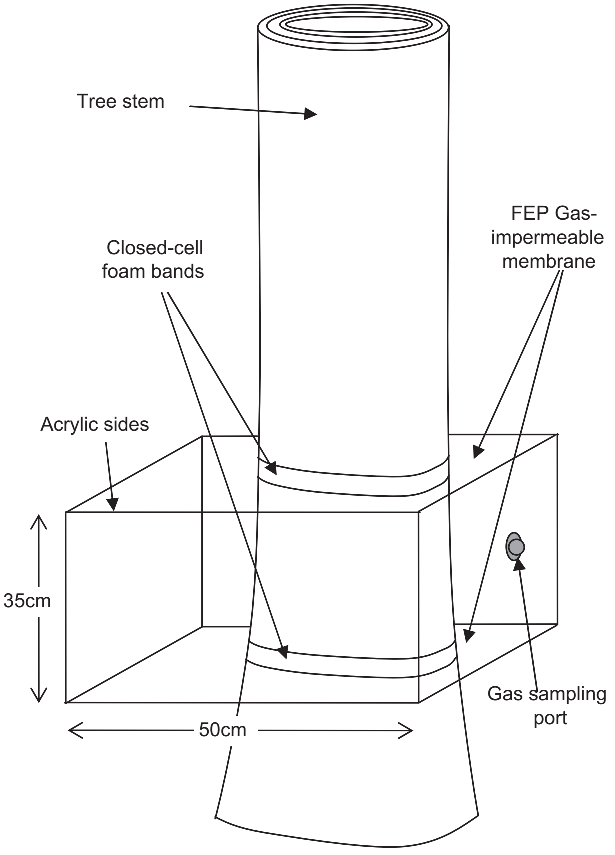

Fig. 1. Experimental methods for measuring methane fluxes from stems of *Alnus glutinosa*.

3. Results and discussion

Significant tree stem CH_4 emission was measured during each sampling visit (linear regression analysis, $P < 0.05$). Fluxes (expressed per unit area of stem) ranged from a mean of 4.1 μg CH_4 m^{-2} h^{-1} in May to 101 μg CH_4 m^{-2} h^{-1} in early October (Table 1), the peak month measured. Stem fluxes measured in October were about 20% of soil fluxes measured at the same time (536 μg CH_4 m^{-2} h^{-1}). They were also of the same order of magnitude as CH_4 fluxes measured from mature *F. mandshurica* sp. in Japan (Terazawa et al., 2007). In contrast to the Japanese study, CH_4 fluxes from Flitwick Moor showed a pronounced seasonal pattern, being an order of magnitude smaller in spring than summer and autumn.

Collectively, our data and those of Terazawa et al. (2007) suggest that many wetland trees that lack outwardly obvious morphological features commonly associated with flood adaptation and gas transport may emit CH_4 that has been produced in anaerobic soils. The data further suggest that estimates of CH_4 flux from forested wetlands, whether seasonally or permanently flooded, are likely to underestimate the emission of anaerobically-produced CH_4 if trees are excluded from measurement. For example, the development of