METHANE PRODUCTION OF SNOW-COVERED SOILS DUE TO OXYGEN DEPLETION INTERNATIONAL SNOW SCIENCE WORKSHOP 2018, INNSBRUCK, AUSTRIA

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ABSTRACT: Methane, one of the most important greenhouse gases is mainly produced by methanogenic bacteria during decomposition of organic material under anoxic conditions. It is known for many years, that conditions, favouring methane production can often be found in snow-covered soils during late winter or early spring, especially in areas where the snow-cover is disturbed e.g. due to skiing slope preparations. However, measurement of gas concentrations in such systems was complicated and usually not possible without disturbance precluding high sampling frequencies, as several days were needed to re-establish stable conditions. Thus the temporal dynamics of oxygen depletion in snow covered soils is still understudied and little is known on methane production in such systems. Only recently new sensors were developed which now provide for the first time the opportunity to measure oxygen and methane concentrations directly at the boundary layer between snow and soil without disturbing the system and thus enabling shorter sampling intervals. In the here presented pilot study, such new sensors will be combined to a measuring system to study oxygen, methane and CO_2 concentrations directly under the snow and the setup will be tested under laboratory and field conditions. The obtained results on oxygen-depletion and methane production will prove the applicability of the sensors for this purpose and provide first insights into these complex situations.

KEYWORDS: Methane, skiing slope, oxygen depletion

1. BACKGROUND AND PROJECT OUTLINE

Beside CO_2, methane (CH_4) is one of the most important greenhouse gases. Although the concentration of methane in the atmosphere is much lower compared to CO_2 and the relatively short residential time of 10 years in the atmosphere (Le Mer and Roger, 2001), methane is about 30-times more effective as greenhouse gas than CO_2 (Shindell et al. 2009). This makes methane an important factor that needs to be considered in the backlight of climate change.

Most of the atmospheric methane stems from biological sources, where it is produced by methanogenic bacteria under anoxic conditions. However, this thus not mean that methane production is not influenced by humans as is shown by the rapid increase in the atmospheric concentrations from 0.8 ppm in 1750 to 1.75 ppm in 2000 (Forster et al. 2007). This strong anthropogenic compound is rooted in the fact, that main sources for methane are found in agricultural systems. Beside ruminants, where methane is produced during plant digestion, rice fields, especially with submerged cultivation, are a major source. It is estimated, that approx. 100 g of methane are released to the atmosphere for each kg of produced rice (Le Mer and Roger, 2001).

The main sources for natural methane production are anoxic zones in sediments and soils, where organic matter is digested by methanogenic bacteria. Usually the top most layers of the substrate belong to the aerobic zone and most (up to 90 %) of the produced methane is directly oxidised by methanotrophic bacteria but not released to the atmosphere. Such anoxic conditions are generally found in deeper substrate layers due to the limited ability of oxygen diffusion, but are especially well established in very wet or water saturated substrates as for example found in different types of wetlands (swamps, bogs,…). There often an only shallow aerobic layer is found on top of the anoxic zone, such that only smaller proportions of the produced methane can be oxidised. As the net-effect between production and consumption is then positive, these ecosystems act as methane sources.

On the contrary, many other (dryer) soils can act as methane sinks (= negative net effect between production and consumption), when the local methanotrophic bacteria of the upper soil layers oxidise more methane than produced by methanogenic bacteria. In such cases, additional methane is taken up from the atmosphere. However, methanogenic and methanotrophic bacteria are present in all soils and whether ecosystems acts as source or sink for methane is determined by the net balance between production and consumption (Hofmann et al., 2016, Praeg et al., 2014). Thus, all changes in environmental conditions, influencing the size and distribution of oxic and anoxic zones, and therefore the ability to produce/consume methane can have strong effects on the net balance. Therefore, also ecosystems that usually act as methane sinks, can transform to methane sources during certain periods of time. This was for example observed after flooding events (Wang and Bettany, 1995), on permafrost (when melting water cannot run-off or penetrate the soil due to frost in deeper layers) or in spring, when soils can also be saturated with water during snow melt (Le Mer and Roger 2001, Pirk, Tamstorf et al. 2016, Smagin and Shnyrev, 2015).

Already in the 1990s it was observed, that especially during late winter and early spring, oxygen concentrations under the snow can decrease dramatically, sometimes even leading to anoxic conditions (Newesely et al. 1994, Newesely, 1997; Newesely, Cernusca, 1999). Such situations primarily occur when the activity of aerobe bacteria in the soil increases with increasing temperatures, leading to a consumption of oxygen. If the consumed oxygen can then not be replaced by diffusion from the surroundings e.g. due to tightly packed snow or the formation of solid, oxygen impermeable ice layers on the border between snow and soil, oxygen concentrations start to drop. Whether these low oxygen levels consequently trigger an increase in methane production is not known, especially as the activity of methanogenic bacteria is stronger influenced by low temperatures – as found under snow covers – compared to their antagonists, methanotrophic bacteria (Le Mer & Roger 2001). On the other hand do low temperatures not per se prevent the production of methane by bacteria (Dise, 1992) and recent studies suggest that the methane production in cold ecosystems might be well underestimated (Smagin and Shnyrev, 2015).

Due to the limited abilities in the 90s to measure oxygen under natural conditions, it was not possible to take samples without disturbing the system. Consequently only snapshot data with a comparably low precision exists at 10 days intervals. Thus it remains still unclear, (a) if anoxic conditions occur or if low levels of oxygen will still be available, (b) if at low oxygen levels methanogenic bacteria will become more active, leading to an increase in methane concentrations and (c) how dynamic those systems are over time.

In the current project we address these questions by applying newly available sensors allowing to measure oxygen and methane concentrations directly at the border between snow and soil under undisturbed conditions in the field. As the method has not been applied before, the project is designed as a pilot study, to test and optimize the setup for these measurements under laboratory and field conditions. The results from the measurements on the field sites will deliver important, first insights to this complex and highly relevant topic.

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