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Short Communication

Responses of CH_4, CO_2 and N_2O fluxes to increasing nitrogen deposition in alpine grassland of the Tianshan Mountains

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ABSTRACT

To assess the effects of nitrogen (N) deposition on greenhouse gas (GHG) fluxes in alpine grassland of the Tianshan Mountains in central Asia, CH_4, CO_2 and N_2O fluxes were measured from June 2010 to May 2011. Nitrogen deposition tended to significantly increase CH_4 uptake, CO_2 and N_2O emissions at sites receiving N addition compared with those at site without N addition during the growing season, but no significant differences were found for all sites outside the growing season. Air temperature, soil temperature and water content were the important factors that influence CO_2 and N_2O emissions at year-round scale, indicating that increased temperature and precipitation in the future will exert greater impacts on CO_2 and N_2O emissions in the alpine grassland. In addition, plant coverage in July was also positively correlated with CO_2 and N_2O emissions under elevated N deposition rates. The present study will deepen our understanding of N deposition impacts on GHG balance in the alpine grassland ecosystem, and help us assess the global N effects, parameterize Earth System models and inform decision makers.

1. Introduction

Anthropogenic activities, mainly in the form of fertilizer application and fossil fuel use, have greatly accelerated the emissions of reactive nitrogen species worldwide (Galloway et al., 2008) and N addition to ecosystems alters physiology of soil microbes and vegetation in a way that leads to altered biogenic fluxes of CO_2, CH_4 and N_2O contributing to global warming. Elevated N deposition induced by human activities will contribute to a number of negative effects such as declining biodiversity, eutrophication of aquatic ecosystems and soil acidification (Guo et al., 2010; Liu et al., 2011; Song et al., 2011) as well as some positive effects such as improving soil N availability and increasing plant productivity (Xia and Wan, 2008). In addition, as atmospheric deposition increases the ecosystem is capable of buffering most of nutrient elements. In Japan, for example, a forested catchment can act as a buffer to retrieve large amounts of N transported eastwards from the Asian continent (Hartmann et al., 2008). Increased leaf N content under elevated N can influence CO_2 emission by increasing autotrophic and heterotrophic respiration and organic matter decomposition. Nitrogen turnover (mineralization and nitrification) directly influences CH_4 uptake and nitrate can decrease CH_4 production by increasing redox potential. N_2O production was mainly from microbial mediated nitrification and denitrification (Dittert et al., 2005; Liu and Greaver, 2009). Most research stresses that GHG production and consumption can be controlled by temperature and soil water content. Simulated N deposition experiments in temperate grasslands/steppes resulted in reduced CO_2 emission and CH_4 consumption and increased N_2O emission, but the reverse or no significant effects have also been reported (Mosier et al., 1996; Bradford et al., 2001). Most research on N enrichment effects have been conducted at North American and European sites, although data are sparse from East Asia for sites that have received N addition through N fertilizer inputs (Liu and Greaver, 2009).

Recently the ecological effects of simulated atmospheric N deposition on some natural ecosystems in China have been studied by some researchers but few studies have assessed the effect of simulated N deposition on all the three GHGs (Liu et al., 2011) and these measurements were short-term and have been carried out only during the growing season (Jiang et al., 2010). CH_4, CO_2, and N_2O fluxes in winter are far from being negligible at the annual scale mainly due to missing winter measurements. The present study was intended to contribute to understanding the effects of N deposition on GHGs in grassland ecosystems, and helping to assess the effects of N globally, parameterize Earth System models and inform decision makers. To better understand the effects of

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N deposition on GHGs in alpine grassland, five N addition treatment sites were selected. In this paper, we focus on the following two aspects: (1) to compare the effects of increased N deposition on CH_4, CO_2, and N_2O fluxes within and outside the growing season in alpine grassland; (2) to analyze the effects of air temperature, soil temperature and soil water content on CH_4, CO_2, and N_2O fluxes at year – round scale.

2. Materials and methods

This study was conducted at the Bayinbuluk Grassland Ecosystem Research Station, Chinese Academy of Sciences (83°42.5′E, 42°53.1′N). The Bayinbuluk alpine grassland is located in the southern Tianshan Mountains of Central Asia, Xinjiang Uygur Autonomous Region of China, covering a total area of approximately 23 000 km^2. Mean altitude is 2500 m a.s.l. From local meteorological data (1980–1999), mean annual precipitation was 265.7 mm and mean annual temperature was −4.8 °C. Ambient N deposition at Bayinbuluk alpine grassland was about 8 kg N ha^{-1} $year^{-1}$ (with 50% dry and 50% wet deposition, according to our monitoring data), slightly below normal critical load (10–20 kg N ha^{-1} $year^{-1}$) of N deposition for grassland worldwide (Bobbink et al., 2010). Five N addition rates were selected: N_0 site (0 kg ha^{-1} $year^{-1}$), N_{10} site (10 kg ha^{-1} $year^{-1}$), N_{30} site (30 kg ha^{-1} $year^{-1}$), N_{90} site (90 kg ha^{-1} $year^{-1}$) and N_{150} site (150 kg ha^{-1} $year^{-1}$), representing control, low, moderate, high and extremely high N deposition levels across China, respectively. Each treatment was made up of four blocks (each 4 m × 8 m with a 1 m – wide buffer zone). The N was applied as ammonium nitrate (NH_4NO_3) in late May and early June each year from 2009 to 2011. During each application, NH_4NO_3 was weighed, dissolved in 8 L water, applied to each block using a sprayer and even distribution of fertilizer was ensured. The control plot received 8L water without nitrogen. All the N deposition treated sites were dominated by *Stipa purpurea* and ungrazed since 2005.

CH_4, CO_2, and N_2O fluxes were measured using a stainless steel chamber with an opaque top (50 cm × 50 cm × 10 cm) and covered with white plastic foam to reduce the impact of direct radiative heating during sampling. Each chamber was placed on a collar (50 cm × 50 cm × 10 cm) with a groove to prevent leakage during gas sampling. Four chambers were employed at each site. Gas inside the chamber was sampled at 0, 15 and 30 min after chamber closure using a 60 ml plastic syringe. CH_4, CO_2, and N_2O fluxes were sampled at the same time period (12:00–14:00 h) from June 2010 to May 2011 (with no sampling in January and February 2011 because of the very low temperatures, the lowest of which was about −40 °C) and four times per month during the growing season and twice per month during winter at all sites. During freeze–thaw process (from 9 April to 9 May), CH_4, CO_2, N_2O fluxes were sampled in 2–3 day intervals (total of ten times). CH_4, CO_2, and N_2O concentrations of gas samples (stored in specific air bags) were analyzed by gas chromatography (Agilent 4890D, Agilent Technologies, Wilmington, DE) within a week. The calculation of CH_4, CO_2, and N_2O fluxes followed the description of Zhang et al. (2005). Air temperature (T_{air}), soil temperature at 10 cm depth (T_{soil}) and soil water content at 10 cm depth (SWC) were monitored during gas sample collection (Auto Weather Station, Campbell Scientific, Logan, UT). Statistical analysis was carried out using SPSS 11.0 and Origin 7.5. One-way ANOVA analysis was performed to determine the significant differences in CH_4, CO_2 and N_2O fluxes among the five N treatments. Linear and non-linear analyses were used to identify significant correlations between environmental variables and CH_4, CO_2 and N_2O fluxes.

3. Results

The patterns of CH_4 uptake rates and CO_2 and N_2O emissions for N_0, N_{10}, N_{30}, N_{90} and N_{150} sites are illustrated in Fig. 1. Maximum CH_4 uptake was reached in August while the peak fluxes of CO_2 and N_2O occurred in July. During the growing season, N addition tended to significantly increase CH_4 uptake rates (excluding N_{10} site) and CO_2 and N_2O emissions at N fertilized sites (Table 1). Mean CH_4 uptake rates, CO_2 and N_2O emissions ranged from 53.3 to 64.9 μg m^{-2} h^{-1}, 76.7 to 93.9 mg m^{-2} h^{-1} and 20.4 to 27.5 μg m^{-2} h^{-1} for the five sites during the growing season, respectively. No significant differences in CH_4 uptake rates, CO_2 or N_2O emissions were found among all sites outside the growing season. CH_4 uptakes were positively correlated with both T_{air} and T_{soil} and negatively correlated with SWC. CO_2 and N_2O emissions were significantly correlated with T_{air}, T_{soil} and

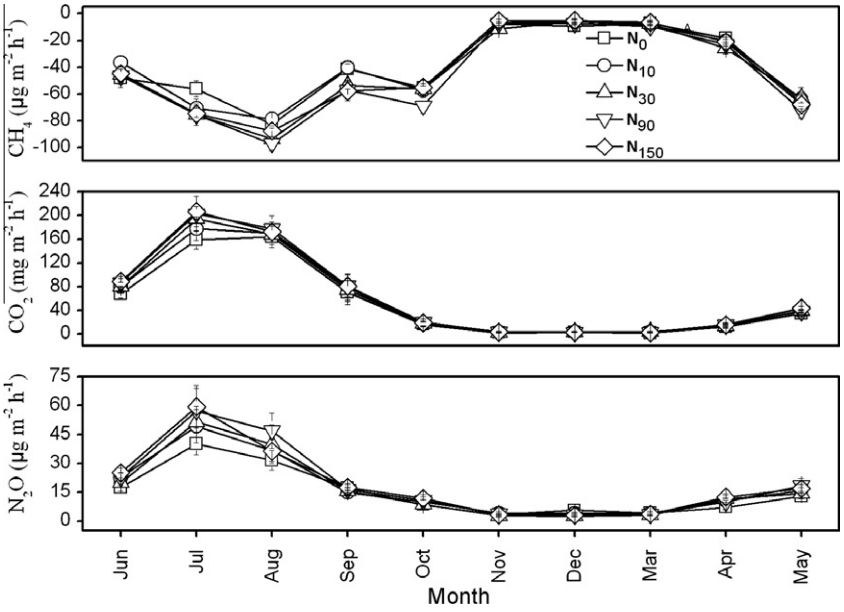

Fig. 1. CH_4, CO_2 and N_2O fluxes at different N deposition sites from June 2010 to May 2011 in alpine grassland of the Tianshan Mountains.