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Episodic release of methane bubbles from peatland during spring thaw

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Natural wetlands are likely to be the single largest source of atmospheric CH_4, a potent greenhouse gas that accounts for about 20% of the total radiative forcing. Northern peatlands probably contribute about one-third of the world's total wetland emissions. Methane emission rates from peatlands have been shown to have a large temporal variability at various time scales. Recent studies have indicated northern peatlands have inter-annual variation which may be attributable to fluctuations in climatic factors, such as annual average temperature or the amount of precipitation. Very large temporal variability at timescales of minutes to days could be caused by ebullition, i.e. release of CH_4-containing bubbles that occurs as episodic events. Fluctuations in atmospheric pressure were shown to be one of the dominant factors controlling the timing and magnitude of the ebullition.

Compared with the inter-annual or the short-term temporal variability, more efforts have been made to understand the seasonal change in CH_4 emission rates. Attempts to explain the inter-seasonal variability by linking it with various environmental factors, such as water table level or peat temperature, have been made mainly during the growing season, often excluding non-growing season variation presumably because of logistical difficulty. Some reports, however, have shown that cold-season CH_4 release represents a non-negligible portion in annual CH_4 budget.

In most northern peatlands, it is clear that drastic changes in physical environments, including melting of snow and near-surface frozen peat, take place during the spring thaw in relatively short periods of time, invoking a corresponding sudden change in CH_4 emission rates. However, field investigations during the thawing moment have been, so far, seldom conducted.

In this paper, in an effort to obtain better understanding of the mechanisms of the possible episodic CH_4 release during spring-thaw from northern peatlands, we aimed at relating CH_4 released into the atmosphere to stored CH_4 in near-surface peat trapped during winter by conducting intensive surface CH_4 flux measurements as well as investigating the state of below-snow CH_4.

Methane flux into the atmosphere during spring thaw has been investigated in a small ombrotrophic peatland (Bibai, Hokkaido, Japan) using the conventional chamber method. More than 50 times of chamber deployment on top of the snow cover was carried out and continued over 165 hours until the surface snow and underlying ice cover on top of the peat layer had completely thawed. Methane emission was almost absent at the presence of snow cover. At the very moment the surface ice cover thawed, a large CH_4 flush (more than 10 mg CH_4 m^{-2} h^{-1}) was recorded, which was on the same order of magnitude as episodic ebullition previously observed in high-summer season. Subsequent emissions showed a gradual decreasing trend with daily peaks appearing in the morning. Gas bubbles trapped in the ice layer on top of the waterlogged peat were preliminary analyzed for the volumetric percentage in the total ice volume as well as their composition of gas species, and we found out that the bubbles occupied about 3.2% in volume and that the mixing ratio of CH_4 in the bubbles was about 20%. The abundance of the bubble-form CH_4 was likely to be sufficient to explain the observed episodic CH_4 release during the thaw. This study shows CH_4 emission during thaw season has great temporal variability, and it occurs as episodic release of bubble-form CH_4 stored in the frozen layer. Omission of the episodic release of stored CH_4 during the spring thaw results in underestimation of annual CH_4 emissions as well as misunderstanding of seasonal CH_4 dynamics. The results also imply the possibility that gas-phase CH_4 may play an important role not only in the growing season but also in the cold season CH_4 dynamics in northern peatlands.