Cold Season Emissions Dominate the Arctic Tundra Methane Budget on the North Slope of Alaska

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Arctic terrestrial ecosystems are major global sources of methane (CH_4); hence, it is important to understand the seasonal and climatic controls on CH_4 emissions from these systems. Here, we report year-round CH_4 emissions from Alaskan Arctic tundra eddy flux sites and regional fluxes derived from aircraft data. We find that emissions during the cold season (September to May) account for ≥50% of the annual CH_4 flux, with the highest emissions from noninundated upland tundra. A major fraction of cold season emissions occur during the "zero curtain" period, when subsurface soil temperatures are poised near 0 °C. The zero curtain may persist longer than the growing season, and CH_4 emissions are enhanced when the duration is extended by a deep thawed layer as can occur with thick snow cover. Regional scale fluxes of CH_4 derived from aircraft data demonstrate the large spatial extent of late season CH_4 emissions. Scaled to the circumpolar Arctic, cold season fluxes from tundra total 12 ± 5 (95% confidence interval) Tg CH_4 y–1, ~25% of global emissions from extratropical wetlands, or ~6% of total global wetland methane emissions. The dominance of late-season emissions, sensitivity to soil environmental conditions, and importance of dry tundra are not currently simulated in most global climate models. Because Arctic warming disproportionally impacts the cold season, our results suggest that higher cold-season CH_4 emissions will result from observed and predicted increases in snow thickness, active layer depth, and soil temperature, representing important positive feedbacks on climate warming.

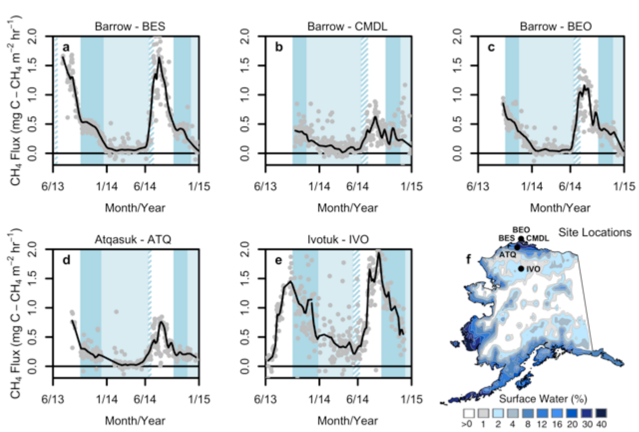

Figure 1. Methane flux (mg C-CH_4 m–2 h–1) measured at the five EC sites on the North Slope, AK at: Barrow-BES (A), Barrow-BEO (B), Barrow-CMDL (C), ATQ (D), and IVO (E) from June 2013 to January 2015 [the gray dots are daily median for a minimum of 24 points per day, and the black line is a 35-d smoothing (lowess) applied to that daily median]. (F) Map of Alaska indicating the location of the sites and the percentage of surface inundation (*SI Materials and Methods*). The zero curtain (dark blue), spring thawing with soil temperature around 0 ± 0.75 °C (diagonal hatching) (Fig. S1 and Table S1), summer (no shading), and the balance of the cold season below –0.75 °C (light blue) periods are indicated (A–E). From Zona et al. 2016.

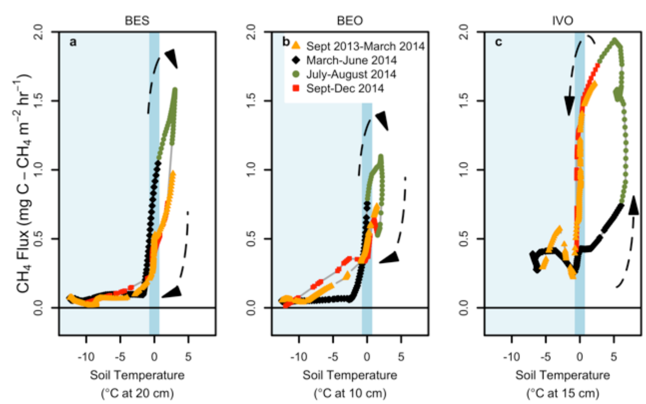

Figure 2. The methane flux variation with soil temperature on the North Slope of Alaska at: Barrow-BES (BES) (A), Barrow-BEO (BEO) (B), and IVO (C) during the indicated periods. The zero curtain period is shaded in dark blue, with soil temperatures below –0.75 °C in lighter blue. The seasonal progression of each phase is indicated by the black arrows. Winter-time data are shown as orange triangles (September 1, 2013 to March 12, 2014) and red squares (September 1, 2014 to December 31, 2014). Data collected during the spring (March 13, 2014 to June, 30, 2014) are shown as black diamonds. Data during the summer period (July 1, 2014 to August 31, 2014) are shown as green circles. From Zona et al. 2016.