Constraining methane formation/removal pathways with stable isotopes in different aquatic environments throughout the summer season in the Kolyma Region, North-East Siberia

E.M. van Winden¹, C.J. Sapart², T. Röckmann², J.E. Vonk¹, C. van der Veen², J. Schade³, L. Lynch⁴, N.S. Zimov⁵

Relevance

The methane flux from arctic wetlands to the atmosphere will likely increase in the future in response to climate change. Analyzing the hydrogen isotope composition of methane (δD(CH₄)) allows a better understanding of its formation and removal in different types of environment. Moreover, the seasonal changes and type of underlying permafrost also affect the δD(CH₄). The δD(CH₄) in different types of environments can be used to better constrain atmospheric models.

Research questions

- Is there a difference in δD(CH₄) between samples taken at Yedoma (Pleistocene-aged) permafrost and floodplain (Holocene-aged) locations, and between different aquatic environments during the summer season?
- What is the source signature of methane reaching the atmosphere in the Kolyma region?

Sampling and methods

Location 68°N, 161°E

Mixing ratios of CH₄ (ppm)

Ebullition samples

A. The monthly averages (±sdv) for δD(CH₄) for June, July, August, September 2013 are -384±25‰, -375±46‰, 385±22‰ and -385±15‰, respectively, typical for acetoclastic methane. Mixing ratios are 2047±734ppm, 2857±720ppm, 1946±67ppm and 2721±410ppm, respectively, showing that the amount of methane in ebullition is widespread.

B. The Pleistocene-age Yedoma permafrost shows no clear difference in δD(CH₄). For Yedoma avg (δDCH₄) -378±32‰ and Holocene-age floodplain samples avg. -396±25‰, in the same range as Walter et al. (2007).

C. Samples taken at locations with a total water column depth <1m are more depleted in D (avg. δD(CH₄) -482±14‰) than samples taken where water depth is deeper than 1m (avg. δD(CH₄) -396±38‰). Due to short travel time of the bubbles, oxidation differences in the water column are unlikely, we instead reason that at deeper sites (1) there is additional CO₂ reduction and/or (2) (anaerobic) oxidation in the sediment.

D. Streams and rivers show higher methane mixing ratios (avg. 2289±663ppm) and are slightly more enriched in D (avg. δD(CH₄) -364±48‰) than lake samples (avg. 3120±513ppm and avg. δD(CH₄) -394±21‰). Streams and rivers are generally more oxygenated, therefore higher oxidation levels are likely responsible for the enrichment of D and lower mixing ratios compared to lakes.

Location 68°N, 161°E

Mixing ratios of CH₄ (ppm)

Ebiffusion samples

A. Summer month

B. Different permafrost

C. Water depth

D. Environments

Location 68°N, 161°E

Mixing ratios of CH₄ (ppm)

A. Keeling plot of different permafrost

B. Keeling plot per month

The Keeling plot approach allows us to calculate the source signature of CH₄ added into a background reservoir. The intersection of the linear fit with the y-axis represents the isotopic signature of the added source.

A. The δD(CH₄) signature of the Yedoma (44±1‰) is more enriched than the samples from the floodplain (14±10‰) and is in the range measured by Walter et al. (2007). Potential sources for this enrichment could be (1) the influence of biomass/waste burning as on average the Yedoma sites are closer to towns, or (2) a contribution of CO₂ reduction in the Yedoma. We will investigate this further with δ13C(CH₄) analysis.

A. The difference in mixing ratio is likely due to the sampling technique in which the height of sampling varies, thus no clear seasonal variations are observed. The average methane source signature for the Kolyma region is -38±10‰. For these isotopes, the different months do not show significant source differences: June δD(CH₄) -38±7‰ and July -39±7‰.

Atmospheric samples

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Conclusion

- Acetate fermentation is the main formation pathway of CH₄ in the Kolyma region. Yedoma (Pleistocene-aged) permafrost is slightly more enriched in D (ebullition: -37±16‰, air: -37±16‰) compared to Holocene-aged floodplain samples (ebullition: -395±25‰, air: -444±10‰). The Yedoma results are in the same range of values as similar studies. Rivers and Streams and lakes with deeper water depth show more oxidized CH₄ decreasing the flux of CH₄ from wetland to atmosphere. During the summer season there are no significant changes in δD(CH₄).

- The source signature for deuterium of methane in the Kolyma region is -38±10‰ as calculated in the Keeling plot.