

Interactive comment on “Methane dynamics in warming tundra of Northeast European Russia” by M. E. Marushchak et al.

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Received and published: 8 October 2015

General comments

This manuscript presents valuable data on CH₄ fluxes from the understudied permafrost region of NE Europe. CH₄ fluxes were measured on the plot scale by closed chambers and on the landscape scale by the eddy covariance approach. The combination of these two approaches is a particular strength of this study. Furthermore, the authors present interesting data on stable carbon signatures of porewater and emitted CH₄ which allows new insights in the processes that are involved in the CH₄ emission. An interesting scenario analysis of landcover changes due to climate warming and permafrost degradation demonstrates the potential effects of such climate-induced landscape changes on CH₄ fluxes. However, the projection of much higher CH₄ emissions

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due to higher temperatures on the basis of a Q10 temperature sensitivity parameterization derived from seasonal flux data appears questionable to me (see specific comment on P. 13946, l. 22-24 and P. 13956).

The manuscript is generally well written; however, I found several comma and smaller orthographic errors (see list of technical comments). More importantly, the wording at several places should be improved for the sake of clarity and consistency with scientific terminology (see list of specific comments).

I recommend the manuscript of Marushchak et al. for publication in Biogeosciences after careful consideration of my comments.

Specific comments:

P. 13932, l. 18: Inappropriate wording: A process can discriminate against the ¹³C isotope, which is heavier than ¹²C; however, it cannot discriminate against a high (better than “heavy”) delta-¹³C value, which is the result of the discrimination.

P.13932, l. 18: I think that your statements about the reasons for the light emitted CH₄ in the abstract and later in the discussion, respectively, are not really in line with each other: In the discussion, you argue that the emitted CH₄ is light because it is transported from deeper peat layers. Here in the abstract, you argue that the light emitted CH₄ is due to the plant-mediated transport. These are two quite different statements which are both not completely clear for me: To the first argument (discussion): Do you have indications for lighter CH₄ in deeper peat layers? This is often the case since there you find CH₄ that is not influenced by the ¹³C discrimination by CH₄ oxidation like in the upper peat layers (or maybe also a higher contribution of hydrogenotrophic methanogenesis to CH₄ production as opposed to acetoclastic methanogenesis), but did you sample also the deeper peat layers at your site? To the second argument (abstract): Do you have discrimination by diffusional transport in mind? Diffusion across the rhizodermis? In the aerenchyma? Does CH₄ also get lighter by CH₄ oxidation along this plant-mediated transport?

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P. 13932, l. 20: Please state here that it was “negatively correlated” with the vascular plant cover.

P. 13933, l. 8: This statement is too imprecise: The “soils in the northern circumpolar permafrost region” (Tarnocai et al. 2009, GBC)” are not equal to the areas of “arctic tundra” (your previous sentence). Furthermore, the estimates of , e.g., Tarnocai et al. (2009) or Hugelius et al. (2014, Biogeosciences) do not refer to “soil carbon” but to “soil organic carbon”. There is also a lot of inorganic carbon in soils.

P. 13933, l. 22. According to the IPCC (2014), the GWP of methane (without inclusion of climate–carbon feedbacks) is 28 (not 25 anymore).

P. 13933, l. 23: Remove “non-frozen”. There are no permanently frozen wetlands.

P. 13934, l. 5: Too vague: How high this resolution should be?

P. 13934, l. 9: What do you mean precisely with “ensemble average”? “Ensemble average” of what exactly? E.g., fluxes from equally sized areas of different land cover types within the ecosystem under study? I see the EC flux more like an estimate for a weighted mean of fluxes from different land cover types within the EC footprint (which changes over time), weighted by the area of the land cover types and the footprint probability density function.

P. 13934, l. 26: Why is the importance of peatlands growing?

P. 13934, l. 27-28: Too general: Permafrost temperatures: Average over all permafrost regions? Some or all permafrost areas?

P. 13935, l. 5-7: The sentence is quite vague: How can a study like the present one improve these projections? By model validation and better calibration? By including additional biogeochemical processes? Do you think that the model of Anisimov has specific deficiencies?

P. 13935, l. 12: I suggest “from pedon to landscape” or similar. “Processes” is not

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comparable to “landscape”. Some processes can act, e.g., on the pedon scale, others act on the landscape scale.

P. 13936, l. 6-11: Please indicate the distance of Vorkuta and Salekhard from the investigation site in addition to the coordinates here.

P. 13939, l. 21: Did you correct somehow for the CH₄ content in the ambient air that you used as headspace air? Or did you use synthetic air without CH₄.

P. 13941, l. 12: I suggest using the unit “g CH₄ m⁻²” for consistency with the units used later.

P. 13942, l. 2: This is wrong usage of permafrost terminology: The active layer is the layer of ground that is subject to annual thawing and freezing in areas underlain by permafrost. It is not the active layer depth does not equal the thaw depth at a specific time during the thaw season. Also, it is not the permafrost which you encounter at the surface before the thaw season starts (Permafrost is ground that remains at or below 0 °C for at least two consecutive years). The top soil is affected only by seasonal (winter) frost.

P. 13942, l. 10-11: What do the “+/-” signs indicate? Spatial variability between parallels or uncertainty estimates of modelling over the year?

P. 13942, l. 20: Temperature of what? Air or soil (at which depth?)

P. 13943, l. 13-14: Sentence is difficult to understand: How can a high delta 13C value decrease the average delta 13C value?

P. 13943, l. 17: For clarity better “. . .the porewater CH₄ at 5 cm and 30 cm depth. . .”

P. 13944, l. 16-20: But it may be appropriate to also mention that your CH₄ fluxes were very similar to the ones measured during June to mid-September in the Lena River Delta by Wille et al. (2008, GCB; 1.87 g m⁻²) and Sachs et al. (2008 JGR; 1.93 g m⁻²). Also, the measurements of Van der Molen et al. (2007) appear very similar to your

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CH4 fluxes given that these authors reported annual fluxes.

P. 13945, l. 28: For clarity, better: "...dissolved in the top soil pore water"

P. 13945, l. 28-29: Please see my comment to the abstract (P.13932, l. 18).

P. 13946, l. 8-9: Could you explain a bit more step-by-step to the reader why the supply of plant-derived C supply for methanogens should lead to the observed correlation?

P. 13946, l. 22-24: Applying the exponential fit function between temperature and CH4 fluxes derived from data collected over the year for modelling future CH4 fluxes is dangerous. When you fit an exponential model to such a seasonal dataset, your Q10 parameter will not only reflect the pure temperature sensitivity of the process but will include seasonal/phenology change. This might lead to substantial overestimation of the temperature sensitivity, as was, e.g., shown by Mahecha et al. (2010, Science) and for tundra by Runkle et al. (2013, Biogeosciences).

P. 13947, l. 15-16: Wrong terminology: The active layer thickness cannot change over the season (see comment on P. 13942, l. 2)

P. 13948, l. 25: Please more precise: Do you mean mean annual temperatures? At a specific depth or depth-interval?

P. 13956: beta parameters: There appears to be a very large spread in this parameters, between plots of same LCT and between years. Since this beta parameter is the parameter that drives the prediction of CH4 fluxes in a future warmer climate, it would be good if you could critically discuss this large spread. How valid/robust is such a fit parameter for describing the temperature sensitivity of CH4 emissions?

P. 13959, figure caption: How have you defined the footprint? How much of the flux source contribution is typically within 500 m distance (radius of outer circle)?

P. 13962: Would be good to indicate the R2 and its significance in the diagrams of the figure caption.

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Technical comments

P. 13932, l. 12: Hyphenate: "CH4-emitting", also ensure consistent use of "CH4" or "methane". E.g., on same page, l. 28, you write "methane emitting" (should also be hyphenated: "methane-emitting").

P. 13932, l. 20: comma before "and" (new independent clause).

P. 13932, l. 21: "The mean..." instead of "A mean..."

P. 13932, l. 24, P. 13933, l. 1: Space between "7" and "°C"

P. 13933, l. 7: No comma before "because" (dependent clause)

P. 13935, l. 1: "composition" of what?

P. 13935, l. 10: "...environment, which is vulnerable..."

P. 13935, l. 13: I suggest hyphenating: "EC- and chamber-based"

P. 13936, l. 24: "waterlogged"

P. 13936, l. 26: Insert "the" before "dominant".

P. 13938, l. 9: "headspace"

P. 13939, l. 25: better "ambient air samples"

P. 13940, l. 12: Add hyphen: "landscape-scale CH4 fluxes", and throughout the manuscript hyphenate two or more words when they come before a noun they modify and act as a single idea (compound adjective), e.g., plot-scale measurements (e.g. p. 13941, l. 17). But: we compare the plot scale with the landscape scale (no compound adjectives).

P. 13940, l. 18. Better "...for CH4 concentration measurements"

P. 13941, l. 17-18: Awkward sentence structure, please revise.

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- P. 13942, l. 1: Insert comma before “and”
- P. 13943, l. 17: Place comma before “and”
- P. 13945, l. 4: hyphenate “area-integrated”
- P. 13945, l. 18: plural “willow stands”
- P. 13946, l. 1: “I suggest “decreasing” instead of “depleting” in this context.
- P. 13947, l. 16: “low-lying”
- P. 13948, l. 4: I suggest adding “the” before “CH₄ exchange”
- P. 13948, l. 16: “drawdown” and “. . . expected to be. . .”
- P. 13948, l. 23: “the” before “last gaciation”
- P. 13950, l. 2: hyphenate “data-based”
- P. 13963: Figure caption: “from June until early October”
- P. 13965: Figure caption: Hyphenate “warming-induced”

Interactive comment on Biogeosciences Discuss., 12, 13931, 2015.