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Discussions

Interactive comment on "Pingo development in Grøndalen, West Spitsbergen" *by* Nikita Demidov et al.

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Reviewer 1 Interactive comment on "Pingo development in Grøndalen, West Spitsbergen" by Nikita Demidov et al. Trevor Porter (Referee)

The authors present stratigraphic profiles of solutes and water isotopes from pore ice of permafrost cores collected from the Fili pingo in West Spitsbergen, and of modern precipitation, tributaries, and a local spring to better constrain the origin of water in the pingo system. Based on the data, the authors deduce that the pingo is springfed, and that its evolution was characterised by several distinct periods of closed and semi-closed conditions, as evidenced by trends in the water isotope and solute data. They also use a Rayleigh isotope distillation model to show that the data diverge from a

closed-system. I found the methods and interpretation were robust. The paper was well written, easy to follow and the topic is well suited for The Cryosphere. Below are several comments meant to help the authors improve the communication of their work, and address one uncertainty that is not discussed. Following these minor revisions I would recommend this paper for publication. Answer: Thank you for your time and effort to review our manuscript. We appreciate your suggestions and answer them one-by-one. According changes in the manuscript are included in the revised version and referred in our replies.

Major comments. I am intrigued by the vertical trends in the water isotope dataset. To a large extent I agree with the interpretation assuming the following conditions: core #9 was drilled exactly in the centroid of the ice body; pingo geometry is conical; and it is reasonable to assume the pingo grew equally on all sides. Largely these points are not discussed. Isotopic stratigraphy of pingo ice could show 'apparent' reversals if the coring angle was off-axis, or pingo growth was asymmetric. Perhaps the authors can comment on this uncertainty. Again, I am in agreement with the interpretation, but would appreciate if this issue of coring angle and pingo growth geometry could be discussed. Answer: We agree that the interpretation of the vertical trends in the down-core profile strictly depends on the drilling position in the centroid of the massive ice body. Although the exact underground geometry of the massive ice has not been detected, we assume from the central drilling position at surface and concentric vertical drilling that the isotopic stratigraphy indeed represents the subsequent freezing stages of the pingo ice. Accordingly, we added in section 3.1 the following sentence: "The drilling position on top of the pingo was chosen in its center to assure that the centroid of the pingo ice body was captured in the core. The coring angle was held vertical." We further added the following sentence to section 5.2: "Assuming a conical geometry of the pingo ice body that grew equally to all sides, the chosen central drilling position on top of the pingo and the strictly vertical drilling allowed capturing subsequent freezing stages of the massive ice."

Minor comments. Abstract. The final 2 sentences are largely unconnected to the research. Please finish the abstract with some kind of significance statement instead. Answer: We changed the sentences as follows: "The presence of permafrost below the pingo ice body suggests that the talik is frozen and the water supply and pingo growth are terminated. The maximum thaw depth of the active layer reaching the top of the massive ice leads to its successive melt with crater development and makes the pingo extremely sensitive to further warming."

P2, L20-22. this sentence is too wordy, and confuses the message. please make it more concise. Answer: We changed the sentence as follows: "They differentiate into group I pingos fed by sub-permafrost groundwater along geologic faults, group II pingos fed by artesian flow of migrating sub-glacial groundwater mainly in river valley positions (in sensu Liestøl, 1977) and group III pingos (in sensu Yoshikawa and Harada, 1995). The latter are found in nearshore environments of post-glacial isostatic uplift and fed through small-scale discontinuities 'groundwater dikes' or taliks in aggrading permafrost within in marine deposits (Yoshikawa and Harada, 1995)."

P2, L24-26. please elaborate on why this is true. Answer: The statement from Liestøl (1996) is still true and based on the scarcity of data from the inner structure of pingos due to lacking drilling or exposures except for the studies by referred in the manuscript in section 1. We added the following elaboration: "This is still valid due to the scarcity of data from the inner structure of pingos because of rarely undertaken drilling."

P3, L26-27. the description of core thickness in relation to different base level elevations is a bit confusing. Please clarify in simple terms. Answer: We changed the sentence accordingly as follows: "The drilling of the Fili pingo in May 2017 started from the surface of central crater at 52.5 m asl and reached a depth of 11.5 m bs (core #9, 77.99355 °N, 14.66211 °E). The borehole was conserved and in April-May 2018 the drilling was continued in the same borehole down to a depth of 25 m bs"

P6, L17. The reported dD-d18O and d-dD slopes (6.7 and -0.2, respectively) are nearly

identical to the slopes observed in modern precipitation. Fig. 3 indicates dD-d18O slope is 6.78, and based on the dD-d18O equation the d-dD slope can be calculated to -0.18 (or -0.2 if rounded to 1 decimal). My point is, your claim that the effects of freezing on the co-isotope slopes are not well supported by the data, since precipitation has these slopes. Answer: To show difference in the d-δD data of the pingo massive ice (Figure 3c in the manuscript) and those of precipitation, we added here Figure R-1. Here is becomes obvious that the d-δD slope of precipitation is –0.06 and thus differs from those of the massive ice data. We therefore assume, that the co-isotope slopes of the massive ice as shown Figure 3 of the manuscript display the freezing effects during formation of the massive ice. The rather uncommon isotopic composition of modern precipitation are subject to a recent study by Skakun et al. (in review) where short-term variations in air mass trajectories are discussed to explain extrema in deuterium excess values. Taking further into account the large scatter in precipitation amounting to about 18‰ in δ18O, to about 127 ‰ in δD (see Figure 3a and Table 1 in the manuscript) and to about 70 ‰ in d (see Figure R-1 above and Table 1 in the manuscript) if compared to those of the massive pingo ice the latter are distinctly smaller. Thus, if precipitation had been a major source for the pingo ice we would expect a much larger scatter in the isotopic composition. Reference: Skakun et al.: Stable isotopic content of atmospheric precipitation and natural waters in the vicinity of Barentsburg (Svalbard), Ice and Snow (Лёд Ðÿ ÐąÐ¡ÐţÐş), in review.

P9, L19-20. it is unclear how the previous sentence justifies this conclusion. Please elaborate. Answer: Based on literature data we assume a fast growth of the pingo massive ice. Accordingly, we changed the text as follows: "Estimations of pingo growth rate in Siberia and North America may reach values of order decimetres per year (Mackay, 1979; Chizhova and Vasil'chuk, 2018). Assuming a similar fast growth of the Fili pingo no or only little changes in isotopic composition of water source over the rather short period of pingo formation are likely. Thus, we assume the second controls on isotopic composition of the Fili pingo massive ice of less importance."

P10, L12-13. If true, you may be able to calculate the rate of pore water recharge based on deviation from isotope distillation model. Answer: The applied isotopic fractionation model does not allow calculating the admixture of water based on the deviation from the freezing line if the original isotopic composition of this additional source is unknown. There are two independent variables, and to find one, one needs to know the other, i.e., this problem is unsolvable.

P12, L10. …. valley evolution can already 'be' drawn. Answer: Changed accordingly.

Figures. The font size and resolution of some of the figures is too low for publication, and in some cases it was difficult to interpret the figures as given. Please revise to conform to the publication standards of The Cryosphere. Answer: To be changed accordingly in the final revision.

Please also note the supplement to this comment:
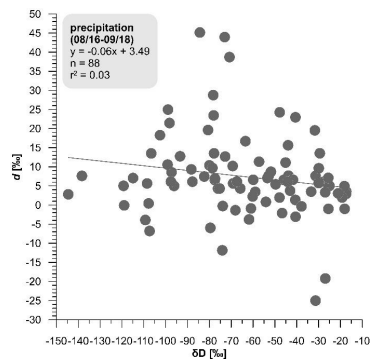https://www.the-cryosphere-discuss.net/tc-2019-76/tc-2019-76-AC1-supplement.pdf

Figure R-1: Co-isotopic plot of d and δD in modern precipitation in Barentsburg not included in the paper.

Fig. 1.