

Interactive comment on “Effects of freezing on soil temperature, frost propagation and moisture redistribution in peat: laboratory investigations” by R. M. Nagare et al.

Anonymous Referee #2

Received and published: 18 July 2011

General comments:

Water and heat flows during soil freezing are complicated processes. Detailed datasets from laboratory experiments are required to clarify the mechanisms. Most soil-freezing experiments have used mineral soils and unrealistic boundary conditions. Therefore, this study proposed a freezing system using peat soil on a proxy permafrost layer and observed temperature and water content changes during freezing. This report includes an interesting data; emphasizes the role and importance of hydraulic and thermal conductivity in water and heat flow during soil freezing, which are well known

C2827

qualitatively. Quantitative discussions and evaluations are necessary. Furthermore, it would be useful to know how using the peat sample and realistic bottom boundary conditions improved the experiment. For example, peat has low bulk density. Is there a volume change due to water redistribution? How did your understanding of the mechanism improve using this boundary condition?

Specific comments

Page 5391, Line 10: Setting a proxy permafrost layer as the bottom boundary condition is interesting. How did you control the temperature of the proxy permafrost layer? If there was no flux- or temperature-control condition for this layer, it differed from classical freezing experiments in the initial condition only, and the heat flux through the soil remained unrealistic.

Experimental setup: At which depth were the sensors placed? The bottom condition of the proxy permafrost layer is unclear.

Page 5392, Line 20: The saturated hydraulic conductivity is important; however, the relationship between hydraulic conductivity and bulk density is more useful for evaluating this experiment. Furthermore, the relationship between hydraulic conductivity and water content (the unsaturated hydraulic conductivity) should be indicated for the following discussion of water flow.

Page 5392, Line 22: The water retention curve is Fig. 1d, not 1c. How can a tension of 1 mm be measured?

Page 5395, Line 7: *the influence of ice on apparent dielectric permittivity was not*

C2828

considered owing to the inability of estimating pore ice content.

When the water content is relatively low, the influence of ice on dielectric permittivity is small and can be neglected. However, high ice content (initial water) $>0.5 \text{ m}^3/\text{m}^3$ is not negligible. The unfrozen water content of peat in Figure 5 is too high when the initial water content is high. Moreover, the amount of residual water appears to be approximately on the order of the initial water content due to the ice permittivity.

Page 5396, Line 13: *A linear temperature profile was achieved by maintaining air temperature in lower and upper chambers at...*

The temperature profile is difficult to see from Figure 11. Showing the temperature and moisture profiles at important times such as 0, 1, 4, 43, 61, 69, 281, and 2000 hr would help to clarify the water and heat flow in the mesocosms. Setting the lower chamber to a constant temperature and establishing a linear temperature profile seems to be the same as the classical soil-freezing experiments found in the literature, not a realistic boundary condition. Where is the innovation mentioned at Page 5391, Line 8?

3.2 Soil freezing characteristics: SFC changed with bulk density; TDR readings were affected by the high ice content. These issues should be fixed before approximating the SFCs as a single curve, which is actually useful for numerical studies. As mentioned by Low, the SFC conforms to a single curve at equilibrium. However, some data at depths that froze rapidly (for example, 5 cm in M1 and 5 and 55 cm in M4) suggest behavior under non-equilibrium states.

Figure 5, 7, 8 9, 10: Figures 5, 7, 8, 9, and 10 show mostly the same data. Consider reducing the number of graphs. Similarly, Figures 4 and 11 can be combined.

C2829

Page 5397, Line 25 et seq.: The unsaturated hydraulic conductivity is important to water flow. How much higher would the hydraulic conductivity need to be to explain the difference? Quantitative discussions are preferable. Additionally, are there any influences from the water table difference?

Page 5397, Line 27: To indicate water flow, profiles are more useful than SFCs. It is difficult to see the flow rate and direction using SFCs only.

Page 5398, Line 3: *Freezing reduces the soil pore pressures significantly due to changes in surface tension, temperature sensitivity of contact angles and increase in volume as water transforms to ice*

Freezing reduces pore-water pressure because soil retains the unfrozen water (e.g., Dash et al. 1995). The effects of surface tension and contact-angle changes are minimal. Volume expansion from water to ice increases pore pressure.

Page 5398, Line 8: *...must have resulted from potential gradient*

How great a potential gradient can cause the loss of water from the 25-cm depth interval?

Page 5398, Line 17: As it is difficult to see the detailed temperature profile in Figure 11, water flow can not be estimated with the freezing state, potential gradient, and hydraulic conductivity.

Page 5398, Line 26: *extremely low hydraulic conductivities* How much? Low water content in the deeper layer would also affect the lower water flow.

C2830

Page 5399, Line 16: ...*extended to peat* What differences between peat and soil can extend the established theory?

Page 5399, Line 26 to Page 5400, Line 3: The relationship between the figures and hydraulic conductivity is not clear.

Page 5400, Line 8: This could indicate water evaporation or sublimation from the mesocosms. However, there was no evidence of vapor flow in the mesocosms, as we are unsure where evaporation occurred during the experiment.

3.4 Soil temperature and frost propagation

The thermal conductivity and latent heat are important to heat flow. How did the thermal conductivity of the peat used in this experiment change? What were the observed influences of the lower boundary condition on heat flow? Quantitative discussions are preferred.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 8, 5387, 2011.