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Interactive comment on "Microtopographic control on the ground thermal regime in ice wedge polygons" *by* Charles J. Abolt et al.

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Thank you very much for your feedback on our paper! After reading your concern about whether our results are relevant to ice wedge cracking, we revisited the literature on the topic. Below we present a more detailed review to contextualize our results, which we will include in the Background and Discussion sections of the next version of the manuscript.

The rule of thumb we cite – that cracking is possible when ground temperatures are below 13°C and cool at a rate of at least 0.1° d-1 for two days or more – comes from Morse and Burn (2013). A similar rule appears in Kokelj et al. (2014). In both cases, these conditions are presented as applying to the "top of the permafrost," without

specifying beneath which part of the polygon. These rules of thumb were established by reviewing a number of prior field investigations in which thermal conditions were monitored at the time of cracking. In some of these investigations, the focus was on temperatures at the top of the ice wedge (Christiansen, 2005; Allard and Kasper, 1998), while in others, temperature was monitored at the top of the permafrost beneath the polygon center (Fortier and Allard, 2005).

These studies, like all recent research on ice wedge cracking, are grounded in the foundational mechanical analysis of Lachenbruch (1962), who used a visco-elastic model of thermal strain in permafrost to determine that cracking is most likely when the permafrost is already cold, and the rate of cooling is rapid. Lachenbruch's analysis assumed uniform temperatures with depth, so that the horizontal stress at a point is a function of lithostatic pressure and the cooling history of the ground. The situation, as you point out, is more complicated if winter temperatures are non-uniform at the upper boundary of the permafrost. After an extensive literature search, we can find no mechanical analysis that quantifies the extent to which thermal contraction at the center of the polygon contributes to the stress experienced by the ice wedge when the wedge remains warmer. However, we can find several studies which either imply or demonstrate that alterations to thermal conditions at the periphery of the polygon are sufficient to change cracking behavior. For example:

- Mackay (1993) writes that the stresses that drive ice wedge cracking in low-centered polygons probably originate "spatially more in the area beneath the ridges, rather than in the areas beneath the polygon centres."

- Watanabe et al. (2017) write that ice wedge cracking activity at Svalbard is most common where "snow-free well-developed polygon rims further intensify the cooling of the active layer."

- Burn (2010) found that cracking in a previously inactive ice wedge was reinitiated after removing grasses that had been growing in the trough, thereby reducing snowpack above the wedge.

- Burn (2004) also writes that, in general, “Troughs are sites of preferential snow accumulation, so that wedges beneath well-developed troughs are relatively warm and rarely crack.”

- Finally, Lachenbruch (1962), in the conclusion of his mechanical analysis, suggests that ice wedge cracking may be suppressed “by increased winter snow accumulation in deepening interpolygonal troughs.”

Our model takes this previous work as motivation for studying the sensitivity of permafrost temperature at the edge of the polygon to rim size and trough depth. Although we acknowledge that we cannot infer thermal stresses or probabilities of cracking from the results of our study, we use the previous research on ice wedge cracking as a precedent to forecast the overall effect on cracking activity as high-centered development effectively increases the insulation of ice wedges. In this light, we believe it is fair to project that thermokarst development likely has an inhibiting effect on cracking.

Regarding the temperature at the bottom boundary of the model, we will update our manuscript to cite Romanovsky’s data set, which is located very close to our field site. The estimate of temperature at 50 m depth in Romanovsky’s data set (-6°C) varies slightly from the number we used from Clow’s data set (-8°C). When we updated the bottom boundary condition in our 2D simulation based on unaltered field site topography, the minimum winter temperature at the ice wedge increased slightly, by $\sim$0.3°C. We are currently re-running our entire ensemble of simulations, and will update the results in the next version of the manuscript.

The Noah land surface model we refer to is used by NASA to estimate surface conditions in the Global Land Data Assimilation System (Rodell, 2004).

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