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Discussions

Interactive comment on "Pathways of ice-wedge degradation in polygonal tundra under different hydrological conditions" *by* Jan Nitzbon et al.

Anonymous Referee #2

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This paper presents novel model developments to account for effects of ice-wedge polygon formations in permafrost regions. The scheme is a tile-based approach applied to the CryoGrid3 Land Surface Model which is evaluated against data from a field site in the Lena River delta, and then effects of different hydrological conditions are investigated. The paper is well written, clear, highly relevant and generally complete. However, some details of model need further clarification, and some aspects of the study can be improved, which should only require moderate effort to address.

Clarifications are needed regarding what is actually meant by micro-topography in the context of the model implementation. The tile-based approach, although elegant, is nonetheless representing a multitude of polygons as a single aggregated, effective polygon system. This means many effects of micro topography within the grid cell are

averaged out. This may cause confusion because micro topography effects may be interpreted to refer to the dynamics actually occurring within and between individual polygons in a cluster. This scale of the dynamics does not appear to be represented by the tile-based approach. Also, it is not clear if/how the scheme can be used for clusters with initially mixed HCP/ICP/LCP polygons, which might be relevant for regions where the intended spatial discretization scale of the LSM encompasses two or all three of the polygon categories.

Treatment of water flow is rather simplistic. Groundwater flow is greatly affected by hydraulic conductivity, which is notoriously heterogeneous and varies greatly for different textures and is also challenging to estimate in the field. The value for K shown in Table 2 is quite large and seems to be taken for granted. No uncertainty or error estimate is provided, which is unusual for hydraulic conductivity measurements. A parameter sensitivity study for K would therefore be useful and could provide more insight to the impact of hydrological flows, and in turn, their potential impact on soil T, WT, etc. in the polygon formations.

The assumption of near-instantaneous/rapid vertical water flow might be overly simplistic. (Section 2.2.3, Fig 3). Although hydraulic conductivities of upper soil horizons applicable to the active layer may be high, unsaturated flow is largely dictated by non-linear soil moisture retention curves. Even a small change below saturation can lead to a large decrease in hydraulic conductivity, for some textures by several orders of magnitude, thereby yielding very slow flow rates. Thus, the rapid vertical water flow assumption may be questionable. This may be important because water flow can carry heat through advection, both vertically and laterally, and if near-instantaneous infiltration is assumed, overly non-conservative heat advection may result.

Results, eg Fig 13: The system behavior is greatly controlled by the external boundary condition (the external reservoir). How realistic is this as a BC? A natural hydrological BC is the catchment boundary which would typically be considered no-flow for water, and then internal features such as lakes/reservoirs would be dynamic, resulting from mass and energy balances including surface and subsurface flows in the catchment. I understand the reservoir concept is used in the study to investigate effects of different hydrological conditions, but it seems this is a somewhat artificial constraint inherent in the model.

Heat flow, Section 2.2.4, Eqn 4 and B1. Eqn B1: How is the thermal conductivity of individual tiles at cells i obtained? (k_alphaˆi and k_betaˆi) Are they a function of the thermal properties of water and ice and soil grains (Table D1, but not apparent in equation B1)?

P11 L19-21: Dry insulating layer – how is this represented in the model? Specifically, how does moisture and air (dryness) influence the thermal properties? I note thermal conductivity of air (or vapor) is not listed in Table D1, nor apparent in eqn B1. See also questions above.

P7 L14-21, Fig 2: Does this mean that all troughs of all polygons are perfectly connected, leading to the same dynamics for all polygons in the grid? Also e.g. Section 2.3.2, Section 2.3.6 – Micro topography is not really represented, it seems all polygons are represented by an single effective polygon-rim-trough system. There is no variability in the dynamics within the multiple and generally diverse polygons as depicted in Fig 2a and 2b.

P11 Section 3.1: Good that full details of the data set is cited but it would help us to know briefly how extensive the data set is, especially how many vertical profiles measuring soil T, moisture, WT etc., exist for each of the different micro-topographic units of the polygonal tundra site. Or is there only one vertical profile per unit type (polygon center, rim, trough)?

Not clear what statistics the error bars represent in e.g. Fig 5 and others. Are these statistics over multiple profiles for each site type, or measurement error, etc.?

P6 Eqn 4: Please clarify what cells i refer to, e.g. vertical discretization.

P7 Eqn 5 and Eqn 7: There is no cells i notation in the Darcy formulations, is this intentional?

P27 Eqn A1: Seems "1" should be cell index "i" to be consistent, typo?

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