Response to comments by Anonymous Referee # 1

Before starting the point-by-point response, we would like to sincerely thank the reviewer for the thorough and insightful evaluation of our manuscript. We greatly appreciate the time and effort invested in providing detailed and constructive feedback, which will be very helpful in improving the manuscript should we be invited to submit a revised version.

Please note that, in the responses below, the reviewer's comments are reproduced in red letters, followed by our replies in black text. Here, we repeat our initial response in italics and newly edited text in standard font. Finally, the modified passages in the manuscript are given in blue.

Major Comments

1. In the sub-sections in 2.3, it would be nice to have a bit more discussion on how the simplifications would be expected to compare to a fully distributed model run at a higher resolution with more robust physics. I am not asking the authors to run a higher resolution to compare to, but rather would like some discussion on how the simplified equations here compare to more robust physics based solutions to these various fluxes (that may be computationally impractical), and/or to the core model simply run at a high enough resolution to consider these flows (and if this is even possible or if these represent processes that would be important even at higher spatial resolutions). This qualitative discussion would also open up an opportunity to highlight the computational benefit compared to what would be needed to fully represent these processes on a typical grid.

We would be happy to provide some discussion concerning the question of tiling in comparison to high resolution. In general, our main motivation for designing the scheme was that it may provide a perspective on a level beyond even ultra-high-resolution setups, e.g. the patterned ground of the second example or the surface depressions in the first example, often feature typical length-scales of tens of meters, yet may be extremely relevant for the hydrological conditions and the thermophysical state of the surface. Thus, we always thought of it as being complementary to rather than in competition with high model resolutions. However, given the abilities of most current-generation land surface models, we would argue that in many ways our scheme is advantageous even for landscape features that can be resolved explicitly and not only with respect to computational demand. Here, a key issue is that most land surface models do not represent any lateral exchange between grid-cells other than river discharge. This means that, by explicitly resolving certain features that, in reality, form a connected landscape the results may actually become less plausible. If, for example, uplands and slopes of a catchment are located in one grid cell and the lowlands in the next, it is quite likely that the lowlands would be too dry without the (sub-) surface runoff coming from the slopes, pos-

sibly resulting in an underestimation of evapotranspiration on the catchment-scale. Having, these features in the same coarse resolution grid cell and instead representing them by laterally connected tiles may therefore provide a more realistic picture of the overall energy and moisture exchange with the atmosphere.

Here, we included a paragraph discussing the (dis-) advantages of surface tiling, relative to high resolution simulations. However, we felt that it would be more appropriate as an opening to the discussion section, rather than as part of section 2.3:

Rapid increases in feasible model resolutions raise the question of whether further development of statistical representations of land-surface heterogeneity and the associated lateral fluxes is still warranted. But while much of what we consider macro-scale spatial heterogeneity is already, or can soon be, explicitly resolved even in multi-decadal simulations, many micro-scale structures – such as the surface depressions or patterned ground considered in our example applications – have characteristic length scales that are orders of magnitude smaller than feasible grid resolutions. Moreover, the ability to resolve landscapes at increasingly fine spatial scales does not necessarily imply that interactions between connected landscape elements are well represented in the models. In fact, the standard configurations of most current-generation land surface models lack an explicit representation of lateral exchanges between grid cells (beyond river routing), and only a few research extensions and coupled frameworks implement such lateral interactions (Qiu et al., 2024). Importantly, increases in horizontal resolution also raise computational costs exponentially: for example, refining resolution from a 100-km- to 1-km grid spacing increases the number of grid cells by a factor of 10,000, whereas the computational demand associated with a more complex statistical representation of surface heterogeneity scales approximately linearly with the number of additional tiles. Consequently, increasing spatial resolutions and more sophisticated tiling approaches may each be more suitable to address different research questions and will likely remain complementary strategies for representing land-surface heterogeneity in the foreseeable future.

2. 2.2.1: Why are circles chosen as the characteristic shape as opposed to, say, rectangles where the shape can be preserved in the n-nested case? Rectangles also would follow the underlying grids informing the tile setup more naturally. Are there presumed issues with the rectangle format? The authors point out some potential issues with the choice of circles, namely the nested setup. I find the potential errors that result from different assumed shape to be concerning; could this be significant? If there is a valley, for example, would the different assumed shape depending on the connection create long term inaccuracies? Would it result in quicker or slower draining of the ridges to the valley? How big are these issues?

The circular geometry was chosen mainly because it is possibly the least bad option for many landscape features such as the patterned ground targeted in our second example or smaller lakes and ponds. Here, the problem with the higher-level nested setups doesn't necessarily arise from the assumed circular shape, but rather from nesting itself, that is having a patch inside another patch, inside another patch, inside . . . , since the contact length and center-to-center distance at nesting level n *depend on the characteristic areas of all tiles on nesting levels* 1 *to level* $n-1$. *Obtaining this information is, unfortunately, not all that straightforward, due to certain infrastructural choices we had to make in the model. If the need to run higher-level nested* *cases arises, it is, therefore, not impossible to adapt the model, but it will require a good amount of work. With the present limitations, the errors for a nesting with more than 3 levels could become very large, because the diffusive fluxes scale linearly with the contact length for two connected patches and are inversely proportional to the centre-to-centre distance, with both of these properties depending directly on the assumed shape of the patches. In a ridge-to-valley example that employs more than three tiles – e.g. ridge, upper slope, lower slope and valley bottom – the drainage would be too slow mainly because the scheme would overestimate the flowpaths and underestimate the interface areas between slope-low, slope-high and ridge.*

In a revised manuscript version we would be happy to discuss the above issue in more detail, and also provide an outlook on how the geometry assumptions could be made more flexible to better approximate the fluxes between non-circular patches, e.g. using (tile- and grid cell specific) shape-factors (S_1; S_2) in the key ratios of perimeter (C) and radius (r): $C = r \cdot 2 \cdot pi \cdot S1$ and radius and area (A): $r = (A \cdot pi)^{0.5} \cdot S2$.

Here, we included the following paragraph in the discussion section:

There are, however, certain aspects which limit the degree of realism that can be achieved with the present implementation of the scheme. One of these is the assumed circular shape of the subgrid scale patches. The representation of the patch geometry in the spatial relationship module is necessarily a simplification, which has important implications for the simulated lateral exchanges. The lateral fluxes depend on the characteristic dimensions of the adjacent patches, and any assumption about their shapes will influence the magnitude of the fluxes: The diffusive fluxes scale linearly with the contact length between two connected patches and are inversely proportional to the center-to-center distance, while subsurface runoff is proportional to the slope, which depends on the height difference between adjacent patches relative to the center-to-center distance. In the present implementation, the circular geometry was chosen as a pragmatic compromise, as it provides a reasonably general approximation for many landscape features, including small lakes, ponds, and patterned terrain, while allowing the patch dimensions to be described by a single parameter, the characteristic area, which can easily be determined from high-resolution observational data. For highly elongated or irregular features, however, these assumptions may lead to over- or underestimation of the lateral fluxes by up to an order of magnitude, potentially affecting the ability of the fluxes to equilibrate the states of neighboring tiles (see 3.2). To overcome these limitations, future developments could improve the flexibility of the scheme by introducing (tile- and grid-cell specific) shape factors (S_1, S_2) in the key ratios of perimeter (C) and radius (r):

$$C = 2\pi r S_1 \tag{1}$$

$$r = \sqrt{A/\pi}\, S_2, \tag{2}$$

where A is the area of the tile.

3. I am not immediately convinced that the given approach would be appropriate for snow, whose redistribution will likely be driven substantially by wind which is excluded from both the scheme itself and the definition of the connectivity matrix (i.e. if the wind usually flows along the boundary between two tiles, the effective connectivity would be very low compared to a situation where the wind flows directly tile to tile).

Is there any evidence that the redistribution of snow is simply elevation based? How strong is this assumption?

What are the implications when it breaks down?

Is it a fair assumption to have it entirely independent of wind direction or magnitude?

More discussion is needed on this. If, for example, the dominant velocity is going upslope it is doubtful that snow would redistribute downslope. If velocities are very low, snow redistribution will be radically different from high velocities. Are tiles, and connectivity, designed for vegetation and subsurface flow the same tiles that would be chosen if snow redistribution was the primary concern? Considering the complex physics that should be at play for snow redistribution, and the importance of wind velocity both in magnitude and direction, and the difference in processes relative to subsurface lateral flow, I think at the least additional background information is necessary in this section to justify this decision, and significant discussion on the implications for complex terrain, different meteorological conditions etc. The snow redistribution method is not seriously considered in the results either. Overall, the snow part feels relatively poorly considered compared to the other sections on lateral connections for heat and liquid water and relies on very different fundamentals (i.e. atmospheric boundary layer becomes important, wind is important, obstructions such as vegetation become important) compared to heat/liquid water. This difference in fundamentals requires much deeper thought and discussion into snow that is not included here. I would encourage the authors to either be much more thorough in the discussion/determinations/limitations of snow processes or, likely better for a succinct publication, save this for a future publication where more background research, justification for the scheme, details on limitations, results focused on the impacts of this process and perhaps a scheme that considers velocity can be included.

We thank the reviewer for this detailed comment and admit that the snow redistribution scheme neglects many factors that determine the real-world process in a large number of settings. As a result, its applicability is very limited, which we would discuss in more detail in a revised version of the manuscript.

The reason why the scheme neglects many of the real-world factors is that it is exceedingly difficult to account for the wind direction in our modeling approach. And without the latter, it is at least arguable whether including a wind-speed scaling would notably improve the model. Instead we decided to employ an approach that neglects the near-surface winds entirely. The inability to account for the wind direction stems primarily from a structural limitation of ICON's land-surface component. Subgrid tiles coexist statistically within a grid cell but are not spatially arranged explicitly; therefore, the model does not *"know" the relative orientation of tiles and cannot diagnose whether wind preferentially connects specific tile pairs or how the connectivity would be for a given wind direction. This would require assumptions about subgrid spatial organization that are not represented in the current framework. Here, it is conceivable to derive such information in the pre-processing and then use direction-specific connectivity matrices in the model. However, while we agree that a more physically complete treatment of wind-driven snow transport is highly desirable, we fear that we do not have the resources to work on this shortcoming in the foreseeable future.*

The elevation-based redistribution is therefore a first-order simplification whose applicability is limited to a subset of surface heterogeneity. It implicitly assumes that the patches represented by the tiles are sufficiently interspersed for the snow redistribution to become independent of the wind direction. We therefore only apply the snow redistribution in case of the micro-scale heterogeneity for which a certain randomness in the distribution may be a permissible assumption.

In the methods section we added the following paragraph to the description:

This is a first-order simplification that neglects key factors such as wind direction and speed, which are critical drivers of real-world snow transport. This is mainly because of the structural design of the land-surface component, where subgrid tiles coexist statistically within a grid cell but are not explicitly spatially arranged. Consequently, the model cannot determine whether wind preferentially connects specific tile pairs or how fluxes would vary with wind direction. As a result, the present implementation cannot be used for the snow transport on the macro-scale but only for micro-scale heterogeneity where the relative arrangement of tiles is sufficiently random for snow transport to become approximately independent of wind direction (see Dicussion). For such conditions however, this elevation-based redistribution can at least account for the preferential deposition of snow in microscale depressions (Clark et al., 2011).

And the following paragraphs were added in the discussion section:

Another problematic aspect is the highly simplified approach to incorporate snow redistribution. In natural landscapes the latter is a complex process, driven by a combination of topography, snowpack properties, vegetation, and especially near-surface wind direction and speed (Clark et al., 2011). Land surface models typically do not represent this process explicitly but some do account for topographic variability when relating (grid-cell mean) snow water equivalent to the snow cover fraction, though not in a way that takes into consideration wind speed or direction (Roesch and Roeckner, 2006; Ma et al., 2019). Similarly, simple topography-based schemes have been employed successfully in previous studies, to account for the effect of snow redistribution between microtopographic features in permafrost landscapes (Aas et al., 2019; Nitzbon et al., 2019; Smith et al., 2022). However, while these approaches may work sufficiently well on the micro-scale, it can be argued that for the hillslope scale the wind direction may no longer be ignored where drifting leads to preferential deposition in the lee of elevations and on sheltered aspects, making them less suitable for the macro-scale transport.

While the current snow redistribution scheme is based solely on differences in surface elevation and neglects near-surface wind effects, it is conceptually possible to extend the approach to account for wind direction and magnitude. In principle, direction-specific connectivity matrices could be pre-computed during the model setup, reflecting the preferential pathways for snow transport under prevailing wind directions. Furthermore, the connectivity between two tiles could be scaled according to the fraction of the boundary aligned with the wind in combination wind-speed-dependent redistribution functions which could, for example, be derived by running dedicated snow pack and snow drift models (Quéno et al., 2024). However, while a wind-aware formulation is feasible in principle, it is beyond the scope of the current study and is left as a potential avenue for future model development.

4 Minor Comments

Figure 4 and lines 243-250: I find this a bit unclear. I understand the tile refined grid, but it definitely takes some work and staring at the image. I would consider trying to do this with a more simplified grid example. In particular, it is hard to understand what tile grid levels are interacting with what sibling grid levels.

We will try to reduce the complexity of Fig. 4 without loosing any of the key information.

Here, we mainly redesigned figure 4 to use colors to indicate the corresponding layers on two connected tiles, and reduced the number of soil layers shown in the schematic (see Fig. 1 below):

Figure 4: it appears as though no water is flowing into the bottom level of the sibling native grid, if I am correct in interpreting the color scheme. This implies that the water in the tile would not flow along the bedrock. Does this introduce errors? Particularly in arid locations with a high elevation gradient? In an extreme case, one could even imagine a saturated zone with an unsaturated zone beneath it if horizontal flow is large, and subsurface is dry. Perhaps I am not understanding this correctly; I would appreciate clarification.

This is correct and we hope to clarify the description accordingly. However, we could not find any sign of this leading to large errors, because the vertical transport subsequently redistributes the water within the column, with (downward) percolation being a key driver.

Here, we clarified that the refined grid is only used to calculate the diffusive exchange between two tiles and to transport the micro-scale below-ground runoff. The macro-scale below ground runoff is transported on the tiles regular grid, meaning that

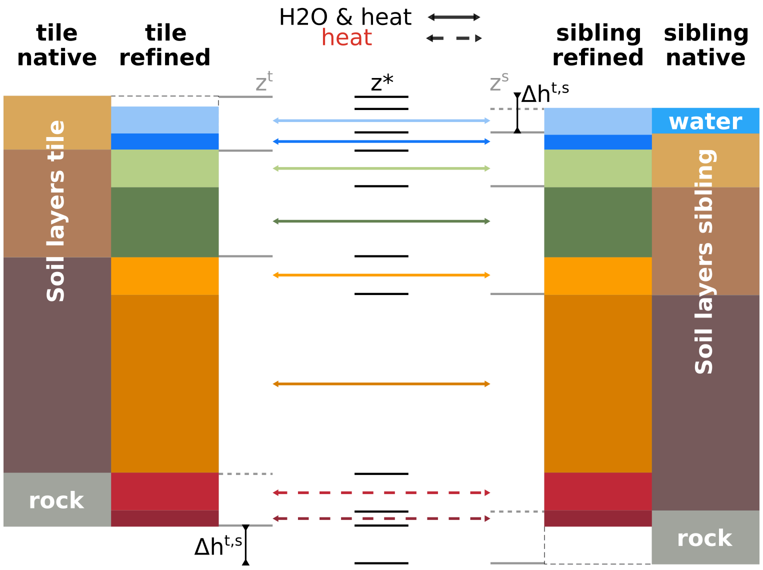

Figure 1. Refined vertical grid
Shown is the vertical grid used by the model to determine the diffusive and convective fluxes between two (micro-) connected tiles. This refined grid z^* encompasses all the layers of the vertical grid on the tile z^t and the layers in the vertical grid on the sibling tile z^s shifted by $\Delta h^{t,s}$ the height offset between the two. Colors indicate corresponding layers on the tile and its sibling, both on the native and on the refined grid.

surface runoff generated in the soil layer above the bedrock boundary is also added to the lowest layer of the tile receiving the runoff, essentially mimicking flow along the bedrock.

In the section describing the vertical grid we added:

This refined grid is also used to map the below-ground runoff on the micro-scale between two connected tiles, while the below-ground runoff on the macro-scale is being transported between two interfacing layers on the tiles' native vertical grid (see sec. 2.3.2).

In the section describing the transport of runoff we added:

In case of macro-scale connections, the height offset is being ignored to retain consistency with our assumptions on the vertical movement of water with the soil column, in particular allowing the water to flow along the bedrock boundary within the grid cell:

$$\theta^s_{upd,i} = \theta^s_i + R^{t,s*}_{blg,i} \cdot \Delta t. \quad (3)$$

Line 65: Error in this phrase; “Max Planck Institute for Meteorology’s- and the AWI Earth System . . . “

Will be corrected.

Here, we changed the formulation to:

... in JSBACH3 the land surface component of the Max Planck Institute for Meteorology’s MPI-ESM and the Alfred Wegener Institute’s AWI-ESM.

145-150: I find this confusing; are the authors saying that the connectivity matrix is then weighted by the area of the tile? Wouldn’t this be problematic for, for example, a riparian zone tile which may be long and skinny and therefore have a small area but large contact perimeter?

We apologize if this formulation was somewhat misleading. This optional formulation does not change any of the geometrical assumptions made for a given tile A. It merely determines the degree to which tile A is assumed to be connected to a sibling B instead of sibling C, based on the (relative) fraction of the grid cell that is covered by each of the siblings. It is therefore only relevant for tiles that are connected to more than one sibling, e.g. the riparian zone being similarly connected to a lowland-ridge and a low-land depression tile. In such cases the characteristic connectivity can be weighted by the respective cover fractions to avoid extreme situations, e.g. that 50 % of floodwater from the riparian zone flows onto the lowland-depressions even though these only cover 1% of the lowland area in a specific grid cell, while the lowland-ridge tile occupies 99% of the lowlands.

Here, we changed the description to the following:

As stated above, the characteristic connectivities $c_{ctc}^{t,s}$ alone may not be sufficient to accurately describe the effective connectivity between a tile and a sibling within a specific grid cell, particulalrly for tiles with multiple connections. Here, an important factor that is being neglected is the relative abundance of the connected siblings within the cell which, for many factors, can be regarded as a reasonable proxy for the likelihood that a larger fraction the tile is connected to a specific sibling rather than to the other siblings. Thus, neglecting the grid-cell composition can produce highly implausible fluxes – for example, a sibling occupying 70 % of the area may receive only half of the runoff generated on the tile, while a second sibling also receives half of the runoff but occupies only 1 % of the grid cell. To avoid such situations, the effective connectivity is assumed to be proportional to the relative abundance of the connected sibling within the cell. In the standard setup, this is implemented by weighting the characteristic connectivities by the cover fraction of each connected sibling (fc^s), while preserving the overall geometric assumptions of the original connectivity matrix:

$$c^{t,s}_{ctc*} = \frac{c^{t,s}_{ctc} \cdot fc^s}{\sum_{k=1}^{nct} c^{t,k}_{ctc} \cdot fc^i} \cdot \sum_{k=1}^{nct} c^{t,k}_{ctc}. \tag{4}$$

This weighting is optional and only relevant when a tile interacts with multiple siblings and, if the connectivity between tiles is inherently independent of the grid cell composition, $c^{t,s}_{ctc*}$ can simply be set equal to $c^{t,s}_{ctc}$.

Lines 580 – 581: A few too many dashes used in place of commas or other separation words which makes it a bit confusing.

Will be corrected.

The formulation was changed to:

This discrepancy arises because the terrestrial water storage and the latent heat flux are not only limited by the available water, with former being additionally limited by the pore volume and the potential depression storage and the latter by the available energy.

Does the subgrid scheme you have implemented increase or decrease subgrid variability in heat/moisture fluxes and soil moisture? We see this for temperature, but not for moisture or the surface fluxes (perhaps I missed this). Does this, qualitatively, match the expectations from remote sensing etc.? I ask particularly in reference to land-atmosphere interactions (which, given one way coupling, is not fully considered here). If subgrid variability is increased, as I suspect, does this pose problems for the typical flux homogenization (flux averaging/aggregation) done between the land and atmosphere given increasing work/emphasis on considering subgrid atmospheric affects driven by surface heterogeneity, such as secondary circulations? (Waterman 2025, Arnold 2024, Fowler 2024, Huang 2022) These questions cannot be fully answered with this analysis, and is not expected to be addressed, but has interesting applications in this area facing growing interest.

In general, the diffusive and conductive fluxes reduce the subgrid-scale variability, while the transport of surface- and subsurface runoff predominantly increases the variability in soil moisture, surface temperature and the turbulent fluxes. So the question whether the lateral transport poses problems for the coupling of land-surface and atmosphere depends on which surface features are being resolved in a given setup. In our first topography-based example, the lateral runoff processes dominate the overall response causing a subgrid-scale variability that certainly invites a reconsideration of the concepts that most flux aggregation approaches are based on: At least in cases in which the tiles represent kilometer-scale patches, the assumption that the vertical fluxes within a grid cell have become horizontally homogeneous at the height of the lowest atmospheric model level (often less than 50m) is highly implausible. However, ICON, as most ESMs, is not equipped to represent spatial subgrid-scale variability within the atmosphere so we couldn't say wether this commonly made blending height assumption introduces mean-

ingful biases. We only tested whether the increased spatial variability leads to technical issues, such as the model becoming instable, which fortunately did not appear to be the case.

In light of the length of the discussion section we chose not to address this issue in the manuscript. In general, we very much agree with the reviewer on the importance of these questions, but, given the limitations of our model and the fact that we ran-land only simulations, we feel that our study does not directly contribute to answering them.

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Response to comments by Anonymous Referee # 2

We thank the reviewer for the careful and thoughtful assessment of our manuscript. We appreciate the constructive and detailed comments, which will help us to improve the clarity and scope of the paper.

Please note that, in the following point-by-point response, the reviewer's comments are reproduced in red letters, followed by our replies in black text. Here, we repeat our initial response in italics and newly edited text in standard font. Finally, the modified passages in the manuscript are given in blue.

Major Comments

1. The scheme relies on fixed characteristic connectivities between tile types. It is unclear how these should be specified for real landscapes. In particular, equation 1 for the weighted connectivity c(t,s) is hard to understand from the text alone. The authors should consider clarifying this concept, as it is vital to the methods that follow. It would strengthen the paper to include an example or add an appendix including it.

We fully agree with the reviewer that – in addition to clarifying the descriptive text – examples constitute a straightforward way to make the concept of the connectivities more readily accessible for the reader. Here, our idea would be to provide the connectivity matrices for the two example applications that are already included in the manuscript, detailing how they were derived for the specific tile-definition. With respect to the question how this would be specified in real landscapes, please see our response to the third comment.

In an attempt to clarify the connectivity concept, we started the respective section with a modified paragraph:

Representing subgrid-scale heterogeneity in land-surface models requires balancing realism with computational complexity and -demand as well as with the availability of data needed to describe interactions between surface elements. In this first T-REX implementation, this trade-off is addressed by adopting a tiling approach that focuses on a small number of generalized landscape elements whose interactions follow a broadly applicable physical logic. Consequently, it is most naturally suited to simplified and idealized tile configurations and not necessarily designed to capture every aspect of spatial heterogeneity that may be important for a specific region. Instead, it targets landscape elements that are expected to play a key role across a wide range of environments, and whose interactions follow a consistent structural logic that can be applied throughout the model domain. This approach allows T-REX to start from simple configurations that are straightforward to set up for idealized cases (see sec. 3.1, 3.2) while providing a framework that can be extended to increase the degree of realism in future simulations (see sec. 4).

The main requirement of T-REX is that the relationships between any two tiles must be describable by a set of characteristic connectivities that reflect their interactions reasonably well. For example, surface runoff generated on elevated terrain will generally flow toward surrounding lowland areas via slopes, suggesting that any grid-cell can be subdivided into elevations, slopes and lowlands, with elevations being hydrologically connected to the slopes which in turn are connected to the lowlands.

Furthermore, we now provide the connectivity matrices for the two test cases and a short overview over the respective assumptions. For the first test case the description and matrices are:

Here, the logic of the tile definition provides the following characteristic connectivities, assuming that the depressions, both on the uplands and lowlands (DU,DL), are fully surrounded by and receive the runoff from relative elevations (EU, EL) and that the surface runoff from the uplands occours via surface channels that are primarily connected to lowland depressions, while the below-ground runoff similarly constitutes inflow to the lowland elevations and depressions (with the actual connectivity being determined by the cover fractions of the two lowland tiles):

$$\mathbf{c}^{\mathbf{t,s}}_{\mathbf{ctc}} = \begin{array}{c} \\ EU \\ DU \\ EL \\ DL \end{array} \begin{array}{c} \begin{array}{cccc} EU & DU & EL & DL \end{array} \\ \begin{pmatrix} 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \end{pmatrix} \end{array}$$

$$\mathbf{c}^{\mathbf{t,s}}_{\mathbf{hfp,micro,srf}} = \begin{array}{c} \\ EU \\ DU \\ EL \\ DL \end{array} \begin{array}{c} \begin{array}{cccc} EU & DU & EL & DL \end{array} \\ \begin{pmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \end{pmatrix} \end{array} \quad \mathbf{c}^{\mathbf{t,s}}_{\mathbf{hfp,micro,blg}} = \begin{array}{c} \\ EU \\ DU \\ EL \\ DL \end{array} \begin{array}{c} \begin{array}{cccc} EU & DU & EL & DL \end{array} \\ \begin{pmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \end{pmatrix} \end{array}$$

$$\mathbf{c^{t,s}_{hfp,macro,srf}} = \begin{matrix} & EU & DU & EL & DL \\ EU & 0 & 0 & 0 & 1 \\ DU & 0 & 0 & 0 & 1 \\ EL & 0 & 0 & 0 & 0 \\ DL & 0 & 0 & 0 & 0 \end{matrix} \quad \mathbf{c^{t,s}_{hfp,macro,blg}} = \begin{matrix} & EU & DU & EL & DL \\ EU & 0 & 0 & 0.5 & 0.5 \\ DU & 0 & 0 & 0.5 & 0.5 \\ EL & 0 & 0 & 0 & 0 \\ DL & 0 & 0 & 0 & 0 \end{matrix}$$

For the connectivities reflecting direct contact in the second example we modified the case description in the following way:

For this application, we assume circular structures, that consists of an organic-rich center (C), with a volumetric organic matter fraction of 95 % at the surface – i.e. the uppermost 0.1 m of the soil, encompassed by the rim section (R), which has a near-surface soil organic matter fraction of 35 %. These two are in turn surrounded by an outer section (O) with mainly mineral soil throughout the below ground column, i.e. an organic matter fraction of 5 % at the surface, resulting in the following connectivity matrix:

$$\mathbf{c^{t,s}_{ctc}} = \begin{matrix} & C & R & O \\ C & 0 & 1 & 0 \\ R & 0 & 0 & 1 \\ O & 0 & 0 & 0 \end{matrix}$$

and for the connectivity due to hydrological flow the manuscript now reads:

In a first step, we assume a radius of one meter, with center, rim and outer section each covering 0.33 m. Additionally, we assume the circle to be level so that there is no vertical offset between the surface of the sections. The latter may not be the most common configuration, since the circular structures often have a distinct micro-topography, e.g. an elevated center in case of a hummock-type structure, but it makes the analysis much more straight-forward, since effects due to the lateral water transport and a lateral coupling with a vertical surface offset are (largely) absent. This provides the following connectivity matrices for connections due to preferential hydrological flow paths, assuming that they are the same for above- and below-ground fluxes (note that macro-scale fluxes are not present in this particular setup):

$$\mathbf{c^{t,s}_{hfp,micro}} = \begin{matrix} & C & R & O \\ C & 0 & 1 & 0 \\ R & 0 & 0 & 1 \\ O & 0 & 0 & 0 \end{matrix}$$

for the low centered structures the connectivities due to hydrological flow paths we changed the text to:

First we focus on a low-centered circle with a 1-m radius, in which the surface of the center and outer section are both located 0.1 m below the surface of the rim, with the connectivities for hydrological flow paths being set in the following way:

$$\mathbf{c}^{\mathbf{t,s}}_{\mathbf{hfp,micro}} = \begin{array}{c} \\ C \\ R \\ O \end{array} \begin{array}{c} \begin{array}{ccc} C & R & O \end{array} \\ \begin{pmatrix} 0 & 0 & 0 \\ 0.5 & 0 & 0.5 \\ 0 & 0 & 0 \end{pmatrix} \end{array}$$

and for high-centered structures to:

For a high-centered structure, in which the surface of the circle center is located 0.1 m above the surface of the rim, which in turn is located 0.1 m above the surface of the outer section – resulting in the following connectivity:

$$\mathbf{c}^{\mathbf{t,s}}_{\mathbf{hfp,micro}} = \begin{array}{c} \\ C \\ R \\ O \end{array} \begin{array}{c} \begin{array}{ccc} C & R & O \end{array} \\ \begin{pmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ 0 & 0 & 0 \end{pmatrix} \end{array}$$

2. The spatial relationship module assumes circular patch shapes to compute center-to-center distances, as shown in equation 3. This is a substantial simplification. How robust are the results to this assumption? Many natural patterns are not circular. I would encourage the authors to discuss this decision more extensively. Additionally, the authors mention that only two-level nesting is allowed. Please discuss the implications of this decision. At a minimum, I consider that the limitations of the circular-patch assumption should be stated clearly.

Here, the reviewer is absolutely right that the circular shape is a substantial simplification with important implications for the simulated lateral exchange. The diffusive fluxes, for example, scale linearly with the contact length for two connected patches and are inversely proportional to the centre-to-centre distance (for a given temperature- or moisture difference between the pair of tiles). And both of these properties depend on the assumed shape of the patches. In extreme cases, in which the represented surface features have an elongated shape, e.g. as a plausible assumption for the floodplains along rivers, the pathways of the diffusive fluxes could easily be an order of magnitude smaller than the centre- to-centre distance based on assumed circles. And as shown by our second example case, this can make the difference between the fluxes being able to largely *harmonize the states of two adjacent tiles or not. The circular geometry was chosen for a number of reasons, first and foremost because it is possibly the least bad option for many landscape features such as the patterned ground targeted in our second example or for smaller lakes and ponds, with many physical and biogeochemical lake models making this assumption. For a broader applicability of the scheme and as future development steps, the assumptions could be made more flexible, to better represent non-circular geometries, using (tile- and grid cell specific) shape-factors (S_1; S_2) in the key ratios of perimeter (C) and radius (r): $C = r \cdot 2 \cdot pi \cdot S1$ and radius and area (A): $r = (A \cdot pi)^{0.5} \cdot S2$. Or, as an additional option, the relevant lengths could be provided directly by the user. Concerning the manuscript, we would be happy to include the above as an outlook in the discussion section of a revised version.*

Here, we included the following paragraph in the discussion section:

There are, however, certain aspects which limit the degree of realism that can be achieved with the present implementation of the scheme. One of these is the assumed circular shape of the subgrid scale patches. The representation of the patch geometry in the spatial relationship module is necessarily a simplification, which has important implications for the simulated lateral exchanges. The lateral fluxes depend on the characteristic dimensions of the adjacent patches, and any assumption about their shapes will influence the magnitude of the fluxes: The diffusive fluxes scale linearly with the contact length between two connected patches and are inversely proportional to the center-to-center distance, while subsurface runoff is proportional to the slope, which depends on the height difference between adjacent patches relative to the center-to-center distance. In the present implementation, the circular geometry was chosen as a pragmatic compromise, as it provides a reasonably general approximation for many landscape features, including small lakes, ponds, and patterned terrain, while allowing the patch dimensions to be described by a single parameter, the characteristic area, which can easily be determined from high-resolution observational data. For highly elongated or irregular features, however, these assumptions may lead to over- or underestimation of the lateral fluxes by up to an order of magnitude, potentially affecting the ability of the fluxes to equilibrate the states of neighboring tiles (see 3.2). To overcome these limitations, future developments could improve the flexibility of the scheme by introducing (tile- and grid-cell specific) shape factors (S_1, S_2) in the key ratios of perimeter (C) and radius (r):

$$C = 2\pi r S_1 \tag{1}$$

$$r = \sqrt{A/\pi}\, S_2, \tag{2}$$

where A is the area of the tile.

3. Both examples use highly idealized tiling configurations (i.e., a two-tile upland/depression split, and uniform concentric circles everywhere in the Arctic). Even though the rationale for selecting these 2 configurations is clear (i.e., testing the effects of different lateral transport processes introduced by T-REX), the results may depend strongly on these assumptions. How sensitive are the findings to these choices? It would be helpful to discuss how one would apply T REX to a more complex

tiling. Can the authors comment generally on their conclusions beyond the toy cases? Perhaps an additional test or sensitivity (even qualitative) could be suggested.

One of the fundamental limitations of the scheme, in its present form, is that it can only be applied to highly idealized tiling configurations, in the sense that the definition of the tiles must provide a set of characteristic connectivities that is globally valid. Thus, the scheme can be used to approximate real world landscapes only to that extent that these can be constructed from such idealized tiles. The four-tile upland/lowland, depression/elevation split, for example, could possibly be extended to include a floodplain tile, since it appears to be a reasonable assumption that large floodplains would predominantly be connected to the lowland tiles. In principle, these topography-based tiles could then further be subdivided based on a second property, say soil types. However, for many factors it will be very difficult to establish a globally valid logic that provides the connectivities. E.g. to which degree would lowland depressions with a coarse-grained soil material be connected to floodplain patches with loamy soils and to which degree to floodplain patches with sandy soils? For a tiling for which there is no such a globally valid logic, the only option (at present) is to assume that the tiles are randomly distributed within the landscape. In this case, a given tile could be assumed to have the same characteristic connectivity with any of the other tiles, with the actual connectivity being largely determined by the cover fractions of the tiles within a specific grid cell. This could be a permissible assumption for many land-surface characteristics such, as vegetation cover, but constructing real-world landscapes with a higher degree of realism would at least require the ability of the model to work with grid-cell specific connectivity matrices, which could be included in a future model development.

We expect the choice of the tile-configuration to have profound consequences for the results not only because it determines the geometry of the patches represented in a setup, but also the properties of the tiles. Unfortunately, we cannot really provide any robust conclusions beyond the toy cases since the application of the scheme to a less idealized setting is still work in progress. Here, our assumption is that the two key factors are hydrology and land cover, with our next goal being to (be able to) run the model with the four-tile upland/lowland, depression/elevation split and allow the model to establish the vegetation composition for the different tiles individually. Such a setup could greatly enhance the inter-tile temperature variability – shown in Fig. 5 – if, for example, the tiles with the better ability to retain water also feature a vegetation mix that transpires more readily. However, it could also reduce the variability, if the wetter tiles feature vegetation with a lower albedo than the dryer tiles, e.g. trees instead of grass.

Considering, that the manuscript is already on the lengthy side, we did not include a comprehensive discussion concerning the potential uncertainties that are connected to idealized or simplified settings. Here, it can be argued that the second case study is in fact a (very limited) sensitivity study, showing the dependency of the spatial temperature variability on the assumed patch geometries. However, with vast possibilities to set up the model for different idealized cases, a comprehensive uncertainty study appears not to feasible and these should be assessed for specific setups individually. Concerning suitable strategies to increase the level of realism in possible future setups, we included the following paragraphs in the discussion section:

The showcases discussed above represent highly idealized applications that focus on a small number of surface and soil characteristics. The scheme is, however, not necessarily limited to such configurations, and more realistic cases can be constructed utilizing its infrastructure. One way to extend the approach to increasingly complex landscape representations is to use a more extensive tiling configuration that captures a broader range of surface heterogeneity while still providing consistent descriptions of the relationships between tiles. For example, the topography-based tiling used here could readily be expanded to include additional (quasi-) topographic landscape elements, such as floodplain tiles that predominantly interact with lowland areas. Tiles could also be further subdivided according to additional properties such as soil type or vegetation. However, defining globally applicable connectivity rules describing tile interactions becomes increasingly difficult as the number of tile characteristics increases. In the absence of such rules, one might assume a random distribution for certain characteristics within a grid cell, implying that the respective connectivities could be treated as being proportional to the cover fractions of the tiles. In many cases, however, this would be a poor approximation. Achieving higher degrees of realism with such a strategy would therefore require additional flexibility in the treatment of tile connectivities, and incorporating grid-cell-specific connectivity matrices derived from external data describing landscape structure represents a natural direction for future model development.

Another strategy, which is already feasible with the current model capabilities, is to define tiles primarily by their characteristic connectivities rather than by specific surface or soil properties. In this case, the connectivities between tiles are globally uniform, while the land-surface characteristics associated with each tile may vary between grid cells. All tile properties, including vegetation, soil parameters, and cover fractions, can be provided to the model individually for each grid cell. High-resolution data could therefore be used to identify areas within a grid cell that, due to their relative position and topographic setting, are likely to interact with their surroundings in a way that matches the connectivity pattern prescribed for a given tile type. For example, a tile A may always interact with tiles B and C in the same prescribed manner, while the surface properties associated with these tiles differ between grid cells. In one grid cell, tile A might represent shrub-covered areas on loamy soils covering only a small fraction of the grid cell, while tiles B and C represent forest and grassland areas on predominantly sandy soils. In another grid cell, tile A could instead occupy a much larger fraction of the landscape and consist mainly of bare ground, while tiles B and C represent wetlands and shrublands. In this way, the connectivity structure remains fixed, while the land-surface characteristics associated with each tile can vary across the domain.

4. In the new tiling structure, many associated parameters are introduced (e.g., characteristic elevations, areas, contact fractions, connectivities, slopes, etc.). The manuscript should explicitly list the variables. Some guidance, or even just a table, with parameter definitions would improve clarity. This is especially important since the formulations presented in equations 3 to 5 can be confusing without context on the variables used.

We would be happy to provide such an overview table in a revised version of the manuscript.

Here, the following table was added to the manuscript as an appendix:

Table 1: T-REX Variables Overview:

Symbol	**Definition**
Tile Connectivities & Geometry (Sec. 2.1 - 2.2)	
A^c_*, A^o_*	Combined area of inner + middle tiles and adjusted area of outer tile based on cover fractions
A^i, A^o	Characteristic area of inner tile t^i and outer tile t^o
$c^{t,s}_p$	Characteristic connectivity between tile t and sibling s for process p
$c^{s,t}_{ctc+}, c^{s,t}_{ctc+}$	Modified connectivity for slope weighting; using connections with either positive or negative offsets
$c^{t,s}_{ctc}$	Connectivity due to direct contact (fraction of tile boundary of t interfacing with sibling s)
$c^{t,s}_{ctc*}$	Weighted connectivity accounting for cover fractions of connected siblings in the grid cell
$c^{t,s}_{hfp,macro,blg}$	Macro-scale below-ground connectivity for hydrological flow paths
$c^{t,s}_{hfp,macro,srf}$	Macro-scale surface connectivity for hydrological flow paths
$c^{t,s}_{hfp,micro,blg}$	Micro-scale below-ground connectivity for hydrological flux flow paths
$c^{t,s}_{hfp,micro,srf}$	Micro-scale surface connectivity for hydrological flow paths
$d^{i,o}$, $d^{m,o}$	Center-to-center distance between inner and outer tiles and between middle and outer tiles
f^i_c, f^o_c	Cover fractions of inner/outer tiles for nested calculations
f^t_c, f^s_c	Cover fraction of tile t and sibling tile s in a grid cell
m^t	Effective slope of tile t combining macro- and micro-scale slopes
m^t_{mac}, $m^{t,s}_{mic}$	Macro-scale slope of tile t and micro-scale slope between two tiles
t^i, t^m, t^o	Inner, middle (in a nested configuration) and outer tile in micro-scale connections
$l^{i,o}$, $l^{m,o}$	Interface length between inner and outer tiles and middle and outer tiles
r^i, r^a	Radius of inner tile i and of combined areas a
r^t, r^s	Radius of tile t and sibling tile s
t, s	Tile (t) and sibling tile (s) in a connected pair
z_p, z^*_p	Vertical position of point p relative to surface and absolute vertical position (accounting for height offsets)
$\Delta h^{t,s}$	Difference in surface elevation between tile t and sibling s
2. Suction-driven / Conductive Flux Variables (Sec. 2.3.1)	
$D^{d,e}_{i*}$	Ingress flux from surface water in depression d to soil layer i^* at relative elevation e
$D^{t,s}_{i*}$	Suction-driven flux between tiles t and s in layer i^*
$d^{t,s}$	Horizontal distance over which the matric potential difference occurs
$f^d_{p,max}$	Maximum inundated fraction of depression d

Symbol	Definition
$l^{t,s}$,$l^{d,e}$	Interface length between tiles t and s and between between surface water in depression d and soil in elevation e
$k_{i*}^{t,s}$	Geometric mean hydraulic conductivity of interfacing soil layers
$\Delta\psi_{i*}^{t,s}$	Matric potential difference between tiles t and s in layer i^*
Δz_{i^*}	Thickness of soil layer i^*
Surface and Subsurface Runoff Variables (Sec. 2.3.2)	
fc_{pnd}^{t}	Fraction of tile t covered by surface depressions (ponded areas)
$fc_{pnd,mx}^{s}$	Maximum pond fraction of sibling tile s
$f_{l}^{lag,t}$	Average lag factor for flux type l (surface [srf] or below-ground [blg]) in tile t
$f_{mac,l}^{lag,t}$	Macro-scale lag factor for flux type l (surface [srf] or below-ground [blg]) in tile t
$f_{mac,l}^{lag,t,s}$	Macro-scale lag factor for flux type l (surface [srf] or below-ground [blg]) from tile t to sibling s
$f_{mic,l}^{lag,t}$	Micro-scale lag factor for flux type l (surface [srf] or below-ground [blg]) in tile t
$f_{mic,l}^{lag,t,s}$	Micro-scale lag factor for flux type l (surface [srf] or below-ground [blg]) from tile t to sibling s
I_{cap}^{t}	Infiltration capacity of tile t
I_{dpr}^{t}	Depression storage capacity of tile t
$I_{pot,sl}^{t}$	Potential infiltration across entire surface area of tile t
$I_{pot,pnd}^{t}$	Potential infiltration below inundated areas of tile t
$I_{pot,sl}^{s}$	Infiltratable water on sibling tile s across entire surface area
$I_{pot,pnd}^{s}$	Infiltratable water on sibling tile s below inundated areas
k_b	Hydraulic conductivity of the soil layer containing the bedrock interface
k_{bot}	Maximum drainage rate from below-ground reservoir
k_{i}^{t}	Hydraulic conductivity of soil layer i in tile t
k_{rock}	Saturated hydraulic conductivity of fractured bedrock
$L_{blg,i}^{t}$	Below-ground reservoir volume of layer i in tile t
L_{srf}^{t}	Surface water reservoir of tile t
m^t	Effective slope of tile t
P	Precipitation
$p_{l}^{t,s}$	Fraction of runoff from tile t received by sibling tile s for flux type l (surface [srf] or below-ground [blg])
$R_{blg,i}^{t}$, $R_{blg,i}^{t,*}$	Subsurface runoff flux on layer i of tile t without and with accounting for retention time
$R_{bot,i}^{t}$	Bottom drainage flux from below-ground reservoir layer i of tile t
$R_{res,i}^{t}$	Restoration flux into pore spaces of below-ground reservoir layer i of tile t
$R_{l}^{t,*}$	Outflow from intermediary reservoir of tile t for flux type l (surface [srf] or below-ground [blg])
$R_{l}^{t,s,*}$	Lateral runoff flux from tile t to sibling s for flux type l (surface [srf] or below-ground [blg])
R_{srf}^{t}, $R_{srf}^{t,*}$	Total surface runoff from tile t without and with accounting for retention time
$R_{srf,h}^{t}$	Horton overland flow from tile t

Symbol	Definition
$R^t_{srf,sl}$	Surface runoff across entire tile t area
$R^t_{srf,pnd}$	Additional surface runoff from overflow of depression storage in tile t
$R^t_{srf,d}$	Dunne-type overland flow from tile t
$\theta^t_{fc,i}$	Field capacity of soil layer i in tile t
θ^t_i	Soil moisture of layer i in tile t
$\theta^t_{sat,i}$	Porosity of soil layer i in tile t
$\theta^t_{upd,i}$, $\theta^s_{upd,i*}$	Updated soil moisture after infiltration on layer i in tile t and on layer $i*$ in sibling s
τ^t_{blg}, τ^t_{srf}	Retention time of below-ground reservoir and surface reservoir in tile t
τ^t_l	Average retention time for flux type l (surface [srf] or below-ground [blg]) in tile t
$\tau^{ret}_{mac,l}$	Macro-scale retention time for flux type l (surface [srf] or below-ground [blg])
v_{blg}, v_{srf}	Lateral flow velocity below-ground and at surface
W^s_{sfc}, $W^s_{sfc,max}$	Current and maximum water in surface depression storage of sibling tile s
ΔW^s_{sfc}	Change in surface depression storage of sibling tile s
Snow redistribution (Sec. 2.3.3)	
$\Delta D^{h,l}_{snw}$	Inter-tile snow flux from tile with higher snow surface (h) to lower snow surface (l)
$c^{h,l}_{ctc*}$	Relative contact length between tile h and l for snow flux calculation
$\Delta h^{h,l}_{snw}$	Initial difference in snow surface elevation between two adjacent tiles
$f^l_{c,rel}$	Relative cover fraction of receiving tile (l); used to weight snow redistribution
f^l_c, f^h_c	Cover fractions of adjacent tiles l and h
D_{snw}	Initial snow deposition flux on tile before redistribution
ρ_{snw}	Density of snow
ρ_{h2o}	Density of liquid water
Heat exchange (Sec. 2.4)	
$C^{t,s}_{i*}$	Convective heat flux due to water movement from tile t to sibling s in layer $i*$
c_{ice}	Volumetric heat capacity of ice
$c_{soil,1}$	Volumetric heat capacity of top soil layer
$c^*_{soil,1}$	Modified heat capacity of top soil layer including effects of surface water and ice
c_w	Volumetric heat capacity of water
$d^{t,s}$	Horizontal distance between the centers of tile t and sibling s
$G^{t,s}_{i*}$	Conductive heat flux between tile t and sibling s in layer $i*$
h_{ice}	Thickness of ice in top soil layer
h_{wtr}	Depth of surface water
$\Delta T^{t,s}_{i*}$	Temperature difference between soil layers $i*$ of tiles t and s
Δz_1	Thickness of top soil layer

Symbol	Definition
Δz_{i*}	Thickness of soil layer $i*$
$l^{t,s}$	Interface length between tiles t and s
$W_{i*}^{t,s}$	Volume flux of water from tile t to sibling s in layer $i*$;
$\lambda_{i*}^{t,s}$	Soil heat conductivity between layers $i*$ of tiles t and s

5. One aspect that remains unclear is whether the snow redistribution scheme accounts for wind direction and speed. These are critical drivers of snow transport in natural systems, particularly in open tundra or alpine environments. Yet, the manuscript does not indicate whether wind forcing influences the redistribution pattern or magnitude. Additionally, the effects of vegetation, such as snow interception by shrubs or reduced wind exposure under forest canopies, are not addressed, despite their role in limiting wind-driven snow transport. These simplifications may be reasonable for a first implementation, but should be explicitly acknowledged. Furthermore, the manuscript lacks dedicated test cases or diagnostic outputs focused solely on snow redistribution. Without a targeted evaluation, it is difficult to assess the realism or the impact of this component relative to the other lateral processes included in T-REX. The authors should consider highlighting this as a current limitation and outlining whether validation or further development is planned.

Unfortunately, the scheme does not account for wind direction or -speed and we also do not see a straightforward way to include these in future development steps. The main reason for this is that ICON's land-surface component, as many other land-surface models, does not "know" about directions. Since, the land surface heterogeneity is never spatially resolved explicitly in the model, there is no information if patches of surface type A are predominately located north, east, west or south of the patches of surface type B. Here, it is conceivable to derive such information in the pre-processing and then use direction-specific connectivity matrices in the model. However, while we agree with the reviewer (that the simplicity of the snow transport is an important limitation) and would be happy to highlight the issue in a revised version of the manuscript, we fear that we do not have the resources to work on this shortcoming in the foreseeable future. As a result, the applicability of the snow redistribution will be limited to cases where it can be assumed that the patches of tiles between which the snow is shifted are randomly distributed and well interspersed so that it is permissible to ignore the wind-direction.

In the methods section we added the following paragraph to the description:

This is a first-order simplification that neglects key factors such as wind direction and speed, which are critical drivers of real-world snow transport. This is mainly because of the structural design of the land-surface component, where subgrid tiles coexist statistically within a grid cell but are not explicitly spatially arranged. Consequently, the model cannot determine whether wind preferentially connects specific tile pairs or how fluxes would vary with wind direction. As a result, the present implementation cannot be used for the snow transport on the macro-scale but only for micro-scale heterogeneity where the relative arrangement of tiles is sufficiently random for snow transport to become approximately independent of wind direction (see Dicussion). For such conditions however, this elevation-based redistribution can at least account for the preferential deposition of snow in microscale depressions (Clark et al., 2011).

And the following paragraphs were added in the discussion section:

Another problematic aspect is the highly simplified approach to incorporate snow redistribution. In natural landscapes the latter is a complex process, driven by a combination of topography, snowpack properties, vegetation, and especially near-surface wind direction and speed (Clark et al., 2011). Land surface models typically do not represent this process explicitly but some do account for topographic variability when relating (grid-cell mean) snow water equivalent to the snow cover fraction, though not in a way that takes into consideration wind speed or direction (Roesch and Roeckner, 2006; Ma et al., 2019). Similarly, simple topography-based schemes have been employed successfully in previous studies, to account for the effect of snow redistribution between microtopographic features in permafrost landscapes (Aas et al., 2019; Nitzbon et al., 2019; Smith et al., 2022). However, while these approaches may work sufficiently well on the micro-scale, it can be argued that for the hillslope scale the wind direction may no longer be ignored where drifting leads to preferential deposition in the lee of elevations and on sheltered aspects, making them less suitable for the macro-scale transport.

While the current snow redistribution scheme is based solely on differences in surface elevation and neglects near-surface wind effects, it is conceptually possible to extend the approach to account for wind direction and magnitude. In principle, direction-specific connectivity matrices could be pre-computed during the model setup, reflecting the preferential pathways for snow transport under prevailing wind directions. Furthermore, the connectivity between two tiles could be scaled according to the fraction of the boundary aligned with the wind in combination wind-speed-dependent redistribution functions which could, for example, be derived by running dedicated snow pack and snow drift models (Quéno et al., 2024). However, while a wind-aware formulation is feasible in principle, it is beyond the scope of the current study and is left as a potential avenue for future model development.

6. The study uses prescribed meteorological forcings (i.e., uncoupled simulation). The authors conclude that the grid-mean surface fluxes are hardly affected by the implementation of T-REX. However, even small changes in moisture or temperature patterns can alter atmospheric response in a fully coupled simulation. The paper should acknowledge this limitation. It would strengthen the conclusions to note that "while our offline results show negligible change in mean FLUX/STATE, coupled simulations would be needed to assess any feedback on climate fully."

We fully agree with the reviewer and will include such a statement in a revised manuscript.

The section now clearly states:

Thus, while our offline results show negligible changes in grid-cell mean fluxes and states, coupled simulations would be needed to assess any feedback on climate fully.

Minor fixes

In the figure 5 caption, correct "sugrid-scale" and "subgrig-scale" to subgrid-scale, and remove the stray comma in "sum of, surface runoff".

Will be corrected.

The caption now reads:

Effects of the lateral water transport on terrestrial water storage, latent heat flux and subgrid-scale temperature variability Shown is the total subgrid-scale lateral flux as the sum of surface runoff ...

In the figure 4 caption the phrase "layers fn the vertical grid" should be "layers in the vertical grid"..

Will be corrected.

The caption now reads:

Refined vertical grid Shown is the vertical grid used by the model to determine the diffusive and convective fluxes between two (micro-) connected tiles. This refined grid z^* encompasses all the layers of the vertical grid on the tile z^t and the layers in the vertical grid ...

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