

GMD Revisions

EGUSPHERE-2025-5512

DReaMIT: A Dynamical Reanalysis Framework for Modelling Surface-Based Temperature Inversions in Cold Environments

Dear Reviewer,

We would like to thank you for taking the time to review our paper. This is greatly appreciated as we understand your time is precious and we couldn't complete the review process without you. We were happy to read your comments, they made us understand where clarity was lacking, and we took this opportunity to improve our manuscript and hopefully provide a better product for the readers.

Best regards,

The authors.

Review 1:

[0] Generalized comment: A major issue is that the authors compare their new method with three existing approaches while assuming that readers are already familiar with these baseline methods. This may limit the readability and broader applicability of the work. I recommend generalizing the formulations of the three comparative methods (Equations 2–5) in terms of absolute/relative elevation and hypsometry, rather than simply citing previous studies. Equations 2–5 differ primarily in their definitions of the height term h , which can be explicitly summarized. Such generalization can directly highlight the novelty of the proposed method and make the contributions accessible to broader readers who may not have a background in climate downscaling.

- ➔ We added a full paragraph in the introduction to better contextualize SBIs and provide a broader and more accessible background to the work of Pozsgay and Gruber (2025). There, we highlight the broader importance of SBIs on downstream applications beyond model development.

- New paragraph.
 - “SBIs remain a major source of uncertainty in reanalysis models. In layman terms, SBIs are weather events where the air temperature increases with elevation, in opposition to the expected behaviour, and leading to a stratified air column with cold and dense air trapped in valley bottoms below warmer layers. In high-latitude mountains, near-surface temperatures are often influenced by surface-based inversions. These conditions are poorly represented by conventional lapse-rate-based downscaling approaches and coarse-resolution reanalysis products, leading to systematic biases in reconstructed surface temperatures. The longer, deeper, and intense these inversions are, the more important a model becomes to efficiently take them into account in reconstructing the near-surface air temperatures, with downstream applications such as permafrost modelling, hydrology, and infrastructure-relevant thermal regimes. Thus, improving the representation of SBIs in reanalysis-derived products can have practical applications for non-specialist users beyond the model development itself.”

➔ The new model presented in this study, based on hypsometry and using a non-linear function, is only compared to a single model, namely the model of Pozsgay and Gruber (2025), which is labelled as the ‘Dawson’ model in Figure 4. This model is presented in Section 3.3.1 and the near-surface modelled temperature is given in Equation (1). Now, the ‘three’ models corresponding to the first 3 columns of Figure 4 are all in reality the one model from Equation (1) but with small differences: (a) ‘Dawson’ uses the exact fitted parameters alpha and beta derived in Pozsgay and Gruber (2025), and the figure shows it is inadequate for spatializing; (b) ‘Absolute elevation’ uses the same model but with a new fit of alpha and beta; (c) ‘Relative elevation’ is the same model but z is replaced by z_{relative} in Equation (1) and a new fit of alpha and beta is performed too. This is now explained with greater care at the end of Section 3.3.1. We added a full paragraph in Section 3.3.1 to summarize this, i.e. carefully lay out the ‘three’ models of the first three columns in Figure 4 and highlight the novelty of the proposed method.

- New paragraph.
 - “In Section 4.2, we will analyze the performance of the model given in Eq. (1) applied to the ‘Dempster’ study sites (see Section 2.1). We will start with the model with the exact fitted parameters of Pozsgay and Gruber (2025), that we will label as ‘Dawson’, and show a lack of spatial transferability of the model. Then, we will take the same model

and allow for a refitting of the parameters in the $\alpha(z)$ and $\beta(t)$ functions, with the elevation variable either remaining the absolute elevation z or being replaced by relative elevation z_{rel} . This will highlight the need for spatializing, finding a more adequate topographic variable, and going beyond the linear regime, which we address by proposing a new model in Section 3.3.2 below where the near-surface air temperature is given by Eq. (4).”

- ➔ The new model is presented in Section 3.3.2 and the near-surface air temperature is given by Equation (4). The main difference with the ‘Dawson’ model of Equation (1) is that the variable encoding the topography is no longer absolute elevation z but hypsometry h , which is defined in Equation (2). Note that Equation (3) is not a new definition but simply gives context to the reader of the physical meaning of the bounds on the hypsometry ($0 \leq h \leq 1$). Finally, Equations (5) and (6) specify the function form of alpha and beta appearing in Equation (5), with the second notable difference of the model presented in this work compared to the one of Pozsgay and Gruber (2025) being the exponential structure of alpha, rather than the linear one.
 - See previous replies and new paragraphs, that also apply here.
- ➔ A clarification of the meaning of the 4 ‘models’ in the 4 columns of Figure 4 was also added in the Results (Section 4.2).
 - Added a sentence to better present the different ‘models’
 - “The first three comparisons are essentially variants of the same Pozsgay and Gruber (2025) framework, differing in calibration and the topographic variable used, whereas the hypsometric DReaMIT formulation represents the substantive model development in the last column.”

[1] Lines 140–145. Please elaborate on the formulation of the hypsometry for broader readership. For each station, is x_0 the station location and z_0 the station elevation? In Equation (2), is $h(x_0)$ a constant value? It appears to also vary with z , and the authors need to clarify this function explicitly.

- ➔ Thank you for pointing out this potentially confusing definition. Indeed, x_0 and z_0 stand for the position and elevation respectively of a given point, e.g. an observation station. The hypsometry of this point, $h(x_0)$, is uniquely defined when the radius d is fixed, which we do in this study. However, we only do so after having carefully analyzed the influence of such radius, and when it is allowed to vary, then $h(x_0)$ becomes a function of the radius d . We added some clarifications before and after

the definition of $h(x_0)$ (Eq. 2), that we explicitly changed to $h(x_0, z_0)$ to reflect the full picture. We hope that they will be helpful in adding some clarity.

- We added part of a sentence to clarify position and elevation of the station.
 - “Next, for a given station at position x_0 (latitude and longitude) and elevation z_0 , the hypsometry is computed by looking at all cells c (coordinates c) within a radius d (we will take $d = 50$ km), and corresponds to the fraction of points with higher elevation within that area”
- We changed $h(x_0)$ to $h(x_0, z_0)$ in Equation 2.
- We added two sentences to explicit the link between hypsometry and elevation on one side, and it how varies with radius on the other side.
 - “Note that the hypsometric value $h(x_0, z_0)$ of a station x_0 is a coordinate transformation of its elevation z_0 and is uniquely defined for a fixed radius d . However, it does vary with the radius d if we let this parameter vary too.”
- Added a plain-language sentence between Eqs. 2 and 3 explaining what a high versus low h value means in practical terrain terms.
 - “we have $h \in [0, 1]$, with high h values indicating low positions in the surrounding elevation distribution, where cold-air pooling is more likely, whereas low h values indicate ridge or upper-slope positions, the edge cases being”

[2] Sections 3.3.4 and 4.2. The description of α is confusing. Why is it referred to as "observed α " (around Line 190)? Given that α is a fitted parameter, it cannot be directly observed like temperature. This wording also hinders the interpretation of Figure 4. Additionally, the blue and orange points in Figure 4 appear to follow an exponential distribution rather than a linear relationship with depth, which tends to support the proposed method.

➔ We thank the reviewer for this very important point, we agree that the manuscript was unclear at this level and implemented a number of modifications. The most important of them being the change from “observed α ” to “effective α ”, which should be a strong improvement. Such points are diagnostic quantities derived from observations and reanalysis, not directly observed parameters. This distinction matters because Figure 4 is central to the paper’s argument: it visually demonstrates why absolute and relative elevation do not fully spatialize the

relationship, while hypsometry largely collapses the two valleys onto a common functional form.

- alpha_observed to alpha_effective in Equation 8 and modified every mention of it in the manuscript.
- FIGURES 4, 7, and 8: We changed alpha_observed to alpha_effective.
- We added a paragraph to better explain the meaning of alpha_effective and how it differs from the modelled fitted value. (Section 3.3.4)
 - “In more details, it is possible to compute mean annual values DT station, DT , and constant β bias for each station individually, and from there, inferring an effective value α effective given Eq. (8) above. When repeating this analysis over a large set of stations, we can produce a scatter plot of mean individual effective α as a function of an elevation variable it being elevation itself, relative elevation, or hypsometry. These points are diagnostic quantities derived from observations and reanalysis, not directly observed parameters. Such results are presented in Section 4.2 and Fig. 4. The various fitted models of α aim at finding a global (within the acknowledged limits) functional form with respect to an elevation variable. Here, α effective is computed independently for each station and can give an insight on the model’s target.”
- We added a sentence to better interpret Figure 4 and explain why the new model is successful at spatializing the relationship, as opposed to the other formulations in the first 3 columns. (Section 4.2)
 - “This visually demonstrates why absolute and relative elevation do not fully spatialize the relationship, while hypsometry largely collapses the two valleys onto a common functional form.”