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 2:

1) The authors mention that a 50 km radius yielded the best empirical fit for calculating hypsometric position, but the physical explanation of this aspect (beyond synoptic vs. local scale) remains unclear and poorly discussed. Specifically, the paper would benefit from a more explicit justification of why the 50 km radius works best for features that actually often operate on a much localized valley scale (e.g., 5 km, which hit a local minimum in performance). Does this large 50 km radius reflect the imprint of the reanalysis grid cells? or is it more indicative of the synoptic-scale boundaries of regional cold-air drainage systems? This distinction would strengthen the physical basis of the model.

- ➔ We added a paragraph addressing the hierarchy of scales at play, linking the sustained duration of SBIs to regional valley connectivity, effectively increasing the radius due to cumulative effects.

- New paragraph discussing the scales to calculate hypsometric position, motivating the 50km radius choice by a better-informed physical reasoning rather than a purely empirical one (Section 5.4).
    - "In subarctic environments, SBIs are sustained over periods of days to weeks rather than hours. During these events, cold-air pooling reflects not only local slope drainage (acting over scales between 1 and 10 km) but also the cumulative redistribution of cold air across interconnected valley systems. Consequently, the relevant topographic control extends beyond the immediate valley and may be better represented by landscape-scale hypsometric position than by local relief alone. We have used a radius arising from the data available and satisfying these approximate characteristic scales, while potentially interacting with the effective resolution of the reanalysis grid cells."

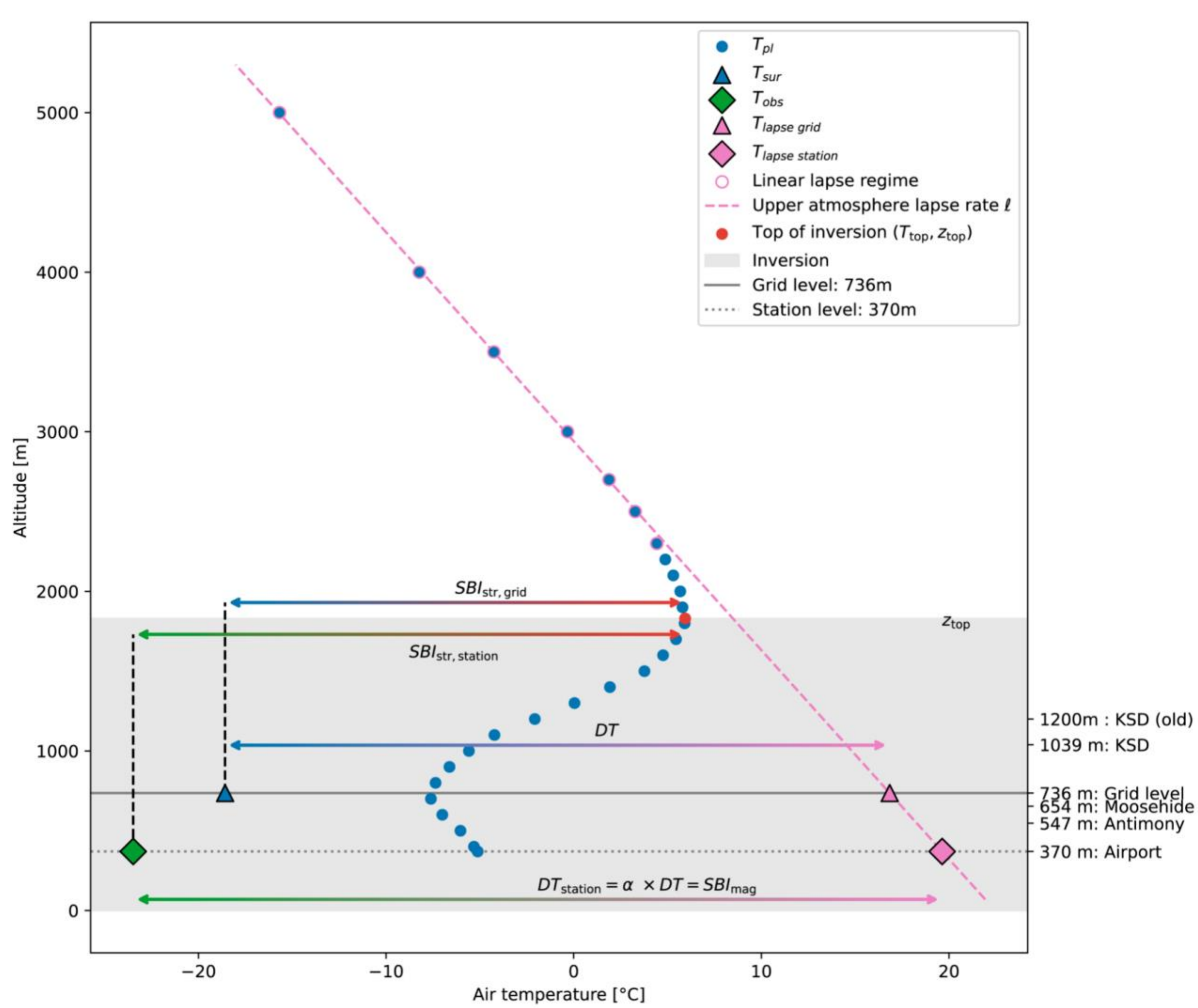
2) I wonder if the authors can discuss (or even better, propose) a threshold of hypsometric range beyond which DReaMIT breaks down? This is motivated by the limitations in flat river dominated regions.

➔ We do not think we can give such a threshold as we do not seem to see a clear pattern suggesting this. We would first like to point out the discussion of Tulita, Old Crow, and Norman Wells, that we think is useful but does not imply that the model "fails" generally in low-relief areas. The dominant controls on near-surface temperature there are not primarily terrain-controlled cold-air pooling. In these locations, river influence, floodplain energy balance, weak relief, and possible reanalysis/grid elevation artifacts may dominate over the hypsometric signal. This distinction helps define the model's domain of applicability more constructively.
    - We added a sentence in Section 5.3 to better lay out the dominant controls for the discussed stations where the model doesn't perform as well, highlighting the fact that the limiting cases do not show failure of the model but rather that SBIs are sub-dominant there.
        - "There, the dominant controls on near-surface temperature are not primarily terrain-controlled cold-air pooling. In these locations, river influence, floodplain energy balance, weak relief, and possible reanalysis/grid elevation artefacts may dominate over the hypsometric signal."

- We also added a plain word sentence at the end of the Conclusion to make the conclusion more actionable for future users of the model.
    - “In other words, DReaMIT is most appropriate where hypsometry is well-defined by meaningful surrounding relief, and users should be cautious in low-relief floodplain settings or where local non-orographic controls dominate the near-surface thermal regime.”

➔ Furthermore, DReaMIT is also correcting reanalysis data artifacts below grid level (see Figure below, taken from Pozsgay and Gruber (2025)), and we believe we need to gather more experience in the precise effects of the model in low range environments before giving definitive thresholds.

Fig. 2.



3) It would be useful to define SBI in a sentence for a non-specialist reader. One sentence goes a long way.

- ➔ This element was indeed missing from the manuscript, and we added a couple of sentences in the Introduction to fill that gap.
    - Added a non-specialist sentence to define SBI in the Introduction.
        - "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."

4) Related to comment 3, the model by Porzsgay and Gruber (2025) is insufficiently summarized. I think adding a paragraph explaining it would provide the reader with a better background to value the present work more.

- ➔ Together with comment 3, we added a paragraph providing a better background for the reader.
    - Added more background in the Introduction.
        - "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."

        - "This model dynamically corrects downscaled reanalysis data at hourly time steps, improving the representation of near-surface temperatures under stable atmospheric conditions."

5) The abstract is not self-contained, referencing aspects such as "Exponentiation of the elevation variable" without sufficient background or context. Perhaps revise for completeness. Also, is it really an exponentiation of the "elevation" variable or the hypsometric position?

- ➔ We agree that this sentence was not appropriate for an abstract and we reformulated it to mention going beyond a simple linear model.
    - o We got rid of "Exponentiation of the elevation variable", giving preference to a vocabulary that is more in line with an abstract style.
        - "The reformulated approach enables a unified calibration across two contrasting Yukon valleys (WS01 and WS02), improving model transferability and reducing site-specific bias. The model also goes beyond the linear treatment of the hypsometric variable to capture the observed nonlinear decay of lapse rates within SBIs, [...]"

6) Introduction (Line 17): define the acronyms ERA5 and JRA-3Q. Also, in Line 19, perhaps use "multiple atmospheric pressure levels"

- o Acronyms defined.
- o Added 'atmospheric' to pressure levels.

7) Introduction (Line 21): "hydrological processes"?

- o Added 'processes' to hydrological.

8) Line 42: what is mean by "normal" lapse rates? Is this meant to say "linear", "dry adiabatic", "moist", etc..

- ➔ We added some clarification to what we mean by normal lapse rate in this situation, based on the way reanalysis data is extrapolated below the grid level using local lapse rate with only the lowermost atmospheric pressure levels.
    - o We specified what we meant by 'normal' lapse rate.

- "This approach addresses a key limitation in downscaling methods, an assumption that the lapse rates are normal below reanalysis grid elevation, i.e. extrapolated temperatures from lowest atmospheric levels and a smooth vertical gradient, disregarding intense SBIs at these low elevations."

9) Line 94: correct "since since 1947"

➔ Done

10) Line 215: "second column" not second row

➔ Done (4 modifications)

11) Line 266: "lapse" not laspe

➔ Done