Review of
“Physical Processes Leading to Extreme day-to-day Temperatures Changes, Part 1: Present-day Climate”
by Kalpana Hamal and Stephan Pfahl
submitted to Weather and Climate Dynamics

General comment:

This manuscript investigates the mechanisms behind extreme day-to-day warming and cooling events at four locations around the globe. To this end, changes in the mean circulation patterns at these locations are examined and variations in the behavior of air parcel trajectories are identified. That way, the study quantifies the contributions of transport (advection), adiabatic heating, and diabatic heating to extreme day-to-day temperature changes. The authors find that advection is the main factor driving extreme temperature changes in the extratropics, whereas advection is of lesser importance for extreme temperature changes in the tropics. I find the study interesting, especially because it focuses on extreme temperature changes rather than extreme temperatures themselves, offering a new perspective on temperature variability in the atmosphere. I do not have significant scientific concerns. However, I see considerable potential for improving the language used. I feel that often inappropriate or too imprecise phrasing detracts from the content and makes it difficult to fully grasp the intended message. I recommend a thorough revision of the manuscript, with each sentence being carefully reviewed for clarity and logical flow. Therefore, I suggest publication after major revisions. Below, I have compiled a list of questions and some ideas for improving the text.

Major comments:

1) To me, it is often unclear whether the text is addressing temperature extremes or extreme temperature variability. I believe this is due to imprecise terminology. For example, throughout the text, the terms "warm events" and "cold events" are used to describe extreme day-to-day temperature change events. However, I find these expressions somewhat misleading, as they may imply that you are looking at warm and cold temperature extremes themselves, rather than on extreme warming and cooling events. The text would be much clearer if "warm events" were replaced with "warming events" and "cold events" with "cooling events."
The same is true for the expression “DTDT extremes”, which I think should be better replaced by something like “extreme DTDT changes”. Furthermore, at some points (introduction, summary), you make a connection between your work and studies focusing on the mechanisms behind the development of warm and cold temperature extremes. I think it should be made clearer at this point that an extreme temperature event does not necessarily have to be linked to extreme temperature variability. A sudden temperature increase does not necessarily occur when it gets particularly hot, and similarly, a sharp temperature drop does not have to happen when it is particularly cold.

2) Overall, I feel that the term "advection" is not applied with sufficient precision. At times, it is used when showing instantaneous wind fields (e.g. L210, L2022), and at other times when discussing trajectories and the transport of air masses (e.g. L211, L217). I believe it is crucial to be very careful about when the term "advection" is used and when it might be more appropriate to use a different term, especially considering that the existing literature is not always clear on this matter. Furthermore, I think it would be very helpful to clarify what is meant by "cold air advection" and "warm air advection," i.e. with respect to what is the air cold or warm. I believe what you mean is that, for instance, the air transported to the location on the day of a cooling event is originally colder than the air that was transported there the previous day. I think it would be very beneficial to be more precise here.

3) My last major comment relates to the adiabatic warming. Whenever you describe the temperature at t-1, you write something similar to L216: “Accordingly, the temperature at t-1 is mainly determined by cold air advection, mitigated by adiabatic warming, ...”. I was wondering if it is not always the case that an air mass at the surface undergoes adiabatic warming. If so, is it truly necessary—or perhaps redundant—to specify each time that the temperature has been affected by some adiabatic warming? The same applies to the initial temperature, which is always lower than the final temperature. I believe the text could be condensed on this point such that greater emphasis on the differences between day t-1 and day t is given.

Minor comments:

L102-117: This paragraph is very hard to follow. I think this is because the expressions used in the formulas are not well described and because equations (3) and (4) are never explained in the text. I suggest to break down the equations to what is really important and to introduce the equations step by step, instead of a full block of equations.

L121-122: The number of identified events should differ between the ERA5 data and the HadGHCND data, since their used periods differ. To which dataset do the numbers refer to?

L131: To better understand the underlying mechanism of what?

L133: Instead of “apply a novel” “introduce a novel” to make clear that this precise decomposition has not been used before?

L133: Lagrangian temperature **variability** decomposition?

L137: The phrase “The Lagrangian decomposition of DTDT changes, as approximated by the trajectories” is odd, since the trajectories do not approximate the Lagrangian decomposition. Rather, the Lagrangian decomposition is obtained from computed trajectories.

L 141: What is decomposed?

L142: I think at this point it would be very worth noting that advection in this approach refers to something different than in the approach by Röthlisberger and Papritz (relates to major comment 2)

L149: instead of “magnitude of σ changes” either “magnitude of DTDT variations, quantified by σ”, or simply “ magnitude of σ”

L150-153: Here it is written “the variability is larger during DJF than in JJA”, followed by “the variability is above 3 °C in DJF compared to 1-4 °C in JJA”. However, 4 °C is larger than 3 °C, such that one could conclude that the variability in JJA is larger than in DJF. Please rephrase this sentence more precisely.

L150-153: Here it is shown that the magnitude in DTDT changes is larger in DJF than in JJA, irrespective of the hemisphere. This means that in the northern hemisphere, the magnitude of DTDT changes is larger in winter than in summer. In contrast, in the southern hemisphere, the magnitude of DTDT changes is larger in summer than in winter. Is this behavior expected? Can you think of any explanations for this behavior?

L153: rephrase “remain consistently”

L153/L155 and other lines: Similar to comment to L149: To my understanding the phrases “σ variations” and “σ changes” do not make sense. I think it would be more accurate to simply use “σ”.

L159-161: “Since the magnitude of σ changes can be expressed as a function of …, Figures 1 and 2 show these related quantities.” Again, I think this sentence is not properly formulated. The Figures 1 and 2 do not show the other quantities because σ can be expressed as a function of them. It is rather that you decided to show them as they are part of the computation of σ.

Figure 1/Figure 2: It would be helpful to use the same colorbars in Figure 1 and Figure 2 to enable an easier comparison.

L183/185: I think it is incorrect to use the phrase “leads to” here. Replace by something like “associated with”.

L184: “smaller” instead of “lower”?

L209: I feel that the phrase “southerly airflow around its western flank” is somewhat misleading as it suggests that you refer to trajectories/air parcels. But what is shown in Figure 4a is the wind.

L211: Similar to the previous comment. I do not think that you can really see “cold air advection” in this plot. You see northerly winds blowing across a temperature gradient, suggesting cold air advection.

L207/L214: I was wondering whether the word “distinct” is appropriate here.

L214: What is meant by “limited” diabatic cooling?

L215-216: I suggest mentioning once that the residual is small, e.g., as the last sentence in the section "Lagrangian Temperature Decomposition," and then omitting it in the following text and the figures.

L222: Again, I think the use of the word advection is somewhat misleading here. I suggest to use “southwesterly wind” instead of “southwesterly advection” (se major comment 2).

Caption Figure 4: You write “selected grid point” but shown is a “grid box”.

L249-267: To shorten the entire paragraph: Could you simply say that a DJF cooling event is essentially the same as a "reversed" DJF warming event? To me, Figures 4a and 4d look quite similar, as well as Figures 4b and 4c. And Figure 5k is more or less the same as Figure 5l, just mirrored.

L285: I suggest to cross the “which are only briefly discussed”, since it gets clear from the “focuses on JJA” that the focus is not on DJF.

L333: For instance, at this point it would be very beneficial to be precise of what is meant by cold air advection and warm air advection, i.e. with respect to what is the air cold or warm (see major comment 2).

L356/L385/L385/L493: What do you mean with “distinct” patterns and “specific” circulation patterns? Do you mean that all events exhibit a similar pattern, e.g., in the 500 hPa geopotential height? If so, I think you cannot deduce that from the plots, as you only show the mean circulation across all events, which might differ substantially from one event to another.

L356-373: Are you referring to cooling or warming events here?

L387-388: At this point, I think one must be very careful with the phrasing. You are looking at a budget, so you cannot say that term 1 and term 2 cancel each other out, leaving only term 3 as important! Imagine term 1 being +5 K, term 2 being -5 K, and term 3 being +5 K. You cannot say that term 1 and term 2 cancel each other out, leaving only term 3 as important, nor can you say that term 2 and term 3 cancel each other out, leaving only term 1 as important.

L416-425: Again, to shorten the paragraph: Could you simply say that DJF cooling events are essentially the same as a "reversed" DJF warming event?

L393: I suggest to write “… **presumably** contributing to larger diabatic heating and higher temperatures”

L500: To better connect to the first part of the sentence, you could insert something like “while the contributions of adiabatic and diabatic processes **are generally smaller and** vary **more** in space and also between warm and cold events”.

L513/514: Here, scientific debate is still going on. There are also studies saying that heat waves in the mid-latitudes are driven by advection (e.g., Harpaz et al. 2014, Sousa et al. 2019, partly Röthlisberger and Papritz 2023).

L537: I do not understand what is meant by the sentence “is approximated through the average temperatures of the trajectories initiated on the corresponding day at their initiation time”.

Technical corrections:

Title: temperature without plural?

L120: 5^{th} and 95^{th} percentiles of the DTDT change **distribution**

L125,136: no plural: DTDT change event?

L190: DTDT **variations**

L193: DTDT **variation** events

L194: DTDT variations

Figures: I think it would be helpful to keep the direction of panel labeling consistent across all figures.

L202/284/353/…: invest the mechanim**s**?

L220: On the day**s** of the ...

L241: smaller **in** magnitude?

L339: compared **to**

L445: result from