Comments on
‚Diabatic jet streak intensification during serial cyclone clustering: the North Atlantic case of February 2022'

General comments

This study investigates the role of cloud diabatic processes in the evolution of an intense jet streak that evolved in tandem with the windstorms Dudley and Eunice in February 2022, and also connects the evolution of the jet streak to the growth environment for the two storms by analysing the evolution of baroclinicity close to the jet streak.
By first analysing the evolution of the jet streak and cloud diabatic as well as dynamical contributions to the jet-relative structure of heating, the authors establish that diabatic heating dominates cross-jet heating gradients during the intensification phase, while diabatic heating on the equatorward side of the jet vanishes toward the decay phase of the jet streak. The authors conduct a sensitivity analysis with modified latent heat of vaporisation constant to show that the intensity of the jet streak depends on the effect of condensational heating.

I enjoyed the study as a concise, well structured, and clear read that cleverly addressed its research objective of analysing the diabatic contribution to the intensification of this extreme jet streak. In particular, I found the along-jet composites of the role of adiabatic versus diabatic heating illustrative of the relative role of cloud diabatics over the course of the object evolution. Testing the sensitivity of jet streak intensification with respect to L_v addresses the relevant question of whether cloud diabatic processes are causal for jet streak intensification.

I look forward to seeing this manuscript published in WCD. However, I have some questions and comments regarding the framing and interpretation of the work. While mostly conceptual, they still seem substantial to me. My main points are listed below:

1. **Terminology and contrasting diabatic processes and Rossby wave breaking**
   1. When talking about conditions for cyclone growth in the introduction, the authors seem to use the terms jet and jet streak interchangeably. When primarily focussing on jet-streak—cyclone interactions, which seems appropriate in the synoptic-scale arguments made here, one might consider sticking to the term ‚jet streak' throughout and only use ‚jet stream' / ‚jet' when referring to the larger-scale or even background system.
   2. Regarding this point, I have the impression that the authors present the influence of RWB and diabatic heating on sustained baroclinicity and intense jet streaks as unnecessarily contradictory. First, the studies that are referenced (e.g. in the introduction) and that highlight the role of Rossby wave breaking during cyclone clustering seem to me to look at the jet from a different (more large-scale, often spatio-temporally averaged) perspective. The present work takes on a more synoptic perspective. This runs throughout the manuscript. I would like to see the authors clarify the different perspectives that are taken on here versus in the referenced literature, rather than presenting the insights from those perspectives as conflicting (which I don't think they are).
2. **Thermal wind balance as a key step of using heating profiles as a proxy for jet intensification and Eulerian tendencies as jet-relative tendencies**
   The authors' Eulerian analysis of jet-relative heating profiles as a proxy for jet dynamics hinges on the assumption that
   1. Eulerian gradients in heating are the same as changes to the horizontal temperature gradient in a jet-relative coordinate system. However, if the jet were a purely advected feature, dynamic contributions would always show positive across-jet heating gradients, even if the jet streak would not intensify.
   2. The heating profile is a direct proxy for jet intensity in case of geostrophically balanced flow. The authors do not comment on or investigate the extent to which geostrophic balance is violated in the jet vicinity. However, substantial ageostrophic flow is an inherent part of jet streak dynamics. This is particularly true in the intensification phase of the jet streak, where upper-level divergence on the equatorward side of the jet is large.
   These points are not just theoretically relevant:
   In the present case study, there are phases in the jet streak evolution in the control run during which the

across-jet heating gradient is positive while jet intensity simultaneously stagnates or declines. The authors briefly comment on this in line 230ff, where they write
‚from +30 h the jet loses strength. Although some differential heating persists (Figure 6a), it appears insufficient to maintain or further intensify the jet.'
I find this point very interesting and would like to see the authors elaborate it. Why do they think that despite differential heating, jet intensity decreases? Is geostrophy breaking down, or are we rather seeing a phase during which jet-axis-relative temperature gradient maybe already decreasing as the jet propagates? To give a qualitative understanding of the relevance of those effects, one might want to compare full flow to geostrophic wind throughout the evolution of the jet streak. This could be done in the Hovmöller-style Figures such as Figure 4, or in additional layers in Figures 3 and 8.

3. **Potential role of a subtropical/polar jet superposition during the event**
The evolution of the jet during what the authors call the ‚organisation phase' of the jet streak evokes the question whether a superposition of the subtropical and polar jet in this event. There have been various studies showing that jet superpositions are often related to extreme weather events and jet streaks. I think it would be a nice addition to the present discussion of literature and the present results to address whether such a superposition could play a role in the present case. In such cases, diabatic processes are known to play a substantial role in shifting the subtropical jet poleward, such that the large relevance of diabatic processes in the present case would fit in well with such an event.
A possible starting point in terms of literature regarding this point might be
Winters, A. C., D. Keyser, L. F. Bosart, and J. E. Martin, 2020: Composite Synoptic-Scale Environments Conducive to North American Polar–Subtropical Jet Superposition Events. *Mon. Wea. Rev.*, 148, 1987–2008, https://doi.org/10.1175/MWR-D-19-0353.1.
I would also be interested to see whether such a superposition took place. To investigate this, the authors could present some vertical cross sections of the jet structure and dynamical tropopause for the time steps for which they already show synoptic maps. Doing this across the L_vs could also provide insight into whether a potential jet merging took place regardless of this parameter, or was maybe inhibited in the low-diabatic-heating case.

Specific comments

Abstract

I found the abstract overall informative and understandable. The short section on the evolution of baroclinicity (14–18) didn't seem quite integrated to me and here, I also didn't fully grasp the key message at the first read. I would like to see this revisited to be more clear.

Introduction

General: You switch between using past and present tense when referencing literature (e.g. line 50: ‚Auestad et al. (2024) show' …, and later (line 55): ‚Auestad et al. (2024) found‚). Consider unifying your use of tense in that regard (Holds throughout the manuscript).

Line 36ff: The RWB argument might benefit of some further literature and slightly more in-depth explanation. For example, classical arguments on eddy-mean-flow interaction ahead of RWB could help make the section more grounded in our basic understanding of jet stream dynamics.

Line 36ff: You predict two arguments on strong jet streaks and enhanced baroclinicity associated with cyclone clustering, but the second argument on trailing cold fronts is, to my mind, not yet connected back to jet-enhancing baroclinicity. Or is the argument actually just that diabatics can — in general — enhance baroclinicity, so maybe they can also do it for the jet?

Line 55ff: The sentence referencing Auestad et al. (2024) seems broken grammar-wise.

Line 59 ff: This is an interesting discussion on whether we can look at the jet as a background to synoptic-scale phenomena. I think that considering jet streaks as synoptic-scale objects with which cyclones can interact is a good way around this problem, but doesn't solve it (I.e., it remains unclear whether jet streaks still ‚guide' synoptic-scale systems in the way a waveguide does. I would suggest clarifying that the approach to look at jet streaks circumvents the aforementioned problem rather than really addressing it (unless I misunderstand your argument, in which case feel free to ignore this)).

Line 71f: In the research question, consider specifying relative to what, or removing the ‚relative' from the statement.

Line 73 ff: You write: ‚We focus on the case study of the intense North Atlantic jet streak along which storms Dudley and Eunice rapidly intensified in February 2022 and quantify contributions of diabatic heating and disentangle causality between the phenomena.' I am wandering between which phenomena you disentangle, and also how this connects to the jet-streak-relative location of diabatic heating.

Section 2:

Line 105f: Cyclone moves ‚through' the jet streak sounds a bit quirky. Consider specifying this (‚moves across from .. to ..' or so?)

Line 115: Consider replacing ‚Concurrently' with ‚During the organisation phase', or something similar that points directly to the process concurrent to which moisture availability is high.

Line 129: This is admittedly semantic in nature, but are jetgenesis and jetlysis established terms? If not, I would suggest you define what you mean by them properly. In contrast to cyclones, which can be readily identified as closed pressure contours, the delineation, and hence also genesis and lysis of jet streaks are less self-evident. Also, given that I assume you are still talking about jet streaks here, consider switching to jet streak genesis / lysis. This would evoke the appropriate synoptic association rather than a large-scale / background picture the term ‚jet' is often associated with.

Line 144ff: Why do you not consider turbulence and radiation? If that is because you are only interested in cloud diabatic processes, I would suggest renaming the contribution from cloud microphysics and convection that you now call ‚diabatic heating' ‚cloud diabatic heating'.

Also, I am unsure here: does ‚convection' refer to turbulence due to convection? If so, does the ‚turbulence' term mentioned before only refer to clear-air-turbulence?

3 Data and Methods

Line 141: consider specifying an approximate grid spacing or resolved wavelength that this resolution refers to.

Line 142: I suggest ‚as well as on the dynamical tropopause, i.e. [YOUR DYNAMICAL TROPOPAUSE DEFINITION]

Line 147: Similar to before, add an approximate grid spacing to the resolution specification (T84).

Line 150: This sentence is a bit hard to read. Consider rephrasing to make more clear the the averaging can lead to mis-interpretations of the location of heating (though you already motivated your choice of method in the introduction. Therefore, I think one could also remove this sentence or simply replace it with at statement that highlights the nicely synoptic perspective of Spensbernger et al.)

Line 154: ‚Herein is u the zonal'. I think this should rather be ‚Here, u is the zonal … ,' and so forth

Line 156ff: consider reorganising this such that you first formulate what you want to achieve with the threshold and then define it and mention the concrete numerical value that you use. I think this would help the flow of the paragraph.

In Figure 2, and concerning line 164-166, I have a few questions:
You write:
‚From this point, **all locations along the jet axis within a 750 km** radius (approximately one Rossby radius of deformation) are selected to construct 2000 km cross sections of various meteorological variables perpendicular to the flow direction along the jet axis.'
In the Figure, the lines seem irregularly spaced and I assume that with ‚all locations', you mean some limited number of points, maybe regularly spaced along the jet axis or just all point that intersect with your grid? I would find it helpful to have a more concrete explanation here. Lastly, I do not yet fully understand why you take the 750 km radius. The jet streak in Figure 2 seems to have its entrance region upstream of the cross section that is most west. Did you choose a fixed radius to make it easier to compare different time steps during the jet streak evolution? I got back to this question when looking at your heating profiles in Figure 5 (esp. d), where it seems to me that with the cut-off, you remove a rather substantial area of the jet-entrance that is influence by cloud diabatic heating.

4 Jet streak life cycle

I really enjoyed the synoptic discussion of the jet streak evolution in this section. I kept wondering about the potential involvement of a merging of the subtropical and polar jet during the organisation and intensification phase of this jet streak. So far, there is no discussion of this phenomenon included in the introduction or discussion.

Line 182: You write ‚the jet pulse'. I haven't heard this term before. Is that a typo or am I just missing something?

Line 189: ‚starts' instead of ‚start' ? In the same line, you write ‚its strength weakens and tilts', but the jet streak tilts, not the strength. How about moving ‚tilts' after the ‚propagate' part of the sentence?

Line 192: Maybe ‚Rossby wave breaking *occurs'* instead of *is ?*

Line 193 f: Here, I would suggest ‚Therefore, Rossby wave breaking is relatively distant from the jet streak centre', since you just elaborated on how far stretched out very high wind speeds are, and to me it seems like it is interacting with the Rossby wave?

Figure 6: Your argument is built on the thermal wind balance and hence the change horizontal temperature gradient due to heating. Because of this, I was wondering whether you might want to remove the mean

heating from each slice in the composite, as it does not contribute to expected changes in wind. I would find this particularly helpful for the propagation and decay phase, where cooling dominates.

5 Sensitivity experiments

Figure 8: I would find it helpful to add some basic layers on the control jet streak (e.g. wind contours above 60 m/s, and maybe the jet axis and jet streak center) to the panels to make it easier to compare the various evolutions.

Figure 9: Similar considerations could be helpful for this figure. Maybe here, a line plot with the maximum wind speed of the control run (axis on the right side of panels?) could help keep the evolution of the control jet streak in mind?

Line 279: The statement ‚Subsequent evolution is largely governed by dynamic processes, with cold-air advection enhancing the cross-jet temperature gradient. This differential cooling persists until the end of the lifecycle, though it weakens over time.‘ Describes an interesting shift in the dominant drivers of temperature gradient change. I would find it instructive to have panels similar to those of fig. 6 b/c to evidence this point, at least in the appendix or supplementary material.

Figure 11: I would find it helpful if the vertical wind shear contours were slightly thicker.

6 Discussion

Line 307ff: I am not sure why you place your findings ‚in contrast‘ to studies highlighting the role of RWB for persistent and zonally extended jets. If I understand the Pinto and Priestley references correctly, they study jet-**stream—**cyclone-clustering interaction as the interaction between some spatio-temporally averaged version of the jet that is more akin to the jet as a background state, whereas your approach is clearly synoptic in nature. I would therefore not contrast your findings with this literature.

Line 328ff: I feel that here, as already in the introduction, an inclusion of other approaches to study diabatic influence on jet streak intensification, and other studies on extreme jets, would be a good addition. For example,
Winters, A. C., 2021: Kinematic processes contributing to the intensification of anomalously strong North Atlantic jets. Quart. J. Roy. Meteor. Soc., 147, 2506–2532, https://doi.org/10.1002/qj.4037.
might be a good starting point for such a discussion, and also references some further work on the topic.

Technical comments

Abstract:

Line 4: hyphens in jet-streak—centred seem inconsistent, is that right?

Line 13: ‚SUBSTANTIALLY weaker jet streak’?

Line 16: ‚much ~~more~~ weaker vertical wind shear’ ?

Section 2:

Line 99: intensification phase OF the jet streak life cycle

Line 103: consider removing ‚field‘.

Line 127: I think the comma after ‚transport‘ is superfluous

3 Data and Methods

Line 139: the last L_v is not subscripted

Line 145f: ‚and find that OpenIFS SHOWS strong similarity'. Also, there is a comma missing after ‚(Figure A1)', and I suggest specifying the ‚purpose' in ‚suitable for our purpose.' In line 146

Line 149: missing comma after ‚cross-jet processes'

Line 173: to the jet axis PROVIDES

4 Jet streak life cycle

Line 177: I think after ‚At 13 February 2022 00 UTC', a comma is missing

Line 180: I think after ‚At peak intensity', a comma is missing

Line 182: Same thing after ‚In the early propagation phase'. There are a few more cases like this in the next lines that I don't comment on individually now.

Line 197: I suggest ‚the jet streak has *reached* its peak intensity.'

Line 207: How about ‚close to the jet axis, there' instead of ‚In close distance, there'

Line 216: ‚.. and precipitation ARE located'

Figures

Figure 1: Caption line 6: first February has a typo. Also, the panel labels are at times hard to identify because of the high transparency of their boxes. Consider making label boxes less transparent. Lastly, the black moisture transport arrows are very hard to make out in regions with high TCWV values. Consider a different color for them (maybe something brighter / more reddish).

Figure 5: Consider adding more descriptive labels to the time-stamp information. Maybe something like ‚intensification phase, propagation phase, and decay phase ‚ since you already use that in the text?