

Weather Clim. Dynam. Discuss., referee comment RC1
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Comment on wcd-2021-37

Anonymous Referee #1

Referee comment on "Systematic assessment of the diabatic processes that modify low-level potential vorticity in extratropical cyclones" by Roman Attinger et al., Weather Clim. Dynam. Discuss., <https://doi.org/10.5194/wcd-2021-37-RC1>, 2021

General Comments

This is an excellent paper. A really good use of combining diagnostics to quantify the effects of different processes in cyclones and find out useful information about differences between cyclone environments when different physical processes are more important. While I have some corrections on the presentation of the results, the scientific results of this paper are relevant and interesting and definitely worthy of publication.

Specific Comments

My main correction to this paper is that the precision with which some of the results are described could be improved. This correction mostly relates to the varying descriptions of quantifications based on figures 4 and 5. The caption in figure 4 states "Percentages indicate the fraction of cyclones with a specific process as the most important one and numbers show the area-weighted mean APV averaged over all cyclones." but the descriptions of the figure often imply different things to this. It would be good to also explicitly say that this is how the percentages and PV anomalies are calculated in the text (in the paragraph at L256).

I think the issue in large part comes from the author not wanting to be too repetitive. However, if you have a good sentence structure it would be much easier, for you and the reader, to repeatedly use this same sentence structure when describing similar results. In section 3.3, the first sentence you use to describe the numbers in figure 4 (L263) is good but you deviate from it in future sentences in ways that can change the meaning of the sentence.

I have listed below the sentences I have found could be misleading. Apologies that this is a long list but hopefully it can be seen as one, albeit long, correction. In some cases I have suggested the simplest change to correct the meaning. However, I did pick up that you sometimes use "primarily" and "dominant" to describe a process modifying PV. If possible it would be better to use primarily as much as possible because you are only quantifying that one APV is larger than other APVs in each cyclone but dominant implies it is much larger than all other APVs which isn't quantified.

- L12: Along the cold front, PV is primarily generated by condensation in over half of the investigated cyclones. For most of the remaining cyclones, convection or long-wave

radiative cooling becomes the dominant process depending on environmental conditions.

- L14: "Results are similar for both seasons"
 - You need to briefly introduce what "both seasons" means.
- L15: Negative PV west of the cold front is produced by turbulent exchange of momentum and temperature as well as long-wave radiative heating
- L16: "The relevance of long-wave radiative heating is reduced during summer"
 - "Summer" should be "warm season"
 - Given the average PV anomaly for long-wave radiative heating is very similar for cold and warm seasons, would it be more accurate to say that the strength/relevance of PV anomalies generated by turbulent mixing is increased in the warm season?
- L17: The positive PV anomaly at the warm front is predominantly generated by condensation in the cold season, whereas turbulent mixing becomes the prevalent process during the warm season.
 - You are only talking about turbulent mixing of momentum but saying "turbulent mixing" implies also turbulent mixing of temperature
 - The average PV anomaly for turbulent mixing of momentum is larger than the average PV anomaly for condensation in both seasons. So isn't the PV anomaly at the warm front predominantly generated by turbulent mixing of momentum even though condensation is the predominant process in the majority of cyclones during the cold season?
- L18: Convection only plays a minor role for the generation of PV at the warm front.
 - While convection is rarely the dominant process generating PV at the warm front in an individual cyclone, it has a large average contribution across all cyclones. The average PV anomaly for convection is larger than the average PV anomaly for condensation even though it is the dominant process in so few cyclones.
- L19: Negative PV along the warm front is produced by long-wave radiative heating, turbulent temperature tendencies, or melting of snow in the cold season
 - This sentence implies that these are the only processes that contribute to the negative PV anomaly. In this case, 19% of warm fronts are dominated by "other" processes and even if that wasn't the case, it does not rule out processes contributing to the negative anomaly but not being the dominant process in any individual cyclone.
- L20: Turbulent temperature tendencies become the dominant process decreasing PV at the warm front in the warm season, together with melting of snow and turbulent exchange of momentum.
 - Become the dominant process -> becomes the most often dominant process
 - Together with -> followed by
- L21: The positive PV anomaly in the cyclone center is primarily produced by condensation, with only few cyclones where PV production is mainly associated with turbulent mixing or convection.
 - Primarily produced by convection *in most cyclones*
- L24: A composite analysis further reveals that PV anomalies generated by convection require a negative air-sea temperature difference in the warm sector of the cyclone, which promotes a heat flux directed into the atmosphere and destabilizes the boundary layer.
 - This implies that PV anomalies generated by convection can only occur when there is a negative air-sea temperature difference. Since you are referring to the composites (that are only over regions where convection is the dominant source of PV), this doesn't rule out PV generation by convection in regions with a positive air-sea temperature difference (or over land). My suggestion would be to replace "require" with "are associated with"

- L263: For the positive PV anomaly along the cold front (Fig. 4a, first panel),

condensation is the most important process in 53% of all cyclones, with an area-weighted mean APV of 0.88 PVU

- This first sentence has the correct structure and other sentences should generally follow this pattern. I would add that the area-weighted mean is the average over all cyclones
- Convection is more relevant than condensation in 29% of all cyclones, contributing 1.17 PVU on average
 - Convection is the most important process in 29% of all cyclones. You don't account for whether convection is more important in the remaining 18% of cyclones where neither condensation nor convection are the dominant process.
- L265: "14% of the cyclones occur in a particular environment promoting intense long-wave radiative cooling, which contributes 0.52 PVU to the positive PV anomaly along the cold front. These cyclones likely do not experience strong cloud formation as the APV value associated with long-wave radiative cooling is markedly lower than the mean contribution from condensation and convection"
 - These two sentences are slightly contradictory. You first say that the cyclones have intense long-wave cooling which would imply these 14% of cold-season cold fronts have a much larger PV anomaly due to long-wave cooling than the cold-season cold fronts where other processes dominate. However, you then suggest that the other processes only generate weak PV anomalies in these cold fronts where long-wave cooling is the dominant process. You would need to calculate the mean PV anomaly for each process in each subset of cold fronts to say which is true here. I don't think this is necessary since you show the composite environments for the different subsets of cyclones in the following section.
- L271: Condensation is again the most dominant process for the generation of the positive PV anomaly along the warm front (Fig. 4a, second panel), increasing PV on average by 0.86 PVU in every second cyclone
 - "increasing PV on average by 0.86 PVU in every second cyclone" implies that this average of 0.86 PVU is taken from the subset of warm fronts where condensation is the dominant PV producing process rather than being an average over all warm fronts
- L272: Turbulent momentum tendencies are responsible for the production of 0.98 PVU in 38% of all cases
 - Again, this sentence implies that the PV anomaly is calculated from a subset of warm fronts rather than being an average over all warm fronts
- L273: Comparatively few cyclones (10%) are found where convection is the most relevant process, increasing PV by 0.94 PVU
 - The PV increase of 0.94 PVU is the average over all cyclone but this sentence implies it is the average over the subset
- L274: Negative APV of -0.38 PVU due to turbulent temperature tendencies are again found in a large number of cyclones (60%)
 - This implies that the negative tendencies are only present in 60% of cyclones but I assume it is the dominant process in 60% of cyclone but likely present if most, if not all, cyclones
- L275: Additionally, about every third cyclone is characterized by -0.45 PVU due to long-wave radiative heating (not shown).
 - This implies that $\sim 33\%$ of cyclones have a negative PV anomaly due to long-wave heating equal to -0.45 PVU but I'm assuming the -0.45 PVU is an average over all cyclones
- L277: In the cyclone center and along the bent-back front (Fig. 4a, third panel), PV is primarily produced by condensation (1.27 PVU in 71%), followed by convection (1.37 PVU in 16%), and turbulent momentum tendencies (1.28 PVU in 12%), consistent with Fig. 3a.
 - The "x PVU in y%" again implies that the PV anomaly is calculated from a subset of cyclones
- L281: The negative PV anomaly along the cold front is mainly influenced by boundary

layer processes (Fig. 4b, first panel)

- Does “boundary-layer processes” mean the combination of turbulent mixing terms and long-wave heating?
- L282: Turbulent momentum tendencies and long-wave radiative heating are the primary processes reducing PV by -1.49 PVU and -1.9 PVU in 46% and 39% of all cyclones, respectively.
 - This sentence implies that the average PV anomalies are calculated from the subset of cyclones
- L283: In addition, turbulent temperature tendencies reduce PV on average by -1.47 PVU in 14% of all cyclones
 - Implies that the average of -1.47 PVU is over the 14% subset
- L284: Considering the most relevant opposing processes, long-wave radiative cooling and turbulent temperature tendencies produce about 1.14 PVU and 1.47 PVU in 46% and 34% of all cyclones, respectively (not shown).
 - Implies that the averages are taken from the subsets of cyclones
- L287: In 38% of all cases, long-wave radiative heating dominates and is responsible for a reduction by -1.51 PVU. In 22% and 21%, turbulent temperature tendencies and melting of snow generate -1.3 PVU and -1 PVU, respectively.
 - Implies that the averages are taken from the subsets of cyclones
- L289: Additionally, various other processes are responsible for the negative PV anomaly in every fifth cyclone, indicating the large variability in relevant processes.
 - Implies that these other processes are only present in $\sim 20\%$ of the cyclones but I assume you mean a different process dominates in 20% of cyclones
- L291: Negative PV tendencies are offset by turbulent temperature tendencies (1.16 PVU in 47%) and long-wave radiative cooling (0.57 PVU in 24%, not shown).
 - Implies that the averages are taken from the subsets of cyclones
- L295: Specifically, long-wave radiative cooling becomes more prevalent (20%) than convection (9%) in generating positive PV anomalies at the cold front, while condensation remains the primary PV producer (55%).
 - Remains the primary PV producer -> is most often the primary PV producer
- L296: Surprisingly, turbulent momentum tendencies (54%) become more important than condensation (39%) and convection (3%) along the warm front.
 - More important -> more often dominant
- L297: Finally, fewer cyclones experience strong PV production due to convection (5%) than turbulent momentum tendencies (16%) in the center, while condensation remains the dominant process (77%)
 - Just because convection is not the dominant process, does not mean that these cyclones do not experience strong PV production due to convection
 - Remains the dominant process -> remains the most often dominant process
- L301: Along the cold front, negative PV is primarily generated by turbulent momentum tendencies (58%), followed by turbulent temperature (18%), and long-wave radiative heating (18%).
 - Primarily generated -> most often dominated by. The average anomaly due to turbulent temperature tendencies is larger so I would say that turbulent temperature tendencies are the primary generator of negative PV here
- L302: Along the warm front, the relevance of long-wave radiative heating found in the cold season (Fig. 4b, second panel) diminishes during the warm season with negative PV being produced by turbulent temperature (50%), melting of snow (14%), and turbulent momentum tendencies (14%).
 - Being produced -> most often dominated
- L314: Expectedly, condensation is the main driver of increased PV along the fronts.
 - Is the main driver -> is often the main driver
- L331: The positive PV anomaly along the cold front is primarily produced by condensation, convection, and long-wave radiative cooling during the cold season (Fig. 4a, first panel)
 - is primarily produced by condensation, convection, and long-wave radiative cooling

-> is usually primarily produced by condensation, convection, or long-wave radiative cooling

- L361: Previously, we showed that the positive PV anomaly along the warm front during the cold season is either produced by condensation, turbulent momentum tendencies, or convection (Fig. 4a, second panel).
 - Produced -> primarily produced
- L364: Conversely, warm fronts modified by turbulent momentum tendencies are predominantly observed over land (Fig. 6b)
 - Modified -> primarily modified
- L369: The second category of warm fronts is related to the production of PV by turbulent momentum tendencies (Fig. 8, second row)
 - Related to -> dominated by
- L382: The positive PV anomaly in the cyclone center is primarily generated by condensation, convection, and turbulent momentum tendencies (Fig. 4a, third panel)
 - is primarily generated by condensation, convection, and turbulent momentum tendencies -> is most often primarily generated by condensation, convection, or turbulent momentum tendencies
- L396: However, higher wind speeds are observed for this type of cyclones
 - Wind speeds -> maximum vertical velocities
- L436: The positive PV anomaly at the cold front is primarily generated by condensation (53% of cyclones), convection (29%), and long-wave radiative cooling (14%) in the cold season (Fig. 4a)
 - Change the "and" to "or"
- L437: Condensation is again found to be the dominant process in the warm season (55% of cyclones), whereas long-wave radiative cooling (20%) becomes more important than convection (9%, Fig. 5a)
 - Dominant process in the warm season (55% of cyclones) -> dominant process in 55% of warm-season cyclones
 - Becomes more important -> is more often dominant
- L443: Cyclones associated with PV generation by long-wave radiative cooling at the cold front
 - Associated with -> dominated by
- L444: This process stabilizes the boundary layer
 - Does "this process" refer to generation of PV by long-wave radiative cooling?
- L448: Negative PV anomalies west of the cold front are primarily generated by turbulent momentum tendencies (46%), long-wave radiative heating (39%), and turbulent temperature tendencies (14%) during the cold season (Fig. 4b)
 - Change the "and" to "or"
- L449: Turbulent momentum tendencies (58%) remain the dominant process decreasing PV along the cold front in the warm season (Fig. 5b)
 - Is this correct? Although it is dominant in a smaller percentage of cyclones, turbulent temperature tendencies provide the largest average PV anomaly
- L450: whereas an increased fraction of cyclones experiences turbulent temperature tendencies (18%) and a reduced fraction is associated with long-wave radiative heating (18%).
 - Experiences -> are dominated by
 - Is associated with -> are dominated by
- L455: Condensation increases PV along the warm front in 49% of all cyclones during the cold season, followed by turbulent momentum tendencies (38%), and convection (10%)
 - The slight change in sentence structure here now implies that condensation *only* increases PV in 49% of cyclones.
- L457: Cyclones associated with PV generation by turbulent momentum tendencies at the warm front primarily occur over land (Fig. 6b).
 - associated with PV generation by -> with PV primarily generated by
- L463: Negative PV anomalies along the warm front are produced by long-wave

radiative heating (38%), turbulent momentum tendencies (22%), and melting of snow (21%) in the cold season (Fig. 4b)

- You've dropped "primarily" from this sentence
- Again change "and" to "or"
- L466: Long-wave radiative heating no longer appears as one of the three most relevant processes to produce negative PV anomalies at the warm front in the warm season (Fig. 5b), with turbulent temperature tendencies (50%), melting of snow (14%), and turbulent temperature tendencies (14%) becoming more dominant.
 - Most relevant -> most frequently dominant
 - More dominant -> more often dominant
- L470: The generation of PV in the cyclone center and along the bent-back front is dominated by condensation accounting for 71% and 77% of all cyclones during the cold and warm season, respectively
 - Condensation has the smallest average PV anomaly across all cyclones of the three processes shown but is most frequently the dominant process in an individual cyclone.
- L472: A larger fraction of cyclones are associated with convection during the cold season (16%) than in the warm season (5%)
 - Associated with -> dominated by
- L474: Finally, turbulent momentum tendencies generate the positive PV anomaly in the cyclone center in 12% (16%) of all cyclones during the cold (warm) season.
 - Generate -> primarily generate

Other corrections

- L260: What fraction of trajectories end up being excluded by these criteria?
- In figures 7, 8, and 9 it is difficult to read the grey contours where they overlap dark colours
- In figures 7, 8, and 9 it is good that you have a diverging colourscale centered at zero for anomalies (T2M - SST and ETSS) but for the other fields it is misleading. Especially when you have centered T2M and SST at zero in figure 9 but not figure 7 or 8. It would be good if you could use a different colourscale in this figure for fields which are not anomalies.
- L335: What happens in your composites of SST when the cyclone is over land?
 - L401: "surface and sea surface temperatures" implies the composites are simply "surface temperature". If this is true can you change the figure captions accordingly

Technical corrections

- L92: processes -> process
- L384: basis -> basins
- L441: only few -> few

Please also note the supplement to this comment:

<https://wcd.copernicus.org/preprints/wcd-2021-37/wcd-2021-37-RC1-supplement.pdf>