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Interactive comment on "Mid-level convection in a warm conveyor belt accelerates the jet stream" *by* Nicolas Blanchard et al.

Anonymous Referee #2

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Blanchard et al. present a detailed analysis of convection embedded in a WCB and how this affects the upper-tropospheric flow. The study is based on observations taken during the North Atlantic Waveguide and Downstream Impact Experiment and convection-permitting simulations. A reference simulation (REF) generally agrees with the observations and represents key features such as the WCB outflow, a dry region below this outflow and the cloud head associated with the bent-back warm front. A second simulation is performed with latent heating exchanges due to cloud processes being turned off (NODIA). A comparison of the two simulations reveals that elongated bands of negative PV are missing the the NODIA simulation pointing to their diabatic origin. Indeed, the analysis of trajectories and vertical cross section through the WCB suggests that mid-level convection embedded in the WCB is responsible for generating

the bands of negative PV in a vertically sheared environment. This is in line with recent studies by Harvey et al. (2020) and Oertel et al. (2020). The study is well written, the figures are mostly clear and the methods are sound. As the paper confirms recent research using novel observations and a slightly different approach (simulations with latent heat release switched on/off), I recommend the article to be published in WCDD after the following comments have been addressed.

Broad comments

1) The REF and NODIA simulations are compared qualitatively throughout the paper. To my impression it would be helpful if the authors provided quantitative estimates of the differences between the simulations since it is sometimes difficult to spot the differences by eye. As an alternative, difference plots would help the reader to fully appreciate the differences (e.g, Fig. 3, 8) which are discussed in the text.

2) The individual subsections are quite often introduced by describing what is shown in the figures. These descriptions are not necessary since they are also provided in the figure captions. Instead, it would be helpful if the authors described the purpose of each subsection in one to two sentences. This would help to guide the reader through the manuscript.

Minor comments

l. 2: Please clarify that "their" is referring to WCBs and not to "ridges".

l. 9: Since the "mesoscale structures" are mentioned here for the first time. Please specify what the "mesoscale structures" are. Are these the tropopause fold and the jet stream core?

l. 22: Also PV gradients along zonal flows form a waveguide. Please include this as well.

l. 32: I'd suggest to also cite at least one of the early studies, e.g., by Browning et al. (1973) and Harrold (1973).

l. 32: Other studies state that WCBs are characterized by "rapid ascent" (e.g., Eckardt et al. 2004). Compared to deep convection the WCB ascent may be considered as "slow". Perhaps specify that the ascent is slow compared to deep convective systems.

l. 36: Please specify what "This" is referring to.

l. 40: Consider to use "Accordingly" instead of "Thus" to avoid the use of the same wording in two consecutive sentences.

l. 52: Please provide a reference for the statement "persisted for several weeks".

l. 72: Specify here that RASTA is a cloud radar.

l. 87: Is it only the latent heat exchange which is set to zero or are there also other diabatic processes set to zero?

l. 91: Why are you defining three 3-D passive tracers at each grid point and not only one tracer per grid point?

l. 98: According to e.g. Browning et al. (1986), WCBs start to ascend from the planetary boundary layer. In terms of their terminology: Are you really identifying a WCB as it was originally defined or is it convection that is embedded in a slantwise ascending WCB?

l. 106: Please specify that it is 2 October 11:00 UTC.

l. 107: I assume you are meaning "in the eastern half" of the simulation domain. "East of the simulation domain" would actually be outside the domain in Fig. 1.

l. 114: In the region of the cyclonically turning WCB the BT is lower than observed by MSG. In contrast, in NODIA the BTs are similar to the observed values. Do you have any hypothesis why this might be the case?

l. 113-121: It would be very helpful if you labeled some of the key features in Fig. 1 (e.g., cloud head, PV tongue).

l. 132: Please consider to indicate the flight direction (e.g., as an arrow) in Fig. 1a.

l. 141: To my impression the slope also indicates the location of the cold conveyor belt which is located below the cloud shield associated with the WCB. If the authors come to the same conclusion this should be mentioned in the text.

l. 147: Consider to replace "until" with "reaching down to".

l. 160: Can the authors comment on whether this low-level jet is also part of the cold conveyor belt?

l. 162: "close to those measured" is a quite qualitative statement. Could you either show a difference plot of the modeled and observed wind speed or provide a quantitative measure such as RMSE? Also showing a scatter plot of observed vs modeled wind speeds could provide a more quantitative estimate of the differences.

l. 165: Consider to remind the reader that you have selected all ascents with w > 0.3 m s^{-1}. Or are you showing air parcels that fulfill the ascent criterion of 150 hPa in 12 h? Please clarify.

l. 171: Also here, a quantitative statement on the differences would be very helpful.

l. 177: Write "profiles" instead of "profile".

l. 180-209: When comparing observations to modeled values at individual grid points, differences might occur due to minor spatial shifts between simulations and observation. To account for these spatial displacements, I suggest to consider the values at several neighboring grid points and to show their variability in Fig. 4. E.g. showing the median value of the grid points together with the interquartile range could be one way to estimate the sampling uncertainty.

l. 215: To my impression there are only two regions of high ascent frequency. One is associated with the bent back warm front and the second region can be found over Greenland. So, what is the reason for splitting the ascent along the bent back warm front in two regions? Please explain in the text.

l. 223: How did you investigate whether the ascents are produced by the warm front dynamics or by orographic forcing?

l. 233: I assume it is Fig. 6a.

l. 234: I assume it is Fig. 6b.

l. 235: I assume it is Figs. 6a,b

l. 236: I assume it is Fig. 6a.

l. 237: I assume it is Fig. 6b.

l. 239: Correct to Fig. 6a.

l. 240: Correct to Fig. 6c.

l. 299: Why are you referring to the brown circles? As far as I understand correctly, the red stars in Fig. 6a indicate the position of trajectories closest to the time shown in Fig. 9.

l. 307: The rapid segments are not only found in regions of high θ_e, but especially in regions with high θ_e gradients. This should me mentioned in the discussion.

l. 307 and the following paragraphs: It is not quite clear to me why the focus is on 2 October 2 UTC. The differences between REF and NODIA in terms of upper-tropospheric PV (at 320 K) are considerably larger at 06 UTC. In fact, at 320 K differences in PV at 2 UTC are very difficult to identify. It seems that at 2 UTC the negative PV is mostly located in the mid-troposphere. So, could you comment on the processes leading to the negative PV at 320 K at 06 UTC? Since the differences between REF and NODIA are pronounced at 06 UTC, the negative PV is likely not only a result of isentropic advection.

l. 309: Please provide the coordinates of the rapid segments that are located further

southwestward.

l. 310: Please specify that you are referring to the black dots in Fig. 9b after the statement "... along the bent-back front". In line 311, please clarify that you are referring to the shading in Fig. 9b when discussing the vertical wind speeds.

l. 322: What exactly to you mean by "on the jet stream side".

l. 335: Fig. 10b is a vertical cross section from south to north. So, how is it possible to see the "western edge of the cloudy area"?

l. 354: Can you quantify a bit how much too low?

l. 359: Is this air mass between the warm front and the Greenland plateau really dry? I agree that radar does not detect any precipitation, but I am not convinced that this air mass is dry. Also, it would be interesting to know whether this air mass (especially in the lower troposphere) is the cold conveyor belt of the cyclone.

l. 360: Please explain why the dry air mass is absent. An explanation as in l. 155 would be helpful.

l. 375: Could you explain why the ascents in the WCB outflow are solely due to cloud diabatic processes and not due to frontal dynamics. I think the statement in its current form is very strong and should be reconsidered carefully.

l. 386: To support the statement that especially anticyclonic segments are associated with negative PV: Could you indicate the location of anticyclonic and cyclonic segments in Fig. 9d?

l. 390: Schemm et al. (2013) performed idealized moist and dry simulations of a baroclinic wave. Their results, in particular with respect to the northwestern edge of the ridge are very similar to the results of this study. Please consider to reference their work.

l. 401: The conditional instability is only mentioned here and in the abstract. Please describe already in the previous Section 5 where exactly the conditional instability can be found. It would be helpful to the reader if the regions of conditional instability were highlighted in the figures or if the latitude longitude coordinates of the unstable regions were provided.

l. 406: This is somewhat related to my previous comment on l. 307. Comparing the evolution of PV at the 320-K isentropic surface in Fig. 8, I have the impression that the negative PV is not simply advected. If this was the case the PV structure should be very similar in REF and NODIA due to conservation of PV in adiabatic flows (Figs. 8c, d). However, REF is characterized by more negative PV in the northwestern corner of the ridge than NODIA. So this clearly points to non-adiabatic processes. My suggestion is that the statement "these structures are then advected by the upper-level anticyclonic flow into the northwestern edge of the ridge" should be extended in the sense that also the non-conservative processes are at least mentioned.

l. 411: A reference for the statement that models "struggle to represent updrafts that do not start in the boundary layer" is needed.

Figures

Fig. 1: Please label at least one isobar of the MSLP field in b) and c).

Fig. 5: Please indicate the position of the cyclone center with a marker. This will help the reader to follow the description in Section 4.1. Also, what is the unit of the spatial frequency? Is it simply the total number of air parcels or is it the number of air parcels per area? Please clarify.

Fig. 7: What exactly do mean by "number of rapid segments lies above the average"? Does it mean that it is only shown when more than 50

Fig. 9: "Updrafts and potential vorticity" is a bit confusing since also other parameters are shown. Please consider to remove or replace the first sentence of the caption.

References

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