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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 #1

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The paper contains a comprehensive case study analysis of convection embedded in a warm conveyor belt and its impact on the upper-level flow. The study combines unique observations taken during the North Atlantic Waveguide and Downstream Impact Experiment and convection-permitting simulations of the case study. The observations are compared to a reference simulation and an experiment in which heat exchanges due to cloud processes are turned off (called NODIA). Generally, the reference simulation agrees with the observations whereas key features are missing in the NODIA experiment, highlighting their diabatic origin. In particular, elongated bands of absolute negative PV are missing in the NODIA simulation. Their impact on the upper-level flow is hence missing in NODIA. These findings support the theory developed in Harvey et al. (2020) and are consistent with those seen in a different cyclone's WCB (Oertel et al.

2020). The case included in this study has been the subject of several recent articles (Maddison et al. 2020, Blanchard et al. 2020), including a recent publications by the authors, and this contribution adds useful new insights to complement the recent research, particularly with the novel observations within the WCB. I thus recommend the article be published subject to minor revisions. I have a couple of broad comments that should be considered before publication and specific and technical comments listed below.

Broad comments:

Clarification of online trajectories versus the WCB.

A more careful consideration of how the trajectories shown in the article relate to the WCB ascent would be beneficial. The authors select trajectories in the simulation that ascend 150 hPa in 12 hours (based on the 600 hPa in 48 hour criteria for WCBs used in many other studies). As this is a short time period the trajectories shown don't necessarily correspond to the WCB, as the authors note (section 2.3). As the simulations are run for 36 hours I wonder if there are some trajectories that stay in the domain for longer than 12 hours and could be used to show whether the 12 hour ascents do correspond to part of the WCB or not. Alternatively, successive 12 hour trajectories could be compared in an attempt to "piece together" the WCB flow. This cyclone has been shown to have a WCB (e.g. Maddison et al. 2019) so I would suggest emphasising this (in section 2.3) and terming the ascents "WCB proxy" or something similar. Some properties of the trajectories could then be better explained and would allow for a better placement of the results in the current knowledge.

For example, from Figure 7 it appears that the anticyclonic ascents are from the later stages of a WCB ascent (the start at 4km), and the cyclonic ascents from the early part. Also, the characteristic increase and decrease in PV along WCB ascents (e.g. Madonna et al. 2014) is not found here. These should be further explained.

2) Verification of the simulations against the observations.

Throughout the paper the authors compare the reference and NODIA simulations with each other and with the observations. It would be helpful if the authors included some verifications (e.g. RMSE) to clarify and emphasise the comparisons as it is sometimes difficult to see by eye. I would suggest quantifying the simulations' skill in replicating the observed fields in Figures 1, 2 and 3 (comparing points where observations exist). And also comparing the two simulations with each other in Figures 5 and 8. For example, the authors state that the ridge extends further west in the reference simulation so quantifying this somehow (most westward longitude reached for example) would be helpful as it is a bit confusing because of the complicated structure of the ridges. Also the jet stream maxima should be highlighted in the two simulations and discussed more as the title states that the jet stream is accelerated by the convection in the WCB.

3) Labelling features of interest.

Several features are referred to in the text that are not always easily recognisable among the highly detailed plots. The authors give latitude or longitude points to guide the reader but this can be quite cumbersome. Adding labels (maybe shapes or simply letters) to the plots for some of the features would help with the comprehension of the results. The features mentioned in the text that I would suggest labelling include: the high PV tongue, the tropopause fold, the jet cores, the WCB outflow, the bent back front, the low-level jet and the cloud head. Too many labels can of course obscure features and make the plots more complicated but adding one or two labels to some of the figures when latitude/longitude values are needed in the text would be helpful.

Specific comments:

L22: PV gradients form a waveguide on zonal flows too (without upper-level ridges or troughs), this should be mentioned here.

L86-88: more information on the other parameterisation schemes in the model should be given here. In particular, would other schemes contain heat exchanges within clouds that would still be active in NODIA?

L128: is this a second MSLP centre (were there two?) or just an eastward movement of the cyclone? Evidence should be provided if it is a second MSLP centre development.

L206: The fact that the observations are well simulated in REF allows for the attribution of features and their development to diabatic processes. This should be emphasised here.

L220: What are the ascents over Greenland associated with?

L225-226: I find it surprising that there are almost no ascents in the WCB outflow in NODIA. Is it that the WCB is absent or that the trajectories don't meet the ascent threshold used? It could also be a timing issue in that WCB trajectories may be delayed in NODIA. Would figure 5 look different if a slightly later 12 hour window was chosen? Further explanation should be included here.

L243: It would be beneficial here if a brief explanation of why/how the anticyclonic trajectories would be expected to impact the upper level flow, via PV modification for example.

L250-265: can the results be explained here using extratropical cyclone development theory? Does the cyclonic branch of the WCB typically occur later than the anticyclonic? The PV modification along the trajectories is different here than that found in Madonna et al. (2014). There is no increase in PV (as trajectories ascend through heating) and subsequent decrease (as trajectories leave heating). May this have occurred earlier in the ascent? This should be explained here too.

L285: Another feature that is clear in Figure 8 is the PV field is smoother in NODIA. This should be mentioned and explained.

L289: mention that the negative PV bands at 06:00 push the ridge cyclonically to the west as well.

L320-326: Why is there no PV dipole for the strong updraft above 6km altitude? Has the PV signature been dissipated by this time? Please explain this here.

L353: Do heat exchanges still occur in other parameterisations? e.g. cloud scheme?

L383: provide some explanation for the rapid ascending trajectories.

L388: quantify how much further the ridge extends west in REF. The difference looks quite small.

L401: is this region of conditional instability shown? Mention if it is or is not.

Technical comments:

L3: “structures of negative” should be “structures with negative”

L6 (and elsewhere): the authors should explain why the cyclone has been given this name. In the abstract this might not be possible so just saying “a cyclone” here and giving the cyclone its name in the main article may be best.

L7-9: I would remove the sentence “The observations reveal. . .” as the abstract is quite long and this isn’t really necessary here.

L9: change “reproduces well the observed” to “reproduces the observed”

L15: “near the bent back front” in what? The reference simulation?

L17: remove “and” before “with the negative”

L17: thus appear -> the convective cells thus appear

L17: add “the” before “negative PV bands”.

L27: reference to Martinez-Alvarado et al. (2018) here. They show Rossby wave amplitude still decreases in more recent NWP model configurations.

L31-32: change to “WCBs usually flow poleward and upward as coherent. . .”

L33: band -> bands

L34: clouds -> cloud

L34: During ascents -> During WCB ascent

L35: which representation is -> the representation of which is . . .

L39: impact -> impacting

L50: Add why the cyclone is named stalactite

L106: Add sentence introducing the section and what will be included

L116: along -> above

L121: structures -> structures present.

L125: Change the sentence “REF reproduces well the . . .” to “The track of the Stalactite cyclone is well reproduced in REF”.

L128: meridian -> meridional

L145: Highlight where these features are (see broad comment 3)

L147: 40W until z -> 40W, reaching z. . .

L149: part -> part of the domain

L158: except on -> except in

L159: eastern part where it -> eastern part of the domain where it . . .

L159: wind speed values -> wind speeds

L162: simulation completes the description -> simulation provides a complete description of..

L166: number ascents -> number of ascents

L177: profile -> profiles

L183-184: might be worth mentioning that the wind speeds in REF still tend to under-

estimate the observed peak wind speeds

L248: remove “a” before higher. altitude -> altitudes

L252: remove “a” before strong

L255: remove the sentence “some start close to the surface”.

L265: swap thereafter with “in the following section”.

L270: track -> follow

L281: “the eastern part of the northwestern edge” is confusing to me. Consider rephrasing.

L287: merge sentences here: NODIA. But -> NODIA, but

L287: DIA -> NODIA

L288: there -> here

L299: what region is shown in Fig 9 a,b? The red box?

L327: remove “Thus”. Or join to previous paragraph.

L359: is this dry air mass the cyclone’s dry intrusion?

L361: state what the tropopause fold is at the outer boundary of.

L376: explain or motivate why the focus is on the WCB ascents.

L391: Maddison et al. (2020) seems another appropriate reference to add here.

L401: “matches with the organised” -> “matches the organised”

L406: PV structures are -> PV structure in WCB ascent regions are

References:

be consistent with journal abbreviations.

L423: page and volume numbers missing

Figures:

Fig1: add ‘as’ before ‘(a)’

Fig1: What time are the MSLP contours in (b) and (c) shown?

Fig4: mention that the profiles are shown for both observations and simulations in the caption

Fig5: if I understand correctly, the red box is used to select WCB outflow ascents? It is a bit confusing as I initially thought all ascents shown had to have passed through the red box at 11:00? Please clarify this in the text or caption

Fig6: 40 trajectories are plotted, out of how many? Give the number in the text or caption.

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