Answer to Reviewer 2

This paper is the second part of a study looking at the future changes of extratropical cyclones in the CESM model. In this part the authors use Lagrangian trajectory analysis to investigate the pathways of the air parcels and changes in their characteristics on their way to different horizontal and vertical locations in composites of extratropical cyclones.

The results mostly corroborate the findings of the earlier paper, and of other studies, in finding that increased moisture in a warmer climate leads to increased diabatic heating and therefore larger PV production in mid levels. The upper level features are more complex, especially due to the level of focus often being above the tropopause.

I especially like the composite figures showing the tendencies over the past 24 hours, which gives a good understanding of the features of the cyclones.

I have a few comments that I hope might improve some aspects of the manuscript.

We are grateful to the Reviewer for their constructive comments, which will improve the quality of our manuscript. We are pleased to share our answers in this document. The figure and line numbers correspond to the original manuscript. The reviewer comments are in black and our responses are highlighted in blue.

General comments

I wonder at the choice of 250hPa as a level to focus on. This was considered in paper 1 also, but in that paper it is shown that the tropopause average pressure is close to 300 or even 350hPa. If the focus of the study is on the dynamics of the cyclones themselves, then would it not be better to look at a level within the troposphere, where the WCB outflow is having a more direct impact? This also makes the average of the trajectories over the cyclone area at the this level difficult to interpret, and possibly not very useful.

We have reproduced the figure for the 300 hPa level (see Fig. R2 below), resulting in a similar pattern with slight differences. For instance, in the present-day climate, there is a stronger change in pressure, indicating a stronger ascent of the WCB trajectories. The PV tendency composite shows a more evident PV decrease downstream.
However, since our main goal is to provide further insights into the processes shaping the PV anomalies shown in part I, which have been presented on the 250 hPa level we would like to keep the 250 hPa level also in this second part of our study. Furthermore, this is also consistent with other studies (e.g., Priestley & Catto, 2022).

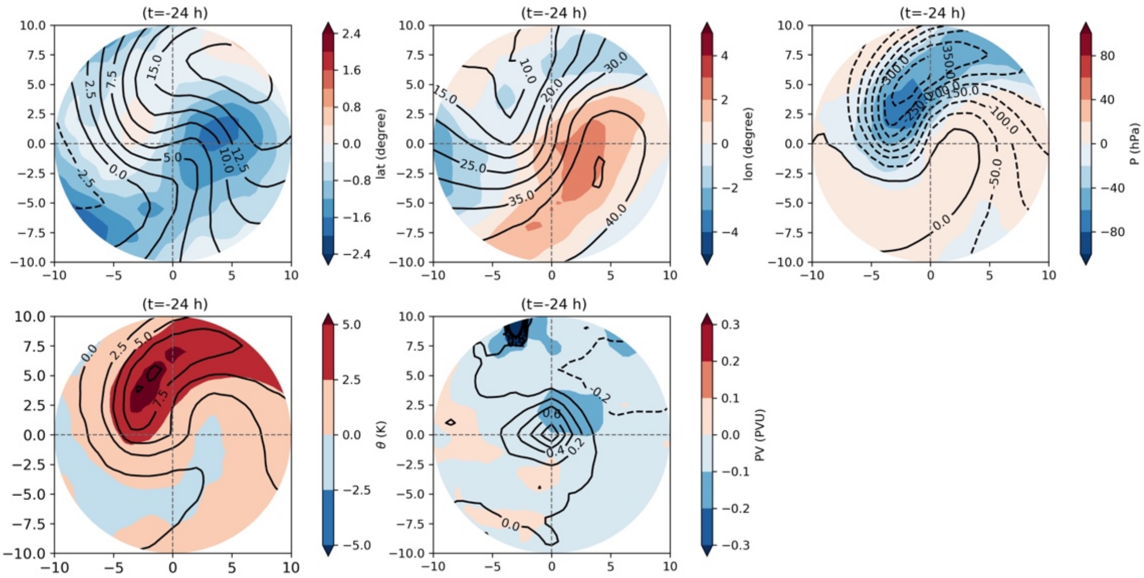

Figure R2. Similar to Figures 3 and 7 but at 300 hPa.

Figs 4, 5, 6: In the section describing these figures, there is a lot of jumping around between these and the horizontal composites. This is because the 700hPa horizontal composites are discussed along with 4, 5, 6, then the 250hPa composites. It might be easier to read and follow if the trajectories from 700hPa are all combined into a single figure that can be discussed with the 700hPa horizontal composites. Then the same for the 250hPa trajectories. The way it is currently presented gives a slightly misleading impression that trajectories at different levels but the same location are more strongly related than they really are.

This is a good suggestion. We will modify the figures as suggested.

More specific comments

Line 12-14: This sentence is hard to read - consider rewording.

We will reword the sentence as follows:
In contrast, projected upper-level PV changes are due to a combination of several processes. These processes include cloud-diabatic PV changes, anomalous PV advection, and likely also radiative PV generation in the lower stratosphere above the cyclone center. For instance, enhanced poleward advection is the primary reason for a projected decrease in upper-level PV anomalies south of the cyclone center.

Line 31: Remove the additional comma.

We will remove this additional comma.

Figure 1: Since you later discuss the two branches of the WCB, I suggest adding the cyclonic branch onto this schematic.

We will add the cyclonic WCB branch to the satellite figure.

In the Methods section I would like a bit more information. I understand this is part 2, but it would be good to have some extra information so the paper can stand alone. For example, Which months? What area? NH or North Atlantic? How many storms does this make? Which cyclone identification?

We have added new information in the Methods:

3 Methods

We study Lagrangian airstreams in the 1% strongest cyclones in the 10-member CESM-LE dataset for the extended winter season (from October to March). This cyclone dataset is described in detail in part 1. Based on the SLP contouring method (Wernli and Schwierz, 2006), we identify and track storms over the North Atlantic region (longitude: -100° to 40° and latitude: 30° to 90°). The cyclone intensity and, thus, the extreme cyclone selection (1% strongest cyclones) are obtained by computing the relative vorticity at 850 hPa at the cyclone center. The number of extreme cyclones is 358 in the present-day and 308 in the future climate. In present-day climate, the cyclones typically travel towards the northeast, with the peak cyclone frequency south of Greenland. At the end of the century, the storm track is projected to shift eastward, implying a higher impact in the north of the United Kingdom and the west coast of Scandinavia.

Line 147-148: This argument only really works for the 700hPa trajectories, since at the higher level the trajectories are not so likely to be coming from above.

We see some trajectories coming from above also at 250 hPa, but of course not as many as at lower levels. We will add a note that this argument refers mainly to the 700 hPa level.

Line 167: Typo in the units.

We will modify g Kg^{-1} to: g kg^{-1}

Figures 4, 5, 6: It may be nice to include the 5-95th percentile range on these figures too.

We will include the 5-95th percentile range to the Figures 4, 5, and 6.

Line 246: I find this more northward motion very interesting. Is this associated with a more poleward propagation of the cyclones? Or can you not infer that from this information? Is it possible to explain this feature in more detail?

The enhanced northward motion is also evident if the cyclones' propagation is removed (see the new figure R1e), albeit with a slightly lower magnitude. It is thus related to both the enhanced poleward propagation, which is consistent with previous studies (e.g., Tamarin & Kaspi, 2016) and a stronger northward flow of the air parcels relative to the cyclone center. A note on this will be added to the manuscript.

Line 249: Similarly to the previous comment, I find it interesting that there is a weakening in the westerly flow. It would be good to link this to projections of a weakened Jetstream either here or in the conclusions/discussion.

The weakening is restricted to lower levels. The tendency at upper levels is to strengthen the westerlies in the region of the jet streak (Fig. 7b).

Line 381: Typo in “cyclones”.

We will change cyclonce to: cyclone

Figure S1: More information is needed in the caption - what level is this showing?

We will add more information, see below:

Figure S1. PV climatology at 300 hPa for the extended winter (October to March) in the North Atlantic region in present-day climate, future climate and their difference (response to climate warming).

References

Priestley, M. D. K. and Catto, J. L. (2022). Future changes in the extratropical storm tracks and cyclone intensity, wind speed, and structure,Weather and Climate Dynamics, 3, 337–360, https://doi.org/10.5194/wcd-3-337-2022.

Tamarin, T. and Kaspi, Y. (2016). The poleward motion of extratropical cyclones from a potential vorticity tendency analysis, Journal of the Atmospheric Sciences, 73, 1687–1707, https://doi.org/10.1175/JAS-D-15-0168.1.