31/07/20

Review of “Vertical cloud structure of warm conveyor belts – a comparison and evaluation of ERA5 reanalyses, CloudSat and CALIPSO data” by Hanin Binder, Maxi Boettcher, Hanna Joos, Michael Sprenger, and Heini Wernli

General comments

The authors investigate the cloud and precipitation associated with WCBs during nine Northern Hemisphere winters with ERA5 reanalyses, CloudSat and CALIPSO data. They use ERA5 to not only depict the meteorological conditions associated with these WCB-produced cloud systems, but also to compare its performance with the measurements. They provide novel findings on the climatology of clouds and precipitation associated with WCBs and their corresponding thermodynamical and dynamical fields. In particular, the small- and mesoscale structures depicted with the satellite measurements are unprecedented. I strongly support the conclusions of this study and its publication in Weather and Climate Dynamics, subject to minor revisions.

Specific comments

L.29. “[...], which can intensify the associated cyclone (Binder et al., 2016)”
Maybe you could add Davis and Emanuel, 1991; Rossa et al., 2000.

L. 51, 54: Blanchard et al. 2020 could be added either on L. 51 or 54 along with Oertel et al. 2019 or 2020 respectively, since it is also an example of embedded convection in a WCB during NAWDEX, respectively an example of mesoscale PV dipoles.

L.106-107: The sensitivity of the CPR ranges from −30 to 50 dBZ.
This is quiet a large interval, could you give an indication of the sensitivity as a function of range (e.g. -30 dBZ at X m a.s.l., 50 dBZ at Y m a.s.l.)? I guess the sensitivity of 50 dBZ is in the case of attenuation?

L. 108: [...], which can amount to more than 10 dBZ km^{-1} […]
Could you give a value or just a qualitative statement of the attenuation if no liquid water is present? Even at 94 GHz, the attenuation by gases and ice is much smaller than the one of liquid water. This would help a reader not familiar to radar attenuation to understand that it is less significant above the melting layer (respectively above the highest supercooled liquid water layer).

L. 159-170: I like the modifications to identify the WCB with respect to Madonna et al. (2014) method, I think it makes totally sense. However a 45% total increase of the number of trajectories is quiet substantial. Could you explain a bit the motivation behind these modifications? Is it motivated specifically by the aim of this study or should it apply to all future WCB detections? Do you expect your results to be sensitive to this increase in the number of trajectories? For instance, it could modify the distribution of the type of WCB included (e.g. more rapidly ascending ones with respect to Madonna et al. (2014) method).

Section 2.4: While the matching between WCB trajectories and CloudSat – CALIPSO overpasses is very well explained, I think a schematic of the method could help to visualise it, if feasible. Otherwise, referring to Fig. 1b could already help.

L. 179: “the 56 preceding and succeeding profiles” seemed to come out of nowhere the first time I read it. I then understood that 113 profiles times the horizontal resolution of DARDAR would make 124 km, but at first it is hard to understand the rational behind these numbers. Maybe it would help the reader to explain where the 56 comes from. This is somehow related to the previous comment. If you include a schematic on the matching, this could be added in it.

L. 239-247: I really like how you summarise the end of a section and introduce a new one.

L.273-275: Do you have a possible explanation for that?

L. 363: “[…], and there is no clear indication for a melting layer in the radar signal.”
Actually if you look at the shape of the reflectivity contours (Fig. 4c), even if it is mainly oriented along the diagonal, there is a change in the curvature which follows the 0°C isotherm, indicating a secondary maximum of reflectivity. I think this could be an indication of the melting layer in the radar signal. To fully appreciate the melting layer signature at W-band, one has to consider the following: (i) For a ground-based W-band radar there is no bright band as is the case at lower frequencies, instead “an abrupt increase in the radar reflectivity without a following decrease at the base of the melting layer” (Kollias and Albrecht, 2005). (ii) For a nadir-pointing W-band radar (e.g. CloudSat) the bright band occurs du to “an increase in radar reflectivity from the dielectric effect of water, followed by a rapid signal decline [...] caused by correspondingly strong signal attenuation.” (Sassen et al. 2007). I think both cases (all WCBs and strong WCBs) nicely correspond to the description of Sassen et al. 2007: we have a maximum of reflectivity followed by a sharp decrease due to attenuation (especially in Fig. 4c, which is consistent with stronger rainfall). It seems that the maximum of reflectivity is not due to the higher dielectric constant of the liquid water coating the melting snowflakes, since it occurs above the 0°C isotherm, but rather to attenuation starting above the melting layer. Hence, it suggests that the attenuation effect is stronger than the dielectric effect. The attenuation starting above the melting layer could be partially explained by the presence of supercooled liquid water droplets (see Fig. 5b and 7b): they are so tiny, that even at W-band they will not significantly contribute to the reflectivity, despite there higher dielectric constant than the surrounding snowflakes. However, they contribute significantly to the attenuation.

L. 434: Even above z_{WCB}=9km I see no gap between the frozen and liquid hydrometeors. Do I interpret this correctly?

Figure 2/5/7: Maybe it could be recalled in the caption that IWC_{DARDAR} includes SWC and hence IWC_{DARDAR} should be compared to IWC_{ERA5} + SWC_{ERA5}. For a reader comparing Fig. 5 and 4 without reading Sect. 4.1, this could be confusing.

Figure 4c: There is a nice secondary maximum of reflectivity for $z_{WCB} > 12$ km and z_{prof} between 3 and 7 km. This is probably associated with the subtropical convective system mentioned in Sect. 4.1. It is also well depicted in Fig. 7a,b and seem to correspond to negative moist static stability (Fig. 7e). Even if subtropical systems are not the focus of this study, it could be mentioned, since it is a rather interesting feature.

Technical corrections

L. 61: According to WCD guidelines, footnotes should be avoided. I personally find it OK, it is just for you to know in case.

L. 92: According to WCD guidelines, Section should be abbreviated Sect. in running text, this should be corrected throughout the manuscript.

L. 175: Suggestion: “A match between a WCB trajectory position and the satellites’ track [..]” would be maybe more precise.

L. 214: Suggestion: “[…], the lower reflectivity and IWC values suggest ice clouds rather than falling snow.” would be more appropriate than “indicate”.

L. 225: “The IWC values strongly increase [...]” would be more precise than “The values strongly increase [...]”

L. 226: “[…] (see grey contours).” You mean the thin black contours of SWC in Fig. 2d?

L. 193, 245, 372: I am not sure if the capitalisation of “Section” is correct if it does not refer to a specific section (i.e. followed by a number)? To be checked.

L.413: you probably mean Fig. 5b.

L. 445: “In the WCB outflow, the PV values are anomalously low ~~PV~~ (< 0.2 pvu).” The second “PV” seems not necessary.

L. 569: Just in case, this article is now in final form in ACP: https://doi.org/10.5194/acp-20-7373-2020

Figure 6: Why not using the same colour for all WCBs and strong WCBs as in Fig. 3d or the opposite?

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