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Comment on amt-2022-252

Raphaela Vogel (Referee)

Referee comment on "The Virga-Sniffer – a new tool to identify precipitation evaporation using ground-based remote-sensing observations" by Heike Kalesse-Los et al., Atmos. Meas. Tech. Discuss., https://doi.org/10.5194/amt-2022-252-RC1, 2022

This paper presents a new tool to identify virga below trade cumulus clouds using ground-based remote sensing observations. The tool was developed using data from the recent EUREC4A field campaign and its modular approach can be applied in multilayer cloud situations. The performance was assessed through comparison with the Cloudnet target classification, and some statistics regarding virga occurrence frequencies and depths are presented. The paper is easy to read, fits well into the scope of AMT, and should be accepted after some revisions. I have three major comments, which are summarized below, along with some more minor comments and technical corrections (in the annotated pdf).

Major comments:

1. Tool description:

I think the tool description can be improved. I couldn't follow the explanation in Section 3.1 as I was missing some crucial information: at what temporal resolution are these analyses done? What is a CBH layer? Other confusing bits of information in Sec. 3 are:

- L152: The module numbering in Sec 3.1 is a bit counter-intuitive: why not put the smoothing as module 1 (instead of 5) and thus start with module 1?
- L154: what does 5% mean here? 5% of a given time period? Or 5% of vertical extent?
- L166-168: this is a very lengthy way of saying that 'two iterations of all 5 steps are made'.
- L168: I thought that LCL data is optional (Fig. 2), but here it seems to be necessary.
- L175: I don't remember a definition of 'valid radar reflectivity'.
- L200ff: These clarifications are helpful, but e.g. the minimum virga length requirement

is only mentioned in Sec 3.3, and comes as a surprise here. These examples could thus be moved after Sec 3.3. Furthermore, instead of just writing 'maximum allowed gap for virga', the chosen default threshold could be mentioned again (I actually thought that 700m is a typo, it seemed too large for me – so repeating it would clarify this choice).

- L204: What is rg19 then? Did the ceilometer miss this second cloud layer due to the strong rain? This should be discussed.
- L210: This step of virga mask refinement is thus not optional (as suggested in Fig. 2, part 3))?
- 4: what does 'filled cloud base' mean?
- L269: I don't see the multiple layers at 05:00 in Fig. 5. Is the 'filled cloud base' considered as a cloud? If so, I'd find this problematic, because there is obviously no cloud there.
- 4&5: Zooming into the detected virga (e.g. Fig 5c, around 04:40 or 05:45), the sub-cloud layer virga is not continuously detected, potentially due to surface rain or (for stratiform inversion cloud) positive Doppler velocity. I find that a bit problematic, as physically these rainshafts should be considered as one object, and the on-off-virga detection is a bit arbitrary. See also my major comment #3.
- To clarify the reason why some sub-cloud layer rain is not classified as virga, it would be helpful if Fig. 4 & 5 could also show the surface rain flag.

The beginning of the summary section 5 mentions that profile-by-profile information is used. I think this information should come at the beginning of Sec. 3, together with information about the temporal resolution of the analyses (e.g., it is unclear what temporal resolution the ceilometer has), and reference to the appendix, which summarizes the configuration (I only realized after the summary that there is an appendix).

I also have some issues with Fig. 2, as (i) the gray thin lines in Fig. 2 are hard to see on my print out, and (ii) the figure claims some steps to be optional, which are discussed as necessary in the text (see above). For Figure 3, the coloring is ambiguous, because detected cloud and virga should also be partly green, because they have a valid Ze. So maybe make two masks (one input and one output), or hatch the boxes with valid Ze. It would also be nice to have an example of a multi-layered cloud situation here.

2. Cloud type classification:

I have some issues with the cloud type classification here. During EUREC4A, I don't remember any situations of stratocumulus or stratus clouds. However, deeper trade cumulus clouds with extensive stratiform cloud layers were very frequent. But these stratiform cloud layers were at some point detrained from a cumulus core rooting in the sub-cloud layer. I.e., the convection and cloud formation was surface-driven and not cloud-top driven as in stratocumulus. From a ground-based single-point perspective, this distinction is of course not easily made, because you might only capture the stratiform part of a cloud.

Although the classifications used here might be in line with the *Stratocumulus Cumulogenitus (C_L = 4)* class of the WMO cloud atlas, I would encourage the authors to reconsider their cloud type classification. In the broader EUREC4A or trade cumulus community, we usually use different names for this ‘cloudiness aloft’ components, which are often called ‘stratiform (cloud) layers’, ‘stratiform inversion cloud’, ‘shallow anvils’, or sheared edges of deeper trade cumuli. Nuijens et al. (2014) or Vial et al. (2019, https://doi.org/10.1029/2019MS001746) are good references for how to deal with these naming issues.

3. Virga vs. evaporation from rainshafts that reach the ground:

I miss the motivation for focusing only on virga rather than all rainshafts. Although raining clouds are less frequent than clouds with virga (your Table 3), in terms of their contribution to total rain evaporation they are likely still very important. So when the main reason motivating this study is to (eventually) investigate rain evaporation, why focusing only on virga? In my eyes, the only physical reason that distinguish virga from other rainshafts is that total versus partial re-evaporation is relevant for the isotopic signal (Torri 2021, https://doi. org/10.1029/2020JD033139). But e.g. from a moisture or heat budget point of view, it doesn’t matter whether rain reaches the surface or not. It would be great if the authors could discuss their reasons for their focus on virga more explicitly.

Minor comments:

1. Review of earlier approaches of virga detection or rain evaporation retrievals: In the introduction, I missed a review of earlier work focusing on virga and rain evaporation in the trades. E.g. Sarkar et al. (2020, DOI: 10.1175/MWR-D-19-0235.1) is a study that comes to my mind, but there are for sure others.

2. Results for single cloud layers: Sec. 3.5 showed that most challenges and limitations pertain to multi-layer cloud situations. To increase the robustness of the results, it would be great to see how the results (e.g. in Fig. 8 and 9) change if only single-layer clouds are considered. These results will likely be more trustworthy.

3. Comparison with Cloudnet target classification: How often does Cloudnet detect drizzle / rain when the VirgaSniffer doesn’t detect anything? I think the comparison in both directions is important.

4. Commas: I’m not an expert on commas, but I feel that some additional commas would ease the reading. I made some suggestions in the annotated pdf.

Technical corrections:

Please find some technical suggestions in the annotated pdf.

Raphaela Vogel

Please also note the supplement to this comment:
https://amt.copernicus.org/preprints/amt-2022-252/amt-2022-252-RC1-supplement.pdf