Response to Reviewer 1' Comments

Comments on "Characterizing the near-global cloud vertical structures over land using high-resolution radiosonde measurements"

General Comments

This paper examines the near-global cloud vertical structures using two years of radiosonde data. I do not find any major flaws with their methodology and conclusions, and the statistical results could be a nice contribution to modeling global cloud radiative effects. However, clarifications are needed to make this paper a compelling story. I suggest returning to the authors for minor revision.

Response: We thank the reviewer for his/her comprehensive evaluation and thoughtful comments, which help tremendously to improve the quality of our work. We have tried our best to address the reviewer' concerns one by one. For clarity purpose, here we have listed the reviewer' comments in black, followed by our responses in blue, and the modifications to the manuscript are in italics. We sincerely hope that the reply and the revisions can satisfy the editor and referee' expectations.

Major Comments

The Introduction section listed several previous works using lowering resolution radiosonde data to retrieval cloud boundaries but did not include a summary of what were found from those works, what are the main statistical and conclusions from those works. Most importantly, the authors should articular what are novel in the current study, in addition to higher resolution data.

Response: Per your kind suggestions, we added the main conclusions of previous studies in the revised version (Manuscript_tracked.docx) as follows:

"Poore et al. (1995) proposed a T-dependent dewpoint depression threshold for cloud detection, *and they found that only high clouds exhibited strong latitudinal and seasonal variation in the thickness of cloud layer*. Wang and Rossow (1995) detected cloud layers using single RH threshold, with the maximum and minimum RH thresholds of 87 % and 84 %, respectively. *They demonstrated that the occurrence frequency of multi-layer clouds varied geographically and multi-layer clouds occurred most frequently in the tropics.* Zhang et al. (2010) improved the single threshold method by using an altitude-dependent RH thresholds to characterize the base and top of cloud layers, *and they demonstrated that multilayer clouds occurred more frequently in the summer*. Another method is the gradient method, in which cloud layers are obtained by examining the variations of RH and T profiles. Chernykh and Eskridge (1996) used a second derivative of the vertical profiles of RH and T to determine cloud boundaries, *and they indicated that the accuracy of the prediction of cloud level was independent of the level type and location*."

In addition to the higher vertical resolution radiosonde data, a novel CVS detection method is developed in this study. We revised the objective of our study as follows:

"The main objective of present study is to provide the first attempt to retrieve near-global vertical structures of clouds, including the number of cloud layers, cloud base height (CBH), cloud top height (CTH), and cloud thickness (CT) of each layer, using two years' worth (2018–2019) of high-vertical-resolution (5–10 m) radiosonde observations from 374 radiosonde stations across the world. *In order to obtain better CVS results, we first develop a novel CVS detection method that integrates the two main methods mentioned above by considering both the vertical gradients of RH and T, as well as the altitude-dependent thresholds of RH*".

Minor Comments

1.Line 17-19: cloud base height correlate with millimeter wavelength radar?
Response: To clarify the sentence, we changed the sentence "It is found that the cloud base heights (CBHs) from the radiosondes have a higher correlation coefficient (R = 0.91) with the millimeter wavelength cloud radar than that with the ERA5 reanalysis (R = 0.49)" to "It is found that the cloud base heights (CBHs) from the radiosondes have a higher correlation coefficient (R = 0.91) with the *CBHs from* millimeter wavelength cloud radar than *those from* the ERA5 reanalysis (R = 0.49)".

2.Line 52: do you mean the Chang and Li retrievals have large discrepancies? Discrepancies relative to what?
Response: Thanks for pointing out this mistake. Chang and Li (2005) have obtained reliable near-global CVS for one-layer and overlapped clouds by applying a new method to MODIS data. Their retrievals can differentiate cirrus overlapping lower water clouds from single-layer clouds, but cannot provide the vertical structures of three- or more-layer clouds. We changed the sentence "However, these retrievals existed large discrepancies, especially for high cirrus overlapping lower water clouds" to "However, these retrievals *lack the vertical structures of three- or more-layer clouds*" in the revised version (Manuscript_tracked.docx).

3.Line 55-56: the last sentence needs to be revised. Polar orbiting satellites can have short revisit periods such as AQUA/TERRA. Do you mean 'narrower nadir views' ?
Response: Thanks for your reminder. The sentence was revised as "*Active sensors* have relatively long revisit periods (e.g., 16-day) and narrow nadir views (e.g., Winker et al., 2007; Kim et al., 2011; Guo et al., 2016)" in the revised version (Manuscript_tracked.docx).

4.Line 58: cloud radars
Response: As suggested, we changed "cloud radar" in Line 58 to "*cloud radars*".

5.Line 75: do you mean the vertical resolution, horizontal resolution, or temporal resolution?

Response: Here, the resolution refers to the vertical resolution. We changed the "resolution" as "*vertical* resolution" in the revised version (Manuscript_tracked.docx).

6.Line 75-79: it will be more intuitive to understand the difference of 'resolution' (whatever it refers to) from previous and current radiosondes if you can provide several numbers here.

Response: Thanks for your great suggestions. We provided the specific value of the resolution for radiosonde used in previous and current studies in the revised version (Manuscript_tracked.docx), as follows:

"The possible reasons can be concluded as (1) the vertical resolution of atmospheric profiles provided by radiosonde is low *(e.g., 76 meters (m); Poore et al., 1995)*, and (2) refined RH thresholds remain lacking for cloud detection".

"With the emergence of growing number of high-vertical-resolution *(5–10 m)* radiosonde measurements worldwide, improved retrievals of CVS on large scale are now plausible".

7.Line 107: change 'considered' to 'included'

Response: Corrected as suggested.

8.Line 115: an accuracy of

Response: Corrected as suggested.

9.Line 124-125: references for the ERA5 reanalysis are needed here

Response: Done. The reference "*(Bell et al., 2021)*" for the ERA5 reanalysis was listed in the References Section as follows:

Bell, B., Hersbach, H., Simmons, A., Berrisford, P., Dahlgren, P., Horanyi, A., Munoz-Sabater, J., Nicolas, J., Radu, R., Schepers, D., Soci, C., Villaume, S., Bidlot, J. R., Haimberger, L., Woollen, J., Buontempo, C., and Thepaut, J. N.: The ERA5 global reanalysis: Preliminary extension to 1950, Q. J. Roy. Meteor. Soc., 147, 4186–4227, https://doi.org/10.1002/qj.4174, 2021.

10.Line 168: enters a moist layer

Response: Corrected as suggested.

11.Line 190: can you explain why a max-RH is needed to detect a cloud layer? What is inter-RH in Table 1 and Figure 2? Is it the RH between consecutive cloud layers?

Response: In the detection of cloud layer, some thin moist layer could be recognized to be cloud layer. Therefore, as previous studies (e.g., Wang and Rossow, 1995; Zhang et al., 2010), we used a max-RH to minimize this issue. To clarify the reason for using max-RH to detect a cloud layer, we added the sentence "*By using max-RH, it is possible to avoid misidentifying some thin moist layer as cloud layer*" in line 207 of the revised version (Manuscript_tracked.docx).

In Table 1 and Figure 2, the inter-RH is the minimum RH thresholds between the consecutive cloud layers. We changed the description "within this distance" to

"*between the consecutive cloud layers"* in line 216 of the revised version (Manuscript_tracked.docx).

12.Line 184-191: do you do any averaging or smoothing for the RH and T profiles, considering they are in high vertical resolution?

Response: Yes, we did average for the RH and T profiles before determining the CVS. Additional text was added at the end of Section 2.2.1 of the revised version (Manuscript_tracked.docx), as follows:

"*Before determination of CVS, the profiles of* $RH(z)$ *and* $T(z)$ *after the above pre-processing are smoothed by the arithmetical averages of* $RH(z)$ *and* $T(z)$ *at the altitudes of* z_{i-1}, z, *and* z_{i+1} $(i \geq 2)$, *respectively*."

13.Figure 3: I suggest change sounding times to 00UTC and 12UTC to be consistent with your intro text

Response: Thanks for your reminder. Here, we revised the 2300 UTC and 1100 UTC to 0000 UTC and 1200 UTC, respectively, in Figure 3, as follows:

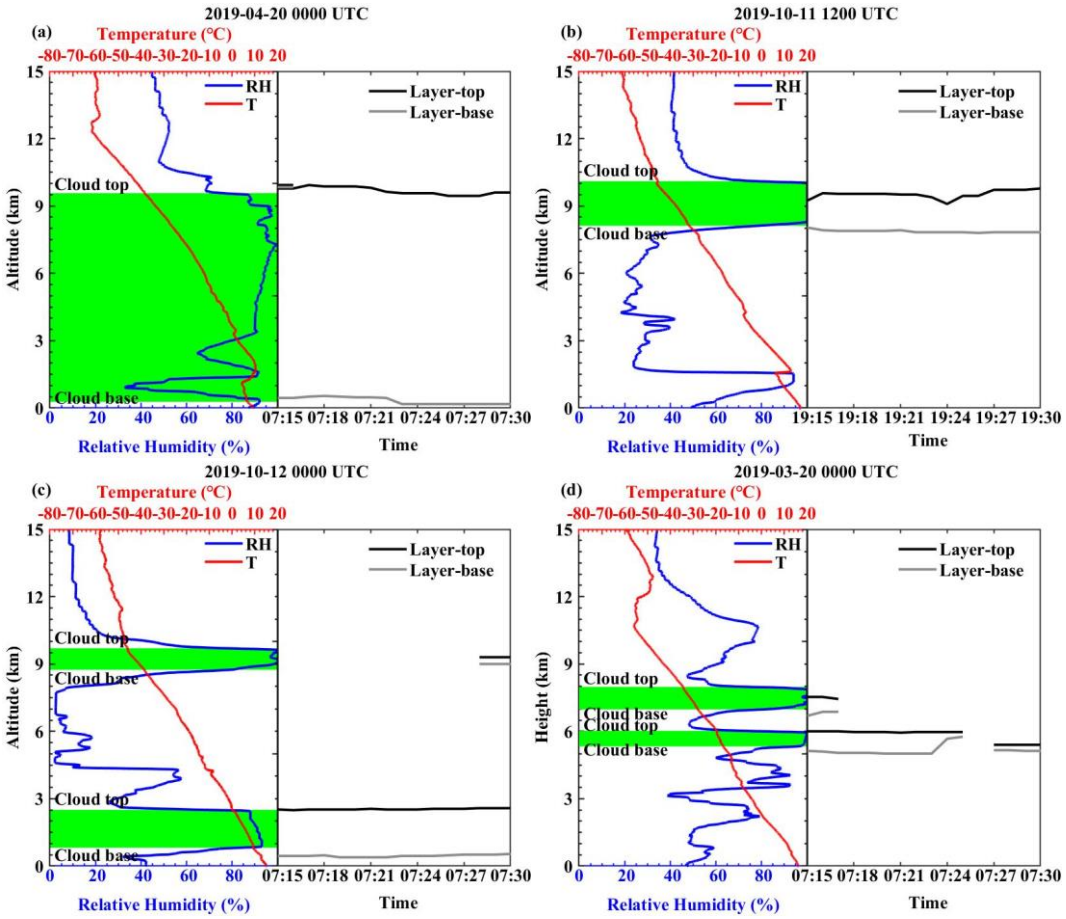

Figure 3. Examples of the detection of CVS by (left) high-resolution radiosonde and (right) Ka-band millimeter wavelength cloud radar (MMCR) at Beijing site for the four selected cases, (a, b) one-layer clouds, and (c, d) two-layer clouds. Green shading represents the cloud layers retrieved from radiosonde. In each subfigure (left), the blue and red solid line represent the RH and T profile, respectively.

14.line 223: maybe change the word ‘correctly’ to ‘reasonably’
Response: Thanks. We changed “correctly” to “*accurately and reasonably*”.

15.line 313-314: these result in the occurrence
Response: Done.

16.line 368: oceanic climate
Response: Done.