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Atmospheric Measurement Techniques Discussions

Interactive comment on "Observation of Cirrus Clouds with GLORIA during the WISE Campaign: Detection Methods and Cirrus Characterization" *by* Irene Bartolome Garcia et al.

Anonymous Referee #3

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In this paper, the authors describe the results of retrievals of ice cloud detections from limb measurements made using the GLORIA instrument aboard in-situ flights during the WISE campaigns. The results are interesting given the unusual (to me) approach, and definitely fit the scope of the AMT journal. The sensitivity to ice clouds with extremely low optical depths is very interesting. I have several comments that I hope would make the paper more accessible to readers interested in cloud detection techniques but not familiar with the constraints of limb measurements.

Major comment

My main concern with the paper is that while I'm familiar with many remote sensing

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and in-situ detection techniques, and with the cloud climatologies they enabled, I had trouble interpreting the results presented in this paper and putting them in perspective against other retrievals. I can't believe I will be the only one. In the minor comments below I try to explain where I had the most trouble understanding.

I am also concerned about the uncertainty in the horizontal location of retrieved clouds associated with the retrieval technique, and I would like to see it discussed, especially when relating the altitudes of detected clouds with tropopause.

Minor comments

p.1, L. 15-17: "It is possible... veils" this is generic information, which has no bearing on the following discussion and actually creates confusion, as the reader might believe it needs to retain the difference between cirrus, cirrocumulus and cirrostratus to understand what follows. I think it can be omitted.

P.2, L.2: "its" => "their"

P.2, L.2: I don't understand what are the "typical operational weather satellites" that are equipped with nadir sounders? Please be more specific. To my knowledge "typical operational weather satellites" are geostationary and provide visible/infrared imagery with near-global coverage. "Nadir sounders" make me think of active sensors, such as radars and lidars, which are not found aboard typical operational weather satellites.

P.2, L.15: "Cloud and Aerosol Lidar" – this is not the meaning of the CALIOP acronym. Please fix.

P.2, L.15: "as Dessler (2009)" why mention this?

P. 2, L.16: "there is not enough evidence of clouds above the tropopause in mid-latitudes" not enough evidence for what? Please be aware that more recent papers look at cirrus clouds above tropopause using CALIPSO data: e.g. Dauhut et al. 2019 https://doi.org/10.5194/acp-20-3921-2020

P. 2, L.22: "LIDARs" => "lidars"

P. 2, L.24: If you are interested in SVC cover derived from CALIPSO, please be aware of Martins et al. 2010 https://doi.org/10.1029/2010JD014519, Reverdy et al. 2012 https://doi.org/10.5194/acp-12-12081-2012, or Wang et al. 2019 https://doi.org/10.1029/2018JD029845

P. 2, L.26: Again, which nadir viewing instruments?

P. 2, L.33: I understand that this is the resolution of a pixel looked on straight from the plane, i.e. in a plane normal to the direction of view. What is the volume of air described by the measurement in a straight line away from the plane, I.e. along the line of sight? Is the tangent altitude the point of lowest altitude along the line of sight? Please mention these precisions.

P. 3, L. 9: "step stone" => "stepping stone"?

P. 3, L. 23: "one profile": what is the vertical resolution of one such profile?

P. 6, Figure 2: I'm not overly familiar with measurements like GLORIA's, so please forgive me if I ask obvious questions. Here are a few things I think I've understood, that I don't think are explicitly stated before the figure, and that would help its understanding if they were:

- I understand each blue line in Figure 2 to be a different line of sight.

- I understand GLORIA scans successive lines of sight, each corresponding to a different angle with the horizontal, and each describing cloud information along the line of sight that corresponds to that angle and to a minimum altitude level.

- I understand that the cloud information (IWC) is integrated along the line of sight, and the obtained IWP used as cloud indicator. It follows that the instrument documents the vertical distribution of clouds across a very large horizontal distance that varies with altitude, eg for 7km ASL the horizontal distance described is 420km, for 15km it is

660km, for 18km it is 720km, etc (according to the lines of Figure 2).

- I understand that analysis of GLORIA data can tell a cloud is located along a given line of sight, which provides some insights into its spatial location. Each value of GLORIA's vertical cloud profiles is representative of a quite long path, that is longest at highest altitudes, and neither horizontal nor vertical: for instance, the lowest line of sight in Figure 2 will document cloud presence at ∼12km ASL 60km away from the plane, at ∼10km ASL 120km away, down to ∼6km ASL 330km away, and then up again.

My understanding of those points sometimes comes from later sections of the text. If my understanding is correct, could you please find a way to include those points in the text before reaching Figure 2, or in the legend of Figure 2, to help readers unfamiliar with the approach?

Figure 2: Would it be possible to add a cloud to this figure and show next to it the cloud profile that would then be generated, with the final base and top altitudes? It would help interpretation by non-experts.

Figure 2: What happens when a cloud is present at high distances from the plane, beyond the tangent, and is picked up by a line-of-sight that shoots low? For instance, a cloud located 600km away from the plane at 14km ASL could appear in the lowest line of sight. In that case, would the cloud be attributed a ∼6km altitude, ie a 8km error ? Is there a way to know whether that situation is frequent, i.e. to quantify the error in vertical distribution due to that uncertainty on the cloud position along the line of sight?

Section 2.1: This might be painfully obvious to the authors, but I'm afraid I'm not sure I understand in which direction the scan is occurring? Are the lines of sight always pointing the same way with respect to the plane? Is the instrument looking in a different direction every time the plane changes direction?

P. 9, Figure 3: Assuming I've understood correctly how to interpret GLORIA's measurements, does it mean that cloud base and top can be located very different distances

away from the plane? Could you comment on whether this might impact the retrieved vertical distribution somehow?

p. 9, L. 7: "the clouds were referred to the tangent point" : Is this assumption made for convenience in absence of useful information, or is there a reason to think it is realistic? Is there a way to verify how frequently this assumption is reasonable or not, and quantify what the related uncertainty means for the cloud profiles?

Figure 3 and others: The WISE flights seem to cover a very large latitude range, from polar to almost tropical regions. Given we don't know where are clouds along the LOS, and what we know about the direction the LOS are pointing to, and the variable flight paths followed by the plane, is there a way to document the horizontal area described by these results?

P. 10, Figure 5: could you add a figure showing the distribution of CI vs. Extinction? It could help quantify whether both variables are interchangeable.

P. 12, L 26: "as discussed in Pan and Munchak (2011)..." The definitions of the tropopause are important, but the geographic colocation of the cirrus and the retrieved tropopause altitude is important as well. Given it is not possible to tell where a detected cloud is along the line of sight, it means there is an uncertainty of several hundred kms on the horizontal location of the detected cloud, with the largest uncertainties at the highest altitudes (closest to the tropopause). Trying to compare the altitude of a cirrus with the altitude of the tropopause when both can be separated horizontally by 600km makes me nervous, especially for clouds which are close to the midlatitude-tropics boundary (where the tropopause can vary by several kms in a few hundred kms). Could you comment on the impact the cloud location uncertainty can have on colocating it with the tropopause, taking into account the latitude?

P. 13, Figure 7: Could you maybe plot the zonally averaged tropopause altitudeon these plots?

P. 14, Figure 8: Would it be possible to separate the distribution of cloud properties depending on whether the clouds were observed in tropical, midlat or polar latitudes? I would expect the vertical extents to vary with latitude.

P. 14, L.5-6: "Spang et al..." this has already been stated close to the introduction. Please avoid repetition.

P. 15, Figure 10: I'm not sure I understand what is to be learned from these figures. If I understand correctly, they show the spatial distribution of detected cloud tops. Are we supposed to compare the left figure that shows all CTH with the right figure that shows only the CTH above the tropopause, and infer the regions where CTH above tropopause occur most frequently? If that is the case: 1) why change the color code between both figures? It makes the comparison much harder. Is the color code showing another point of comparison, or another independent information? 2) Isn't there an easier way to represent the density of CTH above the tropopause relative to the total number of measurements? (Eg counting the number of cloud points in 1x1° or 2x2° boxes ?) 3) why isn't that discussed in the text? I don't understand how Figure 10 relates to what is discussed P. 13 lines 8-12.

P.16, L. 12: The already stated CALIPSO references (Martins and Reverdy) show a larger frequency of SVC and focus on the Tropics, it might make sense to refer to them.

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