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# *Interactive comment on* "Cloud base height retrieval from multi-angle satellite data" *by* Christoph Böhm et al.

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*"The authors propose a method to derive cloud base height from MISR measurements. Here, they make use of the 9-angle viewing capabilities of the instrument and derive all possible cloud top heights within a specified area, the (approximately) lowest z_top is then attributed to be the base height of the cloud field within the specified area."*

Thank you for your constructive feedback. We have addressed your comments in the following way:

*"For this algorithm to work, several preconditions have to be met, as specified by the authors. First, the cloud field has to be inhomogeneous so that MISR can see thin*

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*cloudy layers around the cloud field's edges. Second, it should not be used for thin cirrus. Personally I would say it will probably also have problems in regions with very inhomogeneous cloud bases or in regions with strong convective systems which means very inhomogeneous but also very thick clouds. Due to these restrictions I am not convinced that this product will be an easy-to-use tool for the quantitative assessment of cloud base height in climate models as stated in the conclusions."*

We agree that MIBase has limitations in respect to cloud types. Thin cirrus will be problematic because the MISR clout top height retrieval method is based on frequencies in the visible light range, for which thin cirrus is hard to detect. Therefore, a height limit of 5 km is used for the global application. Heterogeneous cloud base heights pose a challenging scene as well, since we assume that the lower end of the cloud top height distribution is representative for the cloud base height within the region of interest. However, any kind of retrieval method may have trouble with heterogeneous cloud base heights. In the new Section 4.1 "Scene structure influence", we included an investigation of the MIBase performance in dependence on $\Delta z$ and $z_{\text{top}}$ (supplement Fig 2). In short, MIBase performs best for shallow low clouds.

We agree that some constraints have to be taken into account when using MIBase to evaluate cloud base height in climate models. MIBase could still be a valuable tool, if for example the climate model output is limited to clouds below 5 km and cloud fractions below 1. While the comparison of individual clouds suffers from the large uncertainty, evaluation on seasonal and inter-annual scales should yield robust results. We modified the conclusion accordingly.

*"However, the comparison to METAR data shows good results. The article is well written and the method is clearly explained.*
*Nevertheless, I think it could be improved because a better analysis of the situations in which the retrieval does not perform well would be necessary in order to evaluate its capabilities."*



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We agree that such an analysis would be beneficial. Therefore, we included the above mentioned new Section 4.1 in which we present further investigations of the scene structure. Besides evaluating the performance of MIBase in dependence on $\Delta z$ and $z_{\text{top}}$, we also exploited how the configuration of the stereo-derived cloud mask influences the performance. This way we assessed for which scenes the algorithm performs better or worse.

*"Also some statistics that quantify, in how many cases the algorithm could not retrieve a cloud base height is missing. These values should be given for each possible retrieval rejection, a too homogeneous cloud cover for instance, in comparison to the number that would have theoretically been possible."*

To elaborate on this in more detail, we added Section 3.4 "Scene limitations" to the manuscript. Statistics on the situations for which MIBase cannot retrieve $z_{\text{base}}$ are discussed quantitatively. Following the numbers in the new Table 5 and the description in the text, we now allow the reader to comprehend how we ended up with the number of cases which are considered for the calibration and validation of the algorithm. Furthermore, we also extended Section 5.1 by a discussion regarding the number of valid retrievals versus retrieval failure. Figure 10 of the revised manuscript shows the spatial distribution of scenes for which MIBase cannot retrieve $z_{\text{base}}$, i.e. apparent clear sky and apparent overcast.

*"In Fig. 9 b), the ITCZ should be more visible in the Atlantic Ocean and over Africa, there are almost no z_top values over 1.4 km. Even if the analysis is restricted to cases with z_top $<$ 5000 m, I would assume that there should be more z_tops higher than 1.4 km. Could you please comment on that?"*

In Fig. 9b and Fig. 10a, 10b (Fig. 11a, 11b in the revised manuscript), the ITCZ is revealed by the light turquoise band slightly north of the equator, indicating higher $z_{\text{base}}$ and $z_{\text{top}}$ compared to the immediate surroundings to the north and south. This band is most pronounced in the Pacific ocean. Over the Atlantic, it can be seen most





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clearly in the manuscript's Fig. 9c, which shows a band of increased cloud vertical extent in that region. As stated in the manuscript, over continents the diurnal cycle should be kept in mind. MISR has a morning overpass which means, the three year median heights provided here represent the morning heights around 10 a.m. local time. For the Congo Basin, Taylor et al. (2007) investigated the diurnal cycle of cloud top temperature (CTT) retrieved via satellite remote sensing (SEVIRI). According to them, the CTT is lowest around the MISR overpass time with a mean value of about $290$ K during late morning hours. If we take the observed $z_{\text{top}}$ of about $1200$ m and assume a lapse rate of $0.6\,\frac{\text{K}}{100\text{m}}$, the extrapolated surface temperature would be $297$ K ($\approx 24°$C) which seems very plausible.

*"And why is z_top restricted to 5000 m, is this threshold not only applied to z_base in order to exclude cirrus?"*

We agree, that the limit for $z_{top}$ should not be the same as for $z_{base}$. Therefore, we reproduced the figures for the global distribution of $z_{top}$ . This time, the median is calculated only for those $z_{top}$ values for which the respective $z_{base}$ is below the $5000$ m threshold. We updated Fig. 9 and Fig. 11 of the revised manuscript and their respective captions accordingly. Generally, a threshold is necessary to exclude high clouds from the analysis in order to avoid difficulties associated with cirrus clouds. In our opinion the median of $z_{\text{base}}$ and $z_{\text{top}}$ provides less valuable information if low and high clouds are mixed together. From our best judgement, $5000$ m seems like a good choice for a threshold to ensure that the algorithm works properly. The resulting product is not highly sensitive to this threshold as can be seen in Fig. 4 (supplement).

*"Fig. 9 a): Since the number of valid retrievals over the Sahara is so small, it is quite understandable, that the cloud base height jumps between very small and very high values and a warning is given by the authors on page 17. In order to use maps of this kind for a climate model evaluation, many more valid data points would be necessary.*





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*This should be noted in the conclusions."*

We included a note of this in the conclusion: "This makes MIBase a promising tool for the evaluation of climate models on seasonal and inter-annual time scales in data sparse regions if for example the climate model output is limited to clouds below $5$ km and cloud fractions below 1 and if a sufficient amount of MIBase retrievals is provided within the considered region and time period."

*"Fig. 9c): Why is the sample size low over Antarctica? Shouldn't it be covered with approx. 50% cloud cover throughout the year?"*

MISR's stereo-derived cloud mask shows configurations which indicate apparent clear sky conditions in Antarctica for $60$ % to almost $100$ % of the cases (Fig. 10c of the revised manuscript, and Fig. 3a of the supplement). This is in agreement with the cloud cover derived from MODIS presented by Suen et al. (2014).

*"p 4, l 19: please specify "SDCM" in H_SDCM"*

SDCM stands for "stereo-derived cloud mask". We added the abbreviation in parenthesis at the first occurrence of this phrase. In particular, $H_{\text{SDCM}}$ is the threshold height which is applied to derive the stereo derived cloud mask according to Equation 59 in the Algorithm Theoretical Basis documentation by Mueller et al. (2013). We added that this is a threshold height to the manuscript.

*"p 16, l 6: "yielding an overall higher" something is missing here."*

This should be "yielding an overall higher $\Delta z$". Thank you for pointing this out.

*"P 17, l 1: Do you refer to Fig. 9 c) instead of b)?"*





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Yes. Thank you and sorry for the confusion!

Please also note the supplement to this comment:
https://www.atmos-meas-tech-discuss.net/amt-2018-317/amt-2018-317-AC4-supplement.pdf

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