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Atmospheric Measurement Techniques Discussions

Interactive comment on "Detection of multi-layer and vertically-extended clouds using A-train sensors" *by* J. Joiner et al.

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Response to referee # 1

We thank the referee for helpful comments that have improved the manuscript. We respond to each comment below.

1. We have now included the following discussion on the impacts of thin cirrus. "Here, we have focused on multi-layer situations where both MODIS and CloudSat see high clouds. This will generally be the case for high clouds with $\tau > 1$. MODIS may not correctly place the cloud top for high clouds with $\tau < 1$. CloudSat may also not see these high thin clouds. For the trace-gas retrievals men-

tioned above, these optically thin clouds will have a negligible impact; The photon-trapping effect will be very small (Vasilkov et al., 2008) in these situations and thus the centroid pressure of a lower layer should be accurately retrieved. However, the MODIS effective radii retrievals may still be negatively impacted by undetected multi-layer clouds with an optically thin upper layer."

2. We have expanded our discussion on the errors derived from comparison with CloudSat and their implications. For example, we state that "The accuracies obtained in this study should be adequate for most applications related to trace-gas retrievals. However, greater accuracy may be required for applications not discussed or envisaged here."

3. We have now included a sentence, as suggested, on our rationale behind this representation of the cloud top. "This representation was chosen such that the varying thickness of the troposphere is taken into account."

4. The reviewer is correct that Figure 4 has been left out. This has now been corrected. Thank you.

5. Thank you.

6. The reviewer is correct that as written, the algorithm contains a dependence on τ. That dependence was added as an additional check on the cloud mask as some of the retrieved optical depths were less than zero for a confident cloud mask value. In looking at these few pixels, we found that the cloud mask is likely correct in most cases so we removed the check on the CloudSat/MODIS optical depth and now rely solely on the CloudSat cloud mask. We have changed Fig. 5 and the corresponding text appropriately. To remove any confusion, we now show the CloudSat radar reflectivity profiles in place of the CloudSat/MODIS optical extinction profiles in Figs. 7-9 for all locations were the cloud mask indicates clouds are present. We have also zoomed in slightly on Figs. 7-8. The algorithm

change produced some very small differences in the results, which have been updated.

In the process of carefully checking the results, we found an error in the CloudSat classification scheme that affected a small amount of profiles with more than 2 layers. This has been corrected. We also made small modifications to the filtering scheme that allowed more data into the sample space. The changes are reflected in the revised text. For example, we only apply the brightness temperature variability test when CloudSat indicates that the cloud is not multi-layer and we narrowed the variability threshold.

Finally, we added a test on the cloud top pressure to the MODIS-only multi-layer detection. As we had a similar check in the MODIS-OMI algorithm as well as the CloudSat algorithm, this slightly improved the MODIS-only comparisons with CloudSat, bringing them into closer agreement with the OMI-MODIS results on the OMI footprint. This allowed us to simplify the filtering scheme for the MODIS-only results using only a cloud top pressure check. The sample space increased in size and most likely as a result, the comparison with CloudSat is now slightly worse than before. When we run the comparison at the OMI resolution using only this cloud top pressure check, the results are similar. This is now discussed in the paper.

We also checked results obtained with the MODIS multi-layer flag threshold set to ≥ 2 with the additional check on high clouds as compared with our original threshold of > 2. The comparison with CloudSat did not change significantly, but the monthly mean fractions of multi-layer clouds are now in better agreement with the OMI-MODIS results. We now show results with this threshold on the MODIS MLF and have revised the text accordingly.

Finally, the results previously shown at the MODIS resolution had an extra constraint placed upon them (that the fraction of multi-layer clouds within the MODIS footprint had to be $> 50\%$). This was inconsistent with the text and with the re-

sults at the OMI pixel. We have therefore removed the constraint. Results are now consistent with those at the OMI pixel. The fraction of multi-layer clouds increased somewhat, but is still significantly smaller than at the OMI spatial resolution.

None of the above-mentioned modifications affected the overall conclusions in the paper. The main result is that the OMI-MODIS and MODIS-only results at both spatial resolutions are more consistent with each other.

7. The suggested change has been made.

8. The reviewer is correct. Thank you for pointing out this error.

9. The grid is 1° latitude by 1° longitude for these and all other similar figures. This is now clearly stated in the text.

10. We have changed the wording of this statement from "... globally" to "... for a wide range of conditions." We also similarly changed other sentences that used the word "globally." Our comparisons are not truly global. For example, we exclude high latitudes because of the difficulties associated with retrievals over snow and ice.

11. The reviewer is correct that ΔP_{diff} is not always positive as shown in Figure 7. We added the following text. "In theory, ΔP_{diff} should always be positive. When computed from the retrievals, ΔP_{diff} is sometimes negative as a result of errors in the derived cloud-top pressure and/or optical centroid pressure. The color scale in Figures 1 and 2 saturates such that values outside the indicated range are colored as either the high or low end of the color scale. Therefore, negative values of ΔP_{diff} appear as zero."

12. We have changed the color of the tracks as suggested.

13. The symbols are now explained in the figure caption. The description in the text has also been expanded.

Response to referee # 2

We thank the referee for helpful comments that have helped to improve the manuscript. We respond to each comment below.

1. p. 2710, L. 9: We have removed the 2nd explanation of the abbreviation. Thank you.
2. p. 2710, L16-19: We have rearranged the paragraphs on this page to strengthen the statement and added more references.
3. p. 2712, L 5-6: The statement applies only to the previous studies. That has now been clarified.
4. p. 2712 and introduction: To our knowledge this is the first time a multi-layer algorithm has been compared with CloudSat. As suggested, we have emphasized this more strongly in the abstract and introduction. We have also added, as suggested, some sentences in the introduction describing some of the advantages of the present approach as compared with previous studies. “An advantage of our approach is that the combination of photon pathlength-sensitive UV/VIS observations with thermal IR for multi-layer cloud detection can be applied over ocean and most land surfaces. Microwave observations, in contrast, have more limited sensitivity to cloud liquid water over land."
5. p. 2713: As suggested, we have added more description of how the MODIS MLF works.
6. p. 2730: We believe these numbers refer to the pages where the references were cited. For some reason, on the last reference, these seem to be in a slightly larger font and on a separate line. This should be cleaned up in the revised version.

7. Figure 3 was mistakenly used in place of Fig. 4. This has now been corrected.

Interactive comment on Atmos. Meas. Tech. Discuss., 2, 2707, 2009.