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Atmospheric Measurement Techniques Discussions

Interactive comment on "Retrieval of optical thickness and droplet effective radius of inhomogeneous clouds using deep learning" *by* Rintaro Okamura et al.

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The paper describes a new technique for satellite measurements of cloud optical thickness and cloud droplet effective radius. The key feature of the technique is that it takes into account 3D radiative effects and subpixel variability by considering not one pixel at a time, but by performing simultaneous retrievals over 10 by 10 pixel areas. The most important aspect of the technique is the use of a deep learning algorithm. This is a significant new development, and the study makes an important contribution on the path toward more accurate satellite retrievals of cloud properties. Overall, the methodology is sound and the presentation is suitable. However, I believe that a few important improvements are needed in the analysis. My recommendation is therefore to make some major revisions. Please find below my detailed comments.

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Discussion paper

Major issues:

1.

Page 7, Line 8 mentions that “The test dataset used for evaluation should be independent of the training dataset.” My sense is that in this initial study the training and testing datasets are not fully independent, as they come from the very same cloud fields, and that this would be good to mention. (The two datasets include different randomly selected locations within the cloud fields, but the statistics of cloud properties are identical in the training and testing datasets.)

As noted in Page 10, Lines 7-8, it will be an important future step to examine the performance of the retrieval for a wider range of cloud parameters. It is reasonable to leave this (and the evaluation based on fully independent training and testing datasets) to a future paper, but even the current results could offer further insights into the robustness of the proposed retrieval algorithms. Most importantly, one could examine not only the overall results, but also separately the results for open-cell and closed-cell convection cases. This would demonstrate that the same algorithm and training set improves retrieval accuracy for two very different types of cloud structures. I don’t think the currently presented results show this: Overall error statistics may conceivably improve due to improvements for open-cell convection only, without any improvements for closed-cell convection. (Because retrieval uncertainties are likely larger for open-cell convection, it may be best to examine by what percentage DNN-2r and DNN-4w reduce the retrieval errors of IPA retrievals for open-cell and for closed-cell convection.) The paper did a good job in examining results as a function of optical thickness, but the new analysis of already performed retrievals would help because open-cell and closed-cell convection cases differ in horizontal structure even at locations where vertical optical thicknesses are similar.

2.

Page 5, Lines 13 and 22: I wonder why scene parameters are estimated for 8 X 8

pixel arrays when using the DNN-2r method, but only for the central 6 X 6 pixel arrays when using the DNN-4w method. This could make sense if 3D effects acted over larger distances at 3.75 microns than at the 0.86 and 2.15 microns used by the DNN-2r method, but neither my own physical reasoning nor the filter weights in Figure 8 suggest this. In fact, Figure 8 shows that DNN-4w retrievals at a pixel are strongly affected by 0.86 micron radiances 2 pixels away. This suggests that (at least for pixels at the edges of 8 X 8 pixel areas) the DNN-2r method cannot capture the portion of 3D effects caused by areas more than a pixel away. This probably contributes to DNN-2r giving less accurate results than DNN-4w (a tendency mentioned in Page 9, Lines 31-32) and should be mentioned in the discussion of the differences between the two methods at the top of Page 10. (The discussion should also include the impact of additional wavelengths in DNN-4w and algorithmic differences.) Also, it could help to clarify explicitly in the paper whether DNN-2r retrievals inside (not along the edges of) 8 X 8 pixel areas are affected by radiances 2 pixels or more away. If they were, it could even make sense to analyze retrieval accuracy only for pixels in the central 6 X 6 pixels of 10 X 10 pixel areas (similarly to DNN-4w).

Minor issues:

Page 1, Line 23: What is meant by “cloud state”?

Page 2, Line 23: The study by Evans et al. (“The Potential for Improved Boundary Layer Cloud Optical Depth Retrievals from the Multiple Directions of MISR”, J. Atmos. Sci., 2008) should also be mentioned, as it also used a neural net for cloud retrievals.

Page 2, Lines 26-27: What is meant by “feature” and “feature extraction”?

Figure 2: It would help to indicate the time elapsed during the 60 time steps along the horizontal axis, or to mention the time step in the figure caption.

Figure 3: It would help to clarify why there is a fully connected layer near the top of the left column that operates only on radiances and not on the IPA-estimated scene

parameters.

Page 6, Lines 27-29: It would help to clarify whether all pixels within an LES scene are multiplied by the same randomly chosen number, or all individual pixels are multiplied by a different number. (My guess is the first option.)

Page 6, Line 25 and Page 7, Lines 8-10: What does the word “samples” refer to? My guess is that each sample is a 10 X 10 pixel area. If my guess is right, can samples overlap? Also, it would help to mention the total number of pixels in the LES dataset, as this could show whether the training set includes almost all LES pixels or just a small fraction of them.

Figure 7: It could help to include into one of the panels a PDF of true optical thickness values.

Figure 9: The legend should indicate which color shading corresponds to which line/method.

Page 10, Lines 5-6: I am not sure the sentence “In the DNN-4w that we tested, we excluded 3D radiative transfer effects that occurred at horizontal scales greater than approximately 1.5 km (5 pixels)” is correct. Based on Figure 8, I thought that DNN-4w retrievals exclude 3D effects that occur at horizontal scales greater than 2 pixels (560 m). This is because I thought the pixel whose properties we are retrieving is at the center of the filters in Figure 8, which means that only radiances two pixels away are considered. A correction of this sentence or a clarification of the meaning of filters in Figure 8 would help.

Somewhere in the text it would help to comment on whether the speed of calculations would be a concern for using DNN in operational retrievals in the near future. (For example, how does the speed of DNN compare to the speed of IPA and NN retrievals?)

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