Response to Reviewer # 3

We thank the reviewer for the valuable comments. The manuscript has been modified according to the suggestions. The remainder is devoted to the specific response item-by-item of the reviewer's comments.

RC=Reviewer Comments

AR=Author response

TC=Text Changes

This manuscript introduces a cloud property retrieval method "OE-CNN-IR" by integrating the optimal estimation and machine-learning methods to effectively derive the COT, CER and CTH from passive satellite imagery. The method is suitable for both daytime and noghttime conditions. Validation results reveal that the OE-CNN-IR method outperforms stand-alone OE-IR method, especially for optically thick ice clouds. The topic is within the scope of Atmospheric Measurement Techniques. However, the results and discussions in the manuscript lacks rigor, especially for the evaluation and clarification on OE-CNN-IR and TIR-CNN. Specific comments are as follow.

Reply: We thank the reviewer for the valuable comments and suggestions. The paper has been improved after addressing all the comments.

Specific comments:

Line 110: "one representative day each month" what I am concerned is that how the authors choose the representative day? And all the statistical evaluation in the manuscript was based on the 12-days data? That maybe not enough and unrepresentative.

Reply: We have added more detailed information in 2.1.1 (Lines 117-122):

retrievals are compared to MYD06 data from one day each month in 2009 (January 1, February 10, March 12, April 11, May 11, June 10, July 10, August 9, September 8, October 8, November 7, and December 7. The default spacing between adjacent days is 30, and the spacing is set to be 40 if a date lies in the same month as previous date).

…The total sample size of MYD06 for comparison is ~4.7 million.

and in 2.1.2 (Lines 137-139):

the ice cloud product of DARDAR in 2009 is used to evaluate the inversion results during both daytime and nighttime conditions, and ~0.54 million pixels are collocated in the comparison processes.

(Note that only a small portion of MODIS data is collocated with DARDAR. For the comparison of MYD06, there are plenty of pixels, and the computational cost is much higher if we perform a full year of OE-IR calculations, so only 12 days are chosen. The number of pixels collocated with DARDAR is not as large, so data in the whole year is used).

Figure 4: from this figure, the author claimed that the performance of OE-CNN-IR is better than OE-IR, but at the same time, the difference is relatively small for most results with iterations of 0 (i.e., the priori from TIR-CNN) and iterations of 100 or more (i.e., the optimal estimation from OE-CNN-IR). So how to access the optimization or necessity of the new OE-CNN-IR algorithm, or whether the alone TIR-CNN algorithm is considered to be sufficient? Since figure 6 also reveals that the COT\CER\CTH derived form TIR-CNN appear to be closer to MODIS products.

Reply: The retrieved COT, CER and CTH based on TIR-CNN method showed good agreements with MODIS products for both daytime and nighttime in (Wang et al., 2022). Based on this, we chose the TIR-CNN results as a priori. As a result, with a better first guess, the iteration converged quickly. The new Figure 6 illustrates the role of OE in the inversion process, showing that it helps align the simulated brightness temperatures more closely with the observations.

Figure 5: the author's illustration and results reflected from this figure are confusing. They claimed that the retrievals of OE-CNN-IR method align more closely with observations than TIR-CNN, which can be attributed to the OE iterations. However, the performance of OE-IR method is better than that of OE-CNN-IR method both in terms of RMSE and correlation coefficient. From my opinion, the comprehensive discussion combining radiation consistency with optical property evaluation (Figure 6) is more suitable.

Reply: Thank you for suggestions and we have swapped the order of Figures 5 and 6 and rewritten Section 3.1.

The OE-IR BT (brightness temperature) results are slightly better than those of OE-CNN-IR BT. This is primarily because OE-CNN-IR relies on the results from TIR-CNN for its iterations, and since Sa has a significant weight in the cost function, the weight of (y - F(X)) is reduced, while Sa can be ignored in OE-IR. As a result, the comparison between the converged simulated brightness temperatures and the observations is slightly less favorable.

Line 308-309: the performance of CER retrievals using the OE-IR method maybe not comparable to that of the OE-CNN-IR method. Please check.

Reply: Thank you for thorough review. We have made the following modifications (Lines 324-326):

The performance of CTH retrievals using the OE-IR method is comparable to that of the OE-CNN-IR method while the inversion of CER is not very effective due to limitations in the physical mechanisms.

Line 317: "using CNN-IR, OE-CNN-IR and OE-IR" change to "using TIR-CNN, OE-CNN-IR and OE-IR".

Reply: We have revised as suggested.

For the retrieval method, it is unclear that the authors used all the nine IR bands (band 27 - 36) for cloud retrieval or only the three IR bands (band 29,31,32) discussed in section 3?

Reply: We have revised in 3.1 as follows (Lines 330-332):

We utilized the bands 27 to 29 and 31 to 36 as listed in Table 1. However, for the sake of clarity in presentation, we only display bands 29, 31, and 33 in the Figure 6.

Figures 8/9: Compared to the difference between OE-CNN-IR and OE-IR, what I am interested in is the difference between TIR-CNN and OE-CNN-IR, as TIR-CNN retrievals seem to be closer to MYD06 from Figures 6 and 7.

Reply: The evaluation results show that the cloud properties retrieved by the TIR-CNN are well consistent with all available MODIS day-time products (Wang et al., 2022). Although the results from TIR-CNN are more consistent with MODIS, the simulated brightness temperature results are less accurate compared with OE method in Fig 6. Based on this, we chose the TIR-CNN results as

a priori. As a result, with a better first guess, the iteration converged quickly. The new Figure 6 illustrates the role of OE in the inversion process, showing that it helps align the simulated brightness temperatures more closely with the observations.

There is no discussion of the cost function throughout the manuscript, whether all inversion can achieve successful convergence?

Reply: We have added real values in Fig 4 and more detailed description have been added as follows (Lines 263-266):

Figure 4 shows the iterative variations in cost function, COT, CER and CTH for both OE-IR and OE-CNN-IR under various conditions. Both algorithms show a significant decrease with an increasing number of iterations and all iterations can achieve successful convergence. However, the initial value for OE-CNN-IR is lower than OE-IR.