Response to Review

Referee Comment

Effectiveness of Cirrus Detection with MODIS Cloud Mask Data

by Nguyen Huu et al.

This paper aims to evaluate cirrus detections from MODIS by using data from the much more sensitive CALIOP lidar as ground-truth. It specifically tries to quantify how well cirrus can be detected with different spectral tests, and combinations of tests, when applied to MODIS data. The comparisons stratified by the various spectral tests are an interesting and useful breakdown of the various passive sensor cloud detection methods, including the ISCCP techniques. However, the paper is rather poorly written and difficult to follow because it isn't clear how 'cirrus' is defined in this study or how consistent that definition is for the two data products being compared. This leads to some difficulty understanding the methods and interpreting the results (specifically the analysis with respect to the number of cloud layers). While the study has modest scientific merit, it seems to fail to address fundamental questions that arise when interpreting the results. For example, it does not attempt to clearly explain possible reasons that could lead to disagreements between the characterizations from the two sensors, such as quantifying (or at least remarking on, based on previous published works) the MODIS sensitivities as a function of the opacity of the cirrus or due to the presence of lower-level clouds. Relative to CALIPSO, the study does not address how well MODIS data can be used to describe the spatial variability and patterns of cirrus cloud cover, or to track regional changes throughout the course of the year of study. This would seem to be a simple and insightful aspect to add to the study. A major concern involves the contention that the MODIS cirrus detection performs poorly at night, compared to daytime. The contention is based on their findings that indicate CALIOP detects nearly twice as many cirrus clouds globally at night than during the daytime. The day/night differences for MODIS are not discussed and difficult to discern. There is no discussion as to the validity of this diurnal pattern as observed in the CALIOP data, no mention of potential day/night CALIOP sensitivity differences (which are known to be significant), and no discussion on how this influences their MODIS evaluations and conclusions. Overall, the paper could be published but it requires major revisions to address these flaws and improve its significance. In addition, the manuscript has too many grammatical errors should be professionally edited or at least heavily edited by a native English speaker.

Thank you for your constructive feedback. We have carefully addressed the concerns raised in your review. First, we clarified how cirrus clouds are defined in our study. Second, we included a discussion on potential reasons for disagreements between the two sensors. Third, the issue of MODIS performance at night compared to daytime has been re-examined. Finally, the manuscript has undergone editing to improve its clarity, readability, and grammar. We hope these revisions address your concerns and significantly enhance the quality and impact of the paper.

Specific suggestions:

Suggest changing ‘Detection’ to ‘Identification’ in the title

Line 7: change ‘that detects cirrus’ to ‘that enables identification of cirrus’

Thank you for your suggestion regarding the title. According to the dictionaries "detect" means *"to discover or notice the presence of something,"* whereas "identify" is defined as *"to recognize and be able to name someone or something."* Based on these definitions, we believe that "detect" accurately reflects the content of our article, as it focuses on the discovery and analysis of Cirrus cloud. However, as we are not native speakers, we would appreciate further clarification or guidance on how these terms should be interpreted in this context.

The Figure 2 caption should indicate that (a) is daytime, and (b) is nighttime

Corrected, as suggested.

Fig 3 and lines 258-259: The CALIPSO data presented here indicate that there are over 50% more cirrus clouds at night than during the day which is a remarkable diurnal cycle that has not previously been reported in the literature. If it has, please provide citations that indicate that this level of difference is reasonable. Is it possible that this difference results from the increased sensitivity of CALIOP to thin clouds at night compared to daytime?

Added, as suggested.

Fig 4: The reader can’t easily distinguish ATC from ISCCP 3.6. Please adjust the line types accordingly.

Corrected, as suggested.

Authors seem to be mistaking the results to indicate diurnal differences as being the fault of MODIS when in fact the differences shown in the CALIPSO data may be unrealistic and result from the day/night dependency of the CALOP sensitivity (CALIOP more sensitive at night).

Corrected, as suggested.

Line 11: The study revealed that the ATC test…

Corrected, as suggested.

Line 17: replace ‘All of them’ with ‘They’, and ‘radiative’ with ‘radiation’

Corrected, as suggested.

Line 17: remove the word ‘for’ in ‘forcing for is’

Corrected, as suggested.

Line 18: Replace “that means that…’ with ‘Thus, their overall impact are to cool the planet’

Corrected, as suggested.

Line 29: 35.5 is a specific value that means something specific, not in ‘general’. Remove ‘general’ and replace with whatever meaning is implied in the citation (globally averaged?).

Corrected, as suggested.

Line 66: regarding the statement "..to operate day and night with similar efficiency", can you support this with evidence or citations? The lidar sensitivity is not the same during day and night, which could influence how you interpret the results in your study.

Corrected, as suggested.

Line 74: change to "with temporal coverage adequate for climatological research"

Corrected, as suggested.

Line 74: 'not designed for cirrus detection' is incorrect as the imager designs have matured over time to increase the likelihood for detecting cirrus. MODIS has a 'cirrus' channel! The imagers certainly are designed specifically for detecting clouds but their sensitivity to optically thin clouds depends on many factors. Perhaps you mean to say something about the varying capabilities of the imagers over 4 decades...

Corrected, as suggested.

Line 75: Suggest restating your objective. It is already well known that passive sensors are not as sensitive to cirrus as active sensors. I suggest the following starting on line 74: "In this paper, we use cirrus characterizations from CALIOP data to explore the potential for creating a cirrus mask from the operational MODIS cloud data products. Our objective is to determine how well the MODIS products can be used to identify cirrus clouds compared to CALIPSO." In addition, the readers would greatly benefit from a more thorough description of how 'cirrus' is defined for the two datasets being compared and how these definitions are consistent or inconsistent. Do these definitions lead to a fair comparison? Does the fact that CALIOP attenuates at low COT or the fact that the products are vertically resolved lead to any confusion with your comparisons with MODIS?

We have revised the objective as suggested.

Additionally, we have expanded the manuscript on the definition of 'cirrus' in the two datasets to clarify consistency and potential differences. In both cases, cirrus clouds represent the same physical entity, but the difference lies in the sensitivity of the detectors used to observe them, with the key factor being optical thickness (COT). CALIPSO is capable of detecting cirrus clouds with a COT as low as ~0.01, or even less, whereas MODIS typically detects them only when the COT is in the range of 0.4-0.5.

Regarding the "fairness" of the comparison, we recognize this depends on the perspective. It is "fair" if the goal is to assess how much MODIS detects relative to CALIPSO, while acknowledging that MODIS will inevitably miss a significant portion of cirrus clouds due to its lower sensitivity. This provides useful insights into the practical efficiency of the MODIS instrument. However, it may be considered "unfair" for a strict one-to-one comparison, as the significant sensitivity differences preclude equivalence.

On the issue of vertically resolved data, we ensure consistency by integrating CALIPSO data into a column-based measure analogous to MODIS. If cirrus was detected at any level, the entire profile was classified as cirrus, thereby aligning the definitions across both datasets.

Line 80: active 'sensor' data

Corrected, as suggested.

Line 81: The active sensor data was obtained from the CALIOP lidar...

Corrected, as suggested.

Line 82: collocation ‘of’ those

Corrected, as suggested.

Line 92: change what to which

Corrected, as suggested.

Line 103: What are ‘middle’ thresholds? You should clarify this.

Upon review, we realized that the phrase "middle thresholds" was part of a broader context that was inadvertently removed during the editing process. As a result, the remaining fragment no longer holds any meaningful relevance to the text. To address this, we have removed the phrase entirely to ensure clarity and consistency in the manuscript.

Line 120: The MODIS central wavelength is closer to 3.7 than 3.9 um and usually referred to as the 3.7 um channel

We appreciate your attention to detail. However, in the official MODIS documentation, the "3.9-12 µm BTD High Cloud Test" is indeed referenced, and this range is used for high cloud detection, which includes the relevant wavelength band (Ackerman et al., 1998).

Line 166: It would help the reader if you could describe what the CALIPSO ‘cirrus’ subtype represents.

Corrected, as suggested.

Lines 255-265: The data presented here indicate that according to CALIOP, cirrus coverage is nearly twice as large during nighttime than during daytime, yet no explanation for this phenomenon is given and no evidence if this is realistic. Please explain the reasons for this, whether this is a data artifact or not, and discuss the implications for your study. Also missing from this section, or elsewhere in the paper is a day/night evaluation of the magnitudes of the MODIS cirrus cloud coverage and a comparison between the two sensors with respect to the geographic patterns and their correlation. Such an analysis would also seem to be important for testing your hypothesis that MODIS can provide useful information on cirrus clouds. Also, it seems that it would be straightforward for you to examine how well MODIS tracks changes in cirrus cloud coverage during the course of 2015. This could be done in several different ways (seasonal monthly mean maps and/or difference maps, global and select regional monthly mean time series, etc.).

The observation that Cirrus coverage is higher during nighttime than daytime is consistent with findings in the literature based on CALIOP data, although the magnitude of the difference reported in our study is indeed larger. We will include references to these studies in the revised manuscript to provide context and support for this phenomenon. The manuscript already contains analyses of day and night Cirrus cloud coverage from MODIS, as well as comparisons of Cirrus coverage between MODIS and CALIOP in the context of day/night differences. However, we will ensure that these analyses are presented more clearly in the revised version.

Regarding seasonal and monthly analyses, we did not divide the data into such segments because our goal was to develop a consistent method applicable across the entire year; though we will consider incorporating such analyses in future studies. Instead, we focused on comparisons based on latitudinal variations, as Cirrus clouds exhibit a zonal distribution, and

we considered this approach sufficient for the scope of our study. However, if you suggest focusing on specific regions or additional detailed analyses, we are open to incorporating such suggestions in the revised manuscript or in future work. We appreciate your insights and will make the necessary revisions to address these points comprehensively.

Line 268-269: regarding CALIOP 'all cloud' COT values near 4.2, considering that CALIOP is fully attenuated at higher values, are these numbers scientifically meaningful or somehow meaningful to your paper? If so, explain how, and if not, consider eliminating the sentence.

After careful consideration, we have determined that the referenced CALIOP "all cloud" COT values are not directly meaningful to our study. To address this, we have removed the sentence as suggested.

Line 274: Can you clarify what you mean by 'precluded the use of the test'? Precluded the use of the test where?

Thank you for your comment. By the phrase "precluded the use of the test," we meant that the specific indicators in question reach values that, in our judgment, make it impossible to use these tests directly for identifying Cirrus cloud masks. More specifically, the values of these indicators are such that they do not provide reliable or clear discrimination in the context of Cirrus clouds, thus preventing their straightforward application for this purpose.

Line 290: Please clarify what is meant by 'respective radiation range' and why its variation can be attributed to variations in cirrus detection statistics.

By 'respective radiation range,' we are referring to the different wavelengths of radiation used by the individual channels of the instrument. The variation in cirrus detection statistics across latitudes can be attributed to factors such as varying illumination conditions due to the Earth's axial tilt, as well as the presence of phenomena like the polar day and night. These conditions affect the effectiveness of each channel and its corresponding wavelength range, meaning that not all channels can be applied uniformly or with the same level of effectiveness across different latitudes.
This part in the manuscript has been revised.

Line 325-331: This section is impossible to understand which points to a persistent problem trying to interpret the results in the paper related to a poor description of the experimental setup with respect to the definition of 'cirrus' as defined for the datasets obtained from the two sensors, and how these definitions differ or have been rectified to provide consistent information.

Thank you for pointing out the issue. We have carefully revised the text to address your concerns.