



## Calibration of global MODIS cloud amount using CALIOP cloud profiles

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### Reviewer comments:

This paper identified a new set of cloud fractions corresponding to the four MODIS cloud masks using collocated CALIOP measurements. The author suggested using these new fractions to replace those currently used in the operational MODIS product to decrease uncertainties. Other than global assessments, the author further examined how those fractions changed for different MODIS cloud masking algorithm paths and at different latitude regions. The author recommended using local cloud fractions instead of global cloud fractions. As these cloud fractions are crucial to derive MODIS level 3 cloud products, the author compared the cloud amount differences in level 3 cloud products using new set and operational cloud fractions. It showed that using new set of cloud fractions successfully solved several issues of current L3 cloud product.

This work proposed a new set of cloud fractions to replace the current operational cloud fractions in MODIS cloud mask algorithm to improve current MODIS level 3 cloud product. The work is important for cloud climatology community. The reviewer recommended the paper for publication after some minor changes.

### Major comments:

1. Line 71: the author mentioned that “no research-based, objective alternatives to the 0/0/100/100 interpretation currently in use have been put forward”. However Line 250 reviewed the validation work conducted by Wang et al. (2016) which also estimated the cloud fraction for four MODIS cloud masks. The reviewer suggested reviewing Wang’s work in the introduction and also emphasizing what’s new in this work. For example, Wang’s work focused on daytime only, this work included daytime, night time and both day and night time. Moreover, this work examined how those four cloud fractions changed for different MODIS cloud mask algorithm paths and latitude regions.
2. The cloud fractions were derived with two months data, i.e., January and July 2015. While the author demonstrated the fractions could have a large variability depending on environmental conditions. Could they also have a seasonal variation? How valid to apply the same numbers to different seasons for the whole MODIS mission?
3. The author considered CALIPSO data as “ground truth” by including all cloud layers detected by CALIOP. As CALIOP data reported quality flags, it is possible to choose confident clouds only. For example, including clouds with cloud-aerosol discrimination score between 20 and 100 (low, middle and high confidence) or 70 and 100 (high confidence only) by specifying the range of parameter CAD\_Score. Not sure how this filter might change the current findings in the paper.
4. In the paper, the cloud fractions are further estimated for each cloud mask algorithm path and day/night conditions. It is noted that the CALIOP has different detection sensitivity during day and night, i.e., CALIOP is able to detect more thin cirrus clouds around the tropical region at night than during the day. This might help understand the day/night discrepancies in Figure1-3.
5. As briefly touched by the author in Line 238, the level 2 CALIOP cloud layer product reported detected cloud layers only. It is very possible there are aerosol layers detected and those aerosol layers would be reported in aerosol products but not in cloud products. In this scenario, the sky is not exactly “clear”. To avoid confusions, some researchers use “cloud free” instead “clear”.

### Minor comments:

1. Abstract: keep consistency when describing four cloud fraction numbers and cloud mask categories. Line 7: “confident cloudy”, “probably cloudy”, “probably clear”, “confident clear”. Line 14: 21.5%, 27.7%, 66.6%, 94.7%.
2. Line 16: “selected locations”? Please give a few locations as examples.
3. Line 17: “error” → “uncertainty”?
4. Line 18: What is “our method”?
5. Line 19: “robust” is a strong word. Does the author would like to say something like “We recommend using the cloud fraction ratios found in this work to improve MODIS estimates.”
6. Line 20: “other mission”? Other passive missions?
7. Line 24: “W m-2” should be “W m<sup>-2</sup>”.
8. Line 48: “The procedure implemented by NASA...” → The procedure implemented by MODIS science working group?
9. Line 51: “- see, for example, ” → e.g. ?
10. Line 54: “NASA’s approach” → standard procedure? It is not an approach from an agency. Instead, it is from MODIS science working group.
11. Line 54: “... are both allowed and in use.” → “... are adopted by other groups.” ?
12. Line 63: Moved “in Switzerland” after “observations”. It would be nice to specify the number of ground-based observations, i.e., “... compared MODIS data with n ground ground-based observations...”.
13. Line 70: “NASA standard approach” → standard procedure or standard approach?
14. Line 71: “... currently in use have been put forward” is confusing. Does the author mean “... currently widely used are still missing” or something like that?
15. Line 72: “... based on quantitative, empirical lidar observations” is confusing. Does the author mean “... based on a quantitative analysis with lidar observations”?
16. Line 75: The CALIPSO was launched in 2006 instead of 2016.
17. Line 77-78: Consider removing “This is because” and “which means that” to make a concise and formal statement.

18. Line 83: Add “with CALIOP observations” after “... correspond to”.
19. Line 83: Again it is not an approach from an agency. The author probably meant “current standard approach” or “current standard procedure”.
20. Line 84: Does the author mean “Finally, we evaluate whether the MODIS Level 3 standard approach is reliable”?
21. Line 101: Consider removing “This is made available”.
22. Line 103: Consider replacing “product; this was used to assign” with “with”.
23. Line 108: Below 8.2 km, CALIOP has a horizontal resolution 0.333 km not 0.33 km.
24. Line 109: Between 20.2 km and 30.1 km, CALIOP has a horizontal resolution 5/3 km and vertical resolution 180 m. From 30.1 km to 40 km, the horizontal resolution is 5 km and the vertical resolution is 300 m. Please refer to Table 2 in Winker et al. [2006].
25. Line 114: “CAL\_LID\_L2” → level 2 cloud layer products.
26. Line 115: (version 4.20) → (version 4.20, CAL\_LID\_L2\_01kmCLay-Standard-V4-20)?
27. Line 119: “Number Layers Found” variable → “Number\_Layers\_Found” parameter
28. Line 130: “... January and July 2005 ...” should be “... January and July 2015 ...” Any special reasons to choose these two months?
29. Line 141: Add “MODIS” after “perfect” would help a reader understand.
30. Line 147: Based on Table 1, should the number “86.7%” be “64.2%” at night?
31. Line 151: Should the number “77.4%” be “73.3%”?
32. Line 157: Is this region “ITCZ”? Does this high frequency misdetections due to high sensitivity of CALIOP? In other words, CALIOP detected very thin cirrus clouds which are invisible to MODIS.
33. Line 159: “... MODIS tended to falsely detect cloud rather than fail to detect it”. This sentence is confusing. Does this mean higher percentage occurrence or larger area spatial extent? Should “Only” be removed?
34. Line 166: It is not exactly “every fifth MODIS” even though the percentage is about 20%.
35. Line 172-173: “no significant day/night difference” even though it is 12.3% for ‘probably cloud’?
36. Figure 3g and 3h: What does black color over Southern Ocean mean?

37. Line 183: Should 'probably cloudy' be 'probably clear'?
38. Line 186: What does "this" in '..., but this was ...' mean?
39. Table 3: Use same terms to describe snow-covered conditions in the context and table caption. For example, use "Snow-free" and "Snow-covered" or "No snow" and "Snow".
40. Line 205- 215: The author chose three cloud masking algorithm paths for detailed discussion. It would help a reader understand why those three if providing some explanations. Explain "Results" in Line 205 and "A similar pattern" in Line 211. Which results? Which pattern?
41. Line 223: Add a dot between MODIS collection "6" and "1"?
42. Line 225: It is confusing to discuss level 3 product here since no plots or work on level 3 clouds presented so far.
43. Line 235 and Line 240: The author claimed that temporal and spatial separations between Aqua and CALIPSO do not impact the results significantly. If not complicated, it is a good idea to show the plots when using different time and range shifts.
44. Line 246: Explain acronym "AVHRR".
45. Line 316: What is the spatial grid used to plot Figure 8?
46. Line 321: The author drew a conclusion "Whenever MODIS cloud amount is estimated at a spatial resolution of ~10 degrees of finer, ...". There seems no evidence in the paper to support this conclusion. Something missing?
47. Line 324: Discussions on MODIS level 3 cloud product could be moved from "Summary and Conclusions" section to previous "Discussion" section.