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Interactive comment on "Differences in cloud microphysical properties between MODIS Collections 5.1 and 6" *by* John Rausch et al.

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The authors thank both reviewers for their very thorough review of the manuscript and insightful comments and suggestions that improve the manuscript.

Response to the comments of reviewer 2:

The authors describe how the cloud microphysical properties in the latest MODIS Collection 6 differ from those in the previous Collection 5.1 and discuss some of the algorithm changes that are likely responsible for these differences. Since the MODIS products are frequently used for scientific studies, this is a useful contribution to the literature, which I recommend will be published after the following comments have been addressed.

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Discussion paper

General comments

The title does not completely reflect the contents of the paper. The analysis is restricted to liquid clouds over ocean, and this should be reflected in the title. Also, a large part of the analysis concerns CDNC which is not itself a MODIS product.

The reviewer is absolutely correct about this. We have revised the title to the following to address the concern: “Differences in liquid cloud droplet effective radius and cloud droplet number concentration estimates between MODIS Collections 5.1 and 6 over global oceans”

This study initially was an investigation into CDNC differences between both collections. It expanded into a discussion of droplet effective radius since the primary driver of CDNC differences was due to changes in effective radius retrievals. To clarify for those not familiar with the cloud product, we now note in the manuscript that CDNC is not a component of the MODIS cloud product.

The authors focus almost entirely on differences between the two MODIS collections. More information and discussion on the retrieved r_e and CDNC themselves are also needed to place the differences in context. For example, Fig. 5 shows that globally C6 CDNC is about equal for the 1.6 and 3.7 micron channels but lower for the 2.1 micron channel. Can this result be explained? How does this vary regionally (partly covered in Fig. 6)? How does this figure look for effective radius? Does the ‘stratification’ of effective radius from the three channels (i.e. which is largest, which smallest and which in between?) change between the two collections? An idea would be to include a map showing this stratification (6 possibilities) globally.

We agree with the reviewer, that more information on the retrievals would better place the differences in context. We have included panels of annual mean CDNC and re from C6 in the difference plots to better understand the magnitude of the changes between collections. With regard to the stratification, we now discuss the how cloud field inhomogeneity and pixel re-registration contribute to the stratifications observed. We

agree that the stratification changes would be an interesting inclusion, especially given the intercollection differences for the 3.7 micron channel. We did feel that expanding the case study to better understand the contributions to the observed differences was important, and have added 3 figures to the manuscript to better illustrate it. In the interest of not having excessive figures yet understanding why we see the changes between collections, we felt that it is better to expand the case study at the expense of the stratification changes.

Specific comments

P2, L4: Should ‘rejection’ be ‘reflection’?

Fixed

P2, L7: ‘forcing’ should be ‘effect’

Fixed

P2, L8: I think ‘increasing’ should be added before ‘also’. Precipitation efficiency is reduced and cloud lifetime increased.

Also fixed.

P4, L9 and further: Be consistent in the notation of liquid water content and path. The subscript ‘AD’ is sometimes added (e.g., L9 and eq. 2) but sometimes not (e.g., eqs. 2 and 3).

The subscripts are now consistent between equations.

P5, Eq. (3): The optical thickness should be to the power 3.

Tau is now raised to the 3rd in equation 3.

P5, L6: Please explain what ‘k’ actually is.

We have added the expression for k in terms of the volume mean and effective radius. We also mention that k represents the skewness and dispersion of the droplet size

distribution.

P6, L21: I would argue that surface albedo reflectance belongs to the ancillary data (either assumed fixed or calculated from Cox & Munk). The retrieval LUTs need surface reflectance as input, right?

You are correct, it is part of the ancillary data. Since it is a significant source of differences in the LUTs for retrievals between collections for ocean scenes, we include the details of the surface albedo changes in the discussion.

P7, L1: Do you have any reference of the mentioned effect of the change in surface reflectance?

In addition to the expansion of the case study, showing the relative effect of surface reflectance changes in the LUTs, Platnick et al., 2017 is cited.

P7, first paragraph: Do you have any explanation for the increase in r_e,1.6 at high northern hemispheric latitudes? Maybe a general remark could be added (if you agree) that the effect of the CTP change will be largest in the tropics and smaller toward the poles because it depends mainly on water vapour.

Since we didn't focus on CDNC at those latitudes, we hadn't investigated it and don't have a definitive explanation of what is happening there. Considering that retrievals at high latitudes are difficult due to unfavorable solar angles, issues with thermodynamic phase determination and cloud masking, the disagreement is not surprising. The 1.6 mu lookup table is less orthogonal than 2.1 and 3.7 so it would follow that it would be more sensitive to cloud field inhomogeneity. Considering that the focus is on mid-latitudes and the tropics, we feel that the differences don't impact the results of the paper.

P7, L16-21: The information on this case study does not clarify anything, so I suggest to either expand it (e.g., with a figure) or leave it out. I appreciate it is difficult to separate out the effects of the individual changes quantitatively, but can you perhaps

more generally explain the pattern of r_e,3.7 differences in Fig. 2?

We have expanded the section and have included several figures from the case study to illustrate and quantify the contributions to the observed differences in effective radius for each channel due to changes in the LUTs, vis/NIR re-registration and CTP changes. In addition for the 3.7 micron channel we include the effects due to changes in the assumed solar irradiance and the inclusion of above cloud atmospheric emission.

P8, Section 3.3: It is not very clear to me what we actually learn from the independent pixel comparison, especially since few explanations are provided (i.e. for the sign and seasonal variability of differences between independent and common pixel sampling).

We agree with the reviewer that the global scale independent pixel comparison does not contribute significantly to the understanding of the intercollection differences. Due to different pixel sampling, it doesn't allow a 1-to-1 comparison which limits its contribution. The other reviewer had a similar comment regarding the section. We have therefore chosen to omit this section from the manuscript.

P9, L13-19: I suggest to mention here the optical thickness / effective radius retrieval effects of above cloud aerosol, which can be very strong in this region, depending on the SWIR channel used.

Thank you for the suggestion. We now mention above cloud aerosol effects, provided a citation to Haywood et al., 2005, and discussed the how the channels with low degrees of orthogonality in the retrieval space are more impacted.

P9, L15: This is not the biomass burning season for whole Africa but for southern Africa. Also, I would argue that June to October is a better reflection of the average burning period.

This is fixed. We also agree that June – October is more accurate. The manuscript now reflects that.

P9, L17: From Fig. 6a it seems that there is no discernable difference at 3.7 micron.

Thank you, that was an oversight. The manuscript now states there is no difference at 3.7 micron.

âĂĺP16, Fig. 2: To put these difference plots in context, please add effective radius from C6 from the three channels as separate maps.

Completed.

P16, Fig. 2: For comparability it would be better to use the same color scale for all difference plots. It seems -2 to +2 micron is ok for all plots.

We agree. -2 to +2 is now the range of all panels.

P17, Fig. 3: To put these difference plots in context, please add CDNC from C6 from the three channels as separate maps.

Done.

P19, caption Fig. 5: Add ‘Collection 6’.

Figure 5 from the original manuscript has been removed.

Technical comments

All technical comments below have been addressed in the revised manuscript.

P1, L21: remove brackets P2, L3: replace ‘:’ by ‘.’

P2, L10: Suggest to add ‘number’ after ‘droplet’ and introduce abbreviation CDNC (since that has not yet been done in the main text)

P2, L16: Remove ‘properties of’âĂĺ

P2, L24 and further: check use (or not) of brackets with the references

P3, L2: check sentence; what are ‘cloud microphysical estimates’?

Changed to “cloud microphysical properties”

âĂĺP3, L21: Add ‘are’ after ‘results’

âĂĺP4, L18: Add comma after ‘properties’

âĂĺP5, L1: ‘therefor’ should be ‘therefore’?

P5, L22 and further: Be aware that ‘difference less than -1 micron’ is confusing. It actually implies the opposite of what you try to express. Similar phrases occur later in the text.

P6, L8: ‘differences are different’ reads strange; can you rephrase?

P7, L9: Suggest replacing ‘brighter’ with ‘higher’âĂĺ

P7, L18: ‘appear’ should be ‘appears’

âĂĺP7, L23: Suggest changing ‘Finally, an additional’ to ‘A final’

P8, L4: ‘reveals’ should be ‘reveal’ âĂĺ P9, L10: Add ‘liquid’ before ‘cloud’âĂĺ

P9, L17: Replace ‘at this’ with ‘with a’ and add ‘of’ after ‘CDNC’.

P9, L18: Add ‘burning’ after ‘biomass’.

âĂĺP9, L20-22: Sentence is not correct.âĂĺ

P9, L24: Suggest to use the word difference here rather than bias.

P9, L25: Add ‘is’ between ‘micron’ and ‘in’âĂĺ

P10, L6: Replace first ‘a’ with ‘this’.âĂĺ

P10, L6: Add ‘to’ after ‘compared’.âĂĺ

P10, L18: Typo ‘re’

âĂĺP11, L10: Add ‘are’ after ‘here’. âĂĺ P13, L20: African starts with a capital.

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