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Atmospheric Chemistry and Physics Discussions

Interactive comment on "A better understanding of cloud optical thickness derived from the passive sensors MODIS/AQUA and POLDER/PARASOL in the A-train constellation" *by* S. Zeng et al.

S. Zeng et al.

shan.zeng@nasa.gov

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We would like to thank the anonymous reviewer for his careful reading and useful comments that helped in improving our manuscript acp-2012-148 entitled "A better understanding of cloud optical thickness derived from the passive sensors MODIS/AQUA and POLDER/PARASOL in the A-Train constellation".

After discussions with co-authors, the reviewer will find our answers to his suggestions:

1. What motivated this study and what are main objectives? These questions should

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Interactive Discussion

Discussion Paper

be addressed in the Introduction. Since many previous studies have been carried out on COT retrievals, it is necessary to distinguish the present study from them. What are the outstanding issues that haven't been addressed by previous studies? Will they be addressed in the present study? I think clarification of these questions will help readers appreciate the significance of this study.

Concerning the motivation of this work, we added: "In order to establish climate records of cloud cover properties, it is expected that merging of products derived from multiple sensors will be necessary. In addition, inter-comparison of cloud products from different sensors can help in assessing the quality of each. This study was initially motivated by the global inter-validation of cloud products (including but not limited to COT) derived from the two different passive sensors and secondly by the wish to understand and qualify differences observed, accounting for each sensor own characteristics. POLDER makes measurement of clouds in multiple directions but with a quite low spatial resolution (6km$\times$7km) whereas MODIS observes clouds with a higher spatial resolution (1km$\times$1km) but only in one direction. Our assessment of COT for the two sensors is expected to give valuable information to the users of these satellites. This will contribute to establish long-term cloud climatologies with understood limitations and quantified uncertainties." As already answered to the reviewer 1, Zhang et al. (2009) discuss COT differences but only for ice clouds. Here, we present a more extensive study that covers water and ice clouds COT differences and analyze other associated key parameters such as spatial resolution and directional biases. So we added in the introduction: "In a previous study, Zhang et al. (2009) discussed COT differences between POLDER/PARASOL and MODIS/AQUA for ice clouds. They concluded that differences could be principally related to the choice of microphysical model used in the algorithm. Here, we made more extensive comparisons of POLDER and MODIS COT for ice and also for water clouds. We discussed differences not only in terms of microphysical model but also in terms of sensor spatial resolution and viewing geometry. This work follows and is based on previous statistical comparisons of POLDER and MODIS cloud fractions and cloud thermodynamic phases (Zeng et al., 2011a, 2011b).”

2. How many and which moths/years of data are used in the comparison? This should be in Section 2. Also, I’d like to see some discussion on the statistics of the compared pixels. For example, what are the fractions of over cast pixels vs. partly cloudy pixels? How often do MODIS and POLDER agree on cloud phase and how often do they differ. This information will give the readers some large pictures about the overall agreement of the two products.

Our study is based on one-year of observations ranging from Dec. 2007 to Nov. 2008, corresponding to over 100 millions of cloudy pixels. We added the presentation of processing period at the end of section 2: “The comparisons and results presented in this paper are for a full year period from December 2007 to November 2008 allowing sufficient sampling and representativeness with more than 100 millions of cloudy pixels.”

In addition, we added statistic number of different cloudy and phase cases in section 3.3: “. . .we first note that in overcast cases (57% of the cloudy pixels, 5.88E+07 pixels), most clouds have the same phases determined by both sensors: 82% (4.84E+07 pixels) are in agreement with 43% detected as liquid and 39% detected as ice by both sensors.. ” “Comparisons between the two sensors for broken clouds are shown in Figure 4 (e to h). There are slightly less broken clouds (5.88E+07 pixels are overcast compared to 4.38E+07 broken). POLDER and MODIS agree on the phase detected in 84% of the cases and the majority of broken clouds (72%) have liquid phase. ”

3. A reference is needed to support “but not with ISCCP D product where the land-ocean contrast of COT has been removed primarily because a significant increase in the amount of detected thin cirrus has been found over land with a lower IR threshold”. It has been added in the paper. The reference is the same as the one for ISCCP C product (Rossow and Schiffer, 1999).

4. There are several interesting features in Figure 1 that haven’t been discussed.

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Focusing on the Liq.(P)-Liq. (M) comparison, 1) it seems POLDER COT is substantial smaller than MODIS retrieval over the Amazon region and East China. 2) the ITCZ is clearly seen in POLDER retrieval but not seen in MODIS. 3) POLDER retrieval seems to be larger than MODIS retrievals over Southern Oceans although Figure 2a seems to suggest the other way around. It might be inspiring to put some discussion on these features.

In figure 1, color scales of the first two columns are different for a better visualization of geographical similarity of the POLDER and the MODIS COT. The three points mentioned above come from this color scale difference. Indeed looking at the third column representing the differences between the two COT, we almost do not observe these features. Actually around East China, the POLDER COT is larger than the MODIS one, which may be associated with polluted air and smaller droplets (see section 3.1) where POLDER by using a constant droplet size for the retrieval may be subject to systematic biases. To call the attention of readers on the color scale difference, we added in the Figure 1 caption “Important note: for clarity reasons, color scales are different for POLDER and MODIS COT”. And we also add in section 3.1: “Note however that POLDER COTs are globally lower than MODIS ones (color scales are not the same for POLDER and MODIS) except for the case POLDER-liquid/MODIS-ice. These differences will be discussed in section 4”.

5. In the discussion of POLDER and MODIS cloud phase difference, it is mentioned that “In these cases, angular polarized signal from POLDER is sensible to lower water level however the IR and NIR signals from MODIS give more correct information at the cloud top.” Isn’t polarization also only sensitive to cloud top? If I remember correctly, studies suggest that the polarized radiance is only sensitive to first one of cloud optical depth and becomes saturated after about three optical depths. This penetration depth seems to be even smaller than NIR band. This needs to be clarified.

It is correct that polarization signal saturates quickly as a function of optical thickness. It is thus sensitive only to the upper cloud top layer until an optical depth of about 2-3.

However, here we talk about thin cirrus with optical thickness less than 2 and lying above a water cloud. To be more precise, we added in the text: "In such situation, polarization features of underlying water cloud well marked with a strong signal in the cloudbow directions still appears in measured radiances, leading to identification of water phase corresponding to the lower layer. MODIS uses IR channels as part of the phase algorithm decision, which on contrary, leads to ice phase identified as brightness temperature differences used are very sensitive to presence of elevated cold thin cirrus (Riedi et al., 2010)".

6. In pixel-to-pixel comparison, Figure 4d seems to suggest that when liquid cloud is thick, MODIS retrieval tends to be smaller than POLDER value. For example, when MODIS retrieves a COT of 60, the POLDER value is typically around 80. What is the reason for this? Is it because the asymmetry factor difference?

Indeed, for a minority of clouds with large COT, POLDER values appear larger than MODIS one, but this is an artifact due to algorithm differences. We added: "This is an artifact because MODIS algorithm uses an upper limit of 100 for COT retrieval, while POLDER COT has no upper limit with values as large as 200. The averaging process at the POLDER super-pixel scale leads therefore to higher values for POLDER than for MODIS. In addition, for large COTs, the dependence of reflectance on COT becomes weaker, so small changes in radiances lead to large changes in COT".

7. It is mentioned when discussing Figure 7 that "The good statistical relationship between the liquid COTs of the two sensors in Figure 4d is thus not really improved for the scaled COT in Figure 7d." I cannot agree. It seems POLDER and MODIS agree better in Figure 7d than in Figure 4d, especially for large COT values. This is really interesting. It seems to suggest that large MODIS COT tends to have smaller effective radius (i.e., larger (1-g)) so that the (1-g)*MODIS_COT adjustment leads to better agreement with (1-g)*POLDER_COT. This behavior of MODIS COT seems worthy of some discussion.

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Interactive Comment

It was not clear in the paper, but in Figures 7 we zoomed to better visualize the relationships between POLDER and MODIS and cut off larger COT where there were less pixels available for statistics. So, in Figure 7, we only see (1-g)×COT values smaller than 9 that corresponds to COT of about 60 in Figure 4. However, the linear relationship function is still calculated without limitation to 9, including all data. To avoid misunderstanding, we added in the Figure 7 caption: “Note that figures axis are limited to upper values of 9 corresponding to COT of about 60 in Figure 4”.

8. Figure 8 and 9 are really creative and interesting plots. But unfortunately I feel they are not very well discussed and some confusing issues are not clarified. First of all, what does the radial direction of the polar plot corresponds to? Viewing zenith angle? In Figure 8 when SZA is between 60_70 degree, a reddish region is clearly seen over relative azimuth 250_270, which indicates COT retrieval over this angular range is substantially larger than other direction. Note that this region is also clearly seen in the lower center plot where all SZAs are combined. What causes this reddish region? What is scattering angle corresponding to this azimuth angle between 250_270? The fact that the reddish region is so regular makes it suspicious. Is it associated with special scattering angles, like rainbow angles, or it might be indicative of artifacts in theretrieval? Also in Figure 8 when SZA is between 20_30 degree, the COT is obviously larger in the relatively azimuth direction between 270_30 degree. Similar feature is also seen when SZA is between 30_40. What are the reasons for this?

Our graphs were not clear enough. The reddish region with larger COT is due to a poor sampling, with less confidence. The radial direction corresponds to the sinus of the satellite viewing angle. We modified Figure 8 and 9 captions to be clearer. Figure 8 captions now reads: “Polar plots of POLDER COT for overcast oceanic liquid clouds for different solar incidences (1st, 2nd lines and the 1st column of the 3rd lines) and of MODIS COT for all sun zenith angles (lower right corner). Polar angle represents relative azimuth angle between the satellite and the sun (from 0° corresponding to backscattering direction to 359°). Polar radius corresponds to the sinus of the satel-

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lite zenith angle (from sin0°=0 to sin90°=1). Colors encode are the averaged COT values for a given set of geometries. SZA means solar zenith angle range. There is a poor satellite sampling for relative azimuth angles between 240°-300° for POLDER and between 60°-120° and 240°-300° for MODIS".

Interactive comment on Atmos. Chem. Phys. Discuss., 12, 11733, 2012.