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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Impacts of water vapor/aerosol loading trends and land cover on aerosol microphysical and radiative effects on clouds during the Amazon biomass burning season" *by* J. E. Ten Hoeve et al.

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— Although this manuscript includes more years in the analysis than previous studies, why the data were restricted to years 2004 to 2007 only? MODIS data from Aqua satellite is available from 2002 up to the present.

When we performed the analysis, MODIS land cover data from the MCD12Q1 product was only available up to 2007, which is why we did not include years after 2007. We felt that four years (2004-2007) provided an ample amount of data, sufficient interannual

meteorological variability, and a representative sample of aerosol-cloud interactions over the region. Processing of additional years also required additional computational resources at the time.

— In Figure 2, it is not clear if instantaneous and only the pixel over AERONET site data are used. If not, please specify the time interval for AERONET averaging and the spatial resolution for MODIS averaging data for both AOD and CWV comparisons.

We have added a brief discussion to the figure caption that explains the averaging process. Any MODIS pixels centered within a 15-km distance of the AERONET location are included in the average used to construct each point. The time resolution for the AERONET averaging is 1 hour ($\pm$ 30 minutes from the mean MODIS retrieval time).

— Figure 6: If data presented in figure 6b are from a more restricted cloud top pressure interval, why cloud optical depth of figure 6a presents higher variation (vertical scale goes from 4 to 20) compared to values in figure 6b (from 4 to 28)? Is MODIS cloud optical depth reliable enough for this kind of analysis? As explained in page 24936, lines 1-2, if cloud fields are more homogeneous in figure 6b, compared to 6a, why COD presents higher variability?

COD in Figure 6b presents a higher variation compared to Figure 6a largely because there are far fewer retrievals employed in Figure 6b compared to Figure 6a. The total number of retrievals employed in Figure 6b is 202 whereas the total number of retrievals employed in Figure 6a is 1168, nearly 6 times more. We have adjusted the text in the manuscript to say, "Figure 6b shows a similar boomerang pattern of COD versus AOD as Fig. 6a, except with more variation due to a significantly smaller sampling size." We have also clarified the last statement, "This similar COD reduction with AOD among CWV groupings may be because all clouds have similar cloud top pressures and are situated in more homogeneous cloud fields."

We believe that MODIS COD is reliable enough for this analysis since the COD retrieval uncertainty (provided as a scientific data set in the Level 2 product) is small compared to the trends observed. The included figures below show the average retrieval uncertainty for each CWV grouping and each AOD bin for Figure 6a and 6b. There does not appear to be a distinct trend in COD uncertainty with AOD. We do see that the average uncertainty never exceeds roughly 20% for any CWV bin. As a result, the trends in Figure 6a,b would still be present even if the values in Figures 6a,b were adjusted by $\pm$ the average uncertainty in each bin, a very extreme scenario since individual retrieval uncertainties can be positive or negative.

— Page 24936: Reduction of COD is attributed solely by absorption of radiation by aerosol particles. Water vapour also absorbs radiation. What is the effect of different water vapour content in heating the atmosphere and consequences to the cloud field? Could not part of the responsibility attributed to aerosol absorption be due also to water vapour?

Some of the atmospheric heating may be due to water vapor absorption; however, this effect is likely to be minimal. The largest absorption effect (largest decrease in COD with AOD) is found for the lowest CWV grouping and the smallest absorption effect (smallest decrease in COD with AOD) is found for the highest CWV grouping in Figure 6a. If water vapor were significantly contributing to the absorption, we would likely see a greater absorption effect (i.e. greater decrease of COD with AOD) in the highest CWV grouping compared to the lowest CWV grouping, but we do not. To convey this point in the text, we have added the statement on P24936, “It is unlikely that the decrease in COD with AOD is due to absorption by water vapor since the largest decrease (largest absorption effect) occurs for the lowest CWV grouping and the smallest decrease (smallest absorption effect) occurs for the highest CWV grouping.”

To support this argument quantitatively, we ran a radiative transfer model (SBDART) with input values from our study region. The surface albedo, column-integrated water vapor content, latitude, longitude, median day of the season, and surface elevation are all specified in the model specifically for our study region. We have also specified an idealized aerosol layer uniformly mixed between 0 and 3 km, with extinction efficiencies,

single scattering albedos, and asymmetry parameters derived from nearby AERONET stations during the biomass burning season. We ran the model holding aerosol optical depth constant at a value of 0.4 and varying CWV between 2.5 cm and 5.5 cm (the range of values observed in our study) for a tropical atmosphere, and then analyzed heating rates at a height of 3 km near the observed cloud layer. We then hold CWV constant at a value of 4.0 cm and vary aerosol optical depth between 0.0 and 0.8 (the range of values used in our study). When CWV is held constant, and AOD is varied from 0.0 to 0.8, heating rates increase from 0.41 K/day to 2.36 K/day. When AOD is held constant, and CWV is varied from 2.5 cm to 5.5 cm, heating rates increase from 1.24 K/day to 1.35 K/day. Atmospheric heating rates increased 475% with the increase of aerosols between AODs of 0.0 and 0.8, whereas atmospheric heating rates increased only 9% with the increase in CWV between 2.5 cm and 5.5 cm.

— In my opinion, data in Figure 7 is too noisy to allow any conclusion about the aerosol effect on cloud fraction.

We have changed the figure to show COD binned by AOD, identical to the method used in the earlier portion of the paper. In this revised figure, we see a well-defined increase in COD between AODs of $\sim$0.2 and $\sim$0.35, followed by a well-defined decrease at higher AOD values. The lack of smooth increasing and decreasing trends is due to the low number of retrievals available on this one day (167 total retrievals). However, the microphysical increase of COD with AOD is evident in this plot at low AODs, in addition to the radiative/absorption effect at higher AODs. Furthermore, the AOD turning point ($\sim$0.35) is within the range of turning points observed in Figure 6a. We believe that this new visualization better illustrates the relevant trends in the figure.

— Are the differences observed in Table 2 for forested and deforested areas statistically significant? What are the standard deviations? Looking at frequency distributions presented in S.2, it seems that if relative distributions were considered, no significant differences would be observed.

To test if the forested and deforested distributions were statistically different, we performed a two-sample Kolmogorov-Smirnov (KS) goodness of fit test. The two-sample KS test checks if two data sets are sampled from the same underlying distribution. The advantage of the KS test is that it makes no assumption about the underlying distribution of the data, and since many of the distributions in Figure S.2 are non-normal, the KS test is more appropriate than a test that assumes normality. The null hypothesis of this test is that the data are sampled from the same underlying distribution. We find that for all variables, the null hypothesis is rejected at the 99% confidence level for a two-tailed test. Thus, the forested and deforested data are shown to not be sampled from the same underlying distribution, and thus are statistically different. We have added a brief description of this result to Supplementary Material S.2, which is referenced in the text on P24939.

The standard deviations of each variable in Table 1 are shown in the included table below. For some variables, the standard deviations are approximately equal to the mean values (e.g. cloud optical depth, aerosol optical depth, cloud water path, cloud fraction) and for other variables, the standard deviations are quite lower than the mean values (e.g. cloud top pressure, cloud effective radius, column water vapor, low-level stability, 850/1000 hPa temperatures).

— Considering the 5 deg x 5 deg area, what could explain the stability difference between forested and deforested areas, particularly for cases in which forest areas are unstable and deforested areas are stable? According to Figure 1, deforested areas are surrounded by forested area.

We have added to the text some of the causes for the stability difference between forested and deforested areas on P24942. Occurrences of the forested stable/deforested unstable (FSDU) case are likely due to the lower specific heat and thus higher solar absorption / sensible heat flux over the deforested area. This increases the near-surface temperature to a greater extent over the deforested area compared to the forested area, resulting in greater instability over the deforested area. FSDU cases

are by far the more common occurrence compared to forested unstable/deforested stable (FUDS) cases, as we have roughly 5 times more retrievals for the FSDU case compared to the FUDS case in Figure 8d (Supplementary Material S.3).

We cannot be certain of the drivers of the less-common FUDS cases, since we cannot determine cause and effect relationships from observational satellite data alone. Forested unstable/deforested stable (FUDS) cases could be caused by a variety of local factors, including the presence/absence of clouds over the pasture/forest, varying optical thickness of clouds over pasture/forest, varying surface characteristics within pasture/forest land covers, as well as inland breeze mesoscale circulations discussed in the manuscript. Localized cloud cover could cool deforested areas at the surface and the absence of clouds could warm forested areas. Inland sea breezes could also cool surface temperatures over some deforested patches, increasing the stability relative to some forested patches on the same day. Also, the higher surface albedo of the deforested areas could reflect more sunlight relative to the forested areas in some cases, resulting in a relatively lower surface temperature (and thus higher stability) over the deforested areas compared to the forested areas. In addition, we cannot completely rule out the effect of larger regional-scale weather patterns that may affect some areas of the study region and not others.

— Page 24942, line 20: Change NE by NS in: “In this study, a 5 deg NS x 5 deg WE region:”

Changed as suggested.

Interactive comment on Atmos. Chem. Phys. Discuss., 10, 24919, 2010.

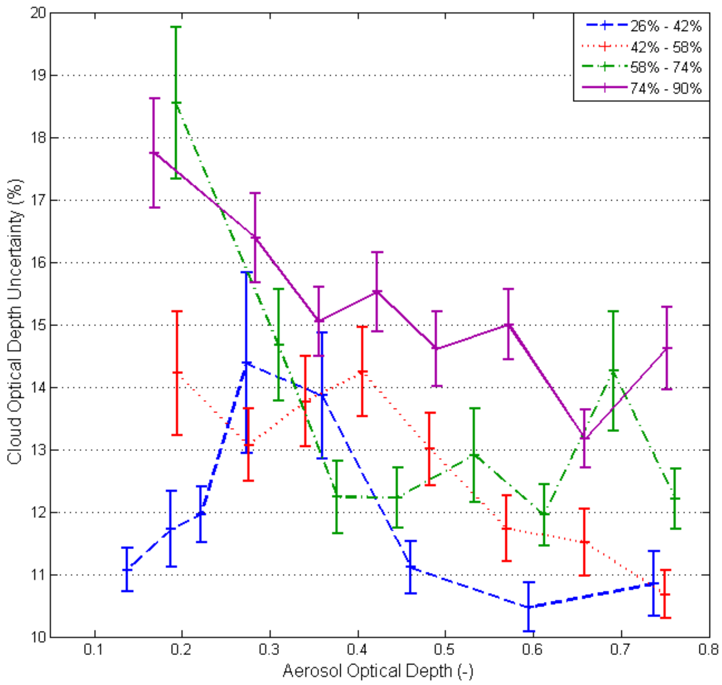

Fig. 1. Cloud optical depth uncertainties in Fig. 6a

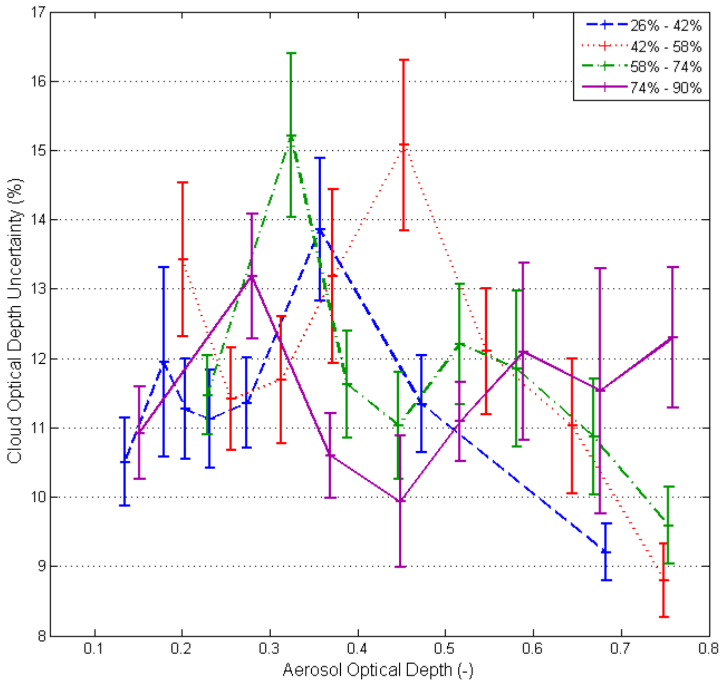

Fig. 2. Cloud optical depth uncertainties in Fig. 6b

	Forested	Deforested
Cloud Fraction (-)	0.40	0.39
Cloud Optical Depth (-)	8.68	8.16
Cloud Top Pressure (hPa)	186.0	194.5
Cloud Effective Radius (μm)	4.59	4.28
Cloud Water Path (g/m^2)	67.4	60.0
Column Water Vapor (cm)	1.27	1.18
850 hPa Temperature (K)	1.6	1.5
1000 hPa Temperature (K)	3.3	3.7
Low-Level Stability [Temperature 850 hPa minus Temperature 1000 hPa (K)]	2.9	3.3
AOD at 550 nm (-)	0.89	0.88

Fig. 3. Standard deviations of variables included in Table 1