Interactive comment on "A novel methodology using MODIS and CERES for assessing the daily radiative forcing of smoke aerosols in large scale over the Amazonia"

by E. T. Sena and P. Artaxo submitted to Atmos. Chem. Phys.

Answers to Anonymous Referee #1:

We would like to thank referee #1 for the very careful review. We have really appreciated the several suggestions and comments that helped us improving the revised manuscript. In bold type, the issues raised by the reviewer, followed for our action in each issue raised.

This paper describes a new methodology to measure the direct aerosol radiative forcing (DARF) at the top of the atmosphere. For this purpose, the authors used the MODIS and CERES satellite instruments during the biomass burning season over the Amazonian region. They compare their DARF results with other studies using a different methodology and with ground-based stations. The structure of the paper is good and we clearly see where the authors go. Results are reasonably well presented and I recommend the paper for publication in ACP after the authors address the following comments.

General comments:

1) The abstract is not concise enough. In particular, I would summarize more the 2nd and 3rd paragraph. I am not sure that you need to detail your methodology here (MODIS clean scenes, etc...). I also dont think that correlation equations need to be written. It makes the abstract heavy. I would remove them and slightly modify your last sentences such as "We showed that our methodology agrees well with other satellite remote sensing studies, ground-based measurements and radiative transfer models..."

We completely agree with the reviewer comments. The abstract was too detailed. We've changed the abstract in the revised version according to the reviewer's suggestions.

2) I have concerns about your explanations attributing the 24h-DARF daily variation that you show in Figure 2 and 3, reported in Section 3.

Page 31524

Line 15-17: You attribute the difference of 24h-DARF between 2 days (13th and 15th of August) to the transport and atmospheric circulation.

Page 31525

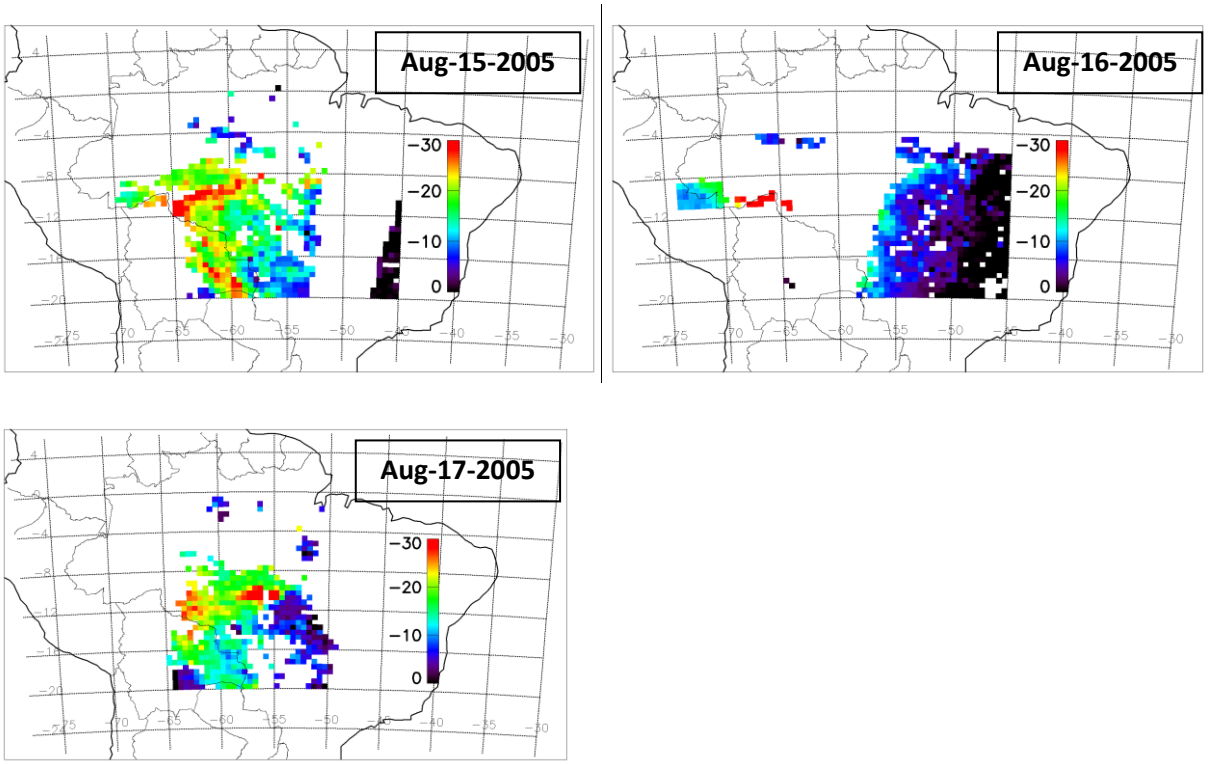
Line 8-9: You attribute the 24h-DARF daily variation to the change in cloud cover.

Where do you see that these variations are due to the transport, atmospheric circulation or cloud cover? I would like to see a plot of the daily cloud cover area in your region for each day (I think MODIS retrieves this product). Are these clouds over burning areas which could decrease 24h-DARF ? In addition, did you look at aerosol emissions for these days (e.g., with a satellite fire product or with a biomass burning inventory (e.g., GFED)) ? On Figure 3, the 24h-DARF shows lower values for 2007 (down to -25 W.m-2) than for 2005 (-20 W.m-2) and 2006 (-15 W.m-2). A quick look at the GFEDv3 inventory seems to be consistent with those results since it shows larger biomass burning emissions in 2007 than in 2005 and 2006. What about 2008, 2009 ? It would be easier to compare different years if you could plot data on

the same plot. Maybe different color lines for each year with a 3 days smooth? There are also several papers in the litterature refering to the transport of aerosols in the Amazonian region that could help.

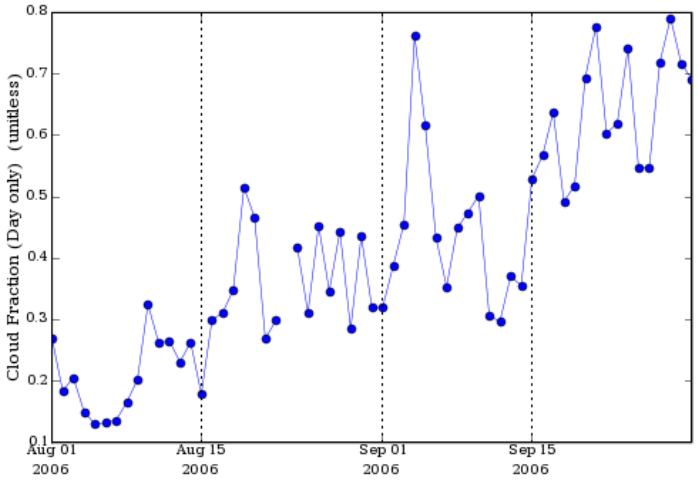
This is a long question, and to answer it fully, we will divide the answer in several topics:

On cloud fraction and CERES and MODIS coverage: Thanks for raising this question. We agree that this point was not clear in the manuscript. Actually, the variation on daily DARF from one day to the next is not caused only by changes in fire locations, transport and cloud coverage. The daily DARF variation is also influenced by differences in the satellite imaged area. Since the Terra satellite track changes from one day to the other, the area scanned by CERES-MODIS one day is not exactly the same as the area scanned on the next day. Due to its polar orbiting track, every day the scanned area changes slightly, finally repeating itself after about 16 days. The figure below shows two examples of the 24h-DARF for Aug-15-2005 (top, left), Aug-16-2005 (top, right) and Aug-17-2005 (bottom).



We can observe in these two pictures the effect of the changing track area. The mean 24h-DARF on Aug-16 is smaller than the 24h-DARF on Aug-15 and Aug-17. This is due to the fact that CERES and MODIS didn't cover the area that was the most impacted by biomass burning aerosols on Aug-16. This section of the manuscript was fully reformulated discussing this effect in details. This feature of the technique is discussed in more details now in the revised manuscript.

The next picture shows an example of the mean daily cloud cover for each day at the study area in 2006. We can observe that changes in cloud cover during the biomass burning season also influence DARF retrievals.



On atmospheric circulation and aerosol transport: During the development of this work, we have analyzed fire products from MODIS and also GOES over the Amazonia during the biomass burning season. The aerosol distribution and RF results presented in this manuscript is consistent with fire maps as well as with AERONET AOD measured at several sites. Several papers discuss biomass burning transport over the Amazonia and were already cited in the manuscript, such as Freitas et al., 2005, Longo et al., 2009 and Andreae et al., 2001. A brand new paper by Mishra et al., 2015, in press in Atmospheric Environment discusses in detail the issue of the correlation between smoke and fire in Amazonia. This paper was now also cited in the revised manuscript as well as some others. We also enhanced the discussion addressing the points the reviewer raised on fire counts and atmospheric transport.

On enhancing Figure 3: We really thank the reviewer and we've accepted the suggestions on enhancing Figure 3 that shows the forcing on a day by day basis during dry season. We modified this figure on the revised manuscript to include all the years analyzed in this work, as suggested. We've tried to put all data in only one plot, but as there were 9 years of data, we found that the plot became very crowded and a bit confusing. So, we decided to include several sequential plots for all years, using the same scale for DARF24h. We also expanded the discussion on the daily variability of the DARF on the manuscript to include all years of data and emphasize the interannual variation of the DARF24h.

3) I would remove the Figure 4. This figure comes from another paper which is cited and it doesnt add anything to your paper. We understand the difference between your approach and that used in previous studies. Your explanations on page 31525 are enough. Maybe same for Figure 6.

We agree that Figure 4 does not add critical information on the paper. We removed it. As for figure 6, we think that it is important in our discussion, so we prefer to keep it in the manuscript.

4) I agree with you when you say that a small SSA variation induces a large 24h-DARF variation for large AOD values (e.g., AOD=5). However, you showed that the mean AOD over Amazonia is about 0.2 to 0.4 during dry seasons. So, it would be more judicious to tell us about the difference in 24h-DARF at these AOD for different SSA. Are those 24h-DARF variations at these low AOD values (0.2-0.4) in range of variations that you observe with AERONET ? You might need to change the x-axis range on Figure 10 as well (e.g., from 0 to 1 or 0 to 2).

Thanks for pointing that out. A variation of 0.03 on SSA for the mean AOD observed over the Amazonia (0.2 to 0.4) would affect the 24h-DARF in about 1 to 2 W/m^2. To evaluate if these values are consistent with the 24h-DARF variation observed with AERONET, the database was divided in AOD bins of 0.05 and the standard deviation of AERONET's 24h-DARF on each bin was analyzed. This analysis showed that for AOD varying from 0.2 to 0.4, the standard deviation of the AERONET 's 24h-DARF on each bin varied between 1.5

and 2.7 W/m^2. This variation is higher than the one obtained using SBDART, because in those simulations, only single scattering albedo was varied and other aerosol and atmospheric properties were fixed. However, there are other variables that influence the 24h-DARF observed by AERONET besides single scattering albedo, such as scattering phase function, size distribution and atmospheric water vapor content. This discussion was included in the revised version of the manuscript. The x-axis range on Figure 10 was also modified, and now ranges from 0 to 2, as suggested.

5) I found the English approximative and heavy but the paper is understandable. Here after, I listed some specific comments but there is space for more improvements.

We've really appreciated the referee's helpful suggestions on improving the overall language of the manuscript. We've followed all the referee's specific comments on correcting the English and we've also reviewed the language over the entire manuscript.

Specific comments:

When several references are mentioned, put them in chronological order please.

In the revised version of the manuscript the citations were put in chronological order.

Page 31516

1) Line 3: Remove "For that,"

Done.

2) Line 8: Replace studies by study

Done.

3) Line 20: ...in the estimate of...

Done.

Page 31517

4) Line 24: Remove "important"

Done.

Page 31518

5) Line 6-9: Rephrase sentence

The sentence was rephrased to: "This strong increase in aerosol concentration is accompanied by a significant modification in particle size distribution, since most of the particles emitted during burning events belong to the fine mode".

6) Line 13-14: Remove "and other properties"

Done.

7) Line 23-24: ...with ground-based remote sensing measurements (ref) or in-site field-campaigns

(ref)

Done.

Page 31519

8) Line 11: ...is estimated to be about...

Done.

Page 31520

9) Line 5: Remove "retrievals"

Done.

10) Line 7: These both instruments...

Done.

11) Line 16: MODIS measures...

Done.

12) Line 19: ...about cloud and aerosol optical...

Done.

13) Line 25: ...aerosol and cloud properties...

Done.

Page 31521

14) Line 2: ...shortwave flux retrievals at the TOA from Terra satellite...

Done.

15) Line 12-13: ...measured in background (Fcl) and polluted (Fpol) conditions.

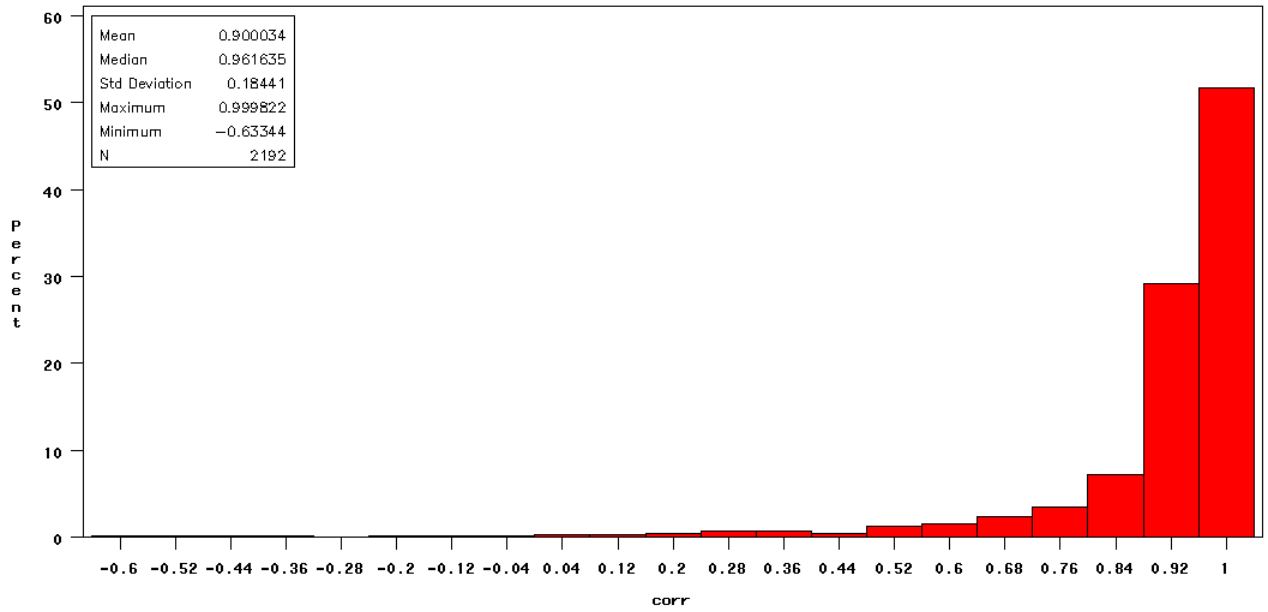
Done.

16) Line 19: Can you explain why you take 0.1 as the threshold for background scenes ? Does it come from another paper ?

To define the AOD threshold for background conditions, we've analyzed AERONET's AOD during the wet season. After checking AERONET data, the threshold of AOD < 0.1 seemed to be an appropriate choice for non-polluted conditions. This discussion was included in the final manuscript.

17) Line 22: Is the example showed in Figure 1, a best case scenario or it is representative of each grid cell ? Why did you choose to show this example more than another ?

That's an interesting question. The example showed in figure 1 is not a best case scenario. If we check the distribution of the correlation between Fcl and cos(SZA), we can see that for about 80% of the cases the correlation is larger than 0.90, as shown in the figure below. These results point out another advantage of applying this new methodology to evaluate the DARF. This point was now emphasized in the revised manuscript.



18) Line 25: "approximation"

Done.

Page 31522

19) Line 13: Remove "of the"

Done.

20) Line 16: CERES radiance measurements

Done.

Page 31523

21) Line 1: Remove "For this,"

Done.

Page 31524

22) Line 9: ...from about -30 to -15

Done.

23) Line 13: ...from -30 to -15

Done.

Page 31525

24) Line 6: Remove "That is"

Done.

25) Line 6-7: Replace more negative by decrease and less negative by increase

Done.

26) Line 8: ...from one day to another...

Done.

27) Line 13-14: ...was calculated by using...

Done.

28) Line 22: Replace "that is, in a" by "with a"

Done.

Page 31526

29) Line 5-7: ...is always lower than...for this 10 year period (2000 to 2009) is -8.2...is -5.2...

Done.

30) Line 16: Replace less negative by larger

Done.

31) Line 22: Replace most certainly by very likely

Done.

32) Line 23: Remove "that was"

Done.

33) Line 26: ...between aerosol optical depths obtained by these two collections is due to the fact...

Done.

Page 31527

34) Line 18-19: correlation

Done.

35) Line 19: ...to 2009 is -0.86+-0.03 which is better than the mean...

Done.

36) Line 24: ...TOA flux estimates...

Done.

37) Line 26: Replace rely by relies

Done.

38) Line 27: ...those flux retrievals.

Done.

Page 31528

39) Line 4: ...in the calculated DARF...

Done.

40) Line 6: ...that accounts for...

Done.

41) Line 23: ...to retrieve AOD and...

Done.

Page 31529

42) Line 23: with 1 within 2 uncertainties ??? I dont understand what you mean here

Thanks. I did not express myself clearly. We rephrased the text to show that the agreement between DARF AERONET and DARF CERES is acceptable within the standard deviations.

43) Line 26-27: AERONET sunphotometers are at the surface and CERES-MODIS instruments are at 705 km aboard...

Done.

Page 31530

44) Line 10-11: In order to properly do that we compare CERES-MODIS data at the TOA with...

Done.

Page 31531

45) Line 4: ...are compatible with 1 and 0, respectively, within one uncetainty ??? Same as before, I dont understand.

Once again, I did not express myself clearly. We rephrased the text to show that the agreement between the BOA Flux from pyranometers and SBDART is acceptable within the standard deviations.

46) Line 9: ...pyronanometer measurements.

Done.

47) Line 16: To me, a slope of 0.86 is not close to y=x. A difference of 14% is not negligeable.

That's true. This sentence was removed from the revised manuscript. The text has been changed in order to further emphasize the sources of uncertainty (surface albedo model, aerosol single-scattering albedo, aerosol phase function, etc.) in radiative transfer DARF that contribute to this difference. Nevertheless, we also emphasize that given all those potential sources of uncertainty the comparison between space-based assessments of the DARF and radiative transfer evaluations of the DARF, using ground-based aerosol measurements a slope of 0.86$\pm$0.06 is still a very good result.

Page 31532

48) Line 8: ...significant and it shows that aerosol single scattering albedo is a critical parameter to

assess DARF.

Done.

49) Line 13: consists

Done.

Page 31533

50) Line 10: ...methodology is applied.

Done.

51) Line 12: Reformulate the sentence: The intercomparison between...

The sentence was reformulated to: "The DARF evaluated using the new methodology proposed in this work was compared with AERONET and SBDART DARF assessments. The results obtained from those DARF intercomparisons were very satisfactory."

52) Line 23: ...resulting in a better correlation between...

Done.

Figure 2: caption, distributions

Done.

Figure 5: What happened in 2004. Can you mention it ?

The year 2004 presents a high amount of MOD04 missing values for aerosol and cloud properties in CERES-SSF database. The percentage of missing MOD04 cloud and aerosol properties was around 45% for 2004, while for all the other years (2000-2003 and 2005-2009) missing values were on average only 10%. CERES science team has been formally contacted and informed about this problem and they are working on understanding it. They expect that this problem won't show up in CERES-SSF Edition 4, which is now being processed and will use MODIS collection 5 for all years, including 2004. In the revised manuscript, we included more information about this problem in Sections 3.2 and 3.3.