Interactive comment on "Modeling South America regional smoke plume: aerosol optical depth variability and shortwave surface forcing" by N. E. Rosário et al.

Response to Interactive comment from J. Reid Referee #2

First, we would like to thank the referee for his thoughtful comments and suggestions.

Referee #2 Comments:

1- *All in all, their AOD analyzes are pretty darn good, even if there is a great deal of divergence at high AODs.*

"But, I think they could have pushed the discussion for this divergence much further. There is not much discussion on the smoke source function, leaving it to references. But I think it should be discussed in detail here in that it is likely what is most related to the AOD fields."

Authors: We agree that the divergences could be further discussed, and we have tried to do so now in order to reply to the interactive comments. We are planning to add a section in the revised manuscript presenting in more detail the period (August 24 -29) characterized by large divergences between the model and AERONET over Alta Floresta. Regarding the smoke source function, since the suggested references present an excellent and full description of it, we thought that leaving it to the references would be ideal for the sake of the paper length. Nevertheless, the previous description on the emission parameterization will be expanded in order to provide more details regarding the smoke source function. In advance, the biomass burning source emission parameterization is based on the combination of GOES-12 WF_ABBA product (cimss.ssec.wisc.edu/goes/burn/abba.html, Prins et al. 1998), AVHRR from CPTEC-INPE (www.dpi.inpe.br/proarco/bdqueimadas, Setzer and Pereira, 1987) and MODIS fire product (Giglio et al. 2003). Fire detection is merged with a 1 km land use and carbon in live vegetation (Olson et al. 2000) data to provide the associated emission factor (Ward et al. 1992, Andreae and Merlet, 2001, combustion factor and carbon density. For each fire detected by remote sensing, the mass of emitted tracer is calculated and its emission in the model follows a typical diurnal cycle of the burning (peak at 15LT). The sources are spatially and temporally distributed and daily assimilated according to the biomass burning spots defined by the satellite observations. Ongoing research in our group (following the scientific community effort) is evaluating emission based on Fire Radiative Power (FRP), preliminary results are already shows differences between our conventional scheme and FRP scheme.

2-*"In particular, I would look at satellite navigation issues, which could be the culprit. Resolution/scan issues can easily result in misdiagnosis of the source fuel. I suggest having a quick glance of Hyer and Reid which discusses these issues."*

Authors: There is a discussion among members of our group and collaborators on the impact of satellite geometry on fire spot detection over South America and consequently on our smoke forecast. There was a general agreement that the MODIS fire detection algorithms may struggle on the edges of the satellite scans, which was mentioned in the manuscript. The results of Hyer and Reid confirmed our suspicions. Their discussion provided clarifying analysis on this issue. Given that we use a multi-sensor product (MODIS, GOES and AVHRR) to estimate our emissions, we need to

evaluate specifically how this MODIS scan issue impacts the overall emission product. For this paper it is hard to perform a detailed analysis of the contribution of the scan issue pointed out, but for sure we are considering a specific study to do so.

3-*"Also, it is a small point, but for biomass burning it helps to compare apples to apples. I would recommend using the Norm O'Neill SDA product available on the aeronet page to compare too. It seems that the high aod events are spikes. Residual cirrus can be a big issue in the tropics (see Chew et al., 2012 in AE for a discussion). In fact, it might even explain some of the differences between aeronet and the model. "*

Authors: We want to thank the referee specifically for this suggestion. The inclusion of Norm O'Neill SDA AERONET product in the comparison analysis had a significant impact on our analysis! It brought relevant aspects that we were missing, and that led us to a more clarifying analysis, mainly regarding divergences between modeled results and observations that occurred for the Cuiaba, Belterra and Balbina sites. When we compared the fine mode aerosol optical depth from the Norm O'Neill SDA AERONET product with modeled optical depth, the events characterized by large disagreements between AERONET and the model disappeared (additional supplement, pdf file). It turns out that during these events the contribution of coarse mode aerosol to the total optical depth was high. An analysis of the Angstrom Exponent (AE) indeed suggested the presence of large particles with a decreasing AE during those events. Opposite to the southern region of the Amazon basin, the cerrado region (Cuiaba) is characterized by large areas of exposed soil, which under windy conditions favors soil dust emission. Although the magnitude of the observed coarse mode contribution is not very usual, peaks of concentration in coarse mode aerosol around Cuiaba have been reported previously (SCAR-B experiment, Kaufman et al., 1998). For Belterra and Balbina, improvements come from the isolation of the fine mode contribution. Over both sites the relative contribution of coarse mode aerosols is higher than at sites located in the southwestern portion of the Amazon forest. With the removal of the coarse mode contribution in AERONET AOD a better agreement was found between the model and observations. However, even using the O'Neill SDA product, there are still divergences between observations and the model over the Alta Floresta site during the large smoke events seen at the end of August (Aug 24-29). This period was selected to provide a further discussion on the AOD field and model x observations divergences over that site, which we are plan to include in the revised manuscript.

Regarding residual cirrus, we think that is unlikely to be a major issue for Cuiaba during the dry season, although is possible that some of the large events attributed to coarse mode aerosol might be a cirrus influence given the approximation of a frontal system towards Central Brazil. It might be more relevant for the sites in the northeast Amazon (Balbina and Belterra).

4-*"If not that, you may want to also look for local sources."*

Authors: Yes, local sources may play a role at the Alta Floresta site. Looking at MODIS images between Aug. 24 and Aug. 31(additional supplement, pdf file), it is possible to see sharp gradients in the AOD field around Alta Floresta, which can indicate an effect of localized sources. Between Aug. 28 and 31 a cold front system brought tricky weather conditions, which had several implications and challenges for the smoke field modeling. Cloud amount increase associated with the instabilities driven by the cold front may also have prevented remote sensing of fire, consequently

resulting in an incomplete updated source emission. Both aspects, local sources and cloud cover, bring us to the two issues pointed out in the manuscript about emission based on remote sensing, which are fire spot omission and source misrepresentation.

5-*"It is likely a more minor term, but hygroscopicity and the impact in uncertainty is hardly discussed and probably should be."*

Authors: Amazonian smoke aerosol hygroscopicity is suggested to be low when compared with other aerosol types. Recent studies suggest that the hygroscopicity may not be negligible regarding some aspects, such intra-seasonal variability of single scattering albedo (Rosário et al., 2011). However, given the degree of uncertainty introduced by emission, transport and removal processes, we think that for the present analysis the hygroscopicity influence on AOD is indeed a minor term, and therefore we did not attempt to pursue it further.

6-*"While AOD is straight forward, flux comparisons are anything but. I understand the rational of only doing comparisons for "clear sky" In fact, with a mesoscale model in the tropics doing the cloud component would be an extremely tough gig. "But, also in the tropics, defining "clear sky" is problematic. It is not clear to me how "clear sky" conditions are defined. What I think they mean is clear lien of site, as defined by aeronet."*

Authors: Yes, isolating cloud influence is a hard task over the Amazon basin. Our "clear sky" samples are meant to be without influence of cloud direct beam attenuation and under minimum influence of the cloud diffuse enhancement effect. Our attempt to isolate "clear sky" scenarios is primarily based on the variance of the surface irradiance measured within a certain period (±15 minutes). Large variances were assumed to be associated with cloud contamination and therefore excluded.

7-*"But, diffuse contributions (reflection of clouds) can be important when one is talking about relatively small departures induced from aerosol particles. This result in the RMSE's relative to signal as being somewhat large. This also makes regression style verification not the best way to go about evaluation."*

Authors: Yes, the cloud enhancement effect on the diffuse solar component can increase ground surface irradiance. We are aware that in the Amazon basin in particular this effect can be important, which makes such analysis complicated. Although we agree that one is unable to fully prevent it, one can see that the majority of the observed "clear sky" samples are consistent with numerical estimations of cloudless sky fluxes using AERONET's AOD and Column Water Vapour (CWV) as input in an independent radiative transfer code (SBDART). We are afraid that we didn't understand clearly the last sentence.

8-*"The cloud issue also makes such calculations of mean radiative flux impact such as in figure 10 product difficult to practically apply. Discussion on this point is warranted."*

We would say that the mean radiative flux impact in Figure 10 should be seen as an evaluation of the impact of aerosol direct radiative effect (DRE) plus the atmospheric response (including cloud cover perturbation) to the inclusion of DRE. We recognize that we should replace the terminology radiative forcing, for example, to aerosol solar flux perturbation, since we are not actually evaluating the radiative forcing induced by smoke DRE in accordance with the definitions of radiative forcing calculations (IPCC,

2007). Therefore, the Figure 10 shows perturbation induced by the smoke aerosol DRE and the associated atmospheric perturbation on the diurnal cycle of the solar flux at the surface. Early in the morning the DRE signal is dominant and during the afternoon a noisy field is seen due to perturbation in the cloud cover.