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Relationship between Amazon biomass burning aerosols and rainfall over La Plata Basin

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Reviewer #3

1^{st} paragraph – Thank you for the general comments on our work.

2^{nd} paragraph – Thank you, your suggestions will be accepted.

3^{rd} paragraph – We modified the introduction and added a new paragraph about deep convection as follow below:

"*Morales et al. (2010) characterized meteorological conditions associated with thunderstorms and non-thunderstorms days over the city of São Paulo and investigated the pollution influence on them. The thunderstorms were basically regulated by dynamical and thermodynamic characteristics while aerosols did not show any significant effect. On the other hand,Albrecht et al. (2011) observed that large-scale and local environmental thermodynamics processes favored the development of intense thunderstorms over the Amazon in the end of the dry season, with no apparent effect of aerosol loading. During the wet season, however, thunderstorms were preferably observed in periods of high CCN concentrations.*

Tao et al. (2007) showed aerosol effects on three different deep convective cloud systems. These authors concluded that higher aerosol concentration can either favor or disfavor the precipitation process depending on atmospheric conditions. Fan et al. (2007) found that rain delay is more sensitive to relative humidity than to aerosol concentrations and only under conditions of significant moisture the aerosols can significantly change convection and rain rate. Numerical studies focused on isolated deep convective clouds performed by Fan et al. (2009) show that in case of strong wind shear, generally, aerosols suppress convection. This effect is more important in humid air than dry air. Fan et al. (2009) also observed an enhancement on convection by enhanced aerosol concentra-

tions under weak wind shear, until an optimum aerosol concentration is reached.”

4^{th} paragraph –

a) Figure 1 shows a climatological distribution of MCS over South America for each season (Silva Dias et al., 2009). The figure is a compilation of results from Velasco and Fritsch (1987), Conforte (1997), Torres and Nicolini (2002), Salio et al. (2007), and Vera et al. (2006). The period of Amazon biomass burning occur during the austral spring and the low level jet can carry aerosol loading downwind to La Plata Basin. The objective of the Figure 1 is to illustrate that MCSs are observed frequently during austral spring over La Plata Basin. Based on this figure it is possible to raise the questions:

”*If the MCS occur under polluted air conditions during austral spring, can the aerosol affect the MCS evolution? And how much would that be in terms of precipitation?*”

b) The results of binplot are presented in the section ”Results and discussions” through Fig. 7. Figure 4 exhibits the daily AOD during September 2007 from AERONET stations. The objective of Fig. 4 is to show that the MCS can occur under high aerosol loading from biomass burning region.

5^{th} paragraph –

a) Andreae et al. (2004) and Freitas et al. (2005) suggest that the low level jet can transport aerosol from biomass burning in Amazon and Central Brazil to La Plata Basin in the dry season which corresponds to austral winter and spring. Thus, on austral spring, the MCSs develop under high aerosol loading conditions and, consequently, may be affected by the aerosol. The objective of this paper is identified statistical relationships between rainfall and AOD that indicates if the aerosol from the biomass burning areas has an effect on rainfall in the La Plata Basin.

b) Several bin widths were tried and the one shown allows to observe clearly a pattern between AOD and rainfall.

c) Only cases when rainfall is observed in the blue box under north wind conditions are used.

6^{th} paragraph –

a) Yes, you are completely right. Indeed, the second eigenvector also detects ω anomalies associated with rainfall anomalies. However, the magnitude of ω anomalies is smaller than AOD anomalies, which may mean that the variability of AOD anomalies is more important than ω anomalies for the variability of rainfall amounts for the second eigenvector. Note also that the ω anomalies from the mode 2 is smaller than mode 1 and AOD anomalies from mode 2 is higher than mode 1.

This result agree with the other two methods used in the paper and indicates that aerosol effect is important under weak dynamic forcing.

b) To make the results more easily transmitted to the readers, Table 2 has been replaced by a new Figure 10 and the paragraphs about the EOF were rewritten as follows:

"*Comgined EOFs were calculated in another attempt to observe the aerosol effect and reinforce the previous results. The combined EOF analyses are used to identify variability patterns from a group of variables. In other words, the eigenvectors detect linear relationships among AOD, RR, ω, and RH. Table 1 shows the variance explained by the first and second eigenvectors and the total explained by these two. The first EOF explains around 43 % of the variance of the dataset for all AOD stations and the second EOF 31 %, together this eigenvectors represent more than 70 % of the data variance explained. The other two EOFs are not shown since they explain a lower portion of the variance. Satellite images for the cases detected by the EOF time series were examined (not shown). It was observed that about 70 % of selected rain events are associated with MCS. The other 30 % are basically related to cold fronts and extratropical cyclones with embedded convective systems.*

EOFs and their respective components AOD, RR, ω, RH for each AOD stations (in colours) are shown in Fig. 10; values represent perturbations with respect to the average. Looking at e_1, it is possible to verify that this eigenvector detects a pattern with small AOD anomalies and large anomalies of RR, ω, and RH, reflecting a pattern basically independent of AOD. The physical interpretation of the first eigenvector is that stronger large-scale upward motion and moister mid-level atmosphere are associated with larger amounts of rainfall. For a moister mid-level environment, the entrainment into the cloud generates less evaporation thus potentially affecting the rainfall production.

The second EOF detects large positive anomalies of AOD associated with large negative anomalies in rainfall for small anomalies of ω and RH. For this pattern, the interpretation is that ω and RH are average while large AOD is associated with rainfall suppression.

The results from the EOF analysis agree with Fig. 7 and 9 in that the dynamic component appears as the main rainfall forcing and the aerosol loading as the second one. The first EOF is related to dynamic forcing whereas the second EOF seems to represent the aerosol forcing. Jones and Christopher (2010) also used EOF analysis to identify possible interactions between aerosols and precipitation in the Amazon Basin. Their results also detected two patterns, one related to atmospheric conditions favorable to rainfall and the other linked to the aerosol forcing, and associated with rainfall inhibition."

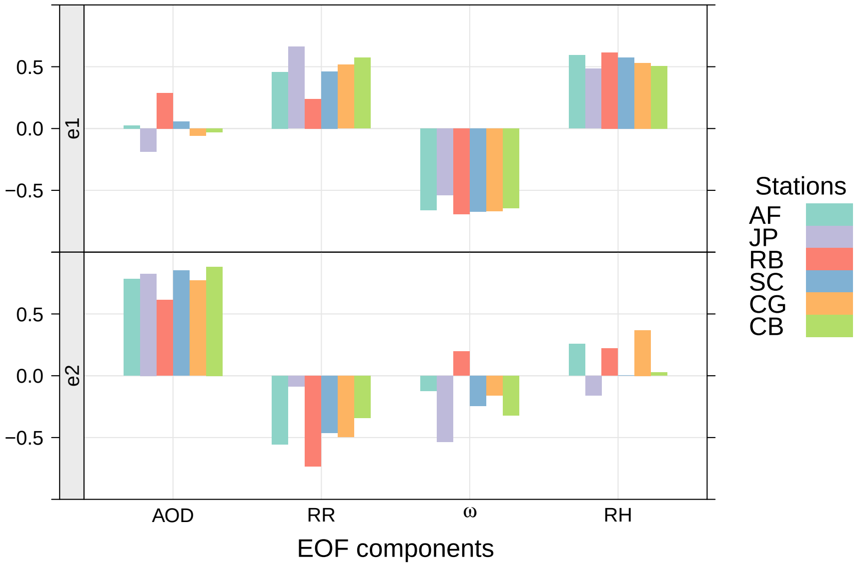

Fig. 10: EOFs and their components AOD, RR, ω, and RH for each AERONET station for all selected cases (see Sect. 2.4) during the months of September-October-November-December of 1999-2012. Colors indicate the stations of Alta Floresta (AF), Ji Paraná (JP), Rio Branco (RB), Santa Cruz (SC), Campo Grande (CG), and Cuiabá (CB).

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