Manuscript prepared for Atmos. Chem. Phys.
with version 5.0 of the LaTeX class copernicus.cls.
Date: 24 December 2013

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

G. Camponogara[1], M. A. F. Silva Dias[1], and G. G. Carrió[2]

[1]Instituto de Astronomia, Geofísica e Ciências Atmosféricas da Universidade de São Paulo, Brazil
[2]Department of Atmospheric Sciences of Colorado State University, USA

Correspondence to: G. Camponogara (glauberic@gmail.com)

Reviewer #2

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

2^{nd} paragraph – The next comments to the reviewers concerns are seen in the next paragraphs.

3^{rd} paragraph – Thank you for the suggestion. We added the following paragraph in the paper about AOD and particle concentration:

"*AOD has been used as proxy for aerosol concentration following the work of Guyon et al. (2003). They showed that the Amazon Basin biomass burning causes the AOD increases with increases Ångström coefficient, indicating that in polluted conditions the fine mode of aerosols predominantly contribute to the aerosol concentration.*"

4^{th} paragraph –

a) The case study is presented to illustrate the dynamic and aerosol scenarios in the spring associated with a MCS development over La Plata Basin. The variables that will be used for the whole period of 1999-2012 are shown for reference.

b) The analyses has been applied to the period from 1999 to 2012 as follow in the first paragraph in section 2. The period of analyses was added in the figures captions.

c) The total number of cases for each AOD station after filtering is:

AOD stations	Total number of cases
Alta Floresta	150
Ji Paraná	33
Rio Branco	109
Santa Cruz	45
Campo Grande	78
Cuiabá	78

d) The cases are all related to the presence of rainfall in the La Plata Basin.

e) The Section about filtering was rewritten as follows:

"*The main assumption of this work is that aerosol from biomass burning is advected from Amazon and Central Brazil to the La Plata Basin under north wind conditions (Freitas et al., 2005). Figure 3 shows the average wind field for of all north wind cases from 1999 to 2012 in the transition from dry to wet season; the blue box represents the area under study in the La Plata Basin where rainfall and aerosol relationships are investigated. The red box is located between the blue box and biomass burning region. A north wind case is defined when the areal average of the meridional wind component over both red and blue rectangles is negative. The cases with wind direction between 30° and 90° over the blue rectangle are discarded to avoid sample contamination from other aerosol sources (e.g., from southeastern Brazil). A further condition to accept a north wind case is that minimum rainfall (< 3 mm as areal average over the red box) is observed between the source region and the study region, so that cases where aerosols would be removed by wet deposition before arriving at the blue rectangle are not considered.*

The aerosol travel time from the origin to the destination is taken into account by defining a time lag as the time period (in days) that aerosols take to travel form the origin station to the La Plata Basin. For each rain event, lagged correlations between RR and AOD retrieved from 1 up to 5 days before the rain event were computed.

The higher absolute value of lagged correlation for each station is used to define the lag as an indicator of the optimal time interval between aerosol sources and the blue rectangle region (i.e., there is a time lag for each AERONET station). The time lags were also calculated based on average wind at 850 hPa and the distance between the origin and destination. The results (not shown) were similar suggesting that the lags were adequate to relate AOD measurements from Amazon with rainfall in La Plata Basin."

f) Yes you are right. The data filtering does not select rain events generated by MCS, but the period chosen (spring season) is when MCS are more frequent and MCS are dominant in the precipitation totals observed over La Plata Basin (Salio et al., 2007). In addition, we examined the satellite images for the cases in the time series of EOF and concluded about 70% of the selected rain events are associated to MCS . The other 30% are basically associated to cold fronts and extratropical cyclones with embedded convective systems. Both cases are of interest here since they happen in the biomass burning season and are selected because aerosol pathways from the north reach convection in La Plata Basin.

5^{th} paragraph –

a) Rainfall fraction is the percentage of rainy grid points over the blue rectangle region (Figure 3) as follow in the section 2.2.

b) Yes, indeed rainfall rate and AOD correlation exhibits a bimodal distribution. We added the discussion on this behavior in the results and conclusions of the paper as fallow:

p.24005, l.5 – "*Another feature of Fig. 7 is an indication of a bimodal distribution of rainfall with AOD; the reasons for that are unknown at this point. The local maxima may be due to different environmental conditions associated with rainfall. We further examine this in the following paragraphs when we separate rainfall according to the dynamic forcing represented by* ω."

p. 24005, l.20 – "*Another feature of Fig. 9 is a bimodal distribution (like in Fig. 7) associated with large rainfall amounts and intense dynamic forcing. This pattern explains the nature of the two modes identified in Fig. 7 that are due to the large-scale upward motion.*"

p.24007, l.5 – "*A bimodal distribution was observed between rainfall and AOD through the binplot (Fig. 7) and 2D-histrogram (Fig. 9). This means that two local maxima of rainfall rate were present under two different AOD regimes. These peaks are generally associated with strong dynamic forcing. In other words, stronger large-scale upward motion causes larger rainfall amounts, which contrasts to the aerosol effects that are associated with rainfall suppression.*"

6^{th} paragraph –

a) Yes, you are right. Unfortunately, EOF does not necessary represent the atmospheric physics, but the EOF is a tool to identify patterns. The relative importance of ω is a result of the EOF analysis. A interesting thing in the EOF analysis is that for one of the patterns detected (the second EOF), the AOD weight is larger as the ω weight is smaller which is the same conclusion as the one drawn from Fig. 9.

b) ω, the vertical p-velocity at 500 hPa, is used to identify the large scale dynamic forcing. Large values of negative ω are associated with enhanced upper motion which favors widespread development of rainfall. In the absence of this forcing, for low values of ω, cases where the large scale dynamics is not forcing rainfall are represented.

c) Basically, the relative humidity RH (average between 700-500 hPa) represents the potential effect of mid-level entrainment into the cloud system. For a moister mid-level environment, the entrainment into the cloud generates less evaporation thus potentially affecting the rainfall production.

d) Yes, the time serial data of EOF is an interesting property that could be explored. When we looked at EOF time serial data, we realized that 70% of the rain cases identified was caused by MCS. We added this information in the paper.

References

Freitas, S. R., Longo, K. M., Silva Dias, M. A. F., Silva Dias, P. L., Chatfield, R., Prins, E., Artaxo, P., Grell, G. A., and Recuero, F. S.: Monitoring the transport of biomass burning emissions in South America, Environ. Fluid Mech., 5, 135–167, 2005.

Guyon, P., Graham, B., Beck, J., Boucher, O., Gerasopoulos, E., Mayol-Bracero, O. L., Roberts G. C., Artaxo, P., and Andreae, M. O.:Physical properties and concentration of aerosol particles over the Amazon tropical forest during background and biomass burning conditions, Atmos. Chem. Phys., 3(4), 951–967, doi:doi:10.5194/acp-3-951-2003, 2003.

Salio, P., Nicolini, M., and Zipser, E. J.: Mesoscale convective systems over southeastern South America and their relationship with the South American Low Level Jet, Mon. Weather Rev., 135, 1290–1309, 2007.