

Response to Reviewer #2 for manuscript ACP-2013-133
(A decadal satellite analysis of the origins and impacts of smoke in Colorado)

We thank the reviewer for her/his thorough evaluation and constructive recommendations for improving this manuscript. Our responses to the reviewer's comments (*in italics*) are listed below.

In this analysis, the authors investigate the impact of fires on aerosol loading and air quality in Colorado from 11-yr period (2000-2012) through both the total column aerosol optical depth (AOD) from satellites aerosol products and observations of surface PM_{2.5} in Colorado.

This is an interesting study and the manuscript has an appropriate structure and it is well written. The methodology and data set used are appropriately presented. The manuscript is worthy to be published and appropriate for the scope of Atmospheric Chemistry and Physics Discussion. However, there are some aspects that need to be clarified and revised before publication.

Major comments:

- The manuscript tries to establish the contribution of fires to the air quality in Colorado. Therefore, a background about the air quality levels in the study region it would be needed in the introduction section. You add a summary about the number of PM_{2.5} and PM₁₀ exceedances per year with non-fire and fire conditions. This could help to determine the background levels and the effect of fires emissions in your air quality levels.

As also suggested by reviewer #1, we added a discussion on background PM_{2.5} levels and exceedances in the Introduction. Please, refer to comment for reviewer #1.

- In the analysis, the authors applied the filter to the MODIS data introduced in Zhang and Reid (2006) which was developed for oceanic regions. Different algorithms are applied to MODIS to obtain the aerosol product over land and over ocean. Could you include any estimation or reference about the errors associate to MODIS/AOD product over land in your study region? I understand that MODIS/AOD is not filtered for smoke, then, could you find other aerosols present that contribute to high AOD in your analysis?

As suggested by the reviewer, we included the best estimate error for MODIS AOD over land in the text.

Section 2.1 (Page 5 Line 11)

Specifically, we use daily AOD data from Collection 5.1, Level 3 with a 1°x1° horizontal resolution, *and the retrieved AOD is estimated to be at least accurate to $\pm(0.05 + 0.15AOD)$ over dark land surfaces (Levy et al., 2010).*

The reviewer is correct stating that MODIS AOD is not filtered for smoke and other aerosols besides smoke may have affected the AOD levels over Colorado. However, in our work we also

analyzed CALIOP data over Colorado that provides an aerosol type classification. As stated in Section 3.4 (Page 13 Line 24) smoke aerosol was by far the predominant type over Colorado during the summer 2012. We however understand the reviewer's concern regarding the effect of other aerosols in our results. For example, dust may be also responsible for increases in PM_{2.5} levels over Colorado. Yet, a climatological study of dust events has shown that these events occur mostly in winter and early spring in periods of low precipitation and with exceptionally high winds. We addressed this issue in the text.

Section 3.1 (Page 9 Line 28)

It is important to note that AOD levels may also be enhanced due to other aerosol types, such as dust. However, a climatological study of dust events over Colorado shows that dust events generally occur during winter and early spring, and in particular during periods of low precipitation and strong winds (CPDHE APCD, 2013). Therefore, the summertime interannual variability in AOD levels observed over Colorado shown here are likely dominated by smoke.

- It would be desirable to include in your analysis AERONET data to evaluate the uncertainty in MODIS AOD. Moreover, AERONET observations can help you to characterize the different aerosol presents in your study region. Boulder site would be the most appropriate choice because inside the Front Range Corridor defined by the authors. For example, in Green et al. (2009) you can find an analysis using collocated ground-based observations (PM₁₀, PM_{2.5} and AOD) and satellites for Illinois.

We thank the reviewer for pointing to the AERONET AOD in Boulder. As also suggested by reviewer #1, we incorporated these data to the manuscript. We refer the reviewer to our response to reviewer #1.

- The CALIPSO Level 2 product categorizes aerosol layers as one of six subtypes (Omar et al., 2009): dust, marine, smoke, polluted dust, polluted continental, and clean continental. It would be desirable that the authors includes in the text, a discussion about if the algorithm is capable to distinguish whether or not biomass burning plumes and the possible errors associated. Additionally, some studies (Mamouri et al., 2009; Koffi et al., 2012) highlight the differences between day- and night-time backscattering profiles from CALIOP. Did you analysis the day- and night-time CALIOP profiles separately? In this case, did you detect differences in the smoke vertical profile between day- and night-time?

Following reviewer #1's comment, we modified our discussion of CALIOP algorithm in section 3.4 to highlight the difficulty of CALIOP algorithm to distinguish smoke aerosols near the surface. We refer the reviewer to our response to reviewer #1 above.

In addition, we thank the reviewer for pointing out the difference between day and night-time CALIOP backscattering profiles. We analyzed the CALIOP extension coefficient day and night-time profiles and found no significant differences. We present all data together as the CALIOP daytime overpasses contained a lower fraction of observations, and the profiles were similar for day/night. We strengthened this point in the text.

Section 3.4 (Page 13 Line 14)

We use CALIOP extinction coefficient observations to assess the relationship between vertical smoke distribution and air quality impacts. *Figure 5a shows extinction coefficient profiles over Colorado during the fire seasons 2012 and 2007-11. In this work, we average all daytime and nighttime aerosol extinction values reported by CALIOP since daytime and nighttime profiles did not significantly differ from each other.*

Minor comments:

Page 8235 Line 18: In the sentence “In the last decade, satellite observations of total column aerosol optical depth (AOD) have provided an important tool to estimate PM_{2.5} levels at the ground (e.g. Engel-Cox 20 et al., 2004), with the objective of developing smoke air quality advisories (Al-Saadi et al., 2005) and establishing links to human health (Evans et al., 2013).” I would remove smoke, because this can be applied to all aerosols, not only for smoke.

Removed ‘smoke’ as suggested.

Figure 3 (panels c and d). The labels of the right vertical axe are confusing. The blue and red colours are no adequate, because MODIS is in grey in these cases.

We respectfully disagree with the reviewer. Following the color code convection adopted in Figure 3a, MODIS AOD is plotted in grey for years 2000-01/03-11 (Figure 3b), in blue for year 2002 (Figure 3c) and in red for year 2012 (Figure 3d). We decided to preserve the color code in Figures 3c-d for clarity.

It would be helpful if Figure 6 and Figure 5 are plotted in the same range and units.

Modified as indicated.