Response to Reviewer 1 for Manuscript acp-2009-513

Title: Smoke injection heights from fires in North America: Analysis of 5 years of satellite observations

Date: January 19, 2010

We thank the reviewer for the review of our paper. Her/his comments (*in italics*) and our responses are listed below.

Comments:

This paper presents a detailed analysis of plume heights observed in North America. The authors use the MISR product and a tool (MINX) to obtain estimates of the plume heights. The study is very detailed and provides interesting information about the statistics related to fires and plume dispersion. The drawback of using MISR measurements is that the maximum fire activity in the late afternoon is generally missed. The authors are well aware of this shortcoming and mention this several times in the manuscript.

We appreciate the positive comments on our manuscript.

Another shortcoming, that is mentioned less frequent, is the fact that pyrocumulus formation is excluded from the analysis (stereo-analysis of MISR data is not possible). This is relevant, since the condensation of water vapour leads to extra lift of the plume (buoyancy). One would expect that cases of pyrocumulus formation would lead to significantly higher plumes. The authors should mention this more clearly in the final paper in my opinion.

The reviewer is correct in noting that pyro-cumulus cloud formation would result in higher plumes. As suggested, we strengthened this point in Section 3.2.1 as follow:

> It is important to note that the digitization protocol used for the MINX analysis intentionally excluded pyro-cumulus clouds, which could lead to significantly higher plumes triggered by the additional buoyancy from water vapor condensation. Hence, some plumes injected above the BL may not be captured in this data-base. [..]

Another issue is the fact that only the vertical temperature profile (stable layers) from the GEOS model are used in the analysis. A good test would be to compare the GEOS winds to the winds observed from the plume dispersion. And I wonder if, apart from stable layers, wind shear may play a role in the plume rise.

We are not sure what the reviewer means by the "winds observed from the plume dispersion". The MINX plume dataset provides the wind speed (across and along swath) computed by the MINX algorithm based on a pre-digitized transport direction of the plume, and the wind direction. We presume the reviewer is concerned about the use of GEOS meteorological fields in the analysis, and perhaps is suggesting that we compare the GEOS wind speed with the estimated

MISR wind speeds for the top of the plumes. We have not performed such as evaluation. However, previous work by Kahn et al., 2007 showed that the MISR cloud-motion-derived wind vectors (speed and direction) compare well with those derived from HYSPLIT trajectories, which are based on NCEP meteorological fields. We agree with the reviewer that the GEOS meteorological fields are one source of uncertainty in our analysis. We rely on GEOS meteorological fields for ambient atmospheric vertical structure because it provided a self-consistent data set. In addition, the GEOS model meteorological fields will be used in future applications to determine the stability profile in a plume parameterization that we are developing.

In addition, the reviewer is correct in pointing that wind shear plays a role in the plume rise. As stated in Kahn et al, JGR 2007, vertical mixing can occur due to free convection, turbulent mixing forced by horizontal wind shear, air mass advection, etc. However, we observe that smoke tends to concentrate in layers of relative atmospheric stability, regardless of the mixing mechanism. As suggested by a reviewer during the pre-discussion stage of the paper, we clarified this point in Section 3.2.2. The text reads now:

> "Kahn et al. [2007] showed that aerosol plumes tend to concentrate within stable layers, regardless of the mixing mechanism."

Another personal comment is the fact that the paper is rather lengthy. Why should readers be interested in statistics for the mean, median, maximum, mode, and individual heights? I understand that you perform the analysis for all these plume height definitions, but the story and the main conclusions do not change if only one or two of these definitions are presented. The authors may consider slimming down the paper on this aspect.

We carefully considered this comment. We feel that it is important to preserve the discussion of results obtained from the five definitions of plume heights to show that our results are independent of any particular definition of plume height. We stress that this discussion is short: one paragraph is Section 2.1.3, one paragraph in Section 3.2.1, and a few lines in Table 2. If we omitted the comparison of different definitions of plume height, it would not change the number of figures or tables. The paper primarily focuses on the results obtained from the median and maximum height definitions.

A last point: the authors are not very clear how these data can be used by modelers. The main conclusions, however, is that this is an excellent paper that presents interesting results.

We agree with the reviewer that this point is not clear in the manuscript. The MISR plume data can be used to evaluate plume rise models. Most such studies to date have focused on case studies, usually of a particular pyro-convective event. In contrast, the MISR plume data provide an opportunity for extensive validation of plume rise models. We have added a comment to this effect in Conclusions, and the text reads now:

> Plume-resolving models can take into account the buoyancy driven by the fire heat, combined with finer-scale meteorology processes (e.g. Freitas et al., 2006,

Trentmann et al. 2006). The 1-D plume-rise model presented by Freitas et al. (2006) has been embedded in a regional model (Freitas et al., 2007) and in a global model (Guan et al., 2008) for exploratory case studies in the tropics. However, the validation of 1-D plume-rise models has focused to date on case studies, usually of particular pyro-convective events. The MISR plume data provide an opportunity for extensive validation of plume rise models, and we are presently using the MISR data to evaluate the model of Freitas et al. (2006).

Recently, Chen et al., 2009 used the observed MISR plume heights over the boreal region in 2004 [Kahn et al. 2008] to derive fire emission injection heights for the global GEOS-Chem chemical transport model. The match between the model and surface aerosol and CO measurements near the fire source was improved by using the MISR-derived injection heights. However, this did not significantly enhance the accuracy of the simulation in downwind regions, possibly because the injection heights used were those reached by the plumes at the MISR overpass time. In current work, we are exploring the relationship between the MISR plume height, radiative energy flux observed by MODIS and atmospheric stability structure using a 1-D plume-rise model. We are also developing a simple parameterization of injections heights based on insights from analysis of the MISR plume heights.