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Atmospheric Chemistry and Physics Discussions

Interactive comment on "A pervasive and persistent Asian dust event over North America during spring 2010: lidar and sunphotometer observations" *by* P. Cottle et al.

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AC: The reviewer makes several excellent points regarding the need for more specific language regarding methodology and about the limitations of qualitative analysis of depolarization ratios. Among the reviewer's primary concerns is the observation that "The authors claim that these events are extreme but on the other hand the also show from the literature that such transport of Asian dust over North America is not unusual. So apart from its duration and spatial extend, which is of course of great interest and importance, it is not evident from the paper, they [sic] way it is structured, where this study improves our knowledge concerning the properties of Asian dust after its trans-

port." To address this point given the qualitative nature of the lidar observations, the authors have refocused the article on extending the work of Uno et.al. (2011), Li et.al. (2012) and Fischer et.al. (2011), to include the fate of the dust layers as they passed over North America and on the contribution of providing high resolution lidar observations of the dust layers on both sides of the continent. Despite the lack of availability of quantitative assessments for particle concentrations, etc., the lidar observations provide an opportunity to observe the vertical distribution and dynamics of the dust layers before and after transit across North America in much greater detail than would be possible through other means, even including satellite lidar observations. To the authors' knowledge, this type of high-resolution range-resolved assessment of depolarization ratios of dust-rich layers has not been previously reported for an Asian dust transport event over eastern Canada.

The authors address each of the reviewer's specific points individually below:

RC: In page 30593 the authors briefly present their lidar measurements and products. They use backscatter ratios without providing any information on uncertainty. They just mention in line 21-23 that extinction and overlap can introduce large changes. No information if these (extinction and overlap) are finally considered and what is the uncertainty. What is the overlap of their system and how this has been estimated?

AC: On the questions of overlap, and how extinction is taken into account, a full discussion of how these are calculated for the system in question (CORALNET) can be found in Strawbridge (2012). The authors have added to the Methodology section a brief account of how the backscatter ratio and volume depolarization ratio are calculated, with explicit references to Strawbridge (2012) where appropriate. It is also worth mentioning that the relevant observations for this article are well outside the range of incomplete overlap for CORALNET so this correction function does not directly affect the findings. As to the uncertainty in the backscatter ratios, this is not calculated. In the article, backscatter used in a strictly qualitative sense: identifying the presence of layers of interest, masking out regions where the signal is too low, and comparing the optical thickness of layers relative to each other. The authors feel that for these applications, a full accounting of the uncertainty is not required. In order to make sure that there is no confusion as to the nature of the data provided, the authors have added several statements into the Results and Conclusions sections explicitly stating that the ratios provided are used qualitatively, not quantitatively.

RC: More important for the discussion of mixing of dust are the measurements of the depolarization ratio. The authors don't make clear what exactly they show. Is this a simple ratio of the two signals? Is this the linear particle depolarization ratio or volume depolarization ratio? How do they calibrate these ratios? If these ratios are not calibrated they can only provide qualitative information concerning the potential different aerosol type. Freudenthaler et al (2009 in Tellus) provide a detailed discussion on that and propose solutions and relevant literature.

AC: The depolarization ratio used here is the volume depolarization ratio. It is defined as a simple ratio of the attenuated backscatter from the two 532nm polarization channels. The difference between particle and volume depolarization is an important one that has now been made explicit in the article. The calibration procedures for this ratio are addressed fully in Strawbridge (2012). A brief description of the definition used here for depolarization ratio has been added to the Methodology section along with an explicit reference to Strawbridge(2012). The uncertainty for this ratio is not calculated and therefore any discussion of mixing is now limited to qualitative comparisons.

RC: In order to be able to make a quantitative discussion about mixing of dust with other aerosol types using depolarization ratios one should provide what are the representative ratios of "pure" types at their source. What is the typical depolarization ratio over the Asian desert? What is the typical depolarization ratio of continental aerosol over Canada etc. If these values are not available or known then the whole discussion is purely qualitatively and as such the whole study should focus more to the dynamics and its extreme behavior rather than the mixing, since the latter is just demonstrated but not quantified.

AC: The authors have added two new references describing the typical depolarization ratios of Asian dust aerosols (Liu 2012, Kai 2008). The observed range of particle depolarization ratios over the source regions varies from 0.28 – 0.34. According to Liu et.al., particle depolarization ratios are likely to be reduced after mixing with fine-mode aerosols from industrial sources in Eastern China, Korea, and Japan, and are further reduced after transport across the Pacific, resulting in ratios typically in the range of 0.15-0.25 over North America, with a slight tendency to continue to decrease in the North Pacific. Although Liu et.al. do not explicitly discuss the trends in depolarization ratio across North America, an inspection of their results for 5-year averages in particle depolarization ratios (Figure 7) reveals a weakly decreasing trend for West to East over North America. Although it would be useful to know typical depolarization ratios in Vancouver and Egbert, the authors are not aware of a study that investigates this property of the local aerosols. However, the NARSTO Particulate Matter Science for Policy Makers (2003) does provide an assessment of long-term average PM2.5 composition for Abbotsford (near Vancouver) from 1994-1995 and for Egbert from 1994-1999. In both locations, the composition is dominated by a combination of sulfates, nitrates, ammonium, black carbon, and organic carbon. Less than 10% was found to be attributable to soil or other particles. Although no specific mention is made about the depolarization ratios, it is reasonable to assume that these fine- and ultrafine-mode particles would exhibit little to no depolarization in a 532nm lidar signal. Of course these values are somewhat dated and are taken as multi-year averages. Given the inherent inhomogeneity and variability in aerosol properties, and the lack of extensive long-term archives of their depolarization ratios, the authors believe that the best available method for assessing the depolarization ratios of the layers with which the Asian dust layers were mixing on the days in question is to observe the depolarization ratios of the well-mixed boundary layers in each location prior to the introduction of dust. In the lidar data from these events, the depolarization ratios for the boundary layer in Vancouver are consistently 150% - 500% lower than the layers identified as "dust rich". This is consistent with what one would expect for what are considered typical aerosol compositions from surface measurements in these areas. The text of the "CORAL-Net Results" section and of the Conclusions have been altered to focus more on the dynamics of the events rather than attempting to draw any conclusions about mixing properties that are not fully supported by the data provided. That being said, the authors feel that even without a quantitative assessment of aerosol concentrations during mixing, one can still infer from the observed patterns of change in the depolarization ratios and the dynamics involved that mixing is likely to have occurred and that the lower volume depolarization ratios observed over Egbert as compared to those observed over Vancouver, is consistent with a relatively lower proportion of dust particles in the layer; even though it would be beyond the scope of the article to determine exactly what species are mixing with the dust (aside from observing that they appear to be fine-mode particles) or to quantify the amounts of different species within a mixed layer. The authors have revised the Results and Conclusions sections to remove any inference about chemical ageing of the dust particles over North America as well as conclusions that hinge on a quantitative interpretation of the lidar data.

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