Dear Editor,

Please find our responses to comments from referee # 1 below in ***bold italics*.**

The role of dust in buffering acid rain has been studied in several regions of the world (Rogora et al. 2004. Tellus 56B, 426–434) and is of special importance for sensitive alpine lakes (Psenner, R. 1999. Water, Air, Soil Poll. 112: 217-227, and references therein). Atmospheric deposition of nutrients, especially phosphorus, is a major factor for the limnology of alpine lakes, e.g. in the Sierra Nevada, Spain (Morales Baquero, R. et al. 2006. Limnol. Oceanogr. 51, 830–837; Pulido-Villena, E. et al. 2008. Aquat. Sci. 70, 1-9; Reche, I. et al. 2009. Limnol. Oceanogr. 54, 869–879) but the general impact on the biogeochemistry of high elevation watersheds is much less studied. Thus, the study of Ballantyne and coworkers on alpine watersheds in the Western US is an interesting contribution to an important topic.

The introduction and discussion have been revised considerably to put our regional observations from the Southwestern US in a global context. In doing so, we have included many of the relevant papers mentioned above by Referee #1.

To disentangle the effects of watershed erosion and deposition from long-range transport, the authors compared two alpine lakes in Southern Colorado, characterized by different watershed to lake area ratios. To judge the significance of their approach one has to ask three questions: Do they convincingly show that (i) dust is the main component of the sediment; (ii) the anticipated increase in dust deposition since the beginning of the last century is stored in the sediment record, and (iii) the ratio of erosion to deposition does significantly affect nutrient levels and ratios?

Question 1 has been answered positively, also the answer to question 2 is convincing. Consequently, also question 3 must be answered positively. I have, however, some problems with the selection of sites etc. and request a convincing reply to my concerns. In my view, the selection of sites and methods is O.K., the presentation of diatom values, however, looks rather scarse – but this is not the main objective of the authors. My biggest concern is that the lakes or tarns are extremely shallow (<1m) which is in sharp contrast to the rules usually followed by paleolimnologists, i.e. to sample undisturbed sediments from water bodies deeper than several meters. Generally, a water level below _2m means that the sediment is freezing, and may thus be heavily disturbed, every winter. I am, thus, not astonished by the large differences in C,N, and P contents of both tarns (Fig. 4). Senator Beck sediments obviously are very low in organic content, supposedly caused by disturbance of the sediment through freezing, wind mixing, UV radiation etc. I am puzzled, therefore, by the dating curves in Fig. 2 which look quite "normal“, although this is difficult to judge from just three 14C values. A comparison with a high elevation lakes in the Alps of comparable watershed characteristics (i.e. mainly rocks) but a low catchment to lake area ratio of 3 showed a sediment accumulation of 1590 mm during the Holocene (Ilyashuk et al. 2011, Quart. Sci. Rev. 175-191), while Porphyry and Senator Beck, though having much larger catchment to lake are ratios (Porphyry=24; Senator Beck = 13), had only 500 and 200 mm, respectively. For this reason, I suspect that some part of the sediment is missing, likely owing to the shallow depth and the resulting disturbances.

We acknowledge that the lakes sampled in this study were rather small and that these lakes would not be suitable for most paleolimnological studies. However, the objective of this study was not to reconstruct the paleoclimate and paleoecology of these alpine watersheds over the Holocene, but rather to assess modern changes in the magnitude and composition of dust

loading to these alpine watersheds. Based on this objective we focused on high elevation watersheds with very little soil and no signs of human disturbance, unfortunately only a handful of small alpine lakes met these criteria.

Although it is possible that the sediments in these small lakes were disturbed, we see no evidence to support this. Lake sediments were inspected for signs of disturbance and cores were extracted from the deepest sections of the lakes, which were aproximately 1.5 meters (revised in the text L 122-125). Cores were examined in the field for any evidence of hiatuses in sedimentation, both cores showed a continuous homogeneous mix of organic and mineral matter. There was no evidence of terrestrial inputs or soil formation that would be expected had the lake dried-up. Furthermore, the age-depth models for these lakes show no discontinuities in sedimentation or age reversals (see revised figs. 2 and 3) and the chemistry shows no anomalous peaks with depth, such as peaks in Ca that might indicate the precipitation of $CaCO_3$ in response to drying. Furthermore, these lakes are covered by several meters of snow during winter months which effectively insulates these lakes and therefore it is unlikely that these sediments freeze. However, it is likely as Referee #1 has suggested that these lakes receive high levels of UV radiation. Because these lakes are shallow and located at high elevations, they are subjected to intense UV that is attenuated somewhat in the water column, but probably reaches the sediment-water interface. Although it is possible that these lakes receive different amounts of UV and that this might explain the apparent differences in organic matter accumulation, the more likely explanation (and the one presented in our paper) is that Porphyry has a much larger watershed to lake area (Table 4) and therefore receives a greater flux of both N and P.

These sediment cores do not span the entire Holocene; they only go back ~ 3,000 to 5,000 YBP, which explains why they only represent ~ 300 and 500 mm of total sediment accumulation, respectively. Ilyashuk et al. (2011) report a wide range of sedimentation rates for lake Schwarzsee ob Sölden in the Austrian Alps 'from 8 to 124 yr cm^{-1}, thus the inverse corresponds to a sedimentation rates from 0.08 mm yr^{-1} to 1.25 mm yr^{-1}. In comparison our sites show very similar sedimentation rates from 0.09 to 0.47 mm yr^{-1} for Porphyry and sedimentation rates from 0.05 to 0.44 mm yr^{-1} for Senator Beck. Thus the range of sedimentation rates in these different catchments located on different continents are at least comparable.
Other lakes located in the Rockies of North America show similar Holocene sedimentation rates. Toney and Anderson (2006) report a Holocene sedimentation rate of 0.08 mm/yr for another sub-alpine lake in the San Juans. Therefore the sedimentation rates reported for these watersheds in Southern Colorado seem to be comparable to other alpine watersheds, but we only captured the last 3 to 5 millenia whereas Ilyashuk et al. 2011 captured the entire Holocene.

How do you interpret the C:P curves in Fig. 4? While C:N curves look quite normal, i.e. the higher C the higher the N value, the C:P ratio seems to behave differently: in Porphyry and Senator Beck it is 60 and 45 at the C and P maximum, 44 and 42 at the C minimum, and 75 and 150 at the P minimum, respectively. I suggest to present N:C and P:C ratios (not C:N or C:P) along the core depth and to remove instead Fig. 3 which is explained in the text and shown by Table 1.

In accordance with the reviewers comments we have inserted a figure showing changes in C, N, and, P mass flux with depth for both lakes (Figure 5). This representation of the raw data shows the clear increase in all three elements in contemporary sediments that is explored in greater detail using the multi-regression approach (Table 3) and graphic techniques (Figure 6). However, we have decided to keep both table 1, which shows the raw data for rare earth elements and Figure 3, which shows the results from our mixing model (Eq. 1). These results are not redundant and highlight a novel bayesian mixing model relying on multiple sources of

information (e.g. elemental concentration and isotopic ratio) used for inferring sources to sediments so we have decided to keep the table and figure separate.

You should say how representative were dust deposition data (From how many snowpack samples collected where and when? Was there an influence of local dust particles?). What about N (nitrate, ammonium) and P concentrations in wet deposition and snowpack?

A total of 30 widespread and discrete dust events were sampled between 2003 and 2007, this more detailed description has been added (L 134-140). For further details on the dust sampling see Lawrence et al. (2010), which is also cited in the methods of our paper. Because the snow-free season is rather short in these alpine watersheds, mass values were used to extrapolate total annual mass fluxes over the entire year, including wet and dry fluxes. All dust events sampled were regional events that were reported across the San Juan Mountains (pers. Comm. Chris Landry).

Can you show some lake water parameters (pH, conductivity, alkalinity, major ions, nutrients)?

Good idea! I had forgotten that we had these data. They have been added as Table 1.

Did you take the sediment core in Porphyry from a greater depth than in Senator Beck?

These cores were taken from approximately the same depth of approximately 1.5 meters.

Can you add lake maximum depths or lake morphometry?

This could be added, but the lakes were no greater that 2m deep and therefore there would only be one contour line within the lakes. The points from which the cores were taken have been added to Figure 1 and represent the deepest portion of the lakes.

Fig. 6 Where are the "red arrows“?

The figure caption has now been updated to refer to the 'grey arrows' in the black and white version of the figure showing elemental loadings to Principle Components and their associated dates.

References:

Lawrence, C. R., Painter, T. H., Landry, C. C., and Neff, J. C.: Contemporary geochemical composition and flux of aeolian dust to the San Juan Mountains, Colorado, United States, J. Geophys. Res., 115, G03007, doi:10.1029/2009JG001077, 2010.

Toney, J. L., and Anderson, R. S.: A postglacial palaeoecological record from the San Juan Mountains of Colorado USA: fire, climate and vegetation history, The Holocene, 16, 505-517, 10.1191/0959683606hl946rp, 2006.