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Interactive comment on "Albedo-induced radiative forcing from mountain pine beetle outbreaks in forests, south-central Rocky Mountains: magnitude, persistence, and relation to outbreak severity" *by* M. Vanderhoof et al.

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Response to Anonymous Reviewers Comments

Manuscript: "Albedo-induced radiative forcing from mountain pine beetle outbreaks in forests, south-central Rocky Mountains: magnitude, persistence, and relation to outbreak severity" [Manuscript No. bg-2013-312]

Authors: Melanie Vanderhoof, PhD Candidate, Christopher Williams, PhD, Yanmin Shuai, PhD, Dan Jarvis, PhD Candidate, Dominik Kulakowski, PhD, and Jeff Masek,

PhD

Journal: Biogeosciences

Date: December 15, 2013

Comments: We thank the two anonymous reviewers for their thoughtful general and specific comments which have been valuable in improving the manuscript. We have responded to all comments and have revised the manuscript accordingly. We hope this version is satisfactory, but we are happy to make additional changes as necessary.

Response to Anonymous Referee #1's Comments (Received and published: 1 September 2013)

General Comments:

Comment: First, this study is not related to biogeochemical cycling or extreme climates. But it has something to do with disturbances that may be related to climate and droughts. It is up to the Editor to decide the relevance.

Response: This manuscript was submitted for consideration of inclusion in the special issue after consulting with Editor, Michael Bahn. However, if the handling Editor deems it not appropriate for the special issue, we are open to the possibility of publishing the manuscript within the regular journal, Biogeoscience. Although this manuscript does not deal directly with extreme weather (e.g. hurricanes, drought, etc.), bark beetle outbreaks are very closely tied to abnormal weather conditions (Christiansen et al., 1987). The current extent and severity of outbreaks across the western United States and Canada has been attributed to climate change conditions, including warmer winters, which have reduced the frequency of cold snaps, known to reduce beetle populations, warmer summers, which have increased the rate of maturation and reproduction of beetles, and drier summers, which have increased tree stress (Berg et al., 2006; Raffa et al., 2008).

Comment: The researcher took advantages of historic field plot survey and remote sensing data to establish Pine Beetle out breaks and land surface characteristic changes. Such a study is timely since very few studies are available to evaluate the implications of disturbances of insects and diseases to regional energy and water balances and general climate. The analysis is reasonable given the uncertainty both MODIS and Landsat albedo data. The models to explain the mechanism albedo change and recovery are sound. The paper is generally well written. However, clarifications are still needed to make the paper more readable to a wider audience.

Response: We thank you for your kind words and support of the manuscript. Thank you also for your constructive comments. We hope we have adequately addressed the requested clarifications both in our response to comments below and in the manuscript revisions.

Specific Comments:

Comment: 1. Explain more about how Albedo and impacts on climate forcing are calculated. For example, I am not sure most reader knows what kernel is.

Response: In the Introduction we have stated, "On an annual basis, an elevated albedo increases short-wave reflectance and reduces net radiation, which may result in a local annual cooling effect." In the Methods the existing description of how climate forcing was calculated was expanded to define what a kernel is: "The TOA radiative forcing was calculated using the "radiative kernel" technique, in which a radiative kernel was derived from a radiative transfer algorithm and climate parameters to quantify the top-of-atmosphere radiative flux response to changes in a feedback variable (e.g. albedo) (Soden et al., 2007). In this case the kernel was used to translate changes in monthly average surface albedo, relative to "healthy forest" values, into changes to TOA radiative fluxes. The kernel, originally provided at 2.5° resolution, was re-sampled to 1° resolution to better match the spatial extent of the study area. The kernel (K) was produced using the ofïňĆine radiative transfer model from the National Center for Atmospheric Research (NCAR) Community Atmospheric Model version 3 (Collins et al.,

2006) as described in (Shell et al., 2008), and reported as the radiative forcing response to a 0.01 change in albedo, where: ãĂŰ∆FãĂŮ_TOA= ∆âĹÌ * K̂âĹÌ (1) where âĹÌ is the land surface shortwave albedo."

Comment: 2. The authors need some literature to backup the estimates. Are there eddy ïňĆux sites or micro meteorological data in the region that report energy ïňĆuxes or albedo. If not, simulated studies for forests can be cited.

Response: A paragraph has been added to the Discussion section providing a direct comparison of our changes in albedo post-outbreak to that observed by O'Halloran et al. (2012) and Vanderhoof et al. (2013). In addition, our observed changes in radiative forcing are directly compared in the Discussion section to that observed by both O'Halloran et al. (2012) and Randerson et al. (2006).

Comment: 3. The authors made a few statements on the implication of increased albedo found from this study on regional evapotranspiration and precip. The speculation is rather far-fetched in my opinion. I would argue that the author should speculate more on the local impacts on soil water balances, snow redistribution, canopy interception, streamïňĆow, soil moisture... These will be immediate impacts and there may have data to cite. I suggest the author check with Dr. John Stednick at Colorado State University for references.

Response: We have modified the discussion regarding potential implications for the hydrological cycle to focus more on local impacts as shown below. In the Introduction, the relevant section has been modified as follows: "In addition to more direct climate effects (e.g. radiative forcing), changes in albedo also have potential local consequences for the hydrological cycle. Earlier snowmelt, due to increased canopy shortwave transmission, as well as increased snow accumulation, from changes in stand structure, have been documented post-outbreak (Bewley et al., 2010; Pugh and Small, 2011; Boon, 2012). Changes to snow accumulation and snowmelt dynamics, in turn, can result in temporary increases in soil moisture (Clow et al., 2011) and stream flow (Bethlahmy, 1975; Potts 1984)."

In the Discussion, the relevant section has been modified as follows: "Lastly, we acknowledge that bark beetle outbreaks have potential consequences for the hydrological cycle as well. Widespread tree mortality in mountain pine beetle infested stands has been shown to result in earlier snowmelt, from increased canopy shortwave transmissions (Bewley et al., 2010; Pugh and Small, 2011), as well as increased stream flow, from a reduction in transpiration and canopy interception (Mikkelson et al., 2013). These changes could reduce water availability during the late growing season, exacerbating tree stress. Alternatively, the documented decrease in winter radiative forcing, due to increased snow visibility, could result in cooler wintertime air temperatures, potentially reducing beetle populations via winter "cold snaps" known to kill beetles."

Response to Anonymous Referee #2's Comments (Received and published: 2 December 2013)

General comments:

Comment: This study uses extensive field measurements coordinated with USDA forest disturbance polygons and MODIS and LANDSAT albedo data to evaluate the albedo change in forests in the Rocky Mountains of Wyoming and Colorado following mountain pine beetle outbreaks for several decades. This is important work because these albedo changes (combined with carbon ïňĆux changes, not discussed here) from forest disturbances represent possible feedbacks to climate change from the biosphere. The study seems like it was executed well and the paper is well-written and without major ïňĆaws. However, I have a few specific reservations about the paper, especially the presentation of results.

Response: Thank you for your kind words and support of the manuscript. We hope we have addressed your specific reservations both below, in our responses to your specific comments, as well as through revisions of the manuscript.

Comment: Also, I am not sure whether it is appropriate for this special issue as it does not relate to extreme weather.

Response: Although this manuscript does not deal directly with extreme weather (e.g. hurricanes, drought, etc.), bark beetle outbreaks are very closely tied to weather conditions (Christiansen et al., 1987). The current extent and severity of outbreaks across the western United States and Canada has been attributed to climate change conditions, including warmer winters, which have reduced the frequency of cold snaps, known to reduce beetle populations, warmer summers, which have increased the rate of maturation and reproduction of beetles, and drier summers, which have increased tree stress (Berg et al., 2006; Raffa et al., 2008).

Specific comments:

Comment: Because of lack of precision in the USDA polygons and potential errors in georeferencing multiple datasets, other studies have excluded spatial data (e.g. MODIS albedo) around the edges of the masking polygons (e.g. USDA data). It does not appear that you have done this, even though you comment on the significant difference between "plot level" and "landscape level" analysis. Could you please elaborate on this effect and explain why you chose not to mask around the edges of polygons, or explain how you treated selection of pixels around the edges?

Response: We agree. Although currently the USDA polygons are the most comprehensive source of bark beetle damage that we have, both for the current outbreaks and historically, these datasets are quite problematic and lack precision. A comment addressing the polygon edge issue was included in the Discussion section, but rightly so, should be included in the Methods section. In addition to the steps outlined in the 2.2 Data section, historic plot locations were placed at the center of polygons larger than a MODIS pixel to increase our confidence and avoid polygon edge effects. A sentence to this effect has been added to the 2.2 Data section. This step helped avoid the dilution effect which can occur when the USFS ADS dataset is used at a "landscape level" analysis, as described in the Discussion section.

Comment: Along the same lines as the previous comment, the discussion of the "plot level" vs. "landscape level" results in the discussion needs significant expansion. These results appear in the discussion without having been outlined in the methods or results. There are also no ïňĄgures to support these results, but they seem significant (i.e." 166% higher increase in albedo in summer", p.11948, line 19). The authors cite a paper in review to support these ïňĄndings, but until that paper is published, I suggest that more info needs to be included in the current manuscript. How was the 166% increase calculated? I suggest it is inappropriate to include this in the discussion unless it can be supported with methods and results, or the other paper is published.

Response: The paper referenced above has since been published in Journal of Geophysical Research – Biogeosciences: Vanderhoof, M., Williams, C. A., Ghimire, B., and Rogan, J.: Impact of mountain pine beetle outbreaks on forest albedo and TOA radiative forcing, as derived from Moderate Resolution Imaging Spectroradiometer, Rocky Mountains, USA, J. Geophys. Res. – Biogeosciences, 118, 1-11, doi:10.1002/jgrg.20120, 2013. The referenced paragraph has been revised extensively to improve clarity. Revisions included adding the actual changes in albedo observed by both studies, instead of the relative % difference. As the paragraph is a simple comparison between the findings of this study and that of others (e.g. Vanderhoof et al, 2013), no additional Methods has been added.

Comment: Figure 2 is the central figure that presents the albedo results, but it convolutes both MODIS and LANDSAT data across multiple seasons and annual scale, all on a single bar graph. I think this could be improved. Perhaps the authors chose a bar graph because the data have been clustered in time? A connected line graph would give better sense of the time progression of the data. I would be comfortable with that the points on a connected line graph had X error bars to indicate the time grouping in addition to the Y error bars already presented. Then perhaps break the ïňĄgure into a couple of panels. I appreciate that all the data are presented in one ïňĄgure so that

the various values are easily comparable, but I have a hard time quickly discerning the overall patterns in the data because seasonal and annual results across two different data sources are jumbled together. The color scheme does nothing to help this.

Response: As suggested, the figure has been modified to be a connected line graph with years since attack on the x-axis and change in albedo on the y-axis. Instead of X error bars on each of the curves, a set of points and X error bars has been added to the bottom of the graph to indicate the temporal width of each "binned" point. The figure has been broken into 2 panels, the first, a comparison of MODIS and Landsat summer and winter curves, and the second, the four MODIS seasonal curves and annual curve. We hope the modified figure is clearer.

Comment: I also think ïňĄgure 5 might work better as a connected line graph, rather than bar, unless the discrete time groups need to be emphasized.

Response: We have modified part of Figure 5 as recommended to show the change in radiative forcing with years since outbreak start. The severity data was not as conducive to a connected line graph, but we have changed the arrangement of the data so that it is easier to interpret how albedo within a given season, changes with outbreak severity. We hope you find the modified figure adequate.

Comment: I also think the ïňĄgures would look more professional if rendered in something other than Excel.

Response: We have modified the formatting of all of the figures to more closely match that used by others. Please let us know if the revised graphs are not adequate or if there are any specific, additional formatting changes you would like us to make.

References Berg, E. E., Henry, J. D., Fastie, C. I., de Volder, A. D., and Matsuoka, S. M.: Spruce beetle outbreaks on the Kenai Peninsula, Alaska and Kluane National Park and Reserve, Yukon Territory: Relationship to summer temperatures and regional differences in disturbance regimes, Forest Ecol. Manag., 227, 219-232, 2006.

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Interactive comment on Biogeosciences Discuss., 10, 11935, 2013.

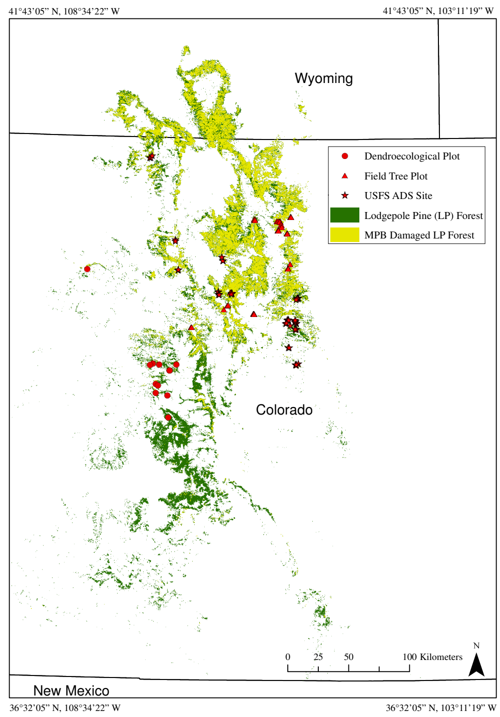

Fig. 1. Plot locations for field tree plots, dendroecological plots and USFS ADS sites.

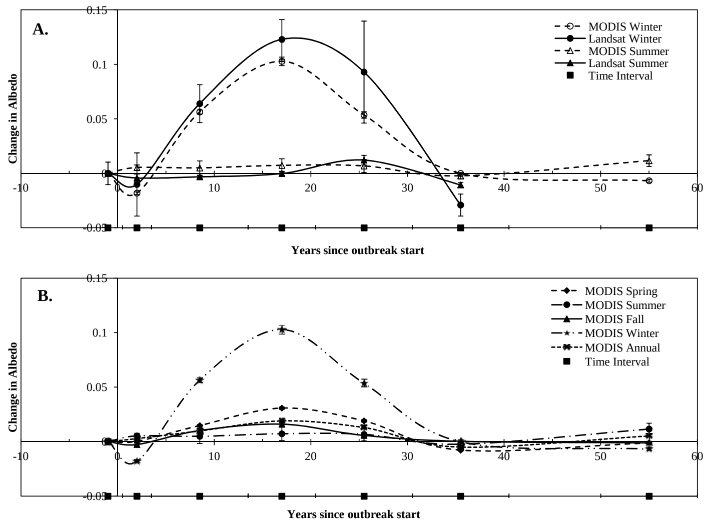

Fig. 2. A) The MODIS versus Landsat change in winter and summer albedo with years since outbreak start. B) The seasonal trend in change in albedo with years since outbreak start as derived from MODI

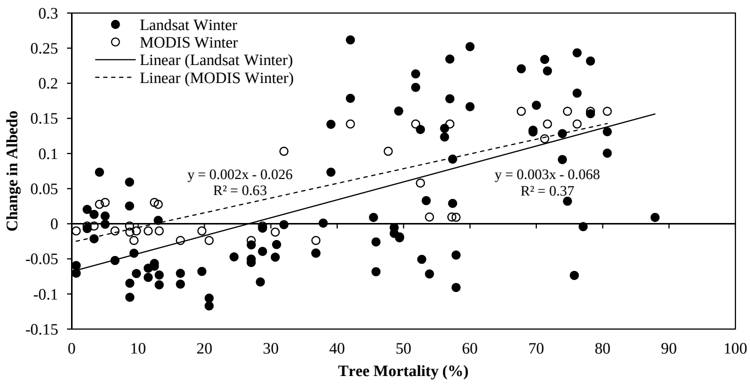

Fig. 3. Change in winter albedo with MPB outbreak severity, defined as percent tree mortality, for outbreaks 4 to 13 years in age (gray attack stage).

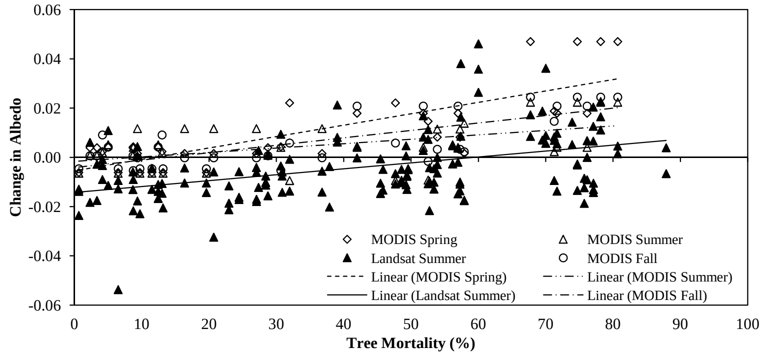

Fig. 4. Change in spring, summer and fall albedo with MPB outbreak severity, defined as percent tree mortality, for outbreaks 4 to 13 years in age (gray attack stage). Linear regression lines shown

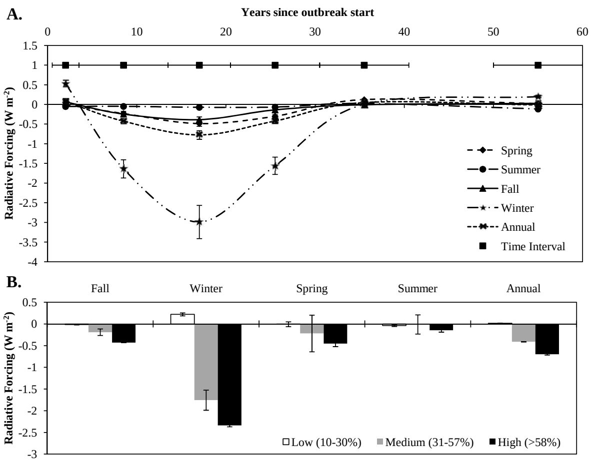

Fig. 5. A). Seasonal pattern in radiative forcing with years since outbreak start, as derived from MODIS albedo. The time interval line indicates the number of years each point is averaged over. Err

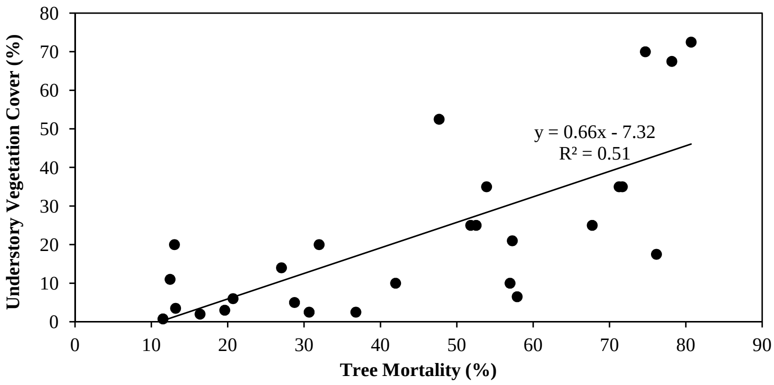

Fig. 6. Understory vegetation cover as a function of post-outbreak percent tree mortality, within gray-attack (4-13 years since outbreak start) dominated field tree plots.

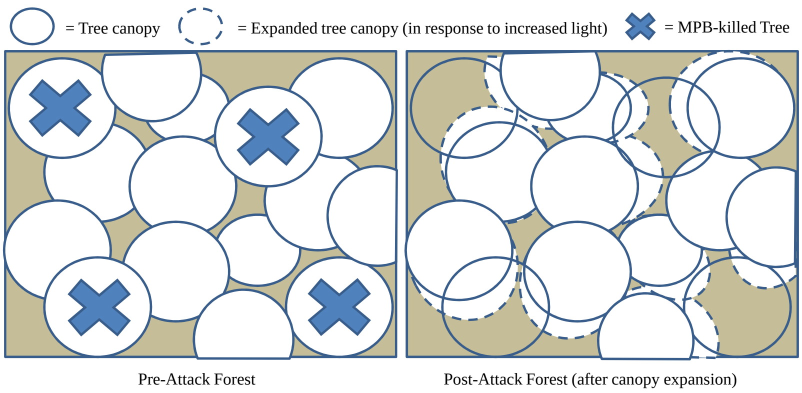

Fig. 7. Remaining canopy and sub-canopy trees can be expected to expand in response to increased light availability post-MPB attack, however we can anticipate that the capacity of this expansion wil

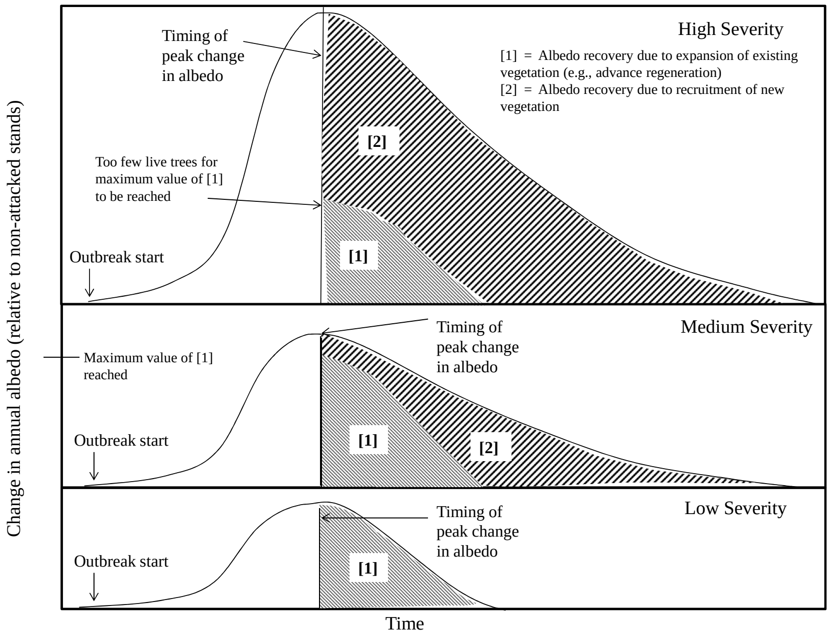

Fig. 8. The theoretical persistence of change to surface albedo due to outbreak severity and the resulting fractional contribution of each regrowth mechanism. It is assumed that an increase in canop