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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Examining the atmospheric radiative and snow-darkening effects of black carbon and dust across the Rocky Mountains of the United States using WRF-Chem" *by* Stefan Rahimi et al.

Anonymous Referee #2

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Based on model simulations, the authors examine the skill of high resolution WRF-Chem on the impact of snow albedo darkening and radiative forcing over western USA. They evaluate the model simulation with various observations. The authors also discussed the radiative differences between BC and dust and intercompared two different pathways (snow direct radiative effect and atmosphere direct radiative effect) of aerosol effect on surface water budget. The spatial and temporal variation of radiative effects are also discussed. The experiments and results are interesting and suitable for publication in ACP after major revision to address following concerns.

1) More discussion on role of dust in the manuscript is needed along with clear explanation and analysis. A)why is dust induced SWE positive over Northern Rockies in Figure 8f,which is inconsistent with the fact that dust-ISRE is positive (Figure 7d) and dust-induced change in albedo is negative (Figure 8i). B) More aerosols always have a negative radiative effect at surface as it either scatters or absorbs incoming radiation at surface. Why is dust surface RE in Figure 12i positive? Although, the authors have tried to explain this by stating the differences in aerosol microphysics, I feel it is not clear. C) Also, this is found over the entire domain not only over the brighter snow surfaces as discussed latter. Therefore, explain in detail line 545 to 550. D)Detailed analysis and discussion should be done to explain why on doubling the dust concentration changes the sign/magnitude of dust induced perturbations on various variables nonlinearly (compared to that with initial dust). For example, in figure 14e, peak dust SDE in may end is $\sim$1.5 Wm2 and the corresponding dust-induced reduction in SWE SWE is $\sim$7% for Northern Rockies. This is very different from the situation in Figure 10 and 11. Dust SDE in Figure 11 is $\sim$1W/m2 and the corresponding dust-induced reduction in SWE is $\sim$ 2%. Please explain and discuss this nonlinearity.

2) A relative issue is this paper is very long which dilutes the main findings. I strongly suggest the author to significantly shrink the length of this paper by moving relatively minor parts/figures to supplementary and organization better to highlight the prime results.

3) Evaluation of snow cover duration should be included in the manuscript as authors report temporal shift in SWE as a main result.

4) Figure 10: The variability in runoff perturbation should be sum of perturbations in precipitation and that in SWE, But this is not the case in Northern Rockies. The precipitation increase and SWE decrease, both are maximum in June, but the runoff maximum is in May, why? This is not clear and need analysis and discussion.

5) In the text, the study period is mentioned as march through June, but in figure 7 it

is February through July. Why?. Also, why is the evaluation period different from the period averaged for results. It should be consistent.

6) I feel BCD is a misnomer and should be better described as LAP, a common term in literature for these light absorbing particles.

7) The authors discuss the differences in this study to previous modelling studies (Wu et al 2018 and Qian et al.,2009) over the same region in detail. One important difference between these 3 simulations is that they all are simulated at different spatial resolutions. The observed differences in the results related to surface elevation could also be due to the inherent variability in terrain height and thus snow depth and associated BCD-in-snow concentrations as also shown in a recent study by Sarangi et al.,2019, ACP (https://www.atmos-chem-phys.net/19/7105/2019/). This should be discussed in context.

8) What is the difference between ISWE and SDE in the manuscript, it seems to be same and used inter-changeably. Again, what is the definition and formula for calculating surface RE? We don't see good spatial correlation between surface RE and corresponding 2-m temperature in many figures? Why? Please define these terms and calculations clearly in methodology near Section 2.4.

9) Include tables like 3 and 4 for all the variables discussed in the manuscript.

10) Line 479» it should be aerosol

11) Line 560»it should be difference

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