Comments to the Author:

Dear authors,

Thank you for your submission to TC/TCD. As you may know, papers accepted for TCD appear immediately on the web for comment and review. Before publication in TCD, all papers undergo a rapid access review undertaken by the editor and/or reviewer with the aim of providing initial quality control. It is not a full review and the key concerns are fit to the journal remit, basic quality issues and sufficient significance, originality and/or novelty to warrant publication. As a result, even a manuscript ranked highly during access review can receive a low ranking during full peer review later. Evaluation criteria are found at www.the-cryosphere.net/review/ms_evaluation_criteria.html. Grades are from 1 (excellent) to 4 (poor).

R: Thank the Editor very much for handling the manuscript. We have taken into account all the comments from the Editor and Referees, and made revisions. Please check the responses and the revised manuscript.

ORIGINALITY / NOVELTY (1-4): 2

Although many studies have reported on core-shell Mie calculations of absorption enhancements, few have linked these studies to coated particles in snow.

R: Yes, this study explicitly resolved the optical properties of coated BC in snow, based on core/shell Mie theory and a snow, ice, and aerosol radiative model (SNICAR), which was commonly ignored in previous studies. Our study indicates the nonnegligible enhancement of snow albedo reduction due to the ‘BC coating effect’.

SCIENTIFIC QUALITY / RIGOR (1-4): 3

The study seems to adequately explore the relevant parameter space for core-shell Mie calculations, but omits some of the larger picture context of how appropriate these calculations are for reality. Although Mie calculations are widely used, BC particles are rarely spherical, and BC mixtures with other species are likely much more complex than uniform coatings on spheres. The assumption that all measured OC resides as coating on BC particles also seems somewhat dubious. Furthermore, many of these BC/OC particles reside within ice grains in the snow, as described in previous works, further complicating the radiative transfer in snow.

R: We agree with the Editor that in real environments, BC mixtures with other species are likely much more complex than uniform coatings on spheres. However, a recent study observing individual particle structure and mixing states between the glacier–snowpack and atmosphere based on field measurements and laboratory transmission electron microscope (TEM) and energy dispersive X-ray spectrometer (EDX) instrument analysis (Dong et al., 2018) told the truth. They found that fresh BC particles are generally characterized with fractal morphology, which has a large quantity in the atmosphere. However, in the snowpack, aged BC particles dominated the BC content and the mixing states of aged BC particles change largely to the internal mixing forms with BC as the core. This process is characterized by the initial transformation from a fractal structure to spherical morphology and the subsequent growth of fully compact particles during the transport and deposition process. Therefore, a core-shell assumption for coated BC in snowpack seems to be plausible. In addition, most filed measurements can not capture the explicit structure of coated BC due to limited observation methods, therefore even if a model for explicit BC structure was developed, researchers are hard to use it for studying the effect of coated BC on snow albedo reductions at present. Moreover, a core-shell assumption for coated BC in the atmosphere is widely applied by most global climate models (e.g. Jacobson, 2001; Bond et al. 2013), so that our parameterizations can be easily linked to most climate models. In summary, we indicate that a core-shell assumption for coated BC in snowpack is plausible and practical for field observations and model simulations at present in despite of the possible uncertainties. However, with the developments of measurement methods and climate models, building a more explicit structure for coated BC in snowpack is actually needed in the future. We have added these discussions in Section 3.4 from Page 19 Lines 15-21 to Page 20 Lines 1-17.

The assumption that all measured OC resides as coating on BC particles were mainly used to show the upper bound of coating effect on snow albedo reduction, which was comparable with the previous studies (e.g. He et al. 2018c). We have added a clarification in the text from Page 22 Line 21 to Page 23 Lines 1-3.

We have added discussions about the mixing of BC and grains in the text, and we demonstrated that users can combine the empirical parameterizations by He et al. (2018c) and Dang et al. (2016) with the empirical parameterizations by us to study the effect of the internal mixing of BC with snow grains, snow grain shape, and coated BC on snow albedo. Details can be seen in our responses to Referee 1 and revised manuscript.

References:

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Dang, C., Fu, Q., and Warren, S. G.: Effect of Snow Grain Shape on Snow Albedo, J. Atmos. Sci., 73, 3573-3583, 2016.

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He, C. L., Liou, K. N., Takano, Y., Yang, P., Qi, L., and Chen, F.: Impact of Grain Shape and Multiple Black Carbon Internal Mixing on Snow Albedo: Parameterization and Radiative Effect Analysis, J Geophys Res-Atmos, 123, 1253-1268, 2018c.

Jacobson, M. Z.: Strong radiative heating due to the mixing state of black carbon in atmospheric aerosols, Nature, 409, 695-697, 2001.

SIGNIFICANCE / IMPACT (1-4): 3

A helpful parameterization is presented that would allow for simplified treatment of coatings, but much uncertainty exists in the applicability of core-shell approximations and of the actual geometry of BC/OC internal mixtures.

R: As seen above, why we used a core-shell assumption for coated BC has been demonstrated, which has been added in the text to improve the reasonability and practicality of our study.

PRESENTATION QUALITY (1-4): 2

The figures seem to present nicely, though the font size of some of the axis labels could be made bigger.

R: We have revised the figures according to your suggestions.

In summary, the paper is a useful and novel contribution and is worth publishing in TCD. Thanks for your contribution.

R: Thanks very much for the Editor's positive evaluations and valuable comments.