Anonymous Referee #1

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We are very grateful for the referee's critical comments and suggestions. The followings are our point-by-point responses to the comments. Our responses start with "R:".

The persistent snow cover in NEC is fairly sparse, thus the forcing by BC and other light-absorbing particles deposited into the surface has no significant sense from this view.

R: Based on the snow cover data (MYD10CM and MYD10C2) from MODIS products (https://modis.gsfc.nasa.gov/data/dataprod/mod10.php), snow depth data from Canadian Meteorological Centre (CMC) (https://nsidc.org/data/NSIDC-0447/versions/1), and snow water equivalent data (GlobSnow-2) from European Space Agency (ESA) Global Snow Monitoring for Climate Research in January-February from 2003 to 2017, we found that the area with snow cover fraction of > 50% and snow duration period of > 30 days is ~75% and ~85% in January-February over Northeastern China (NEC), respectively (Figure S5a and b). This result is consistent with previous studies based on meteorological station data (Zhong et al., 2010) and satellite remote sensing data (Che et al., 2008). In addition, the area with snow depth of > 5 cm and snow water equivalent of > 20 mm is ~70% and ~70%, respectively (Figure S5c and d). Therefore, we note that the snow cover is really high in winter over NEC. We also added further descriptions of snow cover condition in manuscript in Page 14 Lines 14-21, Page 24 Lines 8-14 and in supplements.

On the other hand, local pollutant emissions in NEC have been confirmed some of the most intense in the world (Bond et al., 2004). Previous studies also noted that the typical BC concentrations in snow in NEC range from ~100 ng g^{-1} to ~2000 ng g^{-1} (Huang et al., 2011, Wang et al., 2013), which are much higher than those of ~10 ng g^{-1} to ~100 ng g^{-1} measured in the Arctic, North America and Europe (Doherty et al., 2010, 2014; Peltoniemi et al., 2015). Therefore, we indicate that estimating the radiative forcing by light-absorbing particles in seasonal snow in NEC is significant. Furthermore, we only selected the areas with high snow cover fraction in January-February as the study areas to keep the retrieved radiative forcing more plausible. As a result, the study areas (the identified snow-covered areas in our study) are primarily within the three regions shown in Figure 4. Details could be found in the method section.

And the authors used a remote sensing method to try describing a more uncertainly-locating nature is a far-fetching measure. Therefore, they are strongly suggested to only use in-site measurements (incoming solar radiation, albedo, absorption and etc.) to quantify the absorption due to BC on the snow surface and estimate the forcing directly, instead of using an unprecise ruler to measure a farther object.

R: We agree with the referee's opinion that estimating the radiative forcing due to in-snow light-absorbing particles based on the surface snow field campaigns are more precise than those of remote sensing retrievals or model simulations. However, the surface measurements of snow albedo and in-snow light-absorbing particles are very limited from the regional and global scales. Based on the previous studies, only several field campaigns have been performed in NEC (Wang X. et al., 2013; 2017; Wang Z. et al., 2014) and other areas such as the Arctic (e.g. Doherty et al., 2010) and North America (e.g. Doherty et al., 2014). Due to the large variations of the spatial and temporal distributions of radiative forcing, and the sparse sample sites, estimating the radiative forcing by light-absorbing particles in seasonal snow based on the surface snow field campaigns are limited (Dang et al., 2017). In addition, Zhao et al. (2014) indicated that the uncertainty in estimating the radiative forcing using model simulation is very high due to limited measurement data, which however could be possibly improved by combining remote sensing retrieved results.

Recently, the satellite remote sensing with the advantage of high spatial-temporal resolution has been confirmed as an accurate and useful tool to retrieve the radiative forcing by in-snow light-absorbing particles over high snow cover areas (Painter et al., 2012). We further used the in-situ measurement data obtained by previous studies to estimate the uncertainties and biases of the retrieved radiative forcing based on the satellite remote sensing. We found that the biases of MODIS retrieved radiative forcing in NEC compared with the surface measurements are within the acceptable range (Painter et al., 2012) (see Section 4.4 of the manuscript).

In addition, to validate the spatial pattern of MODIS retrieved I_{LAPs} and radiative forcing in NEC, we added multiple types of snowfall and BC deposition data. For example, we collected four types of snowfall data including the 126-station snowfall data of China in NEC, the observations-based snowfall data from the ERA-Interim reanalysis (http://apps.ecmwf.int/datasets/data/interim-full-daily/levtype=sfc/), the Modern-Era Retrospective Analysis for Research and Applications, version 2 (MERRA-2), and the National Centers for Environmental prediction (NCEP) Climate Prediction Center (CPC) (https://www.esrl.noaa.gov/psd/data/gridded/data.cpc.globalprecip.html) and two types of BC deposition data including reanalysis data from the Modern-Era Retrospective Analysis for Research and Applications, version 2 (MERRA-2) and the modelling data from the Coupled Model Intercomparison Project Phase 6 (CMIP6, the latest CMIP phase) including CESM2, CESM2-WACCM, and CNRM-ESM2-1 historical experiments (Eyring et al., 2016). The results showed that BC dry and wet deposition and snowfall could totally explain 81%-84% of the spatial variance of in-snow light-absorbing particles in NEC based on different datasets, which also confirms the reasonability of the spatial patterns of retrieved I_{LAPs} and thus radiative forcing based on remote sensing in NEC. Detailed revisions please see the manuscript in Page 13-14, Page 31 Lines 9-18 and the supplements.

Above all, we note that satellite remote sensing could be used to retrieve the radiative forcing by in-snow light-absorbing particles in NEC, especially in highly polluted industrial areas, which is also consistent with the previous study by Warren et al. (2013).

Table S1. R^2 between MODIS retrieved I_{LAPs} versus fitted I_{LAPs_fit} using different datasets.

BC Wet Deposition Data	BC Dry Deposition Data	Snowfall Data	R^2 (MODIS Retrieved I_{LAPs} Versus Fitted I_{LAPs_fit})
MERRA-2	MERRA-2	ERA-Interim	0.84[b]
MERRA-2	MERRA-2	MERRA-2	0.82[b]
MERRA-2	MERRA-2	CPC	0.82[b]
CMIP6[a]	CMIP6	ERA-Interim	0.84[c]
CMIP6	CMIP6	MERRA-2	0.83[c]
CMIP6	CMIP6	CPC	0.81[c]

a: CMIP6 data in this study is CIMP6 multi-model ensemble mean data including CESM2, CESM2-WACCM, and CNRM-ESM2-1 historical experiments from 2003 to 2014. So far, only the above three models in CMIP6 provide BC deposition data.

b: data used to fit I_{LAPs_fit} is from 2003 to 2017.

c: data used to fit I_{LAPs_fit} is from 2003 to 2014, which is due to that the data of CMIP6 historical experiments is only updated to 2014.

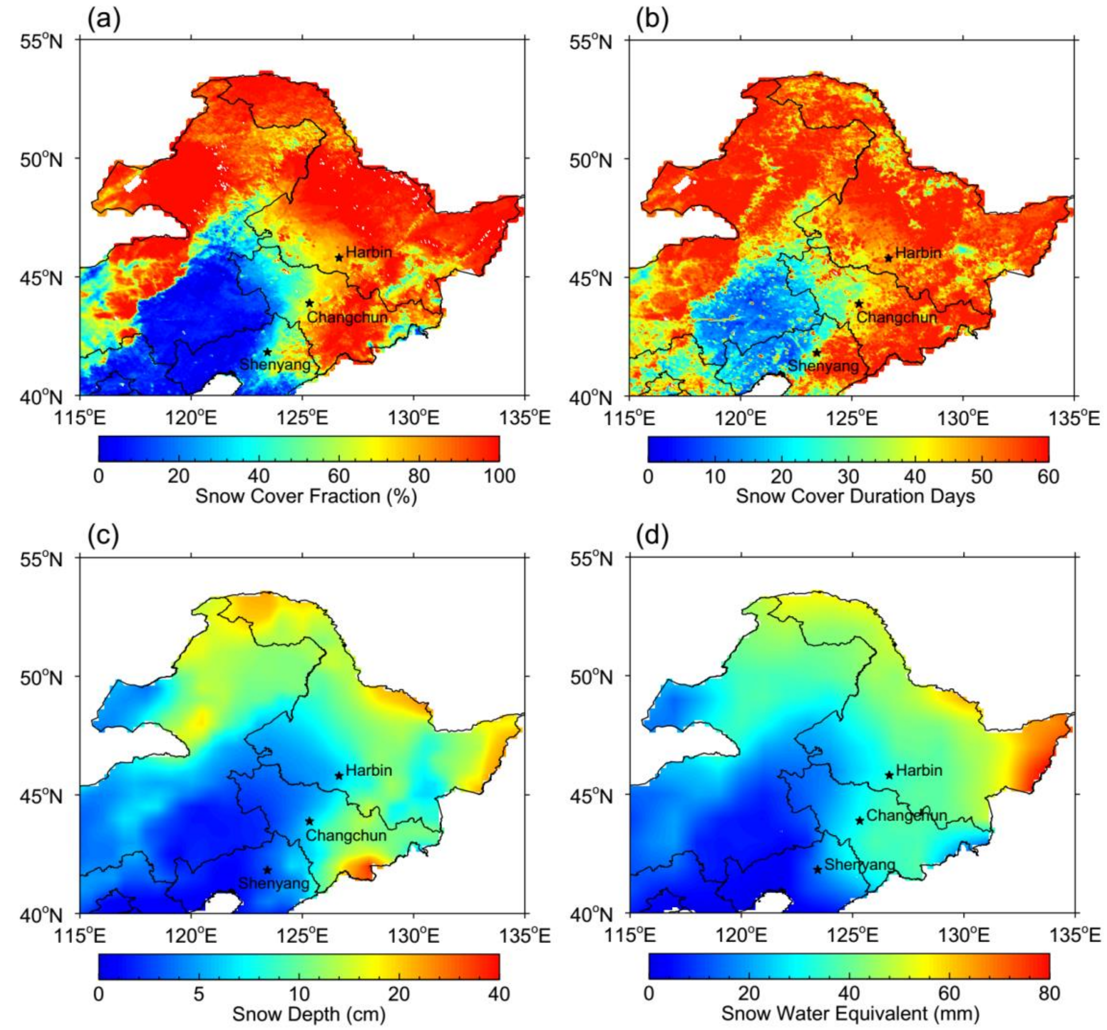

Figure S5. Spatial distribution of average (a) snow cover fraction, (b) snow cover duration days, (c) snow depth, and (d) snow water equivalent in January-February from 2003 to 2017. The data of snow cover fraction and duration days is from MODIS MYD10CM and MYD10C2, respectively. The method calculating the snow cover duration days is from Chen et al. (2015). Snow depth data is from Canadian Meteorological Centre (CMC). Snow water equivalent data is from European Space Agency (ESA) Global Snow Monitoring for Climate Research.

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