Reply to Anonymous Referee No.2

We are very grateful for the reviewer and appreciate your comments and suggestions. All the responses or changes have been made below. The responses are marked blue.

Thank you very much

Kind regards,

Fangping Yan

(on behalf of the co-authors)

This study examines radiative forcing of dissolved organic carbon in snow and ice and its contribution to carbon flux returned to the atmosphere using samples collected form the Laohugou glacier No. 12 (LHG glacier)) in the north-eastern Tibetan Plateau. Radiative forcing is very small (0.1_0.1%) in comparison with black carbon in ice but constitutes about 10% of the black carbon forcing in snow although the uncertainty on this estimation is close to the estimation itself. I suggest that the authors comment on the importance of this forcing carefully given that these are not large figures. Figure 6S and text given in lines 256-258 are confusing as they suggest much higher radiative forcing of dissolved organic carbon. This should be explained more clearly. I also suggest that the two themes – radiative forcing and release of carbon from the glacier into the atmosphere should be given more distinct separation in the text and the latter given more prominence that it has now (a very short section 3.4).

Response: Thanks a lot for the suggestions. Sorry for the confusing statement about Figure 6S and lines 256-258. Figure 6S was intended to explain the relatively higher radiative forcing of snowpit compared to glacier ice. Lines 256-258 were deleted from the text. For section 3.4, we combined DOC concentration of proglacial streamwater collected previously across the TP (Table S2) to estimate the total output of DOC from glacier region of the TP. The result showed that about 12.7-13.2 Gg DOC (Gg=10^{9} g) was exported from glaciers of the TP, which was higher than that of DOC deposition in the glacier region (Li et al., 2016), indicating glacier of the TP is a carbon source at present environment condition. Therefore, we extend this part of our MS to glaciers of the entire TP.

Table S2 Information of the studied glaciers and DOC concentrations (µg L^{-1}) of proglacial streamwater samples across the TP.

Glacier ID	Glacier name	Mountain range	DOC (monsoon)	DOC (non-monsoon)
LHG	Laohugou glacier No. 12	Qilian	325	394
TGL	Xiaodongkemadi glacier	Tanggula	150	212
EV	East Rongbu glacier	Middle Himalaya	139	171
ZD	Zhadang glacier	Nyainqêntanglha	169	222
DML	Demula glacier	Eastern	103	134

		Himalaya		
QY	Qiangyong glacier	Central Himalaya	124	167

Lines 82-83 and lines 102-107: I suggest that Supplement Table 1 should be given together with Fig. 1 in the main text. Both snow pits should be shown on Fig. 1. Or were they in the same place? If yes, clarify in the text (line 103).

Response: Yes, the two snowpits are almost in the same site and marked on Figure 1. Supplement Table 1 was moved into the main text.

Lines 82-83 and Section 2.2: How did you measure discharge? Explain

Response: Thanks a lot for this question, which was also asked by the other reviewer. In detail: The hydrological gauging site was setup at about 0.8 km downstream of the glacier terminus. It meets the requirements for a hydrological gauging site. Horizon walls were built on the both sides of the river, and an automatic barometric sensor (HOBO Water Level Logger, Onset, America) was installed in the wall to record water pressure every 10 minutes to calculate the water levels. There was a bridge across the river to facilitate the flow velocity measurement using propeller blade current meter (Model LS25-1, Huazheng Hydrometric Instrument Ltd). The river channel was divided into nine segments in which flow velocity and water depth were measured. Coupled with mean flow velocity, width of each segment and water depth, discharge at specific water level was obtained. By including maximum and minimum water level in a year, a discharge relationship with water levels was developed. Therefore, using the HOBO water lever record, discharge of all seasons was calculated. This part was added in the supplementary information.

Line 105 and Fig. 1: What is the ‘eastern tributary’? Is it a tributary of the glacier or of the stream? It is not clear from Fig. 1.

Response: Sorry for the missing of the description of this glacier. “Eastern tributary” is one of the branches of LHG glacier No. 12 (Figure 1). “It is divided into two parts of western and eastern branch at the elevation of 4560 m a.s.l (Dong et al., 2014)” has been added in section 2.1.

Line 105: How did you collect ice samples? How did you store them? Crushed or melted before placing in a bottle?

Response: Surface ice (0-3 and 3-5cm) samples were collected using an ice axe directly into 125 mL pre-cleaned polycarbonate bottles after crushing. This method of sample collection was added in section 2.2.

Line 105: Were your samples collected from the surface?

Response: Yes, they were collected from the surface. “71 snow/ice samples” was changed to “29 surface snow and 42 surface ice samples”.

Line 105: Please clarify how many samples of snow or ice collected. You currently give one number for all.

Response: “71 snow/ice samples” was changed to “29 surface snow and 42 surface ice samples”.

Lines 110-111: ‘Clean Hands –Dirty Hands’ procedure: Please explain in plain English, avoiding jargon, what it is.

Response: “Clean Hands-Dirty Hands” is the sample collection protocol in which the person who takes charge of the sample collection should not touch any other things except the samples to avoid contamination, the hands are “clean hands”, while the other people can take charge of other processes and these hands called “dirty hands”.

Lines 115-119: Your numbers of samples from the deserts are low and sand may not make a useful comparison as it is not the material to undergo long-range transport (too large particles). Please comment on the spatial homogeneity / heterogeneity of mineral and elemental composition of desert material

Response: Data of desert sand were deleted from Figure 5. In this study, we focused on the dust in the desert sand, and the desert sands are well mixed, for instance, the 187Os/188Os ratios study showed that for Taklimakan Desert sands are close to the average of Kunlun moraines, river sediments around the Taklimakan Desert and the Tibetan soils. Therefore, the Taklimakan Desert sands are derived from moraines and river sediments around the desert or from Tibetan soils and are homogenized by aeolian activity in the desert (Hattori et al., 2003). Furthermore, because dusts loaded on the glaciers are well mixed during long distant transport from the desert region, mineral and elemental compositions of dust deposited on glacier are also homogenized (Wu et al., 2009). Therefore, “Mineral and elemental composition of desert sands of west China are homogenized by aeolian activity (Hattori et al., 2003), so that the dust samples collected in this study are representative of desert sourced dust in west China” was added into the MS.

Line 117: Is Dunhuang a desert location? Please clarify.

Response: Yes, it is a desert location. This information was added in section 2.2.

Line 147: Provide references supporting your first sentence.

Response: References “Kaspari et al., 2014”, “Qu et al., 2014” and “Ming et al., 2013” were added in the sentence.

Line 161: Use ‘pre-combusted’ instead of ‘pre-burned’.

Response: “pre-burned” in line 161 and 162 was changed to “pre- combusted”.

Lines 188-189: In the text you state “Therefore, the distributions of DOC concentrations in the glacier surface snow and ice were influenced by complicated factors, such as the terrain, surface moraine and atmosphere circulation”. (i) In which way does the ‘terrain’ (whatever it means here) influence DOC? (ii) What is the impact of atmospheric circulation? I suppose you can’t make quantitative conclusions in the absence of continuous measurements but you should at least comment and refer to literature. (iii) In Section 2.2 you refer to the collection of samples from deserts so I assume that ‘mineral dust’ implies ‘desert dust’. If this is the case,

make it clear. How can you tell input of desert dust in DOC concentrations from input of material from local moraines?
Response: For question (i), 'Terrain' means different slopes and faces of the glacier, which will cause different enrichment of particles on the glacier surface, finally cause variations of DOC concentration. (ii) 'Atmospheric circulation' is deleted because it hardly influences the contribution of DOC in glacier surface ice. (iii) "Mineral dust" is "desert dust" Therefore, "mineral dust" was replaced by "desert sourced mineral dust". Research on Sr-Nd isotopic compositions (Xu et al., 2012) has shown that dust loaded on LHG glacier was mainly derived from long range transported dust rather than local moraines.

Lines 210-211: Concentrations of Ca^{2+} in desert dust. Have you compared your desert dust samples with the samples from the local moraines? What other tracers can you use? Do you have absorption spectra for material from local moraines and how is it different from those for your desert material samples?
Response: Sorry for not doing this comparison because according to previous research on Sr-Nd isotopic compositions (Xu et al., 2012), it was well constrained that dust loaded on LHG glacier was mainly transported from deserts rather than local moraines. Therefore we only check the desert sourced dust. Furthermore, according to our observation during sampling collecting process, we found local moraines belong to coarse crusted sand and stones, which should contain little organic matter and hard to be transported to the glacier surface.

Section 3.2: You should bring Supplement Figure 1 into this section and add comments on the profiles of DOC in your snow pits highlighting differences between the layers containing dust and the relatively clean layers.
Response: Supplement Figure 1 was brought into the main text as Figure 3. "Moreover, the profiles of DOC in two snowpits varied with the dust content, DOC concentration of dust layer was much higher than that of clean layers." was added in section 3.2.

Lines 256-258 and Fig. 6S: Please explain the elevation dependence of DOC relative to BOS more clearly
Response: Lines 256-258 were deleted for the misunderstanding.

Add more detailed comments on Fig. 6S.
Response: Paragraph 2 in section 3.3.3 was rewritten and changed to "The high radiative forcing ratio of snowpit samples was caused by its higher DOC/BC (0.65) than that of surface ice (0.012) (Fig. S5), and the low ratio of DOC/BC in surface ice was caused by enrichment of BC in surface glacier ice during the intensive ablation period (Xu et al., 2009)".

Equation 3 show that radiative forcing depends on concentration and Fig. 6S shows the ratios between black carbon and dissolved carbon but a couple of sentences would be required to clarify and strengthen you message.
Response: Two sentences were added into the MS. "It is obvious that the value of is closely connected with relative concentrations between DOC and BC." was added into the method

part 2.3.2. Meanwhile, the expression in part 3.3.3 was modified to “The high radiative forcing ratio of snowpit samples was caused by its higher DOC/BC (0.65) than that of surface ice (0.012) (Fig. S5), and the low ratio of DOC/BC in surface ice was caused by enrichment of BC in surface glacier ice during the intensive ablation period (Xu et al., 2009).”

Section 3.3.3: Too many abbreviations (BrC, WSOC) make reading this section difficult.
Response: These abbreviations were rewritten in full name in the text.

Line 287: Provide references after “: : :the European Alps and Alaska”
Response: References “Singer et al., 2012” and “Fellman et al., 2015” were added in the sentence.

Section 3.4 is very brief. Can you expand it and give it more prominence?
Response: We measured DOC concentrations of proglacial streamwater samples at other 5 glaciers during last three years. Although only two data were achieved for each glacier, the total flux of DOC for all the glaciers of the TP was estimated and the following information was added in the section 3.4.

“When it comes to the entire TP, it is obvious that proglacial streamwater DOC concentrations (Table S2) showed similar spatial variation to that of snowpit DOC (Li et al., 2016), with high and low value appeared at north and south TP, respectively, reflecting good succession of proglacial streamwater DOC concentration to that of snowpit samples. Therefore, it was calculated that DOC flux in proglacial streamwater of the entire TP glacier was around 12.7-13.2 Gg C (Gg = 10^9 g) based on average proglacial streamwater DOC concentration of 193 μg L^{-1} (Table S2) and annual glacial meltwater runoff in China of 66-68.2 km^3 (Xie et al., 2006), which is higher than that of DOC deposition (5.6 Gg C) at glacier region of the TP, agree well with the negative water balance of the glaciers of the TP. Therefore, the TP glaciers can be considered as a carbon source under present environment condition.”

Section Conclusions (Lines 291-293) and Abstract: radiative forcing of DOC is 0.1±0.1% of BC in ice and 9.5±8.4 % for snow. So this in effect is an almost zero addition in case of ice and might be close to zero addition for snow. I suggest that you should convert this into W m^{-2} using data from literature to be more convincing.
Response: Thanks a lot for the suggestion. Since the radiative forcing ratio of surface ice is almost zero, we converted the ratio of snowpit into W m^{-2} based on the previous published data of black carbon in snowpit of LHG glacier (Ming et al., 2013). “Based on the previous published radiative forcing data of black carbon of snowpit of LHG (Ming et al., 2013), for the first time, it is estimated that the radiative forcing caused by snowpit DOC was 0.43 W m^{-2} , accounting for around 10 % of the radiative forcing caused by BC” was added into conclusions section and section abstract was adjusted accordingly.

Figures and Tables Tables 1 and 2: Why are your references in parentheses?
Response：These references were changed according to the writing standards.

Combine Fig. 1 with Table 1 in the Supplement and show both snow pits.

Response：Table 1 in supplement information was moved into the main text, the other snowit was marked on Figure 1.

Fig. 2: Show error bars both ways and add the number of samples in each category.

Response: Adjusted accordingly on Figure 2.

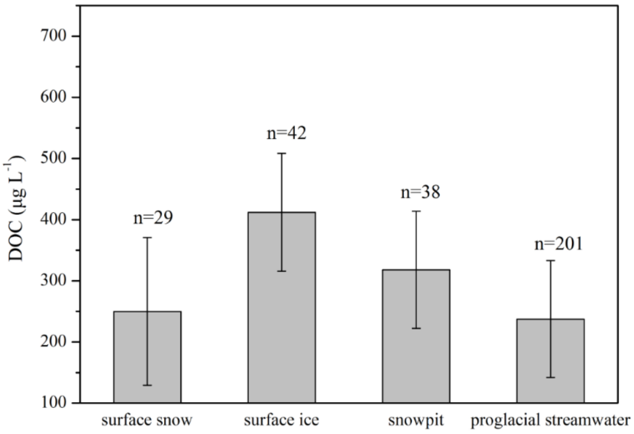

Figure 2 Average DOC concentrations of ice, snow and proglacial streamwater for LHG glacier.

Fig. 3: Why do you need exponential fit here? Linear regression describes this relationship well. Your standard deviation bars are impossible to see.

Response: Yes, based on the data only, the linear regression could be adequate. However, according to the DOC bioavailablity, the exponential one can be more authentic (Spencer et al., 2015), because some DOC are bio-refractory, so that DOC cannot reach zero with long enough resident time. The differences between the parallel samples were very small, so the standard deviation bars were very short.

Fig. 4: What is ‘desert’ and what is ‘dust’?

Response: “Desert” was desert sand collected from the desert at Dunhuang; “Dust” was the dust fall collected during dust storm events at Dunhuang. The spectrum of desert sand was deleted because of the low numbers of the samples. Figure 4 was changed to Figure 5 based on the previous comments as below.

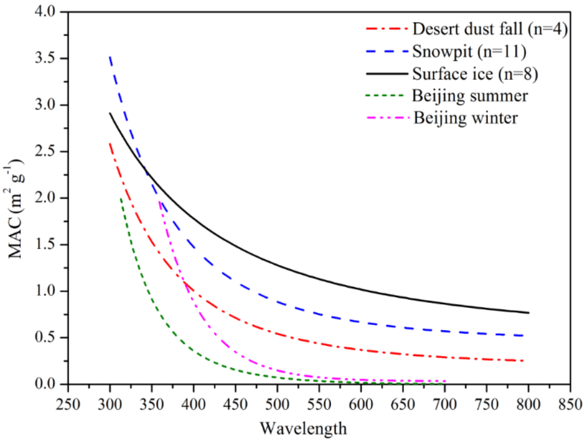

Figure 5 Absorption spectra for the DOC in snow and ice of LHG glacier and the dust and desert sand

from surrounding areas.

Fig.S1: Use the same scales on X and Y axes for both profiles for an easier comparison. Move this figure to the main text.

Response: This Figure was moved to the main text as Figure 3 and the scales were adjusted accordingly.

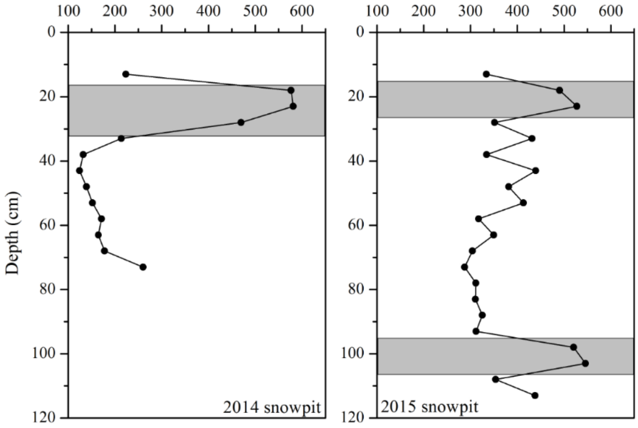

Figure 3 Variation in DOC concentrations in profiles of studied snowpits. The gray rectangles are dirty layers.

Fig. 6S: Are these average ratios for all samples?

Response: They were average DOC and BC ratios of snowpits and surface ice, respectively, "snow" was changed to "snowpit", "ice" was changed to "surface ice" on this figure, and "6S" was changed to "5S".

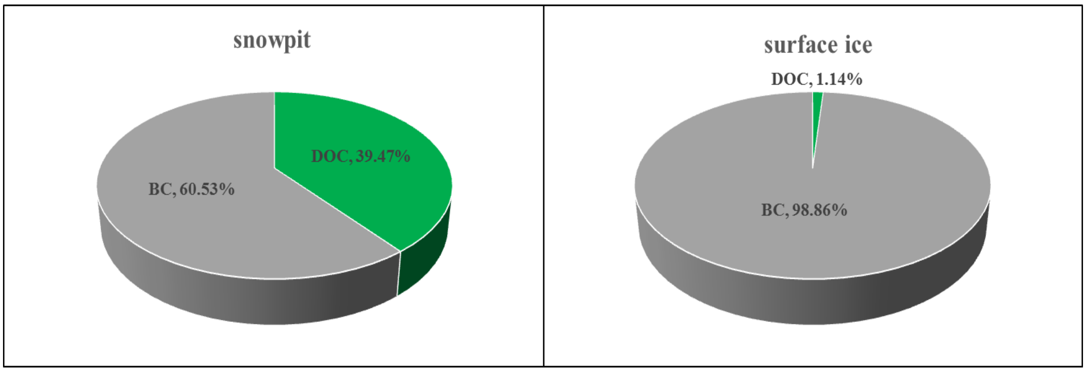

Figure 5S The DOC/BC ratios of snow and ice of LHG glacier.

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