Response to anonymous referee 2

We thank referee 2 for the detailed review. In this response, the reviewer's comments are in black standard font. Our response is in standard blue font and the modifications to the manuscript are in blue bold font.

This study evaluated ablation at ice cliff of Changri, debris-covered glacier tongue using UAV-image and dem (and also Preades). They consider the emergence velocity and also evaluated several kinds of errors carefully. They concluded that recent elevation changes at tongue of Changri Glacier is mainly due to lower emergence velocities, not ablation at ice cliffs. In particular, Figure 4 and 5 are very impressive for me, because it's ideal data to analyze ablation process of debris-covered glaciers (Off course we have to consider distribution of emergence velocity). I think this result can be analyzed for other target. I'm looking forward to read other papers. I have some comments as follows. I hope my comments will help to improve your manuscript.

We thank the anonymous referee 2 for her/his positive appreciation of our work.

<Specific comments> Page2 L21 '35 (Sakai et al., 1998)' » Please refer Table 2 in Sakai et al.(2000) p = 256/26=9.8. The value 35 calculated from Sakai et al.(1998) is inaccurate value.
Modified accordingly

Page 2 L26 'but it has typically been neglected in the calculation of p.' » Which previous study neglected emergence velocity? Please address the references.
As this applies to all the studies listed in the beginning of the section, we added **", for all the above-mentioned studies."** at this sentence.

Page 2 L26 '5.7–6.4 _ 3.9 m a-1' » 6.4 _ 3.9 m a-1 is the value of mass balance in Nuimura et al.(2011)
Thanks for pointing out this mistake, it has been corrected and the correct values are now reported.

Page 2 L28-31 'Emergence velocities will affect the thinning rates of debris-covered ice and ice cliffs equally. But since the cliffs ablate at higher rate, their thinning rate is relatively less influenced than the thinning rate of debris-covered ice. As a consequence, the ratio of the cliff thinning rate divided by the mean tongue thinning rate will overestimate p.' » Those explanation is a little bit ambiguous expression. Please write more clearly.
We modified this paragraph, which now reads as: "**Neglecting the emergence velocities (i.e. comparing thinning rates instead of ablation rates) introduces a systematic overestimation of f_c. This is due to the fact that cliffs ablate at higher rate than the rest of the glacier tongue: ice cliff thinning rates are thus less influenced than the thinning rates of debris-covered ice when neglecting the emergence velocity. As a consequence, the ratio of the cliff thinning rate divided by the mean tongue thinning rate will overestimate f_c. To correctly estimate f_c and the fraction of total ice cliff net ablation, thinning rates need to be corrected with the emergence velocity.**"

Page 3 '2 Study area' »There are basic information of study area in Vincent et al.(2016). But, I recommend that ELA around the Changri glacier and altitudes (Max, min) information are necessary, here.
Modified accordingly

Page 6 L6 I cannot find out the location of cross section in Fig. 1 or 2.
We added them on the figures.

Page 7 section 4.2 and 4.3 Ice cliff is unstable. Sometimes they disappear or newly emerge in one melting season. Are there any ice cliffs diminished or emerged? And you have neglected those ice loss in this study?

The cliff outlines were updated for each year. Globally, we observed little change in the total area covered by ice cliffs (69 876, 71 826 and 69 357 ± 14 000 m² for Nov. 2015, 2016 and 2017, respectively). However, the reviewer is right and there were some substantial changes observed for individual cliffs. This is now discussed in details in section 6.1 ("**Cliff evolution and** comparison of two years of acquisition") and we added a table in the supplement (Table S2) showing the evolution of individual cliffs:

"6.1- Cliff evolution and comparison of two years of acquisition

The total area occupied by ice did not vary significantly from year to year, ranging from 70 ± 14 × 10^3 m^2 in November 2017 to 72 ± 14 × 10^3 m^2 in November 2016. The twelve individual cliffs surveyed showed large variations in area within the course of one year, with a maximum increase of 57 % for the large cliff 06 and a decrease of 34 % for cliff 03 and 09 (Table S2). The total area of these twelve cliffs increased by 8 % in one year. Interestingly, over the same period, Watson et al. (2017) observed only declining ice cliff area on the tongue of Khumbu Glacier (~6 km away). All the large cliffs (most of them are included in the twelve cliffs surveyed with the terrestrial photogrammetry) persisted over these two years of survey, including the south or south-west facing ones (Table 1) , although south facing cliffs are known to persist less then non south facing ones (e.g., Buri and Pellicciotti, 2018). However, we observed the appearance and disappearance of small cliffs, and marginal areas became easier to classify as either ice cliff or debris-covered areas, highlighting the challenge in mapping regions covered by thin debris (e.g., Herreid and Pellicciotti, 2018).

We calculated backwasting rates for the twelve cliffs monitored with terrestrial photogrammetry for the period November 2015-November 2016 (Table 1). The backwasting rate is sensitive to cliff area changes (because it is calculated as the rate of volume change divided by the mean 3D area) and should be interpreted with caution for cliffs that underwent large area changes (e.g., cliffs 01, 02, 03, 06, 09 and 11; Table S2). The backwasting rates ranged from 1.2 ± 0.4 to 7.5 ± 0.6 m a^{-1} , reflecting the variability in terms of ablation rates among the terrain classified as cliff (Fig. 9). The lowest backwasting rates are observed for cliffs 11 and 12, located on the upper part of the tongue, roughly 100 m higher than the other cliffs (Fig. 1 and Table 1). The largest backwasting rates were observed for cliff 01, which expanded significantly between November 2015 and November 2016. The backwasting rates are lower than those reported by Brun et al. (2016) on Lirung Glacier (Langtang catchment) for the period May 2013-October 2014, which ranged from 6.0 to 8.4 m a^{-1} and lower than those reported for surviving cliffs by Watson et al. (2017) on Khumbu Glacier for the period November 2015-October 2016, which ranged from 5.2 to 9.7 m a^{-1}. These differences are likely due to temperature differences between sites. Indeed, the cliffs studied here are at higher elevation (5320-5470 m a.s.l.) than the two other studies (4050-4200 m a.s.l. for Lirung Glacier and 4923-4939 m a.s.l. for Khumbu Glacier)."

Page 8 '4.4.1. Emergence velocity' 'The debris-covered part of the tongue has an area of 1.49 _ 0.16 km2'(Page3 line 16) The uncertainty is induced assuming that there are 20 m uncertainty in the glacier outline Vincent et al.(2016). I think estimation of the tongue area is difficult. I have never been to the Changri Glacier, therefore, I'm not sure the confidence of glacier outline at the terminus. But, in general, it is difficult to estimate outline of glacier terminus at debris-covered glacier. Then, we have to measure ice depths at two cross sections, and calculate emergence velocity between the two cross sections to avoid large error due to glacier area estimation. You can discuss.

This issue was extensively discussed in Vincent et al. (2016), who produced the glacier outline. We agree with the reviewer that debris-covered glacier outline mapping is a timely issue and consequently, we added: "**It is notoriously difficult to delineate debris-covered glacier tongues (e.g., Frey et al., 2012). In this case, we assumed an uncertainty in the outline position of ± 20 m, leading to a relative uncertainty in the glacier area of 11 %, which is higher than the 5 % of Paul et**

al. (2013). In this case, the uncertainty on the glacier outline is not the main source of uncertainty in w_e, but for automatically delineated glacier outlines, this would be an important source of uncertainty."

Page8 L13-14 ' The maximum net ablation measured with stakes within the period 2014–2016 on the tongue of Changri Nup was chosen as an upper limit equal to 2.22 m a-1' » Please explain why you can choose the maximum net ablation measured with stakes can be assumed to be the maximum emergence velocity.

For a glacier in imbalance, the ablation is higher than the emergence velocity and the glacier surface thins. Consequently, the ablation can be seen as an upper bound for the emergence velocity. In this case, we took a rather extreme value for the uncertainty on the emergence. We added:

"**For a thinning glacier, the net ablation is higher than the emergence velocity (Hooke, 2005), consequently, the net ablation can be used as a proxy for the upper bound for the emergence velocity.**"

P13 L3-23 and Fig. 10 ãˇAAˇ In this discussion, you have compared debris-covered and debris-free glaciers in equilibrium and transient (shrinking) regime. But, your target is ice loss at ice cliff. Almost assumptions are based on part of other studies. Further, I cannot accept some assumptions, Ex. ice flux is same at both debris-covered and debris-free glaciers. Usually, debris-covered glaciers are large, and debris-free glaciers is small. Further, each altitude are different. Then, I think we cannot discuss without the observation of debris-free glaciers.

The paragraph referred to by the reviewer has substantially been modified. We added the following sentence about this specific comment: **"The ice flux at the ELA is expected to be driven by accumulation processes, and consequently it is reasonable to assume similarity for both debris-covered and debris-free glaciers.**"

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