Reply to 2nd reviewer Prof. Braithwaite

Thank you for your very positive and valuable comments. We are happy to receive your comments for improving our manuscript. We have enjoyed analyzing in order to reply to your comment. Our manuscript will be improved in accordance with your suggestions.

Your comments are written in Arial font (Blue). And our replies are written in Times New Roman (Black).

Looking at the discussion on pages 3635-3637, I think the authors should use the terms G-average elevation, L-average elevation and W-average elevation to make clear that these are different ways of averaging the median elevations of individual glaciers within each 0.5 by 0.5 degree grid square. The glaciers are characterised by size (area), and the different averages G-, L- and W- take account of different effects of local precipitation, avalanching etc.

We will revise from G-, L-, W-median elevation to G-, L-, W-average elevation in accordance with your comment.

Important parameters in the classic glacier inventories like the First Chinese Glacier Inventory (Shi, 2008) are primary classification of glaciers, e.g. ice caps, outlet-, valley and mountain-glaciers, and aspects of ablation and accumulation areas but these do not appear to be evaluated in the GAMDAM Glacier Inventory. Aspect has a well-known control on the ELA itself and local precipitation conditions expected there (Evans, 1977 and 2006). Similarly, the primary classification of a glacier has a strong control on both glacier size and precipitation conditions. If these two parameters are not evaluated in the GAMDAM inventory it would be worth considering an update to the inventory.

Thank you for your suggestions and introduction of two interesting papers. We also thinking that analysis on ELA depending on size, glacier type, and aspect would be very interesting. Your suggestion will be addressed in our future study once our inventory is revised.

MINOR ISSUES The paper is generally well arranged in sufficiently good English to understand the main points. There are, however, many “micro-errors” that need correction by an English language specialist. This includes missing or superfluous definite and indefinite articles, verb agreements with nouns etc. I make specific small points on the following:

P. 3631 line 3: I assume you mean “Almost all datasets. . .”

We will revise it as you suggested.

P. 3631 line 29-30: The sentence “However, the estimated ELA has a large discrepancy with glacier distribution” needs rephrasing as it is presently meaningless.

We will delete this sentence.

P. 3633 line 4: “Hamper” should be “Harper”.

Thank you for pointing out the error. We will correct it.

P. 3634 line 6 to 9: This would probably read better as “Most precipitation in the interior of High Mountain Asia originates from recycled evaporation, and such a proportion of continental recycling cannot be found in the other continents”

Thank you for your correction. We will revise in accordance with your correction.

P. 3635 line 9: I suggest “. . .the few observed ELA with . . .”

As the 1st reviewer's comment, we will add simple summary of Table S1.

P. 3635 line 25: I suggest “. . .by area-weighted averages of median elevation for individual glaciers”.

We will revise as you suggested.

P. 3637 lines 16-17: I find “The glacier mass balance, however, usually is calculated from only direct precipitation as an input meteorological data” nearly meaningless. Are you talking about mass-balance models?

Yes, we are talking about mass-balance models. We agree with your comment. We will delete the sentence.

C1802

P.3637 lines 27 to 28: I suggest “If calculated, W-median elevation is less than or equal to L-median elevation”.

It was our mistake. We will correct as follows, also taking into account the 1st reviewer's comments:

"When hypsometry upper than median elevation has convex curve, the L-median exceeds the W-median elevation, in that case, we assumed that W-median elevation is equal to L-median elevation."

P. 3638 line 17: Kondo (1990) is not listed in reference list.

We will add in the reference list.

P. 3642 lines 3 to 4: Fujita and Ageta (2000) may have said what you say, but they are over-simplifying as there will be different ablation rates for ice, snow and debris-covered ice, so ablation must depend upon precipitation as well as air temperature and solar radiation.

We will add precipitation in the text.

P. 3642 line 24: You quote Braithwaite et al. (2006) but Braithwaite (2008) would also be a useful reference.

Thank you for your comment. We will revise it accordingly.

P. 3643 line 5: Braithwaite (2008) is a useful extension of the paper by Ohmura et al. (1992) as it takes account of the different climate settings of the glaciers with a family of curves.

Thank you for your comments. We also analyzed the relation between summer temperature and annual snow, classified by annual temperature range (Fig. 5 in Braithwaite (2008)).

Please, read below comments on P. 3660 Fig. 8.

P. 3643 line 19. I once tried (unpublished!) to map glacier precipitation across High Mountain Asia using the degree-day model extrapolated to the median elevation in the World Glacier Inventory, and I found problems in especially the Mount Everest region. This was because air temperatures were too low to give any meaningful melt at the ELA in this region. Presumably zero balance at the ELA is maintained by relatively large sublimation.

Thank you for your very interesting comment.

Actually, in our result using heat balance method, calculated precipitation in Everest region has reasonable results. In more arid regions, for example, West Kunlun, East Pamir, and southern central Tien Shan receive much less precipitation (about 200 mm/yr). Zero mass balance at the ELA might be maintained by large sublimation.

P. 3644 lines 20 to 25: It is interesting that you adjustment ratios less than unity in some parts of your region. Braithwaite et al. (2002) compared "glacier precipitation" with precipitation from a gridded climatology ("regional precipitation") and found ratios of about 2 to 2.5 for many regions, but the ratio was closer to 1:1 for the Alps. Braithwaite et al (2002) suggested that the Alpine part of the climate dataset contained relatively higher-lying stations than other parts of the dataset. Could that be true of the regions where you find a lower adjustment ratio?

The reason of adjustment ratios with less than unity in some region would be

1) Fewer stations for observing climate dataset in High altitude

Monsoon-influenced Asian regions do not have so many stations as shown in Fig. 1 of Yatagai et al., (2012).

2) Precipitation decrease with altitude upper than about 4000 m a.s.l. in Himalayas, which is discussed in section 4.3)

3) We guess if we calculate precipitation for zero mass balance at ELA using ERA-Interim,

the grid with adjustment ratios with less than unity would be getting less, since solar radiation has been over estimated in NCEP/NCAR (Fig. S6 (b)).

P. 3645 line 27: You probably mean < 1 km2 here?

Thank you for your comment. This is our mistake. We will revise it.

Pages 3647 to 3652 Reference list. I have checked your reference list and only missing item is Konto (1990).

Thank you for your attentive check. We will add Kondo (1990) in the reference list.

P. 3653: Nice map! Thank you!

P. 3654: To what do the coloured dots refer? Are these decade averages of observed ELA? On how many glaciers?

We will add the explanation of coloured dots, and number of glaciers.

P. 3657 Fig. 5: I cannot see much difference between these three maps. What about mapping (a) differences L-median minus G-median, and (b) W-median minus G-median?

There is no figure on distribution of median elevation. So, we will show a) as it is (G-median elevation), and (b) differences of L-median minus G-median and (c) W-median minus G-median in the revision.

P. 3658 Fig. 6: It is interesting (and important) that (a) misses the high precipitation in SE High Mountain Asia.

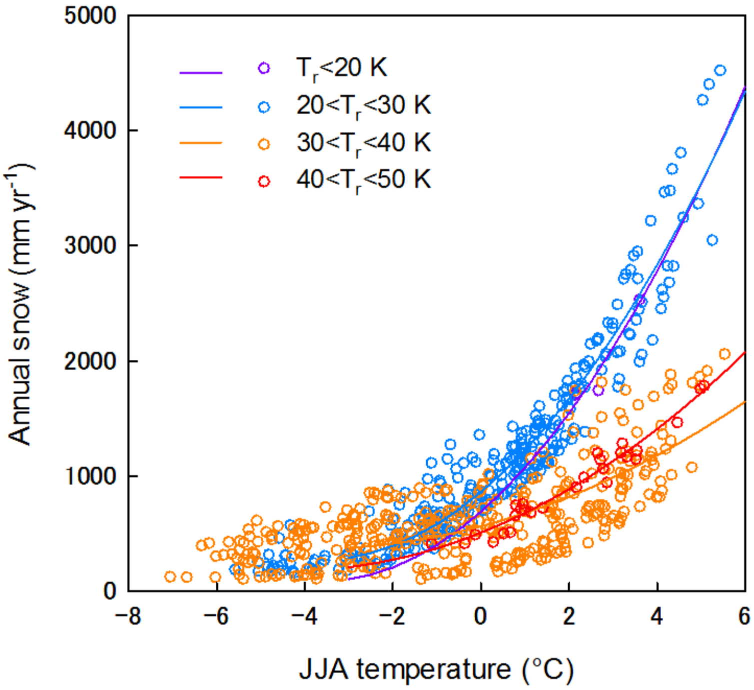
APHRODITE precipitation data products are based on the ground data taken at mainly flat, low altitude regions. We will add them in the discussion section in 4.2.1.

P. 3660 Fig. 8: Note that Figure 5 in Braithwaite et al (2008) shows how the Ohmura dataset can be split into high- and low-accumulation situations using annual temperature range.

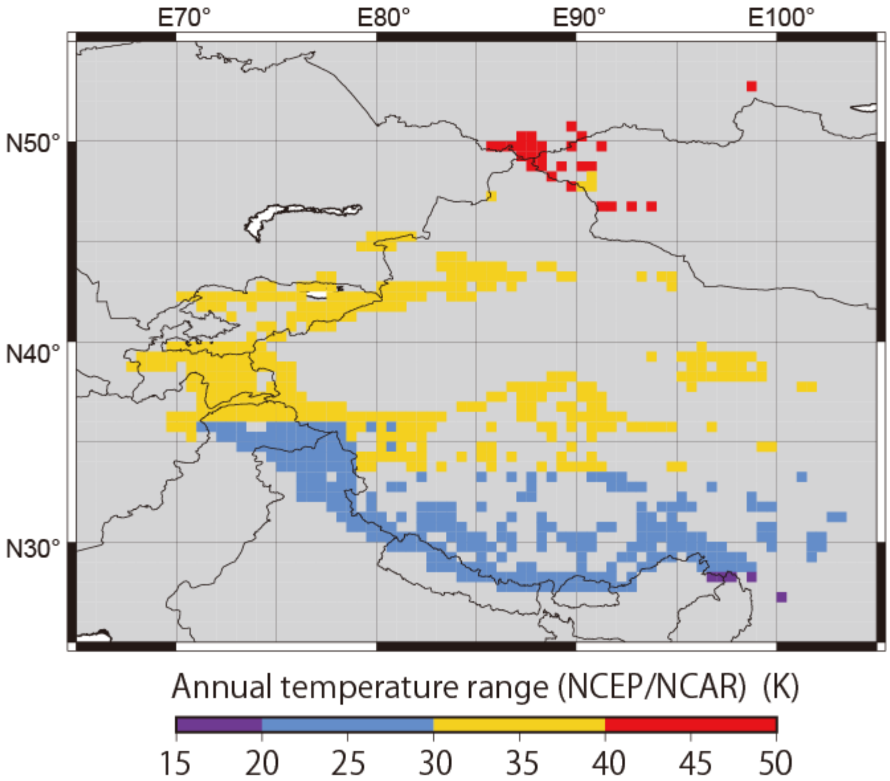
Thank you for your comments. We are also interested in annual temperature range (T_r), but we did not analyze it in the first manuscript.

We will change the input meteorological data from NCEP/NCAR to ERA-Interim in the revised version. We have not finished our calculation using ERA-Interim yet. Below figures made from result calculated using NCEP/NCAR. So, in the revised manuscript, those figures might change a little bit, but, we believe main result will not change much.

We have made a figure, showing the relationship between summer temperature and snow. We classified plots depending on the annual temperature ranges. The relation can be clearly separated by 30 K of T_r. But, plots with T_r<30 K cannot separate clearly between T_r<20 K and 20<T_r<30 K. In the same way, plots with T_r>30 K cannot separate clearly between 30<T_r<40 K and 40<T_r<50 K. The reason would be that those plots have different PDDs in the same annual temperature range.



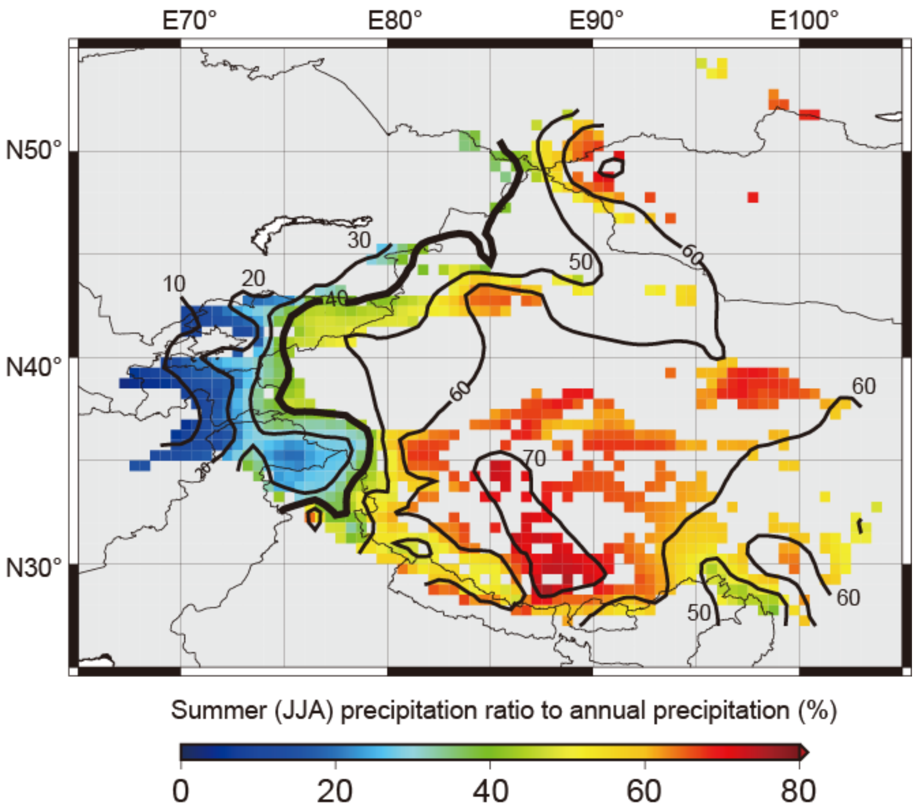
T_r: Annual temperature range



P. 3661 Figure 9: Very good! Do you discuss why you use 40% summer precipitation and not 25% or 50 %?

As we wrote in the first manuscript, "Hengduan Shan, Bhutan, Everest, and West Nepal are strongly influenced by the Indian and Southeast Asian summer monsoons, and glaciers are summer-accumulation type glaciers (SAG). On the other hand, the climate in Pamir, Hindu Kush, and Karakoram are dominated by the westerlies, and glaciers there are winter-accumulation type glaciers (WAG). Himachal Pradesh and Jammu Kashmir (included in the W Himalaya in Fig. 1) are in transition zones, influenced by both the monsoon and the westerlies (Bookhagen and Burbank, 2010)"

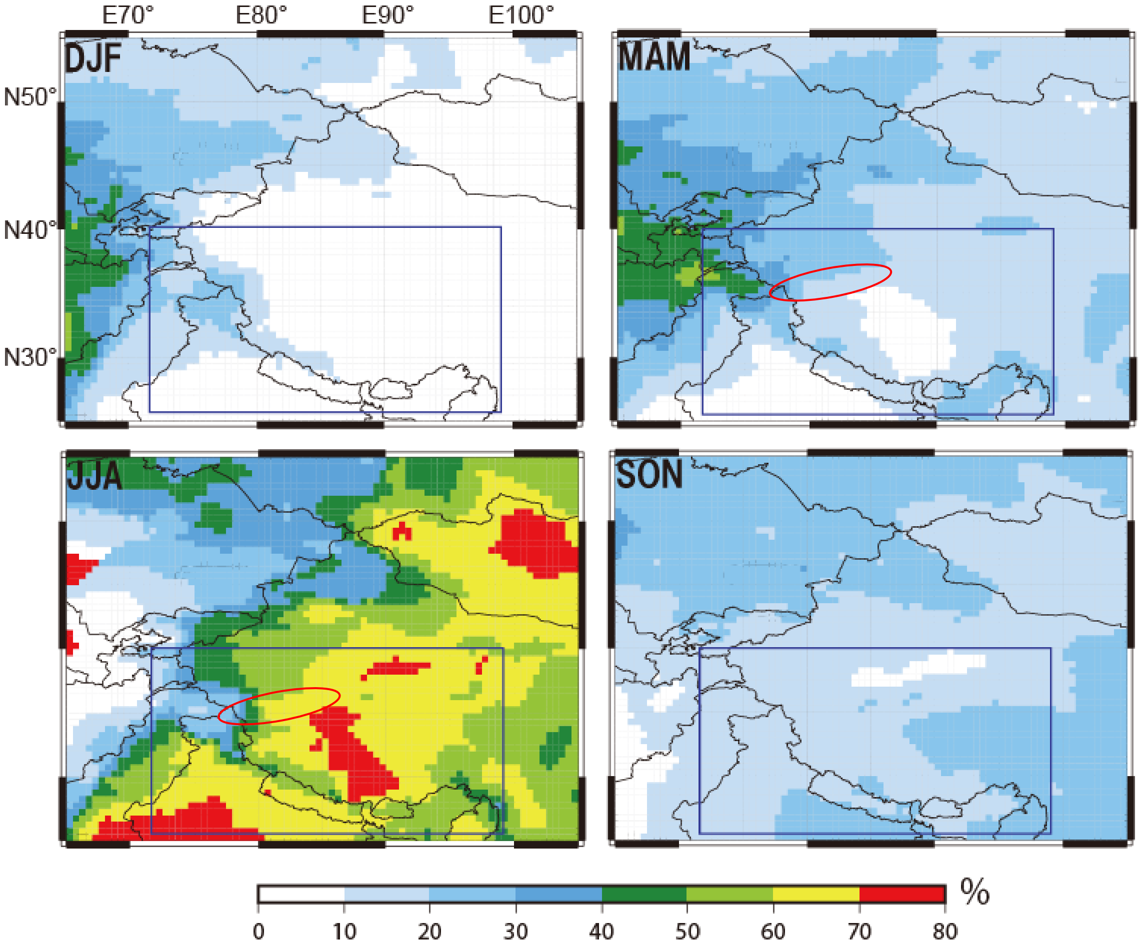
Below figure shows that if we divide SAG and WAG by 25% of summer precipitation ratio, Glaciers in the Karakoram also classified into SAG. If we divide SAG and WAG by 50% of summer precipitation ratio, glaciers in the Hengduan Shan are classified into WAG. These classification would not correspond with previous studies. We will add contour lines with interval of 20% in Fig. 9 in the revision.



P. 3662 Figure 10: Interesting! Thank you!

P. 3663 Figure 11: Please confirm that there are some places where adjustment ratio can be 15 to 20 times.

In accordance with your comment, there is grids, which have high (15-20) adjustment ratio (P_w) in the East Kunlun. Fig. 1 of Yatagai et al. (2012) shows that there are very few rain gauge stations in the Kunlun region. Below figure shows that precipitation in the Kunlun region has much JJA precipitation in APHRODITE data. But, MAM (spring) precipitation might be large in the Kunlun (red ellipse in the below figure) as presented by Massion et al. (2014) (Fig. 8) based on a regional model. Relatively large amount of JJA precipitation would be liquid precipitation, which should not contribute to glacier mass balance. Then, P_{cal} for zero mass balance at ELA in the west Kunlun might be excessively large.



Contribution of DJF, MAM, JJA, and SON to the APHRO-DITE mean annual precipitation from 1970 to 2007

Purple rectangle is the target area of HAR (Maussion et al., 2014).

This figure has almost same color scale with Fig 8 in Maussion et al., (2014).

References

Maussion, F., Scherer, D., Mölg, T., Collier, E., Curio, J., and Finkelnburg, R.: Precipitation seasonality and variability over the Tibetan Plateau as resolved by the High Asia Reanalysis, J. Climate, 27, 1910–1927, doi:10.1175/JCLI-D-13-00282.1, 2014.

Yatagai, A., Kamiguchi, K., Arakawa, O., Hamada, A., Yasutomi, N., and Kitoh, A.: APHRODITE: constructing a long-term daily gridded precipitation dataset for Asia based on a dense network of rain gauges, B. Am. Meteorol. Soc., 93, 1401–1415, doi:10.1175/BAMS-D-11-00122.1, 2012.