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Interactive comment on "Long-range terrestrial laser scanning measurements of summer and annual mass balances for Urumqi Glacier No. 1, eastern Tien Shan, China" *by* Chunhai Xu et al.

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We'd like to thank the referee for the valuable, constructive and detailed comments which certainly helped to improve the manuscript. The corresponding changes and refinements have been made in the revised paper (track changes was used in order to be easily identified) and are also summarized in our reply below. Reviewer comments in normal font, our reply to each comment is provided after the comment and given in bold font.

Reply to comments from anonymous referee 1

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Discussion paper

Chunhai Xu and colleagues present a detailed reanalysis of annual and seasonal glaciological and geodetic balances at Urumqi Glacier No. 1, eastern Tien Shan, China, obtained between 2015 and 2017. This study puts a terrestrial laser scanner (TLS) dataset with high spatial and temporal resolution over the period of record at its value. The comparisons of geodetic results with the glaciological balances from an in-situ network are carried out in a thorough way and include an error assessment according to international practises. The authors mentioned two publications using similar methods (Xu, C., Li, Z., Wang, F., Li, H., Wang, W., Wang, L. (2017), doi:10.1017/jog.2017.45 and Xu, C., Li, Z., Wang, P., Anjum, MN., Li, H., Wang, F. (2018), doi:10.1016/j.coldregions.2018.08.006), which can be seen as preliminary studies to the proposed manuscript. Hence, the discussion paper has been cross-read with the mentioned publications in terms of basic quality issues concerning significance, originality and novelty of the study. Reading the papers, I had the impression that many sections are redundant. Besides the Introduction and Study site sections, the "Data and Methods" and "Uncertainty" chapters also seem to be similar, show no new insights and could at least be omitted by referencing. Furthermore, the Conclusions have redundant elements to the other two studies. Working through the manuscript new information is only provided by i) altering the temporal scale, ii) introducing an approach of density conversion and iii) the consideration of internal processes when comparing the two methods. Although the authors state that they implement a detailed comparison between glaciological and geodetic mass balances at seasonal and annual scales and assess the potential of a novel long-range TLS to monitor glacier mass balance, the obvious redundancy puts the manuscript on the fringe of acceptance. Weighing up these points, I think that the new information provided in this Discussion paper is not sufficient or suitable for publication.

Reply: Thanks for the careful reading! As a matter of fact, the scientific achievements of three publications are totally different. The achievements of the first published paper (2017 in Journal of Glaciology) are to evaluate accuracy and precision of glacier surface elevation changes retrieved from long-range terrestrial laser scanner (TLS), and

to test applicability of such TLS to monitor the mass balance of Urumqi Glacier No.1. Whether agreement between the glaciological and TLS-derived glacier-wide mass balance was pending, potential of such technology applied in seasonal and annual glacier mass-balance measurements in western China had not been assessed. The second publication (2018 in Cold Regions Science and Technology) presents a comparison between cumulative direct glaciological and geodetic mass balance data from 1981 to 2015 for Urumqi Glacier No. 1, so the achievements of the paper are to reanalyze the glaciological mass balance series. In order to achieve the achievements, we try to define the source of the observed uncertainties in glaciological and geodetic methods, and the extent of the mass balances influenced by the different DEMs used, the existing snow cover, the reference area and processes of internal accumulation and ablation.

At present, comparison of glaciological and geodetic mass balances mainly focuses on sub-decadal to decadal scales as the available DEMs usually limit the spatiotemporal resolution of geodetic mass-balance measurements, while seasonal and annual scales have received little attention. This paper uses a long-range TLS to monitor the summer and annual mass balance of Urumqi Glacier No.1 (UG1) as well as delineating accurate glacier boundaries for two consecutive years (2015-17), and discusses the potential of such technology in glaciological applications. Hence, the scientific achievements (aims) of the present study are: (1) to describe the original use of Riegl VZ®-6000 TLS-derived DEMs to calculate summer and annual geodetic mass balances of UG1 for two consecutive years (2015-17); (2) to consider three-dimensional (3-D) changes of ice and firn/snow bodies and density conversion from in situ measured snow/firn densities is applied to make these calculations. Firn compaction and metamorphosis can be therefore captured to some extent; (3) to compare the geodetic results to glaciological glacier-wide mass balances through a detailed uncertainty assessment of the glaciological and geodetic methods; (4) to discuss how to achieve good quality of point cloud data and DEM differencing and to analyze the possible cause of the difference

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Discussion paper

between the two methods; and (5) to take UG1 as a case to assess the potential of such long-range TLS to measure glacier mass balance at the seasonal and annual scales and put forward some main considerations for a broader application of the TLS.

I agree that some chapters of the three publications seem to be similar, especially for "Study site" and "Data and methodology". However, the introduction of the presented study is substantially different from the two others as the different aims of each paper. In the section of Data and methodology, the descriptions of TLS and its data processing (subsection 3.1) as well as Uncertainty assessments (section 4) are more detailed and perfect than past studies, so we have not simply cited the two published papers. The methods of glaciological and geodetic mass balance calculations have been widely used for many publications, especially for a conceptual framework proposed by Zemp et al (2013). Hence we also directly referred the conceptual framework although the contents seem to be similar to our previous papers. Besides introducing an approach of density conversion at seasonal and annual scales, the present study also describes the delineation of accurate glacier boundary of Urumqi Glacier No.1, which updates and corrects previous published boundary (e.g. Wang et al., 2016; Xu et al., 2017). In addition, we implement a detailed comparison between direct glaciological and TLS-derived geodetic mass balance, including glacier-wide mass balances and mass balance elevation distributions derived from the two methods. In section 6, the discussion of data quality and DEM differencing is more in-depth than the first published paper. In the revised manuscript, we added new information to discuss the potential of the long-range TLS, including: 1) advantages and disadvantages between the long-range TLS and other technologies; 2) how to deal with data voids in future application of such TLS; 3) how to reduce the uncertainty of seasonal and annual density; and 4) application of TLS-derived geodetic results to validate the distributed mass-balance model. We hope the revised manuscript is suitable for publication.

With best regards, Chunhai Xu et al.

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