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A FIRST ATTEMPT TO MODEL REGION-WIDE GLACIER SURFACE MASS BALANCES IN THE KARAKORAM: FINDINGS AND FUTURE CHALLENGES

ABSTRACT: GROOS A.R., MAYER C., SMIRAGLIA C., DIOLAIUTI G., LAMBRECHT A., *A first attempt to model region-wide glacier surface mass balances in the Karakoram: findings and future challenges.* (IT ISSN 0391-9838, 2017).

In contrast to the central and eastern part of High Mountain Asia (HMA), no extensive glacier mass loss has been observed in the Karakoram during previous decades. However, the potential meteorological and glaciological causes of the so-called Karakoram Anomaly are diverse and still under debate. This paper introduces and presents a novel glacier Surface Mass Balance Model (glacierSMBM) to test whether the characteristic regional mass balance pattern can be reproduced using recent field, remote-sensing and reanalysis data as input. A major advantage of the model setup is the implementation of the non-linear effect of supra-glacial debris on the sub-surface ice melt. In addition to a first assessment of the annual surface mass balance from 1st August 2010 until 31st July 2011, a sensitivity analysis was performed to investigate the response of Karakoram glaciers to recent climate change. The mean modelled glacier mass balance for the Karakoram during the observation period is -0.92 m water equivalent (w.e.) a^{-1} and corresponds to an annual melt water contribution of ~12.66 km^3. Data inaccuracies and the neglected process of snow redistribution from adjacent slopes are probably responsible for the bias in the model output. Despite the general offset between mass gain and mass loss, the model captures the characteristic features of the anomaly and indicates that positive glacier mass balances are mainly restricted to the central and northeastern part of the mountain range. From the evaluation of the sensitivity analysis, it can be concluded that the complex glacier response in the Karakoram is not the result of a single driver, but related to a variety of regional peculiarities such as the favourable meteorological conditions, the extensive supra-glacial debris and the timing of the main precipitation season.

KEY WORDS: Glacier surface mass balance modelling, Debris-covered glaciers, Ice and snow ablation, Karakoram Anomaly.

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Supplementary material as well as all figures and tables presented in this article are stored in the open access library PANGAEA (Groos & alii, 2017). The input raster data as well as the model results are available upon request by email to the first author (alexander.groos@giub.unibe.ch). For the download of the model, please access CRAN - the Comprehensive R Archive Network: https://CRAN.R-project.org/package=glacierSMBM.

INTRODUCTION

The Karakoram in the northwestern part of High Mountain Asia (HMA) is one of the most extensively glacierised areas outside the polar regions (Dyurgerov & Meier, 2005) and has increasingly attracted attention in recent years due to its glaciological and climatological peculiarities. In contrast to the central and eastern Himalaya, where many glaciers have responded to global climate change in the form of ice mass loss and negative length or area changes (e.g. Bolch & *alii*, 2011; Cogley, 2011; Bolch & *alii*, 2012; Kääb & *alii*, 2012; Cogley, 2016), expansion of individual glaciers has repeatedly been reported from the Karakoram based on in-situ and remote sensing observations (Hewitt, 2005; Hewitt, 2011; Rankl & *alii*, 2014). Several satellite-based geodetic measurements provide evidence that the glacial stability, known as Karakoram Anomaly (Hewitt, 2005), is indeed a regional phenomenon dating back to the 1970s (e.g. Gardelle & *alii*, 2012, 2013; Kääb & *alii*, 2015; Rankl & Braun, 2016; Agarwal & *alii*, 2017; Bolch & *alii*, 2017; Zhou & *alii*, 2017). Investigations