



Inferring glacier meteorology with physical modeling and remote sensing

Shaoting Ren^{1,2}, Evan S. Miles^{2,3,4}, Michael McCarthy^{1,2}, Achille Jouberton^{1,2,5}, Thomas E. Shaw¹, Pascal Buri⁶, Marin Kneib^{7,8}, Prateek Gantayat¹, and Francesca Pellicciotti¹

¹Institute of Science and Technology Austria (ISTA), Klosterneuburg, Austria (shaoting.ren@ist.ac.at)

²Swiss Federal Institute for Forest, Snow and Landscape Research (WSL), Birmensdorf, Switzerland

³Institute of Geography, University of Zurich, Zurich, Switzerland

⁴Department of Geosciences, University of Fribourg, Switzerland

⁵Institute of Environmental Engineering, ETH Zurich, Zurich, Switzerland

⁶Geophysical Institute, University of Alaska Fairbanks, Fairbanks, USA

⁷Institut des Géosciences de l'Environnement, Université Grenoble-Alpes, CNRS, IRD, Grenoble, France

⁸Department of Atmospheric and Cryospheric Sciences, University of Innsbruck, Innsbruck, Austria

Meteorology is crucial to understand the rapid response of mountain glaciers to climate warming, but is often challenging to observe and simulate due to site inaccessibility, instrument maintenance and the complex interactions between glaciers and their surroundings. Recent, high-resolution, globally-available remote sensing observations create an opportunity to exploit the observed changes in glacier volumes and surface properties to infer bias-corrected high-mountain meteorology from climate reanalysis. In this study, we develop a unified method for model inversion based on Monte Carlo simulation and Bayesian inference, and then evaluate it on four benchmark glaciers with extensive in-situ measurements of surface meteorology (Argentière Glacier and Aletsch Glacier in the European Alps, Abramov Glacier and Parlung No.4 Glacier in High Mountain Asia).

Our approach is a multiparameter optimization that uses a physical-based land-surface model (*Tethys-Chloris*) driven by an ensemble of statistically-downscaled ERA5-Land reanalysis datasets, with remote-sensing-derived glacier surface mass balance and glacier albedo as targets. With this method, we obtain the bias of air temperature, precipitation and incoming shortwave radiation to correct the reanalysis data during the period 2015-2019 at the four sites. The results show that the derived multiyear meteorology is spatially variable over the glaciers and agrees with independent in-situ observations at each site. The good performance of this method in different climatic conditions paves the way to derive multiyear glacier meteorology on the world's mountain glaciers and constrain globally a key control on their response to climate change.