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Interactively-coupled simulations of alpine climate and glacier surface mass balance in the Karakoram

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To date, simulations of the surface mass balance of alpine glaciers that employ forcing from a numerical atmospheric model have been performed in an offline manner. However, this approach does not permit feedbacks between the ice/snow surface, the glacier surface boundary layer and the overlying mesoscale circulation. Offline simulations also produce an inconsistent calculation of the turbulent fluxes of heat and moisture over a glacier surface as the forcing variables (near surface winds, temperature, moisture) are themselves modified by these fluxes.

Here we present a new approach to resolving atmosphere-cryosphere interactions, through the use of an interactively-coupled modelling system composed of the Advanced Research version of the Weather Research and Forecasting (WRF) v3.4 atmospheric model and the process-based surface mass balance model of Mölg et al. (2008, 2009). Over glaciated areas, the surface mass balance model updates relevant fields in the atmospheric model, such as surface heat and moisture fluxes, snow depth, surface albedo and roughness, and subsurface temperature. WRF is configured with three nested domains of increasingly-fine spatial resolution (down to 2.2 km) that permits us to build on the approach of Mölg and Kaser (2011) by performing spatially-distributed simulations of surface mass balance without the need for traditional statistical methods, such as extrapolation from point measurements by automated weather stations or interpolation from coarse resolution data using surface and free air lapse rates. Comparison of interactive versus offline simulations reveals that coupling has a non-negligible influence on the near-surface atmospheric conditions and simulated surface mass balance, and may improve the simulation of certain phenomena, such as the diurnal temperature cycle.

We apply the coupled modelling system over the Karakoram region of the northwestern Himalaya with the aim of elucidating the influence of recent climatic variations on the surface mass balance signal of Karakoram glaciers, which are estimated to contain ~1200 to 4000 km3 of ice and to cover approximately 18,000 km2 (Bolch et al. 2012). Understanding the response of glaciers in this region to recent and future climate change is essential for assessing freshwater availability in the river systems that support the heavily-populated region of South Asia.