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Explaining the mechanisms through which regional atmospheric circulation variability drives summer temperatures and glacial melt in western High Mountain Asia (HMA)

Nathan Forsythe, Hayley Fowler, Stephen Blenkinsop, Xiaofeng Li, and David Pritchard
Newcastle University, School of Civil Engineering and Geosciences, Newcastle upon Tyne, United Kingdom (h.j.fowler@ncl.ac.uk)

Comprehension of mechanisms by which atmospheric circulation influences sub-regional temperature and water resources variability in high-elevation mountainous catchments is of great scientific urgency due to the dependency of large downstream populations on the river flows these basins provide. In this work we quantify a regional atmospheric pattern, the Karakoram Zonal Shear (KZS), with a very pronounced annual cycle which we standardise into a dimensionless (seasonal) circulation metric the Karakoram Zonal Index (KZI). Going beyond previous regional circulation metrics such as the "middle-upper tropospheric temperature index" (MUTTI) or the Webster and Yang Monsoonal Index (WYMI) which have focused solely on the South Asian Summer Monsoon (June to September) season, the KZS/KZI provides an indicator which captures the influence and interactions of the westerly jet throughout the entire annual cycle. Use of the KZS and KZI have led us to identify a further regional atmospheric system, the Karakoram Vortex, which propagates "warm high" (anticyclonic postitive temperature anomaly) and "cold low" (cyclonic negative temperature anomaly) patterns across a very broad swath of Central and South Asia in winter but over a much more constrained area of western HMA in summer. The KV exerts this temperature influence through a combination of adiabatic effects and large-scale advection. Quantify KV influence, the KZI shows strong and statistically significantly near surface (2m) air temperatures both across western HMA both as observed through local meteorological stations and as estimated by an ensemble of global meteorological reanalyses. We show that this strong influence on temperature translates to important consequences for meltwater generation from highly glaciated Indus river tributaries which is logical given that previous studies have established the role of air temperature in modulating glacially-derived river flows in western HMA. By improving the understanding of large-scale circulation influences on sub-regional conditions in terms of their sign, strength and the mechanisms through which it acts, the KV/KZI work substantively advances climate science in this domain. The work also thus provides a new set of criteria for assessing the skill of global circulation models in representation of western HMA climate processes.