Current and future precipitation in the Karakoram-Himalaya and the role of western weather patterns

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In the Karakoram mountain range and the upper Indus basin in Pakistan, precipitation takes place mainly in winter and it is associated with the arrival of western weather patterns (WWP) originating from the Mediterranean and the Atlantic regions. Owing to this circulation, Karakoram glaciers receive their water input in winter, mainly in the form of snow, and melt in summer, quite differently from the monsoon-controlled dynamics in the eastern stretches of the Himalayas.

As WWPs originate from the north-eastern Atlantic and the Mediterranean, the North Atlantic Oscillation (NAO), which strongly affects the climate of the North Atlantic and European sectors especially during boreal winter (see for example [1]), has been identified as an important regulating factor for precipitation also in the Karakoram region (e.g., [2], [3]). In particular, previous studies indicated that above than normal precipitation occurs in the Karakoram region during the positive NAO phase.

In this work we further explore the relationship between the NAO and winter precipitation in the Karakoram, by analysing the extent to which the NAO affects the mechanisms of moisture transport from the main moisture reservoirs to northern Pakistan. To this aim, we use an ensemble of precipitation datasets, including three gridded archives based on the interpolation of in-situ rain gauge measurements and satellite observations, and reanalysis data. We propose a mechanism by which the intensified moisture transport during the positive NAO phase toward the Karakoram occurs as an effect of the intensification of lower tropospheric circulation and of evaporation from the main moisture sources, namely the Red Sea, the Persian Gulf, the northern Arabian Sea and, to a lesser extent, the Mediterranean. The extra moisture that accumulates over northern Pakistan and northern India during the positive NAO phase is picked up by WWPs, giving rise to precipitation as they reach the Karakoram slopes.

In this study we also analyse the properties of precipitation in the whole Hindu-Kush Karakoram Himalaya (HKKH) region by comparing the western and eastern stretches of the mountain arc as a whole, using currently available data sets ([4]). We consider again satellite rainfall estimates, reanalyses, observation-based gridded datasets, and a merged satellite and rain gauge climatology. The data from the various archives are compared with simulation results from a number of global climate models included in the World Climate Research Programme (WRCP) Coupled Model Intercomparison Project phase 5 (CMIP5) ensemble and in particular with the EC-Earth model, run at ISAC-CNR.

All observation-based and reanalysis data sets, despite having different features and resolutions, coherently reproduce the mean annual cycle and seasonality of precipitation in terms of spatial averages over the western and eastern subregions of the HKKH. In particular, while for the Himalaya only a strong summer precipitation signal is present, associated with the Indian monsoon activity, the data indicate that the Karakoram, which is exposed to midlatitude westerlies, receives water inputs in winter ([4]).

None of the data sets gives statistically significant precipitation trends in the Karakoram during winter, at variance with what rainfall data from various rain gauge stations spread over northern Pakistan indicate as the general precipitation trend over the last decades in that area (e.g., [5,6]). The longest observational data sets employed here, on the other hand, indicate a statistically significant decreasing trend in summer monsoon precipitation in Himalaya ([4]).

Precipitation data from EC-Earth and in general from the other CMIP5 GCMs are in good agreement with the climatology of the observations (rainfall distribution and seasonality). The evolution of precipitation under two different future scenarios (RCP 4.5 and RCP 8.5) reveals a clear increasing precipitation trend over the Himalaya during summer, probably associated with an increase in wet extremes and daily intensity and a decrease in the number of rainy days, as indicated by the analysis of the EC-Earth daily precipitation output. These are all signatures of the effect, observed globally, of increasing temperatures on the hydrologic cycle (e.g. [7]).

Unlike the observations, some GCMs show an increasing trend of summer precipitation in the Himalaya also in the historical period (1901–2005), while other GCMs are able to consistently reproduce the observed precipitation trend. These differences possibly arise from the way in which aerosols are incorporated in the models, and from whether their indirect effects on clouds and their feedbacks on the climate system are accounted for in the simulations or not. Further and deeper analysis on the representation in the global models of the current and future precipitation climatology and trends in the Karakoram and Himalaya, and in particular on the combined roles of aerosols and rising temperatures in affecting both monsoon circulation and western weather patterns are subject of ongoing and future investigations.

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