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Analyses of temperature and precipitation in the Indian Jammu and Kashmir region for the 1980–2016 period: implications for remote influence and extreme events

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Abstract. The local weather and climate of the Himalayas are sensitive and interlinked with global-scale changes in climate, as the hydrology of this region is mainly governed by snow and glaciers. There are clear and strong indicators of climate change reported for the Himalayas, particularly the Jammu and Kashmir region situated in the western Himalayas. In this study, using observational data, detailed characteristics of long- and short-term as well as localized variations in temperature and precipitation are analyzed for these six meteorological stations, namely, Gulmarg, Pahalgam, Kokarnag, Qazigund, Kupwara and Srinagar during 1980–2016. All of these stations are located in Jammu and Kashmir, India. In addition to analysis of stations observations, we also utilized the dynamical downscaled simulations of WRF model and ERA-Interim (ERA-I) data for the study period. The annual and seasonal temperature and precipitation changes were analyzed by carrying out Mann–Kendall, linear regression, cumulative deviation and Student's t statistical tests. The results show an increase of 0.8 °C in average annual temperature over 37 years (from 1980 to 2016) with higher increase in maximum temperature (0.97 °C) compared to minimum temperature (0.76 °C). Analyses of annual mean temperature at all the stations reveal that the high-altitude stations of Pahalgam (1.13 °C) and Gulmarg (1.04 °C) exhibit a steep increase and statistically significant trends. The overall precipitation and temperature patterns in the valley show significant decreases and increases in the annual rainfall and temperature respectively. Seasonal analyses show significant increasing trends in the winter and spring temperatures at all stations, with prominent decreases in spring precipitation. In the present study, the observed long-term trends in temperature (°C $year^{-1}$) and precipitation (mm $year^{-1}$) along with their respective standard errors during 1980–2016 are as follows: (i) 0.05 (0.01) and −16.7 (6.3) for Gulmarg, (ii) 0.04 (0.01) and −6.6 (2.9) for Srinagar, (iii) 0.04 (0.01) and −0.69 (4.79) for Kokarnag, (iv) 0.04 (0.01) and −0.13 (3.95) for Pahalgam, (v) 0.034 (0.01) and −5.5 (3.6) for Kupwara, and (vi) 0.01 (0.01) and −7.96 (4.5) for Qazigund. The present study also reveals that variation in temperature and precipitation during winter (December–March) has a close association with the North Atlantic Oscillation (NAO). Further, the observed temperature data (monthly averaged data for 1980–2016) at all the stations show a good correlation of 0.86 with the results of WRF and therefore the model downscaled simulations are considered a valid scientific tool for the studies of climate change in this region. Though the correlation between WRF model and observed precipitation is significantly strong, the WRF model significantly underestimates the rainfall amount, which necessitates the need for the sensitivity study of the model using the various microphysical parameterization schemes. The potential vorticities in the upper troposphere are obtained from ERA-I over the Jammu and Kashmir region and indicate that the extreme weather event of September 2014 occurred due to breaking of intense atmospheric Rossby wave activity over Kashmir. As the wave could transport a large amount of water vapor from both the Bay of Bengal and Arabian Sea and dump them over the Kashmir region through wave breaking, it probably resulted in the historical devastating flooding of the whole Kashmir