CHANGING CLIMATE OF THE HIMALAYA–TIBETAN HIGHLAND AND ITS ASSOCIATION WITH THE CLIMATE OF INDIA

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Abstract

The present state of the planet, with the rapid changing of climate, and global warming becoming more apparent around the world, is one of the most worrying concerns the mankind has today. One of the most sensitive and vulnerable regions to the climate change is the Himalaya–Tibetan Highland (HTH), a huge and unique landform on the Earth, situated adjacent to India. This landform influences the climate system in many ways: dynamically due to elevation and thermodynamically due to its temperature contrast with the surrounding atmosphere; locally through sensible and latent heat fluxes into the atmosphere and remotely through the transport of water via its rivers. Thus, it is desirable to understand its changing climate and its association with the climate of India, which is the focus of this thesis.

This research is carried out using observations, reanalyses and modelling studies with the primary focus on the atmospheric component of the climate system. The observed daily surface air temperature and precipitation at 0.25° resolution are analysed from APHRODITE for the period 1961–2007 to understand the past and present climate of the region. For the future climate projection, a set of twenty-one CMIP5 and NEX-GDDP models are validated for the historical period, which suggests that NEX-GDDP is much superior to the CMIP5 data over this region. Thus, for the future projection the NEX-GDDP data from the same set of models are used for the period of 2006–2099 under the RCP 8.5 scenario. In addition, questions concerning causation have been addressed through numerical experiments using NCAR CESM-CAM5, a global climate model. The numerical experiments are conducted at 1° horizontal resolution. To examination the effectiveness of a mitigation strategy — geoengineering — to counteract the warming of the climate of HTH, piControl, 4xCO2 and G1 simulations from eight global climate models participating in the Geoengineering Model Intercomparison Project are analysed.
Observations from APHRODITE show that the HTH region has undergone significant warming (~3–4 °C) during 1961–2007. The warming is more widespread and severe in fall and winter than in summer and spring. The warming is spatially heterogeneous, and an unusual localised but considerable cooling (~2 °C from 1961 to 2007) has occurred over the southeast HTH. The precipitation has changed marginally with insignificant changes over most of the HTH. The monsoon precipitation has decreased over the southern parts (wet parts) and increased over northern parts (dry parts) of the HTH, which could adversely affect the surrounding regions by influencing their regional climate and water supply, and hence there is a need for reliable future projections of the HTH climate. We validated CMIP5 and NEX-GDDP against APHRODITE and found the latter more accurate. Future climate projections under RCP8.5 using NEX-GDDP suggest widespread warming (~5–8 °C) and increase in monsoon and post-monsoon precipitation (up to ~50%) over HTH by the end of the twenty-first century. This suggests that the HTH is highly sensitive and vulnerable to climate change.

To understand the influence of HTH and its changing climate on the climate of India, two sets of numerical experiments are conducted, one to investigate the effects of orographic height, and second to unravel effects of the changes of surface temperature over HTH on the Indian climate. The investigation makes it clear that, in the absence of the orographic effects of the HTH, precipitation over India, HTH, and northern Arabian Sea (AS) would reduce but enhance over the southern AS; Evaporation would marginally reduce over the northern AS and northern Bay of Bengal but enhance over the southern AS; Somali Jet (SJ) would severely (25–30%) weaken and marginally displaced southward which would reduce the large scale moisture convergence and in turn reduce the precipitation over India. Like SJ, the TEJ would also severely (25–30%) weaken and marginally displaced which is coupled with the low level circulation. This also weaken the strength of the Monsoon trough and in turn the strength of Monsoon rainfall over-there. The second set numerical experiments unravels that the decrease
in precipitation over the peninsular India and the increase over the northern India over the last century is partly due to the warming of the Indian Land but not due to the warming of the HTH. Moreover, the weakening of the SJ over the peninsular India some extent due to the warming of the Indian Land but not due to the warming of the HTH which indeed would do the opposite. The investigation further suggests that unlike the topographic effects, surface temperature of HTH does not play any such influential role in the structure and strength of the TEJ.

In order to examine the effectiveness of a mitigation strategy — geoengineering of climate — to counteract the warming climate of HTH, temperature and precipitation are examined from the piControl, 4xCO2 and G1 simulations from eight global climate models participating in the Geoengineering Model Intercomparison Project. It is observed that, higher CO2 would lead to an increase of 7–9 °C over the region, with relatively stronger warming in the winter season. Geoengineering can successfully and significantly counteract the CO2 induced warming over most parts of the region. Higher CO2 would also lead to more precipitation (upto 10–15%) over most parts of this region, with some reduction over the southern and western peripheries. Although Geoengineering would nullify most of these effects, it will marginally overdry during the monsoon season. Amplitude of the annual cycle of temperature as well as precipitation would increase in the higher CO2 world, which would marginally reduce under the geoengineering due to the lesser residual warming and over-drying the summer monsoon season.