EGU21-8365
https://doi.org/10.5194/egusphere-egu21-8365
EGU General Assembly 2021

Climate change in the High Mountain Asia simulated with CMIP6 models

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The High Mountains of Asia (HMA) region and the Tibetan Plateau (TP), with an average altitude of 4000 m, are hosting the third largest reservoir of glaciers and snow after the two polar ice caps, and are at the origin of strong orographic precipitation. Climate studies over HMA are related to serious challenges concerning the exposure of human infrastructures to natural hazards and the water resources for agriculture, drinking water, and hydroelectricity to whom several hundred million inhabitants of the Indian subcontinent are depending. However, climate variables such as temperature, precipitation, and snow cover are poorly described by global climate models because their coarse resolution is not adapted to the rugged topography of this region. Since the first CMIP exercises, a cold model bias has been identified in this region, however, its attribution is not obvious and may be different from one model to another. Our study focuses on a multi-model comparison of the CMIP6 simulations used to investigate the climate variability in this area to answer the next questions: (1) are the biases in HMA reduced in the new generation of climate models? (2) Do the model biases impact the simulated climate trends? (3) What are the links between the model biases in temperature, precipitation, and snow cover extent? (4) Which climate trajectories can be projected in this area until 2100? An analysis of 27 models over 1979-2014 still show a cold bias in near-surface air temperature over the HMA and TP reaching an annual value of -2.0 °C (± 3.2 °C), associated with an over-extended relative snow cover extent of 53 % (± 62 %), and a relative excess of precipitation of 139 % (± 38 %), knowing that the precipitation biases are uncertain because of the undercatch of solid precipitation in observations. Model biases and trends do not show any clear links, suggesting that biased models should not be excluded in trend and projections analysis, although non-linear effects related to lagged snow cover feedbacks could be expected. On average over 2081-2100 with respect to 1995-2014, for the scenarios SSP126, SSP245, SSP370, and SSP585, the 9 available models shows respectively an increase in annual temperature of 1.9 °C (± 0.5 °C), 3.4 °C (± 0.7 °C), 5.2 °C (± 1.2 °C), and 6.6 °C (± 1.5 °C); a relative decrease in the snow cover extent of 10 % (± 4.1 %), 19 % (± 5 %), 29 % (± 8 %), and 35 % (± 9 %); and an increase in total precipitation of 9 % (± 5 %), 13 % (± 7 %), 19 % (± 11 %), and 27 % (± 13 %). Further analyses will be considered to investigate potential links between the biases at the surface and those at higher tropospheric levels as well as with the topography. The models based on high resolution do not perform better than the coarse-gridded ones, suggesting that the race to high resolution should be considered as a second priority after the developments of more realistic physical parameterizations.