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Investigating Cenozoic climate change in tectonically active regions with a high-resolution atmospheric general circulation model (ECHAM5)

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Studies of Cenozoic palaeo-climates contribute to our understanding of contemporary climate change by providing insight into analogues such as the Pliocene (PLIO), and by evaluation of GCM (General Circulation Models) performance using the Mid-Holocene (MH) and the Last Glacial Maximum (LGM). Furthermore, climate is a factor to be considered in the evolution of ecology, landscapes and mountains, and in the reconstruction of erosion histories. In this study, we use high-resolution (T159) ECHAM5 simulations to investigate pre-industrial (PI) and the the above mentioned palaeo-climates for four tectonically active regions: Alaska (St. Elias Range), the US Northwest Pacific (Cascade Range), western South America (Andes) and parts of Asia (Himalaya-Tibet). The PI climate simulation is an AMIP (Atmospheric Model Intercomparison Project) style ECHAM5 experiment, whereas MH and LGM simulation are based on simulations conducted at the Alfred Wegner Institute, Bremerhaven. Sea surface boundary conditions for MH were taken from coupled atmosphere-ocean model simulations (Wei and Lohmann, 2012; Zhang et al, 2013) and sea surface temperatures and sea ice concentration for the LGM are based on GLAMAP project reconstructions (Schäfer-Neth and Paul, 2003). Boundary conditions for the PLIO simulation are taken from the PRISM (Pliocene Research, Interpretation and Synoptic Mapping) project and the employed PLIO vegetation boundary condition is created by means of the transfer procedure for the PRISM vegetation reconstruction to the JSBACH plant functional types as described by Stepanek and Lohmann (2012). For each of the investigated areas and time slices, the regional simulated climates are described by means of cluster analyses based on the variability of precipitation, 2m air temperature and the intra-annual amplitude of the values. Results indicate the largest differences to a PI climate are observed for LGM and PLIO climates in the form of widespread cooling and warming respectively. A global PLIO warming and LGM cooling trend can be observed for most locations in the investigated areas, but the strength varies regionally. The trends in precipitation are less uniform in direction. LGM climate shows the largest deviation in annual precipitation from the PI climate, and shows enhanced precipitation in coastal regions and less precipitation farther inland for both Alaska and the US Northwest Pacific. The climate clusters in those regions are similar for all four time slices, but reveal a stronger northward (inland) drying gradient for the PLIO Alaskan climate. Precipitation is enhanced by ca. 100-200 mm/a in most of the Atacama desert in the PLIO climate. The climate clusters change most notably in the PLIO due to enhanced precipitation in northern Brazil and eastern Peru. During the MH and esp. LGM, the Indian subcontinent and much of Southeast is drier, resulting in the cluster-based categorization of their climates with the drier climate of low-altitude China. Furthermore, simulations show ca. 1000 mm/a less precipitation along the Himalayan orogen during the LGM and 500-800 mm/a more during the MH. Taken together, these results highlight significant changes in regional climatology over active orogens on time scales ranging from glacial cycles to geologic. As a result, the interpretation of paleo erosion rates in these areas from sediment flux inventories, cosmogenic radionuclides, or low-temperature thermochronology techniques warrant careful consideration of these changes.