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The Hadley and Walker circulations and changes of the hydrological cycle during the Holocene and Eemian from climate model simulations

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The intensity of large-scale atmospheric circulation patterns such as the Hadley and Walker circulation has been analyzed in simulations of warm paleoclimates representing the Eemian and Holocene. Variations of large-scale atmospheric circulation may have substantial consequences for the hydrological cycle. Hence, a thorough understanding of the possible mechanisms for large-scale atmospheric circulation changes during warm climates is needed for estimating the future hydrological changes under the influence of global warming. For that purpose, a coupled atmosphere-ocean general circulation model (Kiel Climate Model) was forced by changes in orbital parameters corresponding to the early Holocene (9.5kyr BP) and the Eemian (126kyr BP). Our model results show an intensification of the Southern Hemisphere (SH) winter Hadley cell and northward extension of its rising branch (the Intertropical Convergence Zone) for early Holocene and Eemian in comparison to preindustrial. Additionally, the location of the Walker circulation rising branch is shifted towards the Indian Ocean during early Holocene and Eemian. This effect is related to the intensified East Asian monsoon and associated westward shift of the Hawaiian High, which drives enhanced easterlies over the Indo-Pacific Warm Pool. The simulated vertically-integrated water vapor transport across the equator shows the strongest development of the SH winter Hadley cell over the Pacific Ocean during early Holocene and Eemian due to the wind-evaporation-sea surface temperature (SST) feedback (WES). This means that, during boreal summer, the orbitally-induced increase of cross-equatorial insolation gradient in the tropical Pacific drives southerly winds across the equator thereby strengthening (weakening) the wind speed and, as a result, evaporative cooling over the southern (northern) tropical Pacific leading to further amplification of the initial meridional SST gradient. Therefore, in KCM, the wind-evaporation-SST (WES) feedback is an important mechanism to intensify the Hadley circulation in response to orbital forcing. The WES feedback promotes a stronger inter-hemispheric asymmetry, leading to a weakening of the South Pacific Convergence Zone and to a strengthening of its northern counterpart during the early Holocene and Eemian.