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The vulnerability of water availability in Peru due to climate change: A probabilistic Budyko analysis

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This study provides for the-first-time a water availability analysis at drainage and basin-scale in Peru. Using new gridded datasets of precipitation and temperature, along with six global actual evapotranspiration estimations from remote sensing products, the vulnerability of water resources due to climate change is evaluated. This is addressed under a bottom-up approach and probabilistic Budyko framework that enables us to measure the associated uncertainty. First, to select an adequate estimation of long-term actual evapotranspiration, we compared at basin-scale the remote sensing products with long-term actual evapotranspiration inferred from a water-balance (precipitation minus discharge) and deterministic Budyko (aridity and evaporative index relationship). Later, the probabilistic Budyko is calibrated using the adequated remote-sensed actual evapotranspiration and is cross-validated at country, drainage, and basin-scale. Finally, the water availability vulnerability (measured as the relative change of precipitation minus actual evapotranspiration from historical estimates) and associated uncertainty is computed from the probabilistic Budyko along with climate spaces from variations of potential evapotranspiration (from temperature) and precipitation. The main results show that GLEAM, MEAN, and TerraClimate are the highest-ranked products in terms of estimation of long-term mean actual evapotranspiration across basins with low bias, RMSE, and high R. GLEAM and MEAN present lower bias and RMSE, and TerraClimate estimate very well the spatial distribution of actual evapotranspiration (highest-ranked R). On the contrary, Zhang, MODIS16, and SSEBop are less efficient based on most criteria evaluation. Therefore, as reference for actual evapotranspiration, we select MEAN which represents the linear averaging of remotely sensed products. From this perspective, we expect to minimize the negative bias and preserve the spatial resolution from individual actual evapotranspiration products. Achieved the three main long-term variables, we calibrate and cross-validate the probabilistic Budyko in terms of the evaporative index. The evidence suggests that the regional distribution of the Budyko parameter accomplishes errors of +-2% at the country and drainage-scale and +-9% as average at basin-scale. Thus, the probabilistic Budyko framework provides great performance. Based on this evaluation, we figure out that basins located in the Andes, especially in the southern, showed lower critical precipitation change (less than 10%) to increase the vulnerability of water availability by 25%.

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