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Evaluation of extreme droughts and pluvial in CMIP6 model simulations

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Extreme droughts as well as extreme pluvial, which are extended wet periods, can have sever socioeconomic impacts and are projected to increase in a warmer climate. It is therefore important to accurately simulate these events and their changes in climate models. Here, we evaluate simulations of 18 models participating in the Coupled Model Intercomparison Project Phase 6 (CMIP6) with the Earth System Model Evaluation Tool (ESMValTool). We compare changes in the number of months with extreme droughts and extreme pluvial over land between 1981-2000 and 2002-2021 from CMIP6 to four reanalysis and observation data sets for the global land mean and 46 land regions defined by the Intergovernmental Panel on Climate Change (IPCC). Pluvial events are detected based on the Standardized Precipitation Index (SPI), calculated from monthly mean precipitation data. Droughts were detected with two different indices, the SPI and the Standardized Precipitation Evapotranspiration Index (SPEI) which in addition to precipitation includes potential evapotranspiration. Based on these indices, extreme droughts (pluvial) are defined as the driest (wettest) 2.3% of all month at any location.

Pre-industrial control (piControl) simulations were analyzed to quantify the unforced state, where no systematic changes of extreme droughts or pluvial are found. Although it should be noted, that short reference periods can yield artificial changes. For historical model experiments, extreme droughts calculated based on SPI decrease for most models for the global mean land data and the multi-model mean in many of the IPCC regions. Contrary to that, the reanalysis and observation data do not agree on the direction of the change of extreme droughts for global mean land data. For the individual regions, the mean of the reanalysis and observation data shows opposing trends compared with the multi-model mean change in many cases.

This shows that there is a large uncertainty in the precipitation representation of the reanalysis and observation data sets, which limits the possibility to evaluate changes of the number of droughts in the CMIP6 model results.

For pluvial based on SPI the mean of the reanalysis observation data as well as the CMIP6 multi-model mean agree on an increase for the global mean, although two data sets show a decrease. Also for many regions, the results differ between the mean of the reanalysis and observation data compared to the multi-model mean.

For droughts based on SPEI, most reanalysis and observation data sets and the multimodel mean show an increasing number of months with extreme droughts averaged for global land data as well as for many of the IPCC reference regions over land.