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Evaluating catchment- and global-scale hydrological model simulations of drought across eight large river basins

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Global-scale and catchment-scale hydrological models are often shown to accurately simulate long-term runoff time-series and can generally simulate relatively coarsely-averaged flows (e.g. > daily) well. However, far less is known about their suitability for capturing hydrological extremes, such as droughts. Here we evaluated simulations of runoff from nine catchment scale hydrological models (CHMs) and eight global scale hydrological models (GHMs) over eight large river basins: Upper Amazon, Lena, Upper Mississippi, Upper Niger, Rhine, Tagus, Yangtze and Yellow. The simulations were conducted within the framework of phase 2a of the Intersectoral Impact Model Intercomparison Project (ISIMIP2a). We evaluated the ability of the CHMs and GHMs to simulate observed monthly runoff and hydrological droughts over 30 years. Observed and simulated hydrological drought events were identified using the Standardised Runoff Index (SRI) and were classified based on intensity. Our results show that the GHMs and CHMs performed well in representing observed monthly runoff. For almost all (seven out of eight) river basins, both ensemble means of runoff (GHMs and CHMs) had r squared values >0.8, and the individual models generally all performed well (r squared values usually >0.7 for any given model). However, in the case of drought events, simulations from individual GHMs and CHMs did not perform as well. The number of drought events identified at all intensity levels (i.e. SRI values equal to -1, -1.5, -2, -2.5 and -3) varied significantly for each individual model. While low intensity events were simulated relatively well, all the models, as well as the two ensemble means (GHMs and CHMs) present limited ability to accurately simulate high intensity drought events in all eight basins, in terms of their timing and intensity. This is because for high intensity events, even a slight change in runoff deficit (deviation of runoff from the long-term normal runoff) is magnified and reflected in terms of drought event intensity. By analysing the monthly runoff time-series for several extreme droughts over the historical period, we identify opportunities for improving the models so that extreme droughts may ultimately be better represented by CHMs and GHMs.