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Representation of drought propagation in large-scale models: a test on global scale and catchment scale

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Drought development has increasingly been studied using large-scale models, although, the suitability of these models to analyse hydrological drought is still unclear. Drought events propagate through the terrestrial hydrological cycle from meteorological drought to hydrological drought. We investigated to what extent large-scale models can reproduce this propagation. An ensemble of ten large-scale models, run within the WATCH project, and their forcing data (WATCH forcing data) were used to identify drought using a threshold level method. Propagation features (pooling, attenuation, lag, lengthening) were assessed on a global scale and, in more detail, for a selection of five case study areas in Europe. On a global scale, propagation features were reproduced by the multi-model ensemble, resulting in longer and fewer drought events in runoff than in precipitation. Spatial patterns of extreme drought events (e.g. the 1976 drought event in Europe) derived from monthly runoff data resembled more the spatial patterns derived from 3-monthly precipitation data than patterns derived from monthly precipitation data. There were differences between the individual models; some models showed a faster response in runoff than others. In general, modelled runoff showed a too fast response to rainfall, which led to deviations from historical drought events reported for slowly responding systems. Also in the selected case study areas, drought events became fewer and longer when moving through the hydrological cycle. For droughts events moving from precipitation via soil moisture to subsurface runoff, the number of droughts decreased from 3-5 per year to 0.5-1.5 per year and average duration increased from around 15 days to 50-120 days. Fast and slowly responding systems, however, did not show much differentiation. Also in the selected case study areas the simulated runoff reacted too fast to precipitation, especially in catchments with a cold climate, a semi-arid climate, or large storage in aquifer and lakes. Overall, drought propagation is reasonably well reproduced by the ensemble of large-scale models. However, a better representation of hydrological processes (i.e. evapotranspiration, snow accumulation and melt, and storage) in these models is recommended, before they can be used for predictions in areas where these processes dominate hydrological drought development.