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Basin-scale runoff prediction: An Ensemble Kalman Filter framework based on global hydrometeorological data sets

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In order to cope with the steady decline of the number of in situ gauges worldwide, there is a growing need for alternative methods to estimate runoff. We present an Ensemble Kalman Filter based approach that allows us to conclude on runoff for poorly or irregularly gauged basins. The approach focuses on the application of publicly available global hydrometeorological data sets for precipitation (GPCC, GPCP, CRU, UDEL), evapotranspiration (MODIS, FLUXNET, GLEAM, ERA interim, GLDAS), and water storage changes (GRACE, WGHM, GLDAS, MERRA LAND). Furthermore, runoff data from the GRDC and satellite altimetry derived estimates are used. We follow a least squares prediction that exploits the joint temporal and spatial auto- and cross-covariance structures of precipitation, evapotranspiration, water storage changes and runoff. We further consider time-dependent uncertainty estimates derived from all data sets. Our in-depth analysis comprises of 29 large river basins of different climate regions, with which runoff is predicted for a subset of 16 basins. Six configurations are analyzed: the Ensemble Kalman Filter (Smoother) and the hard (soft) Constrained Ensemble Kalman Filter (Smoother). Comparing the predictions to observed monthly runoff shows correlations larger than 0.5, percentage biases lower than $\pm$ 20%, and NSE-values larger than 0.5. A modified NSE-metric, stressing the difference to the mean annual cycle, shows an improvement of runoff predictions for 14 of the 16 basins. The proposed method is able to provide runoff estimates for nearly 100 poorly gauged basins covering an area of more than 11,500,000 km^2 with a freshwater discharge, in volume, of more than 125,000 m^3/s.