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Functional relationships reveal differences in the water cycle representation of global water models

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Global water models are widely used for policy-making and in scientific studies, but substantial inter-model differences highlight the need for additional evaluation. Here we evaluate global water models by assessing so-called functional relationships between system forcing and response variables. The more widely used comparisons between observed and simulated fluxes provide insight into model behavior for the representative area of an observation, and can therefore potentially improve the model for that area. Functional relationships, by contrast, aim to capture how system forcing and response variables co-vary across large scales, and thus offer the potential for model improvement over large areas. Using 30-year annual averages from 8 global water models, we quantify such functional relationships by calculating correlations between key forcing variables (precipitation, net radiation) and water fluxes (actual evapotranspiration, groundwater recharge, total runoff). We find strong disagreement for groundwater recharge, some disagreement for total runoff, and the best agreement for evapotranspiration. Observation- and theory-derived functional relationships show varying agreements with models, indicating where model representations and our process understanding are particularly uncertain. Overall, our results suggest that model improvement is most important for the representation of energy balance processes, recharge processes, and generally for model behavior in dry and cold regions. We argue that advancing our ability to simulate global hydrology requires a better perceptual understanding of the global water cycle. To evaluate if our models match that understanding, we should explore alternative evaluation strategies, such as the use of functional relationships.