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Improvement of streamflow prediction skill in large catchments: the effect of floodplain parameterization using a spaceborne DEM

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Streamflow prediction is important for both water resources management and flood control. Varieties of hydrodynamics models have been developed for improving the streamflow prediction skill, yet streamflow prediction in large catchments is still difficult because the movement of water during flood events is regulated by much smaller-scale topography than the grid resolution of typical hydrodynamics models applied to large catchments. Here we propose a new framework for modeling streamflow in a large catchment, which describes water exchange between river channels and floodplains as sub-grid-scale processes. The newly developed model, Catchment-based Macro-scale Floodplain model (CaMa-Flood), is a distributed river routing model, which receives runoff from a land surface model and predicts water storage and streamflow at each grid-box. Total water storage in each grid-box is divided into a river channel reservoir and a floodplain reservoir so as to balance the water surface elevation in the two reservoirs. Geometry of the river channel and floodplain reservoirs, which determines the relation between water storage and water level, is objectively parameterized from the flow direction map and the DEM from the 90-m resolution HydroSHEDS datasets. Streamflow (i.e. outflow from each grid-box) is calculated along the prescribed river network map using a diffusive wave equation. Total water storage of each grid-box at the next time step is predicted by a mass conservation equation, which uses input runoff, inflow from the upstream grid-boxes, and outflow to the downstream grid-box. The grid resolution of CaMa-Flood was set to 0.25 degree (about 25 km) in this study. Simulations of daily-scale streamflow are executed for river basins with large floodplains, such as the Amazon, Congo, Orinoco, Ganges, Mekong, Mississippi, Ob, Lena, and Yenisei. In order to discuss on the effect of floodplain parameterization, the daily-scale streamflow simulated by the models with and without floodplain reservoirs are validated against in-situ gauged hydrographs. It is found that the predictability of daily-scale streamflow is significantly improved when floodplain infilling and draining processes are incorporated into the model. The model without floodplain reservoirs significantly overestimates flood peak discharges because flood water is immediately discharged downstream without staying in the floodplains. The simulation with floodplain reservoir also well reproduced the seasonal cycle of flooded area and water surface elevation compared to satellite observations, so that the streamflow prediction skill by the model with floodplain parameterization seems to be robust. We concluded that floodplains play an important role for regulating the streamflow variations in large catchments, and floodplain parameterization is essential for improving the predictability of daily-scale streamflow by hydrodynamics models for large catchments.