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A vegetation-based time-varying parameterization framework for improving hydrological modeling under non-stationary conditions

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Temporal stability of model parameters is one major concern in hydrological modeling especially under non-stationary conditions including climate change and variation in catchment characteristics. In this study, we focus on the impact of variation in catchment characteristics on model parameters stability. According to the annual cycle of vegetation phenology inferred by the variability of NDVI, we split one year to growth period (May-October) and dormant period (November-April), and calibrate the parameters of a semi-distributed model (the THREW model) to 19 growth periods and 19 dormant periods during 1982-2000 in the upper Han River basin of central China (the largest tributary of Yangtze River). The results show that the calibrated parameters present significant non-stationarity, where the variation magnitude for the dormant periods is larger than that for the growth periods. The variation of the parameters can be attributed to the variation of vegetation cover, which is the most visible and detectable feature in all catchment characteristics experiencing change during the study period. Furthermore, it can be considered as an index representing the self-organization of catchment characteristics due to co-evolution of vegetation, soil, topography, geology, and so on, and even the feedbacks between climate and various catchment characteristics. We develop a time-varying parameterization scheme consisting of 14 unitary regression equations for NDVI and model parameters, and embed this scheme in the hydrological model. The correlation coefficients between model parameters and NDVI are 0.50-0.75 for the growth periods, and 0.42-0.63 for the dormant periods, indicating that the variability of calibrated parameters can reflect the changing conditions of the study area. The simulations of the modified parameterization scheme suggest that considering time instability of model parameters can improve the modeling performance for both high flows and low flows under non-stationary conditions. We also demonstrate the impact of model structure on the temporal stability of model parameters. Using the single parameter model (e.g. Budyko methods), the lumped-Xin'anjiang model, the distributed-Xin'anjiang model and the THREW model, we found that the variation in parameters of complicated models has stronger correlations with variation in catchment characteristics than that of simple models. At last, we explore the behavior of parameters related to the evapotranspiration process and that related to runoff generation under non-stationary conditions.