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A linear dynamical systems algorithm for streamflow reconstruction reveals history of regime shifts in northern Thailand

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Catchment dynamics is not often modeled in streamflow reconstruction studies; yet, the streamflow generation process depends on both catchment state and climatic inputs. To explicitly account for this interaction, we contribute a linear dynamic model, in which streamflow is a function of both catchment state and paleo-climatic proxies. The model is learned using a novel variant of the Expectation-Maximization algorithm, and it is used with a paleo-drought record—the Monsoon Asia Drought Atlas—to reconstruct 406 years of streamflow for the Ping River (northern Thailand). The dynamic model has higher accuracy than conventional linear regression: all performance scores increase by 40–67% in the instrumental period. Furthermore, the reconstructed streamflow time series is complemented with that of a state variable, which provides valuable insights about the catchment, e.g., a history of regime shifts. Furthermore, the new dynamic model is capable of readily generating stochastic streamflow replicates. With improved performance and more desirable features at only a marginal increase in computation, our novel technique can replace linear regression and bring more value to streamflow reconstruction.