Information Analysis of Catchment Hydrological Patterns Based on Stochastic Soil Moisture Model

Hydrological cycle takes on different patterns across scales. The bottom-up and top-down simulation strategies face inconsistency when confronted with scale cohesions. Neither of the two methods could clarify how water heat correlation pattern emerges with temporal upscaling, nor can they explain the influence of underlying surface nonuniformity on long-range hydrological responses, for these are problems lying in their fuzzy domain boundaries. The failure forces us to introduce a compromise perspective to explain the scale transition.

Admitted that different models process observations with different requirements and accuracies, few frameworks provide comprehensive evaluation of the hydrological observation and simulation system. An ideological trend of applying information theory in hydrological simulation evaluation is gaining its popularity for its round theoretical foundations. The trend is dividing into two forks, one stresses the characteristics of the random source of the hydrological observations within Shannon's descriptive complexity framework, while the other considers only the number of bits in the ultimate compressed version that could generate the observations using Kolmogorov's intrinsic complexity. The two theories are correspondent, but their connection in the hydrological context have not been well clarified.

By representing precipitation with a Compound Poisson Process, a series of point-scale stochastic soil moisture model were constructed. This research first derived the stochastic descriptions of the runoff and evapotranspiration processes based on the stochastic differential soil moisture equation. The temporal unscaling was implemented according to the large number law applied on the stationary solution of the stochastic process equations. By introducing the soil moisture storage capacity curve from Xinanjiang Model, the original point scale stochastic model was spatially upscaled to the catchment scale. The elastic factors influencing long term catchment hydrological patterns were derived through mathematical analysis of the stationary catchment scale soil moisture probability function.

The validity of the functions were examined with daily catchment hydrological observations from the MOPEX data set within an information theory perspective. The information content required to specify each component of the hydrological patterns at various temporal scales was depicted by quantized Shannon entropy of the runoff data, while the information provided by hydrometeorology terms was expressed with mutual information. An improved approach combining K-nearest neighbour method and non-linear support vector regression was employed to tackle with high dimensional information term estimation. Results showed a maximum point of potential simulation performance around a seasonal scale for most of the catchments. This point responded to the temporal scale upscaling scheme of the hydrological stochastic equations, however, it could not be detected with the existed water balance models applied in this research.

At last, a data compression experiment was carried out to approach the Kolmogorov complexity of the hydrological observations across temporal scales. Compressing schemes incorporated truncated Fourier transition, typical compress algorithms and hydrological models to estimate the intrinsic complexity hidden in the data. The results were compared with the information contents estimated in the previous chapter to clarify the connections and distinctions between Shannon's and Kolmogorov's perspective applied in hydrological simulation.