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Scaling Laws in River Runoff

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Ever since the seminal discoveries of Harold Hurst and John Hack in the fifties, spatio-temporal scaling laws have been found in many river systems around the world. This prevalence of scale-invariance hints at fundamental self-organization principles that lead to the emergence of large-scale phenomena that are independent of the details of the underlying local hydrological processes. It should thus be possible to incorporate these principles and reproduce these scaling laws in our hydrological models.
Traditional hydrological (error) models largely ignore these principles. Their notorious inability of getting the statistics of extreme and rare events right might partly be due to this negligence. We demonstrate this problem by means of a typical hydrological error model, a normal AR1 process added on top of the Box-Cox transformed output of a deterministic bucket model. This process breaks scale invariance by introducing both a volume and a time scale. With long runoff records from the Meuse catchment, we demonstrate that the observed auto-correlation of the transformed residuals is in startling contrast to the assumed AR1 process, and resembles much more a scale-invariant pink noise process. Furthermore, the residuals violate the assumed normality and are much more fat tailed. We end with proposing stochastic modeling tools that allow us to incorporate scaling laws into traditional hydrological models, which hitherto were solely based on conservation laws.