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Explaining the Hurst phenomenon by spatial aggregation

M. Mudelsee (1,2)

(1) Climate Risk Analysis – Manfred Mudelsee, Wasserweg 2, 06114 Halle (S), Germany (www.climate-risk-analysis.com), (2) Institute of Meteorology, University of Leipzig, Stephanstrasse 3, 04103 Leipzig, Germany (mudelsee@uni-leipzig.de)

Long memory is a statistical property of river runoff time series, which can lead to a clustering of extreme events such as floods. Few physical mechanisms, such as climate instationarities and storage cascade mechanisms, have been presented to explain this "Hurst phenomenon," and none has been quantitatively tested because of the scarcity of long, homogenous records. Here I report the design of a sensitive test, which reveals that the long memory of runoff is a direct result of spatial aggregation in the river network (Mudelsee, 2007, Water Resources Research, doi:10.1029/2006WR005721). I find that in over 100 year long instrumental records the long-memory parameter, d, increases downstream with the basin size, A, until saturation. The long-memory parameter is thereby estimated using exact maximum likelihood fitting of statistical ARFIMA(1, d, 0) models with bootstrap error bars. A conceptual runoff model is presented, where spatially variable precipitation is transformed by storage processes into short-memory contributions, which are further aggregated within a river system. The model is able to reproduce the observed $d(A)$ growth curves qualitatively. As a consequence of long memory, estimates like flood return periods have larger error bars than previously thought. In view of projected changes in climate and the hydrological cycle, these findings show that decadal-scale variations in drought or flood risk can in principle be predicted for individual rivers, with higher predictability downstream. Spatial aggregation may also explain long-memory in other networks, such as computer networks or the brain.