Comparison of the Hurst exponents of historical and GCM rainfall time series

Nick van de Giesen[1]
Center for Development Research, Bonn University, Germany

Luis J. Mata
Center for Development Research, Bonn University, Germany

Abstract. The existence of long-term persistence in precipitation and streamflow is a well known, yet incompletely understood, phenomenon that has direct consequences for the management of water resources (Rodriguez-Iturbe & Bras, 1993, Chapter 5). In the 1940's, Hurst (1951) discovered that hydrological time series show longer periods of droughts and floods than were to be expected if the processes had both finite memory and finite variance. A good measure to quantify this phenomenon is the Hurst exponent, H:

$$R(n)/\sigma \propto n^{H} \tag{1}$$

in which R(n) is the range of a sample of size n, and σ the standard deviation of the sample. The range is the maximum deviation of cumulative actual behavior from average behavior within a sample. If processes produce uncorrelated Gaussian (white) noise, the cumulative behavior is that of a random walk (Brownian noise) with H=0.5. Hydrological series usually have H>0.5, and often H≈0.7. The Hurst exponent has become a standard characterization tool for non-linear systems and H<>0.5 should be understood as consequence of the underlying non-linear dynamics.

After an overview of tests of different algorithms to calculate H, results are given for historical rainfall series, and rainfall series derived from the ECHAM4 General Circulation Model (GCM). GCM's are not known for their accuracy when it comes to rainfall. Most rain calculated within the large cells of a GCM is calculated on the basis of untested empirical schemes for convective rain. Still, GCM's are used to predict the availability and scarcity of water resources in decades to come, usually after a correction on the basis of historical time series (Vörösmarty *et al.*, 2000). As H is a measure of extended droughts and floods, one should test if a GCM gives the correct H value in order to make proper predictions. If a GCM truly represents the atmospheric dynamics, its Hurst exponent should be close to that of the historical time series.

Two cases are presented for the period 1901-1995: Venezuela and Ghana. Historical data are derived from the CRU dataset (Hulme *et al.*, 1999) and the GCM data are based on an 1860-2099 run of ECHAM4 with scenario IS92a by the Max Planck Institute in Hamburg (Roeckner *et al.*, 1996). A surprisingly good fit for H was found:

Country	Grid point	H-historical	H-GCM
Venezuela	6°59'N/64°41'W	0.638	0.641
Ghana	9°46'N/0°00'E	0.586	0.598

Clearly, one can not decide on the general validity of GCM-produced Hurst exponents on the basis of just these two cases, but these first results are promising.

[1] Center for Development Research
Bonn University
Walter-Flex-Str 3
53113 Bonn, Germany
Tel: +49 228 731720
e-mail: nick@uni-bonn.de

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