Hydrol. Earth Syst. Sci. Discuss., 2, S769–S776, 2005
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European Geosciences Union

Hydrology and Earth System Sciences Discussions

Interactive comment on "Scale invariance of daily runoff time series in agricultural watersheds" *by* X. Zhou et al.

Anonymous Referee #2

Received and published: 29 September 2005

General Comments

In the manuscript runoff time series from several agricultural watersheds are analysed with respect to scale invariance and long-range dependence. The authors report scale invariance over certain time scales for binary series generated from the runoff series by use of a threshold. They identify two distinct scaling regimes separated by a time scale of approximately 1 year. Furthermore, Rescaled Range analysis (R/S) is used to estimate a Hurst coefficient. For basically all watersheds, they report long-range dependence for time lags smaller than approximately 15 to 18 months characterised by a Hurst coefficient $H \gtrsim 0.8$. For time lags beyond 15 to 18 month they suggest that "the long-term persistence dissipates".

The manuscript is basically well structured and appealingly written. In an extensive introduction, the authors try to motivate the use of their concepts and outline the relevant questions they are addressing.

I agree with the authors that transferring results from gauged to ungauged catchment of possibly different size is a relevant question in hydrology. Furthermore, it is clearly advantageous to have rules how to map characteristics from small to large catchments and from small to large time scales. The elegance and simplicity of scale invariance and self-similarity is very attractive and can surely be helpful with respect to the problems considered. However, it should be thoroughly checked whether the requirements for the application of those concepts are given and the data at hand is reasonably well represented by this approach.

The dependence or correlation structure is a relevant characteristic of a process, especially with respect to further analysis, e.g. trend analysis (Bloomfield, 1992; Smith, 1993), confidence intervals of parameter estimates (e.g. regression) (Beran, 1994), critical values for tests (Krämer and Sibbertsen, 2002) or extreme value statistics (Coles, 2001; Koutsoyiannis, 2003). A characterisation of the correlation structure only with the Hurst exponent does in general not provide sufficient information (Kallache et al., 2005).

Concepts of scale invariance and long-range dependence have been frequently applied to environmental data (Kiraly and Janosi, 2002; Caballero et al., 2002; Fraedrich and Blender, 2003) including river run-off (Klemes, 1974; Montanari et al., 1997). Especially the R/S scaling (Hurst, 1951) has its origin in hydrology. However, I am not aware of any application of these concepts explicitly to an agricultural watersheds. In this respect, the manuscript presents a novel analysis.

The conclusions presented in the manuscript are questionable because

1. in the first part (estimated fractal dimension) the results might be mainly due to the yearly cycle which has not been removed (as suggested e.g. in Radziejewski and Kundzewicz, 1997). To support this, Fig. 1 (left) in this comment shows

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the box counting result for a Gaussian white noise series with a yearly cycle added. The figure qualitatively resembles Fig. 1 from the manuscript, especially regarding the two distinct scaling regimes. Furthermore, it is difficult to follow the interpretation of the results. The authors report a prominent time scale of one year and "scaling properties vary with the time scale". Those findings seem to be in contradiction with the absence of a typical time scale and scale-invariance.

2. In the second part (estimated Hurst exponent), the authors do not strictly respect the definition of long-range dependence (e.g. Beran, 1994) which requires, loosely speaking, power-law scaling with $H > 0.5$ for *large* lags. A Hurst coefficient of $H \approx 0.5$ for large lags, as reported, indicates the absence of long-range dependence, irrespectively of the behaviour on small scales. A Hurst exponent of $H < 0.5$ characterises a very unstable phenomenon (Beran, 1994, Ch. 2). In this analysis, an estimation of $H < 0.5$ might be an artefact due to the presence of the seasonal cycle (cf. Hu et al., 2001 for the influence of sinusoidal trends on DFA). A power-law in the R/S plot for small lags only indicates some memory but is not an evidence for long-range dependence neither for a power law decay of the autocorrelation function in that range (Maraun et al., 2004). Figure 2 (left) shows the R/S analysis of log-normal distributed white noise with a yearly cycle added (left) and without a yearly cycle (right). This figure demonstrates how a sinusoidal trend influences the R/S analysis. An increased Hurst exponent is suggested for lags smaller than the period of the trend and a decreased exponent (and possibly also $H < 0.5$) is suggested for larger lags. The left panel of Fig. 2 compares qualitatively well to Fig. 3 in the manuscript.

The manuscript needs to discuss to which extend the results reported are a consequence of the yearly cycle and whether scale invariance and long-range dependence are adequate concepts for the data presented when this cycle is removed. Since the seasonality is a strong signal in river runoff, it might very well dominate and supress other characteristics of the records. It should be clarified what is meant by the term long-range dependence, since it seems that this concept has been confused with power-law scaling in the R/S analysis. It might be antvantegeous to consider also more flexible and advanced methods to assess long-range dependence as discussed in Taqqu et al. (1995) and Beran (1994).

Detailed Comments

- Ch. 1: In the introduction the authors use the term "scaling" in different contexts : transfer from small to large catchments or from small to large temporal resolution, geometrical and dynamical scaling properties, scaling of a statistical distribution. The reader might get easily lost since the interrelationship is not sufficiently explained or referenced.
- Ch. 2.3: A more carefully explanation of the R/S method would facilitate the reproduction of the results presented. Especially, the notation could be improved.
- P. 1763, l. 10: Typing error in the reference: Maldelbrot
- Ch. 3.1: It should be emphasised that the fractal dimension is estimated for some binary series gained from the runoff series by use of a threshold and not from the runoff series itself.
- Figs. 1,2: Plots would become clearer if four different symbols were used for four different data sets.

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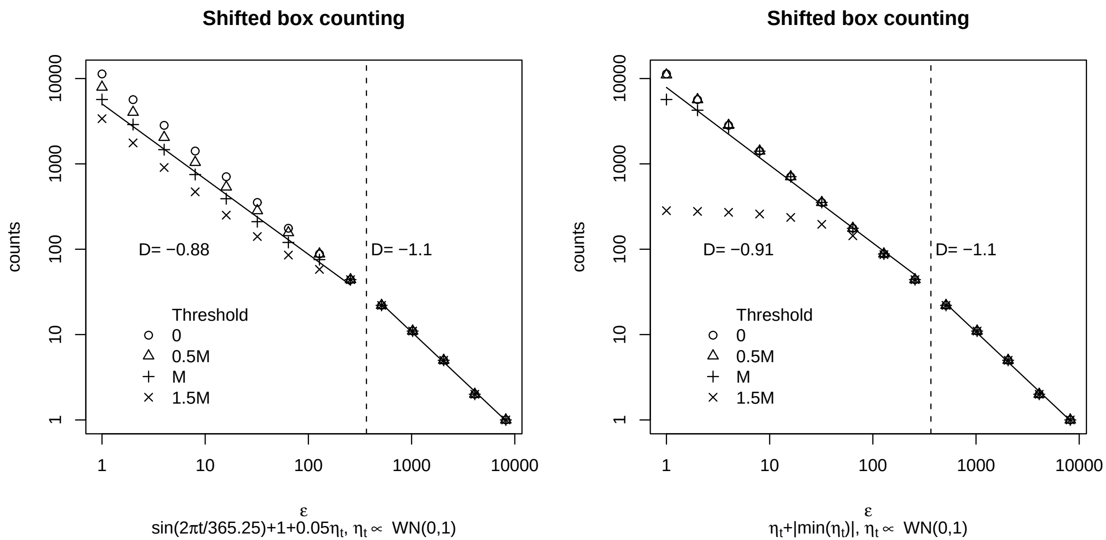

Figure 1: The shifted box counting methods applied to binary series for different thresholds gained in the way described in the manuscript from a Gaussian white noise series with a seasonal cycle added (left) and without seasonal cycle (right). A straight line is fittet for a threshold equal to the mean, seperately for box sizes smaller than 365 (vertical line) and larger 365.

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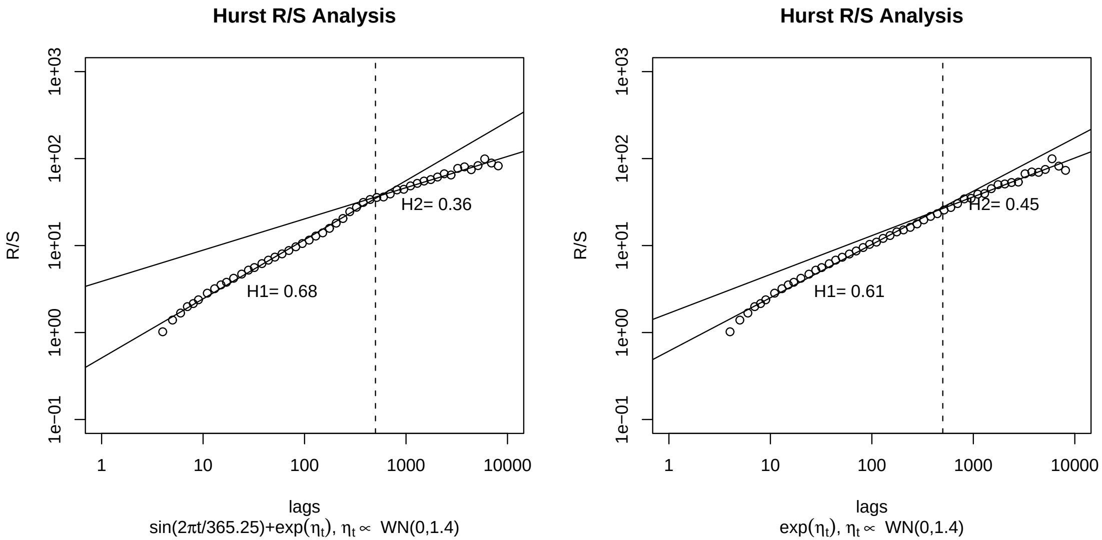

Figure 2: The Hurst R/S analysis for a log-normal distributed white noise series with a seasonal cycle added (left) and without seasonal cycle (right). A straight line is fitted seperately for scales smaller 500 (vertical line) and larger 500.

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