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Hydrology and Earth System Sciences Discussions

Interactive comment on "Detecting long-memory: Monte Carlo simulations and application to daily streamflow processes" *by* W. Wang et al.

W. Wang et al.

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We are grateful to both reviewers for their detailed comments. First of all, we would like to reply to the anonymous reviewer #2 for his comments on the paper.

(1) We agree that it would be more convincing by giving analytical demonstrations in addition to the Monte Carlo simulations, but we admit that, as pointed out by the reviewer, it is not tractable and therefore beyond our present study so far.

(2) It would be interesting and valuable to give physical explanations to any finding obtained with data-driven methods, namely, the methods based on the data themselves. But this is also not an easy task usually. In fact, we expected a stronger relationship between the intensity of long-memory and the watershed size because it seems to be physically logical. While our finding that the intensity of long-memory is only very

weakly related to the scale of the basin is more or less surprising to not only anonymous reviewer #2 but also ourselves, it seems to be not surprising to the anonymous reviewer #1. Therefore, this finding would be more or less controversial, and yet to be substantiated.

(3) Thanks for the specific comments, which would be fully considered in the revision of the paper.

Next, we would like to reply to the anonymous reviewer #1 for his critical comments.

(1) Indeed there are many methods which are available for estimating the differencing parameter d in the ARFIMA(p,d,q) model. It is not the purpose of the authors to make a comprehensive comparison of all the available methods. We simply want to compare the efficiency of three most popular methods in detecting the existence of long-memory. The fact that the aggregated variance method and the detrended fluctuation analysis are used by some authors does not mean that those methods are better or more popular than the Lo's R/S test method (Lo, 1991), the GPH test method (Geweke and Porter-Hudak, 1983) and the MLE method. In fact, as a heuristic method, the aggregated variance method suffers from the presence of short-memory, and the detrended fluctuation analysis method was much less used in literature (e.g., Montanari et al, 1999; Reisen et al., 2001).

(2) We concede that one of the motivations for using the S-MLE method is its availability in the software S-PLUS. While the Whittle's estimator was preferred by many contributions of the previous literature, the reviewer should not deny the value of the algorithm of Haslett and Raftery (1989). It is also a MLE method of considerable popularity (see e.g., Kendziorski et al. 1999). The use of S-MLE method also makes the result of our study quite reproducible because of its easy availability.

(3) We don't think it is a redundancy to emphasize that the efficiency of the long memory estimators increases with increasing sample size. Although it seems to be a theoretical issue with respect to the relationship between the efficiency of the long memory

estimators and the sample size, without some intensive Monte Carlo simulations, no answer is readily available to such a practical question as "how many data are required to get a reliable estimate of the intensity of long-memory in my application?". In some studies regarding the evaluation of the long-memory estimators, the effect of data size is not sufficiently considered. For example, when Agiakloglou et al. (1993) found that GPH estimators performed poorly for AR(1) processes with high autoregressive coefficient (e.g., 0.9), their conclusion was based on a comparatively small data size, ranging from 100 to 900, whereas our results show that when the data size is large enough, the GPH estimator is still reliable for cases of AR(1) processes with autoregressive coefficient 0.9. In some other studies, while the effect of data size on the efficiency of the long-memory estimators was recognized, how the estimates will be biased (i.e., upward, downward, or no bias) with the increase of data size are not well documented, especially for the cases of time series with strong serial dependence which is common for daily streamflow processes. For example, Lo (1991) only considered the simulations of AR(1) processes with autoregressive coefficient 0.5, AREFIMA(0,d,0) processes with d = 1/3 and -1/3, and the data size ranged from 100 to 1000. Reisen et al. (2001) considered the Whittle's estimator, the GPH method and several modified versions of GPH method, and made simulations mainly based on data series of 300 points. While they noticed that n=300 may not be large enough for some of the methods to perform better, they only conducted a study with n = 10,000, d=0.2 and one replication. To our knowledge, only Kendziorski et al. (1999) investigated the necessary data size to get an unbiased estimate of long-memory parameter with the S-MLE method, and found that S-MLE gave biased results of long-memory parameter Hurst coefficient for fractional Gaussian noise processes of any length and for fractionally differenced processes of lengths less than 210, but the results are not in agreement with our simulation results.

(4) We should have mentioned here that the daily mean discharges and mean standard deviations, used to deseasonalize the original series were first of all smoothed by using the first eight Fourier harmonics. In fact, this is a well accepted practice when deseasonalizing the hydrological time series, as shown in our other papers (e.g., Wang

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et al., 2005; Wang et al., 2006).

(5) We do not think it is an inconsistency by saying that on one hand, the S-MLE method is a good indicator of the presence of long memory, on the other hand, caution must be taken if an estimate of zero is obtained with the S-MLE, because the zero estimate is simply a special case of the estimates with the S-MLE method which can be easily identified. According to the simulation results, there is no doubt that the S-MLE method can distinguish the AR processes and ARFIMA processes better than the other two methods.

(6) The conclusion that the observed river flows possess long memory are based on (i) first of all, most streamflow series are shown to exhibit long-memory by at least two of the three methods, especially the GPH method and the S-MLE method; (ii) for the five cases where the S-MLE method gives zero estimates, only in one case the Lo's test accepts the null hypothesis of short-memory, whereas the GPH method, which is more reliable than the Lo's test, indicates the existence of long-memory, and we believe that the zero estimates given by S-MLE method are wrong. It would be interesting to try some other methods to give further evidence of the existence of long-memory in streamflow processes, but we believe that it is a safe conclusion to say that daily streamflow processes possess long memory not only because of our study results, but also according to many contributions of the previous literature (e.g., Montanari et al., 1997; Rao and Bhattacharya, 1999).

(7) We are happy to see that the reviewer seems to be in agreement with us regarding one of our conclusions that the size of the watershed is not very effective on the long memory behaviour. It is interesting to notice that, on one hand, the reviewer claims that "it is well known that the long memory behaviour cannot be justified only by the basin size", which indicates that he believes the basin size is one of the factors affecting the long memory behaviour; on the other hand, he arbitrarily claims that "the weak effect of the basin size on the estimation of long memory detected by the authors is simply an artefact of the presence of short-memory" because "Most of the rainfall-runoff

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models proposed by the hydrologic literature do not exhibit any long memory structure independently of the basin size ", indicating that he believes there is no reason of any effect of basin size on the memory of basin size on the memory of streamflow processes. As a matter of fact, no rainfall-runoff model is an accurate representation of the real-world processes. That no basin size is dependent long memory structure in the rainfall-runoff model is not a proof of no presence of long-memory. In fact, we expected a stronger relationship between the intensity of long-memory and the watershed size, so is the reviewer #2, who considered it to be a "rather surprising finding that intensity of long-memory is only very weakly related to the scale of the basin".

(8) The source of long-memory is not the focus of the present study. Of course it would be interesting to investigate the sources of the long-memory in the streamflow processes, and we have tried to give some explanations, but it seems to be not an easy task so far.

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