CEE7430 Homework 7: Long term persistence. "When will Lake Mead go dry?"

Due: 3/31/09

Reading:

- Loucks, D. P., J. R. Stedinger and D. A. Haith, (1981), Water Resource Systems Planning and Analysis, Prentice-Hall, Englewood Cliffs, NJ, 559 p. Chapter 6 sections 6.6 on Hurst and Fractional Brownian Noise
- Feder, J., (1988), Fractals, Plenum Press. Chapter 8 on Fractal Records in Time and Chapter 9 on Random Walks and Fractals.
- Tarboton, D. G., (1994), "The Source Hydrology of Severe Sustained Drought in the Southwestern United States," Journal of Hydrology, 161: 31-69.
- Barnett, T. P. and D. W. Pierce, (2008), "When will Lake Mead go dry?," Water Resour. Res., 44: W03201, http://dx.doi.org/10.1029/2007WR006704
- Bras, R. L. and I. Rodriguez-Iturbe, (1985), Random Functions and Hydrology, Addison-Wesley, Reading, MA, Chapter 5, p 210-225.

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1. Carefully read Tarboton, D. G., (1994), "The Source Hydrology of Severe Sustained Drought in the Southwestern United States," Journal of Hydrology, 161: 31-69. Write a 2 page abstract summary. I am looking for you to summarize the key ideas in the paper and comment critically on assumptions, methods, results and conclusions in terms of their correctness and significance. [Do not be shy in commenting on any shortcomings because I am the author - this was over 10 years ago]

2. Carefully read Barnett, T. P. and D. W. Pierce, (2008), "When will Lake Mead go dry?," Water Resour. Res., 44: W03201, http://dx.doi.org/10.1029/2007WR006704. Write a 2 page abstract summary. I am looking for you to summarize the key ideas in the paper and comment critically on assumptions, methods, results and conclusions in terms of their correctness and significance.

Perform the following assignment working in groups of two students each. By working in groups I hope you can share some of the workload and also benefit and learn from working together and discussing the solutions and having a second person to check for correctness.

Aggregate the Natural flows data you have for the Colorado River (from http://www.usbr.gov/lc/region/g4000/NaturalFlow/current.html) into annual water year totals, (converting to million acre feet, MAF, units if necessary) for consistency with these papers.

3. Calculate the mean and std deviation of annual flow at Lees Ferry and the uncertainty in these quantities. Compare your calculations with results reported in the papers read.

4. Prepare a rescaled range (R/S) plot (similar to Feder figures 8.4 and 8.6) and std deviation versus block length plot similar to the left side of Figure A1 in Barnett and Pierce and estimate H from these.

5. Develop the following models for simulation of annual flow in the Colorado at Lee's Ferry
   i. AR(1)
   ii. ARMA(1,1) with parameters from Bras tables 5.1-5.6 chosen to match H.
   iii. Fractional Gaussian noise using successive random additions (Feder pages 180-183)

   Evaluate each model in terms of its reproduction of a suite of test statistics including mean, std deviation, skewness, marginal distribution, autocorrelation function, Hurst exponent, storage-yield curve.

6. Simulate as long a series as seems reasonably doable using your computational resources from each model and prepare R/S and standard deviation versus block length plots. Comment on whether, and at what length of record each model diverges from the estimated H and whether it converges on some other value for H.

Let's try reproduce some of Barnett and Pierce's results. Pick whichever of your models you think is best from the results above and develop 10,000 simulations of system inflow to represent the years 2009-2060.

7. Starting from an initial condition of 25.7 MAF (Barnett and Pierce page 2 for June 2007) with depletions following figure 3 and paragraph 10 as well as evaporation/infiltration losses (-1.7 MAF, paragraph 10) use 10,000 simulations from your model to estimate the no climate change probability of exhausting storage over the years 2009-2060. Compare your results to Barnett and Pierce figure 5.

8. Estimate from figures 2, the minimum power pool storage initial condition in June 2007 and use simulations from your model to estimate the no climate change probability of reservoir storage dropping below the minimum necessary for power generation. Compare your results to Barnett and Pierce figure 6.

9. Try to obtain updated information on present storage in the system and update your answers for 7 and 8 conditional on present conditions.

10. Figure 7 in Barnett and Pierce examines the sensitivity to changes in net inflow. Adjust the 10,000 simulations from your model according to a net inflow change to evaluate the probability of going dry by 2027 from your model over a range of net inflow changes. Compare your results to the middle figure of figure 7.

11. Discuss what you have learned from this exercise about the probability of Lake Mead going dry and the role of natural variability, growth in demand and climate change in this question relevant for the water resources of the Southwestern US.