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An unorthodox physically-based stochastic treatment of tree rings: Some practical lessons learned from a 40-year involvement in stochastic hydrology

A talk given on July 12, 2007, in the HW2003 Workshop on *Analysis of Variability in Hydrological Data Series*, at the IAHS General Assembly in Perugia, Italy

1 - Early inspiration

I owe my first inspirations for looking deeper into the stochastics of tree rings to beavers with whom our family shared enjoyment of the ‘Klemeš Lake’ some 30 years ago[1]. However, in those days I was preoccupied with stochastic hydrology, so the pursuit of this interest had to wait.

2 - Final inspiration

Its time came two years ago when a lot of tree rings became exposed in our neighborhood by a rather severe storm – that was the final incentive for embarking on the long delayed experiment in stochastic treatment of tree-rings. The additional factor was that by then it was clear to me that stochastic hydrology was of little help in solving our practical water-related problems[2]. So I had a load of tree trunks transported on my driveway and got to work, applying my stochastic expertise as systematically as I could.

3 -Checking for nonlinearities

The first thing to do was to check the data for nonlinearities and get rid of them by a proper transformation. Contemplating which might be the most appropriate one in this case, the scene of my last inspiration came to mind. I saw myself sitting in what could be justly regarded as ‘log space’ - and that led me to use the log-transformation, so popular in hydrology and beyond.

4 -Log transformation, general

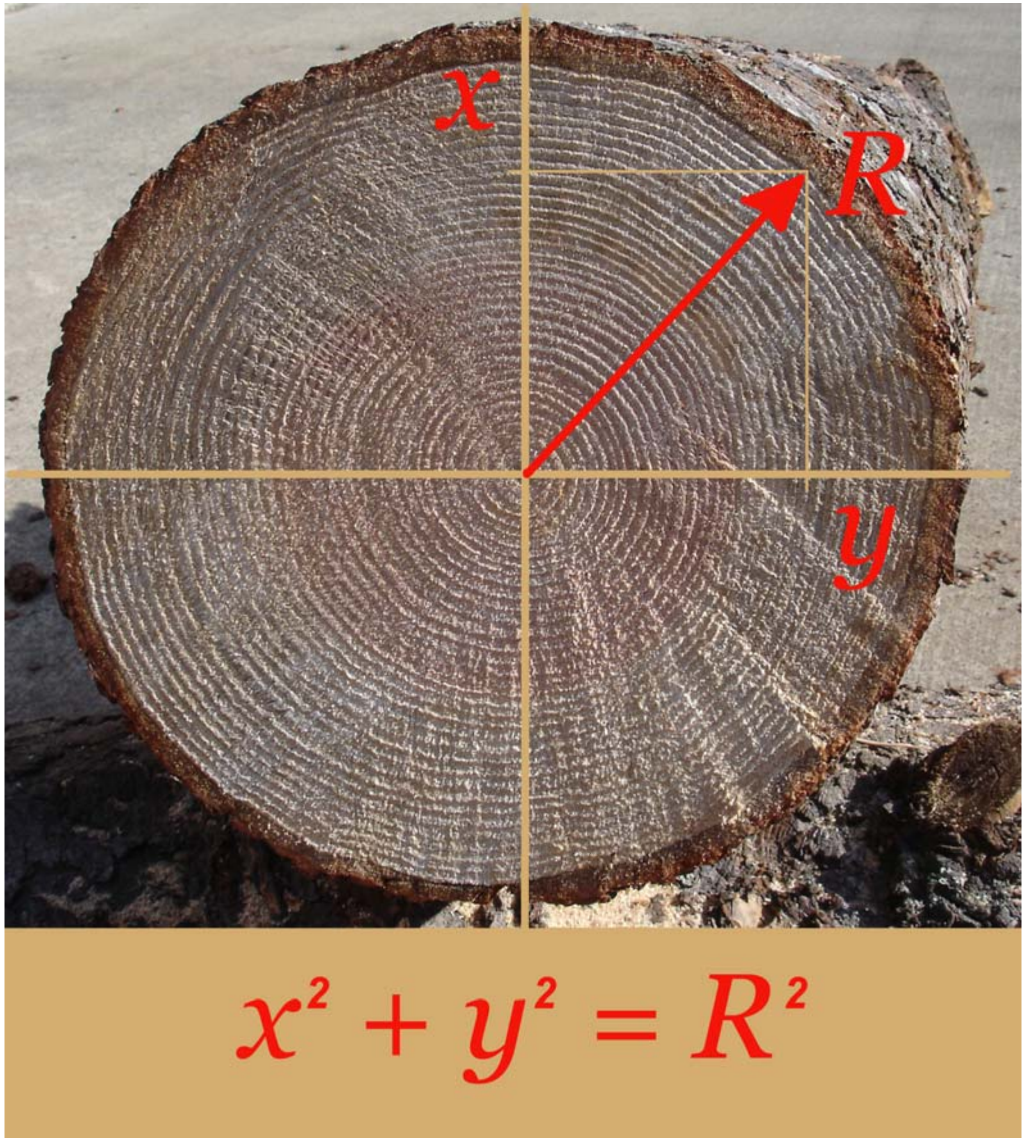
The first version I tried linearized my samples quite satisfactorily, but it did not preserve their stationarity – they kept rolling and made the work rather difficult.

5 -Log transformation, stationarity preserving

So I resorted to a higher level of sophistication and applied a stationarity-preserving technique which performed to my satisfaction. Of course, a computerized method would be faster – but time is of little concern in retirement and, by doing it manually, one notices some interesting things which a computer might well miss.

6 - Physical basis of circular shape

For example, the beautiful regularity of the concentric circles the rings form suggested to me again the old question I have often asked in hydrological contexts[3,4]: "What is the physical basis of the observed pattern?", in this case of the fact that all the rings obey the same equation? Then, reminded of the latest developments in stochastic hydrology[5], the obvious simple answer struck me: It is their self-similarity, stupid! Indeed – and what is even more striking - the self-similarity applies not only in the ***R*** direction shown here, but even in the direction perpendicular to the plane of the cut as can be easily verified by inspection ...



7 - Self-similarity

... simply by comparing the two conjugate planes of the cut.

8 - Scale invariance of self-similarity

Moreover, as I have carefully verified, this self-similarity is scale-invariant: it applies from the largest log to the smallest twig. To my knowledge, none of these insights have yet been published, not even posted on the internet!

9 - Checking sample variability

After finishing with the transformations, I was faced with the problem of assessing the sampling variability – which alone justifies my participation in this workshop. Being somewhat out of touch with the latest theoretical developments, I consulted my 10-volume Encyclopedia of Statistical Sciences and decided that...

10 - Eye estimate

... the EYE ESTIMATE[6] was just perfect for the given purpose.

EYE ESTIMATE 613

EYE ESTIMATE

Strictly speaking, this term means an estimate in which the only measuring instrument is the human eye. By customary usage, it includes all estimates in which there is an element of judgment, so that the value of the estimate is not predetermined exactly by the

11- Samples too big

Starting to process the samples I found that, although linear enough, they were too big to be tackled with my hardware.

12 -Split-sample technique

This gave me an opportunity to apply in practice the split-sample technique which I had advocated already more than 20 years ago[7].

13 - Data disaggregation

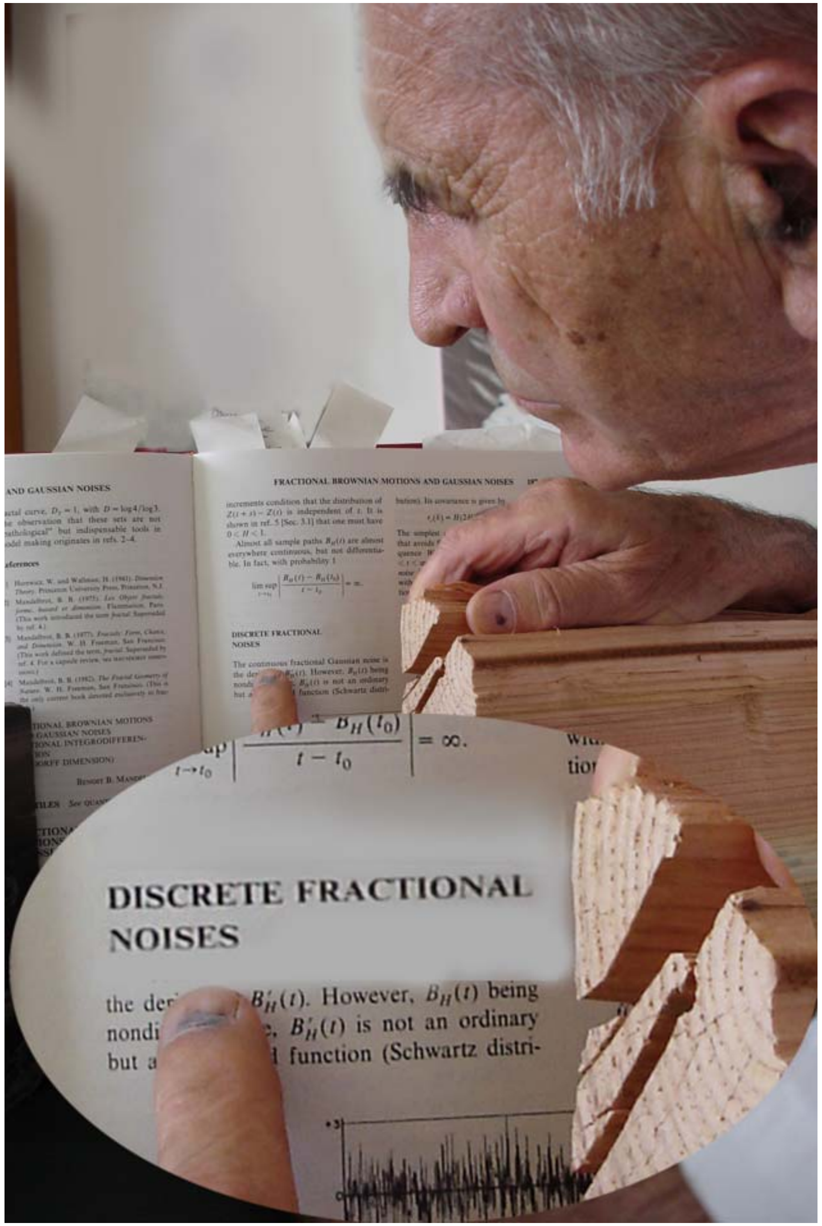
The task accomplished, I proceeded to data disaggregation which was one of the high points of the exercise, and definitely most fun.

14 - Markov chains inadequate

As you of course well know, Markov chains are often not sufficient in putting some order into data series.

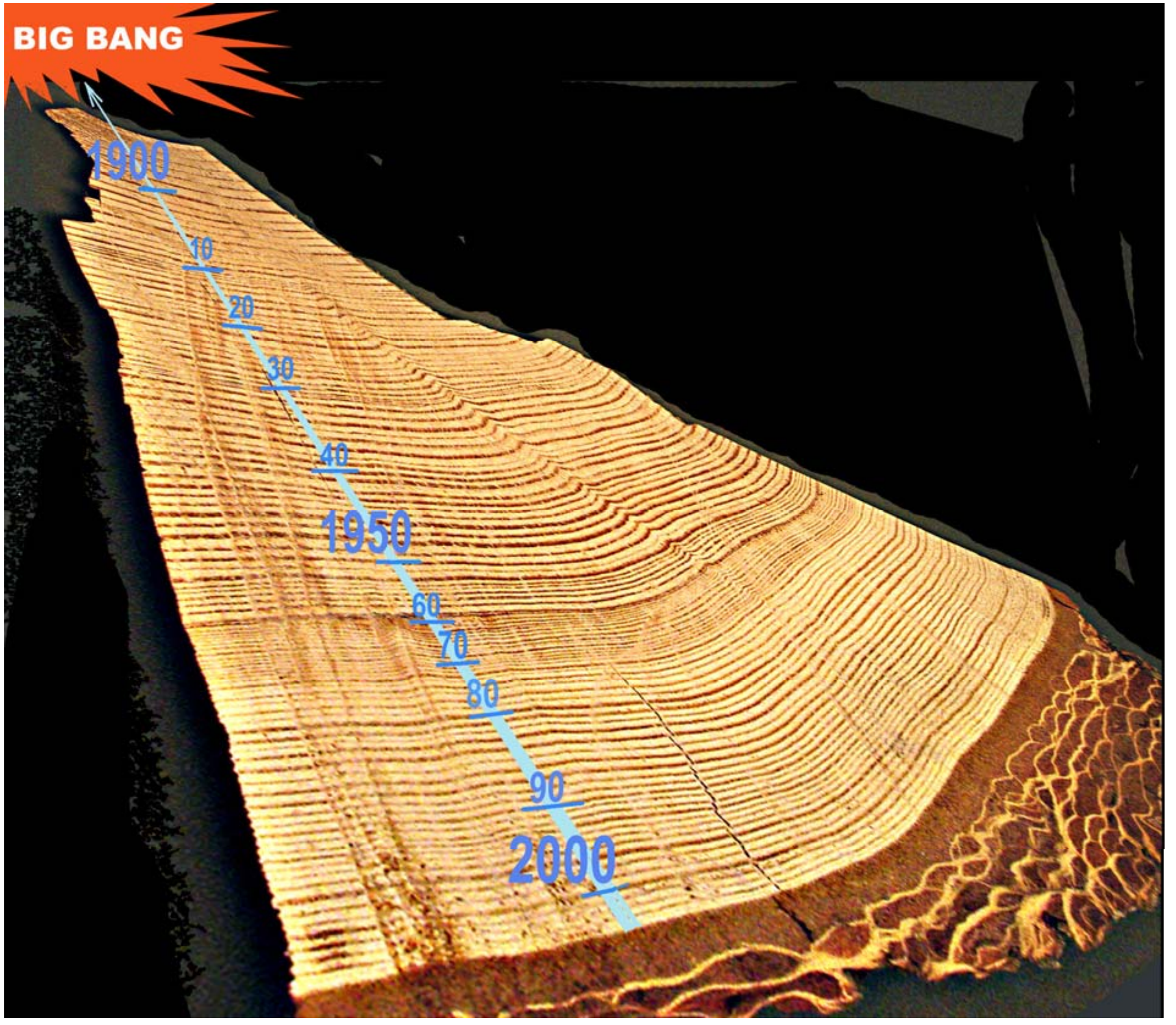
15 -Discrete fractional noises

And, as in this case, there may occur some discrete fractional noises in the data, and consulting the literature[8] may not always help in finding out how to get rid of them. Throughout the whole experiment, I found a small hand ax more useful for the purpose than the Encyclopedia.



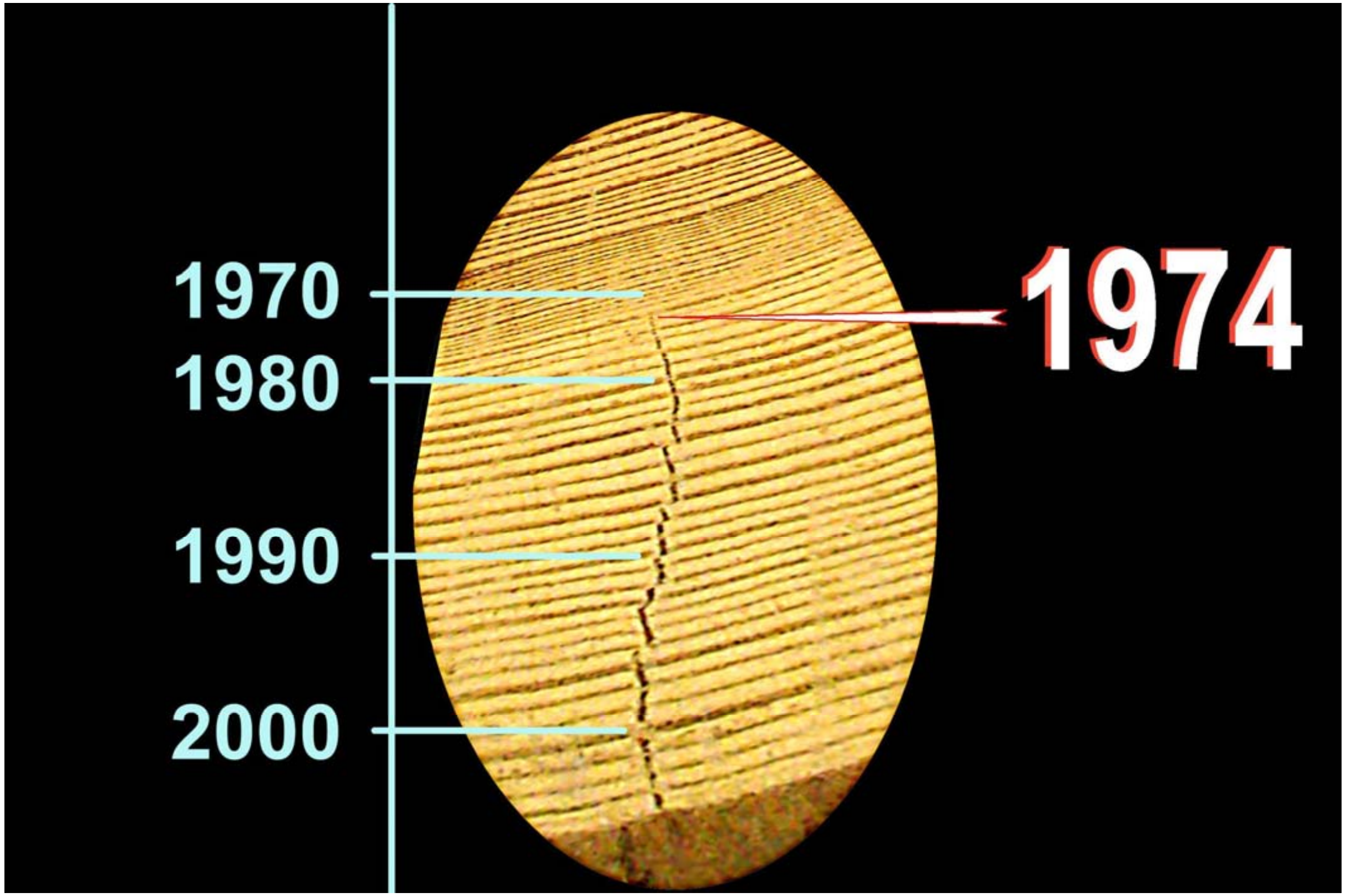
16 - Long memory process

Having successfully eliminated the distraction caused by fractional noises, I found it quite easy to fit long-memory processes to the samples. It appeared to me that the processes were nonstationary, but this is not the place to raise the issue. Suffice it to take note of the fact that not only I (and great many others) were distressed by the 1960s, but even some trees were: this one, for example, had almost stopped growing during the period. What also attracted my attention, was the crack down in the middle.



17 -Hurst paper crack

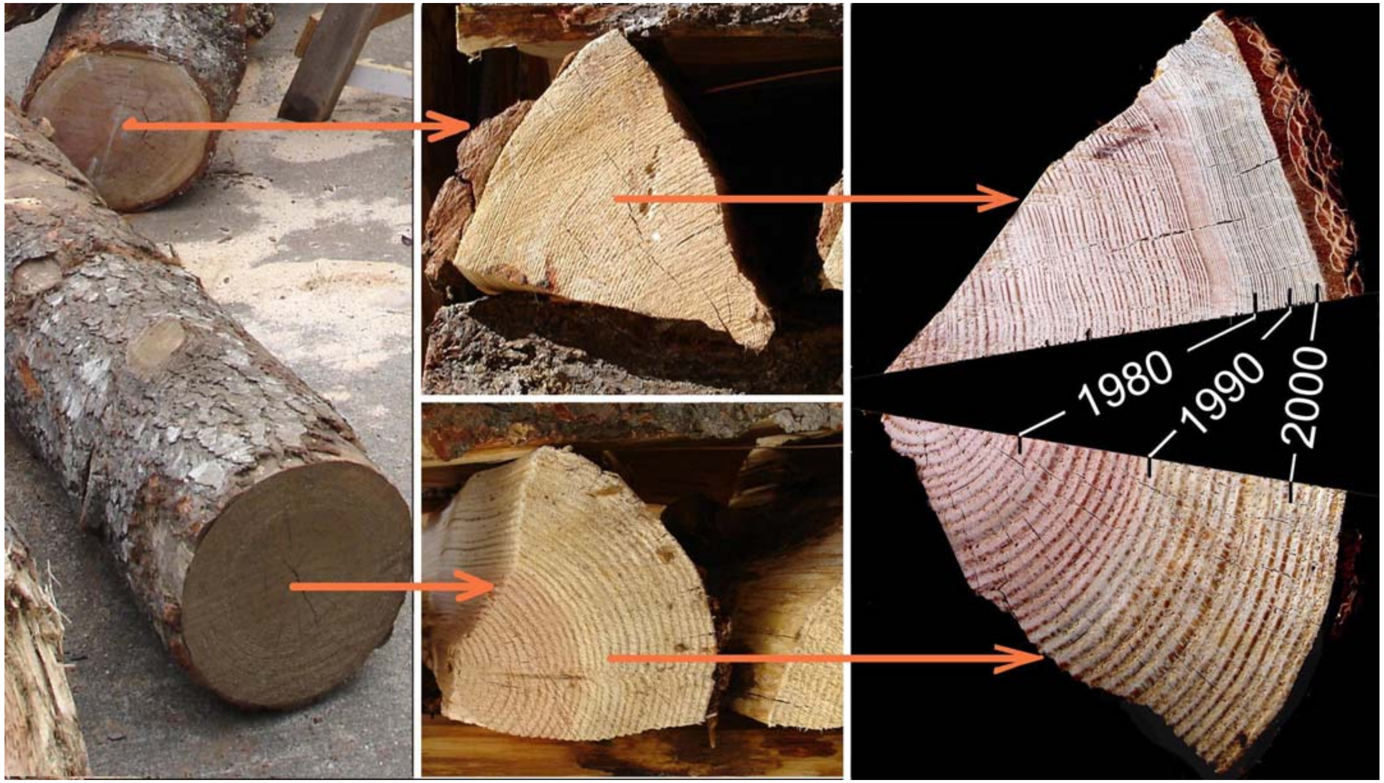
When I examined it more closely, I found that it started in 1974 when, as some believe, my ‘Hurst paper’[9] started a small crack in time series modeling; but of course, neither crack has had serious consequences. This one would soon heal if the tree had not been cut down, the other is bound to follow suit soon.



18 - A puzzle

Looking closer, you will see not only that cracks do heal, but something much more interesting and puzzling: two trees, growing no more than 50 meters apart, are about the same size but differ significantly in their age, one being about 140 years old, the other about 35.

19 -Climate change



This remarkable fact must have escaped the notice of theorists using tree-ring series as proxies for the reconstruction of past climate since otherwise it would have made front-page headlines: for it provides an unambiguous proof that two (or perhaps more?) different climates can peacefully coexist in parallel a mere stone throw apart - at least in our neighborhood on 'Triangle Mountain' in Victoria, British Columbia.

20 -Scaling application

I tried to shed some light on the problem using the latest advances in scaling[9] and, indeed, I found that the two samples scaled to exactly 6 kilograms.

21- Configuring hardware

After all these preliminary analyses, the time came to embark on mass processing of the data, a task estimated to take the entire winter. It was therefore imperative that the central processing unit be carefully configured to ensure its smooth operation throughout the duration of the project.

22 -Data processing

This care paid off – the processing worked without a hitch and gave one the warm feeling which always accompanies a successful completion of a hard job.

23 - Insights

And the insights and inspirations it provided in the process!! ...

24 -Insights -Strange attractors

... including a completely new perspective on deterministic chaos: its two attractors that often spontaneously appeared and vanished, were not only mysterious, elusive and beautiful, but, knowing that they were safely confined within a solid deterministic framework, they didn't seem strange at all.

25 -Repeatable experiment

The only question remaining to be answered the following spring was whether the experiment I had performed was repeatable. After pondering the matter, I came to the conclusion that, in principle, it was – but better by somebody else.

26 - Conclusion

The moral of my talk is this: The most fun and perhaps the greatest value of doing something is in doing it. The results may well go up in smoke, be wrong, become obsolete and forgotten, but some new ideas may have emerged in pursuing them, and some of them may somewhere, sometime, bear fruit. As the Nobel Prize winner, Sir Peter Medawar, once said, “I reckon that for all the use [my research] has been to science, about four-fifths of my time has been wasted, and I believe this to be the common lot of people who are not merely playing follow-my-leader in research”[10].

References

[1]) V. Klemeš (2007), 20 years later: What has changed – and what hasn't, *Association Lecture, IAHS General Assembly, Perugia*; Exhibit 17 (http://www.itia.ntua.gr/e/docinfo/831/).

[2]) Ibid., Exhibits 18 – 26.

[3]) V. Klemeš (1974), The Hurst Phenomenon - A Puzzle?, *Water Resources Research*, l0, 4.

[4]) - (1978), Physically Based Stochastic Hydrologic Analysis, In: *Advances in Hydroscience* (V.T. Chow, editor), Vol. ll, New York, l978.

[5]) Cf.(1), Exhibit 3.

[6]) Kotz and Johnson (editors)(1982), *Encyclopedia of Statistical Sciences*, Vol. 2, p. 613, John Wiley, New York.

[7]) V. Klemeš (1986), Operational testing of hydrologic simulation models, *Hydrological Sciences Journal*, 31, 1.

[8]) Cf.(6), (1983), Vol. 3, p. 187.

[9]) Cf.(1), Exhibit 4.

[10]) Cited from V. Klemeš (1988), A Hydrological Perspective, *Journal of Hydrology*, 100.