

Misconceptions in water resource studies

When you try to explain the behaviour of water, remember to demonstrate the experiment first and the cause next.
Leonardo da Vinci (c 1500)

British civil engineer RE Hurst studied this record in order to determine the river flow properties required for the design of the proposed Aswan High Dam further upstream. He found anomalies in the data that were also present in the data relating to other environmental processes.

During the following years civil engineers, hydrologists and mathematicians were unable to determine the cause of these anomalies. Now, here in South Africa, as well as in many other countries with dry climates, the demand already exceeds the available secure water supplies from many river systems. In this situation there is an urgent need for refined research on reliable numerical characterisation of the hydro-meteorological processes. This in turn requires a numerical (as different from descriptive) understanding of the causative mechanisms.

This has been the objective of the writer of this article for the past 40 years. With the assistance of his staff, students and professional colleagues, he has produced more than 200 publications and presentations on this and related issues. The situation came to a head in 2008 when, at his request, the writer addressed



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INTRODUCTION

Civil engineering is the oldest of all the professions, being as old as civilisation itself. One of its major functions is and always has been related to the provision of water for human consumption. The early civilisations in the Middle East relied on river flow as the source of drinking water, and the annual flooding of the floodplains for the growing of crops once the floods subsided. It was soon realised that the annual river flows and floods not only varied from year to year, but that there were alternating sequences of above and below average flows. There was a need to observe and record these values. Joseph's biblical prophecy of seven good years followed by seven years of famine is a good example of the interpretation of this data.

In 640 AD a water level observing structure was installed on Rodda Island in the Nile River near Cairo. This was used to provide the longest hydrological record available anywhere. In the early 1950s the

the SAICE Council on two occasions with an urgent warning of the strong likelihood of impending severe global droughts during the period 2009 to 2016. His article on this subject was published in the June 2008 issue of *Civil Engineering*.

Within months of publication severe droughts occurred along the southern Cape coastal area where seawater desalination plants had to be installed at Mossel Bay, Sedgefield and Plettenberg Bay. In the years that followed severe droughts occurred over large areas of southern Africa, as well as in other continental regions. Unfortunately there was no response to the warnings from any source nor implementation of measures to reduce the serious consequences of the droughts.

CLIMATE CHANGE

The situation became considerably more complicated after the publication of the report of the United Nations' Intergovernmental Panel on Climate Change (IPCC) at the end of March 2014. The title of the report was "Climate Change 2014: Impacts, adaptation and vulnerability". There have already been many responses on the Internet that are critical of this publication. The following is a very short summary of this writer's views within the context of South Africa's future water supplies. The climate change issue is dealt with in detail in the writer's comprehensive *Handbook on analytical methods for water resource development and management*. It can be downloaded free of charge from the writer's website (www.droughtsandfloods.com).

1. The thrust of the IPCC report is that global warming will result in increases in frequency and magnitude of life-threatening floods, droughts and threats to water supplies, and that this is already occurring in South Africa. However, there is no evidence in South Africa's extensive hydro-meteorological database to support these assertions. Temperature does not feature in water resource studies. The postulated global temperature increase is no more than that between breakfast and morning tea on a sunny day.
2. There are no major ports in the world that have been changed to accommodate rising sea levels.
3. High school students in physics have no difficulty in understanding that energy from the sun drives the world's

climate. This is greater in the equatorial than in the polar regions. Natural climatic variability is driven by variations in the receipt and poleward redistribution of this energy, and its radiation back into space in the process. An understanding of variations in the solar energy received on earth and their causes is fundamentally necessary for water resource studies, but is completely ignored in the IPCC reports.

4. The important solar linkage is dismissed, despite the fact that it has been addressed for more than the past 100 years here in South Africa and elsewhere. This writer and his colleagues have conducted and published research on this topic that is a world first, but is ignored by the South African climate change community.
5. The fact that volcanic emissions have a far greater influence on global climate than human activities is conveniently ignored in the IPCC report.
6. The report is descriptive and not quantitative. As a result it cannot be used for practical applications. Climate change theory cannot be used to resolve South Africa's water supply problems.

TOWARDS A SOLUTION

It has now become critically important that all those who will be involved in the development and application of methods to minimise the consequences of the inevitable water shortages (droughts) and high flows (floods), that can restore the water stored in the dams after the droughts, should have a clear **quantitative** understanding of the hydro-meteorological processes involved.

Chatfield (1980) in his book *The analysis of time series* stated that the reader who has grasped the basic concepts of time-series analyses should always be prepared to use his common sense in tackling a problem. The first step in any time-series analysis should always be to plot the data. Not only will a graph show up a trend, but it also enables one to look for 'wild' observations or outliers which do not appear to be consistent with the rest of the data. The treatment of outliers is a complex subject in which common sense is more important than statistical theory.

The notes that follow are in accordance with Chatfield's recommendations. The explanations are kept as simple and understandable as possible.

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First round analyses

This section is presented in the first person. When I started teaching hydrology at the University of Pretoria, I had a class of just over 50 final-year civil engineering students. They would traipse into the lecture room at the start of the lecture, listen patiently and then traipse out again. There was no eye contact and no enthusiasm.

I thought that I could overcome their indifference with a simple example. I gave them copies of the title page of my 1978 technical report *Long-range prediction of river flow: a preliminary assessment*, together with the data on which the graphs were based.

I drew their attention to the title of the report shown in Figure 1, then referred them to panel 1A. It is the histogram of the annual data. "Do you notice that there are more low values than high values?" They nodded their heads.

"Now look at the second panel, 1B. This is the histogram of the departures from the mean value. The difference between the numbers and magnitudes of values below the mean and above the mean is clear." They nodded their heads again. I explained that this was because the data is not Normally distributed. I started losing them.

I continued by explaining that we could overcome this skewness by using the logarithms of the data. They were lost and I was cross. I asked them: "Why are you having so much difficulty understanding logarithms? Archimedes

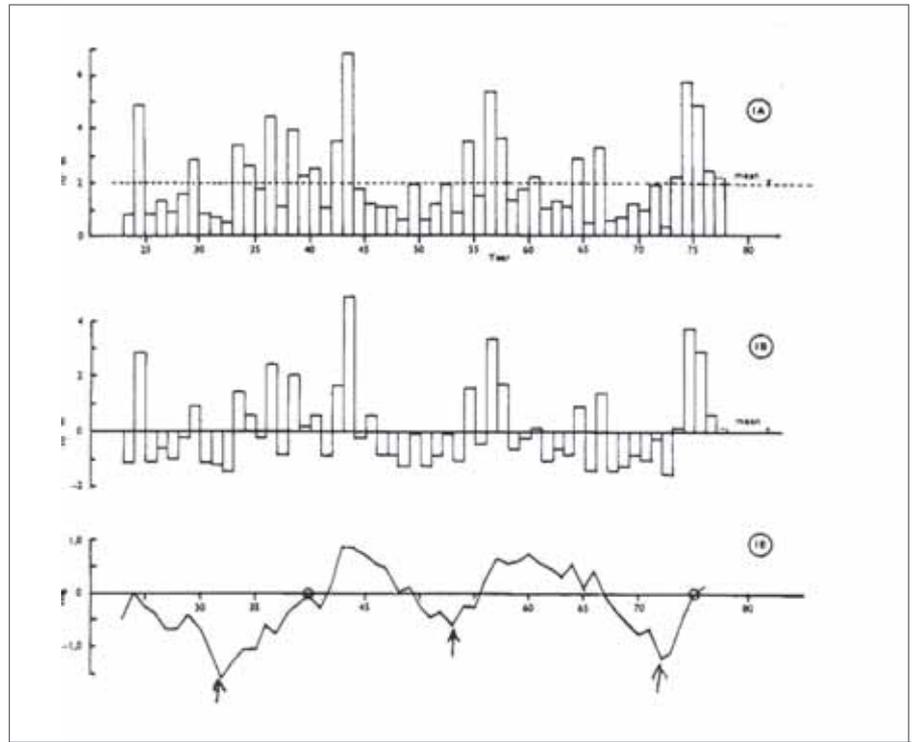


Figure 1: Cover page of the technical report *Long-range prediction of river flow*

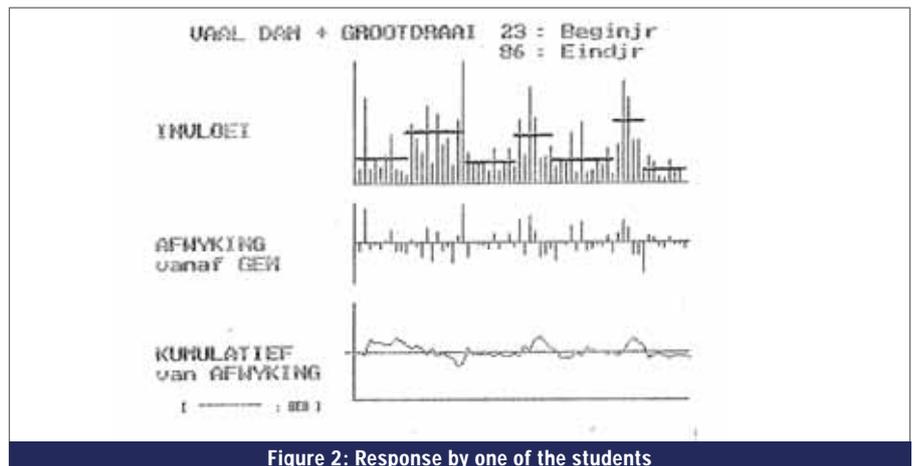


Figure 2: Response by one of the students

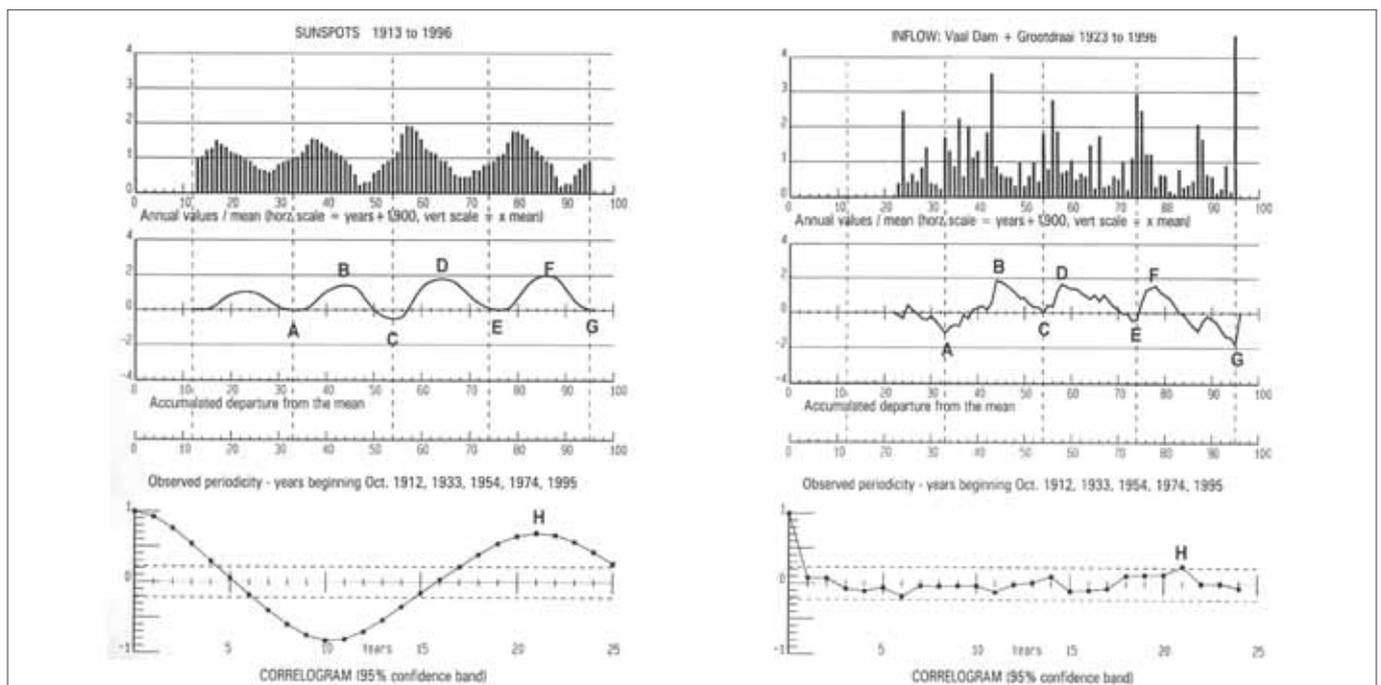


Figure 3: Comparisons of the characteristics of annual sunspot numbers with corresponding characteristics of the annual flows in the Vaal River

invented them more than 2 000 years ago and I applied them during my first year at university." There was an immediate reaction from a student at the back of the class. "Yes, but that was much closer to Archimedes' time."

The ice was broken. We all relaxed. I continued with my explanation. I explained how panel 1E was derived from the logarithms of the cumulative departures of the annual values from the mean value.

"Can you see the sawtooth pattern in the figure?" I asked. They nodded their heads again. I explained that this is caused by a regular anomaly in the mean value, i.e. the mean is not constant as most of us assume when examining a set of data.

I then gave them their first task. They had to divide the data into segments and determine the mean values of the individual segments in such a way that the cumulative departures from these values no longer displayed a discernible pattern. I would later describe the concepts of randomness, white noise and various

probability distribution functions.

Figure 2 was produced by one of the students. Notice the very clear alternating changes in the record mean values required to eliminate the pattern in the cumulative departure plot.

That was more than 20 years ago. Final year civil engineering students, after a single lecture, were able to identify and quantify periodic, alternating sequences in the data. Today, climate change scientists continue to deny that this periodicity exists in the hydro-climatic data.

They also deny the existence of statistically significant linkages between solar activity (in this case sunspot numbers) and river flow (illustrated in Figure 3).

How on earth can climate change scientists ignore the basic properties of river flow that have been known and documented since biblical times and are readily determined by university students after a single lecture? How can Global Climate Models (GCMs) incorporate these properties in water resource studies? The South African authorities have been seriously misled.

ADVANCED METHODOLOGY

It is vital that all those directly or indirectly involved in the development and management of South Africa's water resources should start by realising that the Joseph Effect of alternating flood and drought sequences has been known since biblical times. It is therefore essential that those involved should have a sound quantitative knowledge of multi-year, multi-site hydro-meteorological processes in the first instance.

The only document in South Africa that covers all the fields of knowledge required for water resource development and management is the writer's handbook (referred to above), which is available free of charge from his website. It contains 13 PowerPoint presentations with more than 800 slides, including repeats. As a start the reader of this article should download and study the introduction in Chapter 1 of the handbook. Then download and study the report "Development of a subcontinental drought prediction method". Only when the reader has a sound knowledge of the material in these two documents

