

## Chapter 4

# Climate and solar activity

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## 1. Quick summary

**In this report I raise issues that seriously question the scientific integrity of current climate change science.**

It is shown in this chapter that the IPCC statement regarding the minimal role of variations in solar activity on climate is seriously in error. The regular variations in solar activity are the dominant cause of multi-year climatic variability in the African subcontinent. Adverse climatic variations resulting from human activity are undetectable against this background.

This in turn raises the fundamentally important question. Why was the synchronous linkage between solar activity and climatic responses that has been **observed, studied, confirmed and reported for more than a century** in South Africa and elsewhere, and reported by Tyson and other South African climatologists thirty years ago, completely ignored by South African and international climate change scientists? It is very difficult to believe that they were unaware of these studies that are well reported in the historical climatological and hydrological literature. I expand on this below.

# *PART 1: THE THEORY*

## 2. The IPCC edifice

The IPCC edifice rests on a single assumption. The compilers of the IPCC documentation assumed that the earth's climate is a closed system with no meaningful non-terrestrial influences. From this it follows that reasons for observed historical climatic changes have to be sought within the system and extrapolated into the future. It is claimed that human activities are the source of the observed changes, principally the production of the so-called greenhouse gasses produced by burning fossil fuels. **Remove this assumption of a closed system, then the whole argument for exclusive human causality collapses.**

### 2.1. Closed system?

The argument for a closed system may be summarised as follows. It is maintained that the rate of incoming solar radiation (energy) is sensibly constant. This energy is unevenly distributed over the globe, being greatest in the tropical regions and least in the polar regions. This creates an energy gradient. This in turn results in a poleward redistribution of the energy through the atmospheric and oceanic processes. It is in the mid-latitudes within the region of about  $10^{\circ}$  to  $30^{\circ}$  that the rate of poleward redistribution of solar energy is greatest. Tropical cyclones are a visible manifestation of this process.

Refer again to the illustrations in Chapter 2 and note the complex path followed by parcels of energy as they move through the atmospheric and oceanic systems.

There is a large measure of instability in these atmospheric and oceanic systems. The instability is relatively short-lived in the atmospheric processes but has longer durations in the oceanic processes due to their greater mechanical and thermal inertia.

This instability has two components. There is a stable, predictable (deterministic) component as demonstrated by the direction followed by the major ocean currents. Superimposed on the stable components are the unpredictable (probabilistic) components as demonstrated by the more volatile atmospheric processes that vary from day to day.

Traditionally for practical applications, two different routes have been followed to describe these multi-year properties numerically (as different from mathematically at this stage). The following is the route followed by water resource engineers and hydrologists. It is assumed that the recorded data series has a sensibly constant (deterministic) mean value with unpredictable, random (probabilistic) component about this mean value. The statistical properties of the distribution about the mean are well described in the hydrological literature. Having determined these values, it is a routine matter to generate equally likely synthetic sequences for water resource planning and operation procedures.

Climatologists have traditionally followed a different route. The (generally unstated) assumption is that the processes are fully deterministic. Spectral analysis methods are used in an attempt to determine the multi-year characteristics of the data series. Smoothing techniques such as moving averages and binomial filters are used to suppress short-term variability. As will be shown below, this procedure masks the critically important, sudden transitions from drought to flood conditions, as well as the other consequences of instability phenomena that are present in all atmospheric and oceanic processes, on all time and space scales.

## 2.2. Oscillation or resonance?

If the earth's climate operates within a closed system, i.e. it is not influenced by non-terrestrial forces, then the above approaches, whether by hydrologists or climatologists, leave some important questions unanswered. This can be illustrated by asking a single question: what causes El Niño? This is a well-known and well-studied phenomenon of quasi-regular, multi-year warming and cooling of the waters of the Pacific Ocean, and corresponding apparent linkage with the earth's climate over large areas of the globe.

The general assumption is that there is a causal linkage between Pacific Ocean temperatures and global climate. If this is so, then this leaves the question, what causes El Niño unanswered. If something happens regularly, then the cause is either regular oscillations in the driving mechanism, or a resonance in the receiving mechanism. Which is it? If the earth's climate operates in a closed system, then the only remaining cause is that the earth's climate system resonates like the movement of a pendulum. But there is no evidence to support this theory.

The only remaining theory is that the regular, multi-year changes in the earth's climate are responding to non-terrestrial influences. The centuries-old view, supported by a wealth of observations, is that there is a synchronous linkage between sunspot activity and climate-related processes. **There can be no doubt whatsoever that such a synchronous linkage exists.**

The only remaining issue is whether or not there is a **causal linkage** between non-terrestrial activity and the earth's climate that can account for the regular, predictable, statistically significant, periodicity described in the earlier chapters of this report.

My understanding of the studies reported in the literature is that there is as yet no general agreement on a theoretical basis for such a causal linkage. Therefore,

observation theory based on the wealth of data from many sources, many aspects, and many processes, will have to be invoked. It will be demonstrated below that the results of the study are unequivocal.

### 3. Time series analyses

The following passage is from the technical summary of Working Group 1: The Scientific Basis: Section D. *The Simulation of the Climate System and its Changes* of the IPCC report of 2001.

This section bridges to the climate change of the future by describing the only tool that provides quantitative estimates of future climate changes, namely, numerical models...

The complexity of the processes in the climate system prevents the use of extrapolation of past trends or statistical and other purely empirical techniques for projections...

The degree to which the model can simulate the responses of the climate system hinges to a very large degree on the level of understanding of the physical, geophysical, chemical and biological processes that govern the climate system.

Unfortunately, **this procedure is fundamentally flawed**. The interest is in climate change. Climate in turn does not refer to an instant in time but to a period of time. For example, agricultural and water supply droughts have durations measured in years. The interest is therefore in the properties of future multi-year time series not in changes in mean conditions. Global climate models (GCMs) are inherently incapable of producing information in this format.

It is clear from the above extracts that the climate change researchers did not appreciate the fundamental difference between process theory, which they applied, and observation theory, which is the foundation of the applied sciences. A simple example is the biblical reference to Joseph's prediction of seven years of plenty followed by seven years of famine. More than three thousand years ago the administrators in the ancient Egyptian civilisations were aware of this anomalous grouping of sequences of wet and dry years and the ability to predict future conditions, whereas the IPCC researchers maintained:

The complexity of the processes in the climate system prevents the use of extrapolation of past trends or statistical and other purely empirical techniques for projections... (My emphasis of this fundamental error.)

I developed my successful prediction model in the 1990s. I demonstrated its success in 1995 and again this year (2006). South African climatologists are without doubt aware of my successful prediction model and my studies since then, via my frequent memoranda.

## *PART 2: THE EVIDENCE*

### **4. Famines in India; floods and droughts in South Africa**

*The yellow line rising steeply to a maximum and then falling away gradually to a minimum is the sunspot curve - a curve which ought to be graven on the mind of every man and woman in South Africa. Hutchins 1889.*

#### **4.1. 1889: Hutchins**

In 1889 – more than 100 years ago – colleagues of D.E. Hutchins, conservator of forests in Knysna, persuaded him to publish a compilation of his lectures in a book with the title *Cycles of drought and good seasons in South Africa* in which he demonstrated a remarkable insight into global climatic processes. He used this information to develop a multiyear climate prediction model. This ability still eludes modern climatologists.

Hutchins was one of a generation of scientists and civil engineers who served in the British Colonial Office in India and then migrated to South Africa. He was stationed in Mysore, India when, in 1876, 1,5 million people out of a population of 5 million in the state starved to death during a severe drought. It had been noted previously that there were linkages between sunspot numbers and famines dating back to 1810. These were characterised by droughts being broken by severe floods associated with periods of sunspot maxima. Many scientists at that time, including Hutchins, were involved in the search for predictable linkages between droughts and sunspot numbers. Hutchins details their efforts in his book.

He came to South Africa in 1883 where he continued his research. He studied documents and had discussions with others who had observed that droughts in South Africa were often broken at 11-year intervals by floods that occurred in 1822, 1841, 1863, 1874 and 1885 coincident with sunspot maxima. Hutchins made a number of pertinent observations in his book that remain valid today. These include:

I found that there was a close correspondence between the average price of food grain and the average number of sunspots. Many sunspots: good rains and cheap grain. Few sunspots: bad rains and dear grain.

What that correspondence is can be seen at a glance by inspecting the sunspot curve and the rainfall curve, shown together in this diagram. The yellow line rising steeply to a maximum and then falling away gradually to a minimum is the sunspot curve - a curve which ought to be graven on the mind of every man and woman in South Africa. If our merchants had had this curve in their heads they would have hesitated before shipping mealies from South America at the end of 1885, when there was such a strong probability amounting almost a certainty, that the breaking up of the drought was impending.

Hutchins also showed that the linkage between floods that broke the drought and sunspot numbers was greatest in the temperate climates and did not appear in the tropics nor in Europe and North America that were further from the equator. His studies were driven by a real need and were not just an academic enquiry.

He continued:

This confirmation comes from the Cape Town Observatory. The returns for thirty years from the Cape Town Observatory show a close correspondence between sun-spots and temperatures the maximum of temperature lagging a year behind the minimum of sun-spots. (p17).

At Cape Town, the correspondence between the mean rainfall and mean sunspot frequency has long been an established fact. (p25).

For these reasons we ought to consider the Cape Town Observatory rainfall figures as of great importance to ourselves, an importance enhanced by the fact that they go back to the year 1842. For the three cycles comprised in the period 1842 to 1875 the mean annual rainfall at the Royal Observatory, Cape Town, was: –

During Minimum Sunspot years	21.05 inches.
“ Intermediate “	23.59 “
“ Maximum “	27.95 “

Then, in 1892 Lord Kelvin in a presidential address to the Royal Society precipitated a rift between theoretical scientists who maintained that variations in solar activity were too small to be the cause of the climatic variations, and those who produced solid evidence to the contrary. This rift between abstract process theory, and observation theory solidly based on historical records, continues through to the present day.

Lord Kelvin made a serious error. The issue was of major importance as millions of lives had been lost, and a successful forecasting method could have saved thousands of lives in future. Even if there was the slightest possibility of a causal linkage, it was his duty to recommend further research, not summarily reject decades of observations and studies.

An OCR copy of Hutchins’ report is provided in Appendix F. It makes very interesting reading in the light of the IPCC’s denials more than 100 years later.

#### **4.2. 1966 to 1970: Commission of Enquiry into Water Matters**

In 1966 the South African government appointed a multidisciplinary Commission of Enquiry into Water Matters. The Commission published its report in 1970. The following extracts from the report are relevant to this chapter. Other excerpts appear in later chapters.

Forecasting of climatological conditions:

For some time past, attempts have been made to establish a correlation between rainfall and sunspot cycles, but in South Africa there seems to be little connection between sunspot activity, or changes in the intensity of sunspot activity, and rainfall.

Several pages of the report were devoted to research on this topic. They varied from the optimistic to the pessimistic. For example:

At the beginning of the present century, the famous astronomer, Sir Norman Lockyer, wrote that one of the foremost achievements of the new century would be to forecast well in advance the incidence of famine in India or drought in Australia by means of analyses of sun-spot spectra. Lockyer thus implied that a solution to the problem of long-range forecasting was practically in sight. He was evidently convinced that sunspots were responsible for all large-scale variations in climate...

There is, at the moment, no satisfactory model to explain the inter-relationship of the sun and the earth’s atmosphere. It is also highly questionable whether sun-spot numbers, data for which are readily available and extend over many years, constitute the best parameter for describing the sun’s activity.

Investigations by Abbot, Claydon and several other researchers nevertheless furnish adequate evidence of an orderly relationship between the sun's activity and the frequency of certain types of weather conditions and this clearly deserves further examination. There are frequent occurrences of other meteorological phenomena that cannot be explained on the presumption that the earth and its atmosphere constitute a closed system, so it follows that investigations are called for into possible influences beyond the earth's atmosphere.

Compare this balanced view presented by the South African Commission of Enquiry more than 30 years ago with the entirely dismissive statement in the IPCC's *Summary for Policymakers* published thirty years later in 2001.

Natural factors have made small contributions to radiative forcing over the past century:

Since the late 1970s, satellite instruments have observed small oscillations due to the 11-year solar cycle. Mechanisms for the amplification of solar effects on climate have been proposed, but currently lack a rigorous theoretical or observational basis.

It is very difficult to believe that the writers of this passage were unaware of the wealth of literature to the contrary published during the past 150 years. While the precise nature of the solar processes has yet to be identified, the consequences are undeniable at any reasonable level of scientific enquiry.

**The denial in the IPCC documentation can only be justified on the basis of political necessity, not scientific reason.**

#### **4.3. 1978 to 2006: Alexander**

In my technical report *Long range prediction of river flow: a preliminary assessment* (1978a) published by the Department of Water Affairs. (Appendix C to this report.) I demonstrated that sudden periodic changes occur in most South African rivers. I continued:

The purpose of the present assessment is to examine the records of river flow in South Africa in an attempt to ascertain whether they show a periodicity or correlation with sunspot phenomena that could be used as a predictive tool.

I concluded:

While there is some visual evidence of correlation between river flow and sunspot numbers, both phase and amplitude differences are too large for this relationship to be used for predictive purposes. The phase and amplitude of the sunspot cycles themselves are not accurately predictable which compounds the difficulty.

However, I continued my studies and observed the behaviour of annual flows in the Vaal River. Over the following years it was fascinating to see the cumulative departure curve follow the pattern of previous sequences. The periodicity had not yet reached the 95% level but the signal was very clear. I developed a simulation model that I presented at several South African and overseas conferences. By 1993 I was very confident that the next reversal would occur within two years. I submitted my paper *Floods, droughts and climate change* (1995) to the SA Journal of Science in 1993. It was published in August 1995. Floods developed over a wide area of Southern Africa within three months of publication. Hundreds of lives were lost, communications were disrupted and considerable damage was caused. The solar minimum occurred five months after the commencement of the floods.

I pursued my studies with renewed vigour. Records were now long enough to detect 21-year periodicity in the data at the 95% level of statistical significance using standard serial correlation analyses. The periods commenced with sudden changes from sequences of drought years that were suddenly broken by floods that persisted in the following years. The years in which these reversals occurred were closely synchronous with the years in which the sunspot minima occurred. The years in which the reversals occurred in South Africa's major river are as follows with the corresponding sunspot minima in parentheses. They were 1932/33 (1933), 1941/42 (1944), 1953/54 (1954), 1965/66 (1964), 1972/73 (1975), 1986/87 (1986), 1995/96 (1996), and 2005/06 (2006).

The annual flows during the three years preceding the reversals averaged 60% of the record average annual flows and the subsequent three years averaged 156% of the average annual flows. The average sunspot numbers in the three years before and after the sunspot minima were 17 and 100 respectively. It is very clear that the sudden changes in river flow are closely linked with corresponding changes in sunspot numbers, and are not random events. This relationship exists despite the long and complex energy path starting at the sun and ending with the potential energy of the water in the river, which is a function of its elevation above sea level.

The probability that these observations are chance related is close to zero, but I needed proof. I therefore assembled a very large and comprehensive hydrometeorological database consisting of more than 11 000 annual observations from 198 sites and seven different processes – rainfall, river flow, flood peak maxima, open water surface evaporation, groundwater levels, the southern oscillation index, plus more than 6 000 regional, widespread rainfall events. The data were entirely from the published records of the responsible government authorities, and were not manipulated in any way before or during the analyses. I started with simple graphical presentations. A clear and unambiguous picture emerged.

The non-random grouping of sequences of dry years followed by sequences of wet years with sudden reversals from drought sequence to flood sequences was clear and unambiguous. The 21-year periodicity and its concurrence with the double sunspot cycle were present in all processes other than open water surface evaporation. But this was still not sufficient proof of a causal linkage.

It has long been known that there is a concurrent linkage between sea-surface temperatures in the Pacific Ocean (the El Niño and La Niña effects) and the climate in South Africa and elsewhere. It was tacitly assumed that there was a causal linkage between these effects and climate. In November last year (2005) we were approaching the end of a periodic sequence. Drought conditions still prevailed over the summer rainfall region of southern Africa. I issued a flood alert stating that there was a more than 75% probability of widespread, flood-producing rainfall occurring over southern Africa during the summer rainfall season. Climatologists disagreed and said that floods were unlikely because the La Niña conditions had not yet developed in the Pacific Ocean.

Widespread flooding commenced during the last week in December. By the end of February, rivers were in flood over a wide region of southern Africa from Namibia in the west through to Mozambique in the east. Most dams were full and the desert flora were greener than at any time in memory.

Even more importantly, La Niña conditions developed from January onwards in the Pacific Ocean, and the sunspot minimum occurred during February. My successful prediction based on the statistically significant periodicity in the hydrological and



rainfall data, and its concurrence with the development of La Niña and the sunspot minimum can only lead to one conclusion. There is a strong and unequivocal causal relationship between solar activity on the one hand and the occurrence of climate reversals in southern Africa and the change in temperature of the Pacific Ocean on the other.

**I have achieved something that no South African climatologists have achieved. I have solved the problem identified by the Commission of Enquiry into Water Matters more than 35 years ago, and fulfilled Lockyer's century-old prediction. I have produced a multi-year climate prediction model that can be applied for the development and planning of scarce water resources. It is a world first. In the process, I have demonstrated very serious deficiencies in current climate change science.**

## *PART 3: THE ANALYSES*

### **5. Sunspot database**

Conventional sunspot cycles were used as indicators of solar activity. The following data are from website information distributed by the World Data Centre for the Sunspot Index (2005). There were eight complete cycles during the past century. These commenced with the sunspot minimum that occurred in June 1913, and ended with the sunspot minimum that occurred in March 1996. The lengths of the cycles were 10, 10, 11, 10, 10, 12, 10 and 10 years, with a mean of 10.4 years. These values are within a narrow range of between 10 (minimum) and 12 (maximum) years. A corresponding increase in solar activity during the past century is reflected in the increase in the numbers of sunspots per cycle, commencing with the cycle that started in 1913. Alternating cycles are identified by negative values. The sunspot numbers per cycle were +442, -410, +605, -757, +950, -705, +829 and -785. The maximum was more than twice that of the minimum that occurred only three cycles earlier.

The lengths of the corresponding double sunspot cycles were 20, 21, 22 and 20 years with a mean of 20.8 years, a minimum of 20 years and a maximum of 22 years. The average number of sunspots in the alternate cycles that make up the double cycles were +706 and -664, demonstrating a meaningful difference in sunspot activity in the alternating cycles. As will be seen, the alternating sunspot cycles have appreciably different effects on the hydrometeorological processes.

It will later be demonstrated that it is not the annual sunspot densities that are important in identifying the relationship, but the rate of change in the densities. This is not apparent in the conventional graphs of the sunspot cycles where all numbers have positive values. The sunspot numbers in the alternating sunspot cycles were therefore given negative values, and an arbitrary graph origin of -200 was used for convenience in order to present all values as positive numbers. This is a requirement for statistical analyses where logarithms are employed. (Alexander 2002b). These are graphical datum changes and do not affect the interpretations.

### **6. Methodology**

The emphasis was on simple arithmetical and graphical interpretations rather than mathematical interpretations. The reasons were that mathematical analyses such as harmonic and spectral analysis methods suppress the important, sudden changes that are present in hydrometeorological time series, and may also introduce oscillatory behaviour that is not present in the data.

Standard serial correlation analyses were sufficient to identify statistically significant serial dependence and/or cyclical behaviour should they be present. This procedure followed the standard time series analysis methods that require that the processes be identified graphically in the first instance, and only subsequently be described mathematically. (Chatfield 1982). Additional information on the methodology developed by the author for hydrological time series analyses, is detailed in Alexander (1994, 1995a and 1997).

### **7. Trend analysis**

Conventional statistical trend analyses could not be performed in the presence of the large periodic variations in the data described below. However, simple arithmetical

and graphical analyses demonstrated increases in rainfall in 75 of the 81 rainfall districts with complete records, totalling 9% for South Africa as a whole for the 78-year period 1921 to 1999. Forty-two districts had increases of 10% or more, 12 districts had increases of more than 20%, and four districts had increases of more than 40%. There was also an increase in the numbers of widespread, heavy rainfall events during the latter half of the past century.

There were also increases in open water surface evaporation observed in 14 of the 19 accepted data sets studied. No trends were discernible in any of the other processes studied. If present, they were overwhelmed by the natural variability of these processes.

### 7.1. Numerical comparison

The next aspect studied is illustrated in Table 2, which lists the annual flows in the Vaal River at Vaal Dam as percentages of the mean annual runoff at the site. Vaal Dam is the major source of water for South Africa's largest metropolitan, industrial and mining region. This is the most analysed hydrological record in South Africa. The full period reversals (heavy horizontal lines) refer to the years when the sudden reversals from low flow sequences to high flow sequences occurred. These identified the commencement of the 21-year periods. [These are not exactly 21-years apart.] The light horizontal lines identify the commencement of the mid-period reversals.

Year	Inflow	Year	Inflow	Year	Inflow	Year	Inflow
23/24	39	43/44	353	63/64	58	83/84	79
24/25	246	44/45	87	64/65	149	84/85	30
25/26	42	45/46	66	65/66	27	85/86	36
26/27	66	46/47	58	66/67	175	86/87	46
27/28	44	47/48	57	67/68	31	87/88	208
28/29	83	48/49	33	68/69	35	88/89	165
29/30	142	49/50	100	69/70	60	89/90	65
30/31	40	50/51	33	70/71	52	90/91	59
31/32	36	51/52	60	71/72	102	91/92	13
32/33	24	52/53	100	72/73	23	92/93	26
33/34	170	53/54	45	73/74	112	93/94	92
34/35	131	54/55	181	74/75	295	94/95	17
35/36	87	55/56	80	75/76	247	95/96	464
36/37	225	56/57	277	76/77	123	96/97	N/A
37/38	59	57/58	188	77/78	122	97/98	N/A
38/39	202	58/59	69	78/79	31	98/99	N/A
39/40	112	59/60	75	79/80	63		
40/41	131	60/61	105	80/81	62		
41/42	54	61/62	50	81/82	19		
42/43	185	62/63	68	82/83	12		

The reversals in the flows in the Vaal River from drought sequences to flood sequences evident in Table 2 correspond closely with similar reversals in sunspot density. This is evident in Table 3. In all but one sequence (Vaal River 1965/66, data not available), the three-year totals after the minima of both river flow and sunspot numbers, are substantially greater than the three-year totals before the minima. This information demonstrates the close association between major variations in river flow and corresponding variations in sunspot activity, with a high degree of confidence.

Three-year totals of flows in Vaal River (% of record mean)			Three-year totals associated with the corresponding sunspot minimum		
Minimum year	Three previous years	Three subsequent years	Sunspot minimum	Three lowest years	Three subsequent years
1932/33	100	388	1933	25	250
1941/42	297	625	1944	56	277
1953/54	205	538	1954	50	370
1965/66	234	241	1964	53	247
1972/73	177	654	1975	73	275
1986/87	112	438	1986	60	400
1994/95	135	464+	1996	48	277
Average	180	478	Average	52	300

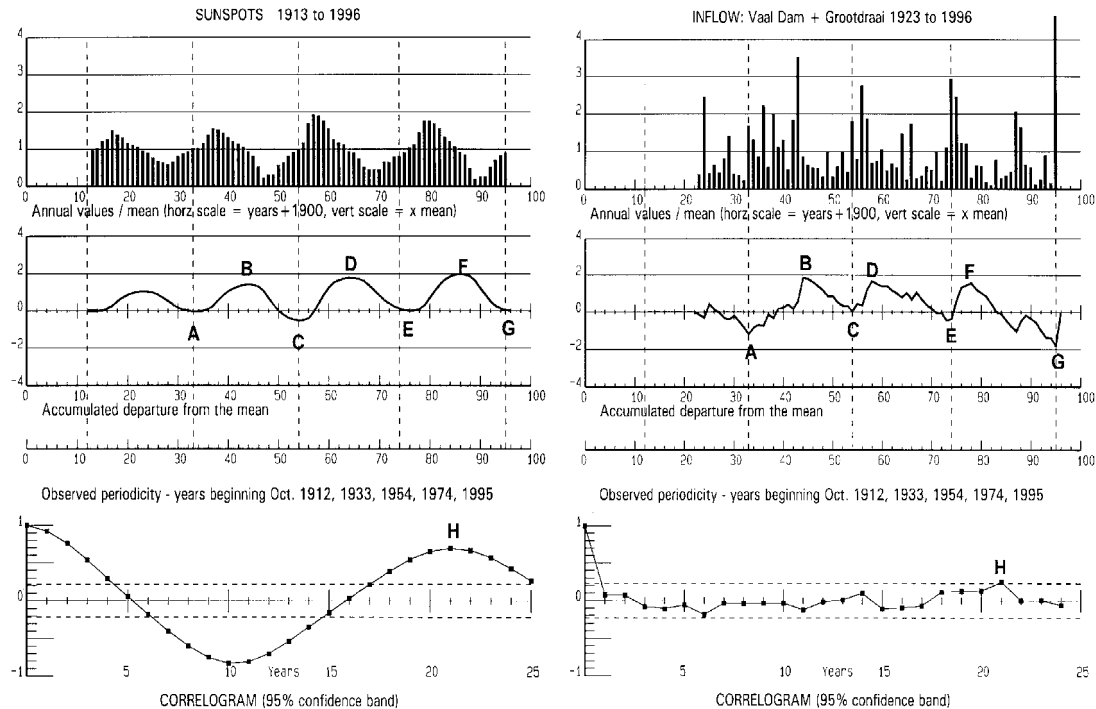
There are several interesting features in this table. There is an almost three-fold, sudden increase in the annual flows in the Vaal River from the three previous years to the three subsequent years. This is directly associated with a six-fold increase in sunspot numbers. The second important point is the consistency in the range of sunspot numbers before and after the reversal. The totals for the three prior years varied between 25 and 60, and the totals of the three immediately subsequent years varied between 250 and 400. It is very clear that these are systematic changes associated with the sunspot minima, and are not random events.

This relationship exists despite the long and complex energy path starting at the Sun and ending in the river flow that enters Vaal Dam. The only residual energy is the potential energy, which is a function of the elevation of the water mass above sea-level. This residual energy has its origin in solar activity; followed by the arrival on the Earth's atmosphere, continents and oceans; followed by the poleward movement of the energy through complex atmospheric and oceanic processes; followed by the systems that produce the rainfall; and finally by the complex rainfall-runoff processes. The survival of the periodic signals on its own demonstrates a strong and unequivocal relationship between variation in solar activity and the corresponding variation in climatic responses.

## **7.2. Graphical comparison**

The next issue is the nature of the solar-induced periodicity of the hydrometeorological processes.

Fig. 1 shows graphical comparisons of the properties of the double sunspot cycle with those of the Vaal River. This follows the method developed by Alexander (1978) and successfully used to predict the climate reversal from drought to flood sequences that occurred in 1995. (Alexander 1995).



**Figure 1. Comparison of the characteristics of annual sunspot densities with corresponding characteristics of the annual flows in the Vaal River.**

A reference datum value of  $-200$  was used in the sunspot data in order to accommodate the negative values. This has no effect on the interpretations. The top panels are the conventional dimensionless histograms, where all values are expressed as multiples of the record mean values. While the cyclicity is apparent in the sunspot panel it is not recognisable in the river flow. The river flow histogram shows the high degree of asymmetry about the mean value with many more values less than the mean value than above it. This is typical of river flow data in dry climates.

The most informative graphical presentations are those in the second panels, which show the accumulated departures from the record mean values. These are obtained by subtracting the mean values (1.0) from each of the values in the histogram. Some of the values will be negative. These are accumulated one at a time and the sum plotted.

An increase in the accumulated departures of the sunspot numbers during the period of record is immediately apparent. The maximum negative departures occurred at the start of the 21-year periods, identified as (A), (C), (E) and (G).

The comparison with that of the flow in the Vaal River is very instructive. The reversals at points (A), (C), (E) and (G) are virtually identical with the corresponding reversals in the sunspot data. They occurred during the hydrological years beginning October 1933, 1954, 1974, and 1995. The rising limbs A-B, C-D and E-F are sequences of years where the inflows were greater than the mean value. The falling limbs B-C, D-E, and F-G are sequences where the inflows were less than the mean value. These alternating sequences were reported in the early hydrological literature

where they were referred to as the Joseph effect, after Joseph's biblical prophecy. (Mandelbrot and Wallis 1968).

The third panels are the correlograms. This is a standard calculation procedure in time series analyses. The statistically significant cyclicity in the sunspot data is clearly apparent. The 95% confidence limits are  $\pm 0.22$ . The minimum and maximum (H) autocorrelation coefficients occur respectively at 10 (-0.83) and 21 (+0.70) years, which are well in excess of the 95% confidence limits.

The statistically significant cyclicity in the sunspot cycles is no longer present in the correlogram of the annual flows in the Vaal River, where the residual coefficients indicate random noise. The only, but very important, residual serial correlation, is the statistically significant 21-year periodicity. This is identified at (H) in the bottom panel of the figure.

### 7.3. 21-year periodicity in hydrometeorological data

Table 4 shows the presence of 21-year concurrent periodicity in South African hydrometeorological data. The degree of statistical significance is dependent on the length of the record as well as the magnitude and nature of the variability about the mean. The periodicity is almost certainly present in all hydrometeorological data series, other than evaporation, but has not yet reached a high level of statistical significance at some of the sites.

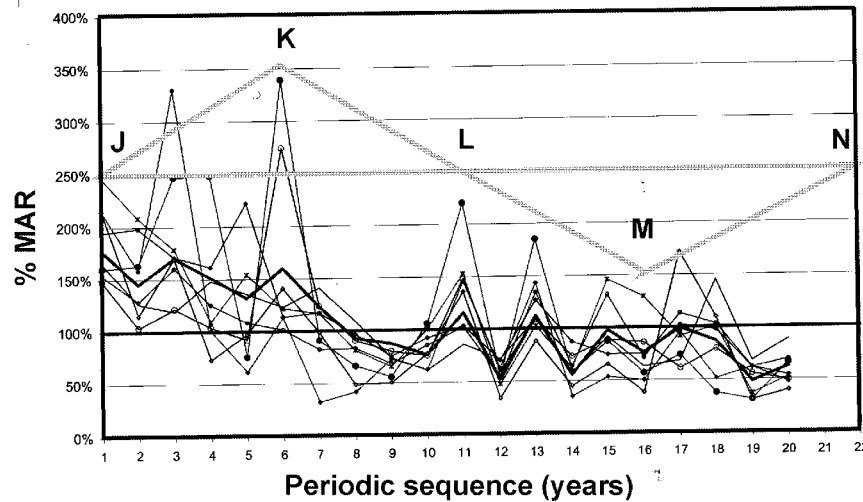
Process	Nr of sites	Record years	Periodicity			
			95%	Present	None	Not determinable
Evaporation	20	1 180	0	0	20	0
Rainfall	93	7 141	18	67	8	0
River flow	28	1 877	7	12	5	4
Flood peak maxima	17	1 235	4	7	2	4

While the reversals are a characteristic of the start of the periods, the periodicity refers to the whole spectrum of values. For example, a significant correlation exists between all the fifth values after the commencement of the periods, all the ninth values, and so on. This relationship is stronger than the relationship between successive values in the hydrometeorological data where no statistically significant serial correlation exists. (See the plot of the first year in the correlogram for the Vaal River in Fig. 1.)

### 7.4. Nature of the periodicity

Fig. 2 illustrates the nature of the periodicity in river flow at a number of representative sites in South Africa. The procedure used for each site was to extract the data in 20-year sequences starting in October of the following years: 1912, 1933, 1954, 1974 and 1995. Then the average values for each year of the sequence divided by the record mean annual runoff (MAR), were determined and plotted. The reference period used for calculating the MAR was that from 1954 to 1974 as it was the only period that was common to all data sets. The selection of a reference period does not affect the results. This procedure was repeated for the other sites. The rainfall and

flood peaks exhibited similar characteristics, although the rainfall amplitudes were less and the flood peak amplitudes were greater than those of river flow. The diagrammatic double sunspot cycle is included in the figure for ease of comparison.



**Figure 2. Characteristics of the periodic sequences of river flow at representative dam sites. The double sunspot cycle is diagrammatically superimposed.**

While there is a large scatter in the plotted results, the general trend is clear and several conclusions can be drawn from it. Major flood events are associated with the first half of the first sunspot cycle, (J-K). This is the sub-period when the **rate of increase** in sunspot density is greatest, (see Table 3 above), and is associated with global atmospheric and oceanic turbulence at this time. This in turn generates the processes that produce heavy, widespread rainfall events that generate river flow.

In contrast, sunspot density decreases during the second half of the first cycle (K-L). This is a quiescent sub-period with reduced turbulence in the poleward energy distribution process, and consequent absence of high rainfall events that generate river flow. Droughts occur as a result of the absence of these events.

The characteristics of the second of the two sunspot cycles (L-M-N) are very different from those of the first cycle (J-K-L). Fewer heavy rainfall events occur. Droughts become increasingly prevalent during this cycle. It is postulated that this is the consequence of the differences in solar activity between the two cycles as well as the lesser sunspot density.

There is also a clear, diminishing, annual oscillatory pattern during the beginning of the second sunspot cycle (L-M) that is not present in the greater scatter during the first cycle. No possible causes can be offered.

## 8. Further confirmation

Further confirmation of the linkage between the rate of increase in sunspot density and rainfall over South Africa as a whole is shown in Table 5, which shows the relationship between the months during which the maximum rainfall occurred and the corresponding years in which the sunspot minima occurred. The lag is the difference

in years when the sunspot minima are used to predict the rainfall maxima. The lower panel is a repeat of the upper panel, using the flood peak maxima observed in the Mkomazi River, south of Durban.

<b>Table 5. Comparison of ranked maximum values with sunspot minima</b>				
South African rainfall			Sunspot minima	
Rank	Month	mm	Year	Lag (years)
1	Mar 1925	211	1923	+2
2	Jan 1974	149	1976	-2
3	Feb 1939	148	1933	+6
4	Feb 1988	145	1986	+2
5	Jan 1923	138	1923	0
6	Jan 1976	136	1976	0
7	Feb 1955	132	1954	+1
8	Jan 1958	130	1954	+4
<b>Ranked flood peak maxima in the Mkomazi River</b>				
Flood maxima			Sunspot minima	
Rank	Year	m <sup>3</sup> /s	Year	Lag (years)
1	Mar 1856	7 000	1856	0
2	Mar 1925	6 260	1923	+2
3	May 1959	6 200	1954	+5
4	? 1868	6 130	1867	+1
5	Mar 1976	2 140	1974	+2

The 1856 peak was concurrent with the flood peak in the Mgeni River, where floodwaters flowed across Durban and into Durban harbour. These floods occurred in March 1856. The maximum recorded flood engraved on the buttress of the Georges V Bridge built in 1760 across the Loire River in Orleans, France occurred in June 1856. The sunspot minimum occurred in December 1855. (World Data Centre for the Sunspot Index 2005). This correspondence in time (months) and space (hemispheres apart) is far too great to be coincidental.

Six of the eight rainfall events and four of the five flood peak maxima occurred within two years of the sunspot minima. This confirms that these extreme events are sensibly synchronous with the reversals in sunspot density associated with the sunspot minima as shown in Table 2.

It is also important to note that these maxima were recorded 80 years ago (rainfall) and 149 years ago (Mkomazi floods), and that there is no evidence of an increase in time that could be associated with global warming. Historical observations in several other rivers confirm that the floods in the mid-1800s remain the highest on record.



### 8.1. Alternating wet and dry sub-periods

Analyses showed that the rainfall and river flow during the first half-period (first sunspot cycle) are appreciably higher than the second half-period. For example, for the first ten years of the period, the average of the maximum annual river flow values for all sites analysed was 675% of the record mean values compared with the average of the following ten years of only 380% of the record mean values. This is probably associated with the sign of the sun's magnetic polarity. Other analyses not reported here showed that the high values in the first half-period are the result of widespread, heavy rainfall events, while the low values in the second half-period are the consequence of the absence of these events.

Tyson (1987) provided evidence supporting the presence of alternating sequences of years with high and low rainfall over large regions of South Africa. He noted the oscillatory nature of the data and although he was unable to trace its cause. **He concluded that its physical reality was considerable in South Africa and in other countries.** He noted that the 11-year solar cycle was mentioned in the literature but he did not discuss it further.

Bredenkamp (2000) studied groundwater resources. He used the cumulative departure method as his principal tool, for which he developed a mathematical relationship. He demonstrated the presence of wet and dry sequences from 1919 through to 1992 based on water level observations at Lake Mzingazi; discharge from the Uitenhage springs corrected for abstractions; water levels at Lake St Lucia; and groundwater levels at the Wondergat sinkhole in a large dolomitic formation. These all have high storage/input ratios that smooth out the short-term fluctuations.

Table 6 is a combination of the independent observations by Tyson (1987) and Bredenkamp (2000), each relating to different climatic processes and different analytical methodologies, and a comparison with sunspot cycles. The first and most important observation is the presence of alternating sequences of wet and dry years, and the corresponding alternating sequences of sunspot cycles. **While the comparative years are not precise, there can be no doubt at all that a meaningful relationship exists with sunspot cyclicity.**

<b>Table 6. Wet and dry sequences</b>				
Years	Wet/dry	Length of sequence		Sunspot cycles
		Wet	Dry	
<b>Bredenkamp: Mzimgazi + St Lucia + Uitenhage + Wondergat</b>				
1919-24	Wet	5		1913-22
1925-29	Dry		4	1923-32
1930-39	Wet	9		1933-43
1941-53	Dry		12	1944-53
1955-62	Wet	7		1954-63
1965-71	Dry		6	1964-75
1972-78	Wet	6		1976-85
1980-83	Dry		3	-do-
1984-90	Wet	6		
<b>Tyson: South African rainfall</b>				
1905-15	Dry		10	1901-12
1916-24	Wet	8		1913-22
1925-32	Dry		7	1923-32
1933-43	Wet	10		1933-43
1944-52	Dry		8	1944-53
1953-61	Wet	8		1954-63
1962-70	Dry		8	1964-75
1971-80	Wet	9		1976-85

Compare the lengths of the sequences of wet and dry years with the biblical seven years of plenty followed by seven years of famine. The ancient Egyptians were well aware of these alternating sequences in the annual flows of the life-giving Nile River.

## **8.2. Mathematical modelling**

The final stage was the development of a mathematical simulation model for water resource development and management applications that accommodates the characteristics described in this report. There was no need to invoke linkages with solar activity. Nor was it necessary to include the postulated adverse consequences of global warming, such as increases in floods and droughts and threats to water supplies, for which there was no evidence. The methodology developed by the author is described in Alexander. (1994, 1997).

## PART 4: CONCLUSIONS

### 9. Interpretation

The following view was expressed in the IPCC's Summary for Policymakers (IPCC 2001):

Since the late 1970s, satellite instruments have observed small oscillations due to the 11-year solar cycle. Mechanisms for the amplification of solar effects on climate have been proposed, but currently lack a rigorous theoretical or observational basis.

A very recent development is the publication *Surface Temperature Reconstructions for the Last 2,000 Years* by the US National Research Council (NRC) of the National Academies. It was published in June 2006. The principal issue was the causes of global temperature increases within the context of climate change.

The following sources of proxy evidence were provided under the heading *What kinds of proxy evidence can be used to estimate surface temperatures for the last 2,000 years?* They were instrumental records, documentary and historical records, tree rings, corals, ice cores, marine and lake sediments, boreholes, and glacier length records. Details were provided explaining how the proxy data were used to reconstruct surface temperatures.

Chapter 10 of the NRC report was devoted to climate forcings and climate models. The following is a summary.

- The main external climate forcings experienced over the last 2,000 years are volcanic eruptions, changes in solar radiation reaching the Earth, and increases in atmospheric greenhouse gas and aerosols due to human activities.
- Proxy records are available for reconstructing climate forcings over the last 2,000 years, but these climate forcing reconstructions are associated with as much uncertainty as surface temperature reconstructions.
- Greenhouse gases and tropospheric aerosols varied little from A.D. 1 to around 1850. Volcanic eruptions and solar fluctuations were likely the most strongly varying external forcings during this period, but it is currently estimated that the temperature variations caused by these forcings were much less pronounced than the warming due to greenhouse gas forcing since the mid 19<sup>th</sup> century.
- Climate model simulations indicate that solar and volcanic forcings together could have produced periods of relative warmth and cold during the preindustrial portion of the last 1,000 years. However, anthropogenic greenhouse gas increases are needed to simulate late 20<sup>th</sup> century warmth.

Page 97 of the report is devoted to solar variability. These are two short extracts.

Proxy records of solar irradiance have been used, often in combination with recent satellite measurements and solar modelling experiments, to obtain reconstructions of solar irradiance over the last two millennia...

Significant uncertainties exist in all the records because of the shortness of the calibration record and our incomplete physical understanding of solar activity and its influence on irradiance.

As shown in this and the two previous chapters of this report, the presence of regular, multiyear, predictable, periodicity in the water-related climatic processes and the linkage with solar activity is beyond doubt. Surely it must be obvious that if irradiance changes are too small to account for the synchronous linkages with sunspot activity, there must be some other solar mechanisms at play.

The argument that solar activity is too small to account for multi-year variations in climate, and that consequently greenhouse gasses must be the cause of the observed variations is patently false.

In 1889 Hutchins published a very perceptive and well-documented linkage between solar activity and climate-related responses. (Hutchins 1889). This linkage was repudiated by many eminent solar physicists, who for the past hundred years have maintained, and still maintain, that these correlations lack causal mechanisms supported by high quality data. In this report a causal linkage is demonstrated with a high degree of confidence based on a detailed study of a very large climate-related database.

Hopefully, the information provided here will assist solar physicists identify the specific characteristics of the solar processes that cause these climatic features that were noted and documented in South Africa more than a hundred years ago, and on a number of occasions since then.

## 10. Conclusions

The following conclusions are based on the four-year study of a very large and comprehensive hydrometeorological database.

1. There is an unambiguous, regular and therefore predictable, statistically significant (95% level), 21-year periodicity in South African annual rainfall, river flow, flood peak maxima, groundwater levels and lake levels.
2. This periodicity is directly related to, and concurrent with, the double sunspot cycle.
3. The single, 11-year sunspot cycle is not statistically evident in the serial correlation analyses. The reason is that the alternating cycles have different characteristics. This explains why climate change researchers were unable to detect climate change characteristics that corresponded with the sunspot cycle. They should have searched for linkages with the double sunspot cycle.
4. The commencement of the responses to the double and single sunspot cycles are characterised by sudden reversals from low rainfall and river flow (drought) conditions to conditions of high rainfall and floods.
5. There is a direct correspondence between these reversals and sudden increases in annual sunspot numbers and reversals of solar activity that occur at the time of the sunspot minima.
6. The abrupt rate of increase in solar activity also causes abrupt increases in the poleward redistribution of solar energy, which in turn results in increased frequency and magnitude of the widespread, heavy rainfall-producing systems. Quiescent periods have the opposite effect.
7. The responses to the two sunspot cycles that comprise the double sunspot cycle are fundamentally different. The sequences of rainfall, river flow, floods, lake and groundwater levels associated with the first cycle are appreciably

higher than those of the second cycle. These alternating ‘wet’ and ‘dry’ sequences are well reported in the hydrological literature, but their relationship with sunspot cycles was not investigated prior to this study.

8. The general view of many climatologists and solar physicists that variations in solar activity are too small to account for observed variations in climate will have to be reviewed. Scientists who hold these views should also be aware that it is essential that the linkages between solar activity and climatic responses described in this report be incorporated in any global climate model used for predicting the influence of the accumulation of greenhouse gas emissions, if it is to produce verifiable results for practical applications. (Alexander 2002a, 2004, 2005a, 2005b).
9. Many other properties can be identified in hydrometeorological time series analyses that could provide valuable insights into the nature and quantification of the linkages between solar activity and the hydrometeorological responses.

## 11. Final confirmation

At the risk of oversimplification, this is the route that climatologists have followed in their long-term climate predictions. They noted the concurrent linkage between sea surface temperatures (SSTs) in the Pacific Ocean (El Niño and La Niña) and South African climate (dry and wet conditions respectively) and assumed that there was a **causal** linkage between the SSTs and our climate.

As long ago as in 1995 at the international IGBP conference here in Pretoria after I presented my *Floods, droughts and climate change* study, I asked the question ‘*What causes El Niño?*’ I received the joking response that if I could answer that question I might qualify for the Nobel Prize. Well, I can now answer that question. It is the direct consequence of changes in solar activity. The occurrences during the two months (January and February 2006), have provided the proof that I needed.

In a number of my memos and publications I demonstrated an undeniable linkage between changes in solar activity and concurrent changes in South African rainfall and river flow. The strongest, and scientifically undeniable linkage, is that between reversals in solar activity of which sunspot minima are a measurable manifestation, and the concurrent, sudden reversals from drought to flood sequences that started in December 2005. The sunspot minimum that identifies the end of the 23<sup>rd</sup> sunspot cycle has just occurred.

### But what about La Niña?

In my Flood Alert distributed on 9 November last year I wrote:

Exactly ten years ago, in November 1995, South Africa experienced severe, widespread floods that broke several years of severe drought. The conditions then were very similar to the present situation. We have already entered the turbulent period associated with the occurrence of the Sun’s reversal of magnetic polarity. The tropical cyclone activity that includes Katrina, is a consequence of this activity.

My prediction (not forecast) is that there is a better than 75% probability of widespread, flood-producing rainfall occurring between now and the end of April. Please note that there is a 25% probability that this will **not** happen. This order of accuracy is much the same as the daily weather forecasts.

The prediction is based solely on the assumption that the observed periodicity in flood-frequency analyses will continue.

I received responses to my flood alert from three experienced climatologists who are on my distribution list, to the effect that floods were unlikely. As one of them commented ‘*By ignoring current conditions, you are wasting your time. Pacific sub-surface temperatures are only slightly below normal in the 100-200 m layer*’. This response is very important and I am grateful for it, as it proves the point that I am about to make.

This comment shows that climatologists (in general) assume that there is a **causal linkage** between the Pacific sea surface temperatures and South African climate. However the La Niña phenomenon only commenced developing a month after my flood alert and concurrent with the commencement of the floods.

All three conditions developed simultaneously: the commencement of La Niña; the commencement of the floods; and the sunspot minimum that is an indicator of a sudden increase in solar activity. It now becomes obvious that the floods were not caused by Pacific sea surface temperatures (La Niña), but that the floods **and** La Niña were both caused by sudden, regular, and therefore predictable, changes in solar activity.

Furthermore, my successful prediction of imminent floods, demonstrates beyond all doubt that my analytical methods, based on observation theory applied to a very large and comprehensive hydrometeorological database, are superior to the mathematical global climate models based on process theory. There can be no doubt about this.

#### **Causal linkages update**

The latest news from Namibia is that springs and fountains have started flowing in this arid area for the first time in memory. This indicates that the groundwater storage is saturated by the unusually large volume of rainfall that has occurred.

From a hydrological perspective, these are known as ‘high outlier’ events in that they do not form part of the family of normal occurrences. (See Alexander 2002, *Statistical analysis of extreme floods*). This in turn negates the view in the IPCC publications that climate consists of random fluctuations about a stable mean condition. This is not so. It can be shown without difficulty that the means of the principal climatic responses, rainfall and river flow, are not constant but vary systematically with time. This fact has been known since biblical times, studied by hydrologists for the past fifty years, and quantified numerically in my paper *Development of a climate prediction model*. (Alexander 2005a).

#### **Floods are beneficial**

Another disturbing feature in the IPCC publications is the view that global warming will result in an ‘intensification of the hydrological cycle’, which in turn will result in an undesirable increase in damaging floods. Once again, this assertion is incorrect as the present extensive floods in sub-equatorial Africa demonstrate. There was minimal loss of life as the emergency services were well organised, and no major structures failed.

In dry climates the heavy, widespread, flood-producing rainfall saturates the soils, increases crop production, increases groundwater storage, causes rivers to flow strongly, which then replenishes water stored in dams. As a rough estimate, more than 75% of the water supplies from storage dams in dry climates are derived from flood inflows, and less than 25% from ‘normal’ river flow. Few of the rivers in these regions are perennial, while nearly all the smaller rivers only flow as the result of specific, heavy rainfall events.

### **Finally**

The lack of knowledge of basic, climate-related, stochastic processes in the 'consensus views' of climate change scientists in the IPCC publications is very disturbing on two grounds. The first is that the naïve assumption of random variability about a stable mean condition. The facts are that the mean itself changes systematically and predictably. This undermines the faith in the conclusions reached in the publications. The second is that it is simply impossible to accommodate the results in the format produced by current global climate models, in any amelioration or mitigation studies. An example of the required format for climate-related studies is given in Alexander 2005a.

### **Where does this leave climate change theory?**

Climate change theory rests heavily on mathematical models of global climate, which in turn are based on unprovable process theory. These models do not accommodate the undeniable effects of solar activity and are therefore untrustworthy. This is illustrated by the inability of these models to provide provable evidence of their reliability when replicating real world processes.

My analysis of South African rainfall data shows that rainfall has increased, not decreased. It will continue to increase as long as the causative mechanisms remain unchanged. The global climate model is clearly unreliable and the outputs no more than speculative.

These aspects of climate change are of fundamental importance to the future prosperity of South Africa. In this report it is shown with a high degree of confidence that the multi-year variability of South African climate is directly related to solar activity. The postulated adverse climatic changes resulting from human activity, if present, are undetectable against this background and are therefore no cause for concern.

**There is no evidence of changes in climate during the past century that can be attributed to unnatural causes. Nor are such changes likely to occur in future. The alarmist claims by climate change lobbyists are groundless.**

## **12. Verification studies**

The full data set in computer-readable format is available on request to those who would like to verify the conclusions or to carry out further studies along these lines. The information includes station reference data, which allows verification from the official authorities that supplied the information. Other than minor patching of missing data, the data were not smoothed, filtered or otherwise manipulated in any way before or during the analyses. The calculations were simple can be replicated without difficulty. No mathematical models were used in the analyses.

## **13. Additional references**

Alexander, W.J.R.1978. *Long range prediction of river flow – a preliminary assessment*. Technical Report TR80, Department of Water Affairs, Pretoria.

Alexander, W.J.R. 1994. Anomalies in the stochastic properties of river flow and their effect on reservoir yield. In: Jan-Tai Kuo and Ko-Fei Liu eds. *Proceedings of the Republic of China-South Africa Bilateral Symposium on Water Resources*, Taipeh, Taiwan, 1994, 131-142.

Alexander, W.J.R. 1995b. Floods, droughts and climate change. *S Afr J Sci* **91**, 403-408.

Alexander, W.J.R. 1997. Predictability of widespread, severe droughts, and their effect on water resource management. *Proceedings, 5<sup>th</sup> International conference on southern hemisphere meteorology and oceanography*. Pretoria. Invited guest presentation.

Alexander, W.J.R. 2002b. Statistical analysis of extreme floods. *J S Afr Instn Civ Engg*, **44** (1) 2002 20-25.

Alexander, W.J.R. 2005a. Development of a multi-year climate prediction model. *Water SA* Vol 31 No 2 April 2005.

<http://www.wrc.org.za/downloads/watersa/205/Apr-05/1788.pdf> (Full paper).

Alexander, W.J.R. 2005b. Linkages between Solar Activity and Climatic Responses. *Energy & Environment*, Volume 16, No 2, 2005.

<http://www.ingentaconnect.com/content/mscp/ene/2005/00000016/00000002/art00003>

(Abstract only.)

Bredenkamp D.B. 2000. Groundwater monitoring: a critical evaluation of groundwater monitoring in water resources evaluation and management. Water Research Commission Report No. 838/1/00.

Commission of Enquiry into Water Matters. 1970. RP 34/1970 Government Printer.

Hutchins D.E. 1889. *Cycles of drought and good seasons in South Africa*. Wynberg Times Steam Printing Office. Wynberg

Intergovernmental Panel on Climate Change 2001. *Summary for policymakers*.

Mandelbrot B.B. and Wallis J.R. 1968. Noah, Joseph, and Operational Hydrology. *Water resources Research*, Vol. 4 No 5 October 1968.

Stoker P.H. and Chao J.K. 1991. The solar magnetic cycle and global marine temperature variation. *S Afr J Sci* **87**, 51-55

Tyson P.D. 1987. *Climatic change and variability in Southern Africa*. Oxford University Press.

World Data Centre for the Sunspot Index 2005. Yearly sunspot numbers from 1750 to 2004. <http://sidc.oma.be>