

CLIMATE CHANGE SCIENCE IS AN UNVERIFIED HYPOTHESIS

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Summary

It is fundamentally important to understand that climate is not a steady state phenomenon with random variations about constant mean values. Natural changes of the mean value itself occur on all time scales from years through to millennia. The determination of human influences on climatic processes has to be sought against this background.

Climate change theory rests on two interlinked hypotheses. The first is that increasing discharges of carbon dioxide into the atmosphere will result in increases in global temperatures. The second hypothesis is that increases in global temperatures will have a whole range of undesirable consequences. The consequences of greatest concern are the postulated increases in the hydrological extremes (floods and droughts) and irreversible damage to the natural environment.

Hypothesis verification is a fundamental scientific requirement. In this situation the obvious verification route to follow is to examine the worldwide wealth of hydrological data extending from biblical times through to the present. If the hypotheses are valid and the consequences are as serious as claimed, there should be very clear and unambiguous increases in the hydrological extremes.

Studies by this author and others demonstrate that there have been no long-term unnatural changes in the hydrological and environmental processes during the period of record. Consequently, the second critical hypothesis has no substance. Therefore the very basis of climate change science is without foundation.

Background

The discharge of carbon dioxide and other gases into the atmosphere from coal-fired power stations, transport, industrial activities and other sources increased steadily during the past 100 years. It is claimed that these emissions create a greenhouse effect in the atmosphere. This will result in increases in global temperatures. It is further claimed that the principal hydroclimatological consequences of the temperature increases will be adverse changes in rainfall, river flow, floods and droughts as well as irreversible damage to the natural environment.

The Intergovernmental Panel on Climate Change (IPCC) was established in 1988. It produces detailed assessment reports at five-yearly intervals starting in 1993. In that year the author was requested to host a small meeting of scientists who wished to discuss the climate change issue. During the meeting the author informed the participants that there was no evidence in the hydroclimatological data that supported the concerns. His comments were ignored.

In view of the importance of the issue, the author submitted a formal paper to the South African Journal of Science. It was titled 'Floods, Droughts and Climate Change', in which he demonstrated that there was no evidence that supported climate change theory. The paper also predicted an imminent change from drought to flood conditions. The paper was published in August 1995¹. Floods commenced from January 1996 onwards.

During the subsequent years the author and his colleagues continued their published studies in the field of water resource development and flood magnitude/frequency analyses^{2,3,4}. In 2004 the author was a member of a team of international experts appointed to advise the Japanese authorities on the establishment of an international water research institute. During a break he asked the team what they thought of the climate change issue. The response was unanimous. It was nothing more than an unverified hypothesis.

International relations in the field of climate change reached a peak in 2008 and have deteriorated since then. The 17th Congress of the Parties organised by the United Nations Framework Convention on Climate Change (UNFCCC) was held in Durban in December 2011. The UNFCCC consists of representatives of the 149 United Nations countries. It has now become unlikely that the majority of the members of the UNFCCC, particularly the developing countries, will abide by the nebulous decisions reached in Durban. These were

that legal ratification of national commitments to reduce carbon dioxide emissions would be achieved by 2015, and implemented by 2020. This is unlikely to happen.

To make matters worse, the European Union has announced that it will implement carbon taxes on all airlines travelling to and from Europe. It made this decision without consulting other nations. Two of the principal nations that will be affected by this decision, China and the USA, have already protested and threatened to take retaliatory action. A very serious international situation has now arisen. There are prospects of global trade wars. It is against this background that the author has written the following notes.

Exploratory studies by the author

The largest and most comprehensive hydroclimatological database yet assembled in South Africa was studied. It consisted of 18 000 observations from 200 data sets and eight different hydroclimatological processes. Details are provided in Table 1.

[Insert Table 1.

The sites were selected on the basis of their geographical representativeness and long, reliable records. All except two of the records (Southern Oscillation Index and Zambezi River flow) were extracted from official databases operated by the South African Weather Service and the Department of Water Affairs. Other than minor patching of missing data, the data were not smoothed, filtered or in any way manipulated before or during the analyses. This is an essential requirement for hydrological time series analyses. The use of annual data avoids the need to accommodate seasonal changes.

As the concern was the possible consequences of climate change, the search was for simultaneous characteristics in the time series that were common to multiple sites and multiple processes. These included trends, extremes and sudden changes. Anomalies at a single site or a single process did not meet these requirements. Despite the diligent search using a number of different methods, no such characteristics could be found other than a very clear, synchronous linkage with sunspot activity.⁵

What then is the basis for the claim that greenhouse gas emissions have had dramatic, adverse effects here in South Africa? If they have already occurred, climate change scientists have a professional responsibility to identify them and prove that they are not the consequence of normal climate variability. This has not happened.

Applied climatology

The basic problem is that few seem to appreciate that there is a fundamental difference between the pure and the applied sciences. The issue is the determination of likely future conditions. This can only be achieved by studying past conditions and extrapolation into the future. This requires the application of expertise in the fields of time series analyses and stochastic processes. It is clear from the IPCC's assessment reports distributed during the past 20 years that they are ignorant of these requirements that are bread and butter issues in applied hydrology.

Their fundamental mistake is the basic assumption that climate is defined as average weather, i.e. that it is a steady-state phenomenon. This is provably false. In technical terminology:

- The annual values are sequentially independent but not serially independent.
- The sequential values are not identically distributed as both the mean values and the distribution about the mean values change from one year to the next.
- The series are not stationary in time because of the presence of statistically significant serial correlation.

Furthermore, the development of computer models to undertake these studies requires the assessment of modelling difficulties such as accommodating problems of dimensionality, uncertainty and scale that have to be considered and overcome. The global climate computer models are fundamentally incapable of reproducing these characteristics. The next step of applying stochastic theory to predict future conditions is beyond their comprehension.

With the above in mind, climate change studies should be conducted in four phases:

Phase 1: Studies of the natural climatic processes that are vulnerable to disturbances.

Phase 2: Numerical quantification of the natural hydroclimatological processes, including their variability in space and time.

Phase 3: Studies of possible disturbances of the climatic processes by human activities.

Phase 4: Quantitative estimation of the likely consequences of these disturbances relative to the natural conditions.

It must be emphasised that proof of the processes such as global warming, is not proof of the consequences such as increases in floods and droughts. This is basic.

The whole procedure can be bypassed by direct numerical analyses of the wealth of published hydroclimatological data in the search for changes that cannot be attributed to natural variations. Unfortunately, notwithstanding its existence for more than 20 years, the IPCC in its regular assessment reports ignores the critical Phase 2 requirements without which Phase 4 estimates have no practical significance.⁶

Other examples of undesirable practices by many climate change scientists and their institutions are illustrated in this submission. Normally, these issues would be of little interest outside the scientific community. Unfortunately due to the publicity and the public's trust in the honesty of science, costly decisions are about to be made by governments that will inevitably result in damage to national economies without having any influence at all on the climate change processes.

Serious situation

Table 1 details the database used by the author for recent studies. Attempts to identify changes that could be attributed to increased greenhouse gas emissions were unsuccessful. The author made several attempts to discuss these issues with climate change scientists but his approaches were rejected. Several of these scientists then resorted to personal vilification tactics such as the publication of an anonymous article in the magazine *Nosweek*, in an attempt to suppress contrarian views. This has become a characteristic international reaction to opposing views.

A very serious situation has now arisen. The South African authorities are in the process of committing this country to costly and demonstrably futile measures to reduce our so-called greenhouse gas emissions from coal-burning power stations, transport and industrial activity.

Unfortunately, South Africa has no scientific body with the authority to evaluate and comment on the faulty and in some cases corrupt science that is now being practised by a

handful of climate change scientists, and the confused requirements described in the United Nations publications.

As demonstrated in this submission, climate change scientists have in addition purposely or through their ignorance chosen to ignore a number of basic requirements of scientific investigations and applications.

Drought analyses

Droughts are the dominant climate related concern in regions with dry climates. Their principal adverse effects are reduction in agricultural production and threats to water supplies. They are the consequence of prolonged periods of deficient rainfall and river flow. It is fundamentally important to note that it is the presence of multi-year variations in these processes that are critical. This factor has been known and observed since the beginning of civilisation. Joseph's biblical prophecy of seven good years followed by seven years of famine is a good example. (Genesis 41: 29,30).

Another more recent historical example is the South African author D.E.Hutchin's book 'Cycles of droughts and good seasons in South Africa' published in 1889⁷. There were a number of historical reports during the first half of the last century of studies of repetitive droughts.^{8,9,10}

Commission of Enquiry into Water Matters

In addition to the drought problem, the rapid depletion of South Africa's remaining water resources has become a critically important national issue. By the 1960s it became clear that South Africa's water resources would approach depletion soon after the end of the century. As a result of these circumstances the South African government appointed a multidisciplinary Commission of Enquiry into Water Matters in 1966.

The Commission published a comprehensive report in 1970¹¹. The following terse extracts from the Commission's report are very important. They reflect the position as it was more than 40 years ago and the foresight of the Commission's members.

- Very great advantages in the management and practical utilisation of our water resources would follow if a measure of reliability could be achieved in the long-term forecasting of climatological conditions.

- The Commission regards it is essential that research and attempts to acquire the necessary data to make long-term weather forecasting possible be actively supported.
- The possible value of long-range weather forecasting to planned water utilisation is thus of deep concern.
- Also to be emphasised is the fact that long-range weather forecasting is affected by long-term climatic fluctuations. Although these are receiving considerable attention, progress in this direction is hindered by lack of reliable data.
- Assessment of a specific technique must be based on results of observations extending over many years.
- The ability to forecast for one or more seasons in advance is within reach of the present generation.
- Some meteorological conditions exhibit the tendency to persist longer than might be expected as a matter of chance and use may be made of this tendency to venture a forecast.
- The drought phenomenon remains one of the country's most vexing problems and it is in drought prediction that long-term forecasting can probably be of the greatest value.
- Long-range weather forecasts, even though approximate, can be of tremendous benefit in the management of water resources. Even were it possible to forecast that next year will be wetter or drier than usual, with perhaps some indication of the probable degree of departure from the mean, this would greatly aid the taking of decisions that might be of vital importance to the country's economy.

Several pages of the report were devoted to research on the linkage with sunspot activity.

- 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 sunspot 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.

Notice once again the emphasis on multiyear variability. Climate related processes are not steady state phenomena. This author, staff and colleagues made the fulfilment of these recommendations the principal target of research in the subsequent years.

Predictable periodicity

The following tables and illustration are an example of studies of the predictable periodicity in the hydroclimatic data conducted by the author, his staff and colleagues^{12,13}. Table 2 shows the annual flow record in the Vaal River at Vaal Dam for the period 1923/24 to 1995/96 expressed as percentages of the mean. The mid-period and full period sudden reversals from drought sequences to flood sequences are identified in the table.

[Insert Table 2]

Figure 1 shows a comparison of the periodicity of the annual sunspot numbers with synchronous characteristics of the annual flows in the Vaal River. The alternating wet and dry sequences and their correspondence with the alternating sunspot cycles are particularly important. There are other examples of the multiyear oscillating wet and dry periods in the climatological literature¹⁴.

[Insert Fig 1.]

Table 3 shows the sudden changes in the flows in the Vaal River from drought sequences to flood sequences and corresponding changes in sunspot activity. The synchronous relationship is unambiguous. 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.

[Insert Table 3.]

Tables 2 and 3 and Fig. 1 are examples of the material from the joint paper ‘Linkages between solar activity, climate predictability and water resource development’ by Alexander, Bailey, Bredekamp, van der Merwe and Willemse published in the Journal of the South African Institution of Civil Engineering in June 2007⁵.

Compare this with the nonsensical statement in the Report No. ENV-S-C 2005-073 produced by 15 authors from six organisations in June 2005 with the impressive title ‘A Status Quo, Vulnerability and Adaptation Assessment of the Physical and Socio-Economic Effects of Climate Change in the Western Cape’¹⁵ which dismisses the obvious synchronous relationship with sunspot activity.

South Africa’s well-documented information on this linkage during the past 100 years was completely ignored in the Western Cape report. Instead, the report quoted a British scientist Foukal¹⁶ as proof that variations in solar radiation do not influence South African climate. In their paper Foukal *et al* claimed that the brightness of the sun had not changed significantly over the years and therefore it could not be the cause of climatic variations. This statement displays a total ignorance of the manner in which energy from the sun influences global climate. The assumption that this energy can be equated to the sun’s brightness is incredibly naïve.

The following statement in the Western Cape report would be laughable if it was not so serious. ‘Economic sectors such as insurance, banks (through the underlying secured assets), transport and communication infrastructure and construction may all be affected to some degree by climate change.’ Regrettably, this all-inclusive statement illustrates a complete ignorance of how modern society functions. These are only two of the many examples of the speculative and alarmist nature of the Western Cape report and complete lack of numerical proof of the postulated consequences.

It is now necessary to examine these deliberate deviations from sound scientific practices against the background of international events.

Budapest Declaration on Science

In 1999, the world's two most influential international scientific bodies, the United Nations Educational, Scientific and Cultural Organisation (UNESCO) and the International Council for Science (ICSU), held a world conference in Budapest on Science for the Twenty-First Century. The conference produced a 'Declaration on Science and the Use of Scientific Knowledge'¹⁷. The following summarise the principal recommendations detailed in the report.

- The need for active collaboration across all the fields of scientific endeavour, i.e. the natural sciences such as the physical, earth and biological sciences, the biomedical and engineering sciences, and the social and human sciences.
- The need for a vigorous and informed democratic debate on the production and use of scientific knowledge.
- Greater interdisciplinary efforts, involving both natural and social sciences, are a prerequisite for dealing with ethical, social, cultural, environmental, gender, economic and health issues.
- The practice of scientific research and the use of knowledge from that research should always aim at the welfare of humankind.
- The social responsibility of scientists requires that they maintain high standards of scientific integrity and quality control, share their knowledge, communicate with the public and educate the younger generation.

Sadly, it has become common practice among national and international scientists in the field of climate change and its consequences to ignore each and every one of these fundamental scientific requirements.

Academies of Science

In 2005 the Academies of Science of eleven nations published a short document titled ‘Global response to climate change’¹⁸. The countries were Brazil, Canada, China, France, Germany, India, Italy, Japan, Russia, United Kingdom and the United States of America.

The document acknowledged that climate change is real; emphasised that the causes would have to be reduced; and that nations should prepare for the consequences of climate change. The academies called on world leaders including those meeting at the G8 summit to be held at Gleneagles in Scotland in July 2005 to:

- Acknowledge that the threat of climate change is clear and increasing.
- Launch an international study to explore scientifically informed targets for atmospheric greenhouse gas concentrations, and their associated emissions scenarios, that will enable nations to avoid impacts deemed unacceptable.
- Identify cost effective steps that can be taken now to contribute to substantial and long-term reduction in net global greenhouse gas emissions.
- Recognise that delayed action will increase the risk of adverse environmental effects and will likely involve a greater cost.
- Work with developing nations to build a scientific and technological capacity best suited to their circumstances, enabling them to develop innovative solutions to mitigate and adapt to the adverse effects of climate change, while explicitly recognising their legitimate development rights.
- Show leadership in developing and deploying clean energy technologies and approaches to energy efficiency, and share this knowledge with all other nations.
- Mobilise the science and technology community to enhance research and development efforts, which can better inform climate change decisions.

The following paragraph in the document is particularly important.

- The task of devising and implementing strategies to adapt to the consequences of climate change will require worldwide collaborative inputs from a wide range of experts, including physical and natural scientists, engineers, social scientists, medical sciences, those in the humanities, business leaders and economists.

It is also important to note that three of the signatory academies were from the major developing nations; Brazil, China and India. Yet it was these nations plus South Africa that wrecked the UNFCCC conference in Copenhagen at the end of 2009. What went wrong during the short four year intervening period?

Stern Review

The G8 meeting in Gleneagles responded to the concerns of the Academies of Science by appointing a distinguished economist Nicholas Stern to review the climate change situation. He then called for submissions on this subject. The reason for the appointment of an economist to undertake this investigation only became clear in later years.

When this author responded to the Stern Review's call for submissions in November 2005, he believed that he could make a valuable contribution that reflected an international perspective with emphasis on the situation on the African continent. The author submitted two comprehensive documents. The first was his report 'Risk and Society - an African Perspective'¹⁹ commissioned by the United Nations International Decade of Natural Disaster Reduction (IDNDR) secretariat and financed by the South African Department of Foreign Affairs. It was based on interviews with the responsible authorities of many African countries with emphasis on natural disasters; their causes and consequences; how these countries responded to them; and his recommendations for future mitigation measures.

The second submission was his technical report 'An Assessment of the Likely Consequences of Global Warming on the Climate of South Africa'²⁰. The 92-page report included 14 tables, 16 figures and 50 references. The author produced this on his own initiative. He described the results of his studies of the largest and most comprehensive hydroclimatological database assembled and studied for this purpose anywhere. All the data were obtained from data published by the responsible national authorities. His analytical methods were simple and could be replicated by anybody familiar with time series analyses. His conclusion was that the effects of human activity on floods, water resources and natural disasters, if present, were undetectable against the background of natural variability.

The purpose of his 92-page technical report was described on its title page. 'The purpose is to provide linkages between climatic processes and hydroclimatological responses. This is

required for the reconciliation of climate change theory with observational deductions derived from extensive studies of a comprehensive South African database.'

The conclusions were summarised on the first page under the heading: 'Climate change: there is no need for concern'. They were:

Results of global warming from whatever cause:

- Clearly discernible increase in rainfall over South Africa
- Increase in the numbers of beneficial, widespread, heavy rainfall events
- Increase in evaporation. This has both beneficial and adverse effects
- Increase in river flow, e.g. Zambezi River at Victoria Falls
- Increase in groundwater levels, e.g. in a dolomite compartment near Zeerust

These are altogether different processes at sites located hundreds of kilometres apart, and in different climatic regions. They are also mutually consistent with changes (where detectable) that are concurrent in time. The beneficial increases are in accordance with the global physical processes and international studies.

Continued global warming will NOT:

- Pose a threat to water supplies
- Adversely affect agricultural production
- Increase the risk of floods and droughts
- Increase the spread of malaria
- Increase the eutrophication of water in dams
- Increase soil erosion
- Result in the loss of natural plant and animal species
- Result in desertification

The report continued with the statement that there is no believable evidence to support these adverse claims and that it would be most unwise for South African authorities to force the

implementation of costly measures based on unverifiable global climate models and abstract theory for which there is no believable evidence.

Why did the Stern Review totally ignore the thorough studies detailed in this author's submissions? They were not even mentioned in the final report despite this author's protests.

Clash of theories

The theory used in climate change analyses is totally different from widely used observation theory. Climate change theory is based on process theory which is incapable of being verified numerically, while observation theory is based on the analysis of data routinely recorded and published by the responsible authorities. The outputs can be readily verified. The magnitude/frequency relationships that are the foundation of water resource and flood studies cannot be determined using global climate computer models, however complex.

It is an elementary requirement that meaningful changes in any process cannot be determined without quantifying the natural conditions in the first instance. This is where climate change theory fails. Climate change scientists and their institutions are aware of this. They have gone to extreme, unscientific measures to suppress all contrarian views and vilify those who express them. Did they really believe that their vilification tactics would not be exposed?

Royal Society

In September 2006 the UK Royal Society made an unprecedented request to oil companies to cease funding research that did not acknowledge that human activity was the direct cause of climate change and all its postulated adverse effects. The Royal Society also requested the media not to report any adverse research. Research funding in the UK encouraged alarmist research and discouraged contrarian research. Vigorous debates never occurred.

Why did the Royal Society oppose the fundamental requirement of vigorous debates in matters of major national importance? Even more importantly, why did South African scientists not object to this procedure instead of adopting it?

Environmental concerns

The worldwide practice of linking climate change with environmental damage lies at the very heart of the present difficulties. The public and the responsible government agencies have been deceived by the provably erroneous views presented in the climate change literature.

Once again, the fundamental assumption is that natural environmental processes are steady state phenomena. Consequently, observed changes can be attributed to anthropogenic global warming. Natural multi-year variability in these processes is ignored.

During the 1970s and 1980s the author occupied senior research posts in the Department of Water Affairs. He and his staff participated in several multidisciplinary studies with scientists in other institutions. There are few, if any scientists in southern Africa who have a wider, longer, and more scientific experience in the interfaces between the climatological, hydrological, environmental and sociological sciences than this author has. Recently he travelled extensively through southern Africa. Figure 2 illustrates the routes travelled.

During these travels he searched for evidence of environmental damage that could be attributed to climate change but found none. Figure 3 shows healthy quiver trees and other succulent vegetation in an arid region of Namibia where it is claimed that climate change has caused environmental damage.

[Insert Figs 2 & 3]

He offered to make his extensive set of photographs together with their positions, date and time, available free of charge to the South African National Biodiversity Institute but this was refused. The obvious reason was that the photographs demonstrated that claims of environmental damage in these regions had no substance.

On one occasion he offered to participate in an inspection of the areas where it was claimed that climate change related damage had occurred. His offer was rejected.

Radiative forcing

The concept of radiative forcing is central to climate change theory. The IPCC's Fourth Assessment Reports published in 2007⁶ describe radiative forcing as the concept used for quantitative comparisons of the strengths of the different human and natural agents in causing

climate change. The report claims that human caused radiative forcing is likely to be at least five times greater than that due to solar irradiance changes.

This patently ridiculous claim illustrates the fundamental ignorance of climate change scientists. Historical observations and recent studies ^{1,2,4,5,13,21} demonstrate that the influence of changes in received solar energy and its redistribution by natural atmospheric and oceanic processes, is the dominant cause of the well documented multi-year variability in the hydroclimatological processes. There are no other scientifically meaningful changes in these processes that can be attributed to increases in greenhouse gas emissions. None whatsoever.

One issue is abundantly clear. There is no scientifically believable evidence that human activities have resulted in climate related adverse consequences on a scale that justifies the proposed costly emissions control measures. Climate change scientists are aware of this. It explains their refusal to participate in discussions with those in the applied sciences as well as their reluctance to comply with the basic requirements for the advancement of science.

Conclusions

To summarise, during his long professional career from 1950 to the present, despite diligent studies and observations, this author was unable to identify any region in southern Africa where unnatural climate variability has caused irreversible damage to the biological processes. This was despite worldwide dramatic increases in undesirable greenhouse gas emissions during this period and many claims that this had already caused serious environmental damage in South Africa and elsewhere in the world.

Even more importantly, despite a diligent study extending over a number of years of a comprehensive hydroclimatological database, this author and his professional colleagues were unable to find any evidence of the postulated causal relationship between increasing emissions of greenhouse gasses and increases in damaging floods, droughts and other hydroclimatological processes. Consequently current climate change theory is no more than an unverified hypothesis. For more detailed analyses refer to Alexander 2012 : ‘Handbook on analytical methods for water resource development and management.’ ²¹

Today, the lives and livelihoods of tens of millions of people on this planet are at risk due to the alarmist views by climate change scientists and their institutions based on unverified hypotheses and blatant disregard for the fundamental requirements of scientific endeavour.

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References

1. Alexander WJR. Floods, droughts and climate change. S Afr J Sci. August 1995.
2. Alexander WJR. Long range prediction of river flow - a preliminary assessment. Dept Water Affairs. Tech Report TR 80. Govt Printer. June 1978.
3. Alexander WJR. Computer models for the detection of environmental changes.. SAICE Computer Divn. Civil Engineering, May 1990.
4. Alexander WJR. Floods, droughts, sunspots and wheat prices. The development of a drought prediction model. Civil Engineering, June 2004.
5. Alexander WJR, Bailey F, Bredenkamp DB, van der Merwe A, and Willemsse N. Linkages between solar activity, climate predictability and water resource development. J S Afr Inst Civil Eng. Vol 49 Nr 2. June 2007.
6. Intergovernmental Panel on Climate Change (IPCC). Climate Change 2007. Impacts, Adaptation and Vulnerability. Fourth Assessment Report 2007.
7. Hutchins DE Cycles of drought and good seasons in South Africa. Wynberg Times Steam Printing Office. 1889.
8. Department of Agriculture, The great drought problem in South Africa. Government Printer, Pretoria. 1926
9. Kokot DE An investigation into the evidence bearing on recent climatic changes over southern Africa. Irrigation Department Memoir, Government Printer, Pretoria. 1948.
10. Alexander WJR The likelihood of a global drought in 2009-2016. Civ Engg. June 2008.
11. Commission of Enquiry into Water Matters. Report RP 34/1970 Government Printer. 1970.

12. Alexander WJR, Development of a multi-year climate prediction model. *Water SA*, Vol 31, No2. April 2005, 209-217.
13. Alexander WJR, Linkages between solar activity and climatic responses. *Energy & Environment*, Vol 16 No2 2005. Multi-science Publishing Co Ltd UK. 239-253 . May 2005.
14. Tyson PD *Climate change and variability in southern Africa*. Oxford University Press, Cape Town. 1987.
15. CSIR Report No. ENV-S-C 2005-073. *A Status Quo, Vulnerability and Adaptation Assessment of the Physical and Socio-Economic Effects of Climate Change in the Western Cape*. 2005.
16. Foukal PV, Mack PE and Vernazza JE, The effect of sunspots and faculae on the solar constant *Astrophys. J*, 215 , 952-959. 1977.
17. UNESCO/ICSU World Conference on Science. *Declaration on science and the use of scientific knowledge*. 1999
18. Joint Science Academies statement: *Global response to climate change*. 2005.
19. Alexander WJR *Risk and Society - an African perspective*. United Nations IDNDR commissioned study. Geneva, Switzerland. Report published by the United Nations, July 1999.
20. Alexander WJR *An assessment of the likely consequences of global warming on the climate of South Africa*. Extended summary November 2005.
21. Alexander WJR. *Handbook on analytical methods for water resource development and management*. 2012.

Table 1. Database used in the analyses			
Set	Process	Sites	Observations
1	Water surface evaporation	20	1 180
2	Concurrent rainfall	20	1 180
3	District rainfall	93	7 141
4	River flow	28	1 877
5	Flood peak maxima	17	1 235
6	Groundwater	4	312
7	Southern oscillation index	1	114
8	Regional widespread rainfall	15	6 171
	TOTAL	198	17 975

TABLE 2. VAAL RIVER - ANNUAL FLOW RECORD 1923/24 TO 1995/96 Expressed as percentages of the mean, showing the mid-period and full period sudden reversals from drought sequences to flood sequences.							
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		

Table 3. Comparison of sudden changes in the annual flows in the Vaal River with corresponding sudden changes in sunspot numbers					
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

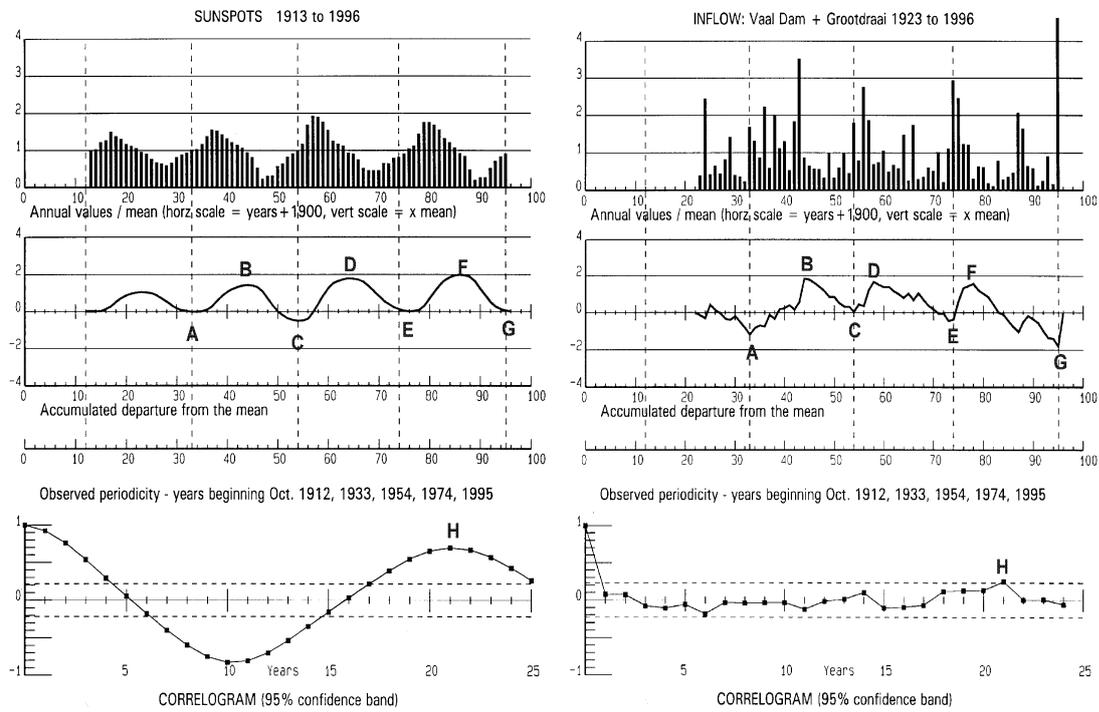


Figure 1. Comparison of the characteristics of annual sunspot numbers with corresponding characteristics of the annual flows in the Vaal River.

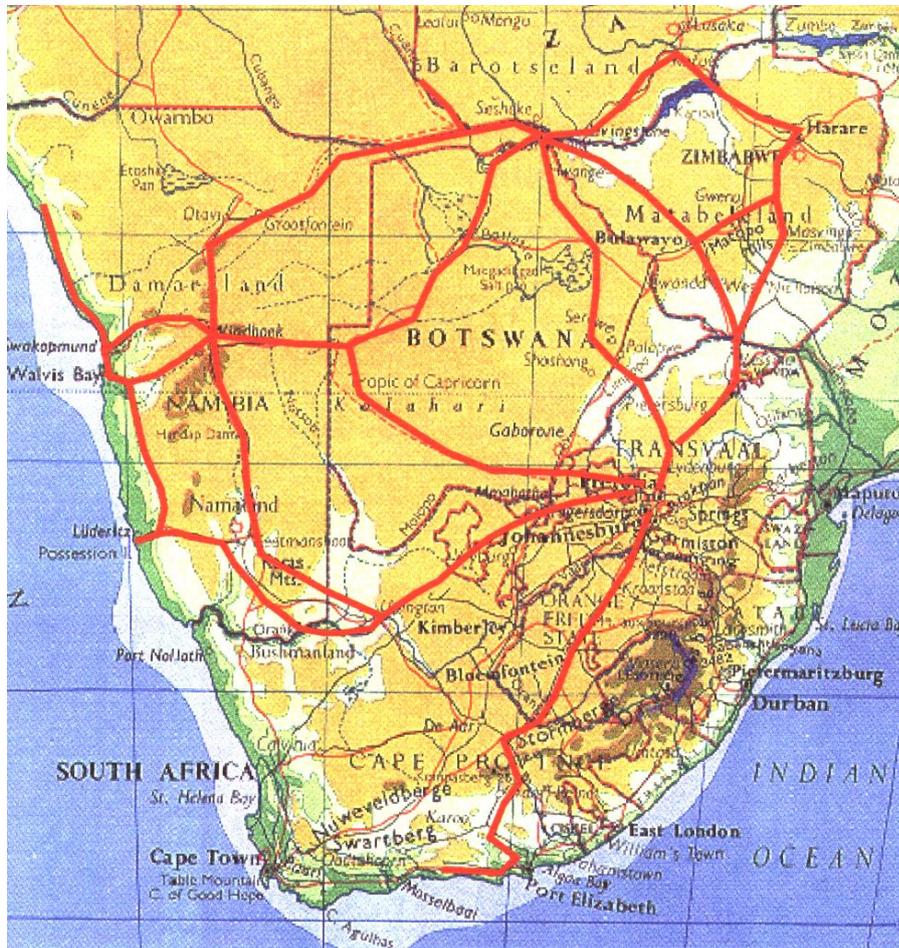


Figure 2. Routes travelled in southern Africa in search for evidence of environmental damage



Figure3. Luxuriant growth of succulents in the arid region of Namibia