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Rhodes Fairbridge and the idea that the solar system regulates the Earth's climate

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ABSTRACT

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Rhodes Fairbridge died on 8th November, 2006. He was one of Australia's most accomplished scientists and has a special connection with Australia. In July, 1912 his father Kingsley established Fairbridge Village near Perth. It contains a chapel of elegant simplicity designed by one of the world's most famous architects of the time, Sir Herbert Baker, as a labour of love to commemorate Kingsley. Rhodes is one of the few scientists to research the sun/climate relationship in terms of the totality of the sun's impact on the earth (i.e. gravity, the electromagnetic force and output and their interaction). When the totality of the sun's impact is considered, having regard to the relevant research published over the last two decades, the influence of solar variability on the earth's climate is very strongly non-linear and stochastic. Rhodes also researched the idea that the planets might have a role in producing the sun's variable activity. If they do and if the sun's variable activity regulates climate, then ultimately the planets may regulate it. Recent research about the sun/climate relationship and the solar inertial motion (sim) hypothesis shows a large body of circumstantial evidence and several working hypotheses but no satisfactory account of a physical sim process. In 2007 Ulysses will send information about the solar poles. This could be decisive regarding the predictions about emergent Sunspot Cycle No 24, including the sim hypothesis. According to the sim hypothesis, this cycle should be like Sunspot Cycle No 14, and be followed by two that will create a brief ice age. During the 1920s and '30s Australia's Bureau of Meteorology published research about the sun/climate relationship, especially Sunspot Cycle No 14, showing that it probably caused the worst drought then on record.

ADDITIONAL INDEX WORDS: *solar inertial motion, barycentre, n-body problem, sunspot cycle, drought, climate change, global warming, IPCC, meteorology, nonlinear, non-stationary.*

RHODES W. FAIRBRIDGE[i]

Rhodes W Fairbridge, one of Australia's most accomplished intellectuals and an early expert on climate change, died on 8th November, 2006 in his home in the historic town of Amagansett, overlooking the Atlantic on the northern edge of Long Island, New York. He was 92 and had remained an Australian citizen all of his life. One of Australia's most accomplished intellectuals, Rhodes W. Fairbridge was born in what is now Fairbridge Village in Western Australia in 1914 and was named after his father's friend and mentor, Cecil Rhodes. Rhodes had spent his boyhood in the idyllic setting of Fairbridge Village, working closely with his parents. Fairbridge Village,[ii] located some ninety kilometres south of Perth, is a living monument to the altruistic vision, hard work and intellectual strength of his parents, Ruby and Kingsley, after whom it is named. There, in July, 1912 they founded the Fairbridge Farm School. Kingsley, a Rhodes Scholar, founded the Child Emigration Society three years earlier at Oxford University with the support of his fellow Rhodes Scholars. Kingsley, inspired by Cecil Rhodes, dedicated his life to the achievement of his vision of providing the poor and orphaned children of the slums of England with a sense of self-worth and with the opportunity to live a fulfilling and productive life. This was to be the purpose of the Fairbridge Farm School.

Fairbridge Village, the Patron of which is the Governor of Western Australia, is now the site of major cultural events including an annual festival of popular culture, organised mainly for and by young people. DOLAN and LEWIS (2004) point out that the architectural jewel in the crown of Fairbridge Village is a beautiful chapel,[iii] built in 1930-31, whose elegant simplicity shows the admiration in which Rhodes' father, Kingsley, was held by one of the world's most famous architects of the time, Sir Herbert Baker. He designed the chapel and supervised its construction, carried out by the Western Australian Government, as a pure labour of love to commemorate the memory of Kingsley Fairbridge. It was financed by other Englishmen who shared Sir Herbert's admiration of Kingsley. Sir Herbert Baker considered that Kingsley lived the true values of altruism and honour that were central to Cecil Rhodes, who had also been his patron.[iv]

Rhodes had little formal schooling until the age of 10 when his father died unexpectedly in 1924, aged only 39. Rhodes was taken to England, where he attended a new experimental school in Hampshire. It was here that his lifelong interest in geology, science and maps was established. Whilst his undergraduate education was at Queen's University, Ontario and Oxford, he was awarded a Doctorate of Science from the University of Western Australia in 1944, at the age of 30, bypassing the usual PhD prerequisite. The main parts of the thesis, *Subaqueous Sliding and Slumped Blocks,* formed Rhodes' first two scientific publications in 1946 and 1947 (FAIRBRIDGE, 1946a, 1946b). Rhodes was also with the RAAF in General MacArthur's headquarters during 1943 to 1945, as Deputy-Director of Intelligence.

After the war Rhodes lectured in Geology at the University of Western Australia. In 1954 he accepted a post as full professor with tenure at Columbia University, eventually becoming Professor Emeritus of Geology some years before his retirement in 1982.

Rhodes Fairbridge was the first to document that the ocean levels rose and fell over long time scales. His first paper on this theme was published in 1950 (FAIRBRIDGE, 1950). The major paper that included what has become known as the *Fairbridge Curve of the Holocene Eustatic Fluctuations* was published in 1958 (FAIRBRIDGE, 1958, 1960, 1961a). He conducted detailed observations off Western Australia and drew together similar data from elsewhere in the world. On the basis of this work, Rhodes formulated the hypothesis that sea levels had been rising for the last 16,000 years and that the rise showed regular periodic oscillations of rise and fall over the period. This hypothesis, radical for its time and roundly rejected, is now acknowledged as a feature of the history of the planet. The periodic oscillations have continued throughout the last 6,000 years to the present time, but with diminishing amplitude. They show relatively rapid rises and falls of up to four metres, although up to three metres is more common. These take place over periods of no more than 10 or 20 years. Such rises or falls would now have catastrophic consequences for the world. The Fairbridge curve predicts that they will happen over the next 100 years and possibly within our lifetime.

Since his first major publication on the subject in 1958, Rhodes emphasised that changes in the average sea level involve three main categories of variables: the shape of the basins that contain the oceans; the volume of water in them; and local variations in land adjacent to the ocean basins.

He contributed to many disciplines, especially to our understanding of the periodicities of climate change. He authored or edited more than 100 scientific books, including many text books and several scientific encyclopaedias and more than 1,000 scientific papers (FINKL 1987), which also contains an annotated bibliography of all of Professor Fairbridge's main publications to 1986. He was largely responsible for the establishment of several major scientific institutions and journals such as the Coastal Education and Research Foundation that, among other things, publishes the *Journal of Coastal Research*. He held many distinguished leadership positions in the international scientific community and has made many lasting contributions to science.[v] He was editor or co-editor of eight major encyclopaedias of specialised scientific papers, many of which he authored. The encyclopaedias have been in the following disciplines: oceanography; the atmospheric sciences and astrogeology; geomorphology; geochemistry and the earth sciences; geology; sedimentology; paleontology; and climatology. He was editor of the *Benchmarks in Geology* series, with more than 90 volumes in print and was the general editor of the *Fairbridge Encyclopaedias of the Earth Sciences*. These major productions have significantly advanced and systematised each of the specialised sciences.

Professor Emeritus Fairbridge had the honour of having three volumes of papers specially prepared to celebrate his life and work (RAMPINO, *et al*., 1987), (FINKL, 1995), and (FINKL, 2005), in honour of his 70th, 80th and 90th birthdays respectively.

Throughout his long scientific career, Rhodes Fairbridge drew attention to a vast mass of scientific evidence about the periodicities of climate change. He showed that the periodicities are revealed in a rich variety of sources, including: geology; geomorphology; glaciations; sediments; sand dunes; beach rock; the circulation of the ocean; geomagnetic records; the records of the isotopes of carbon, oxygen, beryllium, chlorine and hydrogen in tree rings, ice cores, biota, rocks, air and water (FINKL 1987, 1995 and 2005).

SOLAR INERTIAL MOTION

NEWTON (1687) showed that the sun is engaged in continual motion around the centre of mass of the solar system (i.e. the barycentre) as a result of the gravitational force exerted by the planets, especially Jupiter and Saturn.[vi] He came to this conclusion analytically (not by observation) by working through the consequences of his law of gravitation. The sun is in free-fall around the barycentre as a result of planetary gravitational force.

The sun orbits the barycentre inside a circular area which itself is just over two solar diameters in diameter. This might be negligible for the solar system but it is highly significant in relation to the size and nature of the sun. Amongst other things, the sun may be travelling through its own electromagnetic fields during various stages of its journey. Unlike planetary orbits around the barycentre, the sun's orbit around the barycentre differs greatly from orbit to orbit. The general form of the sun's barycentric orbit is an epitrochoid, a big circle continuous with a little ring nestling asymmetrically inside it. At one phase, the orbit is nearly circular, almost two solar diameters in diameter. At another phase, the Sun is impelled on a backward, or retrograde, journey in which it undergoes a tight loop-the-loop, crossing over its own path in a loop that is less than one solar radius. The epitrochoid's asymmetric ring arises from the sun undergoing the retrograde loop-the-loop. No alignment of the planets in relation to the Sun repeats itself exactly, because the solar system is chaotic, containing intrinsic randomness. As a result, no two epitrochoid-shaped solar orbits are the same. Nevertheless, they can be classified into eight distinctive patterns, each of about 179 years' duration, which is also the time taken for the planets to occupy approximately the same positions again relative to each other and the sun. In this time the sun completes about nine orbits, or one planetary cycle. Fig 1 depicts solar inertial motion.

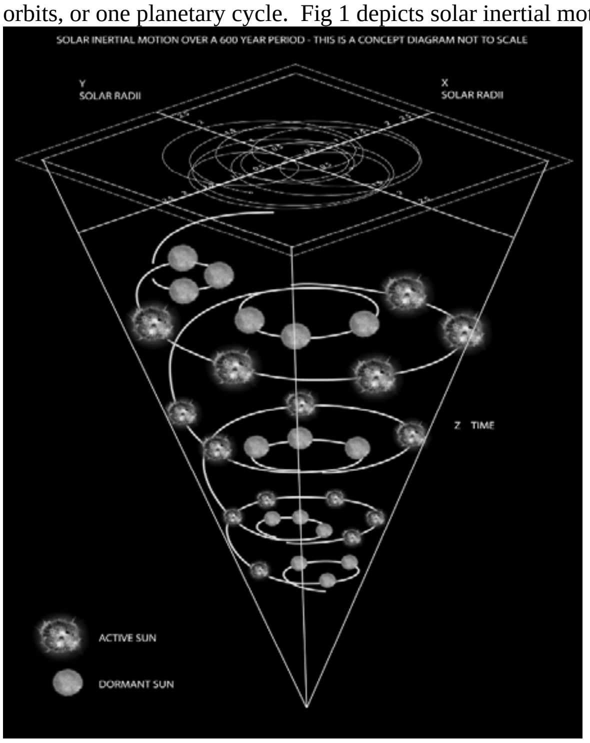

Figure 1: Concept Diagram of Solar Inertial Motion
Illustrated and produced by Daniel Brunato, University of Canberra, 2006

During the late 1950s and early 1960s, Rhodes Fairbridge began to explore the hypothesis that there might be a regular input of energy to the earth of astronomical origin. According to this hypothesis, the many regular periodicities that are revealed in, for example, tree rings, ice cores, biota, rocks, sediments, sand dunes, beachridges, strandplains, geomagnetic records, glaciations, geology, geomorphology and the extensive layers of sediments such as those that make the striking Hudson Bay varves, would require the same type of regular input of immense energy as that which drives the tides. Rhodes Fairbridge considered that climate change was regulated by forces outside the normal terrestrial atmosphere and its dynamic systems. He was one of the early advocates of the idea that the large-scale episodes of major climate change had astronomical origins. FAIRBRIDGE (1961c) spoke of Milankovitch's 'elegant mathematical theory', drawing attention to its strengths and weaknesses, including some doubtful assumptions and conflict between evidence and prediction, which have only recently been addressed. He looked for the type of energy and regularity, like the lunisolar tides, that controls the earth's daily and annual motions. This led him to explore solar periodicities, principally the sunspot cycles, as the source.

Rhodes Fairbridge found that since 1911, scientists had published research documenting periodicities in the motions of the planets in relation to the sun. These suggested that the barycentric motion of the sun in response to the planets might have a role in the sun's activity cycles. This research also suggested that there could be links of scientific interest between these cycles, the planets and climate periodicities. JOSE (1965) published curves showing substantial agreement between the sunspot cycle numbers and the rate of change of the solar orbital angular momentum. Other researchers have published evidence supporting the hypothesis that some feature of the sun's barycentric motion contributed to variable solar activity. During the 1980s, Rhodes Fairbridge began to research this hypothesis and examined possible relationships between solar barycentric orbital activity and the earth's climate. He developed the thesis that had been introduced by other investigators that the sun's variable torque (measured by rate of change of angular momentum) exerted by the planets twisting and turning the sun on its epitrochoid-shaped cycle of barycentric orbits changed the sun's activity levels.[vii]

DE JAGER and VERSTEEGH (2005) reported that the accelerations of the sun caused by the planets seem to completely disappear in the accelerations observed inside the sun and therefore cannot influence the solar dynamo significantly. However, DE JAGER and VERSTEEGH (2005) may have been looking for the wrong phenomena. DE JAGER and VERSTEEGH (2005) appear to have misunderstood solar inertial motion since SHIRLEY (2006) shows their inappropriate use of rotational equations for modelling particle motions due to orbital revolution. Furthermore, DE JAGER and VERSTEEGH (2005) did not search for the more likely effects solar inertial motion may have on the sun (examined in the literature and reviewed in the following paragraphs). SHIRLEY (2006) has pointed out that, assuming the sun is homogeneous, all of its components will undergo the same freefall motion. As a result, the free-fall motion itself could not be the reason for any relationship between the sun's epitrochoid-shaped orbit and variations in solar activity. There is considerable evidence that the sun is not homogenous; it is generally a fluid body, and whilst the solar nuclear fusion core is more like a solid than anything else, the viscosity, elasticity and density of the remainder of the sun varies from waterlike to diaphanous gas. The sun also has several distinct internal structures, which generally have the sun's oblate sheriod shape (except the core, which is generally spherical). The structures and material of which the sun is made are in constant movement spatially and temporally. Additionally, there is increasing evidence (reviewed on the next page from the publications of Rozelot and colleagues) that the internal structure of the sun is characterised by a dynamic lumpiness that is variable throughout the sun, and over time.

PALUS *et al*. (2007) found that there is a statistically significant measure of the influence on the solar cycle by the planets. TSUI (2000) has found there are non-inertial Coriolis forces acting on the sun as a result of its barycentric motion. He conjectured that these would be sufficient to significantly modulate the cyclical rhythm of the solar dynamo. Noting that the tidal force, like all tidal forces, has vertical and horizontal components and that the vertical component of the planets' tidal force on the sun is negligible, BLIZARD (1987) reported that the horizontal tide may be significant because in a period of half a solar rotation, the horizontal displacement of planetary tide would be 560 km and its velocity 0.93 m/sec. It is to be expected that the horizontal, not the vertical, component would be a candidate. In the case of the Earth-Moon system, the vertical tidal force is negligible; it is the horizontal component that results in the tides we experience.

BARKIN and FERRANDIZ (2004) derived an analytic expression for the elastic energy of planet tidal deformations induced by other bodies, including the central star, in a planetary system. BARKIN and FERRANDIZ (2004) found that the elastic energy is not simply a sum of the elastic energies of the separate pairs of bodies but contains additional terms that are non-linear functions of the superposition of the lunisolar tides. As a result, there are large and significant variations in conditionally periodic variations in the elastic energy of the lunisolar tides. BARKIN and FERRANDIZ (2004) did not use the full expression for elastic energy, only up to the second order. Using a heliocentric perspective of the planets orbiting the sun and, given a model of the sun analogous to the one of the earth used by BARKIN and FERRANDIZ (2004), and using the full expression for elastic energy, a similar result may be found for the effect of the superposition of the planetary tides on the sun. This expression would be a function of the tidal forces acting on the sun by each planet. The additional terms would be the non-linear functions of the superposition of all of the planetary tidal forces.

BLIZARD (1987) presented evidence that the precessional effect on the sun of the planets depends on the degree of oblateness of the sun and on the angle of inclination of the plane of a planet's orbit in relation to the sun. Since the sun is a fluid, the precessional effect may induce a fluid flow towards the equator of the sun from both hemispheres. The flow of plasma on the sun directly affects solar activity. BLIZARD (1987) also noted that the sun's axis of rotation is tilted with respect to the invariable plane and that the degree of tilt varies. She presented evidence suggesting that the sun's variable axial tilt as it rotates in relation to the invariable plane whilst orbiting the barycentre appears to vary directly with solar orbital motion. The effect is, amongst other things, of a force to align the sun with the plane of the solar system, which the sun resists. BURROUGHS (2003) reported that the sun's barycentric motion affects its oblateness, diameter and spin rate.

In several papers, Rhodes Fairbridge (for example, FAIRBRIDGE 1984, FAIRBRIDGE 1997 and, FAIRBRIDGE and SANDERS 1987) described how the turning power of the planets is strengthened or weakened by resonant effects between the planets, the sun and the sun's rotation about its axis. He further described how resonance between the orbits of the planets amplified the planets' variable torque applied to the sun. He also pointed out that there was a measurable resonant effect between the sun's orbit and spin and that this was amplified by the planets' variable resonance. Rhodes

Fairbridge's argument is that the resonating frequencies may amplify the relatively weak torque effects of the planets on the sun, if the resonance acts on both the sun's rotation about its axis and the sun's barycentric orbital motion. This may happen as the sun is undergoing retrograde motion in tight loops. Accordingly, orbital resonance of two, three or more planets may have a significant effect on the sun. Rhodes Fairbridge emphasised that the sun's spin-orbital resonance can be further amplified by the planets' own spin-orbital resonance. Additionally, he reported that the distance of the sun from the earth varies as the sun orbits the barycentre. He calculated that the distance could vary by about 1 per cent. Rhodes Fairbridge noted that this variation could have climate change consequences in a similar way as happens in Milankovitchs' theory. There may also be a lunisolar tidal consequence of the 1 per cent variation in the sun's distance that could be calculated. WINDELIUS and CARLBORG (1995) provide a convenient review of the relevant science about solar orbital angular momentum up to the mid-1990s.

JUCKETT (2000) has pointed out that there is no satisfactory model, based on first principles, that can explain the many different cycles in solar phenomena. These include the sunspot cycles (including all of the known periodicities in the sunspot time series, epochs of extremely low sunspot activity); the reversal of the sun's magnetic poles; a variety of north/south asymmetries of various solar activity dynamics; and convection zone rotational velocities. The solar dynamo theory, which has been the subject of intensive research for some 50 years, provides an elementary model of the main physical processes of the sun. However, the dynamo theory cannot explain these periodicities, nor predict the sunspot cycles or any other cyclical solar phenomena. JUCKETT (2003) outlined the elements of a theory that shows how the sun's barycentric orbit can modulate the intrinsic oscillations of the solar dynamo and generate all known cyclical solar phenomena. He hypothesised that this would happen as a result of the conservation of the solar system's angular momentum achieved by the non-linear mixing of solar orbital momentum and a spin-orbit transfer function. It is as if some of the sun's orbital angular momentum is transmitted to solar rotation so as to conserve the solar system's angular momentum, which is necessarily constant as a result of the law of the conservation of angular momentum.[viii] JUCKETT (2003) hypothesised that the planetary-driven spin-orbit coupling is a continuous generator of the oscillatory behaviour of the sun. His theory also predicts several new phenomena.

Spin-orbit coupling will occur if the mass distribution of a celestial body deviates from spherical symmetry. The degree of asymmetry is measured by the gravitational quadropole moments of the body. PIREAUX *et al* (2006) established that the mass of the sun shifts within it during the sunspot cycle and as a result the sun's shape departs significantly from spherical symmetry. These departures seem to extend in variable ways throughout the sun. This changes the physical shape of the sun, but more importantly, has a measurable impact on the orbits of the planets. As a result, there is dynamic non-linear, stochastic and periodic interaction between the mass of the sun shifting internally within it and the planets**.** (ROZELOT, *et al*., (2004). The motion of the sun's mass over time and space is non-linear, stochastic and periodic. An unexpected consequence of this may be the need to re-evaluate a key test of Einstein's General Theory of Relativity. Prior to Einstein's theory, the anomalous perihelion advance of Mercury's orbit had been found to deviate significantly from Newton's predictions. Einstein's new theory could account for almost all of the entire observed perihelion advance. Eddington's measurement of Mercury's orbit's perihelion advance in 1919 was a spectacular confirmation of Einstein's reasoning. Rozelot, Pireaux and colleagues (e.g. ROZELOT, PIREAUX AND LEFEBRVE (2004)) suggested that the effect on Mercury's orbit by the internal shifting of the Sun's mass may require a re-appraisal of Eddington's test and therefore of the veracity of General Relativity as the best available account of gravity. Mercury is the innermost of the four terrestrial planets in the solar system, moving with a high velocity in the sun's gravitational field. As a result of slight undulations in this field due to movements of the sun's mass within it, the advance in the perihelion of Mercurys' orbit could be affected. As outlined above, it has also been conjectured that Mercury and the other planets could contribute to the dynamic spatial and temporal internal distribution of the sun's mass through any or all of the processes summarised above.

The gravitational interaction between the sun and the planets causes the barycentric motion of the sun, which is non-linear, stochastic and periodic. There is, therefore, a feedback process between two non-linear, stochastic and periodic processes: the internal shifting mass of the sun affecting planetary orbits and the planetary orbits affecting the internal mass of the sun by shifting it around, perhaps throughout the entire body of the sun. The solar inertial motion (sim) hypothesis states that sim modulates the solar dynamo, weakening or strengthening it (and thus solar activity levels) in accordance with which of the eight distinctive epitrochoid forms characterises the sun's overall motion and whether the sun is in the ordered phase (i.e. along the smooth, near-circular path) or chaotic phase (i.e. along the retrograde loop-the-loop path) of that form. High solar activity occurs whilst the sun is in the ordered phase and the earth warms up. Minimum or no activity occurs whilst the sun is in the chaotic phase and the earth cools, sometimes entering a relatively short little ice age. Each 179 years the sun begins a new cycle of the epitrochoid family of barycentric orbits; the most recent of these began in 1996 with Sunspot Cycle No. 23. Whilst the sun is in the beginning phase of the new epitrochoid cycle, solar output of all types is understood to decline and the climate on the earth cools. The four previous epitrochoid cycles began in about 1790, 1620, 1430 and 1270 respectively. Solar activity diminished during the first several decades of each of these epitrochoid cycles, resulting in a cooling of the earth. For example, Europe between the 1620s to the 1710s (the Maunder Minimum) was a time of intense cold, causing extensive havoc and misery. The Thames froze each winter and the alpine glaciers grew deep into the valleys. Between the 1790s and 1820s (the Dalton Minimum) was also a time of intense cold throughout Europe, with 1816 being considered one of the coldest of the last 250 years.[ix] All of the cold intervals have been well documented in both the standard climatological records and the broader historical record (FAGAN, 2000). Catastrophic volcanic and earthquake events accompanied these cold periods. Nevertheless, the physical process by which sim modulates the solar dynamo has not yet been established, although several testable hypotheses have been published.

The geological record shows that periods of minimum and maximum solar output (and their consequential climate impacts) have occurred throughout at least the last million years. Since the positions of all of the planets in relation to the sun can be readily and accurately calculated hundreds of years in advance, the sun's orbit around the barycentre can also be readily and accurately calculated hundreds of years in advance.

THE SUN'S IMPACT ON CLIMATE

The impact of the sun on the earth's climate has been an active area of scientific inquiry ever since Sir William Herschel presented a series of papers on the subject to the Royal Society in London in 1801. He saw a relationship between solar activity and the series of wheat prices in Adam Smith's *The Wealth of Nations* that was published 25 years earlier in 1776.[x]

During the 1960s and '70s there were several major international scientific conferences devoted to the thesis that the sun has a major role in the regulation of the earth's climate ((FAIRBRIDGE, 1961b); (BANDEEN and MARAN, 1974),[xi] (MCCORMAC and SELIGA, 1979)). During the 1980s and '90s when Rhodes Fairbridge was publishing papers about possible relationships between solar inertial motion, the sun's activity cycles and the earth's climate, the thesis did not attract much scientific interest, although EDDY (1976) had created new interest in the thesis.[xii]

To the extent that the sun regulates the earth's climate, it would do so in three major ways: variations in the quantity, intensity and distribution over the earth of the solar output, including electromagnetic radiation, matter and the sun's electromagnetic field; the variable gravitation force the sun exerts on the earth, the moon and the moon and the earth as a system; and interactions between some or all of these processes. Rhodes Fairbridge emphasised that the answer to the question "*Does the Sun affect the Earth's climate?*" has to be in terms of these three processes. In this regard, he seems to have been a relatively lone voice. Research published in the last five years shows that the sun may have had a much greater role in generating climate change during the last century up until the 1970s than previously considered possible.[xiii] SOLANKI *et al*. (2004) and (2005) and SOLANKI and KRIVOVA (2004a) and (2004b) report that most of the warming of the 20th century has occurred during two periods, from about 1910 to the mid-1940s and from the mid-1970s onwards. SOLANKI and KRIVOVA (2003a) and (2003b) also found that the sun has been more active during the last 70 years than at any time for more than 8,000 years. Whilst this indicates that the high level of solar activity in recent years is exceptional, it is not unique on the multi-millennial time scale. SOLANKI *et al*. (2004) found that during the last 11,400 years, the sun spent only 10 per cent of the time at a similarly high level of activity. WILLSON and MORDVINOV (2003) report that the analysis of the data about sunspot activity provided by six overlapping satellite observations since 1978 shows that total solar radiation output had increased by approximately 0.05 per cent per decade. SCAFETTA and WEST (2006a) and (2006c) estimate that the sun contributed as much as 40 to 50 per cent of the 1900 to 2000 global warming and 25 to 35 per cent of the 1980 to 2000 global warming. Their methodology implies that their solar output index is a proxy of all solar output, not only of the sun's electromagnetic radiation. However, their methodology does not take account of relationships between the sun's gravitational force (and its interaction with solar output) and climate. BUTLER and JOHNSTON (1994) concluded that their data strongly support the contention that solar variability has been the principal cause of temperature changes over the past two centuries. Reports prepared for the South Florida Water Management Authority[xiv] highlight that 'high solar activity is often associated with wetter periods, while lower levels of solar activity are associated with drier periods'. THEJLL, CHRISTIANSEN and GLEISNER (2003) found that only since 1973 has solar activity, as measured by the geomagnetic index, appeared to have a significant impact on the stratosphere and sea-level pressures. TOBIAS and WEISS (2000) have shown there is a significant resonant amplification between solar periodicities and climate periodicities. They argue that during the last few years there has been a shift in understanding about the dominant role of the sun on the earth's climate throughout the last 11,000 years and especially over the last 60 years. They wrote: *The IPCC dismissed any significant link between solar variability and climate on the grounds that changes in irradiance were too small. Such an attitude can no longer be sustained.* BURROUGHS (2003) concluded that developments about the role of the sun in climate change published between 1990 and 2002 could not be dismissed so easily as the Intergovernmental Panel on Climate Change (IPCC) had done.

Variations in the strength of the sunspot cycle are accompanied by variations in the sun's emission of radiation, dispersal of matter, the strength of the sun's electromagnetic field and the strength of the heliosphere together with now increasingly well-documented changes to the earth's climate arising directly from these variations. Variations in the amount of radiation emitted by the sun over the sunspot cycle are not uniform across the electromagnetic spectrum. An increase in solar activity of, say, one unit, means proportionately more short wavelength energy than long wavelength. Short wavelength radiation (UV and X-rays) ionises the upper atmosphere and heats the middle atmosphere. As a result, atmospheric temperature varies in a non-linear manner with the amount and type of solar radiation. The sun ejects enormous quantities of matter continuously in the form of the solar wind, or periodically as either a mix of high energy protons and electrons (Coronal Mass Ejections, (CMEs)), or as mostly high energy protons (Solar Proton Events (SPEs)). The earth's atmosphere is more sensitive, and more reactive, to the CMEs and SPEs than to the sun's short wavelength radiation, to which it is, in any case, highly reactive. The effect of the solar wind, CMEs and SPEs is to reduce the amount of ozone and as a result, warm the middle atmosphere. The overall effect on climate is more turbulence: stronger winds, more storms and greater precipitation.[xv]

The lunisolar tides are a consequence of the earth and the moon orbiting their common barycentre, the perturbing effect of the sun and the earth and the moon jointly orbiting the solar system's barycentre. Tidal effects, including those arising from the variable rotation of the earth induced by the tides, include variations in rainfall, including floods and droughts; sea-ice conditions; sea-surface temperature; sea-level; atmospheric pressure; frequency of thunderstorms; deep ocean currents; tidal flooding; and the speed of the major ocean currents. Tidal dynamics operate at all levels of the planet, from the gaseous atmosphere to the earth's inner structures: the fluid outer core that surrounds the solid inner core. MUNK and WUNSCH (1998) and WUNSCH and FERRARI (2004) have shown that the tides occur throughout the vertical depth of the oceans, mixing and churning the oceans with profound and periodic effects on climate. KEELING and WHORF (1997) and (2000) have presented evidence for the hypothesis that the lunisolar tidal forces churn the waters of the planet's oceans.[xvi] They hypothesise that there is a long cycle of alternating weak and strong tides resulting in warming and cooling respectively. They have published evidence that suggests the weakening of the tides began in 1975, so that from that time onwards, the oceans began to warm. As reported in the several papers cited above, Solanki and co-workers have shown that a continuing increase in solar output has also warmed the oceans. The combined effect of these two processes may have resulted in the increased warming that has occurred since around 1975. Additionally, the moon and the sun transfer large quantities of energy to earth through the lunisolar tides. According to BARKIN and FERRANDIZ (2004), the tidal forces of the sun and moon acting on the earth as a whole produce elastic energy that resides in the earth's core and crust that is significantly greater than the sum of the elastic energies of the separate pairs of bodies. Some of the elastic energy is dissipated as heat and contributes, as the periodicities of the tides determine, to the warming of the earth and the oceans. Most of the remainder is retained in the solid material of the earth, resulting in deformations, ultimately in the form of earthquakes and volcanoes. Some of the elastic energy is retained by the moon, resulting in moonquakes which correlate closely with earthquakes. BARKIN and FERRANDIZ (2004) found that the formation of elastic energy is non-linear. The moon and the sun periodically amplify each other's gravitational effect on the earth in a non-linear manner that closely correlates with major earthquakes. Major earthquakes and moonquakes coincide with extreme variations in tidal elastic energy.

The earth's geomagnetic field provides a buffer against solar radiation, the solar wind and radiation of all types that is generated elsewhere in the Universe.[xvii] The field's strength depends on solar output and the lunisolar tides. The motion of the earth's two inner cores, which depends on lunisolar tidal forces, the rotation of the earth and the Coriolis Effect, continuously generates the earth's geomagnetic field. The earth's central solid core rotates slowly within the surrounding molten iron and nickel shell, in response to the lunisolar tidal forces, providing it with rotation additional to the rotation it undergoes as a component of the rotating earth. A highly active sun can make the geomagnetic field stronger; a relative inactive sun will make it weaker. Other things being equal, a strong geomagnetic field contributes to a warmer climate; a weaker field to a cooler climate. However, the effect may not be uniform across the planet. Currently, the geomagnetic field seems to be weakening. PALAMARA (2003) found that geomagnetic activity effects on atmospheric circulation are independent of other sun/climate relationships, including the link between the sunspot cycle and atmospheric temperature. The earth is enveloped by a global electric circuit, which extends throughout the atmosphere from the earth's surface to the lower layers of the ionosphere, a height of about 120 kms. It is a vast hierarchy of multi-scale dissipative systems. It is a thermodynamically open system driven by external sources of energy. HARRISON (2004) showed that the global electric circuit is significantly affected in a non-linear manner by all solar output. The circuit is influenced by the rotation of the earth and by the lunisolar tides to which it responds like the oceans, the atmosphere and the rest of the earth. The circuit is also coupled to the earth's geomagnetic field. Specifically, the motion of charged particles through the earth's geomagnetic field generates an electric current, which contributes to the global electric circuit. Additionally, increases in the amount of cosmic rays getting through to the earth tend to amplify in a non-linear manner the strength of the global electric circuit. BOCHNICEK *et al* (1999) found that geomagnetic activity results in a variety of weather and climate effects. These include: divergent temperature fields in the middle and upper atmosphere with consequential changes in the behaviour of the Quasi-Biennial Oscillation; interaction with the global electric circuit resulting in the intensification of cyclones by changes in cloud microphysical processes; and changes in ozone concentration which interact with solar activity effects on ozone production.

The heliosphere envelops the solar system. The heliosphere, and the termination shock sphere within it, deflects cosmic radiation. The earth's geomagnetic field also deflects cosmic radiation. The strength of the heliosphere depends on the sun's activity levels. High levels of solar activity reduce the volume of cosmic rays entering the earth's atmosphere. Conversely, a greater volume of cosmic rays enters our atmosphere during times of low solar activity. A stronger geomagnetic field will deflect more cosmic radiation than a weaker one. Cosmic rays have a significant role in cloud formation; the overall effect being that in times of low solar activity a greater incidence of galactic cosmic rays hits the earth, resulting in more low level cloud cover, more rain and a colder climate. During periods of high solar activity, there is a significantly reduced incidence of galactic cosmic rays. As a result, the climate warms.[xviii]

The earth's atmosphere contains several major oscillating wind currents that have a key role in the regulation of the earth's weather and climate. These wind currents include the El Niño/Southern Oscillation (ENSO); Quasi-Biennial Oscillation (QBO); the Pacific Decadal Oscillation (PDO); the Interdecadal Pacific Oscillation (IPO); the North Atlantic Oscillation (NAO); the Atlantic Multdecadal Oscillation (AMO); the Indian Ocean Dipole (IOD); and the Arctic Oscillation (AO); and the northern and southern polar vortices, which are two permanent cyclones at the poles. FAGAN (1999), (2000) and (2004) has shown how the climate changes rendered by these global atmospheric systems have resulted in major historic changes to cultures and societies throughout the world since the dawn of history.

LABITZKE *et al*. (2005), COUGHLIN and KUNG (2004) and CORDERO and NATHAN (2005) report that the sunspot cycle drives these large-scale oscillating wind currents. For example, strength of the QBO circulation and the length of the QBO period varies directly with the sunspot cycle. COUGHLIN and KUNG (2004) also conclude that at a range of atmospheric heights and at all latitudes over the planet, the atmosphere warms appreciably during the maximum of the sunspot cycle, and cools during the minimum of the cycle.[xix] VAN LOON, MEEHL AND ARBLASTER (2004) established that in the northern summer (July to August), the major climatological tropical precipation maxima are intensified in solar maxima compared with solar minima during the period 1979 to 2002. NUGROHO and YATINI 2006 report that the sun strongly influences the IOD during wet season in the monsoons climate pattern; that is, the December to February period. CAMP and TUNG (2006) found that a significant relationship exists between polar warming and the sunspot cycle. ZAITSEVA *et al*. (2003) found that the intensity of the NAO depends on solar activity. ABARCA DEL RIO *et al*. (2003) have found that the patterns of variation between indices of solar activity, the Atmospheric Angular Momentum index and Length of Day show that variations in solar activity are a key driver of atmospheric dynamics. The United States Geological Survey agency found that changes in total solar radiant output cause changes in regional precipitation, including floods and droughts in the Mississippi River basin.[xx] The tropical oceans absorb varying amounts of solar radiant output, creating ocean temperature variations. These are transported by major ocean currents to locations where the stored energy is released into the atmosphere. As a result, atmospheric pressure is altered and moisture patterns are formed that can ultimately affect regional precipitation. SCAFETTA *et al*. (2004) and SCAFETTA and WEST (2005) have found that the earth's temperature periodicities, particularly those of the oceans, inherit the structure of the periodicity of solar activity. WHITE *et al*. (1997) and REID (1991) have found that the sunspot cycle produces periodicities in the oceans' temperatures. This research shows that sea surface temperatures in the Indian, Pacific, and Atlantic Oceans, whether taken separately or combined, follow measures of solar radiant output derived from satellite observations and the sunspot record.

The sun's separate impacts on the atmosphere and the ocean, and the complex non-linear interaction between the atmosphere and the ocean, is another process that amplifies the non-linear impact of the sun on our climate. Given that solar activity is a key determinant of ocean temperature, the decline on solar activity measured over the last decade should give rise in due course to a cooling of the oceans. LYMAN, WILLIS and JOHNSON (2006) report that the average temperature of the water in the top 750 metres of the earth's oceans has cooled significantly since 2003. This cooling has occurred even as areas of the Pacific Ocean associated with ENSO have warmed over the same period. Whilst the explanation for the unexpected finding that the oceans generally are cooling is still being debated, it is an expected consequence of diminished solar activity.

Decades of research have established that ENSO is the largest source of inter-annual variability operating in the earth's climate system. Furthermore, it has been known for decades that the ENSO regulates Australia's climate. NICHOLLS (1992) established that ENSO is largely responsible for the regulation of Australia's climate. He concluded:

The El Niño/Southern Oscillation has a major effect on Australasian climate. The phenomenon amplifies the interannual variability of the climate and imposes temporal patterns, phase-locked to the annual cycle, on droughts and wide- spread, heavy rainfall episodes. The native vegetation and wildlife are clearly adapted to the pattern of climate fluctuations, especially rainfall variations, imposed by the El Niño/Southern Oscillation. This suggests that the El Niño/Southern Oscillation has been affecting the Australasian region for a very long time. The clear adaptation of the fauna and flora to the patterns of climate produced by the El Niño/Southern Oscillation indicates that paleoclimatic studies in the Australasian region may help determine when the phenomenon started to operate.

Other Australian scientists, (FRANKS (2002); KIEM, FRANKS and KUCZERA (2003); KEIM and FRANKS (2004); and VERDON, KIEM and FRANKS (2004), have found that ENSO, modulated by the Interdecadal Pacific Oscillation, is largely responsible for Australia's cycles of flood, drought and bushfire. Professor Stewart has also shown how this knowledge can be used to better manage Australia's water resources and bushfire risks. ABRAM, GAGAN, *et al*., (2007), a team at the Research School of Earth Sciences at the Australian National University, have recently shown that the Indian Ocean Dipole (IOD) has a more dramatic effect than ENSO on the climate of countries surrounding the Indian Ocean. ABRAM, GAGAN, *et al*., (2007) report that the IOD interacts with the ENSO so as to intensify climatic extremes of flood and drought. TRELOAR, (2002), of the Queensland Centre for Climate Applications, Queensland Department of Primary Industries, reports that the variability in ENSO and sea-surface temperature anomalies may be partly a result of lunisolar tidal factors. He reported that the predictability of tidal effects may make a contribution to improving the accuracy and lead time of climate forecasting. The sunspot cycle is the main determinant of behaviour of the atmospheric oscillations that largely determine Australia's climate: ENSO, IPO and IOD. The sunspot cycle is therefore the main determinant of Australia's climate.

As SCAFETTA and WEST (2006b) report, increased solar activity warms the oceans, increases the volume of water vapour and carbon dioxide in the atmosphere and reduces the oceans' uptake of water vapour and carbon dioxide from the air. As a result, some of the atmospheric carbon dioxide that has been attributed to human activity may have a solar origin. The resultant release of more water vapour and carbon dioxide into the atmosphere may have contributed to the warming that is already the direct result of increased solar output, variations in the sun's gravitational force and interactions between the two. It is to be hoped that in its next series of publications the IPCC will quantify the proportion of greenhouse gases that have been produced by the sun in this manner. EMANUEL (2005) reports that the warming of the oceans, especially since the 1970s, has resulted in increasingly destructive tropical cyclones over the last 30 years. BAKER *et al* (2005) builds on research Professor Fairbridge conducted on Rottnest Island off Perth in the late 1940s and published in 1950. This research was the basis for his pioneering theory of the Fairbridge curve. BAKER *et al* (2005) used evidence of tubeworms to find evidence about sea level changes. The tubeworms attach themselves to coastal rocks at inter-tidal levels, as they have to be covered by seawater for about six hours each day. The careful study of tubeworm casings along coastlines in Australia, Brazil and South-east Asia has revealed that, even within the past thousand years, there have been several sudden changes in sea levels of up to two metres. The UNE team has discovered that each of these large changes took less than 40 years from beginning to end. They have therefore found convincing evidence of large, rapid changes in sea levels around the world in the recent past.

'Most of the climate-change modelling done in Australia and overseas assumes a basically stable natural system underlying the man-made variable of greenhouse gases,' said one of the UNE researchers, Dr Robert Baker. 'Our research indicates that the underlying system is anything but stable and that we would be well advised to take this into consideration in our planning. We're adding a destabilising factor (greenhouse gases) to a system that is already subject to large, rapid changes.'[xxi] BAKER *et al* (2005) have been collaborating on the project for the past eight years and have published nine papers in scientific journals in relation to it.

Rhodes Fairbridge repeatedly emphasised that the entire field of planetary-lunar-solar dynamics, including gravitational dynamics, has to be studied so the dynamics of terrestrial climate can be understood. An improved understanding of the interaction effects of the sunspot cycles and the lunisolar tidal cycles on the earth's climate is necessary, as Rhodes emphasised. When the influence of solar variability is examined in its entirety (as Rhodes insisted it should be), it is clear that the influence of solar variability on the Earth's climate is strongly non-linear, stochastic and significant.

DE JAGER (2005) and VERSTEEGH (2005) have come the closest of recently-published reviews of relationships between the sun and climate to Professor Fairbridge's requirement. DE JAGER (2005) concluded that the role of the sun is significant but as it depends on latitude and longitude, it is incorrect to hypothesise a uniform measure of the sun's impact on the earth's surface. DE JAGER (2005) reported that never during the last 10,000 years has the sun been as active in ejecting magnetised plasma as during the last few decades. He noted that the maximum level of solar activity may have passed recently and that solar activity may continue to decrease in coming decades. VERSTEEGH (2005) reviewed the many difficulties in the way of interpreting sun-climate relationships. He notes the variable nature of sun-climate relationships in relation to latitude and longitude and that the sun induces a non-linear response at any given location. VERSTEEGH (2005) noted that this complicates the assessment of sun-climate relationships and requires the non-linear analysis of multiple long and high resolution records at the regional scale. He reported that the field of non-linear analysis of sun-climate relationships is somewhat underdeveloped, even though the dynamics major climate configurations such as ENSO, NAO and the AO are non-linear. He considered that more research is required to establish relationships between the lunisolar tides, geomagnetism and climate. Whilst the two papers aim to review the totality of the sun-climate relationships, the authors rely on their flawed attempt to refute any relationship between solar inertial motion and solar activity (DE JAGER and VERSTEEGH 2005) and, as a result, ignore all published evidence about that hypothesised relationship. Furthermore, the authors do not cite several relevant studies (eg

BUTLER AND JOHNSTON, 1994; HARRISON (2004), SCAFETTA *et al* 2004; and ZAITSEVA *et al*. 2003) that have established sun-climate links. Additionally, several significant papers have been published since DE JAGER (2005) and VERSTEEGH (2005) went to press.

AN EARLY TEST OF THE SOLAR INERTIAL MOTION HYPOTHESIS IS POSSIBLE DURING 2007 TO 2011

The solar inertial motion hypothesis predicts that the period from about 2010 to 2040 will be one of relatively severe cold throughout the world. The hypothesis predicts that the emergent Sunspot Cycle No 24 will be quieter than Sunspot Cycle No 23 and just like Sunspot Cycle No 14, the weakest cycle in the last 100 years, which began in February, 1902 and ended in August, 1913. More than a dozen predictions of Sunspot Cycle 24 have been published in scientific literature since 1999;[xxii] some based only on statistical features of solar, including sunspot, activity. These tend to predict that Sunspot Cycle 24 will be larger and stronger than its predecessor. Some are based on an understanding of solar physics. DIKPATI, DE TOMA and GILMAN (2006) predict that Sunspot Cycle 24 will be 30 to 50 per cent higher than Sunspot Cycle 23. DIKPATI, DE TOMA and GILMAN (2006) also predict that the cycle will start a year late, some time in late 2007 or early 2008. Their prediction is based on computer simulation of the solar dynamo; however, TOBIAS *et al*. (2006) have drawn attention to the highly speculative nature of this prediction. Amongst other things, they note that the solar dynamo model used by DIKPATI, DE TOMA and GILMAN (2006) 'relies on parametrisation of many poorly understood effects', and the model has no known predictive power. SVALGAARD, CLIVER, and KAMIDE (2005) predict that Sunspot Cycle No. 24 will be significantly smaller and weaker than its predecessor and will be just like Sunspot Cycle No. 14. Their prediction is based on an examination of the strength of the magnetic fields that congregate in the polar regions of the sun a few years before the solar minimum of each solar cycle and relating the strength of those fields to the observed sunspot numbers during the next solar maximum. The polar magnetic fields provide the 'seed' magnetic flux necessary to drive the sunspot activity during the next solar cycle. SVALGAARD, CLIVER, and KAMIDE (2005) theorise that the solar polar fields will be weak during 2007-2008 and will remain weak. They have recently reported that the polar fields are the weakest ever observed.[xxiii]

LIVINGSTON (2004) found that the maximum of Sunspot Cycle No 22 was statistically significantly stronger than the same phase of Sunspot Cycle No 23. PENN and LIVINGSTON (2006) report that over the past eight years, throughout the life of Sunspot Cycle No 23, the maximum sunspot magnetic fields have been decreasing by about 52 G yr^{-1}. They note that a continuation of the documented trends would mean that the number of sunspots in Sunspot Cycle No 24 would be reduced roughly by half and that very few sunspots would be visible on the solar disk during Sunspot Cycle No 25. CLIVERD *et al* (2006) used a previously-validated model of solar variability that includes all known periodicities of solar activity. These include periods of 22, 53, 88, 106, 213 and 420 years that modulate the better known 11-year sunspot cycle. This is the only published model to include all solar periodicities. This model, which generally reproduces the periodicities in the sunspot data recorded since 1750, predicts that Sunspot Cycle No 24 will be quieter than Sunspot Cycle No 14. It also predicts that Sunspot Cycle Nos 25 and 26 will be even more subdued. Furthermore, the model predicts that solar activity will return to more normal levels from Sunspot Cycle No 27 onwards; that is, by around the middle of the century. TOBIAS *et al* (2004) caution against predictions of future sunspot cycle activity, arguing that solar activity is non-periodic, not multi-periodic. TOBIAS *et al* (2004) conclude: '*The future of such a chaotic system is intrinsically unpredictable*.' In October, 2006 NASA announced that as Sunspot Cycle No 24 had begun, and because of the wide divergence in expert predictions about the maximum amplitude and timing of the cycle, it had appointed a panel of world experts to formulate a consensus prediction. The panel will announce its preliminary findings in April, 2007. The panel includes the authors of the major divergent predictions. Professor Tobias has been appointed an advisor to the panel.

SVALGAARD, CLIVER, and KAMIDE (2005) consider it may be possible to gain early in 2007 an indication of what Sunspot Cycle No 24 will be like from observations to be made by the Ulysses solar orbiter. A direct measure of the strength of the solar polar fields will be possible during 2007-2008, when Ulysses makes another pass over the solar poles. If Sunspot Cycle No 24 is going to be weaker than its predecessor, then measurement of the sun's polar fields during 2007-2008 should show that the fields are significantly smaller than they were during the polar passes of 1994 and 1995, when Sunspot Cycle No 23 was in its minimum phase. A finding by Ulysses that the sun's polar fields had significantly weakened would support the hypothesis that solar activity is declining. It would also tend to support the prediction that solar maximum of Sunspot Cycle No 25 would be much smaller than has been observed during the last 150 years or so. It would be a strong indicator of a very cold global climate ahead. Astronomers at the Synoptic Optical Long-term Investigations of the Sun (SOLIS) facility built by the National Solar Observatory (NSO) reported on 16th August, 2006 that Sunspot Cycle No 24 began on 23rd July, 2006.[xxiv] This may indicate that Sunspot Cycle No 24 will indeed be weaker than its predecessor.

Australia's Bureau of Meteorology was one of the first government agencies in the world to publish reports linking solar activity and climate. In 1925 the Commonwealth Government's Bureau of Meteorology published a report linking the features of Sunspot Cycle No 14 and Australia's climate at that time.[xxv] KIDSON (1925) considered that 'The year 1914 was the culmination of what was in all probability the worst drought in Australian history' and attributed the drought to the weakness of Sunspot Cycle No 14. In 1938 the Bureau published another report, QUAYLE (1938), that noted: 'A rough generalisation from the winter rainfall over northern Victoria would suggest that when the new solar cycle begins with a rapid rise to a definite peak then the heaviest rains are in the early years, but when the solar activity begins more gradually and takes four or more years to reach a low or moderate maximum then comparatively poor seasons may be expected in the early part.' This report updated QUAYLE (1925), the first scientific paper published in Australia about the relationship between the sunspot cycle and climate. Quayle's 'rough generalisation' has been corroborated by recent research. The sim hypothesis and SVALGAARD, CLIVER, and KAMIDE (2005) predict precisely this pattern of gradual rise to a very moderate maximum for the emergent Sunspot Cycle No 24.

According to sim hypothesis, Sunspot Cycles No 25 and 26 will be smaller and weaker than Sunspot Cycle No 24, which will be smaller and weaker that Sunspot Cycle No 23, and the earth will enter a little ice age. According to this analysis, as the sun enters Sunspot Cycle No 26, the earth's climate is expected to be much the same as it was during the Dalton Minimum cold period from the 1790s to the 1820s. Subsequent orbits are expected to become more regular. Solar output will increase once the sun leaves the chaotic phase of its orbit around the barycentre. Solar activity is expected to pick up; the warm climate return for the remainder of the century, from about 2050 onwards. It is to be hoped that in its next series of publications, the IPCC includes in its modelling of climate change the consequences of reductions in solar activity expected during Sunspot Cycles No 24, 25 and 26.

THE CHALLENGE OF NONLINEAR, NON-STATIONARY TIME SERIES ANALYSIS

Time series of measures of geophysical and other complex systems are characterised by variations from the mean behaviour that can be very large (catastrophic events) and simultaneously very long (persistence in time). Time series analysis of such data should preferably use methodologies that can detect non-linear and non-stationary relationships and identify reliably and validly the stochastic dynamics of the system. KOUTSOYIANNIS (2000) and (2002) has drawn attention to the challenge that hydrologists and climate scientists generally face in trying to detect meaningful trends in time series of hydrological and other climate data. It is a well-known feature of complex non-linear systems that apparent structure is consistent with randomness. KOUTSOYIANNIS (2003) has shown that in these circumstances the detection of significant trends that arise from real processes requires the use of appropriate statistical methodologies. KOUTSOYIANNIS (2006) has shown that even a simple chaotic system with a few degrees of freedom can produce very complex time series. These look irregular or random, yet have variations from means that can be very large and very long. Such time series, which appear non-linear and non-stationary, depart from most familiar experiences of randomness (e.g. a sequence of throws of an ideal dice). Koutsoyiannis has perfected ideas and methodologies that have been developed over the last 50 years or so. He has shown that the apparent order many might see in time series data could quite reasonably be described as stochastic behaviour. He has shown that since random activity can generate time series that appear to contain functional form, the standard classification of a time series into simply deterministic and random components is a misrepresentation.

HUANG *et al*. (1998) have highlighted the need to use analytic methodologies that clearly reveal any non-linear relationships (that may also contain intrinsic trends) when analysing time series of natural phenomena. HUANG *et al*. (1998) showed that, necessarily, misleading conclusions will be drawn from the uncritical use of time series analytic techniques that assume relationships within the time series are linear, stationary and devoid of intrinsic trends. COHN and LINS (2005) have brought attention to the non-linear and non-stationary nature of climate time series data. COHN and LINS (2005) conclude: *These findings have implications for both science and public policy. For example, with respect to temperature data, there is overwhelming evidence that the planet has warmed during the past century. But could this warming be due to natural dynamics? Given what we know about the complexity, long-term persistence, and nonlinearity of the climate system, it seems the answer might be yes. Finally, that reported trends are real yet insignificant indicates a worrisome possibility: Natural climate excursions may be much larger than we imagine. So large, perhaps, that they render insignificant the changes, human-induced or otherwise, observed during the past century*. As previously noted, the IPCC dismissed any significant link between solar variability and climate on the grounds that the variations in electromagnetic radiation were too small. This opinion not only ignores the totality of the sun's impact on climate and the differential impact of solar output, it is also based on methodologies only appropriate for the analysis of linear and stationary time series. Furthermore, the IPCC did not address the challenge identified by HUANG *et al*. (1998); KOUTSOYIANNIS (2000) and (2002), and (2003); and COHN and LINS (2005). When the requisite sun-climate time series are analysed with methodologies commensurate with the non-linear and non-stationary nature of the time series, significant results are found, as outlined in this paper. These show that if the influence of solar variability is examined in its entirety, as Rhodes insisted it should be, the influence of solar variability on the earth's climate is strongly non-linear and stochastic. Nevertheless, the evaluation of any sun-climate, and solar activity-sim, relationship has not yet fully met the challenge identified by Huang, Koutsoyiannis, and Cohen and Lins. It is to be hoped that in its next series of publications the IPCC will take into account the criticisms of Huang, Koutsoyiannis, and Cohen and Lins.

ADAPTIVE EFFICIENCY IS THE KEY

According to the findings reviewed in this paper, the variable output of the sun, the sun's gravitational relationship between the earth (and the moon) and earth's variable orbital relationship with the sun, regulate the earth's climate. The processes by which the sun affects the earth show periodicities on many time scales; each process is stochastic and immensely complex. The system consisting of the totality of the processes is even more complex. This system does not have a stable underlying structure, even if some of its subsystems do. The total system is, as Douglass North would say, non-ergodic. NORTH (1999) considers we live in a non-ergodic world; he explained that an ergodic phenomenon has an underlying structure so stable theory that can be applied time after time, consistently, can be developed. In contrast, the world with which we are concerned is continually changing: it is continually novel. Inconsistency over time is a feature of a non-ergodic world. The dynamics of change of the processes important to us are non-ergodic; the processes do not repeat themselves precisely. He argues that although some aspects of the world may be ergodic, most of the significant phenomena are non-ergodic.

In 1993 Douglass North, along with fellow economic historian Robert W Fogel, received the Noble Prize for Economics for pioneering work that resulted in the establishment of Institutional Economics, now a central school of modern economics. He introduced the idea of 'adaptive efficiency' to describe how economies and societies work effectively, not at a moment in time, but through time. In his Noble Prize Lecture (NORTH 1993) he reasoned that '*It is adaptive rather than allocative efficiency which is the key to long run growth. Successful political/economic systems have evolved flexible institutional structures that can survive the shocks and changes that are a part of successful evolution. But these systems have been a product of long gestation. We do not know how to create adaptive efficiency in the short run.*'

Professor Emeritus North explains that adaptive efficiency is a society's effectiveness in creating institutions that are productive, stable, fair, broadly accepted and flexible enough to respond to social, political, economic and environmental crises. He explains that an adaptively efficient society will cope with the novelty and uncertainty of a non-ergodic world by the maintenance of institutions which enable trial and error and experimentation, so societal learning is effective, enabling the elimination of unsuccessful solutions and the retention of successful ones.

Douglass North stresses that our capacity to effectively deal with uncertainty is essential to our succeeding in a non-ergodic world. It is crucial, therefore, that the methodologies we use to understand the exceedingly complex phenomena measured in our time series, correctly inform us of the future uncertainty of the likely pattern of development indicated by the time series.

Classical time series analysis that features in the reports of the IPCC necessarily underestimates future uncertainty, whereas scaling methodologies that use the fractal structure of the phenomena estimates future uncertainty more accurately.

In his many publications (for example, NORTH (2005)), Douglass North stresses that if the issues with which we are concerned, such as global warming and the global commons, belong in a world of continuous change (that is, a non-ergodic world), then we face a set of problems that become exceedingly complex. North stresses that our capacity to deal effectively with uncertainty is essential to our succeeding in a non-ergodic world. History shows that regional effects of climate change are highly variable and that the pattern of change is highly variable. An extremely cold (or hot) year can be followed by extremely hot (or cold) year. Warming and cooling will be beneficial for some regions and catastrophic for others. Brian Fagan has documented in detail relationships between the large-scale and generally periodic changes in climate and the rise and fall of civilisations, cultures and societies since the dawn of history. The thesis to which Rhodes Fairbridge devoted much of his life is that the sun, through its relationships with the solar system, is largely responsible for these changes and that we are now on the cusp of one of the major changes that feature in the planet's history. As Douglass North showed, the main responsibility of governments in managing the impact of the potentially catastrophic events that arise in a non-ergodic world is to mange society's response to them so as to enable the society to adapt as efficiently as possible to them. Amongst other things, this would mean being better able to anticipate and manage our response to climate change, to minimise suffering and maximise benefits and the efficiency of our adaptation to a climate that is ever-changing – sometimes catastrophically – but generally predictable within bounds of uncertainty that statisticians can estimate. At the very least, this requires that the scientific community acts on the wise counsel of Rhodes W Fairbridge and presents governments with advice that has regard to the entire field of planetary-lunar-solar dynamics, including gravitational dynamics. This field has to be understood so that the dynamics of terrestrial climate can be understood.

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[i] Biographic detail drawn from the papers about, and the autobiographic essays by, Professor Emeritus Fairbridge in (RAMPINO *et al*., 1987), (FINKL 1995), and (FINKL 2005), and letters about Professor Emeritus Fairbridge by Mrs Dolores G Fairbridge, Leo F Laporte and Allen Lowrie published in FINKL (2005).

[ii] For a diagram of the village see http://www.fairbridge.asn.au

[iii] http://www.abc.net.au/southwestwa/galleries/fairbridge/pages/Chapel.htm

[iv] The chapel is described as "the architectural jewel in the crown of Fairbridge Village" by the Governor of Western Australia, His Excellency Lieutenant General John Sanderson, in his Forward to DOLAN and LEWIS (2004). Sir Herbert Baker himself described his feelings about designing the chapel as a "labour of love" in correspondence in 1931, (DOLAN and LEWIS (2004), page 8), who consider that it is only architectural project Sir Herbert undertook on a voluntary basis. The money to build the chapel was donated by Thomas Wall, and English multi-millionaire who made his fortune from ice cream and sausages. DOLAN and LEWIS (2004) describe Sir Herbert Baker as one of the world's most famous architects of the time (p. 1); one of a tiny group of architects honoured by burial in Westminster Abbey (p. 4); and at the top of his profession in 1928 when invited to design the chapel (p. 51).

[v] An account of these positions in contained in the papers by Charles Finkl about Rhodes Fairbridge in (RAMPINO *et al*., 1987), (FINKL 1995), and (FINKL 2005). Examples include President of the Shorelines Commission of the International Union for Quaternary Research (INQUA) (1961 to 1969); President of the INQUA Neotectonic Commission (1970 to 1974); leader of the joint geological-archaeological expedition in connection with the Aswan dam project and the UNESCO "Save the Monuments" campaign (1960-1961); co-founding editor of the *Journal of Coastal Research* and co-founding trustee of the Coastal Education and Research Foundation.

[vi] The particular theorem Newton proved is Proposition 12 Theorem 12: *The sun is engaged in continual motion but never recedes far from the common centre of gravity of all the planets.* NEWTON 1687, page 816.

[vii] See FAIRBRIDGE, R. W. and SANDERS, J. E., (1987) and FAIRBRIDGE, R. W. and SHIRLEY, J. H., (1987) and references therein for an account of this work.

[viii] The solar system has angular momentum as it rotates around the Sun. Whilst the Sun has over 99 per cent of the mass of the solar system, the planets have about 98 per cent of the solar system's angular momentum. The giant gas planets have most of the angular momentum of the solar system.

[ix] See for example http://mitosyfraudes.8k.com/Calen/Year1816.html

[x] A useful, if brief, history of research about solar variability and climate change, with several key references, may be found at http://www.agu.org/history/sv/articles/ARTL.html

[xi] This symposium was dedicated to Dr Charles Greeley Abbot, a pre-eminent U. S. pioneer worker in the field of the measurement of the Sun's output and the identification of Sun-climate relationships. Dr Abbot, who was aged 101 at the time, addressed the conference, only to die five weeks later.

[xii] In 1999 Jack Eddy recounted in interview with Spencer Weart, the widespread prejudice against the hypothesis that the Sun could generate climate change. The interview may be found at http://www.agu.org/history/sv/solar/eddy_int.html . HOYT, D and SCHATTEN, K., (1997) and SOON, W. WEI-HOCK and YASKELL, S. H., (2003) provide a history of our understanding of the Sun/Earth relationship.

[xiii] A recent compilation of current research may be found in the proceedings of the international scientific conference, ***Solar Variability and Earth's Climate***, held in June/July 2005 in Rome, published in the journal of the Astronomical Society of Italy, *Memorie Della Societa Astronomica Italiana* 76 (4) 2005. The papers can be found on the website http://sait.oat.ts.astro.it/MSAIt760405/index.html. See especially BREKKE, P., "Closing Remarks on the Sun influence on climate change"; GEORGIEVA, K., BIANCHI, C., and KIROV, B. "Once again about global warming and solar activity"; and PONYAVIN. D. I., BARLIAVA, T. V., and ZOLOTOVA, N. V. "Hypersensitivity of climate response to solar output during the last 60 years".

[xiv] www.sfwmd.gov/org/pld/hsm/pubs/ptrimble/solar/workshop/poster.pdf

[xv] The summary in this paragraph is derived from PAP *et al* (EDS) 2004 and the papers presented at the international scientific conference referred to in endnote xiii above held in 2005.

[xvi] The principal author, Dr Charles D Keeling, was the first scientist to measure an increase in the amount of Carbon Dioxide

in the atmosphere. He began this research in 1956; his first paper was published in 1959. He died aged 77 in June, 2005.

[xvii] The summary in this paragraph is derived from PAP *et al* (EDS) 2004; the papers presented at the international scientific conference referred to in endnote xiii above held in 2005; and LAMBECK (1980).

[xviii] This is derived from PAP *et al* (EDS) 2004; the papers presented at the international scientific conference referred to in endnote xiii above held in 2005.

[xix] Some findings are the result of the use of Empirical Mode Decomposition, (HUANG *et al*. (1998)), an improved statistical methodology for extracting information from nonlinear, non-stationary time series data. EMD lets the data speak more directly, revealing its intrinsic functional structure more clearly. It does not does not have the restrictive assumptions of linearity and stationarity that the familiar Fourier-based techniques have, because it uses Hilbert, not Fourier, transforms.

[xx] Relevant papers can be found as the United States Geological Survey agency website **:**
http://ks.water.usgs.gov/Kansas/waterdata/climate/

[xxi] See National Science Week article dated August 19 2005 *Sea level changes give us an urgent message* on the website of the University of New England:
http://www.une.edu.au/news/archives/000327.html

[xxii] These are reviewed in "Cycle 24 Predictions SHINE 2006" at these sites: http://www.leif.org/research/ ; solar cycle 24 (Lund) at http://www.lund.irf.se/rwc/ ;
http://members.chello.be/j.janssens/Engwelcome.html ; and
http://www.ucar.edu/news/releases/2006/sunspot.shtml

[xxiii] In a work-in-progress report published in October, 2006 on Leif Svalgaard's website, Svalgaard, Cliver and Kamide report that "the polar fields right now are the weakest ever directly observed".http://www.leif.org/research/Polar%20Fields%20and%20Cycle%2024%20(Observations).pdf

[xxiv] http://solis.nso.edu/news/Cycle24.html

[xxv] At the time Dr Kidson was the head of the Bureau's research division. In 1927 he was appointed Director-General of the New Zealand Meteorological Service.

[xxvi] Sun spot cycle 24: Svalgaard (2007) reports that Ulysses indicates that the sun's polar fields do not determine the magnetic field, contrary to his theories and contemporary thinking.

[xxvii] Chouhuri, Chatterjee and Jiang (2007) using solar dynamo modelling predict a very low amplitude for sun spot cycle 24 similar to the prediction of Svalgard *et al* (2005). Kapyle (2007) compared the solar dynamo models of Choudhuri, Chatterjee and Jiang (2007) and Dikpati *et al* (2006), concluding that Choudhuri *et al* model the superior of the two. Amngst other things, the model used by Choudhuri *et al* provides that the polordal field generation is intrinsically random whereas the model used by Dikpati *et al* uses sun spot area data as a deterministic source for the polordal field. The Choudhuri *et al* model is considered more realistic. Secondly, the Choudhuri *et al* polar dynamo model was published in 2004 and subject to scrutiny by scientists. The Dikpati model has not been published.

[xxviii] Apparent cooling of the oceans: Willis, Lyman, Johnson and Gilson (2007) have recently submitted a paper for publication in Geophysical Research Letters which reports a correction to Lyman *et al* (2006). Willis *et al* (2007) report that the recent cooling signal into the upper ocean reported by Lyman *et al* (2006) is shown to be an artefact of some of the instruments used to collect data.

[xxviv] The sim hypothesis, solar activity cycles and climatic change: Yousef (1995, 2000, 2005, 2006) reports a similar analysis and series of finding to that presented in this paper. Furthermore, just as this paper derives impliations for Australia, her work derives implications for Egypt and Africa generally.