# Weather Cycles

## Real or Imaginary?

(Second edition)

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# Chapter 1

## The search for cycles

And the seven years of plenteousness, that was in the land of Egypt was ended. And the seven years of dearth began to come, according as Joseph had said: and the dearth was in all lands; but in the land of Egypt there was bread.

Genesis 41:53

Throughout recorded history the fluctuations of the weather have played a major part in human life. Times of feast and times of famine have repeatedly occurred. The biblical story of Joseph's dream, accurately foretelling that 7 good years would be followed by 7 years of famine and describing the action that was taken to store the surplus from the good years to meet the shortages of the bad years appears to be the first recorded example of a periodic variation in the weather over a number of years, but it also shows the huge benefit that can accrue from the accurate predictions of such regular meteorological changes and their impact on harvests, and explains why the possibility of regular fluctuations in the weather has fascinated weather watchers for so long.

There may also be a more fundamental reason for searching for such orderly behaviour in the weather. Because so much of our lives is governed by the rhythms of the seasons, it is natural to look for the same sort of order in the longer term, more chaotic behaviour of the physical world around us. Nowhere is this desire for order more widely expressed than in those who attempt to explain fluctuations from year to year in the weather. The daily and annual progression of the weather is dominated by the predictable rotation of the Earth and its motion round the Sun, and it is therefore natural to ask whether the other fluctuations, which are such a feature of our weather, have a simple explanation.

We all know that the weather is rarely, if ever, behaving normally. Climatology textbooks can tell us what, on the basis of long-term records, the average conditions are for any given place at any given time. But, in practice, it is almost always hotter or colder, or wetter or drier than these normals. Over periods of weeks or months these fluctuations may add up to give a notable cold spell, heatwave or drought. The occurrence of such extremes is a source of constant fascination for meteorologists. They appear on every timescale, from week to week, month to month, year to year and over the decades and centuries. Over all these periods the weather appears to behave in a chaotic way that defies description. Yet we all intuitively suspect that there is some underlying order. Extreme spells of weather seem to be balanced out by the opposite extreme with monotonous regularity. As Wiltshire folklore states:

> There is no debt so surely met
> As wet to dry and dry to wet.

On the longer timescale there is widespread assumption that, say, cold winters or hot summers come every so many years. The general public tends to accept that such patterns exist and that the application of suitable scientific analysis will find the key to unlock the door to long-term predictability of the weather.

Among the meteorological community the debate continues as to whether patterns exist and, if so, whether they either constitute a sufficiently large proportion of the observed variability or are sufficiently well established to provide the physical basis for forecasting. This uncertainty exists, in spite of a huge amount of work over many years. The history of this search, how patterns have been detected and what they tell us about the balance between order and chaos in the weather are the themes of this book.

## 1.1 Social and economic preamble

The story from the Book of Genesis shows that the social and economic implications of major weather fluctuations are profound. Since the advent of reliable instrumental records it has been possible to make estimates of the extent to which various aspects of economic activity have been influenced by abnormal weather events. This provides a basis for making some observations about the potential benefits that might accrue from being able to anticipate periodic fluctuations in the weather. Conversely, apparently regular variations in past economic indicators, such as European cereal prices, may make it possible to draw some inferences about past climatic fluctuations. In theory, this is a practical proposition as such records exist for several hundred years before instrumental records began. Moreover, they can be compared with other indirect records such as measurements of the width of tree rings and wine harvest dates, which have also been obtained in the same area over the same period (see also Chapter 4). So it helps to set the scene by considering what the social and economic implications of weather cycles might be.

The importance of identifying predictable cyclic behaviour in the weather can be gauged from recent events that show some evidence of periodic behaviour. The most celebrated of these is El Niño. This phenomenon, which involves major shifts in both the atmospheric pressure patterns and sea surface temperatures (SSTs) over a large part of the tropical Pacific, occurs every few years. In both 1982/83 and 1997/98 it had a major global impact. In particular, the first of these two events was associated with major droughts in Australia, many parts of sub-Saharan Africa, Brazil and Central America. These extremes inspired a great deal of research, which has provided an increasingly clear measure of how variations in the sea surface temperature play a part in climatic fluctuations around the world. So, if an adequate physical explanation were produced to explain these approximately regular fluctuations, the potential forecasting value of such understanding could have to global economic and social implications.

Similar arguments apply to cold winters in industrial countries. In January 1977, the eastern United States almost ground to a halt. The intense cold precipitated an energy emergency and the total economic cost of the disruption was estimated in 1977 prices to be nearly $40 billion. Subsequent studies suggested that there is an as yet unexplained link between the 11-year cycle in the variability of the Sun and winter temperatures in the south-eastern United States. The link was, however, a complicated one that involved both solar variability and a periodic reversal of the winds in the stratosphere over the equator. Although the value of this proposed connection has not stood the test of time, it is an interesting example of the type of apparently cyclic behaviour that continues to hint at some underlying order in weather patterns. But to have any value, such putative periodic behaviour must be put onto a reliable scientific footing so it can become the foundation of weather forecasts months in advance. Then the potential economic importance of being able to plan, say, energy supplies to accommodate extreme winters will be huge.

Even more important in terms of economic consequences are the cycles of drought that seem to afflict the great plains of the United States. Ever since the dust-bowl years of the 1930s, there has been intense speculation about the existence of an approximately 20-year cycle in rainfall. Subsequent dry periods in the 1950s and again around 1980 reinforced these claims, although it is not yet clear whether the predicted drought around 2000 has truly materialised. The areal extent and the timing of these droughts do not follow a simple pattern, but the implications for US agriculture are clearly substantial. Moreover, because surplus cereal production in the United States has traditionally played a dominant role in meeting shortfalls elsewhere around the world, this behaviour has global consequences.

Similar observations can be made about the economic impact of weather events in the UK and across Europe. The severe winters of 1947, 1963 and 1979 all caused major economic disruption. By the same token, the summer of 1976 demonstrated that even the UK can suffer damaging droughts. In England there is a tendency for hot dry summers to occur every 13 years or so and this provides another hint of underlying periodicity.

Although there is no doubt about the economic impact of weather fluctuations, the converse exercise of seeking to extract information about weather cycles from some economic series is fraught with difficulties. A foretaste of these pitfalls can be seen in Fig. 1.1. This shows that between 1529 and 1541, the thickness of tree rings in oaks in Germany showed a remarkably consistent alternation between thick and thin rings in successive years. This suggests a run of alternating good and bad growing seasons: an inference that is supported by data for the dates of wine harvests (a measure of the quality of the harvest), which are remarkably in step. In contrast, the price of cereals, as measured in a variety of market towns across Europe, does not show any close parallelism, in spite of the fact that the weather probably produced significantly different harvests in each year.

This *hors d'oeuvre* shows the fascinating information that can be extracted from a variety of historic sources both to examine evidence of climatic change and to search for weather cycles. But, do not assume everything is going to be plain sailing. There are a number of snags in the beguiling curves in Fig. 1.1. First, the link between tree-ring width and the weather is complicated. Although hot dry growing seasons tend to produce thin rings and cool wet years produce thick rings, the relationship is by no means simple. Tree-ring width does show changes throughout the growing season but may also be influenced by groundwater reserves from earlier wet seasons. In fact, the wine harvest dates provide a better measure of the weather during the period April to September, as well as being a useful guide to the economic impact of the weather over the period. Second, the behaviour of the cereal prices shows the problems of moving further away from direct meteorological measurements. What must be remembered is that meteorology will be only part of the story. Demographic pressures, civil unrest and other social changes all played a significant part in cereal

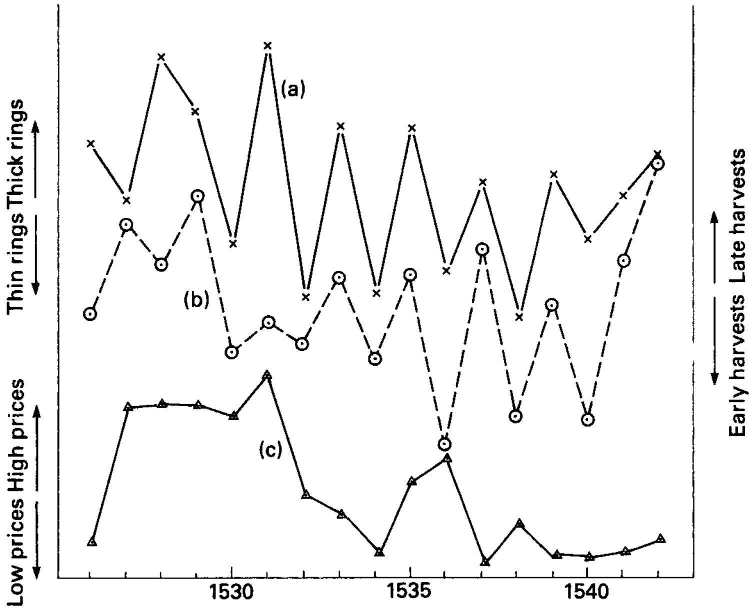


**Fig. 1.1.** Examples of: (a) German tree-ring thicknesses, (b) French wine harvest dates, and (c) European wheat prices year by year between 1526 and 1542. Tree-growth and wine harvest dates showed a marked biennial oscillation during the 1530s.

prices at the time. Third, and perhaps most important, the splendidly regular fluctuation of tree-ring width is the best example of such a 'biennial oscillation'. Elsewhere, the record is much less regular. This identifies a fundamental weakness of many apparently convincing examples of 'weather cycles': they come and go in a most tantalising manner.

These words are a warning for what will follow. Wherever efforts are made to identify the existence of weather cycles, the form of the original data must be subject to critical scrutiny. This is central to examining meteorological data, and is even more necessary when attributing cycles in economic series to underlying fluctuations in the weather. Moreover, it is of paramount important when going so far as to estimate the economic consequences of predicted periodic variations in the weather. Failure to exercise this critical faculty can lead to economic nonsense. This is a discipline that many cycle enthusiasts have not always maintained in their efforts to promote the case for their discoveries.

So much for economics. We must now turn to the case for the cyclic behaviour of the weather, starting with a brief history of the early attempts to explain apparently periodic variations in the weather. This will set the scene for describing the mathematics and science of making reliable investigations of meteorological data and also the latest work on developing the case for and against weather cycles. Behind all this work lies the knowledge that if it could be established why the weather should fluctuate in a regular and predictable manner, the economic benefits would be potentially vast.

## 1.2 History of cycle-searching

Apart from the Book of Genesis, Theophrastus of Eresus, Lesbos, made the first recorded observation of weather cycles in the fourth century BC. He was a younger friend of Aristotle, studied at Plato's Academy, and became Aristotle's chief assistant after Plato's death. Together, they made a study of the whole of nature, with Aristotle taking animals and Theophrastus taking plants. In his study of meteorology he noted that 'the ends and the beginnings of the lunar month are apt to be stormy'. Over 2000 years later the debate still continues about the extent of lunar effects on the weather.

The ancient art of defining patterns in weather, which is encapsulated in folklore, was mentioned earlier. Frequently, these patterns are concerned with month-to-month, or season-to-season variations. Only rarely do these rules extend to changes from year to year. Because the central concern in this book is periodicities longer than a year, it is these more speculative saws that are of more interest. In this context the following example is intriguing:

> Extreme seasons are said to occur from the sixth to tenth year of each decade, especially in alternating decades.

This suggests the detection of periodicities of around 10 and 20 years. As will be seen, these figures are close to two of the most thoroughly studied weather cycles.

There is little evidence that prior to the Age of Reason there was any attempt to quantify the variations. One interesting exception appears to be the 35-year rhythm, which, according to Francis Bacon, was already a subject of inquiry in the Low Countries at the beginning of the seventeenth century. This periodicity was to gain much greater attention in the late nineteenth century when the Swiss Professor E. Bruckner was commissioned by the Russian Government to study changing levels in the Caspian Sea, which caused dislocation of transport. He investigated weather data from all over Europe for rivers, lakes, harvests and vintages and concluded that there was a 35-year cycle affecting weather, and thus the changing levels in the Caspian Sea. As we will see, after languishing in obscurity for much of the twentieth century, this periodicity has re-emerged as a feature in tree-ring studies that may be linked to quasiperiodic fluctuations of the atmosphere–ocean interactions in the North Atlantic. In more scientific studies, the first example of seeking to explain weather variations was by the astronomer William Herschel in the early nineteenth century. He proposed that the changes in the Sun's output could influence the weather. But it was the work of another astronomer that truly set in motion the subject of solar cycles in the weather. In 1844, Heinrich Schwabe discovered that the number of sunspots varied in a regular, predictable way,[1] leading to scientific speculation that our weather could vary in the same pattern.

A measure of the increasing rate of the search of weather records for cycles and hidden periodicities is in Sir Napier Shaw's classic manual of meteorology, published between 1926 and 1932,[2] which noted more than 100 cycles that had been 'discovered'. The complexity of these investigations, their possible implications and underlying weaknesses are neatly encapsulated by a quotation in his more popular book on the drama of the weather:

> The lunar—solar cycle of 744 years has been invoked by Abbé Gabriel. It combines 9202 synodic revolutions, 9946 tropical, 9986 draconitic, 9862 anomalistic, 40 revolutions of the ascending node of the lunar orbit and 67 periods of sunspots. It has harmonics of 372 years, 186 years. The last was relied upon for a prediction, made in the summer of 1925, of a cold winter to follow. The prediction was fulfilled in England by the occurrence of exceptionally cold weather in November, December and January. It must, however, be remarked that February, which is accounted as a winter month, brought the highest recorded temperature of that month for 154 years, and a spell of weather compared with which the first half of May was wintery.[3]

Another example of periodicity cited by Sir Napier Shaw shows the problems of obtaining a close correlation with sunspots over a limited period. The example he gave was of an apparent link between the level of Lake Victoria and sunspots over the period 1902 to 1921 (see Fig. 1.2). Despite the strength of this association, the prediction of a high level of the lake with the next sunspot maximum in 1928 proved incorrect. Subsequently, the low levels of the lake occurred every 5 years or so, and also the range of variation in lake level reduced. Even more important, it is now known there have been bigger and more lasting changes in the lake level unconnected with solar activity. First, a decline of nearly 2.5 m between 1876 and 1898 is believed to have occurred mainly between 1893 and 1898. The second was a rise of nearly 2 m in 1961.

[1] Schwabe (1844). [2] Shaw (1926–32). [3] Shaw (1933).

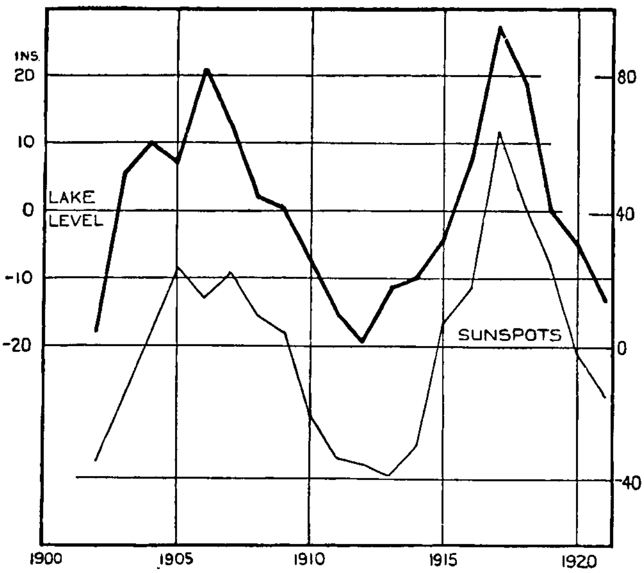


**Fig. 1.2.** The variation in the mean number of sunspots and level of Lake Victoria, East Africa, year by year from 1902 to 1921. (From Shaw, 1933.)

Failures like this gave weather cycles a bad name. In particular, attempts to demonstrate links between sunspots and the weather were frowned on by much of the meteorological establishment. This did not, however, prevent many determined souls labouring long and hard to provide better evidence of the existence of a link. By the late 1970s over a thousand papers had been published on the subject. But every new apparently convincing example of a solar–weather relationship was always subjected to searching statistical scrutiny by a sceptical meteorological community. Indeed, as late as 1978, a review paper by Barrie Pittock of the CSIRO in Australia, in *Reviews of Geophysics and Space Physics*, endorsed by a subsequent update in 1983 in the *Quarterly Journal of the Royal Meteorological Society*, summed up this scepticism.[4] He concluded that 'despite a massive literature on the subject, there is at present little or no convincing evidence of significant or practically useful correlations between sunspot cycles and the weather or climate'. Developments in the last ten years or so have produced results that have proved more difficult to dismiss so firmly. It is these developments that will be examined in detail later.

In part, these developments have been built on a nagging concern that it was difficult to dismiss some cyclic behaviour. The most obvious example is a tendency for many records to show a biennial oscillation. The

[4] Pittock (1978) and (1983).

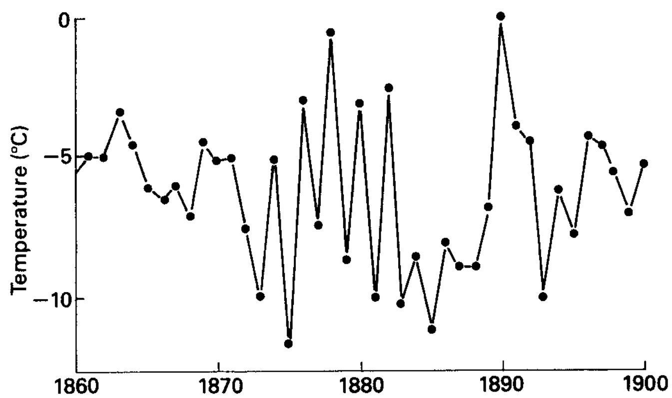


**Fig. 1.3.** The winter temperature record for Marengo, Illinois, showing that between 1873 and 1886 there was a marked biennial oscillation, but outside this period there was no such regular fluctuations.

example in Fig. 1.1 is echoed in many other observations. For instance, winter temperatures in the central United States in the 1870s and 1880s showed remarkably strong biennial behaviour for 11 years (see Fig. 1.3). But as with so many cycles, just when they look like a safe bet, they disappear only to re-emerge unexpectedly at some later date. Nonetheless, many meteorologists published papers noting the apparently impressive evidence of a biennial signal in many meteorological records.[5] By 1963 the weight of evidence was such that the climatologist Helmut Landsberg and colleagues[6] were able to conclude that there was 'no doubt the pulse, slightly in excess of 2 years in period, is a world wide phenomenon'. But they also described this phenomenon as a 'statistical will o' the wisp'. It is a measure of the problem that even now we do not have an adequate physical explanation of this biennial variability in surface weather data.

The search for the underlying cause of obvious roughly regular fluctuations has been more successful. These quasi-cycles may reflect fundamental properties of the natural variability of the global climate. As such they provide clues about the workings of the world's weather even if they may never amount to regular cycles. The expanding range of measurements of different aspects of the climate, such as upper atmosphere observations and satellite measurements, may hold the key to improved understanding. There have been two developing areas of analysis and expanding knowledge of longer-term global weather variability. First, from the early twentieth century onwards a series of studies had developed an orderly picture of

[5] An interesting history of these efforts is found in Chapter 4 of Labitzke & van Loon (1999).

[6] Landsberg *et al.* (1963).

large-scale oscillations in pressure patterns around the world. Later studies focused initially on pressure and sea surface temperatures across the tropical Pacific. By the late 1960s, a more comprehensive view had emerged of how events in the equatorial Pacific were linked to weather development at higher latitudes. These observations held the key to how quasi-periodic fluctuations in the tropics might lead to similar variations on a global scale. The close monitoring of subsequent El Niño events (see Section 5.4) in the tropical Pacific and in particular the record breaking events in 1982/83 and 1997/98 has since provided significant insights into how the atmosphere and the oceans interact to set up these approximately periodic oscillations. It also spurred on new interest in other regular fluctuations around the globe, some of which had been gathering dust since their discovery in the 1920s and 1930s. Now the study of 'oscillations' constitutes a growth area in meteorology.

The second major development in the cycles business was the discovery of an approximately regular reversal of the winds in the stratosphere over the equator. These measurements started in the early 1950s[7] and now clearly show the periodic behaviour of these winds, which reverse roughly every 27 months. This pattern has become known as the quasi-biennial oscillation (QBO). The importance of this upper atmosphere cycle is that, not only is it the most regular and predictable natural oscillation in the climate, but also it may be linked to the quasi-biennial feature in surface weather records noted above.[8] This development offers the prospect of being able to predict long-term variations at lower levels. Before this can happen there are two requirements: first, a satisfactory explanation of the periodic behaviour of the stratosphere as a whole, as the behaviour in equatorial region is pretty well understood, but links with higher latitudes are still the subject of debate; and second, a well-established physical link between changes in the upper atmosphere and consequent shifts at lower levels.

Alongside these advances in measurements has come improved understanding of the complexities of the global climate. In particular, the continued development of computer models of the climate has slowly

[7] See Labitzke & van Loon (1999) and Baldwin *et al.* (2001) for background on the discovery of the QBO and the current state of knowledge on this phenomenon.

[8] The acronym QBO is usually reserved for the stratospheric phenomenon, and its tropospheric cousin is sometimes termed the tropospheric biennial oscillation (TBO), but this gives the impression that the behaviour at lower levels is in some way more regular, so here we will use the generic term QBO for all quasi-biennial oscillations, recognising that the causes of this oscillation in the stratosphere and the troposphere may be different.

unravelled various aspects of the interconnectedness of all the components of the global weather system. But in spite of huge advances in computer power the models are still relatively crude and include greatly simplified assumptions to make the treatment of such parameters as cloudiness manageable. The central challenge is their handling of non-linear relationships between the various parameters in the model such as atmospheric pressure, temperature and wind speed. As with so many other areas of physics, the way round these problems is to establish that within certain limits there is a linear relationship between the various parameters. This means that for small shifts in the system the changes in one parameter are directly proportional to those in the other related parameters. This assumption that only the first-order terms are important and that higher-powered terms can be ignored makes the computation more manageable but imposes major limitations on the models.

The problem of handling non-linearity in physical systems has spawned a whole new area of science – chaos theory (see Section 8.1). This subject became highly fashionable in the late 1980s because of the new insights it provided and because it combined intriguing observations about the balance between order and disorder in the natural world with startlingly beautiful images of this balance. Its relevance here is that the theory had its origins in meteorology, and the weather arguably represents the ultimate challenge for the development of the theory. Whether chaos theory will play a central part in unravelling the specific issues surrounding weather cycles remains to be seen. What is apparent is that it provides a different way of looking at these issues and exerts a stern discipline on any attempts to provide any simple deterministic explanations for cyclic behaviour in the weather.

There is one other aspect of non-linearity that is frequently overlooked – the fundamental role of the annual cycle. It is central to the question of whether the climate is a chaotic system. Clearly, the atmosphere is a turbulent fluid and the chaotic behaviour of weather systems means that, in spite of the massive power of modern computers, numerical weather forecasts lose much of their skill beyond a week. But, although the atmosphere is chaotic on a day-to-day basis, the same need not apply to longer-term averaged conditions. We know that within the broad bounds of the annual cycle the climate in any particular part of the world generally sticks within prescribed limits: the temperature hardly ever rises above −20 °C at the South Pole, or falls below 20 °C in Singapore. The oceans interact with the atmosphere in a way that enables us to use knowledge of their slowly vary characteristics to make useful predictions of seasonal weather.

In addition, as we will see, the much longer variations associated with the ice ages can be largely explained in terms of changes in the Earth's orbital parameters. These results imply that some features of the climate are largely predictable.

There are, however, many examples of when the climate has behaved in a chaotic manner. At the end of the last ice age frequent sudden large changes in the climate occurred in a few years.[9] For instance, around 12 900 years ago, after a sustained warming, temperatures in the North Atlantic region plunged back to ice age severity. Events such as this have been linked with features of the collapse of the huge northern hemisphere ice sheets that was going on at the time. This suggests that, while there have been occasions when the climate behaved in a chaotic way in the past, for the most part its relative stability during the last 10 000 years or so, together with the regularity of seasons, suggest that currently it is not strongly chaotic. Nevertheless, it is not beyond the bounds of possibility that current global warming could eventually shift conditions into a more chaotic mode.

There is a more immediate potentially chaotic consequence of nonlinear behaviour in the climate. This is linked to the dominant role of the annual cycle and how it can combine with other forms of periodic or quasiperiodic fluctuations in the climate system to produce a variety of complex responses. In the case of interannual fluctuations like El Niño events, where the annual cycle is not a simple fraction of the longer-term fluctuation, the annual cycle can have a chaotic influence on the natural frquency of the longer periodicity. This could have profound consequences on our ability to forecast El Niño events.

Against this complicated background, this book will examine the evidence for weather cycles with two underlying aims. The first is to show that, whether or not the case for cycles stands up, the search for them sheds new light on how the climate works. The second is that, without a better understanding of the natural variability of the climate, it will be much more difficult to reach early conclusions on whether anthropogenic activities are having a significant impact. Tackling the threat of the build-up of greenhouse gases in the atmosphere as a result of the combustion of fossil fuels involves substantial adjustments in the nature of modern society. Although there has been considerable progress towards international action on this front, as the easy options are used up there will be a natural inclination to baulk at making more expensive and unpopular changes until the evidence of global warming is beyond doubt. But by then it may well be too late. So

[9] Taylor *et al.* (1993).

it is essential that we know more about how the climate can vary on its own accord to guide us in making these decisions.

With these thoughts in mind, we will explore in detail all the different aspects of the search for cycles and their physical explanation. But before we dive into the fascinating array of claimed cycles and proposed physical causes, the vexed issue of statistical analysis must be confronted.