1 THE SPIRIT OF ENQUIRY

The inquiry of truth … is the sovereign good of human nature.

Francis Bacon

Just before Christmas 2009, an old friend and I were discussing climate change. Because I am a scientist, he asked my opinion about an internet site claiming that global warming is a fallacy and that carbon dioxide is good for the planet. As a geologist I knew about climate changes of the distant past, such as the warm world when dinosaurs roamed and the more recent ice ages, but I could not answer some of the questions he asked, and that prompted me to look into climate science more deeply. My reply to him is this book.

Looking at the newspaper articles and websites on the topic, I found a remarkably wide range of views, running the gamut from 'global warming is real, burning coal and oil caused it, we are doomed' to 'we need to address the reality that increasing amounts of greenhouse gases are causing climate change' and on to 'increased levels of carbon dioxide will grow bigger crops and stop the next ice age'.

The predictions and politicking surrounding the subject confused me, and I needed to find out what is actually known about the subject. Why was it that climate scientists were so concerned about the future? How were they able to predict the course of climate change so persuasively that many of the world's governments were prompted to at least think about the problem, to establish an intergovernmental panel on the subject, to gather at Copenhagen in 2009 to discuss climate change and for many governments to pass legislation designed to limit carbon dioxide emissions?

In the years leading up to that initial discussion with my friend, climate change had become a political issue. Just as everyone had a right to their own political opinions, everyone seemed to discover a right to their own opinion on climate change. Very quickly, two opposing camps were established: in one camp were those who accepted climate change on the basis of the science, and in the other were those who denied the validity of the scientific evidence. But many people were in neither camp. They heard one side, they heard the other, and like my friend they were unsure about whom to trust.

Many of those who deny the science of climate change call themselves 'sceptics'. But all good scientists are sceptics. A scientist's first scepticism is usually aimed at his or her own evidence; unusual results and remarkable conclusions need to be challenged immediately, long before they are made public. Scepticism should involve argument – argument drawing on *all* the relevant evidence. When an argument uses only some parts of the evidence – parts that appear to support the case – the argument becomes adversarial, not sceptical. It is not a defence lawyer's job

to present evidence that will convict the defendant. Rather, the defence selects only evidence that it hopes will deny the prosecution. True sceptics work differently; they query and challenge *all* the evidence.

The website that got me started is run by Leon Ashby, president of a political party called the Climate Sceptics, and it quickly became clear to me that this party's approach is adversarial, not sceptical. As an example, one of its claims, which is repeated by several others, including Professor Ian Plimer, author of the book *Heaven and Earth. Global Warming: The Missing Science* (Connor Court, 2009, from here on referred to as '*heaven+earth*'), and Christopher Monckton (Third Viscount Monckton of Brenchly, often referred to as 'Lord Monckton'), to name two who have achieved prominence on the subject, is that global warming ceased in 1998.

In 1990, the United Nation's Intergovernmental Panel on Climate Change (IPCC) predicted that global temperature would rise about 0.4°C by 2010. The sceptics argue, however, that from 1998 to 2008 global temperature fell by 0.2°C; all the IPCC's predictions are rubbish and there is no global warming. The evidence the Climate Sceptics present for this conclusion is shown in Figure 1.1a.

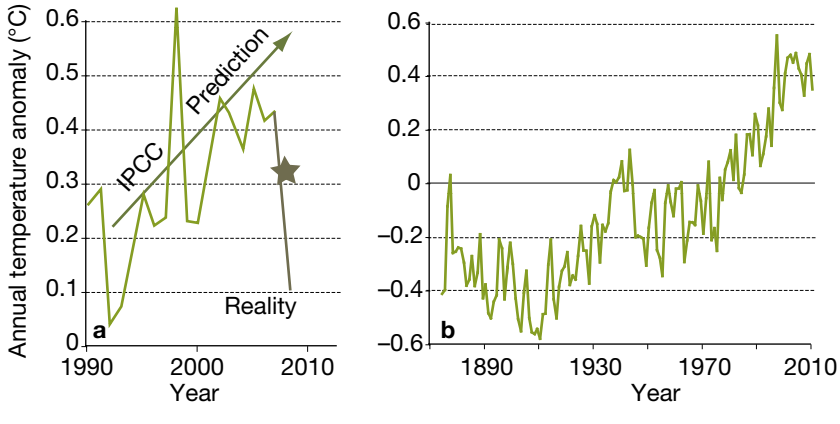

Figure 1.1 a) Global cooling since 1998 copied (in essence) from the Climate Sceptics presentation. I have added the star, the 'reality' for 2008. b) Annual global temperature anomaly from 1880 to 2010 drawn from data published by the Hadley Climatic Research Unit at the University of East Anglia and the Hadley Centre for Climate Prediction and Research, United Kingdom.

The IPCC projection was based on temperature measurements over more than a century, shown in Figure 1.1b. The Climate Sceptics' argument in effect 'cherry-picked' only the temperatures for the period around 1998, the hottest year on record. Compared to that peak, world

temperatures since then have, indeed, been lower. The Climate Sceptics base their argument on two non-scientific interpretations of the data: one ignores data that do not support its hypothesis, in this case all data from before 1990, and the other mistakes the natural variations from year to year as indicative of variations in climate. Ten years is too short to conclude *anything* about climate change, because it is the weather conditions over a long period – 30 to 50 years – that defines the climate.

One hundred and thirty years of observations does provide a reliable climate history. Though there are some irregularities, the graph in Figure 1.1b indicates that the global temperature is rising and it cannot be ignored. Climate science explains the temperature rise as being largely the result of burning coal and oil for the past 200 years, thereby putting the greenhouse gas carbon dioxide into the atmosphere. 'Not so,' say the sceptics. 'The Earth has experienced many changes in temperature over geological time without any contribution by people.' Well, that is true, and you will read in this book about the climate changes of the geological past and why they occurred. Other views are presented, also; *El Niño* events, variations in the Sun's output and cosmic or galactic factors have all been proposed as more reasonable explanations for global warming.

THE HOCKEY STICK

The most famous evidence for global warming followed from a 1998 paper published in the major scientific journal *Nature* by Michael Mann, then a post-doctoral fellow at the University of Massachusetts, with professors Raymond Bradley and Malcolm Hughes. These authors presented a graph of global temperatures over the past six centuries, and a later refinement presented in 2001 (Figure 1.2) has become known as the 'Hockey Stick'.[1] By combining thermometer measurements taken since 1850 with evidence from earlier times, Mann and his colleagues concluded that the past 100 years have been a century of remarkable warming. On the basis of documented determinations of temperature, they showed that the Earth's climate, although fluctuating, had been cooling overall since mediaeval times, 1000 years ago. For 900 years the global temperature fell slowly, though with small ups and downs, by about 0.3°C, but then there was a change. During the 20th century, the global temperature rose by 0.7°C. As is the way of science, the Hockey Stick graph had its critics, and the scientists responded by collecting more data and refining their conclusions. When further work is

shown to be needed, scientists do it, for if there are any problems with their work they want to fix it. Changing one's conclusions does not discredit science, rather it enhances and strengthens it. We will return to the Hockey Stick graph in Chapter 9; in the years since it was first published its shape, its conclusions and its significance for our future have all been confirmed many times over.

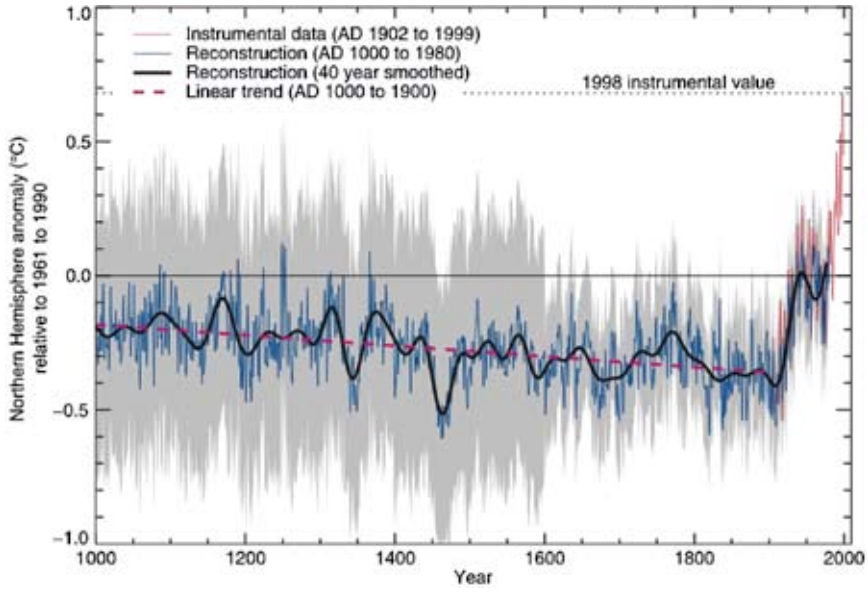

Figure 1.2 The Mann Hockey Stick temperature graph as presented in Figure 2.20 in the *Intergovernmental Panel on Climate Change Third Assessment Report* (2001). The grey shaded area represents the likely error of each data point, while the dashed red line shows the overall trend from the year 1000 to 1900.

In this book you will see just how detailed is the understanding of the world's climate, and you will learn the degree of reliability that can be attributed to the science. Figure 1.2 is such an example. The measured or estimated temperatures join to form the zigzag blue line, with thermometer measurements in red. The grey shading shows the scientists' judgement about the reliability of each measurement. Their best conclusion about the most likely value at any time is the wavy black line. And the dashed red line shows the trend up to 1900. There are ups and downs in the global temperature graph; each is a response to known factors explained in Chapter 3.

From my own point of view as a scientist, perhaps the most disappointing thing about those who criticise the climatologists, rather than

their results or conclusions, is the repeated assertions that the scientists 'fudge' their data to satisfy those who fund their research. Here is Monckton's view, expressed shortly after newspaper reports of allegedly improper email correspondence between scientists at the Hadley Climatic Research Unit at the University of East Anglia, an issue which became known as 'climategate'.

> Many of these organizations are deeply implicated in the Climategate scandal. The emails between them have demonstrated a systematic, self-serving, ruthless readiness to invent, fabricate, distort, alter, suppress, hide, conceal or even destroy scientific data for the sake of reaching the answer they want.[2]

Following the allegation, three independent reviews were promptly conducted of the Research Centre's activities, and all three concluded that there was no evidence of malpractice, Director Phil Jones had no case to answer and those who criticised the scientists had been selective and uncharitable. Lord Monckton is influential in the public domain because newspapers print his views, but his comments in relation to 'climategate' are unsubstantiated.

Scientists are human, they have failings, and there have been examples of scientific fraud, some well documented. However, by far the majority of climate science is done by groups, all of whom must be confident of the reliability of the work of their colleagues. It is difficult to imagine that all have conspired to deceive both their reviewers of their papers and the scientific scrutiny that follows publication.

I am a geologist with a particular interest in near-surface weathered rocks, and I have not published findings on climate science. However, I have a comprehensive understanding of the scientific process, how scientific results are presented and the scrutiny they undergo before they are published. Usually, a scientific paper is presented in four parts:

1) A statement of the purpose of the study and how it fits into the body of knowledge of that scientific field

2) How the study was conducted: there must be enough detail for the study to be replicated by others if they so choose

3) What the study discovered, including all the results that have a bearing on the purpose, not just those that fit its hypothesis

4) What the authors think the results mean.

Every such manuscript submitted to a scientific journal undergoes peer review. Typically, there are at least two reviews by experts in the field

who are selected by the journal editor and who are known not to be colleagues of the authors. Quite commonly a manuscript is subjected to more than two reviews, as well as the one by the editors of the journal. Reviewers tend to be particularly scrupulous about requiring appropriate and adequate descriptions of experiments, reference to relevant work by others and that conclusions are based on data presented within the manuscript.

Scientists tend not to report their results without a string of 'ifs' and 'buts', and this could make it appear that the research is doubtful or that the conclusions are suspect. However, it is not in the nature of science to be dogmatic and assertive, but rather to present the evidence, to weigh and consider it, point out its limitations and report conclusions on the basis of what has been learned.

It is important to remember that scientists are people who possess the range of human emotions like all of us. They do not like being wrong, they do like being right, and they tend always to be ready to correct others. 'Told you so' is just as popular among scientists as within families! When a scientific paper is published with a contentious idea a flood of counter claims and contrary opinions will be quickly offered, challenging the methods, the results and the ideas. No new concept survives without intense scrutiny, both before and after it has been published. And when an idea is criticised, there is never any suggestion of scientists closing ranks to protect their colleagues, for the attacks mostly come from fellow scientists. When, in 1989, an experiment purporting to show nuclear fusion had been achieved at room temperature, it was scientists who pointed out the flaws in the work. When in 2011 neutrinos travelling faster than light were reported, again it was scientists who questioned the results, and in this case it was the researchers themselves who found the mistake.

It is said that you can never prove a hypothesis right, but you can always prove it wrong. But that is only true to an extent. Some hypotheses are of the type that involves a choice between only two possibilities. If one is shown *not* to be true, the other must be so. Such an hypothesis stirred the geological community from 1915 to at least the 1970s. In 1915, Alfred Wegener published a book on the subject of drifting continents. He had noticed the jigsaw puzzle fit between the shapes of South America and Africa, and between North America and Europe, and had seen how the rocks and the fossils matched each other across the Atlantic Ocean. He concluded the two huge landmasses had once been united (see Figure 1.3) and had since drifted apart.

Figure 1.3 Pangaea, the super continent that broke up 200 million years ago, allowing the continents as we know them to drift apart.

Wegener was variously ridiculed or accepted, but mostly derided. The geological world polarised into two camps: those who thought the hypothesis of continental drift was probably right, and those who, unable to conceive a mechanism for this, refused to consider it. 'Drifters' tended to live in the southern continents, where much of the evidence in the rocks was to be found. 'Fixers' were mostly in the United States and Europe, though by 1960 Cambridge and Edinburgh universities certainly had drifters among their geologists. I was studying at the University of Wisconsin in Madison, United States in 1963 when a new geologist was appointed to the staff, a young man from Edinburgh in the United Kingdom. In his inaugural seminar he talked about continental drift and the recent evidence in favour of it. As I left the lecture theatre I walked behind two of the department's senior professors. Their voices were troubled and they were shaking their heads. 'What have we appointed!'

I overheard one say. So strong was the conviction of the fixers that new evidence at first profoundly disturbed them. But as the years passed and the evidence mounted, so their understanding changed.

Continental drift, now called 'plate tectonics', was an 'either/or' theory; either the continents drift or they do not. If instead of 'the continents are drifting' your theory is that 'they are fixed', a single experiment with a global positioning system (GPS) instrument can disprove the 'fixed' and logically prove the 'moving' theory. The continents drift at about 5 to 10 centimetres a year, the same speed as our fingernails grow. The theory of continental drift *has* been proven.

How does the theory of global warming stand in this regard? The opposite theory would be 'the average annual global temperature is not increasing'. Is there evidence that might disprove this theory? You could ask 'how much change and over how long a period would be enough to prove an increase?' For continental drift, the change is about half a kilometre in 100 years. Would 0.5°C in 100 years be enough to disprove the 'no warming' hypothesis?

This book is written for those who hear the arguments for and against climate change and are not sure about them. It is written for sceptics, a term derived from the Greek word for 'enquiry'. This book is written for enquirers. If you want to know what the science is about, if you want to understand climate and climate change, here you will find the issues presented as fairly as I can. I will not be selecting the reports that support (or deny) any particular view of the subject, but I will be selecting reports that have the authenticity that comes from peer review and then public exposure. By 'authenticity' I do not mean that I think the conclusions of the work are 'right'; only that I think the work is good science. The data, the observations and the measurements all have to be good. Good data can last for generations; their interpretation can be anything from brilliant to wrong. I wonder how the theory of climate change caused by the burning of fossil fuels will be viewed in 100 years from now. Interpretations evolve, change and sometimes settle into accepted fact: the Sun *is* at the centre of the solar system, the continents *have* drifted and smoking *does* damage the lungs.

FURTHER READING

For this and all subsequent chapters, the Fourth Assessment Reports of the Intergovernmental Panel on Climate Change (IPCC, 2007) provides detailed summaries and analyses of the science of climate change.

Start with *Climate Change 2007: Synthesis Report*, then for further detail see:

Cleugh H, Stafford Smith M, Battaglia M & Graham P (eds) (2011) *Climate Change: Science and Solutions for Australia*. CSIRO Publishing, free download available at www.csiro.au/Climate-Change-Book

Climate Change 2007 – The Physical Science Basis Contribution of Working Group I to the Fourth Assessment Report of the IPCC (ISBN 978 0521 88009–1 hardback; 978 0521 70596–7 paperback)

Climate Change 2007 – Impacts, Adaptation and Vulnerability Contribution of Working Group II to the Fourth Assessment Report of the IPCC (978 0521 88010–7 hardback; 978 0521 70597–4 paperback)

Climate Change 2007 – Mitigation of Climate Change Contribution of Working Group III to the Fourth Assessment Report of the IPCC (978 0521 88011–4 hardback; 978 0521 70598–1 paperback)

Pittock, AB (2009) *Climate Change: The Science, Impacts and Solutions*. CSIRO Publishing.