

## THE HOCKEY STICK ILLUSION

Here is the definitive exposé of the distorted science behind the iconic global warming graph central responsible for the worldwide panic about climate change.

Part scientific history and part detective story, *The Hockey Stick Illusion* by A.W. Montford uncovers the misrepresentations of data behind Michael Mann's temperature reconstruction, and the tireless scrutiny by Steve McIntyre, Professor Ross McKittrick and others, which has comprehensively discredited it.

**Andrew Montford** studied Chemistry at St Andrews University. He is the respected custodian of the influential blogging site <http://bishophill.squarespace.com>, engaged with scientific research globally. He lives in rural Scotland with his wife and three children.

# THE HOCKEY STICK ILLUSION

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CLIMATEGATE AND THE  
CORRUPTION OF SCIENCE

A.W. Montford



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INTERNATIONAL

The Hockey Stick Illusion

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# DRAMATIS PERSONAE

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## *The Climate Auditors*

- STEVE MCINTYRE Canadian mining consultant who investigated the science behind the Hockey Stick.
- ROSS MCKITRICK McIntyre's co-author. Professor of economics at the University of Guelph.
- PETE HOLZMANN Climate Audit reader who performed the re-sampling of bristlecone trees at Almagre.
- DAVID HOLLAND McIntyre supporter who tried to obtain undisclosed IPCC reviews under British freedom of information legislation.
- CRAIG LOEHLE Ecologist who published a study based on non-tree ring proxies which showed a Medieval Warm Period.

## *The Hockey Team*

- MICHAEL MANN The lead author of the Hockey Stick papers. Initially an adjunct professor of climatology at the University of Massachusetts, later at the University of Virginia. Now at Penn State.
- RAY BRADLEY Co-author of the Hockey Stick papers. Professor of climatology at the University of Massachusetts.
- MALCOLM HUGHES Co-author of the Hockey Stick papers from the University of Arizona.
- KEITH BRIFFA British tree ring researcher. Author of several studies underpinning paleoclimate reconstructions and lead author on the paleoclimate chapter of the IPCC Fourth Assessment Report.
- CASPAR AMMANN Mann supporter whose papers were alleged to have rebutted McIntyre and McKittrick's work.
- ROSANNE D'ARRIGO Paleoclimatologist. Noted for her controversial statement on cherry picking of data.
- GABRIELE HEGERL Paleoclimatologist. Author of an important temperature reconstruction.
- TOM CROWLEY Paleoclimatologist who accused McIntyre of threatening behaviour. Author of an important temperature reconstruction.
- PHIL JONES Climatologist. Maintains the HADCRUT temperature index, author of an important paleoclimate reconstruction.
- SCOTT RUTHERFORD Mann's assistant who delivered the Hockey Stick data to McIntyre. Later author of one of the 'independent confirmations' of Mann's work.

## *Other scientists*

- HANS VON STORCH German climatologist who wrote papers critical of both Mann and McIntyre.
- EDUARDO ZORITA Spanish climatologist who was one of the reviewers of McIntyre and McKittrick's submission to *Nature*.
- GERRY NORTH Professor of climatology from Texas A&M University. Chairman of the NAS panel on

paleoclimatology.

- EDWARD WEGMAN Statistician from Rice University. Author of a review of the statistics of the Hockey Stick that confirmed that the study was flawed.
- PETER HUYBERS Oceanographer who wrote a critical comment on McIntyre and McKittrick's GRL paper.
- IAN JOLLIFFE Emeritus professor of statistics from the University of Aberdeen who was a reviewer of one of McIntyre and McKittrick's critiques of the Hockey Stick. Later revealed that he had missed the flaws in Mann's work.
- LINAH ABABNEH PhD student who updated the critical Sheep Mountain chronology.

### *The bureaucracy*

- RALPH CICCERONE Head of the US National Academy of Sciences who drew up the terms of reference for the NAS panel.
- SUSAN SOLOMON Head of the IPCC's Working Group I who threatened to remove McIntyre as a reviewer if he asked for data from study authors.
- JOHN MITCHELL IPCC review editor who is alleged to have performed his review in his spare time.

### *Journals and journalists*

- MARCEL CROK Dutch journalist who discovered that Mann had calculated the verification  $R^2$ .
- JAMES SAIERS Editor at *Geophysical Research Letters*.
- JAY FAMIGLIETTI Executive editor of *Geophysical Research Letters* who replaced Saiers as editor in charge of the McIntyre and McKittrick paper and its responses.
- SONIA BOEHMER-CHRISTIANSEN Editor of *Energy and Environment* and global warming sceptic.
- STEPHEN SCHNEIDER Editor of *Climatic Change* and global warming promoter.
- DAVID APPELL Freelance science journalist and Mann's outlet in the media.

### *Politicians*

- JOE BARTON Texas congressman and chairman of the House Committee on Energy and Commerce who opened an inquiry into the IPCC and the Hockey Stick.
- SHERRY BOEHLERT Chairman of the House Science Committee who commissioned the NAS report on paleoclimate.



# Preface

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In 2005 I followed a link from a British political blog to Steve McIntyre's Climate Audit site, then the newest addition to the blogosphere. While some of the statistics were over my head, there was plenty to interest a lay reader with an interest in sceptical arguments against the global warming hypothesis. While I was never a daily reader of the site, I found myself returning regularly, learning more and more each time, until I eventually found I could follow most of the postings without difficulty.

From time to time, new visitors to Climate Audit would plead for an introduction to the site and while there were some excellent primers, like Ross McKittrick's *What is the Hockey Stick Debate About?*, there was nothing that explained the story in the level of detail that I felt was required to enable the newbie to get fully up to speed on the intricacies of the science, and from time to time I wondered if my newly-found understanding of the debate would enable me to take on the task myself.

It wasn't until the story of Caspar Ammann's purported replication of the Hockey Stick came to light during 2008 that I finally decided to take the plunge. The antics involved in keeping Ammann's paper alive, despite the catastrophic failure of its verification statistics, was so extraordinary, it seemed almost to be a public duty to make the story more widely known. Over the course of the next two or three days, I summarised a series of Climate Audit postings into a long article on my blog, *Caspar and the Jesus Paper*, as I chose to call the story, briefly turned my sleepy and relatively obscure website – my daily visitor count was probably a couple of hundred a day at the time – into a hive of activity, with thirty thousand hits being received over the following three days alone. To move from ten hits per hour to ten per second was something of a shock.

Many commentators have described *Caspar and the Jesus Paper* as a history of the Hockey Stick, but in truth it covers only a small part of the tale, reproduced here in [Chapters 8](#) and [12](#). There was so much more to tell. I was spurred into telling the full story by the sight of the Hockey Stick in the manuscript of a new science textbook that crossed my desk one afternoon. Two years after it had been discredited the Hockey Stick was still being used as the basis of a programme of environmental propaganda for schools. What made it worse was that the author was using the stick in its 'unofficial' guise, the twentieth century instrumental record grafted onto the end, the separate datasets not revealed to the reader. By the autumn of 2008 I was immersed in telling the tale from beginning to end.

With only one or two minor exceptions, there are no new revelations here. Every part of the debate between McIntyre and Mann has been fully documented on their competing blogs and elsewhere, and to some extent my task as a chronicler has been merely to sort their postings into coherent order and to distil the essence of the statistical arguments into something comprehensible by a lay reader. The reader can decide for themselves if I have been successful in doing this.

I am grateful to several people who provided help and assistance along the way. Steve McIntyre, Ross McKittrick and Roger Pielke Jnr read the manuscript and provided perceptive reviews. Steve and Ross also provided some source materials that I was unable to locate elsewhere. David Holland sent me some unpublished details of his search for the IPCC review comments and Eduardo Zorita allowed me to identify him as the second reviewer of the *Nature* submission. Dr Angela Montford harrassed me over my grammar and spelling and asked many searching questions. Dr Lesley Montford also read the text and made sure I stopped work from time to time.

## Preface to the revised edition

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When I set out to write the *Hockey Stick Illusion* in 2008, I thought I was writing a book that would probably be read by only a handful of people – a few newcomers to *Climate Audit* and some of the more obsessive climate science geeks I would joke with my wife about how we would sell a dozen copies at most. Two significant factors changed all that. First was the risk taken by Tom Stacey in agreeing to take the book on for the ‘Independent Minds’ series, cutting out the ability of the upholders of the global warming hypothesis to ignore the book entirely – to Tom I am eternally grateful. Second, of course, was the advent of Climategate, just weeks before the book’s publication. Strokes of luck like that do not come along very often and 2010 was, in many ways, an *annus mirabilis* for me, plucked from obscurity to become something of a spokesman for those who question aspects of global warming science.

Special mention must be also made of Matt Ridley, who championed the book in the media, and Christopher Booker, who kept finding a reason to mention it in his *Sunday Telegraph* column. The efforts apart, the mainstream media have maintained a determined silence about the book, but in the end this may have mattered little because of impact of the blogs and word of mouth. There have been many champions of the *Hockey Stick Illusion* – readers who lent it to family members and others who bought bundles of copies to distribute to friends and colleagues. To all these supporters I send my heartfelt thanks.

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2011

# Notes on Usages

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There is considerable discussion in the text of the rather frightening sounding ‘Pearson’s square correlation coefficient’ (its meaning and importance, which are relatively straightforward, are explained in [Chapter 2](#)). In different fields of study this measure is signified by either  $R^2$  or  $r^2$ , the former being more common in the social sciences, the latter in the physical sciences. Throughout the text I have preferred the usage  $R^2$ , since this is the style adopted by Steve McIntyre.

There is also much discussion in the text of a statistical technique called principal component analysis. The technique is described, hopefully in a non-threatening manner, in [Chapter 2](#), but it is worth explaining here the particular terminology I have chosen to use. The technique of PC analysis, as I will refer to it, comes in one widely used ‘vanilla flavour’ plus a number of rarely used ones. Much of the story revolves around the use of a novel variant which we will refer to as short-centred PC analysis, although as we will see that its classification as a form of PC analysis is not generally accepted. Elsewhere, short centring has often been referred to as ‘decentred’ PC analysis, but I use the former style as I think it gives a better idea of the what has happened to the underlying data.

Much of the debate over the Hockey Stick has taken place online, on the blogs of the participants. It is therefore inevitable that much of the argumentation does not involve the checking of spelling and grammar that was normal in the past in print-based disputes. Rather than excuse myself of every error by appending a ‘sic’, I have preferred to correct each one, except in one or two cases where a mistake impinged directly upon the story.

Quoting as I do, directly from blog postings, I have had to make many simplifications, both for the benefit of a non-technical readership and for reasons of space. All such changes are marked by brackets and/or ellipses.

Throughout the text, I will use ‘bristlecones’ to refer to both bristlecone pines and foxtails, two closely related species that are critical in the story of the Hockey Stick. The two species are found on adjacent mountain ranges in the USA and, in fact, are so closely related that they interbreed.

# 1 The Hockey Stick

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*And thus Bureaucracy, the giant power wielded by pygmies, came into the world. (Honoré de Balzac)*

The Hockey Stick was a long time in the making. The idea that manmade emissions of carbon dioxide might cause the Earth to heat up can be traced back to the French scientist, Joseph Fourier, who worked at the start of the nineteenth century.<sup>a</sup> Fourier is probably better known for his mathematical studies, but in a seminal paper of 1824, he also described how atmospheric gases might be capable of warming the atmosphere. In the 1850s John Tyndall, the Irish head of the Royal Institution, built on Fourier's work, performing a number of experiments that demonstrated the effect in action.

The term 'greenhouse effect' was not itself used until the end of the nineteenth century. The expression was coined by the Swedish physicist and Nobel Prize winner, Svante Arrhenius. Arrhenius was the first to attempt quantitative work on the warming produced by the atmosphere, and was the first to raise the question of whether manmade emissions of carbon dioxide could actually alter the temperature of the Earth. However, Arrhenius, far from being concerned about this possibility, thought that if man's activities caused a rise in temperature, the effects on humankind would be entirely beneficial. Warmer temperatures, he explained, would lead to higher crop yields and so fewer hungry mouths, an issue which was of great public concern at that time as the population of the planet continued to grow. Arrhenius also put forward a theory that carbon dioxide might be behind the cycle of ice ages and warmings that scientists had perceived in the geological record, and even went so far as to suggest that increasing the levels of carbon dioxide in the atmosphere could actually *prevent* the Earth from slipping into another ice age, again demonstrating a rather different set of concerns to those of many people today.

While Arrhenius's theory attracted the attention of his fellow scientists and a certain amount of controversy at the time, it soon disappeared from the mainstream of scientific life. The theory made a brief reappearance in the early twentieth century when a British engineer and amateur meteorologist called Guy Callendar wrote a number of papers expanding on Arrhenius's work, but the subject remained a scientific backwater until after the Second World War.

In the 1950s, the global warming hypothesis received a boost when accurate measurements of atmospheric carbon dioxide levels started to be recorded by the observatory on Mauna Loa in Hawaii. Until then it had been widely assumed that any carbon dioxide emitted into the atmosphere would simply be absorbed by the oceans, but the Mauna Loa results showed a clear and steady upward trend, and scientists started to dust off the work of Callendar and Arrhenius to work out what this might mean for the climate.

Work continued quietly but steadily in the background. Then in 1977 the pace started to quicken. The impulse was provided by the creation of a separate climate bureaucracy under the auspices of the World Meteorological Organisation (WMO). The WMO had organised the first World Climate Conference, which was held in Geneva two years later, and it is to that first meeting that the beginnings of the global warming movement can be traced.

The conference was instructed to review the state of knowledge of climatic change and variability due both to natural and anthropogenic causes, and also to assess what this meant for humankind. In the way that bureaucracies sometimes do, however, the scientists actually did something slightly but tellingly different to what they had been asked to do. Rather than simply assess the state of scientific knowledge and consider what might happen in the future, they set out the steps they thought policymakers should take in a 'Call to Nations' that was issued at the end of the conference. This statement called for full advantage to be taken of man's knowledge of climate, for steps to be taken to improve

that knowledge, and for potential manmade changes to climate to be foreseen *and prevented*. This was not merely a call for more research, but also a demand for a particular policy outcome: prevention rather than adaptation. One can almost detect the germ of an idea forming in the minds of the scientists and bureaucrats assembled in Geneva: here, potentially, was a source of funding and influence without end. Where might it lead?

A couple of years later there was, to coin a phrase, something of a shift in the climate. James Hansen, a physicist from NASA's Goddard Institute for Space Studies, and a man who has been central to the whole global warming movement, published a breathtaking paper in *Science* in which he claimed that global warming was going to start happening much sooner than had previously been expected and that temperature records would start to be broken by the 1990s.<sup>3</sup>

Another climate conference, this time held in Villach, Austria in 1985, upped the ante even further. This meeting has been described as the first time that a scientific 'consensus' emerged on the issue of manmade or 'anthropogenic' global warming and the conclusions of the conference were certainly more outspoken than its predecessor. Predictably, the delegates called for more scientific research, but again went rather further than would have been expected from a scientific conference. They also demanded that policymakers fund research into the economic, social and political impacts of climate change and consider what steps could be taken to mitigate any future changes. Climatology was moving quickly from being an obscure backwater of scientific research to being an area of study which could shape policy in almost every conceivable area and affect the lives of millions of people around the world. The man in the street might not know it yet, but there were to be some big changes coming.

The first breakthrough in bringing the global warming hypothesis to public notice came in 1988 when Hansen went to the US Congress to explain how the release of carbon dioxide into the atmosphere was likely to affect the climate in coming years. Fortuitously, or perhaps by design, the hearing was held in midsummer on a swelteringly hot day. The baking temperatures outside may well have affected the views of the assembled congressmen anyway, but Hansen was certainly not pulling his punches either. He told the Senate Committee on Energy and Natural Resources that the Earth was hotter in 1988 than at any time in the history of instrumental measurements, and that it was possible to point the finger of blame at the greenhouse effect.<sup>4</sup> His models, Hansen explained, predicted violent extremes of weather including, coincidentally, summer heatwaves.

This no-holds-barred warning seemed to have had the desired effect and it was reported around the world. With headlines secured around the world, 1988 turned into a pivotal year for the global warming hypothesis. A few months later, Margaret Thatcher gave a speech to the Royal Society in which she is quoted as having said that 'we may have unwittingly begun a massive experiment with the system of the planet itself'.<sup>5</sup> Thatcher's conversion to the green cause is credited to her ambassador at the United Nations, Sir Crispin Tickell, although Hansen may also have played a part. Thatcher is said to have read his congressional testimony and he is also believed to have made a presentation to her on his findings. The Royal Society speech was not the only time that she spoke of global warming either. In the heady atmosphere following the finalisation of the Montreal Protocol to ban CFCs and save the ozone layer, the environment was the political buzzword *du jour*, and Thatcher was able to add global warming to the list of green issues she outlined in an address to the UN the following year:

What we are now doing to the world, by degrading the land surfaces, by polluting the waters and by adding greenhouse gases to the air at an unprecedented rate – all this is new in the experience of the earth. It is mankind and his activities that are changing the environment of our planet in damaging and dangerous ways.<sup>6</sup>

The floodgates were open. Politicians were leaping onto the bandwagon and soon the political momentum of the issue would be all but unstoppable as global warming found its way onto front pages and into election speeches around the world. The final step was the formation of a permanent climate bureaucracy and in the same year, 1988, the WMO and the UN together set up the Intergovernmental Panel on Climate Change (IPCC), a scientific body that would report on the state of climate science, advising policy makers on what was known about global warming and what should be done about it. Everything the climatologists had demanded just three years before at Villach had been granted to them.

## Climate science

In its First Assessment Report (FAR), the IPCC was rather circumspect in its conclusions about what was happening to the Earth's climate and the reasons for any change that might be perceived.<sup>7</sup> Despite what Hansen had said in his congressional testimony about there being a high degree of confidence in the causal relationship between carbon dioxide and recent temperature rises, climatology was, and to a large extent remains, a science in its infancy. In the executive summary, the report's authors commented:

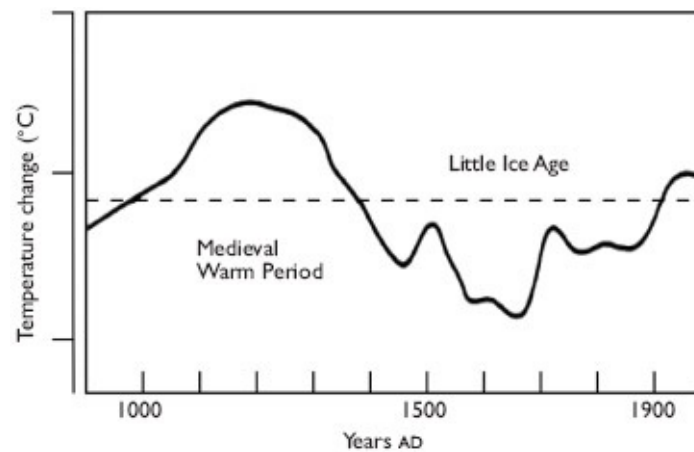
We conclude that despite great limitations in the quantity and quality of the available historical temperature data, the evidence points consistently to a real but irregular warming over the last century. A global warming of larger size has almost certainly occurred at least once since the end of the last glaciation without any appreciable increase in greenhouse gases. Because we do not understand the reasons for these past warming events, it is not yet possible to attribute a specific proportion of the recent, smaller warming to an increase of greenhouse gases.<sup>7</sup>

Their words, and particularly the closing sentence, show the problems that the global warming movement faced. If they were going to persuade policymakers to vote them still more funds and take drastic action in terms of changing the workings of the economy and the way people lived, it was going to be necessary to persuade the public as well, and the public were unlikely to be convinced by science that was sparse and limited in quality.

There was a bigger problem too. The report included a chart showing how global temperatures had varied in previous ages, according to the scientific understanding of the time. This was something of a dampener for the argument for catastrophic global warming because it suggested that past temperatures had been warmer than today in a long period lasting from the eleventh to the fifteenth centuries. This period had been followed by two or three hundred years of much cooler temperatures lasting until the eighteenth century. Since then warming had recommenced, but current temperatures were still thought to be well short of those reached during the medieval warming. This then was a huge problem for those promoting the idea of global warming – how would they convince anyone that a rise of a fraction of a degree in temperature portended something dangerous when the climate had been much warmer in the past?

At the time, the FAR graph was pretty much a representation of what might have been considered common knowledge. The so-called 'Medieval Warm Period' was extremely well represented in medieval annals and other documentary sources and it had come to have at least some impact on the public imagination. Every schoolboy knew that the Vikings had taken advantage of warm temperatures to colonise Iceland and Greenland at the end of the first millennium, and historians had also discovered that grapes had been grown commercially in England at the time. There was a wealth of evidence that the medieval period had been an age of warmth, plenty and a flourishing of culture. The 'Little Ice Age', meanwhile, was equally well known – the Viking evacuation of Greenland at the start of the fifteenth century, the freezing of the Golden Horn in the seventeenth, stories of ice-fairs on the Thames and the winter paintings of Breughel the Elder had all created a strong public perception

of years of biting cold winters. So at the start of the 1990s nobody was going to take issue with the story that the IPCC was telling – of Medieval Warm Period giving way to Little Ice Age before another gentle warming was ushered in.



**FIGURE 1.1:** The Medieval Warm Period as shown in the IPCC First Assessment Report in 1990

The exact origins of the chart presented by the IPCC were, at the time, obscure; rather strangely, the report did not contain a citation or other indication of its authorship. Although it appeared to be schematic or cartoon rather than a proper graph, it must have had some basis in scientific research, but quite what this basis was was not discovered until many years later when it was shown to be derived from the work of a British climatologist called Hubert Lamb.<sup>8</sup> Lamb, while an important scientist, was born in 1913 and the chart turns out to have been based on work he did in the 1960s. The relative antiquity of this climate history might explain the reluctance of the IPCC to explain its provenance. What was still more surprising was that Lamb's work turned out to be largely based on the Central England Temperature Record, a long series of instrumental readings, which dated back to the mid-seventeenth century. In other words, the understanding of world climate history propagated to the public by the IPCC was based, not on any understanding of global climate, but on the records for just one part of England: an odd situation to say the least.<sup>b</sup>

### **The Medieval Warm Period becomes less warm**

In 1994 a pair of tree-ring researchers called Malcolm Hughes and Henry Diaz co-authored a journal review which struck a major blow at Lamb's view of climate history.<sup>9</sup> The two men surveyed the evidence supporting the existence of the Medieval Warm Period, considering all the different types of data that had been used to reconstruct past temperatures since Lamb's time. Their conclusions were that temperatures *had* been higher in some parts of the world – they singled out Scandinavia, China, the Sierra Nevada in California, the Canadian Rockies and Tasmania. However, they emphasised that these warm periods seemed to have happened at slightly different times in different places. They suggested that the warmings had probably had different causes. They also claimed that there was no evidence for any abnormal medieval warming at all in the southeast United States, southern Europe along the Mediterranean, and parts of South America. If they were right, then it would only be possible to conclude that the Medieval Warm Period was, at most, a series of regional warmings.

On its own, these findings might look interesting but otherwise unremarkable. But put in the context of the temperature history of the last thousand years their impact on the climate debate was potentially explosive. Anecdotally at least, the Medieval Warm Period, represented by the bump upwards in temperatures at the left hand side of the IPCC 1990 graph, was being slowly flattened out. And as it flattened, the current warming started to look more and more significant – if current temperatures were in excess of anything seen in previous times, it would be powerful evidence that

manmade global warming had already had a serious and deleterious effect on the world's climate. The flatter the representation of the medieval period in the temperature reconstructions, the scarier were the conclusions.

This was one paper in a single volume of review articles. It would take more than that to overturn an well-embedded paradigm. However, behind the scenes climatologists were busy, and a short time after the Hughes and Diaz paper was released, the public got a brief glimpse of what was happening. It was not at all as it should have been.

## The Deming affair

David Deming was a geoscientist from the University of Oklahoma, whose expertise was in borehole temperatures. From these holes, drilled deep into the Earth's surface, it was possible to extract a profile of the temperatures within the rocks all the way down. This profile was a direct record of what the surface temperature had been in the past. The deeper you went, the older the temperature record you could get. Of course it wasn't as simple as that – there were all sorts of confounding factors affecting the reliability of the results but it was one of the approaches being tried as a way of discerning the history of the Earth's climate.

Deming had recently created a temperature reconstruction for the last 150 years, based on boreholes in North America. In his study, he concluded that North America had warmed somewhat in the period since 1850, but had little to say beyond that. This was good, solid science but not the stuff of newspaper headlines. His findings were, however, considered highly important in climate science circles. With the expectation that temperatures were being driven upwards by carbon dioxide emissions, the Deming study seemed like good evidence to support the hypothesis. Because of the interest, Deming was able to get his work published in one of the world's most important journals, *Science*.<sup>10</sup> And with a storyline of rising temperatures published in such a prestigious publication, he also attracted the notice of some of the most influential people in the global warming industry, who thought they saw in Deming a valuable new recruit to the cause. Deming explained what happened in a later article:

With the publication of the article in *Science*, I gained significant credibility in the community of scientists working on climate change. They thought I was one of them, someone who would pervert science in the service of social and political causes. So one of them let his guard down. A major person working in the area of climate change and global warming sent me an astonishing email that said 'We have to get rid of the Medieval Warm Period.'<sup>11</sup>

This sudden flash of light on a particularly murky shadow of climatological practice is probably unique. Suddenly it was possible to see that the Hughes and Diaz retake on the Medieval Warm Period was not considered enough. The aim was to erase it from the climatological record in its entirety. Although Deming himself did not identify the email's author, Richard Lindzen of MIT has confirmed internet rumours that the email was written by Jonathan Overpeck of the University of Arizona.<sup>12</sup> It was evident to anyone who was watching that, in some quarters at least, there was a concerted effort to rewrite the Earth's climate history so that the Medieval Warm Period disappeared. Unfortunately, few people were watching. Those who noticed what Deming was saying, and tried to raise the alarm, were ignored by the media.

Deming had another interesting story to tell too. A couple of years after the publication of his *Science* article he had been the reviewer for another borehole study, this time written by Shaopeng Huang of the University of Michigan. Huang's results had shown a pronounced worldwide Medieval Warm Period, something that was anathema to those in the global warming mainstream. In fact the study suggested that medieval temperatures might have been well in excess of those in modern times. Deming explained what happened next:



The Huang et al. (1997) study was originally submitted to *Nature*. I was one of the reviewers of the manuscript. I told the *Nature* editors that the article would surely be one of the most important papers they published that year. But it never appeared in print. *Nature* asked the authors to revise the paper twice and then, after a long delay, ended up rejecting it.<sup>11</sup>

This difficulty in getting into print any result that went against the idea of catastrophic global warming was to be a consistent complaint among sceptics, and readers may like to note *Nature*'s treatment of Huang and compare it to later events in this story.

A few months after Deming's revelations about the fate of Huang's paper, the second IPCC report picked up on the changing attitudes towards the Medieval Warm Period. The report's authors noted that:

Based on the incomplete observations and paleoclimatic evidence available, it seems unlikely that global mean temperatures have increased by 1°C or more in a century at any time during the last 10,000 years.

and went on,

The limited available evidence from proxy climate indicators suggests that the 20th century global mean temperature is at least as warm as any other century since at least 1400 AD. Data prior to 1400 are too sparse to allow the reliable estimation of global mean temperature.<sup>13</sup>

This represented a significant change in emphasis by the IPCC. The story in the FAR, of a pronounced Medieval Warm Period with temperatures exceeding modern ones, had been replaced by a new narrative, in which it was said that modern warmth was probably unprecedented – or at least as high as anything seen in the last six hundred years. And if anyone were to question how all the historical records of warm temperatures in the medieval period could be wrong, it was explained that these were a regional phenomenon and that overall, the globe appeared to have been no warmer back then than it was at present.

There was one major problem with the case for the Medieval Warm Period having been a significant regional phenomenon though. This was the paucity of hard data to support the case – the 'limited available evidence' referred to above. It was simple for critics to point out that any conclusions drawn from this data would have to be highly speculative at best. Climate science wanted big funding and big political action and that was going to require definitive evidence. In order to strengthen the arguments for the current warming being unprecedented, there was going to have to be a major study, presenting unimpeachable evidence that the Medieval Warm Period was a chimera.

Enter the Hockey Stick.

## The paper

The Hockey Stick paper made its grand entrance in an article published in *Nature* on 23 April 1998. Its main author was a hitherto relatively obscure scientist based at the University of Massachusetts (UMass) called Michael E. Mann, and it went by the distinctly unmemorable title, 'Global scale temperature patterns and climate forcing over the past six centuries'. Despite this unpromising opening and a style of writing that has been politely described as 'rather obscure',<sup>15</sup> it was to become one of the most cited scientific papers of that year or indeed of any other year. In fact, when the controversy was at its height, one investigator discovered that it had been cited twice as often as was normal for a scientific paper, and years after its publication it was still being referenced at a startling rate in the scientific literature.

Mann was just starting out on his scientific career, receiving his PhD in 1998 at the age of 33. At the time of the paper's publication he was still only an adjunct member of faculty at UMass. Mann

may have been a late developer, but he was ambitious and self-confident and the reception for his paper suggested he was destined for great things.

Apart from Mann, the Hockey Stick paper had two secondary authors: the first was Ray Bradley, colleague of Mann's from the University of Massachusetts, while the other was Malcolm Hughes of the University of Arizona, whom we have already met as one of the authors of the first serious attempt to 'get rid of the Medieval Warm Period'. In the years since its publication the paper has become known by the initials of its authors' names and we will be referring to it as MBH98 from here on.

MBH98 was novel on a number of levels. Firstly, it had been based on a much greater volume of raw data than earlier studies. Mann, Bradley and Hughes had trawled the archives for anything from which they might extract a temperature signal and had come up with a network of 112 'indicators', as they termed them. These are more normally referred to as 'proxies' (see [Chapter 2](#)). Although the majority of the indicators didn't extend back to the critical medieval period, the MBH98 dataset represented a significant advance and struck a blow at those critics who had rejected earlier studies as lacking sufficient data to be reliable. In fact, some of the indicators were actually summaries of large networks of proxies, so there was even more data backing up their reconstruction than was suggested by the reported number of 112 series. This summarising had been done using a statistical procedure called principal components analysis (PC analysis) and this first application of the technique to temperature reconstructions gave the study an air of great technical sophistication, which would again render it much harder to criticise. With a large dataset and state of the art methodology in place, the authors wanted their readers to be in no doubt as to how good their results were, speaking of it as a 'highly significant reconstructive skill'. This suggested a study that was going to be hard to refute.

What then of the findings? The abstract of the paper explained that Mann and his team had been able to reconstruct temperatures since the year 1400 and that recent temperatures were warmer than any other year since the start of their records. In the remainder of the paper, they went on to assess possible reasons for the dramatic change in temperatures by testing how the graph of the reconstruction correlated against possible causes ('forcings' in the jargon), such as atmospheric dust, solar irradiance and carbon dioxide. It will be no surprise to anyone that their conclusion was that the only potential culprit was carbon dioxide. The implications were once again clear: mankind was warming the globe. Here then was the beginning of the end of the process of getting rid of the Medieval Warm Period. All that was lacking was a degree of publicity, something that was to be dealt with in fairly short order, as we will see.

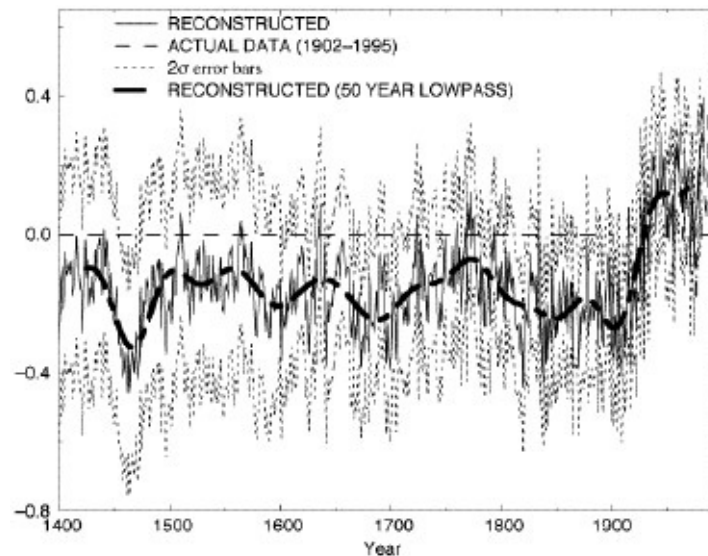
The key graphic in the paper was a chart of the reconstruction of Northern Hemisphere temperatures for the full length of the record from 1400 right through to 1980. The picture presented was crystal clear. From the very beginning of the series the temperature line meandered gently, first a little warmer, then a little cooler, never varying more than half a degree or so from peak to trough. This was the 500-year long handle of the Hockey Stick, a sort of steady state that had apparently reigned, unchanging, throughout most of recorded history. Then suddenly, the blade of the stick appeared at the start of the twentieth century, shooting upwards in an almost straight line.<sup>c</sup> It was a startling change and it was this that made the Hockey Stick such an effective promotional tool. Although to watching scientists, the remarkable thing about the Hockey Stick was not what was happening in the twentieth century portion – that temperatures were rising was clear from the instrumental record – but the long flat handle. The Medieval Warm Period had completely vanished. Even the previously acknowledged 'regional effect' now left no trace in the record. The conclusions were stark: current temperatures were unprecedented.

## The splice

As presented in *Nature*, the Hockey Stick chart was a dreadful example of scientific graphics, with the

authors managing to cram no less than four lines onto the same chart, making it hard for even the most attentive reader to see exactly what it was they were looking at (see [Figure 1.2](#)). One should charitably point to the space restrictions necessary for publication in *Nature*, and the difficulties of presenting information in black and white diagrams.

Presented on top of each other were four sets of numbers: the reconstructed temperature, a smoothed version of these figures, the error bars, and at the right hand side (and easy to miss for the inattentive), the thermometer record for the twentieth century. The inclusion of the instrumental record was instantly controversial, with global warming sceptics accusing Mann of having spliced two entirely different datasets. The effect of this scientifically dubious presentation was, they said, to make the twentieth century portion look more frightening than the underlying data would warrant. Mann's counter-argument to these accusations was that the data was not spliced, but overlaid, and that its inclusion was justified in order to extend the reconstruction from 1980, which was when most of the underlying data ended, right up to the present day.



**FIGURE 1.2:** The Hockey Stick in MBH98

While it is difficult to see exactly what had been done from the black and white graph in *Nature*, later versions of the Hockey Stick were much clearer about the splice/overlay, using colour to distinguish the different datasets, although some well-known users of Mann's work did forget to make the distinction, as we will see later in the story. The IPCC's version of the Hockey Stick is shown on the back cover, with the instrumental overlay shown in red at the right hand side. Clearly, a large proportion of the blade of the stick was not from the same dataset as the handle, although there was undoubtedly a rise in the reconstructed temperatures too. Opinions on the issue remained divided; the first Hockey Stick controversy was off and running.

## Reactions

The paper was clearly expected to be of huge public interest, and a press release was issued by UMass timed to coincide with its publication:

Climatologists at the University of Massachusetts have reconstructed the global temperature over the past 600 years, determining that three recent years, 1997, 1995, and 1990, were the warmest years since at least AD 1400.

The researchers were able to estimate temperatures over more than half the surface of the globe, pinpointing average yearly temperatures in the northern hemisphere to within a fraction of a degree, going back to AD 1400. The study places in a new context long-standing controversy over the relative roles of human and natural changes in the climate of past centuries, according to Mann.

Advanced statistical techniques were used to translate the proxy information into surface temperature patterns, so

With the press release so unequivocal, it is hardly surprising that the media found the story irresistible. Just five days after its publication in *Nature*, Mann was given the honour of an article in the *New York Times*, announcing the results of his study to the world.<sup>17</sup> This was a truly remarkable achievement for Mann, who, as we have seen, had only just finished his PhD, although it should be noted in fairness that he had been active in paleoclimate for some years previously. The story was penned by the *New York Times*' science reporter, William K. Stevens and its headline echoed the press release's certainty about the findings:

*NEW EVIDENCE FINDS THIS IS WARMEST CENTURY IN 600 YEARS*

Interestingly, beneath the headline, much of the article was actually taken up with discussing doubt about the reliability of the study. One scientist quoted in the *New York Times* article wondered if it would ever be possible to get a temperature reconstruction that was reliable enough to tell if the current warming was unprecedented or not. Even Mann himself was quoted as saying that there was quite a bit of work to be done in reducing the uncertainties. However, the headline and another scientist quoted in the study left no doubt that this was expected to be a very significant piece of work.

*USA Today* was much less equivocal though:

*90S WERE WARMEST YEARS IN CENTURIES*

The 20th century has been warmer than the five centuries that preceded it, and 1997, 1995 and 1990 were the warmest years since 1400, says the latest study to relate global climate change to the burning of fossil fuels.<sup>18</sup>

Elsewhere it was the same: NBC website told its readers, 'Millennium ending with record heat', while *Time* magazine went for the jauntier headline, 'It hasn't been this sizzling in centuries'.<sup>20</sup>

## **MBH99**

Buoyed by the success of their first paper, Mann, Bradley and Hughes set about extending the study back to the start of the millennium, publishing their new results in *Geophysical Research Letters*. 'Northern Hemisphere temperatures during the last millennium: inferences, uncertainties and limitations' (which we will refer to as MBH99) was, as the title suggests, a much more cagily worded article. There was so little data available for the first four centuries of the reconstruction that any conclusions could only be extremely tentative. That said, the conclusions were broadly similar – the twentieth century appeared to be anomalous compared to any other period in the last 1,000 years. The global warming bandwagon was on a roll.

There was no let up on the public relations front either. Once again, UMass made sure that the paper received maximum publicity, with a press release that concentrated on the scary bits. Under the headline '1998 was warmest year of millennium, UMass Amherst climate researchers report', the release quoted Bradley as saying, 'Temperatures in the latter half of the 20th century were unprecedented'. Those who read further might have noticed Mann discussing the uncertainties and the sparseness of the data, but this was clearly not the key message, and most media outlets chose not to dwell on the uncertainties when they reported the results to their readers. The newspaper headlines were all written in terms which left no room for any doubt.

## **IPCC: The Third Assessment Report**

The two Hockey Stick papers were good for Mann. Within months of the first paper's publication, he found himself advancing rapidly through the academic ranks with a speed that was simply breathtaking. In 2000, John Daly, a prominent global warming sceptic explained just how dramatic Mann's rise to fame had been, and how influential he had now become in the climatological community.<sup>23</sup>

At the time he published his 'Hockey Stick' paper, Michael Mann held an adjunct faculty position at the University of Massachusetts, in the Department of Geosciences. He received his PhD in 1998, and a year later was promoted to Assistant Professor at the University of Virginia, in the Department of Environmental Sciences, at the age of 34.

He is now the Lead Author of the 'Observed Climate Variability and Change' chapter of the IPCC Third Assessment Report (TAR2000), and a contributing author on several other chapters of that report. The Technical Summary of the report, echoing Mann's paper, said: 'The 1990s are likely to have been the warmest decade of the millennium, and 1998 is likely to have been the warmest year.'

Mann is also now on the editorial board of the *Journal of Climate* and was a guest editor for a special issue of *Climatic Change*. He is also a referee for the journals *Nature*, *Science*, *Climatic Change*, *Geophysical Research Letters*, *Journal of Climate*, *JGR-Oceans*, *JGR-Atmospheres*, *Paleoceanography*, *Eos*, *International Journal of Climatology*, and NSF, NOAA, and DOE grant programs. (In the 'peer review' system of science, the role of anonymous referee confers the power to reject papers that are deemed, in the opinion of the referee, not to meet scientific standards).

He was appointed as a 'Scientific Adviser' to the U.S. Government (White House OSTP) on climate change issues.

Mann lists his 'popular media exposure' as including – 'CBS, NBC, ABC, CNN, CNN headline news, BBC, NPR, PBS (NOVA/Frontline), WCBS, *Time*, *Newsweek*, *Life*, *US News & World Report*, *Economist*, *Scientific American*, *Science News*, *Science*, *Rolling Stone*, *Popular Science*, *USA Today*, *New York Times*, *New York Times (Science Times)*, *Washington Post*, *Boston Globe*, *London Times*, *Irish Times*, AP, UPI, Reuters, and numerous other television/print media.'<sup>23</sup>

As time went on, prizes and titles flowed his way too, with papers he had written lauded on all sides. In 2002 *Scientific American* selected him as one of the '50 leading visionaries in science'; all the work that went in to preparing the Hockey Stick certainly seemed to have been worthwhile.

As Daly had noted, one of Mann's most most significant accolades after the triumph of the Hockey Stick was his appointment as the lead author of the paleoclimate chapter in the IPCC's Third Assessment Report of 2001. Again, we can only stand back in admiration that someone who had published his PhD a matter of a year or so earlier could be invited to head the team writing one of the most critical chapters in one of the most important scientific reports written for decades. Mann had certainly made an impact in the climate world.

Mann's position as lead author did present an apparent problem, however, since in that position he had a clear conflict of interest in assessing the published literature – he was going to be considering his own work. It is unfortunate then that the Hockey Stick was given extraordinary prominence in the Third Assessment Report, particularly in Mann's own chapter on paleoclimate. In fact the whole IPCC report started to look like a locker room, it was so full of hockey sticks. As one observer noted:

[The Hockey Stick] appears as Figure 1b in the Working Group 1 Summary for Policymakers, Figure 5 in the Technical Summary, twice in [Chapter 2](#) (Figures 2-20 and 2-21) of the main report, and Figures 2-3 and 9-1B in the Synthesis Report. Referring to this figure, the IPCC Summary for Policymakers (p. 3) claimed it is likely 'that the 1990s has been the warmest decade and 1998 the warmest year of the millennium' for the Northern Hemisphere.<sup>1</sup>

The IPCC report also 'bigged up' the paper's claims to statistical sophistication, stating that the reconstruction had 'significant skill in independent cross-validation tests'. Whenever the Hockey Stick appeared, it was larger, bolder and more colourful than any other temperature series presented. Mann must have been thrilled with the report. The final icing on the cake was when the IPCC chairman Sir John Houghton, announcing the publication of the report, sat in front of an enormous blow-up

the Hockey Stick itself. This was Mann's moment of triumph: 1998 was officially the warmest year of the millennium, a stunning recognition of his work.

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In the years that followed more and more interest was focused on the Hockey Stick. In particular, it was one of the key arguments used to support the need for the Kyoto treaty. Citations of Mann's work flooded in and its influence and importance grew without restraint, until it came to symbolise the very idea of manmade global warming. As one BBC reporter put it, 'it is hard to overestimate how influential this study has been'.<sup>24</sup> Every home in Canada was sent a leaflet quoting the paper's conclusions and warning of the dangers of climate change. School books told children that the Hockey Stick meant that the world had to change. Politicians told voters that only they could save people from the threat it demonstrated. Insurers, newspapers and magazines, pamphlets and websites were all in thrall to its message; the Hockey Stick swept all before it.

- a The early history of the science of global warming was ably documented by Spencer Weart, on whose work much of this section of the story is based.<sup>2</sup>
- b We should note in passing that the caption to the original FAR graph was unequivocal that it was a representation of *global* temperatures.
- c Readers outside North America may wonder why a straight upward line on the end of a long flat handle should make the graph look anything like a hockey stick: it is, of course, and with delicious irony, an *ice* hockey stick.

*Torture numbers, and they'll confess to anything.*

Gregg Easterbrook

We saw in the last chapter how Mann and his team created the Hockey Stick and the impact it had on the world. Before we go on to tell the story of how his work was undone, we need to learn some paleoclimatology and a little statistics (really, just a little!), so that you can follow what the arguments were about.

### **Paleoclimatology**

So how do you actually go about measuring the temperature of the past? For recent centuries, it's relatively straightforward. Thermometer records go back at least a hundred and fifty years, and in some places, even further than that. In principle, all you need to do is to take all your thermometer readings and work out an average. Of course, many parts of the world are not covered by a thermometer record, and many of the records may be unreliable, and ways have to be found to deal with these issues. Another problem is that as you go back into the nineteenth century, the thermometer coverage of the globe becomes thinner and thinner. However, compared to the situation in earlier centuries, the twentieth century and the second half of the nineteenth can be said to be fairly well understood.

Before about 1850 though, there are very few instrumental records to speak of, and scientists have had to find some other way of assessing the temperature. We saw briefly in the last chapter how attempts have been made to *directly* measure past temperatures from boreholes. This is a procedure which is fraught with difficulty and there are many confounding factors, although the approach is not necessarily worse than any of the other ways we are going to examine. Mostly though, historical temperatures are estimated indirectly using *proxies*. A proxy is simply some quantity that varies with temperature and which leaves some trace after the event that can be sampled and measured. There are lots of different kinds of proxies and we will meet many of these in the course of this story, but the most common ones, and the ones which are of most relevance to the rest of the story, are tree rings.

The basis of the theory of tree rings as a proxy for temperature is that if you pick the correct tree, you can be seen to grow more in a warm year than in a cold one. The annual growth rings will be wider and the wood will be denser. So by taking a core through the tree from the outside towards the middle, it should be possible to extract what is effectively a record of temperatures throughout the lifetime of the tree.

Not all trees respond to temperature in this way though. A tree at the edge of a desert will *not* grow more when it gets hotter because it can't get enough water – scientists say that it is *precipitation limited*. Other trees might be limited by a lack of nutrients or by competition with other species. But according to the theory goes, there are some trees which are indeed limited by temperature. These are trees that are located on the upper tree lines on the sides of mountains – where the forest gives way to rock and grass – or perhaps those that are at the northern limit of their geographical range.<sup>a</sup> To a paleoclimatologist, these special trees are a kind of thermometer. By examining the width (and also the wood density) of the rings of these particular trees, it is thought that you can get an estimate of how warm it was at any point in time in the past – as long as the tree was alive then.

It goes without saying that you wouldn't want to base your temperature estimate on a single tree which might be affected by the conditions in its immediate vicinity, or by insect infestation or some other unidentifiable problem. Any of these factors could affect the record in such a way as to completely ruin the temperature reconstruction. Because of this, dendroclimatologists, as the

scientists who collect tree ring samples are called, put together the ring samples from a number of trees at a particular site into what they call a *chronology*, which shows the average picture of tree ring growth behaviour there. The idea is that all the small variations – issues with insects and so on – average out, so that once you sample enough trees, leaving just the temperature signal behind. And from this you can, in theory, measure the temperature of the past.

In fact it is rarely this simple. There are very large numbers of confounding factors, not least the fact that even if you were to keep a tree at a constant temperature it wouldn't actually grow the same amount each year. Researchers have discovered that trees tend to grow quickly at first and then gradually less and less each year, a fact that, if uncorrected, would produce a matching slow decline in the temperatures reconstructed from the rings. To deal with this, the chronologies have to be standardised. This involves working out an expected growth curve for the trees in question, and then expressing the ring width for any given year as a percentage of the expected ring width, essentially leaving only the temperature-related information – or so the researchers hope.

Even then there are other factors that may destroy the effectiveness of the studies. For example, as has been noted by one researcher that trees within a single site can show completely opposite growth patterns – some grow more in times of higher temperatures, but others grow less.<sup>25</sup> If this tendency is widely replicated then the whole approach of calculating historic temperatures from tree rings is thrown into doubt.

While most of the proxies used in paleoclimate reconstructions are tree ring series, there are other types as well. Ice cores are much used, as well as speleothems (more normally known as stalagmites and stalactites and similar rock formations). Ocean sediments and corals are also used in a similar way. The extraction of a temperature record from these other proxy types mostly involves analysis of the relative proportions of the isotopes of certain atoms in the proxy. The theory is that, for one reason or another, the isotope ratio will be different in a hot year to a cold one. Find the ratio in a sample of your stalagmite and you can work out the temperature. So long as you can also date the sample correctly then you can create a valid proxy series.

For a long time, temperature reconstructions were created using single proxies, but the trend has been increasingly towards multi-proxy reconstructions, using a mixture of different proxy types, and MBH98 fell into this latter category. As we will see, while using a multiproxy approach means that much more data is available, this advantage is offset by the complex statistics required, but that task will have to wait until later in the story.

### *Methodology*

Once you have collected together your proxies, how exactly do you go about reconstructing the temperatures of the past? There are different ways of doing this, but they all fall under one overall framework, which is what we need to describe next.

In very simple terms, we can derive temperatures of the past by calculating the mathematical relationship between tree ring width and temperature in the recent past. Once this relationship has been determined, it is quite simple to reverse it, enabling researchers to work out temperatures in the distant past from the widths of the rings of ancient trees. That's the simple explanation. Let's take a look in a bit more detail.

Paleoclimatologists have proxy records stretching back into the past for several hundred years. Let's say that we have a tree ring chronology which goes back to 1400. We can divide this 600-year period into three parts: the calibration period, the verification period and the reconstruction period (see [Figure 2.1](#)). In our example, the calibration period stretches from 1900 to 2000 and the verification period from 1850 to 1900. In these two periods we already know the temperatures because we have instrumental records. The objective of the exercise is to estimate temperatures in the



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