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What's Happening to the Weather? Australian Climate, H. C. Russell, and the Theory of a Nineteen-Year Cycle

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The theory of a nineteen-year climate cycle put forward by acclaimed New South Wales Government Astronomer Henry Chamberlain Russell is arguably one of his least successful contributions to science. Yet his ability to draw global connections made Russell a pioneer in the field of climate science—one whose innovative thinking helped prepare the way for much later achievements in the field of seasonal prediction. While controversial, Russell's theory sparked intense interest in meteorology and climate cycles and, at a time when extreme weather events were putting pressure on agriculture and pastoralism in New South Wales, it addressed the question of whether the Australian climate was undergoing permanent change. An historical understanding of ideas about climate cycles illuminates current debates on how to address the problems associated with anthropogenic climate change.

Introduction

Henry Chamberlain Russell, meteorologist and astronomer, was acting director of the Sydney Observatory, 1862–4, and succeeded G. R. Smalley as Government Astronomer of New South Wales on 12 July 1870. Russell was an influential figure in New South Wales intellectual circles and a pre-eminent man of science in nineteenth-century Australia, recognized for his scholarly publications on the climate of New South Wales, his work on star positions, his re-establishment of meteorological stations and his limnology (Fig. 1). He published over 130 papers, 69 in the journal of the Royal Society of New South Wales, a body of which he served four times as President. He had a prominent position in British as well as Australian science. He was elected a fellow of the Royal Astronomical Society in 1871 and of the Meteorological Society (later the Royal Meteorological Society) in 1875. In the latter year he also became a member of the Royal Colonial Institute. In 1886 he was the first graduate of the University of Sydney to be elected a fellow of the British Empire's premier scientific society, the Royal Society of London.

In 1879 Russell presided over Australasia's first Intercolonial Meteorological Conference, hosting it at the Sydney Observatory. In the same year he began keeping river records and published a seminal paper on artesian water in the Darling Basin. His *Physical Geography and Climate of New South Wales* first appeared in 1884.

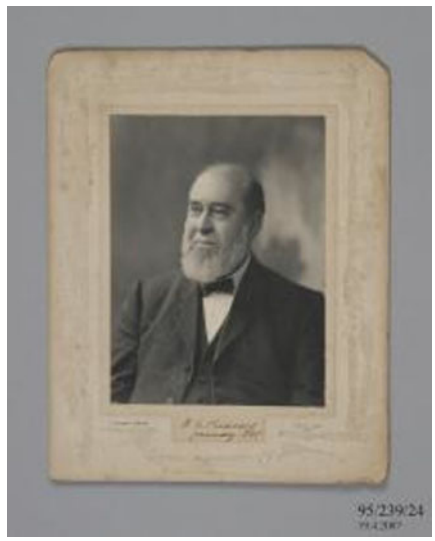

Figure 1. This photograph of H. C. Russell is a large print of the photograph taken in January 1898 by the commercial photographer J. Hubert Newman. It hung in the foyer of the Sydney Observatory for several years. Photo courtesy of the Powerhouse Museum.

In 1888 Russell was the first president of the Australasian Association for the Advancement of Science.

G. P. Walsh describes Russell as a 'pioneer' of the global approach to meteorology, the first to 'think comprehensively about the southern hemisphere'. His greatest contribution,

Walsh argues, was 'the radical suggestion that the movement of anticyclones was a hemispheric phenomenon'.[1] Among Russell's many achievements, I focus here on his contribution as a pioneer of climate science, in particular on what became known as his nineteen-year cycle theory. Although this is not perhaps regarded today as one of his most successful contributions to science, I shall argue that the theory, presented in 1896 under the heading 'On Periodicity of Good and Bad Seasons', demonstrated innovative thinking about the global connectedness of climate that would bear fruit some eighty years later. Russell's ability to draw correlations between extreme weather events in different parts of the world and to use climate data to try to establish some sort of predictability of droughts and floods was a precursor to a more illustrious climate science that now holds a central place in the comprehension of global climate systems and the use of that knowledge for seasonal prediction. Russell's theory drew both doubt and criticism at the time but also intense interest. Russell knew the immense use reliable seasonal prediction would be to agriculture. A harnessing of the combined forces of agricultural science and climate science saw Australia become one of the international leaders in this field in the second half of the twentieth century.[2]

This paper examines Russell's theory of periodicity of good and bad seasons and ties it to a wider interest in climate and weather prediction in the late nineteenth and early twentieth centuries. I argue that both scientists and rural producers were convinced that there was a periodicity in the climate—that droughts and good rains came at regular intervals. I further argue that while this idea was not new, it found fertile ground at the time and was used to explain 'variations' in the seasons—in other words to discount permanent climate change. This belief in the cyclical nature of climate would persist and re-emerge at times of extreme weather events. I argue that an understanding of past attitudes to climate and the extent to which human activity might have an impact on climate illuminates the current debate on how to deal with anthropogenic climate change.

Predicting the Seasons

Russell presented his theory of climate cycles to a meeting of the Royal Society of New South Wales in Sydney on the evening of 3 June 1896. His paper, 'On Periodicity of Good and Bad Seasons', he told society members, had a vital practical application in that it could predict both the recurrence of drought and the likelihood of good seasons.[3]

Russell's theory, that droughts and good rains occurred at regular and predictable intervals based on a nineteen-year cycle, caused quite a stir. Many in the audience were sceptical of Russell's findings. Physicist Professor Richard Threlfall of the University of Sydney, for example, described Russell's theory as a 'very bold undertaking', and regarded the available weather data as insufficient for establishing a climate cycle.[4] However, a report of Russell's theory was published in many of the major and regional newspapers[5] and when the news reached the general public it was greeted with much enthusiasm. Amateur weather watchers, pastoralists and farmers wrote to Russell as well as to the editors of colonial newspapers and journals, asking for more information on seasonal predictions.

In some cases these weather watchers put forward cycle theories of their own. Mr W. Allen of Rockhampton, for example, described Russell's theory as a 'splendid contribution' to the unravelling of the mysteries of nature, one of which he hoped both pastoralists and politicians would take note. He had sent Russell his own weather observations and theory on cycles some two years earlier and claimed it was most likely he had set Russell 'on his voyage of discovery'.[6]

Interest in Russell's theories extended beyond Australia and they were reported in South Africa in the *Cape Times* in January 1897. The *Times* predicted that, in contrast to the sunspot theories that had attempted to correlate climate in the northern hemisphere with cycles in sunspot activity and been largely discredited, Russell's hard work in connection with a lunar influence was 'on the eve of being richly rewarded'.[7]

Russell was never fully recognized in his lifetime for his contribution to climate prediction. As climatologist and climate historian Neville Nicholls has noted, climate science has always been fraught with difficulty. But while the complexity of global climate mechanisms was not sufficiently understood to enable long-range weather forecasting with any degree of certainty until the last third of the twentieth century, there was a flurry of activity and enthusiasm

for predicting good and bad seasons in the first decades of that century. Part of that enthusiasm was due to Russell's work and centred on theories about climate cycles and whether these explained perceived changes in climate.[8]

Natural Climate Cycles and Permanent Climate Change

One of the factors that led to a focus on cycles was noticeable changes in climate—regional variations on relatively short time scales. According to the Sydney newspaper *The Empire* in 1861, the climates of Canada and the northern states of the USA had become milder, as had Australia's. The *Empire* asked: 'Is the heat of our earth cooling down, or the calorific rays of the sun losing their force?' In an attempt to answer the question, the paper's columnist 'M. N.' postulated that a periodic warming and cooling had been experienced in 'all divisions of the world' and on this basis predicted that the years 1866 and 1867 would be notable for extreme weather in Australia.[9] As it turned out, 1866 was the second half of a two-year drought and 1867 saw above-average rains.[10]

There was some enthusiasm for cycle theories in many parts of the world in the late nineteenth and early twentieth century, but climate prediction was then put on hold until what Lamb describes as a 'climate revolution' occurred in the final third of the twentieth century. From the 1970s, a 'moribund climatology', as Lamb describes it, was transformed into a credible 'climate science' that could begin to predict, with a certain amount of accuracy, the weather some six months in advance. Before this, and despite the collecting of data throughout the century, the belief that climate was 'fundamentally unpredictable' held sway.[11]

In Australia, systematic meteorology in Australia was developed through the co-operation of three colonial meteorologists, Charles Todd, R. L. J. Ellery and Russell, who in the 1870s and 1880s laid the foundations of a national system based on a network of observing stations. This led to short-term forecasting that produced considerable public interest with Russell being the first to publish weather maps.[12] Here too, however, according to Neville Nicholls, long-term climate prediction remained in the doldrums for the best part of the twentieth century, despite the discovery of a connection between Australian droughts and those in other parts of the world—of global climate interconnections. While attempts were made in the 1920s and 1930s to link empirical findings to seasonal predictions, this fell away due to a lack of success and by the late 1930s the focus had shifted from climate to daily weather forecasting, particularly for aviation.[13] Yet research continued, spurred by progress in recognizing, through global measurements of sea-surface temperatures, the role of the tropical oceans in short-term regional climate variability as well as in extreme climate events. In particular, as Nicholls comments, collaboration between agricultural scientists and climate researchers led to Australia becoming a world leader in climate forecasting.[14] This was in no small way due to the fact that seasonal prediction was of fundamental importance to an agrarian nation such as Australia in which the climate was marked by high variability.

This is precisely what in an earlier age prompted men such as Russell to pursue cycle theories. Although flaws had been found in earlier theories and Russell's proclaimed periodicity was greeted with initial scepticism in the scientific community, it gained credence at this time both in Australia and overseas for two reasons. First, Russell was a respected man of science and had at his disposal the resources of the Sydney Observatory. He was able to draw on decades of rainfall readings throughout New South Wales. Second, seasonal predictability would if confirmed prove a boon to the pastoralism and agriculture on which the economic future of the Australian colonies depended.

On Periodicity of Good and Bad Seasons

If ever a time was to be ripe for a weather prophet, the late 1890s was it. On the dusty, dry plains of inland New South Wales were men and women who daily faced the harsh climatic realities of the arid western plains. The late 1890s saw New South Wales, and Australia generally, in a poor position both economically and environmentally, with the pastoral industry suffering due to the twin catastrophes of a withdrawal of British capital and extended drought. Many pastoralists had over-capitalized and overstocked in an attempt to recoup their losses once the terms of trade turned against them. In addition, the pastoral industry had spread into highly marginal

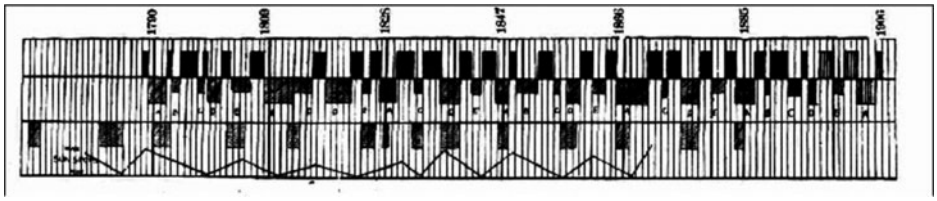

Figure 2. Chart drawn by H. C. Russell to explain his nineteen-year cycle theory. The top line shows the wet seasons in New South Wales, the middle line the drought seasons and the bottom line the droughts in India. Published in *Town and Country Journal*, 18 June 1896, p. 38.

arid zones far from the coast where a falling-off in rainfall put pastoralists in a precarious position as water supplies were exhausted and stock feed ran out.[15] This heightened the interest in seasonal predictions of the weather, particularly from the Government Meteorologist when he foretold good rains in the coming 1897–8 season.

Rural producers welcomed Russell's prediction of a good season in the near future. They had endured an extreme heat wave in January 1896 when furnace-like winds from the interior had pushed temperatures above 40°C across much of eastern Australia. The high temperatures and the shortage of clean drinking water took its toll on human health and thirty cases of typhoid, including one death, were reported near Moree in the north-east of New South Wales. In the far north-west, temperatures at Bourke reached 43°C in the shade and the 'violent' heat was blamed for a further eight deaths.[16] The strong north-west winds and 'burning heat' had robbed the soil of any moisture that might have been left by the late spring rains and resulted in claypan surfaces on which there was not a blade of grass to feed the weakened stock.[17] In the face of these harsh climatic realities, Russell promised that the 1897–8 season would see a return to good rains.

What led Russell to predict a good season with such certainty? His nineteen-year cycle theory, as it became known, had at its foundation a belief in the cyclical nature of climate—that seasons alternated between wet and dry in a definite pattern. While this idea is neither novel nor innovative in today's understanding of climate, when Russell addressed the Royal Society in 1896 a belief in cycles was straining the accepted boundaries of science.

As Government Astronomer and Meteorologist, Russell was able to draw on an array of colonial weather data as well as historical knowledge of ancient weather events such as floods, heatwaves, droughts and frosts. To explain his theory in regard to New South Wales, Russell drew a linear chronological diagram (see Fig. 2) that arranged good and bad seasons in contrast to each other above and below a neutral line. Russell had five different types of droughts differentiated by severity and duration. His chart also demonstrated, he argued, a clear correlation between droughts in India, which he included in a third line on the chart, and New South Wales. Russell was not alone in recognizing this correlation between Indian and Australian droughts. In 1888, a year that saw a major drought in both Australia and India, the South Australian Government Astronomer, Charles Todd, concluded 'there can be little or no doubt that severe droughts occur as a rule simultaneously over the two countries'.[18]

Having plotted the good and bad seasons that had occurred in the past in New South Wales on this linear chart, Russell found that each type of drought recurred predictably within a nineteen-year interval. His diagram began with the good season of 1788 that coincided with the beginnings of European settlement. It is known that the weather was cool and wet between January 1788 and the winter of 1789. This has been deduced from the daily temperature and barometric pressure observations recorded by Lieutenant William Dawes at Sydney Cove and a temperature record kept by William Bradley on board HMS *Sirius* anchored in Port Jackson (Sydney Harbour) in the early months following the First Fleet's arrival in Australia, as well as from anecdotal observations recorded in First Fleet documentary records.[19] By November 1791, however, the weather was so dry that Governor Arthur Phillip recorded that the Tank Stream had stopped flowing into

Sydney Harbour. It did not flow again until 1794. As Groves comments, Phillip judged that this extended dry season was unusual.[20]

By the time of his report to the Royal Society of New South Wales in 1896, Russell had been working on his cycles theory for more than two decades. He first proposed that the climate of New South Wales was based on a nineteen-year cycle in 1871. Rainfall readings from weather stations at South Head and Sydney (most likely the Sydney Observatory on Flagstaff Hill[21]) over a period of thirty years had shown, he said, that there were two distinct periods, the second more or less a repetition of the first. The similarity of the rainfall at intervals of nineteen years suggested to Russell a lunar influence 'for in that period the moon returns to the same position in the heavens'.[22] This led him to claim that if he could prove that rainfall 'followed a law', it 'may yet be possible approximately to predict it'.[23]

Russell returned to the subject on 11 October 1876 when he addressed the Royal Society of New South Wales on 'Meteorological Periodicity'. What he was looking for, he told society members, was the 'true cycle'. His comment acknowledged the theories that had already been put forward by both amateur and professional weather observers that postulated cycles from two years up to fifty years.[24] For example, just six years earlier, in 1870, the Astronomer Royal for Scotland, Professor Piazzi Smyth, had claimed he could predict the temperature of a season a year in advance. Smyth based his predictions on temperature observations in Europe between 1837 and 1869 and found an eleven-year cycle.[25]

Russell was in many ways a reluctant weather prophet when he stood before the Royal Society of New South Wales in 1896. By this point he could draw on 108 years of weather observations in the colony, including floods in the Darling River and Lake George. He expected opposition to his theory and appealed to society members to hear him out: 'I feel some reluctance in coming forward tonight with the result of my investigations', he said, adding that his conclusions would come as a surprise to many. 'For myself, I know that some years ago, if anyone had come to me, stating that it was possible to forecast the seasons many years in advance I should have received the statement with incredulity and an inclination to think lightly of the man who advanced such views.'[26]

Indeed he had said as much himself in a press interview in 1890. At that point he declined to assume the role of the long range weather prophet: 'We can forecast the weather daily with a tolerable amount of certainty, because we know that the atmospheric changes move regularly to the eastward… But to foretell the weather a week, a month, or even a year ahead, is a task which no man in the existing state of meteorological science can do.' As for the cycles theory, Russell had decided that the rainfall records gave no indication of periodicity—that is, of any regularly recurring period of weather change.[27] Six years later, however, after a particularly bad season across most of eastern Australia in 1895–6, Russell returned to his cycles theory and presented it to the Royal Society of New South Wales.

Based on his new analysis, Russell predicted that the years 1897 and 1898 would be 'years of plenty' in contrast to the 'bad years experienced in 1895–96', and this point was not missed in the regional press.[28] Across the colony, 1895 had seen a falling off of rainfall and marked what we now know to be the start of a particularly dry period that devastated eastern Australia from 1895 to 1903. Its importance is acknowledged in the three labels it has been given—the Long Drought, the Great Drought and the Federation Drought—and it was to that date the most prolonged period of below-average rain since the European settlement of Australia.[29]

Identifying ENSO and the IPO

It is now recognized that the Federation Drought was the result of three El Niño events. In Australia, El Niño is the dry phase of a dry-wet continuum known as El Niño Southern Oscillation or ENSO. The climate of the Australian continent is highly variable due to ENSO, and is also influenced by another, longer-term fifteen- to thirty-year climate cycle, the Inter-decadal Pacific Oscillation or IPO. Working in tandem, these cycles bring periods of high and low rainfall to the Australian continent. While the IPO is a relative newcomer to the climate stable, the complex mechanisms of ENSO were largely understood by the late 1960s.

Through the work of the Norwegian scientist Jacob Bjerknes in particular, it was found that ENSO was a coupled system of the ocean and the atmosphere, centred on the equatorial Pacific but

influencing climate in many parts of the world through what were termed teleconnections.[30] Bjerknes built on the work of the British climatologist and mathematician Sir Gilbert Walker who recognized the significance of the see-sawing barometric pressures across the Pacific Ocean and named it the Southern Oscillation. Its index is a measurement of the difference between the atmospheric pressure in Tahiti and Darwin. The Southern Oscillation Index or SOI indicates the state of an ENSO event, that is, its onset and decay. El Niño and La Niña are the two opposite states of ENSO and are associated in Australia with droughts and floods respectively. Since the 1980s, as ENSO events have become more intense and prolonged, El Niño and La Niña have become household terms. This has been particularly so since the 1990s as seasonal forecasting, linked to ENSO, has become more accurate.[31]

Predicting the Seasons

While twenty-first-century climate scientists can confidently identify climate cycles through measurements such as the SOI and sea-surface temperatures, this was much more difficult in the late nineteenth-century when cycle theories were in their infancy. Counter to Russell's prediction, the summer of 1897–8 was particularly dry and saw some of the most extreme weather recorded in Australia, with high temperatures sparking extensive bushfires in south-eastern Australia that began in the second half of December 1897 and continued through the first two months of 1898. There was some respite when conditions changed to a mild La Niña in mid-1898, but it was to be a brief pause in an otherwise difficult and prolonged dry period. Another El Niño developed in 1899, then a third from 1901 that only broke with good autumn rains across most of New South Wales in March 1903.[32]

Notwithstanding Russell's inaccurate prediction of good rains in 1897–8, the periodicity of the climate was to occupy many weather watchers for years to come. Of course, many longed for a break in the weather and the good seasons to return. The question was, when would this occur? Long-term residents of rural districts were consulted. For example, in mid-1901, at the height of the Federation Drought, the *Lachlander* quoted an old-time Condobolin resident on his forecast for tropical drought-breaking rains from the north.[33] In October 1899 the Riverina district was showing the effects of the ravages of drought with 'grass looking very bad and crops failing fast'. As with most of eastern Australia, this district had been in drought for nearly five years. Faith in the return of good times was in evidence but the fear was that it might be too late to save the livelihoods of some: '"Shall we ever get good seasons again?" is often asked when travelling the country now, and though nothing is more certain but that the good seasons will come again, yet it is terribly discouraging, for how some are to pull through is beyond conjecture'.[34]

In August 1896, Russell received a letter from pastoralist John D. Read of 'Bedooba', Dymagee, in inland New South Wales. Read had read a report on the nineteen-year-cycle theory in the *Sydney Mail* of 13 June 1896. He told Russell, 'I have considerable faith in your nineteen years cycle system, I think that you have made a strong case and therefore look to it for guidance'. Read emphasised the importance of climate prediction to pastoralism noting that

> The duration and recurrence of drought is a matter that very seriously effects us in this Western district. I have ever since hearing of your cycle theory some years ago, thought that there was a great deal in it. After a drought everyone gets more or less discouraged consequently pastoral matters are made even worse than the occasion warrants similarly after a few good seasons people are perhaps too much unprepared for a drought. Everyone, however, who has watched the season for any length of time is prepared to admit that when there have been a batch of good seasons we are due for a batch of bad seasons or a drought and that when we have had a drought we are due for a batch of good seasons, when such droughts or good seasons can be expected and their duration is the question that so far has made pastoral pursuits such a lottery.

Getting to the heart of the matter, Read asked Russell when it would rain: 'I would deem it a favour if you would let me know when your book on the periodicity of good and bad seasons will be published and when according to your nineteen years cycle system we might look for any fair fall of rain.'[35]

In June 1896, shortly after Russell's address to the Royal Society of New South Wales, pastoralist and wheat farmer William O'Neill also felt compelled to write to him. O'Neill, one of

the first farmers to grow wheat for grain in the Narromine district in the semi-arid Lower Macquarie Valley, had a theory of his own: 'Having taken an active [interest] in pastoral pursuits in the colonys since 1852 and in agricultural and pastoral pursuits for the last 20 years I have noted that our droughts have [occurred] regularly once in about three years'. 'I now look out for two fair to good years and one bad one', O'Neill told Russell.[36]

As O'Neill informed Russell, his belief in a three-year cycle of good and bad seasons was based on his observations and records of rainfall in the Narromine district over the previous thirty-three years. While the records only pertained to his property, Westbrook Station, O'Neill felt they established a reliable pattern and one that would help him 'weather' Australia's highly variable climate while pursuing the often precarious industries of pastoralism and wheat farming.

A Different Climate

The extent and duration of drought in Australia had been a rude shock for O'Neill, as it was for many colonial pastoralists in the nineteenth century. Although the period when pastoralism was first being established in Australia was relatively mild or wet, the latter half of the nineteenth century saw the occurrence of several severe droughts. As O'Neill related in his letter to Russell: 'My first experience of droughts came as a surprise as I never seen one before in the colonys until 1863, then in '65, followed by '68.'[37]

What shocked O'Neill was a period of protracted drought in Australia from 1864 to 1869 that, as Garden argues, brought immense personal hardship as well as an economic recession that slowed colonial development. The impact of the drought was widespread and resulted in heavy stock and crop losses. Many pastoralists were ruined, including the owner of Bundidjaree Station in the Riverina, T. A. Browne, who wrote a fictional account of these droughts based on his own experiences. Browne and his young family left Bundidjaree 'penniless' in November 1869 and the station passed to the Bank of New South Wales.[38]

These droughts, due to two El Niños from mid-1864 to late 1866 and from late 1867 to autumn 1869, were separated by a short but very wet La Niña in 1866–7. This period was one of great hardship, coinciding as it did with a push to place more farmers on the land in an effort to grow food, to feed the influx of migrants prompted by the buoyant economic period of the 1850s.[39]

O'Neill's experience of those droughts as a station manager prompted his careful recording of rainfall and seasons in an attempt to cope with the vagaries of climate and to manage drought better. As he told Russell: 'I think it will be found that when they are studied and laid to heart that people will exercise more prudence and foresight more especially those who are interested in our producing interests.'[40]

A Lunar Influence

Russell persisted with his cycles theory that linked periodicity in the weather with lunar cycles. He addressed the Royal Society of New South Wales again on this topic in 1901, now proposing that when the moon's course is to the southward in the southern hemisphere much more rain falls than when the moon moves to the north.[41] In reaching this conclusion, Russell had confined his study to the rainfall records from inland pastoral stations, as he had found that coastal areas were prone to the influence of severe storms, the off-shoots of equatorial hurricanes. 'During the southerly motion of the moon for six years', he said, 'there is abundance of rain. Then drought begins, not wholly for want of rain, but in many cases because we have strong north to north-west hot winds'.[42] Unfortunately, as Garden has noted, when Russell's findings are compared with the nineteenth-century rainfall figures, it can be seen that his interpretations and speculations about the influence of the moon on rainfall were in error. [43]

On the Cusp of Ruin

Thus by 1901, after a searing hot summer, it was not only pastoralists and farmers who saw the need to exercise prudence and foresight. The possibility of predicting the seasons several years in advance seemed to hold much promise. The attractiveness of seasonal forecasting made it impossible to dismiss Russell's theory out of hand. As the Rockhampton *Morning Bulletin* observed, 'the immense importance of the question to the pastoral and agricultural industries renders it worthy of the deepest attention'.

Moreover, as the paper sagely acknowledged, the element of 'risk' that climate at that time represented would be substantially reduced by reliable forecasts and the value of rural property 'correspondingly increased'.[44]

Pastoralism as an industry was facing economic ruin at the time. In an effort to put policy in place that would counter the demise of the industry, the New South Wales Government set up a Royal Commission to investigate the economic and environmental problems in the Western Division of that state. [45] As the *Morning Bulletin* noted: 'Of one thing there can be no doubt, that if Mr Russell succeeds in establishing his theory, and in making a successful forecast of the seasons he will rank amongst the greatest of benefactors to pastoralists and agriculturists throughout Australia'.[46]

In 1903, by which time most of eastern Australia had been in severe drought for seven years, Russell's nineteen-year cycle theory was again published in the *Sydney Morning Herald.* It again drew much attention and comment from those whose livelihoods were intimately connected with the weather.

In a letter to the editor, 'DMD' supported Russell's theory of cycles and commented that he had long believed that the climate had alternate seasons of about eight years' duration. As a colonist of sixty years, he could remember past droughts and the month of the year when they were broken by rains. From his memory of the droughts and floods of the 1840s and 1850s, he argued that these cycles were not uniform: 'It is very evident also that there are shorter and longer cycles and that the shorter wet seasons seem to have the peculiarity of bringing with them heavy floods and are followed by shorter and less injurious droughts'.[47]

Human Influence

There were, however, those who did not agree that the changing characteristics of droughts and floods were due to the cyclical nature of climate. 'Old hands', wrote 'DMD', were convinced that the climate had altered: 'It is impossible to dissuade the few that are now alive, and who lived through these olden times, but that the climate has greatly altered in later years, to the less frequency of destructive floods and deep snow falls'.[48] Part of this conviction related to the degree to which human action such as land clearing or tree planting had altered climate. As Garden has noted, some of these ideas were contradictory; for example, the idea that eucalypts would rob the soil of moisture co-existed in the nineteenth century with the notion that trees attracted rain and their removal increased drought.[49]

While the prolonged period of drought at the turn of the twentieth century convinced some that the climate had altered, what to do about it depended on the degree to which they believed that humans could control their environment through the application of science and technology. Recourse to irrigation, for example, was particularly strong in the first half of the twentieth-century. In the twenty-first century, with a consensus among climate scientists that permanent anthropogenic change is responsible for increased temperatures and changes in rainfall patterns since the 1960s, there is a distinction to be made between natural climate cycles and permanent anthropogenic climate change. This distinction is one that often blurs the debate on the necessity to ameliorate the impact of human activity.

Conclusion

Today, the notion that climate is naturally (but irregularly) cyclical is so entrenched that it seems difficult to imagine that this has not always been the case. However, as Lamb explains, the idea that climate was a constant within periods of less than a century held sway until the 1970s. Although work continued on discovering the cause of seasonal variations, in general climatology was considered a lesser science.[50]

The crisis that surrounds the management of permanent, human-induced climate change heightens the need to understand the ways in which climate has been perceived historically. As Clive Hamilton has argued, although Australians in general understand the consequences of a warming world, there is a strange lack of intensity in their concern and this translates into a muted call to arms. This he sums up as a culture of denial underscored by a belief in human ability to manipulate and control the natural environment. While the majority of Australians may acknowledge that anthropogenic climate change is happening, there is a reluctance to commit

substantially to measures to combat that change, particularly where it is perceived that there will be economic penalties.[51]

What is not in doubt is that extreme weather events, combined with Australia's reliance on agriculture and pastoralism, has spurred an intense interest in climate and its prediction. While climate science did not gain credence until the latter third of the twentieth century,the combined efforts of agricultural scientists and climatologists then led to Australia becoming a world leader in climate forecast applications. The early work of men such as Henry Russell in arguing, albeit incorrectly, for a periodicity in the climate was to bear fruit some eighty years later.

As we now know, Australia has a highly variable climate due to the cycles of ENSO underpinned by the IPO. But the ways in which ENSO will respond to global warming is uncertain. As the climate scientist David Karoly has noted, natural variability can obscure long-term warming and can be used by climate-change sceptics to argue against the reality of permanent anthropogenic climate change. The cooler temperatures and greater-than-average rainfall of recent La Niña summers, for example, have been used to argue against the prediction of a continuing upward temperature trend. [52] As happened in the nineteenth century, the extent to which human activity can alter the climate is still being debated, while climate scientists begin to link the frequency of extreme weather events to a warming world. [53]

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6. W. Allen, 'The Periodicity of the Seasons', *Morning Bulletin*, *20* June 1896, p. 5.
7. Russell's Nineteen Year Cycle', *Cape Times Weekly*, 6 January 1897, p. 6. See also 'Collection of newspaper cuttings and manuscripts relating to Henry Chamberlain Russell's theory of a 19 year weather cycle ca. 1896', Henry Chamberlain Russell Papers, MS 7, (Australian Bureau of Meteorology Library, Melbourne).
8. Neville Nicholls, 'Climatic Outlooks: from Revolutionary Science to Orthodoxy', in *A Change in the Weather: Climate and Culture in Australia*, eds Tim Sherratt, Tom Griffiths and Libby Robin (Canberra: National Museum of Australia Press, 2005), pp. 18–29.
9. *The Empire*, 27 May 1861, p. 2.
10. Don Garden, *Droughts, Floods and Cyclones: El Niños That Shaped Our Colonial Past* (North Melbourne: Australian Scholarly Publishing, 2009), p. 7.
11. P. J. Lamb, 'The Climate Revolution: A Perspective', *Climate Change*, 54 (2002), 11–12.
12. R. W. Home and K. T. Livingston, 'Science and Technology in the Story of Federation: The Case of Meteorology, 1876–1908', *Historical Records of Australian Science*, 10 (2) (1994), 109–127.
13. Nicholls, op. cit. (n. 8).
14. Ibid.
15. Don Garden, "The Federation Drought of 1895–1903: El Niño and Society in Australia", *Common Ground: Integrating the Social and Environmental in History*. (Newcastle upon Tyne: Cambridge Scholars Publishing, 2010), pp. 270–292.
16. *Maitland Mercury*, 4 January 1896, p. 3, and 14 January 1896, p. 3.
17. Russell, op. cit. (n. 3), p. 4.
18. 'Droughts in Australia: Their Causes, Duration and Effect. The Views of Three Government Astronomers', *South Australian Advertiser*, 29 December 1888, p. 6.
19. It is likely that Russell used the documentary records only. The weather diary kept by Dawes was discovered in the library of the Royal Society of London in 1977. Russell must not have seen this as he stated that 'there seems little doubt that Dawes kept weather records but there are no records of them'; H. C. Russell, *Climate of New South Wales: Descriptive, Historical, and Tabular* (Sydney, 1877). Gergis, Karoly and Allan cross-referenced these observations with paleoclimate reconstructions to produce a weather record for Sydney from 1788 to 1791; see Joelle

Gergis, David Karoly and Rob Allan, 'A Climate Reconstruction of Sydney Cove, New South Wales, using Weather Journal and Documentary Data, 1788–1791', *Australian Meteorological and Oceanographic Journal*, 58 (2009), 83–98.

20. Richard Groves, 'Revolutionary Weather: The Climatic and Economic Crisis of 1788–1795 and the Discovery of El Niño', in *A Change in the Weather: Climate and Culture in Australia*, eds Tim Sherratt, Tom Griffiths and Libby Robin (Canberra: National Museum of Australia Press, 2005), pp. 128–140.
21. Official observations in Sydney began at the Flagstaff Hill observatory (now called Observatory Hill) in 1859. Its activities flourished under Russell's guidance.
22. Russell, *Meteorological Observations: New South Wales up to the End of 1869 with Remarks on the Climate* (Sydney, 1871), p. 10.
23. Ibid., p. 11.
24. H. C. Russell, 'Meteorological Periodicity', in Russell, op. cit. (n. 19), p. 169.
25. Piazzi Smyth, 'On Supra-annual Cycles of Temperatures in the Earth's Surface Crust', *Proceedings of the Royal Society of London*, 18 (1870) 311–312. See also 'Weather Cycles', *South Australian Register*, 11 January 1871; *Australian Town and Country Journal*, 10 September 1870, p.12; and Douglas V. Hoyt and Kenneth H. Schatten, *The Role of the Sun in Climate Change* (New York: Oxford University Press, 1997), p. 108.
26. Russell, op. cit. (n. 3), p. 2.
27. 'Something about the Weather: Mr Russell's Views', *Sydney Morning Herald*, 21 June 1890.
28. Russell, op. cit. (n. 3), p. 22; 'A Good Season Prognosticated', *Wagga Wagga Advertiser*, 16 January 1897, p. 4.
29. Garden, op. cit. (n. 15), pp. 270–292.
30. Jacob Bjerknes, 'Atmospheric Teleconnections from the Equatorial Pacific', *Monthly Weather Review*, 97 (1969), 163–172.
31. Julia Miller, 'Soakers and Scorchers: A Cultural History of El Niño Southern Oscillation in New South Wales, 1890 to 1990', unpublished PhD thesis, Macquarie University, 2011, p. 15; Garden, op. cit. (n. 10), pp. 4–5. Nicholls, op. cit. (n. 8), pp. 18–29.
32. Miller, ibid., p. 53.
33. Quoted in 'The Weather', *Cobar Herald*, 24 August 1901, p. 4.
34. 'District News: Bolero', *Narrandera Argus and Riverina Advertiser*, 13 October 1899, p. 3.
35. John D. Read to H. C. Russell, 3 August 1896; Henry Chamberlain Russell Papers, MS 7 (Australian Bureau of Meteorology Library, Melbourne).
36. W. O'Neill to H. C. Russell, 5 June 1896; Henry Chamberlain Russell Papers, MS 7 (Australian Bureau of Meteorology Library, Melbourne).
37. Ibid.
38. Garden, op. cit. (n. 10), p. 58.
39. Ibid., p. 25.
40. Ibid.
41. Russell, '"Recurrence of Rain": the Relation between the Moon's Motion in Declination and the Quantity of Rain in New South Wales', *Journal and Proceedings of the Royal Society of New South Wales*, 35 (1901), 113–115. The article was reprinted with commentary in the *Narrandera Argus and Riverina Advertiser*, 27 September 1901, p. 3.
42. Ibid.
43. Garden, op. cit. (n. 10), p. 253.
44. 'Weather Cycles', *Morning Bulletin*, 2 May 1901, p. 3.
45. In August 1900 a Royal Commission into the Condition of the Crown Tenants in the Western Division of New South Wales was established to investigate the failure of pastoralism in the Western Division. The Commission reported in 1901 and reforms to the administration of the pastoral industry, such as extending the period of leases, were put in place by the *Western Lands Act*, 1901.
46. Op. cit., n. 44.
47. 'Periodical Recurrences of Weather Cycles,' *Sydney Morning Herald*, 30 April 1903, p. 6.
48. Ibid.
49. Garden, op. cit. (n. 10), p. 149.
50. Lamb, op. cit. (n. 11), pp. 11–12.
51. Clive Hamilton, "The Social Psychology of Climate Change", in *A Change in the Weather: Climate and Culture in Australia*, eds Tim Sherratt, Tom Griffiths and Libby Robin (Canberra: National Museum of Australia Press, 2005), pp. 187–195.
52. David Karoly, 'Climate Change Science: What's Happening, Where Are We Heading?', talk given at La Trobe University, Melbourne, April 2013. http://www.themonthly.com.au/video/2013/05/21/1369101669/climate-change-science-whats-happening-where-are-we-heading-david-karoly.
53. Scientists speaking at the annual meeting of the American Association for the Advancement of Science in Boston in February 2013 noted that climate change has increased the likelihood of severe weather events in the future; Jane J. Lee, 'Severe Weather More Likely Thanks to Climate Change', *National Geographic*, 13 February 2013. http://news.nationalgeographic.com.au/news/2013/13/130215-severe-storm-climate-change-weather-science/