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the influence of climate on the first european SETTLEMENT OF AUSTRALIA: A COMPARISON OF WEATHER JOURNALS, DOCUMENTARY DATA AND PALAEOCLIMATE RECORDS, 1788–1793

ABSTRACT

This essay introduces a new technique to improve the reliability of the interpretation of how weather and climatic factors have influenced past societies. Using the case of first European settlement in Australia, we argue that historians have largely ignored or misconstrued the influence of climate on past societies. We discuss how cool, wet weather during 1788–1790 (a La Niña) and the drought conditions of 1791–1793 (an El Niño) compromised initial settlement and agricultural development in the colony. We compare meteorological and palaeoclimatic data with historical sources to investigate how water scarcity has profoundly shaped Australian society since 1788.

> The material fortunes of the colony improved quickly after the arrival of the Second Fleet [in June 1790]. The climate exercised its beneficent influence on the sick; the old hours of compulsory labour were restored as food rations returned to normal; new buildings were planned; large tracts of land were cleared at Sydney and Parramatta ... Gradually the material setting began to take a more permanent form.[1]

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THIS DESCRIPTION BY MANNING CLARK of the benign climate and smooth progress of settlement at Sydney and Parramatta after the arrival of the Second Fleet in Sydney, the foundation settlement in New South Wales, eastern Australia, was overly optimistic. Rather, as Richard Grove has identified, from late 1790 the convict settlement came under extra pressure from a severe drought that is now associated with a strong El Niño.[2] Grove is one of the few historians to recognize the drought in 1790-1793 and to associate it with an El Niño event. However, Grove took the issue further and argued that El Niño conditions prevailed from 1788 to 1795. Recent research shows that time frame to be incorrect, and it will be argued that an innovative combination of traditional historical records and scientific data indicate that the weather in the first five years of the Sydney settlement was chronologically more varied and was more complex in its effects. In particular, rather than the weather being "beneficent" as Clark asserted, a drought from 1790-1793 stymied the development of European settlement after the arrival of the Second Fleet.

Despite their obvious significance for the well-being of human society and economy, climate and weather have seldom featured or been evaluated in conventional histories in Australia, except when there have been extreme events such as profound droughts and severe floods. Weather and climate have generally been subsumed under the greater emphasis given to social, political, and economic accounts, so that when historians mentioned climate and weather, it was generally in a perfunctory manner as a subset of the physical environment or because of the effects of extreme weather upon social, political, and economic themes.

Consequently, to date there has been limited exploration by historians of Australian historical records for pre-twentieth century weather information. Aside from the pioneering works of the nineteenth century by Jevons and Russell, and mid-twentieth century work by Foley, there have been very few attempts to reconstruct Australian pre-twentieth century climate using early weather station or documentary records.[3] Even less work has been aimed at analyzing Australia's flood, bushfire, dust storm and cyclone history and past societies' response to historical climate variability.

More recently, climate and environmental historians have urged the need for greater recognition and understanding of the critical importance of environmental factors in shaping human societies, and recognize that research into past weather and climate variability can throw informative light onto many aspects of our history, culture and development. Australian climate historians (e.g. Nicholls) and environmental historians (e.g. Garden) have been particularly drawn to the need to recognize the influence of the El Niño-Southern Oscillation (ENSO) cycle, and gradually such physical forces have come to be factored generally into historical understandings.[4]

This essay goes one step further and sets out to establish the weather conditions that occurred during the foundation years of the settlement at Sydney Cove from 1788 to 1793, and analyze their impact on early Australian society.

To do this, it combines the perceptions of environmental history, historical climatology and palaeoclimatic data (tree rings, corals, and ice core data). We conclude that the effect of climate on the early settlement, especially from 1790-1793, is more significant than has generally been recognized. It is also very evident that the novelty and challenges of the climate, like those of the broader environment, required adaptations and adjustments from the settlers - it was a steep learning curve.

There is a rich but generally neglected body of contemporary accounts of weather conditions. According to Jones, it is rare for documentary accounts of weather to overlap with instrumental records as diarists were often keen to use the newly developed instruments and quickly abandoned their narrative accounts.[5] However, in Sydney from 1788 we are fortunate to have several accounts of weather conditions kept in government officials' journals and diaries including David Collins, John Hunter, Arthur Philip, George Worgan and Watkin Tench.[6]

Arguably even more illuminating is the first climate reconstruction for Sydney Cove from January 1788 to December 1791, undertaken by Gergis, Karoly & Allan, using the earliest weather records kept in the colony of New South Wales.[7] These were a temperature record kept by William Bradley on board the *Sirius* anchored in Port Jackson (Sydney Harbour) in the early months of the First Fleet's arrival in Australia (January to September 1788), and daily temperatures and barometric pressures recorded by William Dawes from September 1788 until December 1791.[8]

A recent palaeoclimatic reconstruction of ENSO, as discussed below, further supports the picture developed by these instrumental measurements and written accounts. The combined evidence from these three sources refutes Grove's conclusion that there was an El Niño drought prior to late 1790, and contradicts Manning Clark's assertion that conditions prior to 1790 were harsher than those that followed.

THE ENSO CYCLE OF 1788-1793

IT IS NOW GENERALLY UNDERSTOOD that the extreme phases of the El Niño-Southern Oscillation (ENSO) cycle frequently result in extreme weather conditions around a large part of the globe. In eastern Australia, El Niño events are renowned for resulting in drought, while La Niña conditions favor the likelihood of above average rainfall. Richard Grove has argued that there was an extended El Niño event from 1788-1795 which not only impacted significantly upon the early settlement at Sydney Cove, but had diverse effects across the globe, even as a factor adding to social distress that culminated in the French Revolution.[9]

In coming to this conclusion about an elongated El Niño, Grove used three South American sources, the Quinn et al. and Ortlieb documentary El Niño chronologies and a coral record by Dunbar et al. from the Galapagos

Islands.[10] However, all of these records come from Eastern Pacific teleconnection regions (rather than incorporating climate signals from both sides of the Pacific basin) and the documentary chronologies developed by Quinn and Ortlieb only reconstruct El Niño events (excluding La Niña episodes). Grove identified an apparent extended El Niño from 1788-93 largely based on one source: the Galapagos coral record. The only year when the Quinn and Ortlieb chronologies agree with the El Niño event suggested by the coral record is in the year 1791. That is, the years 1789, 1790, 1792 and 1793 are not independently verified by either of the documentary event compilations as being El Niño years.

Furthermore, there are concerns about the validity of this multi-year El Niño event reconstruction as there are dating errors in the Galapagos coral core noted by Dunbar et al. at the time of publication. A recent multi-record analysis by Gergis and Fowler has shown that the Galapagos record accurately only captures 50 percent of El Niño events and 38 percent of La Niña episodes detected in modern twentieth-century meteorological records.[11] This suggests that there is a 50 percent chance of an El Niño event being falsely identified and a 62 percent chance of the coral record incorrectly identifying La Niña conditions.

Gergis and Fowler's ENSO chronology incorporates all of the above sources and also includes records from the western Pacific in its reconstruction, overcoming the historical East Pacific bias. A number of percentile-based palaeoclimate reconstructions were used to isolate signals of both phases of El Niño-Southern Oscillation (ENSO). A total of 92 El Niño and 82 La Niña events were reconstructed since A.D. 1525. This annual record of ENSO events can now be used as an independent chronological control for archaeologists and social scientists interested in human responses to past climate events. Significantly, they introduce the first comprehensive La Niña event record compiled to date.

In contrast with Grove, Gergis and Fowler conclude that a very strong La Niña event (not El Niño) was centered on 1788 and spanned to 1790. A characteristic 'phase flip' seems to have occurred in 1791, commencing what is classified as a very strong El Niño year and El Niño conditions that continued until 1793. This conclusion has been confirmed by another western Pacific coral reconstruction. Recently, using a composite coral record to reconstruct tropical rainfall runoff over the Great Barrier Reef since A.D. 1661, Lough showed that the years 1788 and 1790 were periods of high freshwater flow into the Great Barrier Reef, consistent with north Queensland's contemporary La Niña teleconnection pattern.[12] While southern Australia appears to have experienced very dry conditions, 1791-93 register as years of "average" runoff as recorded by corals in northern Australia. A very low runoff year is recorded in 1794, a likely reflection of the 1793-1794 "monsoon year" straddling two calendar years. These more recent studies support the likelihood of a La Niña event spanning the 1788-90 period and a pronounced El Niño event from 1791-93, rather than a protracted El Niño event from 1788-1795 as suggested by Grove.

AUSTRALIA'S EARLIEST METEOROLOGICAL RECORDS

IN 1977, A DISCOVERY WAS MADE that had the potential to illuminate Australia's meteorological record during the founding of the colony in New South Wales. Robert McAfee discovered a meteorological record from 1788-91 that was kept by Lieutenant William Dawes, a scientist who sailed on the First Fleet, in the library of the Royal Society in London.[13] It seems a comment made by one of the founding fathers of Australian meteorology, Henry Chamberlain Russell, that Dawes had kept weather records that could not be found, deterred meteorologists from pursuing the data.[14]

McAfee was more persistent and in 1977 Dawes's daily weather measurements spanning 14 September 1788 to 6 December 1791 were finally copied onto microfilm and featured in an Australian Bureau of Meteorological *Historical Note*, some 200 years after Dawes began his journal.[15] Perhaps because of the large job of transcribing 182 hand-written pages of up to six daily observations of temperature, barometric pressure, winds and weather remarks, further work to analyze the record was not completed, and despite their immense cultural and scientific significance, it took nearly a further thirty years before researchers transcribed the data in the spring of 2008.[16] According to McAfee, a weather journal with comparable detail for this period anywhere in the world is a rare find. For the Indo-Australian region, Dawes's weather journal is only matched by the English East India Company observations made in Madras (Chennai), India, from 1796 onwards.

To supplement Dawes's temperature record, William Bradley's daily noon temperature (°F) observations recorded in a weather journal kept on the HMS *Sirius* while anchored in Botany Bay (January 20-26, 1788) and Port Jackson (January 27 to September 13, 1788) were used.[17] When comparing the small overlap between Bradley's measurements with Dawes's, Bradley's readings are somewhat lower, likely due to the moderating influence of water on daytime temperatures recorded offshore. The average difference in the short period of overlap (16 readings between September 14 and September 30, 1788, one missing value) is 2.1°C.[18]

Gergis et al. recently analyzed the data kept by Dawes and Bradley, and found that the records, despite the limitations of the instruments and the conditions under which they were kept, displayed a seasonal cycle and daily variability that are remarkably similar to that shown by modern-day measurements taken from Sydney's Observatory Hill, and with similar year-to-year variability. The study showed that there is very good agreement between the historical and modern temperature records, with the exception of slightly higher readings in the summer months and marginally cooler winter temperatures.[19] This may be due to the way the thermometers were exposed: that is, the early absence of Stevenson screens that shield meteorological instruments from the influences of direct heat radiation and provide adequate ventilation, moderating the registration of extremes, generally explains the differences between twentieth-century and earlier instrumentation.[20] These results suggest that the work of Bradley and Dawes is useful for examining relative (rather than absolute) climate variations experienced during the first years of European settlement in Australia.

Figure 3 shows the daily temperature records kept by Bradley and Dawes. Bradley's data are noon temperatures drawn from the ship's log from HMS *Sirius*, before William Dawes's observatory was established in September 1788. A definite cool bias in the temperature record is seen throughout 1788. There were a relatively small number of hot days in early 1789, and the summer of 1789-1790 brought a short period of intense heat. It was not until the summer of 1790-1791 that a consistent series of high temperatures in the thirties and low forties (°C) was experienced in Sydney Cove. That period, as is discussed below, coincided with the onset of a hot and dry drought period.

While this data is generally in accord with modern expectations of the effects of ENSO fluctuations, because climatologists have high requirements of scientific "proof" they are reluctant to confirm a direct connection. They believe that despite the apparent presence of La Niña conditions from 1788-1790 and El Niño conditions from 1791-1793 in the Pacific, the temperature record kept by Bradley and the pressure records kept by William Dawes do not show a climatic signal strong enough to be statistically defined as a La Niña event in Sydney (an area with a modest 20th century ENSO signal). They are more content to describe the climate and weather variations during this period as "El Niño-like" or "La Niña-like" rather than asserting the presence of "true" ENSO conditions.

LA NIÑA RAINS, STORMS, AND FLOODS, 1788-90

FROM THEIR FIRST ARRIVAL at Sydney Cove in January 1788, the convicts and their guards faced huge challenges from the physical environment that were compounded by difficulties imposed by distance, ill-preparedness, and bad luck. The soil was difficult to till and the hardwood trees were challenging to remove; much of the seed brought from home had spoiled during the voyage; the convict workforce employed to establish agriculture was inexperienced and unreliable; supplies were limited and were not sufficiently replenished until the arrival of the Second Fleet in mid-1790. The weather also posed some difficulty because of its unfamiliarity (such as the unknown challenges of hot and dry summers compared with England) and because of the frequency and strength of cool periods, storms and floods during the first two years that are likely associated with La Niña conditions.

Wind and weather challenged the process of colonization from the day of foundation. Realizing that Botany Bay, the First Fleet's initial landing place, was unsuitable for permanent settlement, Governor Arthur Philip gave orders for the entire fleet to sail north to nearby Port Jackson. The task was made difficult, nearly ending in disaster, because of stormy conditions. Whether these

Figure 1. Early View of Port Jackson, by William Bradley, 1788.

Courtesy State Library of New South Wales.

can be associated with a La Niña is not entirely clear, but should not be ruled out. On the morning of January 24, 1788, strong headwinds prevented the ships from leaving Botany Bay. Philip Gidley King, a naval officer on the *Supply*, wrote: "the wind blowing strong from the NNE prevented … our getting out … on the 25th … we were obliged … to wait for the ebb tide and at noon we weighed and turned out of the harbour."[21] Captain John Hunter of the *Sirius* recorded that "the wind continued to blow strong all this day … in the evening there was a good deal of thunder and lightening."[22] George Worgan, Surgeon on the *Sirius*, wrote: "Friday 25th … the wind coming to blow hard, right in to the bay, the *Sirius* and the transports could not possibly get out."[23] "A great sea rolling into the bay" continued to buffet the ships, causing ripped sails and a lost boom as the ships were blown dangerously close to the rocky coastline.

According to Marine Lieutenant Ralph Clark: "if it had not been by the greatest good luck, we should have been both on the shore on the rocks, and the ships must most have been all lost, and the greater part, if not the whole on board drowned, for we should have gone to pieces in less than half of an hour."[24] Finally, after what Arthur Bowes described as: "with the utmost difficulty and danger with many hairbreadth escapes got out of the harbour's mouth … it was next to a miracle that some of the ships were not lost, the danger was so very great."[25] By 7 o'clock on 26 January 1788 all of the First Fleet ships had safely arrived in Port Jackson.[26]

Rain and storms continued to punctuate the early days in Sydney Cove, making the establishment of the camp very difficult. Lieutenant Clark noted: "Thursday 31 January–what a terrible night it was ... thunder, lightening and rain. Was obliged to get out of my tent with nothing on but my shirt to slacken the tent poles."[27] Further storms disrupted the disembarkation of the convict women on February 6, when Arthur Bowes described the landing during the startling intensity of a summer storm: "They had not been landed more than an hour, before they had all got their tents pitched or anything in order to receive them, but there came on the most violent storm of lightening and rain I ever saw. The lightening was incessant during the whole night and I never heard it rain faster. About 12 o'clock in the night one severe flash of lightening struck a very large tree in the centre of the Camp, under which some places were constructed to keep the sheep and hogs in. It split the tree from top to bottom, killed five sheep ... and one pig."[28]

This particular storm with its casualties was so extreme that it was mentioned in a number of records including those kept by Phillip, Collins and others. Worgan noted in an account to his brother written five months later: "The thunder and lightning are astonishingly awful here, and by the heavy gloom that hangs over the woods at the time these ... commotions, and from the nature of the violence done to many of the trees, we have reason to apprehend that much mischief may be done by lightning here. Indeed we have experienced its fatal effects since we have been here, for one night 6 sheep, 1 lamb and 2 pigs that were lying under a tree were all killed and the tree violently riven. Two or three other trees have been riven in the same manner by lightning since we came here."[29]

The number of comments on the coolness of the weather in the early months of 1788 is rather surprising given that the settlers came from England but, as noted above, is borne out by Bradley's temperature observations. These show low temperatures during the summer and early autumn, including noon temperatures that reached a maximum of 26.7°C in January 1788, which is considered cool by today's standards. As Figure 3 also shows, Bradley's data implies that the winter in 1788 was a long and cool one.

Another aspect of the weather that was often commented upon in the early months was its changeability, oscillating from wet and cold to hot and humid. Marine Lieutenant John Watts noted:

> During the seven days we were in Botany Bay [January 1788] the weather was generally fine, and very warm. The thermometer on a mean stood at 78° [25.6°C]. It never exceeded 80° [26.7°C] and one day, which was thick and rainy, the wind blowing strongly from the south, it fell to 63°[17.2°C]. In Port Jackson the weather was at first much the same, but afterwards, the days became very hot, and the nights constantly brought on tremendous thunder, lightning, and rain. The thermometer, at eleven o'clock in the forenoon, was generally

> about 80° [26.7°C] but when the sea breezes set in it usually fell two or three degrees. One very sultry day was felt soon after the arrival of the fleet. The thermometer, on board, stood at 88° [31.1°C] and on shore, though in the shade, at 92° [33.3°C]. On the 15th of March was a terrible squall of wind, accompanied by thunder, lightning, and rain. The thermometer then fell from 80° [26.67°C] to 50° [10°C] and in other squalls it frequently fell 15 or 20 degrees [°F].[30]

Worgan was also struck by the sudden changeability: "the weather for the greatest part of the time, serene, moderately pleasant . . ., tho at times the vicissitudes from serenity to squalls of wind, accompanied with terrible thunder and lightning are sudden and violent, and from a dry sultry heat, chilly dampness (occasioned by heavy night dews) considerable. The thermometer on shore in the shade has been up to 85 [29.4 °C] & 90 [32.2 °C] at noon and by sunset has fallen to 50 [10°C] or 60 [15.6°C], the fall of 25 or 30 degrees [F] is common."[31]

Summarizing the climate experienced from January until June 1788, Worgan wrote: "it is just now the middle of winter, and the weather is for ye most part clear, pleasant & moderately warm, but it is very cold at times (Therm 44 [6.7°C]) in the mornings & evenings and I think we have more frequently a rainy, damp, chilly day than we used to have a month ago but no snow, nor frosts."[32]

More "inclement, tempestuous weather" persisted throughout the winter of 1788 making the development of the settlement difficult, and most likely hindering the establishment of agriculture as supplies dwindled and the need for crops became increasingly urgent. Collins wrote: "During the beginning of August much heavy rain fell, and not only prevented the carrying on of labour, but rendered the work of much time fruitless by its effects; the brick-kiln fell in more than once, and bricks to a large amount were destroyed; the roads about the settlement were rendered impassable; and some of the huts were so far injured as to require nearly as much time to repair them as to build them anew. It was not until the 14th of the month, when the weather cleared up, that the people were again able to work."[33]

The wet and cold were not the only problems facing the few farmers who were struggling to grow food for the settlement. A high proportion of the seeds that had been brought on the long voyage failed to germinate, and those that did often withered in the ground because of a combination of inexperience, cool weather, poor soils, and pests. Watkin Tench noted that much of the land seemed "cursed with everlasting and unconquerable sterility."[34] By September, the first crops had largely failed, supplies were increasingly scarce and the colony began to suffer from serious food shortages.

On October 2 the *Sirius* was despatched to Cape of Good Hope (South Africa) to fetch provisions, but did not arrive back until April 1789. Until the *Sirius*'s return, rations were cut back, further reducing productivity in the hunger-weakened colony. While they waited for fresh supplies to arrive, the *Golden Grove* took a small contingent of convicts and marines to the recently established penal colony on Norfolk Island, 1,600 kilometers northeast of Sydney. The land there was pronounced more fertile than Sydney Cove and the local trees of better quality, but the rocky cliffs surrounding the island meant that the timber could not be loaded on the ship for transport back to Sydney Cove. Green turtles were found there and the *Golden Grove* brought a few back to supplement Sydney's food supply. During 1789 everyone from the convicts to Governor Phillip survived on rationed and generally imported food. Indigenous animals (notably kangaroos), birds, and fish provided a dietary supplement, but overall the Europeans showed little interest in the local food, particularly plants, upon which the Aboriginal people had existed for thousands of years, but which the new arrivals found unappetizing.

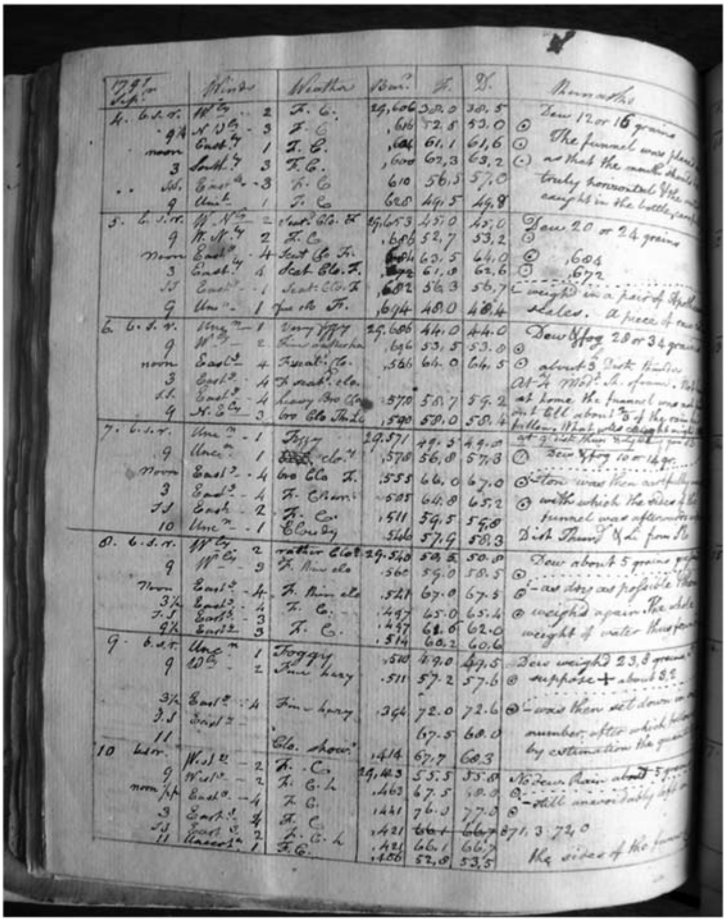
The winter of 1789 appears to have offered little respite. An examination of the maximum temperatures recorded by Dawes shows that it was another relatively cold year, and on one wintery day, June 12, the temperature only reached 6.9°C. The lowest official June temperature recorded at Sydney's Observatory Hill since 1876 is 9.7°C, on June 13, 1899. Even factoring in a cool bias of up to 2°C noted by Gergis et al., the 1789 temperature appears to be cooler than Sydney's long term average recorded by modern meteorological records.[11]

By contrast, the summer of 1789 brought the first onset of really hot weather, although only on a relatively small number of days but including the hottest day in the first five years of settlement recorded by Dawes: 41.4°C on December 25, 1789. However, this is below later official hottest maximum temperatures, and as Dawes's temperature record is found to slightly overestimate maximum temperatures compared with modern twentieth-century observations, it may have been even cooler.[35] Once again, it is worth remembering that limited confidence can be placed on absolute values suggested by the early instrumentation. Nevertheless, such high temperatures placed extra stress on the settlement and its attempts to grow food and live comfortably in the new environment.

The weather remained changeable during this second summer and bursts of high temperature were interspersed with flooding downpours, as Collins recorded in February 1790: "[In] the month of February ... the weather was extremely unfavourable; heavy rains, with gales of wind, prevailing nearly the whole time. The rain came down in torrents, filling up every trench and cavity which had been dug about the settlement, and causing much damage to the miserable mud tenements which were occupied by the convicts; yet, bad as the weather was, several gardens were robbed, and, as at that time they abounded with melons and pumpkins, these became the objects of depredation in common with other productions of the garden."[36]

Bleak weather continued into March, and the situation was further aggravated when in April 1790 the *Sirius*, which was en route to the Cape for supplies and was the settlement's main contact with the outside world and source of

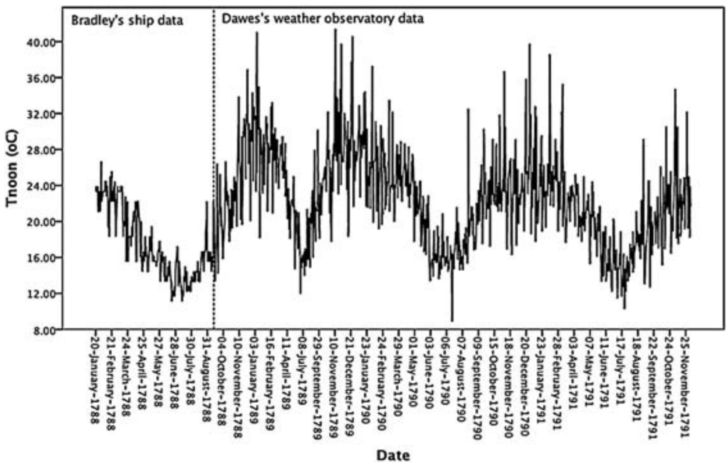
Figure 2. Sample Page of Weather Observations Kept by William Dawes.



Royal Society of London. Photograph by Joëlle Gergis.

supplies, was wrecked on Norfolk Island. Collins wrote: "The weather had been very wet during this month; torrents of rain again laid every place under water; and many little habitations, which had withstood the inundations of the last month, now suffered considerably ... at this time the Supply returned from Norfolk Island, with an account of a disaster which depressed even the unthinking part of the inhabitants, and occasioned universal dismay. A load of accumulated evils seemed bursting upon their heads. The ships that had so long been expected with supplies were still anxiously looked for; and the *Sirius*, which was to have gone in quest of relief to their distress, was lost upon the reef at Norfolk Island ... bad weather immediately ensued, and, continuing for several days, the provisions could not be landed, so high was the surf occasioned by it."[37]

Figure 3. Reconstruction of Weather Conditions.



Compiled by the authors.

A noon temperature reconstruction of weather conditions experienced at Sydney Cove, January 20, 1788–December 4, 1791, using William Dawes's weather journal (September 14–December 6, 1791) and temperatures taken by William Bradley aboard the Sirius anchored in Sydney Harbour (January 20, 1788–September 13, 1788), shows distinct seasonal variation comparable to twentieth-century observations recorded from Sydney. Dotted vertical line shows change in data source from ship to land data.

Spirits would have been even lower if the settlers had realized that the supply ship *Guardian*, which had been belatedly sent from Britain in September 1789, had also been wrecked off South Africa in the previous December. How far the unfamiliar and changeable weather had inhibited the growth of food in the settlement is unclear, but the attempts to produce crops were generally unsuccessful. The loss of the *Sirius* brought Sydney Cove to the brink of famine, and further drastic ration reductions were enforced. Collins wrote: "It was unanimously determined, that martial law should be proclaimed; that all private stock (poultry excepted) should be considered as property of the state ... the general melancholy which prevailed in the settlement when the above unwelcome intelligence was made public, need not be described; and when the *Supply* came to an anchor in the cove everyone looked up to her as to their only remaining hope ... it was determined to reduce still lower what was already too low ... very little labour could be expected from men who had nothing to eat."[38]

It was into this impoverished situation that the Second Fleet arrived in June 1790, bringing some limited supplies but also more than eight-hundred convicts, most of whom through starvation and ill treatment on the voyage were ill, weak, and incapable of work. They compounded the settlement's problems rather than bringing the looked-for relief.

THE FIRST AUSTRALIAN DROUGHT, 1790-1794

WHILE MANNING CLARK CLAIMED that the “the material fortunes of the colony improved quickly after the arrival of the Second Fleet” in June 1790, the situation was not that simple. Indeed, the Second Fleet could hardly have arrived at a worse time for any hopes of making the colony self-sufficient in food production in the short-term. While imported supplies became more regular from the second half of 1790, the weather made self-sufficiency even more difficult. The palaeoclimatic record tells us that in 1791 ENSO moved into an El Niño phase, but it was from mid-1790, in advance of the identified onset of the El Niño, that rain became scarce. The onset of dry conditions a few months in advance of an El Niño is an unusual phenomenon, but is not unknown. Whatever the cause, the drought that commenced in 1790 made life and agriculture even more difficult.

Despite the fact that the colonists suffered the effects of their first Australian drought, including water shortage and further crop failure, apart from Neville Nicholls and Richard Grove there has been little or no mention of the drought or its effects. Even in the drought histories of Australia this first drought is seldom mentioned, and its existence is treated as a footnote to later droughts that had a greater impact on a larger and more complex society. William Stanley Jevons merely stated “the year 1791 was also a drought” after he made a mention of a few months in mid-1789 that had little rain.[39] H. C. Russell cited the extreme heat at Sydney Cove and also quoted Samuel Bennett’s early history of Australia, *Australian Discovery and Colonisation*, which commented that drought was felt in 1790-1791.[40] Foley, in his book *Droughts in Australia* did not go into any detail, although he listed 1788-1791 as a dry period.[41] The first person to become fully aware of the drought and associate it with an El Niño event was climatologist and climate historian Neville Nicholls.[42]

For the colonists, however, the effects of drought were far more intense than historians have previously acknowledged. As early as November 1790 Watkin Tench described the impact of drying conditions on the colony’s food supplies: “Cultivation, on a public scale, has for some time past been given up here (Sydney), the crop of last year being so miserable, as to deter from further experiment; in consequence of which, the government farm is abandoned … Vegetables are scarce … owing to want of rain. I do not think that all the showers of the last four months put together, would make twenty-four hours rain. Our farms, what with this and a poor soil, are in wretched condition. My winter crop of potatoes, which I planted in days of despair (March and April last), turned out very badly when I dug them about two months back. Wheat returned so poorly last harvest, that very little, besides Indian corn, has been grown this year.”[43]

Another sign of the drought was the onset of more sustained hot weather than had previously been experienced by the colonists. Dawes’s temperature record shown in Figure 3 indicates a period of relatively warm and hot

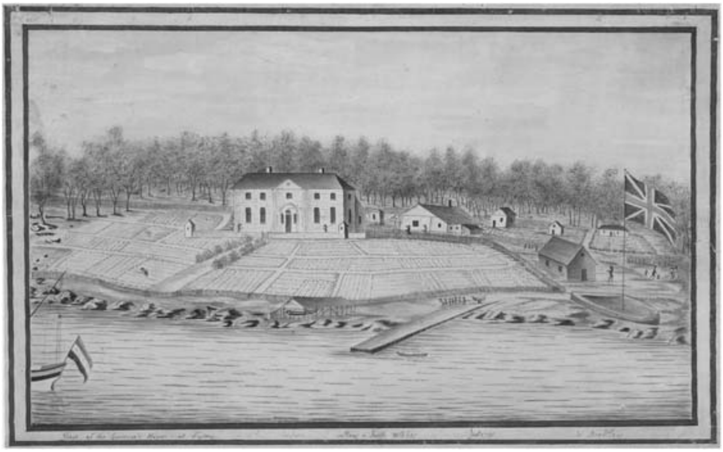
Figure 4. William Dawes (1762-1836).

Courtesy Australian Bureau of Meteorology.

William Dawes was an astronomer, engineer, and surveyor with the founding First Fleet. He recorded the first Australian meteorological observations from September 1788 to December 1791.

temperatures from September 1790 to March 1791. While the data does not show exceptionally high temperatures during the summer, the generally sustained heat and frequent challengingly high temperatures took their toll on both the colonists and the indigenous fauna. Watkin Tench lamented in April 1791 that "I scarcely pass a week in summer without seeing it rise to 100 degrees [37.8°C]; sometimes to 105 [40.6°C]; nay, beyond even that burning altitude."[44] He further commented that, at times, it "felt like the blast of a heated oven" and that: "Even [the] heat [of December 1790] was judged to be far exceeded in the latter end of the following February [1791], when the north-west wind again set in, and blew with great violence for three days. At Sydney, it fell short by one degree of [December 1790] but at Rose Hill [Parramatta], it was allowed, by every person, to surpass all that they had before felt, either there or in any other part of the world ... it must, however, have been intense, from the effects it produced. An immense flight of bats driven before the wind, covered all the trees around the settlement, whence they every moment dropped dead or in a dying state, unable longer to endure the burning state of the atmosphere. Nor did the 'perroquettes,' though tropical birds, bear it better. The ground was strewn with them in the same condition as the bats."[45]

Figure 5. A View of the Governor's House, 1791, by William Bradley.



Courtesy National Library of Australia. Courtesy National Library of Australia.

Collins also commented on the remarkable effect of the heat on the local wildlife experienced on 11 February 1791: "Fresh water was indeed everywhere very scarce, most of the streams or runs about the cove being dried up. At Rose Hill [Parramatta], the heat on the tenth and eleventh of the month, on which days at Sydney the thermometer stood in the shade at 105°F [40.6°C], was so excessive (being much increased by the fires in the adjoining woods), that immense numbers of the large fox bat were seen hanging at the boughs of trees, and dropping into the water ... during the excessive heat many dropped dead while on the wing ... In several parts of the harbour the ground was covered with different sorts of small birds, some dead, and others gasping for water."[46]

Governor Arthur Philip elaborated on the staggering scale of the scene: "from the numbers that fell into the brook at Rose Hill [Parramatta], the water was tainted for several days, and it was supposed that more than twenty thousand of them [bats] were seen within the space of one mile."[47]

On returning from Norfolk Island John Hunter in February 1791, former captain of the doomed *Sirius*, described the scene at Sydney Cove: "All the streams from which we were formerly supplied ... were entirely dried up, so great had been the drought; a circumstance, which from the very intense heat of summer, I think it probable we shall be frequently subject to."[48]

As Hunter's comments suggest, another theme running through early accounts of daily weather was speculation about the longer-term nature of the climate—a searching for patterns and speculation about the regularity and cycles of weather events. These immigrants from a green and pleasant island in the cool/mild climatic zones of the northern hemisphere now found themselves scratching the infertile soils in a very different environment in the high pressure dominated lands of the southern hemisphere sub-tropics. The weather and climate were still largely a mystery but were vital elements in their need to conquer the land and turn it to the production of European agriculture and grazing animals. Drought and the irregularity and unreliability of the weather were of particular concern in these foundation years, and would become even more so over the next two centuries—conditions that we now recognize as largely resulting from the ENSO cycle.

In the absence of experience and meteorological data, the first settlers could only speculate, and as the summer of 1790-91 neared its end, on 4 March 1791 Governor Phillip wrote to the Colonial Secretary: "From June until the present time so little rain has fallen that most of the runs of water in the different parts of the harbour have been dried up for several months, and the run which supplies this settlement is greatly reduced, but still sufficient for all culinary purposes … I do not think it probable that so dry a season often occurs. Our crops of corn have suffered greatly from the dry weather."[49]

This prediction of infrequent dry seasons was wrong, as later colonists and generations of Australians would testify. Nor did the autumn of 1791 bring relief. In modern Sydney, autumn and winter rains are important for recharging reservoirs and rejuvenating parched land, and the failure of these rains can have a devastating effect on agriculture, as it did two centuries ago. In April 1791 Arthur Phillip wrote: "The dry weather continued … the quantity of rain which fell in the month of April, was not sufficient to bring the dry ground into proper order for sowing the grain … this continuance of dry weather, not only hurt their crops of corn very much, but the gardens likewise suffered greatly; many being sown a second and a third time as the seed never vegetated, from want of moisture in the soil."[50]

As a result of the drought, Governor Phillip was, again, forced to tighten rations as the food supply of the struggling colony began to dwindle: "Little more than twelve months back, hogs and poultry were in great abundance, and were increasing very rapidly … but at this time [April 1791] there was seldom any to sell."[51]

David Collins described the dry conditions that persisted into June 1791: "The ground was so dry, hard and literally burnt up, that it was almost impossible to break it with a hoe; and until this time there has been no hope or probability of the grain vegetating."[52] In 1791 Watkin Tench noted: "The extreme dryness of the preceding summer has been noticed. It had operated so far in the beginning of June that we dreaded a want of water for common consumption, most of the little reservoirs in the neighbourhood of Sydney being dried up. The small stream near the town was so nearly exhausted … that a ship could not have watered at it."[53]

The irregularity of the freshwater stream and the worsening drought led to the first documented account of water restrictions imposed on Sydney. To try and control the amount of water flowing past the settlement, holding tanks were cut into the sandstone banks to provide storage for the water.

In November 1791 Collins wrote: “By the dry weather which prevailed the water had been so much affected, besides being lessened by the watering of some transports, that a prohibition was laid by the Governor on the watering of the remainder of Sydney … to remedy this evil, the Governor had employed the stone-mason’s gang to cut tanks out of the rock, which would be reservoirs for the water large enough to supply the settlement for some time.”[54] This became known as the “tank stream,” and may be the earliest example of water conservation in Australia’s European history.[55]

These accounts of extremely hot, dry conditions in the summer of 1791 correspond well to the distinct clustering of warm extremes in noon temperatures seen in Figure 3. This may suggest both the true intensity of experiencing temperatures over 40°C and the fact that the newly arrived Europeans were simply not used to the intense heat of an Australian summer.

How severe the drought was and how badly the colonists were affected by it is partly a matter of conjecture. While the accounts of the colonists indicate that for them the heat and dry were unfamiliar and severe, it is not possible to assess the conditions objectively or to compare with later droughts. Agricultural historian Angus R. McGillivery, for one, gives the impression that upon Phillip’s departure in 1792, the agricultural situation at Port Jackson was very well developed, “demonstrating the capability of its salubrious and secure situation and its bountiful hinterland to refresh mariners and voyagers and to supply and service merchantmen and whalers.”[56] The flourishing gardens and small farms of free settlers were set back by drought, which “had made circumstances very grave for the new colony” particularly prior to the arrival of the supply ships. However, McGillivery asserts that Port Jackson could even continue its role as a port of refreshment in 1791, despite one of the “strongest known El Niño occurrences during the severe 1790-92 global drought.”

Unfortunately, the Dawes meteorological record finished in spring 1791 and we are restricted thereafter to impressionistic accounts. According to Collins, the colony experienced very hot conditions in December 1792:

> The weather during December had been extremely hot. On the 5th the wind blew strong from the northward of west, and, to add to the intense heat of the atmosphere, the country was everywhere on fire. At Sydney, the grass at the back of the hill on the west side of the cove, having either caught or been set on fires by the natives, the flames, aided by the wind which at that time blew violently, spread and raged with incredible fury … at different times during this uncomfortable day distant thunder was heard, the air darkened, and some drops of rain fell. The apparent danger from the fires, drew all persons out of their houses; and on going into the parching air, it was scarcely possible to breathe; the heat was insupportable; and vegetation seemed to suffer much, the leaves of many culinary plants being reduced to powder. The thermometer in the shade rose above one hundred degrees. Some rain

> falling toward evening, this excessive heat abated. At Parramatta, and Toongabbe, also, the heat was extreme; the country there too was everywhere in flames.[57]

By April 1793, Collins reported that: "the rain of April [1793] came too late to save the Indian corn of the season, which now wore a most unpromising appearance."[58] By August 1793: "much apprehension was entertained for the wheat, which began to look yellow and parched for want of rain."[59]

However, from August 1794 there are reports that conditions in the settlement gradually improved, and there were signs that the drought was beginning to break: "Notwithstanding the weather was unfavourable during the whole of this month, the wheat every where looked well, particularly at the settlement near the Hawkesbury."[60] The arrival of more regular supplies was complemented by the clearing and cropping of more fertile and better-watered land around Parramatta and then along the Hawkesbury River. By January 1795 Collins commented on the agriculture now beginning to thrive as heavy rains began to soak the floodplains of the Hawkesbury River: "The Indian corn looked every where remarkably well; it was now ripening, and the settlers on the banks of the Hawkesbury supposed that at least thirty thousand bushels of that grain would be raised among them.... In consequence of the heavy rains, the river at the Hawkesbury rose many feet higher than it had ever been known to do; by which several settlers suffered very much. At Toongabbe the wheat belonging to Government was considerably injured. At Parramatta the damage was extensive: the bridge over the creek, which had been well constructed, was entirely swept away, and the boats with their moorings carried down the river."[61]

The first major drought experienced by Australia's European settlers had finally come to an end, forewarning of the aridity and the environmental challenges that have been a fundamental part of European occupation and economy in Australia. The Sydney founders had begun to speculate upon the limitations of cycles of drought, water availability and poor soils, but because of their sense of racial and cultural superiority, they and later colonists seldom consulted the indigenous people who had known the land for thousands of years. What the colonists faced in the nineteenth century was a long period of trial and error as they gradually shaped some understanding of the environment and its climate.

During the first forty years of colonization there was hope, if not expectation, that like North America the central part of the Australian continent would be occupied by well-watered grassy plains whose rich soils were waiting for agricultural sods to be turned. There might also be a large inland sea that would moderate the climate and provide endless water. What they found, by contrast, was a continent whose best soils are poor by world standards, and are found only in a few places around the coast. The "outback" that they encountered as they pushed inland consists largely of ancient, leached, sandy and infertile soils. The climate is not moderate, but principally arid and semi-arid except in the coastal fringes. The environmental history of Australia, like the settlement of the continent, is largely about the processes of coming to terms with these environmental limitations, and finding ways of overcoming them. The first five foundation years in Sydney had introduced all these factors, but few colonists or historians have recognized the significance of the experience.

CONCLUSION

THE WRITING OF CLIMATE HISTORY, like environmental history more generally, involves rather different methodological challenges from more conventional forms of history, most particularly the need to master and incorporate a level of relevant science–something that does not always come easily to people trained in the humanities. In this article, and in a wider project in which we are involved to build a weather and climate profile of Australia prior to 1900, going back at least several hundred years, we have brought together a team of climate scientists and environmental historians. In many ways it is a natural mix, and we excite each other with the knowledge and the insights we bring to the work. At the same time, there are challenges as we seek to work within each other's concepts and methodologies in such areas as the nature of evidence and conclusive scientific "proof."

A particular issue for those who write climate history is that both historical records and our own tendencies draw us toward examining extreme weather conditions. These were generally the most important events experienced by the past commentators, and historians potentially further exaggerate extreme conditions by noting and emphasizing them. The "normal" conditions that are chronologically more prevalent are seldom commented upon by either party. A further complication is that historical observers vary in the qualitative standards used to reflect climate conditions, and are subject to the diversities of language and cultural and individual experiences. For example, a hot temperature or wet or dry period are relative to the environment in which one is experienced. It has often been pointed out that "drought" is a cultural construct as well as a climatic observation, and the British colonists' perception of climate was formed in a cool and pleasant land where a few weeks without rain was considered a "drought." According to Jones, the best measures are those that are objective (frost day and snow day counts, freezing of rivers, crop harvest dates, and yields) and less dependent on individual observers.[62] However, even when such rich data is available, it is not as definitive as scientific data can be in quantifying past weather conditions.

This article has sought to overcome that limitation by its use of the records kept by Bradley and Dawes in foundation Sydney and of wider palaeoclimatic data, melding them with commentaries on the weather to identify both the conditions that occurred and their effect on the infant settlement. This has shown that weather was more varied and challenging than has been identified previously, as were the effects on the early European settlement from 1790-1793. Cool and wet conditions predominated from January 1788 to winter 1790, and hot and dry weather, a drought, was more prevalent from about the middle of 1790. In all likelihood, this was a reflection of the ENSO cycle at that time, initially a La Niña and then the onset of a strong El Niño.

Wherever possible, we advocate the use of meteorological or palaeoclimatic data for direct comparison with historical sources in the development of credible environmental histories. This provides an independent means of assessing the large-scale climate cycles that may have influenced the local weather conditions. We suggest that the technique proposed here has the potential to improve the reliability of the interpretation of how physical factors like weather and climate have influenced past societies.

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