El Niño, Irrigation Dams and Stopbanks:

Examining the repercussions of the 1876-78 El Niño in Australia and New Zealand

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Our telegrams to-day still inform us of drought in the South [Island of New Zealand], of inconvenience and suffering to the people from want of water, and of imminent danger that there will be a considerable falling off in the harvest… In the North, though under a hotter sun than shines in Otago or Canterbury, we have as yet felt but little inconvenience from the drought, which has, indeed, been not so prolonged as in the South. The rainfall has, however, been considerably less than for the average of years. Last night, there were symptoms that wet weather was approaching, but it may be some days distant. It is somewhat singular that of late a great part of the world has been tormented by drought. The famine in India was caused by the failure of the periodical rains; the suffering and loss in Australia has been great; Egypt is threatened with scarcity, owing to the scanty overflow of the Nile; and we observe by the papers received last mail that the people of New York were alarmed that the Croton supply was about to fail.[1]

The famine in Southern India continues to be very severe, and it is much feared that the July and August crops will be a comparative failure, in which case the pressure on the Indian Government and food resources of Bengal and Burmah [sic] will be immense. The famine in Northern China is far worse than in Ceylon. An appeal from the Netherlands Consul-General in Shanghai for subscriptions to the Eastern world gives a harrowing account of sufferings and deaths, and no Government aid is available for the poor wretches; each 4 dol. subscription is calculated to save a life.[2]

Introduction

These are just two of many reports that can be found in Australian and New Zealand newspapers in 1877 that indicate an emerging awareness of the interconnectedness of climate, and of the shared weather-based hardship that was being suffered across large regions of the planet in 1877. They demonstrate an early consciousness of links that about a century later would be identified as manifestations of an El Niño event which in turn is one of the extremes of the El Niño Southern Oscillation (ENSO). Such reports also underline the fact that the 1876-78 El Niño is recognised as one of the most severe in modern history. Mike Davis drew our attention to it in 2001 in his moving exposé and polemic, *Late Victorian Holocausts*.[3] He gave a graphic account of the tragic results, particularly in the northern hemisphere where there are estimates of human mortality of up to 10.3 million in India and 20 million in China from malnutrition and drought-related diseases.[4]

Australia and New Zealand also experienced climatic fluctuations as a result of the El Niño, though clearly nowhere near the extremes of monsoonal Asia. My study of three El Niño periods, 1864-68, 1876-78 and 1895-1903, and their impacts in Australia, New Zealand and the South Pacific, is presenting a more complex picture of ENSO impacts than has often been recognised. These can be summarised as: the influences of El Niño are highly variable; that El Niño events often held back or retarded colonial settlement, although generally only temporarily; and that their impact on climate was a major factor in the development of public policy relating to land settlement and water distribution.

Some scholars will react to such assertions as representing a new form of 'environmental determinism', a term that is forever damaged by its association with race-based dogma and eugenics. What I argue has nothing to do with race, and is not deterministic in its full sense, but an assertion that the environment, specifically climate in this case, is a *major factor* in the economy, development, success and even survival of human societies. Climatic fluctuations may be even more important in colonial settler societies where learning about and adaptation to climate are critical to success.

The 'discovery' and experience of the El Niño-Southern Oscillation (ENSO) in recent decades, and realisation of their impact on the weather in many parts of the globe, has stimulated not only climatological research. Awareness has been raised that ENSO, more specifically El Niño events, have been influential in human history, and a great deal of research has been undertaken to discover the ways they have shaped the human experience. Consciousness of El Niño has come to act as a prism through which we can view the past. However, one problem with this prism (or indeed in focussing on any singular phenomenon in an historical study) is that distortion and over-emphasis are all too easily portrayed by the writer, or perceived by the reader. It is often difficult to identify with absolute certainty both El Niño-related weather phenomena and their repercussions. However, it is possible to observe trends, and to conclude on the basis of available evidence and probability, that El Niños have at times significantly shaped weather events in Australia and New Zealand. In Australia this produces a higher likelihood of droughts and, depending on location, either droughts or floods in New Zealand. The response to droughts in Australia has been to encourage water conservation, manipulation and redistribution, as can be epitomised by the construction of irrigation dams and artesian bores. In New Zealand, by contrast, the response to heavy precipitation and flooding that is often a result of El Niño events, has been to try to control an excess of water, as epitomised by the construction of levee banks, or stopbanks as they are known locally.

In this article I focus on some aspects of the 1876-78 El Niño in Australia and New Zealand. It has become very clear from my study that despite the newspaper reports cited above, in this El Niño as in others, not only were the weather effects far from uniform across the globe, or in the southern hemisphere, but even within Australia and New Zealand the weather in 1876-78 was notably uneven. There are three principal points I will argue.

The first is the variability of El Niños both spatially and chronologically. In India, China and New Zealand 1877 and 1878 were the most affected years. In Australia it was 1876 and/or 1877 that showed significant rainfall changes in most regions, and only in a minority of places did 1878 show signs of a rainfall deficit.

Second, that while there was drought in Australia it was not one of the most serious since European settlement, and had less impact than those that preceded and followed. It was erratic, profound in some places, but relatively short and sometimes mild in its impact. This raises the whole question of the definition of drought – and very roughly I include three criteria in my working definition.

- an extended period of substantially below average rainfall.
- by extended, I mean one of sufficient length to cause widespread natural repercussions such as very low flows in water systems and the decline and death of indigenous flora and fauna. This is an ecological drought.
- by extended, I also mean sufficient to cause widespread economic and social harm to human populations. This is a human drought.

(One of the issues here is that there are or were different levels of aridity that triggered ecological and human droughts. Australian ecosystems, for example, have evolved over millennia to survive aridity and El Niño droughts. Western agriculture and pastoralism have not, and in many ways were unsuited or inappropriate within such an environment. However, human intervention in the environment and damage to ecosystems reduced their tolerance for aridity, lowered their capacity to survive and brought the onset triggers of ecological and human droughts closer together.)

The third point is that the principal effects of the El Niño in New Zealand in some regions were often the opposite of what has normally been described – not droughts but high precipitation and floods.

El Niño-Southern Oscillation (ENSO)

The basic outline of the complex relationships between Sea Surface Temperatures and the Southern Oscillation Index (the see-saw of barometric pressures measured between Darwin and Tahiti) which we know as ENSO was brought together in the 1960s by Jacob Bjerknes. However, it was the severe El Niños of 1982-83 and then the late 1990s that really attracted attention to the phenomena and promoted scientific research and public knowledge.[5] These days there would be few people in Australia and New Zealand who would not recognise the name of El Niño, and perhaps even the opposite extreme, La Niña.

It is widely understood that during an El Niño there is a greater likelihood of storms and rains in the eastern Pacific – along the coasts of central America and adjacent coastlines in South America and California. In the central and eastern tropical Pacific there is a greater likelihood of cyclones. By contrast, in the western equatorial Pacific and further west the monsoon rains are disrupted and severe droughts can occur in South-East Asia, China and India. In Australia there is a high likelihood of below average rainfall, and in New Zealand there is an unusual patchwork

effect. Even wider connections have been seen – Richard Grove has famously or infamously attributed the French Revolution at least partly to El Niño.[6]

These repercussions are largely a response to a reversal of the Walker Circulation, the east-west circulation of air across the equatorial Pacific that normally produces prevailing easterly trade winds (See Figure 1). When, for unknown reasons, warm water pools in the eastern Pacific, often near Christmas, (hence the name El Niño or boy child), it reduces the 'normal' flow of air along the equator, and can even reverse the wind pattern. Higher barometric pressures to Australia's north can disrupt the monsoon and push the Hadley Cell southward, which in turn displaces the rain-bearing systems that cross the southern half of the Australian continent. Rains fail and drought can result.

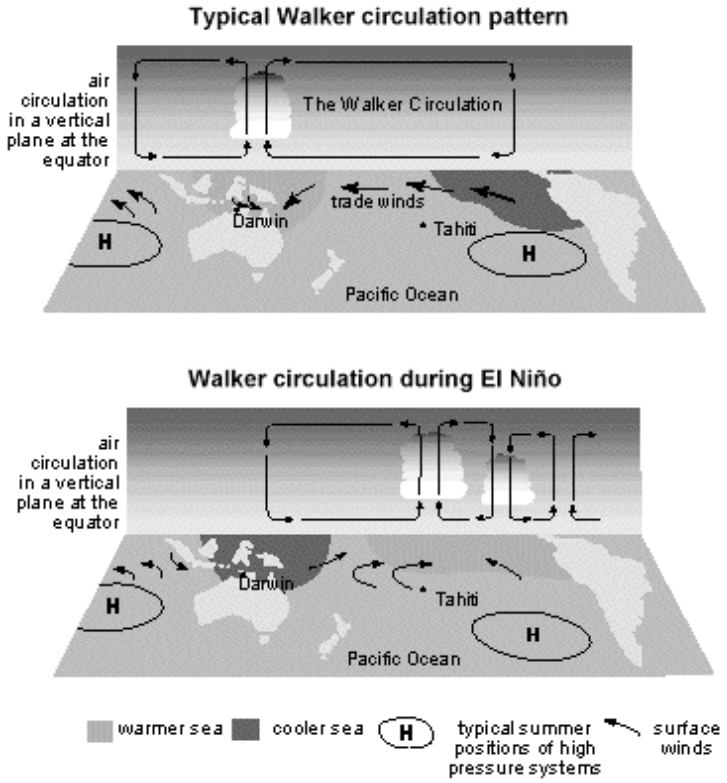

Fig. 1. Walker Circulation – typical pattern and during an El Niño. Bureau of Meteorology, Australia. Source: http://www.bom.gov.au/lam/climate/levelthree/analclim/elnino.htm.

Identification of when El Niños occurred in the 20th century is not very difficult as there is comprehensive data for the main indicators – Sea Surface Temperatures in the Pacific and the Southern Oscillation Index. The second half of the 19th century is a bit less certain, but collection of weather and associated data gathered significant pace and enables the compilation of SST and SOI data that permit a generally accepted chronology of when the most severe El Niños occurred. Prior to the mid-nineteenth century, however, climatic events and influences are less clear, but there has been major research using proxy data to establish the main outlines, especially in South America – research in areas such as dendrochronology, palynology and ice cores, as well as diverse written records of storms, floods and agricultural production. This has

given a general although not universally accepted chronology of El Niños going back over several centuries.[7]

Figure 2 is an example of a compilation of Sea Surface Temperatures for the period of my study. It clearly shows the high spikes of SST that indicate an El Niño event, and very notably that the most pronounced was in 1877-78.[8] However, the effect of that El Niño on regional weather was far from uniform and there is marked spatial and chronological variability. The effects in Australia tended to be brief and erratic, while in New Zealand they were rather more severe.

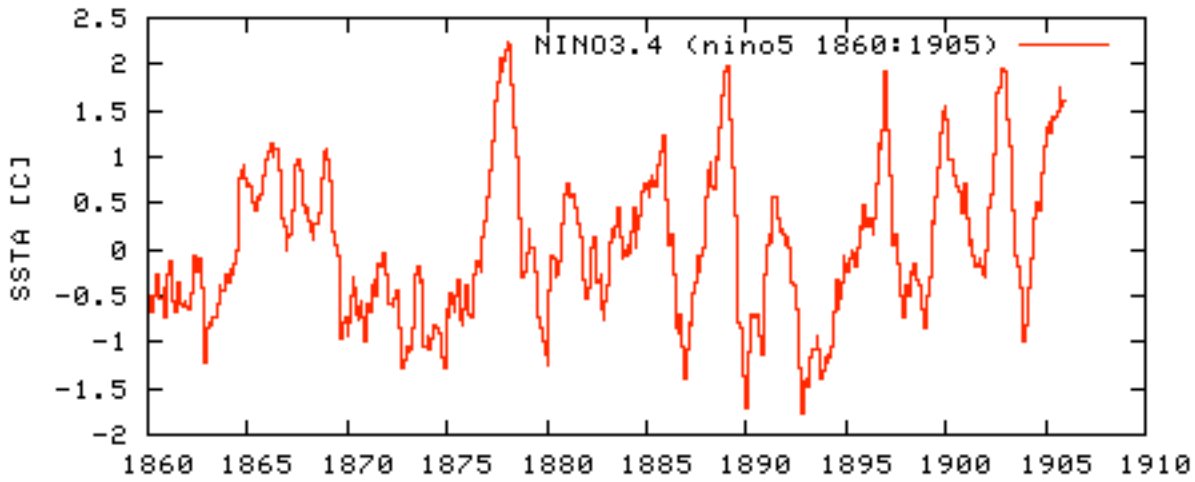

Fig. 2. Sea Surface Temperatures, 1860-1905. Source: Royal Netherlands Meteorological Institute, http://climexp.knmi.nl/.

Sources

Weather recording had only just begun in the Australian colonies and New Zealand in the 1870s, so even where it exists rainfall data cannot always be taken as highly accurate. There are questions about how representative some of the early stations were of the locality in which they were established, and recorded data depend on such matters as the reliability of the local person given charge of the weather station. Hard meteorological data, even when it does exist, can give only a limited insight into climate history.

That is one reason why, as an historian, I have found it desirable and illuminating to use a wide diversity of sources when examining the effects of the El Niños. In particular, local newspapers provide a rich insight into not only what was being experienced at the time, but also what was understood and asserted within the colonial cultures about the climatic conditions and weather. Local papers often provide rich accounts that are an invaluable source for insights into the events and beliefs in a community. They also provide two of the historian's greatest challenges – how to allow for the frailty of human memory and the distorting hyperbole of journalism. All too frequently in dramatic accounts one encounters such phrases as 'the heaviest rain he has ever seen', the 'highest flood that our oldest inhabitant can recall' or 'it has never been so dry since settlement began'. Almost as frequently, a check of the official records, where they are available, will dispute such recollections and judgements. However, these are

methodological challenges to be taken into consideration in the use of such material rather than insurmountable obstacles.

It should also be noted that the rainfall charts in this article show only annual data, and therefore only part of the picture. Monthly figures give a more complex view and indicate high variability; there are months with virtually no rain interspersed with months of well above average falls. Reference is made below to a number of such occasions.

South-eastern Australia

My project is using four case studies in south-eastern Australia: around Burra in South Australia; north-central Victoria and the Riverina region in southern New South Wales, centred on the Murray River town of Echuca; the Hunter Valley in north-central NSW and focussed on Maitland; and the Mary River/Burnett River (Wide Bay) region in Queensland centred on Maryborough and Bundaberg (Figure 3). These were chosen because they represent a range of natural and climatic environments and economic activities,[9] and for three of them there are rainfall records back to the 1870s.

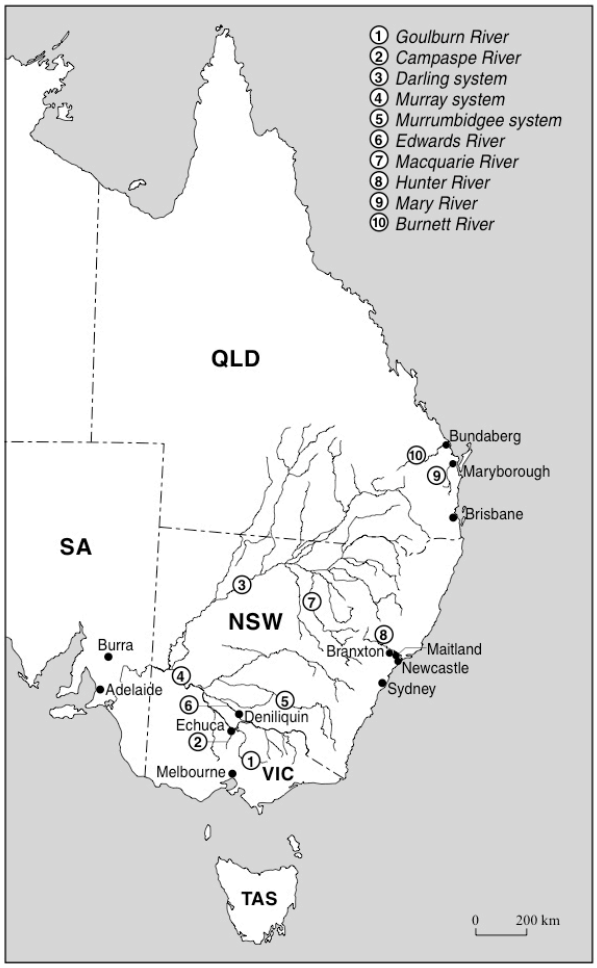

Fig. 3. Map of eastern Australia showing case study sites: Burra in South Australia; north-central Victoria and the Riverina region in southern New South Wales; Hunter Valley (Newcastle and Branxton) in NSW; Mary River/Burnett River region (Maryborough and Bundaberg) in Queensland.

Annual rainfall data (Figures 4, 5 and 6 below) indicate that my South Australian and Victorian/southern NSW case study sites were reasonably hard hit by a drought in 1876 or 1877, but 1878 was a wet year. Further north my case study sites in NSW and Queensland [Figs 7, 8 & 9] were a little below average across 1876-78, but there were wild monthly swings in the rainfall. Not shown by these figures (as there are no detailed or reliable rainfall records for this period in remote regions) is that further west in the arid pastoral zones of NSW and Queensland the drought lasted longer and the effects were more severe. Overall, the rainfall data for south-eastern Australia show 1876-77 as a time of rainfall shortages interspersed with good downfalls. In many regions, good rains returned in 1878. As a result, in most zones drought periods were essentially localised and short (no more than six months), and this was the key factor. While short and intense periods of dry can cause hardship, the most serious Australian droughts (such as those in the 1860s, first half of the 1880s and 1895-1903) have all been the result of the cumulative effects of a number of years of below average rain.

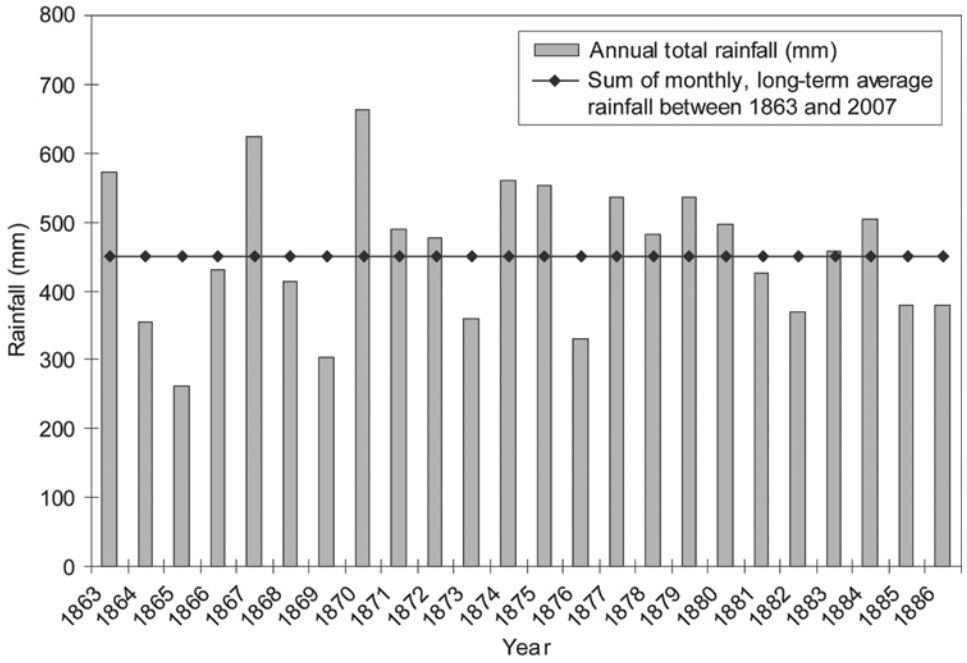

Fig. 4. Burra annual rainfall 1863-1886 and long-term average. Bureau of Meteorology, station 021011

In and around Burra in South Australia, 1876 was the only below average year during the sequence. There were good autumn rains in 1876 but by September there was mounting concern as memories turned back to the devastating 1860s drought:

> The prospects of South Australia have, in the short space of five months, suffered one of the most sudden and terrible reverses known in the history of the colony. We say five months, for the rainy season commences generally before the close of April, and at that time in the present year we had no reason to apprehend a bad season… But the want of the annual rainfall soon changed the aspect of affairs. In the country to the east and north-east [of Burra], a drought began to be feared; and though there were two or three falls of rain which did good for a time, they were

> not followed up by more, and a large portion of the north country is at the present time a desert.[10]

Dust storms became more frequent. However, from early October there was rain in parts of the district which alleviated some of the worst fears. Wheat yields in the 1876-77 harvest, while poor, were not disastrous, and sufficient hay was harvested to avoid a hay famine. The wool clip was light and there were losses of sheep and livestock, including a high proportion of lambs, but the industry was not crippled.[11] By the end of 1876, the worst of the El Niño drought in the Burra region was already over and the next two years would be quite good. There was minimal impact on the town and district, certainly much less than in the El Niños of the 1860s, and the people of Burra were therefore very receptive to the plight of the people of India:

> The Burra Amateur Christy Minstrels, assisted by lady amateurs will give an entertainment in the Institute Hall… in aid of the Indian Famine Relief Fund. The programme is a good one, and the fact, together with the goodness of the cause, should ensure a bumper house.[12]

The *Northern Mail* even felt it necessary to reprimand those residents in the district who did not give to the Fund: 'We trust that for the credit of the district, and the sake of common humanity, these persons will reconsider their decision and give of their abundance to the starving millions of India.'[13]

The wider South Australian experience in this period has been told before, notably by Donald Meinig in the 1960s, although not in the light of its relationship to El Niño as such knowledge was not then available.[14] Meinig showed that following the severe 1860s drought there was a major expansion of agricultural settlement, stimulated by several years of average to good rain in the first half of the 1870s. Areas beyond the previous margins of settlement were thrown open for farmers on credit terms, and a land scramble ensued. The area under wheat grew by about 100,000 hectares between 1872 and 1874, and with generally high yields. By the middle of the decade there was a shortage of suitable new agricultural land and the series of good seasons had provoked such optimism that there was a clamour to do away with the so-called Goyder Line. This was a line of demarcation drawn by Surveyor General George Goyder to show the worst drought affected areas in 1866. It had latterly come to be interpreted as an indicator of where there was sufficient rain for agriculture to be viable; outside Goyder's Line, it was believed, only pastoralism could survive.

Now, with the series of good seasons in the first half of the 1870s Goyder's cautionary line was ridiculed and abundant rain in wheat-growing districts and beyond was seen as proof of a piece of popular mythology - that rain follows the plough. In 1874 the limit on settlement marked by the Goyder line was over-ruled by new legislation, and more good rains in 1875 encouraged a wider spread of settlement, just as the El Niño was setting in. Given the reputation of this El Niño and its effects in India and China, disaster in South Australia might also be anticipated, but this did not happen because the drought in the colony was relatively short and mild. While the harvest of 1876-77 was about half of the previous year, there was good rainfall from early 1877 which encouraged further movement of frontier well beyond Goyder's line over the next few years.[15] South Australia escaped this El Niño relatively unscathed.

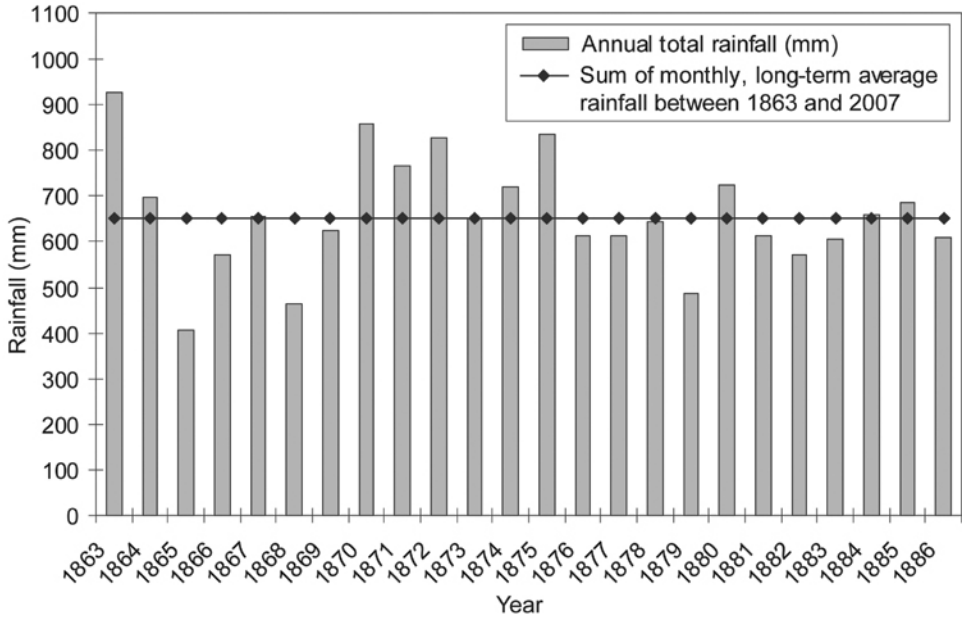

Fig. 5. Melbourne annual rainfall 1863-1886 and long-term average. Bureau of Meteorology, station 86071

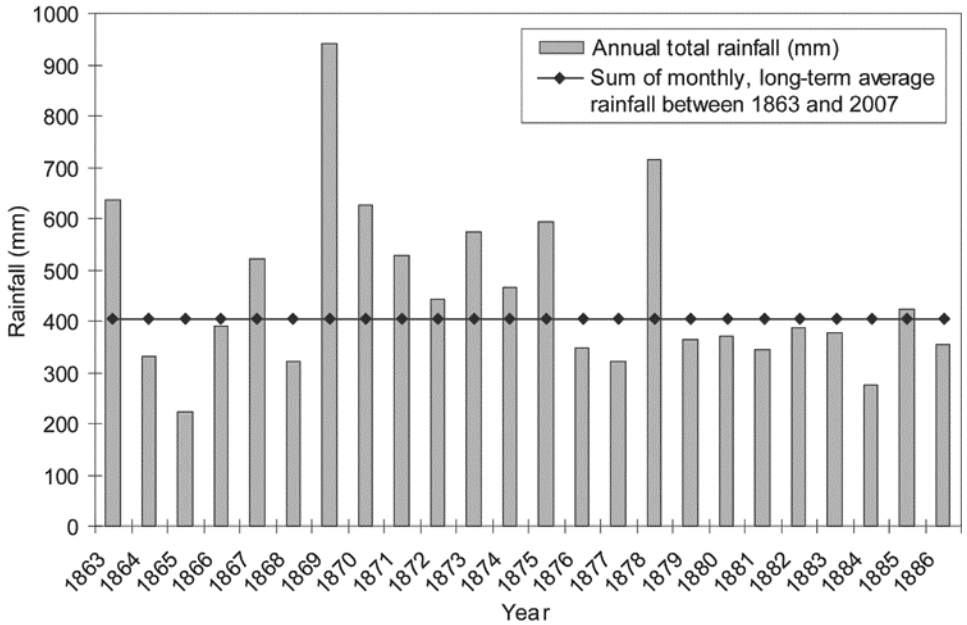

Fig. 6. Deniliquin annual rainfall 1863-1886 and long-term average. Bureau of Meteorology, station 074128

In northern Victoria and southern New South Wales new areas were also opening for agricultural settlement in the 1870s and farmers there were also relatively unimpeded by the El Niño. There are no rainfall figures for Echuca, the main town in my case study, but Melbourne can serve as a reasonably indicative substitute of the general Victorian trends. These show 1876

and 1877 as marginally below average, and 1878 about average. These were not the conditions of a severe drought. Deniliquin in the Riverina region of NSW was more extreme, showing 1876-77 as seriously dry, but 1878 as very wet. Even within the two dry years, however, there was considerable variability. Like Burra, there were good autumn rains in 1876, but thereafter winter was dry and the 'd' word began to be used in spring, especially to the west and north of the Murray River port of Echuca where the *Riverine Herald* expressed its concern in August:

> Fears are entertained in Riverina that there is to be another drought. Feed along the frontages is becoming scarce, and unless a plentiful supply of rain soon comes, stock will suffer great privations from the want of herbage, &c… The result of overstocking is already being felt; on some stations sheep are being travelled for grass, which is everywhere scarce from Moama to the Darling, owing to the continued dry weather, and the sharp biting frosts that have prevailed for the last two months throughout the Riverina district.[16]

Within a week of this being published, however, good rain fell in much of Victoria and southern NSW and it was announced with relief that the 'drought of 1876 is now a thing of the past'.[17] This was over-optimistic and rainfall throughout the region was patchy for the rest of 1876. The summer of 1876-77 was a testing one as there had been little rain in the headwaters of the Murray, and with the normal summer tapering of rain in the Darling and Murrumbidgee catchments, by January 1877 the Murray was particularly low:

> *The Rivers.* – As showing the shallowness of the Murray at Echuca at the present time we may mention that on Saturday last a number of boys and youths were to be seen walking from the bank opposite the wharf, almost into the centre of the stream. The shell of the old "Lady Augusta" – the first boat that navigated the Murray – is now several feet above the level of the water, and in all probability two or three more weeks will see the close of the river season. Both on the Murrumbidgee and the Darling several of the steamers belonging to this port are stuck and have had to discharge or lighten cargo. Our correspondent at Hay telegraphed to us that the river there was scarcely four feet above summer level and we learn privately that it was then falling.[18]

Despite the El Niño there were encouragingly good autumn and winter rains in 1877 and the *Herald* reported in May:

> The accounts from all parts of Victoria, as well as from the neighboring colonies, continue favourable. They agree, indeed, generally in reporting that a finer season has seldom if ever been known. In most parts of Victoria the sowing has been completed, and as may be expected, the appearance of the young crops is entirely satisfactory. During the last fortnight, in which rainy weather has prevailed, there has been no frost in most districts, and the genial and occasionally sunny weather has caused a great growth of grass. As all available means have been everywhere employed to increase the area of cultivation the ensuing crop in Australia bids fair to be larger than hitherto produced, but, of course, everything depends upon the season continuing propitious.[19]

Conditions did not remain so promising, and overall 1877 was drier in many parts of Victoria and NSW than in 1876, but in agricultural regions the year was not a disaster. 1878 then brought

good rain across much of the two colonies, which enabled them to survive the El Niño relatively unscathed.

The Hunter Valley in NSW and its hinterland showed the most extreme conditions of any of my case studies. Newcastle, on the coast, was reasonably below average in 1876 and 1878, with 1878 the worst year in the sequence, a chronology shared by few other places. Branxton, only 50 km further inland, was well below average in all three years, but most seriously in 1877 (Figures 7 and 8). This made conditions in the Hunter difficult, but because its rainfall is much higher than in the southern case studies it was not as damaging. Besides, the drought came in short bursts, often punctuated by substantial rainfall which meant that harvests of grain and vine were generally sound. A mixture of inconsistent weather, semi-damaged crops and alternating optimism and pessimism marked the period, as was captured in this comment from the Maitland *Mercury* upon the Branxton vineyards in March 1877:

> *The Vintage*.—The vignerons of this district are at present actively engaged in the vintage. The owners of the several small vineyards and of large ones in the infancy of their bearing, have completed the task of wine-making with very satisfactory results as regards the quality of the wine obtained it being characterised as excellent. The recent hot weather and the necessity of a seasonable rainfall have been detrimental for the production of any considerable yield per acre—a great proportion of the crop in the several instance assuming more the appearance of raisins than of the fully developed grapes.[20]

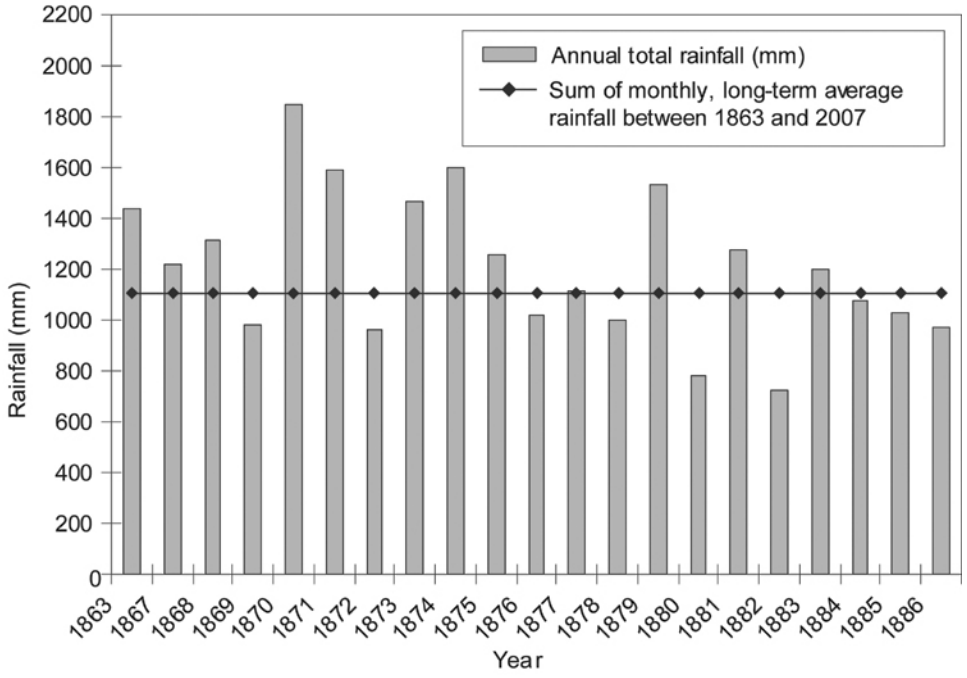

Fig. 7. Newcastle annual rainfall 1863-1886 and long-term average. Bureau of Meteorology, station 61055

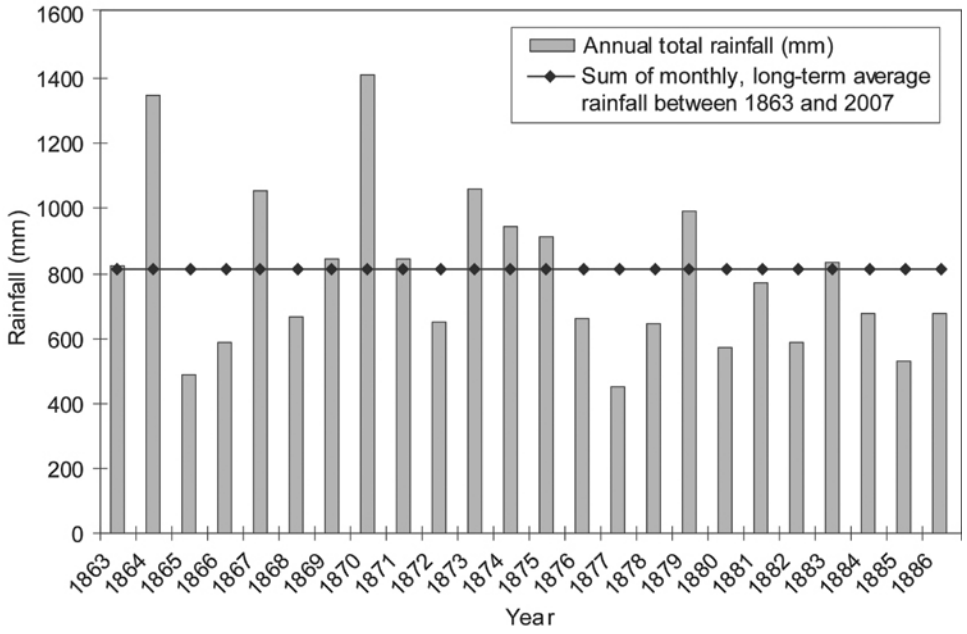

Fig. 8. Branxton annual rainfall 1863-1886 and long-term average. Bureau of Meteorology, station 61014

In April 1878 a correspondent to the *Mercury* described conditions that clearly did not indicate a damaging drought, even allowing for the hyperbole:

> You are rejoicing over the propitiousness of the season on the Hunter since the beginning of February: how much more reason we have for unbounded thankfulness, who have been best with regular supplies of rain just as it was required, ever since the month of August last. Never in the memory of the white man has such exuberance of vegetation been seen at this season of the year; the paddocks around here are fit to mow, grass is everywhere running to seed—there are not half enough of stock in the district to keep it down... People here are beginning to complain of too much rain; but it is not their health they are thinking about, it is the abominable roads in the district, that in wet weather it is a tell and torture to the spirit of man and beast to have to flounder through and over them.[21]

Since conditions in the Hunter were not extreme, the *Mercury* tended to show at least as much interest in weather conditions in the pastoral hinterland, in New England and western NSW, where the worst drought effects of 1876-78 were felt. Indeed, much of the reputation for the severity of the 1876-78 El Niño in Australia was because of the hardship in the pastoral industry in western NSW. It was reported of this region in March 1877:

> *The Drought.* – The *Hay Standard* reports that at the rate at which the flocks are being reduced by deportation and starvation, there will not be many sheep left in the district at the end of the season. On one fine station, having an extensive frontage to the river, only a few head besides the stud stock remain, most of the sheep having been purchased by owners of more favored country. Travelling sheep fare badly; of a mob of 25,000 store sheep that crossed at Hay Bridge, the other day, from Burrabogie, for the Darling, hundreds have been left dead or

> dying in the river bends, and it is believed that a large number must perish before their destination is reached.[22]

The reasons for the severity of the drought in pastoral zones were not confined to a simple deficiency of rain. There were three compounding factors. The first was the reduced resilience of vegetation and soils because of the accumulated effects of over-grazing by millions of alien animals which the land and could not sustainably support. Indigenous flora was evolutionarily adapted for periods of reduced rainfall, but not for the repercussions of intensive grazing by cloven-hooved animals that ate them to the ground. The reduced vegetation cover also exposed soils to heat, wind and the likelihood of erosion. Second, natural water sources were often muddied and exhausted, but even where they remained usable the vegetation around them (and the bores that had been drilled) was soon eaten out. More sheep died of starvation than thirst as all feed within walking distance of water points was consumed. Third, these effects were compounded by the spread of introduced rabbits which contributed significantly to environmental fragility. Together, these three phenomena brought greater soil erosion, evaporation and damage to water systems which precipitated quickly both an ecological and human drought – bare dry land, dead animals and economic collapse.

Nevertheless, even in arid pastoral zones there were some periods of useful rain during the El Niño. Across NSW, therefore, variability and diversity mark the experience in 1876-78. The complexity of the weather was captured by a newspaper report in December 1877:

> A telegram from Gunnedah, N.S.W., states that the drought continues unbroken. There is no grass in any part of the district, and stock are daily dying in large numbers from starvation. The prospect offered by a few months more of dry weather is exceedingly gloomy, and unless the weather changes there will be famine in the district and all the settlers will be ruined. A heavy thunderstorm occurred at Newcastle and Singleton on Monday, with terrific lightning and considerable rain. At the latter town the lightning split a tree near the public school. It is raining heavily in the Goulburn district. Distressing news comes from the New South Wales provinces. Last week hailstorms did much damage to the crops in the Carcoar district. A great quantity of wheat is being mown for hay. The Coonabarraban country is reduced to an arid desert for want of rain, and from nearly all the pastoral districts news comes that the sheep are travelling in every direction in quest of feed and water.[23]

In the Wide Bay region in Queensland, as measured by rainfall at Maryborough, all three El Niño years were slightly below average, but 1878 was the driest (Figure 9). The accumulative effect was potentially harmful but not catastrophic, and there was extraordinary variability within those years, with rainfall jumping all over the place. There were dry spells in each of the three years, but the driest were from February to June 1877 and June to November 1878, which were in different halves of the year and were sandwiched by well above-average falls. Therefore, the impact on crops came down largely to where the rain fell, or did not fall, in the growing cycle. Sugar did quite well and it was maize farmers who suffered more:

> With regard to sugar cultivation in Queensland we find the following interesting particulars by a correspondent of the *Wide Bay News*:- 'The sugar season is all but over, and without doubt it has been the best we have had since sugar became the staple of the Mary. Everywhere the density of the juice has been extraordinarily

> high, and the yield all round wonderfully good. The season, though in the coast districts unfavourable to the maize-grower and the grazier, on account of the long drought, was exceptionally favourable for sugarcane. It is true that the dry weather somewhat retarded the young crop, but not to any serious extent, and the plants and ratoons of the season seem to have recovered already.[24]

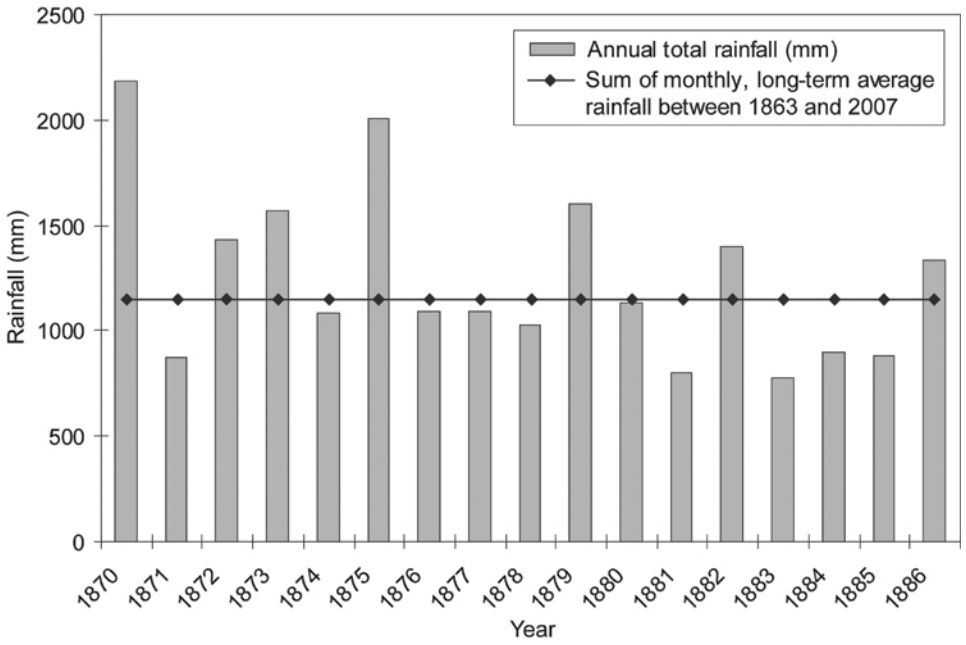

Fig. 9. Maryborough annual rainfall 1863-1886 and long-term average. Bureau of Meteorology, station 40126

Once more, it was further west in Queensland's pastoral zones that the absence of rain was most notable and reports tended to concentrate on those troubles, while closer to Maryborough the patchiness brought hard times interspersed with good times. From June 1878 rain was below average, apart from a reasonable fall in September, on which the *Maryborough Chronicle* commented:

> The influence of the fine rains of a fortnight ago upon garden and field has been magical. Arid, desolate tracts are covered with a rich green carpet, the flower garden has suddenly burst into a huge bouquet of bloom and beauty, and, what to many is of more importance, all kinds of green stuff for the table has suddenly appeared in succulent profusion. The sky and the earth have wedded, and bounteous Nature has yielded her increase.[25]

Even allowing for the local bravado and hyperbole, this is not a depiction of a period of harmful drought.

In summary, across south-eastern Australia virtually all places received less than their annual average rainfall in at least one year in the period 1876-78. Apart from some arid western zones, there were few locations that did not receive at least one good period of rain in every year. It was a time of rainfall shortages interspersed with good downfalls. Drought periods were essentially localised and short.

Prior to looking at these regions in detail I was under the impression that the 1876-78 El Niño had been a major factor in two fundamental movements in South Australia and Victoria – the failure of frontier agricultural settlement in the former, and the drive for irrigation in the latter that resulted in the first major irrigation legislation. However, a closer study shows that it was dry years in the first half of the 1880s that had more impact in both regions. An examination of the most reliable international data shows a reasonable consensus that there were El Niños in 1880-81 and 1884-85.[26] Australian rainfall data (Figs 4 – 8 above) indicates that while the weather was patchy, large areas of South Australia and Victoria and southern NSW experienced below average rainfall for up to five years, with the likelihood of more severe dips in 1882 and 1884. My conclusion is that this extensive period of below average rainfall did a great deal more harm to pastoralism and to the infant agricultural industries in the three colonies than the El Niño of 1876-78.

The cumulative effects of these dry years and ongoing environmental damage precipitated widespread failures among the new farmers in the colonies. Donald Meinig has described the agricultural retreat from the mid-north of South Australia where many farmers survived the first few years, but the deep drought of 1884 resulted in the abandonment of most farms and agriculture outside the Goyder line.[27] It became a country of abandoned farmhouses and ghost towns.

In Victoria there was not such a high level of agricultural attrition or human tragedy, but the climatic challenges resulted in the promotion of a brave new solution – irrigation. The drought of 1876-77 stimulated discussion of many schemes, and the advocates promoted a view, still not uncommon in Australia, that there was plenty of water – it was just in the wrong place at the wrong time. Human ingenuity and engineering, through irrigation, could fix that fault and make the deserts bloom. However, the 1870s drought was not sufficiently profound to trigger government action. By contrast, the dry years of the first half of the 1880s resulted in a series of government initiatives that established Victoria as the main irrigation colony. Most notably, one of those who became interested was a young politician and journalist, Alfred Deakin. In 1884, as the El Niño bit, he was appointed to Chair a Royal Commission on Water Supply. Over the next couple of years his investigations took him to California and India to examine irrigation schemes. It is worth noting that NSW also held a Commission on Water Conservation at the same time.[28] The Victorian Commission's reports and subsequent legislation, laid down many of the principles for water and irrigation in Victoria, one of which was that government should undertake responsibility for major capital works such as dams and the main distribution channels The Goulburn river weir, built 1887-1891, was the first 'national' work under the scheme. The response to El Niño droughts in Australia then and in the twentieth century, it might be said, was encapsulated in the construction of irrigation dams.

New Zealand

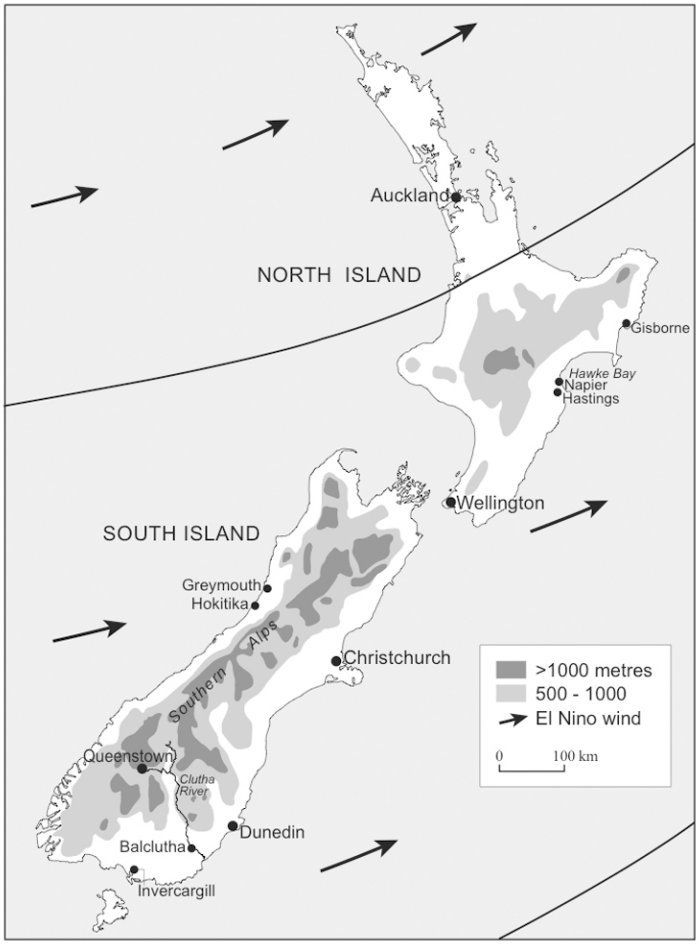

Fig. 10. Map of New Zealand showing main sites affected by El Niño, and the prevailing winds during an El Niño event.

In New Zealand, as elsewhere across the British Empire, there was some knowledge and concern about the dreadful famine in India in 1877, and money was collected for famine relief. The *New Zealand Mail* noted, 'famine caused by droughts is slaying its thousands and tens of thousands of the wretched inhabitants',[29] and the *New Zealand Herald* expressed its horror that 'the bulk of the people (15,000,000) are now emaciated with their ribs sticking out in painful prominence, and their skins covered in [sores]'.[30] A public meeting was held in Wellington in October, presided over by the Governor, to commence collecting relief funds, and smaller communities had similar functions.[31]

The effects of the El Niño of 1876-78 in New Zealand present a very different story, both from those of India and the Australian colonies. There was not the immense misery of India or China, but the weather was extreme, especially in 1878. Unlike Australia, parts of New Zealand were abnormally wet and cold.

It has been recognized for at least the last two decades that during an El Niño some regions of New Zealand experience below average rainfall. This is because during an El Niño the normal westerly wind systems move further northward and cold fronts from the south push

further north and east bringing stronger west and south-west winds that are colder than normal and penetrate further across the islands. Areas in the east of the two main islands, the North Island and the South Island, especially those in the shelter of mountain ranges, are thrown into rain shadow as the winds become warmer and drier after crossing the mountains. The regions most affected are around the Hawkes Bay (Napier and Hastings) and Poverty Bay (Gisborne) regions of the North Island, and on the Canterbury Plains (adjacent to Christchurch) and parts of Central Otago (inland from Dunedin) on the South Island. The data for Napier (Figure 11) show that 1876-78 was a dry period although 1878 was the only significantly below-average year. What is not shown is that the total for 1877 was boosted by a large downpour in February and therefore gives a somewhat distorted picture, as I discuss below. Christchurch (Figure 12) was below average in all three years, and this indicates that the Canterbury Plains were seriously affected. By contrast, Dunedin's rainfall (Figure 13) seems to indicate that it was little affected, which is also a slight distortion, as I explain below.

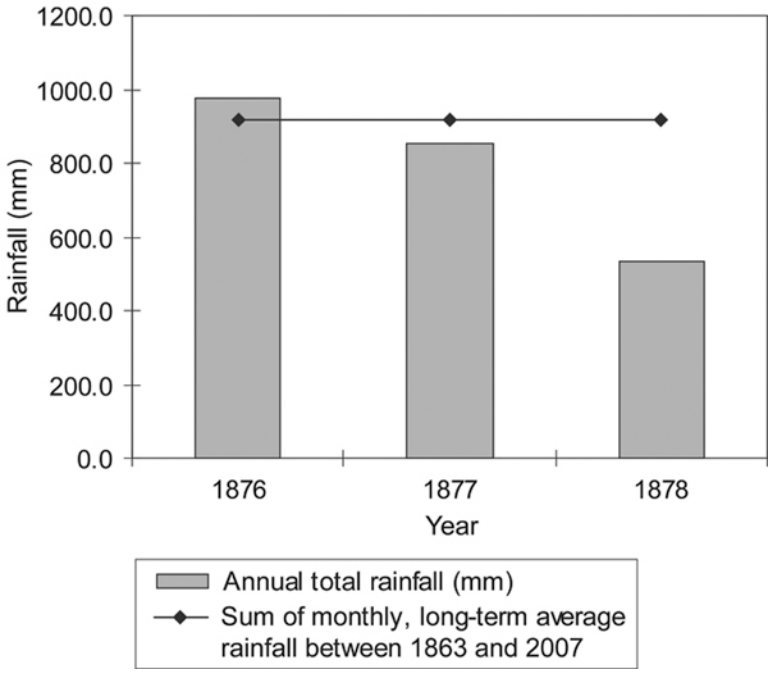

Fig. 11. Napier annual rainfall 1876-78 and long-term average. National Institute of Water & Atmospheric Research, New Zealand, station 2982

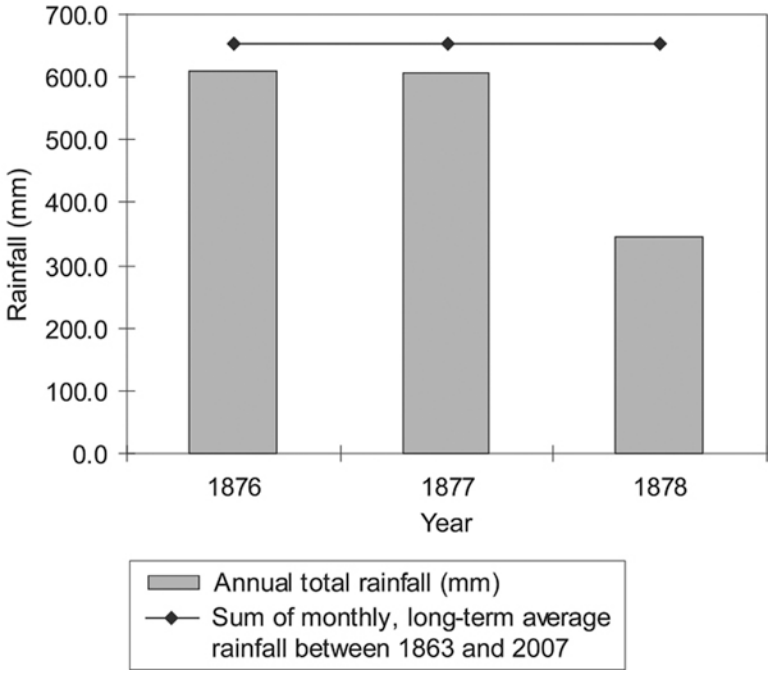

Fig. 12. Christchurch annual rainfall 1876-78 and long-term average. National Institute of Water & Atmospheric Research, New Zealand, station 4858

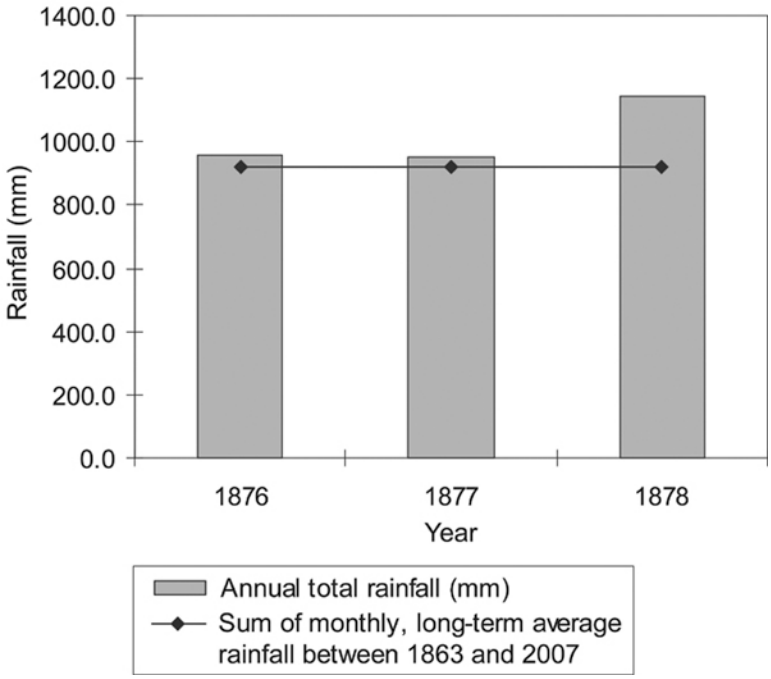

Fig. 13. Dunedin annual rainfall 1876-78 and long-term average. National Institute of Water & Atmospheric Research, New Zealand, station 5378

So, yes, there are rainfall deficiencies in New Zealand which are often called droughts, although in Australian terms they are short, mild and localised. Except for 1897-98, and to a lesser extent 1878, I have found no evidence of nineteenth century droughts that have been long or profound.

In recent years as study of ENSO has increased, there has been wider acceptance that the effects of an El Niño are not limited to below-average rain in eastern zones.[32] There is actually a more dramatic effect. The stronger, colder and moister-than-normal onshore winds that occur during an El Niño, particularly in the west and south-west of the South Island, produce a disproportionate number of New Zealand's most extreme wet and cold weather events - storms, snow and rainfall - and resulting floods. Snowfalls provide perhaps the best correlation. Allowing for problems of definition and identification, the main snowfalls on the South Island up to the 1970s occurred in 1867, 1878, 1888, 1895, 1903, 1931, 1939, 1945, 1967 and 1972. Every one of these is clearly within or is closely associated with an El Niño period. Such a correlation is more than coincidental!

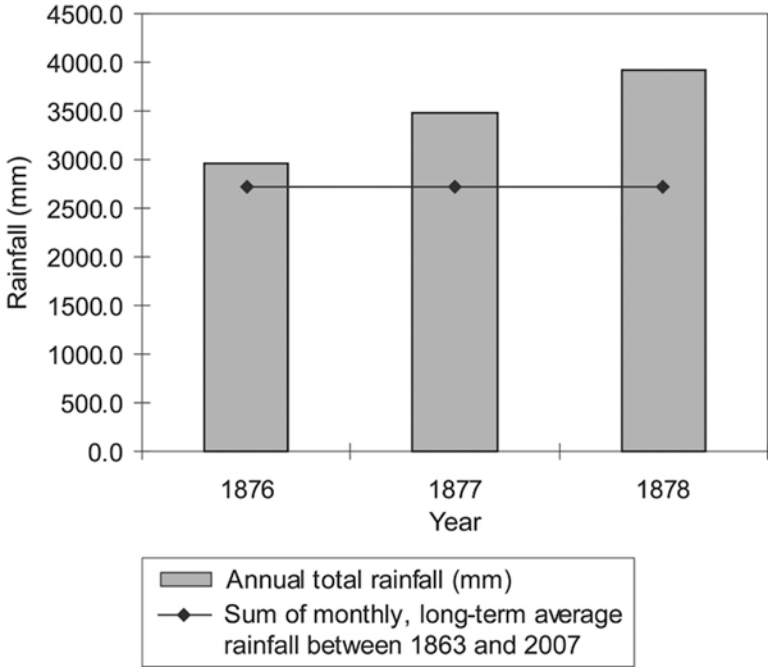

Fig. 14. Hokitika South annual rainfall 1876-78 and long-term average. National Institute of Water & Atmospheric Research, New Zealand, station 3907.

Many parts of New Zealand normally have substantial rainfall, and floods are not infrequent. However, it can also be demonstrated that a majority of the most severe floods, particularly in those regions most exposed to El Niño effects, have been concentrated in El Niño periods. These vulnerable zones lie along the west and south coasts of the South Island, in Southland, Westland and Fiordland. Unfortunately, there is little rainfall data for the 1870s, but longer-term figures show a generally consistent record of heavy rain, snowfall and floods on these coasts and their hinterlands during El Niño events. Such above average rainfall and snow can result immediately in floods, or can lay down such a quantity of snow that flooding can occur when the snow thaws. An examination of long-term rainfall along these coasts, and of

flood records, indicate a significant (but by no means entire) concentration of wettest periods and floods in El Niño years. For the 1870s the only available rainfall data is for the Hokitika South station (Fig. 14), and these clearly show well-above-average falls for this generally wet region. The situation had been the same along this coastline during the 1860s El Niño when the floods had been so serious that in 1866-68 the government undertook large infrastructure works (stopbanks, groins, etc) to try to reduce flood damage in Hokitika.[33]

One of the paradoxes raised by El Niños in New Zealand is that the Hawkes Bay district around Napier, which is generally defined as one of the regions most likely to suffer drought during an El Niño, is also likely to experience floods during an El Niño. It is remarkable that the area experienced four severe floods in the nineteenth century, each in an El Niño period, and each worse than its predecessor - May-June 1867, February 1868, February 1877 and April 1897. This is because during an El Niño the cold and wet winds at times swirl further around from the south and south-east and deluge the east coast of both islands. For example, the rainfall in Napier in 1877 was below average for much of the year, but a south-easterly downpour in February produced 355.1 mm of the year's annual total of 851.2 mm.[34] As a result of such marked fluctuations, which tend to be more extreme during an El Niño, rainfall on east coast sites on both islands can be a hotchpotch of dry periods and intense downfalls. This phenomenon explains the above average rainfall in Dunedin during 1876-78, most notably because of amazing 314.4 mm in June 1878.[35]

A major focus of my study has been on the Clutha River catchment (Figure 15). The Clutha River is the main ocean outlet for a large and connected system of lakes and rivers that drain an area of 20,582 square kilometres on the south-eastern side of the Southern Alps. It stretches for more than 200 kilometres from areas of glacial ice and permanent snowfields in the Alps quite close the western coast, to its ocean outlets on the south-eastern corner of the South Island. About twelve kilometres from its outfall, just downstream of the town of Balclutha, the river divides into two arms. Until 1878 they flowed into a narrow dunal lake which had an exit to the ocean at its south-western end. Between the two branches of the lower Clutha lies a low and flat flood plain, effectively an island, which explains its name, Inch Clutha – Inch is a Scottish term for an island. This topographical configuration of the Clutha system made it vulnerable to flooding. The very large alpine catchment flowed into a flat plain with a narrow ocean outlet, and the flatness of the Inch and with a low central wetland was a dangerous combination.[36]

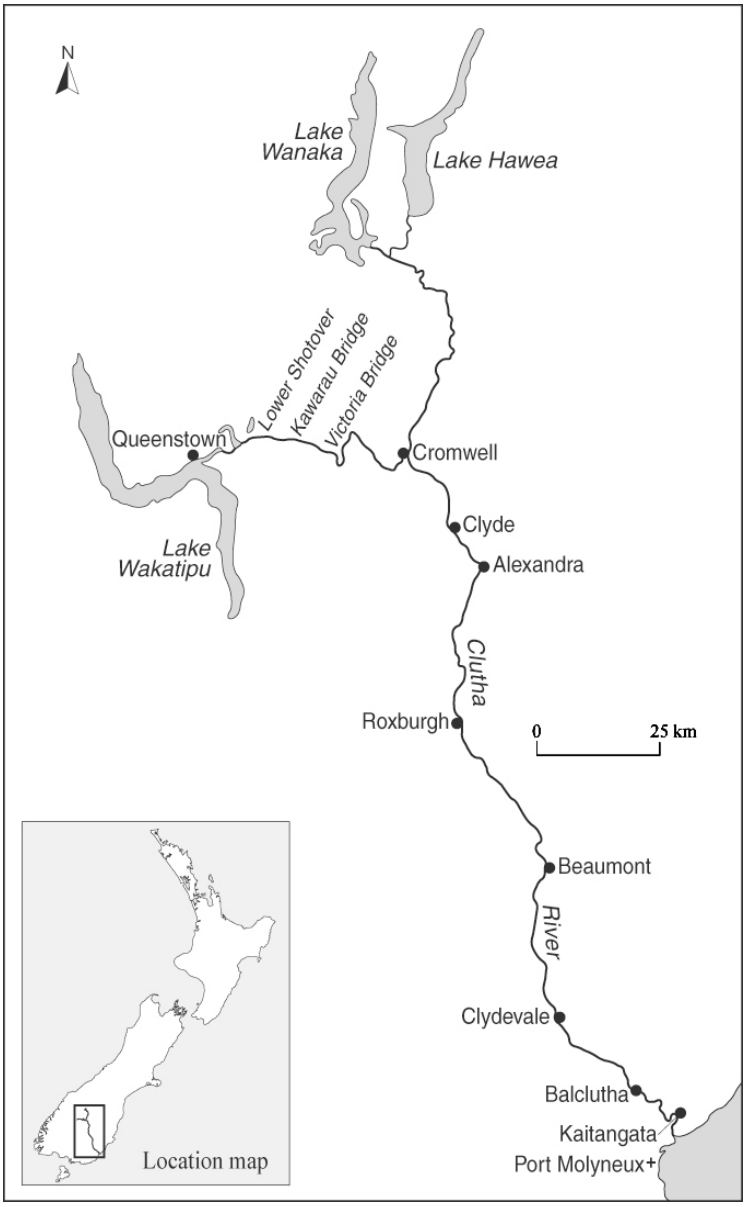

Fig. 15. Map of the Clutha River system, South Island, New Zealand.

In the early years before there were good roads, the Clutha River served as a significant pathway for small vessels that plied the coast and used the stream to reach into the developing hinterland. A small port and township, Port Molyneux, were established beside the ocean outlet, and a townsite was planned that included an Octagon or city 'square' similar to one in Dunedin.

There is evidence of regular flooding of the Clutha system before European arrival, but human intervention in the landscape after settlement increased both the likelihood and extent of floods. Sheep grazing and gold mining were two major industries, with two principal environmental effects. First, grazed and cleared land had less vegetation to retain and filter rainfall, and this allowed much more rapid runoff. Secondly, soil no longer protected by indigenous vegetation or held together by its roots, was much more exposed to water and wind erosion. The soils in many areas of New Zealand are friable and are easily eroded, notably on the

many steep hillsides. New Zealand had always had landslips, but landslips now became a New Zealand phenomenon, and enormous quantities of soil, silt and other detritus found their way into the water systems, silting their channels and blocking their outflows.

The Clutha experienced big floods in January 1866, during the El Niño, when a weather system dropped a substantial volume of rain on accumulated snow in the Alps. The snow melted rapidly and a flood rushed down the mountains. Many miners were trapped and drowned, and there was a great deal of damage to mines and equipment. The water carried a load heavy of silt, trees and human debris. Balclutha was deluged with the 'most destructive flood within the remembrance of the earliest settlers' and Inch Clutha was inundated.[37] There were great losses of gardens, crops and stock. Despite the setback, the mining industry, farms and the townships slowly recovered and development continued. However, in May 1866 Port Molyneux lost its status as a port of entry into the colony, and shipping trade on the river declined.

There was an even greater flood in 1878. Queenstown, which is adjacent to one of the lakes which form part of the catchment of the Clutha system, is one of the few places in the south for which there is 1870s rainfall data, and it experienced nearly double its annual average rain in 1878 – 1525 mm compared with 832 mm average.[38] There were unusually heavy falls of snow from May to August in the high country where mining was slowed to a standstill. On one pastoral property 60,000 head of stock were said to have died, and in lower regions rain began to swamp the river land. There were some colonists who had sufficient experience with local weather and conditions to realise that there were even further dangers in the build-up of so much snow. If rain and rising temperatures brought a rapid thaw and the already overburdened water systems were deluged, there was grave danger of severe flooding like that of 1866. One warning published in the *Clutha Leader* expressed prescient alarm about the vulnerability of the Clutha region:

> I beg through the columns of your paper to call the attention of the inhabitants of Balclutha and the low-lying parts of the vast district that drains itself into the Molyneux [an early name for the Clutha], particularly from Te Houka down to the sea, to the following facts. All over this vast district snow has fallen in such quantities as has never before been seen since this country was inhabited by Europeans, *ergo* should a thaw set in simultaneously a flood is sure to take place that may in all probability submerge Balclutha and the Island, and sweep the banks of the river from above Te Houka of every living thing, - knowing every inch I may say of the district from having traveled much over it, and having often remarked from the formation of the country that should a *general rain take place* some great disaster was sure to happen if the inhabitants of the portion of the district I mention were not warned in time.[39]

The worst predictions came true when late in September a warm north-westerly airflow across the South Island and its snowfields brought several days of warm rains that precipitated a rapid thaw that flooded the Clutha system. In the upper catchment, around the lakes, there was such an outflow carrying a heavy burden of silt, timber and other debris related to land clearing and gold mining, that the system was unable to carry the waters away through the narrow gorges. The rivers and lakes backed up and the towns were flooded, including Queenstown (Figure 16).

Fig. 16. Queenstown in flood, October 1878. The Clutha River and its tributaries were unable to carry away flood waters quickly enough and the water level rose in Lake Wakatipu and flowed through the town. Source: Alexander Turnbull Library.

Further down the Clutha system towns and settlements were also flooded, and numerous bridges and river crossings were damaged or destroyed. At Balclutha, much of the town went under water and the main road bridge was swept away. Inch Clutha became a sheet of water, made worse by the narrow ocean outlet at Port Molyneux that silted up and caused a backflow. However, on about 5 October the water broke through the sand spit to create a new channel into the ocean a little further to the east of Port Molyneux. Like pulling a plug, it allowed a more rapid draining.

There are many stories of loss, bravery and rescue. The most dramatic rescue story, perhaps somewhat exaggerated, was of a carpenter and his 'housekeeper' whose house was swept off its foundations and was carried downstream across the Inch towards the ocean. At the lower end of the Inch their plight was spotted and a boat sent after them, saving the lucky couple soon before the house was swept out to sea. The old school-house on the Inch was also washed away and sailed 'across the sandspit direct for the coast of South America'.[40]

The estimated peak discharge of the 1878 flood at Balclutha, on 30 September, was the largest in its recorded history.[41] Any flood will carry a great deal of debris, but the descriptions of the 1878 flood are notable for their references to the yellow waters and the burden they carried, substantially as a consequence of human activity in the watershed. The floods did great damage, setting back farms, destroying stock, curtailing mining and demolishing bridges, homes, businesses and other infrastructure. A charitable relief fund was established.

Among most lasting and dramatic repercussion of the 1878 flood was the death of a town – or maybe it should be said that Port Molyneux was put out of its misery. A visitor to the area in the 21st century comes across a sign to Point Molyneux that confidently directs one down a road towards the sea, a few hundred metres away. However, just twenty metres along the road it is closed by a gate into what is now a private farm. The sign, in reality, points to a past aspiration rather than to any recent reality. The new river outlet that broke through the spit in 1878 bypassed the port and left it with a sandbar blocking the entrance to its silted former harbour. The town slowly died, the land was taken over for farms, and today the visitor needs a good imagination and a good pair of boots to appreciate the lost vision.

When the 1878 floods overwhelmed the Inch, there was work underway to build protective stopbanks or levees on the lower reaches of the Clutha. These were small and incomplete and had no chance of stemming the flow – they were simply swept away. In due course, however, a major infrastructure programme was implemented, so that now along the lower Clutha it is rather like a much smaller version of the lower Mississippi –snaking its way between bordering levees.

Conclusion

The El Niño of 1876-78 was markedly uneven in its effects across the globe. In Australia it was relatively short, erratic and mild. In New Zealand it was more severe and produced a particularly severe flood in the Clutha system.

If you spend much time in Australia and New Zealand the contrast between the two climates and environments is very apparent. Even without El Niño, Australia is a generally dry continent, and New Zealand an often wet archipelago. What my study has confirmed is that El Niños, such as that in 1876-78, aggravate these extremes. The Australian response has been to establish infrastructure to overcome drought through water capture, conservation and redistribution. The New Zealand response has more likely been directed towards channelling and expelling excess water, to achieve flood control through stopbanking, river diversion and overflow channelling.

For additional details see Don Garden, *Heat, Dust and Deluge: El Niños that shaped our colonial past*, Australian Scholarly Publishing, forthcoming 2009.

Notes

[1] *New Zealand Herald*, 6 Dec 1877

[2] *Riverine Herald*, 1 May 1877

[3] Davis, Mike, *Late Victorian Holocaust: El Niño famines and the making of the third world*, London, Verso, 2001

[4] Davis, pp. 7 & 113

[5] For discussions of the scientific basis of ENSO and its discovery see: Davis; Allan, Rob, Janette Lindesay, David Parker, *The El Niño Southern Oscillation & Climatic Variability*, Collingwood, CSIRO Publishing, 1996; Caviedes, Cesar N., *El Niño in History: storming through the ages*, Gainesville, University Press of Florida, 2001; Couper-Johnston, Ross, *El Niño: the weather phenomenon that changed the world*, London, Hodder & Stoughton, 2000; Nash, J. Madeleine, *El Niño: unlocking the secrets of the master weather-maker*, New York, Warner Books, 2002; Philander, S. George, *El Niño, La Niña, and the Southern Oscillation*, San Diego, Academic Press, 1990;

[6] Grove, Richard, 'Revolutionary Weather': the climate and economic crisis of 1788-1795 and the discovery of El Niño', in Tim Sherratt, Tom Griffiths & Libby Robin, *A Change in the Weather: climate and culture in Australia*, Canberra, National Museum of Australia Press, 2005

[7] For the dating of El Niños see: Quinn, W.H, V.T. Neal & S.E. Antunez de Mayolo, 'El Niño occurrences over the past four and a half centuries', *Journal of Geophysical Research*, 92, 1987; Quinn, W.H. & V.T. Neal, 'The Historical record of El Niño Events' in Raymond S. Bradley and Philip D. Jones (eds), *Climate Since A.D. 1500,* New York, Routledge, 1995; Quinn, W.H., 'A study of Southern Oscillation-related climatic activity for AD 622-1989 incorporating Nile River flood data', in Henry F. Diaz & Vera Margraf (eds), *El Niño: historical and paleoclimatic aspects of the Southern Oscillation*, New York, Cambridge University Press, 1992; Ortlieb, Luc, 'The Documentary Historical Record of El Niño Events in Peru: An Update of the Quinn Record (Sixteenth Through Nineteenth Centuries), In. Henry F. Díaz and Vera Markgraf (eds), *El Niño and the Southern Oscillation: Multiscale Variability and Global and Regional Impacts,* New York, Cambridge University Press, 2000.

[8] Royal Netherlands Meteorological Institute, http://climexp.knmi.nl/

[9] Burra – semi-arid, inland, wheat, sheep and copper mining; Echuca – semi-arid, riverine, inland, wheat, sheep, river port and transport; Hunter Valley – more abundant rainfall, riverine, semi-coastal, mixed agriculture including vineyards, pastoral, coal mining; Wide Bay – sub-tropical, semi-coastal, mixed agriculture especially sugar plantations.

[10] *Northern Mail*, 15 Sept 1876

[11] *Northern Mail.*6 Oct 1876, 5 Jan 1877

[12] *Northern Mail* 12 Oct 1877

[13] *Northern Mail* 12 Oct 1877

[14] Meinig, D.W., *On the Margins of the Good Earth: the South Australian Wheat Frontier, 1869-1884*, Rand McNally, 1962

[15] Meinig; Sheldrick, Janis, 'Goyder's Line: the unreliable history of the line of reliable rainfall', in Tim Sherratt, Tom Griffiths & Libby Robin, *A Change in the Weather: climate and culture in Australia*, Canberra, National Museum of Australia Press, 2005

[16] *Riverine Herald*, 5 Aug 1876

[17] *Riverine Herald,* 26 Aug 1876; also 5, 10 & 15, 29 Aug 1876

[18] *Riverine Herald*, 1 Jan 1877

[19] *Riverine Herald*, 29 May 1877
[20] *Maitland Mercury*, 8 March 1877
[21] *Maitland Mercury*, 20 April 1878
[22] *Riverine Herald,* 6 March 1877
[23] *Riverine Herald*, 6 Dec 1877
[24] *Riverine Herald*, 27 Feb 1877
[25] *Maryborough Chronicle,* 5 Oct 1878
[26] Quinn & Neal; Ortlieb; Royal Netherlands Meteorological Institute), http://climexp.knmi.nl/
[27] Meinig, D.W., *On the Margins of the Good Earth: the South Australian Wheat Frontier, 1869-1884*, Rand McNally, 1962
[28] Powell, J.M., *Watering the Garden State: water, land and community in Victoria 1834-1988*, Sydney, Allen & Unwin, 1989; Blackburn, Gerard, *Pioneering Irrigation in Australia to 1920*, Melbourne, Australian Scholarly Publishing, 1999
[29] *New Zealand Mail*, 20 Oct 1877
[30] *New Zealand Herald,* 13 Oct 1877
[31] *New Zealand Mail*, 20 Oct 1877
[32] For a discussion of the effects of El Niño on New Zealand, see: Brenstrum, Erick, *The New Zealand Weather Book*, Nelson, Craig Potton Publishing, 2003; Sturman, Andrew & Nigel Tapper, *The Weather and Climate of Australia and New Zealand*, second edition, Melbourne, Oxford University Press, 2006; Mosley, M. Paul and Charles P. Pearson (eds), *Floods and Droughts: the New Zealand experience*, Wellington, New Zealand Hydrological Society, 1997; Mullan, Brett, 'Effects of ENSO on New Zealand and the South Pacific', in Braddock, Deborah (ed), *Prospects and Needs for Climate Forecasting*, Proceedings of a workshop sponsored by the New Zealand Climate Committee, Wellington, Royal Society of New Zealand, Miscellaneous Series, 34, 1996; Ward, G.F.A., 'The Southern Oscillation and its Effects on New Zealand Weather', *New Zealand Agricultural Science*, vol 19, no 1, February 1985; Hicks, Geoff & Hamish Campbell, *Awesome Forces: the natural hazards that threaten New Zealand*, Wellington, Te Papa Press, 1998
[33] Rochfort, James, 'On Changes in the Hokitika River', *Transactions and Proceedings of the New Zealand Institute*, vol iii, 1870
[34] National Institute of Water & Atmospheric Research, New Zealand, station 2982
[35] National Institute of Water & Atmospheric Research, New Zealand, station 5378
[36] McLay, Evelyn M., *Stepping Out: a history of Clutha County 1876-1976*, Balclutha, Clutha County Council, 1977; Rutherford, Alma, *Inch: The Reproduction and Update of the Story of the Stirling and Inch Clutha,* Balclutha, Alma Rutherford and Inch Clutha Committee, 1998; Roxburgh, Irvine, *Wanaka and Surrounding Districts*, Christchurch, Upper Clutha Community Committee, 1990; 'Report of Rivers Commission on Clutha River', 1920, NZ Parliamentary Papers, 1920
[37] *Otago Daily Times*, 16 Jan 1866; see also *Bruce Herald,* Jan 1866
[38] National Institute of Water & Atmospheric Research, New Zealand, station 5446
[39] *Clutha Leader,* 16 August 1878
[40] This account based on *Clutha Leader*, Sept-Oct 1878
[41] 'Report of Rivers Commission on Clutha River', 1920, New Zealand, Parliamentary Papers, 1920