The Medieval History Journal

http://mhj.sagepub.com

The Great El Niño of 1789 93 and its Global Consequences: Reconstructing an Extreme Climate Event in World Environmental History

Richard H. Grove

The Medieval History Journal 2007; 10; 75

DOI: 10.1177/097194580701000203

The Great El Niño of 1789–93 and its Global Consequences: Reconstructing an Extreme Climate Event in World Environmental History

Richard H. Grove*

This article explores the global dimensions of an extreme climatic anomaly characterised by a series of El Niño events observable during the late eighteenth century. While similar events, comparable in their extent and severity, can be detected during earlier centuries, archival and physical data available for a later period suggest that the consequences of the El Niño of 1788–96 were most dramatic. Reconstructing this event may be a useful analogue in understanding the effects of comparable phenomena further back in time, especially where data is sparse. This article investigates the shocks triggered off on a global scale by El Niño events that became part of a conjuncture affecting economic systems, intellectual and administrative responses to issues of environment, and popular unrest. The precise relationship between an anomalous climatic situation and revolutionary upheaval, as in the case of France in the late 1780s and 1790s, is still open to discussion. The study of climatic stresses is however important to be able to contextualise a historical phenomenon on a global matrix. It now appears that the history of the Great El Niño of the 1790s can help to illuminate a much larger picture of world history during the last 5,000 years, especially in understanding the connections between El Niño events and the shocks such anomalies have periodically administered to the world economic system.

*Research School of Pacific and Asian Studies, Australian National University, Canberra.
E-mail: richardhgrove@hotmail.com

The Medieval History Journal, 10, 1&2 (2007): 75–98
SAGE Publications ♦ Los Angeles/London/New Delhi/Singapore
DOI: 10.1177/097194580701000203

Historical analyses of long-term global transformations have largely been based in the past on political and socio-economic evidence and considerations. The nature of the current environmental crisis and widespread anxiety over global warming has, however, served to bring world environmental history very much to the fore and to question the explanatory power of older theories in world history. In particular, scholars are now increasingly concerned to look back at the history of global environmental degradation and the impact of capitalism and imperialism on world ecologies. In addition, a need has been felt to investigate in a historical perspective the impact of extreme climate events, whether anthropogenic or otherwise. To interpret the former, one may argue, we need first to try to understand the latter, that is, to learn to interpret the impact of extreme climate events in world history.

This article arises from some reflections derived from two current lines of research: one which traces both the impact that the workings of British imperialism had on the global environment as well the ways in which colonial institutions responded to environmental issues, and another which seeks to uncover the history of global economic shocks triggered off by El Niño-caused climate anomalies over a thousand year period, particularly in the Asian and African tropical context. By the end of the eighteenth century we can begin to observe the development of some well organised information networks as a direct consequence of the territorial and military penetration of the tropics by the Dutch, French and British empires. These information networks enabled colonial scientists to observe and begin to interpret growing volumes of data and evidence of environmental change in a way that would not have been possible half a century earlier. This was associated with the very rapid developments in the professionalisation of science under the British and French East India Companies after about 1770.

By coincidence the 1780s and 1790s, which is the period explored in this article, was a period of extraordinary climatic anomaly, characterised above all by an El Niño event or series of continuous El Niño events, observable from as early as 1788 to as late as 1796. We are beginning to realise now, by a combination of high resolution archival detail and a limited amount of physical proxy data, that this extreme event with its dramatic climatic and historic consequences, which we shall call the Great El Niño, was arguably the strongest and most prolonged El Niño event of the millennium A.D. 1000–2000 (although it could be argued that the events of 1200–1210 and 1296–1408 may have been as extended and severe). It was, using the term coined by Meggers (1994), a Mega-Niño, of which there have only been a very few in the last 1,000 years. The best evidence for this is in the ice cores recently drilled by Professor Lonnie Thompson of Ohio State University in the Chinese/Tibetan Himalaya which show levels of dust which have rarely been paralleled historically. Continuous droughts meant that by 1794 very high levels of dust were present in the atmosphere above South and Central Asia.

The detailed historical record present in the archives of the East India Company by the 1790s as well as in other colonial and European archives, allows us to reconstruct this event. This is valuable, not just for its own intrinsic interest, but because it is a highly useful analogue in understanding the effects of comparable events in earlier centuries. It may shed light, for example, on the relationship between the seventeenth-century economic crisis in South Asia (expressed mainly in terms of famine mortality) and elsewhere, and the undoubtedly severe and anomalous El Niño events that took place during the coldest parts of the Little Ice Age (although the mechanisms connecting those cold periods to El Niño are not understood as yet). The most prominent result of these events in the tropics took the form of drought, often causing crop failure and even famine. But we are increasingly realising too that El Niño events are very closely connected with episodes of epidemic disease, especially water-borne diseases. These episodes, triggered by El Niño, only really became globalised in the seventeenth century, especially during the El Niño episodes and yellow fever outbreaks of the 1640s. Our knowledge of those early episodes is very sketchy. By contrast it is only later, in the years 1789–93, that we perhaps for the first time encounter a climatic analogue sufficiently well documented to be able to typify the shock that a prolonged El Niño event could and can give to the world economic system, in a relatively short-lived and catastrophic way.

The intellectual response to this climatic social and economic shock is almost as interesting to observe. This is because the climatic events meant a conceptual shock to the new imperial information and intellectual networks. For the first time the possibility of globally teleconnected and simultaneous climatic severe events, especially of drought, occurred to intellectuals. For the first time too, the Great El Niño compelled at least two scientists to systematically search the historical record for further evidence of large-scale regional or global climate shocks. Two men in particular, William Roxburgh and Alexander Beatson, significantly both Scotsmen trained at Edinburgh University, started to reconstruct the history of global climate in the three centuries preceding the 1790s. In Roxburgh's case the reconstruction was remarkably detailed and painstaking.

Official imperial worries about climate, above all anthropogenically caused climate change, were not new. As early as 1763, complex theories were being elaborated by French and British thinkers working in the tropics that related deforestation to a decline in rainfall. Many of these theories drew on the work of Duhamel de Monceau, a horticultural and forestry writer who had published a great deal in the 1740s. By the late 1760s, the first colonial forest reserves had been established, intended explicitly to protect rainfall in islands where the plantation economy was important, especially as in Mauritius, Tobago and St Vincent.

After 1709, a year of unusually cold winter and famine in Europe and of famine in India, El Niño events had occurred with less frequency than in the previous 125 years. However, El Niño events after 1734 are, for the first time, recorded in rigorous detail by some observers in South India. An interesting instance relates to Madras, where complete weather diaries were compiled by G.E. Geisler, a German missionary, between 1732 and 1737.[1] These diaries provide especially useful information on the mode of onset of the El Niño of 1737. However, it is not until 1776 that we begin to have access to long runs of instrumental data for El Niño events in South Asia.

Just prior to this, in 1768–71, India, in particular north-eastern India, experienced droughts which resulted in high mortality, counting up to 10 million persons. Partial crop failure in Bengal and Bihar was experienced in 1768, while by September 1769 'the fields of rice are become like fields of dried straw'.[2] In Purnia, in Bihar, the district supervisor estimated that the famine of 1770 killed half the population of the district. Many of the surviving peasants migrated to Nepal, where the state was

[1] Glaser et al., 'Weather and Climate in Madras'. For a fuller analysis of the historical record for El Niño conditions in southern India see Walsh et al., 'The Climate of Madras'. For an analysis of the connections between El Niños and extreme rainfall events in the Asian region see Kane, 'El Niño Timings and Rainfall Extremes in India'.

[2] Hunter, *The Annals of Rural Bengal*: 19.

less confiscatory than the East India Company. Hill comments that 'the plight of Purnea was not an isolated one. More than a third of the entire population of Bengal died between 1769 and 1770, while the loss in cultivation was estimated as closer to one-half'.[3] Famine mortality continued until 1771. Charles Blair, writing in 1874, estimated that the episode affected up to 30 million people in a 130,000 square mile region of the Indo-Gangetic plain and killed up to 10 million of them.[4] It was, perhaps, the most serious economic blow to any region of India since the events of 1628–31 in Gujarat—pestilence and famine. As the droughts ended in December of 1770, serious floods took place throughout north-east India. The ensuing disease epidemics exacted a high proportion of the total deaths that occurred during the period.

The 1768–70 droughts and famines were a profound blow not only to the system of revenue but to the whole rationale of empire. As such they provided the impetus for the evolution of a famine policy. Under the immediate devastating circumstances, Warren Hastings carried out the orders of the Company, 'standing forth as *diwan*'(Hunter 1897: 392) [chief state officer] in 1772, ending the dual system and placing responsibility for the security, administration and economy of Bengal squarely on the Company's shoulders. Hastings' administrative overhaul of Bengal paved the way for the establishment of the British-run, district-level administration which would continue throughout British rule in India. All these developments were triggered by severe El Niño episodes.

In recent history the severity of the El Niño of 1997 and 1998, as well as the La Niña event that followed on from it, has tempted both politicians and scientists to suggest that the 1997–98 event was the worst known in history.[5] Similar hasty claims had been made for the El Niños of 1982–83 and 1991–95.[6] The historical as well as the prehistoric record tend to suggest otherwise.[7] Indeed the documentary evidence suggests that, even

[3] Hill, *River of Sorrow*: 28.

[4] Blair, *Indian Famines*: 88–91.

[5] For example, see statement by United States vice-president Al Gore and NOAA scientists, The White House, 8 June 1998, claiming the 1997–98 El Niño to be the most significant climatic event of the century, and suggesting (without any evidence being produced), that this implied an acceleration of global warming.

[6] For example, see Trenberth and Hoar, 'The 1990–95 El Niño-Southern Oscillation Event'.

[7] Grove, 'Global Impact of the 1789–93 El Niño': 318–19.

in the last thousand years, very much stronger and longer El Niño events have been experienced globally, and particularly during the Little Ice Age between about 1250 and 1860. There are in fact many problems involved in reconstructing the conditions and severity of El Niño events that took place before the instrumental period.

But by the 1780s it starts to become possible to at least partially reconstruct the global impact of a major El Niño event from historical sources with some statistical accuracy. This is because of the wealth of Indian weather and population data gathered by the British East India Company, as well as global weather data compiled during voyages and in new settlements at the time, particularly in the southern hemisphere and not least in Australia.

The 1789–95 El Niño event was of particular significance on account of its strong global effects, the particular sequence of events which it manifested and the very prolonged nature of the droughts it produced, especially in South Asia. It had a major economic and global impact. However, we should note that it was merely the culmination of a succession of unusual weather episodes which had begun in about 1780 and were characterised by extreme events in both temperate and tropical latitudes in Europe and Asia.[8] These years were especially serious throughout South Asia. One year, 1783, which brought famine to almost all India, was memorialised in popular culture throughout India under the name of the *chalisa*. The word itself, which emphatically associates the Hindi number 'forty' with a particular variety of famine, may suggest a characteristic return interval of 40–50 years for severe droughts, an interval which is, very roughly, borne out in reality during the Little Ice Age. The social disruption caused by this particular drought was a long-term one, since nearly 4 per cent of all villages in the Tanjore district of the Madras Presidency were entirely depopulated in the early 1780s and over 17 per cent in the Sirkali region.[9] Up to 11 million people may have died in South Asia as a direct result of the passage of this event.

The drought years of 1789–94 in India were first recognised as having had a global impact by Alexander Beatson, Governor of St Helena, who suggested in 1816 that the drought events of 1791, that had occurred

[8] Kington, *The Weather of the 1780s over Europe*.

[9] See Census of Tanjore, Papers of the Walkers of Bowland, MS 13615 B, National Library of Scotland, Edinburgh.

simultaneously in different parts of the world (he referred particularly to India, St Helena and Montserrat), had been part of the same connected phenomenon.[10] Chronologically, the earliest indications of the event are contained in the manuscript records of meteorological observations made for the East India Company by William Roxburgh, a Company surgeon, at Samulcottah in the Northern Circars of the Madras Presidency (modern-day Samalkot).[11] Roxburgh had accumulated a 14-year set of temperature and pressure data from the early 1770s and was thus able to recognise the exceptional nature of the droughts that began in 1789.[12] These droughts had previously been approached in intensity, he reported to the Company, only by those of a century earlier, in 1685–87.[13] These latter years are also now believed to have been characterised by 'very severe' El Niño conditions in the eastern Pacific, though a year later, in 1687–88. Roxburgh's rainfall figures record the consecutive failure of the South Asian monsoon between 1789 and 1792, with the most severe failure being experienced in 1790 (see Table 1).

Table 1

Monthly Rainfall at Samulcottah, Andhra Pradesh, India May–November 1788–92 (in Inches and Twelfths of an Inch) as Measured by Roxburgh (1793)

	1788	*1789*	*1790*	*1791*	*1792*
May	15.4	1		4	3.6
June	7.2	6	1.8	4.1	5
July	22.3	6.10	4.9	5.6	6.4
August	12.2	21.1	3.8	–	1.8
September	8.9	1.4	4.8	3.9	7.5
October	5.9	10.1	1.5	3.3	13.11
November	6	1.3	1.2	6.4	–
Total	**77.5**	**47.7**	**17.4**	**26.11**	**37.10**

It should be noted that some El Niño events, such as that of 1997, appear to articulate only with a failure of the south-east Asian monsoon rather than with a South Asian failure. In the case of the 1789–93 El Niño event (and the 1685–88 El Niño event) a failure of the monsoon in both regions appears to have occurred.

[10] Beatson, *Tracts on the Island of St Helena*: 10.

[11] Roxburgh, Letter to Sir Charles Oakley.

[12] Roxburgh, 'A Meteorological Diary Kept at Fort St. George'.

[13] Roxburgh, 'Report to the President's Council'.

By November 1792 over 600,000 deaths were being attributed directly to the prolonged droughts in the 167 districts of the Northern Circars of the Madras Presidency alone; up to half the population there died in 1792.[14] (See Table 2.)

Table 2
Deaths from Famine in the Madras Presidency in 1792

Muglatore	141,682
Havelly 1	53,956
Havelly 2	4,874
Peddapore	184,923
Pittapore	82,937
Nandeganah	11,376
Sullapelly	9,018
Poolavam	16,204
Goulatah	12,639
Cotapilly	4,851
Corcoudah	9,035
Ramachandrapuram	7,430
Cottah	7,800
Somapah Villages	2,306
Noozeed	96,210
Char Mahar	16,245

The long drought periods were interspersed by very short periods of intense and highly destructive rainfall. In three days at Madras in late October 1791, 25.5 inches of rain fell, 'more than .... has been known within the memory of man'.[15] Throughout India the famines of 1788–94 resulted in very high mortality. This level of mortality was reflected in local terminology and ways of referring to the event for many years afterwards. In Bijapur, for example, the year 1791 was known in oral history as 'the Skull Famine' when the ground was covered with the skulls of the unburied dead.[16]

[14] Manuscript reports on remissions of Company land revenues due to prolonged droughts and famine in Northern Circars districts of the Madras Presidency, East India Company Boards Collections, ref. no. F/4/12-12-14, sections 735–43, British Library, IOLR, London.

[15] Report in the *Madras Courier*, 3 November 1791.

[16] *Bijapur District Gazetteer*; Horakere, 'Janapada Sahityadalli Baraghala' [Drought in folklore].

In limited areas, such as the Northern Circars, the East India Company attempted to estimate total mortality statistics. In other regions a much rougher but still useful guide is provided by the figures for deserted village sites. In the Gorakhpur district of Bihar, for example, the 19,600 villages extant in 1760 had fallen to 6,700 by 1801, with a mere third of the district falling under cultivation. Not all of these desertions were due to famine deaths, but a high proportion of them probably were.[17] A similar pattern of mortality pertained in southern India during the period, where a pronounced pattern of village desertion can be established; in some parts of Salem district, for example, up to 30 per cent of villages were deserted.[18] Extrapolating from these kinds of figures we may attribute a total famine mortality during 1788–94 of perhaps 11 million to the extended El Niño conditions of the period. However, although the human cost of the episode was very high in the subcontinent, severe consequences were also felt elsewhere, especially further east.

Besides leaving us detailed evidence of the severity and impact of the Great El Niño in India, William Roxburgh began an extensive programme of tree-planting in the Madras and Bengal Presidencies, including teak, other species and drought resistant food crops. The mortality of the 1790s famines must be blamed on the British, who had a responsibility to provide alternative famine foods when the main rice crop failed. As in St Vincent, because of the same El Niño event, severe drought brought about a world wide shift towards forest protection by the colonial authorities, who throughout the nineteenth century, feared the catastrophic consequences of drought, exacerbated as this might be by uncontrolled deforestation.

We may now turn to the broader impact of the Great El Niño, moving eastwards first to Australia, where the new colonial invasion with its accurate record-keeping allows us to reconstruct the global scope of the event. The rainfall deficiency spread towards the east with unseasonably severe droughts being experienced in Java and in New South Wales in the same year.[19] On 5 November 1791 Governor Philip reported that the normally perennial 'Tank Stream' flowing into Sydney Harbour had been

[17] Figures quoted in Simon Commander, 'The Mechanics of Demographic and Economic Growth in Uttar Pradesh': 50.

[18] For an overview see Murton, 'Spatial and Temporal Patterns of Famine in Southern India'. See also Lardinois, 'Deserted Villages and Depopulation in Rural Tamil Nadu'.

[19] Quinn et al., 'Historical Trends and Statistics'.

dry for ‘some months’.[20] It did not flow again until 1794. The drought had begun, Philip records, in July 1790 and no rain had fallen at all till August 1791.

In the Pacific region, there is some limited evidence of El Niño conditions in the western Pacific from the journals of the D ‘Entrecasteaux visit to New Caledonia in 1793, during which cold and severe drought were recorded.[21] Another source of data from the late 1780s is the logbook of HMS Bounty. Temperature readings were made every four hours while at sea, and the lowest and highest temperatures were read while in port. On 6 December 1788, Bligh wrote, while his ship sheltered at Matavai Bay, Tahiti, that:

> I experienced a scene today of Wind and Weather which I never supposed could have been met with in this place. The wind varied from ESE to the NW and the Therm. stood between 78 and 81.5 degrees. By sunset a very high breaking sea ran across Dolphin Bank, and before seven o’clock it made such a way into the Bay that we rode with much difficulty and hazard. Towards midnight it increased still more and we rode until eight in the morning in the midst of a heavy broken sea which frequently came over us. The Wind at times dying away was a great evil to us for the Ship from the tremendous Sea that broke over the reefs to the eastward of Point Venus, producing such an outset thwarting us against the surge....

Bligh’s observations of a typical weather conditions for the time of year indicate that the El Niño episode that began in 1788 was already well under way. A few months later the fact that an El Niño was in progress actually saved the life of Bligh and the men who were cast adrift by the mutineers. Instead of the very hot conditions that would normally have confronted the 23-foot open boat between Tofua in the South Pacific and Timor between 29 April and 14 June 1789, Bligh and his men encountered cold conditions throughout the voyage. Furthermore, instead of a dry

[20] Governor Philip’s diary, reported in McCormick, *First Views of Australia.* In a letter to W.W. Grenville on 4 March 1791, Philip had noted that ‘from June (1790) 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 still 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’; quoted in Nichols, ‘More on Early ENSOs’.

[21] Personal commentary, Thierry Correge, ORSTOM, Noumea, New Caledonia.

heat that would probably have been deadly, the rainfall they experienced was so cold that Bligh instructed his men to soak their clothes in warm seawater and then wear the wet clothes to keep warm! On 11 May Bligh records that 'at noon the sun appeared which gave us as much pleasure as on a winter's day in England'. On 18 June Bligh again records heavy rain, 'which enables us to keep our stock of water up'.[22] The crew all complained of rheumatic pains and cold. Furthermore, the supply of rainwater also allowed Bligh to avoid making lands on small Pacific islands for water, as they might have had to in a normal year. If they had tried to make land it seems likely they might have met a hostile reception and not lived to tell the tale. So the passage of the El Niño, which began in 1788–89, probably means that the story of Bligh and the Mutiny on the Bounty has entered folklore, instead of merely remaining the 'mystery of the disappearance of Captain Bligh and the Bounty' as it almost certainly would have done in a normal year in the South Pacific.

In Mexico, the prolonged aridity that developed during 1791 was recorded in the steady fall in the level of Lake Patzcuaro between 1791 and 1793, giving rise to disputes over the ownership of the land that emerged as a result.[23] As in Europe these events were preceded by summer crop failures. On 27 August 1785 a hard night frost and the ensuing crop failure precipitated the great famine of 1785–86.[24] Not one annual maize crop yielded, during the 1790s in Mexico, an abundant harvest. This was entirely due to El Niño-caused droughts, primarily in June and July. The severest droughts of the 1788–93/94 event did not strike Mexico until 1793, so that the onset of full El Niño conditions did not affect rainfall for more than two years after the same event had caused monsoon failure in India. But wholesale failures of the wheat and maize crops took place in 1793 and 1797.[25] In 1794 the maize crop was again very poor due to almost complete drought. In 1795 the crop returned to near normal, although one might note that drought conditions persisted in that year in many Caribbean islands.[26]

[22] *Log of Captain William Bligh for 1789*, HM Admiralty Records PRO London; Facsimile portion of log published by Pagemaster Press, Guildford, England, 1981.

[23] Endfield and O'Hara, 'Conflicts over Water in the "Little Drought Age"'.

[24] Ouweneel, *Shadows over Anahuac*: 92.

[25] *Ibid.*: 75–91.

[26] Further ENSO caused crop failures also took place in the summers of 1808–11, bringing about a wholesale restructuring of the economy of Central Mexico.

In Egypt, three successive years of exceptionally low floods led to famine and soaring wheat prices. This was followed in 1789 by the plague (called *Ta'oun Ismail Bey*), which lasted for five months. In 1791 and again in 1792, a slight drop below the long-term mean and only 2 cubits or about 1 metre from the optimal level led to a severe famine, according to Antoune Zakry.[27] People were forced to eat dead horses and donkeys and even children. Another series of low floods in 1794, 1795 and 1796 led to a popular peasant revolt. This experience can be compared with that of 1877 when the flood was 2 metres below average, and left 62 per cent of Qena Province and 75 per cent of Girga Province un-irrigated.[28]

Along the Peruvian coast, the great strength of the El Niño current itself during 1791, with its resultant degradation effects on agriculture and fisheries, was well documented by contemporary observers. Flooding of normally arid areas was especially widespread during that year. The first indications of the onset of unusual drought in the Caribbean were felt in the most drought-prone islands of the Eastern Antilles, especially on Antigua and Barbuda. Antigua had already suffered from a long drought in 1779 and 1780 in an earlier El Niño episode. In 1789 the drought occurred again, but with 'redoubled severity'.[29] Even as late as 1837 this year was still referred to by Antiguans as 'the year of the drought'.[30] As a chronicler notes, 'What miseries the Antiguans then suffered I am of course from experience unable to say; but if they exceeded those endured in that eventful year 1837 [a later severe El Niño] they must have been terrible indeed'.[31]

According to the colonial archival documentation, by August 1791 the desiccating effects on the islands of the Antilles were already the severest recorded in writing since the late seventeenth century, and on the islands of St Vincent and Montserrat no measurable rainfall had been recorded by the middle of the month. This information is contained in formal requests made for tax relief by landowners due to harvest failure.[32]

[27] Zakry, *The Nile in the Times of the Pharoahs and the Arabs.*

[28] Willocks and Craig, *Egyptian Irrigation*, 3rd edition.

[29] Oliver, *History of Antigua*: 189.

[30] *Ibid.*: 191.

[31] *Ibid.*

[32] Petition dated 13 August 1791 by William McKealy on behalf of the Council of Montserrat, Leeward Islands, British West Indies; Montserrat Legislative Assembly Proceedings, Government Archives, Plymouth, Colony of Montserrat.

The drought continued on Montserrat until at least November 1792.[33] In the South Atlantic extended and abnormal periods of drought on the island of St Helena were later than those in the Caribbean, beginning in late 1791 and continuing until mid-1794. On St Vincent and on St Helena the droughts were serious enough to prompt government naturalists to call for the formal gazetting of forest reserves with the deliberate intention of encouraging rainfall.[34] The effects of the great El Niño event of the early 1790s took a long time to diminish in the Caribbean and Atlantic. Thus the *Times* index of 1796 indicates that in 1795 there was still an unrelieved drought in Antigua.[35]

In fact the recorded incidence of the El Niño current alone, as documented by Quinn in his famous 1987 paper, may simply not be an adequate guide to the true dimensions, impact and longevity of the 1788–94/95 event. Record low levels of the Nile may more probably indicate its true severity. Thus very low Nile levels from 1790 to 1797 provide some indication of the impact of an El Niño event in reducing monsoonal rainfall on the Ethiopian highlands. Evidence from much of the rest of Africa is scanty. However prolonged droughts in Natal and Zululand between 1789 and 1799 resulted in the *Mahlatule* famine.[36] This was the severest famine known in the written record to have affected Southern Africa prior to the El Niño event of 1862, which caused the worst droughts in Southern Africa of the nineteenth century. The low rainfall in both periods also shows up very clearly in the dendrochronological record.[37]

Throughout the period of the French Revolution between 1789 and 1792 unusual weather and extreme meteorological events in Europe and elsewhere continued to be recorded.[38] In England, for example,

[33] As stated in Letter of 6 March 1792, from the Commissioner of the Council of Trade and Plantations to the Council of Montserrat, Government Archives, Plymouth Montserrat.

[34] Barriendos et al., 'The Winter of 1788–89 in the Iberian Peninsula from Meteorological Reading Observations and proxy-data Records'.

[35] Personal commentary, Michael Chenoweth, 1998 [micheno@smart.net].

[36] Webb and Wright, *The James Stuart Archive*.

[37] Hall, 'Dendrochronology, Rainfall and Human Adaptation': 702.

[38] Cold weather conditions in the winter of 1788–89 were mirrored in the southern hemisphere. On 24 December 1788, the *Guardian*, carrying vital supplies to New South Wales, foundered on an iceberg near the Cape of Good Hope; Source, *The Australian*, 24 December 1998 (Note that similar unusually heavy ice conditions caused the wreck of Shackleton's ship *Endurance* in October 1914).

Parson Woodforde's diary tells us of unusually high temperatures and summer-like weather in January and February of 1790 (comparable to the high temperatures of January 1998).[39] These high winter temperatures were also being experienced in North America. Contemporary observers tell us that horse herds expanded greatly in numbers and facilitated expansion and migrations by the Cree, Assiniboine, Blackfoot and Gros Ventre in parts of Washington, Montana and Wyoming. The first three years of the 1790s were very warm and dry on the northern Great Plains. Fur traders in the region repeatedly remarked about how warm and snowless those winters were. But high temperatures were also accompanied by high rainfall events. On 13 January 1791 the first of a series of very heavy thunderstorms in the region is recorded, in Saskatchewan. This produced some hardships for bison hunters, but horse herds multiplied. Hostilities among native groups were rare in those years. That warm episode ended abruptly in 1793–94. At the end of the El Niño event, the return of cold winters provoked wars between the Indian tribes as conditions deteriorated for them and their horses. Horse herds were decimated, and warfare reached a climax in the next year.[40]

Further south in North America the same conditions gave rise to heavy rainfall and high temperatures relatively far north in the young United States. This brought about an inexorable rise in the mosquito population. As a result, by 1793 the conditions were ideal for the spread of mosquito-borne diseases. These were not long in arriving and on 19 August 1793 Dr Benjamin Rush, a doctor in the relatively northerly city of Philadelphia, noted his first cases of Yellow Fever.[41] This is a disease normally spread in tropical America by *Aedes aegypti*, a mosquito with a pronounced tropical range. By October 1793 the epidemic had killed over 5,000 people in Philadelphia alone, and the epidemic was only ended by a severe frost in November, which killed the mosquitoes. It seems that the epidemic had spread from Haiti, then known as the French colony of Saint Domingue. A slave rebellion was going on in Haiti, sparked off at least

[39] Woodforde, *A Country Parson*.

[40] I am indebted for archival details of the weather in the Great Plains in 1790–93 to Dr Ted Binnema of the University of Alberta at Edmonton who has just finished a dissertation, 'History of the North-western Plains of North America', shortly to be published by the University of Nebraska Press.

[41] Foster et al., 'The Philadelphia Yellow Fever Epidemic'.

in part by the political conditions of the French Revolution, a revolution which had itself been much stimulated by prolonged bad weather and crop failure in Europe in the early stages of the 1788–94 El Niño event. Refugees from the rebellion carried the Yellow Fever with them to the East Coast ports of the United States, where the aberrantly high mosquito population allowed the disease to flourish.

Other diseases also flourished in North America during the period of the Great El Niño. This was particularly the case with influenza, a disease whose epidemics had not previously affected the North American mainland very much. An epidemic spread through all of the United States and Nova Scotia in 1789–90.[42] Between September and December 1789, it spread between Georgia, in the Southern United States, and Nova Scotia. A renewed epidemic developed in the spring of 1790. In April 1790 it affected George Washington and Thomas Pettigrew reports that one Dr Warren recorded that 'at New York, as far as I can learn, its appearance was somewhat later than here, and our beloved President Washington is but now on the recovery from a very severe and dangerous attack of it in that city'.[43] Pettigrew added, observantly, that 'the summer preceding the fall disease was remarkably hot ... the last winter was uncommonly mild and rainy. The diseases of that season numerous, both synocha and typhus [appeared]'.[44] Certainly the very hot summers and mild winters which characterise El Niño conditions in much of North America appear to have encouraged the spread of epidemics in several different diseases, and not least in 1788–94.

In summary, while further archival research is needed to more fully characterise the 1789–94/95 event, the evidence of an intense and prolonged global impact already suggests that it may have been among the most severe in the available written record. As with the 1685–88 El Niño episode, the early stages of the event were observable in southern India more than a year before the El Niño effect was recorded as a warm current along the Peruvian coast. Moreover it appears that in both episodes, a presumed weak phase of the North Atlantic Oscillation (NAO) led to a

[42] T.J. Pettigrew, *Memoirs of the Life and Writings of J. Coakley Pettigrew*, vol. 3, p. 234, quoted in Thompson, *Annals of Influenza*: 199–202.

[43] *Ibid*.

[44] *Ibid*.

very cold winter, high pressure over Europe, a cold wet spring and a summer drought preceding later monsoonal blocking and drought in South and South-east Asia. We are only now realising that this sequence of events and phasing of activity seems to be typical of the severest El Niño episodes, in which the mechanisms of the NAO, the Asian monsoon and the Pacific El Niño/Southern Oscillation are closely articulated. This sequence may take several years to work through the global weather and ocean system.[45] 'Persistent' or extended El Niños, such as that of 1788–95, are an indicator of this.

The developmental sequence of the 1788–93 El Niño may also be instructive and have a further value as a basis for comparison with other subsequent very severe El Niño events since that time and particularly in comparison with the El Niño events of 1877–79, 1982–83 and 1997–98. But it may also serve as a template for understanding much earlier events in the historical record where the data only allows a much flimsier understanding of the sequence of the event.

The Great El Niño, the French Revolution and a Catalonian Revolt, 1787–89

While further archival research is needed to more fully characterise the 1789–93 event, the evidence of a strong global impact already indicates that it was one of the most severe El Niños recorded. In more temperate regions of the northern hemisphere, highly abnormal weather patterns were making themselves felt as early as 1788 in western Europe. There are some indications that an early precursor of the 1788–93 event may have been an unusually cold winter in western Europe in 1787–88, followed by a late and wet spring, and then a summer drought, resulting in the severe crop failures that helped to critically stimulate the explosive social pressures that culminated in the French Revolution.[46] This weather pattern, possibly representing a weak phase in the NAO, would be consistent with a well established strong correlation between inter-annual

[45] Grove, 'Global Impact'.

[46] See Neumann, 'Great Historical Events', and Neumann and Dettwiller, 'Great Historical Events'.

variability in the NAO and Indian summer monsoon rainfall, and specifically between summer monsoon rainfall and the NAO of the preceding year in January.

In France, a very cold hard winter in 1787–88 allowed only late sowings of grain crops and was followed by a late and very wet spring. This came at a time when free trade in grain had been allowed by an edict of the previous year, leading to empty granaries and a sharp increase in grain prices. Grain prices rose by about 50 per cent, that is, the general price index rose from about 95 in late 1787 to 130 in the summer of 1789. The only peasants who profited from high prices were the big landowners and tenant-farmers. The rest of the peasant population suffered severely from the rising price of bread: the small peasant who had to sell in order to pay his taxes and dues was short of grain by the end of the summer. The sharecropper, too, was hard-hit, and so was the day-labourer who had to buy grain in order to feed his family. The dwindling of their resources also brought about a crisis in the vineyards of Champagne, Beaujolais and the Bordelais: sales of wine were reduced because people gave up buying it in order to buy bread, and vine-growers were thus reduced to poverty.[47] In fact, in many parts of France a previous drought, probably associated with an El Niño event of 1785, had already seriously damaged the vital wine-growing industry, especially in Normandy and Picardy. The drought of the summer of 1785 had resulted in heavy losses of livestock, and a slump in the supply of wool. After 1785 the loss in disposable income led to a continuous slump in the sales of wine in parts of the country where much of the population had to buy its bread.

Warm, dry spring-summers are favourable to grain in northern France and north-western Europe. But even in the northern areas of the Paris basin, warmth and dryness can in certain cases be disastrous. A spell of dry heat at a critical moment during the growth period, when the grain is still soft and moist and not yet hardened, can in a few days wither all hope of harvests. This is what happened in 1788, which had a good summer, early wine harvests and bad grain harvests. The wheat shrivelled, thus paving the way for the food crisis, the 'great fear', and the unrest of the hungry, when the time of the *soudure*, or bridging of the gap between harvests, came in the spring of 1789. No one expressed this fear better

[47] Le Roy Ladurie, *Times of Feast*: 74–77; see also Labrousse, *La crise de l'économie française*: especially p. 51, 207 et. seq.

than the poor woman with whom Arthur Young walked up a hill in Champagne on a July day in 1789:

> Her husband had a morsel of land, once cowe, and a poor litte horse, yet they had 42 lbs. of wheat and three chickens to pay as a quit-rent to one seigneur, and 168 lbs of oats, one chicken and one sou, to pay another, besides very heavy tailles and other taxes. She had 7 children, and the cow's milk helped to make the soup. It was said at present that something was to be done by some great folks for such poor ones, but she did not know who or how, but God send us better, *car les tailles et les droits nous ecrasent.*[48]

These kinds of conditions led, in the late summer of 1788, to what we can now see as the first serious rural unrest prior to the revolutionary movements of 1789. Serious unrest and small-scale rural revolts took place in the areas worst affected by the summer droughts, in Provence, Hainault, Cambresis, Picardy, the area to the south of Paris, eastwards in Franch-Comte, around Lyon and Languedoc and westwards in Poitou and Brittany.[49]

So the extreme summer droughts and hailstorms of 1788 were decisive in their short-term effects. This is well described in the journal of a peasant wine-grower from near Meaux.[50]

> In the year 1788, there was no winter, the spring was not favourable to crops, it was cold in the spring, the rye was not good, the wheat was quite good but the too great heat shrivelled the kernels so that the grain harvest was so small, hardly a sheaf or a peck, so that it was put off, but the wine harvest was very good and very good wines, gathered at the end of September, the wine was worth 25 livres after the harvest and the wheat 24 livres after the harvest, on July 13 there was a cloud of hail which began the other side of Paris and crossed all of France as far as Picardy, it did great damage, the hail weighed 8 livres, it cut down wheat and trees in its path, its course was two leagues wide by fifty long, some horses were killed.[51]

This hailstorm burst over a great part of central France from Rouen in Normandy as far as Toulouse in the south. Thomas Blaikie, who witnessed

[48] Young, *Travels in France*: 173.
[49] Lefebvre, *La Grand Peur de 1789*: 47–53.
[50] Desbordes, *La chronique villageoise de Vareddes.*
[51] Le Roy Ladurie, *Times of Feast*: 75.

it, wrote of stones so monstrous that they killed hares and partridge and ripped branches from elm trees. The hailstorm wiped out budding vines in Alsace, Burgundy and the Loire, and laid wheat fields waste to in much of Central France. Ripening fruit was damaged on the trees in the Midi and the Calvados regions. In the western province of the Beauce, the cereal crops had already survived one hailstorm on 29 May but succumbed to the second blow in July. Farmers south of Paris reported that, after July, the countryside had been reduced to an arid desert.

In much of France and Spain a prolonged drought with very high temperatures then took place. This was followed by the severest winter since 1709, which had also been a severe El Niño year, when the red Bordeaux was said to have frozen in Louis XIV's goblet.[52] Rivers froze throughout the country and wolves were said to descend from the Alps down into Languedoc. In the Tarn and the Ardeche men were reduced to boiling tree bark to make gruel. Birds froze on the perches or fell from the sky. Watermills froze in their rivers and thus prevented the grinding of wheat for desperately needed flour. Snow lay on the ground as far as Toulouse until late April. In January, Mirabeau visited Provence and wrote: 'Every scourge has been unloosed. Everywhere I have found men dead of cold and hunger, and that in the midst of wheat for lack of flour, all the mills being frozen' (Schama, *Citizens*: 305). Occasional thaws made the situation worse and the Loire in particular burst its banks and flooded onto the streets of Blois and Tours.

All these winter disasters came on top of food shortages brought on by the droughts of the 1787 summer and the appalling harvests of the summer of 1788. As a result, the price of bread doubled between the summer of 1787 and October 1788. By midwinter of 1788, the clergy estimated that a fifth of the population of Paris had become dependent on charitable relief of some sort. In the countryside, landless labourers were especially badly affected. Exploitation of the dearth by grain traders and hoarders made the situation steadily worse. It was in this context that the French king requested communities throughout France to draw up *cahiers* of complaints and grievances to be presented in Paris. During February to April 1789 over 25,000 *cahiers* were drawn up. From these we can assess not only the accumulation of long-term grievances but also get some idea of the intense dislocation of normal economic life that the

[52] See Monahan, *Year of Sorrows.*

extreme weather conditions of the 1780s and especially 1788–89 had brought about. Increasing difficulty of access to common resources, timber shortage, excessive taxes and gross income disparities were all compounded by bad weather and together created the new political demands and anger that spilled over into active rebellion during 1789.

The excessive cold and food shortages of early 1789 soon meant that any hesitation to break anti-poaching laws or customs was overthrown. Rabbits, deer and other game were all slaughtered irrespective of ownership or regulation in many parts of France. Any gamekeepers or other symbols of authoritarian structures who opposed such actions were soon killed. Many sectors of the populace became accustomed to these kinds of resistance which would soon develop into broader reaction and violent protest. Attacks on grain transports both on road and river followed the same pattern. Bakeries and granaries were also assaulted. Anger at the price of grain and bread in Paris soon found suitable targets for rioting and violence, particularly where the large population of rivermen and quayside labourers were workless due to the Seine still being frozen by April. The riots at the Reveillon factory, in which many hundreds of fatalities took place, were an example of this, and set the stage for a growing cycle of revolutionary violence in Paris itself. A number of pamphlets printed at this time made the very specific point that the supply of bread should be the first object of the planned Estates General and that the very first duty of all true citizens was to 'tear from the jaws of death your co-citizens who groan at the very doors of your assemblies'.[53]

These connections between an accumulation of unusual and extreme weather events and popular rebellion were by no means confined to France. In Spain, the cold winter of 1788–89 was, if anything even more unusual than in France. Here too, persistent summer droughts were followed by a winter of intense cold and heavy snowfall.[54] One observer wrote:

> Autumn this year was colder than normal ... and no one alive has ever experienced the weather so cold in El Prat. It was extraordinary, both what was observed and the effects it caused .... on the 30th and 31st December the wash of the waves on the beach froze which has also never been seen or

[53] Quoted in Schama, *Citizens*: 331.

[54] Barriendos et al., 'The Winter of 1788–89 in the Iberian Peninsula'.

> heard of before. Likewise it was observed that the water froze in the wash-basins in the cells where the nuns slept at the Religious Order of Compassion .... the rivers channels froze and the carriages passed over the ice without breaking it.[55]

Between August 1788 and February 1789, cereal prices in Barcelona rose by 50 per cent.[56] This was in spite of the city being accessible by sea. Between February and March 1789 there was a revolt in the city, known as 'Rebomboris de Pa'. Part of the population set fire to the municipal stores and ovens. The authorities attempted to pacify the population by handing out provisions and taking special measures so that supplies could be sold at reasonable prices. The privileged classes, it is said, also provided money and contributions in kind to pacify the underprivileged. The military and police authorities too adopted a passive attitude, letting events run their course. The authorities then took refuge in the two fortresses that controlled the city and powerful defences were put up in case events got out of control. Despite these measures chaotic rioting took place and in the aftermath six people were executed.[57] Similar riots took place on other parts of Catalonia when the poor outlook for the 1789 harvest became clear and profiteers and hoarders made their appearance. Revolts and emergency actions by municipal authorities took place both in the coast and inland with documentary reports being made in cities such as Vic, Mataro and Tortosa.[58] The fact that these social responses to cold and crop failure did not lead to the same degree of social turmoil and rebellion as in France should not disguise the fact that they were highly unusual.

In the summer of 1789 much of France rose in revolt; while in cities urban crowds rioted. How far the resulting course of revolution had its roots in the anomalous climatic situation of the period, that is, in the

[55] Salvá, *Tablas Meteorologicas*, vol. 1, 1788.

[56] J. Fontana, *Historia de Catalunya. La fie de l'Antic regim i la industrialitzacio* (1787–1868), Edicions 62, vol. 5, Barcelona, quoted in Barriendos et al., 'The Winter of 1788–89 in the Iberian Peninsula'.

[57] J. Mercader, *Els capitans generals*, Viviens-Vives, Barcelona, 1986; Santiago Riera i Tuebols, *Ciencia i tecnic a la illistracio; Francesc Salva i Campillo (1751–1828)*, La Magrana, Barcelona, 1985; J.M. Torras i Ribe, 'La Catalunya borbonica: evolucio i reaccions contra el nou regim', *Historia de Catalunya*, 4 (1978), 178–203 (Salvat, Barcelona), all quoted in Barriendos et al., 'The Winter of 1788–89 in the Iberian Peninsula'.

[58] Barriendos et al., 'The Winter of 1788–89 in the Iberian Peninsula'.

circumstances of a powerful El Niño episode coupled with a weak NAO, is open to debate. What is certain is that the part played by extreme weather events in bringing about social disturbance during the French Revolution simply cannot be neglected. It may be, as de Tocqueville put it, that had these responses to anomalous climatic events not occurred, 'the old social edifice would have none the less fallen everywhere, at one place sooner, at another later; only it would have fallen piece by piece, instead of collapsing in a single crash'.[59] One of the advantages in trying to understand the French Revolution in terms of the succession of prior climatic stresses is that the latter contextualises the former, rather than isolating it as a historical phenomenon independent of global factors.

To quote de Tocqueville again, 'The French Revolution will only be the darkness of night to those who see it in isolation; only the times which preceded it will give the light to illuminate it'.[60] Today, we can merely speculate. Nevertheless it is true that the whole social edifice of *Ancien Regime* France did begin to collapse in the context of anomalous climatic conditions which both preceded and accompanied the revolution, in what was undeniably one of the most prolonged and severe El Niño episodes of the millennium. More importantly, it now appears that the history of the Great El Niño of the 1790s can help to illuminate a much larger picture of world history during the last 5,000 years, especially in understanding the connections between El Niño events and the shocks such anomalies have periodically administered to the world economic system.

References

Barriendos, M., J.C. Pena, J. Martin-Vide and P. Jonsson. 2000. 'The Winter of 1788–89 in the Iberian Peninsula from Meteorological Reading Observations and Proxy-data Records', Actas del Congreso Giuseppe Toaldo il Suo Tempo 1719–97. Scienza e Lumi tra Venetoed Europa, Padova, pp. 921–42.

Beatson, Alexander. 1816. *Tracts on the Island of St Helena*, London.

Blair, Charles. 1874. *Indian Famines; Their Historical, Financial and Other Aspects*, Edinburgh and London.

[59] Alexis de Tocqueville, *L'Ancien Regime et la Révolution*: 96.

[60] de Tocqueville, *L' Ancien Regime et la Révolution*: 249. For a more developed discussion of the agrarian background to the French Revolution see Davies, 'The Origins of the French Revolution of 1789'.

Commander, Simon. 1989. 'The Mechanics of Demographic and Economic Growth in Uttar Pradesh: 1800–1900', in Tim Dyson (ed.), *India's Historical Demography: Studies in Famine, Disease and Society*, London.

Davies, Alun. 1964. 'The Origins of the French Revolution of 1789', *History*, vol. 49(165): 24–41.

Desbordes, Jacques M. (ed.). 1969. *La chronique villageoise de Vareddes (Seine et Marne) aux XVIIe et XVIIIe siecles*, Paris.

de Tocqueville, Alexis. 1952. L*'Ancien Régime et la Révolution*, ed. J.P. Mayer, Paris.

Dyson, Tim (ed.). 1989. *India's Historical Demography: Studies in Famine, Disease and Society*, London.

Endfield, Georgina H. and Sarah L. O'Hara. 1997. 'Conflicts Over Water in the "Little Drought Age" in Central Mexico', *Environment and History*, vol. 3(3): 255–72.

Foster, Kenneth R., Mary F. Jenkins and Anna C. Toogood. 1998. 'The Philadelphia Yellow Fever Epidemic of 1793', *Scientific American*, vol. 279(August): 68–74.

Glaser, Rudiger, Stefan Militzer and Rory Walsh. 1991. 'Weather and Climate in Madras, India, in the Years 1732–37, Based upon Analysis of the Weather Diary of the German Missionary Geisler', *Würzburger Geographische Arbeiten*, vol. 80: 45–86.

Grove, Richard H. 1992. 'The Origins of Western Environmentalism', *Scientific American*, July: 42–47.

———. 1998. 'Global Impact of the 1789–93 El Niño', *Nature*, London, 28 May: 318–19.

Hall, M. 1976. 'Dendrochronology, Rainfall and Human Adaptation in the Later Iron Age of Natal and Zululand', *Annals of the Natal Museum*, vol. 22: 693–703.

Hill, Christopher, V. 1997. *River of Sorrow: Environment and Social Control in Riparian North India, 1770–1994*, Association for Asian Studies, Ann Arbor, Michigan.

Horakere, B.M. 'Janapada Sahityadalli Baraghala' (Drought in Folklore), *Janapada Jagathu* (World of Folklore), vol. 9(5).

Hunter, William, W. 1868. *The Annals of Rural Bengal*, London.

———. 1897. *The Annals of Rural Bengal*, Seventh edition, London, Johnson Reprint.

Janisch, Hudson, R. (ed.). 1908. *Extracts of the St Helena Chronicles and Records of Cape Commanders*, Jamestown, St Helena.

Kane, R.P. 1999. 'El Niño Timings and Rainfall Extremes in India, Southeast Asia and China', *International Journal of Climatology*, vol. 19(4): 653–72.

Kington, John. 1988. *The Weather of the 1780s over Europe*, Cambridge.

Labrousse, Ernest. 1944. *La crise de l'économie française à fin de l'Ancien Régime et au debut de la Révolution*, Paris.

Lardinois, Roland. 1989. 'Deserted Villages and Depopulation in Rural Tamil Nadu, c. 1780–1830, in Dyson (ed.), *India's Historical Demography*:16–48.

Lefebvre, Georges. 1932. *La grande peur de 1789*, Paris.

Le Roy Ladurie, Emmanuel. 1972. *Times of Feast, Times of Famine. A History of Climate Since the Year 1000*, London.

McCormick, T. 1987. *First Views of Australia, 1788–1825: An Early History of Sydney, Chippendale, New South Wales*, Sydney.

Meggers, B. 1994. Archaeological Evidence for the Impact of Mega—Niño Events in Amazonia during the Past Two Millennia. *Cltimatic Change*, 28: 321–38.

Monahan, W. Gregory. 1993. *Year of Sorrows: The Great Famine of 1709 in Lyon*, Columbus.

Murton, Brian J. 1984. 'Spatial and Temporal Patterns of Famine in Southern India Before the Famine Codes', in Bruce Currey and Graeme Hugo (eds), *Famine as a Geographical Phenomenon*, Dordrecht: 71–89.

Neumann, J. 1977. 'Great Historical Events that were Significantly Affected by the Weather: Part 2. The Year Leading to the Revolution of 1789 in France', *Bulletin of the American Meteorological Society*, vol. 58(2): 163–68.

Neumann, J. and Dettwiller, Jacques. 1990. 'Great Historical Events that were Significantly Affected by the Weather: Part 9. The Year Leading to the Revolution of 1789 in France', *Bulletin of the American Meteorological Society*, vol. 71(1): 33–41.

Nichols, Neville. 1988. 'More on Early ENSOs: Evidence from Australian Documentary Sources', *Bulletin of the American Meteorological Society*, vol. 69(1): 4–7.

Oliver, Vere L. 1844. *History of Antigua*, London.

Ouweneel, Arij. 1996. *Shadows over Anahuac: An Ecological Interpretation of Crisis and Development in Central Mexico, 1730–1810*, Albuquerque.

Quinn, William H., D.O. Zopf, K.S. Short and R.T.W. Kuo Yang. 1975. 'Historical Trends and Statistics of the Southern Oscillation, El Niño and Indonesian Droughts', *Fishery Bulletin*, vol. 76(iii): 663–78.

Roxburgh, William. 1778 and 1790. 'A Meteorological Diary Kept at Fort St. George in the East Indies', *Philosophical Transactions of the Royal Society*, vol. 68: 180–90 and 80: 112–14.

———. 1793. Letter to Sir Charles Oakley, dated 23 January 1793, East India Company Boards Collections, Ref no. F/4/99, p. 29; British Library, India Office Library and Records, [IOLR] London.

———. 1793. Report to the President's Council, Privy Council Letters, Vol. clxxxl, Tamil Nadu State Archives (Chennai), dated 8 February 1793.

Salvá, Francisco. *Tablas meteorológicos*, 8 vols, 1780–1824, Archive of the Royal Academy of Medicine.

Schama, Simon. 1989. *Citizens: A Chronicle of the French Revolution*, London.

Thompson, Theophilus. 1852. *Annals of Influenza or Epidemic Catarrhal Fever from 1510 to 1837*, London.

Trenberth, Kevin E. and Timothy J. Hoar. 1996. 'The 1990–95 El Niño-Southern Oscillation Event: The Longest on Record?', *Geophysical Research Letters*, vol. 23(1): 57–60.

Walsh, R.P.D., Rudiger Glaser and Stefan Militzer. 1999. 'The Climate of Madras During the Eighteenth Century', *International Journal of Climatology*, vol. 19(9): 1025–47.

Webb, Colin de B. and John B. Wright (eds). 1976. *The James Stuart Archive of Recorded Oral Evidenced Relating to the History of the Zulu and Neighbouring Peoples*, vol. 1, Pietermaritzburg.

Willocks, William and James I. Craig. 1913. *Egyptian Irrigation*, vols 1 and 2, London.

Woodforde, James. 1985. *A Country Parson: James Woodforde's Diary 1758–1802*, Oxford and London.

Young, Arthur. 1953. *Travels in France*, ed. C. Maxwell, London.

Zakry, Antoune. 1926. *The Nile in the Times of the Pharoahs and the Arabs* (in Arabic), Cairo. (Reprinted 1995 by Maktabet Madtrouli.)