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Chapter 2

Under a weak sun at the southern rim of South America (1540–1650)

Margarita Gascón

Historical documents and archival records contain traces of the sun's past cycles and activity because they interfere with earth's climate, ecosystems and societies.[1] Far from the human-agency controversy of the current global warming, in 1971, Emmanuel Le Roi Ladurie's book made the strong argument that humans have always recorded climate fluctuations and past solar activity (although indirectly) when considering the ups and downs of prices of foodstuff, frost dates, natural disasters such as a persistent drought or an increase in the frequency of floods, and disruptions in daily life due to plagues, famines and pandemics.[2] In the past, solar activity was registered in the records of agricultural yield, natural resources availability, environmental conditions, extreme weather and the overall wellbeing of animals and people.[3]

Within the broader field of environmental history, the climate in its relationship with the sun still lacks a multidisciplinary scholarship. Worse, the historical approach to climate has been accused of methodological problems like inappropriate data easily misinterpreted, large spatiotemporal scales, selection bias towards crisis and collapse, and societies mischaracterised as homogeneous entities.[4] These mishaps based on true examples are serious, but they also apply to many other historical themes. For example, is it proof of a 'bias towards crisis and collapse' that political history frequently focuses on revolutions, social unrest and warfare? By the same token, economic and social historians usually rely on documents produced by those affected by a legal or economic situation that impacted their livelihood. Would interpretations necessarily lead to a mischaracterisation of society 'as a homogeneous entity'? Each interpretation of the past, therefore, poses its own challenge.

Dealing with data based on the perception of varying weather and climate carries peculiar problems. In 2004, Jones and Mann argued that historical sources are impact-oriented and influenced by cultural factors, implying that they cannot be taken at face value. Both authors have based their scepticism on the often-misused pieces of evidence of the freezing of the River Thames as a proxy indicator of the Little Ice Age (LIA),[5] but for some historians, there is nothing implicitly wrong in the subjective factor of human reaction to weather abnormalities and climate-related hazards. On the contrary, it speaks volumes about the consequences of weather and climate on people as much as on environments without humans.[6] Difficulties with data interpretation, however, remain.[7] Events referred to in historical sources are proxy indicators that may relate neither to solar activity alone nor climate variability exclusively but to the interplay of multiple variables.[8] In need of insights into the complex relationship between climate, environment and society in regions and periods for which there are archival sources, Ljungqvist, Seim and Huhtamaa have advanced a model ranging from first-order effects of climate on biomass production to fourth-order cultural effects, with the latter interacting on all the preceding levels. In the first-order impact, the three authors place bio-physical effects, quantity and quality of primary products, including energy, built and natural environment, water availability and microorganisms. The second-order impact includes the influence of climate on livelihoods, economy and health; availability and prices of primary products, markets and transportation systems, epidemics and epizootics. The third-order impact involves social and demographic implications, demographic trends (mortality, fertility and migration), human well-being, subsistence crisis and social conflicts. These three interact with the fourth-order impact that comprises cultural responses, religious, scientific, artistic and societal rituals and reactions, crisis interpretation, cultural memory, learning process and adaptation.[9]

To help reconstruct the lesser-known paleoclimate of the southern hemisphere by using all the available sources of information, this chapter deals with the southern rim of South America as the LIA went on. The European invasion and the early decades of colonisation happened during the first half of this climatic period that lasted from the fourteenth century to the early nineteenth century.[10] By the mid-seventeenth century, the Maunder Minimum (MM) was the most recent grand minimum of solar activity, near its lowest levels in the past 8,000 years.[11] The LIA and the MM left traces in the historical sources and archival records,[12] although the tendency is to consider the MM indistinctively inside the LIA.[13]

We identify weather anomalies and environmental crises in the scattered documents produced in colonies in South America's southernmost areas. The majority of the chronicles are printed, such as the minutes of the town meetings of prominent settlers (*actas de cabildo*), which give insights into the ways of coping with the damages inflicted by heavy rains, river floods, snow in the Andes, disruptions in trading routes and plagues. Because several *actas* for the period of the LIA and the MM have vanished, the remaining ones only provide a patchy reconstruction instead of a continuous series. In the case of archival sources, they are of uneven value. Sources for the late sixteenth and early seventeenth centuries are abundant for Chile because of the war with the Araucanians. However, when the first settlers wrote about their experiences, sometimes it was several years after the fact and, not surprisingly, chronicles contain gaps and mistakes. Being aware of uncertainties, we include only events similar to those recorded for other parts of the planet or anomalies established by geo-chronological methods such as geomorphological, lacustrine, pollen and tree-ring analyses.[14] By so doing, we follow examples of how to use historical records to reconstruct paleo-climates.[15] Even with mishaps, valuable illustrations emerge, and the overall image contributes to understanding past solar activity from a more-than-human agency perspective.

The smoking gun of the LIA in southern South America

The LIA is a well-known climatic period whose impact was attested for much of Europe and the northern hemisphere, but proxy-climate records support the concept of a global scale and the claim for solar forcing of parts of the LIA climate.[16] The person who coined the term Little Ice Age to describe a glacial advance during the Holocene was the Dutch-born American geologist Francois Matthe in 1939. Later on, researchers started to note large regional variability in the timings of glacial advances, so the LIA became a more general term for global scales of cooler climate.[17] Common knowledge today establishes that cooling periods may be triggered by different agents such as solar activity, volcanic eruptions, alterations in the ocean currents, variations in earth's orbit, and even acute demographic changes.[18]

The latter agent is of interest to us. The demographic-change hypothesis considers that the conquest and colonisation of the Americas created the conditions for the onset of the LIA. This hypothesis connects the decrease in temperatures with the demographic collapse of natives that followed the introduction of pathogens by the Europeans. As Indigenous human organisms lacked proper immunisation, lethal diseases such as smallpox, measles and influenza decimated native populations quickly. War, hard-labour conditions, and social and cultural dislocation added to the devastating effects of the pandemics. The result was the massive death of Indians, from between 54 and 61 million in 1492 to just 6 million in 1650. The demographic collapse had environmental consequences, for vast areas of cleared and cultivated land were abandoned and soon reforested. The urban and agricultural retreat of more than 60 million hectares of the continent lowered the planet's temperature by capturing CO_2.[19] The plausibility of the thesis came under fire when Bonneuil and Fressoz calculated the carbon concentration in the atmosphere through proxy indicators. The final value went from around 279 to 272 parts per million (ppm) between the start of the sixteenth century and 1610, meaning that the demographic catastrophe was irrelevant to explain the LIA. In their own words, 'but if this low tide of atmospheric carbon is an ominous stratigraphic marker of one of the most terrible events in human history, the variation does not lie outside the general Holocene range of 260 to 284 ppm'.[20] Despite these figures, the discussion is not entirely over yet. Adding to the debate, two British geographers proposed that Indigenous demographic decline, Neotropical reforestation and shifting fire regimes allow us to set the starting date of the Anthropocene around the onset of the LIA and the European colonisation of the Americas.[21] There is little doubt that the Columbian exchange of people, domesticated plants and animals between Asia, Europe, America and Africa have all relentlessly transformed the biosphere since 1492, and in such an overwhelming way that there are enough tangible stratigraphic signatures to allow potential formal chrono-stratification too.[22]

In the southernmost portion of the Americas, changes in climate due to the reduced solar activity associated with the LIA, changes in different environments as the Europeans introduced domesticated species and lethal pathogens, and changes in most native societies and cultures all came together. Proxy indicators of the LIA are very much present in some sixteenth-century sources. One of them is the letter that the conqueror of Chile, Pedro de Valdivia (1497–1553), wrote to Gonzalo de Pizarro describing the supposedly pleasant and balmy Central Valley. He could not pass up the opportunity to mention that, according to the Indians, the weather was unusually colder and wetter.[23] Another eyewitness, Jerónimo de Vivar (1525?–1558), reported that the word *Chile* derived from *Anchachire*, meaning 'Great Cold' in the native language, although he stressed that Santiago was founded by mid-summer and in a valley with nice weather (12 January 1541). Even so, he reported continuous rains and a plague of voracious rats, frequently seen as a proxy indicator of climate fluctuation.[24] An outbreak of rodents relates to a favourable or otherwise change in the ecosystem for the breeding season or food availability. Thus too much or too little humidity may equally affect a rodent population and its behaviour.[25] Nonetheless, there are reasons to believe that, in the case of the event in Chile, this plague of rats was provoked by wetter conditions. Another indicator of the LIA in Chile comes from an earlier mission to conquer Chile. Diego de Almagro (1475–1538) travelled a pre-Columbian route in Argentina (the Inca route or *qhapac ñan*) that crosses the Andes through the pass of Comecaballos or Pircas Negras (both at 28°SL). It was not supposed to be the unbearable enterprise that it finally was. At 150 km northward of the Central Valley, a heavy snowstorm caught Almagro, already discouraged, unprepared for such unusual weather.[26]

Far from being isolated local events in Chile, that same year of 1536, heavy rains in Buenos Aires produced a flash flood that destroyed the first church and other buildings.[27] Similar continuous rains were recorded for Paraguay in 1539 when the *Adelantado* Domingo Martinez de Irala (1509–56) was unable to leave Asunción and control an Indian uprising due to overflowing rivers.[28] Farther north of Asunción, the pouring rains of 1539 flooded poorly drained flat lands, and the Spaniards who were recognising the area had to march for a month with water at waist level, drinking poor-quality water and barely eating a properly cooked meal.[29] In northern Patagonia, cold weather was predominant, with below-average temperatures.[30] Notwithstanding the difficulties, the first settlers in Santiago strongly believed in advancing colonisation southward. However, their optimism vanished at the end of 1598 when the natives in the Araucanía set the colonies ablaze, and all the Spaniards were either murdered or expelled northward of the Biobio River. The royal response to the rebellion was establishing a border in Concepción protected by a professional army. Afterwards, climate conditions associated with the LIA started to play an interesting role. Soldiers had only one summer month (January) to run a military campaign whose main goal was to destroy the planted fields and deprive the native rebels of agriculture. The rationale was that starvation would reduce warfare capacity and propel a truce.

It would eventually happen that way, but not because of human agency. As we will point out later, a more-than-human agency would create the conditions for peace in southern Chile. In the meantime, and adapting themselves very well to the challenge of the January expedition of the Spanish soldiers, the rebel Araucanians grew some maize (*Zea mays*) by the side of the few paths that the Spaniards would transit during a campaign. These plots, however, were a disguise, just to give the soldiers the illusion that they were destroying the next harvest. In truth, most of the croplands were inaccessible to the army, located in higher altitudes and far away from the paths, which made them impossible even to be seen. A report of 1621 to the king concluded that the Indians in Chile died of laughter, not starvation.[31]

In addition, since the earliest days of their interrelationship with the Europeans, the native diet expanded with growing plants with differential harvesting times. Wheat, for example, was a better fit than maize for a cooler weather. Indians also learned how to shepherd European cattle, mainly sheep (*Ovis aries*), and how to raise farm animals, which demonstrates a substantial output of adaptation to weather, environment and warfare at the same time. There are other examples of how environmental conditions became helpful in warfare. Rebels burned fields to deny pasture to the Spanish horses and forced soldiers into unknown and watery terrains where the Indians easily neutralised the effectiveness of both horses and guns. Likewise, increased rain – due to the LIA or otherwise – made navigable some rivers while others were impossible to cross. The Cautín River was navigable then (it is not today), and it was a safer and faster way of communication among tribes, in contrast with the muddy pedestrian paths that the Spanish soldiers were forced to take in case the rebels or a natural event made impassable an easier road. Indians also allowed large swamps to encroach on the surroundings of Purén and Lumaco since such environmental conditions gave their villages natural protection.[32]

Although lacking precise data, we may speculate that sustained cold weather helped spread or worsen respiratory diseases like influenza brought by the Spaniards. Between 1540 and 1650, at least fifteen outbreaks of undetermined epidemics referred to in the sources affected the tribes.[33] In general, the sources do not specify diseases, except in the case of a smallpox outbreak, perhaps because it was highly visible, often lethal, very contagious, and fast spreading. Between 1520 and 1530, the *variola virus* went from the Great Lakes in Canada to the Argentine pampas, killing in its wake half of the natives who became infected.[34] The so-called 'Spanish disease' terrified Araucanians to the point of revolts. An interesting episode occurred in 1611. Lentils were rejected violently because their appearance suggested to the Indians that they were the cause of smallpox, so when the governor Alonso de la Jaraquemada arrived in Chile with a load of olive oil, wine and varied seeds, and a bag containing lentils was accidentally ripped open, native onlookers spread the news. The governor planned to exterminate the Indians by spreading the horrific disease, so the rumour went, causing the violent insurgency of 1612.[35] *Variola virus* thrives in cold and dry winters.[36] Nonetheless, in the rainy 1619, while the Mapocho River in Santiago caused a flash flood, smallpox and chickenpox killed around 50,000 people.[37] Data accuracy is doubtful since this eyewitness wrote his account several years after the fact. However, the importance lies in a vivid memory that assigned a chronological synchronisation to a pandemic and a flood, the two most frequent and devastating disruptions of colonial life.

Regarding the impact of solar fluctuations on microorganisms and diseases, on account of Covid-19, Nasirpour et al. correlated solar activity and pandemics from 1750 to 2020. According to these authors, solar events not only impacted the atmosphere and led to storms, hurricanes and extreme winters but also influenced infectious disease outbreaks. Variations in the intensity of cosmic rays arriving on the earth, primarily due to sunspots, are related to changes in the sun's surface activity. The minimum sunspot number leads to an increase in cosmic ray flux reaching the earth and causing mutations of viruses. A magnetic field shields the earth against solar particles and cosmic rays, but the magnetic field cannot withstand certain elements during a maximum or a minimum sunspot. Three molecular mechanisms – point mutations, gene recombination and gene range – are responsible for the emerging pandemic virus strains; solar and cosmic rays may be a physical mutagen that causes point mutations that contribute to a pandemic.[38] The conclusion adds another interpretation to the spread of diseases in the Americas during the LIA.

On the Spanish side of the Araucanía, bad weather and severe storms were to blame for some military problems like the four-year delay in the reconstruction of the posts destroyed by the Indians during the uprising of 1553.[39] Persistent bad weather explains other disgraceful outcomes. According to a letter to the Crown in 1639, when an Araucanian chief was asked why he had not destroyed the small fort of Angol, he replied that nature alone would do it. His stealing of the horses was just for enjoyment since it made soldiers a bit more miserable when they had to go on foot to collect dry firewood. The chief was right. Angol was destroyed by the agency of nature and the will of desperate soldiers who needed an excuse to run away from duty. According to a report, not natives but soldiers set Angol on fire, not once but three times in a row.[40] Meanwhile, in the Central Valley, the *actas* of Santiago for 1559, 1567–8 and 1574 reported long rainy seasons. We associate some years with the wet cycle of El Niño Southern Oscillation (ENSO), whose effects from the coast of Ecuador to Chile are well known.[41] There was strong ENSO in 1559 and 1574, and a moderate one in 1567–8. The mega-ENSO of 1578–9 destroyed many native villages in Lambayeque, northern Peru, with storms that lasted '40 days'.[42] It seems that this same ENSO deteriorated environmental conditions in southern Chile. An account of 1580 depicted a 'biblical plague' with the horrific scene of rats eating babies in their cribs.[43]

In a broader regional context, sources from 1583 to 1605 for the Altiplano (a zone susceptible to ENSO) describe a cooler-than-usual period,[44] and we believe that the same applies to the Strait of Magellan. Harsh weather doomed Rey Felipe and Nombre de Jesús, the two settlements that Sarmiento de Gamboa had established in 1584 to control the entrance to the Pacific from the Atlantic. The two colonies were the royal response to the traumatising appearance of Francis Drake off the coast of Ecuador in 1579, where he plundered the heavily protected galleon *Nuestra Señora de la Concepción* (aka *El cagafuego*s or 'fireshitter'). To the surprise of the Spanish, Drake had crossed the Strait in seventeen days, half the time Hernando de Magallanes took. This may well be a proxy indicator of a favourable El Niño condition for navigators.[45] At any rate, the episode points to anomalous local conditions, as later on, Thomas Cavendish would navigate the same route in forty-nine days while John Hawkins did it in thirty-eight.[46] By January of 1587, Cavendish could save only a handful of survivors from Rey Felipe since most had already died of hypothermia, cold-related diseases and starvation. Understandably, Cavendish renamed the place as Port Famine.[47] The dramatic affair in the south paired with events in the north, where all 117 settlers in the Roanoke Island colony disappeared sometime between 1587 and 1590. There was a strong El Niño signal in 1590.[48] In Jamestown, founded in 1607, colonists wrote of bad weather, conflicts with Indians and famine to the point of cannibalism.[49] Once again, only 38 of 104 original settlers managed to survive during the first year.[50]

Meanwhile, Florida had 'nothing but rain all that time'.[51] The Paraná basin underwent the same situation,[52] and the Bolivian Altiplano experienced repeated freezes.[53] Consequently, natural resources to combat cool and wet weather became highly demanded. We cannot consider the following data a proper proxy indicator, but it sheds light on other situations associated with LIA's local effects. The need for firewood reached extremes in the treeless pampas, where the *cabildo* of Buenos Aires had to enforce protective measures to avoid unsustainable timber exploitation. Early in the seventeenth century, the *cabildo* fixed a quota and a fee to extract firewood from any ship arriving at the port. Likewise, cart owners had to provide their muleteers and workers with enough food and firewood before entering the city. Among other consequences of the lack of firewood was the poor quality of the buildings, as well-burnt bricks needed energy. Properties were of sun-dried mud and thatch or adobes, giving the impression of widespread poverty.[54]

According to Zeke Hausfather of the Breakthrough Institute (Oakland, California), worldwide, between 1615 and 1620, severe weather is a proxy indicator of the global LIA induced by a decrease in solar activity. In 1616 Japan experienced the coldest spring of the century. In 1620 an intense cold wave swept across Europe. And in a unique anomaly, the Bosporus froze, and people could walk across the ice between Europe and Asia.[55] Off the coast of Chile and Peru, storms battered for a longer period, extending the restrictive period for navigation imposed by the viceroy to avoid shipwrecks. In central Chile and the lower Paraná basin, downpours provoked inundations and the loss of ploughed fields and grazing land. Advances of the Frías and Rio Manso glaciers in the Patagonian Andes indicate wet and cold years.[56] In the pre-Andean Uco Valley, 150 km southward of Mendoza, the increase in humidity in an otherwise desert environment induced changes that combined well with the new demographic condition of the beginning of the seventeenth century. The dense native population of pre-Columbian times had become irrelevant, probably as lethal diseases had already taken their toll.[57] Extensive tracks of land in the Upper Uco strip close to the mountains and with abundant rivers became easily available for the Spaniards. They started grazing cattle brought in from the pampas, Cordoba and Paraguay. After crossing the Andes through the pass of Portillo de los Piuquenes and once in Santiago, most of the cattle provided the tallow and hides exported to Upper Peru. Processed as jerked beef, this valuable commodity was shipped to the Peruvian coastal *haciendas* to feed the slaves of the cotton plantations.[58]

Highly profitable, the tallow and hide trade involved civilians and the Jesuits in an extensive network. This was disrupted by El Niño when the Paraná River could not be crossed, the pampa plains were underwater, and snow storms kept the passes in the Andes closed. The best example of how El Niño cut each segment is the event of 1609–10. When in Chile, Captain Zavala was charged with purchasing horses in Paraguay. However, the high waters on the Paraná River foiled his efforts. He looked for horses around Córdoba, but herds had been reduced due to endless rains, lack of grasslands and recurring pestilence. Upon returning to Chile with a few horses, Zavala was informed that the pass across the Andes was still closed. At his arrival in Santiago, Zavala went to trial to no avail since bad weather – not him – was the culprit for the ruinous enterprise.[59] Besides, the Jesuit *Carta Annua* of 1610 attested to floods along the Parana River, and the *cabildo* of Santiago reported floods in the capital.[60] Similarly, the 1654 event – when the Jesuits completely lost the cattle sent from Uco to Santiago due to abnormal weather – was also recorded in Santa Fe.[61]

The coming of the Maunder Minimum

The 1640s was a decade of harvest failures in Spain. The year 1641 was the third coldest summer recorded over the past six centuries in the northern hemisphere, the second coldest winter in a century in New England, and the coldest winter ever recorded in Scandinavia. In the Iberian Peninsula, there was an increase in precipitation.[62] They were all proxy indicators of the MM. In 2014 Vaquero and Trigo proposed two phases of the MM based on data for the northern hemisphere. They pointed out a ‘deep’ phase from 1645 to 1700 and the ‘extended’ phase from 1618 to 1723.[63] Here we establish some correlations with events in southern Chile. Colder weather had dire consequences for the spread of infections, and in 1639 a pandemic raged among the Araucanians.[64] This time the disease combined with poor environmental conditions and the eruption of the Villarrica volcano in 1640. This eruption probably accelerated the ‘deep’ phase of MM. Earth System Sciences state that the temperature changes due to volcanic activity are one of the most striking features of LIA periods. It produces significant cooling events due to the emission of sulphur dioxide into the upper atmosphere, forming particulates that scatter incoming sunlight.[65] Proxy data of ENOS determine that it doubled after strong volcanic eruptions in the tropics.[66] Such a conjunction of agents was an eerie prelude to the developments preceding the most important interethnic event of the seventeenth century: the 1641 pact of Quillin.

The meeting in Quillin was celebrated in the long-standing Araucanian tradition of a *koyagtun*. During this annual ceremony, wars were declared, truces decided, marriages arranged and copious libations ingested. In the 1641 *koyagtun*, in Quillin, the natives asked the governor of Chile, Francisco López de Zúñiga, marquis of Baides, to join them, knowing in advance that a peace treaty would include sheep, goats and seeds of European grains among the ‘gifts’ natives would receive in exchange for peace. An eyewitness, the Jesuit Alonso de Ovalle, depicted the events in an account of a series of disasters common to volcanic activity in the mountains of middle latitudes.[67] The lava flows, gas emissions and hot water vapour melted the volcano’s ice cap, causing mud avalanches that contaminated neighbouring water courses and the Villarrica Lake, killing fish and waterfowl, and polluting agricultural fields. Additional thunder and lightning activity, as well as earth tremors, lent a supernatural tone to the scene. In the sky, ashes spewed into the atmosphere, thickening a dust veil that reduced the already weak solar radiation and lowered temperatures. The natives believed mountains were home to spirits who expressed bad omens. More frightening still, this came amid rains that had already reduced agricultural yields, putting the natives on the brink of famine. An image from Ovalle’s book shows a monstrous creature emerging from the underworld, high above in the clouds, with gas effluvia crowning the picture. Two armies are engaged in an allegoric fight below: on one side are the Spaniards under the command of Santiago *Matamoros* (the Spanish army’s saint patron), and on the other, the Indians fleeing in disarray. According to Ovalle, this was God's way of helping the Spaniards to achieve the evangelisation of the Indians.[68]

The mid-seventeenth-century environmental situation in southern Chile has a proxy indicator of an international, imperial venue. The MM helps explain the Dutch's short presence in Valdivia. In 1643 an expedition under the command of Hendrik Brouwer headed for the island of Chiloé from what was at that time a Dutch possession in the northeast of Brazil. The mission was to find support from the rebellious Araucanians and start the Dutch colonisation of the southernmost area of the continent. The port of Valdivia would then be a stepping stone in the route to the Asian markets. This Dutch imperial dream ended up in a fiasco mostly due to a more-than-human agency. When in 1623, the Dutch forces established a bridgehead in northeast Brazil, Spanish authorities became aware that they intended to expand into outlying regions, most probably towards the Rio de la Plata. But instead, in 1643, the Dutch launched the expedition to Chile, just when natives would be of negligible help since they had little if any foodstuffs, blaming the shortage on several years of bad weather and earthquakes. After five months of hunger and a rainy winter, with Brouwer now dead of natural causes, the demoralised Dutch abandoned Valdivia and returned to Brazil, never returning to southern Chile.[69] Similar conditions were still prevailing in 1645 during the Spanish fortification of Valdivia. Complaints to Santiago were about food scarcity, lack of assistance from the natives and the never-ending storms.[70]

Conclusion

The two global fluctuations we have considered connect solar activity with the human developments in southern South America during the sixteenth and seventeenth centuries. The chapter has combined data from archival records with data produced by Earth System Sciences to attest to the impacts of the LIA, the MM and the ENOS in the southernmost portions of the Americas. Whenever possible, we contextualised local events in a broader frame of geohistorical developments. The aim was somehow to decentre humans from the account by stressing how climate change was a historical agent. Both the LIA and the MM were global fluctuations derived from the sun's activity interfering with our planet's climate. In Europe, the climax of the LIA was reached in the 1690s,[71] but we need more studies to clarify a chronology for the Americas. There are proxy indicators of extreme weather and disruptions in societies that can be associated with the effects of the LIA in southern South America. In the case of the MM, the impacts on the Araucanía are clear due to its association with the environmental consequences of the Villarrica eruption and a previous pandemic among the natives.[72]

Despite the difficulties and pitfalls when reconstructing past climate using historical documents, the sources used in this chapter attest to human reactions, and thus they are proxy indicators of climate variations. Earth System Sciences are researching for a better understanding of the relations between the sun and the climate on our planet, but since the dawn of time, historical documents illustrate that humans have always reacted to the sun. Cross-culturally, the sun tends to be the universal and most sacred of all natural things. Associated with light and warmth, weather and food production, as well as the general wellbeing of living organisms, the sun is a nonhuman agent that should be part of historical accounts and explanations.

Notes

1. Nils Stenseth, Atle Mysterud, Geir Ottersen, James Hurrell, Kung-Sig Chan & Mauricio Lima, 'Ecological effects of climate fluctuations', *Science* 297 (2002), 1292–6; Joanna Haigh, 'The sun and the earth's climate', *Living Reviews in Solar Physics* 4 (2007), 5–64; William Bruckman & Elio Ramos, 'El sol y el clima en la Tierra', *Revista Umbral* 1 (2017), 42–53.

2. Emmanuel Le Roi Ladurie, *Times of feast, times of famine: a history of climate since the year 1000*. New York, Doubleday, 1971.

3. There are several examples of the use of historical colonial sources to reconstruct the past Latin American climate; see Enrique Florescano, *Precios del maíz y crisis agrícolas. 1708–1810*. Mexico City, Colmex, 1969; Susan Swan, 'Drought and Mexico's struggle for independence', *Environmental Review: ER* 6, no. 1 (1982), 54–62; Virginia García Acosta, *Los precios del trigo en la historia colonial de México*. Mexico City, CIESAS-Casa Chata, 1988; Georgina Endfield, *Climate and society in colonial Mexico: a study in vulnerability*. Malden, MA, Blackwell, 2008; Bradley Skopyk, *Colonial cataclysms: climate, landscape, and memory in Mexico's Little Ice Age*. Tucson, AZ, University of Arizona Press, 2020. In 1983, the archeologist Gustavo Politis used archival records to understand colonial climate fluctuations and the possible impacts on inter-ethnic relations ('Climatic variations during historical times in Eastern Buenos Aires Pampas, Argentina', *Quaternary of South America and Antarctic Peninsula* 2 (1983), 133–61). Similarly, Margarita Gascón and César Caviedes have considered colonial sources for Argentina and Chile ('Clima y Sociedad en Argentina y Chile durante el periodo colonial', *Anuario Colombiano de Historia Social y de la Cultura* 39, no. 2 (2012), 159–85. For an environmental approach to climate and weather see Friederike Otto ('Attribution of weather and climate events', *Annual Review of Environment and Resources* 42 (2017), 627–46. Joao Lima Neto, 'Primeiras impressões dos cronistas e viajantes sobre o tempo e o clima no Brasil colonial'. *Biblio 3w: revista bibliográfica de geografía y ciencias sociales* 11 (2006), https://www.raco.cat/index.php/ Biblio3w/article/view/71890; Katherinne Mora Pacheco, *Entre sequías, heladas e inundaciones. Clima y sociedad en la Sabana de Bogotá, 1690–1870*. Bogotá, Universidad Nacional de Colombia, 2019. The recent book *Un pasado vivo. Dos siglos de historia ambiental latinoamericana* (Bogotá,

Fondo de Cultura Económica-Universidad de los Andes, 2019) edited by Claudia Leal, John Soluri and José Augusto Pádua does not include climate.

4. Dagomar Degroot, Kevin Anchukaitis, Martin Bauch, Jacob Burnham, Fred Carnegy, Jianxin Cui, Katryn de Luna, Piotr Guzowski, George Hambrecht, Heli Htamaa, Adam Izdebski, Katrin Kleeman, Emma Moesswilde, Naresh Neupane, Timothy Newfield, Quing Pei, Elena Xoplaki & Natale Zappia, 'Towards a rigorous understanding of societal responses to climate change', *Nature* 591 (2021), 539–50, p. 541.

5. Philip Jones & Michael Mann, 'Climate over past millennia', *Reviews of Geophysics* 42 (2004), RG2002.

6. The German cultural historian Wolfgang Behringer argues for a 'strong link between the Little Ice Age and witch persecutions in Europe' (*A cultural history of climate*. Cambridge, MA, Polity Press, 2010, 132). Nonetheless he does not imply a mechanical straightforward relation and, for example, he portrays a climate abnormality that once favoured the access to power of the Ming dynasty in China and a similar one in in 1643 that nevertheless created the deep social unrest that expelled the Ming from power (114). See also Behringer, 'Climate change and witch-hunting: the impact of the Little Ice Age on mentalities', *Climatic Change* 43 (1999), 335–51; Daniel Sandweiss & Alice Kelley, 'Archaeological contributions to climate change research: the archaeological record as a paleoclimatic and paleoenvironmental archive', *Annual Review of Anthropology* 41, no. 1 (2012), 371–91.

7. Hubert Lamb (1913–97) was a pioneer and influential historian with his classic *Climate, history and the modern world* (London, Taylor & Francis e-Library, [1982, London, Routledge], 2005, https://ens9004-infd.mendoza.edu.ar) whose detailed research opens the field of historical climatology but at the same time came under scrutiny about the reliability of the data provided by historical sources (see early criticisms in M. J. Ingram, D. Underhill & Tom M. Wigley, 'Historical climatology', *Nature* 276 (1978), 329–34).

8. A decade ago Stephania Gallini identified two problems; the geographical scale and the type of sources, see 'Problemas de método en la Historia Ambiental de América Latina', *Anuario IEHS* 19 (2004), 141–71, pp. 149–50.

9. Fredrik Ljungqvist, Andrea Seim & Heli Huhtamaa, 'Climate and society in European history', *WIREs Climate Change* 12, no. 2 (2021), 1–28.

10. Jean Grove, *The Little Ice Age*. London, Methuen, 1988; Michael Mann, Raymond Bradley & Malcolm Hughes, 'Global-scale temperature patterns and climate forcing over the past six centuries', *Nature* 39 (1998), 779–87; Mathew Owens, Mike Lockwood, Ed Hawkins, Ilya Usoskin, Gareth Jones, Luc Barnard, Andrew Schurer & John Fasullo, 'The Maunder Minimum and the Little Ice Age: an update from recent reconstructions and climate simulations', *Journal of Space Weather and Space Climate* 7, no. A33 (2017); Armando Alberola, *Los cambios climáticos. La PEH en España*. Madrid, Cátedra, 2014; Philip Blom, *El motín de la naturaleza. Historia de la Pequeña Edad de Hielo (1570–1700)*. Barcelona, Anagrama, 2019.

11. Judith Lean & David Rind, 'Evaluating sun-climate relationships since the Little Ice Age', *Journal of Atmospheric and Solar-Terrestrial Physics* 61 (1999), 25–36; Ilya Usoskin, 'A history of solar activity over millennia', *Living Reviews in Solar Physics* 14, no. 3 (2017); Hiroko Miyahara, Fuyuki Tokanai, Toru Moriya, Mirei Takeyama, Hirohisa Sakurai, Kazuho Horiuchi & Hideyuki Hotta, 'Gradual onset of the Maunder Minimum revealed by high-precision carbon-14 analyses', *Scientific Report* 11 (2021), 5482.

12. John Eddy, 'The Maunder Minimum. A reappraisal', *Science* 192 (1976), 1189–202; John Beckman & Terry Mahoney, 'The Maunder Minimum and climate change: have historical records aided current research?', *Library and Information Services in Astronomy* III (LISA III) 153 (1998), https://www.stsci.edu; Valerie Masson-Delmotte,

Michael Schulz, Ayako Abe-Ouchi, Jürg Beer, Andrey Ganopolski, Jesús González Rouco, Eystein Jansen, Kurt Lambeck, Jürg Luterbacher, Timothy Naish, Timothy Osborn, Bette Otto-Bliesner, Terence Quinn, Rengaswamy Ramesh, Maisa Rojas, Xue Mei Shao & Axel Timmermann, 'Information from paleoclimate archives', *Climate change 2013: the physical science basis. Contribution of working group I to the fifth assessment report of the Intergovernmental Panel on Climate Change*', Cambridge, Cambridge University Press, 383–464; Marc Oliva, 'The Little Ice Age, the climatic background of present-day warming in Europe', *Cuadernos de Investigación Geográfica* 44, no. 1 (2018), 7–13; Chantal Camenisch & Christian Rohr, 'When the weather turned bad: the research of climate impacts on society and economy during the Little Ice Age in Europe. An overview', *Cuadernos de Investigación Geográfica* 44, no. 1 (2018), 99–114.

13. Brian Fagan, *The Little Ice Age: how climate made history*. New York, Basic Books, 2002; Geoffrey Parker, *Global crisis: war, climate change and catastrophe in the seventeenth century*. London, Yale University Press, 2013; Dagomar Degroot, *The frigid golden age: climate change, the Little Ice Age, and the Dutch Republic, 1560–1720*. New York, Cambridge University Press, 2018.

14. Henry Diaz & Vera Markgraf, *El Niño. Historical and palaeoclimatic aspects of the southern oscillation*. London, Cambridge University Press, 1992; Ricardo Villalba, 'Fluctuaciones climáticas en latitudes medias de América del Sur en los últimos 1.000 años: sus relaciones con la oscilación del sur', *Revista Chilena de Historia Natural* 67 (1994), 453–61; Brian Fagan, *Floods, famines, and emperors: El Niño and the fate of civilizations*. New York, Basic Books, 1999; César Caviedes, *El Niño in history*. Gainesville, FL, University Presses of Florida, 2001.

15. Raymond Bradley & Philip Jones (eds.), *Climate since 1500 A.D.* London, Routledge, 1992, María R. Prieto & Ricardo García Herrera, 'Documentary sources from South America: potential for climate reconstruction', *Palaeogeography Palaeoclimatology Palaeoecology* 281 (2009), 196–209; Rudolf Brázdil, Andrea Kiss, Jürg Luterbacher, David Nash & Ladislava Reznicková, 'Documentary data and the study of past droughts: a global state of art', *Climate of the Past* 14 (2018), 1915–60; Teresa Bullón Mata, 'Little Ice Age, palaeofloods and human adaptation on the Jarama River (Tajo Basin, Central Spain) from documentary proxy data', *Cuadernos de Investigación Geográfica* 46, no. 2 (2020), 497–519.

16. Frank Chambers, Sally Brain, Dimtri Mauquoy, Julia McCarroll & Tim Daley, 'The Little Ice Age in the southern hemisphere in the context of the last 3000 years: peat-based proxy-climate data from Tierra del Fuego', *The Holocene* 24, no. 12 (2014), 1649–56.

17. Astrid Ogilvie & Trausti Jónsson, '"Little Ice Age" research: a perspective from Iceland'. *Climatic Change* 48, no. 1 (2001), 9–52.; John Matthews & Keith Briffa, 'The Little Ice Age: re-evaluation of an evolving concept', *Geografiska Annaler* 87 A(1) (2005), 17–36.

18. Stephen Self, Michael Rampino & James Barbera, 'The possible effects of large 19th and 20th century volcanic eruptions on zonal and hemispheric surface temperatures', *Journal of Volcanology and Geothermal Research* 11 (1981), 41–60; Gregory Zielinski, 'Climatic impact of volcanic eruptions: mini-review', *The Scientific World Journal* 2 (2002), 869–84; Thomas Cronin, *Paleoclimates: understanding climate change past and present*. New York, Columbia University Press, 2010; Gifford Miller, Geirsdóttir Áslaug, Yafang Zhong, Larsen Darren, Bette Otto-Bliesner, Marika Holland, David Bailey, Kurt Refsnider, Scott Lehman, John Southon, Anderson Chance, Helgi Björnsson & Thorvaldur Thordarson, 'Abrupt onset of the Little Ice Age triggered by volcanism and sustained by sea-ice/ocean feedbacks', *Geophysical Research Letters* 39 (2012), LO2708.

19. Robert Dull, Richard Nevle, William Woods, Dennis Bird, Shiri Avnery & William Denevan, 'The Columbian encounter and the Little Ice Age: abrupt land use

change, fire, and greenhouse forcing', *Annals of the Association of American Geographers* 100, no. 4 (2010), 755–71; Richard Nevle & Dennis Bird, 'Effects of syn-pandemic fire reduction and reforestation in the tropical Americas on atmospheric CO2 during European conquest', *Palaeogeography Palaeoclimatology Palaeoecology* 264, no. 1 (2008), 25–38; Richard Nevle, William Ruddiman & Robert Dull, 'Neotropical human–landscape interactions, fire, and atmospheric CO2 during European conquest', *The Holocene* 21, no. 5 (2011), 853–64; Matthew Liebmann, Joshua Farella, Christopher Roos, Adam Stack, Sarah Martini & Thomas Swetnam, 'Native American depopulation, reforestation, and fire regimes in the Southwest United States, 1492–1900', CEPNAS 113, no. 6 (2016), E696–E704; Alexander Koch, Chris Brierley, Mark Maslin & Simon Lewis, 'Earth system impacts of the European arrival and Great Dying in the Americas after 1492', *Quaternary Science Reviews* 207 (2019), 13–36.

20. Chistophe Bonneuil & Jean-Baptiste Fressoz, *The shock of the Anthropocene: the earth, history and us*. London-New York, Verso, 2016, p. 27.

21. Simon Lewis & Mark Maslin, 'Defining the Anthropocene', *Nature* 519 (2015), 171–80.

22. Yadvinder Malhi, 'The concept of the Anthropocene', *Annual Review of Environment and Resources* 42 (2017), 77–104.

23. 'Cartas de Pedro de Valdivia que tratan del descubrimiento y conquista de Chile', *Crónicas del Reino de Chile* – Pedro de Valdivia: Cartas; Alonso de Góngora Marmolejo: Historia de Chile desde su descubrimiento hasta el año de 1575'; Pedro Mariño de Lobera, 'Crónica del Reino de escrita por el capitán D. Pedro Mariño de Lobera, dirigida al Excelentísimo Sr. D. García Hurtado de Mendoza, Marqués de Cañete, Vicerrey y Capitán General de los Reinos del Perú y Chile, Reducido a Nuevo Método y Estilo por el Padre Bartolomé de Escobar de la Compañía de Jesús', *Crónicas del Reino de Chile*. Madrid, Maribel, 1960, 9–10.

24. Jerónimo de Vivar, *Crónica y relación copiosa y verdadera de los reinos de Chile*. Santiago, Chile, Fondo Histórico y Bibliográfico José Toribio Medina, [1558] 1966, Volume II, 37, 59.

25. Thomas Madsen & Richard Shine, 'Rainfall and rats: climatically-driven dynamics of a tropical rodent population', *Australian Journal of Ecology* 24, no. 1 (2009), 80–9.

26. Benjamín Vicuña Mackenna, *Ensayo histórico sobre el clima de Chile*. Valparaíso, Imprenta del Mercurio, 1877, 18–19.

27. Antonio Elio Brailovsky, 'Buenos Aires, ciudad inundable', *Lhawet* 1, no. 1 (2011), 15–23, p. 16.

28. *Historia del Paraguay*, vol. 2 has half-title, and v.3–6 added t.-p. 'Los jesuitas en el Rio de la Plata, 1586–1830'. First edition of the work published Paris [1756] 1910, www.archives.org.

29. Ulrico Schmidl, *Viaje al Río de la Plata*. Buenos Aires, Nuevo siglo, [1567] 1995, 3.

30. Villalba, 1994, 164.

31. Margarita Gascón, *Naturaleza e imperio: Araucanía, Patagonia, Pampas, 1598–1740*. Buenos Aires, Dunken, 2007, 45.

32. Jerónimo de Vivar was a soldier in the troops that first entered in southern Chile and described the Indian tactics of warfare with detail, see his *Crónica y relación copiosa y verdadera de los reinos de Chile*. Santiago, Chile, Fondo Histórico y Bibliográfico José Toribio Medina, [1558] 1966.

33. Alejandra Araya Espinosa, *Ociosos, vagabundos y malentretenidos en Chile colonial*. Santiago, Chile, Dibam, 1999, 29.

34. Alfred Crosby, *Ecological imperialism: the biological expansion of Europe, 900–1900*. New York, Cambridge University Press, 1999, 201–4.

35. Gerónimo de Quiroga, *Memorias de los sucesos de la Guerra de Chile*. Santiago, Chile, Andrés Bello, [1628–1704] 1979, 322.

36. Harald Frederiksen, Nemesio Torres Muñoz & Alfredo Jauregui Molina, 'Erradicación de la viruela', *Public Health Report* (1959), 207–15, p. 209.

37. Quiroga, 1979, 338.

38. Mohammad Nasirpour, Abbas Sharifi, Mohsen Ahmadi & Saeid Ghoushchi, 'Revealing the relationship between solar activity and COVID-19 and forecasting of possible future viruses using multi-step autoregression (MSAR)', *Environmental Science Pollution Research 28* (2021), 38074–84.

39. Eugene Korth, *Spanish policy in colonial Chile: the struggle for social justice, 1535–1700*. Stanford, CA, Stanford University Press, 1968, 41.

40. 'El marqués de Baides refiere largamente a su Majestad el Rey el estado de cosas de Chile y el que tienen las de guerra, que hoy está más viva que hasta aquí y más imposibilitado de contenerla por falta de hombres de guerra. Concepción, 19 de marzo de 1640', Biblioteca Nacional, Santiago, Chile, Sala Medina, Manuscritos, Volume 137, Document 2478.

41. William Quinn, Víctor Neal & Santiago Antunes de Mayolo, 'El Niño occurrences over four and a half centuries', *Journal of Geophysical Research* 92/C13(1992), 14449–61 (1987); with a reviewed in Quinn, 1992; Louis Ortlieb, 'Las mayores precipitaciones históricas en Chile central y la cronología de los eventos ENOS en los siglos XVI-XIX', *Revista Chilena de Historia Natural* 67 (1994), 463–85.

42. Lorenzo Huertas, *Ecología e historia. Probanzas de indios y españoles referentes a las catastróficas lluvias de 1578, en los corregimientos de Trujillo y Saña*. Chiclayo, Peru, Centro de Estudios Sociales Solidaridad, 1987, 44.

43. Mariño de Lobera, 1960, 520.

44. María Prieto, Roberto Herrera & Patricia Dussel, 'Clima y disponibilidad hídrica en el sur de Bolivia y NO de Argentina entre 1560 y 1720. Los documentos españoles como fuente de datos ambientales', *Bamberger Geographische Schriften Bd* 15 (1998), 35–56.

45. Caviedes, 2001, 70–1.

46. Juan Ladrillero, 'Relación del viaje al Estrecho de Magallanes', *Anuario Hidrográfico de la Marina de Chile*. Valparaíso: Instituto de Historia de la Marina de Chile, 1880, 423–525; Ricardo Padrón, 'América y el espacio transmagallánico, siglo XVI', *Magallania* 48 – especial 'El Viaje de Magallanes 1520–2020' (2020), 79–102.

47. Robert Southey, *English seamen: Howard, Clifford, Hawkins, Drake, Cavendish*. London, [1774–1843] 1897, 320–70, http://www.archive.org

48. Stuart Browning & Ian Goodwin, 'The Paleoclimate reanalysis project'. *Climate Past Discussion* 11 (2015), 4159–204.

49. Francisco Álvarez, *Noticia del establecimiento y población de las colonias inglesas en la América Septentrional*. Madrid, A. Fernández, 1778, 27.

50. Karen Kupperman, *The Jamestown Project*. Cambridge, MA, Harvard University Press, 2007, and 'The puzzle of the American climate in the early colonial period', *The American Historical Review* 87, no. 5 (1982), 1262–5; Frank Grizzard & Boyd Smith, *Jamestown colony: a political, social, and cultural history*. Santa Barbara, CA, ABD Clio, 2007.

51. Archives of the Indies, 54-5-16, f. 12; 54-5-9, f. 32.

52. María R. Prieto, 'Enso signals in South America: rains and floods in the Parana River region during colonial times', *Climatic Change* 83 (2007), 39–54.

53. Alain Gioda & María Prieto, 'Histoire de sécheresses andines: Potosi, El Niño et la Petite Age Glaciaire', *La Météorologie* 8 (1999), 33–42.

54. Gascón, 2007.

55. Parker, 2013, xxvii.

56. Jorge Rabassa, Aldo Brandani, José Boninsegna & Daniel Cobos, 'Cronología de la "Pequeña Edad del Hielo" en los glaciares Rio Manso y Castafio Overo, Cerro Tronador, Provincia de Rio Negro', 9no Congreso Geológico Argentino, Actas 3 (1984), 624–39; Ricardo Villalba, 'Tree-ring and glacial evidence for the medieval warm epoch and the Little Ice Age in southern South America', *Climatic Change* 26 (1994), 183–97; Mariano Masiokas, Andrés Rivera, Lydia Espizua, Ricardo Villalba, Silvia Delgado & Juan Carlos Aravena, 'Glacier fluctuations in extra-tropical South America during the last 1000 years', *Palaeogeography, Palaeoclimatology, Palaeoecology* 281 (2009), 242–6.

57. Margarita Gascón & María José Ots, 'Pulsos ocupacionales prehispánicos y coloniales en Uco – Xaurúa (Mendoza, Argentina). Conquista, enfermedad y adaptación', *Diálogo Andino. Revista de Historia, Geografía y Cultura Andina* 63 (2020), 67–77.

58. Gascón, 2007, 71–94.

59. 'Carta de Pedro Martínez de Zavala a Su Majestad el Rey, Tucumán, 24 marzo 1610', Biblioteca Nacional, Santiago, Chile, Sala Medina, Manuscritos, Volume 118, Document 2085.

60. Vicuña Mackenna, 1877, 18–19.

61. Actas del Cabildo de Santa Fe, Archivo General de la Provincia de Santa Fe, Rosario, Santa Fe, Argentina, http://www.webs.tecnodoc.com.ar

62. Mariano Barriendos, 'Climatic variations in the Iberian peninsula during the late Maunder Minimum (AD 1675–1715): an analysis of data from rogation ceremonies', *The Holocene* 7 (1997), 105–11.

63. José Vaquero & Ricardo Trigo, 'Redefining the limit dates of the Maunder Minimum', *New Astronomy* 34 (2014), 1–6.

64. 'Carta del Marqués de Baides a Su Majestad el Rey. Lima, 13 marzo 1639', Biblioteca Nacional, Santiago, Chile, Sala Medina, Manuscritos, Volume 136, Document 2467, f. 38.

65. Keith Briffa, Philip Jones, Fritz Schweingruber & Timothy Osborn, 'Influence of volcanic eruptions on Northern Hemisphere summer temperature over the past 600 years', *Nature* 393 (1998), 450–55.

66. Bert Rein, Andreas Lückge, Lutz Reinhardt, Frank Sirocko, Anja Wolf & Christian Dullo, 'El Niño variability off Peru during the last 20,000 years', *Paleoceanography and Paleoclimatology* 20, no. 4 (2005), PA4003, 15.

67. Alonso de Ovalle, *Histórica relación del Reyno de Chile y de las misiones que ejercita en él la Compañía de Jesús: A Nuestro Señor Jesucristo Dios y Hombre ya la Santísima Virgen y Madre Nuestra, Señora del Cielo y de la Tierra, a los Santos José, Joachin y Ana, sus padres y abuelos*. Rome, Imprenta de Francisco Cavallo, 1646.

68. Gascón, 2007, 33–7; *Relación Verdadera de las Pazes que Capituló con el araucano rebelado, el marqués de Baides, conde de Pedrosa, governador y capitán general del reyno de Chile, y presidente de la Real Audiencia / Sacada de sus informes y cartas y de los padres de la Compañía de Jesús, que aco[m]pañaron al real ejército en la jornada que hizo para este efecto el año pasado de 1641*. Madrid, Francisco Maroto, 1642, The John Carter Brown Library. Providence, RI. Book LCCN 43022438.

69. Hendrick Brouwer (1581–1643) *Journael ende historis verhael van der Reyse gedaen bij Costen de Straet Le Maire*. Amsterdam, Broer Jansz, 1646, 53–69, 53, 54,

69; for a general account, see Isidoro Vázquez de Acuña, *Las incursiones holandesas en Chiloé*. Santiago, Universidad de Santiago de Chile, 1992.

70. Francisco Enrich, *Historia de la Compañía de Jesús en Chile*. Barcelona, Roral, 1891, 497.

71. Jürg Luterbacher, Ralph Rickli, Elena Xoplaki, C. Tinguely, Christoph Beck, Christian Pfister & Heinz Wanner, 'The late Maunder Minimum (1675–1715): a key period for studying decadal scale climatic change in Europe', *Climatic Change* 49, no. 4 (2001), 441–62, p. 442.

72. Gascón, 'El Minimo de Maunder en el extremo sur de América. Algunos proxy indicators en fuentes del siglo XVII', *Proceedings* E-International Center for Earth Sciences – ICES 16–2021, Buenos Aires-Mendoza, Comisión Nacional de Energía Atómica y Universidad Nacional de Cuyo, 2022, 105–11, www.uncu.edu.ar/ICES

References

Alberola, Armando, *Los cambios climáticos. La PEH en España*. Madrid, Cátedra, 2014.
Araya Espinosa, Alejandra, *Ociosos, vagabundos y malentretenidos en Chile colonial*. Santiago, Chile, Dibam, 1999.
Barriendos, Mariano, 'Climatic variations in the Iberian peninsula during the late Maunder Minimum (AD 1675–1715): an analysis of data from rogation ceremonies', *The Holocene* 7 (1997), 105–11.
Beckman, John & Terry Mahoney, 'The Maunder Minimum and climate change: have historical records aided current research?' *Library and Information Services in Astronomy* III (LISA III) 153 (1998), Instituto de Astrofísica de Canarias, E-38200 La Laguna, Tenerife.
Behringer. Wolfgang, 'Climate change and witch-hunting: the impact of the Little Ice Age on mentalities', *Climatic Change* 43 (1999), 335–51.
Behringer. Wolfgang, *A cultural history of climate*. Cambridge, MA, Polity Press, 2010.
Blom, Philip, *El motín de la naturaleza. Historia de la Pequeña Edad de Hielo (1570–1700)*. Barcelona, Anagrama, 2019.
Bonneuil, Chistophe & Jean-Baptiste Fressoz, *The shock of the Anthropocene: the earth, history and us*. London-New York, Verso, 2016.
Bradley, Raymond & Philip Jones (eds.), *Climate since 1500 A.D*. London, Routledge, 1992.
Brailovsky, Antonio Elio, 'Buenos Aires, ciudad inundable', *Lhawet* 1, no. 1 (2011), 15–23.
Brázdil, Rudolf, Andrea Kiss, Jürg Luterbacher, David Nash & Ladislava Reznicková, 'Documentary data and the study of past droughts: a global state of art', *Climate of the Past* 14 (2018), 1915–60.
Briffa, Keith, Philip Jones, Fritz Schweingruber & Timothy Osborn, 'Influence of volcanic eruptions on Northern Hemisphere summer temperature over the past 600 years', *Nature* 393 (1998), 450–5.
Browning, Stuart & Ian Goodwin, 'The Paleoclimate reanalysis project'. *Climate Past Discussion* 11 (2015), 4159–204.
Bruckman, William & Elio Ramos, 'El sol y el clima en la Tierra', *Revista Umbral* 1 (2017), 42–53.
Bullón Mata, Teresa,'Little Ice Age, palaeofloods and human adaptation on the Jarama River (Tajo Basin, Central Spain) from documentary proxy data', *Cuadernos de Investigación Geográfica* 46, no. 2 (2020), 497–519.
Camenisch, Chantal & Christian Rohr, 'When the weather turned bad: the research of climate impacts on society and economy during the Little Ice Age in Europe. An overview', *Cuadernos de Investigación Geográfica* 44, no. 1 (2018), 99–114.

Caviedes, César, *El Niño in history*. Gainesville, FL, University Presses of Florida, 2001.

Chambers, Frank, Sally Brain, Dimtri Mauquoy, Julia McCarroll & Tim Daley, 'The Little Ice Age in the southern hemisphere in the context of the last 3000 years: peat-based proxy-climate data from Tierra del Fuego', *The Holocene* 24, no. 12 (2014), 1649–56.

Cronin, Thomas, *Paleoclimates: understanding climate change past and present*. New York, Columbia University Press, 2010.

Crosby, Alfred, *Ecological imperialism: the biological expansion of Europe, 900–1900*. New York, Cambridge University Press, 1999.

Degroot, Dagomar, *The frigid golden age: climate change, the Little Ice Age, and the Dutch Republic, 1560–1720*. New York, Cambridge University Press, 2018.

Degroot, Dagomar, Kevin Anchukaitis, Martin Bauch, Jacob Burnham, Fred Carnegy, Jianxin Cui, Katryn de Luna, Piotr Guzowski, George Hambrecht, Heli Htamaa, Adam Izdebski, Katrin Kleeman, Emma Moesswilde, Naresh Neupane, Timothy Newfield, Quing Pei, Elena Xoplaki & Natale Zappia, 'Towards a rigorous understanding of societal responses to climate change', *Nature* 591 (2021), 539–50.

Diaz, Henry & Vera Markgraf, *El Niño: historical and palaeoclimatic aspects of the southern oscillation*. London, Cambridge University Press, 1992.

Dull, Robert, Richard Nevle, William Woods, Dennis Bird, Shiri Avnery & William Denevan, 'The Columbian encounter and the Little Ice Age: abrupt land use change, fire, and greenhouse forcing', *Annals of the Association of American Geographers* 100, no. 4 (2010), 755–71.

Eddy, John, 'The Maunder Minimum. A reappraisal', *Science* 192 (1976), 1189–202.

Endfield, Georgina, *Climate and society in colonial Mexico: a study in vulnerability*. Malden, MA, Blackwell, 2008.

Fagan, Brian, *Floods, famines, and emperors: El Niño and the fate of civilizations*. New York, Basic Books, 1999.

Fagan, Brian, *The Little Ice Age: how climate made history*. New York, Basic Books, 2002.

Florescano, Enrique, *Precios del maíz y crisis agrícolas. 1708–1810*. Mexico City, Colmex, 1969.

Frederiksen, Harald, Nemesio Torres Muñoz & Alfredo Jauregui Molina, 'Erradicación de la viruela', *Public Health Report* (1959), 207–15.

Gallini, Stephania, 'Problemas de método en la Historia Ambiental de América Latina', *Anuario IEHS* 19 (2004), 141–71.

García Acosta, Virginia, *Los precios del trigo en la historia colonial de México*. Mexico City, CIESAS-Casa Chata, 1988.

Gascón, Margarita, 'El Minimo de Maunder en el extremo sur de América. Algunos proxy indicators en fuentes del siglo XVII', *Proceedings* E-International Center for Earth Sciences – ICES 16–2021, Buenos Aires – Mendoza, Comisión Nacional de Energía Atómica y Universidad Nacional de Cuyo, 2022, 105–11.
Gascón, Margarita, *Naturaleza e imperio: Araucanía, Patagonia, Pampas, 1598–1740*. Buenos Aires, Dunken, 2007.
Gascón, Margarita and César Caviedes, 'Clima y Sociedad en Argentina y Chile durante el periodo colonial', *Anuario Colombiano de Historia Social y de la Cultura* 39, no. 2 (2012), 159–85.
Gascón, Margarita & María José Ots, 'Pulsos ocupacionales prehispánicos y coloniales en Uco - Xaurúa (Mendoza, Argentina). Conquista, enfermedad y adaptación', *Diálogo Andino. Revista de Historia, Geografía y Cultura Andina* 63 (2020), 67–77.
Gioda, Alain & María Prieto, 'Histoire de sécheresses andines: Potosi, El Niño et la Petite Age Glaciaire', *La Météorologie* 8 (1999), 33–42.
Grizzard, Frank & Boyd Smith, *Jamestown colony: a political, social, and cultural history*. Santa Barbara, CA, ABD Clio, 2007.
Grove, Jean, *The Little Ice Age*. London, Methuen, 1988.
Haigh, Joanna, 'The sun and the earth's climate', *Living Reviews in Solar Physics* 4 (2007), 5–64.
Huertas, Lorenzo, *Ecología e historia. Probanzas de indios y españoles referentes a las catastróficas lluvias de 1578, en los corregimientos de Trujillo y Saña*. Chiclayo, Peru, Centro de Estudios Sociales Solidaridad, 1987.
Ingram, M. J., D. Underhill & Tom M. Wigley, 'Historical climatology', *Nature* 276 (1978), 329–34.
Jones, Philip & Michael Mann, 'Climate over past millennia', *Reviews of Geophysics* 42 (2004), RG2002.
Koch, Alexander, Chris Brierley, Mark Maslin & Simon Lewis, 'Earth system impacts of the European arrival and Great Dying in the Americas after 1492', *Quaternary Science Reviews* 207 (2019), 13–36.
Korth, Eugene, *Spanish policy in colonial Chile: the struggle for social justice, 1535–1700*. Stanford, CA, Stanford University Press, 1968.
Kupperman, Karen, *The Jamestown Project*. Cambridge, MA, Harvard University Press, 2007.
Kupperman, Karen, 'The puzzle of the American climate in the early colonial period', *The American Historical Review* 87, no. 5 (1982), 1262–5.
Lamb, Hubert, *Climate, history and the modern world*. London, Taylor & Francis e-Library, [1982, London, Routledge], 2005.

Leal, Claudia, John Soluri and José Augusto Pádua, *Un pasado vivo. Dos siglos de historia ambiental latinoamericana*. Bogotá, Fondo de Cultura Económica-Universidad de los Andes, 2019.
Lean, Judith & David Rind, 'Evaluating sun-climate relationships since the Little Ice Age', *Journal of Atmospheric and Solar-Terrestrial Physics* 61 (1999), 25–36.
Le Roi Ladurie, Emmanuel, *Times of feast, times of famine: a history of climate since the year 1000*. New York, Doubleday, 1971.
Lewis, Simon & Mark Maslin,'Defining the Anthropocene', *Nature* 519 (2015), 171–80.
Liebmann, Matthew, Joshua Farella, Christopher Roos, Adam Stack, Sarah Martini & Thomas Swetnam, 'Native American depopulation, reforestation, and fire regimes in the Southwest United States, 1492–1900', CEPNAS 113, no. 6 (2016), E696–E704.
Lima Neto, Joao, 'Primeiras impressões dos cronistas e viajantes sobre o tempo e o clima no Brasil colonial'. *Biblio 3w: revista bibliográfica de geografía y ciencias sociales* 11 (2006), https://www.raco.cat/ index .php/ Biblio3w/article/view/71890
Ljungqvist, Fredrik, Andrea Seim & Heli Huhtamaa, 'Climate and society in European history', *WIREs Climate Change* 12, no. 2 (2021), 1–28.
Luterbacher, Jürg, Ralph Rickli, Elena Xoplaki, C. Tinguely, Christoph Beck, Christian Pfister & Heinz Wanner, 'The late Maunder Minimum (1675–1715): a key period for studying decadal scale climatic change in Europe', *Climatic Change* 49, no. 4 (2001), 441–62.
Madsen, Thomas & Richard Shine, 'Rainfall and rats: climatically-driven dynamics of a tropical rodent population', *Australian Journal of Ecology* 24, no. 1 (2009), 80–9.
Malhi, Yadvinder, 'The concept of the Anthropocene', *Annual Review of Environment and Resources* 42 (2017), 77–104.
Mann, Michael, Raymond Bradley & Malcolm Hughes, 'Global-scale temperature patterns and climate forcing over the past six centuries', *Nature* 39 (1998), 779–87.
Masiokas, Mariano, Andrés Rivera, Lydia Espizua, Ricardo Villalba, Silvia Delgado & Juan Carlos Aravena, 'Glacier fluctuations in extra-tropical South America during the last 1000 years', *Palaeogeography, Palaeoclimatology, Palaeoecology* 281 (2009), 242–6.
Masson-Delmotte,Valerie, Michael Schulz, Ayako Abe-Ouchi, Jürg Beer, Andrey Ganopolski, Jesús González Rouco, Eystein Jansen, Kurt Lambeck, Jürg Luterbacher, Timothy Naish, Timothy Osborn, Bette Otto-Bliesner, Terence Quinn, Rengaswamy Ramesh, Maisa Rojas, Xue Mei Shao & Axel Timmermann, 'Information from paleoclimate archives', *Climate change 2013: the physical science basis*.

Contribution of working group I to the fifth assessment report of the Intergovernmental Panel on Climate Change. Cambridge, Cambridge University Press, 383–464.

Matthews, John & Keith Briffa, 'The Little Ice Age: re-evaluation of an evolving concept', *Geografiska Annaler* 87 A(1) (2005), 17–36.

Miller, Gifford, Geirsdóttir Áslaug, Yafang Zhong, Larsen Darren, Bette Otto-Bliesner, Marika Holland, David Bailey, Kurt Refsnider, Scott Lehman, John Southon, Anderson Chance, Helgi Björnsson & Thorvaldur Thordarson, 'Abrupt onset of the Little Ice Age triggered by volcanism and sustained by sea-ice/ocean feedbacks', *Geophysical Research Letters* 39 (2012), LO2708.

Miyahara, Hiroko, Fuyuki Tokanai, Toru Moriya, Mirei Takeyama, Hirohisa Sakurai, Kazuho Horiuchi & Hideyuki Hotta, 'Gradual onset of the Maunder Minimum revealed by high-precision carbon-14 analyses', *Scientific Report* 11 (2021), 5482.

Mora Pacheco, Katherinne, *Entre sequías, heladas e inundaciones. Clima y sociedad en la Sabana de Bogotá, 1690–1870*. Bogotá, Universidad Nacional de Colombia, 2019.

Nasirpour, Mohammad, Abbas Sharifi, Mohsen Ahmadi & Saeid Ghoushchi, 'Revealing the relationship between solar activity and COVID-19 and forecasting of possible future viruses using multi-step autoregression (MSAR)', *Environmental Science Pollution Research 28* (2021), 38074–84.

Nevle, Richard & Dennis Bird, 'Effects of syn-pandemic fire reduction and reforestation in the tropical Americas on atmospheric CO2 during European conquest', *Palaeogeography Palaeoclimatology Palaeoecology* 264, no. 1 (2008), 25–38.

Nevle, Richard, William Ruddiman & Robert Dull, 'Neotropical human–landscape interactions, fire, and atmospheric CO2 during European conquest', *The Holocene* 21, no. 5 (2011), 853–64.

Ogilvie, Astrid & Trausti Jónsson, '"Little Ice Age" research: a perspective from Iceland'. *Climatic Change* 48, no. 1 (2001), 9–52.

Oliva, Marc, 'The Little Ice Age, the climatic background of present-day warming in Europe', *Cuadernos de Investigación Geográfica* 44, no. 1 (2018), 7–13.

Ortlieb, Louis, 'Las mayores precipitaciones históricas en Chile central y la cronología de los eventos ENOS en los siglos XVI-XIX', *Revista Chilena de Historia Natural* 67 (1994), 463–85.

Otto, Friederike, 'Attribution of weather and climate events', *Annual Review of Environment and Resources* 42 (2017), 627–46.

Owens, Mathew, Mike Lockwood, Ed Hawkins, Ilya Usoskin, Gareth Jones, Luc Barnard, Andrew Schurer & John Fasullo, 'The Maunder

Minimum and the Little Ice Age: an update from recent reconstructions and climate simulations', *Journal of Space Weather and Space Climate* 7, no. A33 (2017).
Padrón, Ricardo, 'América y el espacio transmagallánico, siglo XVI', *Magallania* 48- especial 'El Viaje de Magallanes 1520–2020' (2020), 79–102.
Parker, Geoffrey, *Global crisis: war, climate change and catastrophe in the seventeenth century*. London, Yale University Press, 2013.
Politis, Gustavo, 'Climatic variations during historical times in Eastern Buenos Aires Pampas, Argentina', *Quaternary of South America and Antarctic Peninsula* 2 (1983), 133–61.
Prieto, María R., 'Enso signals in South America: rains and floods in the Parana River region during colonial times', *Climatic Change* 83 (2007), 39–54.
Prieto, María R. & Ricardo García Herrera, 'Documentary sources from South America: potential for climate reconstruction', *Palaeogeography Palaeoclimatology Palaeoecology* 281 (2009), 196–209.
Prieto, María R., Roberto Herrera & Patricia Dussel, 'Clima y disponibilidad hídrica en el sur de Bolivia y NO de Argentina entre 1560 y 1720. Los documentos españoles como fuente de datos ambientales', *Bamberger Geographische Schriften Bd* 15 (1998), 35–56.
Quinn, William, Víctor Neal & Santiago Antunes de Mayolo, 'El Niño occurrences over four and a half centuries', *Journal of Geophysical Research* 92/C13(1992), 14449–61 (1987); with a reviewed in Quinn, 1992.
Rabassa, Jorge, Aldo Brandani, José Boninsegna & Daniel Cobos, 'Cronología de la "Pequeña Edad del Hielo" en los glaciares Rio Manso y Castafio Overo, Cerro Tronador, Provincia de Rio Negro', 9no Congreso Geológico Argentino, Actas 3 (1984), 624–39.
Rein, Bert, Andreas Lückge, Lutz Reinhardt, Frank Sirocko, Anja Wolf & Christian Dullo, 'El Niño variability off Peru during the last 20,000 years', *Paleoceanography and Paleoclimatology* 20, no. 4 (2005), PA4003.
Sandweiss, Daniel & Alice Kelley, 'Archaeological contributions to climate change research: the archaeological record as a paleoclimatic and paleoenvironmental archive', *Annual Review of Anthropology* 41, no. 1 (2012), 371–91.
Schmidl, Ulrico, *Viaje al Río de la Plata*. Buenos Aires, Nuevo siglo, [1567] 1995.
Self, Stephen, Michael Rampino & James Barbera, 'The possible effects of large 19th and 20th century volcanic eruptions on zonal and

hemispheric surface temperatures', *Journal of Volcanology and Geothermal Research* 11 (1981), 41–60.
Skopyk, Bradley, *Colonial cataclysms: climate, landscape, and memory in Mexico's Little Ice Age*. Tucson, AZ, University of Arizona Press, 2020.
Stenseth, Nils, Atle Mysterud, Geir Ottersen, James Hurrell, Kung-Sig Chan & Mauricio Lima, 'Ecological effects of climate fluctuations', *Science* 297 (2002), 1292–6.
Swan, Susan, 'Drought and Mexico's struggle for independence', *Environmental Review: ER* 6, no. 1 (1982), 54–62.
Usoskin, Ilya, 'A history of solar activity over millennia', *Living Reviews in Solar Physics* 14, no. 3 (2017), https://link.springer.com/article/10.1007/s41116-017-0006-9
Vaquero, José & Ricardo Trigo, 'Redefining the limit dates of the Maunder Minimum', *New Astronomy* 34 (2014), 1–6.
Vázquez de Acuña, Isidoro, *Las incursiones holandesas en Chiloé*. Santiago, Universidad de Santiago de Chile, 1992.
Villalba, Ricardo, 'Fluctuaciones climáticas en latitudes medias de América del Sur en los últimos 1.000 años: sus relaciones con la oscilación del sur', *Revista Chilena de Historia Natural* 67 (1994), 453–61.
Villalba, Ricardo, 'Tree-ring and glacial evidence for the medieval warm epoch and the Little Ice Age in southern South America', *Climatic Change* 26 (1994), 183–97.
Zielinski, Gregory, 'Climatic impact of volcanic eruptions: mini-review', *The Scientific World Journal* 2 (2002), 869–84.

Archival and primary sources

Actas del Cabildo de Santa Fe, Archivo General de la Provincia de Santa Fe, Rosario, Santa Fe, Argentina, http://www.webs.tecnodoc.com.ar
Álvarez, Francisco, *Noticia del establecimiento y población de las colonias inglesas en la América Septentrional*. Madrid, A. Fernández, 1778.
Archivo de Indias, Sevilla. España, 54-5-16; 54-5-9.
Biblioteca Nacional, Santiago, Chile, Sala Medina, Manuscritos, Volume 137, Document 2478: 'El marqués de Baides refiere largamente a su Majestad el Rey el estado de cosas de Chile y el que tienen las de guerra, que hoy está más viva que hasta aquí y más imposibilitado de contenerla por falta de hombres de guerra. Concepción, 19 de marzo de 1640'; Volume 118, Document 2085: 'Carta de Pedro Martínez de Zavala a Su Majestad el Rey, Tucumán, 24 marzo 1610'; Volume 136, Document 2467: 'Carta del Marqués de Baides a Su Majestad el Rey. Lima, 13 marzo 1639'.

Brouwer, Hendrick, *Jourmael ende historis verhael van der Reyse gedaen bij Costen de Straet Le Maire*. Amsterdam, Broer Jansz, 1646.
Crónicas del Reino de Chile, Madrid, Maribel, 1960, https://www.cervantesvirtual.com
Enrich, Francisco, *Historia de la Compañía de Jesús en Chile*. Barcelona, Roral, 1891.
Historia del Paraguay, vol. 2 has half-title, and v.3–6 added t.-p. 'Los jesuitas en el Rio de la Plata, 1586–1830'. First edition of the work published Paris [1756] 1910, www.archives.org
The John Carter Brown Library. Providence, RI. Book LCCN 43022438: *Relación Verdadera de las Pazes que Capituló con el araucano rebelado, el marqués de Baides, conde de Pedrosa, governador y capitán general del reyno de Chile, y presidente de la Real Audiencia / Sacada de sus informes y cartas y de los padres de la Compañía de Jesús, que aco[m]pañaron al real ejército en la jornada que hizo para este efecto el año pasado de 1641*. Madrid, Francisco Maroto, 1642.
Ladrillero, Juan, 'Relación del viaje al Estrecho de Magallanes', *Anuario Hidrográfico de la Marina de Chile*. Valparaíso: Instituto de Historia de la Marina de Chile, 1880, 423–525.
Ovalle, Alonso de, *Histórica relación del Reyno de Chile y de las misiones que ejercita en él la Compañía de Jesús: A Nuestro Señor Jesucristo Dios y Hombre ya la Santísima Virgen y Madre Nuestra, Señora del Cielo y de la Tierra, a los Santos José, Joachin y Ana, sus padres y abuelos*. Rome, Imprenta de Francisco Cavallo, 1646.
Quiroga, Gerónimo de, *Memorias de los sucesos de la Guerra de Chile*. Santiago, Chile, Andrés Bello, [1628–1704] 1979.
Southey, Robert, *English seamen: Howard, Clifford, Hawkins, Drake, Cavendish*. London, [1774–1843] 1897, 320–70, http://www.archive.org
Vicuña Mackenna, Benjamín, *Ensayo histórico sobre el clima de Chile*. Valparaíso, Imprenta del Mercurio, 1877.
Vivar, Jerónimo de, *Crónica y relación copiosa y verdadera de los reinos de Chile*. Santiago, Chile, Fondo Histórico y Bibliográfico José Toribio Medina, [1558] 1966.