PART I

Climate and Its Discontents

CHAPTER 1

The Climate History of North America

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There is a long, proud history in the United States of wrongly conflating weather, climate, and climate change. Most famously, in 2015 Senator James Inhofe brought a snowball to the Senate floor and used it to argue that winter weather in Washington, DC, put the lie to the continued existence of human-caused ("anthropogenic") global warming. Today, climate change deniers continue to make equally absurd claims. Yet even environmentalists with a sounder grasp on science routinely confuse weather and climate change. Many wrongly assume, for example, that global warming accounts for any episode of severe weather, or that hot days in the Arctic mean that warming is progressing faster than previously anticipated.[1]

Weather, climate, and climate change are indeed terms with occasionally confusing and contested meanings that have shifted dramatically through time. This book shows, in part, how meanings have differed between different groups in America, and how they have evolved from early modernity to the present. Yet here at the outset it is essential to define, as precisely as possible, what these terms have come to mean today.

"Weather" now refers to the state of the atmosphere over short timeframes, often but not necessarily in a particular place. "Climate," by contrast, is all about the statistics that allow us to calculate the "normal" range of weather – in other words, the mean and variability (the extremes that can be reached) of weather – over long timeframes, traditionally thirty

[1] Philip Bump, "Jim Inhofe's Snowball Has Disproven Climate Change Once and for All," *Washington Post*, February 26, 2015. Available at: www.washingtonpost.com/news/the-fix/wp/2015/02/26/jim-inhofes-snowball-has-disproven-climate-change-once-and-for-all/?noredirect=on; Thomas Mote, "Greenland's Ice Wasn't Supposed to Melt Like Last Week Until 2070," *The Hill*, August 4, 2019. Available at: https://thehill.com/opinion/energy-environment/456112-greenlands-ice-sheet-wasnt-expected-to-melt-like-this-until-2070.

years. "Climate change," then, refers to a shift in normal weather, either its mean or its variability, that lasts for longer than thirty years.[2]

Even today, these tidy definitions can break down in practice. In particular, the thirty-year timeframe after which weather becomes climate, and after which climate is said to change, has been criticized for being incongruous with both the rapid speed of present-day warming and the lived experience of those who endured past climatic shocks. There is still therefore a blurry boundary between weather, climate, and climate change, but it remains a boundary worth highlighting.[3]

With these modern definitions in mind, this chapter explores how, and with what effect, the climate has changed across the diverse environments that today constitute the United States. It explains how scholars have been able to detect those changes, and acknowledges lingering areas of uncertainty. It then identifies particularly extreme climatic shocks and weather events that influenced indigenous and settler histories from the sixteenth through twentieth centuries. It devotes special attention to the natural climate changes of the "Medieval Climate Anomaly" and "Little Ice Age"; to precipitation anomalies associated with variability in sea surface temperatures and atmospheric circulation; and to major hurricanes along America's eastern coastline. These descriptions are hardly comprehensive, but they offer a rough introduction into the ways in which both climatic trends and weather events that may or may not be associated with those trends have influenced the history of North America.

In the interest of brevity, this chapter does not go into how Americans and their ancestors contributed to changes in climate and weather. Of course, there is a long history of that too, beginning with the prehistoric destruction of large North American mammals (so-called megafauna); continuing controversially with the colonial genocide of indigenous peoples across the Americas (which may have led forests to colonize abandoned land, and thereby pulled enough carbon out of the atmosphere to cool the Earth); continuing of course with the rise of colonialism, capitalism, industrialization, and the present-day Anthropocene; and culminating with the present-day emergence of new technological, cultural, and legal solutions to anthropogenic global warming. This history is no less integral to North America's experience of climate change, but important parts of it

2 "Climate vs. Weather," National Snow & Ice Data Center. Available at: https://nsidc.org/cryosphere/arctic-meteorology/climate_vs_weather.html.
3 Mark Carey and Philip Garone, "Forum Introduction," in "Forum: Climate Change and Environmental History," *Environmental History* 19:2 (2014), 284.

have been told elsewhere, and certainly America's contribution to anthropogenic warming will already be in the minds of anyone who reads this book. What is less well known, however, is the long history of climate change across the present-day United States, or the impacts of that history on human affairs. This chapter accordingly devotes attention to these topics, and thereby provides context for the rest of this book.

Detecting Past Cooling; Tracing Recent Warming

The history of the United States is closely entangled with climate change. This history can be divided in three parts: first, the deep history of glaciation and deglaciation that gave rise to America's present-day environment and influenced the migration and lifeways of its first inhabitants; second, the history of more modest climatic fluctuations that affected indigenous and European communities and their interactions; and finally, third, the resumption of extreme climate change with present-day anthropogenic warming.

We know about each of these distinct stages in America's climate history owing to very different lines of evidence, unearthed or created by different kinds of climatologists: paleoclimatologists who glean statistics from the "natural archives" of tree trunks, ice sheets, or lakebed sediments; historical climatologists who uncover archaeological, textual, or oral sources from the human past; and climatologists who today use computer model "hindcasts" and the big data provided by meteorological instruments scattered around the world and in space.[4]

Beginning in the eighteenth century, the discovery of the fossilized remains of cold-adapted animals at temperate latitudes inspired the idea that the climate of the past might have been much colder than that of the present. In the nineteenth century, widespread evidence of past glacial advances and retreats came to light across Europe and North America, and the notion of a past "Ice Age" eventually gained credibility. Early in the twentieth century, scientists mapped the extent of past ice sheets, and an engineer – Milutin Milankovitch – proposed that changes in the characteristics of Earth's orbit, rotation, and axial tilt explained their expansion and retreat.[5]

[4] For an overview of these very different ways of detecting past climate change, see: Sam White, Christian Pfister, and Franz Mauelshagen (eds.), *The Palgrave Handbook of Climate History* (London: Palgrave Macmillan, 2018).

[5] James Woodward, *The Ice Age: A Very Short Introduction* (Oxford: Oxford University Press, 2014), 13, 21. Jürgen Ehlers, Philip Hughes, and Philip L. Gibbard, *The Ice Age* (Chichester: Wiley-Blackwell, 2016), 12.

Cold War research into the ocean environment – an outgrowth of submarine warfare – inspired scientists to drill cores from the ocean floor that revealed historical fluctuations in the ratio of heavy to light oxygen isotopes in the shells of single-celled organisms. Because light oxygen evaporates more readily than heavy oxygen, and because precipitation drawn from ocean evaporation fed the advance of ice sheets, the oceans were "heavier" in colder periods than they were in warmer climates. Isotopic analysis of marine sediment cores confirmed that ice sheets had advanced and retreated many times over millions of years. Study of the cores also proved that "Milankovitch Cycles" in Earth's orbit, rotation, and tilt were partly to blame, but added many details. It turned out that the periodicity of the cycles changed around 900,000 years ago during a "Mid-Pleistocene Revolution" that sharply increased the extent of glaciation during cold periods. Moreover, it now seemed that the modest climate "forcing" – or influence – of the cycles caused glaciation only because of longstanding trends in the position of the continents, the relief of their surface, ocean circulation patterns, and the composition of the atmosphere. Finally, it came to light that Milankovitch cooling must also have been amplified by "feedbacks" in Earth's climate system: processes that can increase or diminish the impulse that created them. These same feedbacks today amplify the effects of human greenhouse gas emissions.[6]

Marine oxygen isotopes therefore revolutionized the study of ice ages. Yet scientists now use many other "climate proxy sources" – aspects of the natural world that register, but do not directly record, past climatic variability – to "reconstruct" climatic trends associated with glacial maxima and minima at high resolution. Layers in cores drilled from ice sheets, for example, record annual precipitation at the poles, and comparing the ratio of isotopes in those layers can shed light on changes in average global temperature. Using such evidence, scientists now know that our current geological period, the Quaternary, lies at the end of a thirty-five-million-year cooling trend. Its first defining characteristic – the persistence of ice sheets on Earth – is in fact a rarity in the planet's long history. Its second distinguishing feature prevailed during the Pleistocene, the geological epoch that dominated the Quaternary, and it was the relentless alternation between frigid, dry glacials and warmer, wetter interglacials. Changes in Earth's climate more extreme than even the worst-case scenarios for global warming this century often unfolded in very short order, perhaps over just a few decades.[7]

[6] Woodward, *The Ice Age*, 97; Ehlers, Hughes, and Gibbard, *The Ice Age*, 38.
[7] Woodward, *The Ice Age*, 112, 116; Ehlers, Hughes, and Gibbard, *The Ice Age*, 15, 43, 97.

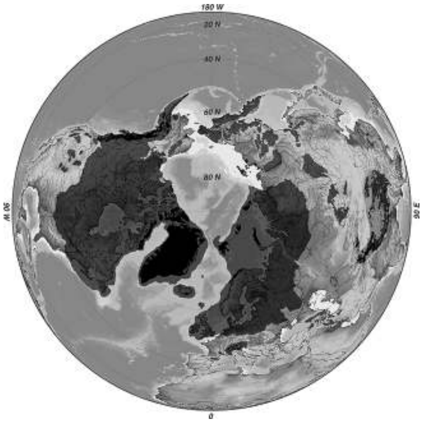

Figure 1.1 Present-day (black) and maximum (grey) glaciation of the northern hemisphere during the Quaternary climatic cycles
Source: Jürgen Ehlers, and Philip L. Gibbard, "The extent and chronology of Cenozoic global glaciation." *Quaternary International*, 164 (2007): 6–20; Ehlers, Hughes, and Gibbard, *The Ice Age*, 42.

The consequences for North America were and remain profound. The Laurentide Ice Sheet expanded during glacials until it reached as far south as present-day New York City and Chicago, making it much larger than the ice sheets that today cover Antarctica (Figure 1.1). The halting retreat of the Laurentide Ice Sheet and the Cordilleran Ice Sheet in the wake of the Last Glacial Maximum (LGM) and the relatively short spasm of cooling known as the Younger Dryas scoured the landscape across much of the northern United States and gave birth to today's Great Lakes.[8]

With the end of the Younger Dryas some 11,700 years ago, the Pleistocene gave way to the Holocene epoch: a long interglacial distinguished on a global scale by a relatively warm, wet, and stable climate. In temperate North America, a gradual warming trend likely peaked around 2,000 years ago, and then until very recently a gradual cooling trend took hold. Precipitation trends rose more persistently, despite some severe century-scale fluctuations, and only reached their Holocene maximum in the past century. The forces that gave rise to frigid, dry glacials persist, however, and repeat glaciations will only be held off over the next several hundred thousand years by the enduring effects of anthropogenic global

[8] Woodward, *The Ice Age*, 131; W. Dansgaard, J. W. C. White, and S. J. Johnsen, "The Abrupt Termination of the Younger Dryas Climate Event," *Nature*, 339:6225 (1989), 532.

warming. Barring human intervention, the Laurentide Ice Sheet will re-emerge and eventually reclaim its losses.[9]

Climatic variability persisted for the entire history of the Holocene, including in recent centuries and millennia. To detect and track climate changes across those timeframes, paleoclimatologists make use of dozens of proxy sources drawn from natural archives, including the unique archives created by living organisms. For example, because new cells in trees are long and slender early in a growing season, and short and stubby toward the end of the season, tree trunks have rings that reveal how much a tree expanded – or in other words, grew – every season. By tracking the changing width of those rings over the lifespan of a tree, scientists can determine how tree growth fluctuated in a region over hundreds and in some cases even thousands of years. They must then correlate recent tree growth to reliable measurements of temperature and precipitation recorded by meteorological instruments in that region. Armed with these statistics, they can use tree rings in living trees, fossilized wood, or even timber in ancient buildings to track climatic fluctuations during growing seasons – typically summer – extending thousands of years back in time. Recently, scientists have started to compare the ratio of heavy to light isotopes in tree rings to gain even more precise measurements of past climatic variability.[10]

Even when used in concert, the evidence exhumed from different proxy sources can have serious shortcomings. The "resolution" – that is, the precision in time and space – of proxy sources is always quite low, and it is often impossible for scientists to use proxies to obtain equally reliable and detailed information about every part of the Earth. Some environmental data – such as changes in storminess and the extent or thickness of sea ice – can be difficult to reconstruct using proxies, and many proxies provide better information in some seasons (summer, in the case of tree rings) than others. To begin to fill in these gaps, scientists turn to many of the same computer models that now forecast the future of global warming. Instead of starting these models in our present, however, they begin them at some point in the past and run them forward, constraining their simulations

[9] Bryan N. Shuman and Jeremiah Marsicek, "The Structure of Holocene Climate Change in Mid-Latitude North America," *Quaternary Science Reviews* 141 (2016), 38–51; Jeremiah Marsicek et al., "Reconciling Divergent Trends and Millennial Variations in Holocene Temperatures," *Nature*, 554:7690 (2018), 92.

[10] Kevin Anchukaitis, "Tree Rings Reveal Climate Change Past, Present, and Future 1," *Proceedings of the American Philosophical Society*, 161:3 (2017), 245. See also: Valérie Trouet, *Tree Story: The History of the World Written in Rings* (Washington, DC: Johns Hopkins University Press, 2020).

where possible with data from other lines of evidence. These model "hindcasts" can verify proxy-based reconstructions; reveal why Earth's climate changed in the past; and suggest how climatic trends played out in places where paleoclimatologists have not yet accessed proxy sources in sufficient quantities.[11]

Yet model simulations typically offer no higher resolution than proxy-based reconstructions, and that can make them ill-suited to reveal exactly how climatic trends affected the weather events that influenced human history. Moreover, they are simplified simulations of real-world conditions and therefore do not provide direct evidence of past climate changes. Fortunately, historians, archaeologists, and geographers can also use records of the human past to reconstruct recent climatic trends. These can either be direct observations of past weather (in the form of qualitative descriptions or quantitative measurements); evidence of activities, such as harvests and waterborne commerce, that must have been influenced by weather; or memories of past environmental extremes that still reverberate in myths, legends, and oral histories. Some sources, such as logbooks written aboard sailing ships, fill more than one of these categories. Sailors both observed weather to aid in navigation and recorded the movement of their ships, which weather directly influenced.[12]

Records of the human past that shed light on past climate change become increasingly numerous and widely distributed around 1450, as a result of numerous historical developments that include the invention of the printing press in Europe, the beginning of the European age of exploration, and the growth of state bureaucracies. Thereafter, some texts can be used like proxies from natural archives to verify model hindcasts and reconstructions compiled by scientists with other evidence. Direct measurements of weather recorded by meteorological instruments can of course be especially useful for historical climatologists, especially after the rapid expansion of weather stations in the nineteenth century.[13]

11 Eduardo Zorita and Sebastian Wagner, "Analysis and Interpretation: Modeling of Past Climates," in *The Palgrave Handbook of Climate History*, 142.

12 Stefan Brönnimann et al., "Archives of Nature and Archives of Societies," in *The Palgrave Handbook of Climate History*, 29.; Dagomar Degroot, *The Frigid Golden Age: Climate Change, the Little Ice Age, and the Dutch Republic, 1560–1720* (New York: Cambridge University Press, 2018), 13; Dennis Wheeler, "Hubert Lamb's 'Treasure Trove': Ships' Logbooks in Climate Research," *Weather*, 69:5 (2014), 136; Dennis Wheeler and Ricardo García-Herrera, "Ships' Logbooks in Climatological Research," *Annals of the New York Academy of Sciences*, 1146:1 (2008), 2.

13 Sam White, "North American Climate History (1500–1800)," in *The Palgrave Handbook of Climate History*, 300; Christian Pfister, "Evidence from the Archives of Societies: Documentary Evidence – Overview," in *The Palgrave Handbook of Climate History*, 38.

Together, all of these sources reveal that the North American climate has fluctuated modestly but, on regional scales, significantly over even the most recent millennia of the Holocene. The precise nature of these fluctuations varies with the ensemble of sources used by scholars in different disciplines, but several periods of relatively persistent warm or cool temperatures stand out. In particular, temperatures across much of North America were generally warm during a so-called Medieval Climate Anomaly (MCA) between roughly 750 and 1100 CE. Temperatures then cooled erratically during a "Little Ice Age" (LIA) that, according to some definitions, began in the Arctic during the thirteenth century and, across North America, reached its coldest points in the seventeenth and nineteenth centuries. In much of North America, the transition to cooler conditions began later than it did in the Arctic, Europe, and Asia, and the cooling trend may have been less significant across long timeframes. Still, the coldest centuries of the LIA may have been over 0.5 degrees Celsius cooler across North America than the late twentieth-century mean. By comparison, as of this writing temperatures have warmed by roughly 0.8 degrees Celsius relative to that mean.[14]

Scientists continue to debate the causes – what they call "forcing" – most responsible for both the MCA and LIA. Most agree, however, that these causes involved some combination of "external forcing" – gradual changes in Earth's orbital characteristics, fluctuations in solar output, and dust veils launched into the atmosphere by stratovolcanic eruptions – and "chaotic" forcing internal to the mechanics of the climate system. Just as they had during the Pleistocene, feedbacks buried in that system amplified initially modest sources of external forcing.[15]

Unlike present-day anthropogenic global warming, the comparatively modest temperature variations of both the MCA and LIA began and ended at different times in different places, or even avoided some regions

[14] Valérie Trouet et al., "A 1500-Year Reconstruction of Annual Mean Temperature for Temperate North America on Decadal-to-Multidecadal Time Scales," *Environmental Research Letters*, 8:2 (2013), 6; Moinuddin Ahmed et al., "Continental-Scale Temperature Variability during the Past Two Millennia," *Nature Geoscience*, 6:5 (2013), 339; W. John Calder et al., "Medieval Warming Initiated Exceptionally Large Wildfire Outbreaks in the Rocky Mountains," *Proceedings of the National Academy of Sciences*, 112:43 (2015), 13261–13266; "GISS Surface Temperature Analysis (v4)," NASA GISS. Available at: https://data.giss.nasa.gov/gistemp/maps/index_v4.html.

[15] Michael Sigl et al., "Timing and Climate Forcing of Volcanic Eruptions for the Past 2,500 Years," *Nature*, 523 (2015), 546; Markus Stoffel et al., "Estimates of Volcanic-Induced Cooling in the Northern Hemisphere over the Past 1,500 years," *Nature Geoscience*, 8:10 (2015), 784; Ilya G. Usoskin, "A History of Solar Activity over Millennia," *Living Reviews in Solar Physics*, 14:1 (2017), 20; Dagomar Degroot, "Climate Change and Society in the 15th to 18th Centuries," *WIREs Climate Change Advanced Review* (2017): 1–20.

altogether. In particular, reconstructions or hindcasts dependent on a single kind of source or model can suggest surprising local variations, partly because they are sensitive to different kinds of weather in different seasons, and partly because some of those variations really existed. For example, tree rings cored from the tree line in Alaska and present-day northern Canada indicate that northern North America endured the cooling of two especially cold waves of the LIA: the so-called Grindelwald Fluctuation of the late sixteenth through early seventeenth centuries, and the Maunder Minimum of the mid-seventeenth through early eighteenth centuries. Tree rings suggest that western North America also cooled during the seventeenth century, even if colder conditions there were not concentrated in a Grindelwald Fluctuation or Maunder Minimum. Yet documentary evidence hints that seventeenth-century cooling was moderate or even nonexistent in some parts of what is now the northeastern United States. According to marine sediments, Chesapeake Bay may actually have been quite warm for much of the seventeenth century and only cooled in the eighteenth century. Sediments also suggest that glaciers advanced in the Canadian Rockies not in the seventeenth century but rather during the early eighteenth century, although changes in precipitation rather than temperature likely accounted for their expansion. Across North America, the LIA was nothing if not complex. Nevertheless, ensemble simulations and reconstructions reveal widespread cooling across most of the continent.[16]

During both the MCA and the LIA, changes in patterns of precipitation coincided with shifts in average temperature, in North America and elsewhere. So-called megadroughts – droughts that persisted for several decades or even longer – repeatedly afflicted western North America during the MCA. Model simulations and proxy-based reconstructions suggest that the cause for these droughts involved a combination of cold sea surface temperature anomalies in the Pacific; warm sea surface

[16] Maude Naulier, Martine M. Savard, Christian Begbin, et al., “A Millennial Summer Temperature Reconstruction for Northeastern Canada Using Oxygen Isotopes in Subfossil Trees,” *Climate of the Past*, 11:9 (2015), 1159; R. D. D’Arrigo and G. C. Jacoby Jr., “Dendroclimatic Evidence from Northern North America,” in Raymond S. Bradley and Philip D. Jones (eds.), *Climate Since A.D. 1500* (New York: Routledge, 2003), 302; Jennifer R. Marlon et al., “Climatic History of the Northeastern United States during the Past 3000 years,” *Climate of the Past*, 13:10 (2017); H. C. Fritts and X. M. Shao, “Mapping Climate Using Tree-Rings from Western North America,” in *Climate Since A.D. 1500*, 279; W. R. Baron, “Historical Climate Records from the Northeastern United States, 1640 to 1900,” in *Climate Since A.D. 1500*, 83; Thomas M. Cronin et al., “Medieval Warm Period, Little Ice Age and 20th Century Temperature Variability from Chesapeake Bay,” *Global and Planetary Change*, 36:1–2 (2003), 17.