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Source Note: The Textual Record of Climate Change at Sea

Abstract

Anthropogenic climate change is today transforming Earth's oceans with alarming speed, imperiling the fate of all of us on land. Preindustrial and overwhelmingly natural climate changes were, in the Holocene, far smaller in scale and speed than those of today. Yet they too reshaped the oceans and thereby powerfully influenced historical societies. This short essay aims to inspire a new wave of scholarship on the social impacts of past climate change at sea by introducing environmental historians to the rich and still largely underexploited treasure trove of sources that make such work possible. It describes these sources and their relative merits; explains how they can be used to identify, or "reconstruct," periods of past climate change; and shows how they may be used to reveal human responses to those changes. It devotes special attention to the preindustrial period, for which scholarship is especially scant, and to textual evidence from archives in Europe and North America, which is plentiful as early as the seventeenth century. Uniquely, it shows how these sources may be used to write environmental histories of the oceans.

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SHIP LOGBOOKS AND THE CLIMATE OF THE PAST

It is critically important for climatologists to know how Earth's climate changed in the past. Climate reconstructions reveal much about the unusual magnitude of, and causes for, present-day anthropogenic warming. More importantly, they suggest how Earth's environment will respond to and perhaps reinforce warming across different spatiotemporal scales.[1] Scholars may uncover past climate changes in three overlapping ways: by simulating the physics of Earth's past climate using computer model "hindcasts"; by employing "proxy" sources that register, but do not directly record, past climate change (most famously from "natural archives" such as ice cores or tree rings); and, for recent centuries, by using measurements compiled with meteorological instruments. Much of this work is done by scientists, especially paleoclimatologists, but "historical climatologists" may contribute by using records of the human past. Documents can test reconstructions compiled with other sources; permit reconstructions of environmental trends that are very hard to discern using models or natural archives; and reveal with uniquely high precision—or "resolution"—how global climate changes unfolded in time and space.[2]

Historians can use three kinds of documents to detect environmental change across the oceans. The first are records of direct observations of weather, water, and sea ice conditions; the second are records of activities more or less directly influenced by weather and water; and the third are hybrids that combine these categories. These documents in turn divide into three additional groups: first, documents written at sea on ships, boats, or—beginning in the twentieth century—submarines; second, documents written on the coast within sight of the sea; and, third, documents written inland that record weather or activities influenced by the sea.

Documents written at sea, in the immediate proximity of environments affected by, and contributing to, climate change, are often especially valuable for historical climatologists. "Ship logbooks," which are registers of weather and daily or hourly activities aboard vessels at sea, may be the most useful sources of all. Logbooks have their origins in the fifteenth century, when European mariners started to use new nautical technologies to leave familiar coastlines. They needed to know their location in order to determine not only where they were but also how they might arrive at their destination and avoid potential danger. Yet, although they could determine latitude by keeping track of the sun and stars, they could not accurately calculate longitude until the eighteenth-century invention, and the widespread nineteenth-century adoption, of the marine chronometer. They were

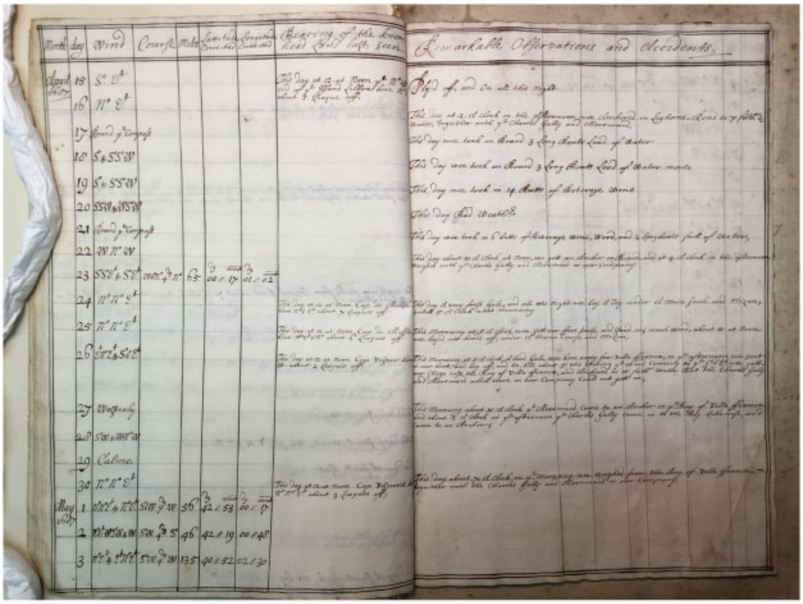

Figure 1. A legible and well-organized logbook, more typical of the eighteenth century than the seventeenth, written aboard the British warship *Dragon* in 1687. Credit: "*Dragon*, 6 August 1686–16 September 1689," ADM 51/269, National Archives, London, United Kingdom.

therefore forced to use "dead reckoning," a technique that required knowledge of three variables: a ship's speed, course, and drift from its course. Since the direction and velocity of the wind accounted for much of that drift, at least one officer meticulously recorded wind and often other weather conditions aboard most European ships (figure 1). Mariners measured winds unencumbered by obstacles that, on land, may redirect or slow wind and thereby obscure the real character of regional atmospheric circulation.[3]

From the sixteenth century, mariners aboard European ships wrote hundreds of thousands of ship logbooks, which were densely packed with systematic weather observations. By the eighteenth century, rising maritime traffic created a truly global network of abundant weather observations, from Svalbard in the Arctic Circle to Tokugawa, Japan. Thousands of logbooks are today stored in national and maritime museums and archives, especially those in seafaring nations across Europe, the Americas, and Asia. Rich collections of logbooks written before the twentieth century are readily accessible, for example, in the Archives of the National Maritime Museum, the National Archives, and the British Library in the United Kingdom; in the National Archives and Records Administration, the New Bedford Whaling Museum, and the Smithsonian Institution in the United

States; in the Nationaal Archief, Utrechts Archief, Westfries Archief, and Zeeuws Archief in the Netherlands; in the Archivo del Museo Naval and the Archivo General de Indias in Spain; and in the Archives Nationales in France.[4] Other logbook collections are housed in hundreds of less prominent archives, museums, and libraries, especially in coastal communities, and, as we will see, a growing number have been photographed, digitized, and stored online. To historical climatologists, ship logbooks provide not only unusually numerous, but also relatively reliable, records of past weather. Many sailors used nautical instruments and drew on extensive experience to make their observations. More importantly, the success of voyages and the safety of crews depended on accurate accounts of local environmental conditions, particularly weather. Logbooks written by sailors from different nations also followed an increasingly standardized format over the course of the seventeenth and eighteenth centuries. Using logbooks, it is therefore unusually easy for scholars to glean weather and journey information from texts written in many languages and stored in many archives.[5]

Still, scholars should guard against the assumption that logbooks always described weather and life at sea as it really happened. Weather observations in logbooks are as fallible and potentially biased as any account in any historical source. Logbooks written aboard British naval ships—arguably, the most frequently used by historical climatologists—in fact copied most (but not necessarily all) wind measurements earlier recorded in simple tables, called log-boards, and are therefore secondary sources for the purpose of weather reconstruction. Scholars should verify logbook observations of weather using logs written by different officers aboard the same ship or by officers aboard different ships in the same fleet. Painstaking work may also be required to reconstruct where logs were actually written and what wind directions mariners really endured because early modern mariners did not always accurately estimate their longitude or consistently describe whether they recorded wind directions with reference to the real or magnetic north poles. Moreover, mariners recorded wind velocity using dozens of now-obsolete nautical terms that varied between different languages and nautical cultures and that can only be translated with difficulty into readings on the modern Beaufort wind force scale. Logs kept by captains or especially admirals, which survived in larger quantities in early periods compared to logs kept by subordinate officers, may also not include systematic weather observations. Before the late eighteenth century, ships also did not sail in sufficient numbers through most parts of the world for scholars to use surviving logbooks to create comprehensive regional—let alone, global—weather reconstructions. And while logbooks survive in large numbers for later periods, many have been lost. Of the ten thousand voyages made by UK whalers to the vicinity of Greenland and Svalbard between the seventeenth and twentieth centuries, for example, logbooks survive for just two hundred. Tens of thousands of logbooks, chronicling the experiences of sailors on ships ranging from sixteenth-century Manila galleons to Second World War merchant vessels have been either purposefully or accidentally destroyed. Scholars must at least acknowledge the difficulty of determining how representative surviving logbooks may be of the many that no longer exist.[6]

OTHER TEXTS AND ONLINE DATASETS

For these reasons, ship logbooks are most valuable for climate reconstruction when used alongside other textual evidence. Journals kept during exceptional voyages—journeys of exploration, for example—may provide similar environmental data, often richer in detail but less systematic and reliable. Most have been published; many are now accessible online. Accounts of the passage of ships through ports and tollhouses, the annual catch brought in by fishermen or whalers, or the duration of ship voyages may provide further evidence of closely related changes in sea surface temperatures, the distribution and extent of sea ice, or patterns of prevailing wind. In some cases, such sources systematically record those changes over centuries. Correspondence, diary entries, intelligence reports, newspaper articles, and (for earlier periods) chronicles may systematically or anecdotally describe weather at sea or blown in from the sea, often at high resolution and occasionally for decades. These sources are often stored in municipal or maritime archives in coastal cities, from Santander to San Francisco; from Valparaiso to Jakarta. Records of maritime insurance or lists of ships lost at sea, which is available, for example, in the Lloyds Insurance Company collection at the London Metropolitan Archives, may provide hints of changes in the frequency or severity of storms or perhaps of the regional extent of sea ice, although many factors other than weather delayed or doomed ship journeys. Paintings, illustrations, and even literature may provide further insights into the changing frequency and severity of weather events at sea, provided they were created for the purpose of accurately depicting reality.[7]

All of these sources have distinct shortcomings, and the historical actors who created them were typically less inclined to record weather as frequently, systematically, or accurately as mariners at sea—when they recorded it at all. Yet, when used together, the sources can provide a robust and reliable record of changes in marine environments. Many also supplement non-textual human records of the oceanic climate, such as oral histories preserved by Indigenous communities; shipwrecks caused partly by storms and scattered in

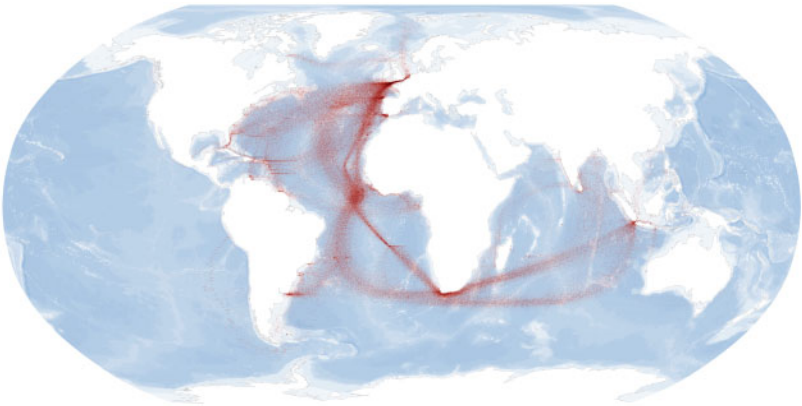

Figure 2. All of the logbook entries in the CLIWOC database, mapped. Credit: Steven Ottens and Dagomar Degroot, "Climatological Database of the World's Oceans," *HistoricalClimatology.com*, https://www.historicalclimatology.com/cliwoc.html.

past areas of heavy trade; or archaeological remains along the coast that bear testament to activities that must have been influenced by change in marine environments, such as fishing and settlement, for example.[8]

If carefully contextualized and verified, information in textual proxies of oceanic climate change can be quantified and entered into databases. This information has therefore attracted the attention of several well-funded research projects, some of staggering scope. The Climatological Database of the World's Oceans (CLIWOC) initiative, for example, quantified and digitized data in nearly three hundred thousand surviving ship logbooks written between 1750 and 1850 (figure 2), while the Sound Toll Registers project did the same for some 1.8 million tolls paid at the tollhouse of Elsinore by ships travelling into and out of the Baltic Sea. Old Weather, an ongoing and even more ambitious undertaking, enlists citizen scientists to transcribe environmental information in nineteenth- and early twentieth-century logbooks written by whalers or naval officers during Arctic journeys. These and many other datasets are freely available online.[9]

RECONSTRUCTING CLIMATE CHANGES AT SEA

By using online datasets, or by creating databases of their own, scholars are now attempting to reconstruct previously unexplored aspects of past climate change at sea and to verify existing reconstructions compiled by scientists. Some of the most important reconstructions are those of wind direction and velocity. Even reconstructions of changes in prevailing wind across small spatiotemporal scales can suggest broader, occasionally global, changes in atmospheric or oceanic circulation, pressure, and temperature that must have followed at least partly from oscillating modes in Earth's climate system, such as the North Atlantic Oscillation or the El Niño Southern Oscillation.[10]

Today and in the past, climate change has especially profound impacts on environments shaped by permanent or seasonal sea ice. Yet quantifying, reconstructing, and mapping sea ice observations in textual evidence presents unique challenges for historical climatologists. Records of sea ice in harbors and heavily trafficked waterways—or records of dues paid at ports and tollhouses—can yield easily quantifiable data, some of which historical climatologists have already graphed and mapped. However, reports of sea ice at high latitudes in correspondence, logbooks, or journals typically give evocative, but unclear, descriptions of sea ice density, which makes it harder to determine just how much sea ice there might have been in different regions from year to year and how past sea ice compares to present-day conditions. The resolution and reliability of Arctic sea ice reconstructions compiled with surviving documents, for example, is therefore often quite low.[11]

A small number of scholars have attempted to use documentary evidence to reconstruct changes in the speed, direction, and temperature of oceanic currents. In general, mariners rarely described the flow of water, but they did so more frequently in the Arctic because currents helped direct the movement of sea ice that could block and imperil ship voyages. But if reports of oceanic currents are generally anecdotal, they may be used to qualitatively verify quantitative reconstructions compiled with scientific evidence. In particular, the flow of water at the periphery of major oceanic currents, such as the Atlantic Meridional Overturning Circulation, may reveal much about the fluctuating strength of those currents.[12] Many ship logbooks also either systematically record precipitation at sea or anecdotally record extreme precipitation, and most note winds that must have influenced precipitation on land. Some researchers have therefore used logbooks to quantify and then graph precipitation at or near the sea, marking, as we will see, a potentially important resource for environmental historians.[13]

Documentary reconstructions of historically important storms, or trends in the frequency and severity of storms, are much more common.[14] Most documents that directly describe weather at sea or blown in from the sea faithfully report storms, especially severe storms such as tropical cyclones, and so are relatively easy to quantify.[15] However, storm reconstructions based on textual evidence of shipwrecks or damage to coastal infrastructure should be treated with caution. Storm damage, of course, reflected both complex social conditions (such as the maintenance of infrastructure or the seaworthiness of ships) and environmental circumstances beyond the severity of storms (such as the direction of winds or the height of tides).[16]

Since scholars may compile text-based climate reconstructions of marine environments for very different reasons, because relatively few scholars have attempted to develop such reconstructions and because the data considered by each scholar may be quite different, there is not yet a generally agreed upon method of reconstructing marine environmental information in textual sources. The most common ground exists in studies of wind direction. Several important publications have converted wind direction measurements from the thirty-two-point system used by mariners in logbooks to a one-, four-, or (very recently) eight-point format, partly because the statistical study of sailors' measurements has revealed them to be biased in favor of four-, eight-, or sixteen-point compass readings. By simplifying the thirty-two-point system, scholars have created "directional indices" that resemble the ordinal scales that historical climatologists use to quantify qualitative observations of temperature on land. Influential publications also attempt to verify weather information in ship logbooks using other sources, including instrumental data (for more recent periods) or correspondence, intelligence reports, and diary entries. Few calculate error or confidence in reconstructions, in part because those considerations are difficult to quantify.[17]

The most convincing publications not only compare weather information in different documents but also compare textual evidence to data from natural archives or model simulations. After all, documents rarely, if ever, provide a complete picture of environmental change at sea. Rather, they offer remarkably high resolution, regional or local, surface-level glimpses into dynamics that can often be traced across longer time frames or across greater scales in vertical or horizontal space, using scientific methods and sources.

Recently, for example, researchers have linked documentary weather observations in the CLIWOC database to datasets that homogenize and synthesize evidence from both textual and natural proxies, such as the National Oceanic and Atmospheric Administration's International Comprehensive Ocean-Atmosphere Data Set. Indeed, there appears to be "a high consistency and homogeneity" both within wind measurements derived entirely from ship logbooks and between such measurements and the data obtained from diverse sources that register the marine climate. While such work has led to reconstructions that appear to trace aspects of the oceanic climate far into the past at high resolution, scientists occasionally assume that documentary evidence of past environmental change can be taken at face value or that accessible datasets created by historians using documents are necessarily comprehensive in scope. Efforts to develop newly accurate reconstructions of marine climate change by synthesizing textual evidence with other kinds of data should therefore draw on the expertise of both scientists and historians, ideally in multidisciplinary teams.[18]

FROM HISTORICAL CLIMATOLOGY TO HISTORY

Because many environmental historians decenter humans in their histories, some may find value in reconstructing climate changes for their own sake. Yet, no doubt, many will be more interested in the historical interactions between climate change and people at or near the sea. Reconstructions by themselves may hint at those relationships or enable seemingly unrelated sources to be read in new ways that account for the influence of climate change on human history. Yet, for most environmental historians, the most exciting aspect of many documents used for climate reconstruction is that they permit new kinds of marine "climate history": the study of the past social impacts of, cultural attitudes toward, and perhaps contributions to climate change. Until now, climate historians have overwhelmingly focused on land-based histories and largely ignored life at sea. Yet bodies of water from oceans to rivers have been central to nutrition, commerce, and conflict from antiquity to the present. Many documents that shed light on marine climate change, moreover, permit climate history at unusually high resolution, revealing how global climatic trends have affected local environments and, in turn, daily, or even hourly, life at sea.

The hundreds of thousands of surviving ship logbooks, for example, may be read in many different ways that all open new perspectives on distinct human responses to climate changes. First, environmental conditions that reflected climatic trends influenced the act of recording environmental data in log-boards and logbooks, in ways occasionally exposed by the material culture of logbooks (figure 3). Storms at sea, for example, could lead to erratic handwriting in logbooks or even water damage. Second, weather powerfully influenced the course and speed of ships, as recorded in logbooks, so that it is possible to quantify the effect of different kinds of weather on voyages in distinct marine environments. Third, logbooks were not only navigation aids but also legal documents that provided a qualitative record of daily or even hourly activities aboard ships: from sailors swept overboard to maneuvers through sea ice; from encounters with hostile vessels to measurements of the seabed. Many such descriptions suggest how weather, sea ice, and, occasionally, ocean currents affected different aspects of life aboard ships and in port.[19]

Environmental historians are discovering that logbooks, when read in these three ways, can connect the climatic histories recovered by historical climatologists and paleoclimatologists with the human

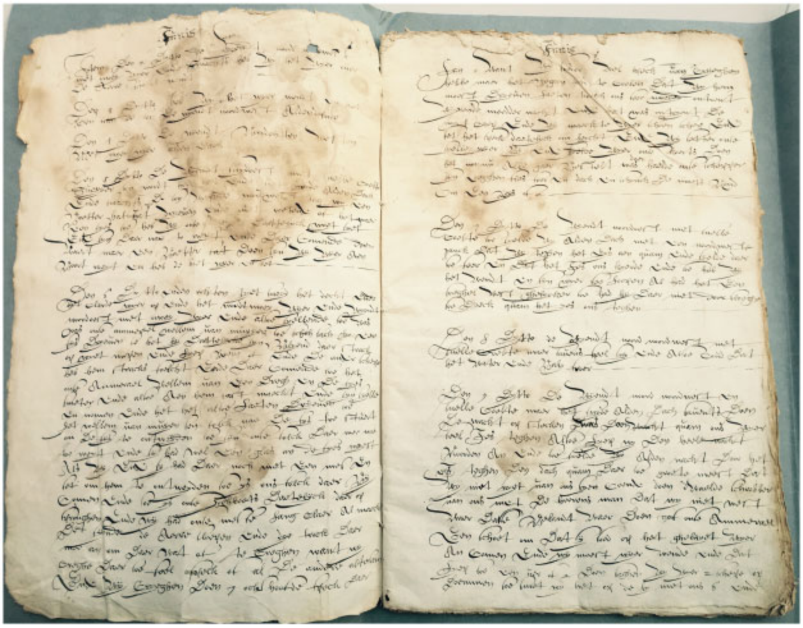

Figure 3. In this weatherworn Dutch ship logbook, written in a ragged style more characteristic of the seventeenth century, an officer describes how a whaling crew bound for the Arctic frantically attempted to evade sea ice in 1615. The crew had the misfortune of setting sail during a particularly cold stretch of the "Little Ice Age." Credit: "Journaal van een Groenlandvaarder, 1615," 0120 Oud archief stad Enkhuizen 1353–1815 (1872), Westfries Archief, Hoorn, Netherlands.

histories crafted by historians. Logbooks written by Dutch whalers on seventeenth-century journeys to the Arctic, for example, can be read as evidence of resilience in a northern climate that was, at the time, cooling amid volcanic eruptions that launched sunlight-scattering sulfur into the stratosphere. The very act of writing in such conditions registered a remarkable capacity to endure. Whaling logbooks also include observations of changes in the extent, thickness, and distribution of sea ice in the Arctic and especially along the coast of the Svalbard archipelago and the island of Jan Mayen. Those observations not only verify and, in some cases, complicate low-resolution reconstructions of sea ice developed using proxy sources from natural archives but also reveal how the speed and course of journeys to the Arctic responded to changes in the Arctic environment.

Records of daily or hourly activities in the logbooks, meanwhile, reveal how shifting weather patterns and, in turn, local sea ice affected the safety of the crew, the outcome of whaling operations, the causes and conduct of conflict between rival whalers, and, ultimately, diplomatic relations between whaling companies and countries. Used together, whaling logbooks, journals, and correspondence suggest, for example, that cooling in the Arctic reduced the threat of violence between whaling fleets by encouraging whalers to cooperate in the few coastal bays along Svalbard and Jan Mayen that remained free of ice during the summer whaling season. Shifts in the concentration and accessibility of a key resource—the whales prized by whalers—did not lead to conflict, indicating that the resources uncovered by retreating sea ice in today's warming Arctic may not provoke the hostilities between Arctic powers that some political scientists, journalists, and military officers anticipate today.[20]

While logbooks tell micro-histories of adaptations to weather and the weather trends of climate change, they can nevertheless illuminate broader narratives. Logbooks written aboard the fleets that fought the naval wars of the seventeenth century, for example, reveal that shifts in atmospheric circulation, associated with episodes of volcanic cooling, changed the winds that prevailed during battles at sea. Those changes made it much more likely, for example, that Dutch fleets could claim an essential tactical advantage—the position between the enemy and the source of the wind, which was named the "weather gage"—when sailing into battle against English, French, or Spanish opposition. When verified using evidence in intelligence reports, correspondence, and diary entries, logbooks suggest that climate change played a key and previously overlooked role in Dutch naval victories of the seventeenth century—victories that established, and then extended, the commercial dominance of the contemporary Dutch Republic.[21]

Logbooks therefore reveal not only how climate change unfolded at sea but also how it altered local environments, prompted diverse human responses, and affected those aspects of life on land that depended on what happened at sea. Environmental historians are today just beginning to use logbooks to uncover how knowing, confronting, and adapting to changeable oceanic environments have long been an essential part of exploration, commerce, conflict, and resource extraction at sea.[22] Yet there is far more work to be done.

Both historical climatology and climate history transform our understanding of the past and open new windows on the present and future crisis of anthropogenic climate change. Historical climatology contributes to reconstructions that reveal the global and local baselines against which today's climate is changing and uncover the meteorological extremes possible in local environments. Climate history, in turn, unearths case studies of past experiences with climate change: social experiments that show which strategies work and which fail in the face of a fluctuating environment. Yet all of this work is woefully incomplete if it ignores the oceans that cover more than 70 percent of the world's surface and govern much that happens on land. Climate histories of the oceans are urgently needed, and the sources that allow them to be written have never been easier to access.

Dagomar Degroot is an associate professor of environmental history at Georgetown University. He is the author of *The Frigid Golden Age: Climate Change, the Little Ice Age, and the Dutch Republic, 1560–1720* (Cambridge University Press, 2018), the co-founder of the Climate History Network, and the founder of the popular website HistoricalClimatology.com.

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