Figure 1. Journal and illustrations by Ira A. Poland of a whaling voyage aboard the ship *Bengal of Salem*, Massachusetts; George G. Russell, Master; Saturday, March 24, 1832. Special Collections, Providence Public Library; Wh B466 1832j. Photo credit: Jayne Doucette/© Woods Hole Oceanographic Institution; used with permission

Extracting Global Maritime Weather Data from New England Whaling and Portuguese Navy Logbooks (1740–1960)

Corresponding author: Timothy D. Walker, twalker@umassd.edu, Department of History, University of Massachusetts Dartmouth
Caroline C. Ummenhofer, Department of Physical Oceanography, Woods Hole Oceanographic Institution

Abstract

In climate research, long datasets that describe weather conditions extending back in time to the pre– or early industrial age are invaluable. Such data helps scientists to establish a historical baseline for weather and climate variability, against which to measure changes over time, better understand anthropogenic departures, and illuminate interactions between different components of the climate system. To provide such information, a maritime historian and an oceanographer have combined their skill sets to expand the body of weather knowledge for some of the most remote regions on the planet. A rich trove of maritime weather information is contained in the vast repositories of ships' logbooks from New England whaling and Portuguese Navy vessels, in which officers recorded weather information multiple times each day over the course of their voyages. Researchers are building a database to extract centuries-old weather information from approximately 4,200 North American whaling and 2,200 Portuguese Navy logbooks dating to the middle eighteenth century.

Keywords

climate research, whaling, logbooks, Portuguese Navy, maritime archives

At the height of the age of whaling under sail in the mid-nineteenth century, nearly 10,000 seasoned mariners and novice "green hands" left ports in the U.S. and Europe each year to hunt for whales. Logbooks from these voyages served as a legal record of the journey; the officers of each vessel kept a daily log to systematically document onboard events and activities. Crucially, these logbook entries include detailed descriptions of weather conditions being experienced by the ship throughout each day. Shared afterward in home ports among owners, agents, and fellow captains, such logbooks informed decisions about when and where to send future whaling ventures. Collectively, this body of documentation constitutes the most chronologically broad and geographically extensive survey of pre-modern ocean conditions and sea life ever conducted—a feat of cumulative observation difficult to replicate, because the natural world has since changed so dramatically.[1] These logbooks now provide abundant material for researchers interested in a range of topics, including climate change (Figure 1).

For the safety and success of future voyages, mariners in the eighteenth and nineteenth centuries knew that it served their best interests to note hazards to navigation on their charts and logs, and to document comprehensive weather data, recorded at intervals of each "watch" rotation, when the crew members on duty changed. The logbooks thus contain, in addition to the vessel's noon latitude and longitude position, systematic weather observations: estimates of wind strength and direction, sea state, precipitation, cloud cover and fog, air temperature, speed and direction of ocean currents, and notable storm events. However, the notoriously parsimonious whalers rarely carried any but the most essential navigational instruments, even into the twentieth century. So, weather observations given in the whaling logbooks are almost never noted as quantitative instrumental measurements, but instead in qualitative descriptive language, which must be interpreted by modern historians and scientists.

In climate research, long datasets of weather conditions extending back in time help scientists to establish a historical baseline for weather conditions, against which to measure recent changes and better understand human influences on weather and climate. That is, to know if conditions being experienced currently are abnormal, scientists need to understand what weather patterns were like in the past, over the longest possible arc of time. "Climate is what you expect, weather is what you get," as the saying goes and rightly so: climate represents long-term average conditions for the environmental conditions (temperature, rainfall, pressure, etc.) for a particular spot and particular time of year. In contrast, weather conditions represent instantaneous conditions that vary on synoptic timescales—that is, on a scale of days to weeks. As such, individual weather events represent the individual building blocks that make up a particular location's long-term climate record.

To provide such information, we have combined our skill sets in modern maritime history and oceanography and climate science, respectively, to undertake an extensive research project that will expand the body of weather records that can be used to assess changing weather and climate conditions over time. Such work is particularly valuable for gaining a better understanding of remote, data-poor regions on the planet. A rich trove of maritime weather information is contained in the vast repositories of ships' logbooks, especially from New England whaling vessels, in which officers routinely recorded weather information multiple times each day over the course of their voyages.

We have begun to build a database with maritime weather information extracted from currently 150 logbooks of an estimated total of 4,200 North American whaling logbooks going back to the

middle eighteenth century. These primary source maritime documents, which together account for about 80% of extant known logbooks of U.S. age-of-sail whaling voyages, are all conveniently archived in five publicly accessible, geographically proximate repositories in Massachusetts, Rhode Island, and Connecticut. These include about 250 logbooks held at the Mystic Seaport Museum G.W. Blunt White Library; 2,500 archived in the New Bedford Whaling Museum; circa 500 at the New Bedford Free Public Library, the Nantucket Historical Association (c. 400 logbooks), and the Providence Public Library in Rhode Island (c. 800 logbooks covering 1,000 voyages) (Figure 2).[2]

Figure 2. Research scene: extracting weather data from the logbook of the whaling ship *Isaac Howland* of New Bedford, Massachusetts; Tristram Pinkham Swain, Master; Monday, August 13–22, 1836. Special Collections Reading Room, Providence Public Library; Wh I73 1835j, pp. 88–89. Photo credit: Jayne Doucette/© Woods Hole Oceanographic Institution; used with permission

Instrumental weather data prior to 1900 is sparse, especially for regions beyond Europe and North America, and over the ocean. A growing field of scholarship, namely historical climatology, addresses this knowledge gap by locating, extracting, and interpreting a range of archived historical weather records.[3] Building on the lessons and successes of earlier historical climatological research, like the Atmospheric Circulation Reconstructions over the Earth (ACRE), the International Comprehensive Ocean-Atmosphere Data Set (ICOADS), and the Old Weather projects,[4] our work recovers, quantifies, and analyzes climate records from these unique but underused caches of sailing logbook records. Further, our project is designed to dovetail with the Climatological Database for the World's Oceans (CLIWOC) project, which consists of data from over 287,000 logbooks written aboard Dutch, English, French, and Spanish sailing ships. The vast majority of these logbooks date from between 1750 and 1850.[5] Finally, by integrating disparate scholarly subfields, historians and oceanographers together can push the climate record back into the first half of the eighteenth century, showing how weather patterns over the oceans have evolved over the past three centuries, with much broader geographical distribution than is currently available to climate scientists.

The United States whaling industry, based in just a handful of New England ports, is perhaps the best documented of any early-modern business endeavor. Vast collections of records that the whaling business produced have been carefully catalogued, preserved in the above-named key New England archives and libraries.[6] Of the approximately 15,000 documented "Yankee" whaling voyages, roughly half are accounted for, described in about 5,500 extant logbooks that survive in public repositories or are known to be in private hands.[7] Many more are assumed to survive but are either unreported in private collections, or perhaps forgotten, hidden in attic or basement storage. Every year, previously unknown logbooks come to light, newly acquired by repositories through donation or purchase.

This extraordinary body of documentation presents a singular opportunity for climate researchers: through our collaborative project that spans the humanities and hard sciences, historians and climate scientists can derive invaluable, unique logbook weather data going back over 280 years.

This project initiates and leverages cross-disciplinary international synergies of effort by bringing together a team of experienced researchers in oceanography, climatology, and maritime history.[8]

Figure 3. Dr. Timothy D. Walker, maritime historian of the University of Massachusetts Dartmouth, working to extract and record climate data from a logbook at the Nantucket Historical Association research library reading room. Photo courtesy of Timothy D. Walker

Together with a team of student researchers, in 2019 Walker began examining an initial group of logbooks (Figure 3), extracting information from the handwritten entries and entering it into a computer database, from which Ummenhofer and her students can conduct climate analysis. An initial proof-of-concept phase included the examination and data extraction from a group of 150 logbooks, selected purposely to represent chronological and geographical criteria. First, the chosen logs cover a broad range of voyage dates; second, they all chronicle journeys that passed through the Azores archipelago en route to the Indian Ocean—the least studied of the tropical oceans. The yield of this first phase of archival work, which also facilitated the refinement of the project's research methodology, was approximately 80,000 days' worth of data, with each day at sea typically providing three to four weather reports in a 24-hour period.

The COVID-19 pandemic closed archives and slowed the project, but in 2022, having demonstrated the effectiveness of our research concept and methodology, we began expanding our project to include Portuguese naval logbooks archived in Lisbon. Using these two profoundly important but as yet unexploited caches of archival documentation—New England "Yankee" whaler and Portuguese Navy ships' logbooks—our project assesses historical weather patterns over the far reaches of the world's oceans, rarely visited and largely undocumented by other global mariners between approximately 1740 and World War Two.

Until the early twentieth century, most weather observations given in the New England whaling logbooks, as well as the Portuguese, were almost always qualitative descriptive terms using a specialized nautical vocabulary common to age-of-sail mariners. To convey meaning accurately to other contemporary professional mariners during the sailing ship era, the language whalers used to describe weather phenomena had to be consistent and coherent. Thus, the shipboard terms that officers used to describe weather at sea were remarkably standardized, making it possible for modern researchers to assign quantitative values to historical qualitative terms.[9] For example, when a logbook keeper wrote that his ship experienced winds described in the log as a "fresh breeze" or a "strong gale," climate researchers today can match these terms to the Beaufort Wind Force Scale, devised by the Irish hydrographer Francis Beaufort in 1805, to derive a quantitative wind speed value.[10] While approximate, of course, this method yields weather data for remote times and places—regions of the globe rarely visited by other mariners—that cannot

be easily known in other ways, and is therefore of exceptional value to scientists.

Systematic research on Portuguese Navy logbooks archived in Lisbon has not yet begun for this project, but an initial survey has been completed, so some comparative comments are possible. Portuguese Navy logbooks differ from "Yankee" whaling logbooks in a number of significant ways. First, the date range of the Lisbon collection is longer, running from the 1760s (following the massive earthquake of 1755 that destroyed earlier records) to the 1960s. Military ships typically carried larger crews that operated these vessels with greater regimentation. There were numerous junior officers whose on-board training regimen included logbook-keeping and making navigational calculations. Hence, the logbooks of the Portuguese Navy tend to be quite detailed (Figure 4), with more frequent wind and weather observations given each day while underway (sometimes even hourly), in comparison to the more relaxed log-keeping habits of the New England whalers. Beginning during the late nineteenth century, Portuguese naval vessels began to carry more sophisticated nautical instrumentation than the earlier whalers had, so we expect that the data available from these ships will be more precise. So, later Portuguese logbook records may even provide instrumental measurements for surface air temperature and pressure.

Because the focus of this research begins in the mid-eighteenth century, the project chronology tracks with the beginning of the Industrial Revolution and follows the subsequent expansion of human fossil fuel use globally. So, this research can help provide insights about alterations consequent to expanding industrialization during this key period of history—sometimes called "the Great Acceleration" of the Anthropocene era.[11] Once immersed in archival investigation, poring through scores of volumes of preserved manuscript records, project researchers are likely to uncover additional unexpected data.

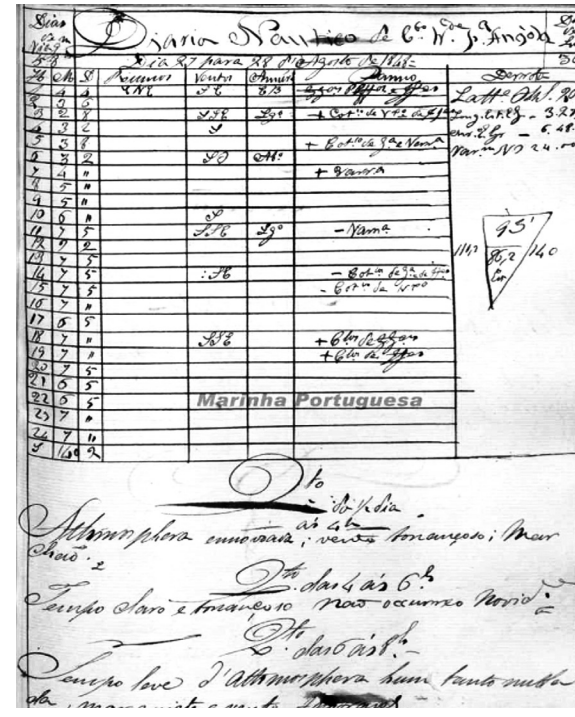

Figure 4. Logbook page of the Portuguese Royal Navy brigantine *Audaz* on a voyage from the Cape Verde Islands to Angola (August 27–28,1848); Arquivo Histórico da Marinha, Nr. 1159 (6-VII-6-3). Photo courtesy of the Arquivo Histórico da Marinha, Belém, Portugal

It is important to stress that, unlike the wealth of information that earlier researchers have already retrieved from British, French, and Spanish mercantile or military age-of-sail logbooks,[12] extant New England whaling and Portuguese Navy logbook collections from the eighteenth to the twentieth centuries are underused for this purpose. Additionally, whaling and Portuguese Navy records provide a much broader, more diverse global geographic coverage than do the logbooks from most other contemporary sailing vessels, which tended to closely follow what were, even by the mid-1600s, well-established sea lanes, for reasons of navigational efficiency and safety. Put simply, the whalers and the Portuguese military ships regularly sailed in waters where other European vessels rarely ventured, so the weather data they collected is valuable, and can fill in critical gaps in the historical

Figure 5. Freehand illustration of Saint Helena Island, Atlantic Ocean; in the journal of Robert Weir, aboard the whaling bark *Clara Bell* of Mattapoisett, Massachusetts; March 27, 1856. Mystic Seaport Museum; G. W. Blunt White Library; Log 164

climate record. The meteorological and hydrographic data in these logbooks cover the North Atlantic, the South Atlantic, the Pacific, and the Indian oceans—including coastal regions of former Portuguese colonies in the Mozambique Channel, Arabian Sea, the waters around Madagascar, and transits to/from western India. Moreover, these maritime records predate most extant instrumental maritime weather observations that are useful for climate research.

Project Research Methods

We survey, mine, and analyze age-of-sail logbooks, along with related documentation, held in various libraries and archives in New England and Portugal. We first assessed this material, identifying and compiling lists of relevant logbooks; we then began to systematically extract the required data and enter it into a purpose-built, dedicated project database using a webpage with fillable data fields—from which it can be exported for climate data analysis. To date (late November 2023), researchers have analyzed approximately 150 whaling logbooks and collected about 86,000 individual days' worth of data. Each day contains, on average, three separate weather observations.

To check the consistency of weather data reported in the logbooks of different vessels, researchers are tasked with noting when two or more ships are navigating in the same place at the same time. Portuguese military vessels often sailed jointly as part of a flotilla or squadron. Whaling vessels were usually solitary sailors; as competitors for the same prey, they rarely navigated in company with other whaling ships for any length of time. However, while cruising the waters within known whaling grounds around the globe, encounters between whaleships at sea were relatively common. The whalemen noted such encounters in their logbook entries, naming familiar whaleships, aboard which they often had family or friends. A normal practice when two or more whaling vessels would meet on the high seas was to "speak" a passing vessel, exchanging basic information rapidly, including longitude calculations to check their position reckoning. Whaling captains might even decide to heave to and have a "gam"—a longer visit when crewmen could board another vessel to exchange news, supplies, or, if one of the ships was homeward bound, send letters to family.[13] Such incidents allow cross-reference and comparison of weather observation data in each vessel's logbook, to ensure that atmospheric conditions are being consistently reported. That is, when archival researchers know that two ships were in the same place at the same time, they can compare the two vessels' logbook entries to see if they are in agreement.

An important point to highlight is that this work cannot at present be done by computer or machine reading. No two logbooks are alike (Figures 4–10). The paleography (old-style cursive handwriting) is varied and complex, with spelling, grammar, and abbreviations that are not standardized. Further, the organization and the penmanship of every logbook is unique. The formatting of the unruled pages is idiosyncratic, as varied as the personalities of each log keeper. Extracting data, therefore, depends on trained human readers who not only can decipher archaic cursive penmanship but also recognize historical maritime jargon—the esoteric vocabulary of professional seamen prior to mechanized seafaring. Computer analysis or even transcription of this manuscript material is simply beyond the capacity of current digital technology.[14]

By following research protocols established by the ACRE and Old Weather projects, historical records' estimates of marine and coastal weather conditions can be quantified to be of use for climate analysis purposes. Portuguese ships' records in particular are likely to supply a complementary dataset to existing records, since most shipping in the age of sail followed seasonal winds, but maritime routes heading toward disparate Portuguese colonial enclaves allow for the collection of weather pattern information well outside of regions known or typically frequented by other European powers, for which we have data.

After relevant information from the historical logbook documents is transcribed and recorded, qualitative descriptive terms are then interpreted and encoded into quantitative formats. The Old Weather project employs similar logbooks from various whaling archives (but focused instead on the Arctic region to collect data on northern hemisphere sea ice coverage,[15] rather than general weather across global oceanic regions). In due course, project data is intended to complement efforts by the ACRE project team, as well as ICOADS.

Recorded information about marine weather conditions will be quantified to address salient scientific questions of current climate research—again following protocols established by ACRE and the Old Weather project. These include measuring the robustness and the long-term context of variations in the Earth's atmospheric circulation, namely changes in "basin-scale"[16] surface wind and pressure patterns, such as the equatorial trade winds, global monsoons, or storm tracks.

The systematic daily meteorological information obtained from a ship can provide revealing information to modern researchers, giving valuable (if limited) insights about the surface wind conditions encountered, particularly over areas with historically poor data coverage—as is the case with the ocean regions where many New England whalers and Portuguese Navy vessels navigated during the eighteenth and nineteenth centuries. In the absence of any data at all for a given time and place, a ship's logbook can provide a window on past weather.

Figure 6. "What Is Your Longitude?" flag hoist; journal of a voyage of the whaling bark *Smyrna* of New Bedford, Massachusetts; George Bliss, Master; Sunday, July 5, 1857; encounter with the whaler *Elizabeth*; South Atlantic Ocean. Special Collections, Providence Public Library; Wh S667 1853j, p. 279. Photo courtesy of the Providence Public Library

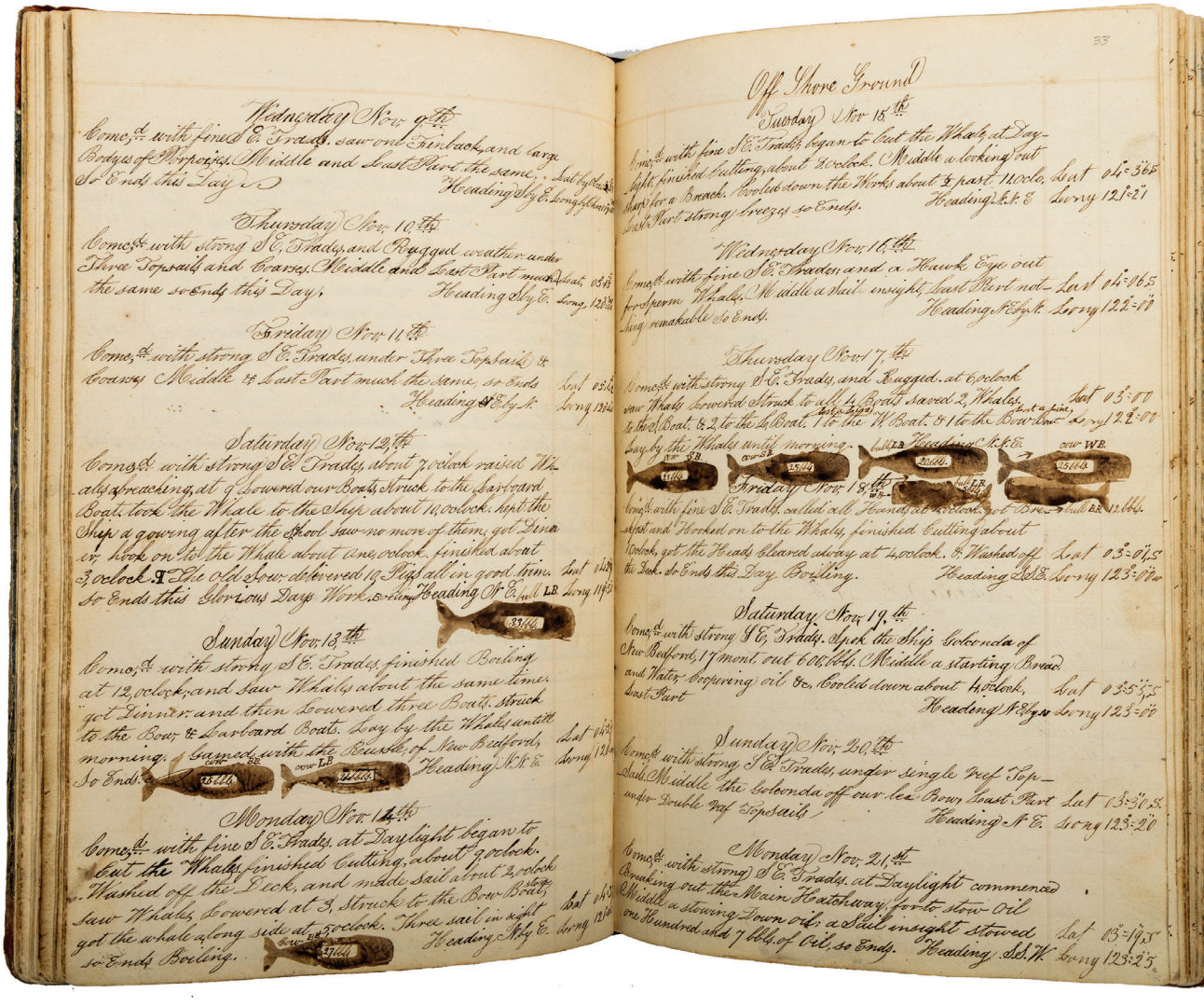

Figure 7. Representative pages from the logbook of the whaling bark *Charles W. Morgan* of New Bedford, Massachusetts; voyage of 1841–1845; November 9–21, 1844. Mystic Seaport Museum; G. W. Blunt White Library; Log 143, pp. 65–66

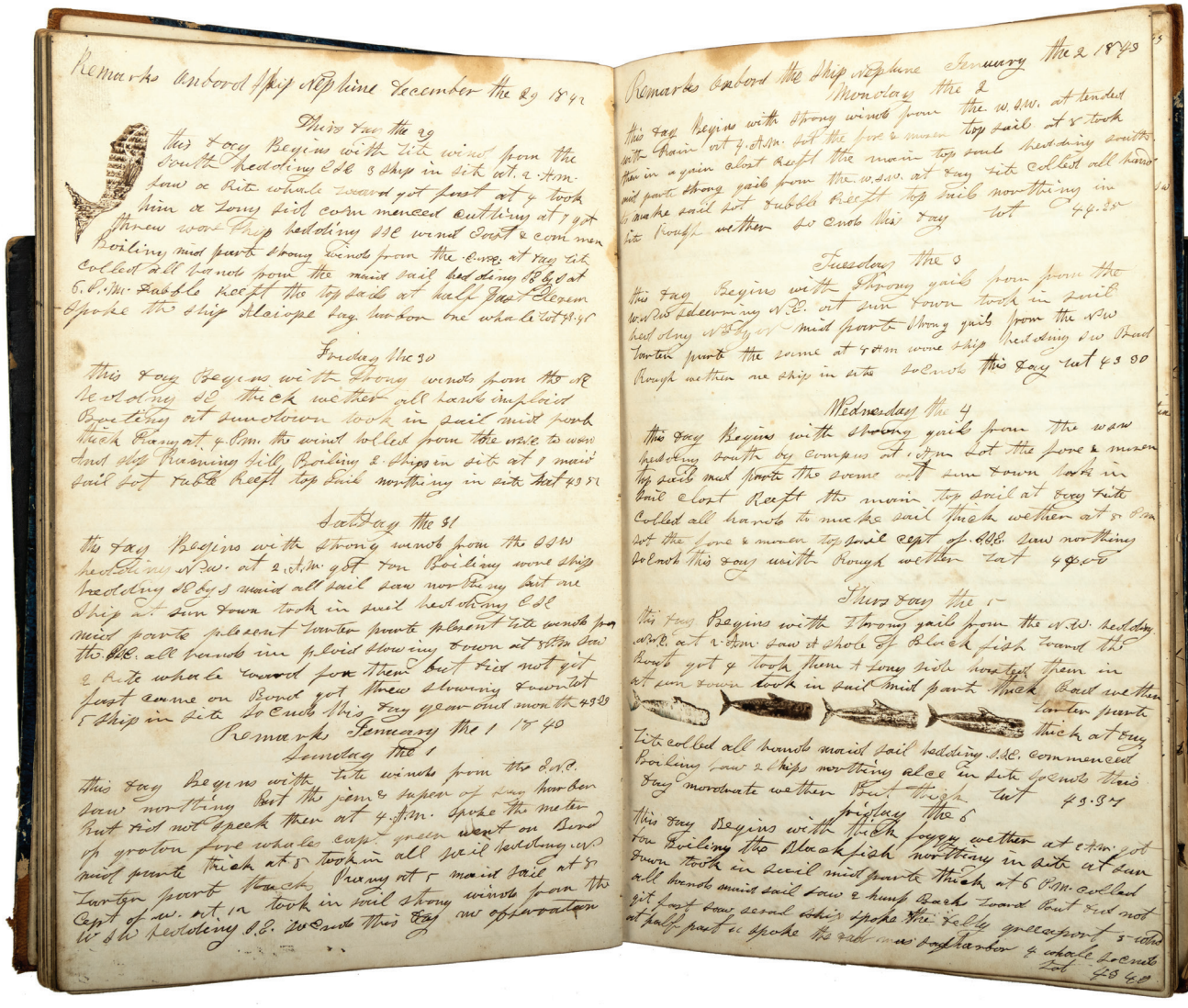

Figure 8. Representative pages from the logbook of the whaling ship *Neptune* of New London, Connecticut; voyage of 1842–1844; December 29, 1842–January 6, 1843. Mystic Seaport Museum; G. W. Blunt White Library; Log 63

For examples of geographic areas where this research can shed useful new light, consider the following: due to North Atlantic prevailing wind and current patterns, almost all whaling vessels that departed from New England ports passed either near or through the Azores archipelago. Data gathered from these Atlantic Ocean voyages could allow tracking of variability and change in the Azores High, a large subtropical semipermanent center of high atmospheric pressure critical to regional weather. For example, the Azores High steers rain-bearing weather systems that bring moisture to Western Europe, including the Iberian Peninsula. It is also a core region of interest due to its associated wind patterns that age-of-sail mariners had to contend with during their voyages.

A similar high-pressure center exists over the South Indian Ocean, which is another main focus area of this project. The Indian Ocean has experienced robust warming trends in recent decades, yet the region suffers from particularly sparse long-term instrumental weather observations. The Indian Ocean is the least observed tropical-temperate ocean; it is also particularly vulnerable to human influences.[17] One of the defining characteristics of the region, the South Asian monsoon system, is the largest of Earth's monsoon systems, and thus an important part of the global atmospheric circulation. Moreover, the Asian monsoon is a vital source of freshwater for the mostly agrarian societies surrounding the Indian Ocean, with well over a billion people vulnerable to the vagaries of the monsoon and its effects on agriculture and economic well-being. This research project aims to provide a long-term context for variability of winds and pressure changes across the Indian Ocean.

We intend to combine our newly recovered historical data with existing observational and reanalysis information to understand how wind patterns in the North Atlantic, Indian, and Pacific oceans have varied in the past across a range of timescales from seasonal and decadal to multi-decadal timescales. Of particular interest are changes in strength and position (latitudinal and meridional) of the subtropical high systems complementing paleoclimate records,[18] as well as changes in the monsoon in the Indian Ocean (especially seasonality and timing of the arrival of the monsoon winds).

Project Challenges—Keeping Researchers on Target

One of the challenges for the project researchers (who are mostly graduate and undergraduate students) is to keep on task with their eyes on the prize—collecting key weather data—and not get distracted by the abundance of fascinating human interest detail found in the whaleship logbooks. Because they were intended to be a legal record of all important events on board during a given voyage, logbooks often contain, written alongside the mundane weather and navigation information, riveting insights into the arcane lives of long-ago crew members. Whaling was a dangerous business. Untimely deaths by drowning, falling from the rigging aloft, having a whaleboat stove in by a leviathan's flukes, or other accidents, are all too frequent occurrences described in the curt prose of voyage records. Tensions between crew members, living for years together in the tight confines of the forecastle, sometimes boiled over into fights with lethal consequences.

A single vessel can provide multiple examples of the drama and misfortune that might befall a whaling ship's company on multiyear voyages to the other side of the world. As a case in point, the bark *Atlantic* sailed from New Bedford under the command of Benjamin Franklin Wing on October 2, 1865, bound for the Cape of Good Hope and the Indian Ocean. This vessel had been at sea for nearly nine months when racial tensions among the crew erupted into violence. On May 22, 1866, the African American cook, James Brown, stabbed

a European-descended Yankee seaman, James M. Foster, with a double-edged knife, inflicting a mortal wound. The log entry notes that Brown, who was described as "mulatto" in the *Atlantic* crew roster, was overheard justifying his assault because Foster had referred to him using an ugly racial slur. The ship's officers responded to this murder by clapping the perpetrator in double irons, and setting a course to Port Louis in Mauritius, where on May 29 "Brown the Assassin," under authority of the U.S. Consul there, was transferred to a homeward-bound whaler, the bark *Osceola II* of New Bedford (operated by the same consortium of ship owners as the *Atlantic*), so he could be tried in the United States.[19]

Six months later, while cruising the Mauritius whaling grounds east of Madagascar, the *Atlantic* suffered a serious head-on collision after midnight on November 12, 1866, with a vessel the crew was not able to identify—though it was not another whaler. The force of the collision carried away the *Atlantic*'s entire head rig: the jibboom and bowsprit, figurehead, starboard headrails, anchor, and cathead; it also broke the fore topmast and sprung the foremast. When hailed, the captain of the unknown vessel, described in the *Atlantic* logbook as a "large double topsail ship…painted dark…with a considerable gilt work about her stern," refused to identify himself or his ship. However, before proceeding on his journey he acknowledged his fault in the accident, saying that the whaler had had the right of way—which explains his desire to remain anonymous. Following this extraordinary hit-and-run incident, the *Atlantic* was left to limp back to Mauritius, where a steam tug towed her into Port Louis. There the unfortunate whaler was surveyed for insurance purposes, after which the crew conducted extensive, time-consuming, and very costly repairs.[20]

Misfortune continued to stalk captain Benjamin Franklin Wing and the bark *Atlantic* in the waters around Mauritius. A decade later, not far from the scene of the nocturnal collision, the same whaler suffered what the voyage logbook termed "a disaster at sea." On June 10, 1877, two entire whaleboat crews—ten men altogether—were lost in a single evening when, as night set in, a storm blew up unexpectedly while the boats were away from the ship in pursuit of their prey. The remaining crew aboard ship kept lanterns hung in the rigging all night to guide the boats home, but several strong squalls swept the area, and at daybreak no sign of the whaleboats was visible to the horizon. Although the *Atlantic* cruised the immediate vicinity for six days, hoping the men would find their way back, eventually the captain decided to sail to Mauritius in hopes that his crewmen had somehow managed to make landfall there and save themselves. Such was not to be, unfortunately.[21] This lone incident accounted for the loss of nearly one third of the *Atlantic*'s entire crew.

Project Goals and Objectives

Clearly, whaling and Portuguese Navy logbooks are indispensable records, an invaluable resource for creating climate reconstructions. Experts of the global ACRE Project have identified these caches of preserved records as important for ongoing climate research. These collections contain unique indications of weather conditions—evidence from all over the world, at known, carefully recorded places and times, representing literally millions of daily weather observations for the world's maritime regions. This material needs to be inventoried, scanned, and digitized by skilled archival specialists, and then analyzed by academics for climate data. Advocating for, facilitating, and assisting in the digital preservation of this material is an additional central project goal. While images of logbooks will not be included in the project weather data database, having entire whaling logbook collections made freely available to the public

Figure 9. Page from a journal kept by David Young aboard the whaling ship *Franklin* of Sag Harbor, New York, with land profile drawings; voyage of 1833–1837; March 14–18, 1835. Mystic Seaport Museum; G. W. Blunt White Library; Log 898

as high-definition digital images on the Internet Archive[22] is key to the project's research model, allowing for the data mining and analysis of these maritime records from any computer at any time. Digitized Portuguese naval records will be maintained on the website of the Historical Archive of the Portuguese Navy.[23]

In the coming years, this research project will build up a vast mosaic of weather data points from thousands of vessel logbooks. All together, we have identified approximately 6,400 U.S. and Portuguese logbooks to mine for this study. Based on our experience to date, about 500 days' worth of data can be derived from an average whaling logbook—though no two logbooks are the same, and voyage lengths varied tremendously, from six months to several years in duration. Seagoing vessels typically recorded their position (latitude and longitude) at noon; the whalers logged weather conditions two to four times a day, while Portuguese naval logbooks commonly include eight or more daily weather observations.

Our project will add significantly to the vast stock of historical data points that already exists for other early European and American vessels. Because of the geographical distribution of Portuguese colonial spaces, and of the global whaling grounds frequented by whalemen, these records collectively constitute unique extant historical material, documenting weather data in far-flung, isolated, and understudied places.

Our project aims to document nearly three centuries of weather and climate variability related to large-scale oceanic wind patterns; it will allow us to assess how changes in maritime weather observed in recent decades fit into a long-term context—something currently severely hampered by the availability of only a short instrumental record for many remote ocean regions. Given its innovative and interdisciplinary nature, this work will also serve as a general proof-of-concept project, that can inspire analogous future projects using additional sources, expanding this promising approach

to other untapped archives in the U.S., Portugal, and beyond. This work aims ultimately to help scientists and public policy makers with a practical understanding of past climatic variability—with a view toward addressing the many modern-day challenges of societal vulnerability to extreme weather and climate change.

Innovation and Anticipated Project Impact

The first intended impact of the project is to extend known climate and weather records in the Indian and Atlantic oceans. It is crucial to gain a better understanding of the Indian Ocean's variability and long-term trends, which have large implications for rainfall and drought in surrounding countries. The project will provide new data from data-sparse regions of the world's oceans, going centuries further back in time than is currently possible. This temporal extension and geographic infilling will strengthen ongoing international efforts (of which the ACRE and Old Weather project databases are integral parts) that form the backbones of climatological datasets upon which reanalyses and other climate scholarship depends.

The second intended impact of the project involves education and collaboration. Beyond the implications for science, the project provides an opportunity to create collaborative interdisciplinary working relationships between Portuguese and U.S.-based researchers. This interaction will build international research capacities and strengthen ties between several institutions of higher learning in Europe and the U.S. Further, this project will help to educate the next generation of interdisciplinary scientists by mentoring and training students across several fields: in archival historical research, physical oceanography, climate science, and paleo-reconstructions.

The primary tangible project outputs will be the project database and research articles showcasing the project's research methodology in scholarly journals in several research fields: maritime and early modern Portuguese history, and climate

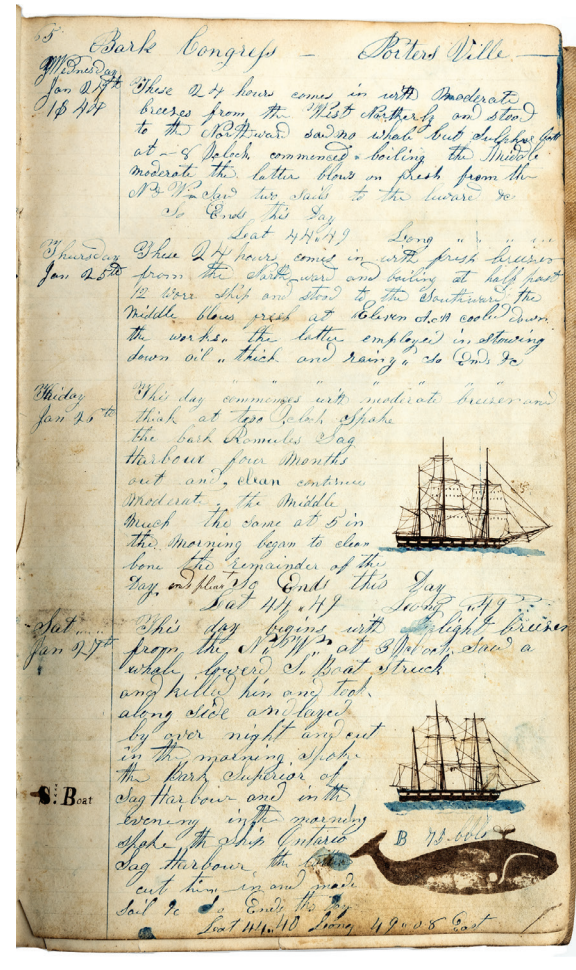

Figure 10. Page from the logbook of the whaling bark *Congress* of Mystic, Connecticut; voyage of 1842–1844; January 24–27, 1844, with drawings of ships they encountered and a whale. Mystic Seaport Museum; G. W. Blunt White Library; Log 770

science. This research complements other efforts by, for example, ACRE, to inform a much larger ongoing international effort using age-of-sail logbooks and other maritime records to gather and assess historical climate data.

Disclosures: No potential conflicts of interest to report. Funding from the Henry L. & Grace Doherty Charitable Foundation, National Science Foundation under BCS-1852647, FM Global, the UMASSD Provost Office, and the James E. and Barbara V. Moltz Fellowship for Climate-Related Research at WHOI.

Acknowledgments: This work was supported by the Henry L. & Grace Doherty Charitable Foundation, National Science Foundation under BCS-1852647, and FM Global (all to CCU and TDW). TDW gratefully acknowledges support from the UMASSD Provost Office, and CCU the James E. and Barbara V. Moltz Fellowship for Climate-Related Research at WHOI. Archival research by Abigail Field, Len Travers, Madison Eastman, Michael Zajac, Stephen Luce, Samuel Chace, Riley O'Connor, Amanda Cutler, Jennifer Sullivan, Olivia Weise, Aidan Barlow-Diemer, Sandra Cruickshank, and Maria Rocha is gratefully acknowledged.

Endnotes

1 Richard King, Kripa Bansal, Mia Hines, et al., "Captain Joy's Last Voyage: What a Whaling Captain's Logbook Can Teach us about Sperm Whales and our Oceans," in *Earth Island Journal* , Summer 2023, https://www.earthisland.org/journal/index.php/magazine/entry/how-data-from-whalers-logbooks-inform-marine-and-climate-research.

2 Not all the volumes in these collections are logbooks suitable for the project's planned research, so the figure of 4,200 usable documents is an estimate from the 4,450 volumes held in these repositories.

3 Martin J. Ingram, David J. Underhill, and Tom M. L. Wigley, "Historical Climatology," *Nature* 276, no. 5686 (1978): 329–334; Rudolf Brázdil, Christian Pfister, Heinz Wanner, Hans Von Storch, and Jürg Luterbacher, "Historical Climatology in Europe–the State of the Art," *Climatic Change* 70 (2005): 363–430; Dagomar Degroot, Kevin Anchukaitis, Martin Bauch, et al., "Towards a Rigorous Understanding of Societal Responses to Climate Change," *Nature* 591 (2021): 539–50, https://doi.org/10.1038/s41586-021-03190-2; Dagomar Degroot and Steven Ottens, "Climatological Database of the World's Oceans," Historical Climatology, accessed November 6, 2023, www.historicalclimatology.com/cliwoc.html); Dagomar Degroot, Kevin Anchukaitis, Jessica Tierney, et al., "The History of Climate and Society: A Review of the Influence of Climate Change on the Human Past," *Environmental Research Letters*, 17 (2022), doi:10.1088/1748-9326/ac8faa; Sam White, Qing Pei, Katrin Kleemann, et al., "New Perspectives on Historical Climatology," *Wiley Interdisciplinary Reviews: Climate Change* 14, no. 1 (2023): https://wires.onlinelibrary.wiley.com/doi/full/10.1002/wcc.808.

4 Respectively, http://www.met-acre.org/; https://icoads.noaa.gov/ and https://www.oldweather.org/. The research output of these initiatives is extensive, but representative examples include, for ACRE: Rob Allan, Philip Brohan, Gilbert P. Compo, et al., "The International Atmospheric Circulation Reconstructions over the Earth (ACRE) Initiative," *Bulletin of the American Meteorological Society* 92 no. 11 (2011): 1421–1425; for ICOADS: Scott D. Woodruff, Henry F. Diaz, Steven J. Worley, et al., "Early Ship Observational Data and Icoads," *Climatic Change* 73 (2005): 169–194, https://doi.org/10.1007/s10584-005-3456-3; Eric Freeman, Scott D. Woodruff, Steven J. Worley, et al., "ICOADS Release 3.0: A Major Update to the Historical Marine Climate Record," *International Journal of Climatology* 37 (2017): 2211–2232, https://doi.org/10.1002/joc.4775; and for Old Weather: Philip Brohan, Rob Allan, J. Eric Freeman, et al., "Marine Observations of Old Weather," *Bulletin of the American Meteorological Society* 90 (2009): 219–230, https://doi.org/10.1175/2008BAMS2522.1.

5 R. García-Herrera, G.P. Können, D.A. Wheeler, et al., "CLIWOC: A Climatological Database for the World's Oceans 1750–1854," *Climatic Change* 73 (2005): 1–12, https://doi.org/10.1007/s10584-005-6952-6; G.P. Können and F.B. Koek, "Description of the Cliwoc Database," *Climatic Change* 73 (2005): 117–130, https://doi.org/10.1007/s10584-005-6946-4; P.D. Jones and M. Salmon, "Preliminary Reconstructions of the North Atlantic Oscillation and the Southern Oscillation Index from Measures of Wind Strength and Direction Taken During the Cliwoc Period," *Climatic Change* 73 (2005): 131–154, https://doi.org/10.1007/s10584-005-6948-2; Degroot and Ottens, "Climatological Database of the World's Oceans" (2021) (available at: www.historicalclimatology.com/cliwoc.html).

6 See Michael P. Dyer, "*O'er the Wide and Tractless Sea": Original Art of the Yankee Whale Hunt* (New Bedford: Old Dartmouth Historical Society/New Bedford Whaling Museum, 2017), 13–17; 39–47.

7 Judith Navas Lund, Elizabeth A. Josephson, Randall R. Reeves, and Tim D. Smith, *American Offshore Whaling Voyages, 1667–1927,* vol. 1 (New Bedford: Old Dartmouth Historical Society/New Bedford Whaling Museum, 2010),

4–5. See also Stuart C. Sherman (compiler), Judith M. Downey, and Virginia M. Adams (editors), *Whaling Logbooks and Journals, 1613–1927* (New York: Garland, 1986), vii–viii.

8 Evan Lubofsky, "Mining Climate Clues from our Whaling Past," *Oceanus Magazine* 54 (2019): 32-35, https://www.whoi.edu/news-insights/content/mining-climate-clues-from-our-whaling-past; Woods Hole Oceanographic Institution, "Mining Climate Data through Historical Records," https://ummenhofer.whoi.edu/historical-records/.

9 See Roberto Gustavo Herrera, Ricardo García-Herrera; Luis Prieto, et al., *CLIWOC multilingual meteorological dictionary, An English-Spanish-Dutch-French dictionary of wind force terms used by mariners from 1750–1850* (De Bilt, Netherlands: Royal Netherlands Meteorological Institute, 2003).

10 United Kingdom Meteorological (MET) Office, "Beaufort Wind Force Scale," https://www.metoffice.gov.uk/weather/guides/coast-and-sea/beaufort-scale.

11 See John Robert McNeill and Peter Engelke, *The Great Acceleration: An Environmental History of the Anthropocene since 1945* (Cambridge, MA: Harvard University Press, 2016), 1–12.

12 See, for example, W. Jeffrey Bolster, *The Mortal Sea: Fishing the Atlantic in the Age of Sail* (Cambridge, MA: Harvard University Press, 2012); Jones and Salmon, "Preliminary Reconstructions of the North Atlantic Oscillation," 131–154; Woodruff et al., "Early Ship Observational Data," 169–194; Brohan et al., "Marine Observations of Old Weather," 219–230; Andrew R. Mahoney, John R. Bockstoce, Daniel B. Botkin, et al., "Sea-ice Distribution in the Bering and Chukchi Seas: Information from Historical Whaleships' Logbooks and Journals," *Arctic* (2011): 465–477; David Barriopedro, David Gallego, M. Carmen Alvarez-Castro, et al., "Witnessing North Atlantic Westerlies Variability from Ships' Logbooks (1685–2008)," *Climate Dynamics*, 43 (2014): 939–955; Dennis Wheeler, "Hubert Lamb's 'Treasure Trove': Ships' Logbooks in Climate Research," *Weather* 69, no. 5 (2014): 133–139; Matthew Ayre, John Nicholls, Catharine Ward, et al., "Ships' Logbooks from the Arctic in the Pre-Instrumental Period," *Geoscience Data Journal* 2, no. 2 (2015): 53–62; Ricardo Garcia-Herrera, David Barriopedro, David Gallego, et al., "Understanding Weather and Climate of the Last 300 Years from Ships' Logbooks," *WIREs Climate Change* 9 (2018), https://doi.org/10.1002/wcc.544; Javier Mellado-Cano, David Barriopedro, Ricardo García-Herrera, et al., "Euro-Atlantic Atmospheric Circulation during the Late Maunder Minimum," *Journal of Climate* 31 (2018): 3849–3863, https://doi.org/10.1175/JCLI-D-17-0261.1; Javier Mellado-Cano, David Barriopedro, Ricardo García-Herrera, et al., "Examining the North Atlantic Oscillation, East Atlantic Pattern, and Jet Variability since 1685," *Journal of Climate* 32 (2019): 6285–6298, https://doi.org/10.1175/JCLI-D-19-0135.1; Javier Mellado-Cano, David Barriopedro, Ricardo García-Herrera, et al., "New Observational Insights into the Atmospheric Circulation over the Euro-Atlantic Sector Since 1685," *Climate Dynamics* 54 (2020), https://doi.org/10.1007/s00382-019-05029-z.

13 Margaret S. Creighton, *Rites and Passages: The Experience of American Whaling, 1830–1870* (Cambridge: Cambridge University Press, 1995), 82–3, 168–72, 193.

14 That's not to say that information technology research teams are not trying—several projects based at academic institutions in Europe and North America have been working on this problem, but the results are not yet sufficiently developed to "machine read" and extract the required data from highly varied and often damaged maritime records. See Bram Caers, "Automated Reading of Medieval Manuscripts: An Alternative for Paleography Classes?," *Leiden Medievalists Blog*, July 20, 2022, https://www.leidenmedievalistsblog.nl/articles/automated-reading-of-medieval-manuscripts-an-alternative-for-palaeography-classes. See also Jenna Schoen and Gianmarco E. Saretto, "Optical Character Recognition (OCR) and Medieval Manuscripts: Reconsidering Transcriptions in the Digital Age," in *Digital Philology: A Journal of Medieval Cultures* 11, no. 1 (2022): 174–206, and Vincent Jolivet, "Handwritten Text Recognition for Documentary Medieval Manuscripts," in *Journal of Data Mining and Digital Humanities* (2023).

15 Mahoney et al., "Sea-ice Distribution," 465–477; Ayre et al., "Ships' Logbooks," 53–62.

16 That is, on the scale of a full ocean basin, with weather patterns influenced by the geography and topography of the region. See Adrian E. Gill, *Atmosphere-Ocean Dynamics* (San Diego: Academic Press, 1982), 31–38.

17 L.M. Beal, J. Vialard, M. K. Roxy, et al., "A Road Map to IndOOS-2: Better Observations of the Rapidly Warming Indian Ocean," *Bulletin of the American Meteorological Society* 101 no. 11 (2020): E1891–E1913.

18 Nathaniel Cresswell-Clay, Caroline C. Ummenhofer, Diana L. Thatcher, et al., "Twentieth-century Azores High Expansion Unprecedented in the Past 1200 Years," *Nature Geoscience,* 15 (2022), 548–553; Diana L. Thatcher, A. D. Wanamaker, R. F. Denniston, et al., "Iberian Hydroclimate Variability and the Azores High during the last 1200 Years: Evidence from Proxy Records and Climate Model Simulations," *Climate Dynamics* 60 (2023), 2365–2387.

19 Logbook of the *Atlantic* (bark), of New Bedford, MA; Benjamin Franklin Wing, master, on a whaling voyage between 1865 and 1868 (New Bedford Whaling Museum, number NBWM.ODHS 797), 46–48; May 22–29, 1866.

20 Ibid., 69–74; November 12-December 28, 1866.

21 Logbook of the *Atlantic* (bark), of New Bedford, MA; Benjamin Franklin Wing, master, on a whaling voyage between 1876 and 1879 (New Bedford Whaling Museum, number NBWM.ODHS 798), June 10–16, 1877.

22 The Internet Archive is a nonprofit digital library based in the United States, founded in 1996; it provides free access to collections of digitized materials such as websites, music, and audiovisual and print materials. https://archive.org/

23 Historical Archive of the Portuguese Navy, https://ccm.marinha.pt/pt/biblioteca/arquivohistorico.