Sailing ship records as proxies of climate variability over the world's oceans

by R. R. Garcia and R. Garcia Herrera

The study of climate requires a characterization of the mean state and variability of the atmosphere and ocean over long time scales. Over the last 50-75 years, it has been possible to define the global climate by means of systematic observations made over large geographical areas; more recent data even include global observations made from satellite platforms. On the other hand, instrumental records are sparser in the early 20th century, and not generally available before the late 1800s. It is clear then, that characterization of the climate in the modern sense is not possible beyond the last 100 years or so. Nevertheless, non-instrumental records exist that provide reliably dated measures of climate variability on annual and even daily time scales over large portions of the world's oceans.

These data are derived, one way or another, from the sailing ships of the European maritime powers in the 16th through 19th centuries. The relevant information is often contained in logbooks, the more recent of which (from the 18th and 19th centuries) provide records of actual meteorological variables, such as wind speed and direction. The earlier voyages, in the 17th and even 16th centuries, are seldom represented by complete logbooks but, as we shall see, they can provide proxies from which surprisingly specific inferences about climate variability can be made.

In this feature we discuss two examples that illustrate the potential of sailing ships' records for the reconstruction of oceanic climate. The first is furnished by the voyages of the Manila galleons, the ships that plied the route between Acapulco, Mexico, and the Philippine Islands for nearly the entire colonial period of Mexico's history. The second example is the Climatological Database for the World's Oceans (CLIWOC), a work in progress that demonstrates how the massive amount of information recorded in the logbooks of European ships in the 18th and 19th century can be used to construct a climatological database for the Atlantic, Indian, and part of the Pacific oceans.

The Manila galleons

From 1565 through 1815 the Spanish colonies of Mexico and the Philippines maintained a trade route between Acapulco and Manila that, in most years, saw at least one trans-Pacific round-trip between these ports. A thorough description of the Manila trade is given by Schurz [1]. Although the Acapulco-Manila voyages lasted some 250 years, complete logbooks for what was essentially a commercial, civilian enterprise are few and far between. On the other hand, there exists a rather complete documentation on the dates when the galleons departed from Acapulco and arrived at the Strait of San Bernardino, the gateway to the Philippine Islands and Manila. After suitable tests for uniformity and internal consistency these data can be used to describe secular changes in voyage duration from 1590 to 1750 [2].

Figure 1 shows a plot of voyage duration between Manila and the Strait of San Bernardino. The dots represent the

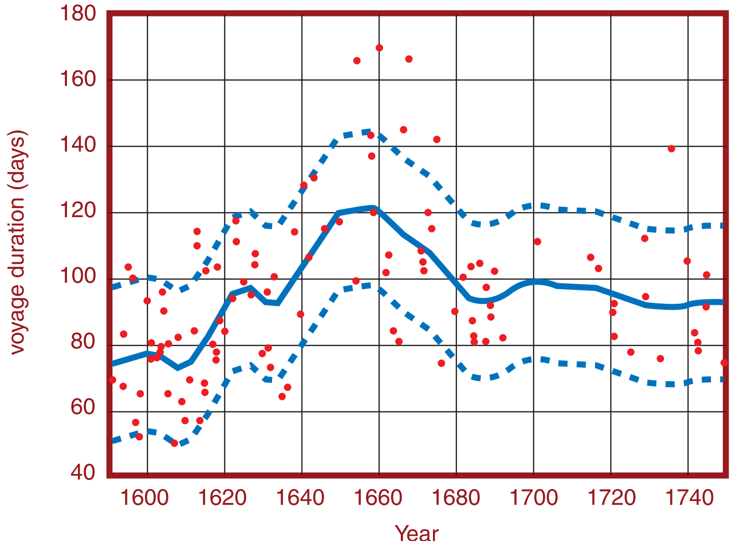

Figure 1. Duration of the voyage between Acapulco and the Strait of San Bernardino, from 1590 to 1750. The solid and dashed continuous curves indicate the 30-year running mean, and the running mean ±1 standard deviation, respectively.

individual voyages, the continuous solid curve is a 30-year running mean, and the dashed curves denote the mean ±1 standard deviation. There is a remarkable increase in voyage duration between the early 1600's (when the voyages lasted 80 days on average) and 1660 (when their duration peaked at 120 days). After 1660, voyage duration again became shorter, dropping to about 90 days by 1690. The difference in voyage duration between 1600 and 1640 is 40 days, considerably larger than the standard deviation of the data. As shown by Garcia et al, [2] it is highly unlikely that this secular change was due to societal or technological factors; instead, it can be interpreted as a reflection of variability in the wind system of the western tropical Pacific that has a counterpart in the modern record.

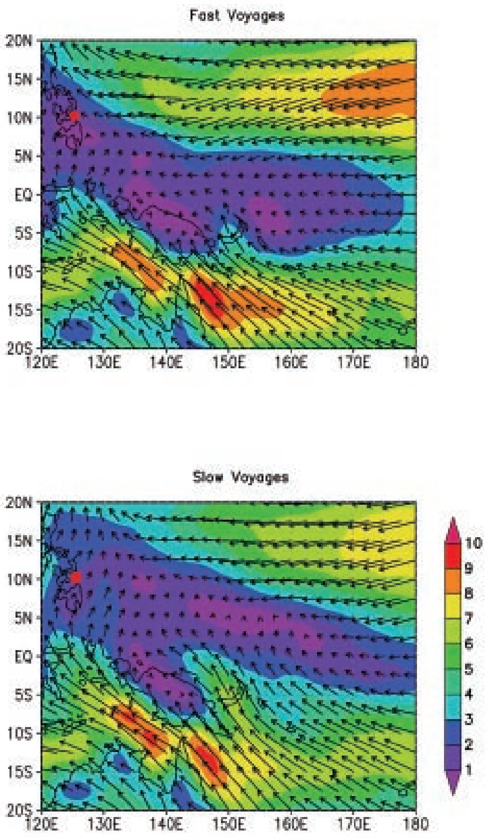

Figure 2.

June wind composites for the 9 slowest and 9 fastest "virtual voyages" between Acapulco and the Philippines. The color coding denotes magnitude in m s^{-1}. The ships approached the Philippine archipelago at 10–15° N; the red dot denotes the location of the Strait of San Bernardino. Fast voyages are made when the southwest monsoon trough is displaced southward, allowing the ships to reach the strait of San Bernardino with the trade winds. When the monsoon trough is displaced northward, winds are unfavorable (southerly or southwesterly), delaying the approach to the Philippines.

Because the duration of the Acapulco-Philippines voyage is an integrated measure of the strength of the winds en route, it does not provide direct information on the nature of the winds or their variability. However, one can devise modern analogues to the voyages that make possible detailed inferences. This has been done by using winds from the NCAR/NCEP reanalysis to construct "virtual voyages" between Acapulco and the Strait of San Bernardino (the ambiguity inherent in such reconstructions is considerably reduced by the fact that the route followed by the galleons remained essentially constant during the entire period of the voyages). When virtual voyages were calculated from modern data for the period 1948–1999, it was found that groups of the slowest and fastest voyages were associated with distinct circulation patterns in the western Pacific. These patterns, shown in Figure 2, differ principally in the position of the summer monsoon trough in early boreal summer. Because the ships approached the Philippines in June, an anomalous northward displacement of the monsoon trough resulted in unfavorable (south or southwesterly) winds being encountered on the approach to the Strait of San Bernardino, causing considerable delays in the voyage. On the other hand, a southward displacement of the trough allowed the ships to proceed under the favorable trade wind regime, resulting in much earlier arrival times.

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Further examination of modern wind data for the 20th century shows that displacements in the position of the monsoon trough, such as those shown in Figure 2, are common, with considerable decadal variability. Thus, it is plausible to interpret the increase in voyage duration experienced by the galleons in the 17th century as being

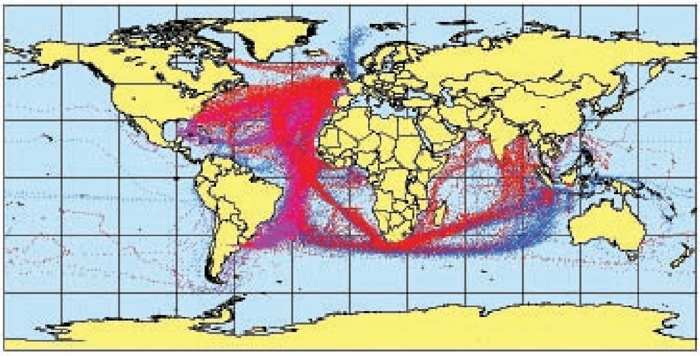

Figure 3. Observational coverage for the period 1750-1850 provided by logbooks from Spanish (purple), Dutch (blue), and British (red) ships.

due to variability in the southwest monsoon similar to (but of even greater amplitude and duration than) that found in the modern record.

The Manila galleon data are valuable because they provide an unambiguously dated record with nearly annual resolution over a period of 160 years. It is a rather special case because the nature of the data (voyage duration) mean that they are not an unambiguous proxy for any climate variable, and thus requires considerable a posteriori knowledge to yield useful information.

The CLIWOC Project

The CLIWOC project [3, 4], on the other hand, deals with information that is much more specific; the great majority of the data are observations of wind speed and direction, precipitation, cloudiness, and ice cover taken from logbooks recorded during the 18th and 19th centuries. These observations, although non-instrumental, usually rely on estimates made according to some well-defined, quasi-objective scale (instrumental temperature and atmospheric pressure records begin to appear in the 19th century, but they are relatively few in number). Most of the data are derived from ships belonging to the navies of Spain, Britain, the Netherlands, and France, although records from non-military voyages are also available (Spanish postal ships, and ships associated with Dutch and British trading companies). CLIWOC is a collaboration of Spanish, British, Dutch, and Argentine research institutions, funded through a European Union grant.

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CLIWOC has recently compiled a list of available logbook observations for the period 1750-1850. As shown in Figure 3, the coverage of some oceanic regions is remarkable. Both the North and South Atlantic oceans are densely covered, a reflection of the trade and military connections between Spain and Britain, on the one hand, and their colonies and former colonies in North and South America, on the other. The Indian Ocean is also well sampled, mainly by British and Dutch ships. Only in the Pacific is the coverage sparse, except for coastal regions of the Americas, Oceania and Australia. In the 18th century, most logbooks record observations every two hours; in the 19th century, especially after the general adoption of the marine chronometer, frequent observations of winds were deemed less necessary to establish accurately the ship's position, and logbook entries were made typically three times a day.

The principal goal of CLIWOC is to produce and make available to the scientific community a daily oceanic database for the Atlantic, Indian and Pacific oceans covering the period 1750–1850. Existing logbooks provide enough data to construct a daily record for each of these oceanic regions. Of particular interest, given the abundance of observations over the North Atlantic, is the possibility of studying the North Atlantic Oscillation, a well-recognized pattern of variability that exerts a strong influence on European climate, from the Arctic to the Mediterranean. Perhaps the most significant aspect of CLIWOC is the systematic use of a readily available, high quality, under-utilized source of climate data. This has not been attempted before in the degree of detail proposed, or over such a large geographic area.

The examples discussed above illustrate the mostly untapped potential of historical marine data for climate reconstructions. The successful interpretation of the length of voyage data from the Manila galleons shows that even indirect climate proxies can be valuable when used in the context of modern observational and theoretical knowledge. The CLIWOC project constitutes a pioneering effort to analyze, catalog and map climate-related data from a very large collection of pre-instrumental but otherwise reliable observations. The next few years will reveal the extent to which the potential inherent in these data can be realized in scientific studies.

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Global change and resource sustainability: some fishy thoughts

by K. Alverson, R. Sonnerup, G.W. Kent Moore and G. Holdsworth

The term “sustainability” has been cropping up in IGBP publications rather frequently of late. Since much of the science that underpins IGBP is global, one might take this to be an issue of global sustainability. Talk about ‘the global life support system’ does indeed seem to provide this impression - and in a few cases there may indeed be a global sustainability problem with a global solution. Ozone and greenhouse gases, for example, are globally distributed, globally produced, play key roles in global climate dynamics and are, or should be, globally regulated. For the most part, however, sustainable resource management boils down to regional issues, albeit often with systemic, global repercussions. When we really get down to trying to tie large scale climate variability, ecosystems and human resource usage together in a holistic way, the discussion invariably focuses on local scales. Here we present an example from the North Pacific.

North Pacific climate variability over the past 50 years, the period over which good instrumental records exist, includes a decadal scale oscillatory mode as well as at least one apparent abrupt shift in 1976. Within the broad area from 10°N to 70°N and 160°E to 80°W, over the past 50 years, there is little or no average surface warming, but the averaging masks a distinct dipole pattern of climatic change. Over this time period the regional warming trend over parts of western Canada has been a staggering 1°C/decade, with this warming partly balanced by a concurrent cooling over much of the central North Pacific ocean (Figure 1) [1].

Evidence suggests there have been broad-scale marine ecosystem responses to aspects of this climatic variability, in particular the 1976 shift [2]. Given this apparent coupling of a somewhat predictable climatic variability and large scale ecosystem response, there seems to be a possibility of putting global change science for sustainability

Continued on page 16...