Early ship observational data and global climate studies

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Abstract

Many of the available digital ship logbook data back to the late 18th century have been assembled in the International Comprehensive Ocean-Atmosphere Data Set (ICOADS), which has been widely used for global climate studies. We review the makeup of the available data and metadata, pending additions, and data homogeneity issues, focusing on the period before 1950. Prospects for future enhancements in the quality and coverage of the data and products, to further benefit scientific research, are discussed.

1. Introduction

Surface marine meteorological data from ships' logbooks and telecommunications as well as other in situ ocean observing systems have been collected, quality controlled, and summarized in products of the International Comprehensive Ocean-Atmosphere Data Set (ICOADS[*]), currently at Release 2.1 (1784-2002; Worley et al., 2005). This paper discusses characteristics and usage of ICOADS data prior to 1950 (see also Woodruff et al., 2005). During that period most of the data are ship observations, compiled from a wide array of international sources (Fig. 1). Noteworthy data features illustrated by Fig. 1 include the predominance of US and Dutch (Netherlands) data until the late 19th century, when a mix of other national collections and international projects begins to add to ICOADS, and large data gaps around the two World Wars.

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[*] The Comprehensive Ocean-Atmosphere Data Set (COADS) (Woodruff et al, 1987; Woodruff et al., 1998) was renamed ICOADS (Parker et al., 2004) in recognition of its strongly multinational basis in data and cooperation.

The earliest data currently in ICOADS are from the US Maury Collection (1784-1863). However, only scattered voyages exist in the 18th century, and the bulk of the data appear after 1830. The collection is named after US Navy Lt. Matthew Fontaine Maury, who convened the first international Maritime Conference at Brussels in 1853 (Maury, 1854). That meeting recommended a set of international observing and reporting practices for keeping “abstract logs” of ship meteorological observations.

After the 1853 Conference, transitions are evident in the data and reporting practices, e.g., in the number of observations per day from the US Maury Collection (Fig. 2). The 1853 practices were reviewed at a follow-up meeting (Maritime Conference, 1875), and have evolved over the subsequent 130 years into the observing practices and data and metadata management for today’s Voluntary Observing Ships (VOS). The VOS procedures are overseen by the World Meteorological Organization (WMO) and the Joint WMO/IOC (Intergovernmental Oceanographic Commission) Technical Commission for Oceanography and Marine Meteorology (JCOMM).

The increasing international standardization of observing and reporting methods, as initiated in 1853, has significantly contributed to our ability to examine ship data for climate signal information, and the 150th anniversary of the 1853 Conference was recently celebrated (Brussels, Belgium, November 2003) in association with the Second JCOMM Workshop on Advances in Marine Climatology (Parker et al., 2004).

2. Research usage

Ship data are critical for global climate studies, because they extend into the past much earlier than many other meteorological and oceanographic observations, and because the oceans cover over two-thirds of the globe. Due to their long-term continuity, ship data help benchmark satellite and buoy data, and are combined in blended analyses (e.g., Reynolds et al., 2002; Rayner et al., 2003). They also provide a key input for historical atmospheric reanalyses (e.g., Kalnay et al., 1996), as well as for national and international assessments of climate and global change (such as Folland et al., 2001).

In addition, ICOADS has been used for a variety of more far-reaching investigations including ship stack emissions (Corbett and Koehler, 2003), and fisheries and other biological applications (Mantua et al., 1997; Hays et al., 2003). Studies of climate variations through proxy data, such as from ice cores, coral growth (Dunbar et al., 1994), and marine organism shells, are leading to new climate understandings for the pre-instrumental era—and early observations from ICOADS can be important for calibration of the proxy data.

Global historical reconstructions (e.g., Smith and Reynolds, 2003) of sea surface temperature (SST), a key climate variable, are a leading application of early ship data. Variations in spatial coverage through time (Fig. 3) have arisen from historical changes in ship routes, changes in maritime commerce, and augmentations made for the contemporary climate observing system (such as the introduction of drifting buoys in the late 1970s). These variations and gaps pose a fundamental analysis challenge, since SST patterns in areas with sparse data (e.g., the World Wars in Fig. 1, or Pacific Ocean areas in the 1860s in Fig. 3) can only be estimated.

Smith and Reynolds (2004) have integrated SST from ICOADS with land surface temperatures (LST) from the Global Historical Climatology Network (GHCN). Anomalies of the observations of SST and LST were analyzed onto 5° grids, monthly. Separate reconstructions of SST and LST were performed using the same methods, and then merged into a global analysis. The SST and LST reconstructions are compared in Fig. 4 with an independent UK analysis. The results are characterized by narrower confidence intervals in the pre-1950 SST compared to LST data, disagreements in the World War II period (a period of sparse data and possible data biases), and trends of increasing SST and LST, at least in recent decades.

3. Pending archive additions

Given adequate resources to continue the expensive tasks required (i.e., imaging and digitizing old historical logbook records, accurately converting historical data into modern data units and into common formats, and blending these data into ICOADS) major improvements in temporal and spatial coverage are still possible in the pre-1950 period. Fig. 5 compares the periods-of-record of major digitized or undigitized datasets that are candidates for blending (see also Diaz and Woodruff, 1999; Woodruff et al., 2004), with existing ICOADS temporal data density.

To highlight features of a few of these collections:

- Japanese Whaling Data: This collection (Mierzejewska et al., 1997) should provide significant augmentation of sea level pressure (SLP) coverage in the Southern Hemisphere (mostly after 1949, however).

- US Marine Meteorological Journals: These densely sampled observations (recorded every two hours) were digitized in cooperation with China from logbooks that also contained detailed instructions to the observers. Those metadata are also planned for imaging, for scientific access and comparison with modern practices.

- German Maury Collection: This collection was loaned to the US by Deutscher Wetterdienst (DWD) for imaging, and has been proposed for digitization under further cooperation with China. Fig. 6 shows the cover of an abstract log ("Recommended by the [1853] Maritime Conference of Brussels") from a US Navy ship in the collection. We speculate that the many US observations in this collection may have ended up in the DWD archive because Maury went to Europe during the US Civil War.

- Climatological Database for the World's Oceans 1750-1854 (CLIWOC): This European Union-funded project digitized data from large collections of logbooks that mainly reside in Dutch, Spanish, and UK archives (mostly pre-instrumental observations of wind and weather). Some of these data were from UK and Dutch East India Company Collections, similar to early hourly logbook forms (see Fig. 2) from the US Maury Collection. However, the CLIWOC project digitized only the local noon observations, coincident with the daily reported latitude and longitude (whereas Maury observations throughout the day were keyed, and missing positions interpolated for blending into ICOADS). Variations in sampling frequency are among the data inhomogeneities that can impact research studies based on marine data.

4. Data inhomogeneities

Ship data are now available from ICOADS for a continuous period of over 200 years. However, as discussed in sec. 1, observing and reporting practices have also evolved, both before and after the landmark 1853 Conference. Changes in early observational methods have been widely discussed for SST and air temperature (e.g., Folland and Parker, 1995; Smith and Reynolds, 2002) and wind (e.g., Cardone et al., 1990). Observational changes and data inhomogeneities are less well understood in elements such as SLP, humidity, cloudiness, waves, and weather.

The following are examples of other historical data problems:

- Calendar and time questions in the US Maury Collection: Some of the earliest logbook forms were hourly (Fig. 2), without any indication of noon or midnight, and with some elements reported for the “first,” “middle,” and “latter” parts of the day. To convert these data into modern time units, assumptions were made that the early maritime data ended at noon (Catchpole, 1992), and that noon to 8:00 p.m. was always the first part of the day (Oliver and Kington, 1970). This is counter to our thinking today, but then noon was the time at which position could be best determined and so marked the beginning of a new reference period. As a result, date and time should be considered approximate with possible uncertainties of ±1 day and ±12 hours, respectively.

- Greenwich Mean Noon (GMN) observations in the US Merchant Marine 1912-46 Collection: Around 1888, the US starting switching from the systematic observations made throughout the day in its Marine Meteorological Journals (see sec. 3), to “simultaneous” observations that were taken once daily worldwide at GMN (i.e., 12:00 UTC in modern terminology). The change was made to construct daily synoptic weather charts, and in hopes that “the number of observers would increase in the same ratio as the services required of them would diminish" (Page, 1901). However, modern climate analyses may need to carefully weigh the method of including these data (which prior to 1912 are undigitized), so as to avoid introducing false variations, due to observations made at different times in the diurnal cycle.

- SLP biases in the US Maury Collection: Another clear influence from the 1853 Brussels Conference is evident in this collection, as SLP data started to be reported together with simultaneous temperature measurements, which were made from a thermometer attached to the mercurial barometer (Fig. 7). After the collection was blended into ICOADS, SLP biases were discovered (Todd Mitchell, personal communication). The lack of attached temperature measurements for most of the pre-1854 SLP data may be an important factor contributing to the biases. In spite of limited metadata associated with the Maury data, further research could lead to new methods to help mitigate these biases.

5. Conclusions and future work

This paper illustrates some basic improvements in data observing and reporting practices initiated at the 1853 Brussels Maritime Conference. The focus of that Conference was on "establishing a uniform system of meteorological observation at sea, and of concurring in a general plan of observation on the winds and currents of the ocean; with a view to the improvement of navigation, and to the acquirement of a more correct knowledge of the laws which govern those elements" (Maury, 1854). Since then the data have generally evolved to be even more accurate and reliable, and remain critically important for global climate studies and many other research endeavors.

Adequate resources, and sustained international cooperation, are still required if we are to continue to make improvements to the international historical marine archive. The task of digitizing old ship data is extremely labor intensive (e.g. due to the archaic handwriting and terminology). However, it is possible to extend the pre-instrumental record of (primarily wind) data back to about 1700, if the resources can be found to digitize and process additional European records. The

UK archives would be especially useful—at this time only 5% of the UK logbooks have been abstracted, versus an estimated 50%/100% from Dutch/Spanish sources.

In developing new digitization initiatives, it is important to consider the tradeoffs between the less-costly keying of data once as day (as for CLIWOC), versus the ICOADS method of keying all available meteorological observations, which may yield data that could describe the diurnal cycle. In addition to the costs of digitization, processing the digitized records into usable data is also expensive and time consuming, so careful consideration should be given to digitizing all the data.

In the future, it may be possible to use other aspects of the CLIWOC work to further improve the US Maury and other early data for ICOADS. For example, CLIWOC developed extensive dictionaries of early terms used for reporting wind force. This allows the conversion of descriptive wind phrases into Beaufort force codes so that the data can be transformed into scientific units. In contrast, the processing of the US Maury Collection translated only a small number of documented wind terms—many other terms were digitized, but left un-translated. In the future, it may be possible to use or adapt the CLIWOC (UK) dictionary to reprocess the Maury wind data. This is another example of the vigorous international cooperation advocated by Maury and first brought to fruition at the 1853 Maritime Conference.

There is a wealth of climate information in the early historical ship records. This information is very useful in understanding climate change and the scenarios we are facing in the modern era. Efforts should be continue to recover as much information as possible from historical archives.

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Figures

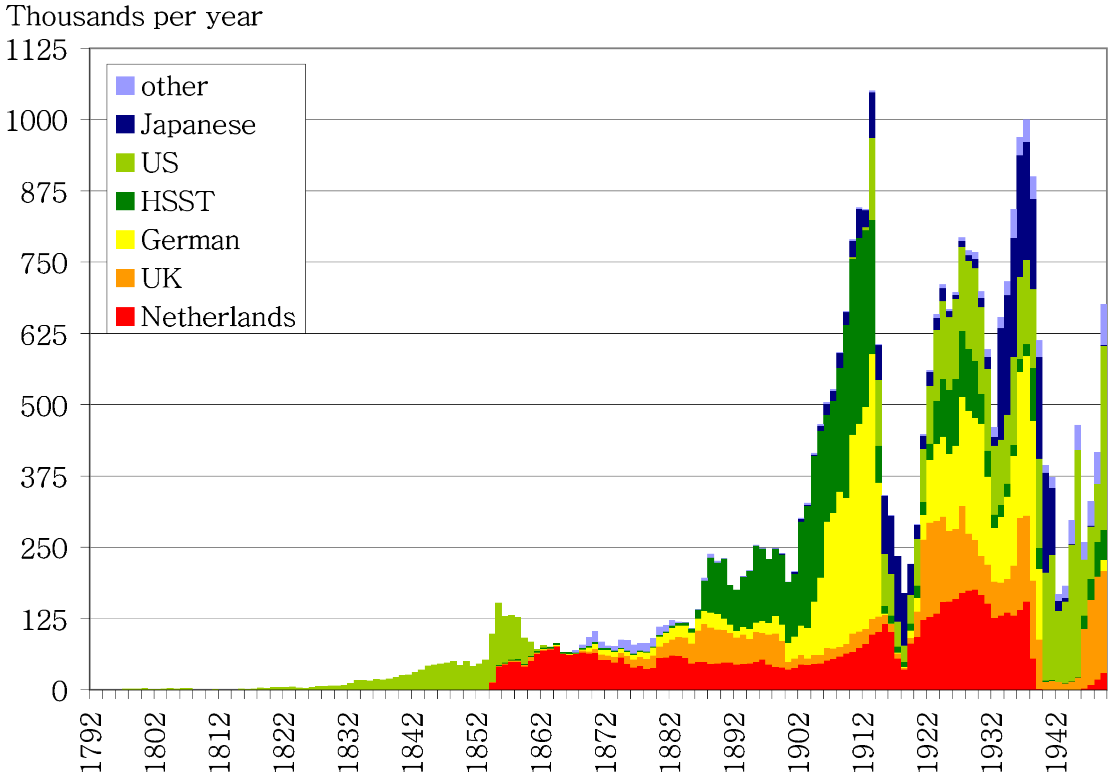


Fig. 1: Thousands of reports per year through 1949 currently available in ICOADS, stratified by national sources, and from the international Historical Sea Surface Temperature (HSST) Data Project.

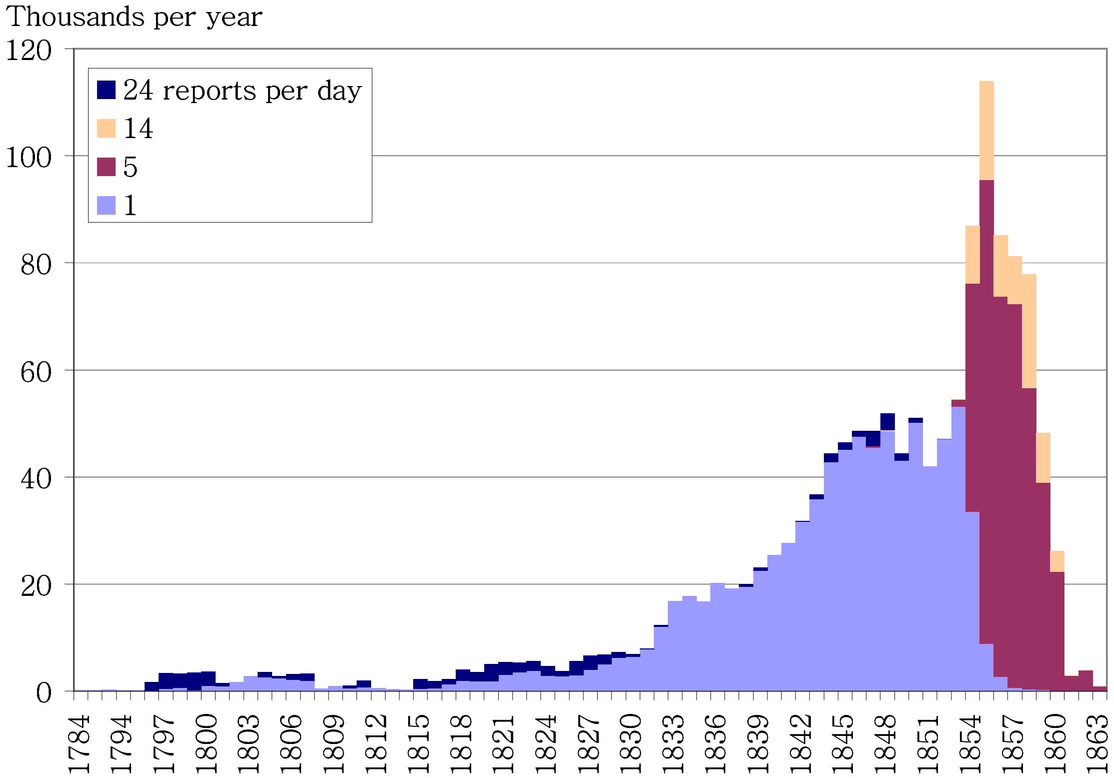


Fig. 2: US Maury Collection reports per year, stratified by the number of observations reported per day in each type of abstract log: 24 (hourly), 14, 5, or 1 (once daily, at local noon when latitude and longitude were generally observed).

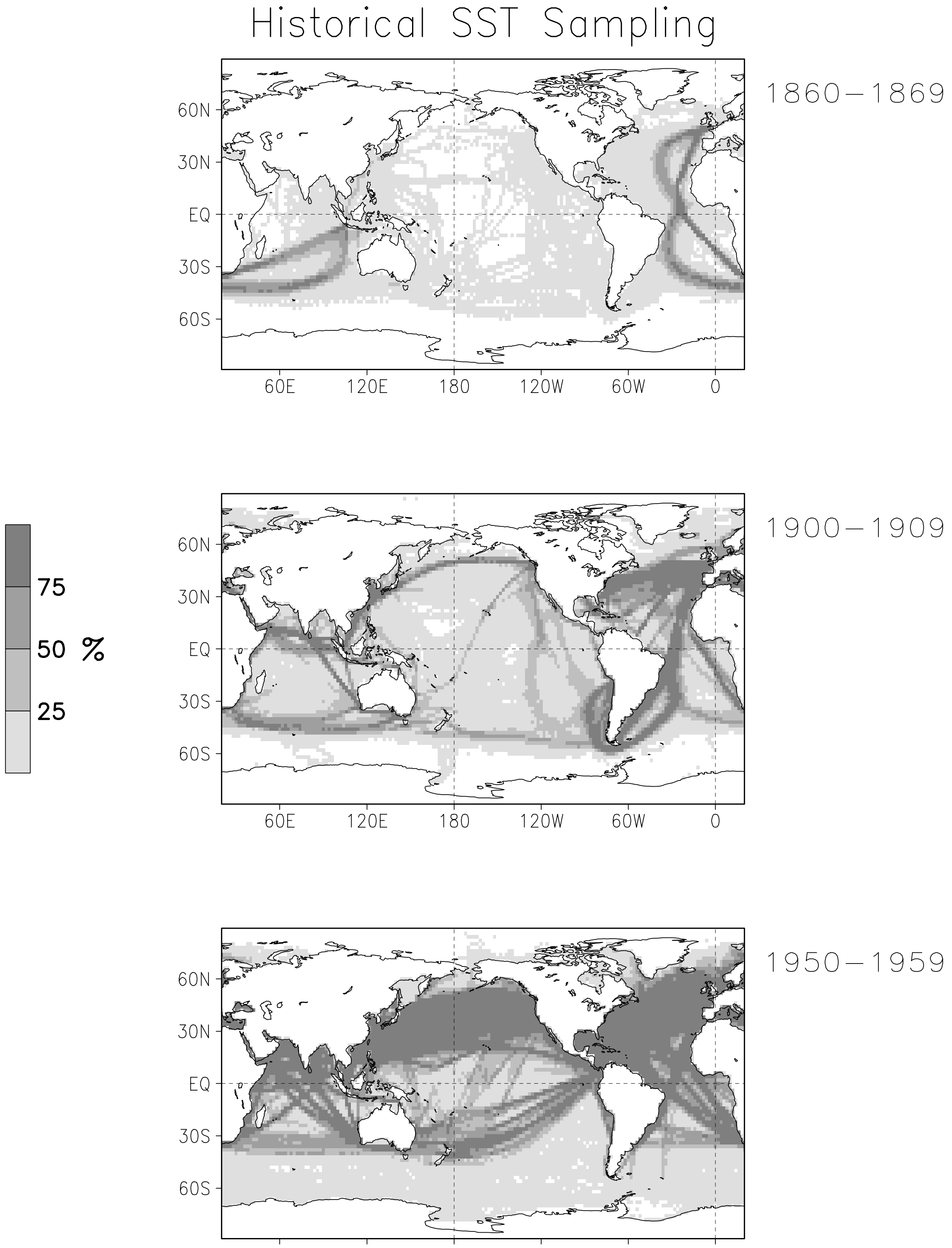


Fig. 3: Historical SST sampling for three example decades. The maximum (100%) is achieved when all 120 months in the decade have at least one observation in each 2° latitude × 2° longitude box.

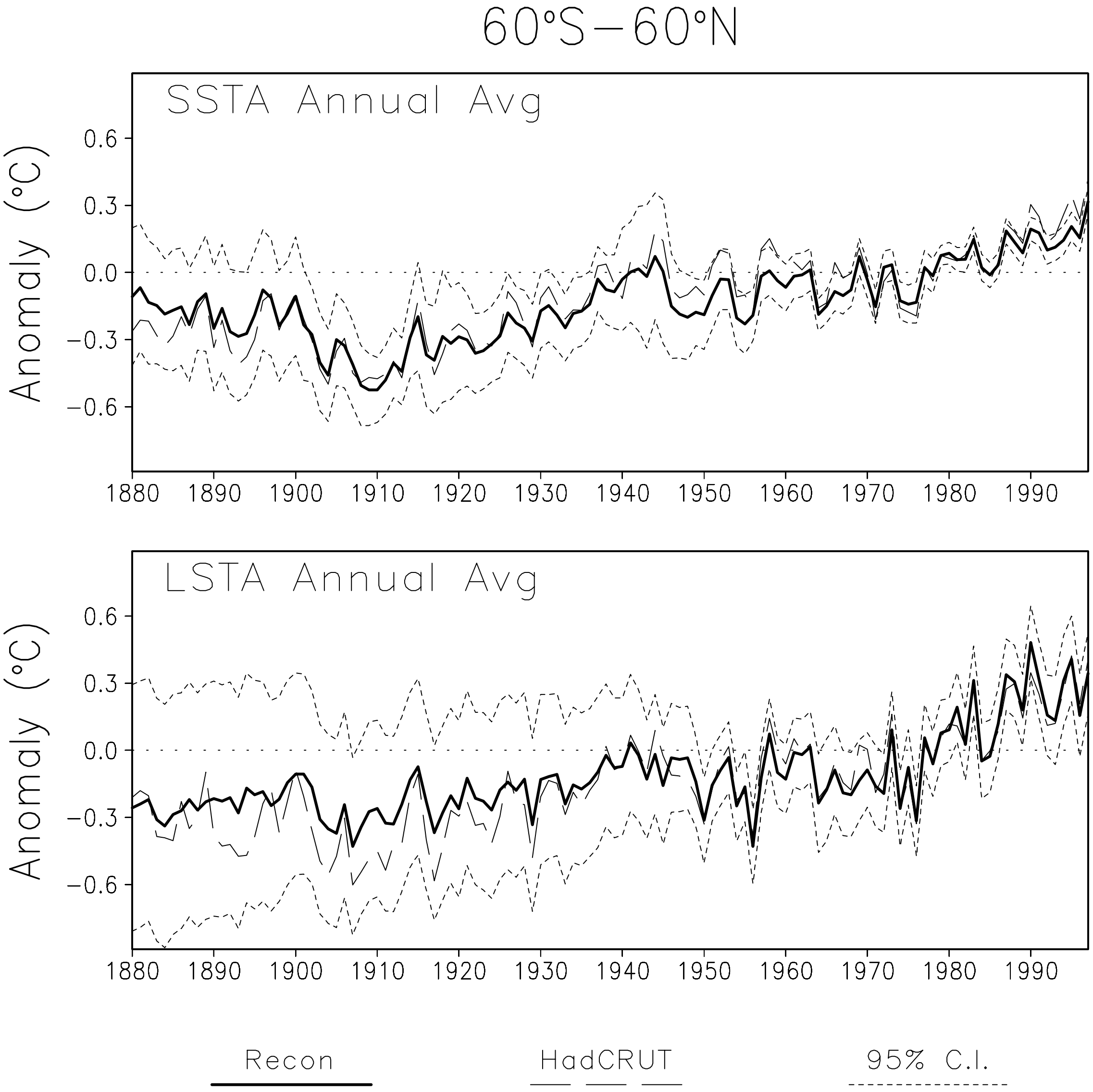


Fig. 4: Near-global spatial and annual averages of SST and land surface temperature (LST) anomaly reconstructions labeled (Recon) for SST anomalies (SSTA) and for LST anomalies (LSTA), with 95% confidence intervals (labeled C.I.). Also shown are UK land and ocean analyses (labeled HadCRUT) from Parker et al. (1994).

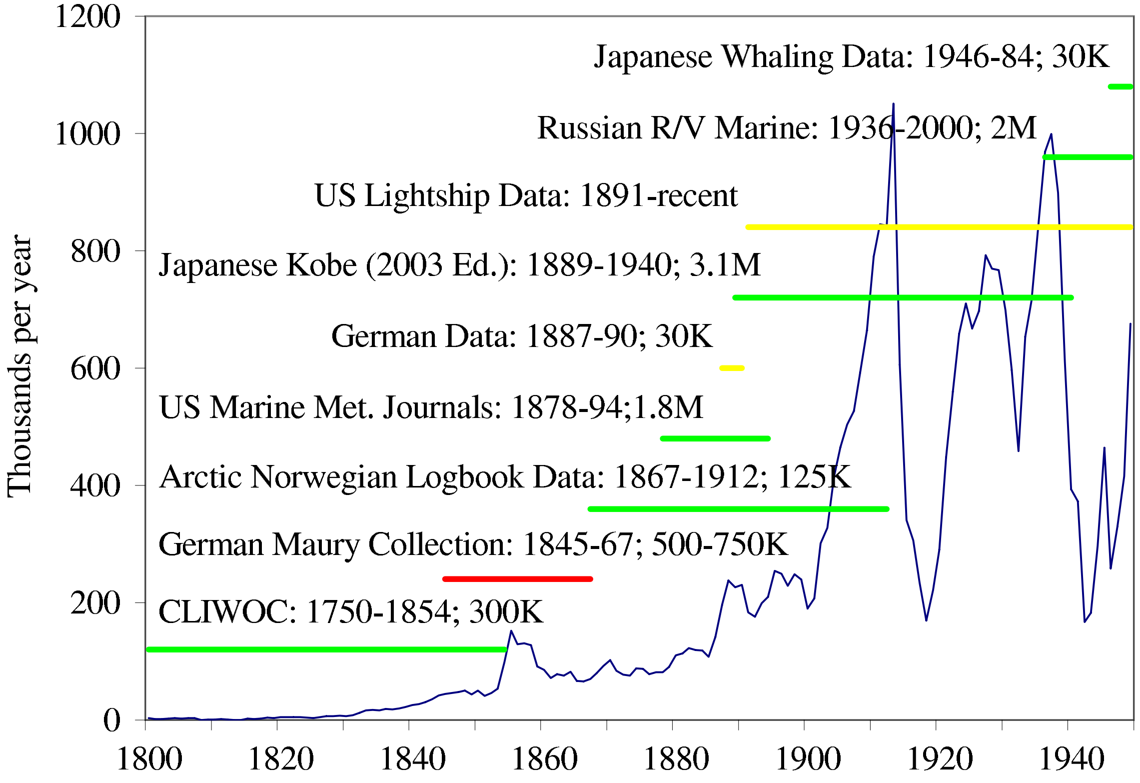
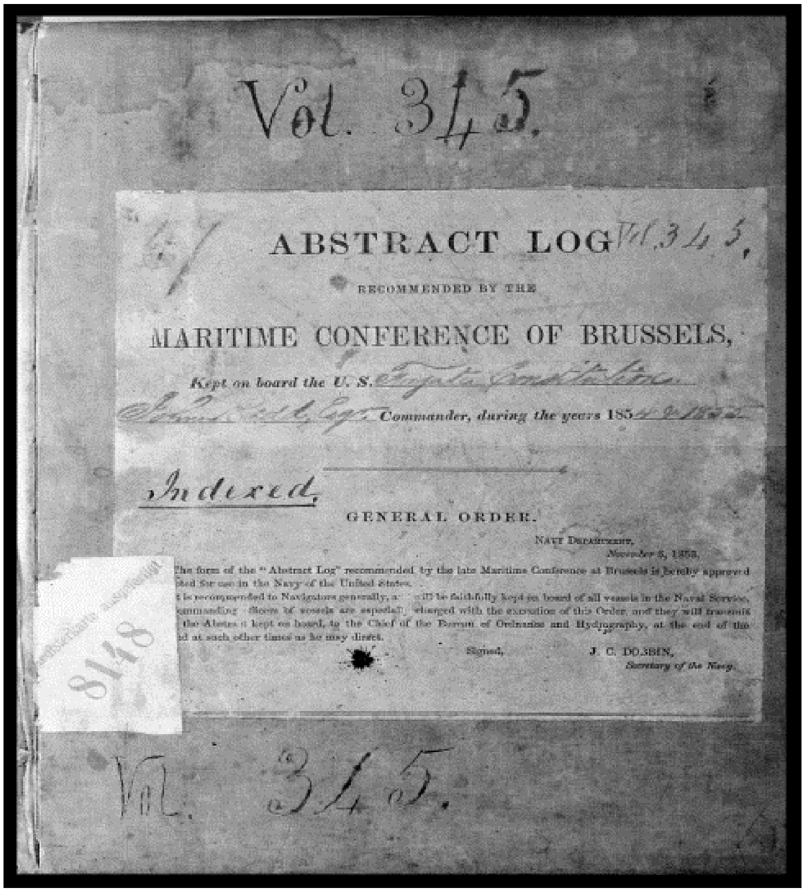


Fig. 5: Lines span periods-of-record of undigitized (red), partly digitized (yellow), or fully digitized (green) ICOADS blend candidates through 1949 (many additional data have not yet been blended for 1950 forward). The estimated total number of reports (thousands or millions) for each collection is listed, if available. The curve shows thousands of reports per year currently in ICOADS.



Vol. 345.

ABSTRACT LOG Vol. 345.

RECOMMENDED BY THE

MARITIME CONFERENCE OF BRUSSELS,

Kept on board the U. S. Frigate Constitution

John Rudd, Esqr. Commander, during the years 1854 & 1855

Indexed.

GENERAL ORDER.

NAVY DEPARTMENT,
November 5, 1853.

The form of the "Abstract Log" recommended by the late Maritime Conference at Brussels is hereby approved
ted for use in the Navy of the United States.
t is recommended to Navigators generally, a [illegible] will be faithfully kept on board of all vessels in the Naval Service,
ommanding [illegible] of vessels are especially charged with the execution of this Order, and they will transmit
the Abstract kept on board, to the Chief of the Bureau of Ordnance and Hydrography, at the end of the
d at such other times as he may direct.

Signed, J. C. DOBBIN,
Secretary of the Navy.

8148

Vol. 345.

Fig. 6: Abstract log of the US Frigate *Constitution*, 1854-1855: Naval Observatory volume #345; DWD Registration #8148 (reprinted from Braun, 2000).

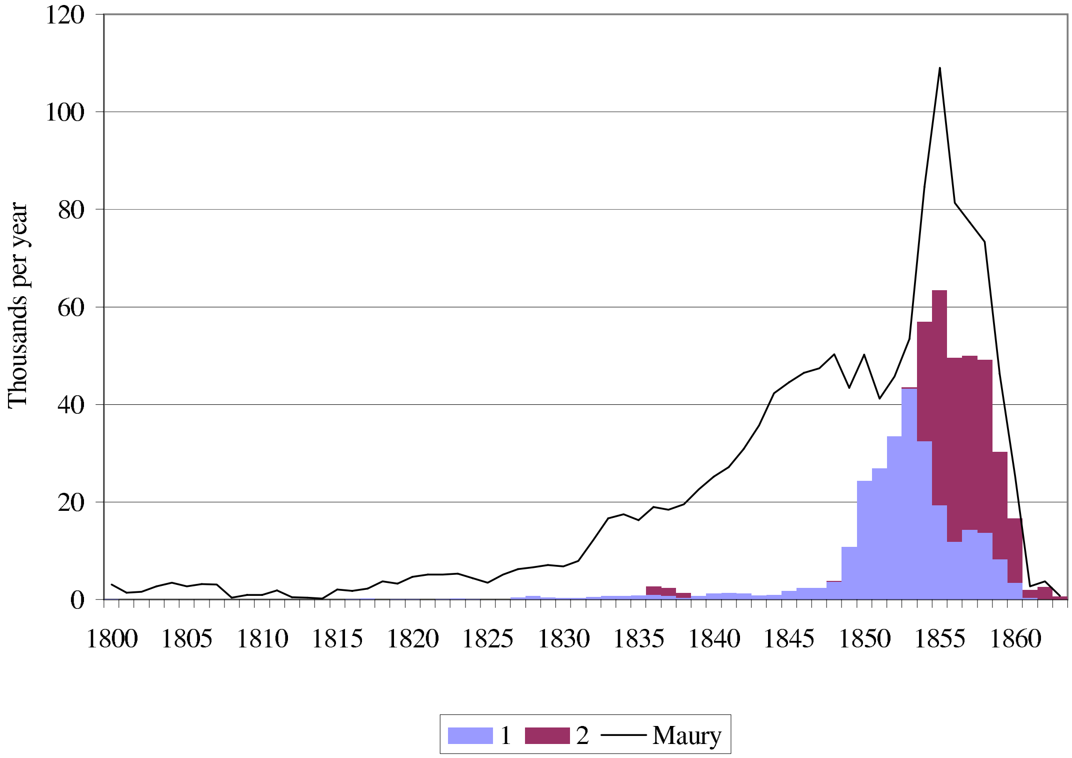


Fig. 7: US Maury Collection reports per year (curve). SLP (bars) and other instrumental observations become prevalent only after the 1853 Brussels Conference. Bar types indicate which corrections were applied: 1) only the gravity correction, 2) both temperature and gravity corrections. A gravity correction was applied to each SLP observation, but a temperature correction was only applied if an attached temperature observation was also available, as recommended in 1853.