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Reconstructing West Pacific Sea Surface Temperatures Using World War II Ship Observations

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Abstract

Climate models utilizing sea surface temperature (SST) data sets reveal a warm SST anomaly during World War II (WW2). Causes for warming during this time show biases in ship observations that are not from natural causes. SST measuring techniques using buckets and engine room intake are potentially two of the main causes for this warming, and corrections to these data have been made. However, loss of ship information and loss of data from the punch card digitization process could impact these measurements as well. Corrected SSTs from ships use punch card digitized data that may have associated data loss. WW2 ship observations from the National Oceanic and Atmospheric Administration (NOAA) archives office are used to construct two SST datasets of the West Pacific for one month at different times and compare it to uncorrected data from the International Comprehensive Ocean – Atmosphere Data Set (ICOADS). After comparing the two datasets, the NOAA archived data show a slight variation in SSTs with the NOAA archived data. Results reveal a potential sample size issue with the ICOADS data, suggesting further expansion of future datasets.

1. Introduction

Sea surface temperatures (SSTs) are a major component of climate analysis and are typically measured at a depth of 20–30 cm below the surface (Davis et al. 2019; Chan et al. 2021). The use of SST data helps climate scientists understand the current state of the climate and how it may change in the future (Kennedy et al. 2011). SSTs affect the transportation of heat, moisture, and wind flows worldwide. Over the last 25 years, SST records have indicated a warming trend connected to anthropogenic forcing (Ashfaq et al. 2011). Warming oceans lead to changes in extreme precipitation, temperature, and global circulation patterns (Ashfaq et al. 2011).

Climate models utilize SST datasets to set the initial conditions for model runs. The most comprehensive SST dataset to date is the International Comprehensive Ocean–Atmosphere Data Set (ICOADS); (Freeman et al. 2016). The data set is built upon surface marine observations from the late 17th century to 2014 (Freeman et al. 2016). The ICOADS data are vital for other SST datasets, such as the Extended Reconstructed Sea Surface Temperature (ERSST) and Hadley Centre SST, version 3 (Huang et al. 2017). Despite the importance and usefulness of the records, observational SST data used in datasets such as ICOADS have pitfalls. Freeman et al. (2016) state "The quality and completeness of observations in the present ICOADS are strongly related to the source of the observations, the formats used to store the data, and any conversions used."

Both ERSST and HadSST datasets utilize the latest version of ICOADS (ICOADS Release 3). Marine data are collected from journals, ship logs, and observations (Freeman et al. 2016). However, these collections can have missing data or incomplete observations (Freeman et al. 2016). SST measuring techniques during World War II (WW2) also impacted the observations. Bucket and engine room intake (ERI) measurements were taken for SST measurements during WW2 (Chan et al. 2021). The most common were ERI measurements as the war progressed (Chan et al 2021). ERI measurements were susceptible to two problems. First, the water was taken from 5 –15m below the surface and was susceptible to warming around 0.1° to 0.5°C due to the warmth of the engine room (Thompson et al. 2008; Chan et al. 2021). In contrast, bucket measurements experienced the effects of latent and radiative heat loss after being pulled from the ocean, leading to cooler than actual SSTs (Thompson et al. 2008). Canvas buckets from United Kingdom ships typically cooled around 0.4°C (Chan et al. 2021).

ERSST versions 4 and 5 (ERSST4 and ERSST5), along with HadSST4, indicate a warming trend during WW2 between 1941–1945, known as the World War II warm anomaly (WW2WA); (Chan et al. 2021). However, other SST data analyses have produced results showing cooler SSTs during WW2. The HadSST3 indicated cooler temperatures when compared to the ERSST and HadSST4 (Cowtan et al. 2018). One potential issue with these conflicting data is that the strength of El Niño during 1939–1941 may not be well understood due to the uncertainty in the SST record (Kennedy et al. 2019).

However, several scientists have made efforts to correct the warm bias. Cowtan et al. (2018) attempted to use coastal observations with ship and buoy observations to assess SSTs. The results were similar to HadSST3 data, indicating that SSTs during WW2 were not warmer. Pfeiffer et al. (2017) utilized coral geochemical signatures of $\delta_{18}O$ and Sr/Ca to calculate SSTs in the West Indian Ocean (WIO). $\delta_{18}O$ and Sr/Ca are used as paleoclimate temperature indicators, and are found in scleractinian corals[6]. Results were independent of historical ship observations and indicated that SSTs during WW2 were not as warm as the ERSST and HADSST4 suggest (Pheiffer et al. 2017). Corrections to both ERI and bucket measurements have been attempted, with Chan et al. (2021) utilizing the linear mixed effect method to correct for biases in both techniques. The resulting SST values are similar to Cowtan et al. (2018).

Although the Chan et al. (2021) corrections show that the WW2WA is an artifact of observational techniques, one other issue is present with the data. ICOADS ship observations are based on punched card digitization and are susceptible to limited data parameters (Freeman et al. 2016). The Wood et al. (2021) UN Decade of Ocean Science and Sustainability project proposal details several data issues, such as fragmentation, rounding artifacts, measuring techniques and loss of ship ID information.

Using the actual historical ship observations, however, helps to alleviate this issue by going directly to the unaltered data source. The goal of this project is to use the ship observations from WW2 in the West Pacific to create an SST data set for the month of September 1944. The observations include SSTs, ship ID and location information. The SST data will be plotted and then compared to the uncorrected SST ICOADS dataset for that same time. The scope of this work is limited to analyzing one month, but SST data from this project can be further corrected in future work.

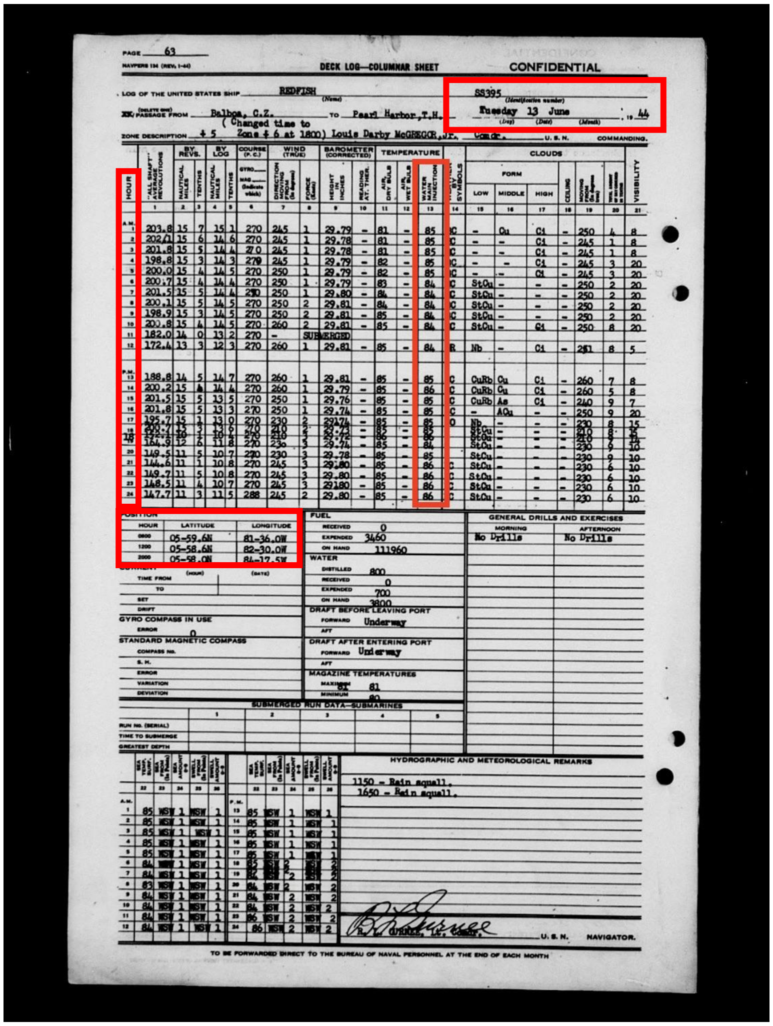
2. Data

SST data for this project come from ICOADS release 3.0 and WW2 observations. The latter observations are contained on reels and paper observations imaged at the National Centers for Environmental Information in Asheville, North Carolina. The ICOADS data are focused on a region in the South Pacific between 110°E–175°E and 20.5°N–21.5°S. The data come from June of 1944 at 1200 HRS (0400 UTC) and 2000 HRS (1200 UTC), where 1200 HRS and 2000 HRS is military time.

3. Methodology

Most datasets derived from ICOADS show the WW2WA. Davis et al. (2019) state that one of the major issues concerning SST data reconstruction is measurement technique and observations with unknown ships. From the imaged ship observations, a dataset is constructed using day, ship name, and SSTs for June 1944 at 1200 HRS (0400 UTC) and 2000 HRS (1200 UTC). An example of an observation is shown in Figure 1. A similar dataset is created using the ICOADS data, apart from ship name since ship ID is provided as a number in ICOADS. Daily averages are calculated from both datasets and compared in time series plots. The ICOADS data for 1200 HRS (0400 UTC) have a maximum of six observations for one day, indicating that the observations are from six ships. For 2000 HRS (1200 UTC), there is a maximum of five observations for one day, indicating observations from five ships. The observational data sets include 36 ships for

1200 HRS and 35 ships for 2000 HRS. Comparing both datasets are done by using linear regression. Wilks (2011) describes this method as “ … the linear relationship between two variables, say x and y.” With linear regression, x is denoted as the predictor variable and y is the predictand (Wilks 2011). For this analysis, the ICOADS data are the predictor and observational data are predictand.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DECK LOG—COLUMNAR SHEET

CONFIDENTIAL

LOG OF THE UNITED STATES SHIP REDFISH SS395

PASSAGE FROM Balboa, C.Z. TO Pearl Harbor, T.H. Tuesday 13 June 44

HOUR	LATITUDE	LONGITUDE
0800	05-59.6N	81-36.0W
1200	05-58.6N	82-30.0W
2000	05-58.0N	84-17.5W

GENERAL DRILLS AND EXERCISES — MORNING: No Drills — AFTERNOON: No Drills

HYDROGRAPHIC AND METEOROLOGICAL REMARKS

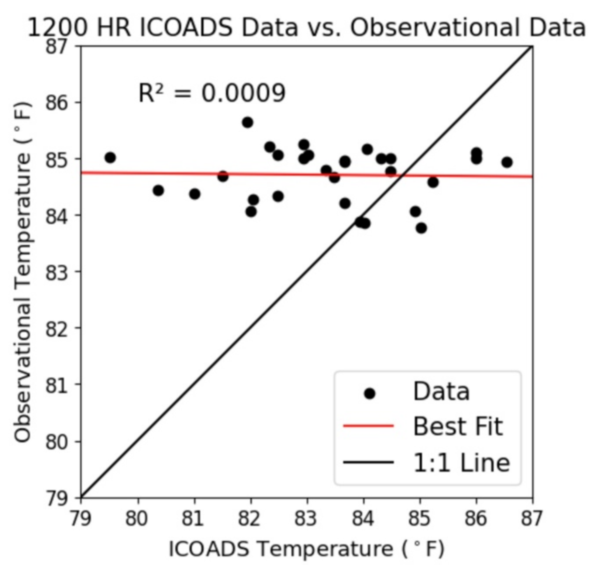
1150 - Rain squall.
1650 - Rain squall.

Figure 1. An example of a ship observation, with highlighted time (left column), latitude and longitude (bottom left), SST data (right column) and date (top left).

4. Results and Discussion

Figure 2 shows the linear regression plot of the 1200 HRS observational data compared to the ICOADS data. Figure 3 shows a similar plot using the 2000 HRS data. Comparison of the datasets reveals a poor correlation between them, where R = 0.03 for 1200 HRS, and R = 0.364 for 2000 HRS. A 1:1 line is used to display a comparison of the best fit line and the data. These values are found by taking the square root of the R^2 values found by linear regression. The average daily SSTs for the 1200HRS

ICOADS data was 29.45°C (85.010°F), and the observational data was 29.28°C (84.71°F), 0.17°C (0.3°F) cooler. The 2000 HRS daily average for the ICOADS set was 28.54°C (83.37° F), and the observational data was 29.26°C (84.67°F), 0.724°C (1.303°F) warmer. A cause for the slightly differing temperatures between the ICOADS and observational datasets, may be due to the number of ship observations used. For the 2000 HRS ICOADS data, observations for 7, 9,11, and 16 June were missing. In order to obtain a line of best fit, data from the same four days was removed from the observational data. Results indicate a larger data pool enhances the resolution of the daily averages, potentially causing a further difference in the temperatures between the observational data and the ICOADS data.



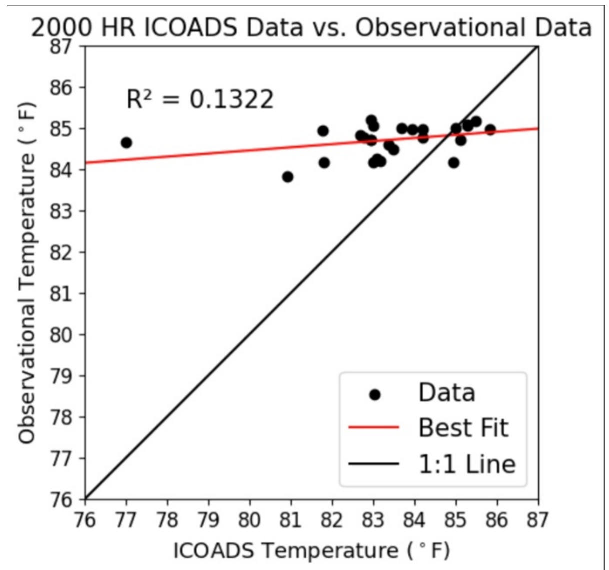


Figure 2 (Left). Comparison of ICOADS data and the observational data. Comparison of the observational data to ICOADS reveals a poor correlation for 1200 HRS (0400 UTC). **Figure 3 (Right)**. Comparison of ICOADS data and the observational data show similar results to the 1200 HRS (0400 UTC) data for 2000 HRS (1200 UTC).

5. Conclusion and Future Work

My comparison of the 1200 HRS and 2000 HRS ICOADS data to the observational data revealed 0.17°C (0.3°F) difference; the observational data at 1200 HRS measured slightly cooler. The data comparison at 2000 HRS revealed that the observational data was 0.724°C (1.303°F) warmer than the ICOADS data. Linear regression for June 1944 at 1200 HRS (0400 UTC) revealed an R = 0.03, and R = 0.364 for 2000 HRS (1200 UTC). The poor correlation between the two data sets may be a result of ICOADS having few ship observations compared to the observational dataset.

Given the small pool of daily observations found in the ICOADS data, a more comprehensive dataset needs to be created to fill in the lack of data. Although this project looks at a small part of the larger SST data, it is the first time that the raw observations have been used for scientific study. Beginning with this initial focus on the South Pacific, this project aims to create a better resolution of SST averages with historical observations. However, more work is needed in order to gain a better understanding of how the SST data from WW2 ship observations will compare to the ICOADS data. The linear regression test performed in this project was done as a simple comparison of the observational data and the ICOADS data. Though helpful in gaining an initial understanding of how the observational data and ICOADS data compare, more robust statistical tests can be done with this data.

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