The "bucket" was non standard P 418

A Study of the Quality of Sea Water Temperatures Reported in Logs of Ships' Weather Observations

J. F. T. SAUR

U. S. Bureau of Commercial Fisheries Biological Laboratory, Stanford, Calif.

(Manuscript received 27 August 1962, in revised form 14 January 1963)

ABSTRACT

The differences between sea water temperature reported in the Log of Ship's Weather Observations and specially observed sea surface temperature were studied for 6826 pairs of observations taken in the Pacific Ocean from 3 Military Sea Transport Service ships and 9 U. S. Navy Radar Picket ships during 92 different trips. For each trip the mean difference (*trip* bias), using the surface temperature observations for the reference, and the standard deviation of the differences were computed. These results were combined to give similar measures for each ship (*ship* bias and standard deviation) and estimates of these measures for a large number of ships (*fleet*).

Reported sea water (injection) temperature observations vary considerably in quality. The *fleet* bias, or mean difference, of injection temperature observations as compared to surface temperature observations is estimated to be 1.2±0.6F and the standard deviation of differences to be 1.6F. Among the 12 ships, the *ship* bias, or mean of all differences derived from observations of a given ship, ranged from −0.5F to 3.0F, which is probably due to variations of the thermometer accuracy and of the thermometer installations between ships. The standard deviation about these means was 1.3F, which is a measure of the variability of present data records, *provided* that the bias for each ship could be determined and a correction applied.

The variability of differences in the observations from a single ship is attributed to the system of taking and reporting sea water temperature observations from an injection thermometer. To improve the reliability of reported sea water temperature observations, a change to an electrical resistance or thermistor thermometer, specially designed and installed to measure the sea water temperature and having a remote indicator on the ship's bridge, is recommended. If this change were made, it is estimated from trip data that the standard deviation of differences would be reduced to less than 1.0F.

1. Introduction

Historically, observations of sea water temperature have been taken and recorded as a part of marine weather observations. For U. S. ships, a fraction of the weather observations are reported by radio, collected, disseminated by teletype, and used for synoptic forecasting. Many more are recorded on log sheets (Log of Ship's Weather Observations, Weather Bureau Form 415-5, formerly 1210F) which are collected by the Marine Centers, U. S. Weather Bureau, and are deposited at the National Weather Records Center.

The sea water temperature observations have been little utilized in the past except for climatological studies, such as for the *Atlas of Climatic Charts of the Ocean* (U. S. Weather Bureau, 1938), *World Atlas of Sea Surface Temperatures* (Hydrographic Office, 1944), and more recently the *Marine Climatic Atlas of the World, Vols. I and II* (Chief of Naval Operations; 1955, 1956). Now, however, descriptions of oceanic phenomena with greater resolution in time as well as space are needed. For example, Namias (1959) has shown how variations in feedback of energy from the ocean to the atmosphere—dependent upon ocean temperatures—may play an important role in long-period variations of prevailing wind circulations. Also, month-by-month charts of sea surface temperature in the North Pacific Ocean are being compiled from these observations by the Bureau of Commerical Fisheries Biological Laboratory, Stanford (1962), for the purpose of studying the effects of environmental variations on abundance and availability of commercial fishes.

Reported sea water temperature observations are known to be of uncertain accuracy, however. The sea water temperatures on ships of U. S. registry are generally read from a thermometer in the engine room mounted at some location in the sea water injection system of the ship and are commonly called "injection temperatures." The effect of heating within the system, the procedures for taking and reporting the observation, observational error, inaccuracy of the thermometer, and real differences between the sea temperature at the intake level and the sea surface, all contribute to differences and variability in readings between injection and surface temperatures.

Oceanographers often state that the injection temperatures on the average are about 1F higher than surface bucket temperatures. This belief probably arose from studies of temperatures taken with bathythermogram observations during World War II, but no documentation seems to be readily available. In describing the preparation of charts of Air-Sea Temperature Difference, the *Marine Climatic Atlas of the World, Vol. I* (Chief of Naval Operations, 1955) states, "Due principally to the extremely variable and often unreliable quality of ships' sea temperature observations, these charts are seasonal and contain isopleths only." When one considers that a temperature decrease of 1C in only 1 meter of water can release enough heat to increase the temperature almost 4C in the lower 1000 meters of the atmosphere, observations of sea water temperature should certainly be made with comparable or, preferably, higher accuracy than those of air temperature.

Franceschini (1955) compared the temperature distribution of the surface water in the Gulf of Mexico as determined by certain short-period averages of commercial vessel reports to the distributons as determined from three oceanographic surveys made in 1951 and 1952. Using this indirect method, he concluded that in the Gulf of Mexico short-period averages of ship reports could be used for practical purposes, e.g., forecasting air mass modification. However, he found it necessary to determine and apply corrections—some as large as 5F—to the reports from commercial vessels, when there were fewer than 10 reports per quadrangle for which the average temperature was computed. His success was probably due, therefore, to a fairly high density of observations and relatively uniform temperature conditions throughout much of the Gulf of Mexico.

At our laboratory, for the construction and use of the monthly charts of sea surface temperature in the North Pacific Ocean, a measure of the reliability of the observations was needed. The uncertainty regarding accuracy of historical data made it desirable to obtain some direct measurements of the difference between reported sea water temperatures and sea surface temperatures. This information would further assist in establishing a course of action with regard to future observations.

Through the cooperation of U. S. Weather Bureau observers aboard Military Sea Transport Service ships operating in the Pacific Ocean and U. S. Navy personnel aboard radar picket ships operating off the west coast of the United States, such direct measurements have been obtained during a $2\frac{1}{2}$-yr period. An analysis of the differences between paired observations of sea surface temperature, as taken by a bucket thermometer, and of sea water temperature, as reported in the weather log from injection measurements, is given here.

2. Observational program

For the period May 1959 through May 1960, data (given in Table 1) were obtained from three transports of the Military Sea Transport Service (hereafter referred to as MSTS). These MSTS ships operated on trans-Pacific routes from San Francisco, and occasionally from other west coast ports, to Japan and/or western Pacific bases of the United States, such as Okinawa, Manila and Guam. Occasionally stops were made at Honolulu.

For the period September 1960 through January 1962, data were obtained from nine U. S. Navy radar picket ships (Table 1). Seven were liberty ships converted for

TABLE 1. Ships participating in program of surface temperature observations.

Military Sea Transport Service
USNS General H. J. Gaffey
USNS General E. D. Patrick
USNS General D. I. Sultan
Radar Picket Ships
USS Interceptor (AGR 8)
USS Interdictor (AGR 13)
USS Interpreter (AGR 14)
USS Locator (AGR 6)
USS Picket (AGR 7)
USS Scanner (AGR 5)
USS Tracer (AGR 15)
USS Koiner (DER 331)
USS Lowe (DER 325)

radar picket duty (AGR class) and two were destroyer escorts (DER class). Data were obtained from each ship for about one year. These radar picket ships operated out of San Francisco to five stations located about 300 mile off the west coast of the United States, maintained positions within a 50-mile-diameter circle for a period of 21 to 30 days, and returned to port. Station assignment was rotated, but the range of temperature encountered on any given trip was small compared to that for a trip by an MSTS vessel.

Sea surface temperature. Special thermometers and thermometer holders were furnished to each ship for making the observations of sea surface temperature. The holder, or "bucket," was designed at Scripps Institution of Oceanography specifically for taking sea surface temperature observations. An inner plastic cup holds a water sample around the thermometer bulb. This is separated by an air space from an outer metal case which protects the plastic cup from damage and acts as a shield against radiation and evaporation while the temperature is being read. The thermometers were graduated in 0.2F and could be read easily to the nearest 0.1F. Each thermometer was checked in the laboratory to assure an accuracy of ± 0.15F and most were found to be accurate to ± 0.10F or better. Except for infrequent gross reading errors, such as an error of 10F, it is estimated that the probable error (0.6745σ) of observation would be about 0.1F.

Aboard the MSTS ships the special observations were made twice daily, workload permitting, by the Marine Observers of the U. S. Weather Bureau, Marine Center, San Francisco, with the 0600 and 1800 GMT weather observations. From the radar picket ships, four observations a day were taken by the aerological personnel at 0000, 0600, 1200 and 1800 GMT.

Sea water temperature. An attempt was made to insure that the sea water temperatures obtained for the comparative analysis were as representative as possible of those routinely reported. In enlisting the cooperation of ships' weather personnel for obtaining the special surface temperature observations, care was taken not to alter the usual routine of the ship for obtaining the sea water temperature for entering in the Log of Ship's Weather Observations.

The instrument used for these observations is generally a standard industrial hot water (sometimes called "hot well") thermometer, which is a mercury-in-glass thermometer whose bulb is protected by a thin metal case. This bulb is further seated in a second metal case or "well," which is semipermanently installed in the pipe. It protects the thermometer from the water and pressure and permits the removal and exchange of thermometers without shutting down and draining the injection system. The thermometers, although used for measuring the sea water temperature, have ranges as great as 30F to 180F and 30F to 240F and are graduated in 2F or sometimes 5F intervals. The sea water temperatures are reported in whole degrees Fahrenheit.

The size of the pipe, location and depth of intake, location of overboard discharge, location of thermometer, etc., vary greatly among classes of ships, and some minor differences may exist between installations on ships of the same class. In addition to a main injection system, there are other sea water lines for auxiliary equipment on which thermometers are also mounted. As a further complication, many ships have more than one engine room.

On the ships participating in this program, the depth of the sea water intake ranged from 10 to 22 feet below the surface and the inner diameters of the pipes from 8 to 20 inches. The thermometers were located along the injection lines from within a few feet of the hull to as much as 25 feet inboard at the entrance of the line to the condenser jacket.

An "oiler" maintains a rough log hourly of the readings from the various thermometers and gauges in the engine room. The smooth engine room log is prepared just prior to the end of each 4-hour watch. There seems to be no standard procedure among ships as to which reading of sea water temperature is given to the weather personnel or bridge. The sea water temperature data used in this analysis were taken from the weather logs.

3. Analysis of data

Prior to the statistical analyses, gross errors appearing on the data sheets in both the surface temperature observations and the injection temperature observations were eliminated by inspection. During this process, frequent large and variable differences were noted between paired observations taken by MSTS ships in the Yellow Sea and very close to the south coasts of the Japanese islands of Kyoshu and Shikoku. It appeared that these were due to large natural variations and were not typical of observations from the open ocean, so all observations from these regions were eliminated.

Table 2 gives for each ship the total number of observational pairs of injection and sea surface temperatures used in this analysis, the number of sets of observations for each ship and the minimum and maximum of observations per set (trip). Since it is not the intention to indicate here that a certain ship may report more or less reliable temperatures than others, ships are henceforth identified only with a prefix for the type of ship followed by a letter.

TABLE 2. Observational pairs of injection temperature and sea surface temperature by ship.

Ships	Number of trips	Total observations	Observations per trip: Minimum	Observations per trip: Maximum
Military Sea Transport Service				
MSTS—A	11	445	14	52
MSTS—B	9	412	31	59
MSTS—C	7	326	19	62
Radar Picket Ships				
AGR—D	7	783	105	116
AGR—E	6	582	61	132
AGR—F	9	882	78	130
AGR—G	5	370	53	90
AGR—H	6	592	87	113
AGR—J	7	669	69	114
AGR—K	8	697	60	113
DER—L	8	399	20	76
DER—M	9	669	68	83
Total	92	6826		

In this study, the difference, δ, between the reported sea water (injection) temperature, T_I, and the surface (bucket) temperature, T_S, defined by

$$\delta = T_I - T_S, \tag{1}$$

is being examined. Two statistics are employed: a) the bias of the injection temperature (mean difference), $\bar{\delta}$, defined by

$$\bar{\delta} = \frac{1}{N}\sum_{j=1}^{N}(T_I - T_s)_j = \frac{1}{N}\sum_{j=1}^{N}\delta_j, \tag{2}$$

where N is the number of observational pairs; and b) the standard deviation of the differences, s_δ, defined by

$$s_\delta = \left[\frac{\sum_{j=1}^{N}(\delta_j - \bar{\delta})^2}{N-1}\right]^{\frac{1}{2}}. \tag{3}$$

The bucket temperature is used as a reference under the assumption that errors in these temperatures are small and contribute little to the variance of the difference between injection and bucket temperature.

Three different ways of grouping the observational data were employed. Distinction is made by designating the statistics determined from the observations of a single trip of a given ship as the *trip* bias and the *trip* standard deviation. Statistics based upon all the observations from a given ship are termed the *ship* bias and *ship* standard deviation. When all observations from all ships are grouped together, the statistics are called the *fleet* bias and *fleet* standard deviation.

Caution is required if the latter statistics are to be applied to any particular set of observations taken from the files at the National Weather Records Center, where those in Deck 116, for example, are from many types of ships, with merchant vessesl predominating. The statistics in this study are based upon a sampling of only 12 ships and, particularly, only 3 different classes of ships, none of which were merchant ships.

4. Results

Trip bias and standard deviation. A typical distribution of the differences, δ, from one trip of an MSTS ship is shown in Fig. 1. The *trip* bias is 1.5F and the *trip* standard deviation is 1.3F. Regression analyses were made on trip data to determine whether or not the differences were a function of temperature, but no such dependence was found.

Table 3 shows the manner in which the *trip* bias and *trip* standard deviation may vary between different

TABLE 3. Trip bias, $\bar{\delta}$, and trip standard deviation, s_δ, for each trip of radar picket ship AGR-K.

Month	Year	No. of obs.	$\bar{\delta}$ (F)	s_δ (F)
Aug.-Sep.	1960	89	1.8	0.7
Sep.-Oct.	1960	93	1.3	1.3
Jan.	1961	60	0.5	0.5
Mar.	1961	85	1.7	0.9
Apr.-May	1961	113	1.8	1.1
Jun.-Jul.	1961	105	0.9	1.0
Aug.-Sep.	1961	75	0.3	0.7
Sep.-Oct.	1961	77	1.3	0.8

trips of the same ship. For this particular ship, AGR-K, the *trip* bias varied from 0.3F to 1.8F and the *trip* standard deviation varied from 0.5F to 1.3F. The variability from trip to trip is characteristic of almost every ship, as seen in Fig. 2 and Fig. 3, which show for each ship the distributions of the *trip* biases and the distributions of the *trip* standard deviations, respectively.

Ship bias and standard deviation. All temperature differences observed from a single ship are used to compute the *ship* bias and *ship* standard deviation, which are shown in Table 4 for each ship, along with the value of the *pooled trip* standard deviation. In this sample of 12 ships the *ship* bias ranged from −0.5F to 3.0F. The *ship* standard deviations range from 0.9F to

TABLE 4. Ship bias, $\bar{\delta}$, ship standard deviation, s_δ, and pooled [illegible] standard deviation, $\langle s_\delta \rangle$, for each ship.

Ship	No. of obs.	$\bar{\delta}$ (F)	s_δ (F)	$\langle s_\delta \rangle$ (F)
MSTS—A	445	1.2	1.5	1.3
MSTS—B	412	1.3	1.1	[illegible]
MSTS—C	326	−0.5	1.1	1.1
AGR—D	783	1.5	1.0	[illegible]
AGR—E	582	1.1	1.0	[illegible]
AGR—F	882	2.2	0.9	[illegible]
AGR—G	370	3.0	1.8	[illegible]
AGR—H	592	1.1	1.4	[illegible]
AGR—J	669	1.5	1.9	[illegible]
AGR—K	697	1.3	1.1	[illegible]
DER—L	399	0.1	1.2	[illegible]
DER—M	669	0.1	0.9	[illegible]

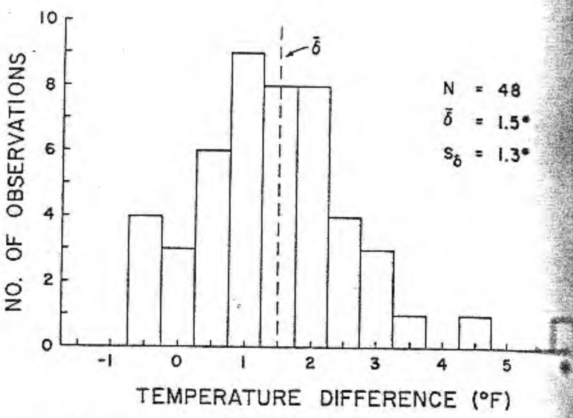

FIG. 1. Distribution of temperature differences, δ, for one trip of an MSTS ship, June–July 1959.

1.9F. The amount by which the *ship* standard deviation exceeds the *pooled trip* standard deviation depends upon the inconsistency of the *trip* biases for that ship.

Fleet bias and standard deviation. These measures were computed using the data from all ships, except that the computations were adjusted to give equal weight to the results from each ship regardless of the differing number of observations. The *fleet* bias from these 12 ships was found to be 1.2F and the *fleet* standard deviation to be 1.6F. For the 12 ships the *pooled ship* standard deviation is 1.3F and the *pooled trip* standard deviation is 1.[illegible]

5. Discussion

The 95 per cent confidence limits for the *fleet* bias were found to be 1.2±0.6F. On the assumption that the 12 ships sampled are not greatly atypical, one may conclude that injection temperatures reported in logs of ships' weather observations probably have, on the average, a real positive bias as compared to surface temperature. The results support the belief that injection temperatures exceed surface temperatures by about 1F. This bias is opposite in algebraic sign to that which might be expected from the occurrence of vertical temperature

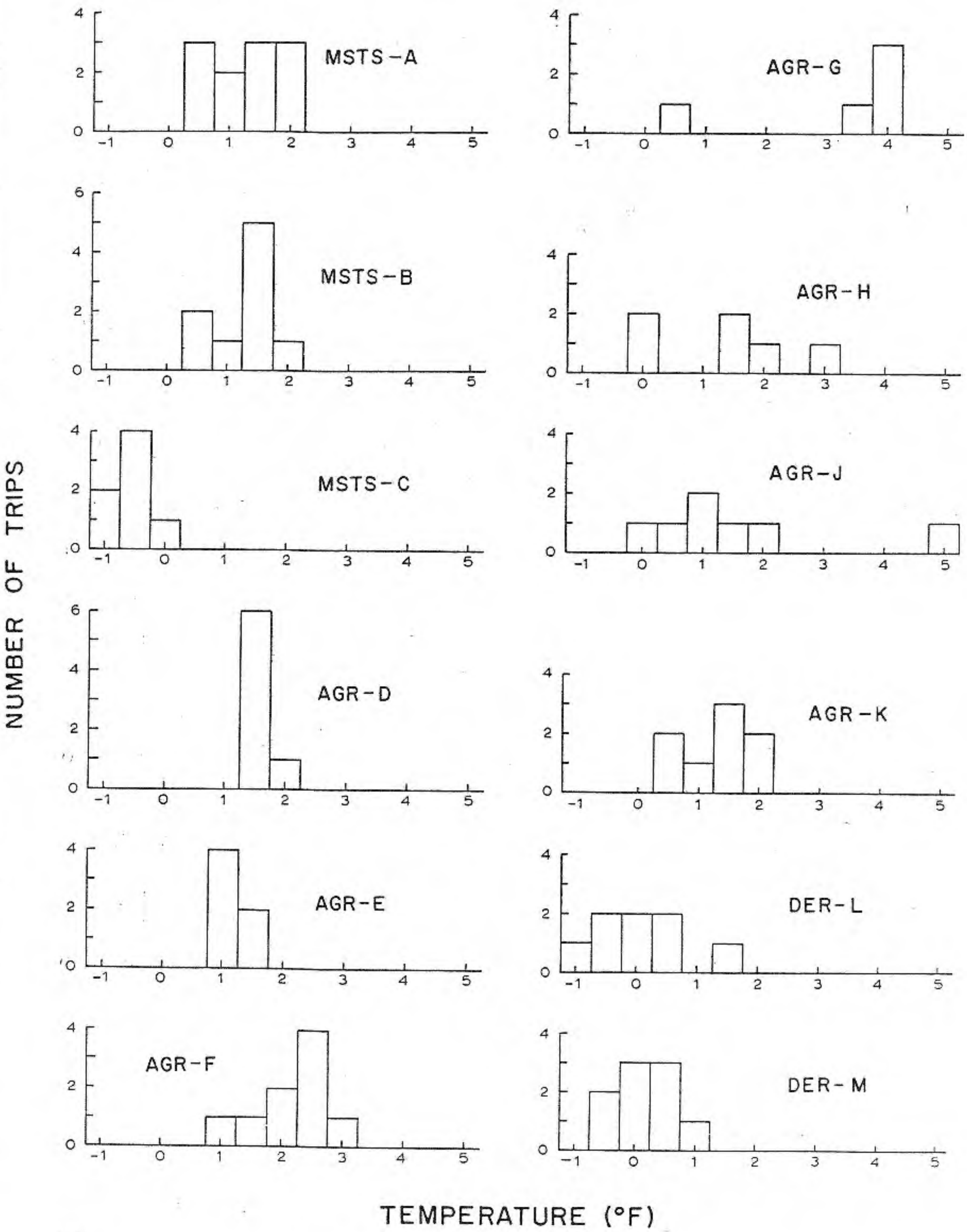

FIG. 2. Distributions of *trip* bias for each ship.

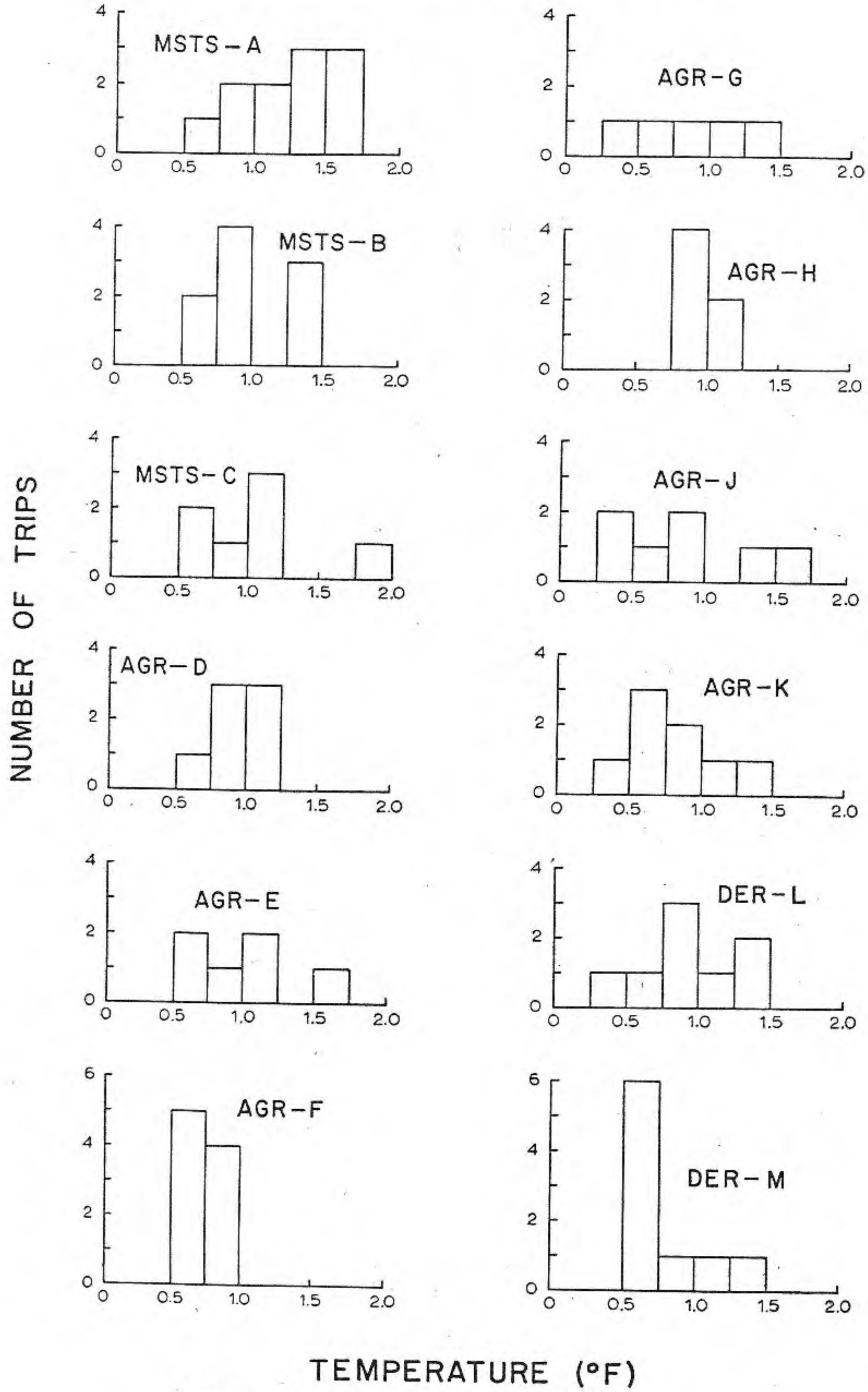

FIG. 3. Distributions of *trip* standard deviation for each ship.

gradients between the surface and depth of sea water intake.

The main purpose of this program was to obtain information on the quality of data reported in the routine manner. It was felt that placing an independent observer aboard the ships in an attempt to determine the causes of the differences would have defeated this purpose. My first subjective opinion would attribute the bias to the temperature of the water in the pipe probably being raised by the heat of the engine room prior to reaching the thermometer. However, as a result of visits to the ships, my second impression is that, because of incrustation or fouling, poor exposure of the well to the flow on some ships and possible air space inside the well, heat conduction along the metal fittings to the thermometer bulb may have a greater effect in causing bias than warming of the water.

The between-ship variance of bias, i.e., the inconsistency of *ship* bias, could well be caused by the variations from ship to ship in the conditions cited in the above paragraph. Thermometer errors must also be included as a cause of between-ship variance of bias.

Some special observations made aboard five U. S. Coast Guard Weather Ships[1] have demonstrated some of the problems encountered with injection temperatures. The injection thermometers were demounted and checked at several temperatures against an accurate standard thermometer. Temperature errors from the five thermometers ranged from −2.0F to 3.9F. Results of other observations indicated that the differences between injection temperature corrected for thermometer error and surface temperature "varied erratically both among ships and on individual ships at different speeds."

In the analyses of existing sea water temperature observations in which the ship is identified, it may sometimes be possible to determine the *ship* bias relative to many other ships by a procedure which evaluates internal consistency of the data, and to apply a constant correction to all of the observations from the particular ship. The estimated reliability of the data to be expected after applying this "calibration" procedure is indicated by the *pooled ship* standard deviation of 1.3F. This is probably the best that one can do to improve the quality of existing sea temperature records and those that continue to be read from present thermometers in injection systems.

It is believed that a major portion of the variability represented by the *ship* standard deviation stems from a lack of specific instrumentation aboard the ships for the purpose of making sea water temperature observations. For example, due to the lack of rigid procedures, there may be an appreciable and variable lag from the time of taking a thermometer reading in the engine room to the time for which it is logged in the weather report. Due to the movement of the ship, the observation would thus have an incorrect position.

The data from the three MSTS ships were examined for this "lag" effect by selecting all the differences for which the absolute change in surface temperature during the preceding 12 hours, ΔT_{12}, was 1.4F or greater. At normal speed a ship would move about 200 miles during a 12-hour period. The differences were separated into two groups, according to whether the ship was moving into warmer water or into colder water. The distributions of the differences for one ship, MSTS-C, show definitely, Fig. 4, that when the ship is traveling from warm to cold water (ΔT_{12} negative) the bias of injection temperature was 1.7F higher than when the ship was traveling from cold to warm water (ΔT_{12} positive). This difference between the two means is significant beyond the $P=0.001$ level. For the other two MSTS ships, the shifts in the means were 0.7F and 0.3F, which are significant at the $P=0.02$ and 0.07 level, respectively.

These results indicate that the injection temperature

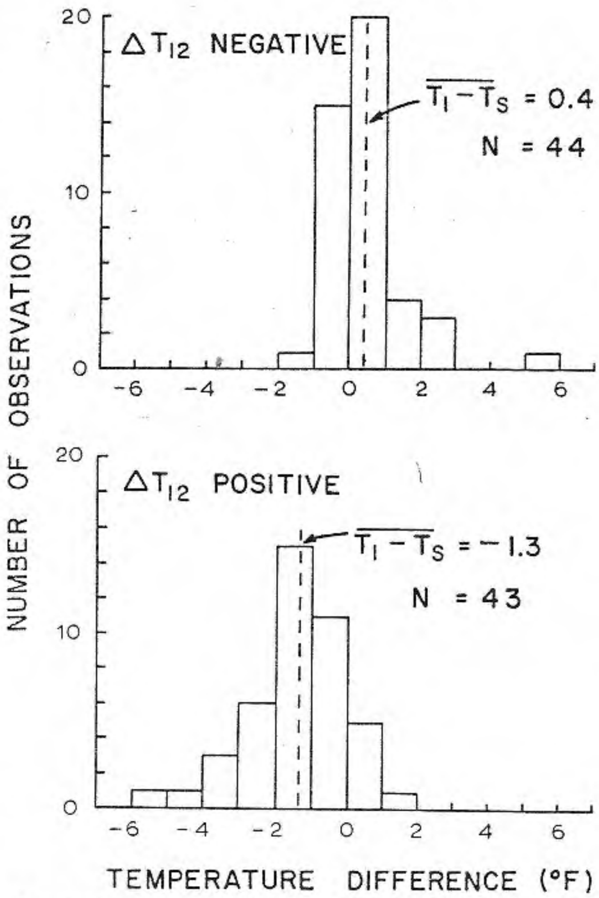

Fig. 4. Shift in distribution of differences between reported sea water temperature and surface temperature, when surface temperature has changed (ΔT_{12}) more than 1.4F from the preceding 12-hr observation; ship MSTS-C.

[1] Robinson, Margaret K., 1962: Report to the Eastern Pacific Oceanic Conference on comparisons of bucket and injection temperatures on Pacific Ocean weather stations. Unpublished manuscript presented to the Conference on October 3–5.

may be read sufficiently in advance of the time of the weather observation frequently enough to introduce a substantial error into the data when the ship is traveling through water of changing temperature. The few outlying large differences (Fig. 4) show that the error is sometimes very large.

Need for new instrumentation. The results of this investigation indicate that steps should be taken as soon as possible to provide special instrumentation aboard ships for the specific purpose of obtaining reliable measurements of sea water temperature. In the preparation of specifications for such equipment, there are two primary considerations:

a) The sensing element should be located so as to measure correctly the temperature of the sea water, and
b) A remote indicating or recording device should be located where the logs of the weather observations are prepared.

An instrument utilizing an electrical resistance or thermistor element mounted on the outside of the hull, forward near the keel, and no more than a few meters below the water line, is recommended as one possible solution. A more complex system to avoid possible complications of biological fouling of the element would involve a water scoop with a short run of piping and shut-off valves inside the hull of a cool forward compartment, so that the element could be removed for cleaning. Either of these would have the advantage of removing the element from the influence of the injection system and could also be located so as not to be influenced by any overboard discharges. Another consideration is that such instrumentation could be installed at a standard depth below the surface on all ships, for example, at 3 meters.

A dial indicator, rather than a recorder, is recommended for installation at the weather station on all ships except oceanographic research ships. This would avoid a need of special attention by ships' personnel for the operation of the equipment.

A conservative estimate of the improvement in the data which might be expected from installing proper instrumentation aboard the ships can be seen by the decrease from the *ship* standard deviation to the *pooled trip* standard deviation for the same ship (Table 4, columns 4 and 5, respectively). As previously mentioned, the *pooled trip* standard deviation from these 12 ships is 1.0F. This statistic eliminates the effects of change in bias from one trip to another, but it still contains the effects of changes in procedures during a trip and of time lag between observation and recording in the weather log. For these reasons, it is believed that the standard deviation of data from ships using new instrumentation similar to that proposed would be reduced to less than 1.0F.

6. Conclusions

Sea water temperature observations read from sea water injection thermometers and reported as a part of the Ship's Weather Observations vary considerably in quality. The differences between paired sea surface temperatures and reported sea water temperatures are not consistent within the limits one might expect from the vertical gradients of temperature in the sea. The differences not only vary from ship to ship, but also exhibit a large degree of variability between trips of a given ship, or even during a trip. The data illustrate the conclusions of the World Meteorological Organization, Commission for Instruments and Methods of Observation (1957), that "intake measurements of water temperature suffer from lack of proper location of the thermometer, from unsatisfactory thermometers, and from crudeness of reading or timing."

The average bias of reported sea water temperatures as compared to sea surface temperatures, with 95 per cent confidence limits, is estimated to be 1.2±0.6F on the basis of a sample of 12 ships. The standard deviation of differences is estimated to be 1.6F. Thus, without improved quality control, the sea temperature data reported currently and in the past are for the most part adequate only for general climatological studies.

The *ship* bias (average bias of injection temperatures from a given ship) ranged from −0.5F to 3.0F among the 12 ships. This inconsistency of bias between ships is probably due mainly to the differences in thermometers and their installations. If the *ship* biases can be determined and corrections applied to existing sea water temperature records, it is estimated that the standard deviation of differences would be reduced to 1.3F.

The relatively large variance of differences from a single ship is believed to result from the use of injection temperatures and the shipboard procedures for reading, communicating and eventual logging of the temperature. To improve the quality of the data it is recommented that new instrumentation, specially designed for taking sea temperatures, be installed aboard ships.[2] The element should be free of the influences of the injection system, preferably be located at a standard depth on all ships, and have a remote indicator at the location aboard ship where the weather observation is logged. The data from this study indicate that with such instrumentation the standard deviation of differences between reported sea water temperatures and sea surface temperatures could be reduced to *less than* 1.0F.

[2] A personal communication from A. J. Lee, Fisheries Laboratory, Lowestoft, England, states that a thermistor thermometer has already been designed, successfully tested, and installed aboard English weather ships. Although the element was mounted in the sea water injection pipe, special tests were made to assure that on the test ship the temperature was not influenced by overboard discharges and was the same as that at the equivalent depth in the sea. The instrumentation is further being considered for installation on certain ships operating on regular schedules in the North Sea.

Placement of new instrumentation on existing merchant and naval ships would take a considerable period of time. In the interim period, observations taken by both types of instrumentation and procedures would be reported. Further, the Commission for Instruments and Methods of Observations, World Meteorological Organization (1957), has recommended "that bucket measurements (of sea temperature) be made in quiet, sunny weather at low latitudes." It would, therefore, seem appropriate that steps also be taken to have the method of observation reported along with the temperature and that this information be retained in data records.

Acknowledgments. Grateful acknowledgment is made of the cooperation of R. C. Nichols, Marine Supervisor, U. S. Weather Bureau, San Francisco, and CDR Donald C. Kirk, USN, Commodore, Radar Picket Suqadron ONE, which made possible the establishment of the observational program, and of the assistance of the Marine Observers, U. S. Weather Bureau, San Francisco and the Navy aerological personnel, who took the observations aboard the MSTS ships and the Navy radar picket ships, respectively. The supply of equipment to the ships and the liaison with the personnel regarding the methods of observation was done by David K. Justice. I wish to express my thanks to L. E. Eber and O. E. Sette for many helpful suggestions.

Author's Note. When originally preparing this manuscript I had overlooked an excellent early paper by C. F. Brooks [Observing Water Temperatures at Sea. *Mon. Wea. Rev.*, 54, June 1926, pp. 241–253]. His apparent objective of demonstrating the superiority of condenser intake temperatures to those observed using a canvas bucket and his statement in the synopsis, "A record from the condenser intake pipe appears truly representative of the surface temperatures under virtually all conditions," if taken out of context, tend to obscure the other valuable information he presents regarding sources of errors in condenser intake observations and in reported temperatures. For example, he mentions "lack of simultaneity" and presents data showing indirectly the increase in range of errors because of this, but dismisses the effect as "of little consequence in comparing averages." The article ends with a section, "The Case for Condenser Intake Thermographs." I can heartily recommend Brooks' paper, including the summary of the discussion of the oral presentation (American Meteorological Society, January 1925), and a written comment by F. G. Tingley, which follows, as informative and of historical interest.

REFERENCES

Bureau of Commercial Fisheries Biological Laboratory, San Diego, 1960–; Sea-surface temperature charts, Eastern North Pacific Ocean. Published monthly in *California Fishery Market News Monthly Summary, Part II—Fishing Information*, San Diego.

Bureau of Commercial Fisheries Biological Laboratory, Stanford, 1962: *Monthly Mean Charts, Sea Surface Temperature, North Pacific Ocean.* U. S. Bur. Comm. Fisher., Circular 134, Washington, 36 pp.

Chief of Naval Operations, 1955: *Marine climatic atlas of the world, Volume I, North Atlantic Ocean.* U. S. Navy, NAVAER 50–1C–528, Washington, D. C., 275 pp.

——, 1956: *Marine climatic atlas of the world, Volume II, North Pacific Ocean*, U. S. Navy, NAVAER 50–1C–529, Washington, D. C., 275 pp.

Franceschini, Guy A., 1955: Reliability of commercial vessel reports of sea surface temperatures in the Gulf of Mexico. *Bull. marine Sci. of the Gulf and Caribbean*, 5(1), 42–51.

Hydrographic Office, 1944: *World atlas of sea surface temperatures.* U. S. Navy, H. O. Pub. No. 225, Washington, D. C., 48 pp.

——, 1959–: Mean sea surface temperature chart. Published for each month and for each mid-month 10-day period. U. S. Navy H. O., Washington, D. C.

Namias, Jerome, 1959: Recent seasonal interactions between North Pacific waters and the overlying atmospheric circulation. *J. geophys. Res.*, 64, 631–646.

World Meteorological Organization, 1957: Measurement of sea-surface water temperature. Recommendation 17 in *Commission for Instruments and Methods of Observation, Abridged Final Report of the Second Session, Paris, 18th June–6th July 1957*, W. M. O. 64, RP. 26, Geneva, 48–49.

U. S. Weather Bureau, 1938: *Atlas of climatic charts of the oceans.* W. B. No. 1247, Washington, D. C., 65 pp.