On the question of mesoscale patterns in the sea surface temperature field in the tropical Atlantic

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(Manuscript received November 24, 1965)

ABSTRACT

The space variability of sea surface temperature, as indicated by observations from individual merchant ships and research vessels, is considered in investigating the question of the existence of mesoscale patterns in the sea surface temperature field in the tropical Atlantic. This approach offers strong evidence that mesoscale patterns are considerably weaker than those indicated in an article previously published in this journal.

Introduction

In a paper published in *Tellus*, PERLROTH (1962) presented analyses of the sea surface temperature field for portions of the tropical Atlantic as illustrated by Figure 1, which indicate temperature differences of several Fahrenheit degrees over distances of the order of 10 miles. Since these analyses were prepared from ship data composited for a 27-day period, the mesoscale patterns were viewed as persistent and relatively stationary features. The existence of such patterns would imply that relatively large variability should be indicated by the temperature records from individual ships. Since variations of this type were not in accord with our experience, or with recent observations made in other oceanic regions (WOLFF, 1963), it was decided to investigate the question of the space variability of the water temperature in the tropical Atlantic by use of data from individual ships.

Temperature variability indicated by synoptic ship observations

The first part of the investigation centered on the area and the time period considered by PERLROTH (1962). A portion of the available ship data has been used in evaluating the actual water temperature variability and this is compared with the hypothetical variability which would be expected for a ship traversing a field of the type shown in figure 1.

Ship tracks in the area considered by PERLROTH (1962) were predominantly northnorthwest–southsoutheast during the period over which he composited the sea surface temperature data (August 20 to September 15, 1961). These tracks tended to cluster in relatively narrow lanes since most ships were traveling to and from Puerto Rico, or the Mona Passage to the west of Puerto Rico, and ports on the upper East Coast of the United States. The space variability implied by Perlroth's analyses is illustrated by the dashed profiles shown in Figures 2 and 3 which were constructed between arbitrary points located within the main shipping lane. Two sets of beginning and ending points have been used for the profiles since there was some change in the primary zone of concentration of tracks between the last part of August and the early part of September. The temperature analyses, of course, spanned these periods.

The dashed profiles of figures 2 and 3 can be viewed as approximations to continuous recordings which might have been provided from a ship traversing the area under the assumption that conditions were constant over the compositing period and accurately depicted by the analysis. Superimposed on each of temperature profiles are observations from three ships which passed close to the terminal points (32.0 N, 71.0 W; 22.6 N, 68.0 W in late August

[1] The research which led to the preparation of this note was supported by the National Science Foundation under Grant GP-621.

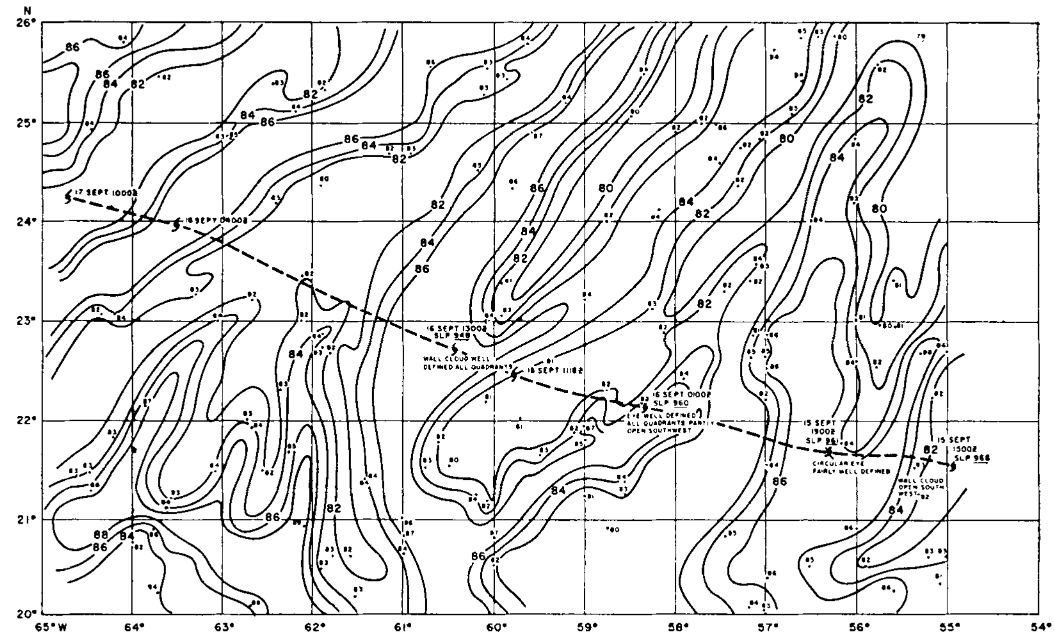

FIG. 1. An analysis of the sea surface temperature field prepared from data composited over the period 20 August–15 September 1961 (from PERLROTH, 1962).

and 31.0 N, 71.0 W; 22.7 N, 68.1 W in early September). Since the ships did not move exactly on the line between these two sets of points, no attempt was made to position the data points with great accuracy. Instead, the six-hourly reports have been equally spaced between the terminal points, which have been projected on a straight line between the stated coordinates.

The observations from the individual ships plotted on figures 2 and 3 are incapable of showing the type of detail interpolated from the analyses since the temperatures were reported at six-hourly intervals and were read to the nearest Fahrenheit degree. These curves are, however, very suggestive that the true variability is appreciably less than that implied by the analysis.

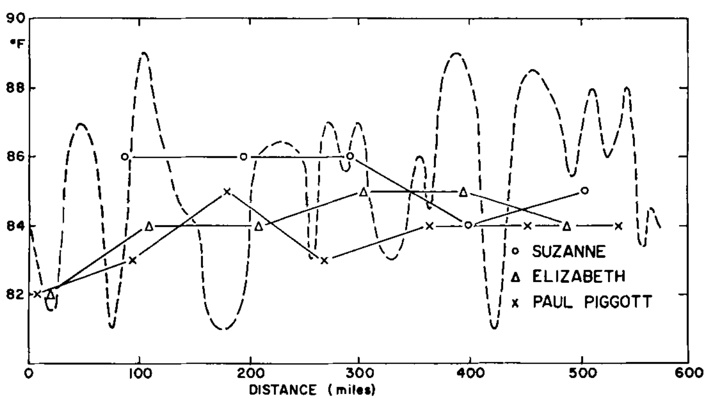

FIG. 2. Profile of the sea surface temperature between 32.0 N, 71.0 W and 22.6 N, 68.0 W (dashed curve) as determined from the temperature analyses prepared by PERLROTH (1962). The solid curves show sequences of observations from individual ships which passed near the stated coordinates during late August 1961.

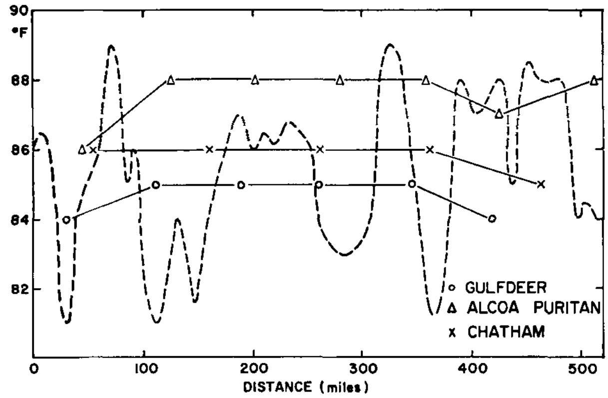

FIG. 3. Temperature profile of the sea surface temperature between 31.0 N, 71.0 W and 22.7 N, 68.1 W as determined from the temperature analyses of PERLROTH (1962). The solid curves show sequences of observations from individual ships which passed near the stated coordinates in early September 1961.

For a statistical examination of the variability indicated by the individual ships and that suggested by the temperature analyses, six-hourly temperature changes were obtained from the logs of 12 ships which traversed the area in late August and from an equal number of ships in early September. The beginning and ending points of each of the 24 ship tracks were superimposed on the charts presented by Perlroth and values were read at equally spaced points corresponding to the average six-hour movement of the ship over the period of the track used. Frequency distributions of the six-hour temperature change as determined from the ship logs and from values interpolated from the analyses are shown in figure 4. The distributions obtained from the observed data (upper set of graphs) are very similar for the two periods with much smaller ranges and a lower frequency of large values than shown in the distributions obtained from the interpolated data (lower set of graphs). The mean variability computed from the six-hourly changes in the inferred data was 2.0F in each period while the observed data gave 0.5 and 0.6F in the two periods.

Temperature variability indicated by research vessels

The variability determinations discussed above are based on observations made at rather long time intervals (six hours) and utilized routine observations which are of questionable accuracy[1] (ROLL, 1965). By considering other time periods and other geographical areas, some sea surface temperature data from research vessels can be presented for comparison. Greater accuracy would be expected in such data and the variability can be considered over shorter time periods.

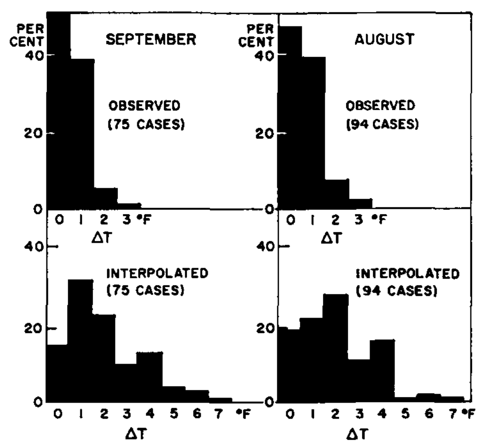

FIG. 4. Frequency distribution of six-hourly changes in sea surface temperature obtained from the observations of 12 ships in late August and 12 ships in early September (upper set of graphs). The lower graphs show the distribution of hypothetical six-hourly changes in sea surface temperature along the ship tracks as determined from values interpolated from the temperature analyses of PERLROTH (1962).

[1] It should be noted, however, that the same type of data were used in the preparation of the analysis given in Figure 1.

TABLE 1. *Observed sea surface temperature range determined over one-hour intervals from records of the RV Crawford.*

The N–S track was from 24 N, 62 W to Barbados during the period August 7–9, 1963. The E–W track was from Barbados to 13 N, 55 W and return during the periods August 11–12 and September 3–4, 1963.

	N–S Track	E–W Track
0.1 F or less	15	18
0.2 F	22	16
0.3 F	7	5
0.4 F	5	4
0.5 F and greater	2	3
Total number of intervals	51	46

The variability of the sea surface temperature in the Eastern Pacific in the latitude belt between 20 and 35 N, as determined by data taken on several cruises of a specially equipped vessel, has been investigated by WOLFF (1963). Observations were available at 24-second intervals but the data presented are primarily in the form of the maximum temperature change observed during each five nautical mile segment of the track. Wolff found the temperature change over this interval to be less than 0.4 F in about 75 per cent of the cases and exceeding 1.2 F in only three of 692 five-mile segments. In contrast, gradients exceeding 1.0 F per five miles are shown in many areas on figure 1.

A measure of the three-hour variability of water temperature during a traverse of the general area considered in the previous section has been determined from data taken in August 1963 by the University of Miami research vessel *Pillsbury* (National Oceanographic Data Center, 1965). The ship was moving eastward at latitudes of 25–27 N at a speed of 6–9 knots and data have been used for the portion of track between 75 and 55 W longitude. The mean three-hourly variability over 32 periods was approximately 0.4 F with no three-hourly change exceeding 0.9 F. These values are, therefore, quite consistent with those shown for the observed data in figure 4 and much less than the interpolated values presented in the same figure.

Data were taken by the research vessel *Crawford*, of the Woods Hole Oceanographic Institution, in early August 1963 during a north-south pass through the area shown in figure 1. A continuous recording of sea temperature was provided by a system which used a thermistor mounted about 3 ft below the surface in the bow of the vessel. Data on the maximum temperature range observed during each hour were determined for the portion of the ship track between 24 N and Barbados (Table 1).[1] Similar data are also shown for a ship track from Barbados to a point near 13.0 N, 55.0 W and return. The ship speed was 10–12 knots so that the track segments were about twice as long as considered by Wolff in the study previously cited. The hourly variability values indicated by Table 1 are considerably smaller than found by Wolff but, of course, much of his data came from somewhat higher latitudes. The mean variability over the north–south track was 0.27 F for 51 hourly periods and 0.21 F for the east–west track during 46 hourly periods. The fact that nearly half of the data for the north–south track were taken south of the area covered by figure 1 does not account for the low variability in comparison with what might be inferred from the temperature analyses. In fact, the 23 available hourly ranges north of 20 N latitude gave a mean hourly variability of 0.22 F compared to 0.27 for the complete north–south track as shown in Table 1.

While the *Crawford* was "on station" (within a few miles of 13 N, 55 W) the interdiurnal variability was less than the hourly variability observed on the east–west track. The 24-hour mean temperature change computed from observations made at the four standard synoptic times was 0.17 F over the 20-day period August 14 through September 3, 1963. The maximum observed change over a 24-hour period was 0.9 F and less than 10 per cent of the computed values were in excess of 0.5 F.

Summary and conclusions

The data presented in the previous sections on the observed space variability of the sea surface temperature in the tropical Atlantic suggest very strongly that mesoscale patterns of the type presented in Figure 1 are largely fictitious. There is no doubt that strong meso-

[1] These data, which were taken from the original records, were made available by Dr. Michael Garstang of Florida State University.

scale thermal patterns exist near the borders of major ocean currents, as shown for the Gulf Stream by FUGLISTER & WORTHINGTON (1951) and for the Equatorial Current by CROMWELL & REID (1956). VOORHIS & HERSEY (1964) described a number of "thermal fronts" in the southern Sargasso Sea, across which there were changes of more than one degree Celsius, but all of their cases were during the winter months and they stated that "little or no frontal activity has been observed during the summer months". There is, however, some evidence for weak, small-scale thermal patterns in the tropical oceans in the summer months. MALKUS (1957) found warm spots a few kilometers in breadth which were as much as 0.5 F warmer than their surroundings. The duration of such features was suggested to be of the order of a few hours.

The rather marked discrepancy between the variability statistics discussed above and the mesoscale patterns of figure 1 could be accounted for either by time changes in the temperature field over the 27-day compositing period or by systematic errors in the temperature observations. Significant time changes would not appear likely since PERLROTH (1962) mentions in his discussion that seven-day composites showed patterns similar to those for the 27-day period.[1] The latter alternative seems much more likely in view of the problems of accurately determining the sea surface temperature (ROLL, 1965). Most observations of the sea surface temperature are made in the intake system of the ship and bias can be introduced by the depth of the intake, by the lack of proper insulation of the thermometer from thermal effects of the ship and by improper calibration of the thermometer.

In an investigation of systematic errors in sea surface temperatures, SAUR (1963) found that mean values computed from observations of a single ship varied as much as 3 F from those reported by other ships moving along the same track. If differences of this order are fairly common, it is easy to visualize that a combination of observations from a number of ships, some with bias toward low values and others toward high values, could lead the analyst to draw very pronounced small-scale patterns of the type appearing in figure 1.

There is little doubt that there are systematic errors in the observations of sea surface temperature (cf. ROLL, 1965; SAUR, 1963) and there is little question that errors of this type complicate the analysis of the thermal fields using either synoptic or composite data. It would therefore seem that in the preparation of analyses it would be preferable to use means or medians determined over some appropriate area rather than individual reports. An averaging procedure would seem especially appropriate for relatively long compositing periods (longer than a week or so) since other effects arising from time changes in the temperature field are undoubtedly present in many cases.

[1] It is not the purpose of this note to take up the question of short period fluctuations in the structure and intensity of tropical cyclones which PERLROTH (1962) attempted to associate with thermal features of the type shown in figure 1. It is of interest, however, that recent studies (LEIPPER, 1965; JORDAN, 1965) suggest that intense tropical cyclones have a marked modifying influence on the sea surface temperature field.

Acknowledgement

The writer wishes to express his appreciation to Dr. Michael Garstang for helpful suggestions and for providing data taken by the research vessel *Crawford*, and to Silvio F. Lombardi and Victor Wiggert for their assistance in processing the data used in this paper.

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К ВОПРОСУ О МЕЗОМАСШТАБНОЙ СТРУКТУРЕ ТЕМПЕРАТУРНОГО ПОЛЯ ПОВЕРХНОСТИ МОРЯ В ТРОПИЧЕСКОЙ АТЛАНТИКЕ

Рассматриваются пространственные изменения температуры поверхности моря, измеренной отдельными торговыми и исследовательскими судами. Исследуется вопрос о существовании устойчивых мезомасштабных температурного поля поверхностного слоя воды в тропической Атлантике. Наше исследование дает веские основания считать, что эти мезомасштабные структуры выражены значительно слабее, чем это было указано в статье, ранее опубликованной в данном журнале.