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# MAXIMUM AND MINIMUM MONTHLY MEAN SEA SURFACE TEMPERATURES CHARTED FROM THE "WORLD ATLAS OF SEA SURFACE TEMPERATURES"<sup>1</sup>

BY

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## INTRODUCTION

Maximum and minimum water temperatures are of interest in oceanography in many connections. Among their more important uses, they afford the most valuable simple index of temperature conditions for analyses of the distributions of marine organisms.

The "World Atlas of Sea Surface Temperatures," issued by the Hydrographic Office (1944) of the United States Navy Department, incorporates a large share of the previously published temperature data, together with records in the Hydrographic Office files totalling in the millions. Since the Atlas is therefore the most comprehensive treatment of surface temperatures available, and is likely to be a standard reference for some time, preparation of maximum and minimum charts conforming to its data seemed desirable. Such charts are given here in Plates I and II. The method of preparing them is described below, followed by some comments on the degree of reliability which should be accorded them and the Atlas.

## METHOD OF PREPARATION

The Atlas plots the isotherms of monthly mean temperatures of even 5° F. intervals, giving monthly charts for the Atlantic, eastern Pacific, western Pacific and Indian Ocean sectors of the globe. Isotherms for intermediate 2½° F. values are also given for some months in some regions, but these have not been used here.

From the monthly Atlas sheets for an ocean, a separate map was traced for each 5° temperature value, superimposing the courses of all its isotherms during the twelve months. Figure 69 illustrates the procedure with the isotherms of 75° F. in the South Atlantic. The whole area occupied at any time during the year by a particular monthly mean temperature was thereby determined. The distribu-

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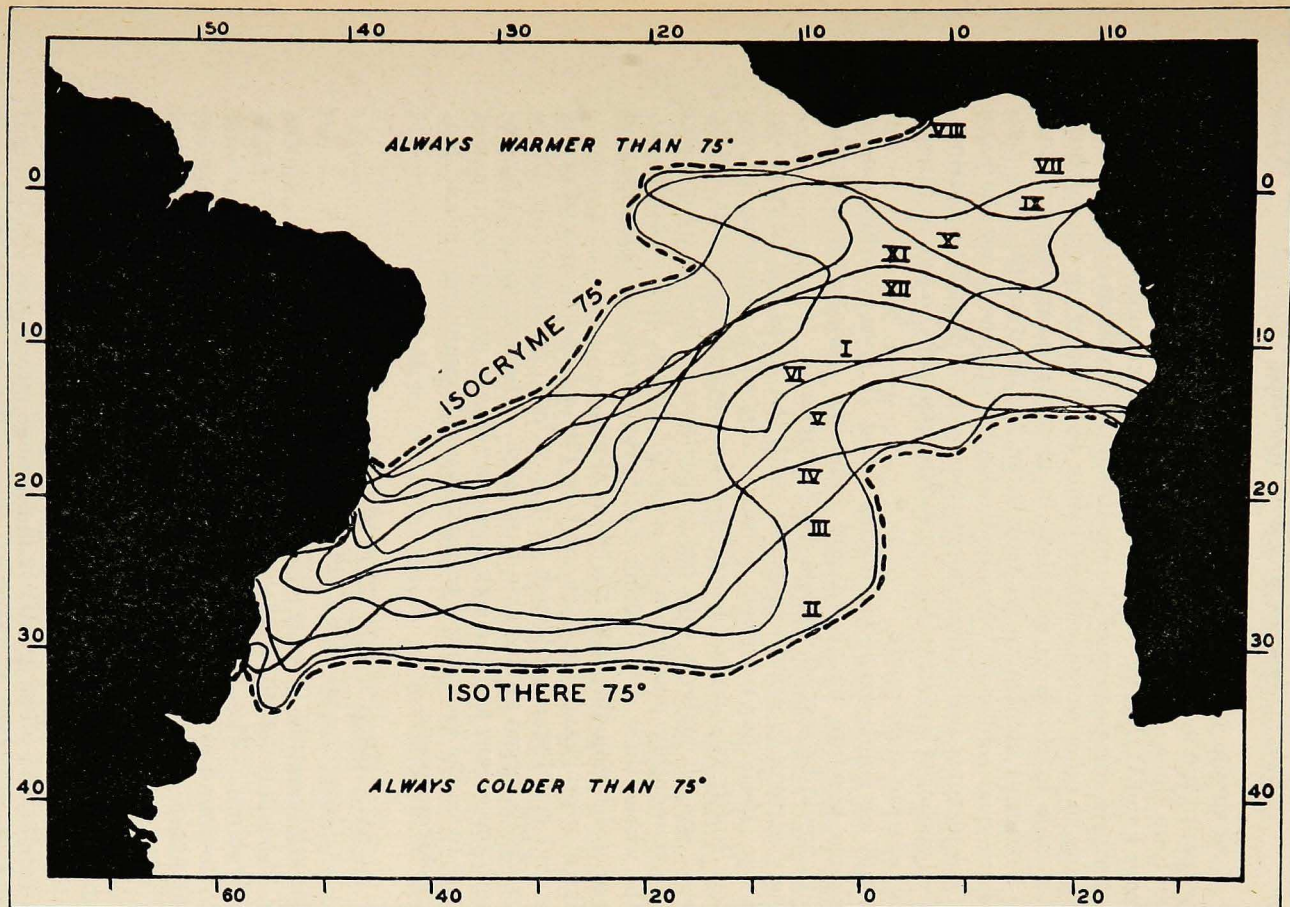


Figure 69. Illustration of the method of determining the courses of isotherms and isocrymes given in Plates I and II. The isotherms of 75° F. for each of the twelve months in the South Atlantic are superimposed on one chart. An area is thereby determined in which the surface water is sometimes more and sometimes less than 75°. The equatorward boundary of the area provides the isocryme, the isotherm of 75° at the time of greatest cooling, irrespective of the month in which this occurs. The poleward boundary of the area provides the isotherme, or isotherm of maximum warming, in the same way.

tion of maximum monthly mean temperatures was determined from the poleward limits of all such areas and the distribution of minimum means from the equatorward limits.

Plates I and II thus give the maximum and minimum monthly mean temperatures irrespective of the months in which these occur. Their isotherms, in other words, connect points which warm up or cool down to the same extremes as measured in monthly mean temperatures. Such isotherms are known as ISOTHERES (equal warmth), and ISOCRYMES (equal coldness). Nominal calendar months being the basis of all calculations, rather than the warmest and coldest 30-day periods, the designations CALENDAR MONTH ISOTHERES and CALENDAR MONTH ISOCRYMES are appropriate.

It may be emphasized that Plates I and II give monthly means. Of course absolute maximum and minimum temperatures at any locality would be several degrees more extreme.

One exception to exact conformity with the Atlas has been made. Fuglister (1947) has reviewed more recently all of the data for the western North Atlantic and has prepared revised charts of that region. Plates I and II conform with his delineations of the maximum and minimum monthly means for the area (Fuglister, 1947: pl. 13, 14). On the whole, these do not differ significantly from the isotheres and isocrymes determinable from the Atlas alone.

Mercator projection has been used for Plates I and II instead of the sinusoidal equal-area projection of the Atlas. Hydrographic Office Chart 1262B served as the main base map. The arrangement whereby both the oceans and the continents are shown as unbroken masses appears to be the best suited to most general oceanographic and biogeographic purposes.

#### ACCURACY OF THE WORLD ATLAS AND OF PLATES I AND II

The Atlas, and the present charts of isotheres and isocrymes, appear to be reasonably reliable in the general patterns of temperature distribution shown. The highest sustained temperatures for the year round are found in the Indo-West Pacific Tropics, and in small sectors of the eastern Pacific and the western Atlantic Tropics, all of which have monthly means always in excess of 80° F. and mostly between 80° and 85°. The maximum temperatures, on the other hand, are found in the Persian Gulf, where monthly means exceeding 90° F. occur in summer, although winter monthly means in part of this area fall to about 60°. The greatest annual range, more than 40°, is found in the inner end of the Yellow Sea, where maximum means in excess of 75° and minimum means of less than 35° occur in the Gulf of Pohai.

Major upwellings and other large features of circulation in the surface waters are indicated by pockets, inflections and deviations of the individual isotherms. Not all irregularities of the isotherms are to be regarded as equally significant in this way, however, some resulting from peculiarities in the data or from procedural techniques such as charting the isotherms and isocrymes with as little smoothing as possible. It can be doubted, for instance, that the three warm spots enclosed by the isocrymes of  $80^{\circ}$  on the west coast of Central America are in reality as complex as the chart indicates.

Commentaries on the over-all accuracy of the Atlas are given by its compilers, and, indirectly, by Fuglister (1947). The former state that the delineation of isotherms for intervals smaller than  $5^{\circ}$  F. generally would give a false impression of the adequacy of the source data. Fuglister discusses the distortions introduced by the method used in compiling and reducing data, in which random numbers of observations for various years are averaged by months for one-degree quadrangles of latitude and longitude. Steep gradients tend to be spread horizontally in this technique, partly by use of the quadrangle as the smallest measure of area, partly because the positions of gradients may vary somewhat from time to time, and partly because of inaccurate fixes of observations.

Comparison of the charts with detailed local data for a number of points in Europe, America, and Africa shows that the Atlas information is only approximately correct for the most inshore waters. This, of course, is unavoidable, partly for the foregoing reasons and partly because local detail can not be charted on a world map of convenient scale. Caution is required, therefore, in using the present charts in biological investigations involving shore collections, or in similar applications.

Inadequacies of the source data of the Atlas, chiefly in higher latitudes, probably account for certain other limitations which should be noted. Interpolated isotherms are given in some cases and contribute portions of the isotherms and isocrymes of the mean ice limit,  $35^{\circ}$ , and  $40^{\circ}$  in Antarctic waters. Elsewhere, occasionally no isotherms are provided. For such reasons it has been impossible to chart the  $55^{\circ}$  isotherm in the Sea of Okhotsk, the  $35^{\circ}$  isotherm north of Bering Strait, and the blank portions of the mean ice limits. The delineations in the Arctic, particularly those for summer regarding the Siberian and Canadian coasts from the Kara Sea to Baffin Bay inclusive, must be taken with considerable reservations. The U. S. Hydrographic Office (1946) "Ice Atlas of the Northern Hemisphere" does not indicate that a majority of these coastlines are ice bound in the warmest months, as the World Atlas suggests, but does plot a large, persistent free ice

field in western Baffin Bay which can not be reconciled with the course of the 35° and 40° isotherms there. These and other discrepancies are partly offset by the fact that there are great year-to-year variations around the average conditions in the Arctic, notably for ice distribution, and delineations of mean positions of isotherms there are at best of only provisional interest.

In preparing Plates I and II it has been found that a few isotherms in the Atlas do not join perfectly from one sector of the oceans to the next. The differences are seldom more than 2° of latitude, however, and are of no great consequence. Smoothed transitions across the overlaps have been used where necessary for the isotherms and isocrymes.

The collection of more extensive data will doubtless warrant eventual revision of at least portions of the thermal picture in Plates I and II. If judiciously used, nevertheless, the present charts are serviceable for most purposes to which they can be put. Over a year of testing, they have proved highly satisfactory for the analysis of biological distributions as carried out in this laboratory (Hutchins, 1947).

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