A PRELIMINARY STUDY OF A RELATION BETWEEN SURFACE TEMPERATURE OF THE NORTH INDIAN OCEAN AND PRECIPITATION OVER INDIA

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ABSTRACT

This paper describes the procedure and results of a surface isotherm analysis of the North Indian Ocean for June 1920, a dry monsoon year, and June 1933, a wet monsoon year. It was found that June sea-surface temperatures were higher during the year of excessive rainfall as compared to a year of deficient rainfall. This positive parallelism is evidence which supports the hypothesis that the amount of rainfall over India during the southwest monsoon depends upon the variation of the surface temperature of the North Indian Ocean.
1. INTRODUCTION

The oceans and atmosphere interact in such complicated ways that it is impossible to separate cause and effect. The complex relationships between the oceans and the weather are difficult to examine due to the lack of accurate observations from many regions of the world.

Sverdrup (1943) quoted studies by Helland-Hansen as evidence of the interaction between the oceans and the weather. It was shown that in the norwegian Sea the surface temperature and the water temperature showed considerable change from year to year. It was found that the inflow of water of different temperature affected the weather along the Norwegian coast and the ice free areas in the Barents Sea.

One feature of the interactions between the oceans and the weather might be shown by finding a possible relationship between the variation of sea-surface temperature and the fluctuation of rainfall. The available data and time made it necessary to restrict a study to the finding of
a possible relationship between the surface
temperature of the North Indian Ocean and the
amount of rainfall over India during the south-
west monsoon.

Air which has been in contact with the
surface of the North Indian Ocean is advected
over India by the steady winds of the southwest
monsoon. The moisture content of the monsoon air
depends upon the rate of evaporation from the
sea surface. Evaporation is known to be related
to the sea-surface temperature. Therefore, the
hypothesis that the amount of rainfall over
India is dependent upon the difference in sea-
surface temperature of the North Indian Ocean
from year to year is physically reasonable.

Sea-surface temperature data were taken
from ship observations, carefully selected from
British, Dutch, and German vessels by the Royal
Dutch Meteorological Service. The observations
cover the North Indian Ocean from longitude 50E
to longitude 100E, and from the equator north-
ward to coastal areas. The largest density of
observations was found in a strip three degrees of latitude wide from the Gulf of Aden to Sumatra. Several years of observations were available during the months of the southwest monsoon. The years of 1920 and 1933 were selected as years of opposite extremes of rainfall from data of Banerji and Randas (1945). These data showed that twelve of thirty provinces in India experienced drought in 1920, and seven of thirty provinces had flood conditions in 1933. June was chosen because it was the month in which the most sea-surface temperature data were available for 1920 and 1933.

2. PROCEDURE

The month was divided into periods of five consecutive days to be used as a check for continuity of the temperature fields throughout the month. From these five day mean temperature fields a monthly mean temperature field could be obtained.

For each five day period temperatures were plotted to the nearest tenth of a degree
centigrade at points of observation. Different colors and underlining were employed to aid in the detection of obvious errors. The local time of each observation was plotted as a superscript so that the diurnal change in temperature also could be examined for errors. A five day mean sea-surface temperature for each one degree of latitude by one degree of longitude square was computed and plotted in the center. Each five day period was analyzed to obtain isotherms for every one degree centigrade over the North Indian Ocean wherever data were sufficiently dense.

The study was then limited to the three degrees of latitude strip where the observations were most dense. An interpolated mean temperature value was obtained at each intersection of meridian and latitude circles for each five day temperature field. In areas where data were lacking extrapolated values were obtained from analyzed fields. The interpolated values were averaged to give a monthly mean at each one-
degree intersection. The monthly mean values were plotted and analyzed to yield monthly mean isotherms for June of each year. Fig. 1 shows the mean sea-surface isotherms for the month of June 1920, the drought year. Fig. 2 shows corresponding information for June 1933, the flood year. Finally, the change in mean sea-surface temperature was found at each intersection by subtracting the value for June 1920 from the value for June 1933. The sea-surface temperature differences were plotted and analyzed as shown in fig. 3.

3. RESULTS

From fig. 3 it is seen that approximately ninety percent of the area studied showed a positive difference. Therefore, the evidence supports the hypothesis that the amount of rainfall over India during the southwest monsoon depends upon the variation of the surface temperature of the North Indian Ocean.

Sverdrup (1943) stated that observations made by the Meteor indicated that the average
Fig. 3  Sea Surface Isotherm Difference $T_{90} - T_{20}$
diurnal variation of sea-surface temperature in the tropics was between 0.2\degree C and 0.3\degree C. This diurnal variation is smaller than most of the sea-surface temperature differences found in the present study. The average sea-surface temperature found for June 1920, the dry year, was 27.37\degree C, and for June 1933, the wet year, 27.75\degree C. Studies by Krummel (1911), showed that the average surface temperature in this region of the Indian Ocean is 27.55\degree C.

Other interesting features of the study are found by checking the five-day mean temperature fields for continuity. Upwelling in the western portion of the Indian Ocean was evident on all the five-day mean isotherm patterns for both years. The minimum sea-surface temperatures observed near the center of the upwelling are shown in table 1. There is a tendency for the minimum sea-surface temperature to decrease as the month progresses. The colder bottom water is an indication that the upwelling increases as the southwest monsoon winds become steadier
with time.

**TABLE 1**

MINIMUM SEA-SURFACE TEMPERATURE IN UPWELLING

<table>
<thead>
<tr>
<th>June</th>
<th>1933</th>
<th>1920</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - 5</td>
<td>25.8C</td>
<td>25.4C</td>
</tr>
<tr>
<td>6 - 10</td>
<td>24.7C</td>
<td>24.1C</td>
</tr>
<tr>
<td>11 - 15</td>
<td>25.2C</td>
<td>23.6C</td>
</tr>
<tr>
<td>16 - 20</td>
<td>22.8C</td>
<td>22.1C</td>
</tr>
<tr>
<td>21 - 25</td>
<td>21.0C</td>
<td>no observation</td>
</tr>
<tr>
<td>26 - 30</td>
<td>18.9C</td>
<td>18.7C</td>
</tr>
</tbody>
</table>

The isotherms over the other regions of the ocean are usually oriented in an east-west direction except in coastal waters and when small scattered isotherm cells interrupt a smooth pattern. These cells may be based on undetected erroneous observations or local eddies from ocean currents of the North Indian Ocean. The difference between sea-surface temperature observations of the two years seems to be greater in the latter part of the month. It was found that observations during June 1933 were more abundant than in June 1920.

The use of two months of data is not sufficient evidence upon which to base a correlation
between two variables in the ocean-atmosphere system. Data from other months, years, and areas should be studied to make the hypothesis more conclusive. There is, therefore, need for further study of the oceans as a thermal source of energy affecting the general circulation of the atmosphere and smaller weather systems.
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BIBLIOGRAPHY

