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SEA–SURFACE TEMPERATURE ANOMALIES AND HURRICANE PREDICTION

SERGIO SERRA C.*and
ENRIQUE BUENDIA C.*

RESUMEN

Es sabido que la temperatura de la superficie del mar (T_S) es un parámetro importante que afecta la formación y el movimiento de los huracanes. El efecto de la temperatura de la superficie del mar puede ser expresado en términos de anomalías. Este estudio intenta determinar el potencial de las anomalías pronosticadas de T_S en la predicción a largo plazo de ciclones tropicales. Las anomalías pronosticadas se obtuvieron usando un modelo desarrollado por el Dr. Adem. Los resultados preliminares de este estudio indican cierta eficiencia en los pronósticos.

ABSTRACT

It is known that the sea-surface temperature (T_S) is an important parameter which affects hurricane formation and movement. The effect of sea-surface temperature may be expressed in terms of temperature anomalies. This study is an attempt to determine the potential of predicted T_S anomalies in makin long-range tropical cyclone prediction. The predicted anomalies were obtained from a model developed by Julian Adem. The results of this preliminary study indicate that the forecasts have some skill.

* *Instituto de Geofísica, UNAM.*

INTRODUCTION

Although important progress has been achieved in recent years, hurricane forecasting is not a completely solved subject at the present time. In order to develop, hurricanes need some conditions which are well-known in tropical meteorology. Some of these conditions have been treated from a climatological point of view in the excellent work by Gray (1968) and in an extended report by Gray (1975). By studying the above mentioned papers, one realizes that almost all the conditions build the adequate environment for the release of energy. Only one of the conditions accounts, indeed, for the generation of the large energy amounts required to plant the hurricane generation process. This condition is the existence of a large warm oceanic area with surface temperatures higher than 80°F down to a depth of 60 meters for several days. Such a crucial condition and a modest attempt to supplement Gray's work motivated as to undertake the present study.

Our study is based on predictions of sea-surface temperature (T_S) anomalies. A thermodynamical model developed by Adem (1962, 1964) produces long-range forecasts for several parameters, among them temperature anomaly in the upper layer of the oceans. Therefore, we took advantage of this existing model and tried to apply it, mainly to hurricane generation and motion.

MONTHLY SEA-SURFACE TEMPERATURE ANOMALIES

Monthly sea-surface temperatures can be expressed in terms of anomalies with respect to monthly climatological ("normal") values. These anomalies are representative of oceanic regions which are much larger than the usual space-scale of hurricanes. In addition, hurricanes have a life cycle (time scale) which is generally much less than a month. Therefore, it seems that the forecast of the sea-surface temperature anomalies can give an idea of possible hurricane formation and movement. As it is possible to forecast reasonably well the monthly anomalies of sea-surface temperature by means of a thermodynamical model, we are suggesting the use of forecasted sea-surface temperature anomalies for this purpose.

PREDICTION OF SEA SURFACE TEMPERATURE

Sea surface temperature anomalies may be predicted with the aid of Adem's (1970, 1973) thermodynamical model. The model is based on the thermal energy conservation equations for the earth's surface and for the troposphere. The equation for the earth's surface (the ocean in this case) can be written as follows:

$$ST_o + AD_o + TU_o = E_s - G_3 - G_2 \tag{1}$$

Terms in Eq. (1) are: the storage of energy in the ocean (ST_o), the heat added to the sea-surface by short and long-wave radiation (E_s), the loss due to evaporation from the sea-surface (G_3), the horizontal transport of heat by the mean ocean currents (AD_o), the sensible heat given off to the atmosphere by vertical turbulent transport from the sea-surface (G_2), and the horizontal turbulent transport (TU_o).
The thermal energy conservation equation in the troposphere can be written as follows:

$$ST_t + AD_t + TU_t = E_t + G_5 + G_2 \tag{2}$$

Terms in Eq. (2) are: the storage of energy in the troposphere (ST_t), the heat added to the troposphere by short and long-wave radiations (E_t), the horizontal turbulent transport in the troposphere (TU_t), the heat gained from water vapor condensation in clouds (G_5) and the sensible heat (G_2). The prediction is based on ocean and atmospheric condition during the previous monthly period as initial conditions.

HURRICANES AND SEA-SURFACE TEMPERATURE ANOMALIES

For this study, we used observed and forecasted sea-surface temperature anomalies for selected oceanic regions in the northern hemisphere and one-month periods. Dr. Julian Adem kindly made the used observed and forecasted anomalies available to the authors. The relation of these anomalies to tropical cyclone formation and track is illustrated by a few examples. These examples are for the northeast Pacific and the western Atlantic hurricane, areas which are chosen on account of their proximity and particular interest to Mexico.

Monthly sea-surface temperature observed anomalies and hurricane tracks are shown on the maps in Figures 1, 2, 3 and 4. The first case study is for the period July 16 – August 10, 1972 (a twentyseven day period) and is illustrated in Figure 1. The track of Hurricane Bonny in the northeast Pacific is shown; no hurricane formed in the western Atlantic. Sea-surface temperature negative anomalies were observed for some of the usual hurricane formation regions. The second case study is for September 1973 (Figure 2). In this case, hurricanes tend to move, in general, towards regions of sea-surface temperature positive anomalies. The third case study illustrates the rare Hurricane Brenda of August 1973 (Figure 3). After crossing over the northern part of the Yucatan Peninsula, Hurricane Brenda moved southward may be due to sea-surface temperature positive anomalies near the peninsula. The fourth case study is for July 1973 (Figure 4). Hurricane Alice developed in the Atlantic Ocean; it formed over a sea-surface temperature positive anomaly area and move towards an area showing even larger positive anomalies. Hurricanes Doreen and Emily formed in the northeast Pacific over sea-surface temperature positive anomaly areas. Doreen decayed after moving towards a less positive anomaly area; Emily decayed after encountering a negative anomaly area.

One of the main objectives of this work is to show the possible use of the forecasted anomalies, and we can say that mainly over the sea they agree with the observed data, in Figure 5 we can observe the forecasted anomalies for the month of September 1973 and it can be observed that the forecasted anomalies have very good correlation with the observed ones. In figure 6 it can be observed the anomalies forecasted for August 1973 and in both hurricanes is possible to explain the tendency to enter over land in the Mexican area, by the way it is important to mention that in general these particular forecasts are checked in particular for the Mexican territory and adjacent oceanic regions.

In Figure 7 which is the last illustration the forecast T'_s anomaly indicates a very strong positive anomaly and therefore in principle it is possible to forecast a very strong activity in that region, that is in the northeast pacific, in that month we had four hurricanes.

CONCLUSION

This study shows, on a preliminary basis, the potential of forecasted sea-surface temperature anomalies as an aid for the long-range prediction of tropical cyclones. An improvement of this forecasting method would require: (1) a better knowledge of the initial sea-surface temperature conditions to be used in the Adem's prediction model and (2) statistical correlations between hurricane parameters (e.g. number of hurricanes, hurricane tracks) and sea-surface temperature monthly patterns. Item (1) can possibly be achieved by using sea-surface temperatures derived from infrared measurements by satellites. Item (2) is a study which is currently being undertaken by the authors of this paper.

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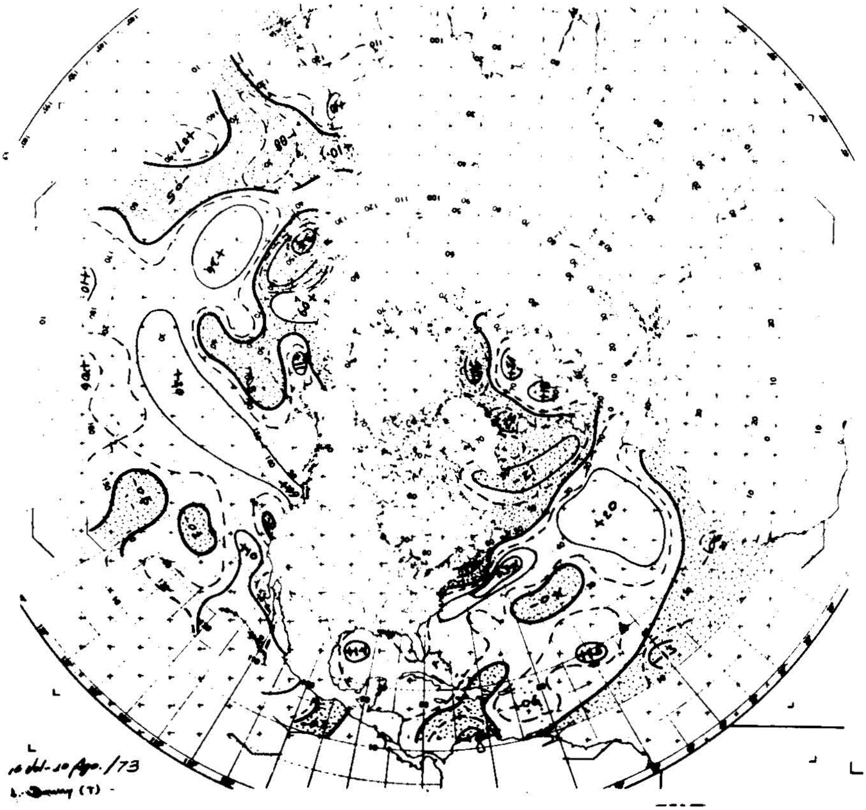

Fig. 1. $\overline{T}_S$ – anomaly observed for July 16 to August 10, 1972 and track of Hurricane Bonny.

Note: All the figures are done for the same projection, however from figure 5 an enlargement is done so to emphasize the Mexican Republic.

Fig. 2. $\bar{T}_S$ – anomaly observed for September 1973 and hurricane tracks for that month.

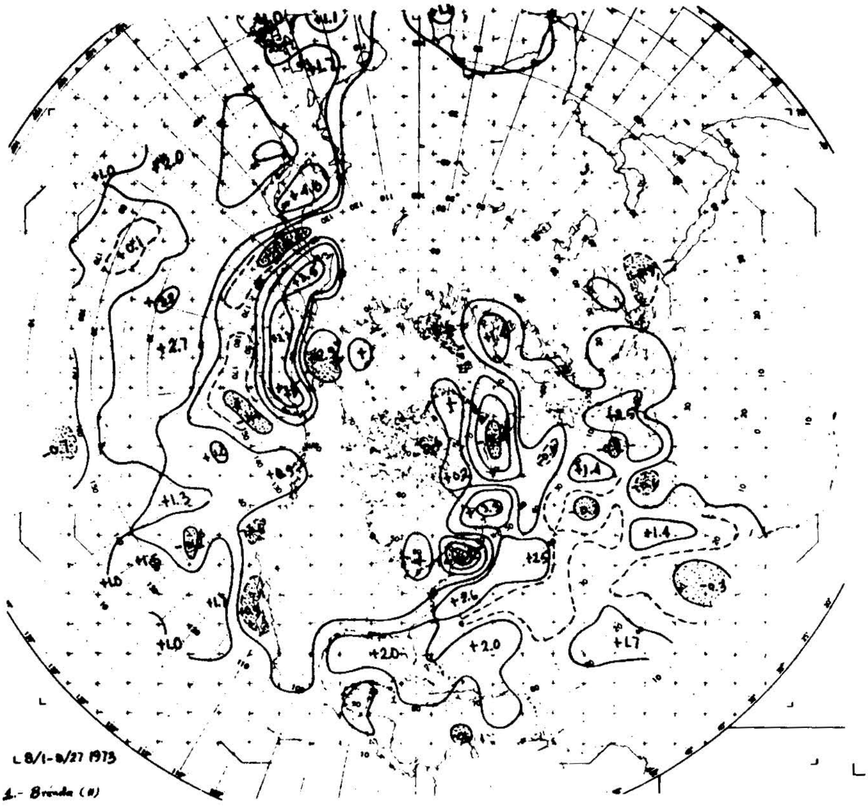

Fig. 3. $\overline{T}_S$ – anomaly observed for August 1973 and track of Hurricane Brenda.

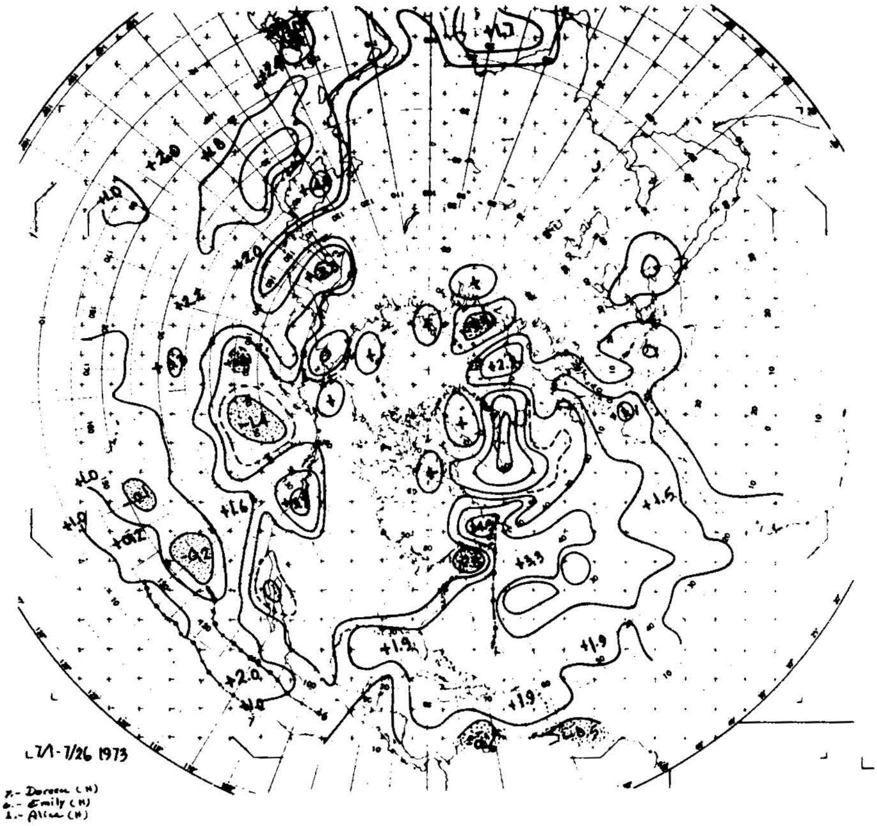

Fig. 4. $\overline{T}_S$ – anomaly observed for July 1973 and tracks of Hurricanes Alice, Doreen and Emily.

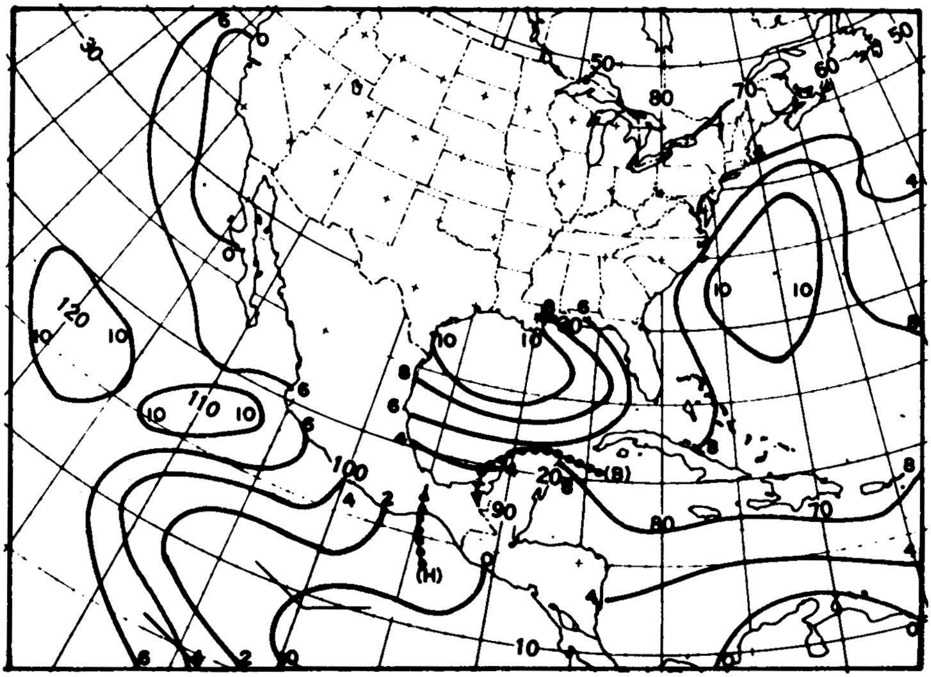

Fig. 5. $\overline{T}_S$ – anomaly forecast for August 1973 and tracks of Hurricanes Brenda and Heather.

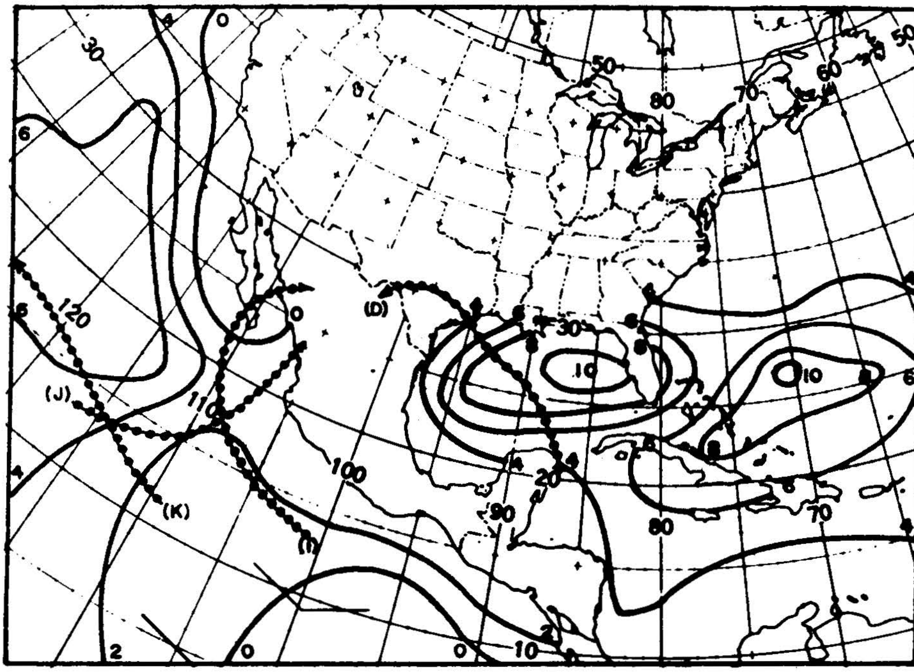

Fig. 6. $\overline{T}_S$ – anomaly forecast for September 1973 and tracks of Hurricanes Irah, Jennifer, Katherine and Delia.

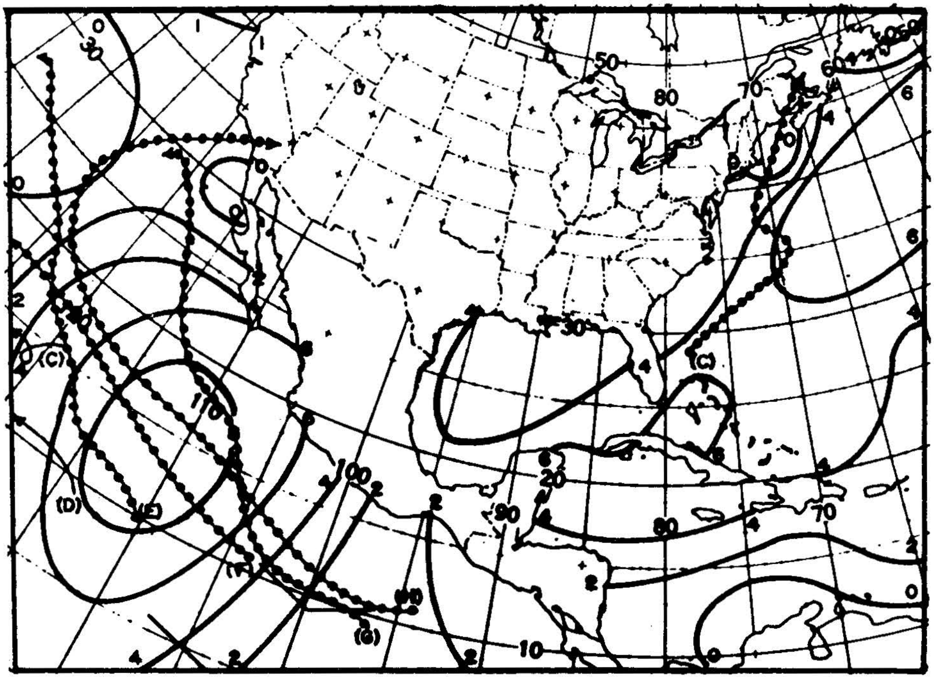

Fig. 7. $\overline{T}_S$ – anomaly forecast for August 1972 and tracks of Hurricanes Estelle, Fernanda, Gwan, Hyacinth and Celeste.

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