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PERIODIC VARIATIONS OF PRECIPITATION IN THE TROPICAL ATLANTIC OCEAN

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ABSTRACT

Statistical analysis of the satellite-borne Electrically Scanning Microwave Radiometer data in the tropical Atlantic region reveals that the rainfall near local noon is higher both in frequency of occurrence and intensity than the rainfall in the same area near local midnight. Another striking feature that stands out from the analysis is an oscillation with a period of 3.3 days in rainfall occurrence and intensity. This periodicity is consistent with easterly waves traveling from the African continent to the region under study.

Quantitative rainfall maps for the tropical Atlantic region bounded by 25°N to 10°S and 95°W to 15°E were derived from satellite-borne Electrically Scanning Microwave Radiometer (ESMR) data. The basis of production of the maps is the selective response to liquid water in the atmosphere of ESMR operating at 19.35 GHz carried on board the Nimbus 5 satellite. Because the emissivity of water, ϵ_W, in the vicinity of 19GHz is low (≈0.4) and inversely proportional to the thermodynamic temperature T_W, whereas the brightness temperature as observed by the satellite-borne radiometer is proportional to the product ϵ_W T_W, the oceans provide a convient background to the ESMR system, and this facilitated rainfall mapping over wide oceanic regions.

Calibration curves for interpreting ESMR brightness temperature in terms of rainfall rate were obtained from the model proposed by Wilheit, Chang, Rao, Rodgers, and Theon, which assumes a Marshall-Palmer distribution of raindrops, and permits the solution of the equation of radiative transfer considering both absorption and scattering. The theoretical curves were compared with (1) ground truth from radar and (2) the results of a specially designed ground-based experiment during which upward-viewing microwave brightness temperatures were compared over a period of several months with directly measured rain-rates. The agreement was good.

A number of problems presented themselves when an attempt was made to generate rainfall maps from satellite ESMR data. More than fifteen sources of error (including anomalous mode, saturation, over-sensitivity to freezing height level, inadequate sampling and field of view) became apparent. However, applying approximate corrections to these errors as far as possible, global oceanic maps were generated. These maps were compared with the best available climatological data. The results showed that notwithstanding the various short comings, it is possible to utilize ESMR data for studies on certain scales – studies involving large spatial and temporal averages.

With the objective of investigating the local characteristics in the GATE region a set of rainfall maps were generated for the rectangular area bounded by latitudes 25°N and 10°S and longitude 95°W and 15°E. The rain-rate data were averaged over 1 degree latitude by 1 degree longitude grid cells. Precipitation charts were produced separately for daytime and nighttime observations for each of the days of the GATE period viz. 15 June through 30 September 1974. Figure 1 reproduces the map of daytime precipitation for the first day and Figure 2 the night-time precipitation for the same day.

Statistical analysis of these rainfall observations for the entire GATE period was made with a view to gaining insight into the day-night variations and other small time scale fluctuations in oceanic rainfall. Figure 3 represents the frequency of rainfall occurrence in the entire area as a function of time, separately for day-time and night-time precipitation. Similar curves for the average rainfall intensity in the region are presented in Figure 4. The figures reveal that in the tropical Atlantic, rainfall near local noon is higher both in frequency and in intensity than that near local midnight. The overall ratio of the day to night frequency of occurrence for the entire region and for the entire period of GATE is 1.4:1.0. The overall ratio of day to night rainfall intensity is 1.7:1.0.

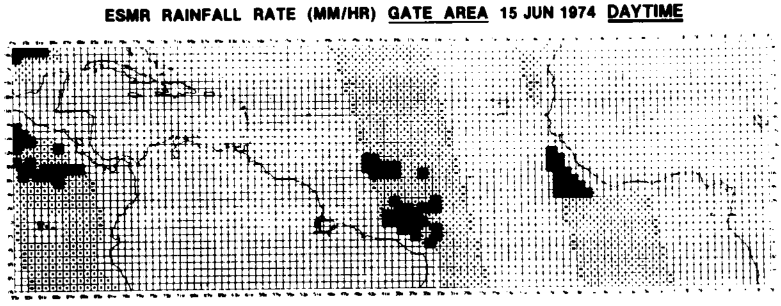

Fig. 1-Map of precipitation near local noon for the first day of GATE.

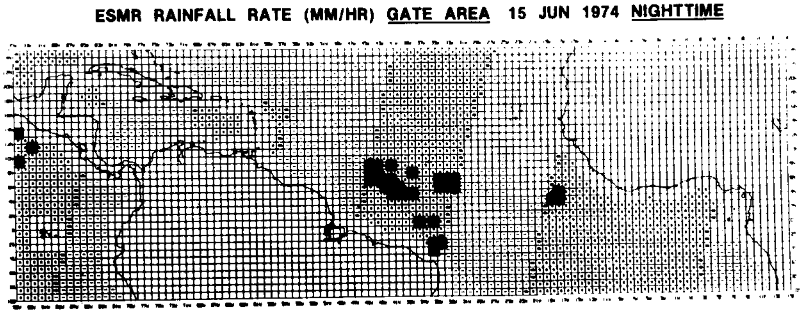

Fig. 2-Map of precipitation near local midnight for the first day of GATE.

RAIN FREQUENCY-GATE PERIOD (15 JUNE-30 SEP 74)

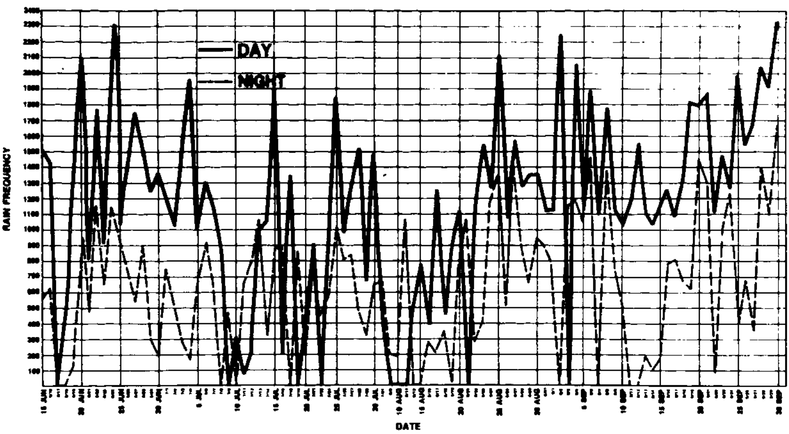

Fig. 3–Curves of frequency of rainfall occurrences vs. time (day and night).

RAIN INTENSITY-GATE PERIOD (15 JUN-30 SEP 74)

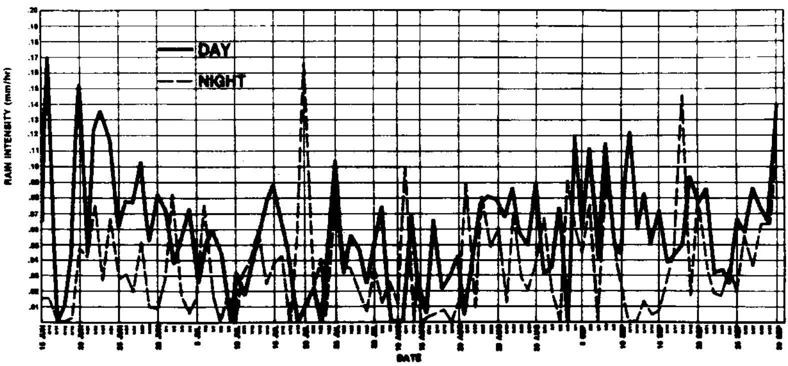

Fig. 4–Curves of average rainfall intensity vs. time (day and night).

Dynamical considerations do not favor such large variations being uniformly valid over all oceanic areas in general. For, precipitation is indicative of vertical motion, and ascending motion over large areas needs to be compensated by descending motion in other areas. It is therefore concluded that the observed diurnal variation is a location-dependent characteristic of the tropical Atlantic Ocean. It is possible that outside the tropical region the diurnal variation is opposite in phase.

The graphs in Figures 3 and 4 display an interesting small time-scale oscillation. Analysis of the curves reveals a fluctuation of periodicity 3.3 days in rainfall occurrence as well as intensity. It is well known that easterly waves over Africa have a similar periodicity. Thus, the time scale of the oscillation observed in our analysis is consistent with easterly waves traveling from the African continent over the tropical Atlantic belt under study.