An Observational Study of Convergence and Rainfall over South Florida[1]

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ABSTRACT

Relationships between convergence and rainfall at subsynoptic scales of motion are studied observationally. Data are based on special surface wind and rainfall observations in the South Florida peninsula during the period 11–13 July 1971. It is shown that larger scale convergence produces smaller scale convergence which, in turn, induces rainfall. The convective rainfall lags behind the large (peninsular) scale convergence by approximately 2 hr. In addition, the smaller scale divergence associated with rainfall produces larger scale divergence. The importance of the results in relation to parameterization and short-range forecasting of convective rainfall is discussed.

1. Introduction

This note concerns a study of convergence and rainfall over South Florida. The purpose of this study is to determine the relationships between convergence and rainfall at different scales of motion. Such relationships are important because they contribute knowledge to 1) the parameterization of cumulus convection in terms of the larger scale flow, and 2) the short-range forecasting of convection. Three scales of motion, all of which are subsynoptic, are considered: (i) the small or cumulus scale [order of 1 mi], (ii) the medium scale [order of 10 mi], and (iii) the large scale [order of 100 mi]. These three scales are shown schematically in Fig. 1.

The relationships between convergence and rainfall were analyzed for selected afternoon periods on 11, 12 and 13 July 1971. These three days were characterized by a deep easterly to southeasterly flow and by a small vertical wind shear at low and middle tropospheric levels over South Florida.

2. Data and analysis

Data for this study were taken from various sources, primarily from special surface wind and rainfall observations which were obtained during cloud seeding experiments by the NOAA Experimental Meteorology Laboratory. Special surface wind and rainfall information was in the form of continuous records from especially designed observational sites (about 20 anemometer tower sites and about 60 recording gauge sites). These sites were part of a mesoscale surface network which was located south of Lake Okeechobee in 1971 (Fernandez-Partagas, 1973). Other sources for this study were surface hourly observations from airport stations and meteorological radar observations over South Florida.

The above-mentioned observations were analyzed in order to determine the time evolution of convergence

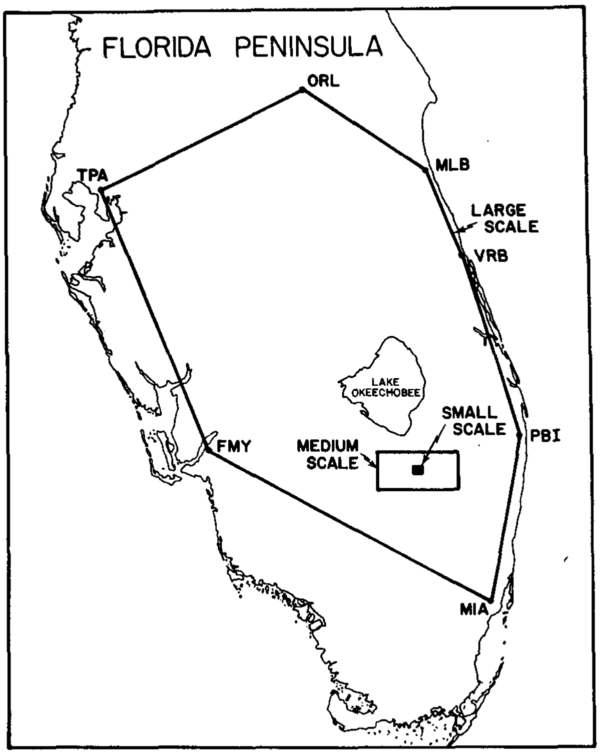

FIG. 1. Schematic diagram showing the observational area and the different scales used in this study.

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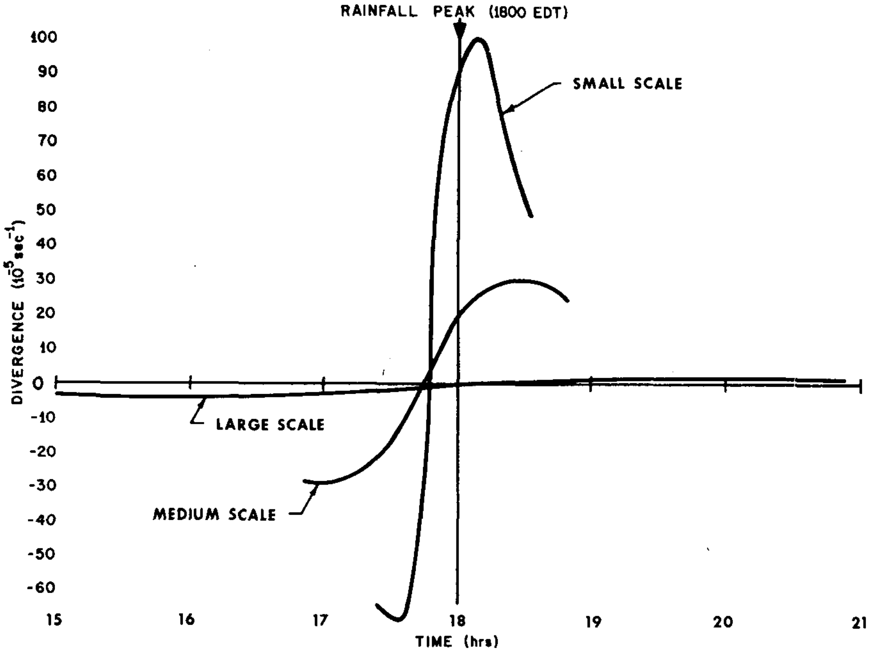

FIG. 2. Diagram showing convergence-rainfall relationships among the large, medium and small scales.

and rainfall for each of the three scales. In order to estimate the values of convergence and rainfall at the small and the medium scales, we established a rectangular grid covering the surface network area. The grid distance is 1.5 statute miles. The methods of analysis are described as follows:

a. *Small scale*

This scale (order of 1 mi) is designed to represent the cumulus scale which corresponds to the grid distance of 1.5 statute miles. By using a centered finite-differencing scheme, convergence at each grid point and at 15-min intervals was computed by the kinematic method from streamline-isotach analyses. Corresponding values of rainfall were obtained from isohyetal maps. The values of convergence and rainfall at each grid point were plotted against time. By examining the plots for all grid points (over 200 cases for the period 11–13 July 1971) a representative curve for convergence and another for rainfall were obtained.

b. *Medium scale*

The medium scale (order of 10 mi) corresponds to the total area (220 mi^2) covered by the surface network. The area encloses all the grid points which are used in the small-scale analyses. Average values of convergence and rainfall for this area were obtained at 15-min intervals by averaging corresponding values for all grid points. The average values were then plotted against time (three pairs of curves for 11–13 July 1971). After examination of the various plots, a representative curve for convergence and another for rainfall were obtained.

c. *Large scale*

The large scale (order of 100 mi) corresponds to the scale of approximately the southern half of the Florida peninsula. This area (13,400 mi^2) is enclosed by the polygon Tampa-Orlando-Melbourne-Vero Beach-West Palm Beach-Miami-Ft. Myers-Tampa. Hourly surface wind observations from airports were used for convergence computations. These computations were made by a line integration of the normal component of the wind along the perimeter of the polygon and then dividing the integral over the area enclosed by the polygon. Rainfall was assumed to be proportional to the percentage of the total area which was covered by radar echoes (Fernandez-Partagas and Estoque, 1972). Again, a representative curve for convergence and another for rainfall were obtained.

3. Results

The curves of convergence for the small, medium and large scales are combined to produce the summary graph in Fig. 2. The corresponding curves for rainfall are not reproduced; however, the time (1800 EDT) of the peak rainfall is indicated in the diagram. This time is approximately the same for all the scales because the large- and medium-scale rainfall is simply the summation of small-scale rainfall. The time of peak rainfall is indicated because it is a characteristic feature of rainfall which, in turn, is the effect of convergence at the various scales. This diagram, therefore, is convenient for studying the cause and effect relationships between convergence and rainfall.

Fig. 2 indicates that the smaller the scale of motion the larger the maximum divergence and convergence. For the small scale, these values are 1×10^{-3} and -7×10^{-4} sec^{-1}, respectively. The corresponding magnitudes of divergence and convergence for the medium scale are 3×10^{-4} sec^{-1}. For the large scale, divergence and convergence extrema are both several units of 10^{-5} sec^{-1}. Note that the convergence maximum is greater than the divergence maximum at the large scale. On the other hand, the peak divergence value is greater than the peak convergence value at the small scale. Finally, convergence and divergence extrema have an equal magnitude for the medium scale.

A more important feature of Fig. 2 is the systematic progression in the times of occurrence of the convergence peak. It may be seen that the convergence peak of the large scale occurs about 2 hr before peak rainfall. The medium-scale peak occurs about 1 hr before peak rainfall and the small-scale peak about $\frac{1}{2}$ hr before peak rainfall. Maximum divergence is observed to occur at the small scale a few minutes after peak rainfall. This divergence is followed by the maximum divergence at the medium scale (about 45 min after peak rainfall) and then by the maximum divergence at the large scale (about 2 hr after peak rainfall). These results indicate that larger scale convergence produces smaller scale convergence which, in turn, induces rainfall. On the other hand, the results indicate that the divergence which takes place after peak rainfall gradually progresses from the smaller into the larger scales of motion. This progression indicates that smaller scale divergence produces larger scale divergence.

4. Conclusions

The results of this study are important in relation to the problems of parameterization and short-range forecasting of convective rainfall. In connection with the parameterization problem, the results are significant in two ways. First, they provide observational support for the hypothesis that larger scale convergence induces convective-scale rainfall. Second, the results indicate an additional complication in formulating parameterization schemes. This complication is due to the lag between large-scale convergence and convective-scale rainfall and, hence, convective heating. This lag is not incorporated in current schemes. Although this lag is a complicating factor in parameterization, it is an advantage from the point of view of short-range forecasting. Due to this lag one can use large-scale convergence as a short-range predictor for convective activity.

Caution must be exercised in generalizing the results of this study. There are two important limitations. One of these is a problem of representativeness: Are the values of convergence and rainfall for the selected surface network representative of other areas within the large scale domain (southern Florida peninsula)? Another limitation is the fact that the results of this study are appropriate only to the particular synoptic conditions described in the second paragraph of Section 1. It is expected that different conditions could significantly modify these results.

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