GARP TOPICS

No. 31 March 1974

An occasional series reporting on U. S. and international GARP scientific, technical, and planning activities, developments, and programs, presented as a public service to the meteorological community by the American Meteorological Society through arrangements with the U. S. Committee on the Global Atmospheric Research Program of the National Academy of Sciences-National Research Council. Opinions expressed in GARP TOPICS do not necessarily reflect the point of view of the U. S. Committee.

Interannual Variations in Convective Activity over the GATE Area

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Abstract

Based on five years of satellite brightness data the year-to-year variations in convective activity are investigated over the GATE area.

The monthly-mean brightness data suggest that in the B-scale region, centered at 8.5N, 23.5W, the probability of intense convective activity during the summer of 1974 (the GATE period) is quite large. During the majority of the summer months investigated the intertropical convergence zone was found close to the latitude of the B-scale network.

The daily brightness records show that one may expect a high day-to-day variability with a predominant period of about 4 to 5 days. This may limit the range of extrapolative predictability of cloud clusters in the B-scale area to only a few days.

1. Introduction

In the planning of a large observational experiment such as the GARP Atlantic Tropical Experiment (GATE)[1] questions necessarily arise concerning the magnitude of year-to-year variations in the atmospheric circulation. One specific question important for GATE is how great the chances are that the atmospheric conditions will be highly abnormal during the summer of 1974. It would, for example, be unfortunate if during the summer little or no convective activity occurred in the regions of intensive study, such as the B-scale area.

Following a recent suggestion by Dr. J. Smagorinsky, member of the Joint Organizing Committee of the Global Atmospheric Research Programme (GARP), the present authors have undertaken a study aimed at answering some of the questions raised above. The observational basis for the study is a collection of five years of daily brightness data from several meteorological satellites for the years 1967 through 1971. In the present paper the natural variability in brightness is estimated over the entire GATE area, located between latitudes 10S and 20N, and longitudes 95W and 50E. However, the main emphasis will be on conditions in the vicinity of the B-scale network, centered at 8.5N, 23.5W. This network was designed primarily to study cloud clusters in the eastern Atlantic.

The brightness over oceanic regions is a good measure of cloudiness. However, there is some uncertainty

[1] The scientific objectives and observational programmes of GATE are discussed in a WMO report by Kuettner, Rider and Sitnikov (1972).

as to the relationship between brightness and convective activity. In individual cases this uncertainty can usually be resolved through the study of movie loops made from photographs of the particular clouds systems by geostationary Applications Technology Satellites (ATS). From this type of evidence it appears that in most cases over tropical oceans there exists a one-to-one correspondence between values of high brightness and the occurrence of strong convective activity. In future research of this kind simultaneous infrared measurements of cloud top temperatures should probably be used for a better interpretation of the brightness information. For further discussion of other related research the reader is referred to a recent paper by Martin and Scherer (1973) published in this same GARP Topics series.

During recent years the NESS author and his colleagues at the Meteorological Satellite Laboratory have made extensive compilations of daily brightness data averaged in 5° latitude by 5° longitude squares. These macroscale averages were derived from mesoscale archives based on video data from the operational polar orbiting meteorological satellites (see, e.g., Bristor *et al.*, 1966, and Booth and Taylor, 1969). Some of the necessary adjustments to the original brightness data from the Advanced Vidicon Camera Systems (AVCS) have

MEAN BRIGHTNESS 1967 - 1971

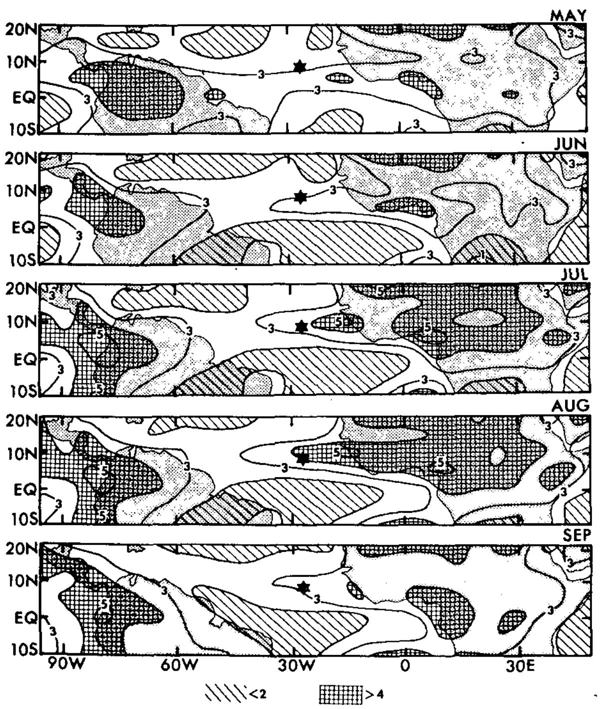

FIG. 1. Climatological monthly-mean brightness patterns over the GATE area (10S–20N, 95W–50E) for May, June, July, August, and September based on daily brightness data from the years 1967 through 1971. The star indicates the location of the center of the B-scale network. Brightness values may vary between 0 (total absorption of solar radiation in the 0.8-μm channel) and 10 (total reflection). Land areas are stippled.

MONTHLY-MEAN BRIGHTNESS

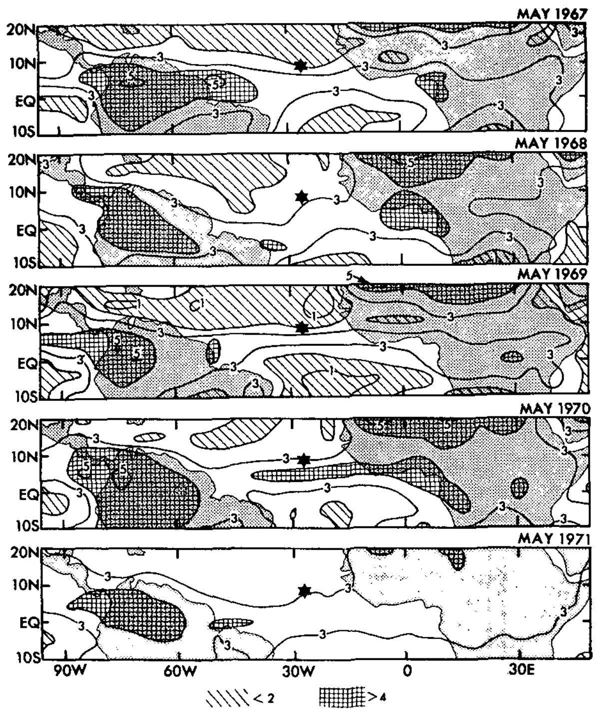

FIG. 2a. Mean brightness patterns over the GATE area for five May months (see also legend Fig. 1).

been discussed and actually applied to the data before February 1968 by Taylor and Winston (1968) and Winston (1971). The more recent data were adjusted using a similar method by the present NESS author. As a final processing step, all data [2] for the years 1967 through 1971 were reprocessed to provide normalized brightness values with a linear scale ranging from 0 to 10. This range represents a variation from total absorption (zero) to total reflection (ten) of solar radiation in the visible channel. The maximum response of this channel for the different satellites is on the average at a wavelength of 0.8 μm. From this unique set of brightness data the present authors have selected the months of May through September from the years 1967 through 1971 for further calculations.

2. Monthly-mean brightness

The climatological mean conditions over the GATE area in summer as calculated from the five-year sample are shown in Fig. 1. The maps cover the area between latitudes 10S and 20N and longitudes 95W and 50E, i.e.,

[2] The 1967 data were acquired by ESSA 3 in May and September, by ESSA 5 in June through August. In 1968 both ESSA 3 and ESSA 5 were used for the period May through August (ESSA 5 north of the equator) and ESSA 7 for September. In 1969 ESSA 9 supplied data for the entire period. In 1970 there was a switch from ITOS 1 to ESSA 9 early in May and then a return to ITOS 1 on June 18 for the remainder of the period. In 1971 NOAA 1 was used until June 21 and ESSA 9 afterwards.

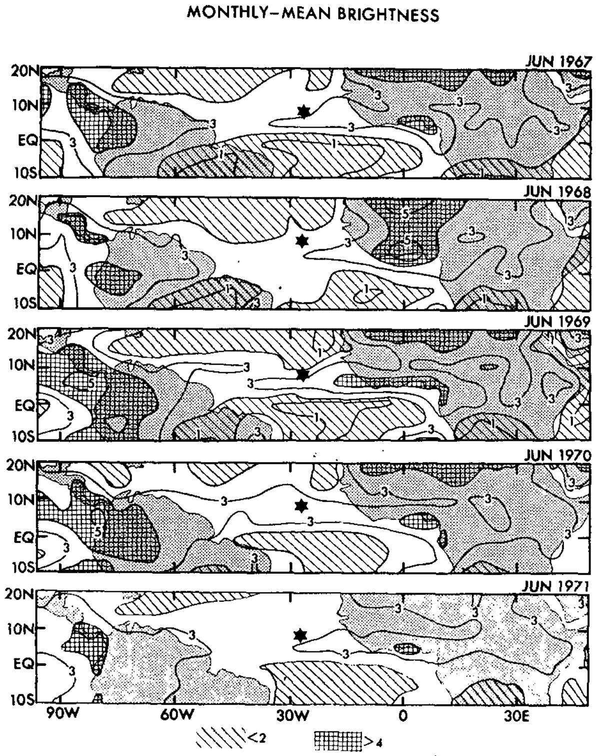

FIG. 2b. Mean brightness patterns over the GATE area for five June months (see also legend Fig. 1).

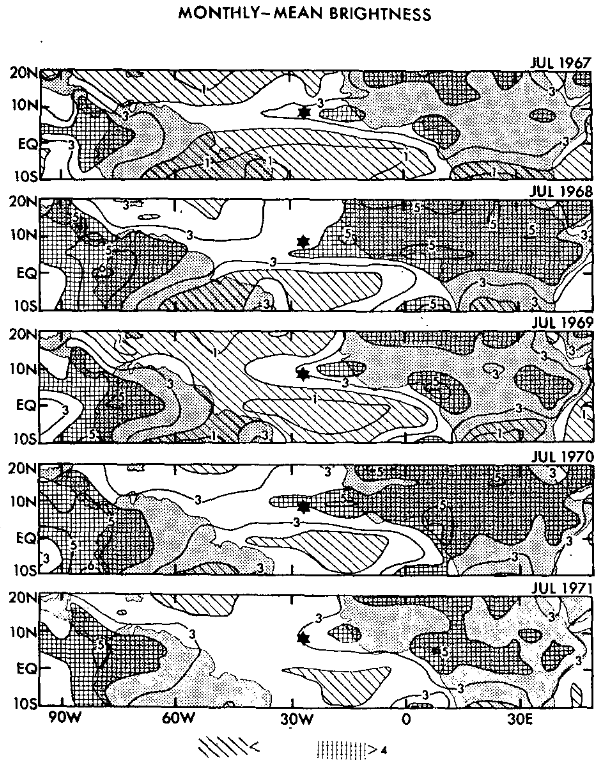

FIG. 2c. Mean brightness patterns over the GATE area for five July months (see also legend Fig. 1).

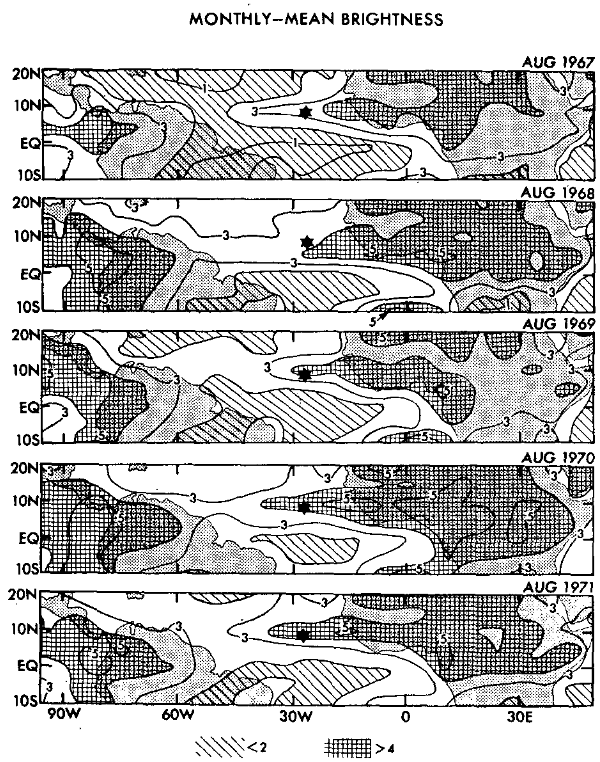

FIG. 2d. Mean brightness patterns over the GATE area for five August months (see also legend Fig. 1).

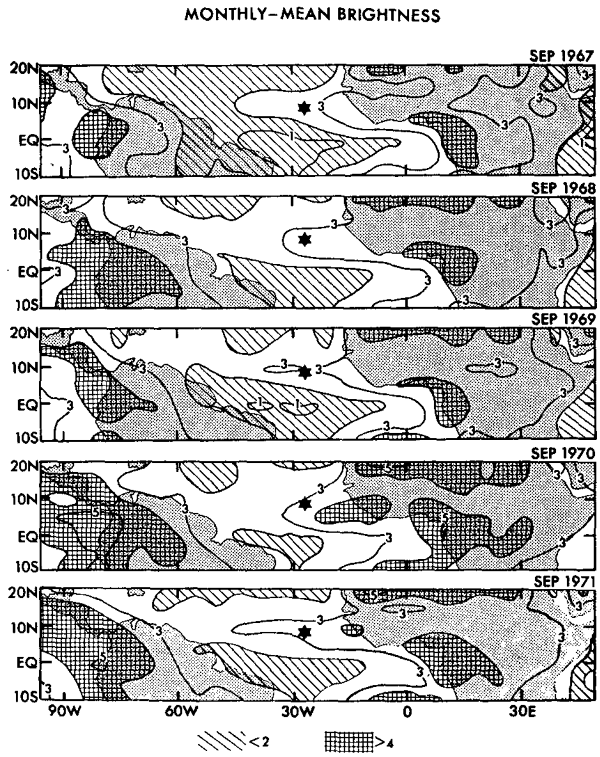

FIG. 2e. Mean brightness patterns over the GATE area for five September months (see also legend Fig. 1).

the entire GATE area except a small area north of 20N in the Caribbean. A star indicates the center of the B-scale array at 8.5N, 23.5W, a location most recently proposed by the GARP Tropical Experiment Board (1973). The monthly brightness distributions north of the equator show a more or less zonal belt of maximum brightness associated with the intertropical convergence (ITCZ). Over the eastern Atlantic this belt migrates northward from a latitude of about 5N in May to about 10N in August. Simultaneously with this northward shift there is an increase in brightness intensity. The location of the B-scale network was selected in the zone of maximum convective activity in summer, largely on the basis of climatological pictures such as shown here. As mentioned earlier, the main problem to be addressed in this paper concerns the question whether the chosen location is also a favorable one for a particular summer, such as the summer of 1974. Further prominent features on the maps are a large maximum in brightness over Central America and northern South America that slowly moves westward from May to September, and also the general increase in brightness over Africa toward the end of the summer. There is overall good agreement between the maps in Fig. 1 and earlier photographic representations of the same basic brightness information published in an atlas by Miller and Staff (1971).

The brightness distribution over the GATE area for individual years is given in Figs. 2a through 2e. The main features of interest as discussed above are found to be present every year. For example, in each May the ITCZ[3] is found to be located several degrees to the south of the B-scale network and later it seems to pass through the network or at least to be very close to it during July, August, and September. Nevertheless, there

[3] For a detailed discussion of fluctuations in the position of the ITCZ see Gruber (1972).

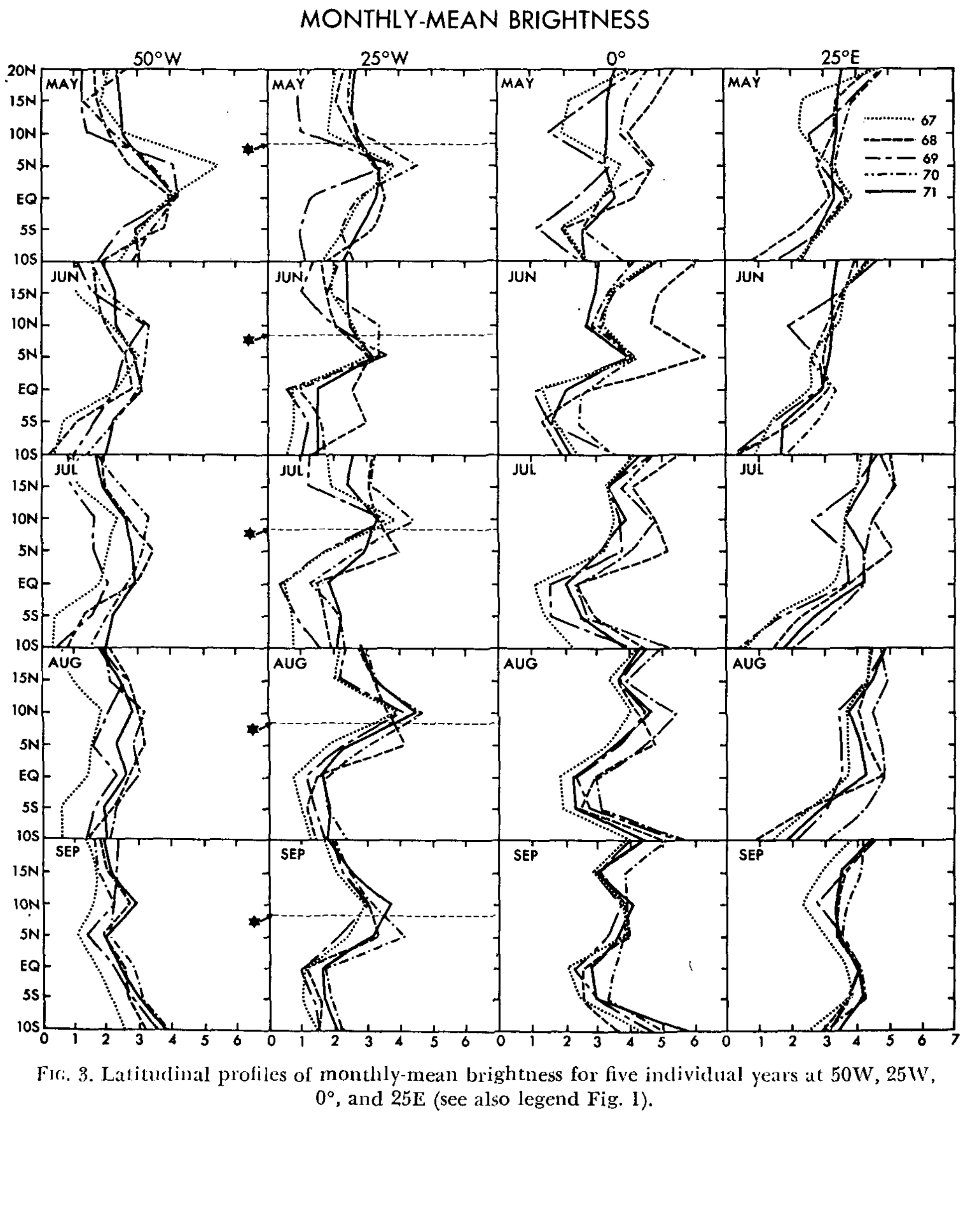

FIG. 3. Latitudinal profiles of monthly-mean brightness for five individual years at 50W, 25W, 0°, and 25E (see also legend Fig. 1).

are also obvious interannual differences both in position and in magnitude of the areas of maximum brightness.

As in the climatological mean case, the present maps were obtained by an objective analysis of the basic 5° by 5° averaged brightness data. The averaging process makes the data handling easier, but limits, of course, the resolution. Thus, the exact position of the ITCZ can only be obtained with an accuracy of several degrees of latitude. It would be of interest in future work to investigate higher resolution brightness data near the ITCZ and compare these with charts of the possibly related sea surface temperature anomalies.

To focus more on the B-scale area two different presentations of the same basic data as used before are shown in Figs. 3 and 4. In Fig. 3 the mean brightness for individual years is plotted as a function of latitude for longitudes 50W, 25W, 0°, and 25E. It is of interest to note that at 25W during practically every June, July, August, or September month there is a peak in brightness near the B-scale latitude, presumably associated with the ITCZ, and that the spread in intensity of the maximum is rather small. The important implication is that during a given year one may expect to always find a high level of activity in the B-scale area. Of course, one should bear in mind that the present record of five years constitutes a rather small sample and that it can only provide a first indication of what to expect in the summer of 1974.

Longitudinal profiles of brightness are shown in Fig. 4. It seems that the highest brightness values are located somewhat east of the B-scale network, just off the African coast.

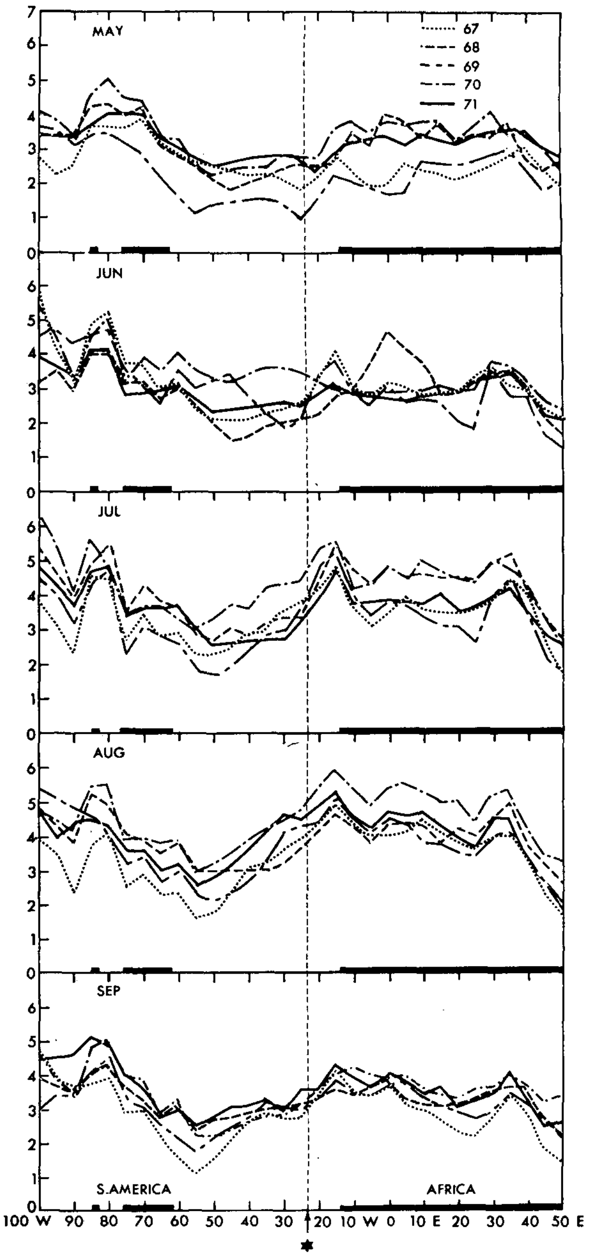

FIG. 4. Zonal profiles of monthly-mean brightness for five individual years at 10N (see also legend Fig. 1).

3. Day-to-day variations in brightness

The basic brightness data also contain interesting information concerning the day-to-day variability. Some of this information is shown in the form of time series of daily values in Fig. 5 for the available grid points between 15S and 20N along the 25W meridian.

Some points of possible interest are the following:

1) For every year the highest level of summer activity is found away from the equator between about 5N and 10N.

2) If one compares the records at 5N and 10N with those at 15S it is clear that relatively high values also do occur at 15S at times. However, at that latitude the high brighness values occur most frequently with stratus decks, whereas the peaks at 5N and 10N are almost always related to cumuliform cloudiness. The character of the cloudiness becomes evident if one examines, for example, ATS 3 movie loops.

3) The daily plots in Fig. 5 do not show clearly the passage of the ITCZ over any one of the grid points. This is surprising because in Figs. 2a through 2d the axis of maximum brightness at 25W appears to cross both the 5 and 10N latitude circles between May and August while increasing in intensity at the same time. These observations probably tend to indicate the intermittent character of the ITCZ.

4) The data at 5N and 10N show a predominant period of about 4 to 5 days, perhaps connected with easterly waves. Unfortunately because of time and computer limitations, we were not able to make more quantitative estimates of the relative intensity of these waves.

5) The daily plots at 5N and 10N further suggest that it will be difficult to make extrapolative predictions of

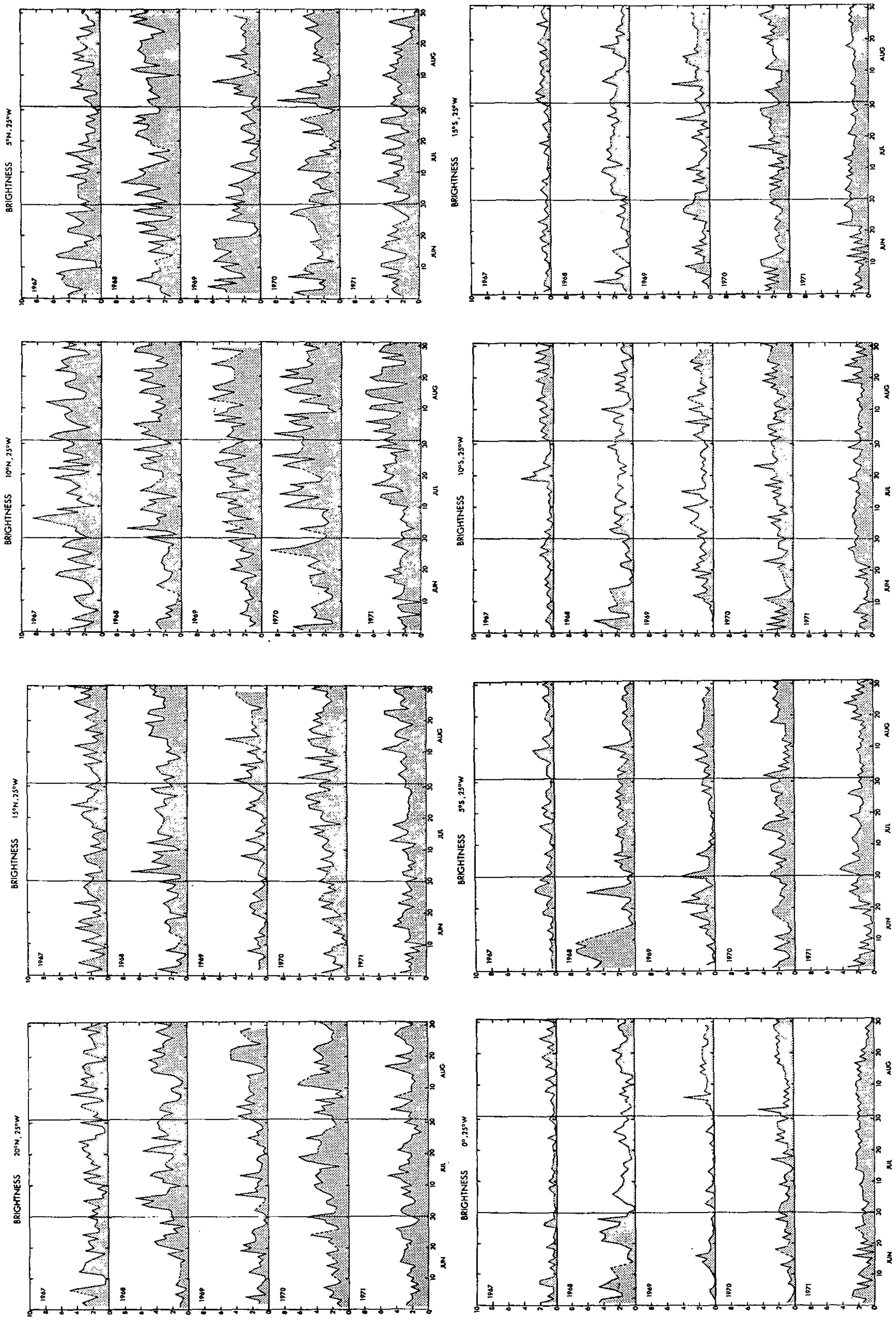

FIG. 5. Time series of daily brightness values at 5° interval between 15S and 20N along the 25W meridian.

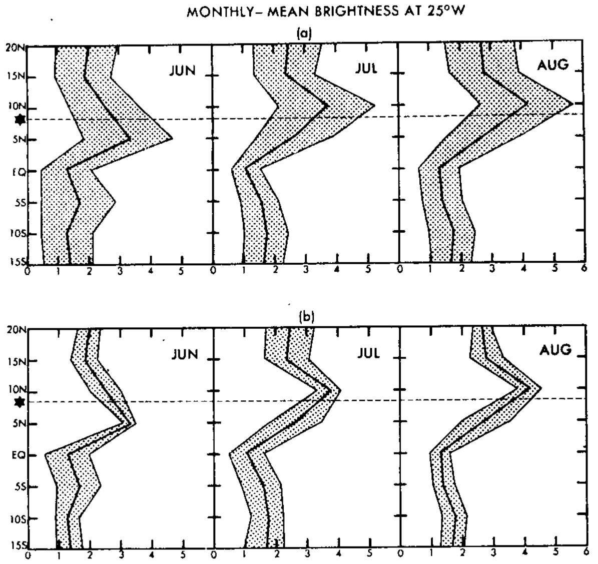

FIG. 6. Latitudinal profiles of monthly-mean brightness ± standard deviation along the 25W meridian based on data from 1967 through 1971; a) standard deviation computed from daily observations, b) standard deviation computed from monthly-mean data.

convective activity in the B-scale area beyond a period of 2 to 3 days.

6) In spite of the care taken in reducing the basic brightness measurements, some indication of the difficulties involved can be found in the plot at the equator. First of all there is an obvious jump in the record for the year 1971 between 21 and 22 June. At that time the operational satellite NOAA 1 became unusable and the aging ESSA 9 was reactivated as the primary video data source. Unfortunately the sensitivity of the ESSA 9 system had decayed markedly by 22 June 1971—i.e., 8 to 27 counts instead of 6 to 62. This flatness materially limited any technique for normalizing the data.

7) Small ripples with a two-day period (three days in the case of ESSA 5 data) are evident in the daily plots, especially at and south of the equator. These ripples reflect the effects of diminished solar illumination upon the eastern portion of a data swath and the interleaved orbital characteristics of the sensing satellites.

4. Summary and concluding remarks

In the preceding discussion a description has been given of the year-to-year variability in brightness over the GATE area as measured from meteorological satellites during the summers of 1967 through 1971.

Of prime concern has been the question of estimating the probability of high convective activity near the location 8.5N, 23.5W, the center of the B-scale network. Our conclusions can perhaps best be summarized in graphical form. Thus Fig. 6 shows a latitudinal profile of the monthly-mean brightness at 25W averaged over the years 1967 through 1971. The range of uncertainty is shown in two ways a) based on all available daily data and b) based on monthly-mean data only.

The profiles suggest the following points:

1) Day-to-day variations are quite large in the B-scale area and seem to occur during every year. They will tend to limit the local predictability by simple extrapolation of such phenomena as cloud clusters to only a few days (see in Fig. 6a the widening of the stippled area near 8.5N).

2) For any one year one can expect a high level of mean activity in the B-scale area during July and August (see in Fig. 6b the pinching of the stippled area near 8.5N).

Acknowledgments. The authors are grateful to Dr. J. Smagorinsky for suggesting this study and for valuable comments and to Mr. A. F. Krueger, Drs. A. Gruber, K. Miyakoda, D. R. Rodenhuis, V. E. Suomi, and J. S. Winston for useful discussions and suggestions. Mr. M. Rosenstein expertly drafted the figures.

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