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16. **Summary/Notes**

The F-region critical frequency, foF2 and the peak height, hmF2, predicted by the CCIR model are compared with their values observed by ionosondes over two Brazilian low latitude stations, namely, Cachoeira Paulista (22.68°S, 45°W) and Fortaleza (3.89°S, 38.44°W) for the months March, June, September and December, 1978. The results suggest (in agreement with some previous works) that attempts should be made to improve the prediction system, taking into account the day-to-day variabilities of the F region critical frequencies, rather than improving the median prediction, which is only desirable for local times around sunrise and sunset. Also the overall day-to-day variability of the F-region over Cachoeira Paulista seems to be larger than over the mid-latitude station Port Stanley, in the same hemisphere. The CCIR prediction of hmF2 is found to be systematically higher than that deduced from ionograms for both Cachoeira Paulista and Fortaleza.

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ABSTRACT

The F-region critical frequency, foF2 and the peak height, hmF2, predicted by the CCIR model are compared with their values observed by ionosondes over two Brazilian low latitude stations, namely, Cachoeira Paulista (22.68°S, 45°W) and Fortaleza (3.89°S, 38.44°W) for the months March, June, September and December, 1978.

The results suggest (in agreement with some previous works) that attempts should be made to improve the prediction system, taking into account the day-to-day variabilities of the F region critical frequencies, rather than improving the median prediction, which is only desirable for local times around sunrise and sunset. Also the overall day-to-day variability of the F-region over Cachoeira Paulista seems to be larger than over the mid-latitude station Port Stanley, in the same hemisphere.

The CCIR prediction of hmF2 is found to be systematically higher than that deduced from ionograms for both Cachoeira Paulista and Fortaleza.

1. Introduction

In recent years there have been a few attempts to verify the validity of ionospheric propagation predictions by the CCIR model using observational data from ground based and satellite born ionosondes and from in situ measurements. Burge et al (1973) and King and Slater (1973), comparing the electron densities and heights of the F_2-peak, predicted by the CCIR and those measured from ionosondes, observed that the broad features of the predicted global distribution of these parameters do, in general, agree with the observations. However, there were pronounced latitudinal ionization gradients, particularly in the region of the equatorial anomaly, which could not be reproduced by the CCIR model that predicts rather slowly varying features in both latitudinal as well as longitudinal ionization distribution. The results of Sheik et al.(1978) from satellite in situ measurements, also led to similar conclusions. All these results do indicate significant discrepancies between the predicted and the observed parameters for certain regions of the globe, specially in the southern hemisphere. The discrepancy over the southern hemisphere is not surprising in view of the limited data available.

In the present work we have undertaken a comparative study of the *F2*-peak parameters, namely *foF2* and *hmF2* predicted from CCIR model (CCIR Report 340, 1966) with the data available from two Brazilian stations, namely, Cachoeira Paulista (22.68^{o}S, 45^{o}W) and Fortaleza (3.89^{o}S, 38.44^{o}W), both of which are under the influence of the equatorial anomaly. Further, Cachoeira Paulista is located near the center of the South Atlantic Magnetic Anomaly. We have selected data for the months March, September, June and December, to represent the equinoxes, winter and summer conditions respectively.

2. Results

For each of the months studied we determined the diurnal behaviour of the median values, lower and upper quartiles, minimum and maximum values and the standard deviations in *foF2* and *hmF2* at hourly intervals for both Cachoeira Paulista and Fortaleza. The results are presented in Figures (1) and (2). The *foF2* and *hmF2* values from 1800 LT to midnight are not available for Fortaleza due to the occurence of the equatorial Spread *F* in the ionograms. From Figure 1(a) we may note that, in general, there is reasonable agreement between the prediction and the observed median values of *foF2* over Cachoeira Paulista, specially in the months of June and September, although minor discrepancies are present during evening hours, in these months. During March and December the predicted *foF2* values are significantly lower than observed values, specially in the evening and night hours. These disagreements might arise as a result of the fact that, owning to the small number of inputs from the Brazilian region, the longitudinal asymmetry in the equatorial anomaly crest is not adequately represented in the CCIR model.

Over Fortaleza (Figure 1(b)) the agreement between the prediction and observation is more uniform, except during the daytime hours in June when the prediction falls short of the observed values.

The standard deviation in *foF2* and *hmF2* shows diurnal as well as seasonal variations and, in general, has larger amplitude over Cachoeira Paulista than over Fortaleza.

Figure 2 presents comparison of the *hmF2* values predicted from the CCIR and the monthly median calculated using the relationship given by Shimazaki (1955), namely,

$$hmF2 = \left\{ \frac{1490}{M(3000)\,F2} \right\} - 176,$$

where the median $M(3000)\,F2$ was obtained from the ionograms. The values of *hmF2* (CCIR) were obtained from the predicted $M(3000)\,F2$.

We may note from Figure 2 that the predicted *hmF2* does not agree with the observational results, being, im most part, systematically higher than the observed median values for both Cachoeira Paulista and Fortaleza. The discrepancy seems to be more pronounced over Fortaleza than over Cachoeira Paulista and it is a minimum in March over Cachoeira Paulista. One important reason for this systematic difference between the CCIR prediction and the results from observations could probably be inherent in the method of determining *hmF2* from the ionograms. It would be interesting to see how this difference would be modified if the *F2*-peak height determination were based on true height analysis of the ionogram. On the other hand, Bilitza et al. (1979) showed that because of the fact that the layer ionization was not taken into account in Shimazaki's (1955) formula to calculate *hmF2*, it is necessary to introduce correction in this formula in order to obtain more realistic results. In fact, the results of Bilitza et al showed that the *hmF2* values calculated using Shimazaki's formula were well above those determined from incoherent scatter radar over Millstone Hill (43^{o}N, 288^{o}E) for summer noon conditions when significant underlying ionization was present.

The percentage error in the CCIR prediction with respect to the observed median values, defined as:

$$\frac{|foF2\text{ (observed median)} - foF2\text{(CCIR)}|}{foF2\text{ (observed median)}} \times 100,$$

is presented in Figure 3 (solid line). Plotted in the same Figure (broken line) is the percentage of the ranges of the quartile values defined as

$$\frac{foF2\text{ (upper quartile)} - foF2\text{ (lower quartile)}}{foF2\text{ (median)}} \times 100.$$

Similar parameters calculated for the case of *hmf2* are presented in Figure 4.

In general, the percentage error in CCIR prediction of *foF2* seems to be small during daytime, but tends to become significant during nighttime. Largest errors are present in the early morning and evening hours in most of the seasons. Similar local time dependence of the percentage errors in the CCIR prediction of *foF2* was presented also by King and Slater (1973) in the case of a few northern and southern hemisphere mid-latitude stations. We may notice also that the ranges of the quartiles values of *foF2* are generally higher than the prediction error, with the exception of few daytime hours in summer over Cachoeira Paulista and in winter over Fortaleza. The difference between the two factors gets significantly enhanced during morning and night hours.

The mean values of the monthly median percentage prediction errors for Cachoeira Paulista and Fortaleza, presented in Table 1, vary approximately from 7 to 14% in the case of *foF2* and 7.5 to 18% in the case of *hmF2*, whereas the observed ranges of the quartiles (presented in the same Table) in *foF2* vary approximately from 13 to 30% and in *hmF2* from 9 to 19%.

The means of the errors of *foF2* are thus significantly lower than the means of quartile ranges. Therefore, in order to improve the prediction of *F*-region critical frequencies, attempts should be made to include in the prediction system the day to day variability of the *F*-region, rather than trying to further improve the prediction of the median values, in agreement with the conclusion of King and Slater (1973). Prediction of the mean values should, however, be improved for sunrise and sunset hours, and during nighttime hours during some months.

In the case of *hmF2*, the difference between the ranges of quartiles and the errors in the median prediction seems to be not very significant, there being no definite diurnal trend in either of them. This behaviour should be seen in the light of the discussions made above in connection with the Figure 2.

The percentages of the errors in the prediction and of the ranges of the quartiles for Cachoeira Paulista are compared with those for a mid-latitude station, Port Stanley ($52^{o}S$, $58^{o}W$) (taken from King and Slater 1973) in Figure 5, for the case of *foF2* and in Figure 6 for the case of *hmF2*. It may be observed that the prediction error in *foF2* is more pronounced over Port Stanley in June whereas the range of quartiles shows the opposite tendency. The diurnal behaviour of the percentage prediction error is remarkably similar for the two stations in winter (June) and equinoxes (September), whereas during the summer nights (December) Cachoeira Paulista has significantly higher prediction error. The range of quartiles is systematically higher during pre-sunrise hours in all the seasons, and during night hours in winter (June) and summer (December), over Cachoeira Paulista. Only during summer daytime does Cachoeira Paulista show less day-to-day variability than Port Stanley.

In the case of *hmF2*, the quartile ranges are similar at Cachoeira Paulista and Port Stanley, whereas the percentage error is found to be significantly higher over Cachoeira Paulista.

3. Conclusions

The CCIR prediction of the *foF2* for the Brazilian low latitude stations, Cachoeira Paulista and Fortaleza, shows general agreement with the observed monthly median values of the *foF2*, during most of the months included in the present study. However, prediction errors are observed near sunrise and sunset hours during nearly all the months and during nights hours in some months. The day-to-day variability in the observed *foF2*, represented as the range of quartiles, are significantly higher than the mean prediction error, thereby suggesting that improvements in prediction method should be attempted by including day-to-day variability in the CCIR prediction system rather than improving the prediction of the median values. Prediction of the latter should, however, be improved for certain hours of the day, mainly near the sunrise and sunset. The predicted *hmF2* for Cachoeira Paulista and Fortaleza is found to be consistently greater than the observed median values of the *hmF2*. To improve agreement between the two, it might be necessary to determine *hmF2* from formulas that consider the underlying ionization of the refleting layer.

The day-to-day variability in the *F*-region seems to be larger over Cachoeira Paulista (and to some extent also over Fortaleza, although not shown separately here) than over the southern mid latitude station, Port Stanley. While these variabilities could be produced as a result of the ionospheric response to geophysical events such as magnetic storms, large scale travelling ionospheric disturbances etc, the relatively larger variability over Cachoeira Paulista compared to Port Stanley could probably be due to the location of the former within the region influenced by the equatorial geomagnetic anomaly. Thus, more detailed study should be undertaken to resolve the different sources of the *F* region variability so that attempts could be made to incorporate such variations in the CCIR Prediction system.

4. Acknowledgements

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MONTH	*foF2*				*hmF2*			
	C. PAULISTA		FORTALEZA		C. PAULISTA		FORTALEZA	
	error	range	error	range	error	range	error	range
March (equinox)	13.9	17.1	11.1	15.9	7.5	15.4	12.5	8.7
June (winter)	7.6	29.7	12.4	19.0	15.7	13.3	13.4	18.7
September (equinox)	7.5	24.2	7.1	22.4	17.6	10.8	14.5	11.2
December (summer)	10.0	17.7	7.9	12.8	14.9	12.8	10.1	8.7

Table 1 - Average values (% of observed median) of the observed quartile ranges of *foF2* and *hmF2* and errors of the corresponding predicted medians for Cachoeira Paulista and Fortaleza.

Figure Captions

Figure 1 (a) Monthly median values, (thick solid line within shaded area), ranges of quartiles (shaded area), standard deviations (solid line, σ) and minimum and maximum values, (thin solid line) of *foF2* observed over Cachoeira Paulista, compared with the CCIR prediction of *foF2*, for March, June, September and December 1978,

(b) Similar parameters as in (a) in the case of Fortaleza, compared with the CCIR predictions of *foF2*.

Figure 2 (a) Similar parameters as in Figure 1, calculated for *hmF2* over Cachoeira Paulista, compared with the CCIR prediction of *hmF2*, for March, June, September and December, 1978.

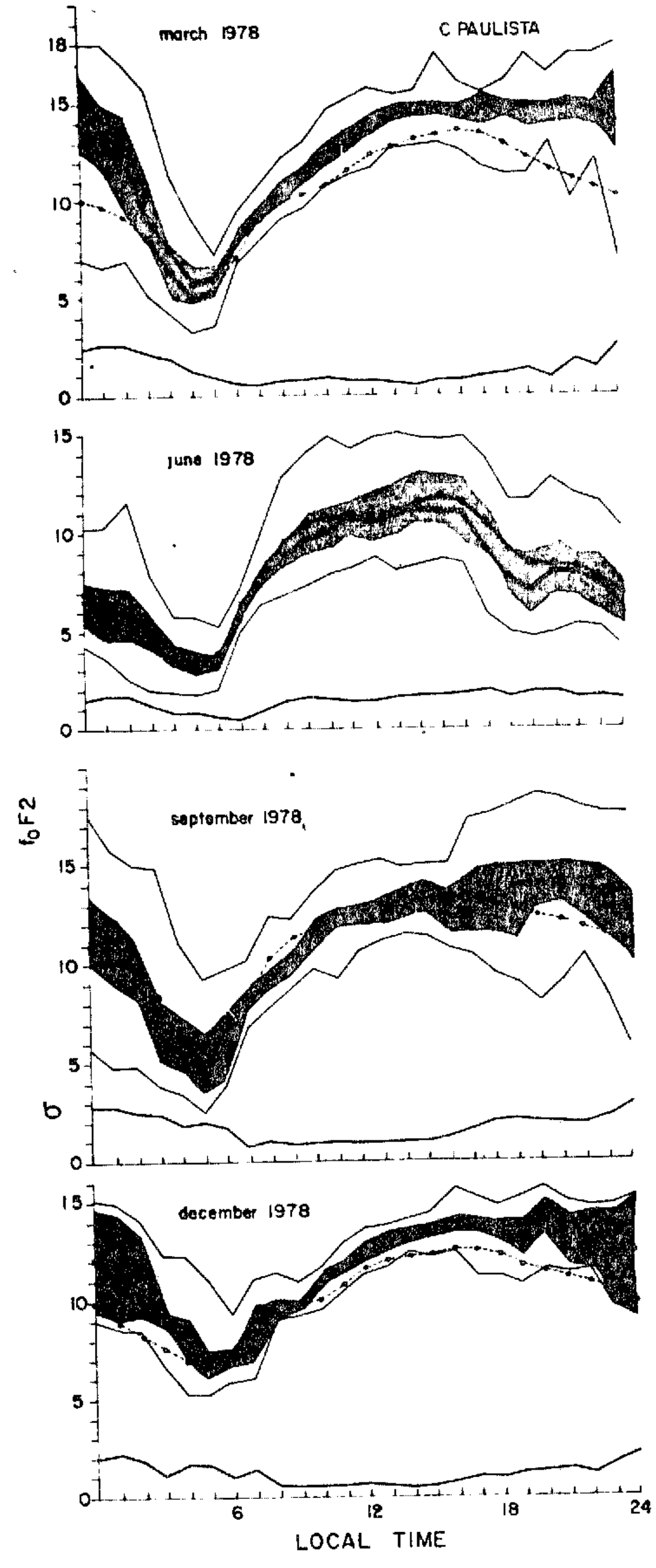
(b) Similar parameters as in (a) in the case od Fortaleza, compared with the CCIR prediction of *hmF2*.

Figure 3 A comparison of the percentage prediction error, (solid line) with respect to the monthly median, and the range of quartiles, (broken line), of the observed *foF2* over Cachoeira Paulista and Fortaleza for June, September and December, 1978.

Figure 4 Similar comparison as in Figure (3) in the case of *hmF2*.

Figure 5 A comparison of the percentage prediction error (left half) for Cachoeira Paulista (solid line) and Port Stanley (xx). The right half shows a comparison of the range of quartiles for Cachoeira Paulista (broken line) and for Port Stanley (solid circles).

Figure 6 Similar comparison as in Figure (5) in the case of *hmF2*.


march 1978
C PAULISTA
18
15
10
5
0
june 1978
15
10
5
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f_oF2
september 1978
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5
σ
0
december 1978
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5
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6
12
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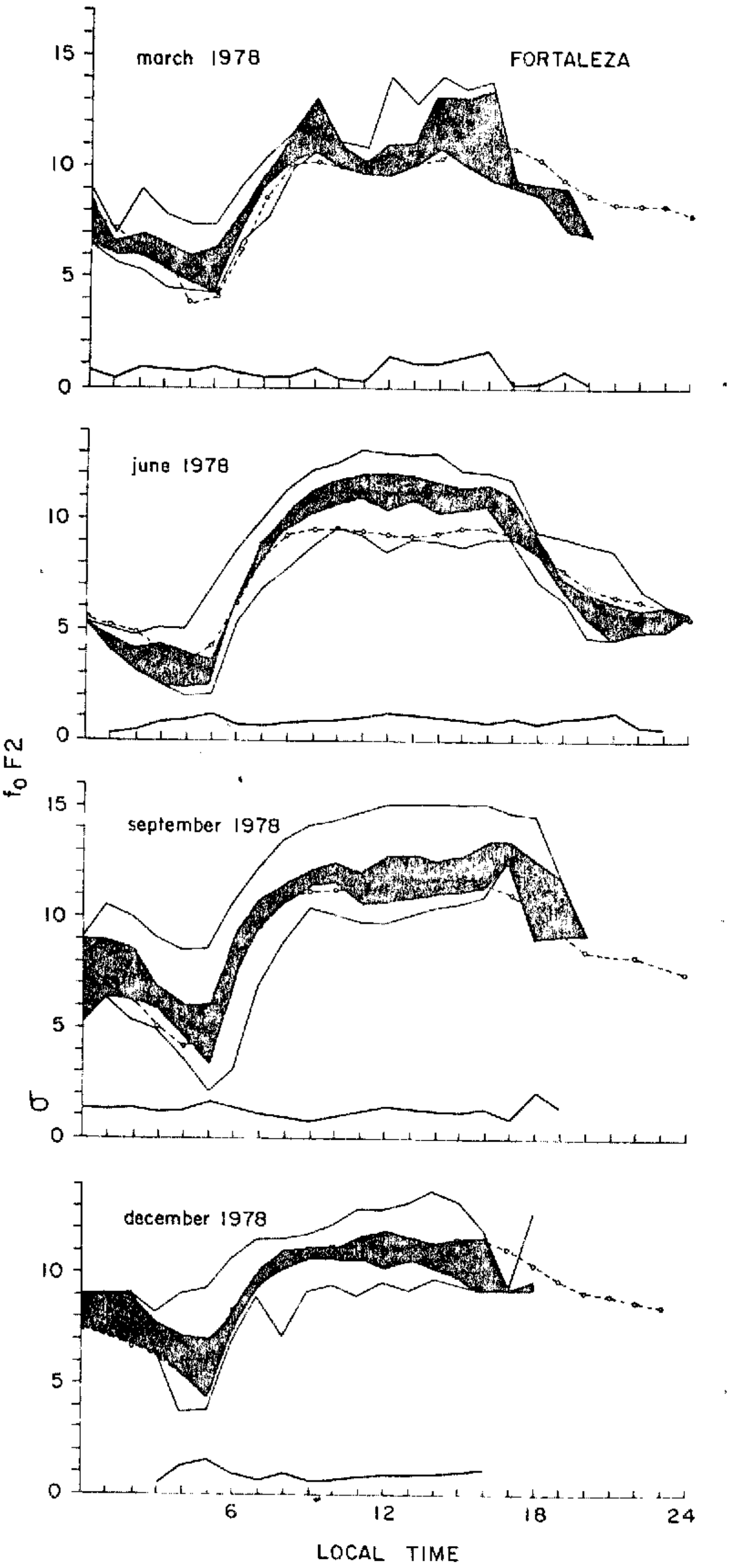
24
LOCAL TIME

Fig. 1a


march 1978
FORTALEZA
june 1978
september 1978
december 1978
f_oF2
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12
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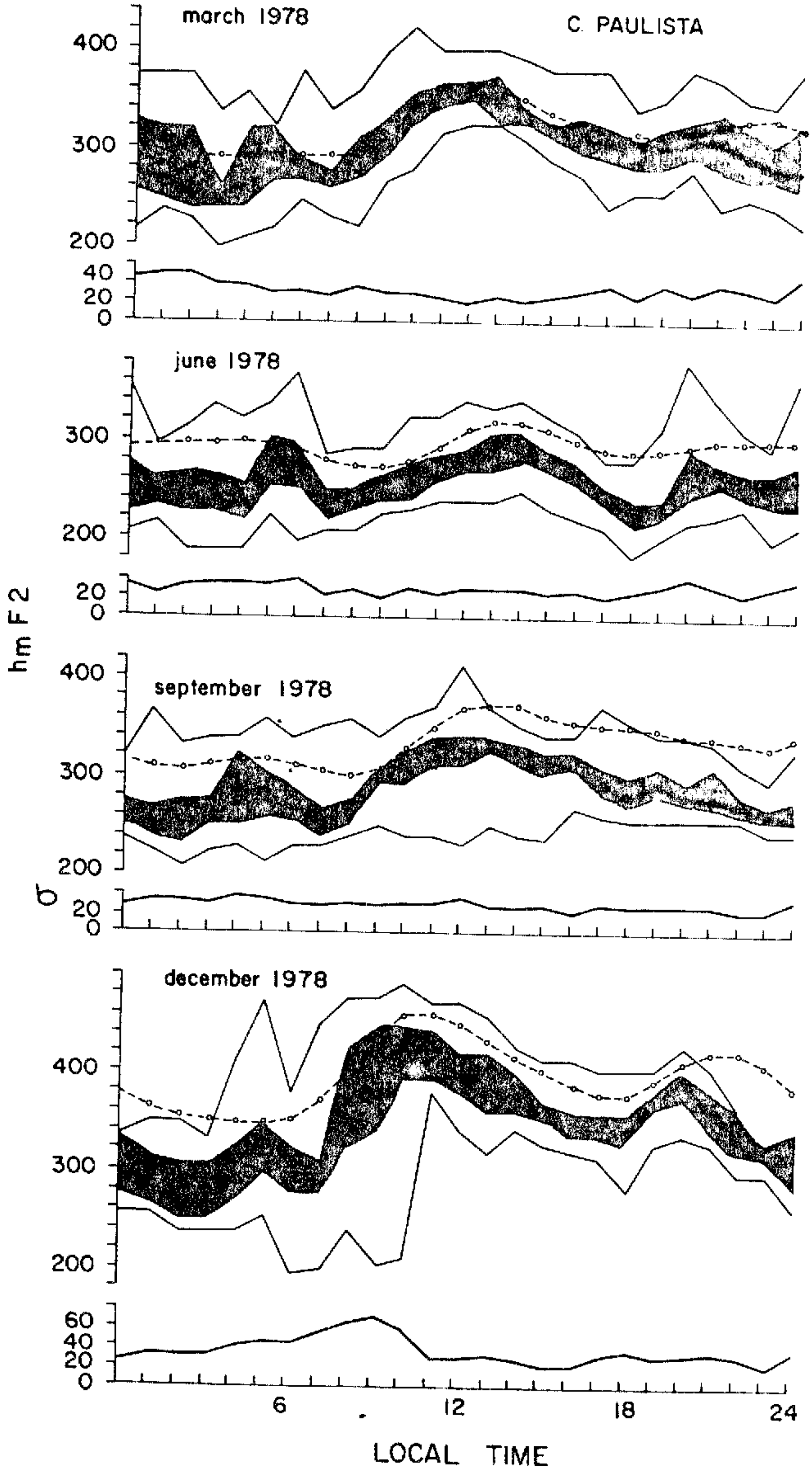
LOCAL TIME

Fig. 1b


march 1978
C. PAULISTA
june 1978
september 1978
december 1978
hmF2
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400
300
200
40
20
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60
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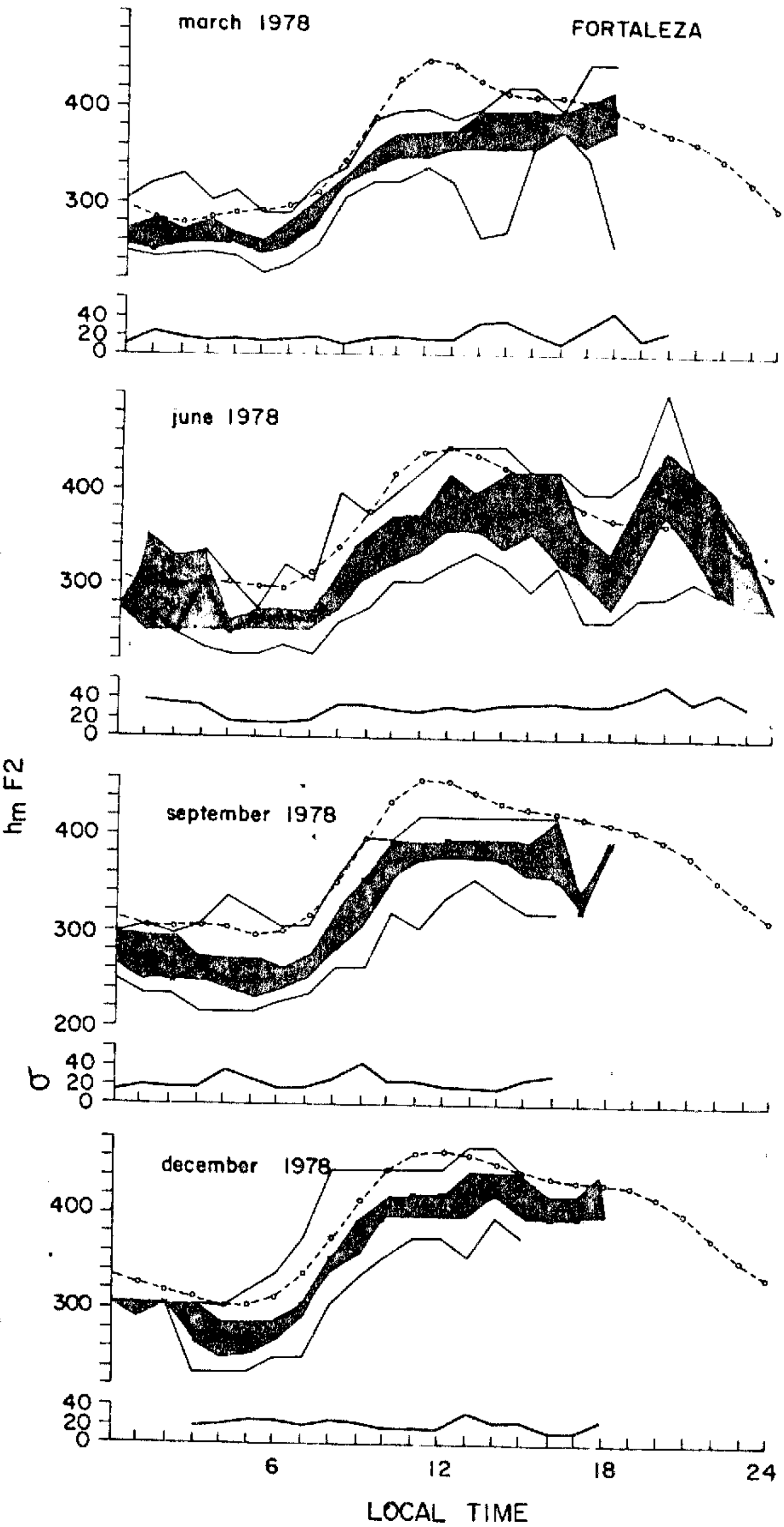
LOCAL TIME

Fig. 2a


march 1978
FORTALEZA
june 1978
september 1978
december 1978
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LOCAL TIME

Fig. 2b

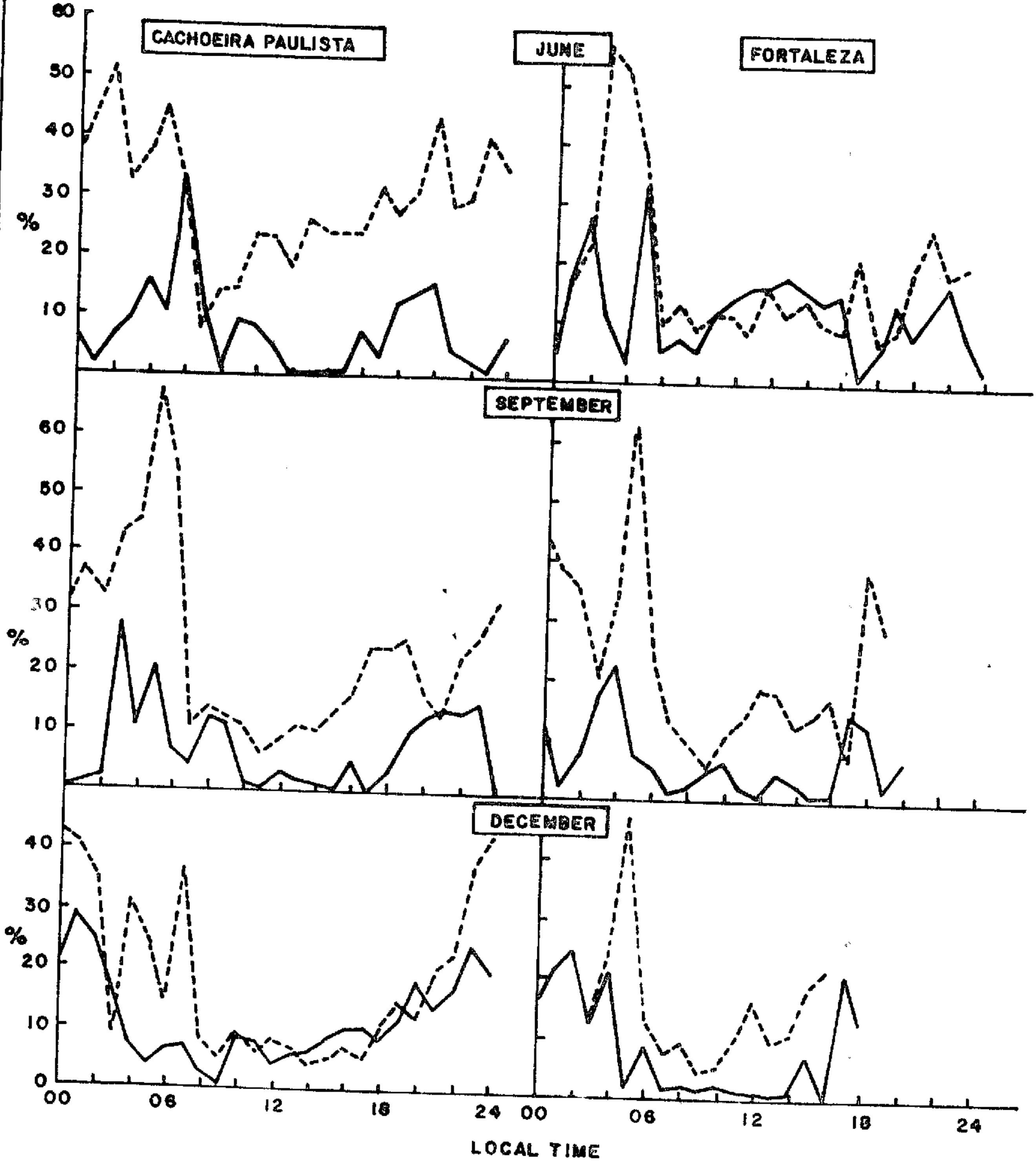
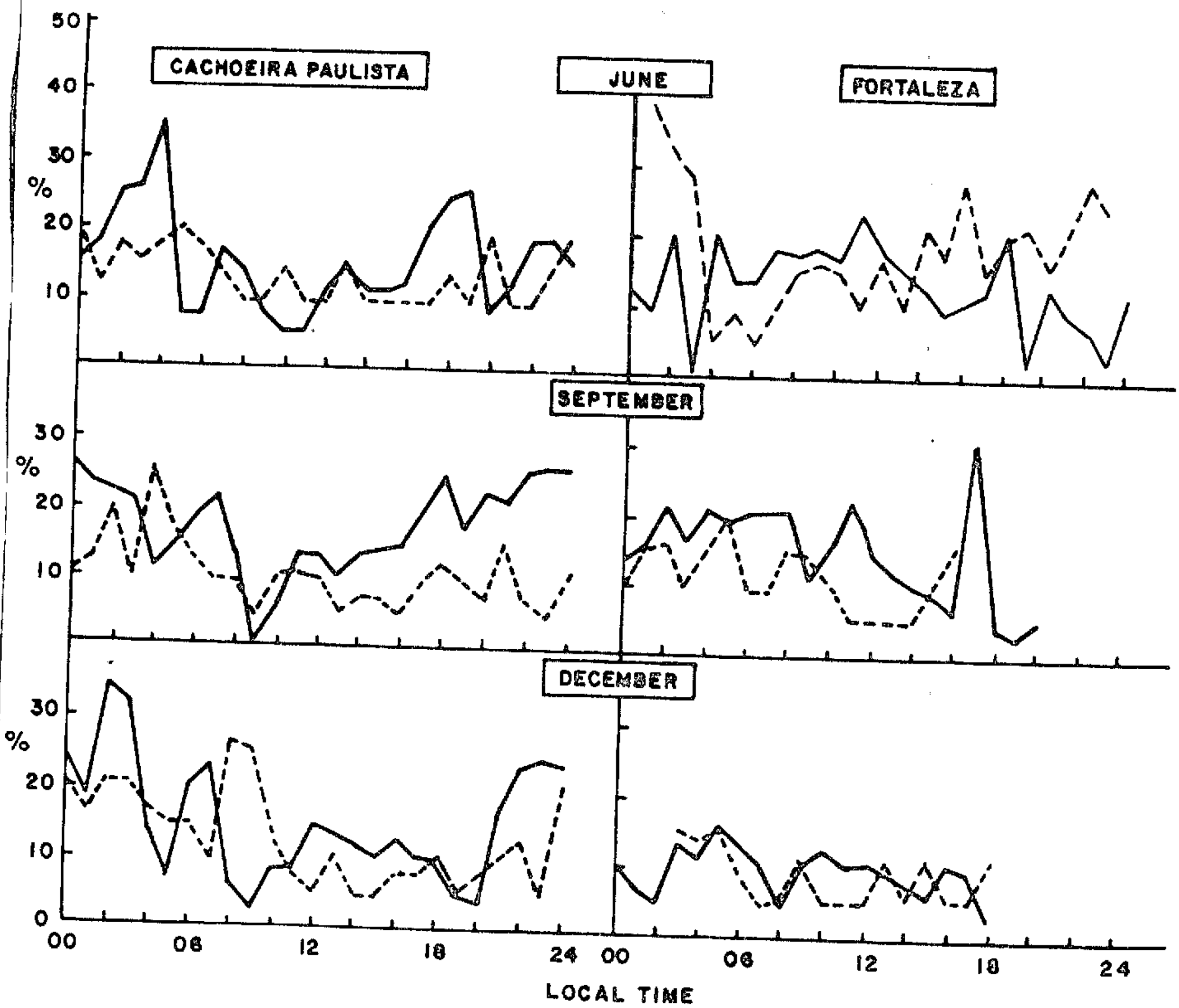

CACHOEIRA PAULISTA
JUNE
FORTALEZA
SEPTEMBER
DECEMBER
%
LOCAL TIME

Fig. 3



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CACHOEIRA PAULISTA
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Fig. 4

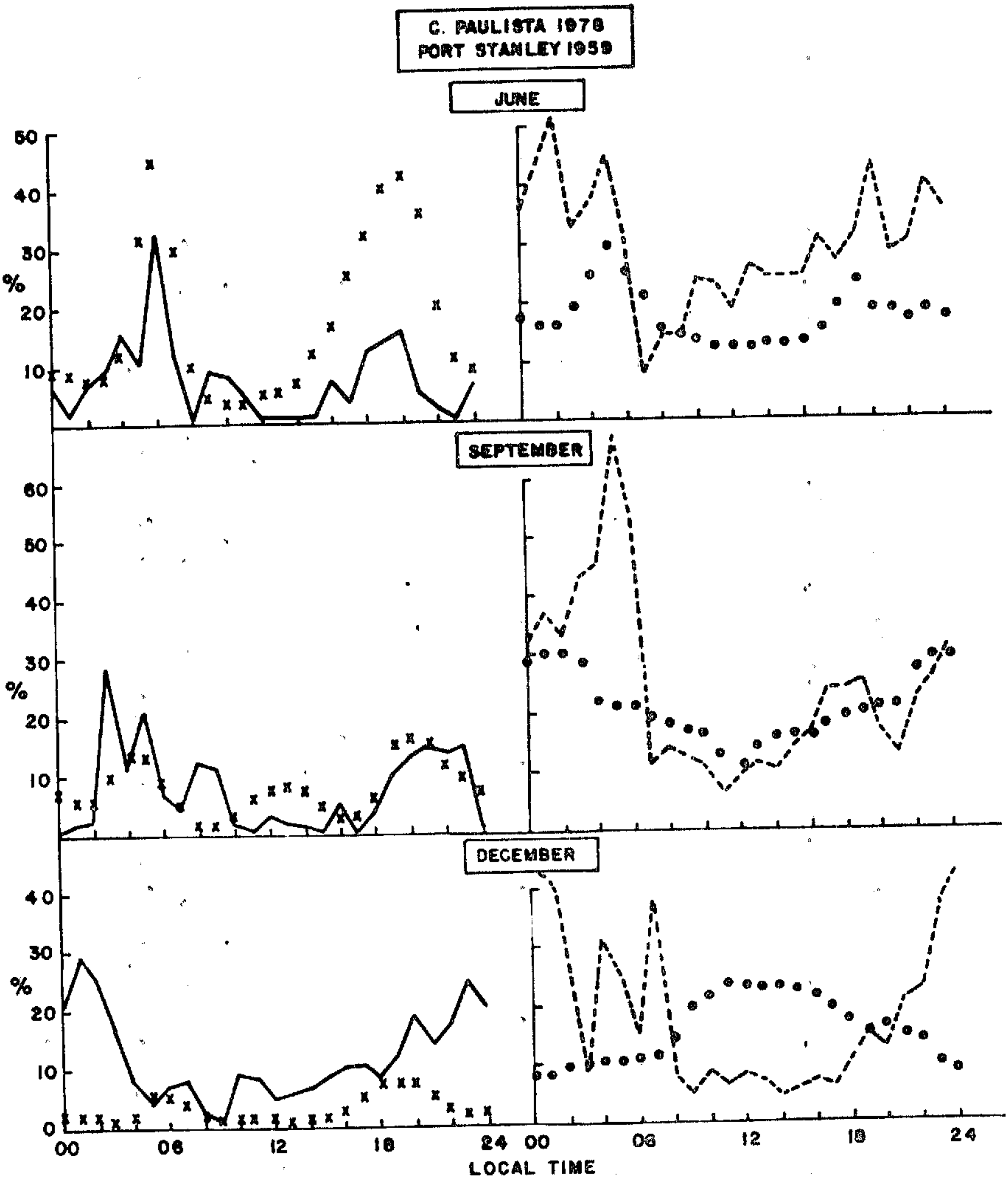
C. PAULISTA 1978
PORT STANLEY 1959
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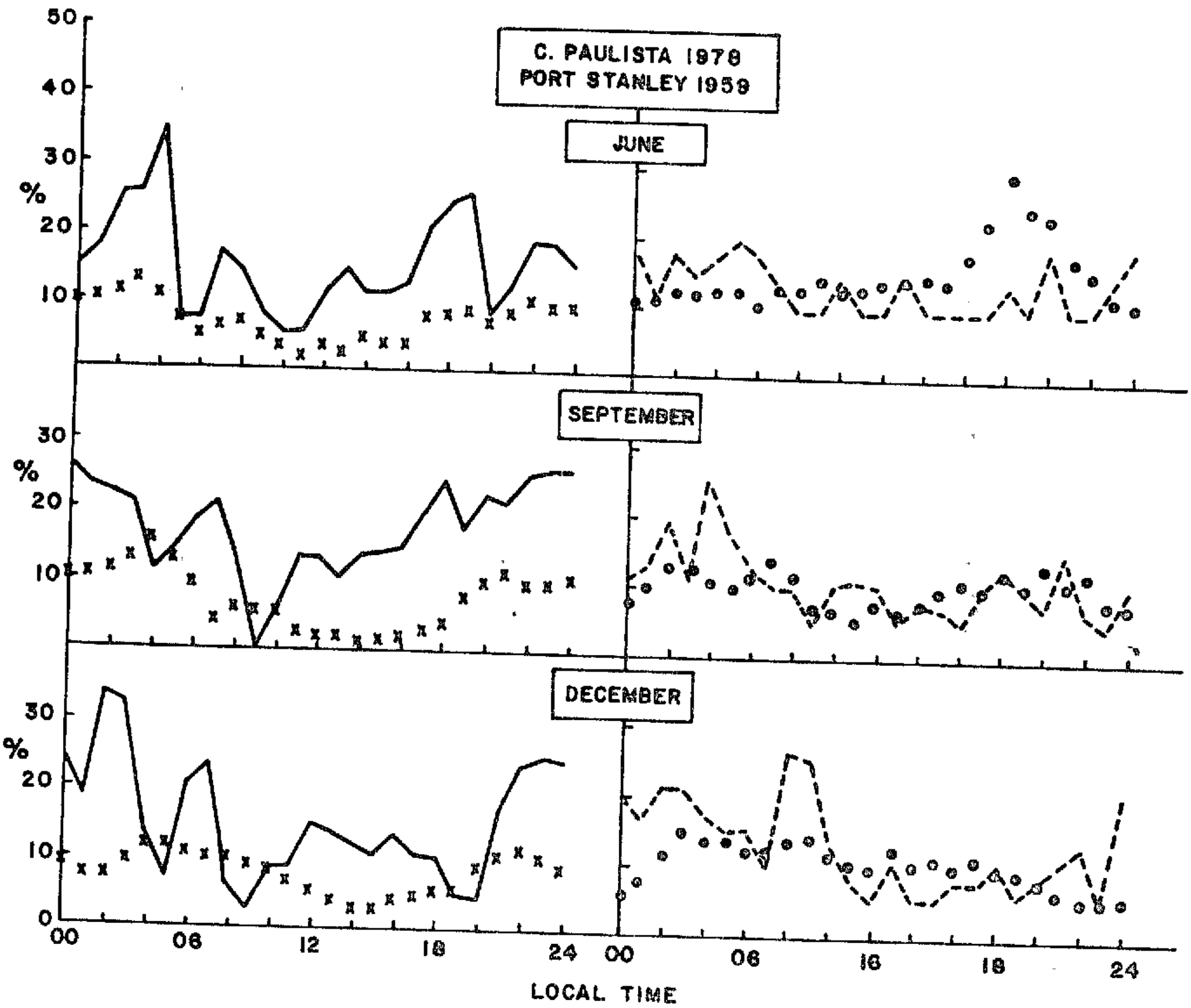
Fig. 5


C. PAULISTA 1978
PORT STANLEY 1959
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LOCAL TIME

Fig. 6

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