CONCERNING SOME FEATURES OF THE CURVES OF OCCURRENCE-FREQUENCY OF pc's AT OBSERVATORIES IN THE EQUATORIAL ZONE

by

Antonio Romañá, S.J.

Translated from
Geomagnetica (Publication commemorating the 50th Anniversary of the Magnetic Observatory of San Miguel, Azores). National Meteorological Service, Lisbon, 1962, pp. 217-227

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E.R. Hope

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CONCERNING SOME FEATURES OF THE CURVES OF OCCURRENCE-FREQUENCY OF pc's AT OBSERVATORIES IN THE EQUATORIAL ZONE

Antonio Romañá, S.J.
Ebro University

At the Symposium on Rapid Magnetic Variations held at Utrecht from the 1st to the 4th of September, 1959, Miss Hutton [1] presented an interesting diurnal variation curve of the occurrence-frequency of hours with pc's in the recordings of earth currents in Ghana, a curve which exhibits the pecularity of having its principal maximum between 19 hrs and 20 hrs of Mean Local Time (which in Ghana coincides with Universal Time); two other well-defined maxima appear between 5 and 6 hrs and between 9 and 11 hrs LT. In the discussion which followed, Reverend Father Cardús and Professor Selzer drew attention to the existence of other pc maxima during the night hours in the Tamanrasset and Kerguelen magnetic records, at least during certain periods of the year. Since pc's are generally considered as a phenomenon with a typically daytime maximum and a minimum about midnight, it seems clearly indicated that we should look to see how far this anomaly extends to other observatories, and whether it affects the magnetic records as well as the earth-current records.

In a paper read at the symposium recently held at Kyōto, Father Cardús has studied the world-wide frequency curves of hours with pc's on the basis of data sent to Committee No.10 of the IAGA during the International Geophysical Year and its prolongation, the Year of International Geophysical Cooperation; that is to say, from the 1st of July, 1957, to the 31st of December, 1959. Although this material is not as complete and homogeneous as might be desired, it nevertheless seems adequate to give an idea of the [diurnal] variation of the phenomenon over the greater part of the globe; we do not venture to say "over the whole globe", because of the scanty data from the southern hemisphere and the almost entire lack of cooperating observatories in certain capitally important regions of the planet, for example, the American region.

Listed in the annexed table are the observatories that have sent their pc data to the Committee, with details of their geographic coordinates, number of months of observations, type of recording, etc. The name-symbols in square brackets indicate stations not officially accepted by the Observatories Committee of the IAGA.

It may be seen at once that the geographic distribution is not very homogeneous; moreover, the proferred data vary a good deal in quantity and quality from one observatory to another. Therefore a quantitative statistical study of the whole of this material is very difficult, and in some respects impossible. But if it is a matter of qualitative study the situation is different. Since not a few observatories have sent their data regularly and have adhered to the norms established by the Committee, it is possible, relying on these observatories, to arrive at sufficiently trustworthy results, and then to use the

OBSERVATORY	Symbol	COORDINATES				Pulsations recorded: earth-current (tel.) or magnetic	Type of recording	Number of months	DATA RECEIVED	Hours of maximum pc frequency, mean local time	Hours of minimum pc frequency, mean local time
		geographic		geomagnetic							
		φ	λ	Φ	Λ						
Tikhaya Bay	BT	+80° 20′	52° 48′	+71.5°	153.3°	tel.	continuous	24	1958; 1959	9-10	19-03
Barentsburg	[Bb]	+78° 39′	16° 23′	+74.5°	132.9°	»	»	19	1957 X; 1958; 1959 I-VI	9-10	17-01
Cape Cheliuskin	CC	+77° 43′	104° 17′	+65.9°	177.5°	»	»	21	1957 VIII-X; 1958; 1959 I-VI	9-10	18-04
Tiksi	Ti	+71° 40′	128° 54′	+60.5°	191.4°	»	»	23	1958 II-XII; 1959	6-7; 10-11	21-01
Tromsö	Tr	+69° 40′	18° 57′	+67.1°	116.7°	mag.	»	13	1957 VIII-IX; 1958 VI-XII; 1959 I-IV	2-3	12-24
Lovozero	[Lz]	+67° 58′	35° 05′	+62.8°	127.3°	tel.	»	23	1957 VII-X; 1958; 1959	4-5; 9-10	17-21
Lerwick	Le	+60° 08′	358° 49′	+62.5°	88.6°	mag.	»	28	1957 IX-XII; 1958; 1959	9-10	17-20
Leningrad	Ln	+59° 57′	30° 42′	+56.2°	117.1°	»	—	—	Combined curve only	5-6; 10-11	21-01
Borok	[Bo]	+58° 02′	38° 58′	+52.9°	123.3°	tel.	continuous	28	1957 VII-X; 1958; 1959	10-11	23-03
Eskdalemuir	Es	+55° 19′	356° 48′	+58.5°	82.9°	mag.	»	28	1957 IX-XII; 1958; 1959	12-13	19-03
Voloshin	[Vo]	+54° 06′	26° 31′	+51.4°	110 5°	tel.	»	1	1958 IV	12-13	20-04
Shatsk	[Sh]	+53° 59′	41° 51′	+48.5°	123.8°	»	»	24	1957 VIII-X; 1958 I-IX; 1959	11-12	21-02
Wingst	Wn	+53° 45′	9° 04′	+54.5°	94.0°	mag.	»	30	1957 VII-XII; 1958; 1959	13-14	19-03
Petropavlosk-on-Kamchatka	[PK]	+53° 06′	158° 38′	+44.4°	218.2°	tel.	»	28	1957 VII-X; 1958; 1959	10-11	21-02
Witteveen	Wi	+52° 49′	6° 40′	+54.2°	91.0°	tel. & mag.	»	30	1957 VII-XII; 1958; 1959	9-10	17-03
Noord Oost Polder	[NP]	~ +52.7°	~ 5.9°	~ +54°	~ 90°	tel.	»	17	1957 XII; 1958; 1959 I-IV	9-10	19-02
Irkutsk	Ir	+52° 28′	104° 02′	+41.0°	174.4°	»	»	11	1957 IX-X; 1958 VII-XII; 1959 I-III	9-10	19-01
Valentia	Vl	+51° 56′	349° 45′	+56.6°	73.4°	mag.	»	30	1957 VII-XII; 1958; 1959	11-12	18-02
Hartland	Ha	+51° 00′	355° 31′	+54.6°	79.0°	»	»	30	1957 VII-XII; 1958; 1959	11-12	19-02
Manhay	Ma	+50° 18′	5° 41′	+52.0°	88.8°	»	»	28	1957 IX-XII; 1958; 1959	9-10	20-01
Dourbes	Db	+50° 06′	4° 36′	+51.1°	88.1°	»	»	22	1958 III-XII; 1959	10-11	19-03
Lwow	Lw	+49° 54′	23° 45′	+48.0°	105.8°	tel.	»	20	1957 VII-X; 1958; 1959 I-IV	9-10	20-02
Budkov	Bu	+49° 04′	14° 01′	+49.1°	96.2°	tel. & mag.	»	24	1958; 1959	{tel: 7-8 {mag: 11-12	{t 19-23 {m 20-02

Chambon-la-Forêt	CF	+48° 01′	2° 16′	+50.4°	83.9°	»	»	30	1957 VII-XII; 1958; 1959	8-9	21-24
Sakhalinsk	Sa	+47° 00′	142° 48′	+36.9°	206.7°	tel.	»	23	1958 II-XII; 1959	13-14	20-03
Alushta	[Au]	+44° 41′	34° 25′	+40.9°	113.6°	»	»	28	1957 VII-X; 1598; 1959	9-10	21-02
Memambetsu	Mb	+43° 55′	144° 12′	+34.1°	208.3°	mag.	»	27	1957 X-XII; 1958; 1959	10-11	23-02
Alma Ata	[Aa]	+43° 16′	77° 22′	+33.1°	151.1°	tel.	»	29	1957 VII-XI; 1958; 1959	7-8	20-02
Tiflis (Dusheti)	Tf	+42° 05′	44° 42′	+36.7°	122.1	»	»	8	1957 VII-X; 1958; I-IV	10-11	19-04
Toledo	Tl	+39° 53′	355° 57′	+43.6°	75.7°	tel. & mag.	»	30	1957 VII-XII; 1958; 1959	7-8	20-03
Onagawa	On	+38° 26′	141° 28′	+28.3°	206.8°	mag.	»	30	1957 VII-XII; 1958; 1959	8-9	21-02
Ashkabad	Ak	+37° 57′	58° 06′	+30.4°	133.1°	tel. & mag.	»	22	1957 VII-X; 1958 II-XII; 1959 I-VII	9-10	22-02
San Miguel	SM	+37° 46′	334° 21′	+45.6°	50.9°	mag.	»	21	1957 X-XII; 1958; 1959 I-VI	8-9	18-04
Kakioka	Ka	+36° 14′	140° 11′	+26.0°	206.0°	tel. & mag.	»	15	1957 X-XII; 1958	tel: 9-10 mag: 8-9	t 23-02 m 21-02
Simosato	Ss	+33° 35′	135° 56′	+23.1°	202.3°	mag.	»	30	1957 VII-XII; 1958; 1959	9-10	23-24
Kanoya	Ky	+31° 25′	130° 53′	+20.5°	198.1°	»	»	24	1958; 1959	9-10	22-01
Quetta	Qu	+30° 11′	66° 57′	+21.6°	139.7°	»	»	23	1957 IX-XII; 1958 I-IX, XI-XII; 1959 I-V, VII, IX-XII	7-8	17-01
Tamanrasset	Ta	+22° 48′	5° 31′	+25.4°	80.6°	»	»	29	1957 VII-XII; 1958 I-IX, XI-XII; 1959	5-6; 12-13	17-24
M' Bour	MB	+14° 24′	343° 03′	+21.3°	55.0°	»	»	16	1958 IX-XII; 1959	13-14; 8-9	21-02
Ghana	[Gh]	~ +6.5°	~ 395.5°	~ +10 1/2°	~ 70°	tel.	—	—	Combined curve only	19-20; 9-11; 5-6	03-04
Paramaribo	Pa	+ 5° 50′	304° 50′	+17.0°	14.5°	tel. & mag.	continuous	22	1957 VII-XII; 1958; 1959 I-IV	17-18; 5-6	23-03
Bangui	Ba	+ 4° 26′	18° 34′	+ 4.6°	88.5°	»	»	12	1958	17-19; 6-7	24-02
Hollandia	Hn	− 2° 30′	140° 30′	−12.5°	210.3°	»	»	21	1957 VIII-XII; 1958; 1959 I-IV	17-18; 13-14; 10-11	22-03
Port Moresby	PM	− 9° 26′	147° 13′	−18.7°	218.0°	mag.	»	3	1959 X-XII	6-7; 13-14	24-02
Apia	Ap	−13° 48′	188° 14′	−16.0°	260.2°	»	»	23	1957 VIII-XI; 1958; 1959 I-VII	12-13; 7-8	01-02
Watheroo	Wa	−30° 19′	115° 53′	−41.8°	185.6°	»	»	19	1957 VIII-XII; 1958; 1959 I-II	14-15	20-03
Hermanus	Hr	−34° 26′	19° 14′	−33.7°	81.7°	»	»	30	1957 VII-XII; 1958; 1959	13-14	21-02
Kerguelen	Kg	−49° 21′	70° 15′	−57.2°	128.0°	tel. & mag.	selected hours	6	1957 IX-XII; 1958 I-II	(10-11; 16-17)	(01-04)
Oasis	Oa	−66° 06′	92° 09′	−77.4°	160.8°	tel.	continuous	17	1957 VIII-XII; 1958	12-13	18-06
Mirny	Mi	−66° 33′	93° 00′	−77.0°	146.5°	»	»	30	1957 VII-XII; 1958; 1959	13-14	21-05
Charcot	Ct	−69° 23′	139° 01′	−78.3°	234.5°	mag.	selected hours	10	1958 III-XII	(6-7; 4-5; 10-12)	(23-24)

remaining observatories, with due precautions, just to confirm or question these results. In this way the data of the Ghana and Leningrad Observatories, for which we have only the over-all curves presented at the Utrecht Symposium, may be utilized either directly or for comparison with other data here presented and discussed [1, 2].

In his above-cited paper, Father Cardús deals primarily with the local-time dependence of the diurnal frequency variation of hours with pc's at the different observatories and the influence thereon of the seasons (Lloyd seasons). For our part, we shall limit ourselves to noting certain features of the said occurrence-frequency curves at primarily the equatorial observatories, features which appear to confirm the phenomenon exhibited in the Ghana curve.

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Everywhere, save for a few exceptions, occurrence-frequency curves of hours with pc's take the form of a simple diurnal wave with the maximum between 7 hrs and 15 hrs LT (on the average a little before 10 hrs LT) and the minimum around midnight. Only at Tromsö is the maximum set back to between 2 hrs and 3 hrs LT, but this is a very uncertain finding, because of the scanty data from the observatory in question. Indeed we only have to add, to the data utilized, the data for the first three months of 1960 (all that have been received later than 31 December, 1959) to see that the maximum tends to stretch out to a later hour; it no longer lies between 2 hrs and 3 hrs, but between 2 hrs and 4 hrs.

The few exceptional observatories with pc frequency curves departing from the usual form and showing more than one maximum are the following:

Higher latitudes, north:-

Tiksi Ti, Lovozero [Lz], Leningrad Ln.

Equatorial or subequatorial:-

Tamanrasset Ta, M'Bour MB, Ghana [Gh], Paramaribo Pa, Bangui Ba, Hollandia Hn, Port Moresby PM, Apia Ap.

Higher latitudes, south:-

Kerguelen Kg, Charcot Ct.

The three [northern] observatories Tiksi, Lovozero and Leningrad have the principal maximum in the morning hours (at 6-7, 4-5 and 5-6 hrs respectively). The same thing seems to occur at Charcot, but this station has to be discarded because of the extreme variability of the actual number of times that pc's have been recorded at various hours of the day; the resulting hourly values are therefore hardly comparable. On the same grounds the Kerguelen curve must be omitted from our study. For two out of the three [northern] observatories above mentioned, namely Lovozero and Leningrad, the double-maximum phenomenon had already been pointed out by Afanasieva [2]. She attributed it to the presence of a highly ionized region in the upper atmosphere during the first hours of the morning in the high latitudes, the electromagnetic oscillations of which would manifest themselves in magnetic and earth-current pc's

at the earth's surface, just as the regular maximum occurring shortly before noon would be the consequence of another region of the same nature located in the illuminated hemisphere of the earth above the lower latitudes. The morning maximum at Tiksi would confirm this explanation, but against it one may cite the existence of other polar-region pc curves having a single maximum at a later hour (for example, Tikhaya Bay BT, Barentsburg [Bb], Cape Cheliuskin CC). Another difficulty is that in the lower latitudes there are observatories having this maximum at a relatively early hour intermingled with other observatories having the maximum at a late hour, and all without any detectable law of geographic distribution. Moreover as regards Lovozero one should not forget the effect on the morning maximum that here may be exerted by the pc's of period T ~ 5-15 seconds, which according to Mme Troitskaya [3] obey different laws from the rest of pc's, of period T ≥ 20 seconds.

Figure 1 shows the frequency curves of hours with pc's at the eight remaining observatories [equatorial and subequatorial]. To facilitate comparison all these curves have been plotted in local time, and the scales have been so chosen that the amplitudes in the graphs are all of the same order. The units employed are, in the Ghana curve, percentages; in the remaining curves, the absolute number of hours with pc's recorded at each observatory during all the months for which data have been received. We have previously noted that such curves have only a purely qualitative value, but in our opinion they suffice for comparing the hours of the respective maxima and for deducing therefrom the real differences of diurnal regime for pc's in the different regions of the globe. The adoption of more suitable units, permitting comparison of the curves from the quantitative viewpoint also, turns out to be extremely difficult, for we have only to compare the data lists for one and the same month at different observatories, and sometimes even those of different months at the same observatory, to show that at different places no very definite, unique criterion is forthcoming, and indeed not always any such criterion even at the same place. Nevertheless for anyone who prefers it so, we add to Figures 1 and 4, in parentheses, the percent equivalents of the scale values, calculated with respect to the total hours recorded at each observatory. In Figures 2 and 3 the equivalent percentages are not shown, but they are the same as in Figure 1. All the months are taken as having 30 days, and no account has been taken of individual gaps in the records; it does not seem necessary to seek any such degree of refinement, in view of the already stated intrinsic uncertainty of the data.

Returning to our examination of the curves, we immediately notice that the [equatorial] Paramaribo, Bangui and Hollandia curves have their principal maximum about sunset, and thus strongly resemble the Ghana curve, the principal maximum of which extends from 17-18 hrs to 19-20 hrs local time. On the other hand the [subequatorial] Tamanrasset, M'Bour, Port Moresby and Apia curves, although they also exhibit two very definite maxima, nevertheless have them at the normal hours for the morning and midday maxima as seen in the world-wide generality of pc curves. To be sure, in the Tamanrasset, M'Bour and Port Moresby curves there is a hint of a secondary maximum in the final hours of the afternoon or the early hours of the night; yet these additional features are so tenuous that it is impossible to speak of secondary maxima in any proper sense, and moreover, if to the data for the time-period here utilized we add those recorded in 1960, the said hints of secondary maxima come out still more vaguely.

Let us briefly consider the two groups of curves, equatorial and subequatorial.

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1) The curves for Paramaribo Pa, Bangui Ba, and Hollandia Hn. The first and third are curves of exclusively earth-current pc's. In the Bangui curve (Fig. 1) we were under the necessity of including both earth-current and magnetic pulsations, though taking the first as norm. The data are given by this observatory in combined form, not specifically separated; nevertheless, since in many cases the period and amplitude of the two components (earth-current pc's and magnetic pc's) were indicated, the rule which we adopted for plotting the curve was to utilize only the cases in which earth-currents were specifically mentioned and those in which there was no explicit mention of either component (thus giving one to suppose that the phenomenon appeared in all curves). That is to say, we excluded the cases in which there was specific mention of magnetic pc's only. As regards the Paramaribo and Hollandia curves, another point is to be noted. From simple inspection of the lists of pt's and pc's at these stations it is immediately perceived that in spite of the same terminology being employed, the classification at these observatories was in fact made on the basis of a criterion different from that formulated by the Committee. But thanks to the fact that, along with the beginning and ending times for the phenomenon was a whole and for its most conspicuous characteristic intervals, the periods and amplitudes for each case are faithfully given, it proved possible to rework the classification in accordance with the general norm, and thus recover the data entire. In order to avoid all subjectivity, we traced the curves, first taking as pc's only the pulsations of period T ~ 20-35 seconds and of duration not less than 2 hrs, then taking as pc's all pulsations of period T ~ 10-50 seconds without any lower limit of duration. As one may see in the case of Paramaribo (Fig. 1) the two curves, the first in the form of a solid line and the second dotted, are clearly of the same form, the sole appreciable difference being the higher value of some ordinates, with consequent accentuation of some traits and a slight drift of the second curve's principal maximum toward a later hour. The seasonal curves in Figure 2 correspond to the first of these cases.

The comparison of these three curves with the Ghana curve seems to establish very well the reality of the principal maximum at about sundown in earth-current records from the equatorial regions. Although Ghana and Bangui are quite near to each other, Paramaribo and Hollandia are sufficiently distant from the first two observatories, and sufficiently distant from each other, to make the circular arc Pa-[Gh]-Ba-Hn extend over more than half the terrestrial equator (about 200° of longitude). We say "maximum around sundown" and not "night maximum" because in the equatorial zone the sun sets about 18 hrs LT all year round. In the Ghana curve and likewise at Paramaribo and Bangui a second maximum is observed about the hour of sunrise, a maximum that either does not exist in the Hollandia curve, or gives some hint of existing one hour earlier. On the other hand, in the Hollandia as in the Ghana curve there is the midday maximum, which is absent in the Paramaribo curve and only lightly hinted in the Bangui curve.

As for the influence of the different seasons on the times of the maxima (Fig. 2), all we can say is that at Bangui there is a somewhat greater separation between the morning and evening maxima in the summer solstice months, in

perfect agreement with the effect reported by various authors [4] for higher latitudes --- namely, a summer decrease and a winter increase in the number of hours without pc's. At Paramaribo and Hollandia, on the other hand, the seasonal effect on the time of the evening maximum is well marked. It is the equinoctial months (dashed line) and the summer solstice months (solid line in the Paramaribo graph and dotted line in the Hollandia graph *) that are responsible for this effect; the winter solstice months on the other hand have scarcely any influence at Hollandia, while at Paramaribo they tend to make the evening maximum earlier. As for the morning maximum, at Paramaribo it is retarded a little in winter, in the same way as is observed at Bangui; this maximum is practically non-existent at Hollandia. We have already noted that at Paramaribo there is no trace of the midday maximum recorded in Ghana; at Hollandia this maximum shows up between 9 and 11 hrs LT in summer and winter, and between 13 and 14 hrs LT at the equinoxes, although in the latter case the rise starts from 9 hrs LT, and is reinforced between 11 and 12 hrs LT.

2) The Tamanrasset, M'Bour, Port Moresby and Apia curves. All four (Fig. 1) are for magnetic pc's. The Port Moresby curve is based on such brief data (three months, October to December 1959) that it is indispensable to supplement it with later data to see whether the presence of the double maximum is confirmed for the whole of the year, or whether it is just accidental, or belonging only to that part of the year that is represented, more or less, in the curve. The last curve in Figure 4 shows that if we add to the data for the last three months of 1959 the data for the year 1960, the morning maximum becomes much more pronounced and on the other hand the midday maximum tends to disappear; here it is of interest to point out that it is not from any mutual compensation between individual seasonal curves --- though these are not shown [for Port Moresby] --- that the shape of the annual curve results; the seasonal curves all exhibit the same course of diurnal variation. The difference between the two maxima also tends to diminish in the M'Bour curve (Fig. 1) when the 1960 data (Fig. 4) are added to the antecedent data. On the other hand it is not possible to know what would happen in the Apia curve, because no pc data for the year 1960 have been received from this observatory. It remains to point out that the minimum or dip in the late morning hours both at Apia and M'Bour (Fig. 1) is due to the influence of the equinoctial months and winter solstice months (Fig. 3); in the curves for the summer solstice months the tendency is evident, at both stations, for the double maximum to disappear, leaving only the principal maximum in the early afternoon hours.

At Tamanrasset what happens is quite different. The addition of the 1960 data (Fig. 4) accentuates the features of the curve of Figure 1, making it obvious that we are dealing with a real effect. Particularly noticeable (Fig. 3) is the persistence of the inversion of the summer curve, with night values much higher than those during the day (though this means that we cannot properly speak of an evening maximum distinct from the morning maximum). The first part of the summer curve, until 16 hrs LT, fairly well reflects the shape of the annual curve and the curves for the other two seasons, but from then onward there is a steady increase which makes this curve definitely inverted with respect to the other three, thus confirming the observation

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* The curves are marked in the same way with respect to the groups of months, but the seasons are opposite at Paramaribo (northern hemisphere) and Hollandia (southern hemisphere). [Translator.]

[about night maxima at certain seasons of the year] made by Rev. Father Cardús at the Utrecht Symposium, to which we have referred at the start of this paper. It will not be superfluous to note that among the magnetic observatories here studied, Tamanrasset is the only one at which the recording is carried out with inductive loops, that is, in a manner more similar to that of earth-current recording.

Summarizing what has been said, we believe the following conclusions are adequately established:

1) In the equatorial regions the curves of frequency of hours with pc's, in the earth-current records, exhibit a diurnal variation different from that which they generally have at higher latitudes.

2) It seems clear that they exhibit their principal maximum around sunset.

3) It seems likewise proved that in the Tamanrasset magnetic records there is, during the summer solstice months, a clear predominance of nocturnal pc's, with the minimum occurring in the early afternoon hours.

A more thorough study of the question would require that we have much more data at our disposal and that we be more certain of the homogeneity of the data. On this account:

4) It is to be desired that all observatories in the equatorial zone should record magnetic and earth-current pc's with equipment and procedures as uniform as possible, and should send their data regularly to Committee No.10 of the IAGA.

5) It is likewise advisable that from now on the limits of the pc periods should be broadened to 5 and 90 seconds, and that one should show separately the data corresponding to the three types of pc's defined by the Helsinki Assembly, namely, regular pc's of period T ~ 5-15 seconds, regular pc's of period T ~ 20-40 seconds, and irregular pc's of period T ~ 50-90 seconds, it being understood that the period is not that of the principal pulsation, but the dominant period.

As we see, the obscure points in the study of pc's are numerous, and their nature is such that it is only by close collaboration between observatories that we shall ever elucidate them. Indeed in the above consideration of the problem our object has been only to indicate the reality of the difficulties, even as regards points that appear well established, and to make clear the necessity of the closest and most orderly collaboration in the continuing study of these problems.

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Equatorial

Subequatorial

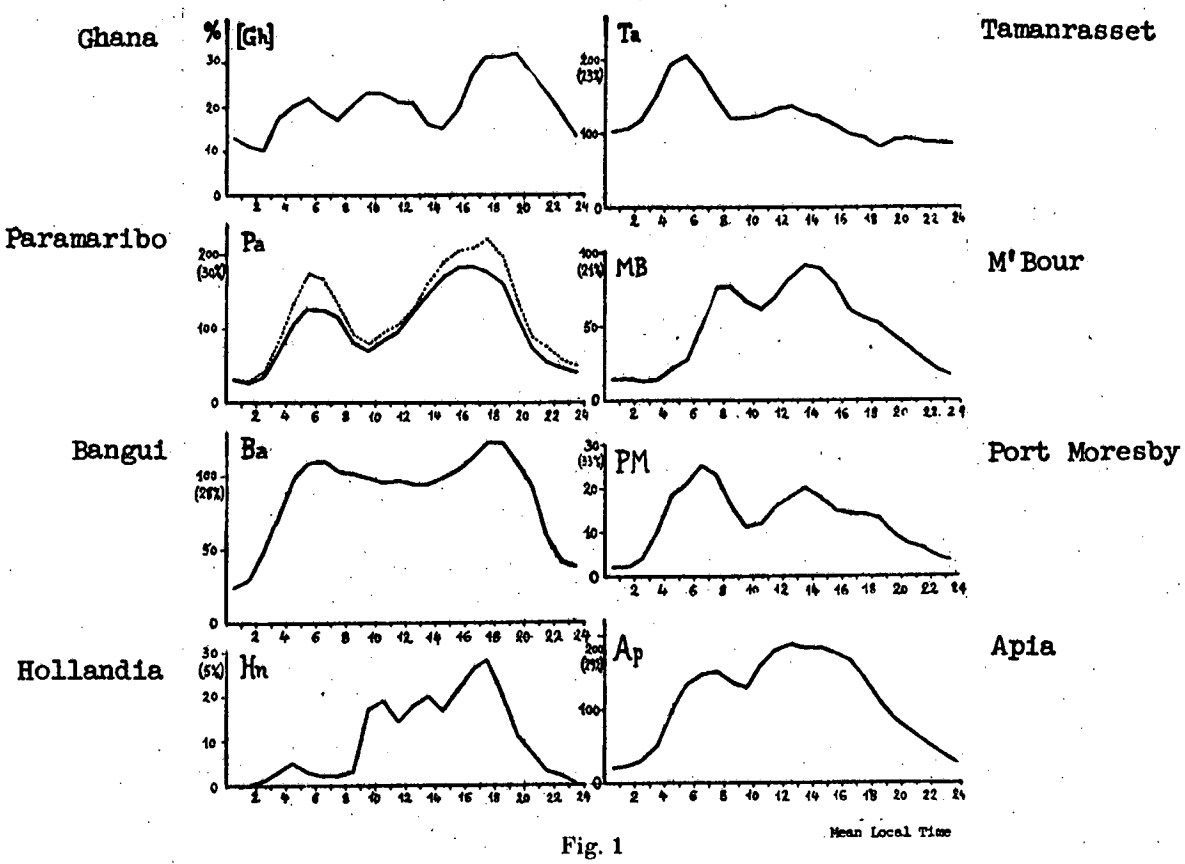

Fig. 1

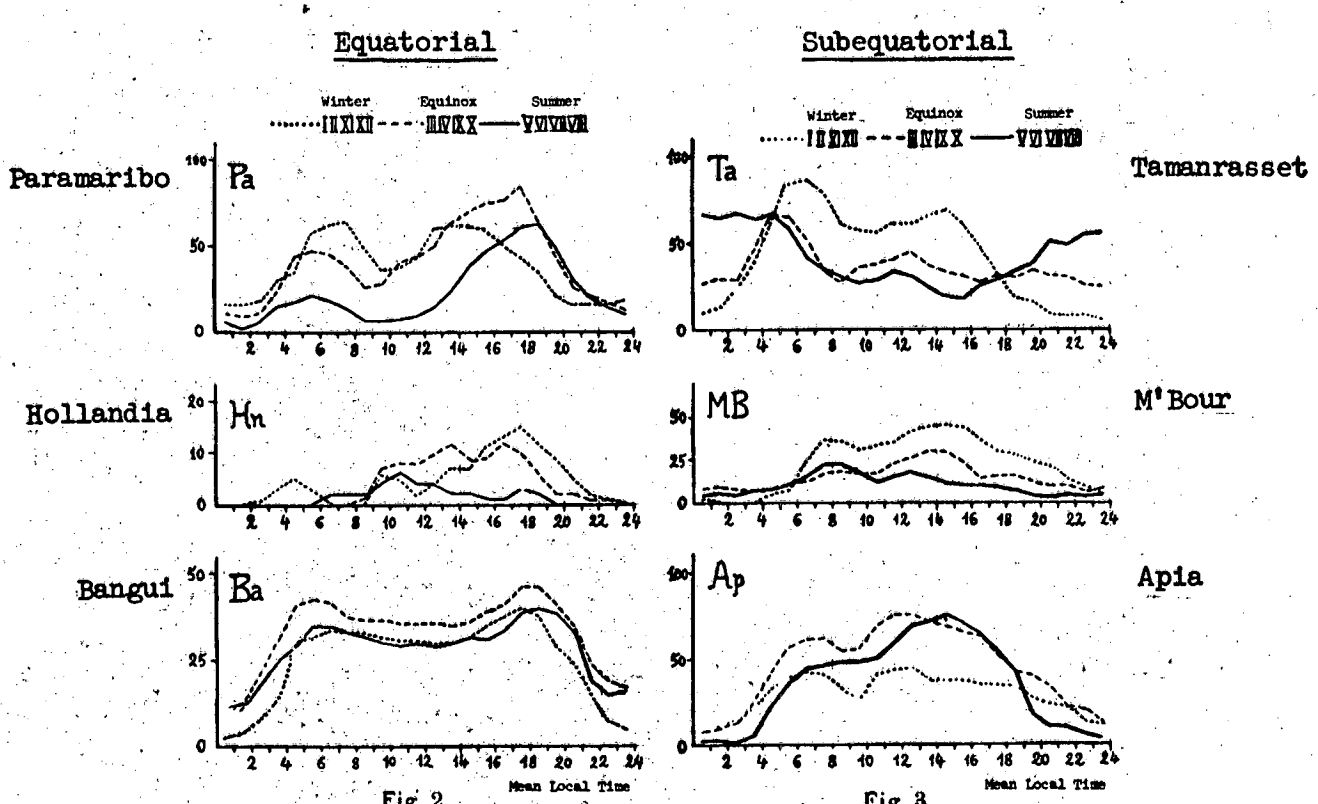

Fig. 2

Fig. 3

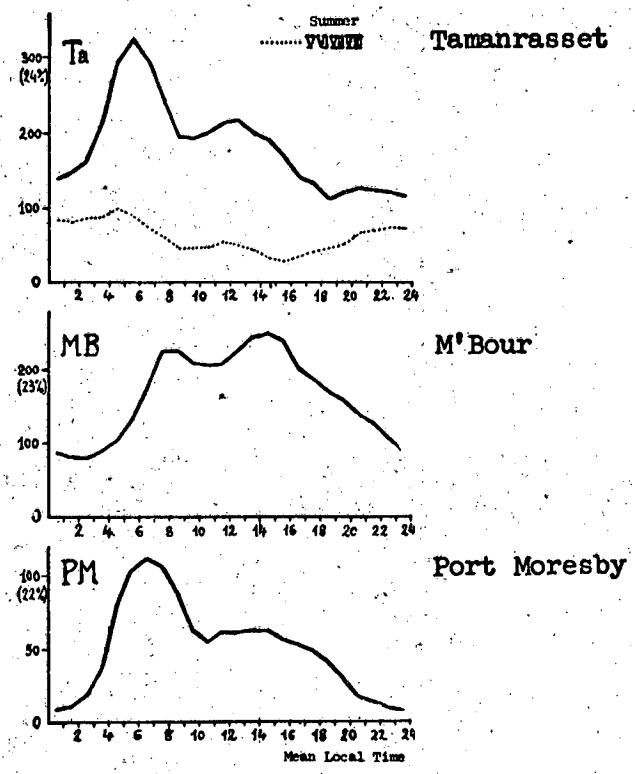

Fig. 4