5) Y. Kato and T. Saito: J. Geomagn. Geoelectr. **10** No. 4, (1959).
6) Y. Kato: Sci. Rep. Tôhoku Univ., Ser. 5, Geophys. **11** August (1956).
7) A. J. Desseler, W. E. Francis and E. N. Parker: J. Geophys. Res. **65** No. 9, September (1960).
8) V. A. Troytskaya: J. Geophys. Res. **66** No. 1, January (1961).
9) J. Bouška: Studia Geophys. et Geod., **5** (1961) 179.

Discussion

Saito, T.: I think dotts of *ISc* plotted against *ASc* do not distribute on such a fine linear belt, but very scattered. For example, the ratio *ISc*/*ASc* is very large in the case of gradual commencement of the storm, while it is small at the time of sharp beginning which often follows the severe storm.

Bouška, J.: I am aware of the facts that the relation in the figure is slightly idealized by the selection of storms. Only best registered and apt to be analyzed *Sc* were selected. The dependence is most simple and requires a detailed investigation using a greater number of first-class quick-run magnetograms. However the positive correlation is clear.

JOURNAL OF THE PHYSICAL SOCIETY OF JAPAN Vol. 17, SUPPLEMENT A-II, 1962
INTERNATIONAL CONFERENCE ON COSMIC RAYS AND THE EARTH STORM Part II

II-1B-P1. Geomagnetic Rapid Variations during IGY and IGC

A. ROMAÑÁ, S. I. and J. O. CARDÚS, S. I.
Observatorio del Ebro, Tortosa, Spain

This paper is simply a presentation of some of results which can be obtained with the monthly data sent to IAGA Com. 10 on Geomagnetic Rapid Variations for the period of IGY and IGC (July 1957-December 1959).

The phenomena reported are: 1) pulsations (*pt*) and bays, 2) storms sudden commencements and sudden impulses, 3) solar flare effects and 4) pulsations from rapid run magnetograms (*pt* and *pc*).

We shall not deal with solar flare effects because the data reported are too incomplete and we shall not say anything about storm sudden commencements because the hour of occurrence of them have been already reported and no new feature, as daily or seasonal variation could be derived from the existing material.

§1. Trains of Pulsations (*pt*)

In this statistical study of *pt*'s we deal only with *pt*'s reported from normal magnetograms. There have been 70 observatories reporting *pt*'s as separate from bays and there seems that a uniform criterion for selection has not been applied: some observatories have only reported 1, 2 or 3 *pt*'s in 30 months and others have given 670 and 543 for the same period.

The geographical distribution is shown in Fig. 1 (underlined symbols). The observatories are distributed into 8 latitude zones in accordance with their geomagnetic latitude as recommended for the IGY:

polar stations	$L \geqq 60$
subauroral	$45 > L > 60$
minauroral	$20 > L > 45$
equatorial	$0 > L > 20$

and following their local time. As it is immediately seen, there is still a great majority of stations in the northen hemisphere (49 in the North and 21 in the South) and some latitude zones are very poorly represented.

We have studied the daily distribution of *pt*'s: we plotted for each observatory the

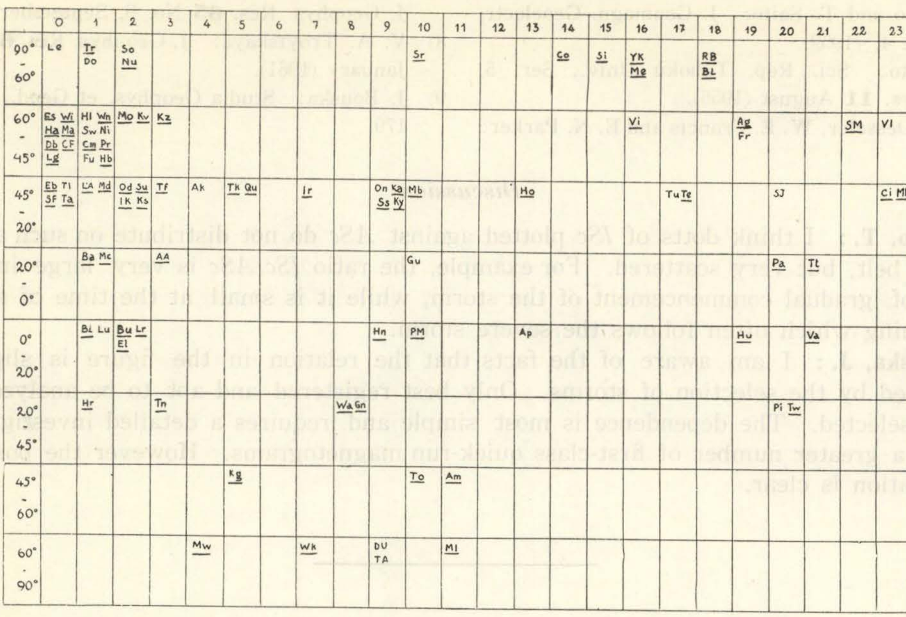

Fig. 1. Geographic distribution of observatories reporting bays and *pt* (underlined)

Table I.

	North		South	
	hour of maximum	angular coefficient	hour of maximum	angular coefficient
Polar stations	×	×	×	×
Subauroral stations	22.7	−1.01	×	×
Minauroral stations	21.6	−0.60	24.6	−1.12
Equatorial stations	22.0	−1.00	23.5	−1.02

hours in which they reported a *pt* and we combined these data for each of the 8 zones and 24 different local times. Adding conveniently these plots it was possible to get for each local time and latitude's zone the daily variation of *pt*'s. The curves show always a local night maximum and in order to get a clearer idea of the hour of maxim occurrence we plotted for each zone the hour of maximum against universal time and it was easy to calculate the regression line which gives the hour of maximum for each zone in local time. These times are shown in Table I. We added the angular coefficients because they give an indication of the accuracy of the determinations: if all the hours were as they should be, the angular coefficients would be in every case −1.

The results show some variations from zone to zone, but we think that in some zones the number of *pt*'s reported is too

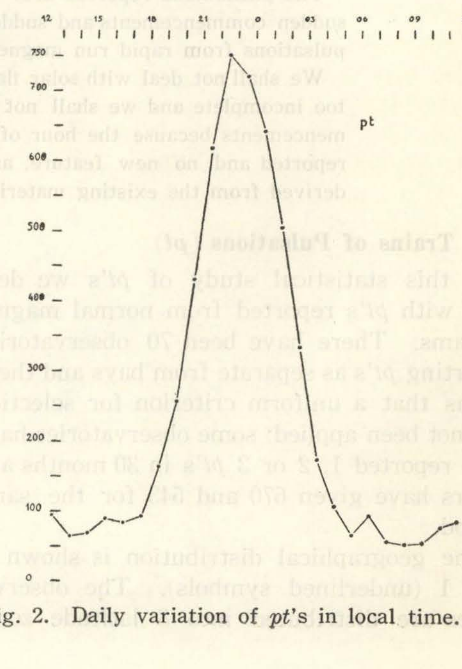

Fig. 2. Daily variation of *pt*'s in local time.

small to draw any significant result as for the variation of the hour of maximum with latitude.

The predominance in the night of the *pt*'s is better illustrated by Fig. 2 obtained adding the daily variation of *pt*'s for each observatory in local time; it is clear that from 06^h to 18^h the number of *pt*'s reported is absolutely insignificant.

This result of the night predominance of *pt*'s is not a new one, but will be useful in the discussion of the results of bays which will follow.

§ 2. Bays

Bays were formerly reported as polar sudden commencements (*psc*) because they are closely associated with the polar elementary storms, but for the IGY it was considered that they should be reported in accordance with their different form of appearance: bays without pulsations (*b*) (only in case they were of class A): bays without pulsations but with a sharp beginning (*bs*), bays with pulsations (*bp*) bays with pulsations and with a sharp beginning (*bps*).

As a whole there is an overwhelming majority of *bp* and practically only a few *bps* and *bs*; no indications can be drawn from the data sent to Com. 10 of the relative predominance of bays without pulsations (*b*) because only the very clear cases (A) are reported.

There were 91 observatories reporting bays but some of them did not give the signs in the three components and a few of them reported them only as bays (*b*) without classification into *b*, *bs*, *bp* and *bps*.

The geographical distribution is shown in Fig. 1; the distribution is similar to the one adopted for *pt*'s. There is still a greater predominance of observatories reporting bays in the northern hemisphere than in the case of *pt*'s (67 in the North and 24 in the South), but, on the other hand, it is pleasant to see the relative great number of polar stations reporting regularly into Commitee 10 (6 in the North and 5 in the South).

The number of bays reported varies greatly from observatory to observatory, (*e.g.* Tt, 4 bays; C.F, 500), and it is just impossible from such inhomogeneous data to find whether there is some privileged zone on the earth where bays are more frequent.

In order to study the daily variation in the frequency of bays we used the same method as for the *pt*'s. In Fig. 3 we give the plottings done with the hours of maxima for each zone of latitude, north and south hemispheres and the whole earth. The numerical values are shown in Table II.

We think, as in the case of *pt*'s that the results are too uncertain in some cases to draw from them any accurate deduction about changes in the hour of maximum with latitude.

In Fig. 4 we give the daily variation of all the bays reported (11,952) added in accordance with their local time. The maximum occurs in the interval 22-23, which is slightly different from the one we have calculated before; the reason is the different method used in the calculation; in Fig. 5 we added all the bays given by all the observatories and it gives greater emphasis on those observatories which reported a greater number of bays, but in Fig. 4 the hour of maximum for each zone and local hour are considered separately and therefore they have the same statistical value independently from the number of bays which enters in the calculation.

Table II.

	North		South	
	hour of maximum	angular coefficient	hour of maximum	angular coefficient
Polar stations	22.4	−0.94	−02.3	−1.28
Subauroral stations	22.0	−0.96	23.0	−1.00
Minauroral stations	23.2	−1.05	23.6	−1.03
Equatorial stations	24.3	−1.18	23.2	−1.03
Total	23.2	−1.00	24.1	−1.07
Whole earth	hour of max.	23.5	ang. coeff.	−1.02

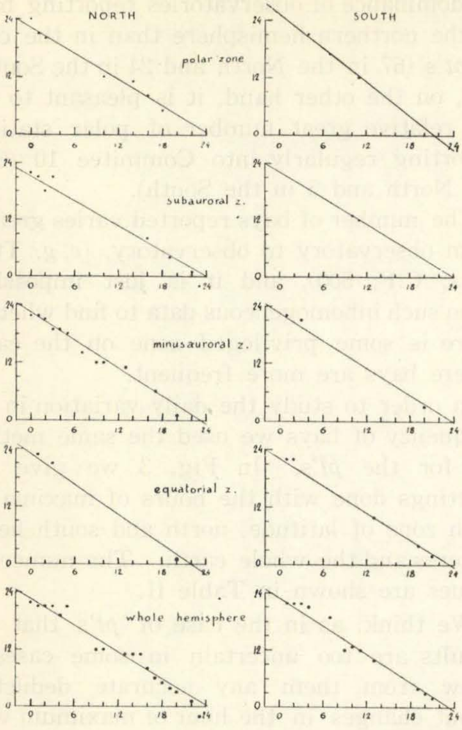

Fig. 3a. Hour of maximum of bays by zones and hemispheres.

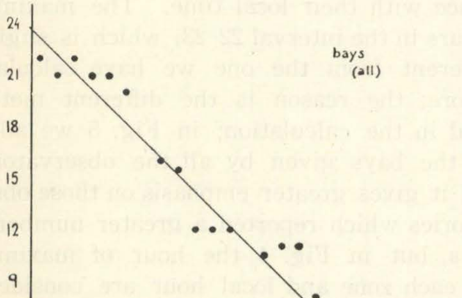

Fig. 3b. Hour of maximum of bay, whole earth.

It may be worth noting that the hour of maximum deduced with these data is similar but slightly different from the one we obtained before with data from many observatories in the period 1955-1957; then the hour calculated was 22.9±0.3 and now it is 23.5. A reason for the difference may be that then we used each observatory as a single value

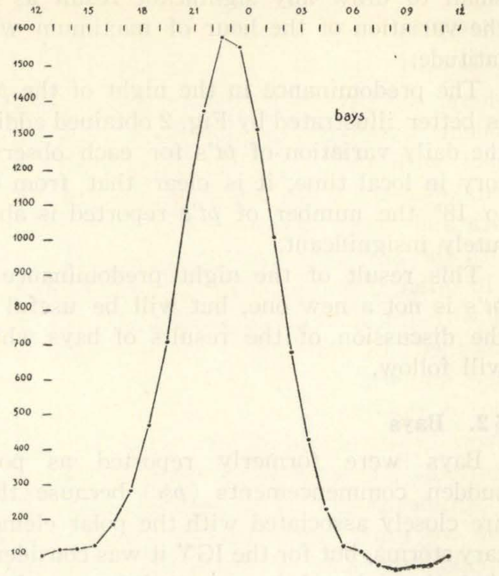

Fig. 4. Daily variation of bays in local time.

and we plotted them separately in accordance with the precise longitude of the observatory and now we have considered all the observatories having the same local time together and we have plotted them jointly as a single value. Another reason may be also that the hour of maximum occurs really around midnight, but its hour changes slightly; as a matter of fact we found that, using the *psc*'s data of the IAGA Bulletins No. 12, the hour of maximum occurrence for the years 1950 to 1954 were: 20-21, 19-20 and 22-23, 21-22, 20-21, 22-23; and combining the results of the five years, the maximum was in the interval 22-23 h.

The Bays in the Horizontal Plane. Many authors have studied the average characteristics of geomagnetic bays and from them it is easy to deduce some picture of how a bay appears and decays. In the data sent to IAGA Commitee 10, the signs of the bays in the three components are usually given although some observatories very seldom or never report them.

It was considered of interest to study with these data the behaviour of the bays in the horizontal and in the vertical plane.

Princep for the bays at Tortosa and afterwards Rougerie for those of Val-Joyeux, Romañá for Mexico and again Princep for Cheltenham, Tucson and San Juan have shown that geomagnetic bays appear in the horizontal plane in a given order

D DH H HD′ D′ D′H′ H′ H′D

where the stroke means a negative component: these results are in very good agreement with the vector diagrams obtained by Hatakeyama for the bays observed at Toyohara and with the results obtained by Steiner with the bays at O'Gyalla and others.

In order to see what result could be obtained with the data of Com. No. 10 we have classified all the bays in accordance with their signs in the horizontal plane and when one of the signs was doubtful (either not given or given as $\pm$ or $\mp$) the datum was omitted. These data were also divided into 8 latitude zones and 24 local hours columns and we draw the curves for each of the groups. In most of the cases the resulting curves did not show any clear maximum due to small number of data which entered in every group; nevertheless in the northern zone it was possible to find for three of the zones the probable hour of maximum occurrence of a number of types of bays and they were

auroral zone		subauroral zone		minauroral zone	
HD′	$21^h.7$	HD	$20^h.6$	D	$20^h.0$
HD	22 .0	D	21 .0	HD	22 .2
H′D	23 .1	H	22 .0	H	22 .3
H′D′	24 .1	HD′	23 .5	HD′	1 .0
		H′D′	24 .0	H′D	18 .5
		D′	01 .3		
		H′D	17 .0		

As we see in the case of the minauroral zone, the succession of the types of bays is just the one found by other authors and in the case of the subauroral zone the order is almost the same with only the change of HD before D, but practically both at the same hour (20.6 and 21) and the change of D′ after H′D′ which is not very significant due to the small number of bays which entered into the computation; in the auroral zone there is also the change of HD′ and HD, but again they appear almost at the same time (21.7 and 22.0).

As we wanted to see whether these results could be extended to the other data we combined in local time all the bays reported for each of the 8 types and we found their daily

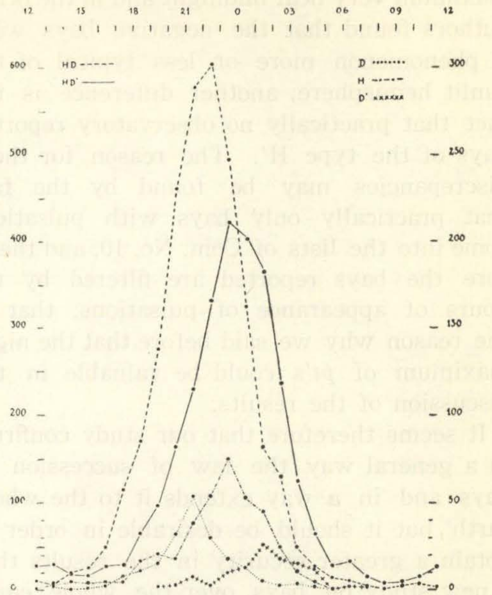

Fig. 5. Daily variation of positive bays in local time.

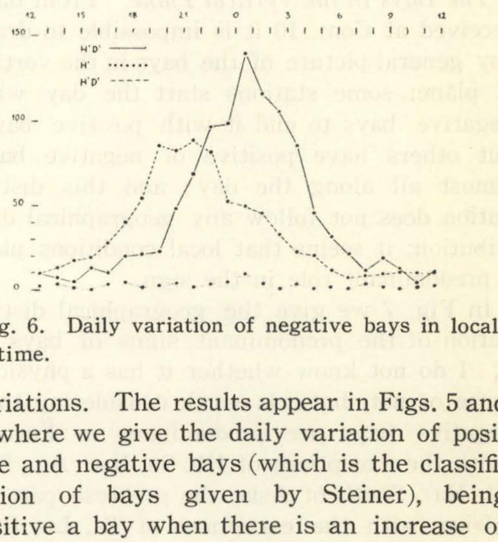

Fig. 6. Daily variation of negative bays in local time.

variations. The results appear in Figs. 5 and 6, where we give the daily variation of positive and negative bays (which is the classification of bays given by Steiner), being positive a bay when there is an increase of H, and negative when there was a decrease.

As we see the positive bays appear in the order found by other authors

D HD H HD′ D′

and the negative bays

H′D H′D′

with no maximum in the case of H′.

Although these results show good agreement with other investigations there are some striking differences which must be pointed out: In our study with data of Com. No. 10 almost all the types of bays have their maximum very near midnight and in the other authors found that the negative bays were a phenomenon more or less typical of the sunlit hemisphere; another difference is the fact that practically no observatory reported bays of the type H′. The reason for these discrepancies may be found by the fact that practically only bays with pulsations come into the lists of Com. No. 10, and therefore the bays reported are filtered by the hours of appearance of pulsations; that is the reason why we said before that the night maximum of *pt*'s could be valuable in the discussion of the results.

It seems therefore that our study confirms in a general way the law of succession of bays and in a way extends it to the whole earth but it should be desirable in order to obtain a greater security in the results that a new study on bays over the whole earth was done but without the limitation of pulsated bays.

The Bays in the Vertical Plane. From data received at Com. 10 it is impossible to draw any general picture of the bays in the vertical plane: some stations start the day with negative bays to end it with positive bays, but others have positive or negative bays almost all along the day; and this distribution does not follow any geographical distribution; it seems that local conditions play a predominant role in the sign.

In Fig. 7 we give the geographical distribution of the predominant signs of bays in Z; I do not know whether it has a physical sense or not, but it is worth considering that negative bays are predominant in Europe (with the exceptions of Hb, Su, Kw, Aq, Eb, Vl, Ha), South of Asia, the greatest part of Africa (with the exceptions of Ta, Lu, Ba),

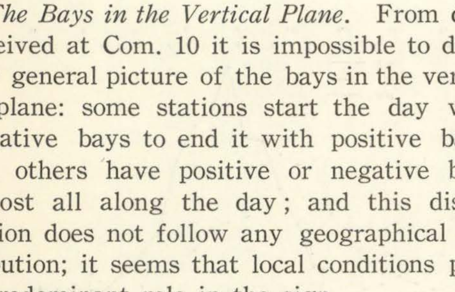

Fig. 7. Predominance of positive or negative bays in the vertical plane.

and North America (except in the northern coast) and that positive sign in Z is predominant in a good part of Asia with Japan, Australia, and South America.

§ 3. Continuous Pulsations

Daily Variations

It is unfortunate that only 23 observatories have reported consistently *pc*'s and that only a very few of them have classified the *pc*'s in accordance with their period.

With the data we had we could only study their daily and seasonal variation without distinguishing polar or equatorial stations or different types of periods.

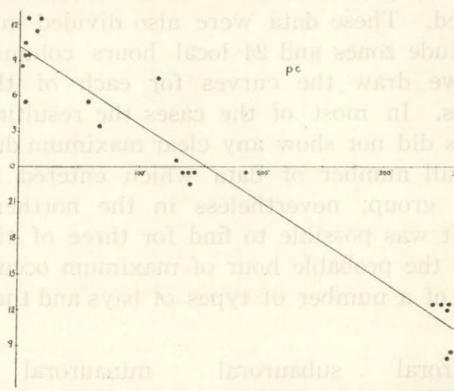

Fig. 8. Hour of maximum of *pc*'s.

The hour of maximum in local time is $10.8^h \pm 0.5$ although there seems to be two predominant hours (Fig. 8) centered roughly at about 8^h and 12^h. If we consider only the observatories at a similar longitude which occurs with most of the European and African ones we could not find any clear change in the hour of maximum with latitude; *e.g.*: Es, Ve, Wn in Europe, MB in central Africa and Hr in South Africa have all of them the maximum in the interval 12–13^h and observatories located between 45° and 55° of latitude north as CF, Ma, Wi, Db, Bu, Ha, Wn, Es and Vl have maxima at the intervals 8–9, 9–10, 10–11, 11–12 and 12–13.

Added all the daily variations in local times we obtain Fig. 9, which shows that the *pc*'s are certainly a phenomenon of the light hours of the day. As in the case of *pt*'s the different methods used in the computations give slightly different times of the maximum, but in both methods the result is that the *pc*'s maximum appears in the late hours of

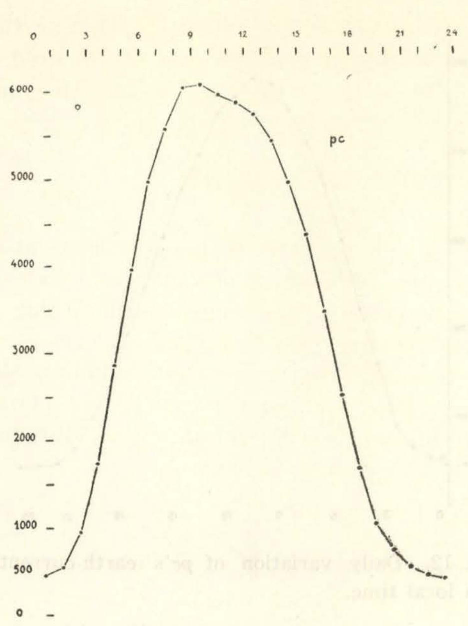

Fig. 9. Daily variation of *pc*'s in local time.

the local morning.

Seasonal Variation

In many cases it has been possible to see the annual variation of the occurrence of *pc*'s using the Lloyd's seasons: the result is that in all cases with a few exceptions the maximum for summer is the greatest, with minimum in winter and middle values for equinoxes. It is a good confirmation of these results the case of Hr and Wa for which summer and winter are inverted as being in the southern hemisphere and the curves show also this inversion. The few cases which do not follow completely this order are Es, Ka and Ap with slightly inhomogeneous data and WB and Ta which appear as if they were southern observatories.

The hour of maximum shows a tendency to appear earlier in summer than in the equinoxes confirming the fact that *pc*'s are strongly ruled by the light hours of the day, but as it is not certain at all that the hour of maximum of the equinoxes appears earlier than the winter one, we prefer not to draw any absolute result of it.

It seems that the difference in the hours of maximum of *pc*'s in different observatories may be due to the fact that not all observatories have the same criterion for selection; it is a pity that not all observatories follow the indication of Com. 10 in reporting the predominant period because we could not select *pc*'s of the same periods. From a quick examination of few cases reported with their periods and from the experience we have at Tortosa there seems to be, as other authors have also pointed out, three different types of *pc*'s: the normal ones with period 15-20^s and fairly regular and these have the morning maximum; *pc*'s of longer period and very irregular: there may appear easily during night hours and usually they precede or follow magnetic disturbances; and finally *pc*'s of shorter periods than 15^s, frequently very regular, which appear during magnetic storms and follow naturally its hours of appearance.

I wish to draw also the attention to the fact (that can be seen by the simple inspection of the lists of *pc*'s given quarterly in the provisional list distributed by Com. 10) that in many occasions the *pc*'s registered in Japan coincide very well with *pc*'s registered in Central Africa.

Earth Currents

We shall deal only with one phenomenon reported by earth-current observatories, namely with *pc*. Prof Thellier at the IAGA Symposium at Copenhagen (April 1957) pointed out that the *E-C* were a very good way of observing short-period pulsations and afterwards the investigations presented at the Utrecht symposium and at the Helsinki General Assembly by Mme. Troitskaya and others have shown how right was Prof. Thel lier's assumption.

Another reason for this work is the small number of magnetic observatories which have sent data regularly to IAGA Com. No. 10 (only 23) and we thought that it may be most interesting to complement these data with the ones from the the *E-C* observatories (29) specially since most of them are located in zones where no magnetic observatory sent regular information.

Its geographical distribution as shown in Fig. 10 is not very good; moreover some of them have only fragmentary data as Vo and Kg and others have not make distinction between magnetic and telluric pulsations; finally some other observatories, as NP, Pa and Hn have used a classification of pulsations different from the one accepted by Com. No. 10. The most homogeneous group is no doudt the group from the USSR observatories

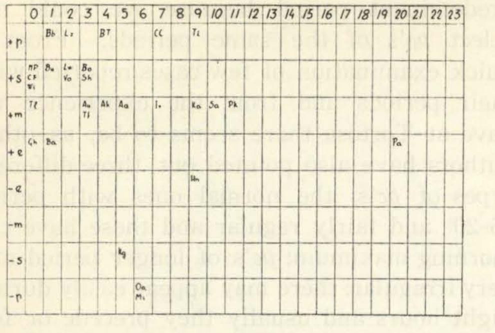

Fig. 10. Geographic distribution of earth-current observatories.

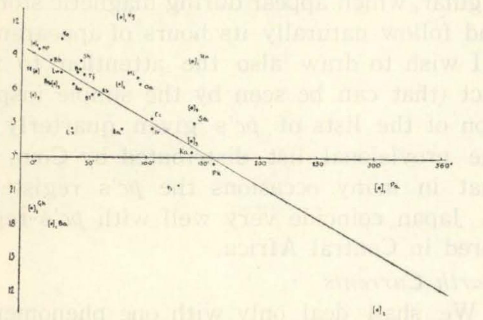

Fig. 11. Hour of maximum of *pc*'s in earth-currents.

(with the exception of Vo) and Ka and Bu.

The symbols used are those adopted by the IAGA in its Bulletins No. 12 and a few new ones for stations which have no symbol yet accepted. When we plot the hour of maximum occurrence of *pc*'s against local time we obtain a figure (Fig. 11) which is comparable with the one we got from magnetic observatories although some special features must be underlined: a) The dispersion is in some cases larger than in magnetism. b) On this may be the cause some observatories present two (and also three) clear maxima which have been plotted into brackets with a small sub-index. The observatories indicated into brackets have not been used in the calculation of the regression line which gives us the hour of maximum occurrence of *pc*'s in local time.

The hour of maximum occurrence is $09^h.2 \pm 0.5$ almost one hour earlier than the obtained for geomagnetic *pc*'s although it is possible to find also two groups of observatories besides the principal with maxima at about 17^h and 12^h LT.

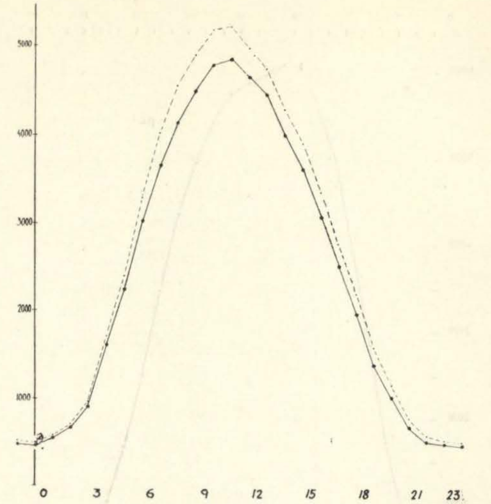

Fig. 12. Daily variation of *pc*'s (earth-currents) in local time.

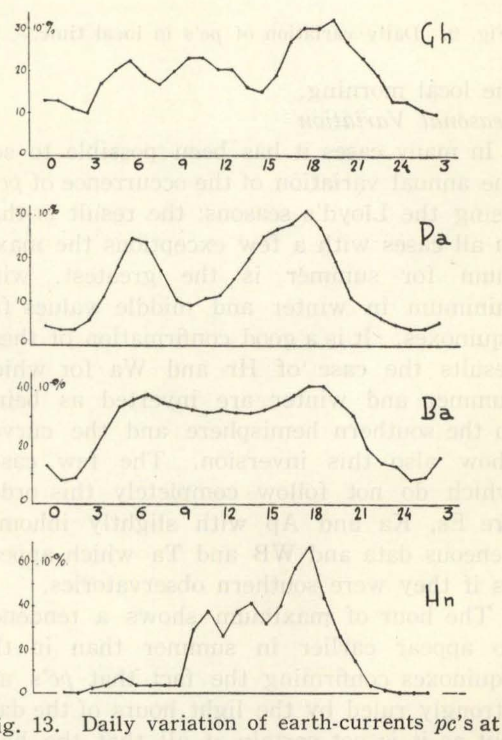

Fig. 13. Daily variation of earth-currents *pc*'s at some observatories, presenting more than one maximum.

As we did for the geomagnetic stations we have added the results of all observatories in LT and we obtained the daily variation of *pc*'s in Earth Currents (Fig. 12). The solid curve is obtained using observatories which report only earth-current pulsations and the dotted curve adding the observatories which report mixed data from earth-current and magnetic records.

The observatories with curves which show more than one maximum are confined to the equatorial zone with the exception of Lz, which as already noted by Mme. Troitskaya at Utrecht shows other peculiar characteristics. In Fig. 13 we present some of these curves in LT. As it is easily seen all these curves present a clear maximum late in the afternoon and this is the predominant one, in many cases there is also a maximum which may be connected with the sunrise (Hn is an exception) and in some cases as in Gh the three maxima appear in the curve.

The existence of the three maxima (or of two) may be due either to the fact that pulsations with different periods are included in the statistics or to a real phenomenon peculiar to the equatorial region. I wish to add that we have only two magnetic observatories reporting *pc*'s in the equatorial zone (PM and Ap). At PM there is a slight indication of the existence of the evening maximum, although the small mumber of *pc*'s reported makes it rather doubtful and at Ap there is no indication of this maximum; I think this feature of the equatorial stations must be investigated more carefully in the future.

JOURNAL OF THE PHYSICAL SOCIETY OF JAPAN Vol. 17, SUPPLEMENT A-II, 1962
INTERNATIONAL CONFERENCE ON COSMIC RAYS AND THE EARTH STORM Part II

II-1B-P2. Characteristics of Geomagnetic Pulsations

J. A. JACOBS

Institute of Earth Sciences, University of British Columbia
Vancouver 8, B.C., Canada

The classification of geomagnetic micropulsations is discussed, and the question is raised of a revision of the definitions of changes in the geomagnetic field over a much broader spectrum. The paper then gives an account of the research, both observational and theoretical, at present being carried out in the field of micropulsations at the Institute of Earth Sciences, University of British Columbia.

§ 1. Introduction

I would like to begin on a philosophical note and to ask in all seriousness why are we interested in rapid variations in the Earth's electric and magnetic fields and whether or not the same information cannot be obtained more easily from other upper atmospheric phenomena? There are a host of such phenomena (such as visual and radar aurora, airglow, whistlers, solar flares, cosmic rays, ionospheric disturbances) which may be lumped together under the title "solar terrestrial relationships", and it is not surprising that correlations should exist between many of these events. In many instances we may be observing different manifestations of what was originally some solar disturbance, but it is not easy to distinguish between what is fundamental phenomenon and what may turn out to be relatively unimportant side issues. Of course, if for example an increase in activity in a certain sub-audio frequency band is found to be a precursor of geomagnetic storms as Maple has suggested, then such a result would be of fundamental importance. But it must not be forgotten that whereas in the laboratory, experiments can be carefully planned and executed with a view to settling definite questions, Nature, on the other hand, is continually making a multitude of "experiments" simultaneously all over the Earth. It is not easy to disentangle all these experiments and to sort out cause and effect—this may require long periods of observation from many stations well distributed over the