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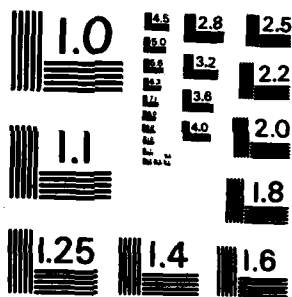   ROQUETAS (SPAIN) IONOSPHERIC SECTION
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SCIENTIFIC REPORT N° 3

PRELIMINARY RESULTS ON TID OVER EBRO

FROM TEC DATA

L. F. Alberca S.I.
J.O. Cardús S.I.
E. Galdón S.I.

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OBSERVATORIO DEL EBRO
IONOSPHERIC SECTION
ROQUETES
(Tarragona) Spain

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FROM TEC DATA

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A

ABSTRACT

Faraday rotation data recorded at the Ebro Observatory in
January 1979 have been analyzed by the maximum entropy method
to obtain the spectrum of TID's travelling through the   sta-
tion. The results indicate that most of the TID's in this
month have periods shorter than 30 minutes and appear only
between 7hr and 20hr UT. Their diurnal variation depends   on
their frequency. A less sophisticated analysis of the data of
the whole year shows a clear seasonal dependence of the   num-
ber, period and diurnal variation of TID's.

CONTENTS

INTRODUCTION.

The studies of the travelling ionospheric disturbances (TID) began long ago with the experimental works of Munro (1948, 1950, 1958), but the theoretical interpretation of TID's dates from paper of Hines (1960) that has become classic. Since then, the hypothesis that TID's are ionospheric manifestations of internal gravity waves in the neutral atmosphere has been progressively confirmed and now is commonly accepted.

TID's have been observed from records of different parameters related to the Ionosphere, obtained by different methods: the reflection height of radio pulses (cfr. Munro, 1958), the Doppler shift produced by changes in the reflection height of radio waves of highly stabilized frequency (Herron, 1974), the Faraday effect on polarized radio waves from beacon satellites (Titheridge, 1971), etc.

An analysis of the data obtained by the different methods seems to indicate that TID's can be divided into two main groups. Perturbations of long period (till 2 and 4 hours)and high horizontal speed (between 400 and 1000 m s^{-1}) appearing as waves of a few cycles (very often only one),and medium scale perturbations, with periods between about 12 minutes and 1 hr and horizontal speeds between 100 and 250 m s^{-1}). This second group can be subdivided into another two:one that consists of train-waves of several cycles,usually in the shortest period band, and another that contains only one cycle of longer period than the former ones.

The sources that produce the different perturbations can also be different. The long period perturbations seems to be caused by Joule heating of the Ionosphere in the auroral zone during magnetic substorms (Chimonas and Hines,1970, Testud, 1970, Titheridge,1971) while several causes have been poin-ted out for the medium scale perturbations besides the Joule hea-

ting of the auroral zone (Francis,1974); for instance: the equa
torial electrojet (Chimonas,1970), meteorological perturbations
in the lower ionosphere (Jordan,1972, Bertin et al.1975) such
as turbulent winds (Tolstoy and Miller,1975). Tornadoes or ty-
phoons (Hung and Smith,1979; Tustsui and Ogawa,1973), etc.,per-
turbations on the low stratosphere circulation (Okuzawa et al.,
1978) the supersonic movement of the solar eclipse shadow (Ber-
tin et al.,1977), nuclear explosions (Row,1967) and other kinds
of artificial excitation (Perkins and Francis,1974), etc.

An important aim in TID's studies is the identification of
their sources. As a previous step to do it in a general way
we shall obtain the daily distribution of TID's according to
their frequency, trying to find the influences of other perio-
dic variations.

METHOD OF ANALYSIS.

We use Faraday rotation data that in our latitude are pro
portional to the total electron content of the Ionosphere along
the day. The data were obtained from the signal of the italian
beacon satellite SIRIO, located at 15º W. The corresponding
subionospheric point for 420 Km ionospheric height was at
37.1ºN, 1.5º W.

Before the analysis of the data, we separate the TID's
from other unperturbed variations (diurnal,etc).Although theo-
retically unnecessary, this separation is most convenient in
order to prevent TID's of being masked by the much larger re-
gular variations.

The period of the unperturbed variation is several times
greater than the periods of TID's, therefore,the unperturbed
variation can be obtained by filtering the data trough a low
pass filter. The TID's are finally separated by subtracting
the filtered curve from the original data.

We used the Alavi-Jenkins (1965) filter. It is a running

weighted mean of the form

$$F_i = \sum_{j=-m}^{m} \frac{1}{2(m+1)} \left(1 + \cos j \frac{1}{m+1}\right) f_{i+j}$$

where f_{i+j} and F_i are respectively the original and final values. The upper limit of the frequencies that can pass the filter depends on the value of m, the filter length. We fixed the filter length m=50 for our work. With this filter length, and taking into account that contiguous data are separated 1.2 minutes, all waves of period less than 100 minutes are eliminated by the filter, while the variation of period greater than 250 minutes remain unchanged.

The m values at both ends of the filtered data are distorted by the filtering and must be eliminated in subsequent analysis. As an exemple, we show in fig,1 the data of Jannuary 1st 1979 between 6h 50m and 21h 10m. The results of filtering the data with different filter lengths (m=10, 50, 60 and 70) appear in fig.2. As can be seen, all perturbations are eliminated with the filters of length m=50 or greater; but in addition to that, the filters of m=60 and 70 produce a too great smoothing of the two diurnal variation maxima.

The perturbations obtained by subtracting the different curves of fig.2 from the curve of fig.1 are shown in fig.3. When the filter length is increased, the low limiting frequency decreases, as expected. Each of the two very sharp peaks that appear in all curves of fig.3 a little before 15 hr and a little before 17hr corresponds to one erroneous datum. We left them in the figure to show the sensitivity of the filter.

The TID's separated from the unperturbed diurnal variation can be analyzed by the simple Fourier method to obtain the periods of the perturbations. Nevertheless this method only gives frequencies that are exact multiple of the fundamental one, corresponding to the analized interval. Therefore a great number of data have to be taken in each analysis
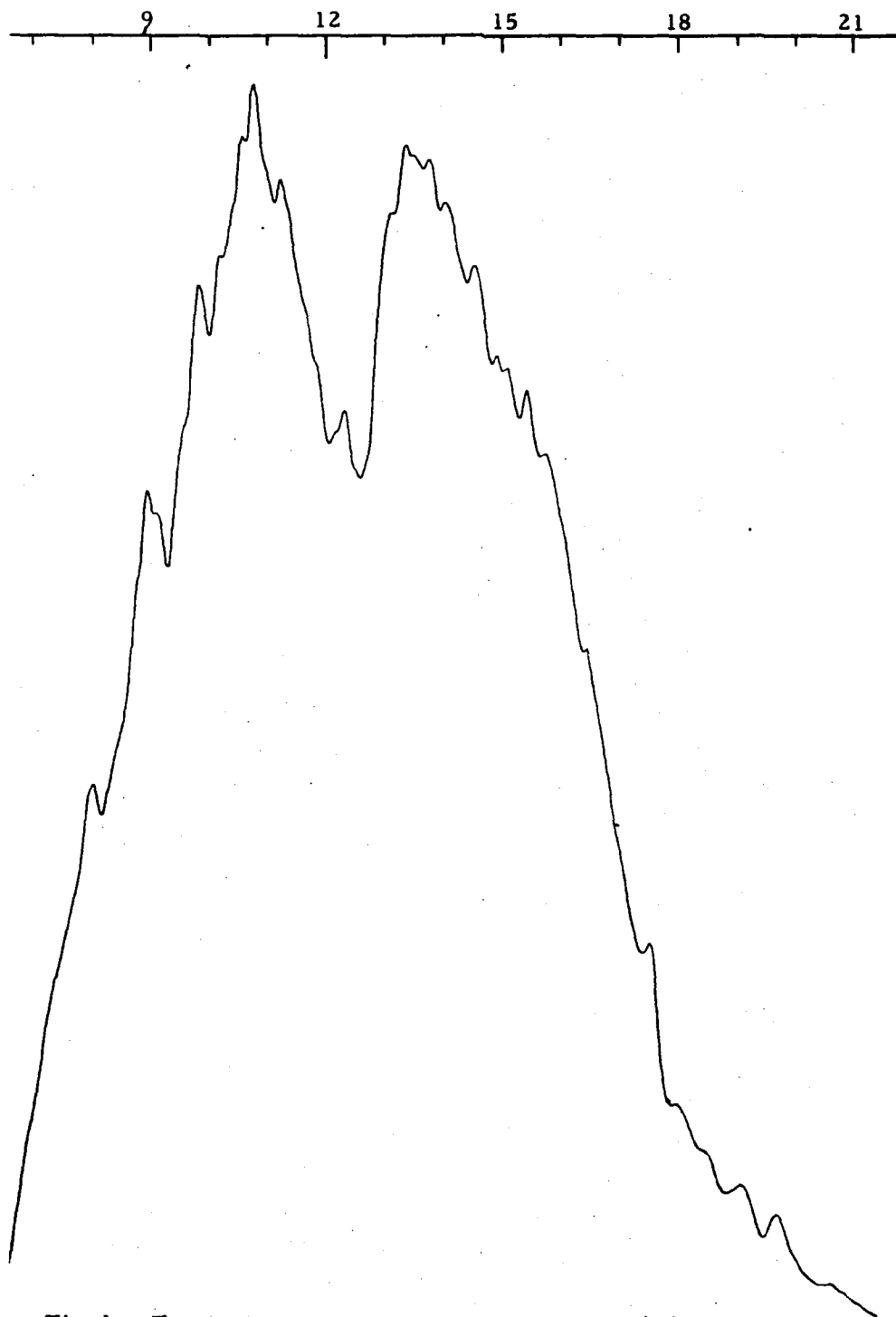
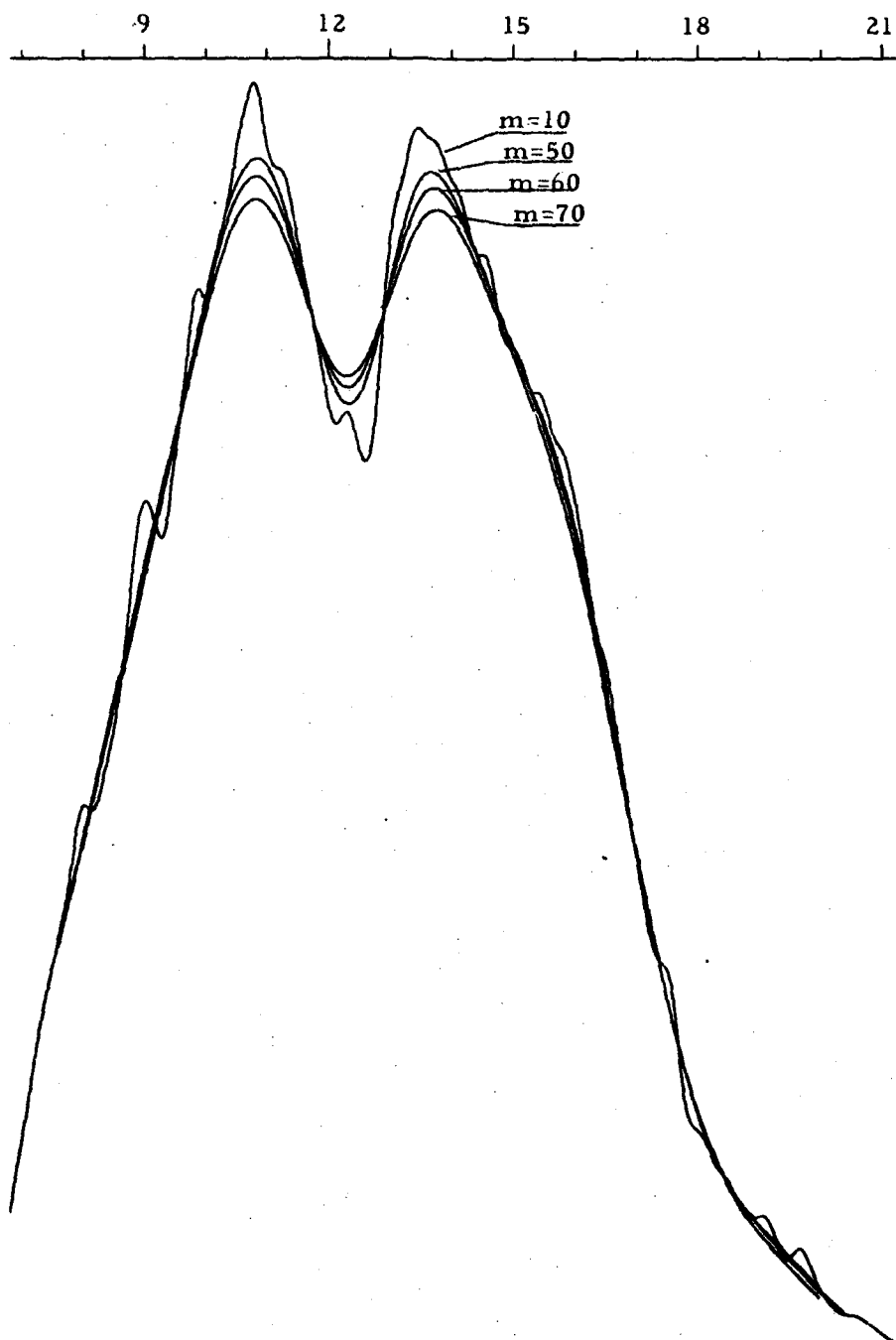Fig. 1. - Total electron content variation on 1/1/79

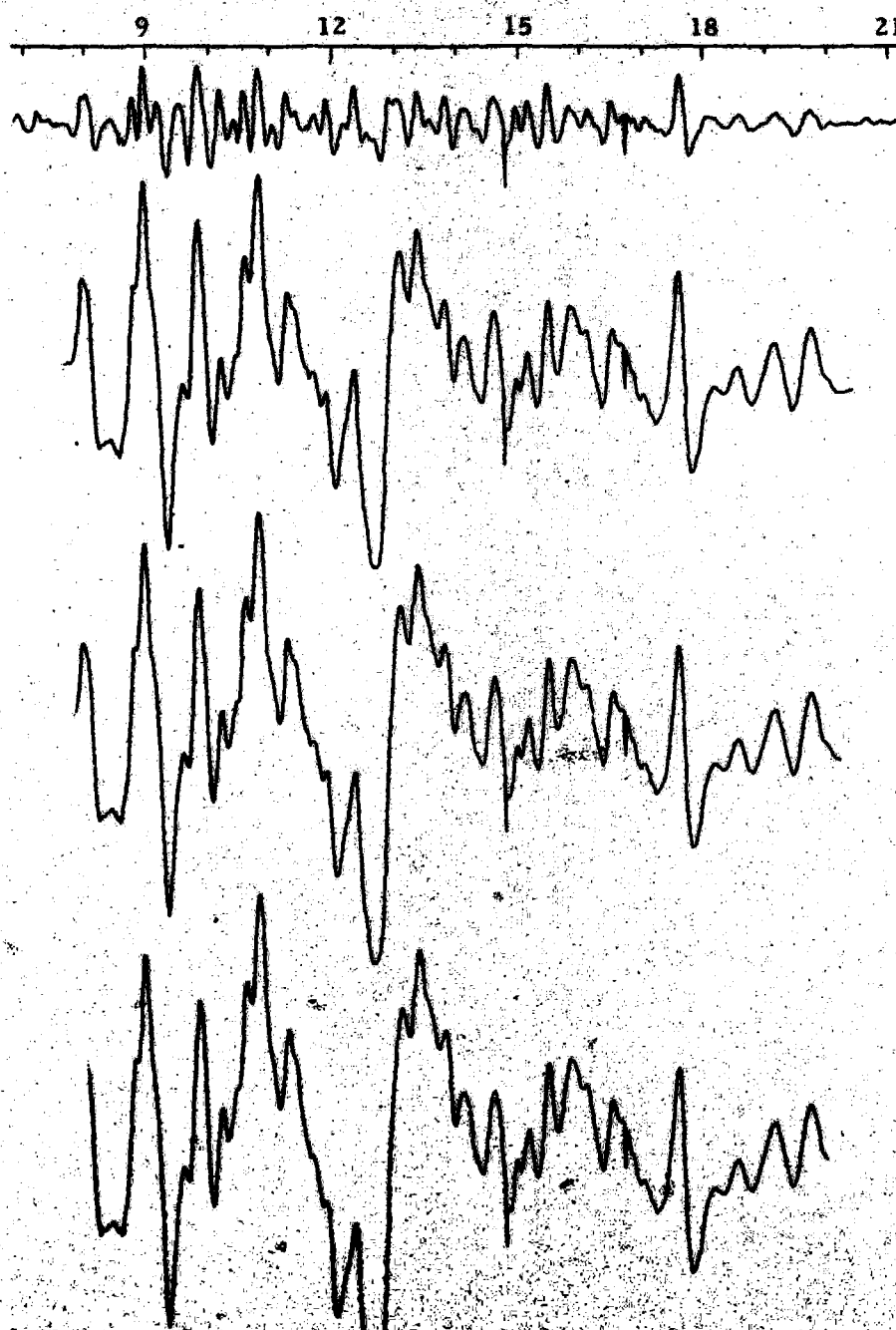Fig. 2. - Result of filtering the TEC curve of fig. 1 with different filter lengths.

Fig. 6 TEC perturbations obtained by subtracting the background trend.

to obtain enough accuracy in the determination of the frequen-
cies. Such an increase in the length of the analized interval
diminishes the time resolution. To avoid these difficulties we
used the maximum entropy instead of the Fourier method. As it
is well known., the main difficulty, not fully solved, of this
powerful method consists in the right election of the filter
length. An empirical criterion often used, suggests a filter
length about 25% to 50% of the series to be analyzed, for
short series (less than 10 periods of the signal) and about
5% to 15% for long series. As we have divided the curves into
intervals of two hours in our analysis and since the periods
of the perturbations we are looking for are greater than 12
minutes, we used a filter length of 50% in accordance with
the above criterion. On the other hand we have taken the con-
secutive two hour intervals overlapped one hour. With this
method each perturbation is contained within one interval in
most cases.

RESULTS.

We analyze the Faraday data of January 1979 by the method
just described. In that month no TID was observed between
20UT and 7UT of the following day, therefore we eliminated
this period from the analysis.

We obtained the frequency expectrum for each two hour in-
tervals chosen as explained above, in the band of interest
(between 10 minutes and 94 minutes) with a sweep frequency in
crement of 10 cycles per minute.

Variation along the month.

The TID's periods found for the different two hour inter-
vals between 7hr and 18hr in every day of the month are shown
in figs. 4a to 4e. As can be seen, there are TID's of very
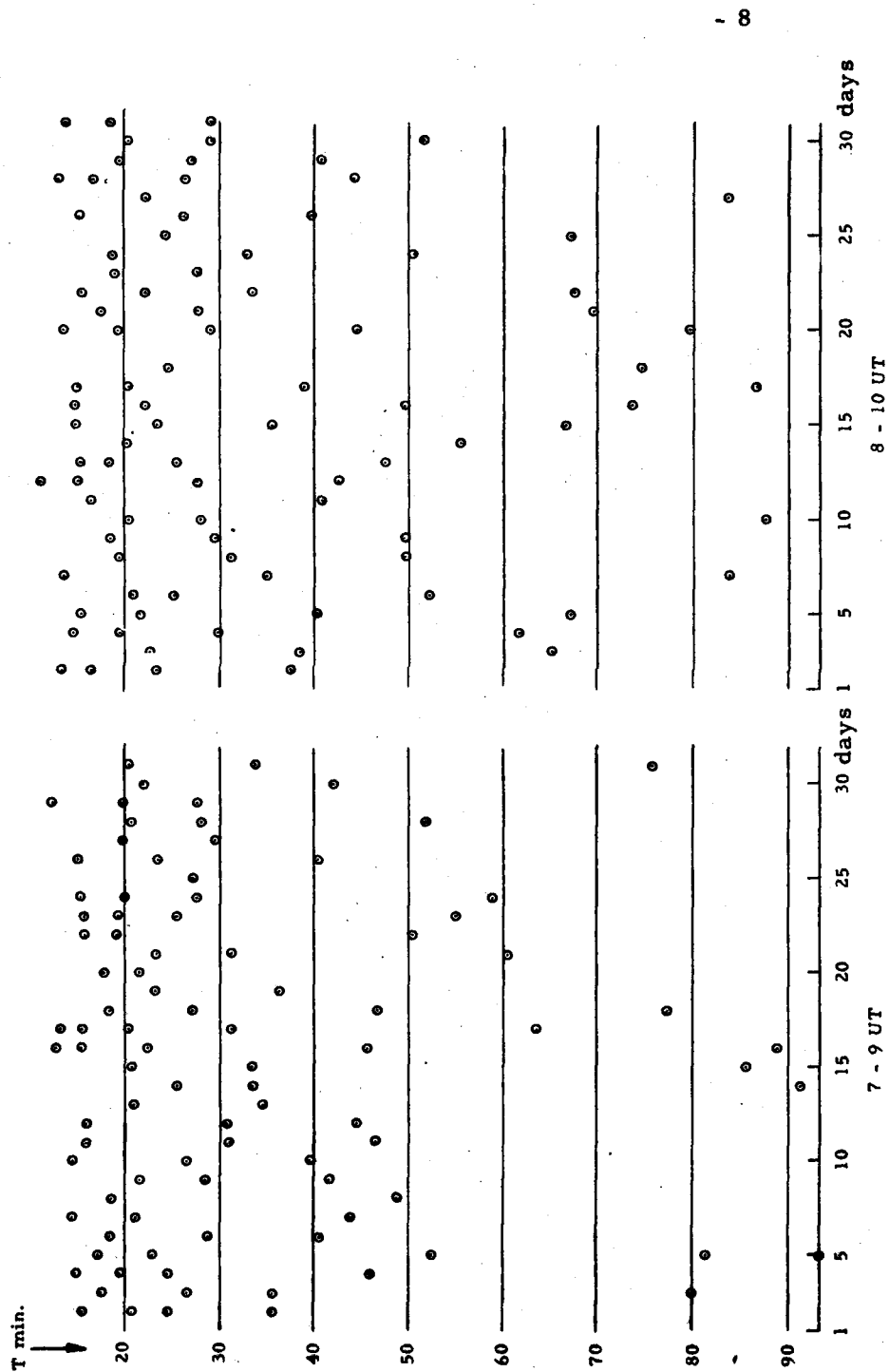different frequencies every day disorderly distributed along

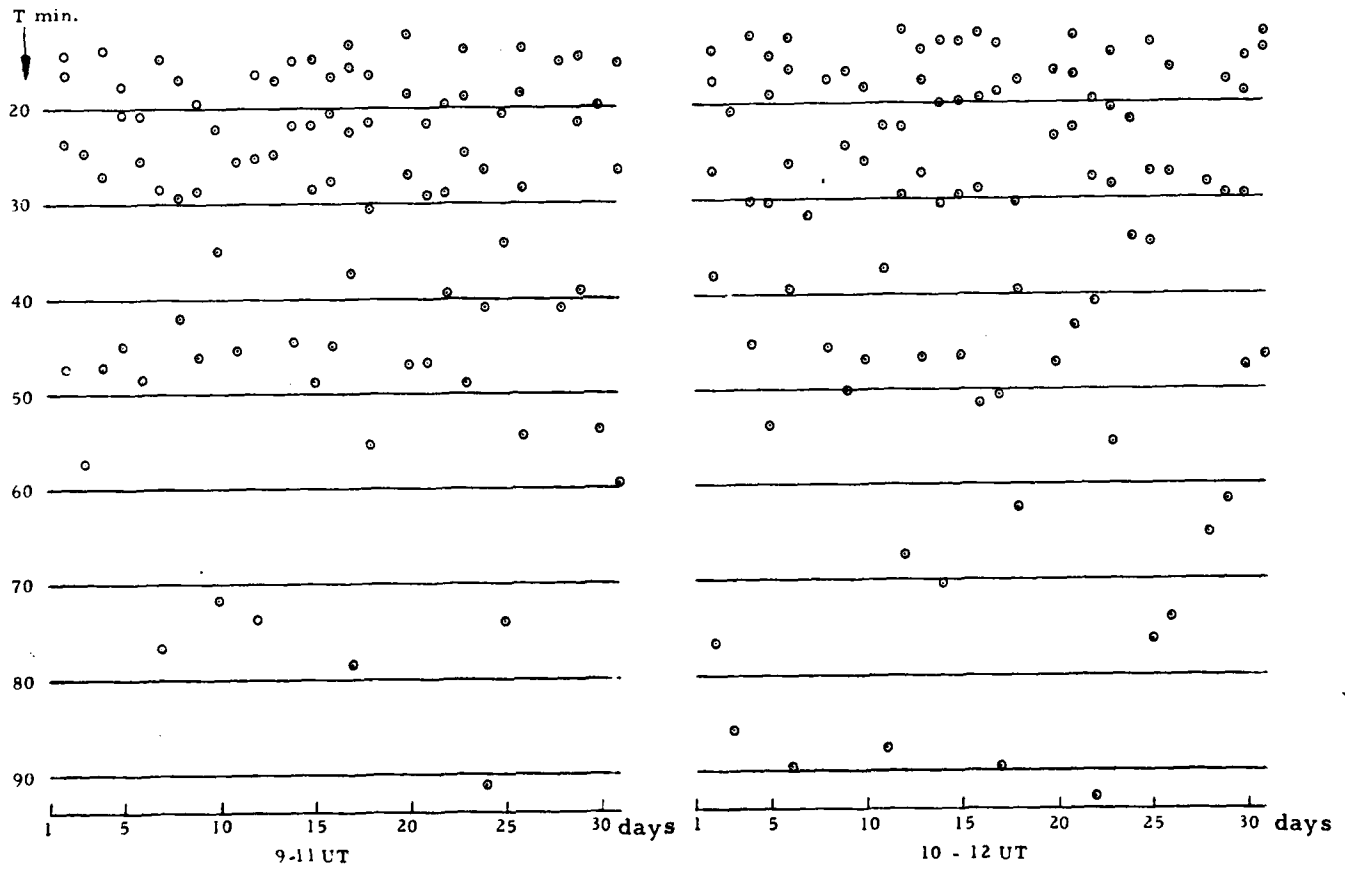Fig. 4a.- TEC perturbation periods for the different days of January 1979.

Fig. 4b. - TEC perturbation periods for the different days of January 1979.

Fig. 4c. - TEC perturbation periods for the different days of January 1979.

Fig. 4d. - TEC perturbation periods for the different days of January 1979

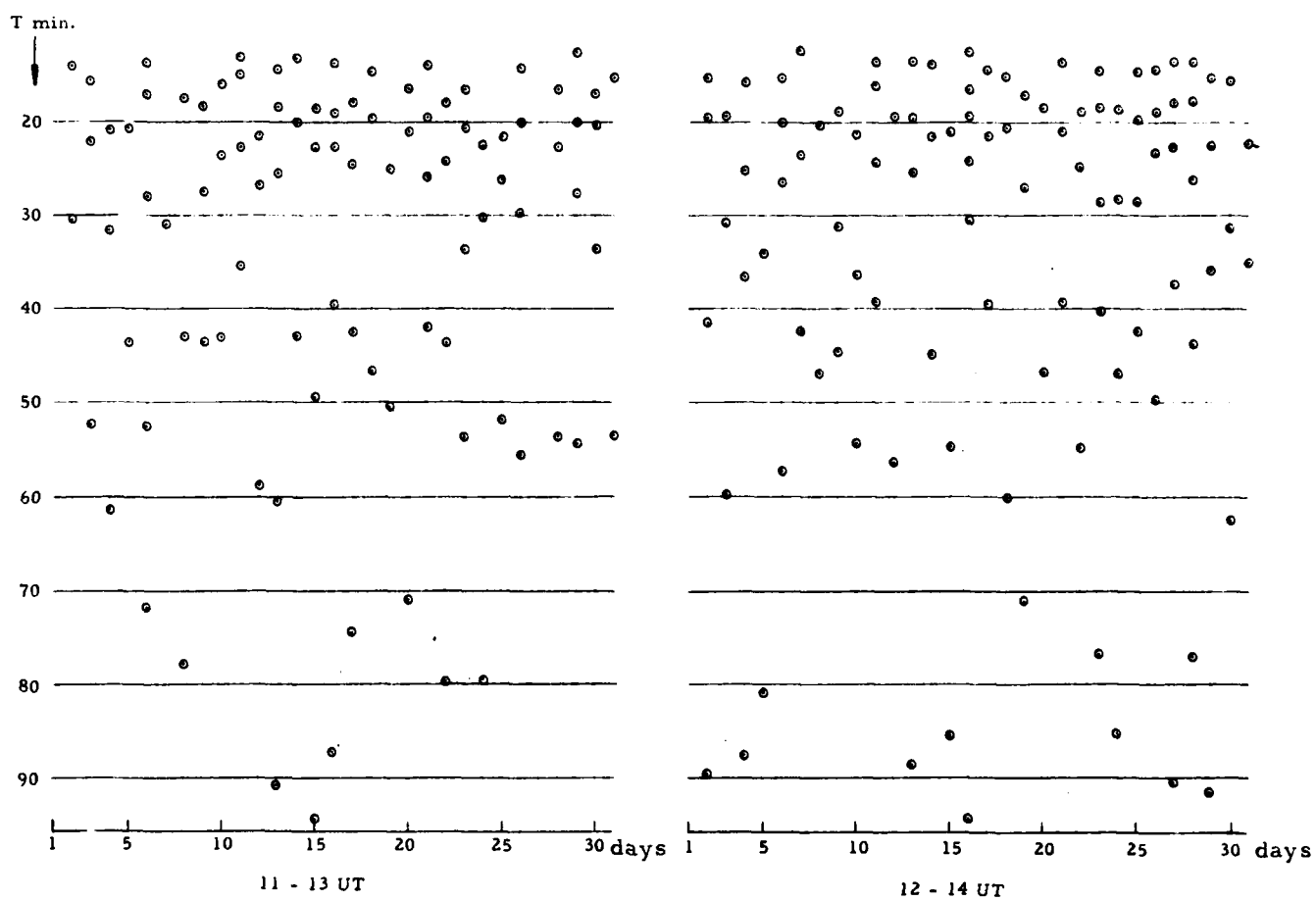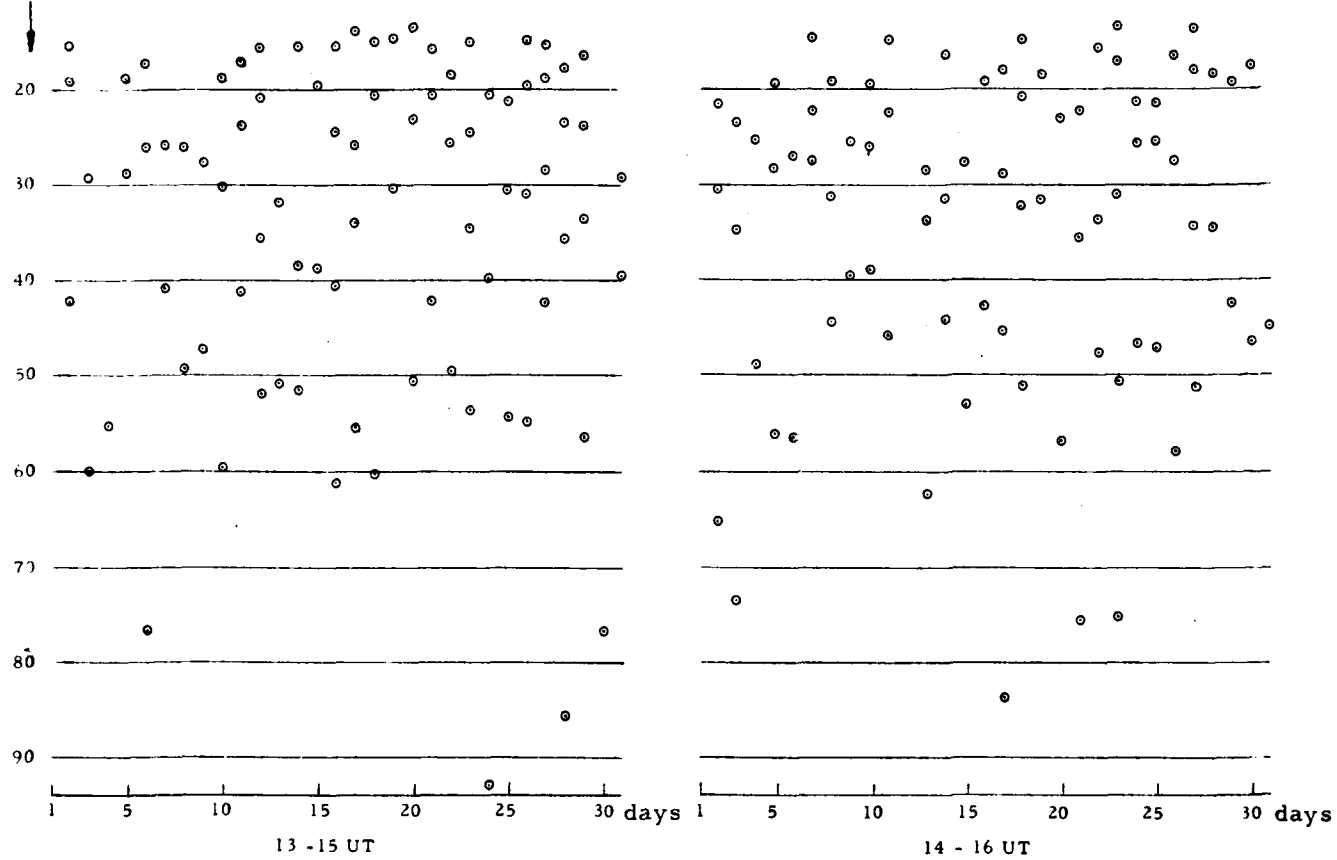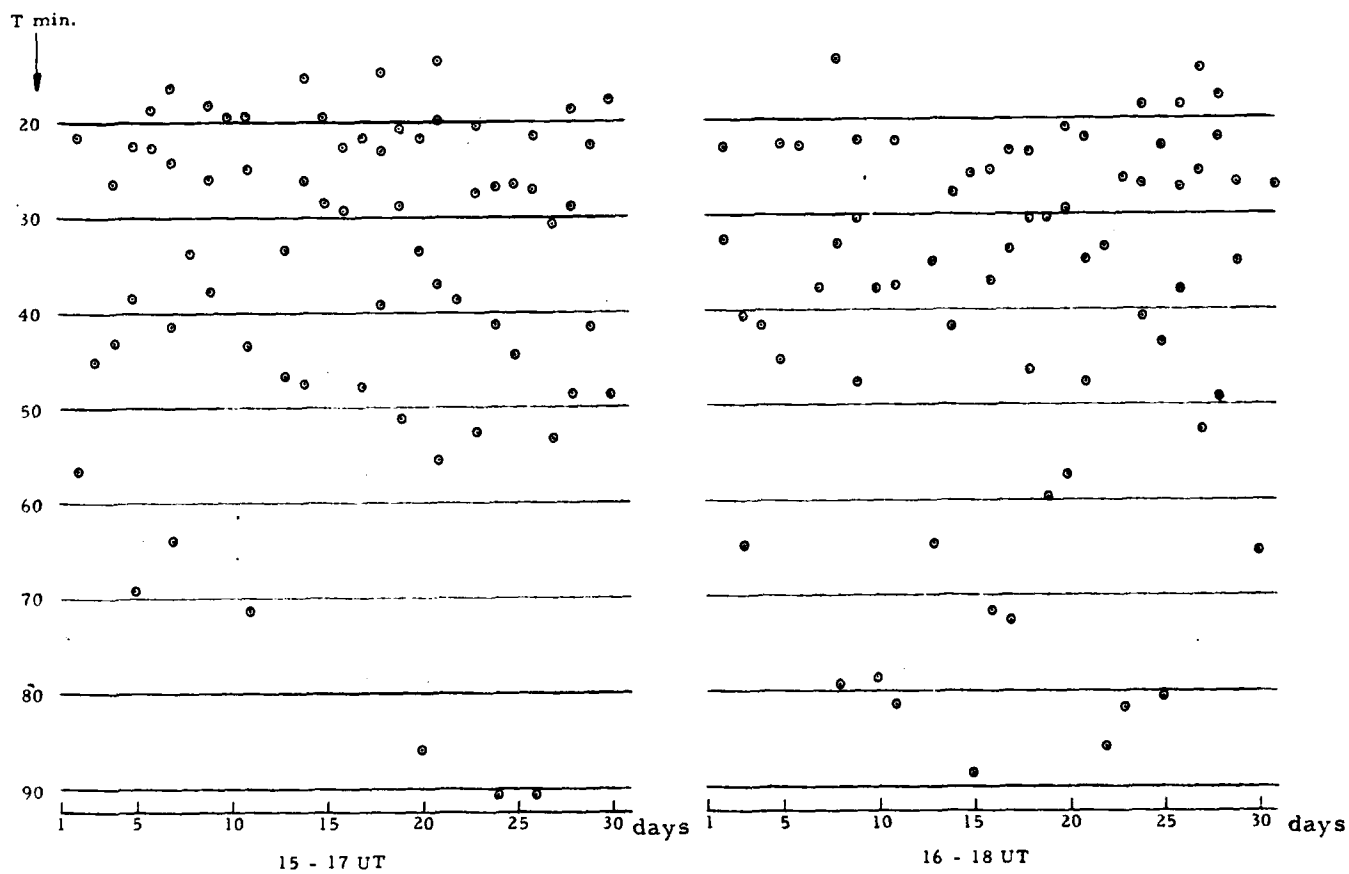Fig. 4e. - TEC perturbation periods for the different days of January 1979.

the month. In spite of the dispersal of points, a pattern is
apparent in the distribution of periods. In fact, most of the
TID's have periods shorter than 30 minutes, and the number of
TID's decreases with increasing periods.There is also another
feature that increases the disorderly appearance of the points
and that can be caused by the method of analysis itself. We
are refering to the fact that in the zone of the short periods
two points corresponding to different but near frequencies of-
ten appear at the same hour on the same day. In   the method
used the analyzed curve is transformed into an addition of pu-
re sinusoidal waves. For instance, a dumped sinusoidal wave
shall be considered as a part of the pulsation resulting from
the addition of two pure sinusoidal waves of near periods. The
refore the points just mentioned, appearing at the same hour
on the same day can correspond to only one wave of an interme-
diate period.

We show in fig.5 the number of perturbations correspon-
ding to different periods for the whole month.The results have
been normalized to obtain in the vertical axis the number   of
perturbations per hour. The periods have been distributed   in
small intervals of ten minutes. In fig.5a all data have been
considered. In figs.5b-5d only the data corresponding to 4 hour
intervals centered respectively at 9hr, 12hr, and 15hr have
been taken. The solid lines represent only aproximate fittings.

The facts, already mentioned,that TID's number decreases
with the increasing period and that most of the TID's have pe-
riods shorter than 30 minutes are apparent. On the other hand
only in the 12hr curve the highest point corresponds to the pe
riod interval between 10 minutes and 20 minutes while in the
other curves the maximum corresponds to the interval between
20 minutes and 30 minutes. This can indicate that the shorter
periods tend to appear at midday.

The shape of all curves is similar, with a much stronger
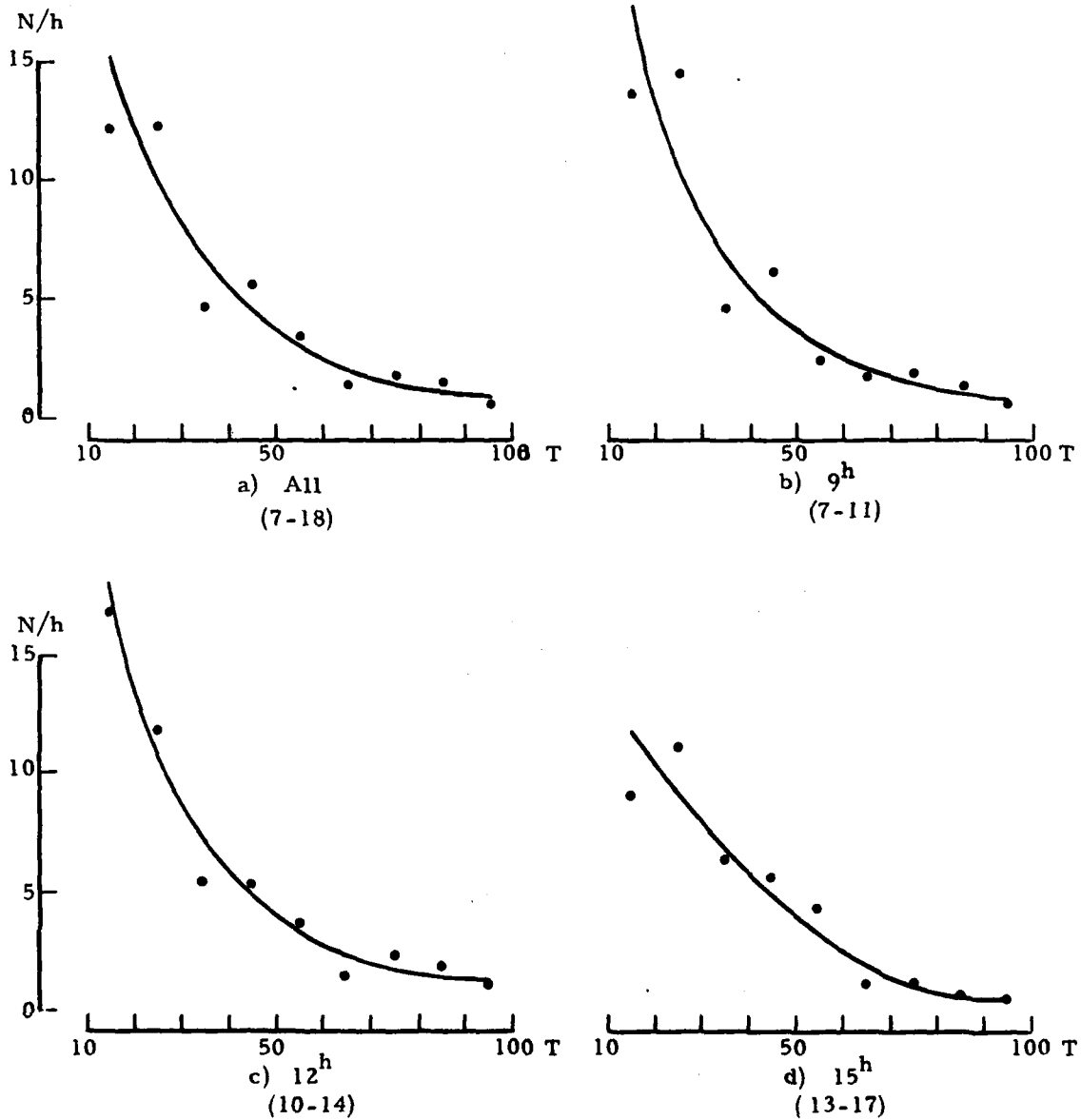slope for the short periods than for the longer ones; but the

Fig. 5. - Variation of the number of perturbations per hour (N/h)
according to the period for different day, intervals.

slope corresponding to the 15hr curve is clearly smaller than
the slope of the other curves. This difference of slope is cau
sed by the relatively low number of TID's in the short period
region.

Diurnal variation.

The distribution of the perturbation frequencies that
appear at different time of the day for all days of the month
are given in figs. 6a to 6d. The periods appear in ordinates
in a logarithmic scale. The hours indicate the central time
of the two hour intervals considered for the analysis. The
blank regions on days 12 and 27 correspond to times with no re
cords of Faraday angle. The blanks on other days, for instance
on 31st, correspond to times without perturbations. What has
been said about the dispersal of points of fig.4 is also valid
for these figs.

The figs. 6a-6d show that the short period limit of the
perturbations remains approximately constant till about midday.
Shortly after this time the points of smaller periods tend to
desappear and only the perturbations of longer periods remain.

This effect is better seen in fig. 7 where the diurnal varia
tion of the number of TID's of different periods is shown. The
results have been normalized, as in fig.5, to obtain in ordina
tes the number of perturbations per hour. The hours correspond to
the central time of the two hour periods as in fig. 6. The pe-
riods considered are indicated on the curves in minutes.

The curve corresponding to all perturbations has a small se
condary minimum at 10hr and a maximum at 13hr; from this time
it descends steeply till 17hr when reaches its minimum value.
The curve corresponding to the periods between 10 minutes and
30 minutes shows that the number of short period perturbations
remains almost constant till midday, increases slightly at 13hr
and decreases quickly from this time to 17hr. The number of per
turbations with periods between 30 min. and 50 min seems to be
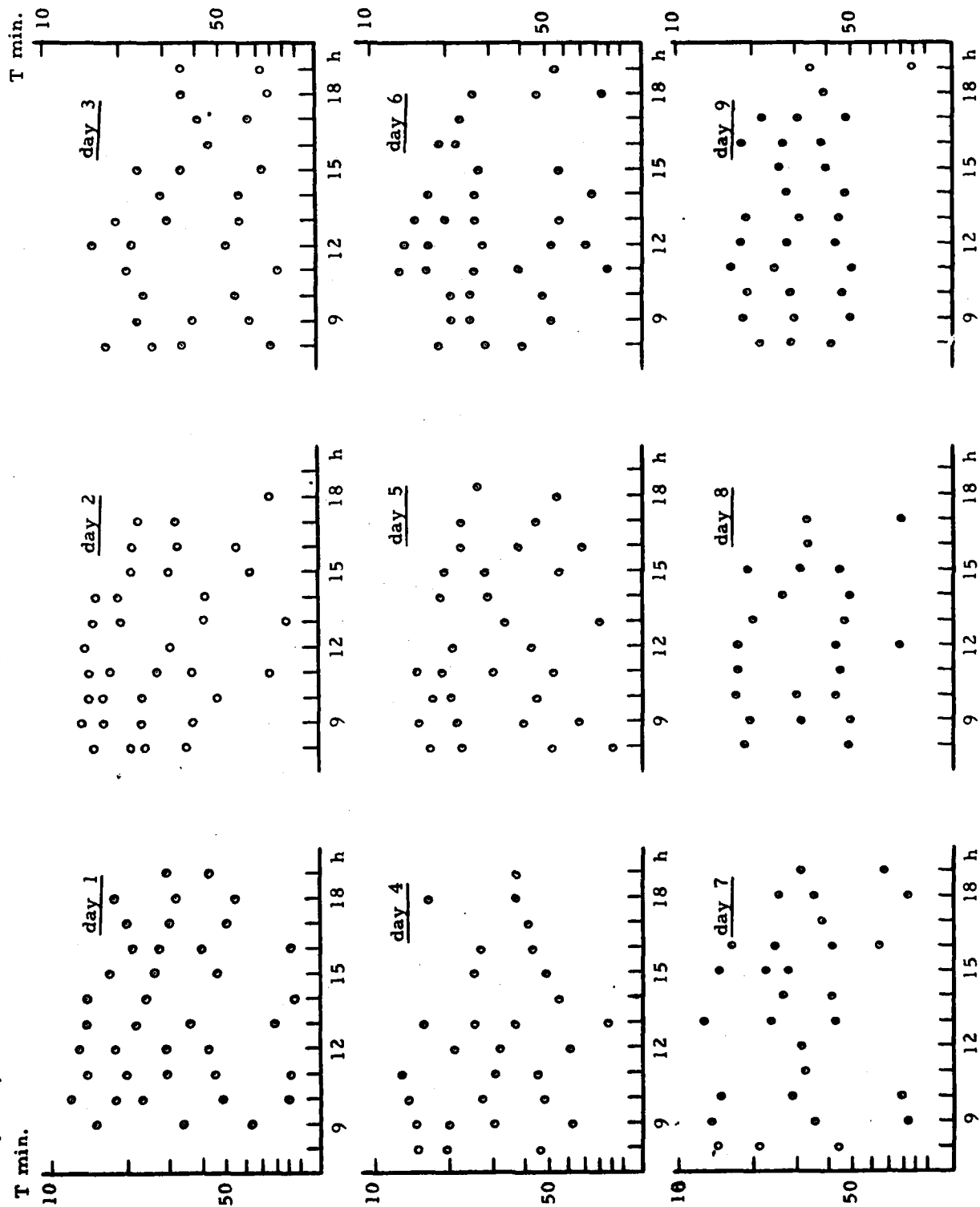
Fig. 6a. - Hourly distribution of the TEC perturbation periods (T)
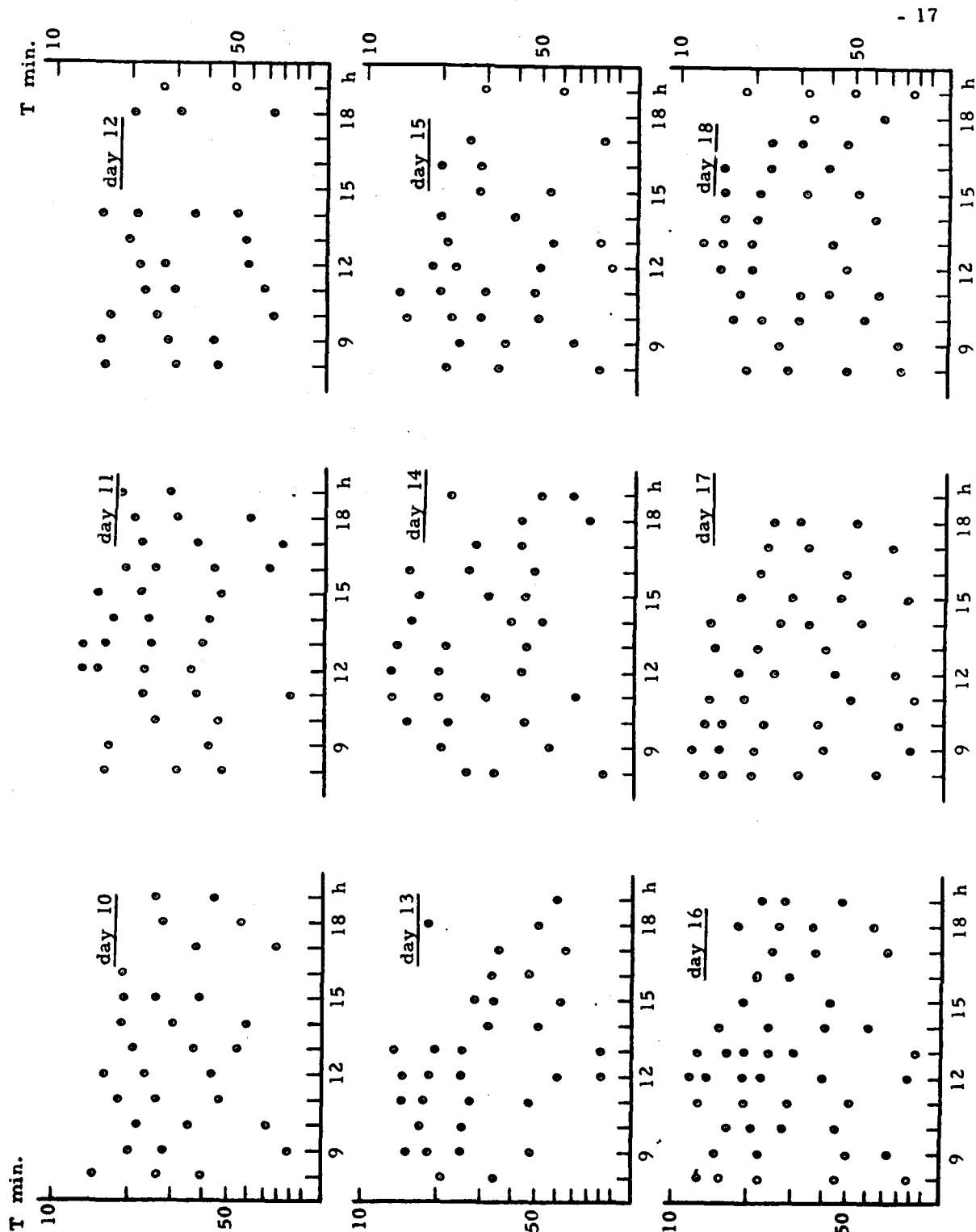for every day of January 1979.

Fig. 6b. - Hourly distribution of the TEC perturbation periods (T) for every day of January 1979.
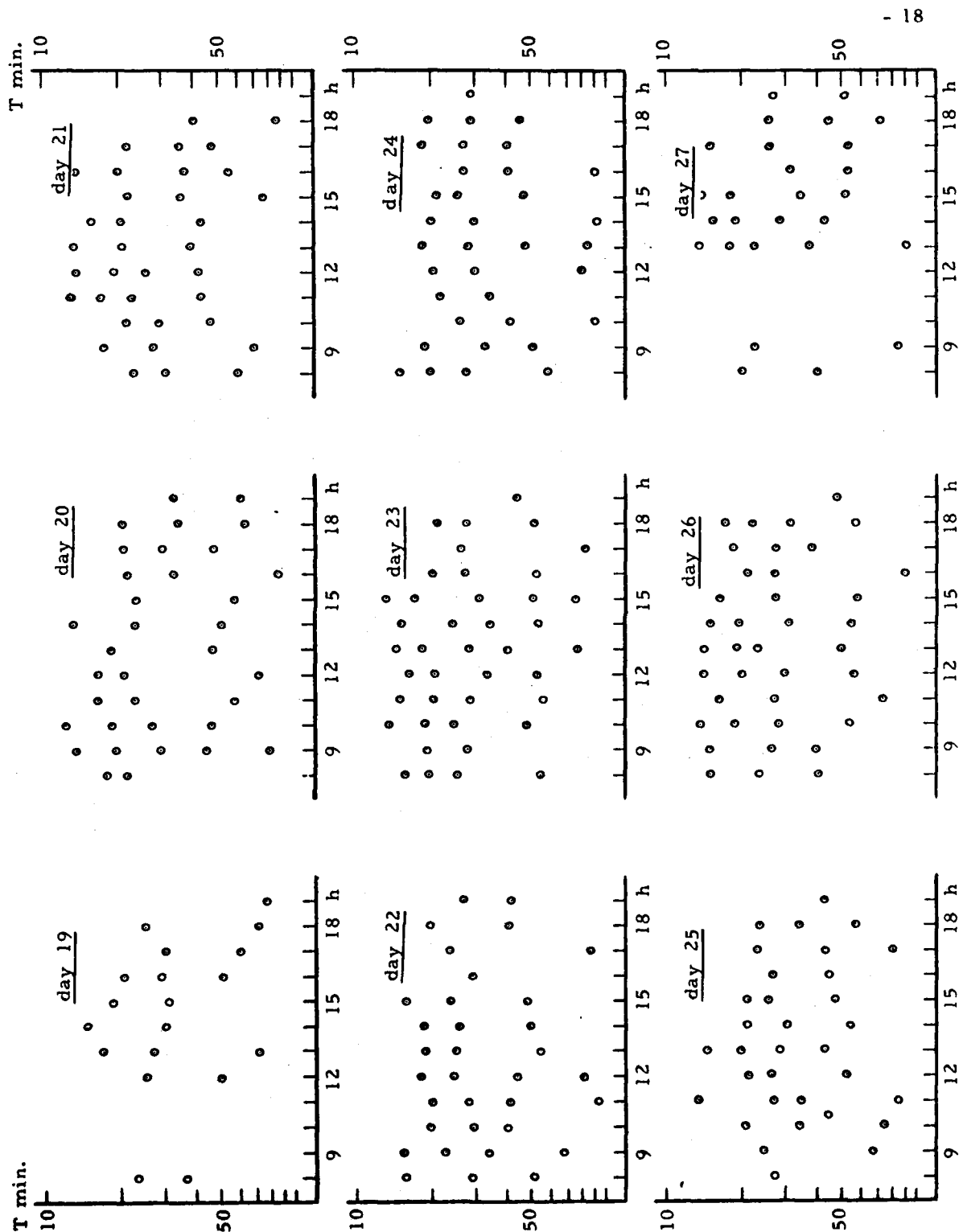
Fig. 6c. - Hourly distribution of the TEC perturbation periods (T)
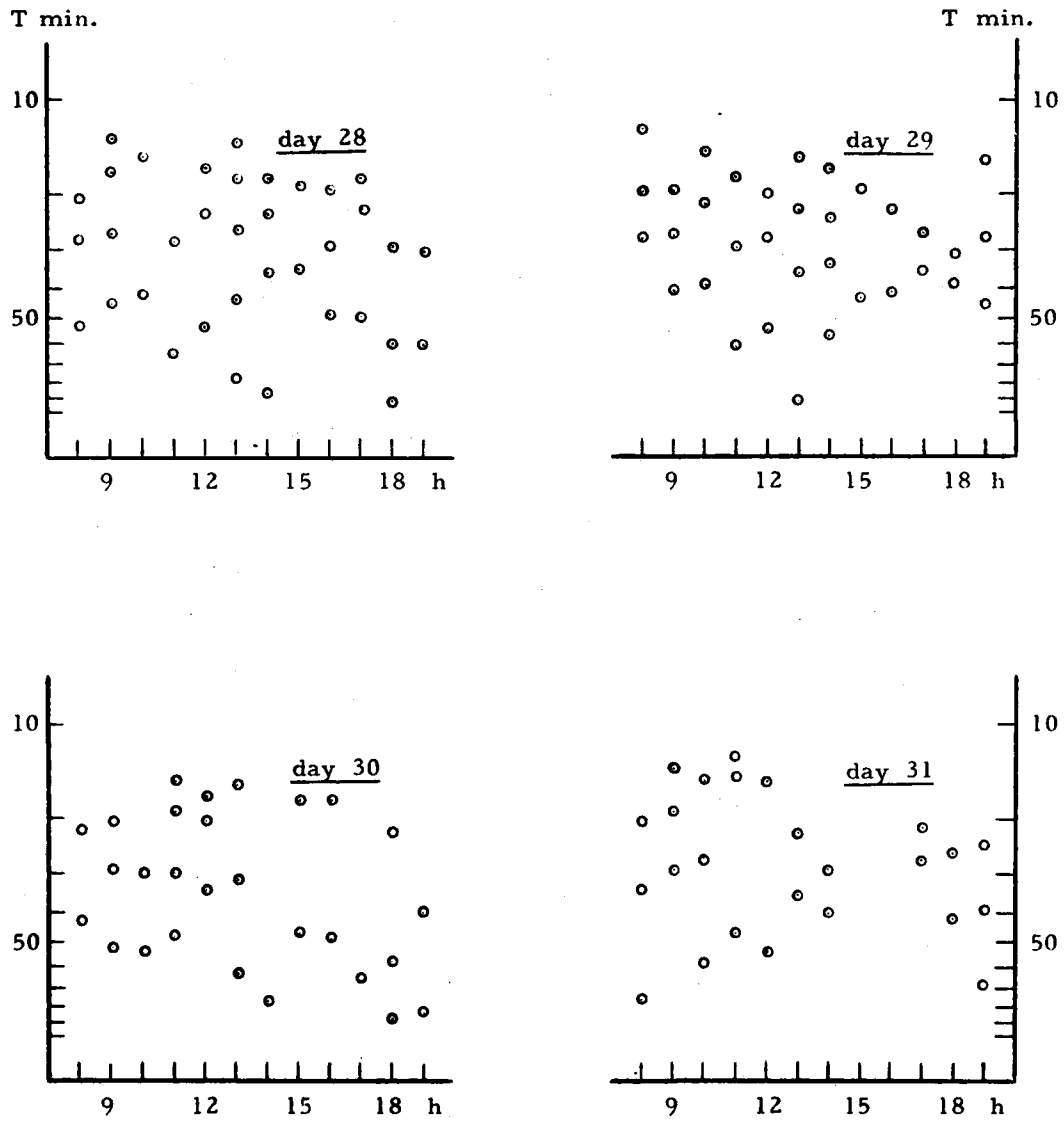for every day of January 1979

Fig. 6d. - Hourly distribution of the TEC perturbation periods (T) for every day of January 1979.
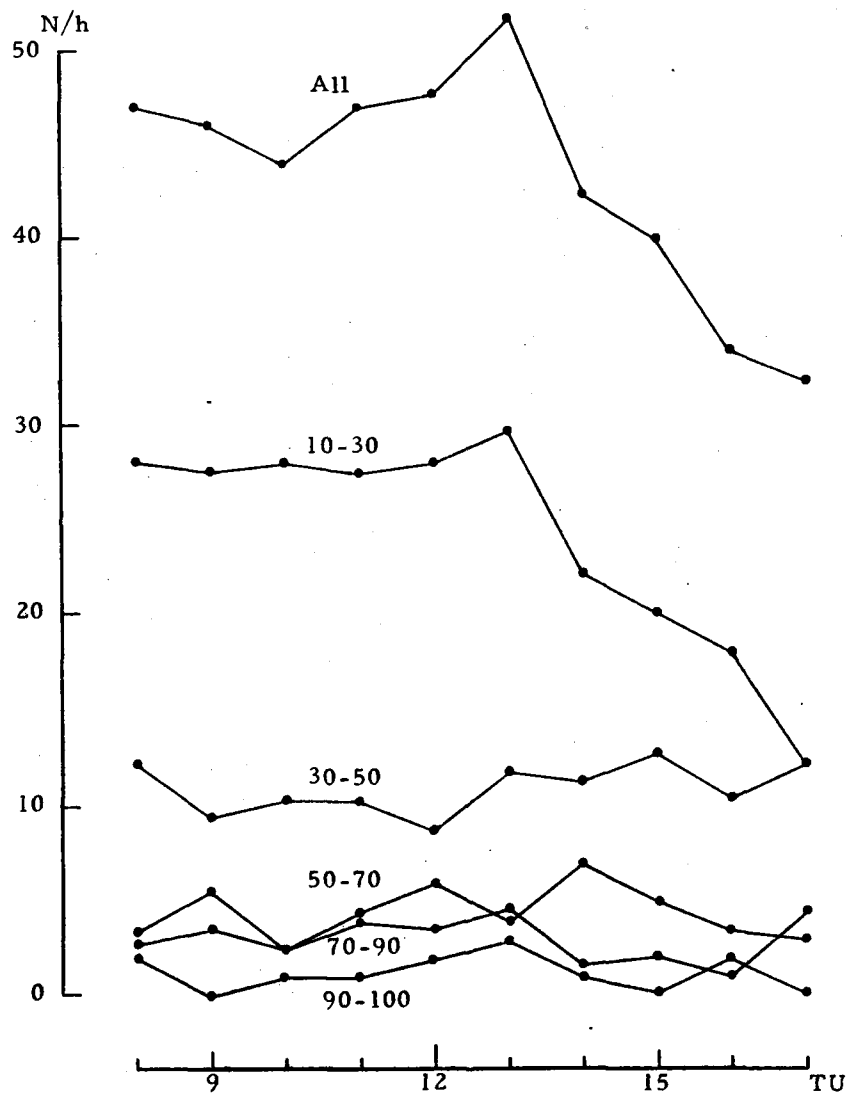
Fig. 7. - Diurnal variation of the number of perturbations per hour (N/h)
for the different perturbation periods indicated on the curves.

a little higher after 12hr than before although the differences
along the day are very small. Lastly it seems that the perturba
tions with periods longer than 50 minutes do not have diurnal
variation.

Although only the January curves of Faraday angles have
been measured, a first statistical analysis has been done with
the records of the whole year to find the TID's diurnal varia-
tion in other seasons. The results indicates a greater abundan
ce of TID's in winter than in summer and differently distribu-
ted in both seasons. The number of perturbations during day-ti
me is smaller in summer than in winter. On the contrary, during
night there are more perturbations in summer than in winter. In
this last season night perturbations practically disappear. The
periods of the night perturbations are usually longer than the
day-time ones. The last result would be in agreement with the
trend shown by the curves of fig.7.

As it is well known gravity waves of long period have a
more horizontal energy propagation than the short period ones,
so that they can reach greater distances with small dumping.
Therefore, the long period perturbations, that prevail in late
hours and during night, can have been produced far away from
the observing station. On the contrary, the short period waves,
are usually produced near the Observatory and their appearance
depend strongly on the Sun's position.

Soicher et al. (1982) find for Haifa that the number of
TID's is maximum in winter and minimum in equinoxes. According
to their work, there is a different daily distribution of TID's
for the different seasons; TID's appear most frequently between
8hr and 12hr UT in winter, between 16hr and 20hr in equinoxes
and between 20hr and 24hr in summer. They find also that the
periods of TID's depend on the season: in winter the periods
of TID's are less than 20 minutes and in summer they are usua-
lly longer than 40 minutes. In general these results agree with
ours, although small differences exist. These discrepancies can
be explain by the different methods used. For instance, our cri-
teria for the selection of TID's probably allow a greater num-

ber of them to be taken into account; therefore, even with the
same set of original data, our analysis would give a larger
diurnal interval of appearance of perturbations and a wider
band of the periods of TID's in every season than the analy-
sis of Soicher et al. do.

CONCLUSION.

The Faraday rotation records obtained in the Ebro Observatory from the SIRIO geostationary satellite signals in January 1979, have been digitized and analyzed by the maximum entropy method in order to obtain the frequency spectrum of the TID's travelling through the Observatory. The results indicate that most of the TID's recorded in this month have periods shorter than 30 minutes. The number of TID's decreases strongly when the period is increased above this value. The perturbations appeared only during the interval between 7hr and about 20hr, and their diurnal variation depends on their frequency. The short period perturbations (less than 30 minutes) appear at about 7hr, their number remains almost constant till about midday when,after a slight increase at 13, decreases steeply till the end of the interval. It seems that perturbations of periods between 30 minutes and 50 minutes tend to be more abundant after midday than before 12hr. Perturbations of longer period do not have a clear diurnal variation except for the fact, already mentioned, that they do not appear at night.

A seasonal dependence of the diurnal variation of TID's can be deduced from the not measured records of the whole year. In fact, while the perturbations appear only in day-time during winter,long period perturbations are also observed at night during summer. The number of the perturbations is smaller in summer than in winter.

This work is to be continued with the analysis of the curves of the whole year in order to obtain the seasonal variation accurately and to find the causes of the different behaviour of short and long period perturbations.

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20. Abstract

Faraday rotation data recorded at the Ebro Observatory in January 1979 have been analyzed by the maximum entropy method to obtain the spectrum of TID's travelling through the station. The results indicate that most of the TID's in this month have periods shorter than 30 minutes and appear only between 7hr and 20hr UT. Their diurnal variation depends on their frequency. A less sophisticated analysis of the data of the whole year shows a clear seasonal dependence of the number, period and diurnal variation of TID's.

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