D.G. - REAT -

OFFICE DE LA RECHERCHE SCIENTIFIQUE ET TECHNIQUE OUTRE-MER

Centre d'Adiopodoumé

Rapport de M.ELDIN, Directeur de recherches en Bioclimatologie à l'ORSTOM, sur le congrés qui s'est tenu à BENGHAZI (Libye) du 29 octobre au 4 novembre 1976, concernant l'étude physique de l'énergie solaire et ses applications.

Le congrés, organisé par l'Arab Physical Society et l'Arab Development Institute, avec le concours du gouvernement libyen, s'est tenu dans la somptueuse université de GHARYOUNIS, dans la banlieue de BENGHAZI (Libye).

Il a reuni une centaine de spécialistes du rayonnement solaire venant des pays arabes (31) mais aussi d'Europe, des Etat Unis, d'Amérique du Sud, d'Inde, du Japon, et de Côte d'Ivoire.

Les sujets traités ont été :

- Mesure du rayonnement solaire
- Conversion de l'énergie solaire
- Applications de l'énergie solaire

Environ 70 communications ont été présentées par les pays suivants :

U.S.A	15	communications
Inde :	9	"
France :	7	"
Egypte :	6	"
Arabie Saoudite :	5	"
Iraq :	4	"
Italie :	4	"
Koweit :	3	"
Belgique, Brésil, Espagne, Angleterre, :	2	communications

Argentine, Turquie, Japon, Libye, Liban, Pologne, Côte d'Ivoire : 1 communication.

J'étais le seul congressiste à travailler en Afrique Noire Les résultats que j'ai exposé concernant le rayonnement solaire en zone intertropicale humide ont été accueilli avec intérêt ca l'on trouve fort peu de données dans la littérature scientifiq sur ce sujet et pour cette zone géographique.

Une après-midi du congrés a été consacrée à une discussion sur la création d'un centre d'étude de l'énergie solaire, dans le cadre de l'Arab Development Institute. Les Libyens souhaite que ce centre soit établi sur leur territoire.

Il me semble important d'attirer l'attention des responsables du commerce extérieur sur les points suivants :

1°/- Les industriels étrangers se servent de ce genre de réunions scientifiques pour vanter les performances et les prix de leurs réalisations, de la façon suivante : Monsieur X, Docteur es-sciences, Ingénieur de la Société Y, présente une communication à caractere scientifique dans laquelle le nom de la société Y, apparaît ou n'apparaît pas suivant la discrétion de Monsieur X. Mais, de toutes façons, l'on sait que Monsieur X appartient à la Société Y qui fabrique tel ou tel matériel. En dehors des séances l'on vient demander à Monsieur X des précisions, des prospectus, ou même une interview sur les produits de la société Y.

C'est ce qu'a fait le Dr Erhard FRANCK de la maison DORNIER (Allemagne Fédérale) qui a présenté une communication :"Solar heat pipes for practical applications" et a donné, hors séances, une interview: "the prospects of directly converting solar energy into electric power" vantant les mérites des piles solaires DORNIER.

C'est également ce qu'a fait le Dr Laurence R. ANDERSON, Technical Director, Energy Programs Lockeed Research, California, U.S.A. qui a présenté une communication intitulée "Solar Energy Activities in the U.S.A." , tout en faisant de la publicité pour les "maisons solaires" fabriquées par la société LOCKEED.

2°/- La libye cherche à investir sur son territoire, de préférence dans des réalisations très luxueuses : Université de BENGHAZI, mise en valeur du DJABEL AKDAR, Usines,... les sommes importantes que lui rapporte le pétrole. La Libye souhaite créer un Centre d'Etude du rayonnement solaire. En effet, elle est consciente :

- Que ses reserves de pétrole, bien qu'importantes, ne sont pas inépuisables.

- Que des installations de conversion de l'énergie solaire de petites puissances (quelques dizaines de KW) pour l'éclairage, l'alimentation de postes de radio ou télévision, le pompage, le chauffage et la déssalinisation de l'eau,.. . sont très intéressantes pour des postes isolés, pour lesquels construire un groupe électrogène et amener du fuel couterait très cher.

ABIDJAN, le 22 Novembre 1976

M. ELDIN

October 1976

SOLAR RADIATION EXTINCTION BY A WET TROPICAL ATMOSPHERE - INCIDENCE ON EVAPOTRANSPIRATION AND PHOTOSYNTHESIS OF PLANT CANOPIES

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The results presented here have been obtained in Ivory Coast, near ABIDJAN ($5^{o}19'$ N, $4^{o}13'$ W, altitude 29 metres) by a team of research workers of the "Office de la Recherche Scientifique et Technique Outre-Mer" working on climatic determinism of plant canopies evapotranspiration and dry matter production.

Among climatic factors which determine these two main metabolic functions, solar energy at ground level plays an essential role. It explains why an analysis of solar radiation attenuation has been performed. On the basis of eight years of global solar radiation measurements, we try here to point out the role of absorption by atmospheric components (mainly O_3, O_2, CO_2 and water vapor), of scattering by gazeous molecules and of extinction by aerosols and clouds.

I. Variations of solar radiation all through the year:

Graph 1 shows how global solar radiation (G) fluctuates during the year. Each point represents the interannual mean of ten days measurements. The curve (E) represents the extra-terrestrial solar radiation calculated from a value of solar constant E_o = 1353 W.m^{-2} (1.94 cal.cm^{-2}. mn^{-1}) - (THEKAEKARA- ...

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First, it must be pointed out that:

(i) Values of G are very low compared with extraterrestrial ones. Transmission coefficient T = G/E has a mean value of .43.

(ii) Amplitude of fluctuations of G is much greater than that of E, due to very different attenuations of solar radiation all through the year. Indeed, T varies from .29 (August) to .52 (April) (Fig.2).

II. Trying to analyse factors of solar radiation extinction

We tried first to assess the influence of permanent atmospheric components and of water vapor in the measured extinction. For this purpose, we used data given by ROBINSON (1966) concerning global radiation at low latitudes ($25^{o}N < \varphi < 25^{o}S$) at sea level, under a clean and cloudless sky, with a .34 cm thick ozone layer and 2cm deep precipitable water slab.

These data were adjusted to take into account the actual thickness of ozone and precipitable water layers over ABIDJAN. By $5^{o}N$ in latitude, it is usual to consider that the ozone layer is.24cm thick and that this value hardly fluctuates during the year (ROBINSON - 1966).

Mean precipitable water thickness values ($\bar{w}$) have been calculated by CARDON (1976) from radiosondages with meteorological balloons up to an altitude of 7000 m above ABIDJAN. Results are reported in the following table:

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	Long dry season possibility of Harmattan blowing in altitude 1/12 to 15/2	Long dry season without Harmattan 15/2 to 1/5	Long rainy season 1/5 to 15/7	Short dry season 15/7 to 1/9	Short rainy season 1/9 to 1/12
$\bar{w}$ (in cm)	4.2	5.3	5.5	4.8	5.1
s_w (Standard error in cm)	0.9	0.5	0.7	0.3	0.6

Allowing for these considerations, values of global solar radiation (G_*) that would be obtained in Southern Ivory Coast under a clean, wet and cloudless atmosphere are shown in Fig. 1. The ratio G_*/E remains nearly constant throughout the year, varying between .70 and .71 (Fig. 2).

Therefore the area between G and G_* represents extinction by aerosols and clouds.

Following MONTEITH's work (1972) an attempt was made to identify the respective roles of clouds and aerosols. It consists of drawing the curve G_M representing the interannual mean of the highest daily values of G recorded during each month of the year. It is assumed that at least once a month there is a cloudless day for which the measured global radiation G does not differ from G_* except for the depletion due to aerosols. By using interannual average ~~mean~~ (G_M) one expects to characterize the mean aerosol content of the atmosphere for each month of the year (Figs. 1 and 2).

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During the short dry season (August and September) it may happen that there are no sunny day during the whole month. In this case it is clear that this method does not work. Nevertheless, the relative position of G_*, G_M and G gives us a good hint of extinction by aerosols and clouds respectively.

From the end of December to the beginning of February, the amount of aerosols in the atmosphere is important. During this period there is, in altitude, a variable thickness of continental air containing a very great amount of solid particles drawn away by Harmattan wind when passing over the SAHARA and SAHEL. Under this continental dry air mass lies a very wet oceanic air layer (Monsoon) which contains aerosols originated from sea (ELDIN - 1971).

From February to May the aerosol amount decreases; continental aerosols are progressively replaced by marine aerosols and the later are thrown down to ground by increasingly important precipitations (Fig.1).

Results concerning the long rainy season and the short dry season (June to September) are not easy to explain for it is difficult, as mentioned before, to separate the role of cloudiness and aerosols during this period.

From October to November (short rainy season) the aerosol amount of the atmosphere is low again and - as for the beginning of long rainy season - it is decreasing in relation with increasing precipitations.

The area between the curves G_M and G (Figs. 1 and 2) reflects the mean cloudiness all through the year. By itself, this cloudiness leads to solar extinction varying from about 10% (end of February) to about 30% (end of June and August) (Fig.2).

We also drew on Figures 1 and 2 the curve G_m representing the interannual average of the lowest daily values of G recorded during each month of the year. So the area between the curves G_M and G_m gives a good hint of the mean maximum cloudiness throughout the year.

III. Utilization of solar radiation by plants

Almost the whole radiation absorbed by a plant canopy less its own long wave radiative emission, the so-called: net radiation (R_n), is transformed into sensible heat and is lost by convection in the atmosphere or used for evapotranspiration.

A study (ELDIN-MONTENY-LHOMME- 1976) concerning a forage crop of the gramineous plants: Panicum maximum, well supplied with water, pointed out that maximum evapotranspiration (ETRM) is sharply correlated with R_n and that about 80% of the latter is used as latent heat of vaporization. Fig. 3 shows evolution of Panicum maximum ETRM in relation with R_n for different leaf area ratio (I.F) of this canopy. Each point of this graph is for a 15 minutes period.

So it is important to evaluate R_n from G which is a more usual actinometric measurement.

MONTENY and GOSSE (1976) pointed out (Figs. 4 and 5) that for Southern Ivory Coast instantaneous net radiation of a bare soil, with an albedo α may be obtained by:

$$R_n = 0.843\ (1 - \alpha)G - 41{,}4. \quad (R_n \text{ and G in W.m}^{-2})$$

For a Panicum maximum canopy with albedo α' these authors found:

$$R_n = 0.895\ (1 - \alpha')G - 57{,}4$$

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For the same crop, but for integrated values on a whole day the formula:

$R_n = 0.896\ (1 - \alpha')\ G - 57{,}4$ (with R_n and G expressed in $J.cm^{-2}.day^{-1}$) gives better estimates.

Besides, GOSSE (1976) has found that a Paspalum notatum grass has a daily ETRM directly correlated with global radiation G (Fig.6). Three straight lines represent the correlation for the three main weather patterns encountered throughout the year.

With regard to photosynthesis, it is the visible part (V) of global radiation which is important and it is necessary to know the magnitude of G and V/G. For this purpose, MONTENY has performed measurements of G and V with an Eppley pyranometer fitted out with a R.G.8 filter which has a good transmission for infra-red radiation (I.R.) with wavelengths $\lambda > 710$ nm. So, the radiation (V) obtained by the difference (G - I.R.) is not exactly the visible part of the global radiation but corresponds to the spectra $300 < \lambda < 710$ nm. Graphs 7 to 12 describe the magnitude (D) and evolution of G, V and diffuse radiation for six typical days of the year.

Results are reported in the following table: (next page)

	G $J.cm^{-2}.day^{-1}$	V/G	D/G
27-12-74: Beginning of long dry season - No Harmattan. Small amount of aerosols	2000	0.47	0.24
30-12-74: Harmattan well characterized at low altitude. Relatively dry air. Large amount of continental aerosols	1460	0.43	0.63
22-1-75: More marine aerosols. Much less continental aerosol. More wet air.	1480	0.42	0.46
10-3-75: Fine day of the middle of long dry season. No continental air mass at all, even in altitude. Large amount of precipitable water. Some clouds.	1800	0.50	0.49
10-4-75: Exceptionally fine day. Abundant rain the day before. No cloud. Very few aerosols. High Humidity.	2230	0.54	0.18
9-5-75: Beginning of the long rainy season. Rain the day before, but clouds are reappearing. Very wet air.	1920	0.52	0.47

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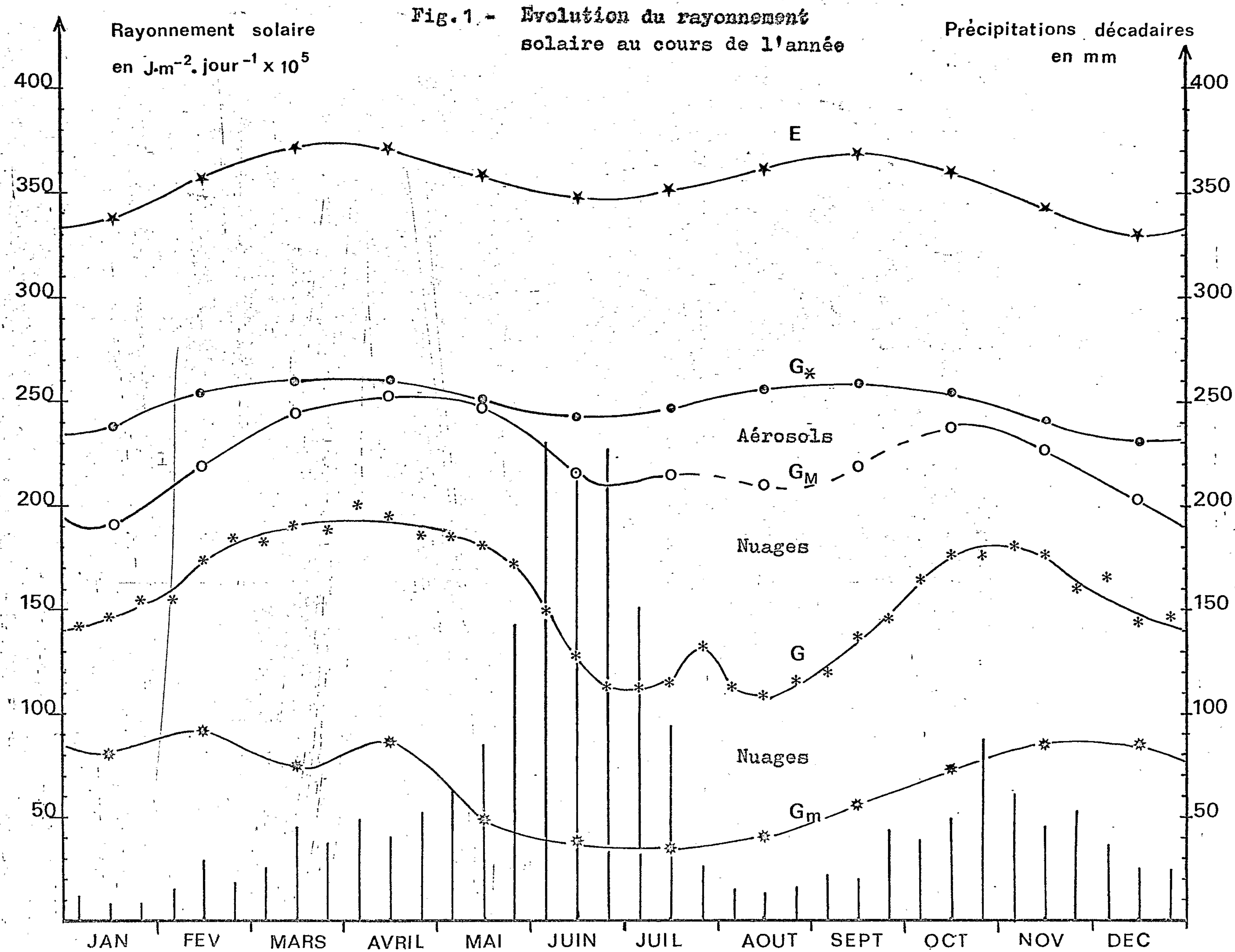
It is interesting to notice that V/G varies from 0.42 to 0.54.

Besides, the daily values of G measured during eight years are comprised between 100 and 2.700 $J.cm^{-2}.day^{-1}$.

These important fluctuations of G and V/G explain why maximum evapotranspiration of forage crops fluctuates from near 0 to 7 $mm.day^{-1}$ and why its photosynthesis efficiency for a whole day varies between 2 and 8 % when its leaf area ratio is greater than 1.

Fig.1 - Evolution du rayonnement solaire au cours de l'année



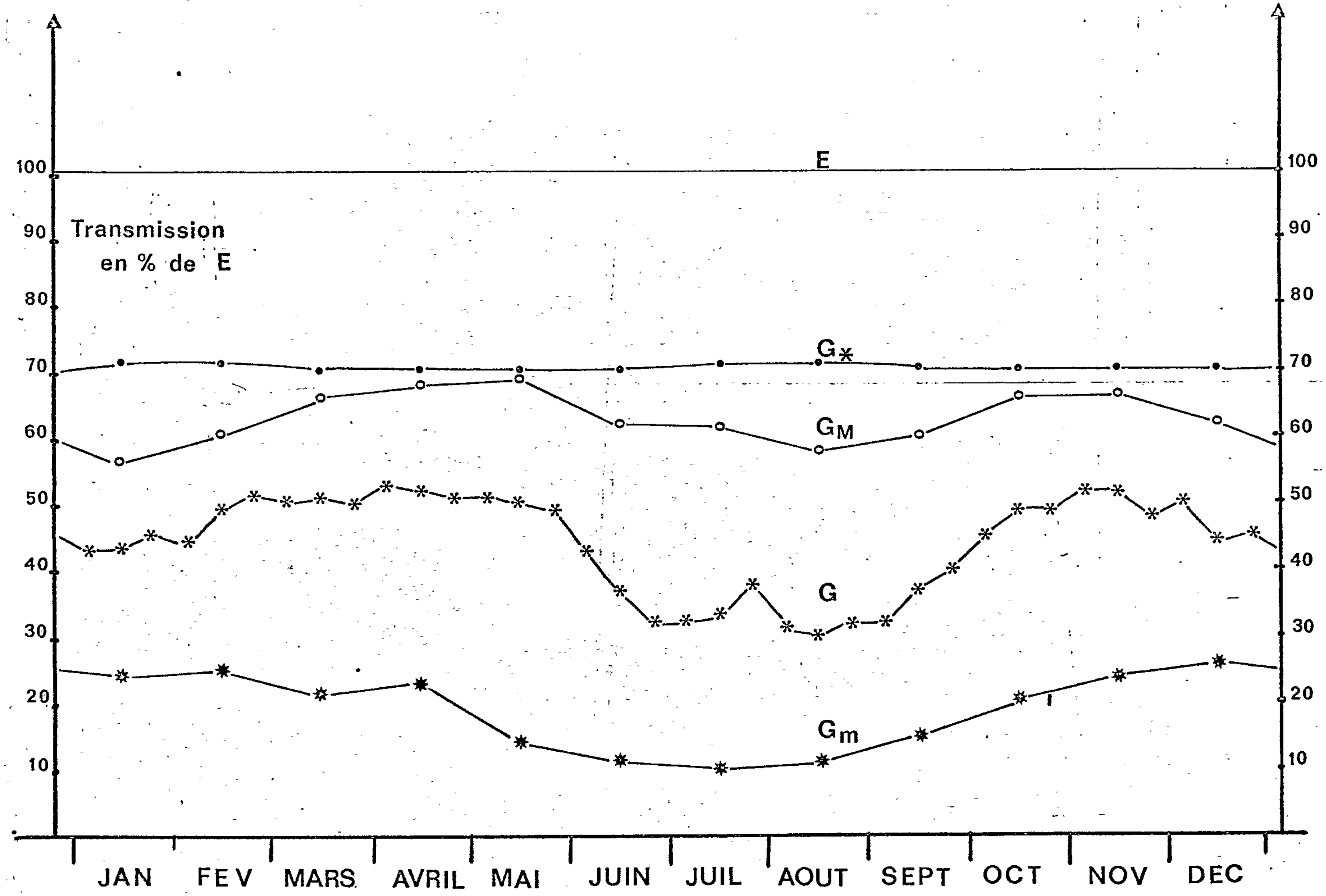


Fig. 2- Evolution au cours de l'année de la transmission du rayonnement solaire.

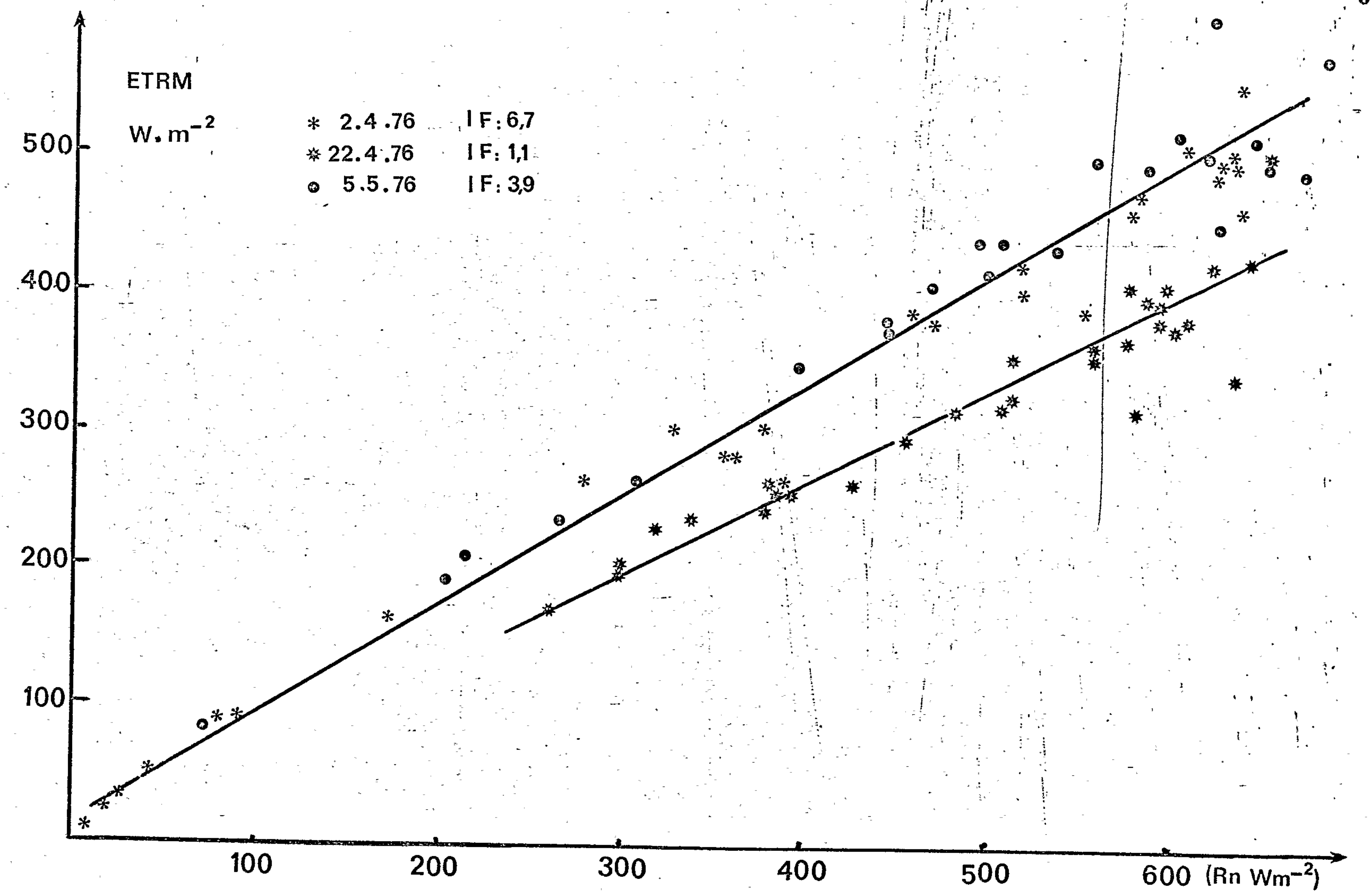


Fig. 3- Evapotranspiration réelle maximale ~~horaire~~ d'une culture de Panicum maximum en fonction du rayonnement net.

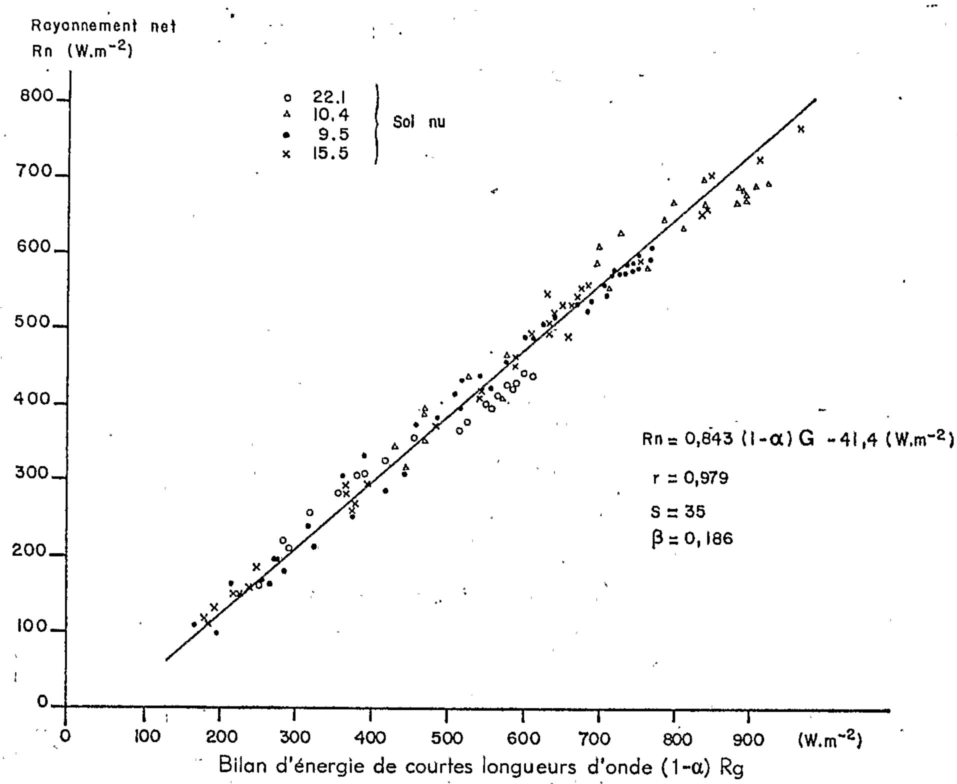


Fig.4 Relation entre le rayonnement net d'un sol nu et G

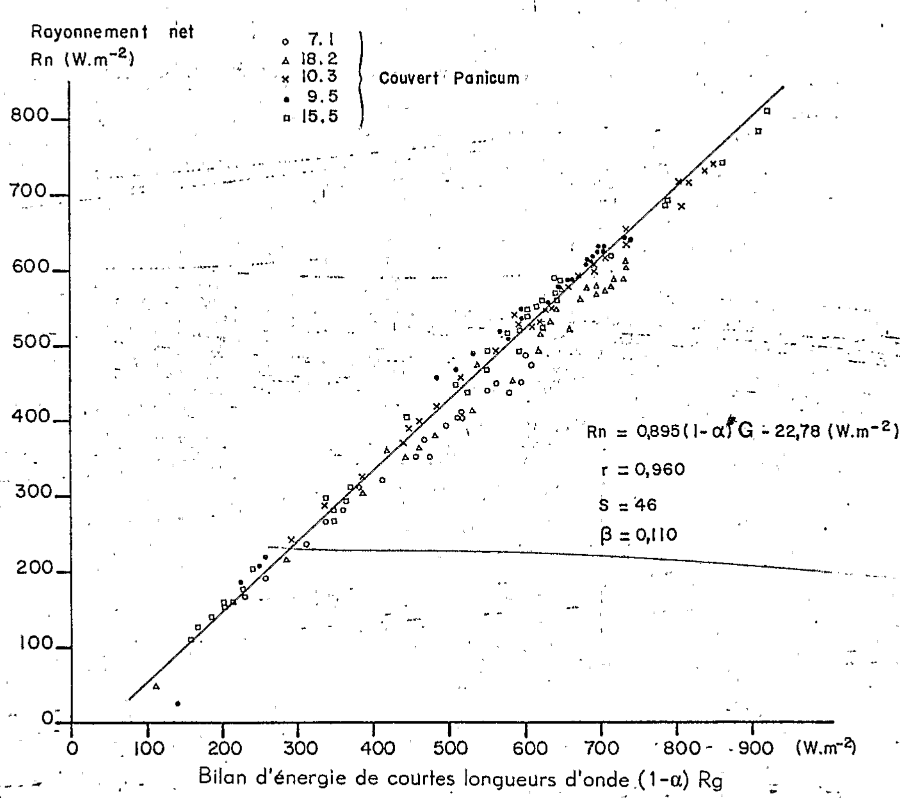
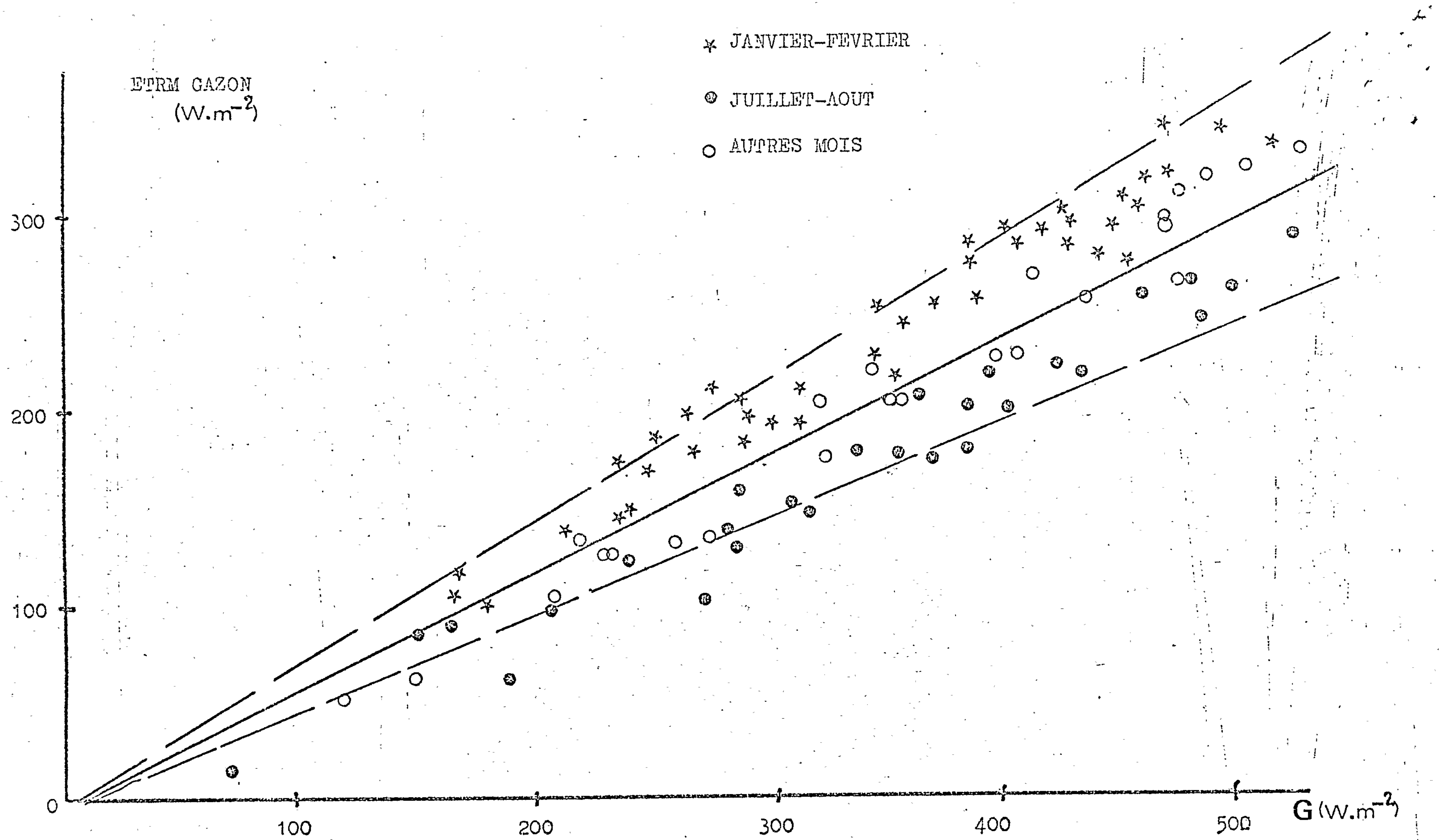


Fig.5 Relation entre le rayonnement net d'un Panicum et G



- Fig. 6. Reletion entre l'évapotranspiration maximale quotidienne d'un gazon et le rayonnement global pour les trois principaux types de temps de l'année.

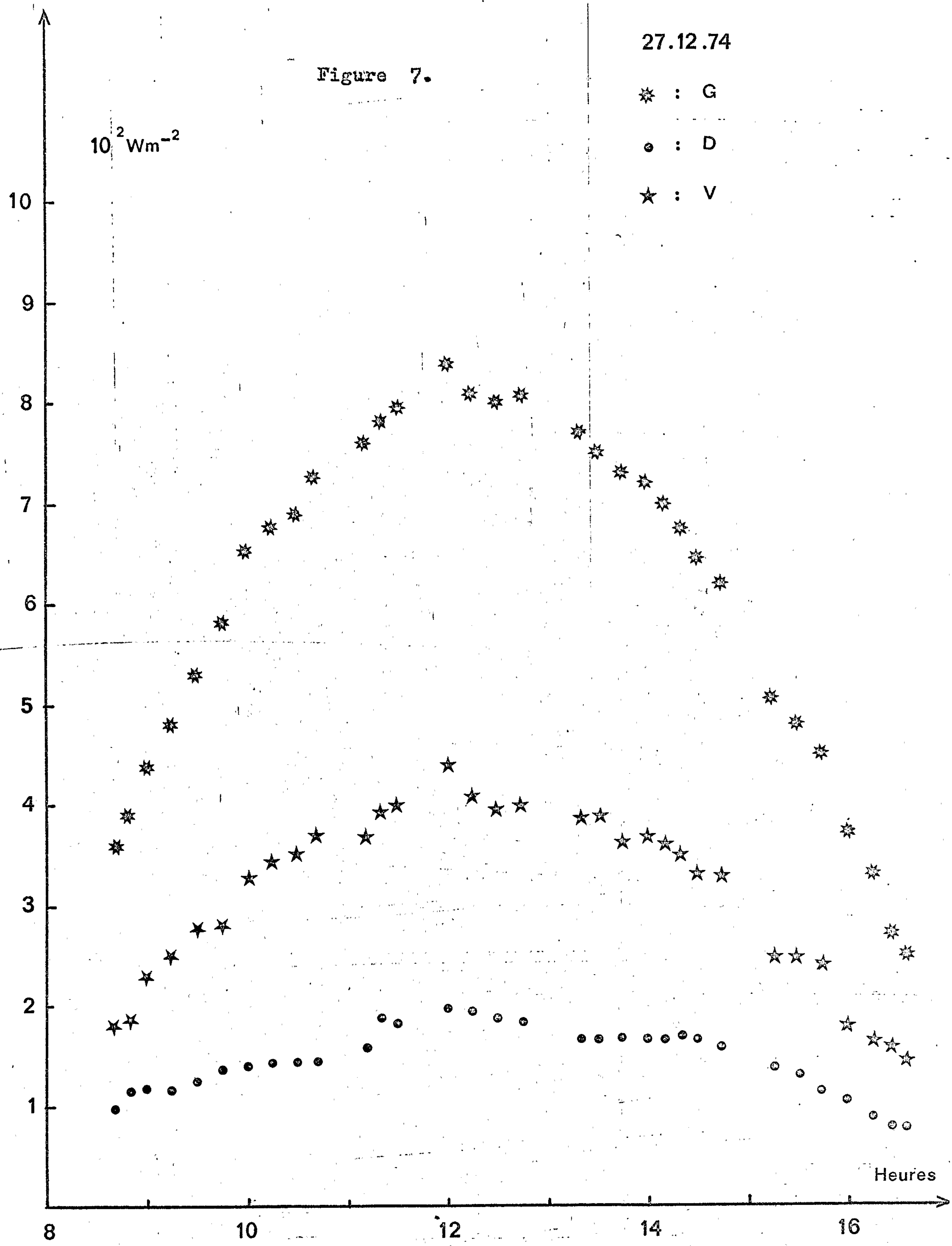


Fig. 7- Evolution des rayonnements global, diffus et visible au cours d'une journée

Figure 8.

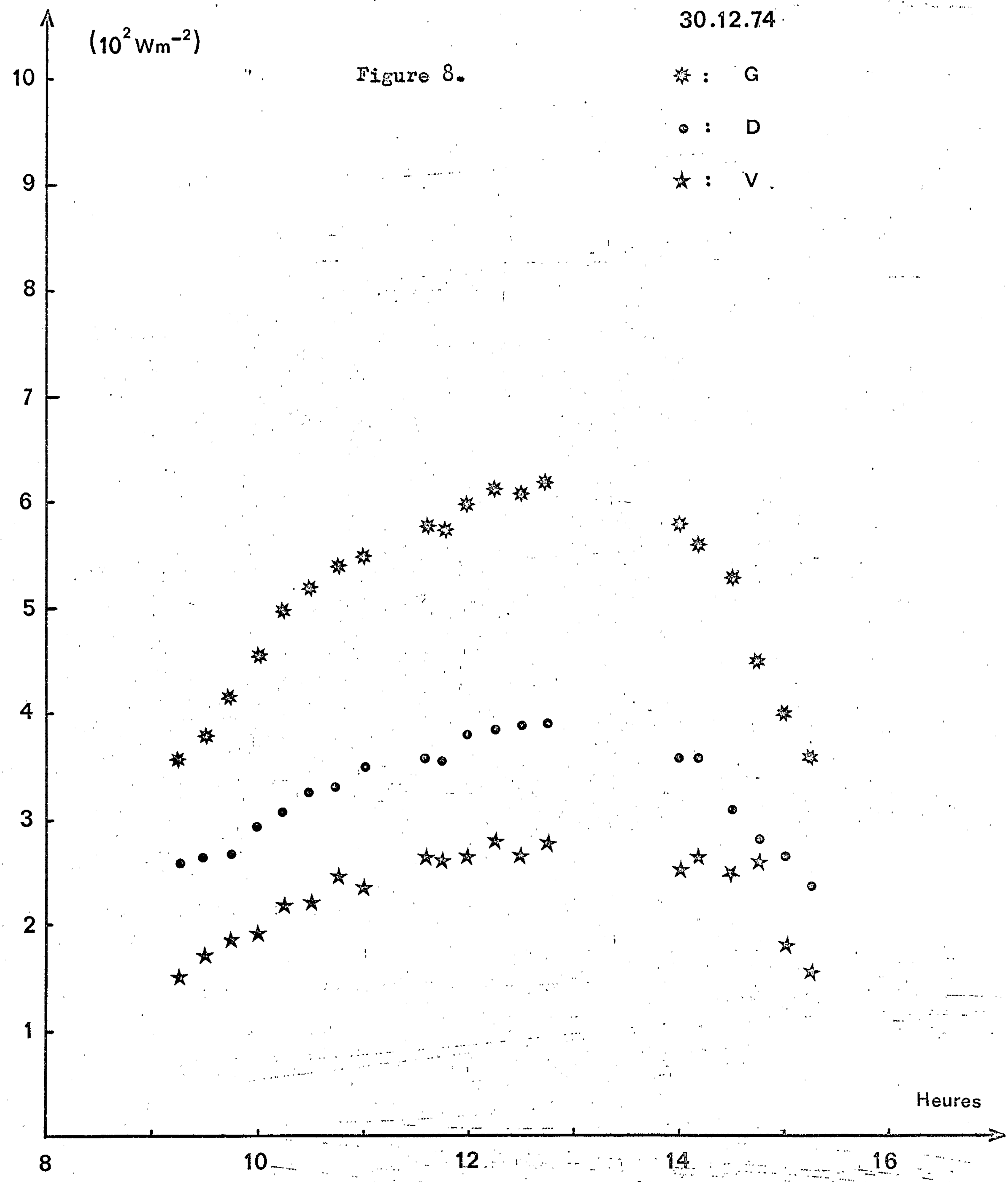


Fig.8- Evolution des rayonnements global, diffus et visible au cours d'une journée

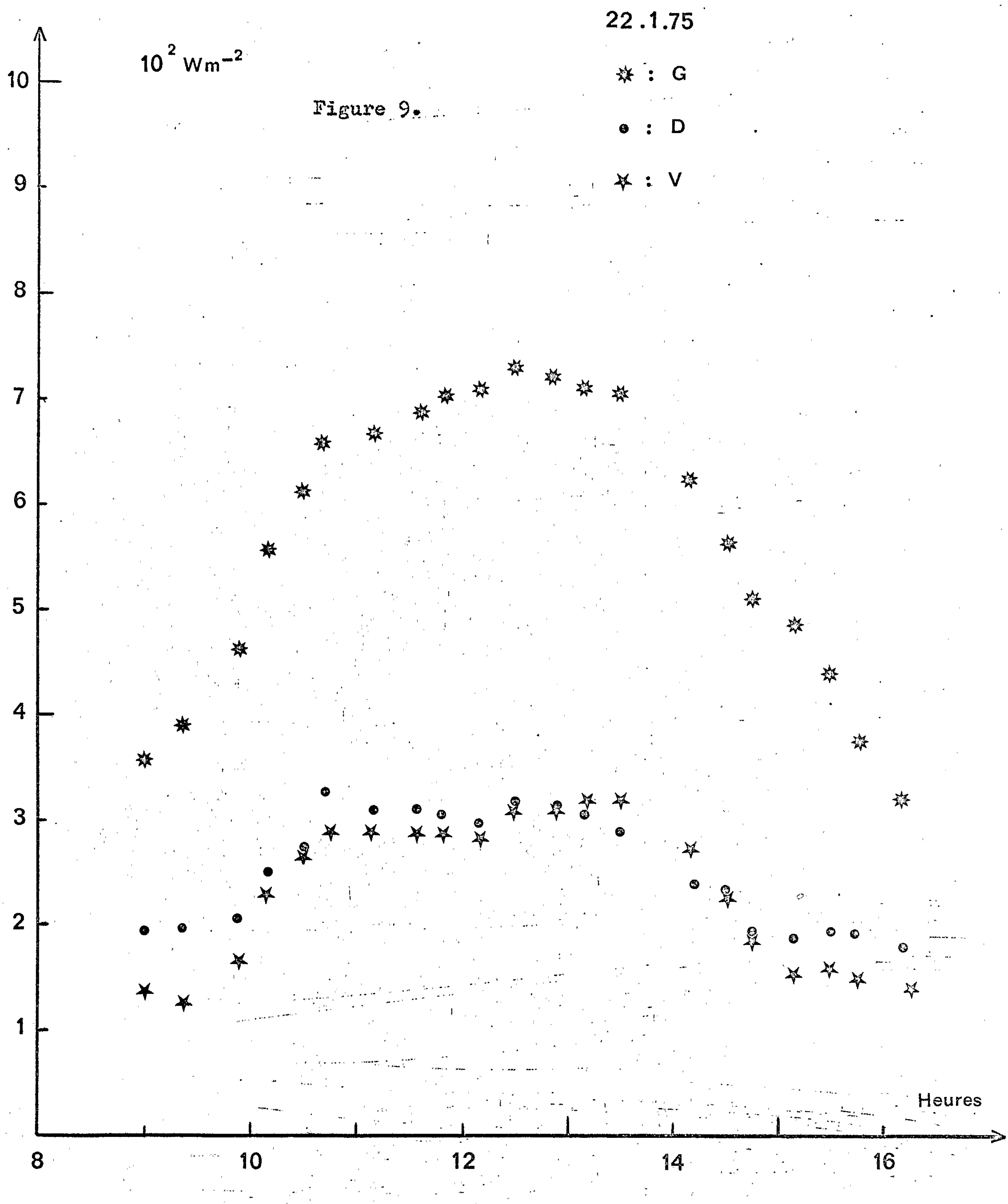


Fig.9- Evolution des rayonnements global, diffus et visible au cours d'une journée

-Figure 10.

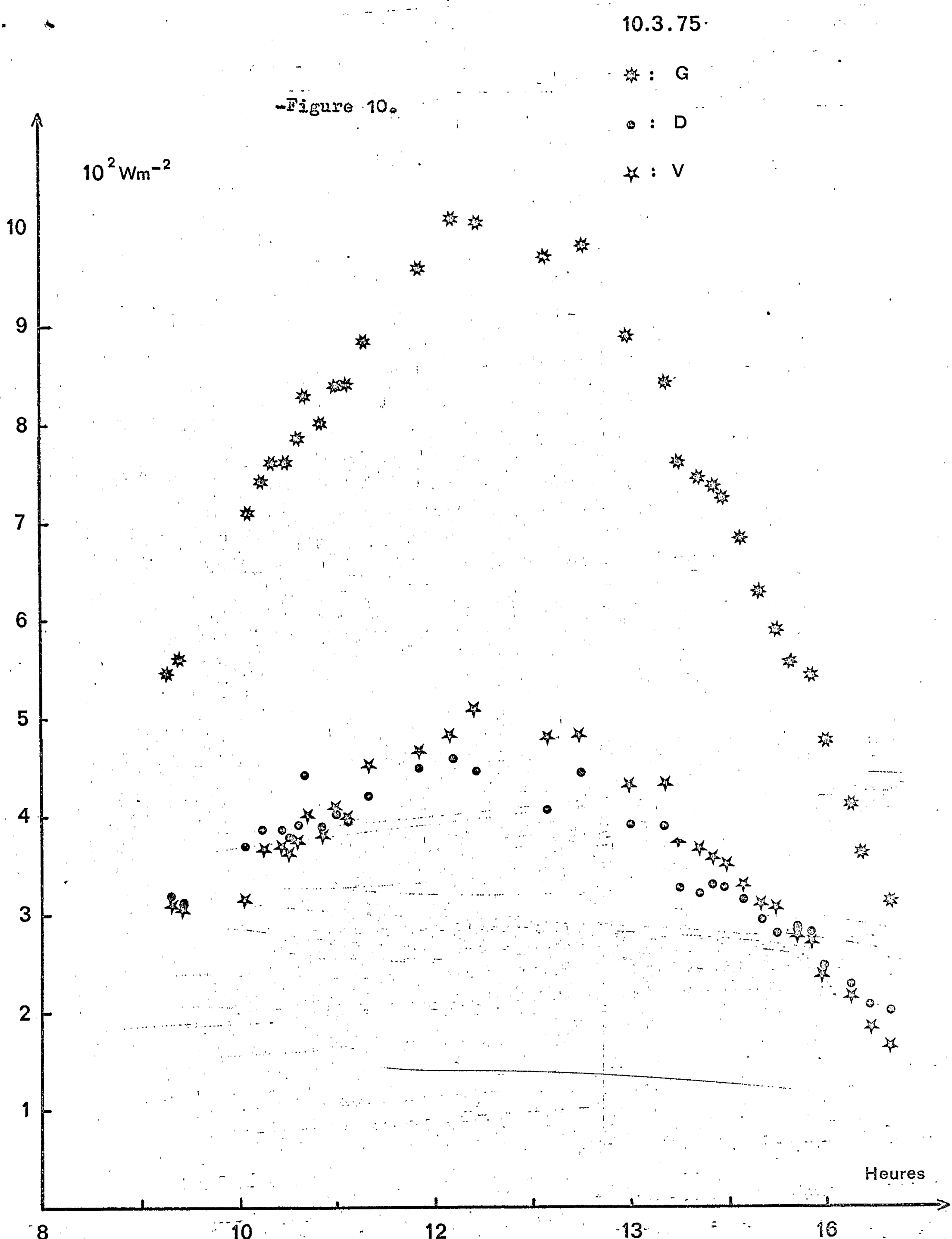


Fig. 10- Evolution des rayonnements global, diffus et visible au cours d'une journée

- Figure 11.

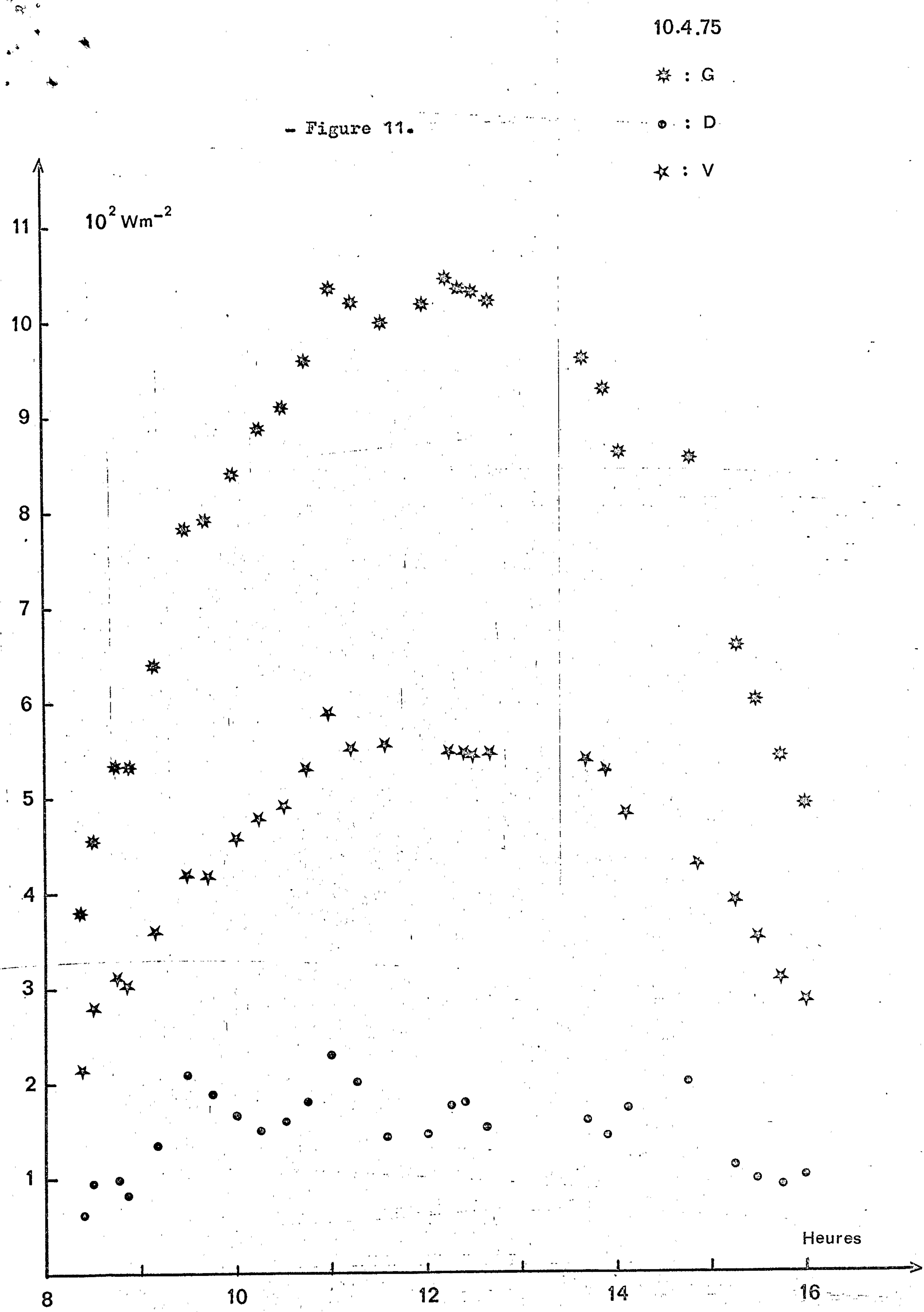


Fig.11- Evolution des rayonnements global, diffus et visible au cours d'une journée

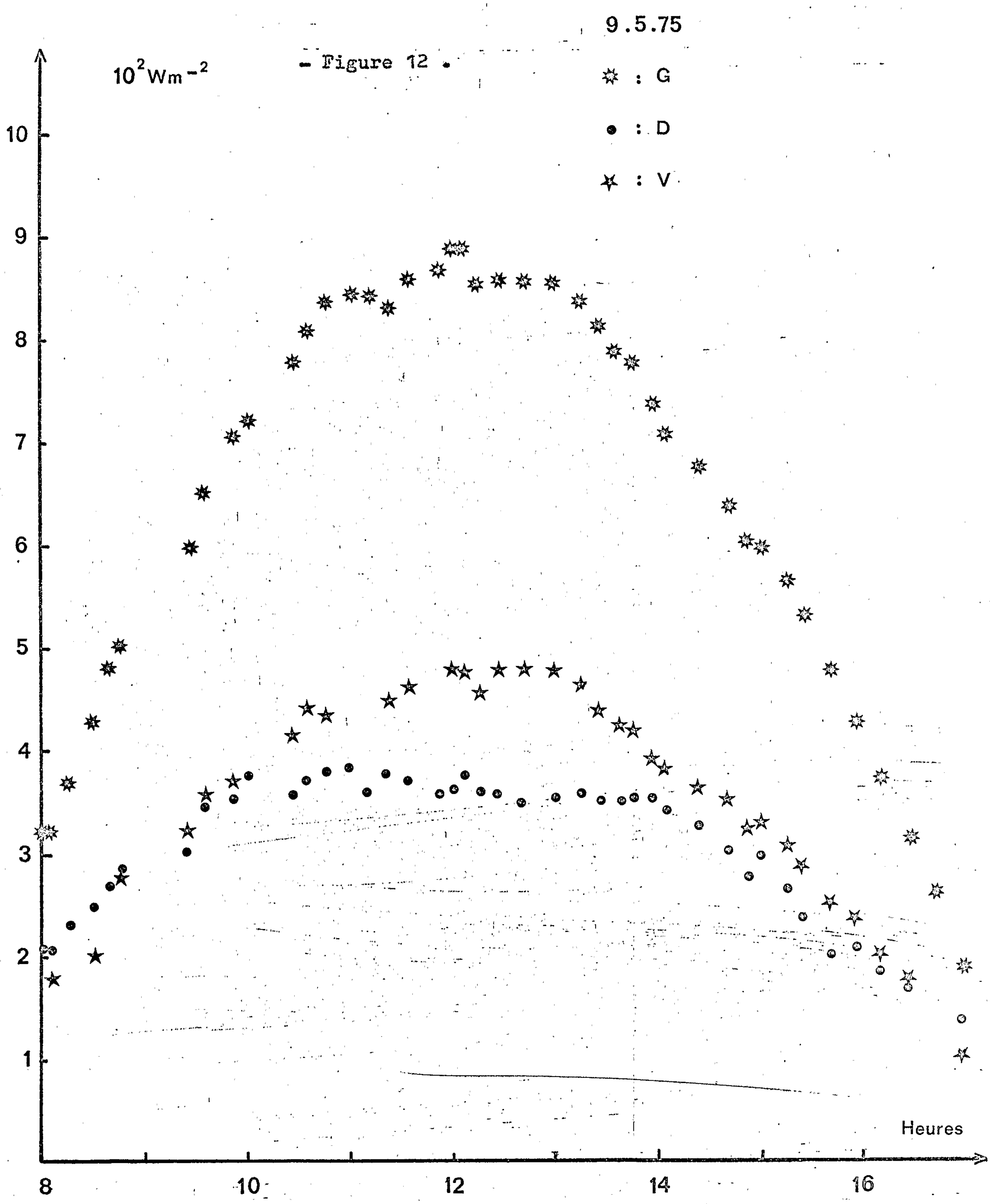


Fig.12- Evolution des rayonnements global, diffus et visible au cours d'une journée

- B I B L I O G R A P H I E -

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