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Global and diffuse radiation at the surface (1978-1985) Evidence of El Niño and El Chichon

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RESUMEN

Se analizan los datos de radiación solar (global y difusa) de las 10 y 11 horas (T.L.) para el periodo de 1980 a 1985, obtenidos del Observatorio de Radiación Solar del Instituto de Geofísica, UNAM. De estos datos se analizan también los que coincidieron con máxima insolación (MI), medida con un heliógrafo de Stokes.

Con los promedios mensuales y anuales de ambos conjuntos de datos, se hace evidente el efecto de los aerosoles del volcán Chichón (1982) en la radiación difusa.

En los promedios totales y de MI de la radiación solar global se observan incrementos importantes producidos por el fenómeno de El Niño (incremento de la temperatura en superficie en el Océano Pacífico) de 1982 a 1983.

ABSTRACT

Solar radiation data (global and diffuse) provided by the Solar Radiation Observatory of the Institute of Geophysics of the National University of Mexico, corresponding to the period 1980 to 1985, are analyzed. Two sets of data where selected. The first contains all 10 and 11 hours (L.T.) data and the second contains only the values corresponding to maximum insolation (MI), as recorded by a Stokes heliograph. Therefore the influence of clouds is minimized with the second, corresponding to cloud free condition.

From the analysis of the annual and monthly averages the effects of El Chichon (1982) are clearly visible in diffuse radiation.

The effects of El Niño phenomenon (increases of the surface temperature of the Pacific Ocean) from 1982 to 1983, are apparent in the global radiation averages.

1. Introduction

In a previous paper (Gay *et al.*, 1986) we tried to find in solar radiation data collected at the surface, evidence of the presence of the volcanic dust cloud injected into the atmosphere in the spring of 1982 by the Mexican volcano El Chichon.

We analyzed solar global and diffuse radiation, which was made available to us by the Solar Radiation Observatory of the Institute of Geophysics of the National University of Mexico (ORS-UNAM). We concluded that the effects of the aerosols upon the global and diffuse radiation measured in 1982 and 1983 were masked by other atmospheric phenomena occurring during the same period of time. Evident decreases in solar radiation at the ground produced by the presence of the stratospheric aerosol layer of volcanic origin were not observed. Instead, important increases of global radiation occurred around the middle of 1982 and the spring of 1983. The behavior of the sea surface temperature of the Pacific Ocean, during the same period corresponding to an El Niño event, showed a double maxima, with a peak in 1982 and the second in 1983, suggesting a possible relationship with the global radiation observed at the ORS-UNAM.

After analyzing different possibilities to explain the increases of solar global radiation measured at the surface in 1982 and 1983, we propose the warming of the sea surface waters of the Pacific as the (indirect) cause. During this period the El Niño event was related to a decrease in rainfall occurring in most of the country that lasted until the end of 1983. In particular, the southern part of the city, where the ORS-UNAM is located (lat. 19 20°, long. 99 11°), recorded a very low relative precipitation for the period 1978-1985 (Mosiño, 1986). Mosiño and Morales (1988) studying the possible relationship between tropical cyclones, El Niño and the precipitations at Tacubaya's Meteorological Observatory in Mexico City, found that during intense Niños like the one in 1982-1983, the number of hurricanes and thunderstorms in the Atlantic ocean decreases and the rains at Tacubaya become scarce. Precipitation at the ORS-UNAM, in general, is less than at Tacubaya and the weather becomes very dry. Therefore with a drought over the Mexican plateau and the presence of dry continental air, cloud formation is inhibited and consequently global radiation increases.

For diffuse radiation we found that the 1982 values were very high. These were attributed to the presence of the El Chichon volcanic dust cloud. The most important features of this record occurred during March and April, months of the eruptions.

Because the global and diffuse radiation data were considered as annual and monthly averages of daily totals, different atmospheric phenomena influence these values. Cloudiness affects global radiation, and rainfall affects diffuse radiation by eliminating atmospheric aerosols through a washing process.

2. Data and discussion

With the purpose of minimizing the influence of the clouds, we analyze annual and monthly averages obtained from hourly data of global and diffuse radiation corresponding to two morning hours: 10 and 11 hrs., local time. These correspond with minima of precipitation probabilities for the whole year (Camarillo, 1984). For comparison, from this set of data we constructed another in which only data for maximum insolation was considered (as measured by Stokes heliograph). This set represents values with minimum of cloud influence and will be referred to as MI (maximum insolation).

3. Results and discussion

Figure 1 shows from the average of 10 and 11 hrs data both annual averages of global radiation (□) and global MI (+); diffuse radiation (◇) and diffuse MI (△), and direct radiation computed as the difference between global and diffuse.

The first thing we notice is that global radiation for maxima insolation is larger than the global radiation in which we considered all 10 and 11 hrs data, without regard to the insolation conditions. This shows the blocking effects of clouds on global radiation. On the other hand, the diffuse radiation for maxima insolation is smaller than the diffuse radiation calculated with all 10 and 11 hrs data. This shows that clouds contribute positively to the diffuse radiation.

In what follows we will concentrate on MI data and we will compare it with the data of Gay *et al.*, 1986, which we have actualized up to 1985 (these are averages over daily totals). This comparison will shed light on the effects of clouds on global and diffuse radiation since it is made between two sets of data, one in which the effect of clouds has been minimized (MI). The MI annual averages of global radiation show maxima in 1980 and 1983 and minima in 1979 and 1982 (Fig. 1) while daily values show a single minimum in 1981 and a maximum in 1983 (Gay *et al.*, 1986). Taking cloudiness as the most important cause of variation of global radiation, we can explain the data for 1981 and 1983 as being produced by the presence or absence of clouds, in very rainy or very dry years, respectively.

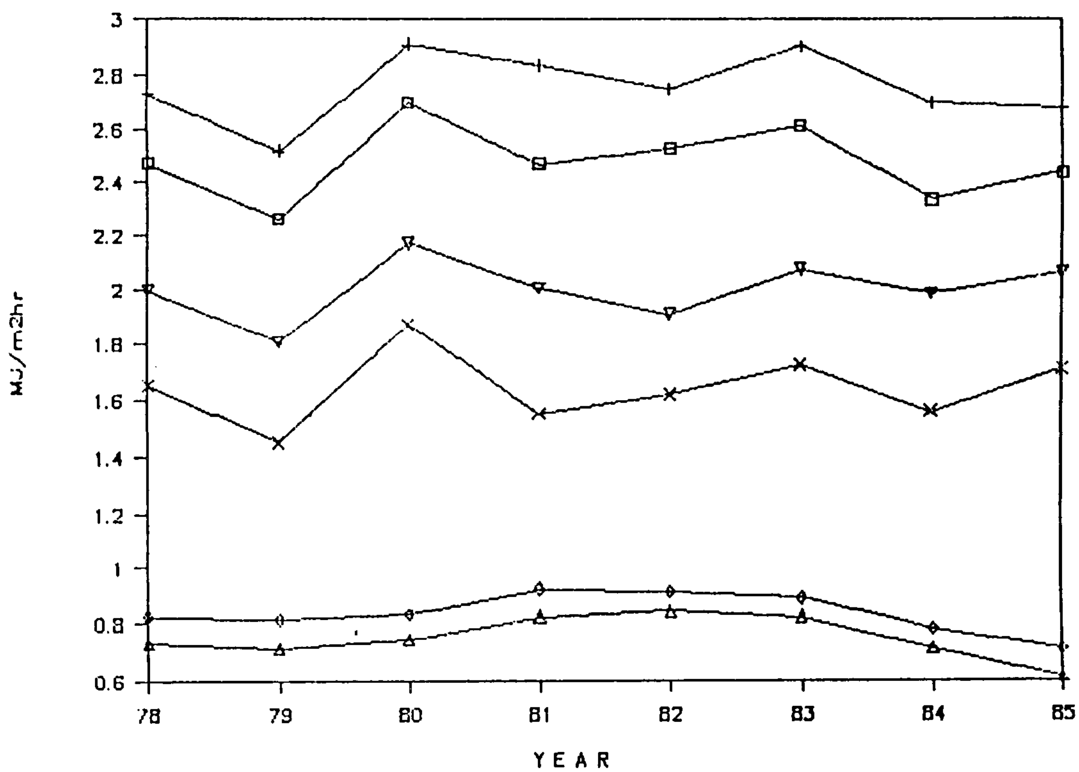

Fig. 1. Annual radiation averages for 10 and 11 hours: Global radiation (□) and Global MI (+); Diffuse radiation (◇) and Diffuse MI (△); Direct radiation (*X*) and Direct MI (∇). Global and Diffuse radiation are obtained using all 10 and 11 hrs data. Global MI and Diffuse MI are obtained using only those 10 and 11 hrs data that coincided with maximum insolation as measured with a Stokes heliograph.

Apart from the precipitation data, insolation data also show that clouds were much more abundant during 1981 than during 1983. The maxima insolation data can be thought of as representing background values affected by very high and transparent clouds. Therefore the minima of 1979 and 1982 and the maxima occurring in 1980 and 1983 were due to the presence or not of high clouds of the cirrus type. These are typical of the time of the day (10 to 11 hrs L.T.) we are considering. Although 1981 was a rainy year it does not show a minimum at this time of the day, because the clouds that produce rain in the Valley of Mexico are of the convective type and appear mostly in the afternoon (Mosiño, private communication).

We mentioned that the minima of 1979 and 1982 were due to the presence of clouds. However for 1982 another reason has to be considered. The annual averages of diffuse radiation (also Fig.

1 (∇)) show the 1979 minimum and the 1982 maximum. Both are explained in terms of the different contribution of atmospheric aerosols (by scattering of solar radiation) to diffuse radiation. It is certain that the maximum of 1982 was due to aerosols injected in the atmosphere by the eruptions of the El Chichon volcano, occurred at the end of March and beginning of April of the same year. The minimum of 1979 in diffuse radiation (MI) only represents the contribution of high clouds.

We should notice that although the volcanic dust cloud persists in the stratosphere during 1983 (McCormick *et al.*, 1984), the global radiation (Fig. 1 (+)) increases to a maximum, indicating that some phenomenon overcomes the decreasing effects of the volcanic cloud. The relative 1983 high values of diffuse radiation indicate the continuing presence of the volcanic aerosols. In the analysis presented in Gay *et al.*, 1986, there is no clear evidence of the presence of the El Chichon volcanic cloud, in the averages of daily totals of global radiation. In the case of data of maximum insolation the Chichon effects become apparent in both global and diffuse radiation for 1982 and only in diffuse radiation for 1983.

Monthly results for 1982 and 1983 are shown in Figs. 2 and 3 as departures from the monthly means calculated from 1978-1985 data excepting 1982 and 1983. Figure 2 shows the results for global radiation, for mean days (calculated from daily totals as in Gay *et al.*, 1986) and Figure 3 for maximum insolation MI. Fig. 2 shows two important minima for 1982; the first occurring during January and February and the second in the month of May, which is the month right after the El Chichon eruptions and might have been influenced by them. However, it is difficult to

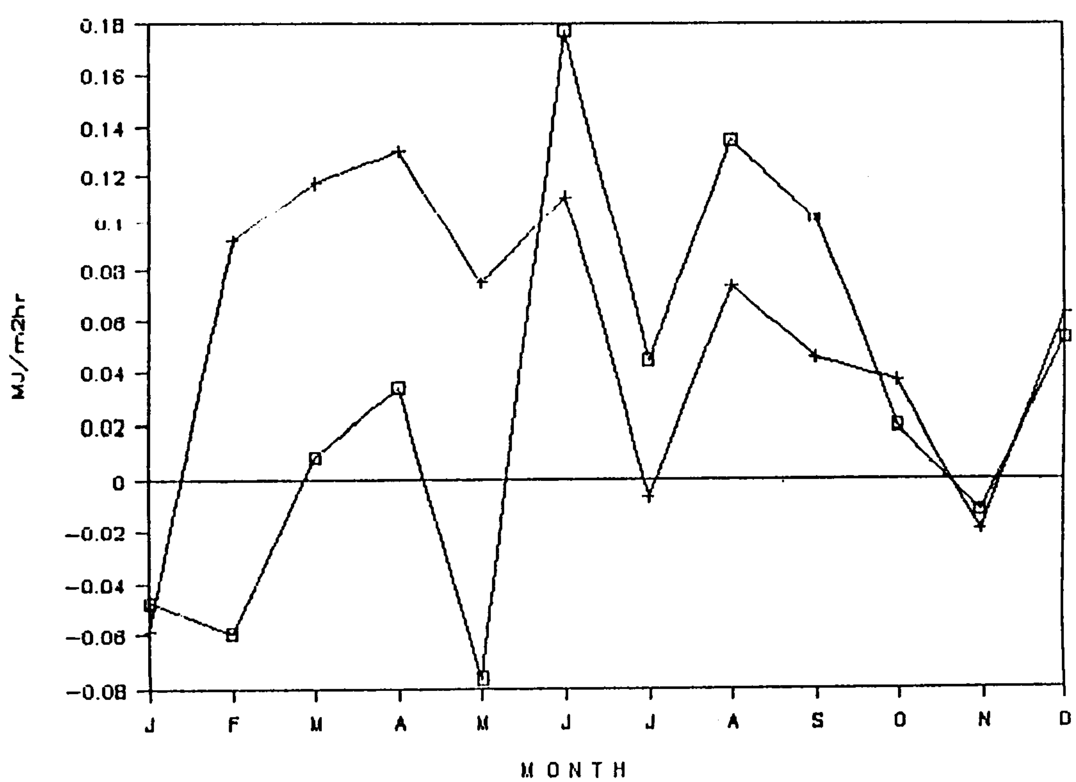

Fig. 2. 1982 (□) and 1983 (+) Global's monthly departures from 1978 to 1985 averages (except for 1982 and 1983) for daily totals.

discount the possible influences of clouds since severe isolated thunderstorms occurred during the month. In June the radiation reaches its maximum and remains above the average, except for a few months, for the rest of the year and the next (1983). The variations of the global radiation reflect the behavior of cloudiness, that in general terms decreased (global radiation increased) from June 1982 to June of 1983. The results for MI global radiation (plotted in Fig. 3) show very low values for January and February of 1982. Then there is an increase in radiation in March and then again a decrease, remaining below average for three months (May, June and July). After these the global radiation increases again and remains above average for the rest of the year (1982) and the next. We have to remember that the results of MI have been obtained from radiation data considered less influenced by clouds. Therefore in interpreting the variations, other factors must be summoned. In the case of the relative low values of May to July, we presume they were due to the presence of the El Chichon cloud which had been recently injected (end of March and the begining of April) in to the atmosphere. The minimum of January and February of 1982, is given in the context of high insolation (data from ORS-UNAM, private communication) so it was not produced by clouds. Rather it seems to indicate the presence of an important amount of atmospheric aerosols whose origin we do not know but coincides in time with the appearence of the mystery cloud of probable volcanic origin detected by the lidars of different groups (Mroz,

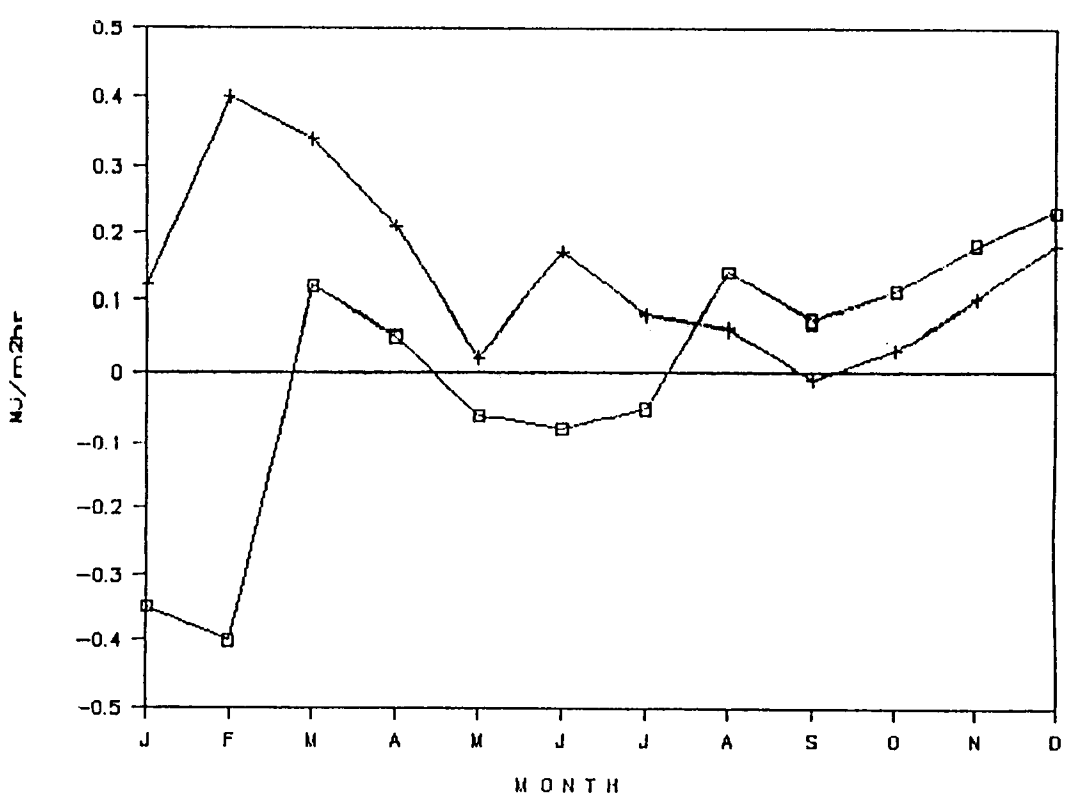

Fig. 3. Same as in Figure 2, but for the case of Global MI.

1984, DeLuisi, 1983).

The results for diffuse radiation are shown in Figs. 4 and 5. In Fig. 4 we observe that the diffuse radiation for daily total averages starts with a value above the average in January (1982),

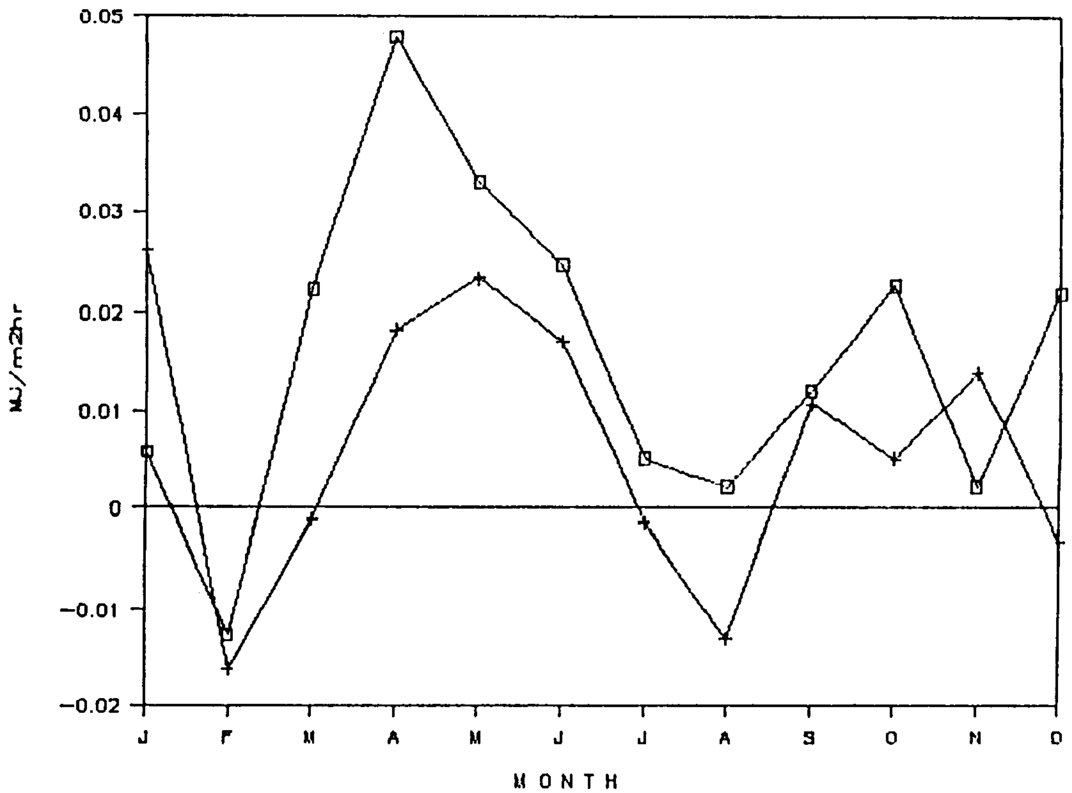

Fig. 4. 1982 (□) and 1983 (+) Diffuse radiation departures from monthly averages (1978-1985) for daily totals.

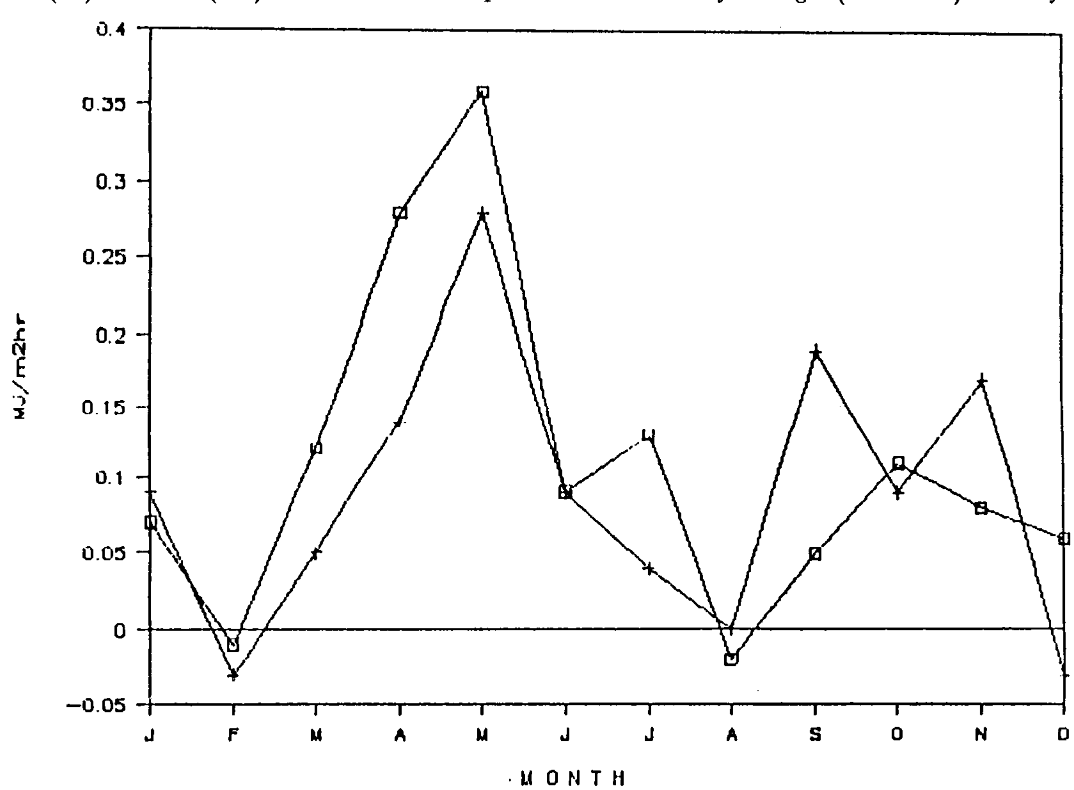

Fig. 5. Same as in Figure 4, but for the case of Diffuse MI.

then decreases in February and augments afterward peaking in April, to start decreasing again but remaining above the average for the rest of the year. During 1983 this radiation stays above the average for most of the year. The peak in April is due to the contribution to the diffuse radiation from the scattering produced by aerosols of volcanic origin (El Chichon) whose effects can be felt the rest of the year and the next. These effects can be seen more clearly in Fig. 5 where we have plotted the results of diffuse radiation for MI. In this case, the peak is reached in May and the values remain practically above the average until the end of 1983. The fact that the month of maxima in both figures is not the same can be explained in terms of the precipitation that occurred in May and that is reflected in Fig. 4 (daily averages) but not in the results of Fig. 5. This precipitation washed away part of the aerosols contributing to the diffuse radiation, therefore, lowering its value.

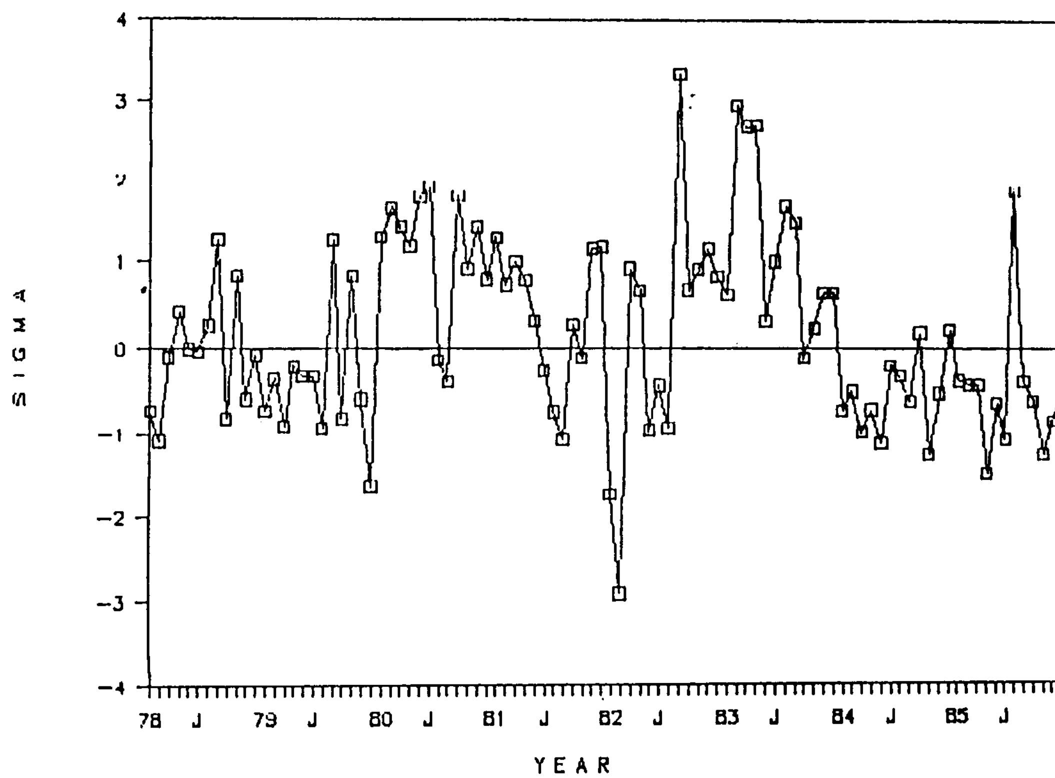

Fig. 6. Global radiation (MI) departures from monthly averages in units of sigma - the standard deviation - for each month.

Many of the features we have described up to now are summarized in Figures 6 and 7, where we have plotted for the MI values the departures from the monthly averages, measured in terms of the standard deviation for each month and for the complete record (1978-1985). In Fig. 6 we show the results for global radiation. It is clear that the largest departures correspond to the summer months of 1982 and during the spring of 1983. These variations follow approximately the changes in surface temperature measured during the same period (Gay *et al.*, 1985, Conde and Gay, 1990), which in turn are a manifestation of the El Niño event.

The relative high values occurring in 1980 are related to the prevailing dry conditions of that year. Another feature worth noticing is the very low values for the global radiation occurring during January and February of 1982. Since the data being considered correspond to morning hours and these are cloud free (MI data) the most probable explanation is given by the presence of the mysterious cloud previously mentioned. Our results then provide more evidence about the occurrence of this phenomenon. The Chichon eruptions at the end of March and beginning of April cause the decrease of global radiation as shown in the figure for the months of May, June and July.

A question arises as to why the mysterious cloud is much more notorious than the Chichon cloud, which occurred practically on top of the observatory. The answer is that the mysterious cloud occurred during normal climatic (dry, cloud free) conditions while the Chichon cloud occurred in a period coinciding with the onset of El Niño, whose effects regarding the global radiation opposed those of El Chichon. In other words, while the El Chichon cloud tends to decrease the global radiation, the El Niño acts to increase it.

In Fig. 7 we show the results for diffuse radiation. The important increase occurring in 1982 is clearly visible and high values are still present during 1983. The interpretation of data for 1982 has already been discussed in terms of the increment in the atmospheric aerosol load produced by El Chichon. The larger values for 1983 indicate that the volcanic cloud was still present in the atmosphere. We must mention at this point that the aerosols whose scattering contribute most to the diffuse radiation measured at the surface are in the troposphere. During 1982 and 1983 these aerosols were fed from the stratosphere by sedimentation of the volcanic cloud whose bulk remained above the 20 Km altitude for a long time (1982-1983). The fact that aerosols are tropospheric can be inferred from the abrupt changes observed in the plot probably produced by the washing effect of precipitations.

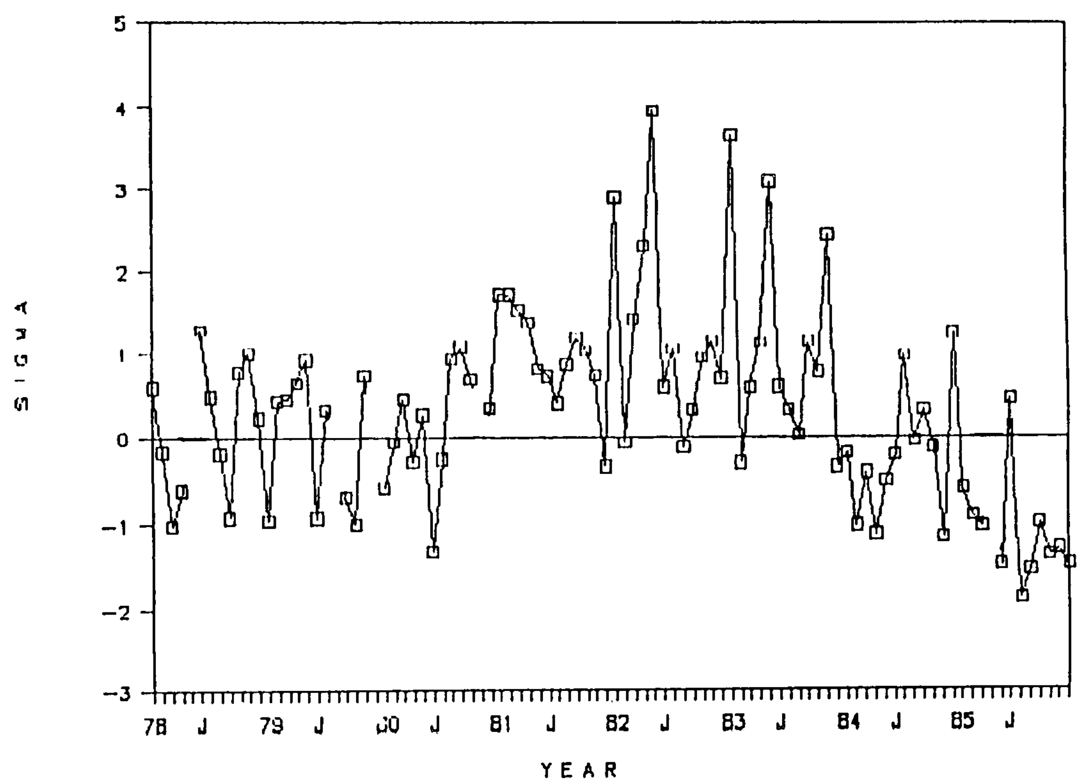

Fig. 7. Diffuse radiation (MI) departures from monthly averages in units of sigma - the standard deviation - for each month.

The notable presence of tropospheric aerosols during this period was also pointed out by Hirono (1988) who calculated aerosol profiles from Lidar observations in order to use the information in models for the air circulation induced by the presence of volcanic clouds and study the possible trigger mechanisms for El Niño events.

There are other features in the plot worth noticing. The first is the relative high values of diffuse radiation during the spring of 1981, which we have not mentioned, and the decrease during the summer coinciding precisely with the rainy season for that year. The probable origin of the aerosols of that spring was the construction of a subway station at 500 m in a straight line from the Observatory, that produced clouds of dust. These were washed out by the intense rains that occurred that summer. In general terms we can say that the variability of the diffuse radiation is controled to a certain extent by precipitation.

4. Conclusions

Our record of global and diffuse radiation (1978-1985) shows the mark of the El Chichon and El Niño occurring during 1982 and 1983. El Chichon is recognizable in the diffuse radiation record by the important increases occurring in 1982 and 1983. Global radiation on the other hand does not clearly reflect this event but for a marginal decrease occurring during May to July. However, the important increases during 1982 and 1983 can be indirectly attributed to the occurrence of El Niño with its drying effect on the atmosphere and the inhibition of cloud formation, as illustrated also in our record for daily totals.

Both parameters, global and diffuse radiation, consistently indicate the existence during January and February of 1982 of an event capable of blocking global radiation and increasing diffuse radiation, indicating the presence of the mysterious cloud.

The acknowledgement of both phenomena: El Niño and El Chichon which was not very clear in our previous attempts (Gay *et al.,* 1985 and Gay *et al.,* 1986) was possibly due to the minimization of the effects of clouds when data for maximum insolation corresponding to two hours, 10 and 11 hrs (local time) and under conditions of maximum insolation were used.

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