Geofísica Internacional (1996), Vol. 35, Num. 4, pp. 421-424

A correlation between visual observations and instrumental records of cloudiness in Mexico

Adalberto Tejeda[1] and Alfonso Vargas[2]

[1] *Ciencias Atmosféricas de la Universidad Veracruzana, Xalapa, Veracruz, MEXICO.*

[2] *Facultad de Física de la Universidad Veracruzana, Xalapa, Veracruz, MEXICO.*

Received: July 10, 1995; accepted: May 23, 1996.

RESUMEN

En este trabajo se explora la utilidad climática de las observaciones visuales del estado del cielo a nivel medio mensual, mediante la búsqueda de relaciones estadísticas de alto nivel de ajuste con la heliofanía diaria media mensual medida con el heliógrafo Campbell-Stokes, para 56 puntos de México durante el periodo 1951-1980. Se muestra que el modelo estadístico obtenido para todos los puntos y todos los meses tiene un nivel de ajuste mayor que agrupando los datos por meses, por tipos de climas o por cinturones de latitud. Este modelo es una herramienta útil para estimar las horas promedio mensual de brillo de sol en lugares de México donde sólo se cuente con observaciones de largo periodo del estado del cielo.

PALABRAS CLAVE: Cubierta nubosa, estimación de la heliofanía.

ABSTRACT

This paper develops an empirical relationship between visual point cloudiness observations and mean monthly values of daily bright sunshine measured by Campbell-Stokes recorders in Mexico. We use 56 observation points over the period from 1951 to 1980. The statistical fit obtained from the total data base including all stations and all months is better than the fit for data grouped by month, climatological type or latitude. This model is useful for estimating the mean monthly bright sunshine in sites with visual cloudiness observations.

KEY WORDS: Point cloudiness, sunshine estimation.

1. INTRODUCTION

The surface meteorological network in Mexico includes 56 stations which have information of the duration **n** of bright sunshine measured by Campbell-Stokes recorders and visual observations of point (or local) cloudiness (**PC**) for the period 1951-1980. In addition there are almost 4,000 climatological stations in Mexico with records of visual observations of point cloudiness but no Campbell-Stokes recorders. We propose relationships between **n** and **PC** for meteorological stations, to be able to use the information of the climatological stations at sites where there are no sunshine recorders.

According to Moriarty (1991), overcast means that (for a ground based observer) there is no visible blue sky; clear means there are no clouds, and patches of clear sky imply that there is both cloudy and blue sky. Cloud cover means the visual fraction of sky area which is overcast, as distinct from the fraction of the ground surface which has clouds vertically above it. The daily cloudiness **PC** has the following values: **PC**=1 for overcast days, **PC**=0.5 for periods with patches of clear sky, and **PC**=0 for clear conditions.

For purposes of estimating direct solar radiation, the cloud cover estimated in this way is more appropriate than the fraction of the ground surface with clouds vertically above it (Moriarty 1991).Since the opaque cloud cover reported by a ground-based observer is an all-sky average, it should be modified by a function of the solar elevation if it is to be used as an estimate of the probability of bright sunshine. In this paper we have not made this modification because we compared mean monthly values of **PC** and **n**.

Stigter (1982 a) reported an overestimation of cloud shade area (or shade duration, obtained as the difference between astronomical minus real sunshine duration), when using point cloudiness data. Stigter (1982 b) showed that this overestimation is not constant throughout the year but varies with the season. Stigter (1983) concluded that the monthly values of point cloudiness data in Tanzania have a large standard deviation.

According to some authors Table 1 shows the relationships between visual or point cloudiness (**PC**) and the relative sunshine (**S**):

$$\mathbf{S} = \mathbf{n}/\mathbf{N} \qquad (1)$$

where **n** is the duration of bright sunshine measured by a Campbell-Stokes recorder, and **N** is the potential astronomical sunshine duration on the horizontal plane.

We propose some statistical relationships between mean monthly values of **PC** and **S** for the network in Figure 1 for the period 1951-1980.

2. DATA AND METHODS

In order to estimate the mean monthly sunshine duration based on visual point cloudiness observations we use the following information:

(a) Mean monthly values of:

x_1: frequency of overcast days, when the average of visual observations of the cloud cover is between 6/8 and 8/8

x_2: frequency of partially cloudy days (3/8 to 5/8),

x_3: frequency of clear days (0 to 2/8).

(b) Mean monthly values of daily bright sunshine (**n**),

Table 1

Empirical relationships between relative sunshine (S) and point cloudiness (PC).

AUTHOR	RELATIONSHIP	COMMENTS
Harrison and Coombes, 1986	$S = 1 - 0.159\ \mathbf{PC} + 0.837\ \mathbf{PC}^2$	For 43 sites in Canada
Harrison and Coombes, 1986	$\mathbf{PC} + S = (1.305 + 0.128) - (0.0024 + 0.0005)\phi$	ϕ, latitude
Rangarajan *et al.*, 1984	$S = 1 - 0.220\ \mathbf{PC} - 0.550\ \mathbf{PC}^2 - 0.100\ \mathbf{PC}^3$	$8°\ N \leq \phi \leq 20°\ N$
Rangarajan *et al.*, 1984	$S = 1 - 0.450\ \mathbf{PC} - 0.300\ \mathbf{PC}^2 - 0.150\ \mathbf{PC}^3$	$20°\ N \leq \phi \leq 36°\ N$
Stanghellini, 1981	$S = \mathbf{a}\ x_2 + \mathbf{a}\ x_3 + \mathbf{c}$	For 35 sites in Italy. **a**, **b** and **c** are differents for each month.
Hoyt, 1977	$\mathbf{PC} + S = (1.176 + 0.016) - (0.0009 + 0.0003)\ \phi$	$20°\ N \leq \phi \leq 50°\ N$
Reddy, 1974	$S = 1.02 - \mathbf{PC}\ \exp(-0.25\ \mathbf{PC}^{0.5}) + 0.08 \cos 4\phi$	$\phi < 45°\ N$
Reddy, 1974	$S = 1.06 - \mathbf{PC}\ \exp(-0.25\ \mathbf{PC}^{0.5})$	$> 45°N$
Malberg, 1973	$\mathbf{PC} + S = 1.240 - 0.0018\ \phi$	$30°\ N \leq \phi \leq 70°\ N$

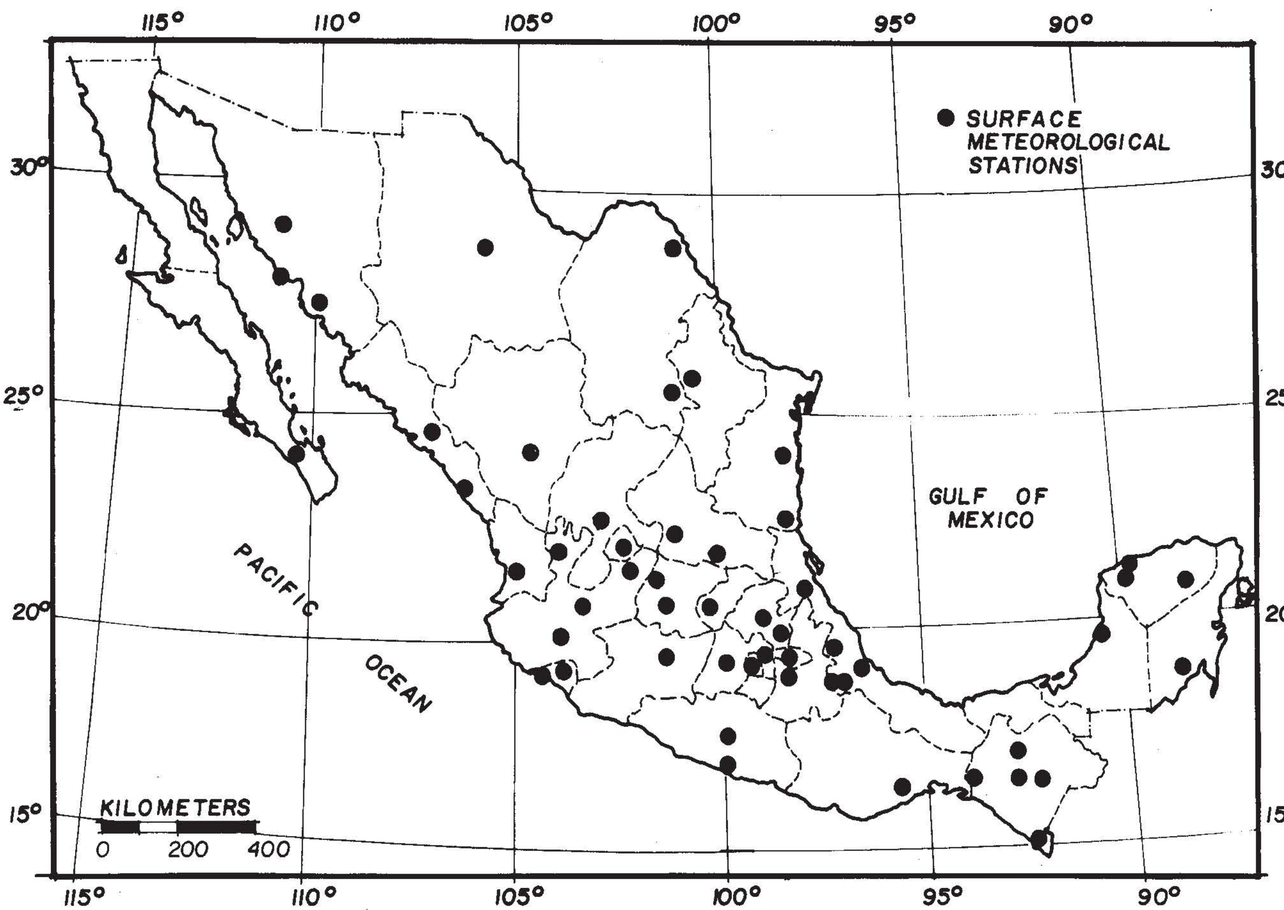

Fig. 1. Geographical location of the surface meteorological network in Mexico.

(c) Daily astronomical or potential sunshine in hours for each station on the 15th of each month, calculated according to Hernández *et al.* (1991, p. 149):

$$N_{15} = (2/15)\cos^{-1}(-\tan\phi \tan\delta_{15}), \quad (2)$$

where ϕ is the latitude and δ_{15} is the solar declination on the 15th of each month in degrees. δ_{15} was evaluated by:

$$\delta_{15} = 23.45 \sin[0.968(284+p)] \quad (3)$$

where p is the Julian day of the year (Hernández *et al.*, 1991).

For each month and site we propose to evaluate the mean monthly point cloudiness complement ($\overline{PQ}$) as:

$$\overline{PQ} = \frac{x_3 + 0.5x_2}{x_1 + x_2 + x_3}, \quad (4)$$

and the mean monthly relative bright sunshine or relative sunshine duration (S) by

$$\bar{S} = \bar{n}/N_{15} \quad (3)$$

Based on Table 1, we have done three types of correlations between $\bar{S}$ and $\overline{PQ}$.

First, we use all stations to obtain a regression equation for each month (Table 2). All correlation coefficients are below 0.8, but the root mean squared errors (RMSE) between observed and estimated data are small. Seasonal clusters of the data base also lead to small confidence levels.

Next we consider groups of data according to climate type (García, 1981). Table 3 shows that the correlation coefficients are not significant. We have included the mean monthly frequency of days with fog (F), as in Barbaro *et al.* (1981). However, the correlation coefficients are not improved and the regression coefficients of F are very small (10^{-3} or less).

Table 2

Empirical relationships between mean monthly values of relative sunshine ($\bar{S}$) and point cloudiness complement ($\overline{PQ}$) in Mexico.

Month	Equation	Linear Correl. Coef.	RMSE (%)
January	$\bar{S}=0.80\ (\overline{PQ})^{0.62}$	0.70	18
February	$\bar{S}=0.84\ (\overline{PQ})^{0.66}$	0.69	16
March	$\bar{S}=0.76+0.33\log\overline{PQ}$	0.54	12
April	$\bar{S}=0.22+0.57\ \overline{PQ}$	0.53	11
May	$\bar{S}=0.76+0.34\log\overline{PQ}$	0.72	9
June	$\bar{S}=0.30+0.50\ \overline{PQ}$	0.78	7
July	$\bar{S}=0.33+0.44\ \overline{PQ}$	0.69	7
August	$\bar{S}=0.38+0.38\ \overline{PQ}$	0.62	7
September	$\bar{S}=0.33+0.41\ \overline{PQ}$	0.69	7
October	$\bar{S}=0.32+0.47\ \overline{PQ}$	0.69	8
November	$\bar{S}=0.35\exp(0.88\ \overline{PQ})$	0.62	18
December	$\bar{S}=0.29\exp(1.1\ \overline{PQ})$	0.63	19

Table 3

Empirical relationships between mean monthly values of relative sunshine ($\bar{S}$) and point cloudiness complement ($\overline{PQ}$) in Mexico, for the best adjustment in each climatic type(according to García, 1981).

Climatic type	Equation	Linear Correl. Coef.	RMSE (%)	Sample size*
Warm	$\bar{S}=0.35+0.40\ \overline{PQ}$	0.67	8	204
Arid and subarid	$\bar{S}=0.29+0.52\ \overline{PQ}$	0.68	8	252
Temperate	$\bar{S}=0.30+0.47\ \overline{PQ}$	0.66	10	216

* The sample size is equal to the number of stations multiplied by 12 months.

Finally, we group the stations by latitude circles: four circles below and one above the tropic of Cancer, all with similar sample sizes. The regression models are shown in the first five rows of Table 4. The significance levels are satisfactory only for latitudes above 20.5° N. Still, for all stations and all months (the total sample), the significance levels are generally higher than for monthly or latitudinal data groups. The linear regression equation (last row of Table 4) has a correlation coefficient of 0.9 and the RMSE is 9.6% between observed and estimated data, which is satisfactory.

Table 4

Empirical relationships between mean monthly values of relative sunshine ($\bar{S}$) and point cloudiness complement ($\overline{PQ}$) in Mexico, for the best adjustment in each latitudinal belt.

Latitude (ϕ, in °N)	Equation	Linear Correl. Coef.	RMSE (%)	Sample size*
< 19°	$\bar{S}=0.28+0.44\ \overline{PQ}$	0.65	11	144
$19° \le \phi \le 20.5°$	$\bar{S}=0.37\exp(0.7\overline{PQ})$	0.61	18	180
$20.5° \le \phi \le 22°$	$\bar{S}=0.34+0.48\ \overline{PQ}$	0.70	8	156
$22° \le \phi \le 23.5°$	$\bar{S}=0.32+0.48\ \overline{PQ}$	0.70	7	60
> 23.5°	$\bar{S}=0.30+0.49\ \overline{PQ}$	0.98	9	132
$14° \le \phi \le 33°$ (all stations and months)	$\bar{S}=0.31+0.49\ \overline{PQ}$	0.90	10	672

* The sample size is equal to the number of stations multiplied by 12 months.

3. CONCLUSION

Based on the regression model shown in the last row of Table 4, we may estimate the mean monthly bright sunshine or mean monthly sunshine duration ($\bar{n}$) for sites in Mexico which have only visual point cloudiness records. The best data fit yields

$$\bar{n} = N_{15}\left(0.31 + 0.48\left(\frac{x_3 + 0.5x_2}{x_1 + x_2 + x_3}\right)\right) \quad . \qquad (6)$$

This empirical relationship enables us to estimate the value of $\bar{n}$ for nearly 4,000 sites in Mexico with a correlation of 0.9 with instrumental measurements, and an RMS error of 0.1 times the daily mean monthly astronomical sunshine duration (N_{15}). The last factor of Eq. (6) as proposed in this paper originates in our Eq. (4) and is useful in order to estimate $\bar{n}$.

The fits of Tables 2, 3 and 4 obtained from monthly, latitudinal or climatological data grouping are less reliable than the model of Eq. (6) which uses the total data base.

ACKNOWLEDGMENTS

We are grateful to Mr. M.A. Hobart for his suggestions to improve the manuscript.

BIBLIOGRAPHY

BARBARO, S., G. CANNATA, S. COPPOLINO, C. LEONE and E. SINAGRA, 1981. Correlation between relative sunshine and state of sky. *Solar Energy, 26*, 537-550.

GARCIA, E., 1981. Modificaciones al sistema de clasificación climática de Koeppen. Talleres Offset Larios (México), 252p.

HARRISON, A. W. and C. A. COOMBES, 1986. Empirical relationship of cloud shade to point cloudiness (Canada). *Solar Energy, 37*, 417-421.

HERNANDEZ, E., A. TEJEDA and S. REYES, 1991. Atlas solar de la República Mexicana. Universidad Veracruzana, Xalapa, 155p. (Available copies).

HOYT, D.V., 1977. Percent of possible sunshine and total cloud cover. *Mon. Wea. Rev., 105*, 648-652.

MALBERG, H., 1973. Comparison of mean cloud cover obtained by satellite photographs and ground-based observations over Europa and the Atlantic. *Mon. Wea. Rev., 101*, 893-897.

MORIARTY, W. W., 1991. Cloud cover as derived from surface observations, sunshine duration, and satellite observations. *Solar Energy, 47*, 219-222.

RANGARAJAN, S., M. S. SWAMINATHAN and A. MANI, 1984. Computation of solar radiation from observations of cloud cover. *Solar Energy, 32*, 553-556.

REDDY, S. J., 1974. An empirical method for estimating sunshine from total cloud amount. *Solar Energy, 15*, 281-285.

STANGHELLINI, C., 1981. A simple method to evaluating sunshine duration by cloudiness observations. *J. Appl. Meteo., 20*, 320-323.

STIGTER, C. J., 1982a. Estimation of areal cloudiness at some near-equatorial stations in Tanzania. *Weather, 37*, 11-16.

STIGTER, C. J., 1982b. Sampling and estimation of better defined cloudiness for Dar es Salam. *Solar Energy, 28*, 49-53.

STIGTER, C. J., 1983. An explanation of uncertainties in Point Cloudiness/Solar Energy relationships. *J. of Climate and Appl. Meteor., 22*, 336-338.

Adalberto Tejeda[1] and Alfonso Vargas[2]

[1] *Ciencias Atmosféricas de la Universidad Veracruzana. A.P. 465, Xalapa, Veracruz, MEXICO.*
E-mail: atejeda@speedy.coacade.uv.mx.
[2] *Facultad de Física de la Universidad Veracruzana, A.P. 270, Xalapa, Veracruz, MEXICO.*