Observations Concerning the Empirical Relationship of Cloud Shade to Point Cloudiness (Romania)

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ABSTRACT

Monthly average values from 29 weather stations of Romania show that, in general, point cloudiness (PC) is greater than cloud shade (CS) by as much as 0.2. Four previously proposed empirical relationships of cloud shade to point cloudiness were verified under the climate and latitudes of Romania; in all cases new coefficients of regression were determined.

1. Introduction

Many methods of computing solar radiation have been developed on the basis of long-term averages of bright sunshine (e.g., IEA 1984). However, sunshine records are not always kept at weather stations; yet, long-term records of observed total cloud cover are available for most stations of the world. Consequently, it is useful to establish relationships between sunshine and cloud cover, because in this way solar radiation may be computed over a considerably larger geographical area. The subject was previously approached by Reddy (1974) and Rangarajan et al. (1984) for India and Harrison and Coombes (1986) for Canada. The main purpose of this note is to report on the empirical relationship between cloud cover and bright sunshine for the Romanian climate and latitudes.

2. Cloud shade and point cloudiness data

For a given period of time we will use S and PC (point-cloudiness) to denote the fraction of possible bright sunshine and the average fractional total cloud amount observed by eye, respectively. The complement of S is often called cloud shade $CS = 1 - S$. The relationship of PC to CS was investigated for 29 Romanian weather stations selected to give broader coverage of the country in both latitude and longitude (44.1°–47.8°N, 21.3°–29.7°E). Details concerning these stations and the five-year period chosen for collecting the monthly average values of PC and CS can be found in Bădescu (1989). In computations we used all 1740 points (PC, CS). The 348 multiyear monthly average values are shown in Fig. 1 in the form PC–CS versus CS. Note that some of these values are superposed. In general, point cloudiness is greater than cloud shade by as much as 0.2 and the difference PC − CS is a maximum for PC = ~0.3–~0.7. When PC exceeds 0.7 this difference tends to become negative. Relatively similar results have been found by other authors. Reddy (1974) obtained for the Indian Latitudes (L = 8°–36°N) a yearly variation of PC − CS between 0.02 in March and 0.17 in August. At the same latitudes, Raju and Karuna Kumar (1982) and Rangarajan et al. (1984) find PC − CS to have maximum values of 0.25 and 0.2, respectively, for PC in the range 0.4–0.7. Harrison and Coombes (1986) found for the latitudes of Canada (L = 42°–74°N) that PC − CS can be as high as 0.3 and is a maximum for PC = ~0.3–~0.7.

There are three reasons why values of PC − CS are different from zero. First, an overestimation of cloud cover by the ground-based observer compared to sunshine derived cloud cover can occur from perspective problems faced by the observer (Harrison and Coombes 1986). Clouds obscure a greater fraction of the sky when viewed near the horizon than when viewed overhead. This effect is greater for moderate amount of cloud (PC = 0.3–0.7) and vanishes for near overcast skies, as seen from Fig. 1. Second, the sunlight can penetrate thin clouds sufficiently to operate a sunshine recorder. Consequently, a new type of overestimation may occur, which cannot be attributed to the weather observer. Underestimations are also possible because of the formation of frost on the globe of the sunshine recorder (Harrison and Coombes 1986) or in the case of high atmospheric humidity, which sometimes makes impossible the burning of sunshine cards. The last situation was observed in Romania at Sulina, where the weather station is located on the sea surface (Neacşa and Susan 1984; Bădescu 1987). A third factor that influences the value of PC − CS is latitude; some previous studies showed that PC − CS decreases with

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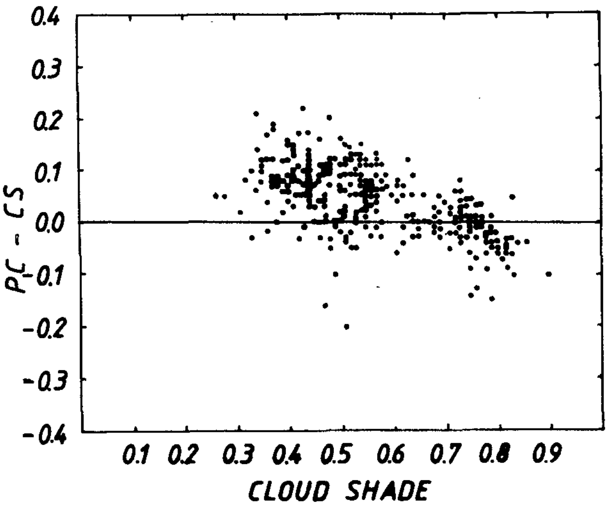

FIG. 1. Five-year monthly average values of PC − CS vs cloud shade for 29 Romanian meteorological stations.

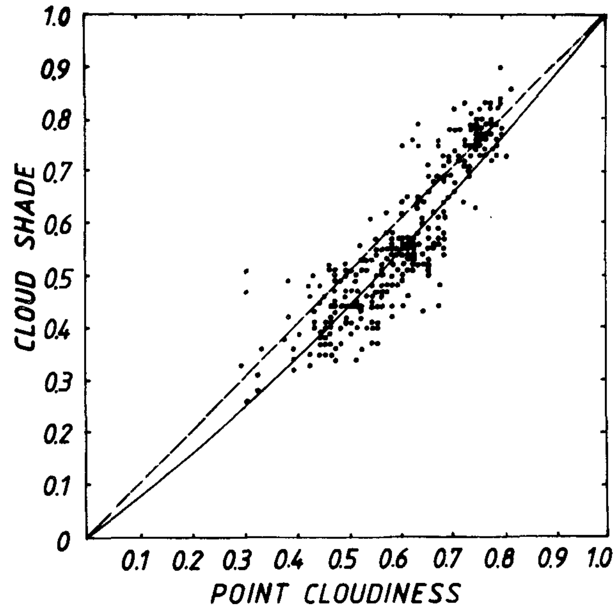

FIG. 2. Cloud shade (CS) vs point cloudiness (PC) for 29 Romanian meteorological stations (five-year monthly average values). Least squares best-fit second-order regression equation is CS = 0.738 PC + 0.279 PC^2.

increasing latitude (Malberg 1973; Hoyt 1977; Raju and Karuna Kumar 1982; Harrison and Coombes 1986).

3. Relationship of cloud shade to point cloudiness

The empirical equations proposed in the literature relating CS and PC have the following three forms:

$$CS = \alpha PC + \beta PC^2 \tag{1}$$

$$CS = \alpha PC + \beta PC^2 + \gamma PC^3 \tag{2}$$

$$CS = PC^\alpha + \exp(-\beta\sqrt{PC}) + \gamma \tag{3}$$

where the values of the coefficients α, β, and γ can be found in Table 1. The same table contains the new values of α, β, and γ, which were determined by a least squares fit of the regression equations (1–3) to the data of Fig. 2. Another regression equation that was fitted has the form:

$$CS = \alpha + \beta PC. \tag{4}$$

In the case of Eq. 3 the least squares technique was applied to the points (ln CS, PC) by choosing $\gamma = 0$.

We verified the accuracy of Eqs. 1–4 by using both the old and the new values of α, β, and γ. As statistic indicators of accuracy, we used the mean-bias error (MBE) and the root-mean-square error (RMSE) ex-

TABLE 1. Validation of some empirical relationships of cloud shade (CS) to point cloudiness (PC) (Eqs. 1–4) under the climate and latitudes of Romania. MBE, RMSE, and d_2 are the mean-bias error, the root-mean-square error, and the index of agreement of Willmott (1985), respectively (for d_2 see Eq. 5). m_{obs} is the mean of the observed values of CS.

References	The number of the regression equation (see text)	Coefficients of regression			Latitudes (°N)	Indicators of accuracy		
		α	β	γ		MBE / m_{obs} (%)	RMSE / m_{obs} (%)	d_2
Reddy (1974)	3	1.000	0.250	0.06	45–90	−0.4	14.7	0.899
Rangarajan et al. (1981)	2	0.220	0.550	0.10	8–20	−32.6	34.8	0.714
Rangarajan et al. (1984)	2	0.450	0.300	0.15	20–36	−22.8	25.9	0.804
Harrison and Coombes (1986)	1	0.159	0.837	—	42–74	−23.7	26.8	0.817
Present work	1	0.738	0.279	—	44–48	−0.1	12.2	0.949
Present work	2	1.046	−0.703	0.75	44–48	−0.0	12.1	0.949
Present work	3	1.107	0.551	0.00	44–48	3.5	12.8	0.942
Present work	4	0.004	0.920	—	44–48	0.7	12.9	0.934

CORRIGENDUM

The co-authors of the "Reply" that appeared in the October *Journal of Applied Meteorology,* Vol. 29, No. 10, were inadvertently not listed on the Table of Contents, which is corrected as follows: