Comparison of Radiation Computations Using Observed and Estimated Precipitable Water

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ABSTRACT

Hourly values of total solar radiation are computed by two methods at 11 stations in all regions of the United States for a two-year period. In the first method, precipitable water is computed from radiosonde observations while in the second method it is estimated from surface dew point. Annual differences were 1% or less at 10 of the 11 stations and less than 2% at all stations for both years. Differences in individual months were also less than 2% at all stations with few exceptions.

1. Introduction

Solar radiation undergoes absorption and scattering in the atmosphere, resulting in an attenuated direct beam and diffuse flux of radiation in all directions. Over a period of years, a radiation model has been developed at The Center for the Environment and Man, Inc. This model includes the effects of Rayleigh scattering, absorption by water vapor and permanent gases, and adsorption and scattering by clouds and pollutants. A description of the model and comparison of computed and observed fluxes is given by Atwater and Brown (1974).

The radiation model was employed to compute hourly values of total and direct-beam solar radiation at nearly 50 stations in 12 metropolitan areas in 1971 and 1972, years of high and low insolation, respectively, in many regions of the United States. A major objective of this application was to investigate intra- and inter-regional variations of total solar radiation. During the course of the study, one of the questions which arose concerned the error involved in radiation computations from using surface dew point to estimate precipitable water as compared to computing precipitable water from a radiosonde sounding. This question is addressed in this note.

2. Theory

The absorptivity due to water vapor through an atmospheric layer which is added to the extinction of a dry, hazeless atmosphere, is

$$a_w = 0.077\left(\frac{u}{\cos z}\right)^{0.3} \tag{1}$$

(see McDonald, 1960), where u is the precipitable water vapor (cm) above layer z.

The precipitable water computed from radiosonde data of the atmosphere is

$$u = -\frac{1}{g}\int_p^0 q\,dp, \tag{2}$$

where p is the surface pressure, g gravity and q specific humidity. When upper air data are not present, an empirical equation based on Smith (1966) was used:

$$u = \exp[0.07074\ T_d + \tau], \tag{3}$$

where $\tau = -0.02290$ from April to June and $\tau = +0.02023$ in the remaining months, and T_d is dew point (°C). The value for τ was approximated from Smith

TABLE 1. Comparison of differences in computed total solar radiation using surface dew point and radiosonde data.

Station	Year	Month of greatest difference	Average daily difference* (W m^{-2})	Percent difference	Average annual difference* (W m^{-2})	Percent difference
Athens, Ga.	1971	February	1.8	1.3	0.2	0.1
	1972	March	1.3	0.1	0.3	0.2
Tucson, Ariz.	1971	June	8.5	2.3	3.8	1.6
	1972	May	6.3	1.4	1.3	0.5
Green Bay, Wisc.	1971	July	−5.1	2.1	−0.2	0.1
	1972	May	3.0	1.1	1.2	0.8
Ft. Worth, Tex.	1971	March	1.9	0.9	0.3	0.2
	1972	August	1.9	0.8	0.7	0.4
Boston, Mass.	1971	April	1.4	0.8	0.8	0.5
	1972	April	1.6	0.8	0.7	0.5
Omaha, Neb.	1971	March	−1.8	1.1	−0.1	0.1
	1972	May	−3.1	1.3	−0.6	0.4
New York, N.Y.	1971	April	1.3	0.7	0.4	0.3
	1972	March	1.3	1.0	0.4	0.3
Miami, Fla.	1971	April	−1.2	1.0	−0.4	0.3
	1972	July	0.9	0.4	0.2	0.1
Bismarck, N.D.	1971	August	2.1	0.8	0.9	0.6
	1972	September	2.6	1.5	1.5	1.0
Charleston, S.C.	1971	February	2.3	1.7	0.8	0.5
	1972	October	1.5	0.9	0.7	0.4
Denver, Colo.	1971	June	2.0	0.7	0.4	0.2
	1972	October	1.6	1.3	0.7	0.4

* Total solar radiation computed using surface dew point minus total solar radiation computed using radiosonde data.

(1966) for cities in the radiation model application described here.

3. Results

Radiosonde observations as well as surface observations were available at 11 of the stations included in the study. Total solar radiation was computed both with and without the radiosonde data at the 11 stations and the results are summarized in Table 1 for 1971 and 1972. The results indicate that both on an annual and on a monthly basis, the computed total solar radiation is usually slightly higher when the surface dew point is used to estimate precipitable water. By inference, then, the computed precipitable water [Eq.(2)] slightly exceeds the estimated precipitable water [Eq. (3)] on the average.

The average annual difference in total solar radiation is less than 2 W m^{-2} each day at all stations in both years, with only one exception. In Tucson in 1971, the average daily difference is 3.8 W m^{-2} which is only 1.6% of the average daily total radiation.

Table 1 also gives the month in each year in which the largest difference in total solar radiation occurred. Again the largest difference occurred in Tucson in June 1971 where the two methods differed by 8.5 W m^{-2}, still only 2.3% of average daily radiation received that month. The results in the table clearly demonstrate that use of the surface dew point to estimate precipitable water introduces only very minor errors into the computations of total solar radiation in this study.

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