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Mapping Average Daily Pan Evaporation

By David A. Woolhiser,[1] M. ASCE and D. E. Wallace[2]

Introduction

Estimates of average daily pan evaporation are frequently useful as an index of potential evapotranspiration in simplified water balance studies (3). Daily Class A pan evaporation data are available for many stations in the United States and are summarized as monthly averages. If it can be assumed that the stochastic nature of the evaporation process, and its correlation with other climatological factors such as temperature or precipitation, is unimportant, monthly averages of daily pan evaporation can be used as input to water balance models. Monthly average pan evaporation rates could be mapped to provide convenient model input

[1]Research Hydr. Engr., Southwest Rangeland Watershed Research Center, ARS-USDA, 2000 East Allen Road, Tucson, Ariz. 85719.

[2]Geologist, Southwest Rangeland Watershed Research Center, ARS-USDA, 2000 East Allen Road, Tucson, Ariz. 85719.

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parameters. An alternative approach is to fit Fourier series to average monthly pan evaporation data and map the Fourier coefficients to provide a regional description. This procedure requires fewer parameters, and also provides a means of varying the average daily evaporation rate within a month.

The purpose of this note is to present maps of the mean, amplitude, and phase angle of the first harmonic of Fourier series which describe mean daily Class A pan evaporation for the United States east of the Rocky Mountains. Western stations were not included, because the mountainous terrain would usually preclude the possibility of interpolating between stations.

Procedure

Average monthly Class A pan evaporation data were obtained for 146 U.S. stations east of the Rocky Mountains (4). The period of record was variable, and ranged from 8–30 yr. The average monthly values were converted to daily values, and the average daily rate was assumed to occur at mid-month. For the northern stations, no pan evaporation rates are reported for months when freezing occurs. Evaporation for these months was estimated by prorating the difference between previously estimated average annual Class A pan evaporation (2) and the sum of the monthly totals for the months reported. This prorating was done using similar proportions to the nearest station where all monthly data were available. For the northern tier of states, the monthly pan evaporation rates for November through April were estimated by this method. These estimates of monthly pan evaporation, for the winter months in the northern states, were made only to provide 12 equally-spaced values for Fourier series fitting.

The 12 average daily pan evaporation rates for each station were then fitted with a finite Fourier series which was converted to a series in the polar form:

$$E_i(n) = C_{io} + \sum_{j=1}^{6} \left\{ C_{ij} \sin\left(\frac{nj}{T} + \theta_{ij}\right)\right\} \quad (1)$$

in which $E_i(n)$ = the average pan evaporation for day n, n = 1, 2 ... 365, for the ith station; C_{io} = the average daily pan evaporation; C_{ij} = the amplitude of the jth harmonic; θ_{ij} = the phase angle of the jth harmonic in radians; and $T = 365/2\pi$. Day 1 was taken as January 1, and the extra day in leap years was ignored. A single harmonic explained more than 95% of the variance of monthly mean pan evaporation for most of the stations.

The estimated values of the parameters C_{i0}, C_{i1}, θ_{i1} for all stations were plotted on maps, and isolines obtained by linear interpolation were drawn for the mean and amplitude (Fig. 1 and 2). The estimated phase angles in radians are plotted in Fig. 3. Although trends are apparent with the phase angle θ_{i1}, ranging from −1.80 radian in Nebraska to −1.28 radian in Florida, the noise component is large enough that we present only a map showing values of the phase angle rather than isolines. Recently published maps of May–October pan evaporation and annual free

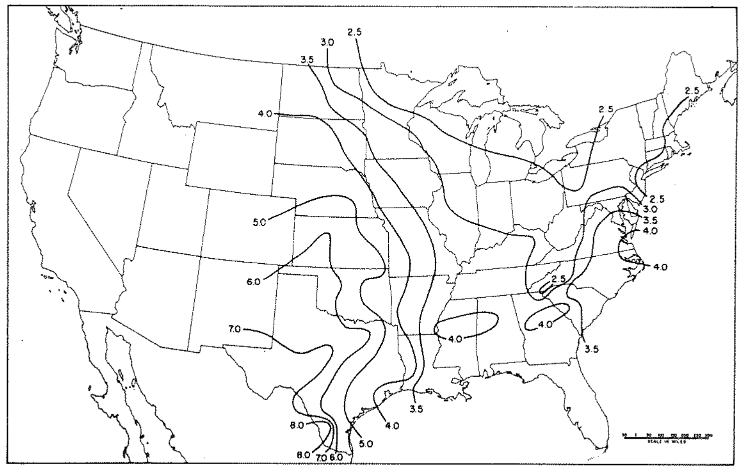

FIG. 1.—Mean Daily Class A Pan Evaporation for U.S. East of Rocky Mountains

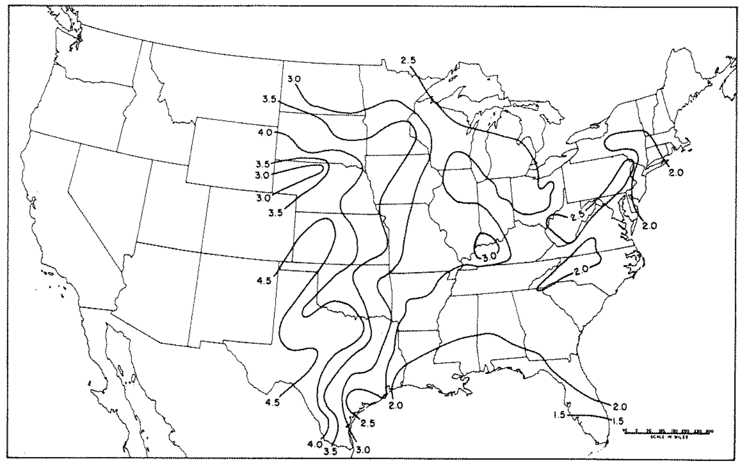

FIG. 2.—Amplitude of First Harmonic

water surface evaporation (1) were used for guidance in drawing the isolines of mean daily evaporation. The user should be cautioned that fitting with only one harmonic results in negative predicted pan evaporation rates for some winter months in Minnesota, Wisconsin, and Michigan, and these negative values should not be used. Obviously, correlation of Fourier-fit pan evaporation predictions, with sublimation or other water loss mechanisms during the winter, should be carefully evaluated before using even the positive estimates in water balance calculations.

Fourier series parameters for average daily pan evaporation can be

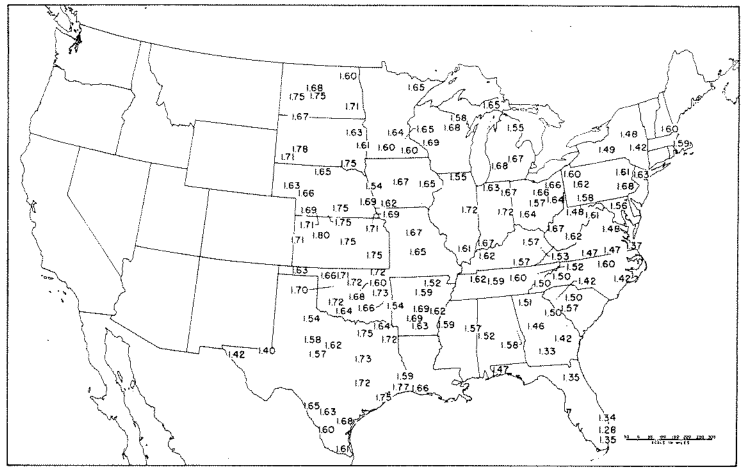

FIG. 3.—Phase Angle of First Harmonic

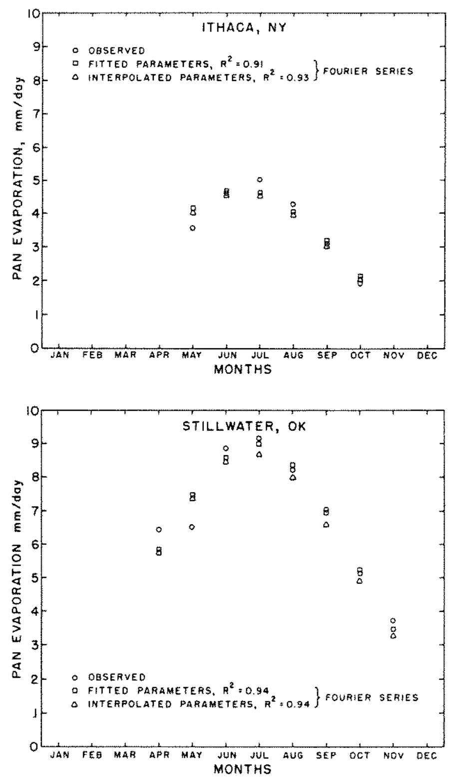

FIG. 4.—Comparison of Observed and Computed Average Daily Class A Pan Evaporation

readily obtained by linear interpolation from the maps of means and phase angles (Figs. 1 and 2) for locations where evaporation data are not available. Estimates of phase angle can be obtained by averaging nearby values.

To demonstrate the magnitude of the errors introduced by the Fourier series with only one harmonic and the errors from interpolating on the maps, pan evaporation was calculated for two stations, Ithaca, N.Y. and Stillwater, Okla. Observed and calculated curves for both stations are shown in Fig. 4. The original data for mean daily evaporation, and the fitted Fourier series with one harmonic, are also plotted for each month. The values of the coefficient of determination, R^2, shown in Fig. 4, do not include the estimated monthly values for months when freezing occurs that were used to obtain the original Fourier series fit. The differences between observed and Fourier series predictions with the interpolated parameters include errors due to truncation of the Fourier Series, differences due to length of record, and real differences due to pan exposure. Without more detailed study, it is impossible to assess the relative contribution of each.

Summary and Conclusions

Voluminous data on monthly averages of Class A pan evaporation can be described concisely, and with reasonable accuracy, by mapping the parameters of Fourier series describing the seasonal variations. The parameter maps, shown in Figs. 1, 2, and 3, provide a rather quick and easy method of estimating average daily pan evaporation, and can be used to provide ready input to simple water balance models. Observed daily evaporation values, or simulated data utilizing detailed stochastic models, must, be used if the probabilistic structure of the process, and its correlation with other climatic inputs, are to be preserved.

Appendix.—References

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