# A Daytime Radiation and Cloud Climatology from Time Series of Measured Surface Irradiance

*M. S. O'Malley and C. E. Duchon*
*School of Meteorology*
*University of Oklahoma*
*Norman, Oklahoma*

Pyranometer measurements spatially integrate the effects of clouds on the shortwave energy budget that fundamentally drives the daily and annual cycles of heating at the earth's surface and lower troposphere. In addition to their value in energy studies and the radiation budget, time series of irradiance can also be used to categorize clouds. This value-added feature of irradiance could become an inexpensive alternative to human observations of clouds and set the stage for a new kind of cloud climatology. Time series of two years of Eppley Precision Spectral Pyranometer (PSP) data were examined, and examples of a daytime cloudiness index and a daytime cloud-type frequency are presented.

The basis for classifying clouds is that each cloud type or combination thereof has a set of statistical properties that can be used to define it. It is hypothesized that their statistics are sufficiently dissimilar to prevent a significant overlap for the cloud classification process. Two simple statistics that appear applicable are the mean and the standard deviation. The former is a measure of the average amount of irradiance over a period. The latter is a measure of the cloud structure created by cloud elements passing between the sun and the sensor. Together, the mean and standard deviation can be used to describe basic cloud types.

The first step in the cloud classification is to scale a modeled clear-sky irradiance (Meyers and Dale 1983) according to zenith angle to yield one reference value for each day. The factors obtained in this scaling process are then applied to the corresponding zenith angles in the measured irradiance time series. This scaling procedure will remove the diurnal cycle of irradiance in the time series.

The next step is to apply a 21-minute running mean to the scaled observed time series. From this step, the mean and standard deviation of the 21-minute window are obtained. A time series of these means and standard deviations can be seen in Figure 1.

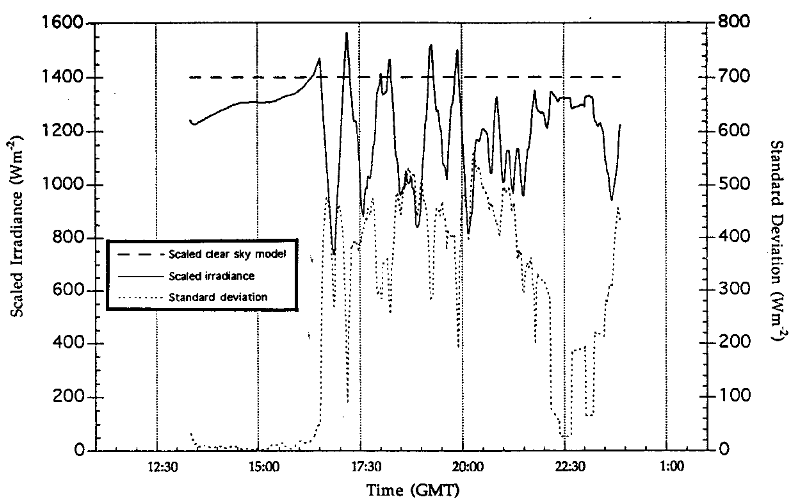


**Figure 1**. Mean and standard deviation of the scaled irradiance time series after a 21-minute moving average window has been applied on March 31, 1995.

The final step is to plot the associated 21-minute standard deviation versus the ratio of the mean of the scaled observed irradiance to the clear-sky scaled irradiance and then classify cloudiness into one of seven categories: no clouds, cirrus, cumulus, cumulus and cirrus, stratus, fog and/or precipitation, and other. For example, cumulus clouds have very large standard deviations and ratios slightly under one; stratus clouds have much lower standard deviations and ratios.

In addition to the cloud classification method, a daytime cloudiness index (Cl) has been developed. The CI is an index that accounts for the fractional diminution of insolation due to clouds, in contrast to percent cloud cover which is independent of radiation. The CI is defined by the following:

$$\text{CI} = 1 - (\text{measured irradiance}/\text{modeled clear sky irradiance}) \quad (1)$$

The measured irradiance and modeled clear-sky values are averaged over half-hour periods. A graph of the CI for March 1995 is shown in Figure 2. Ninety-five percent of all CI values for a given half-hour are less than the 95th percentile point. A CI of zero can be interpreted as clear sky or clouds having zero net effect on the average insolation over that half-hour. A CI value of one indicates that clouds are attenuating the total amount of irradiance at the surface. From this computation of CI, the true time dependence of insolation and the attenuative effects of clouds can be seen.

One way to estimate the accuracy of the cloud classification method is to compare the output of the classification scheme to human observations taken at the Central Facility. Comparisons to human observations were made for the SE sky quadrant before solar noon and for the SW sky quadrant after solar noon. Overall, the irradiance method matched the human observations better than 60% of the time, with the best results for clear skies, stratus, and precipitation and/or fog. The clear- sky match was best in the colder season where higher concentrations of aerosols and water vapor are not of large concern. The stratus and precipitation and/or fog classification matched best in the warmer seasons with deeper moist convection.

With the cloud types determined, a monthly cloud type frequency was compiled. The overall tendency was for clear skies to decrease and cumulus clouds to increase throughout the day. This tendency was most evident in the warmer seasons when daytime heating and moist convection were most prevalent. There did not appear to be any clear diurnal trend in CI, however. Most months had median CI values (50th percentile) between 0.5 and 0.9, with the extreme percentiles very close to 0.0 and 1.0. There were notable exceptions in dry, summer months where the 100th and 95th percentiles dipped to 0.5. Monthly precipitation and the CI structure appear to be strongly related, confirming that precipitation events are the largest attenuators of radiation.

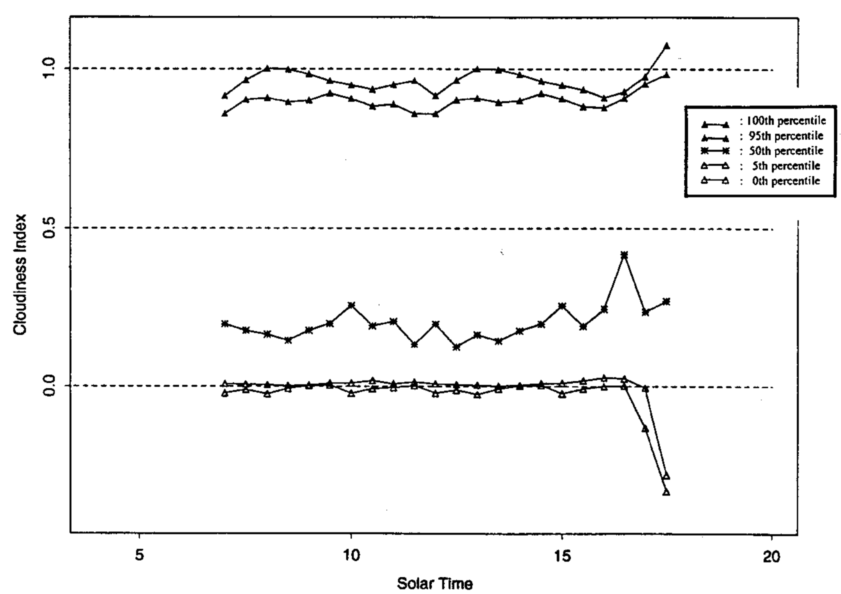


**Figure 2**. Cloudiness index for March 1995.

Thus, time series analysis of pyranometer data can be used to create not only a radiation climatology, but a cloud climatology as well. The availability of pyranometer data from Atmospheric Radiation Measurement (ARM) extended facilities and 111 Mesonet sites provides an opportunity to investigate both the spatial and the time distributions of cloud-types and the CI. In turn, these distributions can be compared with satellite estimates of cloudiness.

## Reference

Meyers, T.P. and R.F. Dale, 1983: Predicting daily insolation with hourly cloud height and coverage. J. *Clim. and Appl. Meteor.*, **22**, 537-545.