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# The Cedar-Sauk Field Station as a background site for urban-rural spectral comparisons of direct beam solar radiation in the visible

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## THE CEDAR-SAUK FIELD STATION AS A BACKGROUND SITE FOR URBAN-RURAL SPECTRAL COMPARISONS OF DIRECT BEAM SOLAR RADIATION IN THE VISIBLE

The general effects of urban atmospheric pollutants on incoming solar radiation have been observed for many years. Estimates of shortwave depletion usually fall in the 15-20% range (Landsberg, 1956, p. 589), but only a few studies have concentrated on depletion across the spectrum. Such studies have generally been concentrated on absorptive effects of gases in the infrared and the ultraviolet (see Kondratyev, 1969 and Robinson, 1966 for examples). The visible spectrum has largely been ignored.

Essential to a study of urban spectral depletion effects is a properly chosen rural background site for comparison purposes, free from urban influences. The results of this type of comparison would be of interest to many fields, including plant growth studies, architectural planners, animal husbandry, and others.

A study of differences in the urban-rural visible spectrum of direct beam solar radiation is presently being made for the city of Milwaukee for different synoptic air mass conditions. Preliminary results indicate that the Cedar-Sauk field station provides a good representative rural background site. In order to determine how well the Field Station represents rural conditions, urban-field station comparisons of two types of preliminary data were made with similar urban-rural studies done for other areas. Both the urban-field station visible spectrum differences, and the differences in turbidity, representing aerosol pollution amounts, proved to be in good agreement with the results of other studies.

Measurements of the visible spectrum of direct radiation were taken for three days under the same synoptic air mass condition (October 20-22, 1973) for the Field Station and two representative urban locations. The instrument used, an ISCO spectroradiometer, consists of a spectral sensing device equipped with a collection mirror, wedge interference filter, chopper, amplifying source, and a chart recorder. Spectral intensities between 0.425 and 0.725  $\mu\text{m}$  were taken for every 0.025  $\mu\text{m}$  wavelength band, using a probe pointed directly at the sun. Comparisons between rural and urban values were made by optical path length, or the thickness of the atmosphere between the instrument and the sun, rather than by time of day. This eliminates effects of small differences in altitude between measuring sites, insuring that differences are due to pollution fluctuations rather than variations in path length. [The path length was calculated from the zenith angle of the sun (*Smithsonian Meteorological Tables*, 1966, p. 422)].

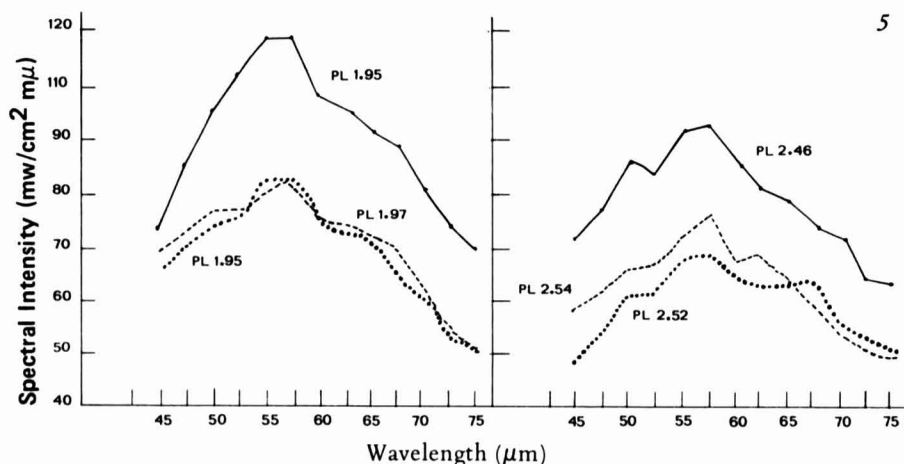


Fig. 1. Rural-urban direct visible spectral comparisons for two comparable path lengths (PL) on three consecutive similar days (October 20, 21, 22, 1973) (Cedar-Sauk, solid lines; Sabin Hall, dashed lines; Jones Island, dots). a. For path length 1.95, b. For path length 2.50.

Comparison of background spectral data taken on October 20 with city data taken on October 21 and 22 indicates that the Cedar-Sauk values over the whole spectrum averaged 20% higher (Fig. 1). Meteorological conditions for the three days were virtually identical: high pressure, winds from the southwest around 9 knots, temperatures in the 70's, and relative humidity around 80%. The overall urban decrease of 19.2% on October 21 and 21.6% on October 22 is in good agreement with Sprigg and Reifsnyder's averages (20-25%) for New Haven (1972) and with Randerson's values of total (direct and diffuse) visible radiation (23%) for Houston (1970). In all three studies, the wavelength range from 0.425 to 0.550 was significantly more depleted in the city than the longer wavelengths.

In the Milwaukee study, urban depletion was fairly consistent over all wavelengths, but there is an interesting deviation when the two optical path lengths are compared. The curves for path length 1.95 show basically the same pattern between days. Curves taken later in the day (optical path length about 2.5) indicate less depletion for wavelengths 0.65 to 0.75  $\mu\text{m}$  under urban conditions. There are two possible explanations for this. At higher sun zenith angles (or longer path lengths), direct radiation travels through a greater atmospheric mass. Especially under urban pollution conditions, shorter wavelengths are scattered considerably more, allowing greater relative amounts of longer wavelength radiation to reach the earth's surface (Kondratyev, 1969, p. 178).

Since aerosol size is very important in determining depletion of the visible beam of direct radiation (Sprigg and Reifsnyder, 1972, p. 6506), the change in the urban curves for the longer wavelengths might indicate a change in the aerosol size distribution. Under high sun conditions (path length 1.95), the uniformity of pattern indicates that the aerosol size range was the same in both the Field Station and the urban atmospheres, but greater aerosol amounts were in the latter (Randerson, 1970, p. 547). However, since short wavelengths are

scattered more by small particles, under low sun conditions (path length 2.50), the greater scattering in the shorter wavelengths might indicate that a decrease in the aerosol size range occurred in the Milwaukee atmosphere as the afternoon wore on.

The major cause of depletion in the visible spectrum under clear skies is due to aerosol particulate scattering rather than gaseous absorption (Threlkeld and Jordan, 1957). Therefore, in support of the spectral measurements, turbidity ( $\beta$ ) values, indicating the general amount of aerosol attenuating the direct solar beam through the entire atmosphere (Angstrom, 1964), were found. Direct radiation was measured by a Linke-Feussner pyrheliometer equipped with a Schott RG-2 filter (wavelength cut off  $0.636 \mu\text{m}$ ) and turbidity was calculated from tables (WMO Operations Manual, 1971).

Background turbidity measurements taken at the Field Station compare well with those from other rural areas of similar geographical location. The Cedar-Sauk turbidity values for noon averaged about 0.03 for October 20. Values for two small cities, Huron, South Dakota and St. Cloud, Minnesota averaged slightly higher, about 0.06. The lowest national values for turbidity were found to be 0.02 under continental polar air mass conditions in the Colorado Rockies (Flowers, McCormick and Kurfis, 1969, p. 958). Summertime values for the Field Station are representative as well. For example, turbidity at the Field Station at noon on June 1, 1974 was found to be 0.07, which compares well with 0.08 for the Colorado Rockies. The higher summertime turbidity values are attributed to greater summertime atmospheric aerosol amounts due to surface convective heating (Idso and Kangieses, 1970).

Turbidity data for October 20-22, 1973 indicates a slight build-up of aerosols in the city on October 21, and a noticeable build-up on October 22, the third day of high pressure stagnant conditions (Fig. 2). The Milwaukee study will attempt to prove that this build-up of aerosols is directly responsible for the decrease in the urban direct beam conditions as shown in Fig. 1.

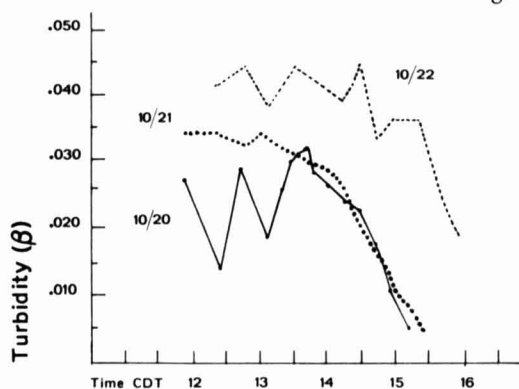


Fig. 2. Turbidity values for an October synoptic air mass situation at three sites (Cedar-Sauk, solid line; Sabin Hall, dots; Jones Island, dashed lines).

In conclusion, the turbidity and spectral data presented above demonstrate that the Cedar-Sauk Field Station is representative as a rural background site. It can be considered virtually free of any urban influences except under extreme southerly flow conditions. Variation in background atmospheric measurements can thus be attributed to changes in characteristics between synoptic air masses (Flowers, McCormick and Kurfis, 1969). Since specific air masses have characteristic temperatures, humidities, and densities, the measurements taken at the Field Station can be considered as representative of background values for that particular air mass.

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