ATMOSPHERIC ATTENUATION OF SOLAR RADIATION AT ADELAIDE

By T. J. Lyons and B. W. Forgan

SUMMARY

Attenuation of solar radiation at Adelaide is estimated by a comparison of simultaneous readings taken at an urban and semi-rural site. These show that the city contributes over one-third of the total turbidity and the role of the aerosol layer is to scatter rather than absorb solar radiation.

I. INTRODUCTION

The attenuation of solar radiation by urban atmospheres has been observed by many workers, (for details refer Peterson 1969, 1971, and Chandler 1970). However, due to the importance of short-wave radiation on the energy budget, continuous recording of global radiation was introduced as part of the Adelaide Climatic Survey. Adelaide, latitude 34°56'S and longitude 138° 35'E lies on a coastal plain bounded on the west by the relatively shallow depression of Gulf St. Vincent and on the east by the Mount Lofty Ranges (highest peak 726 metres). These ranges present steep scarps to the Adelaide plains and hence it is possible to monitor solar radiation at particular levels through the urban atmosphere. Continuous records of global radiation taken on the plain and at a height of one hundred and sixty metres illustrate a marked similarity in the total global radiation.

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recorded on clear days, even with pronounced inversions over the plain site. Consequently, in order to investigate further this effect, simultaneous measurements of the direct component as well as the global radiation were undertaken at the two sites, and these results are compared.

2. Theory

In order to estimate the total short-wave radiation falling on a horizontal surface the simple model adopted by Monteith (1962) and Idso (1969, 1970) and outlined by Fleming (1971) was used. This model considers absorption by water vapour, scattering by dust, scattering by water vapour and scattering by a dry dust-free atmosphere. It is also assumed that absorption takes place first, followed by scattering and that the scattering is half forward and half back, giving rise to the diffuse radiation component without further absorption. Although ozone and carbon dioxide absorption are not directly accounted for, Fleming (1971) assumes them to be included in the dust-free scattering.

In applying the model, the dust factor was varied until the direct component predicted by the model agreed with the observed value. Thus in effect, the model was used to generate a dust factor and a diffuse component for comparison with the observations.

3. Experimental Observations

(a) Sites

Simultaneous experimental observations were made on cloudless mornings at Flinders University and Adelaide Airport. Both sites were chosen because of their relatively obstruction-free horizons and hence only a minor correction had to be applied to the measured global radiation.

Adelaide Airport, at an elevation of seven metres above mean sea level, lies approximately six kilometres south of the main industrial area in the Adelaide Plains. Hence radiation sensors employed here are reasonably representative of the urban environment. Flinders University, on the other hand, is at an elevation of one hundred and sixty metres and is well above the main residential areas on the plain, in a semi-rural environment. In general, lower-level inversions in the area rarely rise above one hundred and twenty metres and hence pollutant emitted within the city is generally kept below the level of the Flinders University site.

(b) Sensors

Global radiation at the sites was measured using Solar Radiation Instruments Ltd. pyranometers. Both sensors had been initially calibrated by the C.S.I.R.O. Division of Atmospheric Physics at Aspendale, Victoria, and were recalibrated at Flinders University before the experiment.

The direct component of solar radiation was measured using Linke and Feussner actinometers (Kipp and Zonen) which had been calibrated by the manufacturer. Two actinometers were also run against each other at Flinders University prior to and after the experiment as a comparative check on this calibration.

As well as measurements of the direct beam component, estimates of the atmospheric turbidity were obtained through measurements of the transmittance of the solar beam by the red filter Schott RG2. The attenuation due to haze may be expressed as (Ångström 1961),

\[ A_D(\lambda) = ma_D(\lambda) \]  \[ A_D(\lambda) = m\beta\lambda^{-\delta} \]

where \( a_D \) is the extinction coefficient of the haze,

\( \lambda \) is the wavelength and \( \delta \) varies from 0 to 4 and is a good indication of the distribution of the number of haze particles as a function of their size.

Following Ångström an average value of 1.3 was adopted for \( \delta \) and hence

\[ a_D(\lambda) = \beta\lambda^{-1.3} \]

where \( \beta \) is the turbidity coefficient.

4. Results

The similarity of the global radiation observed at the urban and rural sites was investigated
Figure 1. Global and direct beam (as measured by a horizontal sensor) at both the Flinders and Airport stations.

through the simultaneous measurement of direct and global radiation during cloudless periods. Measurements taken on two representative mornings on which a pollution haze persisted over the city and orographic clouds did not develop until the afternoon, were utilized for data. On both days readings were taken manually every five minutes from sunrise. However, because of the errors involved in low solar altitude measurements of global radiation, only readings taken at a solar altitude greater than 20° were considered.

This similarity in the global radiation measured at the two sites is clearly illustrated in Fig. 1.

Figure 2. Variation of Ångström's turbidity coefficient with time on 5th October 1973 at Flinders and Adelaide.
On this morning a marked pollution haze persisted over the city until well after 11h true solar time (T.S.T.). An interesting feature of this haze was that the inversion lifted in the late morning above the height of the Flinders University site and this is shown in the direct beam readings (Fig. 1) and the turbidities (Fig. 2).

The contribution of the city area to the total turbidity can be seen in Fig. 2 by the separation of the two traces. For the two days on which data were taken an average value for this would be approximately one-third of the total turbidity, which is in agreement with the results of Fisher and Sturdy (1971) for a small, lightly industrialized city.

![Figure 3. Calculated global radiation versus measured global radiation for the Flinders data.](image)

A notable exception to this appears in Fig. 2 where, due to the onset of a weak sea breeze, the haze layer above the airport site was more rapidly dispersed than that above Flinders. The high turbidity readings at Flinders University are due to the lifting of the inversion which subsequently broke up. This break up was accompanied by elevated seaward transport of the pollution, similar to that observed by Lyons and Olsson (1972), thus leading to an increase in the turbidity readings at Adelaide Airport.

Using the above results, the dust factor was varied until the direct component predicted by the model agreed with the observed value.

The accuracy of this method is illustrated by Fig. 3 which shows the agreement between the calculated and observed global radiation.

Throughout these calculations the precipitable water at both sites was estimated from the 23h gmt (i.e. 0830 local standard time) radiosonde ascent at Adelaide Airport.

The mean attenuation coefficient defined by Beer’s Law has been shown to be similar to that observed in other cities (Lyons 1974).

5. Conclusions

Although Lettau and Lettau (1969) proposed that ratio of aerosol absorption to scattering is greater than one for a city, our results suggest that the major role of the pollutant layer appears to be an increase in scattering rather than absorption. This is illustrated by the increased diffuse radiation observed at the urban site in comparison with a negligible variation in global radiation between the urban and rural sites, and is supported by similar evidence given by Mani et al. (1974).

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NOTE ON JET CIRRUS EMISSIVITY

By L. F. HUBERT

Mr. Platt's paper (1975)* confirms some earlier estimates I have made of jet cirrus emissivity. His confirmation is gratifying because my results were based on somewhat more tenuous grounds and the technique of the National Environmental Satellite Service (NESS) for estimating the height of cirrus cloud targets is based on my earlier work. Readers may be interested in those studies and the present modus operandi.