SHORTER CONTRIBUTION

Low-level aerosol effects on earth's surface energy balance[1]

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(Manuscript received May 27; revised version August 10, 1974)

Atmospheric aerosol can interact with solar and thermal radiation and thereby alter earth's climate. The interaction that has received the most attention has been the postulated reduction in solar radiation intensity at the earth's surface, due to an increase in the aerosol concentration of the atmosphere, which would tend to lower temperatures in the biosphere (McCormick & Ludwig, 1967; Bryson, 1968). Recent calculations, however, have shown that this conclusion is very tenuous—possibly even false—because of the large forward to backward scattering ratio of anthropogenic aerosols (Charlson & Pilat, 1969; Mitchell, 1971). In this context, the thermal radiation interaction, which produces a type of "greenhouse effect" (Idso, 1972, 1973), thus emerges as perhaps the deciding factor in determining the direction of temperature change due to man's possible effects upon the aerosol content of the lower atmosphere. This paper presents results of an experimental investigation into that possibility.

On 14 May, 1973, a field of smooth bare soil (approx. 60 m × 80 m) in south Phoenix, Arizona, was irrigated with about 10 cm of water. On 15 May, the following data were obtained every 20 minutes from previously installed equipment: incoming solar radiation from an upright Eppley[2] pyranometer, reflected solar radiation from both an inverted Eppley pyranometer and an inverted Kipp solarimeter, net radiation from three Fritschen (1963, 1965) net radiometers, wet and dry bulb air temperatures from four fine wire (0.05 mm) copper-constantan thermocouples, and surface soil temperature from three thermocouples just barely covered with a thin layer of soil.

The sky on 15 May was initially cloudless, and the air was clear with a visibility of 67 km reported by the National Weather Service at Phoenix International Airport. In late afternoon, however, the experimental area was struck by a weak duststorm of the haboob type (Idso et al., 1972; Idso, C. W., 1973) generated by cool-air downdrafts from cumulonimbus clouds that had formed and remained over the mountains north and east of Phoenix. At 1645 the leading edge of the outflow which had picked up considerable dust from surrounding farm lands and desert areas reached the experimental site, and by 1657 the National Weather Service reported visibility to be 11 km with blowing dust present in all quadrants, indicative of the aerosol's large areal coverage. The diffuse dust suspension extended to about 2 000 m height and persisted past sunset. The abrupt drop in air temperature and increase in vapor pressure associated with the arrival of intense storms of this type were not observed in this instance (Fig. 1A, B). However, a plot of net radiation vs. net solar radiation did show a distinct break at the time of the arrival of the dust, with a new relation of identical slope but different intercept prevailing for the remainder of the day (Fig. 2).

In analyzing the significance of these observations, let us define an effective atmospheric emittance $\varepsilon_A = R_A/\sigma T_A^4$, where R_A is atmospheric thermal radiation, T_A is screen-level air temperature, and σ is the Stefan–Boltzman constant. Then, the two intercepts representing the constant values of the net thermal

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[1] Contribution of the Agricultural Research Service, U.S. Department of Agriculture.

[2] Trade names and company names are included for the benefit of the reader and imply no endorsement or preferential treatment of the product listed by the U.S. Department of Agriculture.

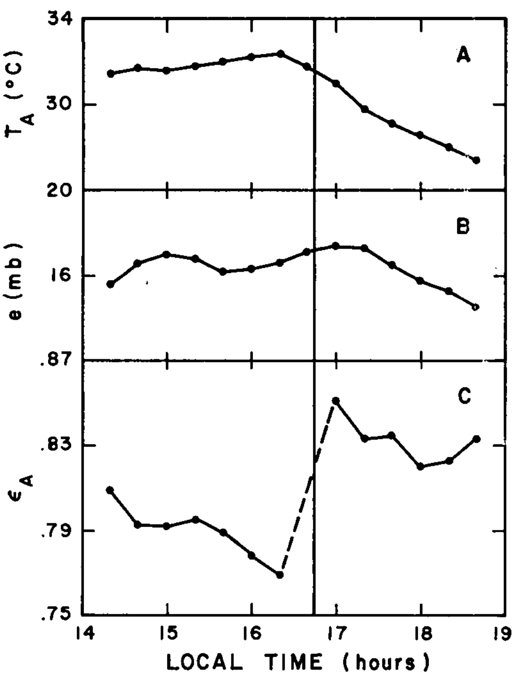

Fig. 1. Variations of air temperature (A), vapor pressure (B), and effective atmospheric emittance (C) with time on 15 May 1973 over smooth, bare, wet soil at Phoenix, Arizona.

radiation (L_N) before and after 1645 may be used to evaluate R_A by using the relation $L_N = R_A - \sigma T_s^4$, where T_s is the surface soil temperature, thereby allowing us to calculate ε_A. This procedure yields the curve of Fig. 1C. As shown there, effective atmospheric emittance, and hence downward atmospheric thermal radiation, increased about 10% with the introduction of the fine dust aerosol.

To find the effect of the dust upon the transmission of solar radiation to the earth's surface, diurnal trends of this parameter were plotted in Fig. 3 for 15 and 17 May, the latter also essentially a cloudless day reported by the National Weather Service to have a near constant visibility of 64 km. The dust aerosol of 15 May, though distinctly visible, produced *no measurable effect* upon the total transmission of solar radiation, although the ratio of diffuse to direct solar radiation was probably altered, as has been shown is generally the case (Idso, 1971). Thus, the net effect of this small increase in low-level background aerosol concentration was to increase the total radiant energy received at the earth's surface. In view of this finding, it appears that if man ever begins to raise the background aerosol content of earth's atmos-

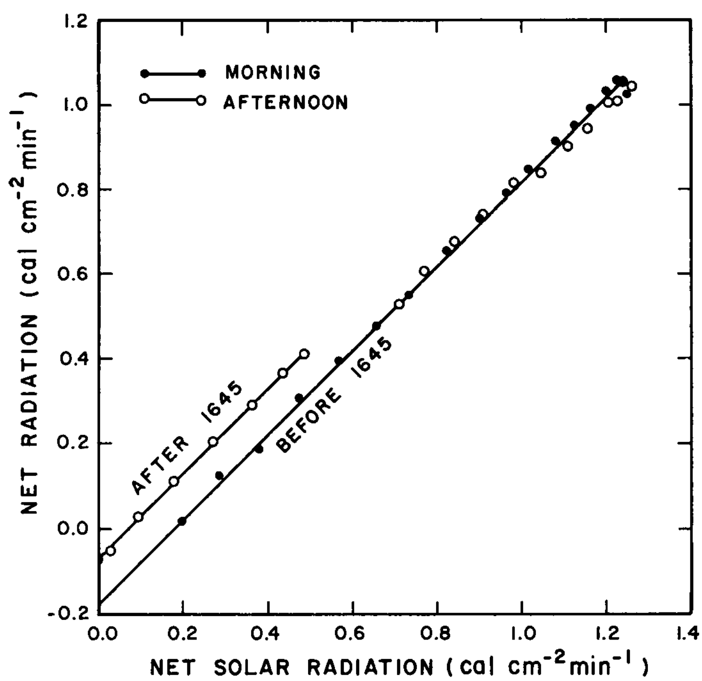

Fig. 2. Net radiation vs. net solar radiation on 15 May 1973 over smooth, bare, wet soil at Phoenix, Arizona.

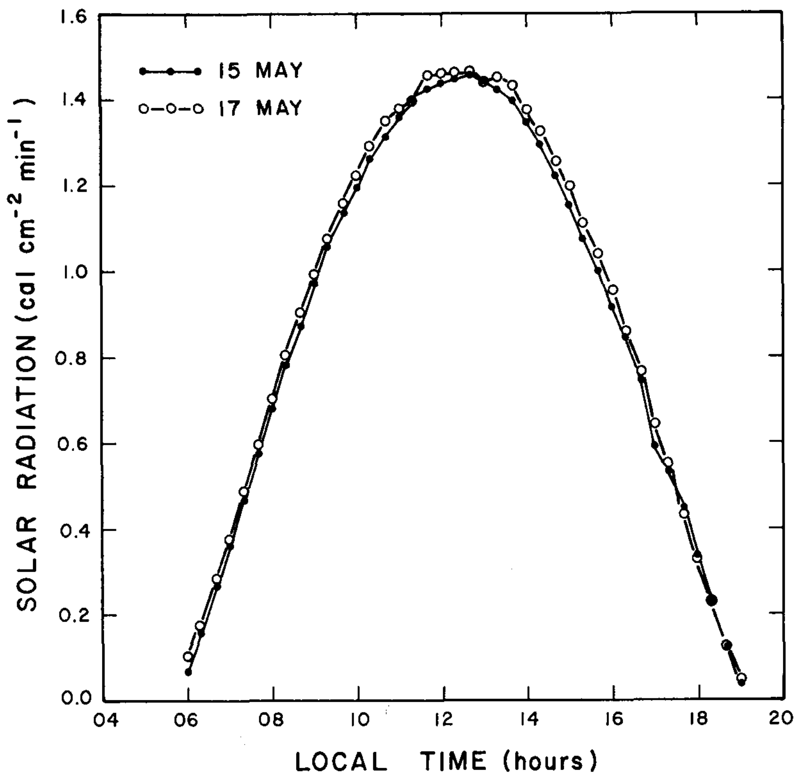

Fig. 3. Diurnal trends of incoming solar radiation at Phoenix, Arizona, on 15 and 17 May 1973.

phere through increased industrial activity, the global climate may initially become warmer, rather than cooler. More studies are needed on different types of aerosols, however, before this assessment can be generalized beyond the specific findings of this one unique observation.

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