551·510·42: 602

Twilight Detection of Aerosol Layers

E. K. BIGG

C.S.I.R.O., Radiophysics Laboratory, Sydney, Australia

(*Received 8 December 1958*)

1. Introduction

In previous papers (Bigg 1956 a, 1956 b) I have described how use may be made of a differential light intensity method for detecting aerosol layers in the atmosphere. Briefly the technique is as follows—

A photocell receives light from a very small region of the sky during twilight, and the associated amplifier is designed to measure directly the proportional rate of change of illumination. This measured quantity can be written $1/I \times dI/dT$ where I is the intensity of illumination and dI/dT its time rate of change. I changes only slowly with time compared with dI/dT and the fluctuations of $1/I \times dI/dt$ (as distinct from slow trends) are almost entirely due to the differential term. In the quoted papers, the hypothesis was advanced that fluctuations in the differential term are due to the scanning of aerosol layers by the earth's shadow. Since the height to which the shadow reaches (in the absence of light absorption) can be calculated, the height of the layers can be deduced and an idea of their intensity gained from a curve of $1/I \times dI/dt$ plotted as a function of shadow height, h. (One may equally well plot $1/I \times dI/dh$ but as $1/I \times dI/dt$ represents the actual measurement, it is to be preferred).

Megrelishvili (1958) has discussed the experiment in detail and reached two conclusions—

(*i*) Because of extinction of the sunset rays, 20 km is the least height accessible to investigation,

(*ii*) Because of the finite depth of the earth's shadow it is impossible to resolve two well-defined aerosol layers 5 km or less apart.

Both these statements are true for short wavelengths or observations near the zenith. Neither conclusion is correct for the technique actually used and I should like to explain why this is so.

2. The effective height

It must first be emphasised again that the most important quantity in the measurement is dI/dt, not I. Given an earth shadow which varies continuously from zero illumination at the boundary to full illumination, say 20 km higher, any variations in dI/dt due to scanning of aerosol layers will be heavily smoothed if the layers are less than 20 km thick. But, given an earth shadow in which there is a large *discontinuous jump in illumination* at the lower boundary, with a slow continuous increase above, then the aerosol layers will be revealed by dI/dt at their real heights, for the discontinuity will obviously contribute far more to a rate of change than the variation due to the slowly

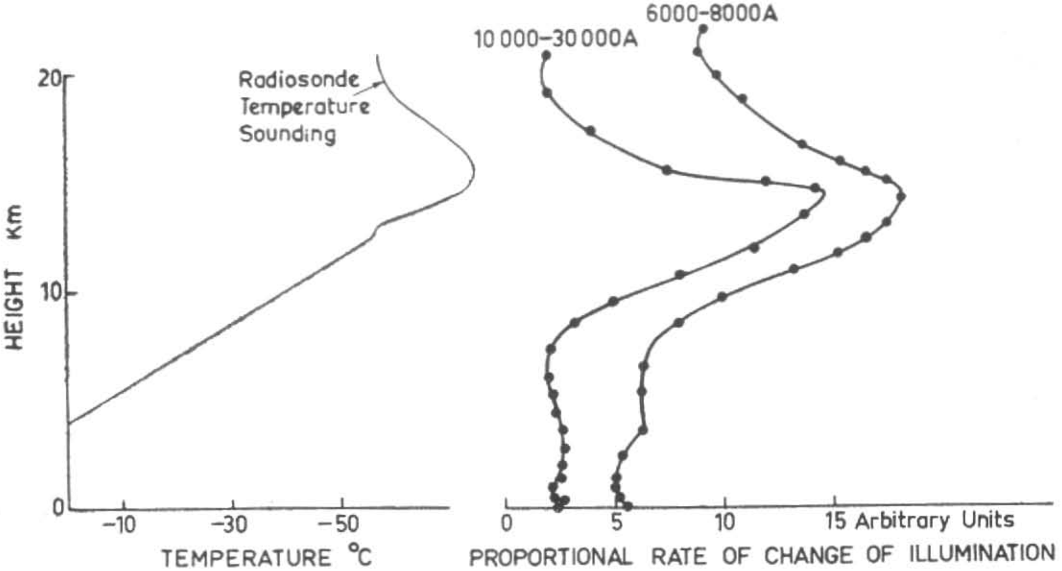

Fig. 1. Comparison of proportional rate of change of illumination at different wavelengths with temperature sounding

changing illumination in the upper reaches of the shadow.

Thus, all that is required to produce a curve which gives a true representation of layer height, is to choose a sufficiently long wavelength so that the grazing ray is left with an appreciable intensity. From the two curves given by Megrelishvili it is clear that this lies somewhere between 5000 and 9000 A. In fact, if a wavelength of 6000 A is used, the typical changes in dI/dt emerge, and there is little alteration even at wavelengths greater than 10000 A. To illustrate this, in Fig. 1 is plotted the experimentally obtained points in a simultaneous observation in which the first photocell accepted wavelengths in the range 6000-8000 A, and the second 10000-30000 A. It will be seen that the latter produce a somewhat sharper curve (showing the extent to which the greater thickness of earth shadow at the shorter wavelengths influence the result but that *the height of the maximum is unchanged*. The temperature sounding made a few hours earlier is shown for comparison, showing that the maximum dust concentration in this case was centred near the base of the temperature inversion.

Thus it is unnecessary (and wrong) to add 20 km to calculated heights as Megrelishvili has supposed.

3. Resolving power

Megrelishvili's claim that it is not possible to distinguish between two layers closer than 5 km apart by this method is invalid for the same reason.

Resolving power is influenced by the following factors—

(*a*) the wavelength of light accepted,

(*b*) the solid angle from which light reaches the photocell,

(*c*) the sharpness of the boundaries of the aerosol layers, and

(*d*) the amount of scattered light which reaches the photocell from these layers.

These factors influence the resolving power by determining the ratio of that part of dI/dt arising from the discontinuous light change at the earth shadow boundary to the part arising from the upper reaches of the shadow.

For best resolving power for a given set of dust layers one should use—

(*a*) the longest convenient wavelength in order to achieve the maximum discontinuity in illumination at the shadow boundary, and

(*b*) the smallest "beamwidth" possible in the light-gathering equipment in order that the discontinuity shall be uniquely defined.

The layers will be most emphasised by observing at a large zenith angle, for this makes use of the great preponderance of forward scattered light. However, this requirement also emphasises absorption and secondary scattering so that a compromise such as 70° is usually more suitable.

A convenient experiment to test the resolving power and the effective height yielded by the method is provided by the presence of isolated stratiform cloud patches during twilight. The height of these may be found by triangulation, or from balloon data. Whenever conditions have been suitable this experiment has been performed. As a typical result, using 6000-8000 A light, and a zenith angle of 70°, a patch of thin cirrostratus known to be at 10 km was observed after sunset. Its effect was first evident in the graph of $1/I \times dI/dt$ against h at a height of about 5 km, but the half-width of the maximum (centred at 10 km) was less than 2 km.

4. Conclusion

The height and a measure of particle concentration of aerosol layers can be found by the twilight fluctuations of $1/I \times dI/dt$ providing that suitable experimental methods are employed. Measurements, as well as theoretical considerations, show that the heights measured are exactly equal to the real heights, when proper techniques are employed.

The very long series of measurements which Megrelishvili has made is probably unique and may reveal many important features of the behaviour of these aerosol layers. I hope that he will re-examine his long-wavelength, high zenith angle observations in this light and publish his conclusions.

REFERENCES

Bigg, E. K.	1956(a)	*Nature*, **177**, pp. 77-79.
	1956(b)	*J. Met.*, **13**, 3, pp. 262-268.
Megrelishvili, T. G.	1958	*Indian J. Met. Geophys.*, **9**, 3, p. 271.