CHAPTER 7

Atmospheric Transmission

Up to this point, our discussion of the interaction of radiation with matter has focused mainly on reflection, refraction, absorption, and emission by *surfaces*, either real or "virtual" (note that in the last chapter we crudely treated the atmosphere as a translucent, gray, isothermal "surface" for the purpose of some simple radiation budget calculations).

Only in Section 2.5 did we briefly consider the absorption of a monochromatic EM wave propagating *through* a homogeneous medium whose index of refraction N included a nonzero imaginary part. I pointed out that, in this homogeneous absorbing medium, the intensity I_λ falls off exponentially with distance:

$$I_\lambda(x) = I_{\lambda,0} \exp(-\beta_\mathrm{a} x), \tag{7.1}$$

where β_a is an absorption coefficient that depends on the physical medium and on the wavelength of the radiation.

We are now ready to generalize this result to the atmosphere. Specifically, we will have to adjust (7.1) to allow for two minor complications:

1. The fact that a beam of radiation can be attenuated not only by *absorption* (i.e., conversion of the energy of the radiation to

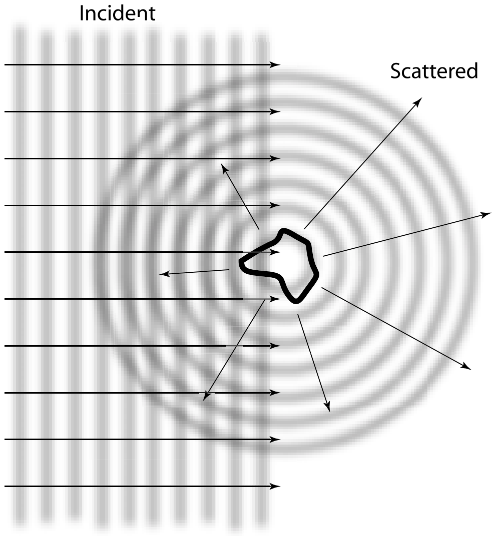

Fig. 7.1: Scattering of an incident wave by a particle.

heat or chemical energy) but also by *scattering* (redirection of radiation out of the original direction of propagation, usually due to interactions with particles; Fig. 7.1). This will require us to define a more general *extinction coefficient* to replace the absorption coefficient β_a appearing above.

2. The likelihood that the strength of the absorption or scattering will vary significantly along the path, so that our mathematical starting point must be the differential equivalent to (7.1), in which we initially consider the change of intensity of the radiation as it traverses an infinitesimal distance ds, over which the extinction coefficient can be assumed constant.

In addition to the above two *minor* complications, there is one more *major* complication that I will defer until a later chapter: the fact that radiation can be scattered from other directions *into* the direction of propagation, thereby enhancing its intensity. But for now we will continue to focus strictly on line-of-sight transmission and depletion of radiation, which can be understood entirely in terms of *local* properties encountered along that line of sight.

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Let us start by illustrating the first of the above points with the help of a classic classroom demonstration[1] in which the instructor places three transparent Petri dishes partly filled with water onto an overhead projector and projects their silhouettes onto the screen. Because the water and the dishes are transparent, nearly all the light from the projector passes through unattenuated, so that the shadows cast by the dishes are barely perceptible.

Into one of the dishes the instructor then introduces a few drops of India ink; into another, a tablespoon or so of milk (Fig. 7.2a). Those two dishes now cast strong shadows, indicating that the light from the projector has been significantly *attenuated* or *extinguished* (Fig. 7.2b). The mechanisms for the extinction are quite different, however. In the case of the black ink, the energy carried by the light is largely absorbed and, presumably, converted to heat. In the case of the white milk, the light lost from the original beam is not absorbed but merely *scattered* out of its original direction of propagation and into all other directions.

Here are two ways to convince yourself of the truth of the above statement:

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[1] C. Bohren, 1987: *Clouds in a Glass of Beer*. Wiley, New York

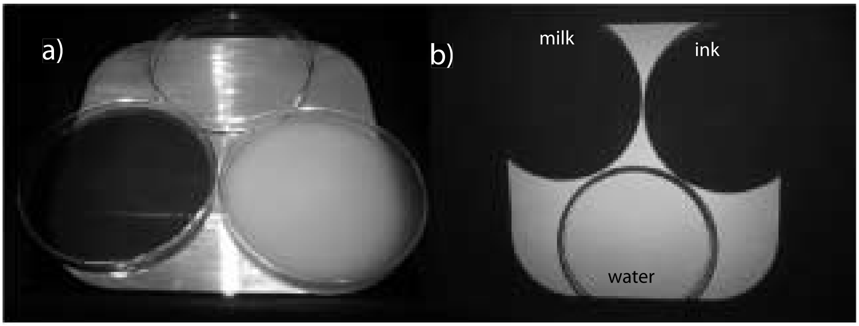

Fig. 7.2: Demonstration of radiative extinction using an overhead projector. (a) Three dishes of liquid, as positioned on the light source of the projector. The clear liquid is water, the black liquid is diluted ink (an absorbing medium), and the white liquid is diluted milk (a scattering medium). (b) The projected images of the three dishes. The dark shadows for milk and ink demonstrate that absorption and scattering are equally effective at depleting transmitted radiation.

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