CHAPTER 5

Radiative Properties of Natural Surfaces

In the previous chapter, we looked at what happens when radiation encounters a smooth surface separating two homogeneous media, such as air and water. We saw that a handful of relatively simple formulas are able to describe all important aspects of this interaction, including the angles of reflection ($\Theta_r = \Theta_i$) and refraction (Snell's law) and the fraction and polarization of the radiation that is reflected (the Fresnel relationships).

The above relationships are sufficient to understand a handful of significant radiative phenomena in the atmosphere – the existence of rainbows, halos, and parhelia, or the glint of the setting sun off a calm water surface. Unfortunately, most surfaces encountered in nature are not so simple. Most land surfaces are covered by soil, sand, vegetation, rough rocks, or snowpack, none of which are either smooth or homogeneous. Water surfaces are usually roughened substantially by wind waves, so that even though the laws of specular reflection apply, at least approximately, at each individual point on the surface, the pattern of reflected sunlight is considerably more diffuse and complex when viewed over a larger area.

Most natural surfaces do not lend themselves to a precise theoretical treatment. Therefore, we must be satisfied with characterizing their radiative properties in a more empirical way; e.g. via

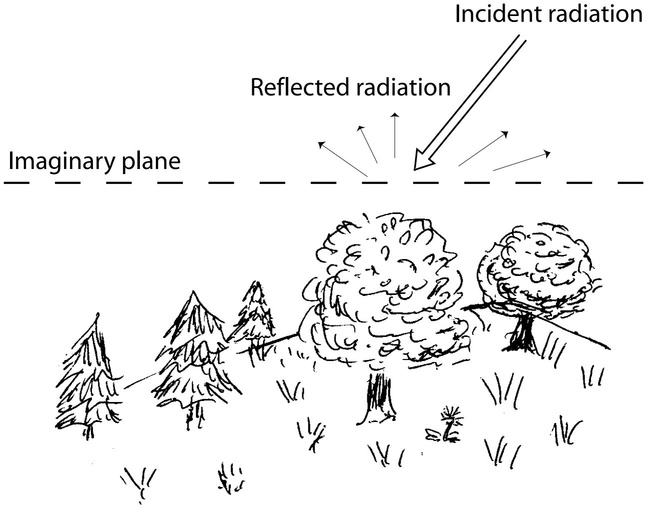

Fig. 5.1: Example of how one treats an irregular surface as an equivalent plane surface.

direct measurements of how much radiation they reflect and absorb at various wavelengths and in what direction(s) the radiation is reflected as a function of the incidence angle.

5.1 Natural Surfaces Idealized as Planar Boundaries

As already pointed out, most natural surfaces cannot be viewed as planar boundaries but rather are highly irregular and inhomogeneous. As seen from very high altitude, a forest may appear as a fairly smooth green surface, but up close, it is anything but smooth. Rather, it is a messy mix of foliage, branches, trunks, shrubs, dead leaves, soil and (mostly) air filling a layer some 10 or more meters thick.

For the purposes of our discussions to follow, however, we can pretend that a forest is indeed a flat surface by imagining a transparent horizontal plane just above the highest treetops and ignoring the details of what happens to radiation *below* that plane (Fig. 5.1).

All we really need to know, from an atmospheric perspective, is that when radiation (e.g., sunlight), incident from above, passes downward through that imaginary surface, some fraction of it is never seen again. We can safely assume that that fraction was absorbed and converted to heat or some other form of energy. The fraction of the incident radiation not absorbed reemerges (by what detailed mechanism we need not inquire) in various directions and contributes to "upwelling" radiation illuminating the atmosphere from below.

The above simplified picture is particularly useful when we're willing to limit our attention to the *average* radiative effects of forests and other natural "surfaces" over fairly large areas. Cloud layers may also sometimes be viewed in this simplified way, if we're willing to overlook the details of what happens *inside* the cloud layer and focus only on the upwelling and downwelling radiation through an imaginary horizontal plane just above cloud top or just below cloud base.

I should mention one caveat before you embrace this approach too firmly: when considering *emission* of radiation from a complex medium (as we will in later chapters), it is really only safe to treat it as an equivalent "surface" if there is also a single more-or-less unique temperature that can be ascribed to every participating point in the scene.

5.2 Absorptivity and Reflectivity

When radiation is incident on the earth's surface, some fraction is reflected and the remainder absorbed. The fraction absorbed we call the *absorptivity*, while the fraction reflected is the *reflectivity*.

We will use the symbols a and r for absorptivity and reflectivity, respectively. Obviously neither quantity can be less than zero nor greater than one.

In general a and r depend on the wavelength λ. A surface that is highly reflective at one wavelength ($r \sim 1$) may be highly absorbing at another ($r \sim 0$). For example, grass and other vegetation appears green because it reflects green, yellow, and blue wavelengths more strongly than red and orange. Often we will make the wavelength