and Fig. 3.1. It is important to understand that there is nothing special about the precise frequencies defining the boundaries between bands; in most cases, these boundaries were decided more or less arbitrarily and have no real physical significance. There is for example no abrupt change in the behavior of radiation as one crosses from the microwave to the infrared band in the vicinity of 1 mm wavelength. The exception of course is the visible band, whose boundaries are defined by the range of wavelengths (approximately 0.4 to 0.7 μm) that the normal human eye can see. Other animal species might have defined this band differently. Many insects, for example, can see well into the ultraviolet band.

Note that there are three rather distinct ways in which a particular spectral band can make itself "interesting" to atmospheric scientists:

Diabatic heating/cooling - As pointed out in the introduction, radiative transfer is one of the most important mechanisms of heat exchange in the atmosphere, and is the *sole* mechanism for heat exchange between the earth and the rest of the universe. For reasons that will become clearer later, not all spectral bands contribute significantly in this category.

Photochemistry - Many of the chemical reactions that take place in the atmosphere, including those that produce smog, as well as some that help cleanse the air of pollutants, are driven by sunlight. In addition, the existence of the ozone layer is a direct result of photochemical processes. The photon energy $E = h\nu$ is a crucial factor in determining which spectral bands are "players" in atmospheric photochemistry.

Remote sensing - Any frequency of radiation that is absorbed, scattered or emitted by the atmosphere can potentially be exploited for satellite- or ground-based measurements of atmospheric properties, such as temperature, humidity, the concentration of trace constituents, and many other variables.

In this book, we shall restrict our attention to radiative processes relevant primarily to the troposphere and stratosphere. With this constraint in mind, we may now undertake a brief survey of the major spectral bands.

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3.2.1 Gamma Rays and X-Rays

Gamma rays and X-rays, which are associated with wavelengths shorter than $\sim 10^{-2}$ μm, are usually produced by nuclear decay, nuclear fission and fusion, and other reactions involving energetic subatomic particles. The most energetic of photons, gamma and X-ray radiation can easily strip electrons from, or *ionize*, atoms and decompose chemical compounds. As such, ionizing radiation poses significant hazards to life. It is therefore fortunate that the strongest natural sources are extraterrestrial — so-called *cosmic rays* — and thus affect primarily the upper levels of the atmosphere. The intensity of gamma and X-ray radiation arriving at the top of the atmosphere is typically reduced by well over half for each 100 mb of atmosphere that it traverses, so that very little of this radiation makes it to the lowest levels. But airline passengers are exposed to nonnegligible levels of cosmic radiation.

In the lower troposphere, most natural radiation observed in this spectral band is traceable to radioactive materials in the earth's crust, such as uranium and its daughter isotopes. Although such sources are widely distributed, most are (thankfully) rather weak.

The gamma and X-ray bands are the only bands that have no major significance for any of the three processes identified in the previous section. Fluxes of radiation in these bands are not large enough to have a measurable effect on the heating or cooling of the lower and middle atmosphere. For various reasons, including the absence of strong natural terrestrial sources and the relatively strong attenuation of ultrashort wavelength radiation by the atmosphere, remote sensing of the troposphere and stratosphere is not a practical proposition in these bands. Finally, although these types of radiation can potentially participate in chemical reactions, their role is minor compared with that of ultraviolet radiation (see below). In the view of lack of strong relevance of this band to meteorology, we will not consider it further in this book.

3.2.2 Ultraviolet Band

The ultraviolet (UV) band occupies the range of wavelengths from approximately 0.01 μm on the X-ray side to approximately 0.4 μm on the visible-light side. The sun is the sole significant source of natural UV radiation in the atmosphere. However, the fraction of sunlight at the top of the atmosphere that falls in this band is small, only a few percent of the total power output. Nevertheless, this contribution is very important. The UV band is further divided into the following sub-bands:

UV-A extends from 0.4 down to 0.32 μm. Radiation in this sub-band is a significant component of sunlight, comprising close to 99% of the total solar UV radiation that reaches sea level. Although UV-A radiation is invisible to the human eye, it stimulates fluorescence (the emission of visible light) in some materials — e.g., “Day-Glo” markers, highway safety cones, and yellow tennis balls. So-called “black lights” used with fluorescent posters are artificial sources of UV-A radiation. Although the wavelengths are shorter, and therefore more energetic, than those of visible light, UV-A is still relatively innocuous with respect to living organisms. This is fortunate because the atmosphere is rather transparent to UV-A.

UV-B extends from 0.32 down to 0.280 μm. Because of its even shorter wavelength, its photons are energetic enough to initiate photochemical reactions, including injury of tissues (e.g., sunburn) and even damage to cellular DNA, leading to increased risk of skin cancer in exposed individuals. Fortunately, most UV-B (approximately 99%) is absorbed by ozone in the stratosphere. However, thinning of the ozone layer by human-manufactured chemicals is believed to be responsible for a significant increase in the amount of UV-B now reaching the surface.

UV-C extends from 0.280 to $\sim$0.1 μm. The most energetic UV sub-band, virtually all UV-C radiation is absorbed in the mesosphere and uppermost stratosphere, where much of its energy is expended on the dissociation of O_2 into atomic oxygen. The remainder is absorbed by ozone.

UV radiation is interesting in all three of the respects outlined earlier. As we have already mentioned, it is a major player in atmospheric photochemistry. Also, satellite remote sensing of ozone and other stratospheric constituents is possible in this band. Finally,

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