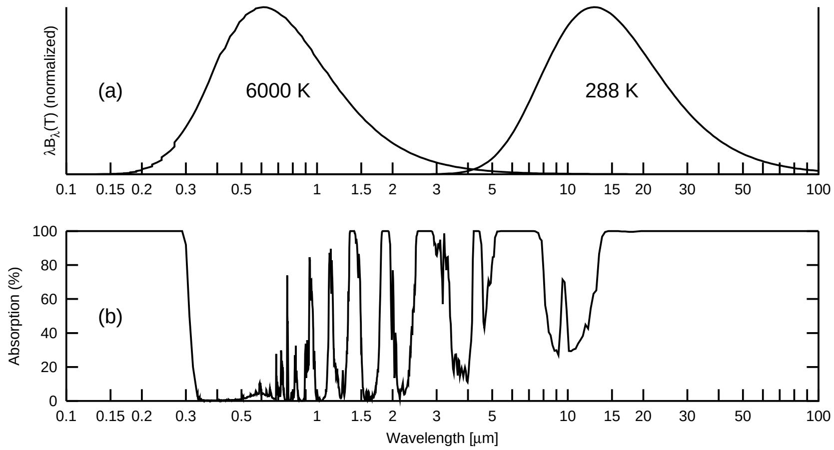

Fig. 3.3: Overview of the relationship between solar and terrestrial emission and the transmission properties the atmosphere. a) Normalized blackbody curves corresponding to the approximate temperature of the sun's photosphere (6000 K) and a typical terrestrial temperature of 288 K. b) A coarse-resolution depiction of the absorption spectrum of the cloud-free atmosphere.)

the steady-state climate of the earth depend heavily on the absorptive and emissive properties of the atmosphere in the IR band, but we now believe that the climate can change in response to human-induced increases in IR-absorbing trace constituents ("greenhouse gases") in the atmosphere, such as water vapor, carbon dioxide, methane, and chlorofluorocarbons (CFCs).

Because so many major and minor constituents of the atmosphere have distinctive (and often very strong) absorption features in the IR band, there are countless ways to exploit this band for remote sensing of temperature, water vapor, and trace constituents. On the other hand, the IR band is unimportant for atmospheric photochemistry, because photon energies are below the threshold required to dissociate most chemical compounds.

Atmospheric scientists tend to subdivide the IR band into three sub-bands: the *near IR* band, the *thermal IR* band, and the *far IR* band.

The near IR band is in one sense a continuation of the visible band, in that the primary source of this radiation in the atmosphere is the sun. It extends from 0.7 to 4 μm. Approximately half of the sun's output is found in this band, so that all but 1% of solar radiation incident on the top of the earth's atmosphere is accounted for by the UV, visible, and near IR bands together.

Unlike the case for the visible band, however, the atmosphere is not uniformly transparent to all near-IR wavelengths but rather exhibits a number of significant atmospheric absorption features. Thus, a moderate fraction of near-IR radiation from the sun is absorbed by the atmosphere in this band. For some wavelengths, e.g., near 1.3 μm, absorption is nearly total.

The range from 4 μm to 50 μm encompasses what we will refer to as the *thermal IR* band. Different sources quote various upper wavelength bounds on the thermal IR band, some as low as 15 μm. We have chosen the 50 μm bound because significant thermal energy exchanges via radiative transfer in the atmosphere occur up to approximately this limit. The thermal IR band is "where the action is" in view of both the magnitude of the energy exchanges and the enormous complexity of the atmospheric absorption spectra in this band. We will have much more to say about this band in later chapters.

For our purposes, the *far IR* band represents wavelengths between about 50 μm and 1000 μm (1 mm). Energy transfer in the atmosphere at these wavelengths is insignificant relative to that associated with the thermal IR, near IR, and visible bands. There are some potential applications of the far IR band to remote sensing, especially of cirrus clouds, but otherwise this region of the spectrum is relatively uninteresting to meteorologists.

3.2.5 Microwave and Radio Bands

Moving through the EM spectrum toward longer wavelengths (lower frequencies), one leaves the far IR band and enters the *microwave band* at a wavelength of about 1 mm, or at a frequency of about 300 GHz (GHz = gigahertz = 10^9 Hz). The lower bound (in frequency) is often taken to be around 3 GHz, or 10 cm wavelength. Thus, the microwave band encompasses two decades of frequency. At lower frequencies still, and continuing down to zero, we have the *radio band*. Note that both for historical reasons and because the numbers are low enough to be manageable, it is most common to use frequency rather than wavelength when describing microwave and radio band radiation.

From an engineering point of view, one of the distinguishing characteristics of the radio band is that the frequencies involved are low enough to be amenable to generation, amplification, and detection using traditional electronic components and circuits. By contrast, the much higher frequencies and shorter wavelengths of IR and visible radiation require mirrors, diffraction gratings, and / or lenses. The microwave band occupies a gray area, as many of the components in microwave circuits have a quasi-optical character — e.g., waveguides, resonant cavities, feedhorns, and parabolic reflectors.

The microwave band has risen greatly in prominence in recent years for its role in remote sensing of the atmosphere and surface. Radar, which was first developed during World War II, is now the principal means by which meteorologists monitor severe weather and study the dynamics of convective cloud systems. Satellites with sensors operating in the microwave band have proliferated since the mid-1970s and are now a very important component of our weather satellite programs, both for research and operationally.

The utility of the microwave band is greatly enhanced by the relative transparency of clouds, especially at frequencies well below 100 GHz. The properties of the surface and of the total atmospheric column — can be observed from space under all weather conditions except rainfall.

The radio band, which by some definitions includes the microwave band, continues down to zero frequency. Frequencies lower than around 3 GHz tend to interact very weakly with the atmosphere and therefore have only limited applicability to atmospheric remote sensing. Also, because of the long wavelengths involved, it is difficult to achieve good directionality with antennas of managable size (especially on satellites).

Two notable examples of remote sensing in the radio band do bear mentioning: 1) ground-based Doppler wind profilers operating near 915 MHz, which observe scattering from turbulence-induced fluctuations in atmospheric density and humidity, and 2) lightning detection systems, which are sensitive to low-frequency "static" emitted by lightning discharges. Apart from these cases, radio wavelengths are of very limited interest to meteorologists.

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