2.2. How Satellites work

2.2.1 Radiation in the atmosphere

The electromagnetic spectrum

We are all familiar with the colours of visible light, going from red through green to blue. What we see as different colours of light is electromagnetic radiation with different wavelengths. Red has the longest wavelength (0.7 microns, 1 micron = 1×10^{-6}m) and blue the shortest (0.4 microns). Visible light is only a small part of the full electromagnetic spectrum. Conventionally the spectrum is divided into a number of wavelength ranges (called bands) ranging from gamma rays and x-rays with the shortest wavelength through to radiowaves with the longest. The complete spectrum is shown in Figure 2.2.1.

There are two important sources of radiation used in satellite remote sensing of the Earth's environment: the sun and the earth itself.

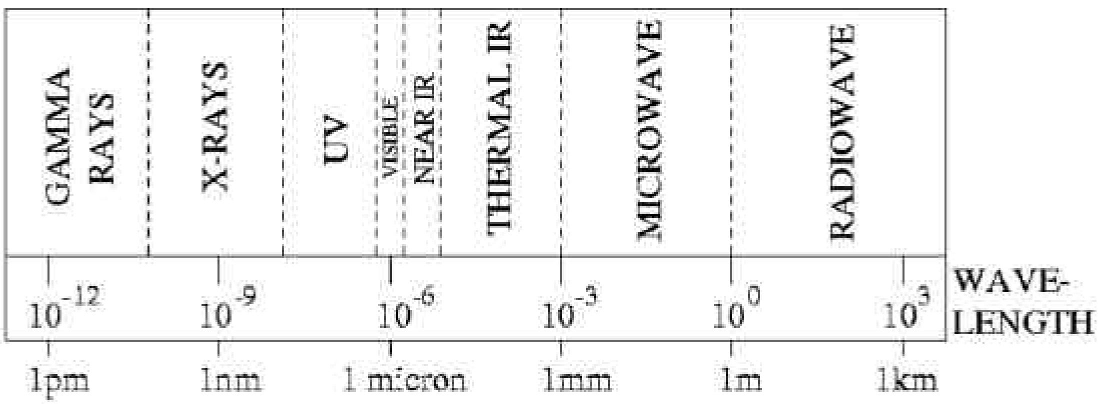

Figure 2.2.1: The Electromagnetic Spectrum.

Blackbody radiation

Every object emits radiation due to its temperature. Radiation at all wavelengths is emitted but for a given temperature there is a wavelength where the energy emitted per second (power) is greatest. The warmer the object, the shorter the wavelength of maximum emission, and the greater the rate of energy emission. A perfect emitter is known as a blackbody, hence the name blackbody radiation. Many objects behave as blackbodies over part of the electromagnetic spectrum but at other wavelengths the power emitted is less than that from blackbody.

Both the sun and the earth emit blackbody radiation. The sun has a surface temperature of approximately 6000^0C. The earth has a mean surface temperature in the region of 20^0C. Figure 2.2.2 shows how power per unit area emitted by a black body varies with wavelength at solar and terrestrial temperatures.. The solar curve shows the solar radiation intensity which would be detected at the top of the earth's atmosphere.

The sun emits most radiation with wavelengths between 0.2 microns and 10 microns. The peak wavelength is approximately 0.5 microns, which is in the middle of the visible range of wavelengths. (This is not a coincidence, the human eye has evolved to take advantage of the brightest wavelengths available.) Radiation from the earth has wavelengths from 3 to 100 microns, with a peak at approximately 10 microns. The peak intensity is much lower than the solar peak because the energy is emitted over a wider range of wavelengths. However, the total energy emitted by the earth should equal the total energy received at the top of the atmosphere.

Conveniently, there is very little overlap between the two spectra. This allows us to make a distinction in remote sensing between solar and terrestrial radiation.

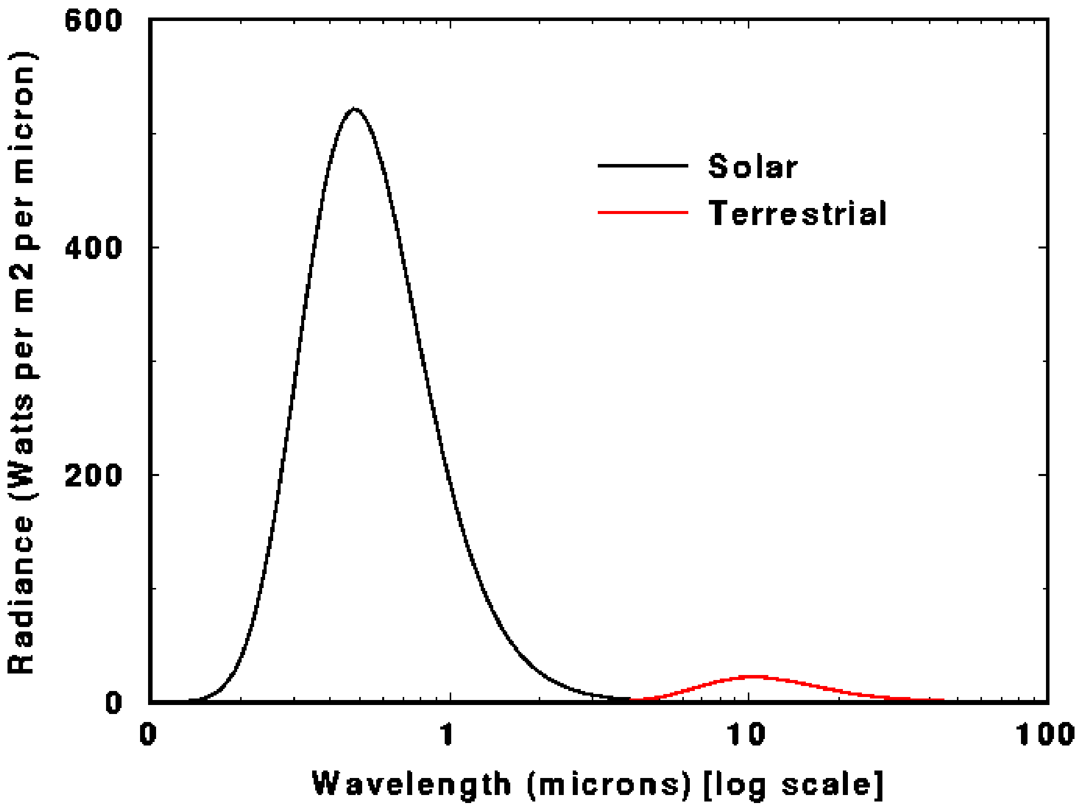

Figure 2.2.2: Solar and Terrestrial Spectra.

Absorption and Scattering in the atmosphere

Radiation is absorbed by gases in the atmosphere. Different gases absorb radiation at different wavelengths. For instance, visible radiation from the sun passes through the whole atmosphere to the surface with little attenuation, but ultra-violet radiation is strongly absorbed by a thin layer of ozone at a height of 20-25km. The absorption of the atmosphere as a function of wavelength is shown in Figure 2.2.3. The effects of individual gases are labelled.

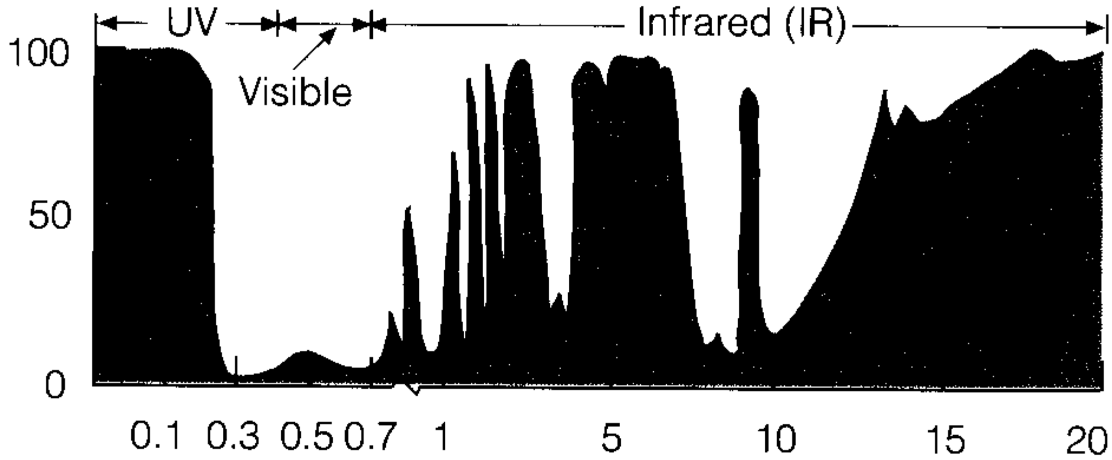

Figure 2.2.3: The absorption of the atmosphere as a function of wavelength (microns). 100 means atmosphere totally opaque, 0 means atmosphere totally transparent.

In addition to being absorbed, radiation is also scattered by the atmosphere. Scattering occurs when radiation is deflected by interaction with molecules or particles, but is unchanged otherwise. In the earth's atmosphere, scattering of radiation is more likely at short wavelengths (less than 0.5 microns). For instance, the shorter blue wavelengths in the visible range are scattered by the atmosphere more than red wavelengths, resulting in the appearance of blue sky. Important scatterers in the atmosphere are water vapour and dust particles. From the point of view of a satellite, scattering acts to reduce the intensity of radiation received.

Meteorological remote sensing has to make sense of this complex interplay of effects. Those parts of the spectrum in which the atmosphere is transparent are used to observe characteristics of the Earth's surface. The upper sections of the atmosphere are examined by choosing those parts of the spectrum where the atmospheric gases absorb (and emit) electromagnetic radiation. Section 2.6 Types of Image examines the images produced by the meteorological satellites. The remainder of this section examines the instrument used by satellites to observe the earth, known as the radiometer.

2.2.2 Satellite radiometers

All meteorological satellites are equipped with a radiometer. The radiometer produces an image that may look like a photograph but is actually a digitised image made up of a series discrete point values in rows and columns called pixels. The radiometer measures the intensity of the radiant energy coming from the earth's surface and atmosphere in a selected wavelength band, called a channel. Radiometers are usually equipped with several channels. When the radiometer channel collects a certain amount of radiant energy it registers a count. The number of counts is therefore proportional to the intensity of the radiation. The value is also dependent on the detection efficiency and the amplification of the electronic circuitry of the radiometer. The overall relationship between radiation and counts is given by the radiometer's calibration.

The area viewed instantaneously by the radiometer is called the footprint, shown in Figure 2.2.4. The total radiation from the footprint is assigned to a pixel (or PICture ELement) centred on the middle of the footprint. It is an average of the characteristics within the footprint so some of the detail is lost. The size of the pixel is known as the resolution. Confusingly, as the pixel size gets smaller, the resolution is described as getting higher.

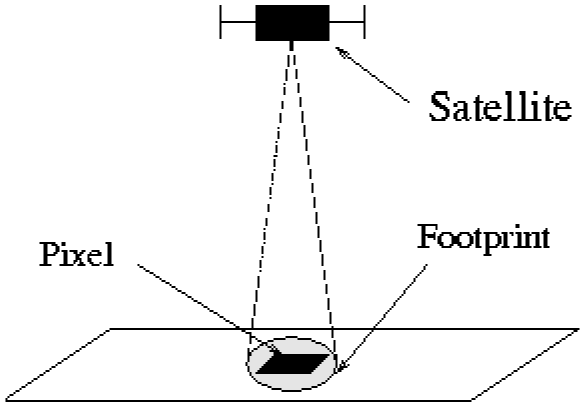

Figure 2.2.4:The footprint and pixel

The resolution depends on the field of view, altitude and viewing angle of the radiometer. Usually, the radiometer has a vary narrow field of view (of the order of milliradians) to obtain high resolution images. In order to build up an image of a sizeable area of the Earth, a scanning system must be employed to physically change the direction in which the radiometer is pointing. The radiometer scans across, and the adjacent pixel is assigned a value. A complete image is built up by the radiometer when all the pixels in the image have been assigned values. Scanning systems vary according to the satellite. Two very distinct systems are described in the sections 2.3 Geostationary satellites and 2.4 Polar orbiting satellites .

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