Lecture 3

Energy and Temperature (Part 1)

3.1 Atmospheric Influences on Insolation

As the sun's radiant energy travels through space, essentially nothing interferes with it until it reaches the atmosphere. Solar radiation reaching the top of the atmosphere does not pass unimpeded through the atmosphere, rather is attenuated by a variety of processes. Three processes- the *absorption*, *scattering*, and *transmission* of solar radiation-directly affect the distribution of temperature throughout the atmosphere. Fig. 3.1 shows the various processes that affect the solar radiation in the atmosphere.

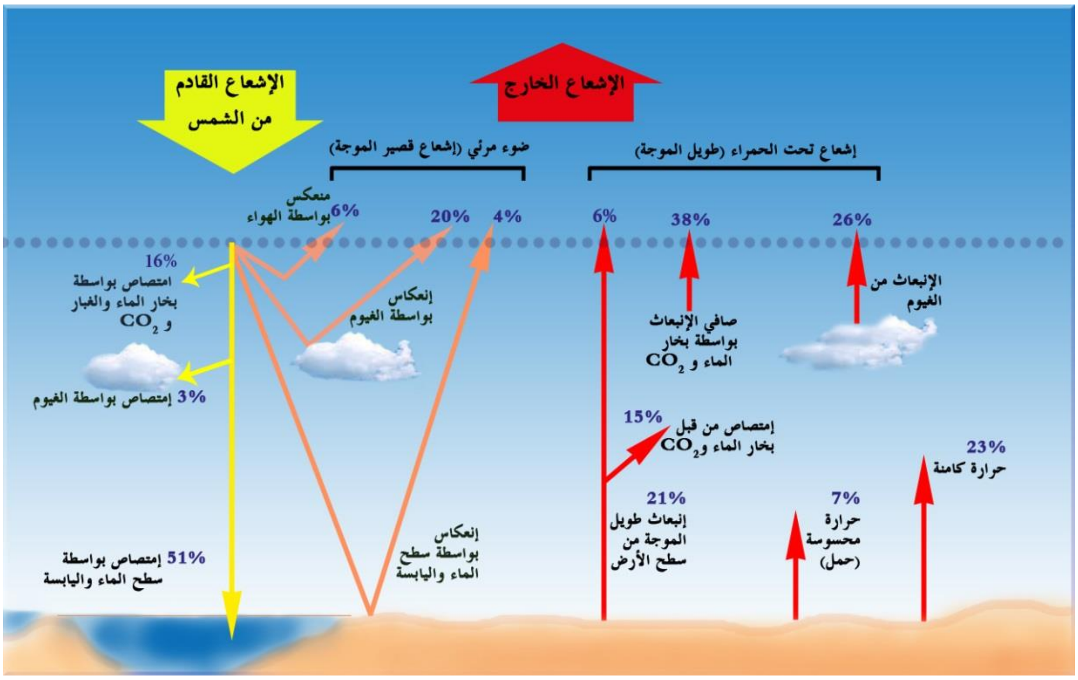

Fig. 3.1 Various proceses on the solar radiation in the atmosphere

3.1.1 Absorption

Atmospheric gases, particulates, and droplets all reduce the intensity of insolation by *absorption*. The gases of the atmsphere are not equally effective at absorbing sunlight, and different wavelengths of radiation are not equally subject to absorption. UV, is almost totally aabsorbed by ozone in the stratosphere. VIS radiation, in contrast , passes through the atmosphere with only a minimal amount of absorption. If the atmosphere were aable to absorb all the incoming solar energy, the sky would appear completely dark. Near-infrared radiation, which represents nearly half the radiation emmited by the Sun, is absorbed mainly by two gases in the atmosphere: water vapor and (to a lesser extent) carbon dioxid.

3.1.2 Reflection and Scattering

when sunlight strikes very small objects, such as air molecules and dust particles, the light itself is deflected in all directions—forward, sideways, and backwards. The distribution of light in this manner is called scattering (Scattered light is also called diffuse light). Because air molecules are much smaller than the wavelengths of visible light, they are more effective scatterers of the shorter (blue) wavelengths than the longer (red) wavelengths. Hence, the sky is turning to blue color during the daytime. At midday, all the wavelengths of visible light from the sun strike our eyes, and the sun is perceived as white. At sunrise and sunset, when the white beam of sunlight must pass through a thick portion of the atmosphere, scattering by air molecules removes the blue light, leaving the longer wavelengths of red, orange, and yellow to pass on through, creating the image of a reddy or yellowish sun.

Sunlight can be reflected from objects. Generally, reflection differs from scattering in that during the process of reflection more light is sent backwards. Albedo is the percent of radiation returning from a given surface compared to the amount of radiation initially striking that surface. Albedo, then, represents the reflectivity of the surface. In Table 3.1, lists the albedo of various surfaces.

Surface	Albedo (percent)
Fresh snow	75 to 95
Clouds (thick)	60 to 90
Clouds (thin)	30 to 50
Venus	78
Ice	30 to 40
Sand	15 to 45
Earth and atmosphere	30
Mars	17
Grassy field	10 to 30
Dry, plowed field	5 to 20
Water	10*
Forest	3 to 10
Moon	7

*Daily average.

Table. 3.1 Typical albedo of various surfaces

Rayleigh Scattering

The individual gas molecules which are actually smaller than about 0.1 λ of the incoming raadiation desperse rdiation in a manner known as Rayleigh Scattering. It primerly affects shorter wavelengths. Rayleighy scattering is particularly eeffective for visible light, especially those colors with the shortest wavelengths, so blue light is more effectively scattered by air molecules than is longer wavelength red light. As parallel beams of radiation enter the atmosphere, a portion of the light is redirected away from its origional direction. A person looking upward, away from the direction of the Sun, can see some of the scatterd light that has been redirected toward the viewer. Because blue light is among the shorest (and therefore most easily scattered) of the visible wavelengths, the scattered radiation contains a higher proportion of the blue light than yellow, green, or other longer wavelength light. Rayleigh scattering is also largely responsible for the redness of sunrises und sunsets. When the Sun is slightly over the horizon, sunlight must travel a greater distance through the atmosphere, and the longer path increases the amount of scattering. As the direct beam travels its long path, the shortest wavelengths of radiation are depleted, so the longer wavelengths constitute an increasing percentage of the direct sunlight. The sky in the general vicinity of the Sun thereby takes on a reddish tint due to the depletion of the green and blue (shorter-wavelength) light.

Mie Scattering

Aerosol particles are consdierably larger than air molecules and scatter sunlight by a process known as Mie scattering. Unlike Rayeigh scattering, Mie scattering is predominantly forward, diverting relatively little energy backward to space. Futhermore Mie scattering does not have nearly the tenedency to scatter shorter wavelength radiation that Rayleigh scattering does. Thus, on hazy or polluted days (when there are high concentrations of earosols) the sky appears gray, as the whole range of the visible part of the spectrum is effectively scattered toward the surface.

Transmission

When solar radiation travels through the vacuum of outer space, there is no modification of its intensity, direction, or wavelenth. However, when it inters the atmosphere, only some of the radiation can pass unobstructed to the surface. A clear, dry atmosphere might transmit as much as 80 percent of the incoming solar radiation as direct beam radiation without scattering or absorption. This is what you experience on a sunny, unpolluted day with sharp, distinct shadows. In contrast, when it is cloudy or hazy, only a small fraction of solar radiation will reach the surface as direct radiation.

3.2 Surface – Atmsophere Radiation Exchange

Eerth's surface and atmosphere radiate energy almost completely in the longwave portion of the spectrum. Longwave radiation emitted by Earth's surface (terrestrial radiation) is largely absorbed by the atmosphere which in turn will increase the temperature of the atmosphere. The clear atmosphere absorbs longwave radiation far better than solar radiation, mainly due to the presence of water vapor and carbon dioxide (good absorbers of longwave radiation). However, a portion of the longwave spectrum can pass through the atmosphere relatively unimpeded. The wavelengths in the band 8-12 microns, not readily absorbed by atmospheric gases, is called the *atmospheric window* (see Fig. 3.2). Clouds on the other hands absorbs all wavelength radiation. This explains why cloudy nights do not cool off nearly as rapidly as do clear nights.

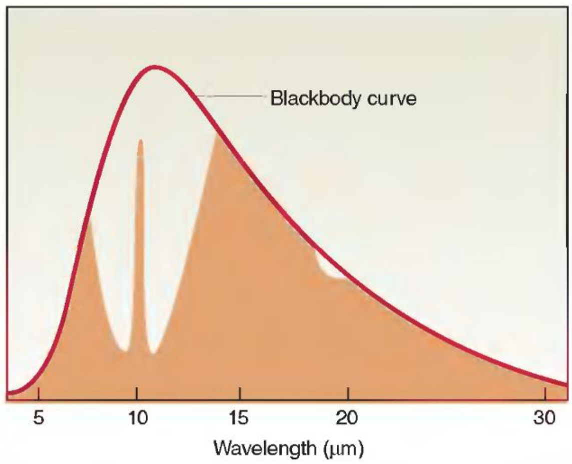

Fig. 3.2

The gases of the atmosphere absorb most of the energy with wavelengths outside of the range of 8 to 12 microns. The earth's surface acts nearly as blackbody in its emission of radiation.

3.3 The Latent Heat and Sensible Heat

The heat energy required to change a substance, such as water, from one state to another is called **latent heat**. Evaporation is a cooling process because the energy needed to evaporate the water–that is, to change its phase from a liquid to a gas–may come from the water or other sources, including the air.

The energy lost by liquid water during evaporation can be thought of as carried away by, and "locked up" within, the water vapor molecule. The energy is thus in a "stored" or "hidden" condition and is, therefore, called latent heat. It is latent (hidden) in that the temperature of the substance changing from liquid to vapor is still the same. However, the heat energy will reappear as **sensible heat** (the heat we can feel and measure with a thermometer) when the vapor condenses back into liquid water. Therefore, condensation (the opposite of evaporation) is a warming process. Nearly 600 calories are required to evaporate a single gram of water at room temperature. Figure 3.3 summarizes the various process of changing the state of water.

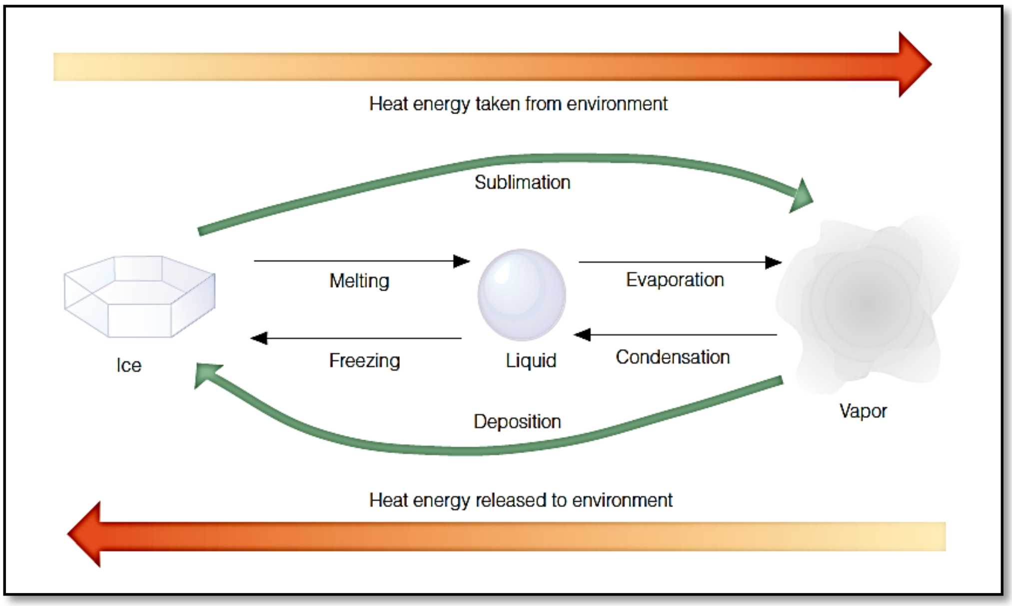

Fig. 3.3 Heat energy absorbed and released

Homework:

1. Explain how the absorption and scattering of radiation in the atmosphere affect the receipt of solar radiation at the surface.
2. Which two gases are most effective at absorbing longwave radiation?
3. What does the term albedo mean?
4. What characteristics of Rayleigh scattering cause it to create a blue sky?
5. What properties of Mie scattering distinguish it from Rayleigh scattering?
6. Why are overcast days typically gray?
7. What is the atmospheric window?
8. Describe sensible and latent heat.
9. Which natural surface has the highest albedo?
10. How much of solar radiation is absorbed before entering the atmosphere?