Lecture 4

Energy and Temperature (Part 2)

4.1 The Greenhouse Effect

The interactions that warm the atmosphere are often collectively referred to as the **greenhouse effect**, but the similarity to a greenhouse (that used to grow plants) is not strictly accurate. Greenhouses, such as the one shown in Figure 4.1, are made primarily of glass, which is transparent to incoming shortwave radiation but opaque to outgoing longwave radiation. The glass therefore allows in more radiation than is allowed to escape, causing the temperature inside the structure to be warmer than outside. In that regard, a greenhouse is similar to the atmosphere, which also transmits most of the incoming solar energy but absorbs the vast majority of longwave radiation emitted upward by the surface.

The analogy breaks down when we incorporate the effect of convection. A greenhouse not only reduces the loss of energy by longwave radiation but also prevents the loss of sensible and latent heat by convection. In contrast, the *greenhouse gases* do not impede the transfer of latent heat and sensible heat. Thus, it would be more accurate if the term "greenhouse effect" were replaced by "atmospheric greenhouse effect"

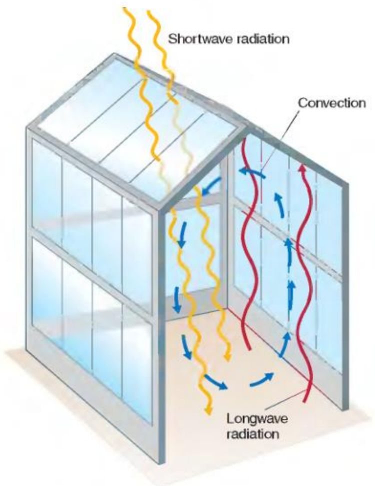

Fig. 3.1 Various processes on the solar radiation in the atmosphere.

- Warmer inside
- More incoming shortwave radiation.
- less outgoing longwave radiation
- The glass prevents convection from getting out.

4.2 Global Temperature Distributions

One of the most immediate and obvious outcomes of radiation gain or loss is a change in the air temperature.

Air Temperature: Temperature is a physical quantity expressing hot and cold. Temperature is measured with a thermometer. It is calibrated in various temperature scales and units of measurement. The most common used scales are the Celsius scale (°C), the Fahrenheit scale (°F), and the Kelvin scale (^{o}K). The coldest theoretical temperature is absolute zero, at which the thermal motion of all fundamental particles in matter reaches a minimum. Temperature is a proportional measure of the average kinetic energy of the random motions of the molecules.

Figure 4.2 shows a distribution of January surface air temperatures. The **isotherm** is the line that connects the points of equal temperature. Temperature tends to decrease poleward in both hemispheres.

Note 1 The latitudinal temperature gradient is greatest in the hemispheric winter (January in N.H. is, and July in S. H.). This ocurrs because the midday sun angle and the length of day both decrease with latitude. During summer, the lower midday sun angles at at the higher latiitudes are offset by longer days, so the temperature gradients are

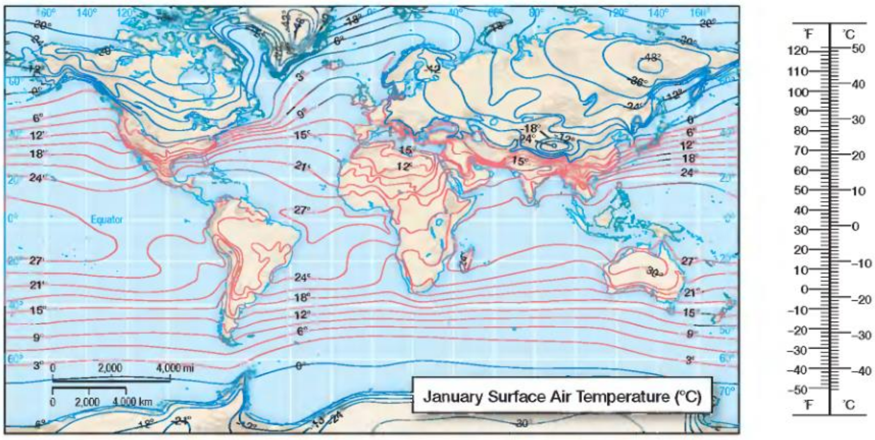

Figure 4.2 distribution of mean January surface air temperatures

4.3 Influences on Temperature

Certain geographical factors combine to influence temperature patterns across the globe. These factors include: latitude, altitude, atmospheric circulation patterns, land and sea distribution, ocean currents, and local conditions.

1. *Latitude*: Most people know that outside the tropics, the annual mean temperature decreases with latitude.

Note 2 The tilt of Earth's axis influences the amount of solar radiation available at any latitude on any paricular day. Within the tropics, theeer is relatively little annual vriation in the length of day and the midday solar angle, so energy receipts exhibit little change through the course of the year.

2. *Altitude*: Temperatures in the troposphere typically decrease with altitude above sea level.
3. *Atmospheric Circulation Patterns*: An organized pattern of atmospheric pressure (such as low- and high-pressure systems) and air flow across the globe strongly influences the movement of warm and cold air, with a direct effect on temperature. These circulations also influence the development of cloud cover, which has an indirect effect on temperature.
4. *Contrasts between Land and Water*: Water bodies are far more conservative than land surfaces with regard to their temperature, meaning that they take longer to warm and cool when subjected to comparable energy gains and losses.
5. *Warm and Cold Ocean Currents*: Ocean currents can move and carry large amount of energy which. Heat is transferred and promotes higher air temperatures.

4.4 Daytime Heating and Nighttime Cooling

In Figure 4.3, Surface temperature increases whenever the energy gains exceed energy losses. On clear days (no clouds) (a) the availability of solar radiation in the middle of the day produces a large surplus that persists into the afternoon, but at night the longwave radiation loss results in substantial cooling. Overcast conditions (b) suppress the diurnal change in temperature mainly by reducing the incoming solar radiation gain during the day and by supplying more downward longwave radiation from the atmosphere at night.

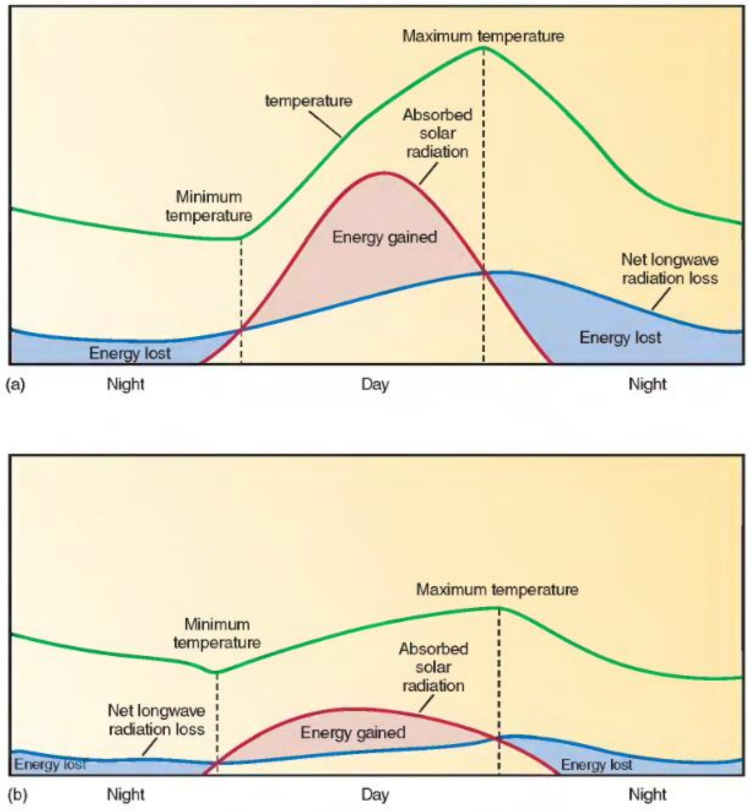

Figure 4.3 Daily heating and nighttime cooling

4.5 Effects of Cloud Cover and Wind on Temperature

During the day the cloud cover can greatly reduce the daytime input of solar radiation and likewise reduce the magnitude of the net longwave radiation loss over the entire 24-hour period (as in Fig. 4.3 b).

Strong winds also moderate daily temperature ranges because the higher wind speeds promote greater forced turbulence. When the turbulence increases, the enhanced vertical movement causes more mixing of the cold air above with the hot air below.

4.6 Measurements of Temperature

The measurement of temperature is very common in many fields of life. The most accurate thermometers contain mercury, the only metal that exists as a liquid at normal Earth temperatures. It is useful to know the daily maximum and minimum temperatures. In the maximum thermometer, the mercury is allowed to expand outward the bulb when the temperature increases but prevented from contraction back into the bulb when the temperature decreases (to reset shake it). On contrary, the minimum thermometer uses dyed alcohol and marks the lowest temperature (see Fig. 4.4). Another instrument for the measurement of temperature is the bimetalic strip, which consists of two thin strips of different metals bonded together.

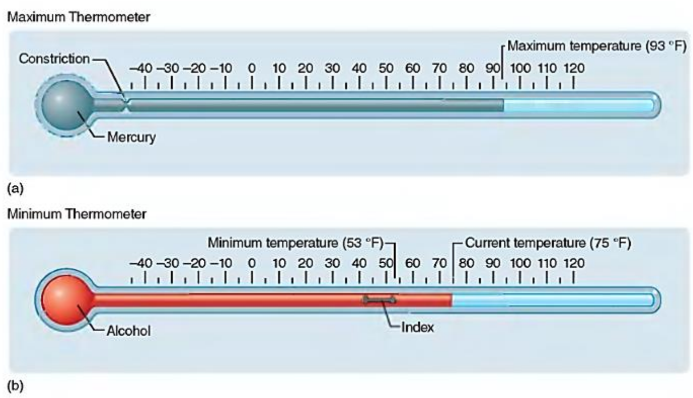

Fig. 4.4 Maximum and Minimum Thermometers

Homework:

1. Why does the term greenhouse effect inaccurately describe how the atmosphere is heated?
2. Define air temperature and explain why it is also a measure of the molecular kinetic energy?
3. What are the most common used temperature scales and what is the theoretical temperature at which the thermal motion of all fundamental particles in matter reaches a minimum?
4. Discuss how geographic factors such as latitude and altitude influence the distribution of temperature across Earth’s surface.
5. What do you know about the thermometers’ types?