curves represent the long-term zonally averaged distribution of absorbed solar radiation and outgoing longwave radiation, as seen at the top of the atmosphere. The bottom curve depicts the difference between the input of energy from the sun and the loss of energy to space. In the tropical belt, more energy is received from the sun than is lost to space in the form of longwave radiation. If there were no compensating processes at work, the tropical belt would continue to heat up to well above its current temperature, and the poles would plunge to even lower temperatures than exist there now. In the polar regions, the reverse is true. The net effect of this radiative imbalance is the creation of a meridional temperature gradient.

Horizontal temperature gradients in a fluid such as our atmosphere inevitably create pressure gradients that in turn initiate circulations. These fluid motions serve to reduce the temperature gradient by transporting heat from warm to cold regions. In fact, they intensify until the net horizontal heat transport exactly offsets (on average) the imbalance in radiative heating and cooling. *All circulations observed in the ocean and atmosphere — from ocean currents to the Hadley circulation to extratropical cyclones to hurricanes and tornadoes — can be viewed as mere cogs in a huge and complex machine serving this higher purpose.*

In fact, if you have previously taken a course in thermodynamics, you might recall that a *heat engine* is defined as a system that converts a temperature gradient into mechanical work. It does this by taking in heat energy at a high temperature and discharging the same amount of heat at a cooler temperature. If you take a second look at Fig. 1.1 you will agree that that is exactly what is occurring in the earth-atmosphere system: a net intake of heat energy in the warm tropics and a net discharge of heat from the cool polar regions.

**Problem 1.1:** Referring to Fig. 1.1:

(a) Estimate the latitude $L_C$ where the net radiation crosses over from positive to negative in the Northern Hemisphere. Also estimate the value of the net radiation at the North Pole. Use the two pieces of information to find the equation of a straight line that approximately describes the net radiation (in W m$^{-2}$) as a function of latitude $L$ between 10$^\circ$N and the North Pole.

Return to: A First Course in Atmospheric Radiation

(b) The latitude $L_C$ is where the northward transport of heat by the atmosphere and ocean is at a maximum in that hemisphere. Explain why.

(c) The rate of meridional heat transport at that latitude equals the total radiation deficit integrated over the surface area of the earth from $L_C$ to the North Pole. Compute this value using the equation you obtained in part (a), keeping in mind that a unit change in latitude is not proportional to a unit of surface area.

(d) Convert your result to a power per unit distance (east or west along the line of constant latitude at $L_C$), using units of kilowatts per kilometer. The radius of the earth $R_E = 6356$ km.

## 1.2 Relevance for Remote Sensing

We have just outlined in broad terms the role that atmospheric radiation plays in redistributing energy over potentially long distances, both within the atmosphere and between the earth-atmosphere system and outer space. But that is not the whole story. EM radiation carries not only energy but also a wealth of *information* about the environment within which it originated and through which it subsequently propagated. Since the early 1960s, virtually all areas of the atmospheric sciences have been revolutionized by the development and application of *remote sensing* techniques — that is, measurements of atmospheric properties and processes at a distance, using radiation sensors placed in space, on aircraft, and / or on the earth's surface.

As we shall see, the interactions of various forms of EM radiation with the environment are extremely rich and complex. Consequently, there are few important atmospheric variables that cannot be directly or indirectly estimated from the vantage point of a satellite in orbit if one is clever enough in the design of both the instrument and the analytical techniques. Today, there are large parts of the globe — especially the oceans, polar regions, and sparsely populated land areas — where meteorologists depend almost entirely on satellite observations for up-to-date information about temperature and humidity structure, wind, cloud cover, precipitation, etc.

Return to: A First Course in Atmospheric Radiation