Environmental Studies 30 -- The Global Ecosystem
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LECTURE 1: World Climates and Their Causes

Purpose

The global pattern of vegetation zones and of climate zones are strikingly similar. Forests occur in moist climates, shrublands and grasslands in drier climates. Compare **Figure 1** with **Figure 2**, looking for other patterns.

Figure 1.1 Map of World Climates
Figure 1.2 Map of World Vegetation Zones

The purpose of this and the next lecture is to help you understand the causes of the different climate regions (Lecture 1) and to show how closely these regions correspond to (if not define) vegetation zones (Lecture 2).

Later we will try to give you a feeling for each vegetation zone. We hope to explain the general characteristics of major plant and animal populations and of traditional and modern human cultures and their land use practices in each zone. We will also look at marine and other aquatic environments.

Global Patterns in Climate

Different regions of the earth have characteristic climates. Refer to **Figure 1**. The pacific Northwest is rainy and cool year-round, Southern Mexico is wet in the summer and dry in the winter. But note that each climate type is repeated in other parts of the world, often at similar latitudes and at similar positions on continents. Study Figure 1 looking for similar climates. For example, dry and hot desert climates occur between 20° and 30 ° latitudes in North America, South America, Africa (both north and south of the equator), and Australia. These are called the Subtropical Deserts.

The key to the occurrence of similar climates lies in the way the winds in the earth's atmosphere circulate, form clouds, and move moisture across the continents. Note in **Figure 3** how similar cloud patterns appear to occur in equivalent regions of the globe. Spiral patterns (called "cyclones") are found in middle latitudes (30° - 60°) of both Northern and Southern Hemispheres, while large clumpy patterns from a ring around the world near the equator (called the **"Intertropical Convergence Zone"**).

Figure 1.3 Satellite Photography of Global Circulation (From Slide in Lecture)
Figure 1.4 Idealized Map of Global Circulation

Figure 4 shows a division of the earth's atmospheric circulation into four idealized latitudinal belts. Each belt has characteristic qualities that, when coupled with the size and location of the continents, cause the major climate regions that we see in Figure 2. The <u>Tropics</u> are characterized by the "Trade Winds." The trade winds from the north and south tropics meet near the equator in the "Inter-tropical Convergence Zone" (ITCZ) and form a band of thunderstorm clouds. Because of the high rainfall, lush jungle forests cover land areas near the ITCZ. Hurricanes are also an important atmospheric feature of the trade wind zone.

The <u>Subtropics</u> are dominated by regions of few clouds and very little rainfall. These are called the **"Subtropical High Pressure Belts."** Where these zones stretch over continents, deserts occur. Over oceans extensive fog banks may develop.

The <u>Mid-Latitudes</u> are regions of cyclonic storms, like we see in **Figure 3**. In the winter, these storms are common in the United States. The storms are carried from the oceans eastward across continents by a strong air flow called the **"Mid-Latitude Jet Stream."** As these winds come from the west, they are called **"Westerlies."** Continental areas near the oceans in the Mid-Latitudes are commonly forested. But farther away from the ocean, storms lose their moisture, and grasslands and shrub deserts occur.

The <u>Polar</u> regions are generally cold and dry. Land in these areas are either permanently covered with snow and ice or are vegetated with small and low tundra plants.

The position of each of the belts shifts with the seasons, 'following the sun.' The belts move slightly toward the North Pole during the Northern Hemisphere summer and toward the South Pole in the Southern Hemisphere summer. This results in some areas remaining with a belt year long, while areas located between two belts experience the weather of one belt for part of the year and the weather of the other belt the rest of the year. California is a good example of a region between belts. We experience the cyclonic storms of the Mid-Latitude belt in winter and the desert climate of the Subtropics in summer.

In the second lecture we will talk more about variations within each of these belts. These variations correspond to the different climate zones in Figure 1, that in turn contribute to the distribution of vegetation zones.

The Driving Mechanisms of Climate

In our discussion of climate, we have yet to ask what drives the atmospheric winds to circulate in the pattern we have observed.

Sunlight serves to heat the earth, its atmosphere and its oceans. At the same time the earth releases heat to space. On infrared photographs of the earth made by satellites at night, you can see this radiative heat. The earth literally glows in the dark, but at wavelengths of light imperceptible to our eyes.

Over the course of a year, the sun's light energy input to the earth must be completely balanced by the earth's release of heat energy, otherwise the earth would become increasingly warmer (or colder, if the heat released was greater than the sun's input). This balance holds true for the earth as a whole, but not at different latitudes. Near the equator more energy is received from the sun than is released to space. Near the poles the reverse is true: more energy is released than is received. This is illustrated below in **Figure 5**.

Figure 1.5 Generalized Balance of Energy for the Earth

The excess energy received near the equator must be transported to the poles to balance the heat lost to space. Otherwise the poles would become increasingly cooler and the equator increasingly warmer. The transportation of energy is done by the atmosphere and the oceans. Winds and ocean currents move air and water that has been heated in the lower latitudes toward the poles. The air and water release heat at higher latitudes and return toward the equator in other winds and currents. See **Figure 6a**. Observe in **Figure 7** that poleward currents, such as the Kuroshio, are warm, and equatorward currents, as the California Current, are cold. How do you think the climate of Europe would change if the Gulf Stream did not exist?

Figure 1.6a, b The Transportation of Energy by Winds
Figure 1.7 Map of the World's Ocean Currents (From Slide in Lecture)

The energy available to heat air or water in the lower latitudes can also be used to evaporate water. The energy required to evaporate water, and later released during condensation, is called the **"Latent Heat of Evaporation"** (or in this context, just **"Latent Heat"**). Energy can then be transported when water vapor (see **Figure 6b**) is carried by winds from one region, where it was evaporated, to another where it condenses to form clouds. A transportation of energy occurs because latent heat energy, stored in water vapor originating in one region, was later released in another region when the vapor was condensed.

At this point we ask how the atmosphere uses the sun's energy to drive the wind circulation and how these winds transport energy poleward. Follow **Figures 8 and 10** closely during this discussion.

In the tropics, the atmosphere is driven much like air in a heated room: hot air rises near the heater, spreads out across the ceiling, sinks when it cools, and returns to the heater intake across the floor. In the Intertropical Convergence Zone (ITCZ) heated air rises approximately ten miles vertically then flows poleward. While this air is rising, huge thunderhead clouds form resulting in high rainfall. A tremendous amount of latent heat is released from the condensation of water vapor. This release of energy drives the circulation with even more strength.

In the subtropics (20° - 30° latitude) the air sinks. As the air sinks it become very dry, just the opposite of air in the ITCZ that, as it rises, becomes more and more moist until clouds form. As the sinking air reaches the surface in the Subtropical High Pressure belts, it diverges flowing either poleward or equatorward over the tropical oceans gathering moisture. These winds are illustrated in both Figures 4 and 8. The equatorward winds are the Trade Winds. The trades bring the warm and moist air to the ITCZ that powers this circulation. These tropical circulation systems are called "Hadley Cells."

Figure 1.8 Generalized Hadley Cell Circulation

Poleward flows from the Subtropical Highs carry warm moist air into the Mid-Latitude belt. When this air meets polar air, cyclonic storms develop. In a cyclonic storm, the warm air is forced upward and poleward over the cold polar air, causing clouds to form. The latent heat released by the clouds increases the strength of the storm forcing more warm air poleward and more cold air equatorward (Figure 9). At polar latitudes, the warm air is cooled and is returned toward the equator as polar air.

Figure 1.9 Structure of a Cyclonic Storm
Figure 1.10 Idealized Cross Section of Global Circulation

We can now see that the sun's energy is used to power a global circulation that results in a general flow of energy poleward. In general, the earth's atmosphere is a system that uses heat as an energy source (at the equator) to do work (drives the winds) while transporting heat to an energy sink (at the poles). Such systems are called "**Heat Engines.**"

This discussion is very idealized. In later lectures we will show you how the atmospheric circulation over different continents and oceans follow this general pattern but with important variations.

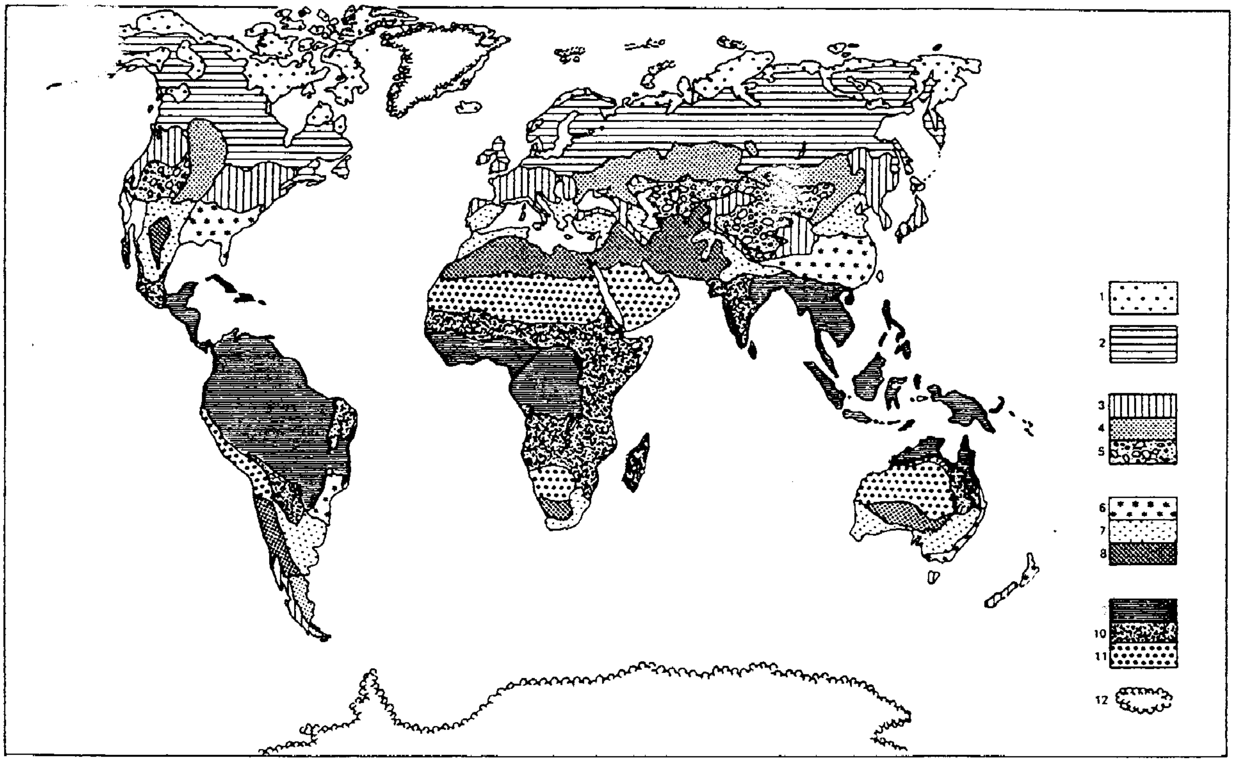

Fig. Thermal zones and bioclimatic regions of Bazilevich et al. (1) Arctic zone. (2) Bore. .ne. (3–5) Temperate zone: 4 semiarid region; 5, arid regions. (6–8) Subtropical zone: 6, humid region; 7, semiarid region; 8, aria .gion. (9–11) Tropical zone. 9, humid region; 10, semiarid region; 11, arid region. (12) glaciers and firn areas (permanent snow). (According to Bazilevic et al. 1970)

Figure 1.1. The World's Climates

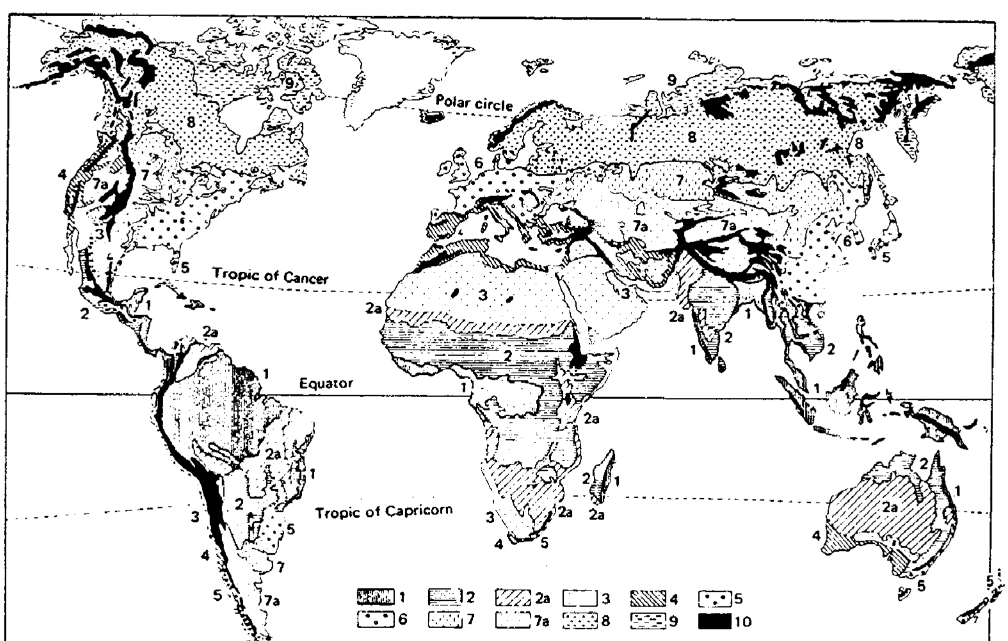

Figure 1.2.

The World's Vegetation.

Fig. Vegetational zones (much simplified, without edaphically or anthropogenically influenced vegetational regions). I. *Tropical and Subtropical Zones:* (1) Evergreen rain forests of the lowlands and mountainsides (cloud forests); (2) semievergreen and deciduous forests; (2a) dry woodlands, natural savannas or grassland; (3) hot semideserts and deserts, poleward up to latitude of 35° (see also 7a). II. *Temperate and Arctic Zones:* (4) sclerophyllous woodlands with winter rain; (5) moist warm temperature woodlands; (6) deciduous (nemoral) forests; (7) steppes of the temperate zone; (7a) semideserts and deserts with cold winters; (8) boreal coniferous zone; (9) tundra; (10) mountains. (From Walter 1964/68)

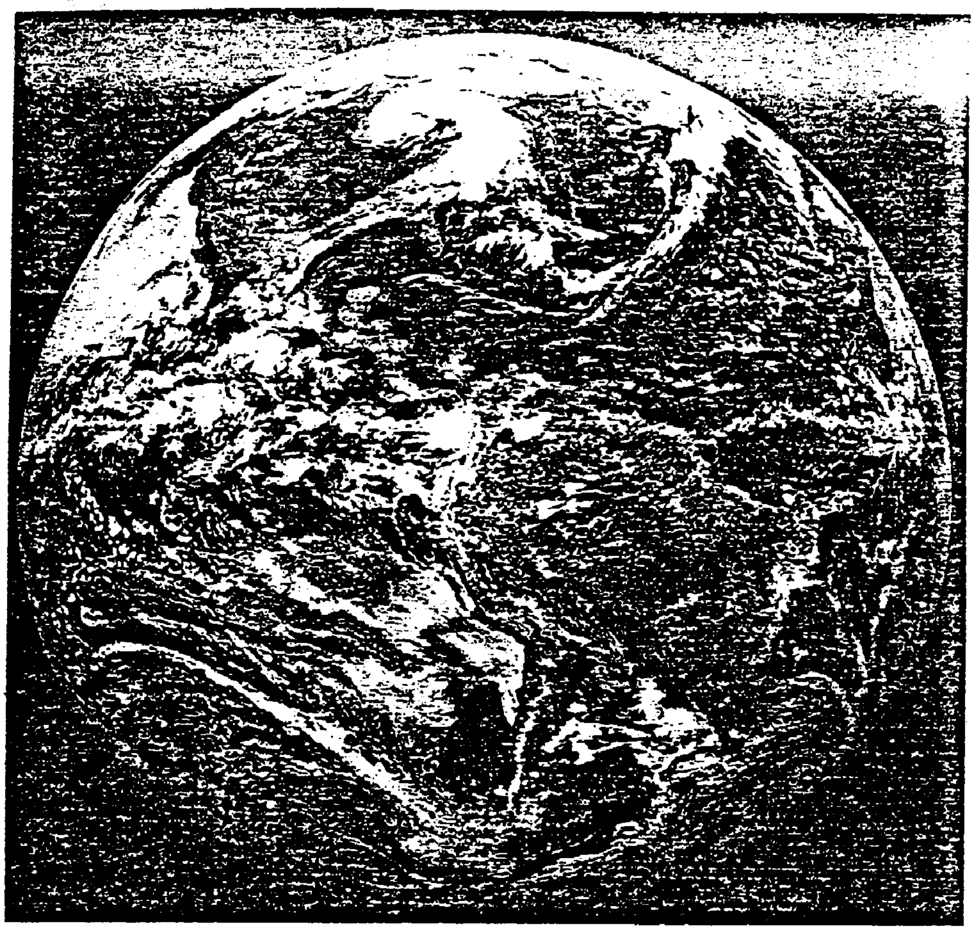

Fig. 1.1 Image of the earth as seen in reflected visible radiation, 1700 Greenwich Civil Time, 12 June 1975. (NOAA photo.)

Wallace & Hobbs, 1977

Atmospheric Science

EST 30 -- Fig. 1.3

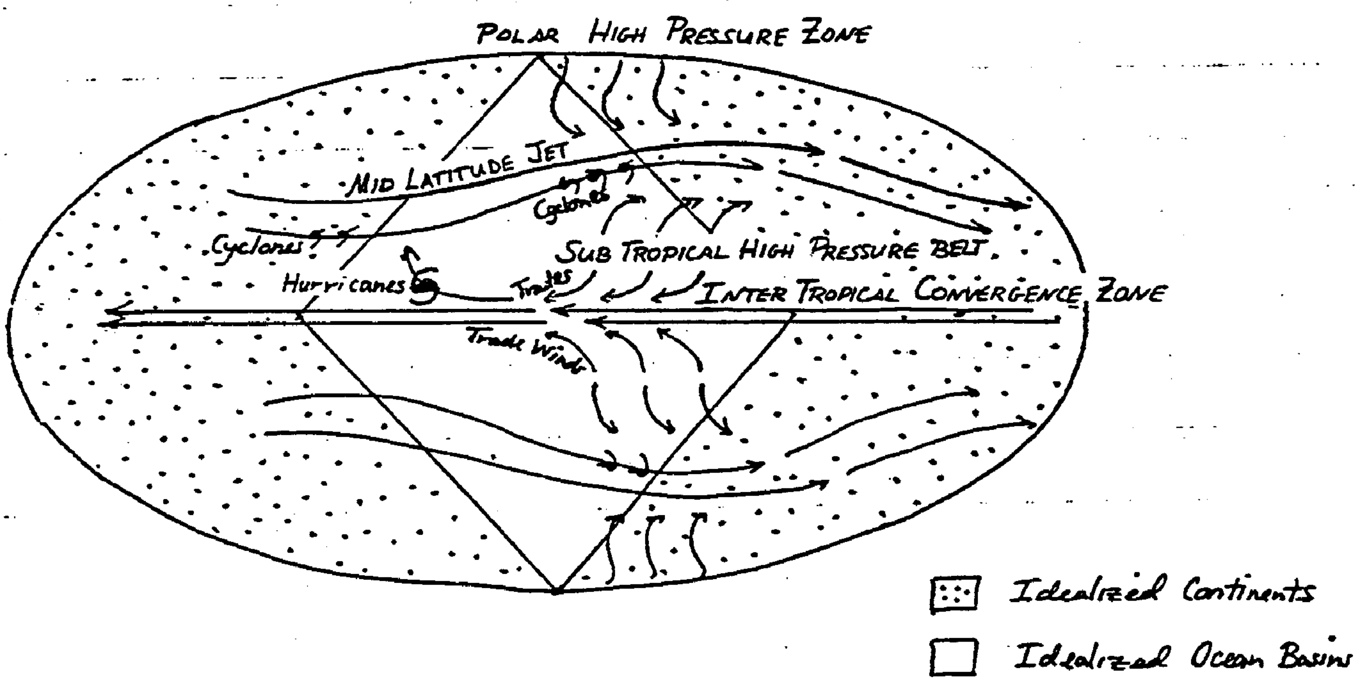

Figure 1.4 Idealized Map of Global Circulation

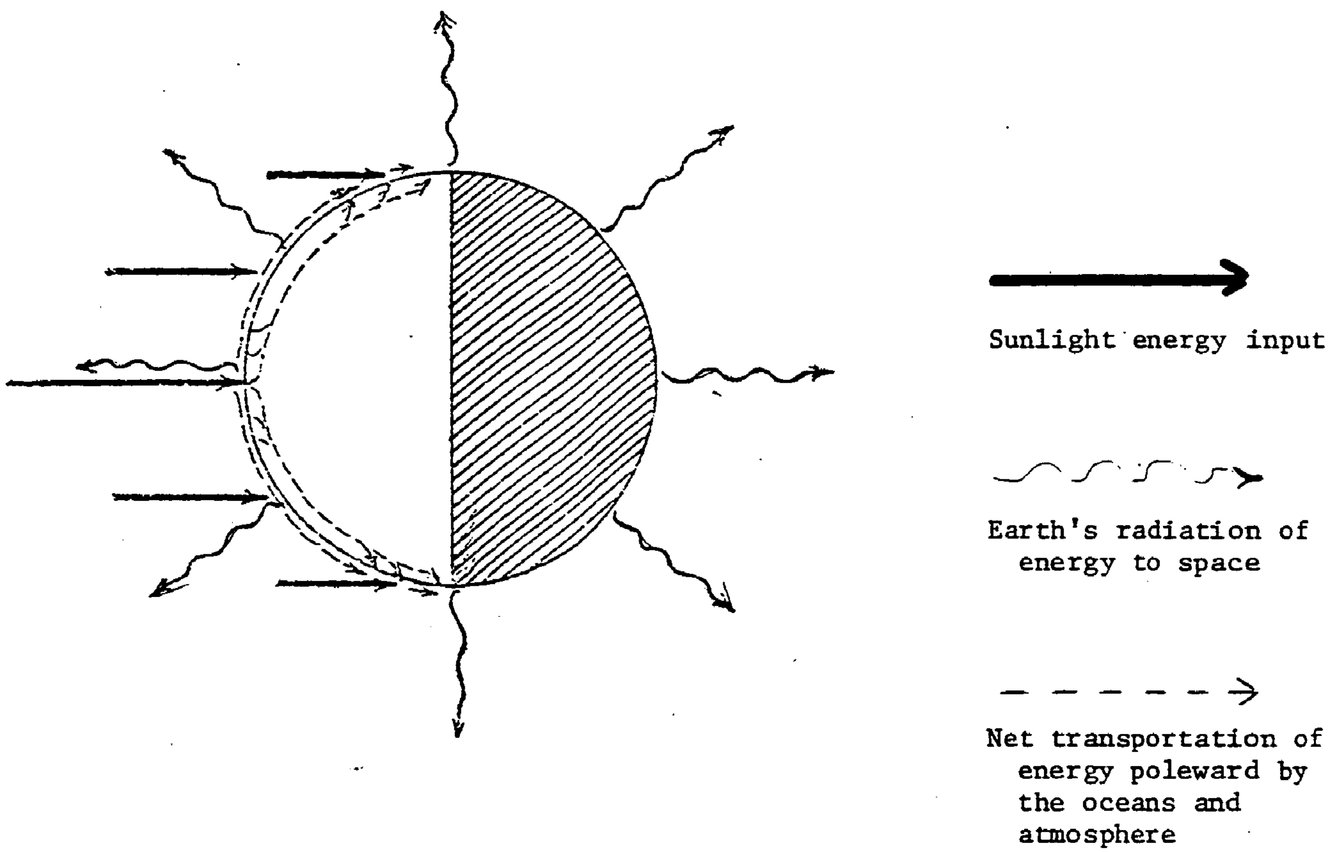

Figure 1.5 Generalized Balance of Energy for the Earth

Balance at the equator:

Sunlight In = Radiation Out + Transport Away

Balance at the poles:

Sunlight In + Transport In = Radiation Out

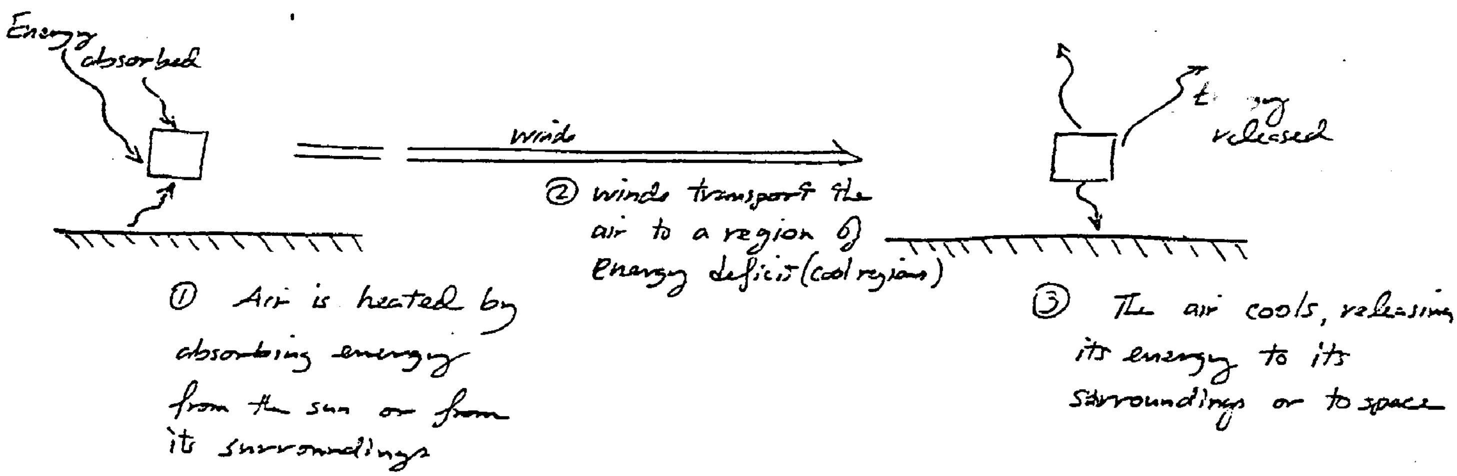

Figure 1.6a Transportation of Energy by Moving Heated Air

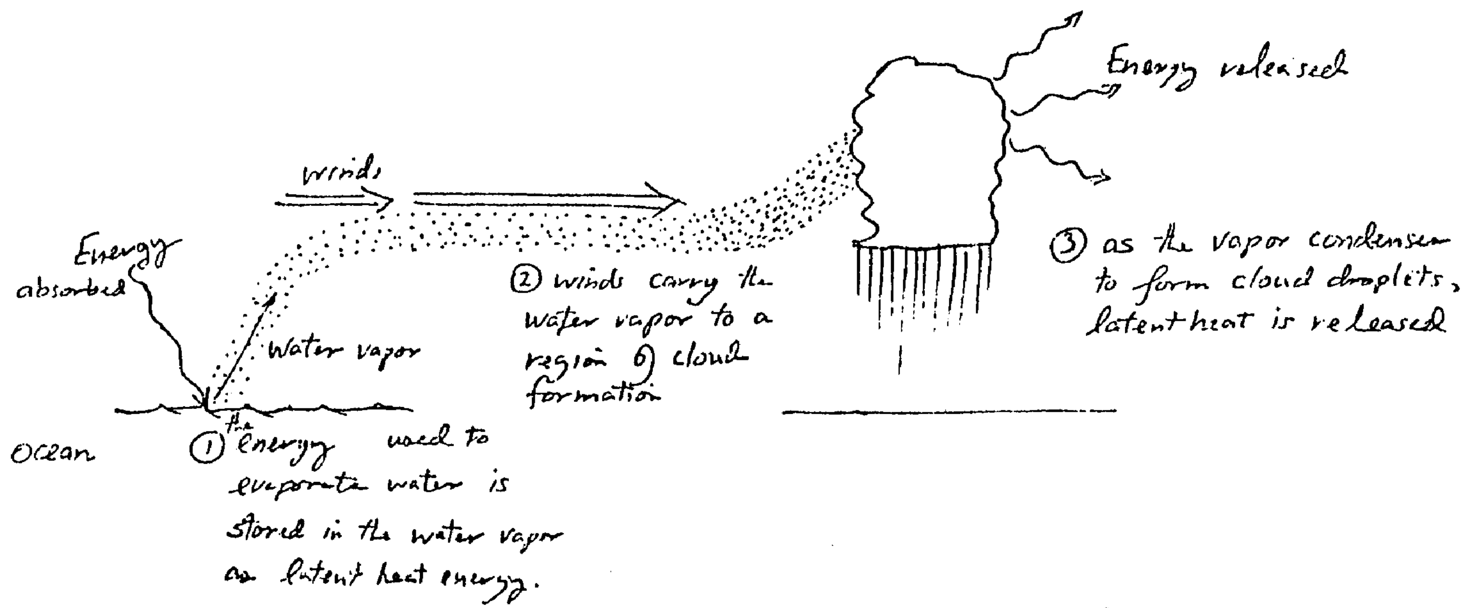

Figure 1.6b   Transportation of Energy by Moving Water Vapor.

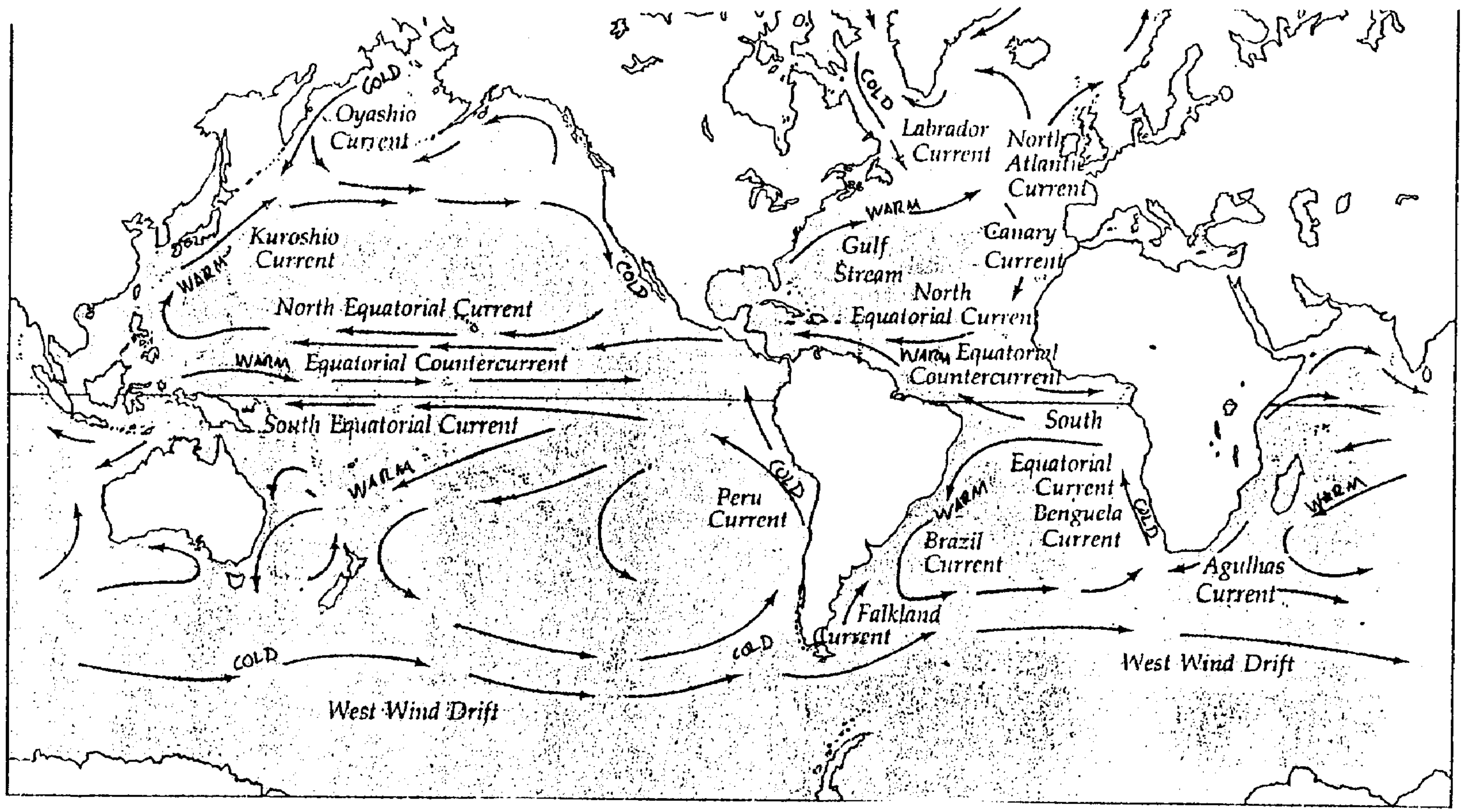

Figure 1.7 Oceanic surfa[illegible] [illegible]rculation (Ingmanson & Wallace, 1973. Oceanography: An Introduction)

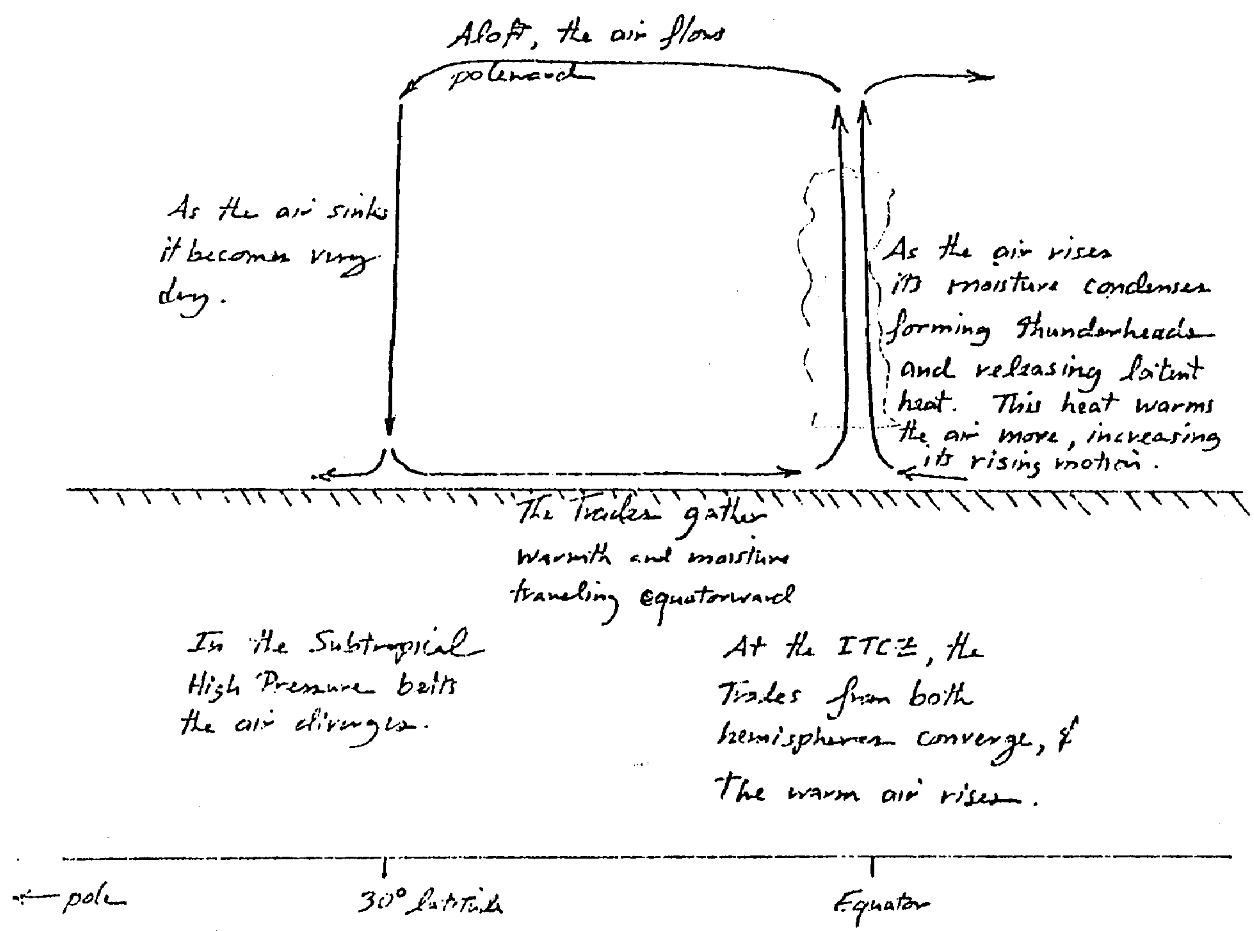

Figure 1.8 Generalized Cross-Section of the Hadley Cell Circulation

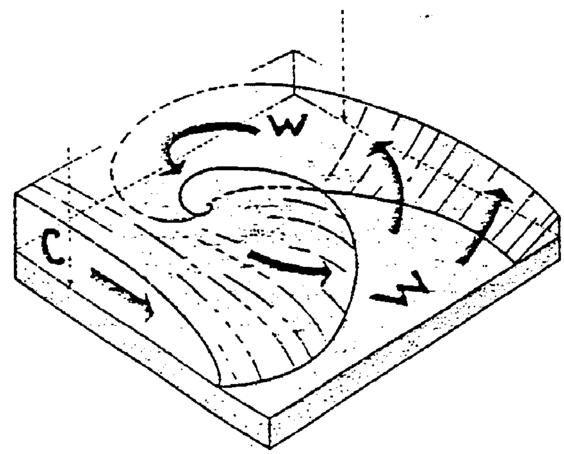

Figure 1.9 Idealized Diagram of Mid-latitude Cyclonic Storm, Illustrating Air-masses.

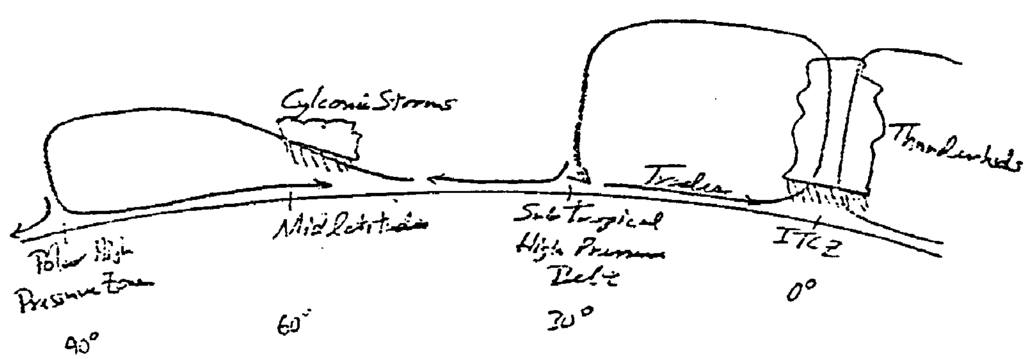

Figure 1.10 Idealized Pole-Equator Cross-section of Global Circulation

E.S. 30
Spring

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Discussion Questions

1. What does it mean to describe the earth's weather system as a "heat engine?"

2. Can you guess, using the very basic theory presented in this lecture, how climates would change if:

    a. The inclination of the earth's axis of rotation were less.

    b. The amount of radiant energy from the sun increased (or decreased).

    c. The amount of dry land changed relative to ocean area.

    d. The distribution of land changed via continental drift.

    (Each of these processes has been hypothesized to be a factor in long-term climate evolution).