

World Ecosystem and Geography

Environmental Science and Policy 30

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Objective

- The idea is not to read books about nature but to read nature like a book*
- Teach you to use natural historian's observational methods to interpret the world
 - Theory driven observations
 - Leading to more or less sound hypotheses about what is going on

* That is not to say that reading books is not useful to reading nature. We just don't want to confuse means with ends!

Why Biogeography?

- Big scale patterns easy to observe
- Layperson needs no special tools
- Exemplifies the basic principles of ecology and evolution
- Fun and interesting!

Example of natural history observation:
James Hutton, John Playfair: Uniformitarianism hypothesis and an ancient earth



Course Syllabus

World Climates

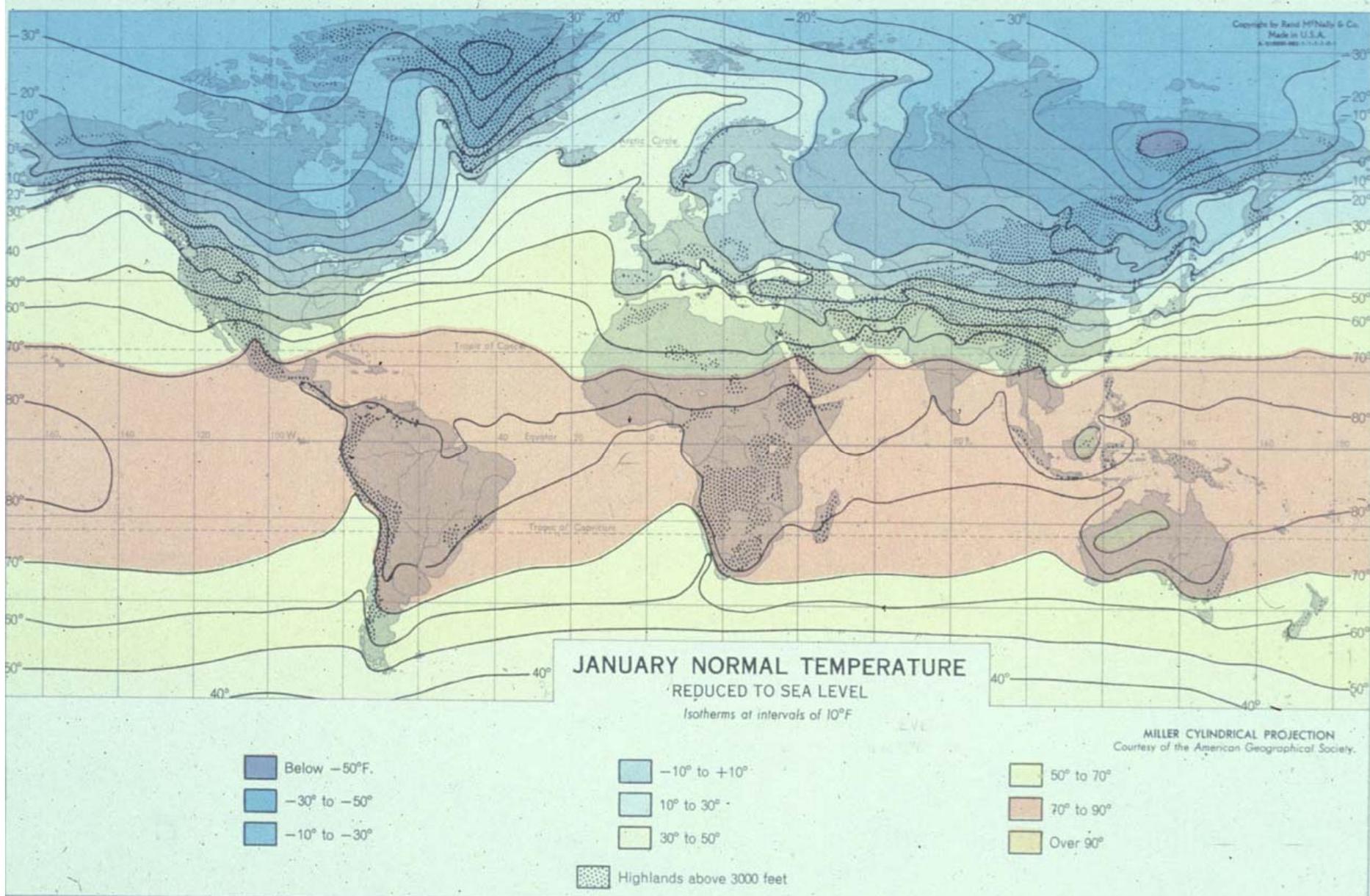
ESP 30 Lecture 1

Pursuing the biome tool

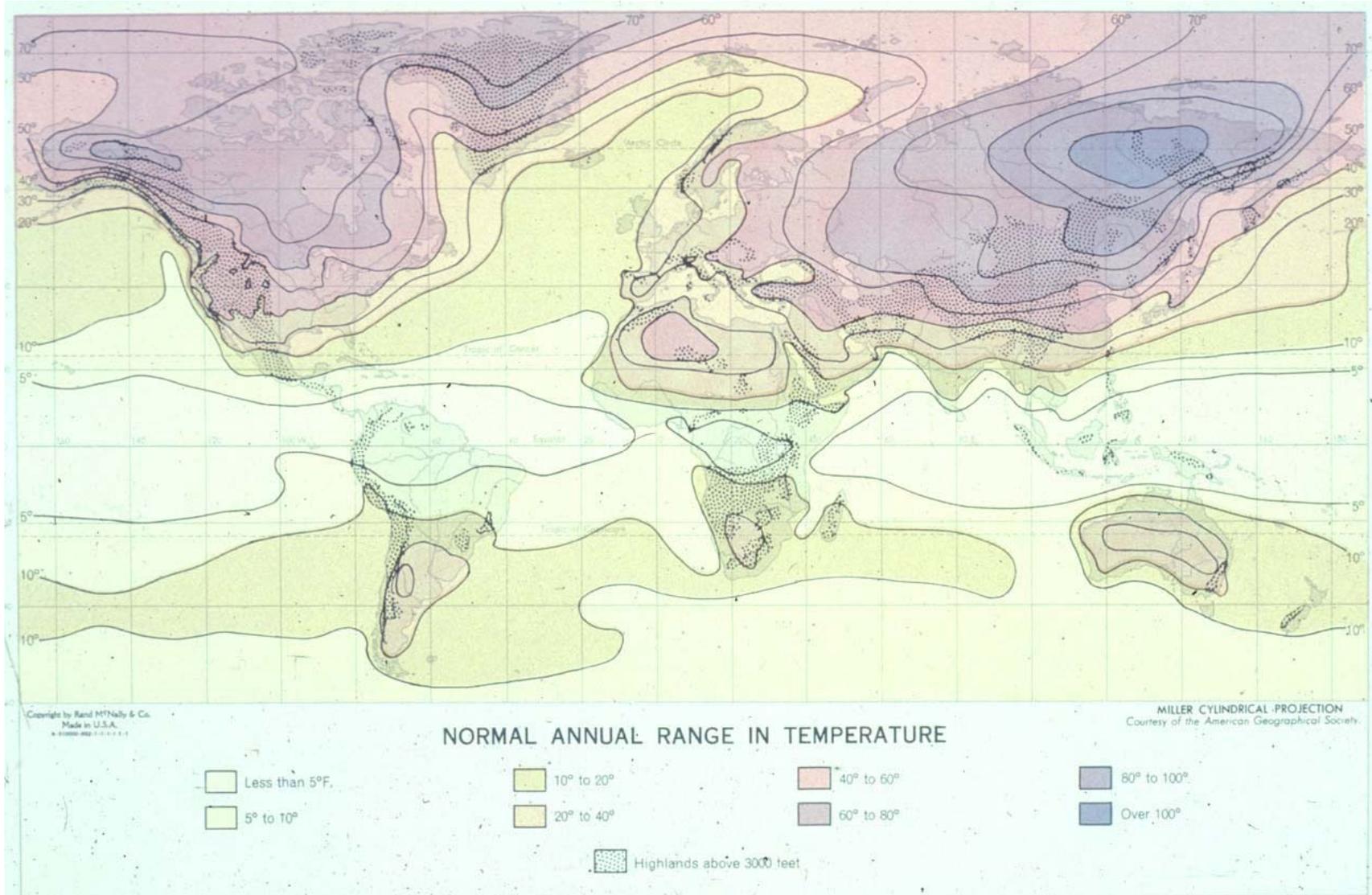
In this course we will use the biome concept as a conceptual tool to cut the awesome complexity of nature to humanly manageable proportions*. Biomes are large scale units of biological pattern on the face of the globe. We start with the patterns of the dominant physical driver of biotic patterns, climate. Biomes are a “bottom up” concept focused on plants as the biotic interface between physical-chemical environmental influences and the animal components of ecosystems.

* When we simplify in this way we are not dissing nature and pretending that she is simple. We are just confessing our limited appreciation of nature's awesome complexity and doing the best we can!

Temperature has a strong global pattern



Temperature variability (seasonality) likewise



Strong patterns to rainfall

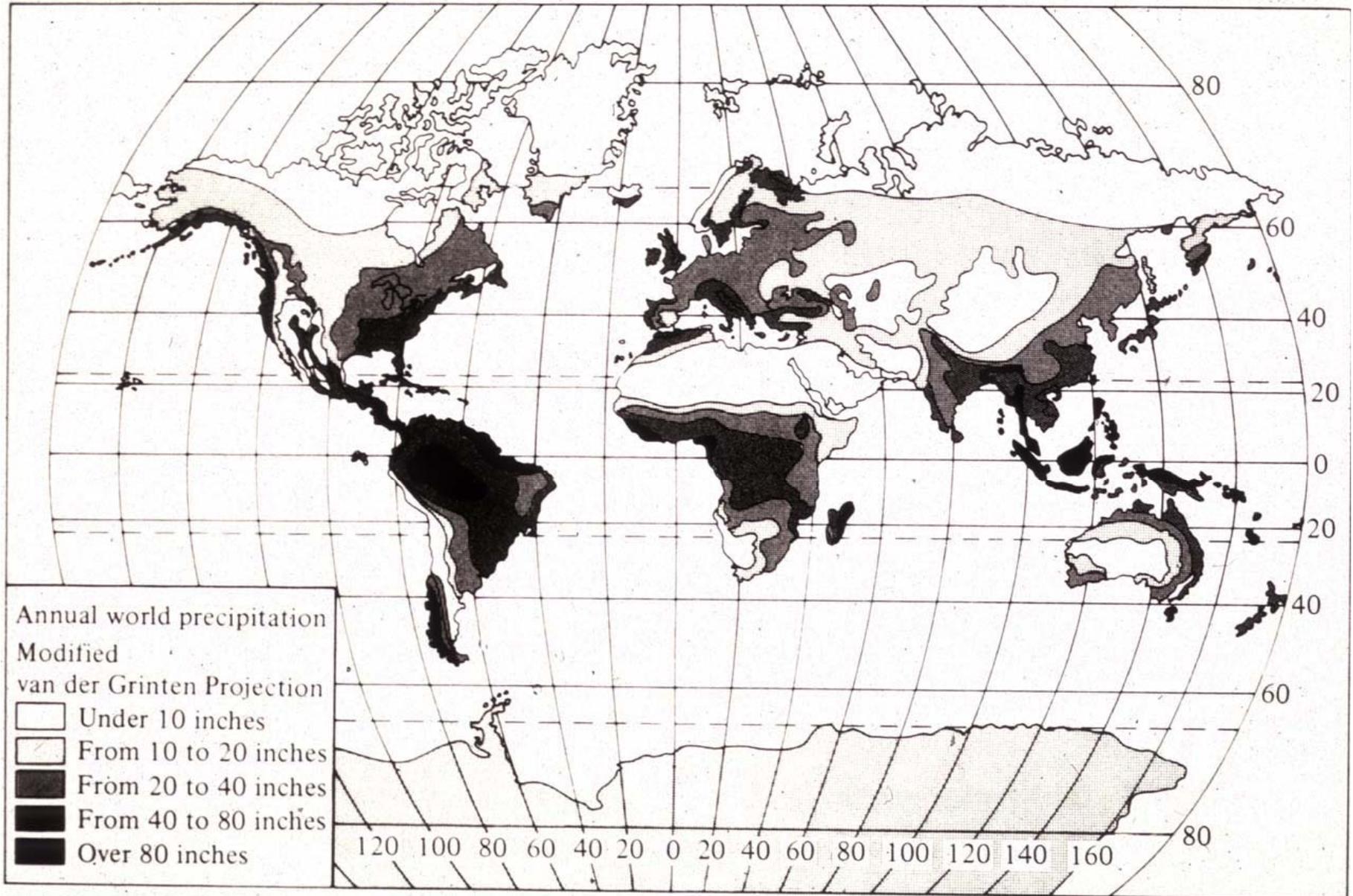


FIGURE 2.5 The geographic distribution of average annual precipitation. [After MacArthur and Connell (1966) after Koeppen.]

Soils, which have an important impact on vegetation, have patterns related to precipitation and temperature

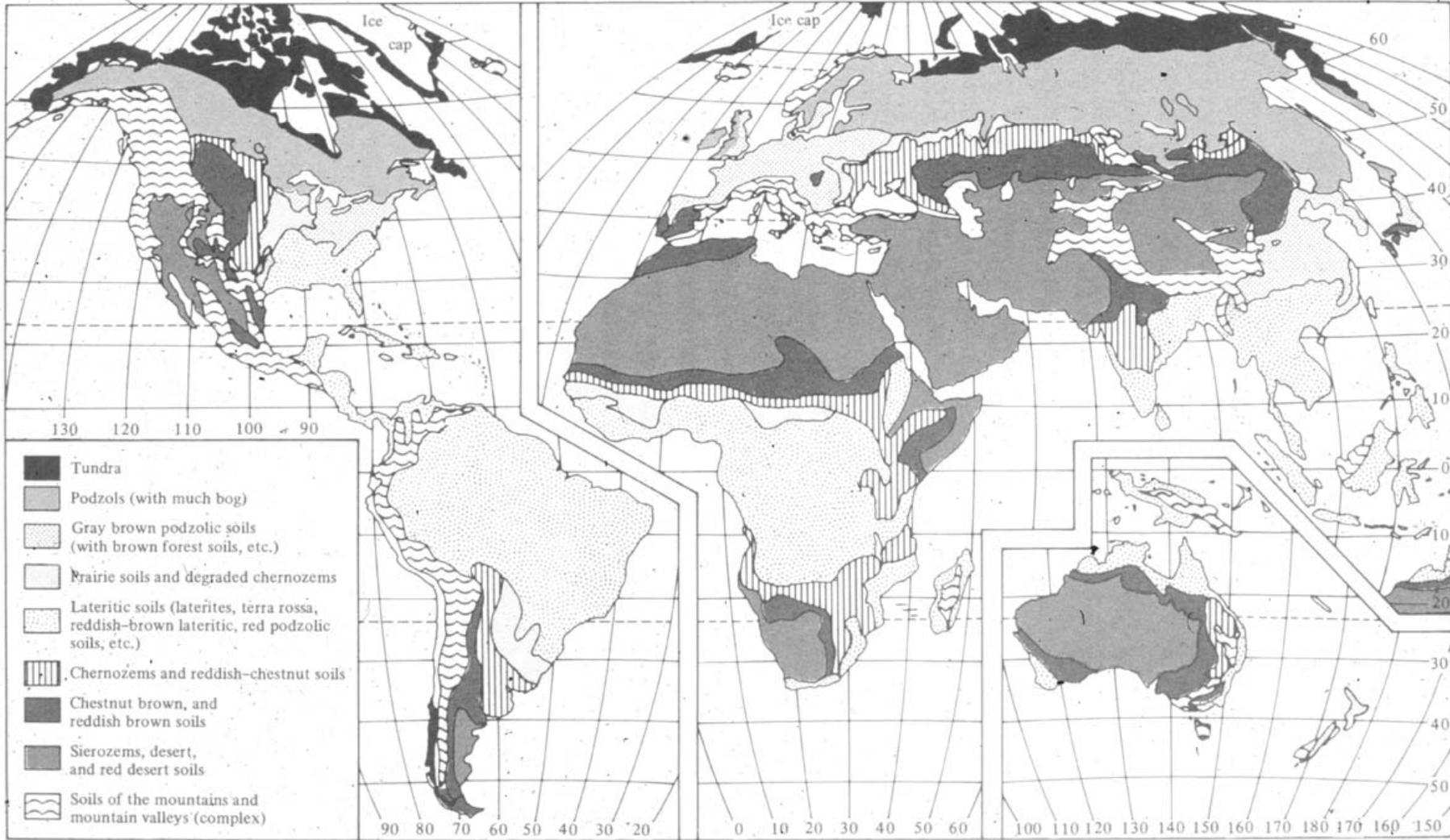
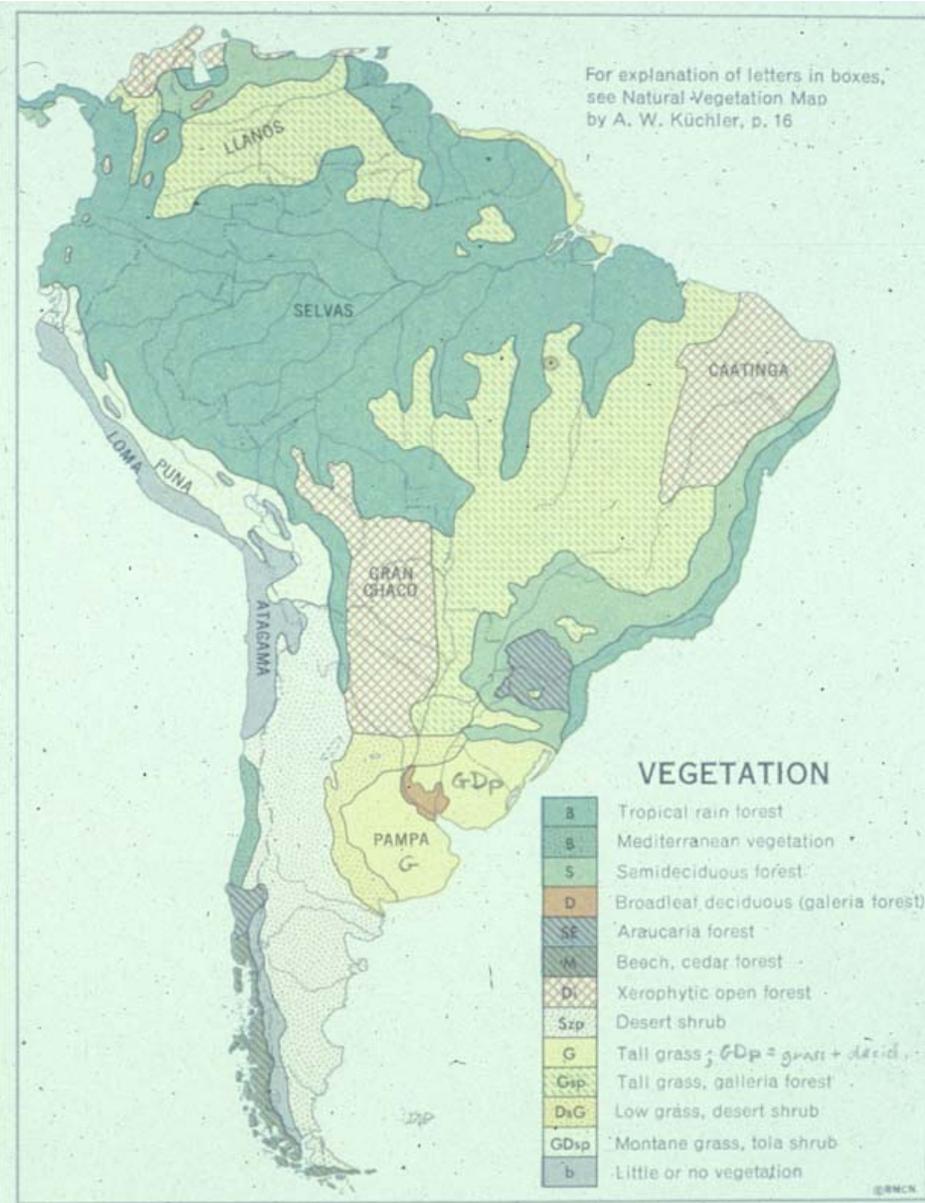
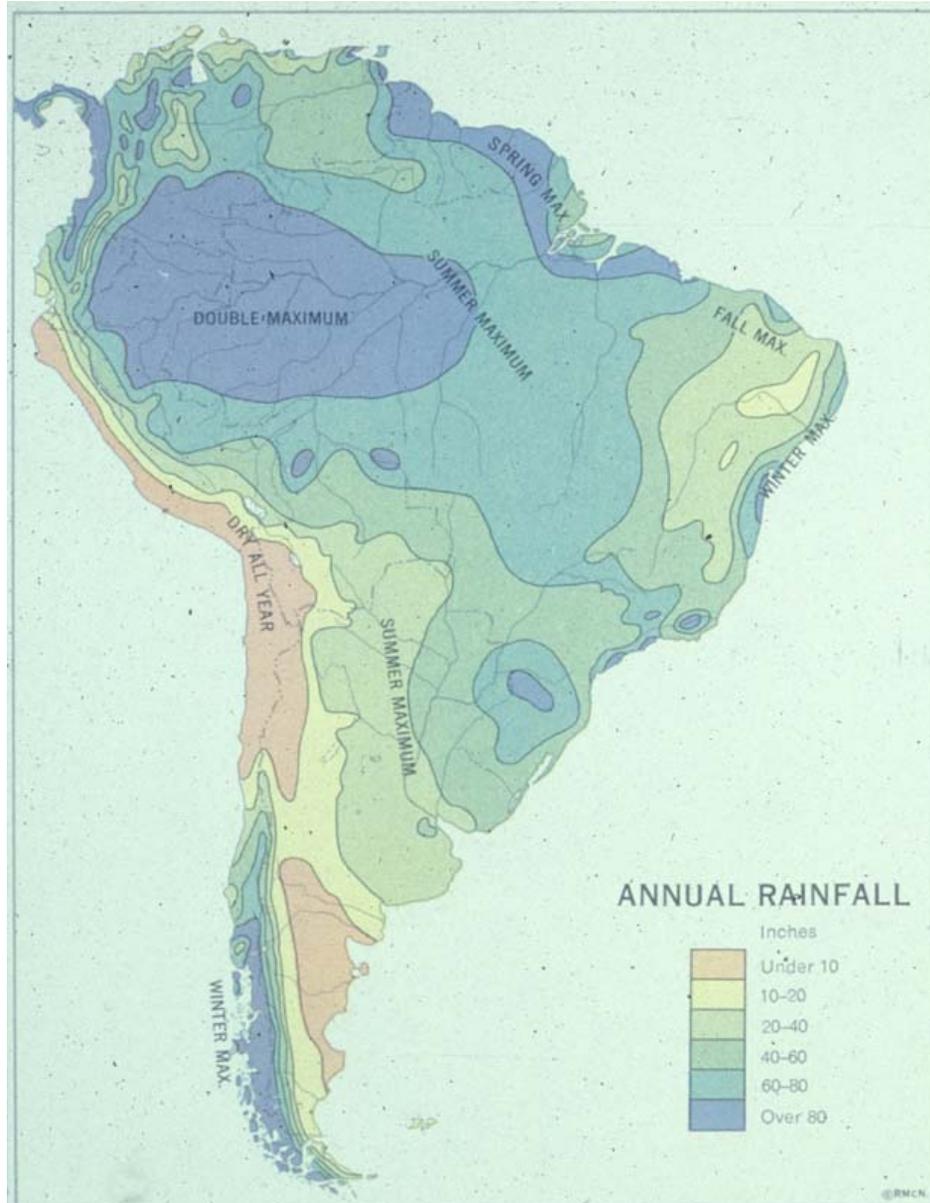


FIGURE 3.12 Geographic distribution of the primary soil types. Compare with Figure 3.1. [After Blumenstock and Thornthwaite (1941).]

Climate and vegetation patterns have a resemblance
(rainfall mainly in South America except for cool south and mountains)



Walter's 9 main biomes

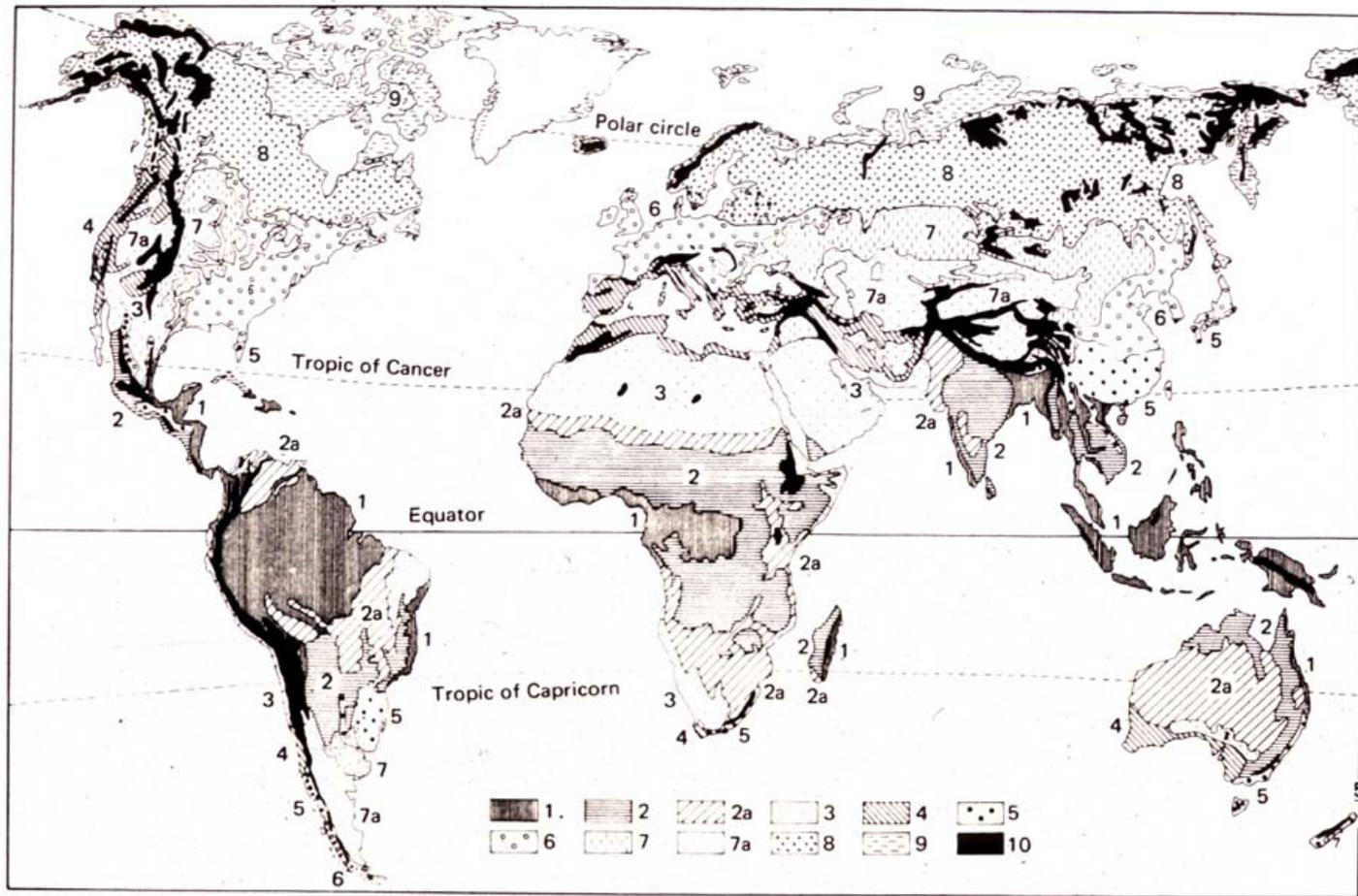


Fig. 13. Vegetational zones (much simplified, without edaphically or anthropogenically influenced vegetational regions). I. Tropical and subtropical zones: 1 Evergreen, rainforests of the lowlands and mountain-sides (cloud forests), 2 semi-evergreen and deciduous forests, 2 a dry woodlands, natural savannas or grassland, 3 hot semi-deserts and deserts, polewards up to latitude of 35° (see also 7 a). 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, 7 a semi-deserts and deserts with cold winters, 8 boreal coniferous zone, 9 tundra, 10 mountains.

The Earth's Climate System

- Earth is a “heat engine”
- that drives air and ocean currents
- Moving water transports heat
- Moving air transports heat and water vapor
- Irregular continents make patterns somewhat messy
- In a nutshell!

Energy income from the sun varies by latitude and season. As an annual average, the equator receives more than twice as much energy as the poles

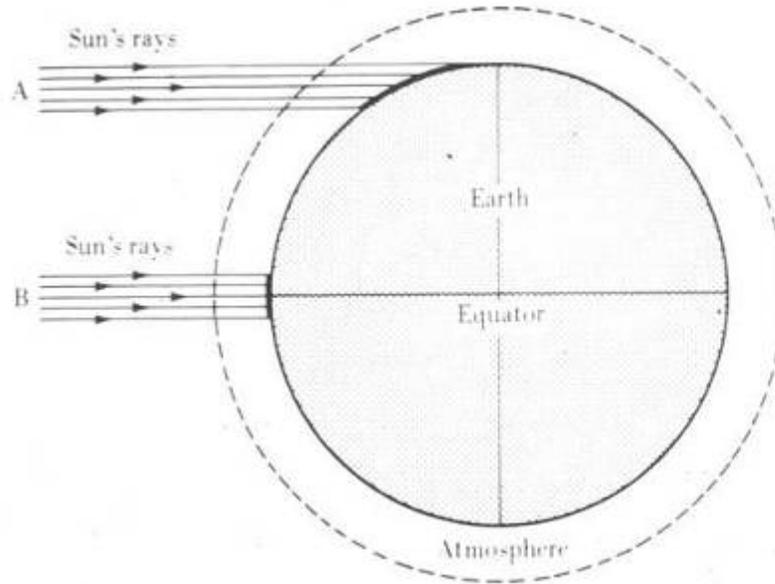


Figure 6.1. The sun's rays strike the polar areas in an oblique manner (A) and deliver less energy at the earth's surface than the vertical rays (B) for two reasons: (1) because the energy is spread over a larger surface in (A) and (2) because it passes through a thicker layer of absorbing, scattering, and reflecting atmosphere.

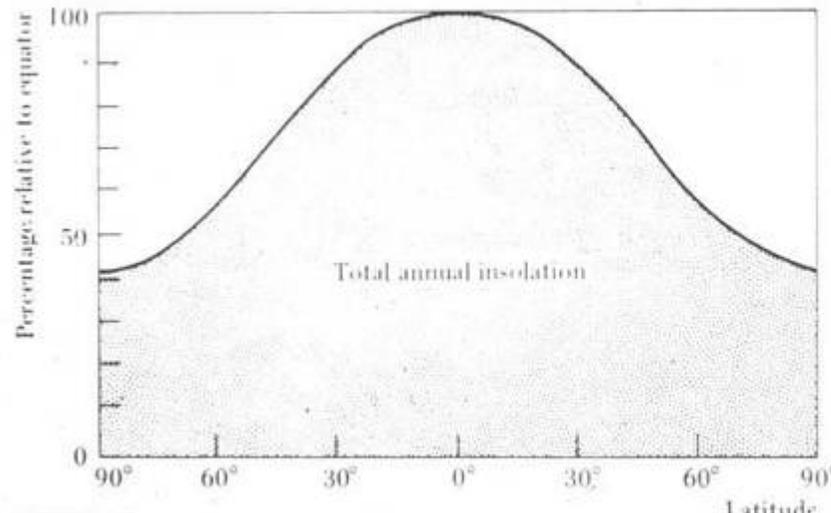
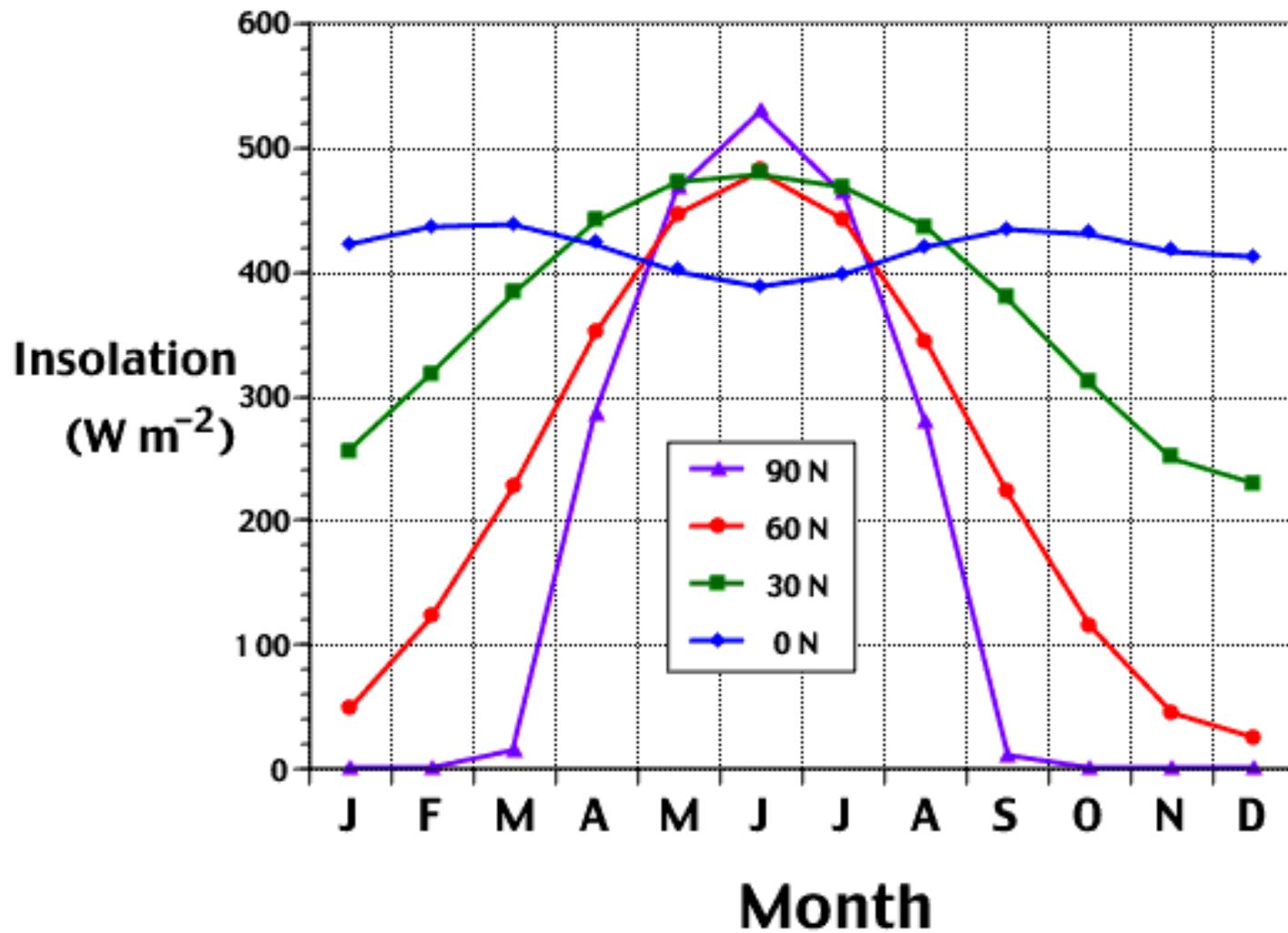


Figure 6.2. Solar insolation falling on different latitudes during the year. The amount of solar energy is expressed as a percentage of the amount falling at the equator. (Data from Trewartha 1954, p. 13.)

Seasonal variation in insolation much greater at higher latitudes



“Heat Engine:” Differential heating of the tropics causes warm air and water to move poleward and cold air and water equatorward. Eventually all the heat that is gained from the sun at short wavelengths (we can see a lot of it) is dumped back to space as long wavelength infrared radiation

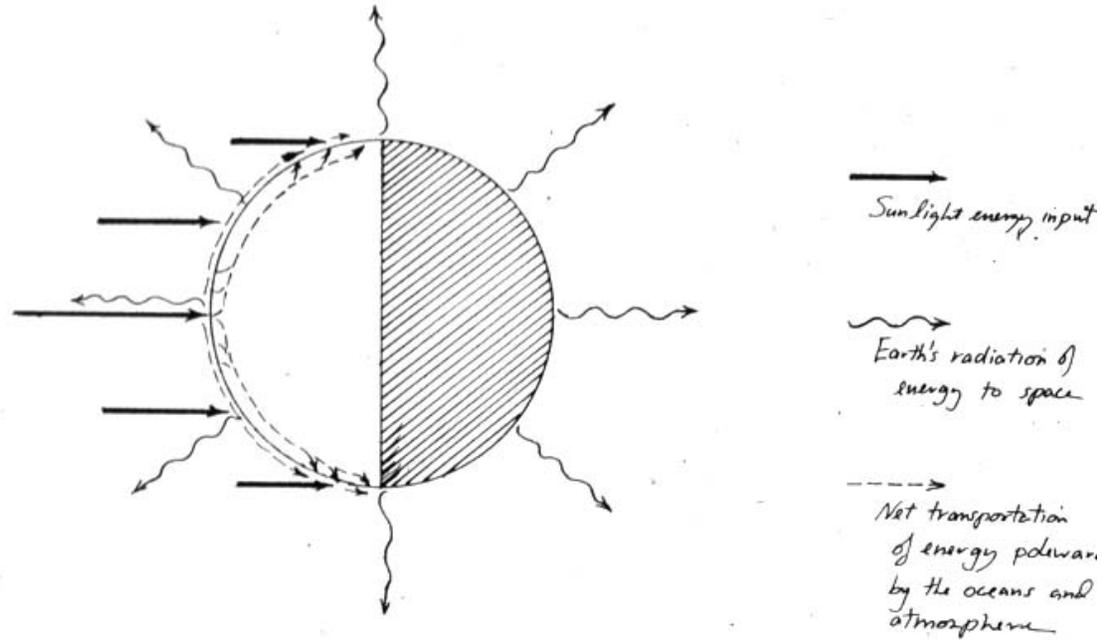


Figure 5

Generalized Balance of Energy for the Earth

Balance at the equator :

$$\text{Sunlight In} = \text{Radiation Out} + \text{Transport Away}$$

Balance at the poles :

$$\text{Sunlight In} + \text{Transport In} = \text{Radiation Out}$$

The idea here is very simple

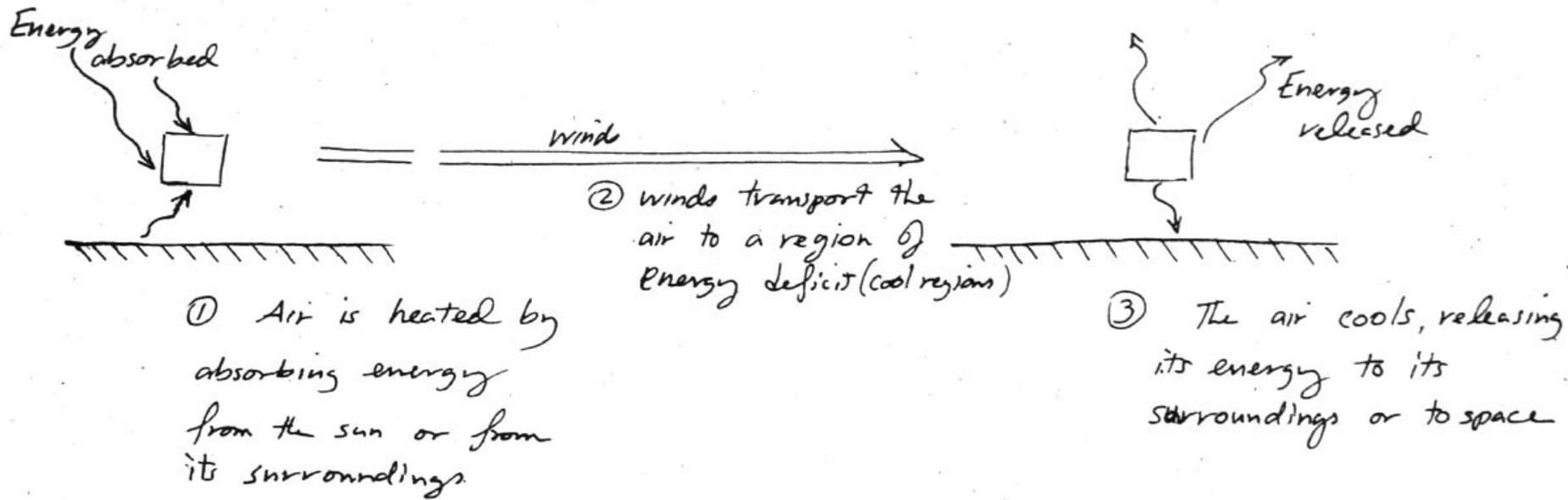
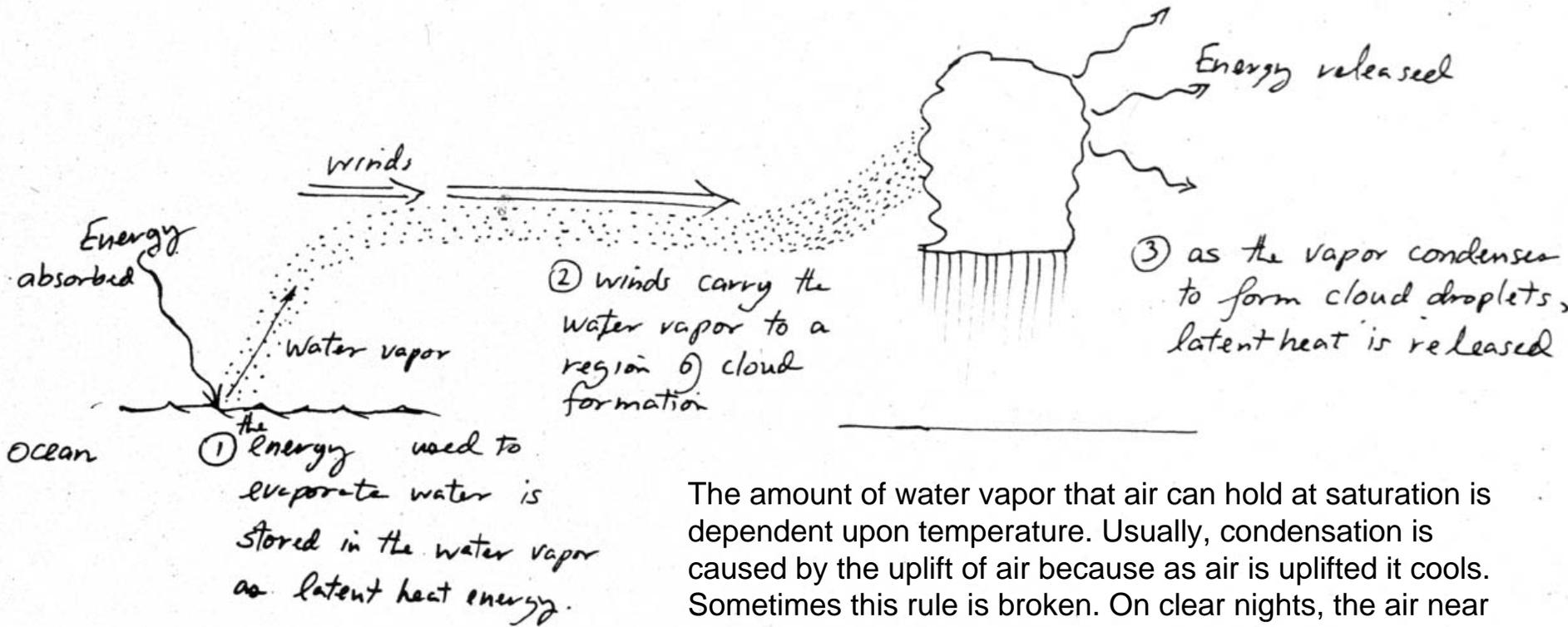


Figure 6a. Transportation of Energy by Moving Heated Air

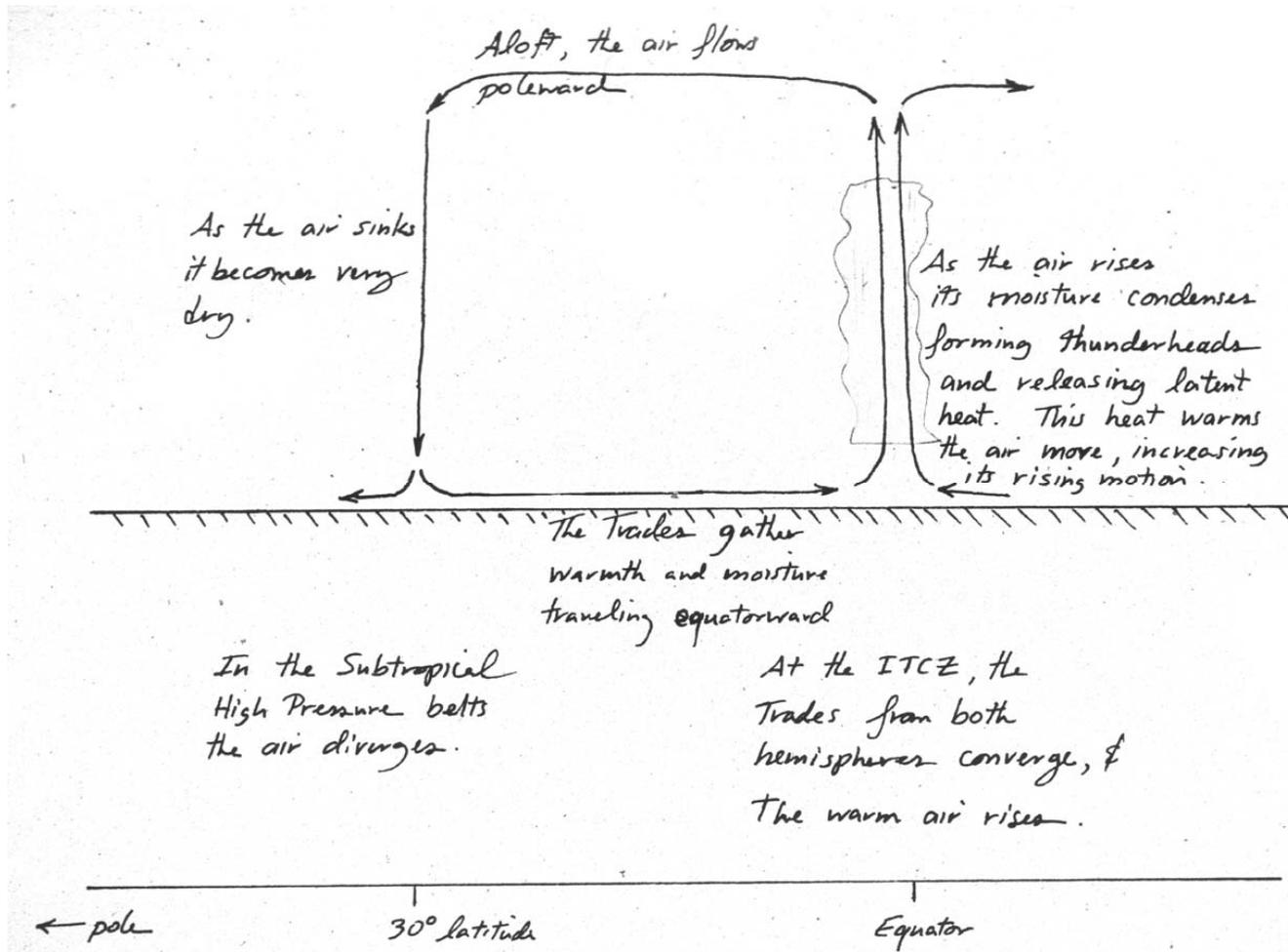
Not so simple: Latent heat is the heat that is used to evaporate water. It takes a lot of heat to evaporate water (2272 J/g). Think of how much colder you feel when your wet; evaporation sucks a lot of heat out of a wet person. But when water vapor condenses, the latent heat becomes heat again; think steam bath. Hence moist air moves a lot of latent heat and when cloud droplets condense they give up that heat. The latent heat of vaporization is what powers thunderstorms and hurricanes. Hot moist tropical air is one of nature's weapons of mass destruction!



The amount of water vapor that air can hold at saturation is dependent upon temperature. Usually, condensation is caused by the uplift of air because as air is uplifted it cools. Sometimes this rule is broken. On clear nights, the air near the ground cools fastest, and often fog forms right near the ground. The Central Valley of CA tule fogs often demonstrate this effect!

Figure 6b. Transportation of Energy by Moving Water Vapor

Tropical Hadley Cell: a relatively simple convection cell. Warm air at the equator rises, cools as it moves poleward, sinks, and reheats as it moves back toward the equator. Hadley's original idea was that the earth would have one giant Hadley cell stretching from the equator to the poles. Coriolis' force rules that out! But Coriolis' force is weak near the equator, hence a slightly warped Hadley cell exists. Note that the energy carried as latent heat by water vapor is very important in the Tropical Hadley Cell.



Poleward of the Tropical Hadley Cell are mid-latitude storm systems. These are twisted versions of Hadley cells in which winds circulate horizontally around high and low pressure ridges and troughs, with vertical motions along fronts as warm air rides up over cold air. The whole system shifts poleward and equatorward with the seasons such that the Intertropical Convergence Zone (ITCZ) is always under the sun.

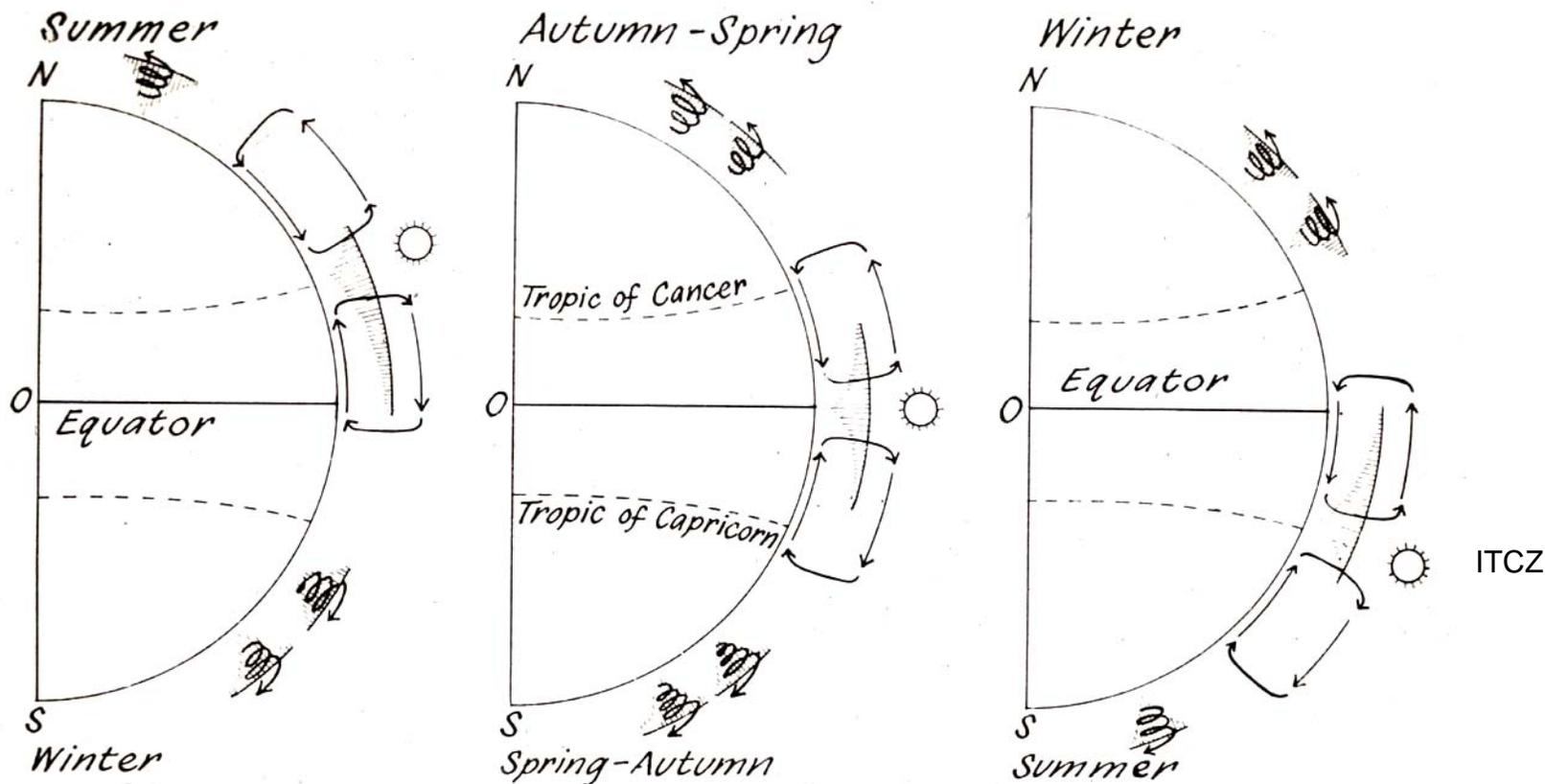


FIG. 14. Schematic representation of the oscillation of the precipitation zones in relation to the position of the sun. Amount of rain is indicated by length of parallel lines. After Walter (1960).

Some of the main components of the global air circulation system

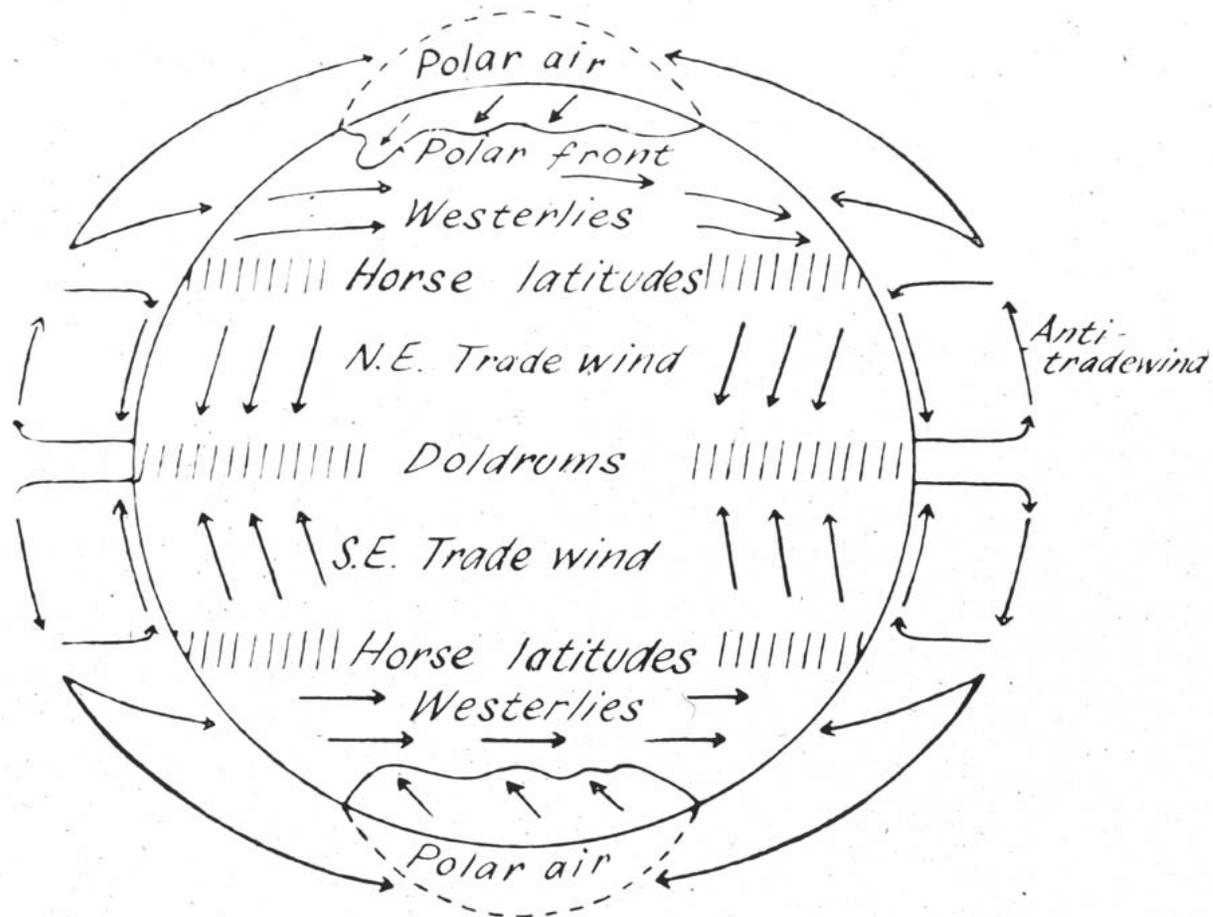
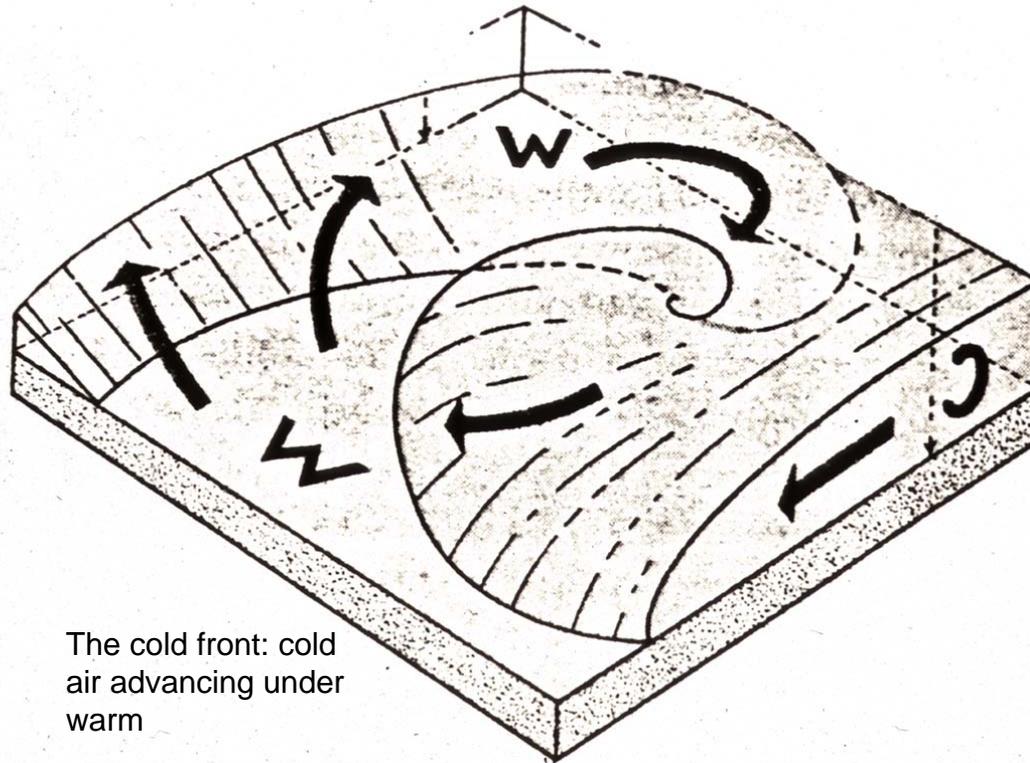


FIG. 13. Air currents at the equinoxes (after Gebauer). From Walter (1960).

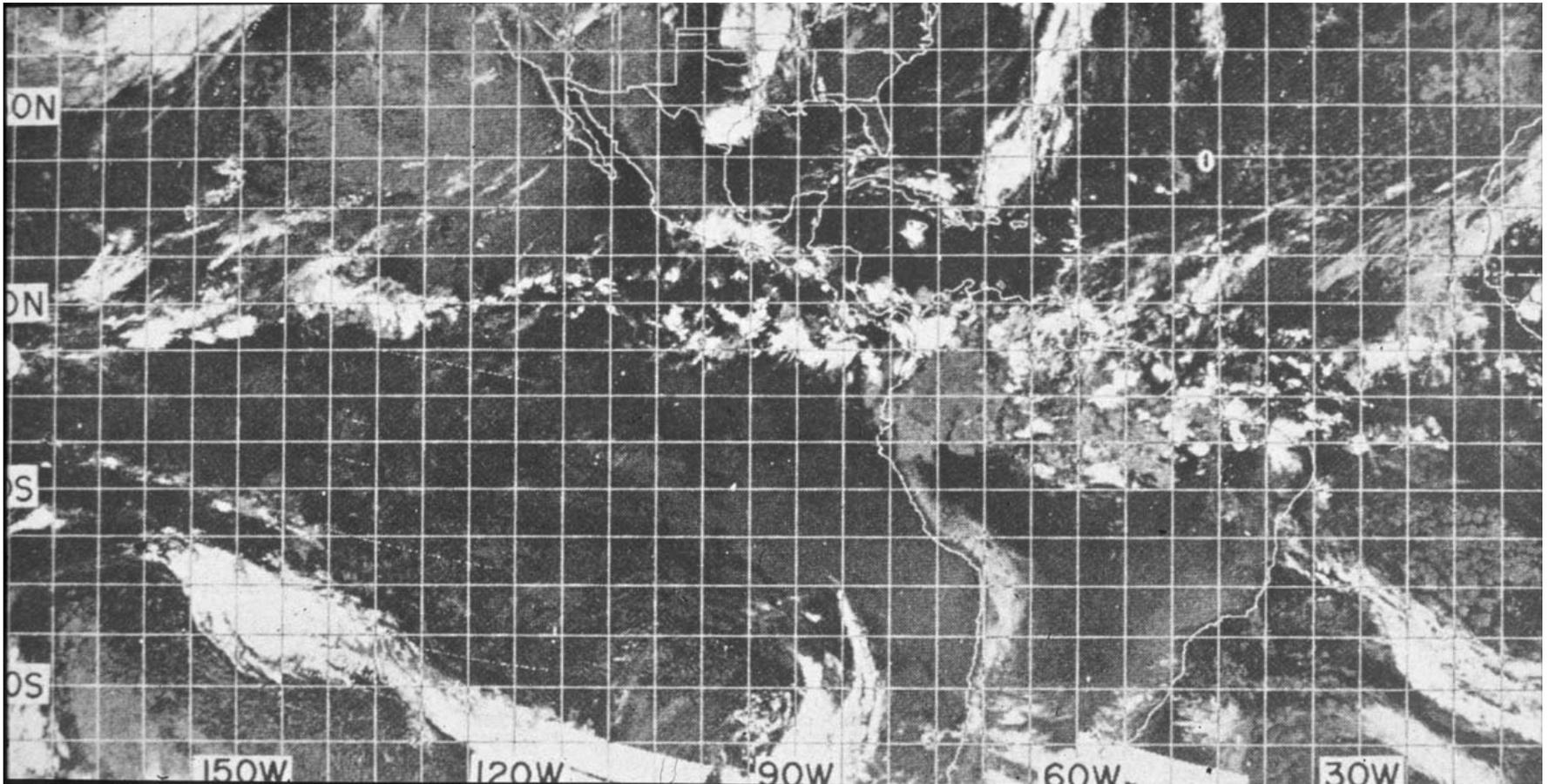
Diagrammatic picture of the circulation in a mid-latitude storm. The warm air mass (w) is moving poleward and is riding up over the cold air mass (c) and the cold air mass is slipping equatorward and bulldozing into the warm air. If the warm air is moist, it will dump latent heat as it rises. This will trigger storms, gentle ones on the warm front because the rises in gentle, but often violent ones on the blunt-nosed cold front. Tornadoes in our Midwest result when relatively quite cold Canadian air bulldozes violently into warm, moist air from the Gulf of Mexico, forcing it to rise abruptly, spilling an immense amount of latent heat into powerful thunderstorms that generate tornados. Latent heat is responsible for another natural WMD!

The warm front:
warm air advancing
over cold

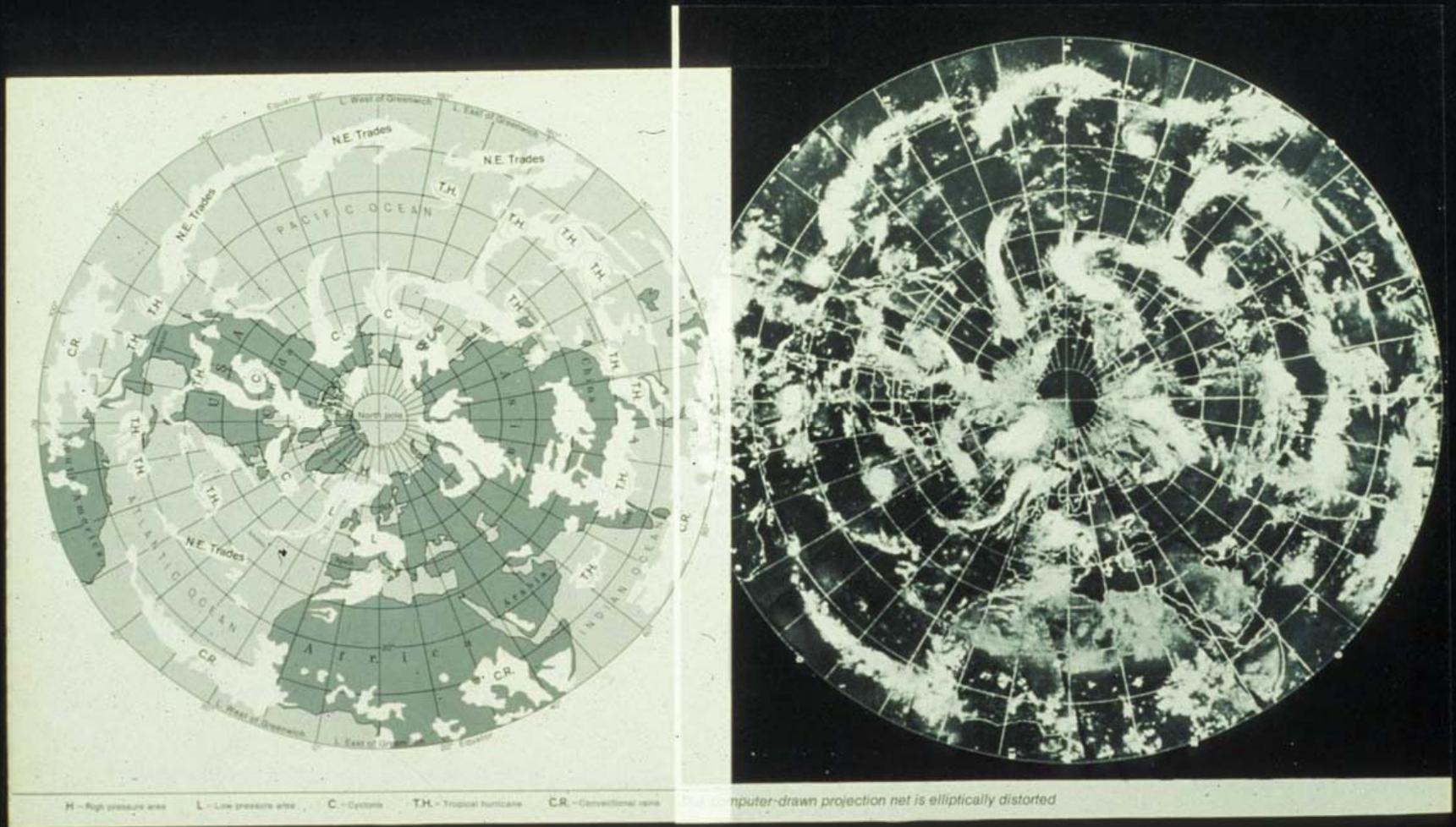


The cold front: cold
air advancing under
warm

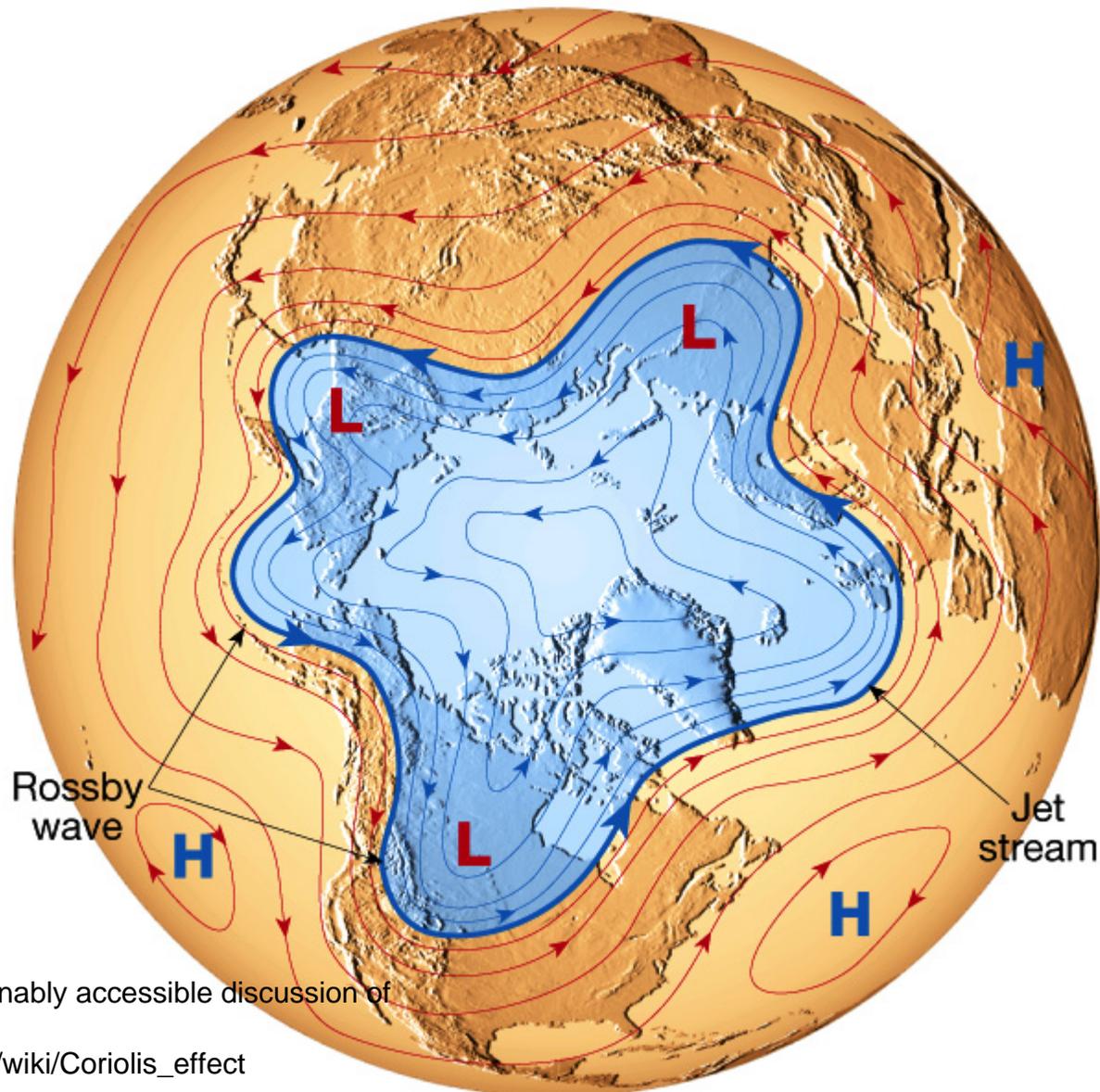
Equatorial satellite view of the earth's weather system. The speckle of clouds in the irregular band just north of the equator is the ITCZ. The mare's tails at the top and bottom of the picture are the tails of mid-latitude storms, Notice the giant storm in the South Pacific stretching toward Chile. A lot of latent heat is moving poleward in that one!



A polar view of the climate and weather system. Note the pinwheel of more or less evenly spaced mid-latitude storms. These are steered by the jet stream, the strong core of the westerlies aloft.



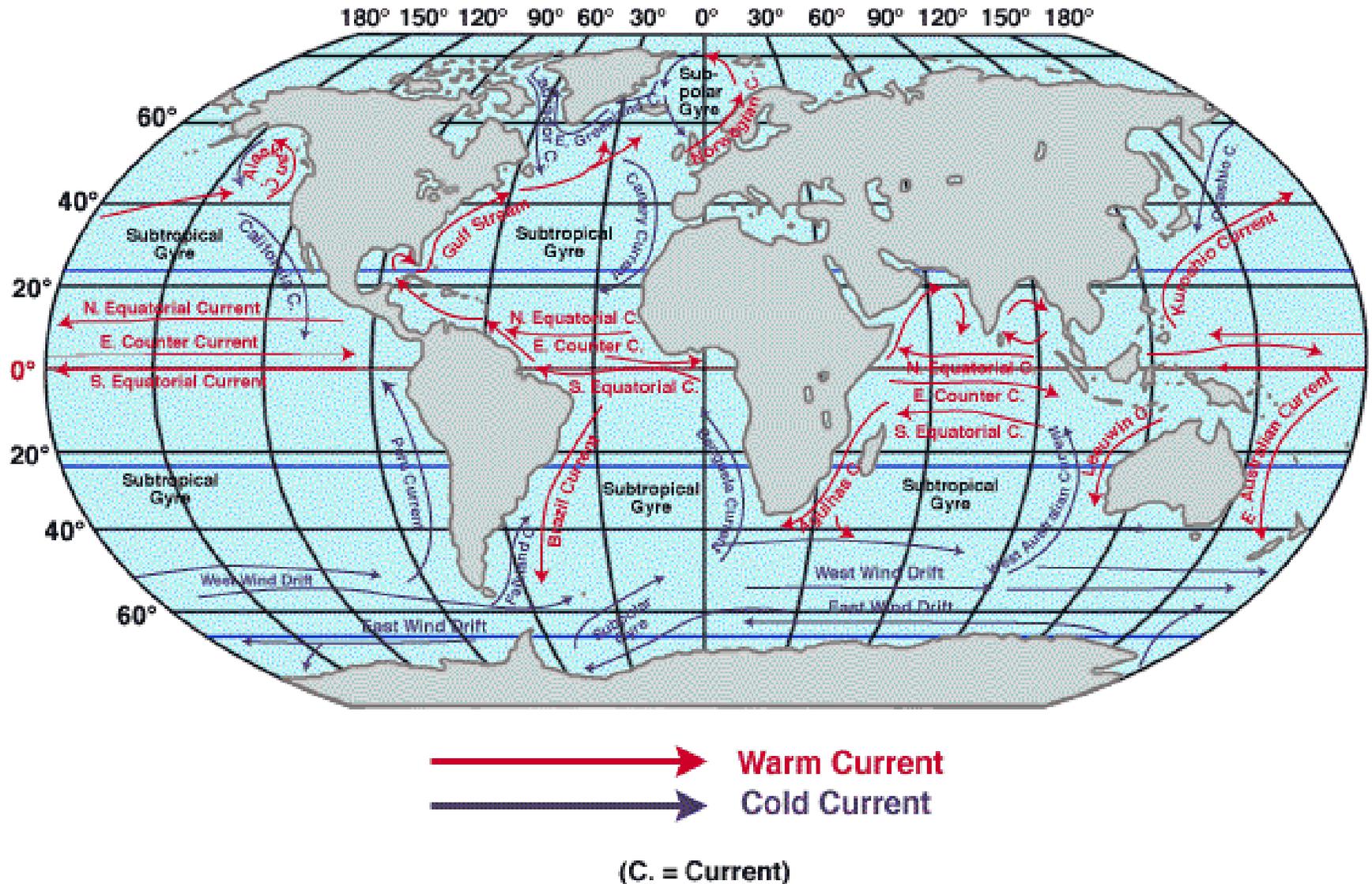
This is the crazy result of how Coriolis force flattens high latitude circulation to generate the mid-latitude storm system. The winds “want” to blow by gravity from the midlatitude high pressure zone into the polar low, generating a Hadley Cell. The Coriolis force (in the N Hemisphere) forces the wind to the right. Complex instabilities throw the jet stream into Rossby waves. The pinwheel pattern is normally not static but rotates westward. If you are confused, join the atmospheric physicists! Atmospheric science turns out to be more challenging than rocket science. We can get a spacecraft to the outer planets but we can’t predict the weather. Reflect on that.



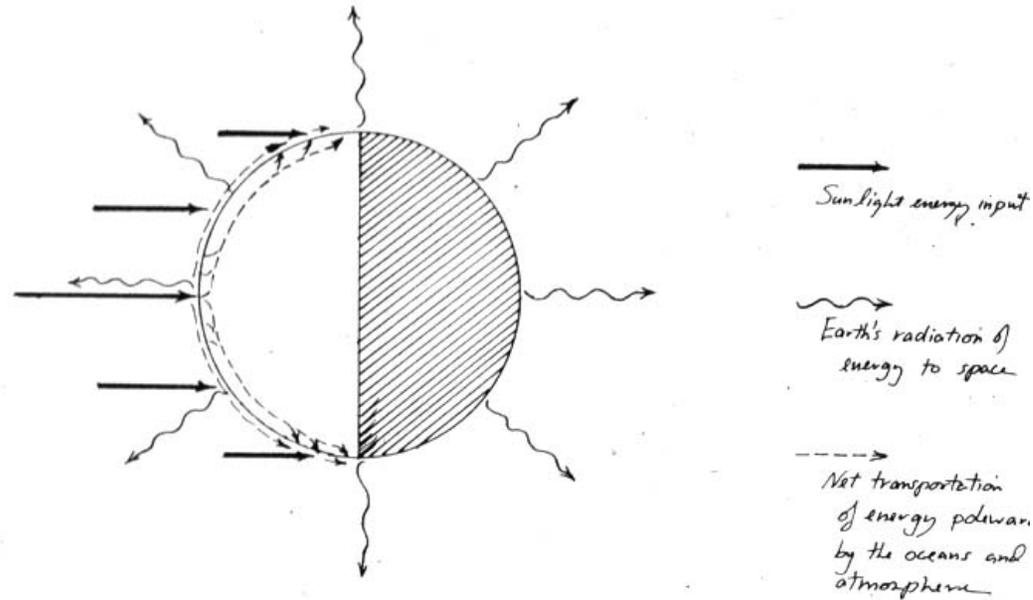
Wikipedia has a reasonably accessible discussion of the Coriolis force:

http://en.wikipedia.org/wiki/Coriolis_effect

Ocean surface currents. Note that each ocean basin is dominated by a gyre that has a cold current running equatorward on its east side and a warm current running poleward on its west side. These currents are driven by the westerly winds centered around 40 degrees and the trade winds toward the equator. Ocean and air currents are roughly equally responsible for the total heat transport from the equatorial regions toward the poles.



The simple heat engine picture: Hadley's very simple physical intuition turned out to be half right but way more complex and weird than he imagined. Lovely!



George Hadley was an 18th Century English naturalist. Gustav Coriolis was a 19th Century French Scientist

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