Global Atmospheric Circulation

Energy from the Sun heats the entire Earth, but this heat is unevenly distributed across the Earth's surface. Equatorial and tropical regions receive far more solar energy than the mid latitudes and the polar regions.

The tropics receive more heat radiation than they emit, while the polar regions emit more heat radiation than they receive. If no heat was transferred from the tropics to the polar regions, the tropics would get hotter and hotter while the poles would get colder and colder.

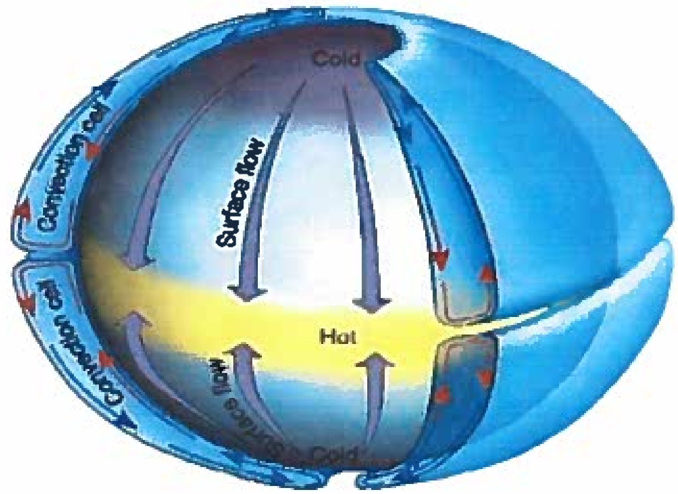


Fig. 1 Air circulation around the globe would be simple (and the weather boring) if the Earth did not rotate and the rotation was not tilted relative to the Sun.

This latitudinal heat imbalance drives the circulation of the atmosphere and oceans. Around 60% of the heat energy is redistributed around the planet by the atmospheric circulation and around 40% is redistributed by the ocean currents.

Atmospheric Circulation

One way to transfer heat from the equator to the poles would be to have a single circulation cell where air moved from the tropics to the poles and back. This single-cell circulation model was first proposed by Hadley in the 1700's.

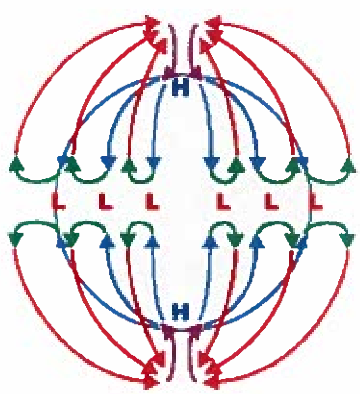


Fig. 2 Hypothetical circulation for a non-rotating Earth. Source: National Weather Service, Southern Regional Headquarters - USA.

Idealised Global Circulation

Since the Earth rotates, its axis is tilted and there is more land in the Northern Hemisphere than in the Southern Hemisphere, the actual global air circulation pattern is much more complicated. Instead of a single-cell circulation, the global model consists of three circulation cells in each hemisphere. These three cells are known as the tropical cell (also called the Hadley cell), the midlatitude (Ferrel) cell and the polar cell.

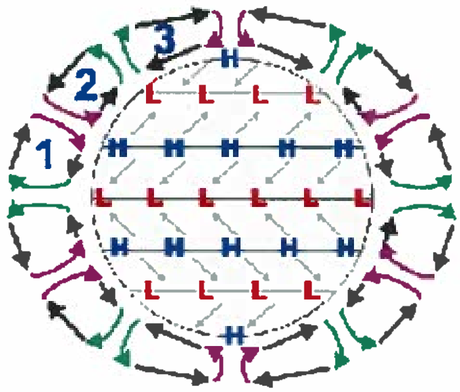
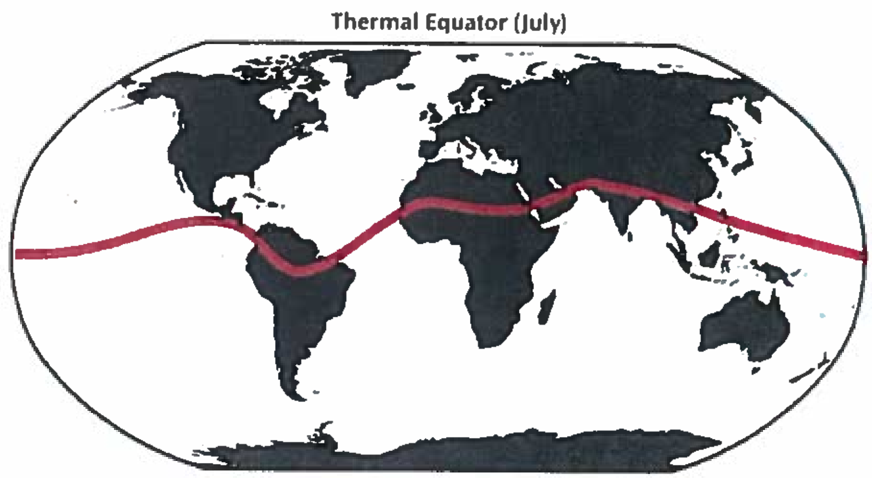
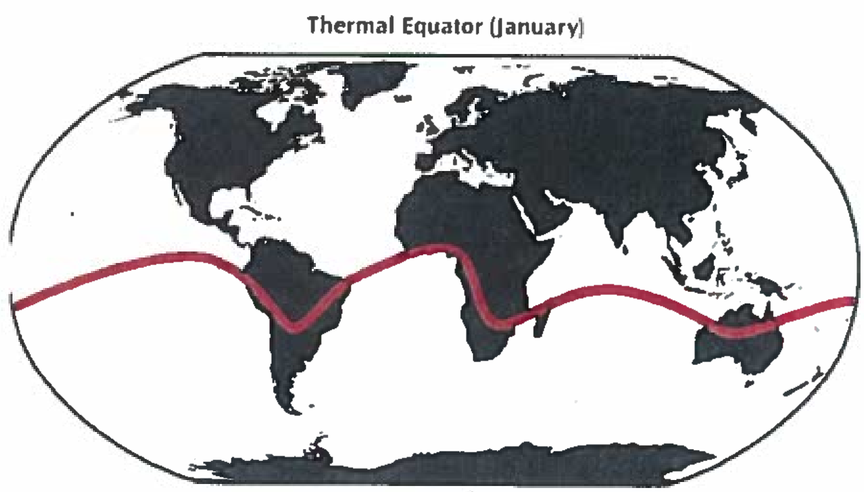


Fig. 3 Idealised global circulation.
Source: National Weather Service, Southern Regional Headquarters - USA.





1. Tropical cell (Hadley cell) - Low latitude air moves towards the Equator and heats up. As it heats it rises vertically and moves pole ward in the upper atmosphere. It is a closed circulation loop, which begins with warm, moist air lifted aloft in equatorial low-pressure areas (the Intertropical Convergence Zone, ITCZ) to the tropopause and carried poleward. At about 30°N/S latitude, it descends in a high pressure area. Some of the descending air travels equatorially along the surface, closing the loop of the Hadley cell and creating the Trade Winds. This forms a convection cell that dominates tropical and sub-tropical climates. Though the Hadley cell is described as lying on the equator, it is more accurate to describe it as following the sun's zenith point, or what is termed the "thermal equator," which undergoes a semiannual north-south migration, as shown above.

2. Midlatitude cell (Ferrel cell) – Theorized by William Ferrel, is a secondary circulation feature, dependent for its existence upon the Hadley Cell and Polar Cell. It behaves much as an atmospheric ball bearing between the Hadley and Polar cells, and comes about as a result of the high and low pressure areas of the mid-latitudes. For this reason it is sometimes known as the "zone of mixing." At its southern extent (in the Northern Hemisphere), it overrides the Hadley cell, and at its northern extent it overrides the Polar Cell. In this cell the air flows polewards and towards the east near the surface and equatorward and in a westerly direction at higher levels. Just as the Trade Winds can be found below the Hadley cell, the Westerlies can be found beneath the Ferrel Cell.

3. Polar cell – Like the Hadley Cell in its simplicity. Though cool and dry relative to equatorial air, air masses at the 60th parallel are still sufficiently warm and moist to undergo convection and drive a thermal loop. Warm air rises at lower latitudes and moves poleward through the upper troposphere at both the north and south poles. When the air reaches the polar areas, it has cooled considerably, and descends as a cold, dry high pressure area, moving away from the pole along the surface but veering westward as a result of the Coriolis effect to produce the Polar easterlies.

Questions for Reflection. Use your own sheet of paper!

1. Why is air circulating at all?

2. Figures 1 and 2 illustrate air circulation around the globe in a simplistic way. These figures do not take into account that the Earth rotates around its axis or the tilt of the rotation relative to the sun. In Figure 1 you have a simple convection cell that creates two pressure zones (seen in figure 2) one low pressure zone at the equator and one high pressure zone at the poles. Describe how air is moving in this simple system.

	Hadley Cell	Ferrel Cell	Polar Cell
How Does Air Move?			
What is the name of the dominant wind pattern you find here?			

3. How does the Coriolis rotation affect the circulation of air?