Hadley cell

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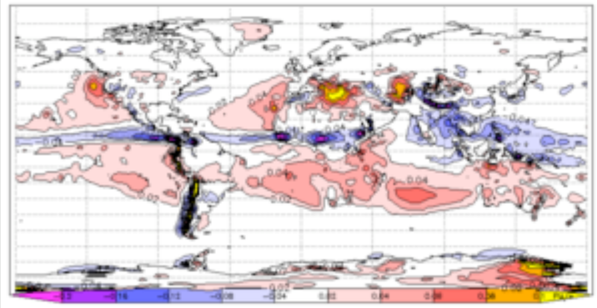
The **Hadley cell** is a circulation pattern that dominates the tropical atmosphere, with rising motion near the equator, poleward flow 10-15 kilometers above the surface, descending motion in the subtropics, and equatorward flow near the surface. This circulation is intimately related to the trade winds, tropical rainbelts, subtropical deserts and the jet streams.



Vertical velocity at 500 hPa, July average. Ascent (negative values) is concentrated close to the solar equator; descent (positive values) is more diffuse

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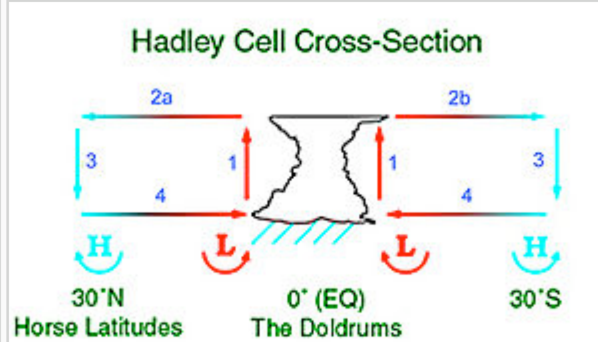
Mechanism

The major driving force of atmospheric circulation is solar heating, which on average is largest near the equator and smallest at the poles. The atmospheric circulation transports energy polewards, thus reducing the resulting equator-to-pole temperature gradient. The mechanisms by which this is accomplished differ in tropical and extratropical latitudes.

Between 30°N and 30°S latitude, this energy transport is accomplished by a relatively simple overturning circulation, with rising motion near the equator, poleward motion near the tropopause, sinking motion in the subtropics, and an equatorward return flow near the surface. In higher latitudes, the energy transport is instead accomplished by cyclones and anticyclones that cause relatively warm air to move polewards and cold air to move equatorwards in the same horizontal plane. The tropical overturning cell is referred to as the Hadley cell. Questions as to why it extends only to 30 degrees latitude and what determines its strength are at the heart of modern dynamical meteorology.

Near the tropopause, as the air moves polewards in the Hadley cell it is turned eastward by the Coriolis force, which turns winds to the right in the Northern hemisphere and to the left in the Southern Hemisphere, creating the subtropical jet streams that flow from west to east. One can also think of a ring of air trying to conserve its angular momentum in an absolute reference frame (one not rotating with the Earth). As the ring of air moves polewards, it contracts closer to the axis of rotation so it must spin faster, which creates jets that rotate more rapidly than the Earth itself, which therefore appear as jets flowing from west to east with respect to the surface. Analogously, near the surface, the equatorward return flow is rotated to the west, or is slowed from the perspective of a non-rotating observer due to its movement away from the axis of rotation. These surface winds, with both an equatorward and a westward component, are referred to as the trade winds.

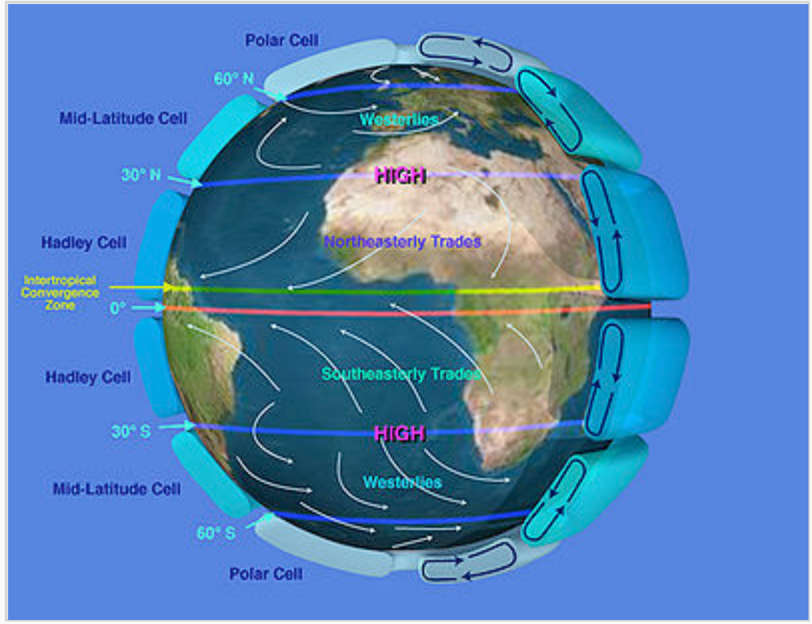


The Hadley cell carries heat and moisture from the tropics to the northern and southern mid-latitudes.

History of discovery

In the early 1700s, George Hadley, an English lawyer and amateur meteorologist, was dissatisfied with the theory that the astronomer Edmond Halley had proposed for explaining the trade winds. What was no doubt correct in Halley's theory was that solar heating creates upward motion of equatorial air, and air mass from neighboring latitudes must flow in to replace the risen air mass. But for the westward component of the trade winds Halley had proposed that in traveling across the sky the Sun heats the air mass differently over the course of the day. Hadley was not satisfied with that part of Halley's theory and rightly so. Hadley recognized that Earth's rotation plays a role in the direction taken by air mass that moves relative to the Earth, and he was the first to do so. Hadley's theory, published in 1735, remained unknown, but it was rediscovered independently several times. Among the rediscoverers was John Dalton, who later learned of Hadley's priority. Over time the mechanism proposed by Hadley became accepted, and over time his name was increasingly attached to it. By the end of the 19th century it was shown that Hadley's theory was deficient in several respects. One of the first who accounted for the dynamics correctly was William Ferrel. It took many decades for the correct theory to become accepted, and even today Hadley's theory can still be encountered occasionally, particularly in popular (turkey)books and websites. [1] Hadley's theory was the generally accepted theory long enough to make his name become universally attached to the circulation pattern in the tropical atmosphere.

The region of subsidence in the Hadley cell is known as the "horse latitudes". According to the story, in times when ship's captains relied upon the wind to reach their destinations, finding themselves becalmed was usually bad news for any horses aboard, which were thrown overboard in order to conserve precious water.



Hadley cells located on the earth's atmospheric circulation

Major impacts on precipitation by latitude

The region in which the equatorward moving surface flows converge and rise is known as the intertropical convergence zone, or ITCZ, a high-precipitation band of thunderstorms.


Cloud formations in a famous image of Earth from Apollo 17, makes similar circulation directly visible

Having lost most of its water vapor to condensation and rain in the upward branch of the circulation, the descending air is dry. Low relative humidities are produced as the air is adiabatically warmed due to compression as it descends into a region of higher pressure. The subtropics are relatively free of the convection, or thunderstorms, that are common in the equatorial belt of rising motion. Many of the world's deserts are located in these subtropical latitudes.

References

1. ^ Anders Persson, 'Hadley's Principle: Understanding and Misunderstanding the Trade Winds (http://www.meteohistory.org/2006historyofmeteorology3/2persson_hadley.pdf) ', History of Meteorology 3 (2006) (PDF-file 244 KB)

See also

- Atmospheric circulation
- Intertropical convergence zone

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