Introduction to Climate and Currents

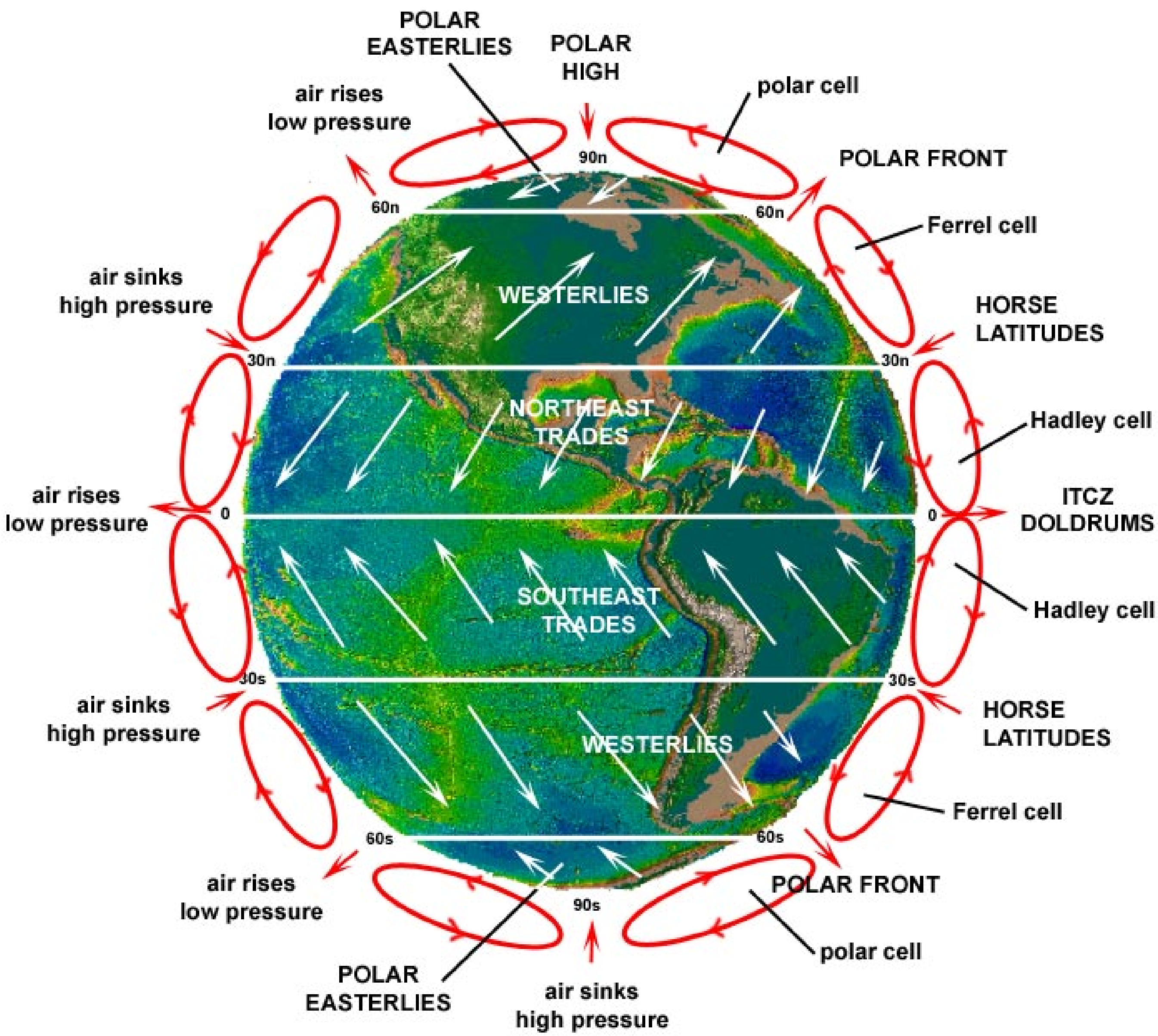
Wind is air moving across the surface of the Earth. Ultimately all winds are generated by unequal heating of the Earth by the sun. Because the sun is millions of miles away from the earth, the rays of light and heat from the sun that reach the surface of the Earth are parallel to one another. But the Earth is round, and only at the equator does energy from the sun fall on a flat surface at a right angle to the sun. At the poles solar radiation fall on surfaces that curve sharply away from the sun.

To demonstrate this, shine a flashlight on a flat surface so that the beam of light is perpendicular (at a right angle) to the surface. Draw a circle around the spot of light. Now tilt the flat surface so that it is at a 45^o angle to the flashlight. Now the spot of light shining on the surface is oblong, not round, and it is now almost two times larger that the first spot. The spot of light is also dimmer now because the light of the flashlight beam is spread over a larger area than before. This same principle applies to the Earth and sun. The equator will always receive more energy from the sun than will comparable areas north or south of the equator. Also, the surface of the Earth directly beneath the sun at high noon also receives more energy than do areas to the east or west. Thus the Earth's surface along the equator is always warmer than are the polar regions, and it is always warmer at noon than at dawn and dusk. The result is that the heat budgets of different regions of the Earth are always unequal because the Earth is always tilted at an angle to the sun and because it spins around 24 hours a day, 365 days a year. Nonetheless, averaged over each day/night period, approximately twice as much heat reaches the equator than the poles each year.

At the equator, radiation from the sun is particularly intense, and the air above the tropical oceans warms rapidly each day. When this air is heated, it expands and becomes less dense, with the result that moist, hot air rises far above the equator. But expanding air cools and cannot retain moisture. Instead, water vapor condenses to liquid water, clouds form and rains fall in the tropics. The dry air then moves north or south as strong upper atmospheric winds, convecting heat toward the poles. As these high winds move toward the poles they press laterally against each other as they converge in higher latitudes. This increases the upper atmosphere air pressure, making the air denser as it is compressed. Eventually this air becomes so dense that it starts to sink, at approximately 30^o north and 30^o south latitude. This brings down dry air onto the major desert regions of the Earth. These drier air masses flow back across the surface of the Earth toward the equator, completing one full cycle of the equatorial atmospheric circulation cell. Named in honor of the scientist who first described this process, the circulation cells between the equator and 30^o north and south are called Hadley Cells. The calm equatorial area where the northern and southern Hadley cells meet is called the **doldrums**.

North of 30^o north latitude and south of 30^o south latitude there are two more atmospheric circulation cells, called Ferrel Cells, that circulate low altitude air masses toward the poles, to approximately 60^o north and south latitudes. When these relatively warm, temperate zone winds reach 60^o latitude, they rise into the upper atmosphere above colder air masses blowing down from the poles. At high altitudes the Ferrel Cell winds flow back toward lower latitudes (toward the equator) until they converge with the winds of the Hadley Cell at approximately 30^o latitude and sink into the lower atmosphere to repeat the temperate zone cycle.

Finally, farther north and south there are two polar circulation cells that are responsible for the flow of air in the Arctic and Antarctic regions. Altogether, then, there are three atmospheric circulation cells in the northern hemisphere and three atmospheric circulation cells in the southern hemisphere. Collectively



Robert Perry, 2002
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the winds in these circulation cells transport heat toward the poles, but the excess heat from the tropics is redistributed rather indirectly in these cycles through the atmosphere.

Because the Earth is a rotating sphere, the winds that carry heat energy into the upper atmosphere do not blow in straight lines toward the north or south. The eastward rotation of the Earth results deflects air moving north to the northeast and air moving south to the southwest in the Northern Hemisphere. In the Southern Hemisphere air moving north is deflected to the northwest and air moving south is deflected to the southeast. This deflection of air or ocean currents due to the rotation of the Earth is called the **Coriolis effect**. The winds that blow across the surface of the oceans from the northeast to the southwest between the equator and 30^{o} latitude, both north and south, are called trade winds. The trade winds are the dominant winds over the Pacific and Atlantic Oceans.

Beneath these winds lies the ocean surface. The winds drag surface waters along as they blow across the water, and this is the force that generates the surface currents of the oceans. Notice that the winds over the North Pacific and North Atlantic circulate in a clockwise direction, whereas the winds in the South Pacific and South Atlantic circulate counterclockwise. Because these winds provide the energy that drives the surface currents, the rotational direction of surface currents in the Northern Hemisphere is a clockwise gyre, or eddy. Surface currents in the Southern Hemisphere rotate in a counterclockwise gyre. Depending on where surface currents originate, they can be cold or warm.

Some of the most important surface currents are:

California Current: This flows from the Arctic waters of the North Pacific down the western coast of Canada, Washington, Oregon and California. The beach and coasts north of Point Conception, located just north of Santa Barbara, generally are chilly all year long because the California Current runs close to shore in these regions. South of Point Conception the California Current veers offshore because the California coast south of Point Conception curves eastward and a warmer eddy flows up the coast from the south, warming southern California.

Gulf Stream: This is an example of a current of warm water originating near the equator. After the Florida Current leaves the Gulf of Mexico it moves vast quantities of water and heat northward through the Straits of Florida. North of the Bahamas another warm current from the tropical Atlantic joins the Florida Current, and together these make up the great Gulf Stream. The Gulf Stream flows north and east, eventually warming the shores of Iceland and the British Isles.

Kuroshio Current: This major surface current flows north along the western side of the North Pacific basin, warming Japan and Korea far to the north of the tropics.

Antarctic Current: This is the largest surface current of all in terms of volume of water transported per year. This enormous current system circulates without interruption from west to east around the continent of Antarctica, driven by the violent West Wind Drift, the wind system that circles Antarctica.

Oceanic gyres strongly affect the global distribution of heat. On the western sides of the gyres, the currents are warm, carrying solar heat from the equator to high latitudes. On the eastern sides of the Pacific and Atlantic Oceans cold currents flow from the polar regions toward the equator, cooling the western coasts of all the continents. Thus, surface currents act like a thermostat to regulate the climates on Earth. Since ocean currents take years to move heat around an entire ocean basin, they affect local weather patterns ashore in somewhat unpredictable ways because these currents never exhibit exactly the same patterns of flow or heat transport. **Weather**, therefore, is considered to be the somewhat unpredictable state of the atmosphere at a specific place and time, and **climate** is an average over time of weather in a specific area. Factors that influence climate and weather are geographical landscape, proximity to large bodies of water, the amount of sunlight in an area, and changing biological and geological conditions.

There are many complex deep currents in the ocean also. Perhaps the most important of these are the deep currents that are generated in the polar regions associated with the seasonal melting of sea ice. Sea ice is frozen seawater, and glaciers and the ice bergs that break off of glaciers are formed from freshwater over land. When icebergs melt they release this fresh water, which floats on the ocean surface because fresh water is less dense than seawater. In contrast, when sea ice melts, very salty water is released at the bottom of the ice floe and fresher water is released at the upper sides of the ice floe. The fresher water, of course, floats, but the cold brine released below the melting ice sinks rapidly to the very bottom of the ocean. This primarily occurs in the Antarctic Ocean, where the dense, cold and salty water accumulates as Antarctic Bottom Water. This bottom water then begins to flow, very, very slowly toward the equator. Because cold water holds large quantities of dissolved oxygen and because this cold, salty water is so dense that it sinks rapidly from the surface to the bottom of the ocean, the Antarctic Bottom Water serves as the main source of oxygen for the deep seas of the world.

Water not only circulates within the oceans as oceanic currents, it also circulates through the atmosphere and across the land. The **hydrologic cycle** describes the circulation of water from the sea to the atmosphere to the land and back to the sea. Water evaporates into the atmosphere primarily due to solar heating. Water vapor eventually condenses, forming clouds which are blown across the Earth's surface by high level winds. When the atmosphere becomes saturated, water in the form of rain or snow or ice precipitates onto the sea or onto the ground. On land this liquid water collects in rivers and lakes or percolates down into the groundwater. Eventually all water finally flows back to its origin, the oceans that cover 70% of the surface of the Earth. Then, for each molecule of water the cycle begins again. Salts in the ocean, of course, do not evaporate, but instead salts make their way to the oceans in runoff water. Water is neither created nor destroyed in the process, but rather it is recycled over and over again through the oceans, the atmosphere, and terrestrial freshwater systems. The same water molecules that first appeared on the Earth's surface more than 3 1/2 billion years ago are still circling through the hydrologic cycle!