

Atmospheric Circulation – Video Tutorial

Let's review some basic terminology we use to describe different latitude regions on the globe. This image shows how the planet can be divided into zones – the northernmost zones, near the poles are referred to as the **polar** regions. Just below the poles, we have the **subpolar** regions. Moving to the equator, we have the **equatorial** zone that runs between the two hemispheres. Just north and south of this zone we have the **tropical** zone. Naturally these zones have upper limits at the locations of the tropic of cancer and capricorn. Just above these tropics is the area known as the **subtropics**. Between the subtropics and the subpolar region lies the **temperate** zone, otherwise known as the **midlatitudes**. So once again, starting from the equator, we move from the equatorial zone to the tropical zone to the subtropical zone to the temperate zone to the subpolar zone to the polar zone.

Pause now.

One more piece to this puzzle before we can describe global wind patterns and air motion: the coriolis effect. Because the Earth is a rotating sphere, anything that's connected to Earth's surface is also rotating with that surface – once every 24 hours. Notice in this picture though that the circumference or area of travel for the equator is much greater than for the poles. That means that objects at the equator are rotating faster than those at the poles. So what happens when an object at the equator moves poleward? Let's imagine an airplane takes off from the Galapagos Islands near the equator and flies North. It lifts off WITH the rotational speed of the equator. It's moving north but also rotating east with the planet. However, it will travel over latitudes that are rotating more slowly. So its net motion will appear to be not just north, but also east. In reality the ground below it is moving east at a slower rate than the plane is. Conversely, if the plane takes off from the north pole and heads southward, it lifts off with a slow rotational speed. As it travels south, the objects below it are rotating more quickly, and the plane will end up west of its target unless corrections are made.

The coriolis effect causes all objects moving above Earth's surface to be deflected to the right of their path in the northern hemisphere and the left in the southern. That includes planes, ocean currents, and winds.

Let's return to the rising and falling air. As air rises, it creates a low pressure on the surface and sucks in surface winds. As these winds move toward the low pressure center, they are deflected to their right in the northern hemisphere. The net result? A counterclockwise flow of air around a low-pressure system. The reverse is true for high pressure. As air moves away and is deflected to its right, the result is clockwise flow of air. This image also reminds us that the rising air that produces low surface pressure will cool, increasing its relative humidity, and bringing rain. The sinking air that produces high pressure systems will warm, decreasing its relative humidity, and bringing clear skies and dry conditions. So when those weather forecasters say a high pressure is coming into the area, what should you expect? Sunny cloudless skies. When they say the pressure is falling, prepare for a storm, they are saying a low pressure is coming into the area, and we should expect rain.

Most of the weather we experience is happening in the lowest level of the atmosphere, the troposphere. The stratosphere sits atop the troposphere with limited mixing, like different densities of water. The tropopause is the boundary between the two – much like the pycnocline in the oceans – and it occurs at about 12 km elevation. Remember that the top of Mt. Everest is at about 9 km elevation, so the tropopause sits just 3 km above that. When air rises from the surface and creates a low pressure on the surface, it stops when it reaches the tropopause and then spreads out to make way for the air that's continuing to rise beneath it. Jet aircraft try to fly above the tropopause to avoid the weather systems and create less turbulent rides.

Now let's look at global atmospheric circulation. Specifically, let's start with a round globe and show what happens to air at various locations around the planet (in general). What do we know for sure? The hottest spot is at the equator (during an equinox), and the coldest is at the poles. So let's start there. Air that is cold will also have a low water capacity. Its density will be the highest possible, and such air should be sinking air. Air that is warm will have a high water capacity. Its density will be the lowest possible, especially if it's over the oceans and has a high relative humidity. This air will be rising. So, in general on planet Earth, during the equinox seasons (Spring and Fall), there should be a low pressure system on the surface of the equator as air rises, hits the tropopause and spreads laterally. At the poles it should be sinking to the surface, creating a high pressure on the surface and spreading out laterally. These arrows are placed on the outside of the globe to indicate they represent what's happening in the troposphere. However their height is GROSSLY exaggerated. Remember, the planet's radius is about 6400 km. The troposphere is only 12 km thick.

What happens to the air that sinks at the poles? It has warmed up with the compression as it sinks, and then it spreads outward from the poles evaporating water all along its path and being deflected by the coriolis effect. By the time it reaches 60 degrees North and South it collides with air masses coming from the other direction. More about this later. What happens to the air that's spreading out in the upper atmosphere and moves away from the equator? Because of its rising, it has cooled and lost a lot of water. As it continues to move away, it's deflected right or left, due to the coriolis effect, and it continues to cool and lose water. Once it has made it to about 30 degrees North and South, it is now so cold and dry that it's denser than the air around it, and it sinks. That sinking air creates a high pressure system on the surface. Air that piles up there will spread outward, just like it does at the poles. It will also warm up with compression, further decreasing its relative humidity and become a major zone of evaporation in the world's oceans and land. This high-pressure zone, also called the **subtropical highs**, corresponds to the desert belts on land and the high surface salinity in the oceans, as discussed last week.

What happens at 60 degrees north and south where we see two air masses colliding? These areas are called the polar fronts, and they represent areas of frequent storms. Ultimately the cold denser air is overridden by the less dense warmer air. Where the warmer air is rising, we get a local low pressure system on the surface and rain along its journey upward and poleward. This air continues moving poleward and losing its water, until it's cold and dry and sinks again at the poles.

This image shows the global precipitation in cm/year – with red the wettest areas on the planet. You can see a clearly defined belt at the equator, which corresponds to **the ITCZ or intertropical convergence zone**. This is where the equatorial low pressure is sucking in air from the north and the south. Those two air masses cross a lot of water, reaching 100% relative humidity and then rising at the equator, creating massive rains. This image also shows the rains associated with the polar fronts.

Going back to our general picture of global atmospheric circulation, let's focus only on the surface winds. We have two sets of winds that are travelling towards the equator – one from the north, the other from the south, as they get sucked up into the ITCZ and pulled away from the subtropical highs. There are also two wind systems that converge at the polar fronts at 60° north and south – the winds that have been pushed outward from the polar highs, and those pushed outward from the subtropical highs. These arrows are curved because they represent winds moving from high to low pressure AND to the right in the northern hemisphere and the left in the southern hemisphere due to the Coriolis effect. They then get names associated with the direction FROM WHICH they are coming. Notice that the **Polar Easterlies** originate in the east and move westward. The **Westerlies** start in the west and move eastward. The **Trade Winds** start in the east and move westward.

Imagine traveling around this globe in a sailboat. You need the wind to move from point A to point B. Are there any locations where the winds would fail you? Where air is not moving horizontally, but instead vertically? These areas receive special names from the mariner community because of the history of life at sea in these locations and the challenges encountered. The ITCZ is also known as the Doldrums. It is an area where sailing ships often come to a standstill, waiting for a breeze to move them along. For the early mariners, while they waited, they would use up their food and water. Fortunately, they wouldn't die of thirst, because at the ITCZ, the one thing they could be assured of was plenty of rainwater! However, what was life like when a sailing ship hit the subtropical highs, otherwise known as the Horse Latitudes? While waiting for a breeze, and eating all food and drink, no rainwater appeared. To the contrary, evaporation rates were high. It is rumored these mariners would toss overboard their horses, rather than watch them die of thirst here. Hence the name, horse latitudes.

Samuel Taylor Coleridge's *Rime of the Ancient Mariner* captures the mood perfectly in these few lines:

Day after day, day after day,
We stuck, nor breath nor motion;
As idle as a painted ship
Upon a painted ocean.
Water, water, every where,
And all the boards did shrink;
Water, water, every where,
Nor any drop to drink.

So one last time, let's return to our general circulation pattern. Remember this is a baseline for the equinoxes. As the seasons change, and the sun's rays hit the tropics directly, the major high and low pressure systems will migrate accordingly.

Pause now.

For more information and more detail, continue on to the next video in this series.

[End credits]

Air-Sea Interactions Series:

Part I: Seasons

Part II: Relative Humidity

Part III: Atmospheric Gases, Heats, and Pressures

Part IV: Atmospheric Circulation

Part V: Weather Phenomena

Atmospheric Circulation

Geoscience Video Tutorial

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