Surface Winds, Surface Ocean Currents, and the Coriolis Effect

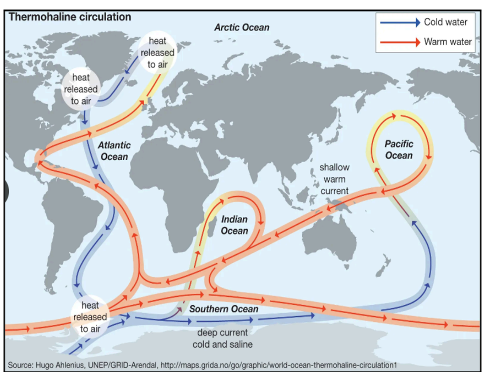
Last time **(CSSG-2.13)** we got a first glimpse of

The Big Three Energy Pumps

The **Deep Ocean Conveyor Belt**, which is driven by the differing gravity pulls on the water as it becomes more or less dense from higher/lower temperatures and higher/lower salt contents.

The big pumps (the **Overturning Circulations**) are near the Poles, where the temperatures drastically fall and salinity drastically increases, causing the water mass to plunge down from the surface to the bottom.

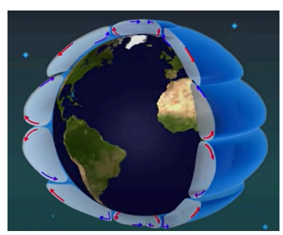
This deep current moves **heat** from the equator towards the poles, brings **nutrients** from the deep ocean to the surface (feeding abundant ocean surface life), brings O_2 to the deeps (allowing deep life) and sucks CO_2 from the atmosphere (delaying the impacts to us on the surface).

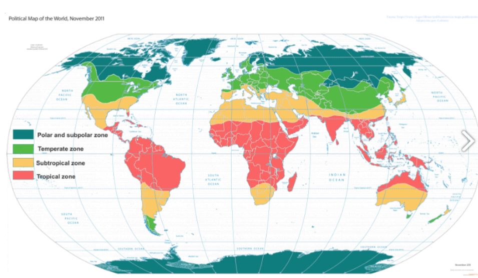


The **Atmospheric Circulation Cells**, which are driven by the difference in temperatures between the Equator and Poles. Air near the Poles is very cold and contracts; near the Equator, it greatly expands upward. This provides an effective downhill slide for air towards the Poles.

On the way, cells form in bands around the Earth as hot, moist air rises to colder altitudes - causing heavy rains in the tropics and in the subpolar zone. In other latitudes, where cold, dry air descends to replace the rising hot air, more arid regions form.

These cells move heat from the equator towards the poles, **establishing climate bands around the earth**.

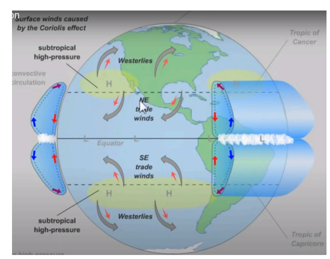


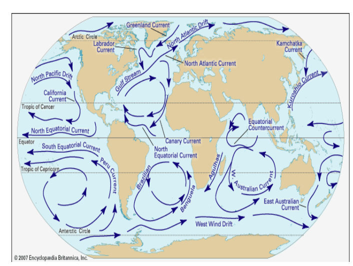


The **Surface Winds and the Ocean Surface Currents which they propel** are driven by the Atmospheric Circulation Cells - with the added impact of the **Rotation of the Earth**..

These new sideways and circulatory actions (as contrasted to the North/South flows of the atmospheric circulation cells), are a result of the **Coriolis Effect**, which is a result of the Earth's rotation**.**

These winds and surface currents move energy into the local ecosystems, climates, and weather.





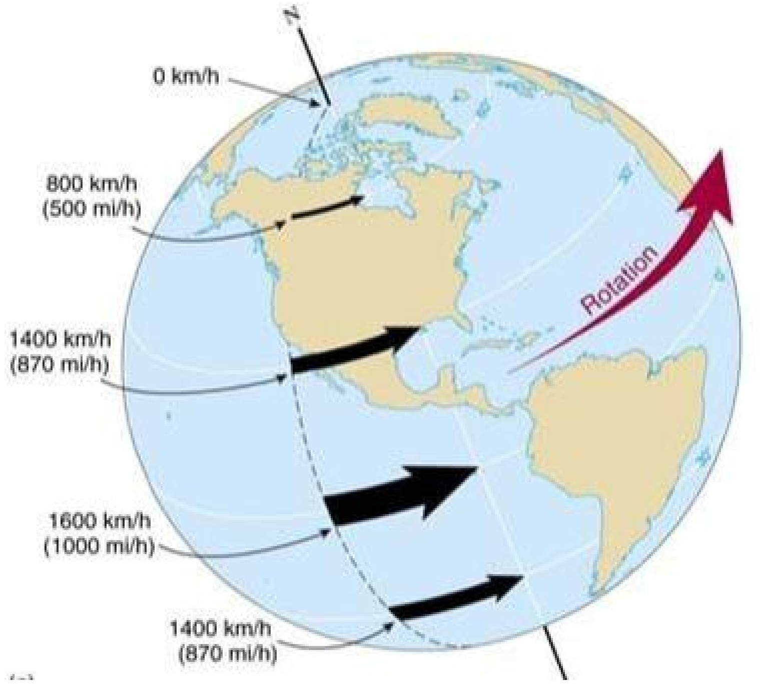
Approximate "Cheat Sheet":

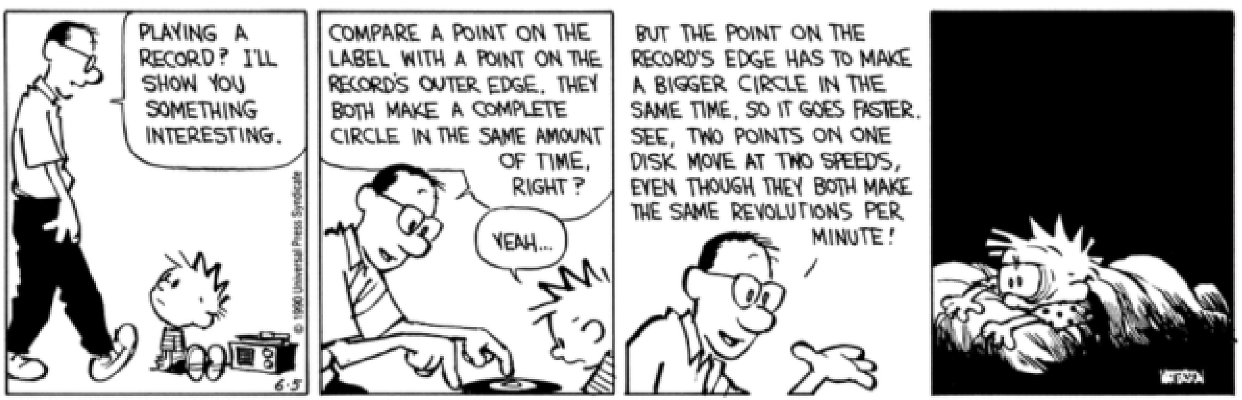
1 meter → 3 feet **1 degree Celsius (^{0}C)** → 2 degree Fahrenheit (^{0}F)
ppm = parts per million CO_2 = Carbon Dioxide
1 tonne = 1000 kilograms = 2205 pounds **1 gigatonne (1 Gt)** = 1 billion tonnes
1 trillion tonnes (1Tt) = 1000 gigatons

Surface Winds, Surface Ocean Currents, and the Coriolis Effect

This study will clarify the **Coriolis Effect**, allowing us to make sense of the **Global Surface Wind Patterns** and the **Ocean Surface Currents** they drive.

First, just notice that the earth rotates and that to get around the circle, air at the equator has to be going a lot faster than air near the poles.





Surface Winds, Surface Ocean Currents, and the Coriolis Effect

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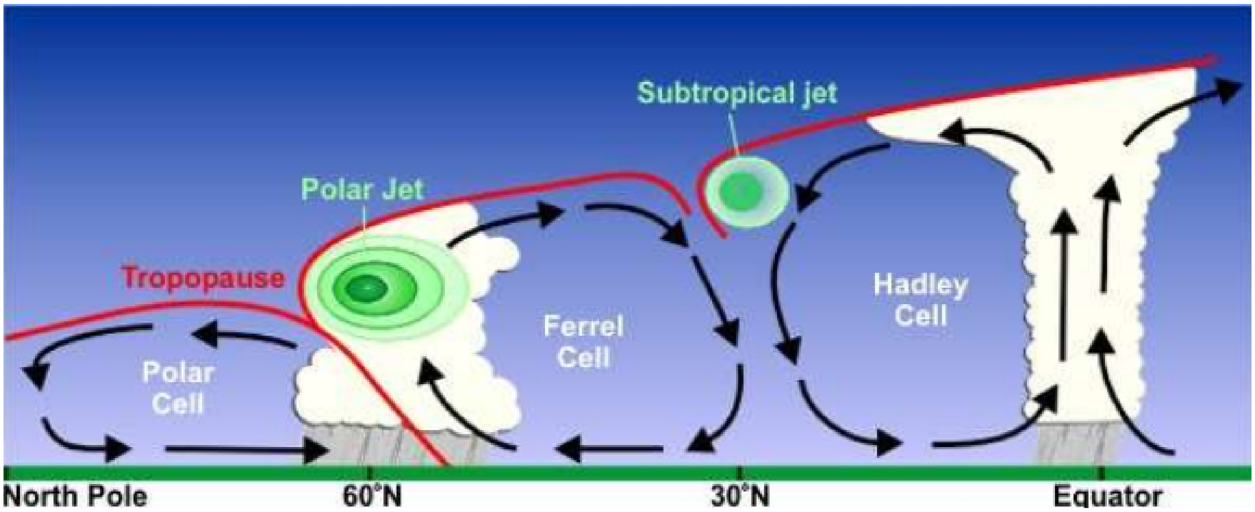
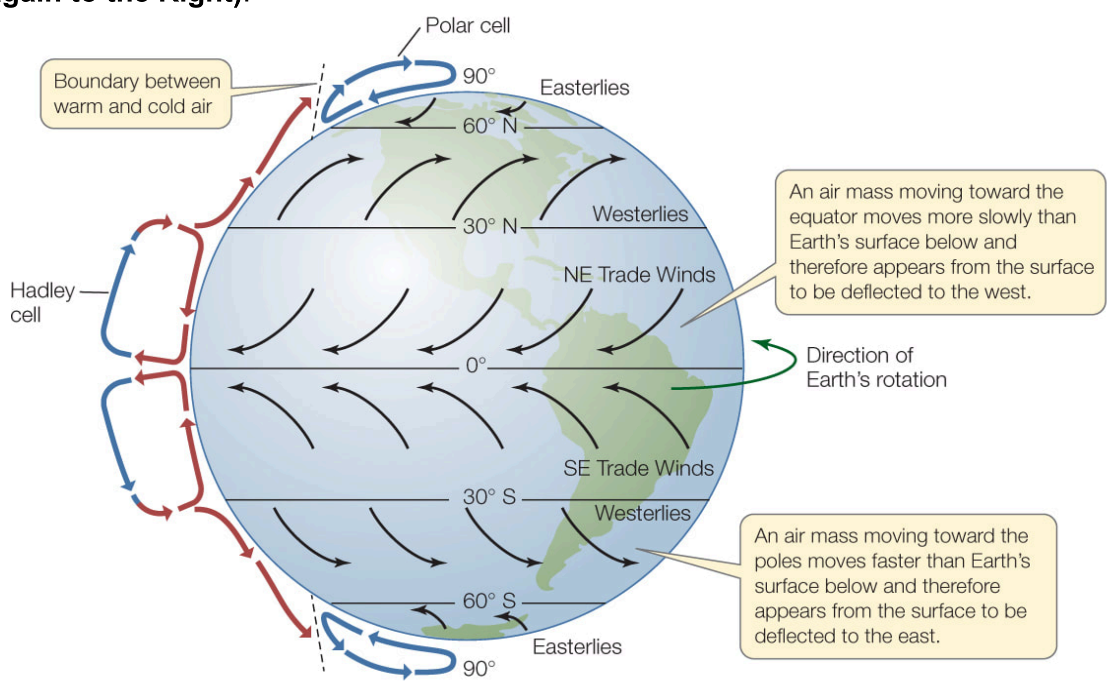
So, let's take a closer look at the atmospheric cells. Note the airflows along the surface:



https://geophile.net/Lessons/atmosphere/atm_circulation_04.html

This means that, if you're air heading back to the equator from the north edge on the Hadley cell (at around 30^0 N), you'll be going at a rotational speed slower than the equator to the south. So, as you head south, you'll end up getting to the equator to the West of where you were aiming **(i.e., Deflection is to the Right)**. Likewise, if you're heading North from the north base of the Hadley cell, you'll be going faster than air nearer the poles and so will veer to the East **(i.e., Deflection is again to the Right)**. Finally, if you're starting at the North Pole and heading South along the surface, you will be going too slow, so will veer to the West **(i.e., Deflection is yet again to the Right)**.



http://www.islandphysics.com/coriolis-effect.html

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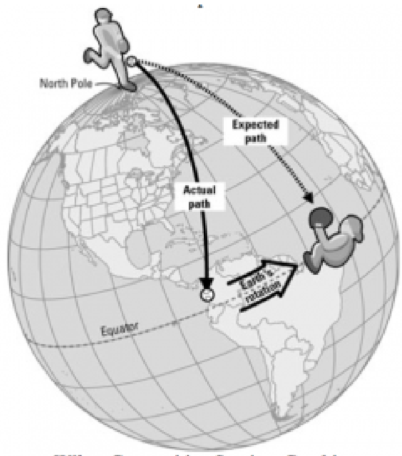
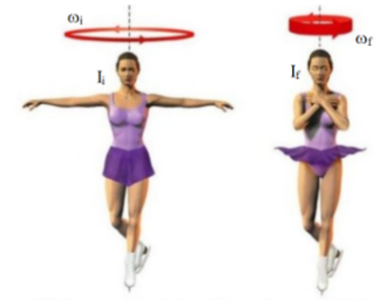
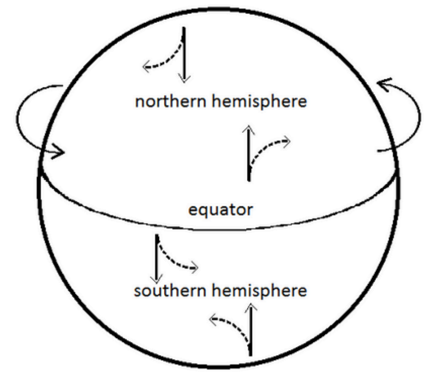
Other ways of saying the same thing:



Wiley, Composition Services Graphics



The skater, as her arms move away from the axis, will slow down; as they approach her core, she will speed up



Of course, if the "ball were thrown South from a mid-latitude, you would get a similar deflection to the Left. Likewise, a "ball" moving North (in the Northern hemisphere) would deflect to the right as well.

And yet another version of this: A point on the equator has to travel 25,000 miles to get around in one day. (That's about **1,000 miles per hour!**). A point near the axis (the pole) can get all the way around by going, say, 25 miles in one day. (That's **1 mile per hour!**). This means that a "ball" moving south from the North Pole would not be going sideways (East-West) nearly as fast as the equator. So the catcher on the equator would move to the right (East) faster than the "ball". We would see this as the "ball" curving to the right.

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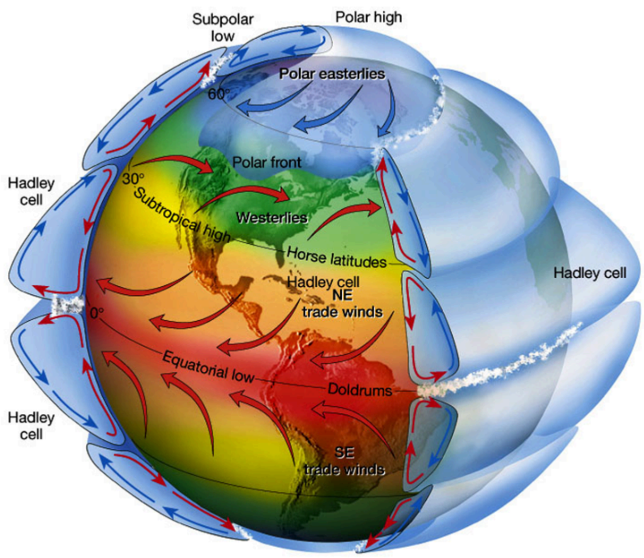
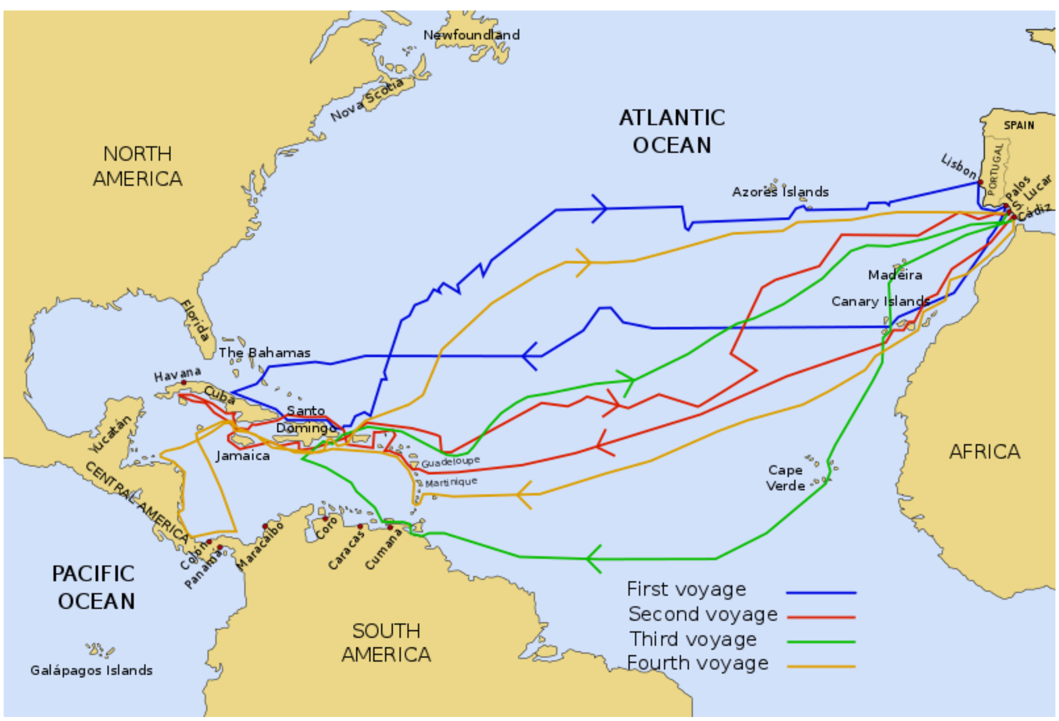
This also applies at any altitude (or depth in the ocean). Here's another depiction of the Atmospheric Cells:



https://eos.org/science-updates/how-do-climate-variations-affect-the-width-of-the-tropics

Winds are named by the direction they are coming FROM. So the NE Trade Winds (which enabled Columbus to make it to the Caribbean) come out of the North East, heading South West. Likewise, the Westerlies (which also generally drive the weather we have in North America) enabled his return towards the East.



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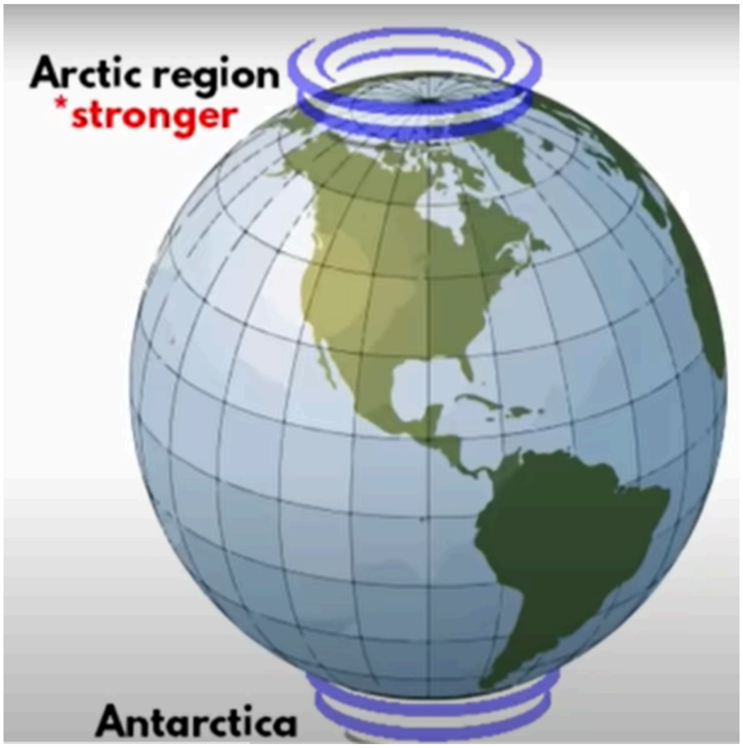
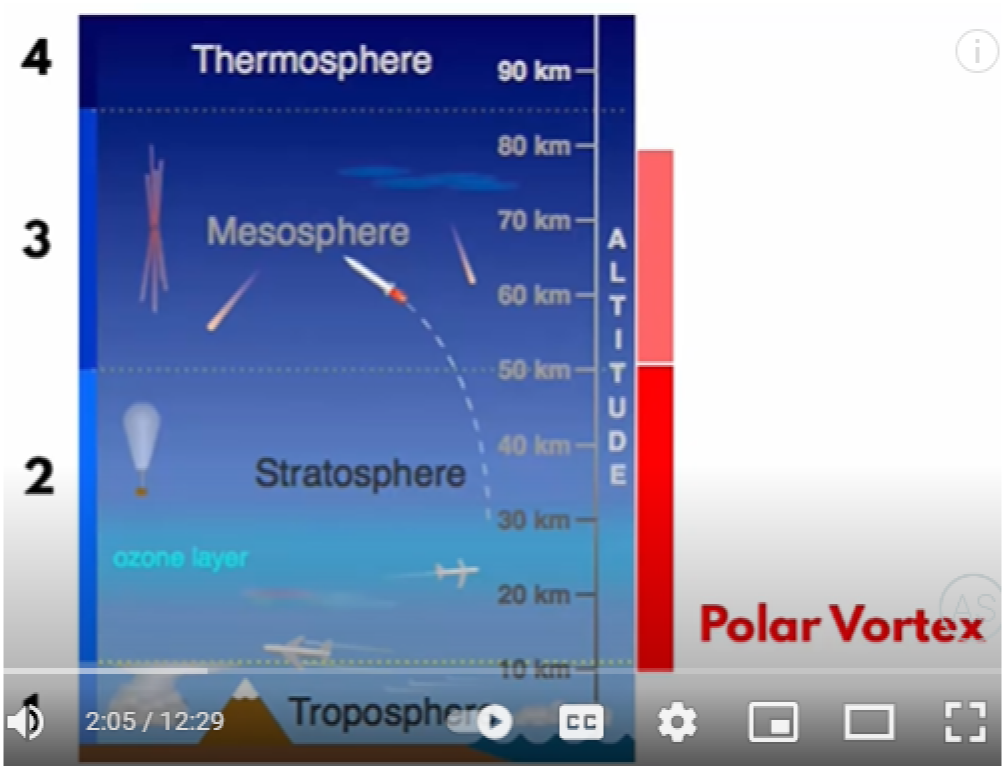
https://en.wikipedia.org/wiki/Voyages_of_Christopher_Columbus#/media/File:Viajes_de_colon_en.svg





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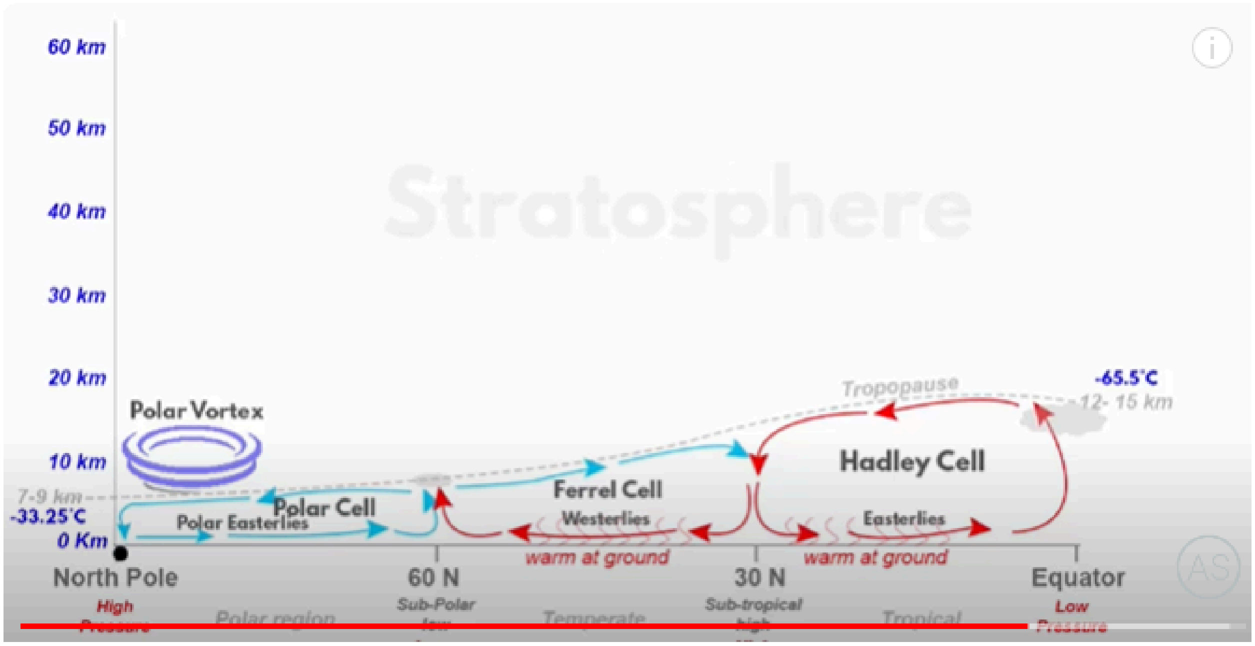

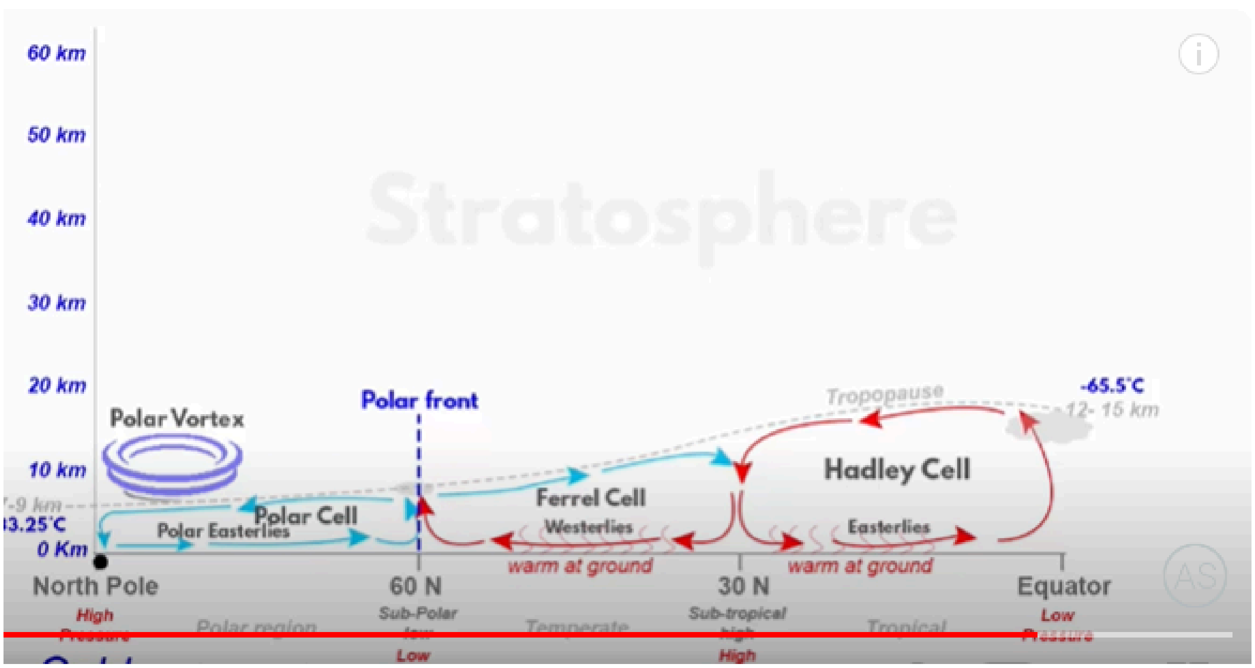

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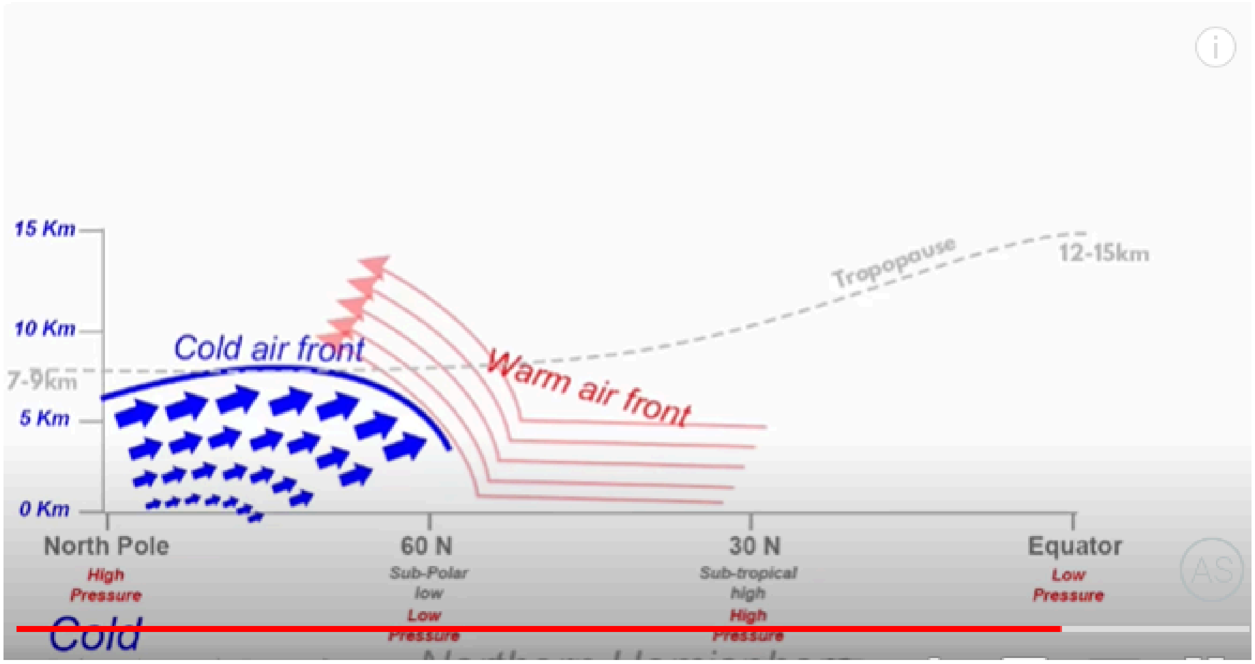

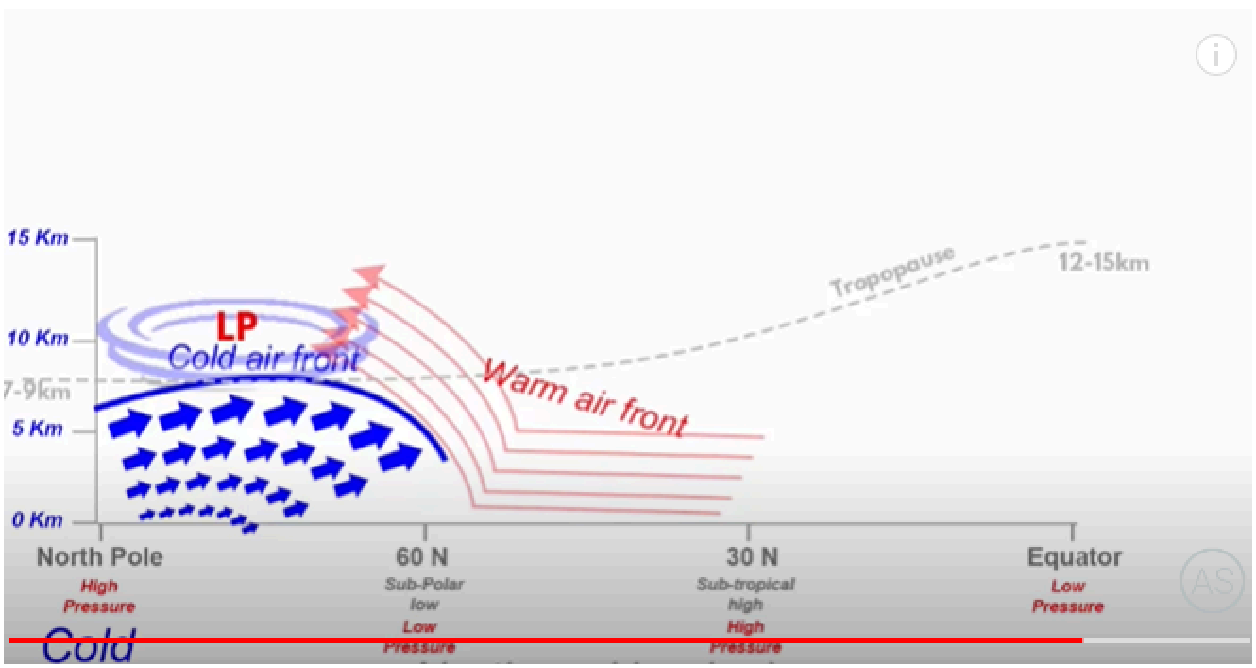

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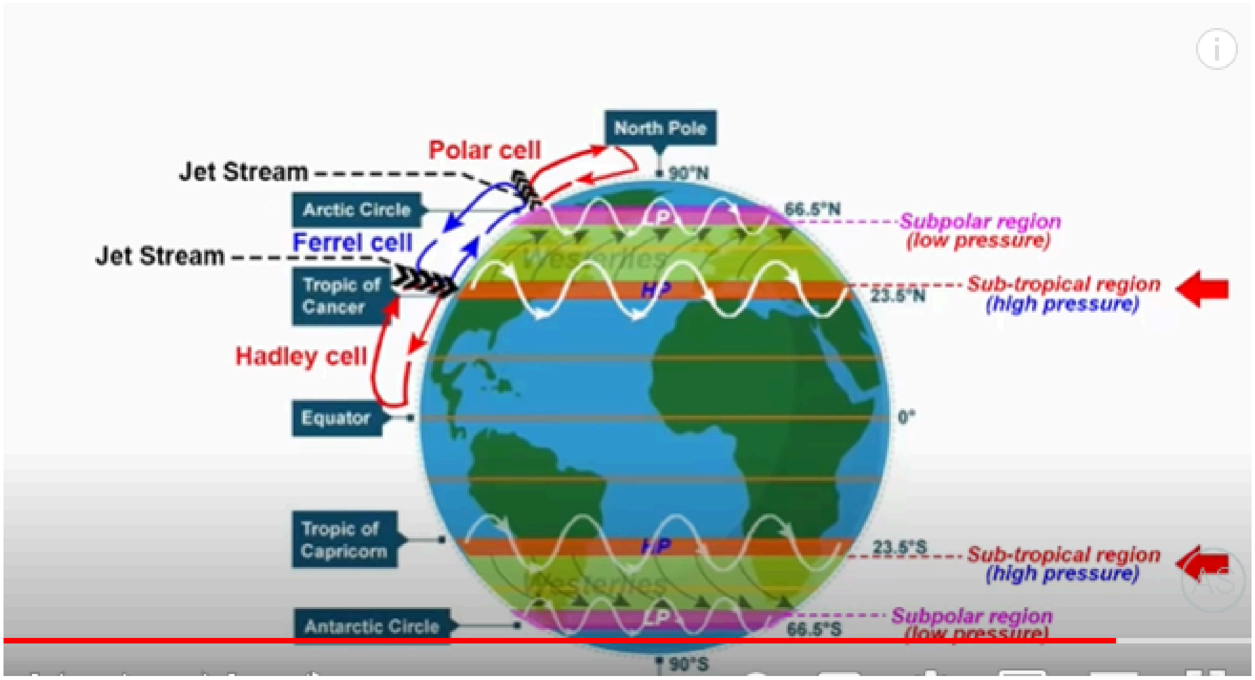

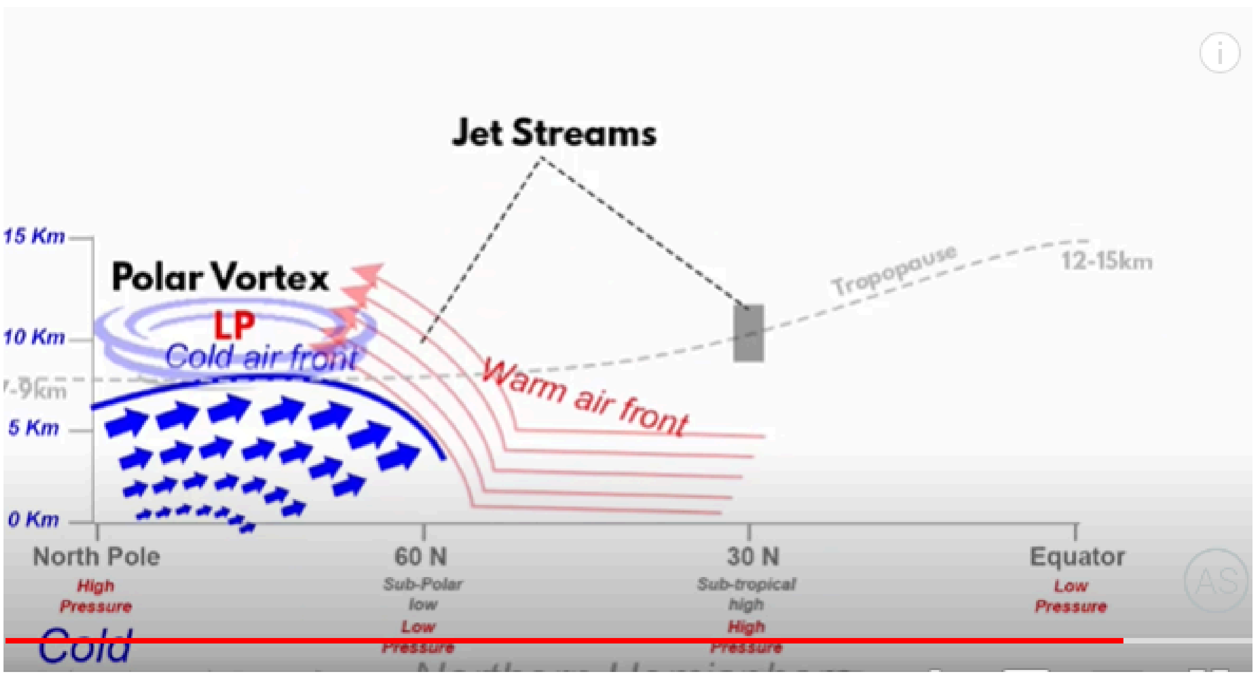

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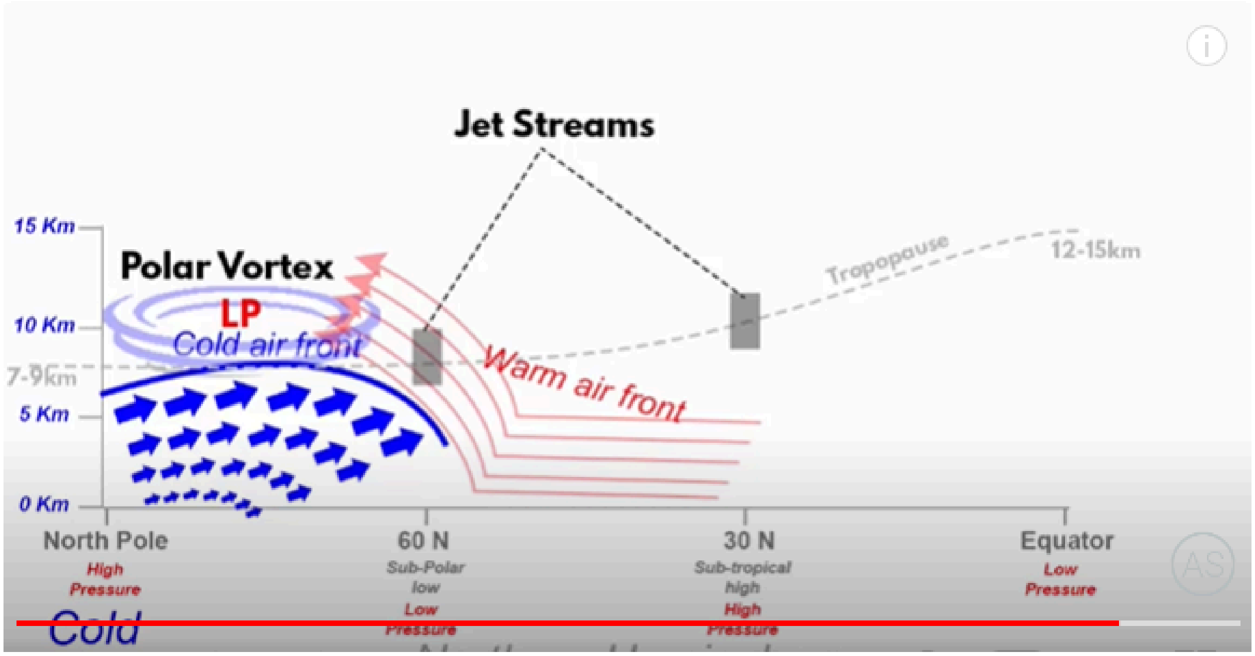

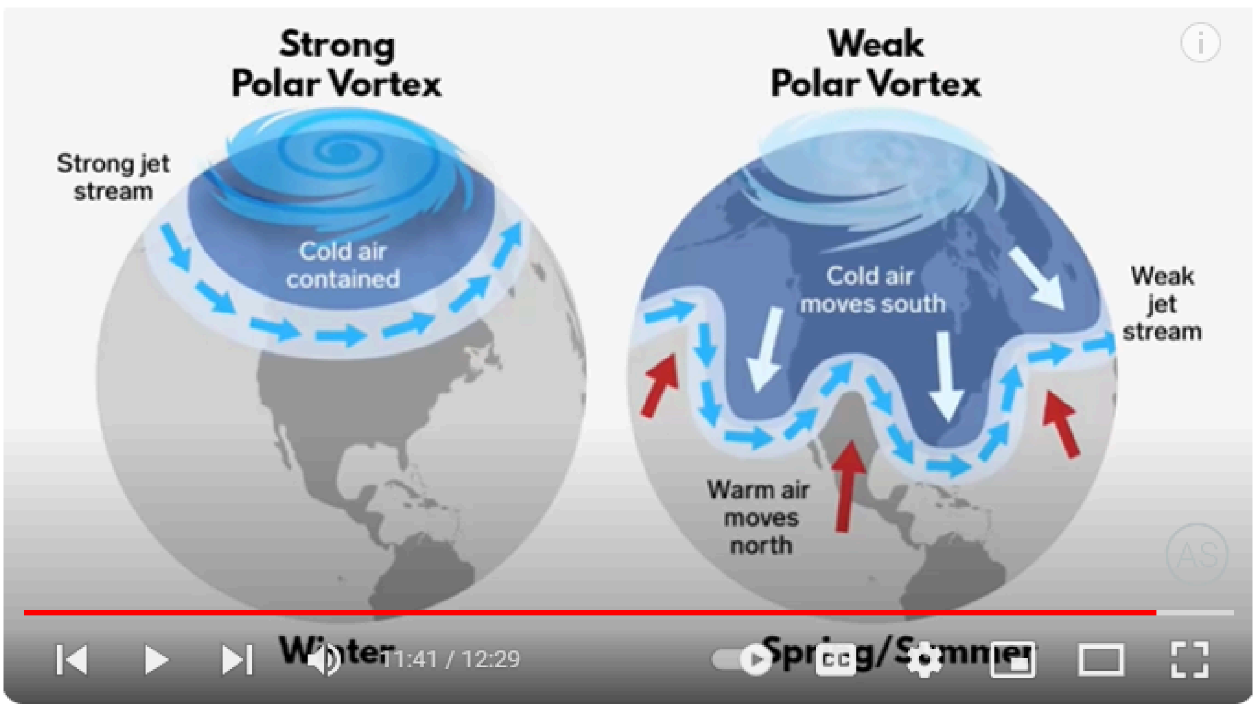

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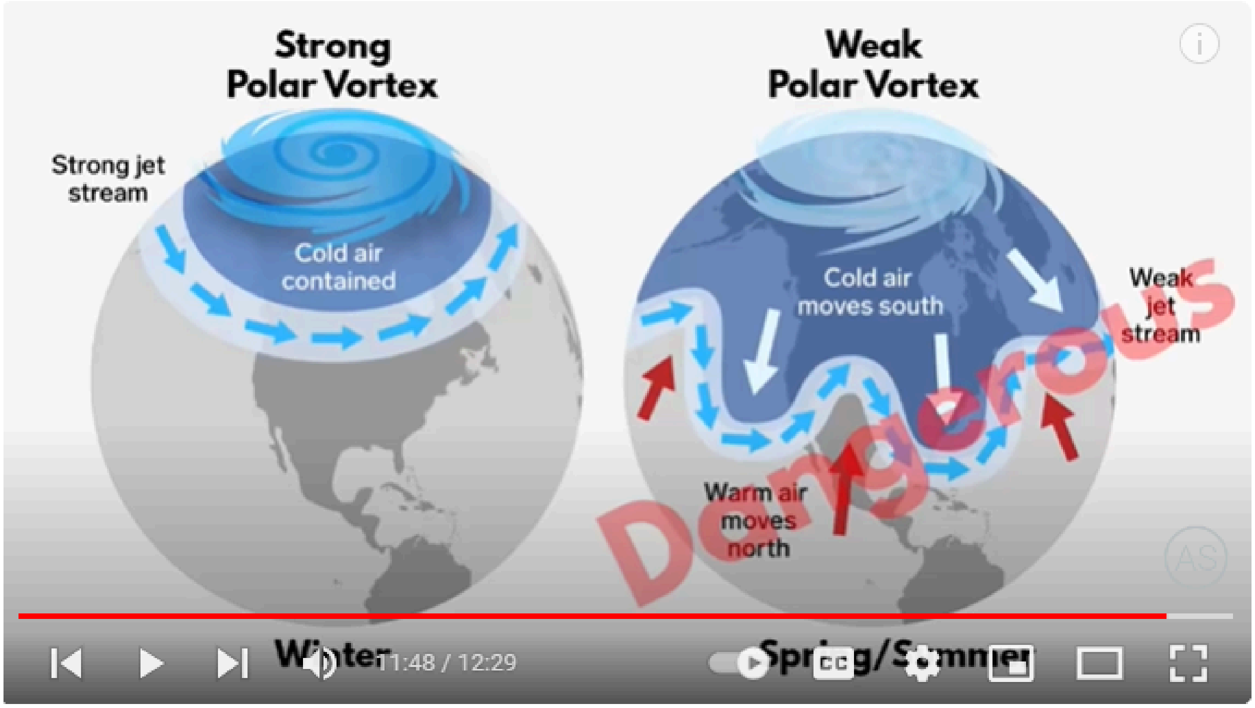

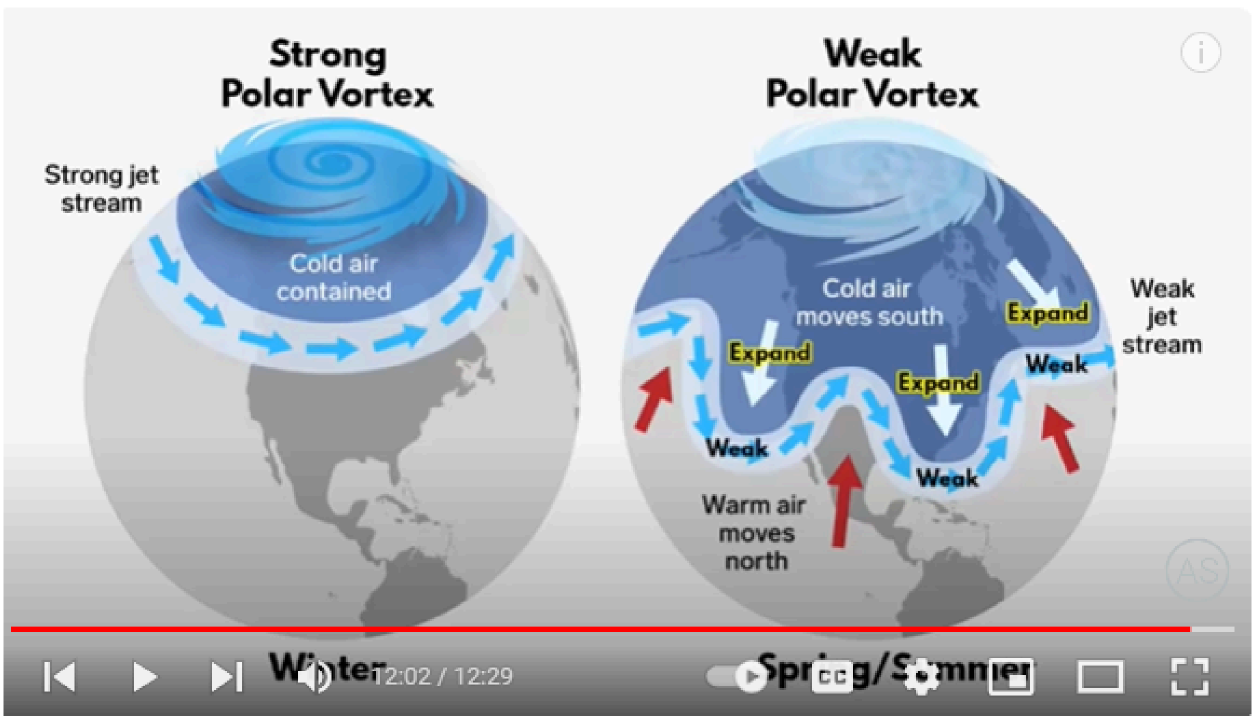

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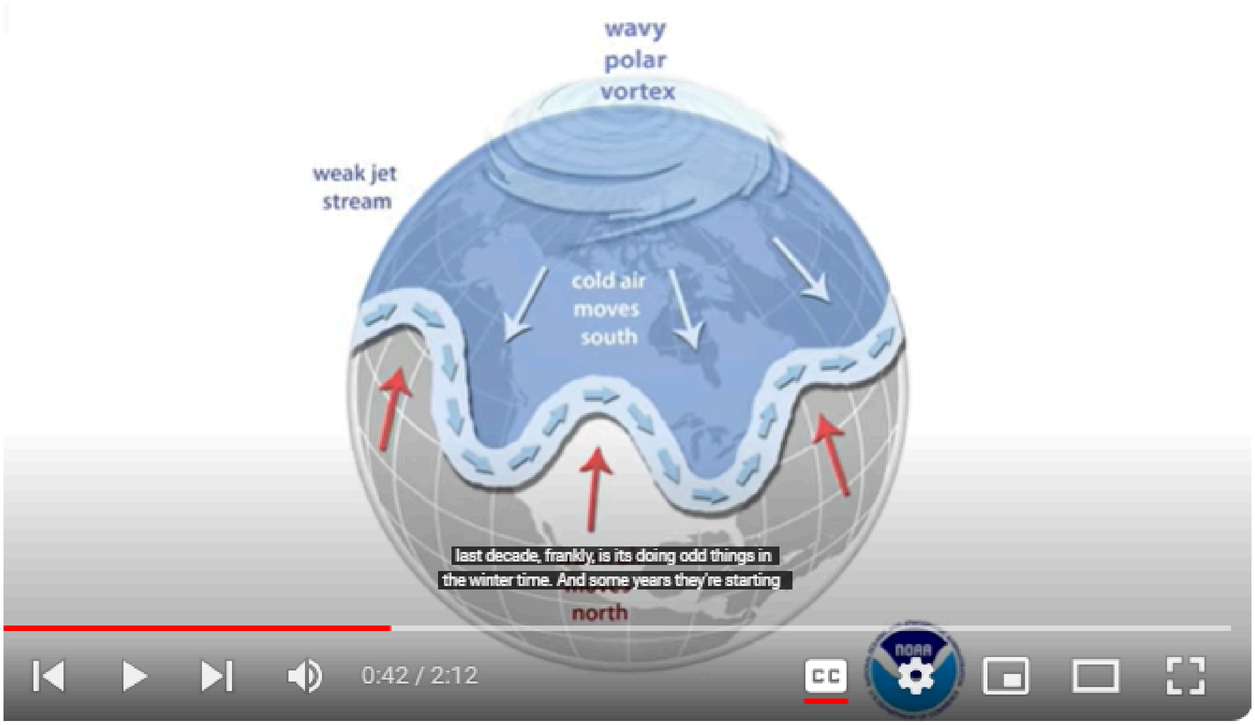

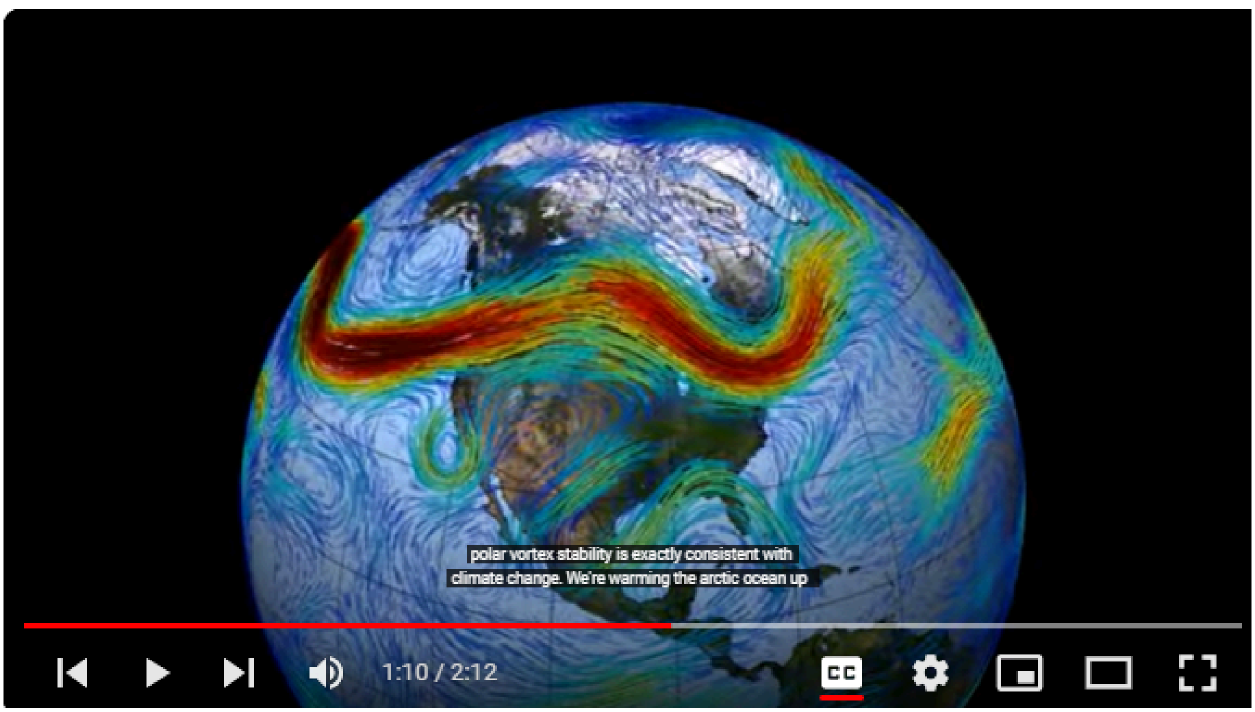

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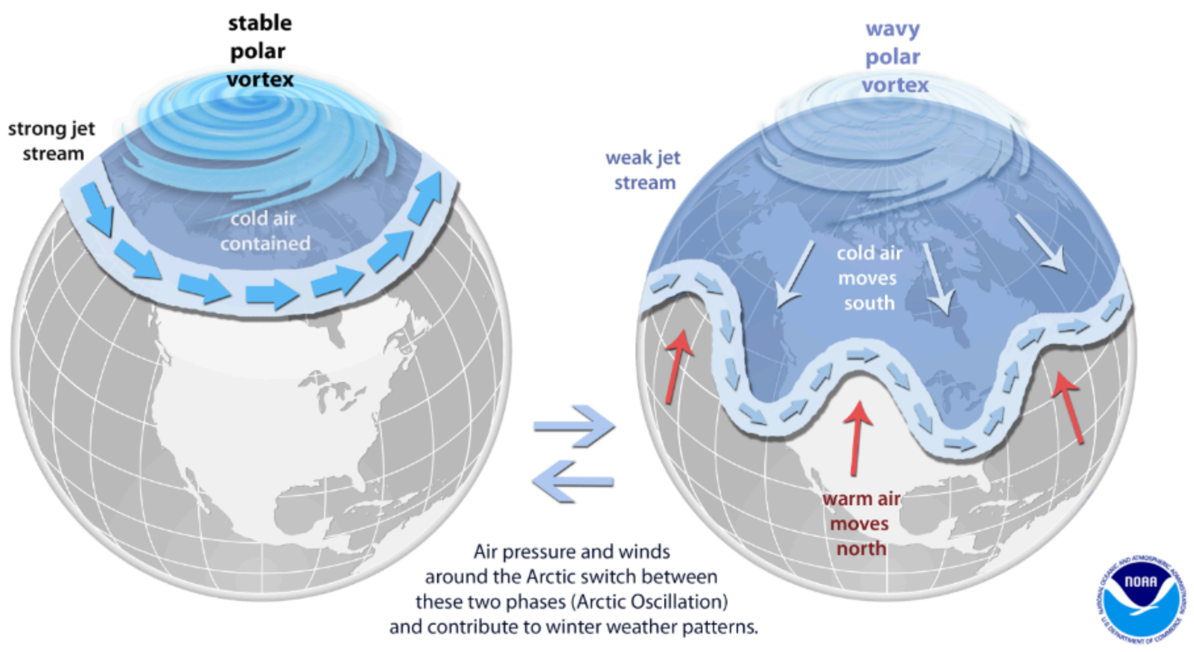
How Is the Polar Vortex Affected by Climate Change?

While the polar vortex is well documented, its behavior has become more extreme as a result of climate change, according to Ullrich. He explains: warming of the Earth has led to the loss of Arctic sea ice, transforming a highly reflective icy surface to a dark absorptive surface. The change is warming higher latitudes and reducing the temperature difference between the warmer mid-latitude and polar regions. This weakens and destabilizes the polar jet stream, causing it to dip into lower latitudes, bringing polar air farther south. Ullrich expects future climate change to further weaken the polar jet stream, bringing rise to more extreme and unusual weather patterns. https://www.ucdavis.edu/climate/definitions/what-is-the-polar-vortex#:~:text=A%20low%20pressure%20system%20creates,polar%20air%20out%20and%20away.



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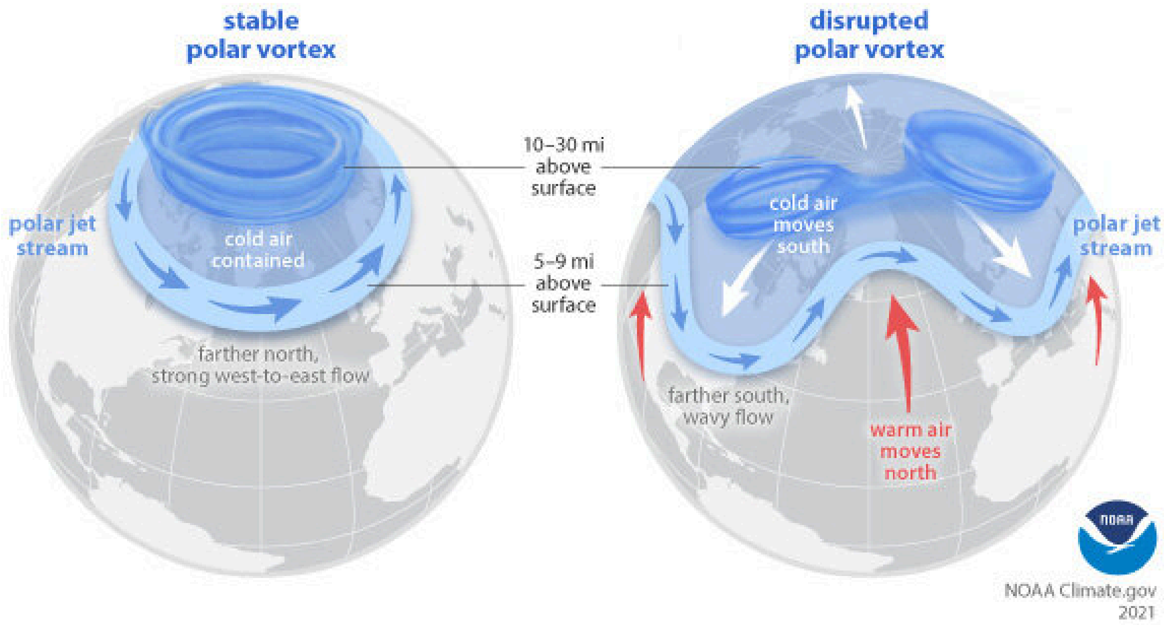
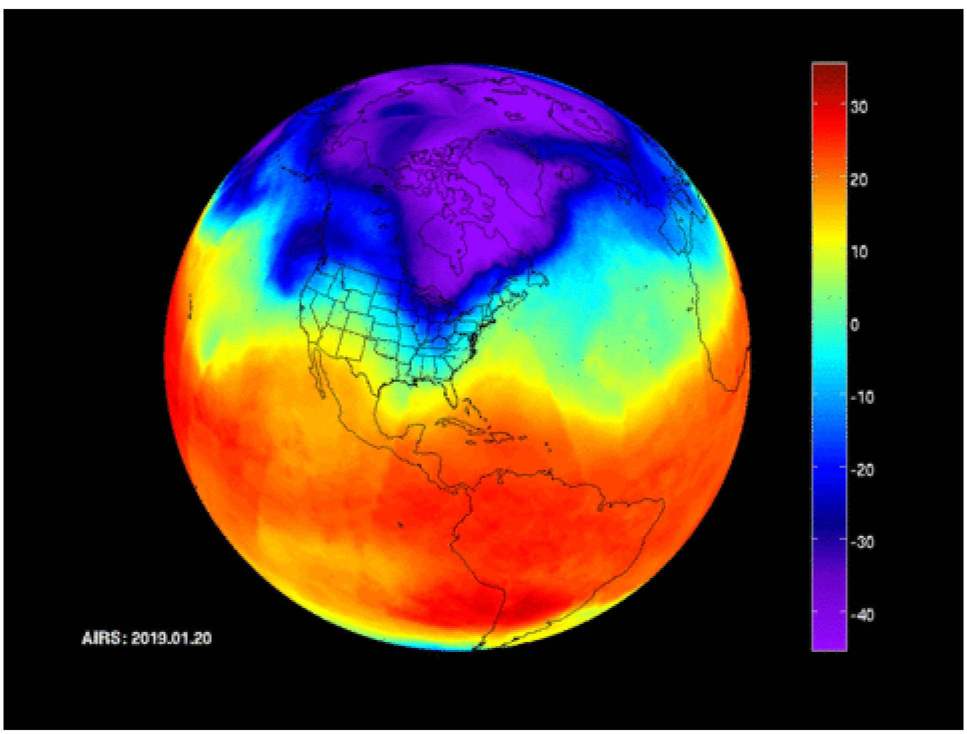


When the Arctic polar vortex is especially strong and stable (left globe), it encourages the polar jet stream, down in the troposphere, to shift northward. The coldest polar air stays in the Arctic. When the vortex weakens, shifts, or splits (right globe), the polar jet stream often becomes extremely wavy, allowing warm air to flood into the Arctic and polar air to sink down into the mid-latitudes. NOAA Climate.gov graphic, adapted from original by NOAA.gov.



NASA's Atmospheric Infrared Sounder instrument captured the tropospheric jet stream moving from Central Canada into the Midwestern United States from Jan. 20 through Jan. 29, 2019, bringing storms and cold Arctic air with it. (Image credit: NASA/JPL-Caltech AIRS Project)

From 1989 to 1998, there were no split vortex events in midwinter. But in recent decades these events have been happening more frequently. This animation shows the polar vortex splitting in 2009. (Image credit: Aditi Sheshadri)

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At last, we can look at the Wind-driven ocean surface currents. Stirred up and driven along by the winds above, major ocean currents move along the surface. So, if we have a feel for the winds, we will understand these ocean surface currents.

But first, note that the atmospheric cells circulate vertically. What goes up and over, has to be replaced. This makes a circulation.

The currents on the ocean surfaces behave the same way. Remember, in the Northern Hemisphere, winds heading south will **veer to the right**, propelled by the NE Trade Winds. Similarly, winds heading North and East (above 30^0 N) - the Westerlies - are dragging the ocean surface in that direction - **again to the right**. The ocean surface circulation is established as moved water is replaced. **FOCUS ON THE NORTH ATLANTIC circulation to get a feel for this**. Likewise, the circulation of surface currents in the SOUTH ATLANTIC go in the opposite direction, because of the coriolis effect

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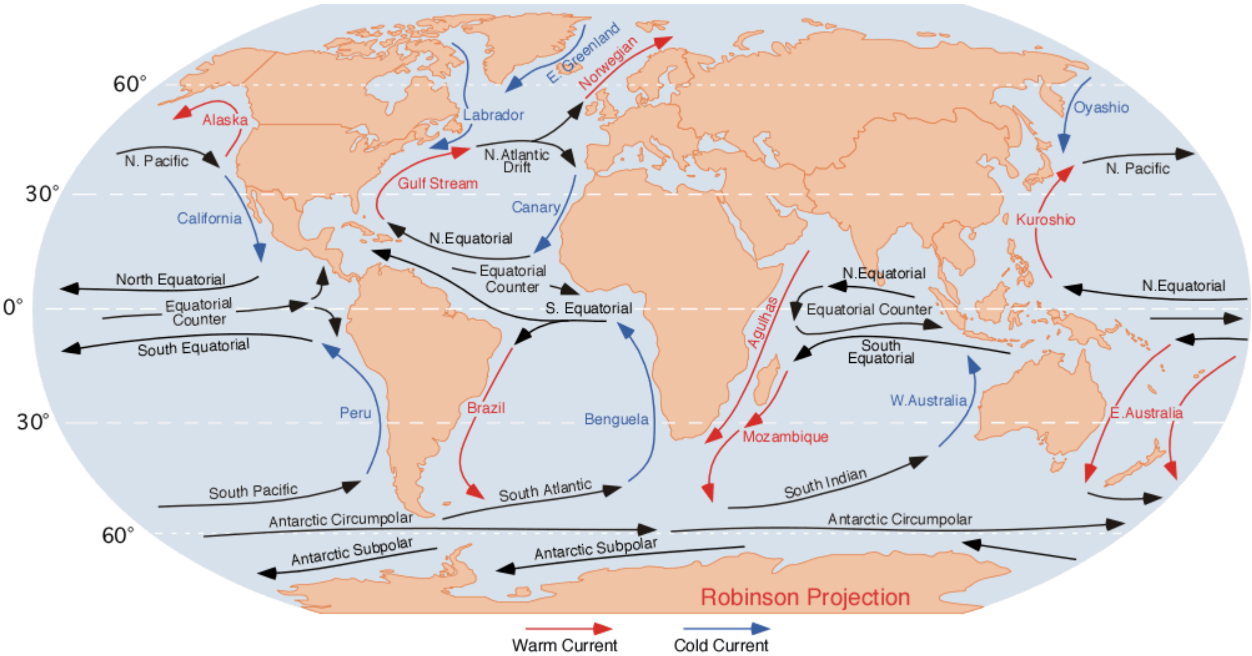
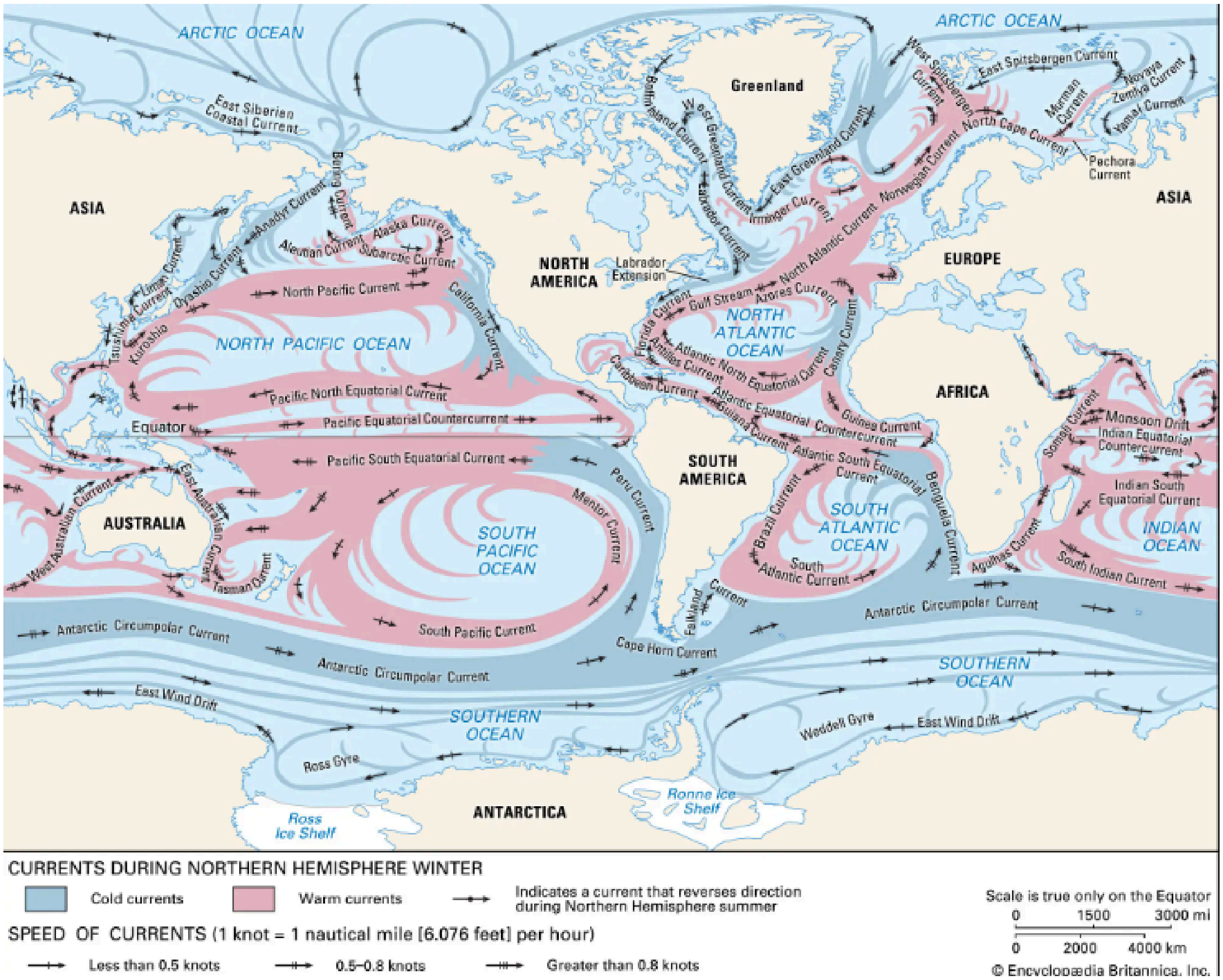
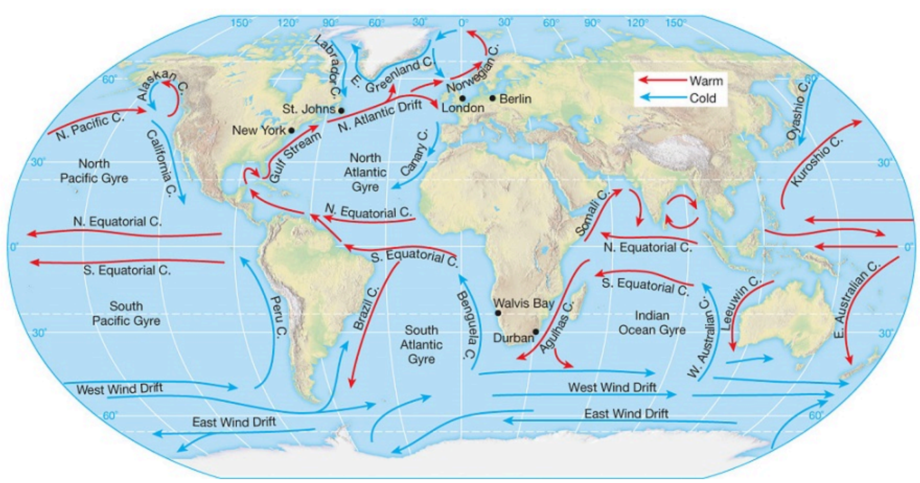
Surface Winds, Surface Ocean Currents, and the Coriolis Effect



Of course the realities are more complex, given the land masses, etc. but the patterns, driven by the surface winds, are straightforward - these are called "GYRES".

Surface Winds, Surface Ocean Currents, and the Coriolis Effect





Surface Winds, Surface Ocean Currents, and the Coriolis Effect

An Important Side Note: You can see that the ocean surface currents rotate in a clockwise direction in the Northern Hemisphere, and counter-clockwise in the Southern Hemisphere.

HURRICANES rotate IN THE OPPOSITE DIRECTIONS from these prevailing winds and ocean surface currents! The reason for this is a little more complex than I want to go through at this point, but it relates to the fact of the winds being sucked to a single low-pressure point, rather than towards bands around the globe. In the Northern Hemisphere, that incoming wind comes towards the low-pressure point from all directions. They do deflect to the right, as expected from the coriolis effect, but all the action is around that point - which results in a counter-clockwise circulation.

Clockwise is correct, but this guy looks like he's going counter-clockwise!

Surface Winds, Surface Ocean Currents, and the Coriolis Effect

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Watch some videos, if you'd like more:

https://www.youtube.com/watch?v=7fd03fBRsuU

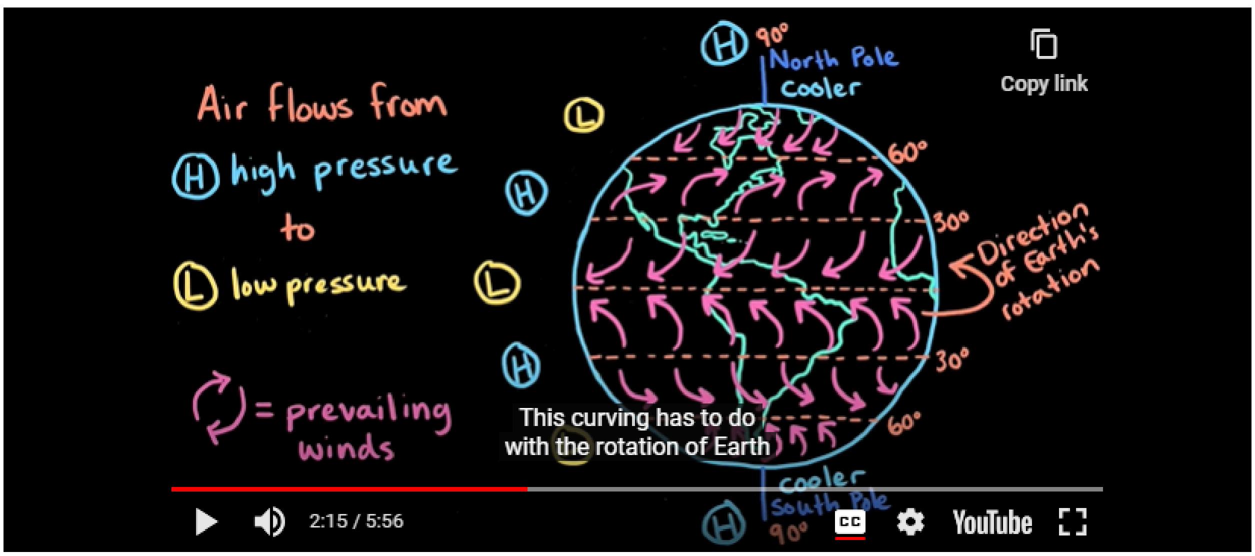
https://www.youtube.com/watch?v=xqM83_og1Fc

https://www.youtube.com/watch?v=PDEcAxfSYaI

https://www.youtube.com/watch?v=Ye45DGkqUkE

1 hour lecture: https://www.youtube.com/watch?v=HjTqdVuEEPo

The one below covers it well and in a very short time. BUT it is too fast and the sloppy graphics diminish its impact. Worth seeing, though.



https://www.khanacademy.org/science/middle-school-earth-and-space-science/x87d03b443efbea0a:weather-and-climate/x87d03b443efbea0a:global-winds-and-currents/v/global-winds-and-currents

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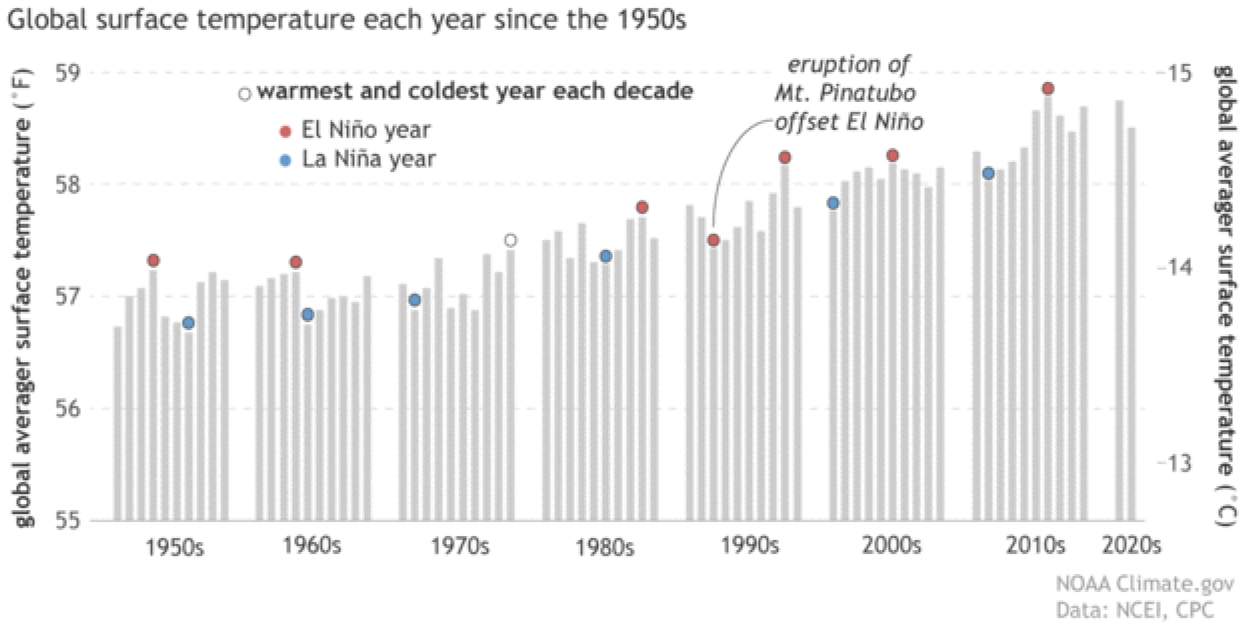

In general, the warmest year of any decade will be an El Niño year, the coldest a La Niña one. This graph shows annual average surface temperatures (gray bars), grouped by decade, from 1950 to 2021. The warmest and coldest years of each decade are topped with circles: red for El Niño-influenced years and blue for La Niña years. **1992 was the coldest year of the 1990s despite being an El Niño year because of the cooling influence of the eruption of Mount Pinatubo in 1991.** NOAA Climate.gov graph based on data from NOAA National Centers for Environmental Information.