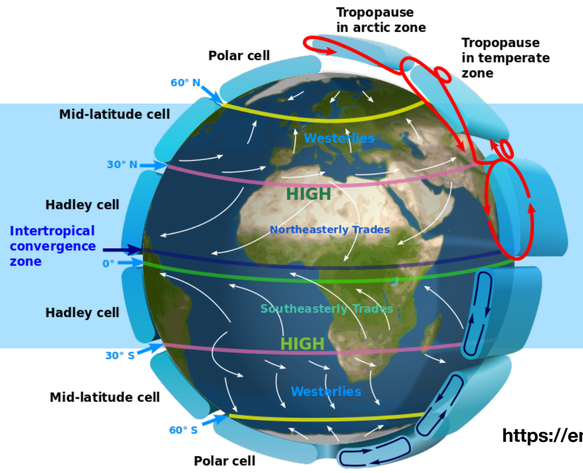
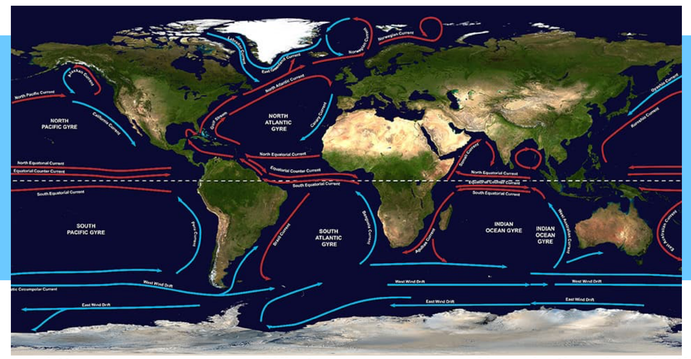
[ESS 15] *Lecture 9: General circulation*



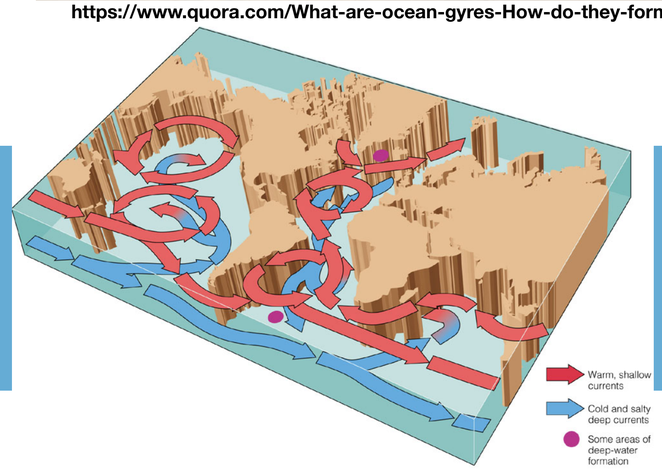
https://en.wikipedia.org/wiki/Atmospheric_circulation

- Three-Cell Circulation in the Atmosphere



https://www.quora.com/What-are-ocean-gyres-How-do-they-form-in-the-ocean-and-how-many-gyres-form-in-the-world-ocean

- Gyres in the Oceans



© 2005 Brooks/Cole - Thomson

- Thermohaline Circulation

Lecture 9: General circulation

Main Focus:

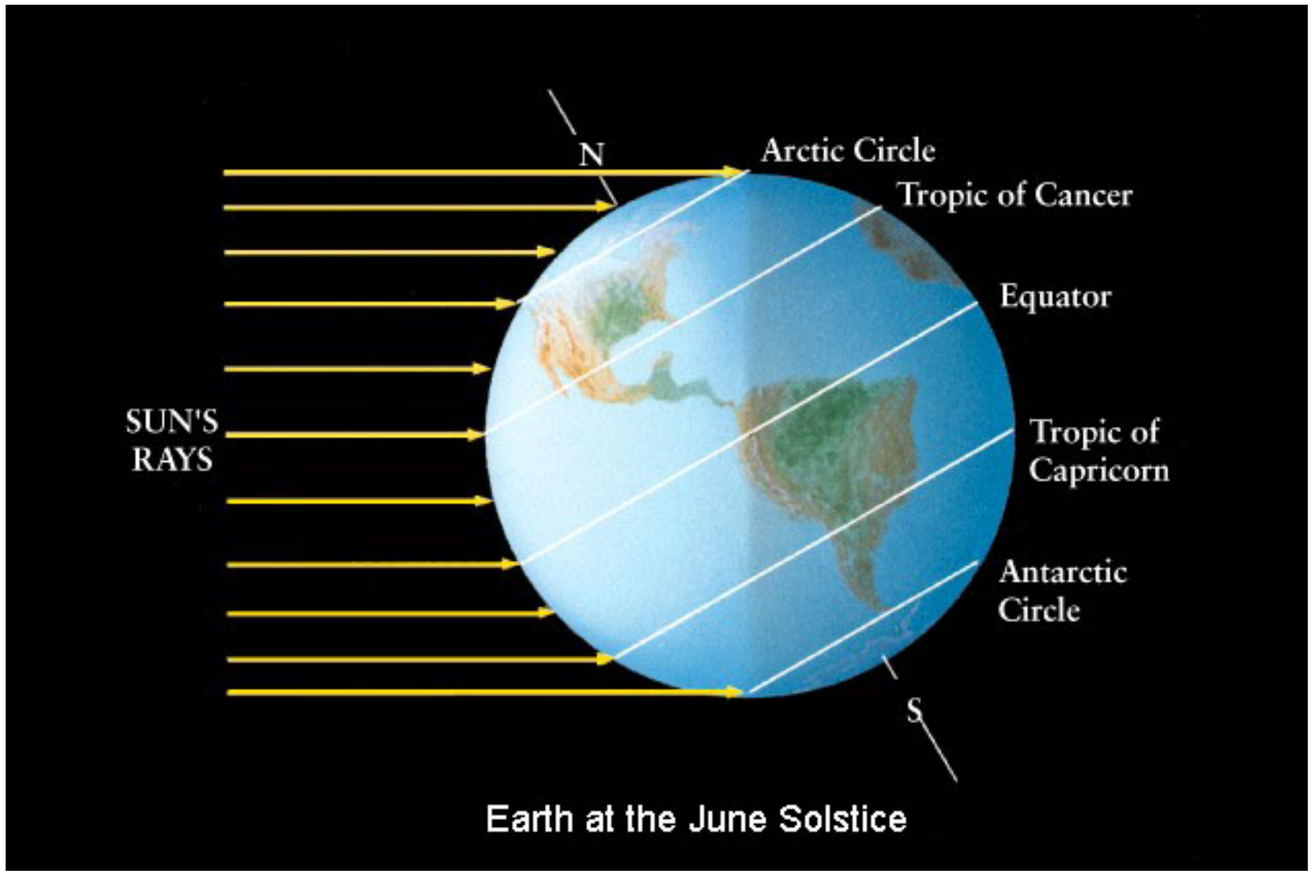
- **Why do we need to know the circulation for the sake of understanding climate and global warming?**

- **What is atmospheric circulation? Ocean gyre? Thermohaline circulation?**

- **How it works?**
  - **Coriolis**
  - **Temperature Difference**
  - **Pressure Gradient**
  - **Density**

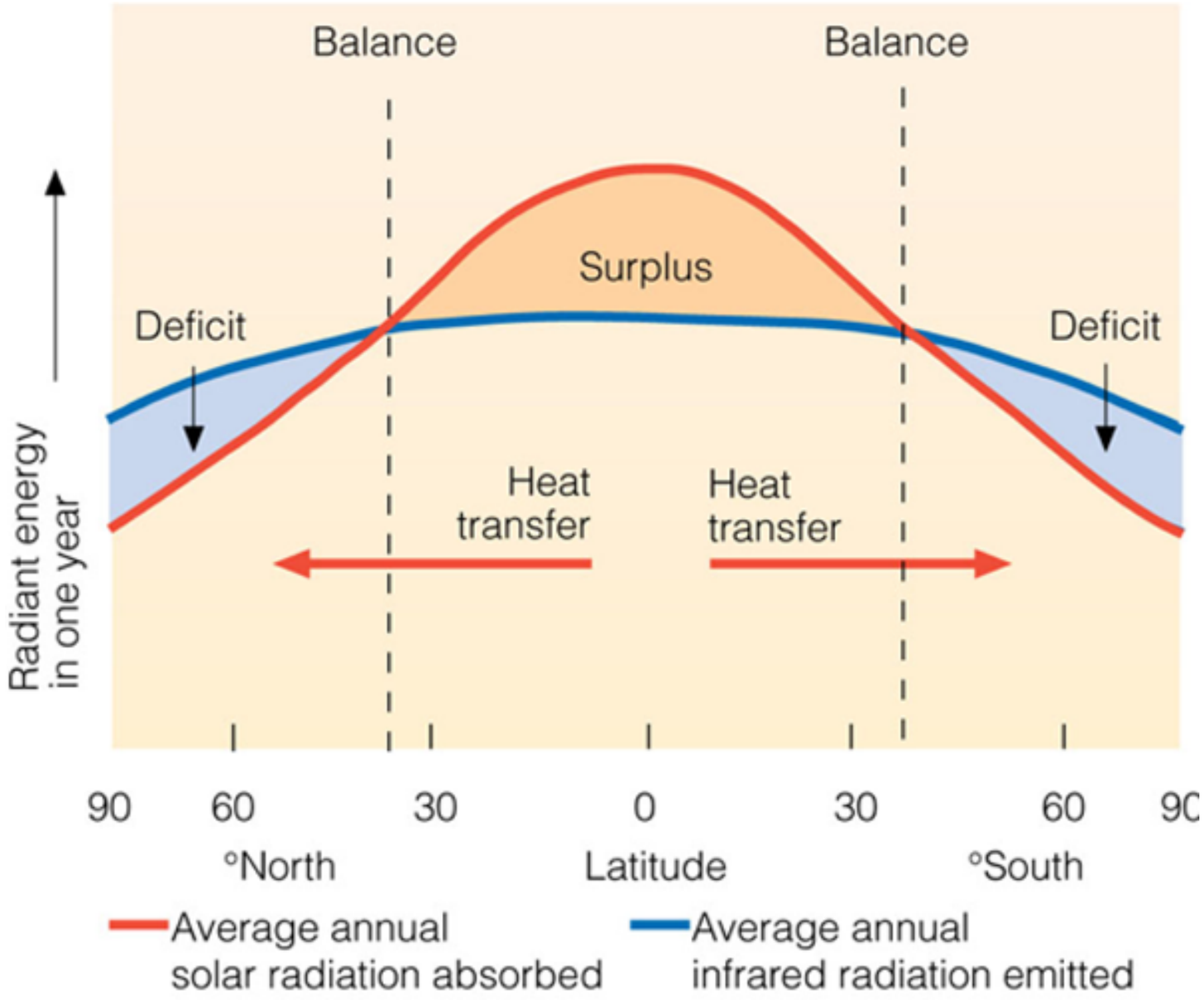
❑ Why we need to know the circulation for the sake of understanding climate and global warming?

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



In summary, the atmospheric circulation and oceanic circulation redistribute the heat to even out the temperature difference between the tropical region and polar region.

Heat Redistribution



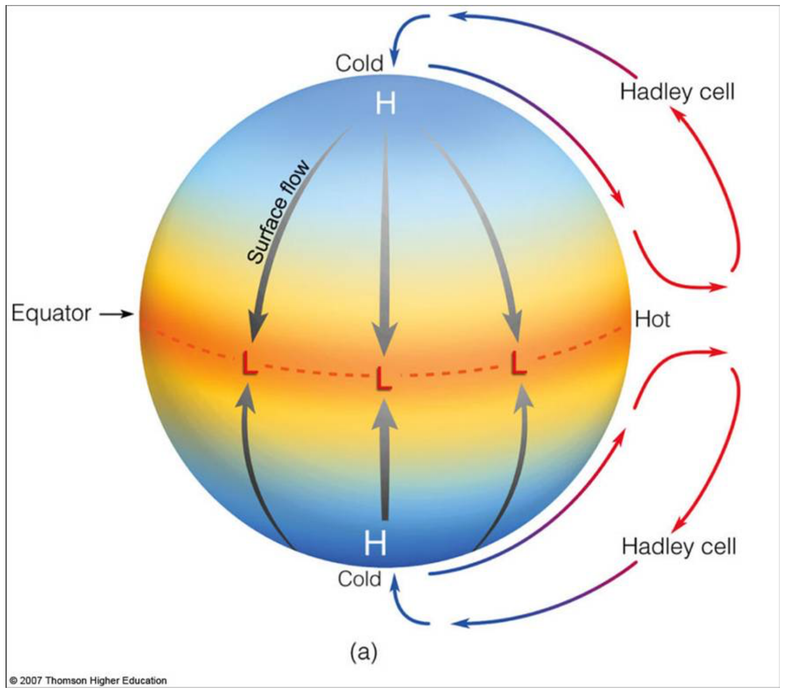
http://www.faculty.luther.edu/~bernatzr/Courses/ES185/Climate/climate.html

Atmospheric Circulation

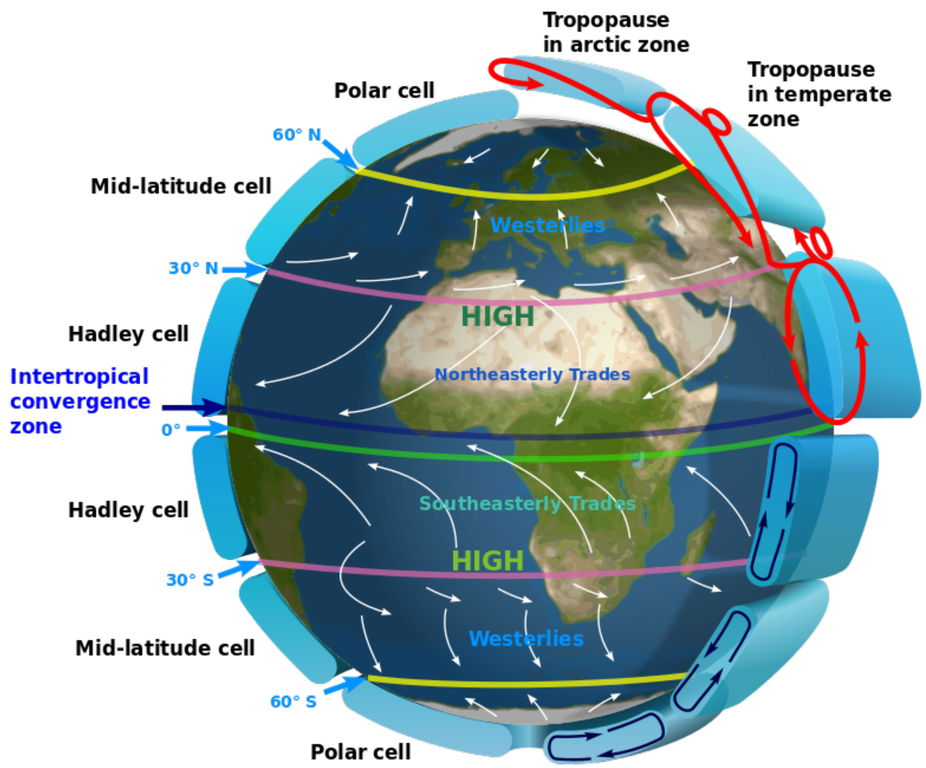
Temperature Difference

Temperature Difference + Rotation

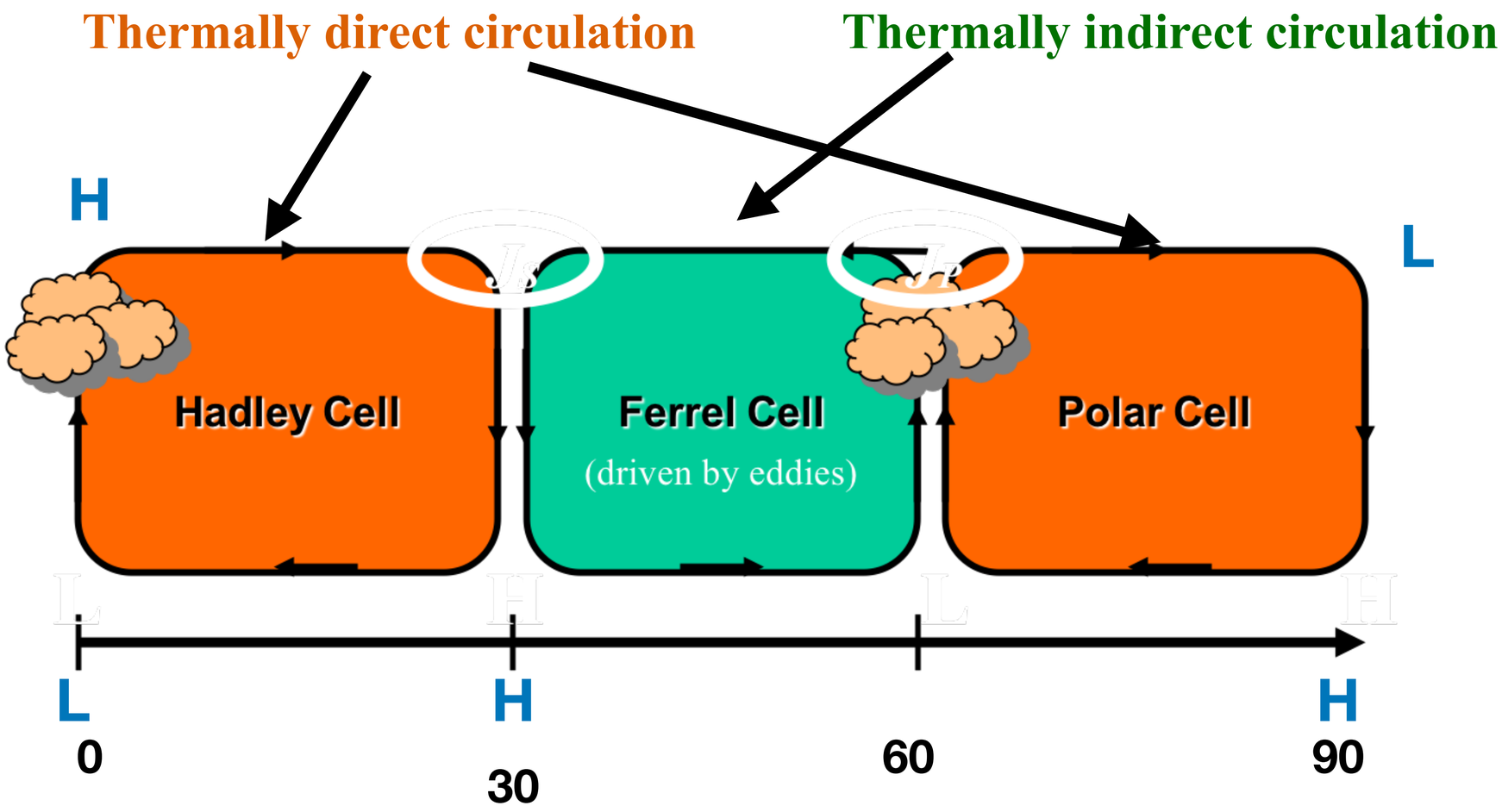
One cell circulation model



Three cell circulation model



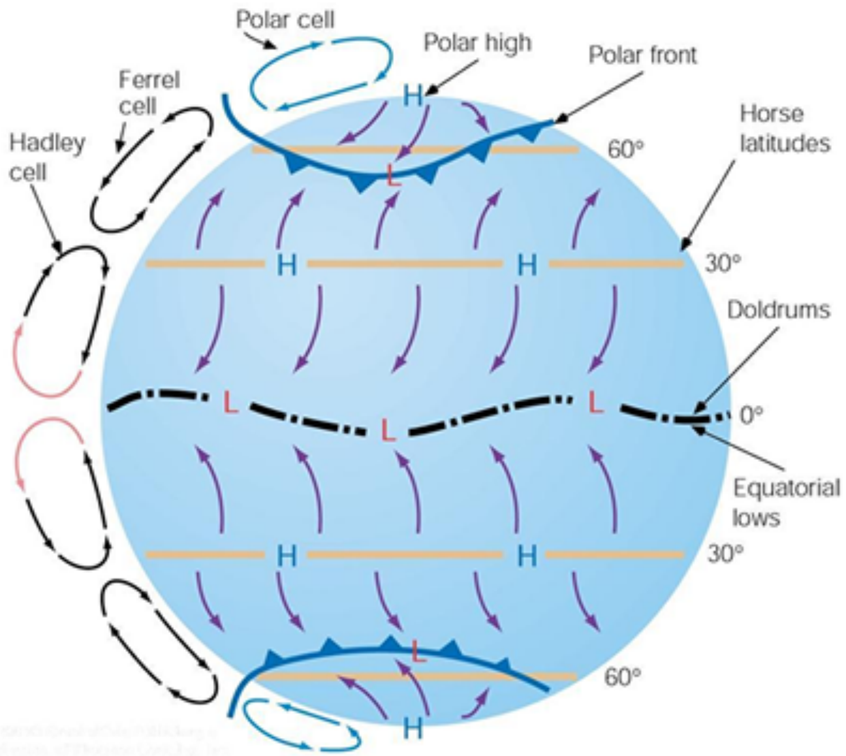
https://en.wikipedia.org/wiki/Atmospheric_circulation



◉ The first is the rotation of the earth on its axis.

◉ Another contributing factor is the radiative cooling of the upper most air as it travels pole-ward. This cooling causes the air to increase in density, which leads to sinking motion.

Is the Three-Cell Model Realistic?



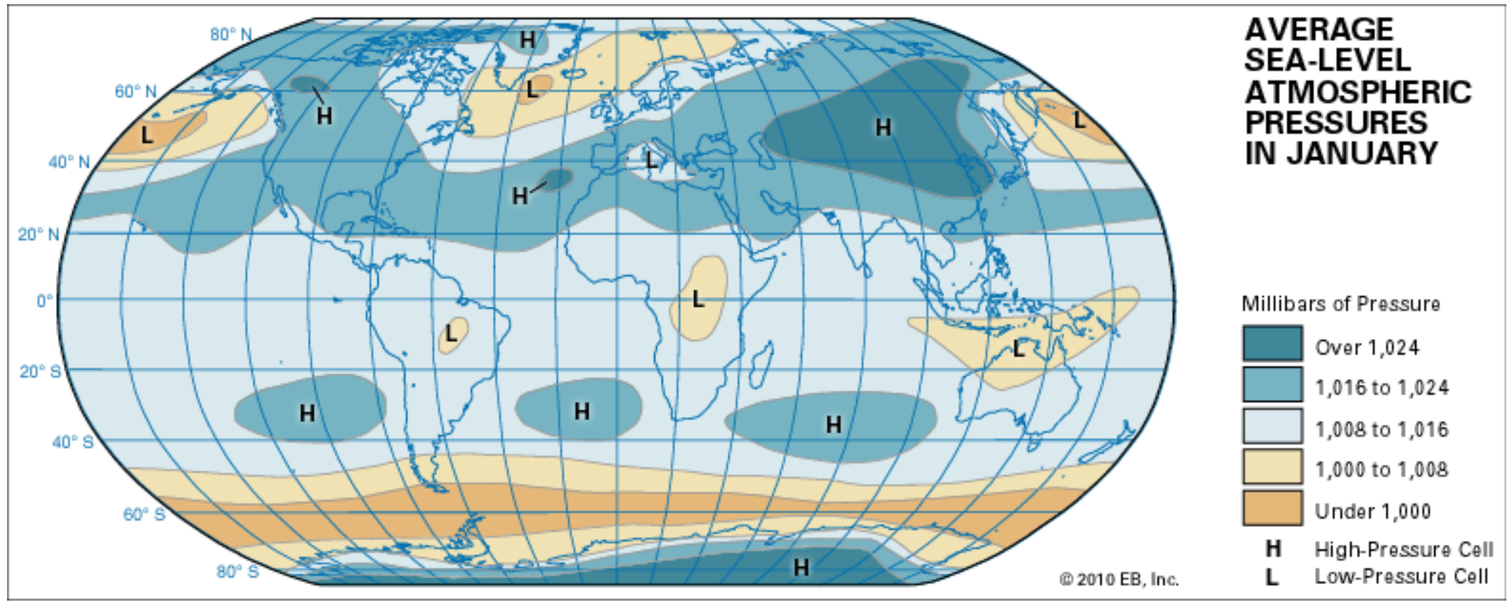
Yes and No!

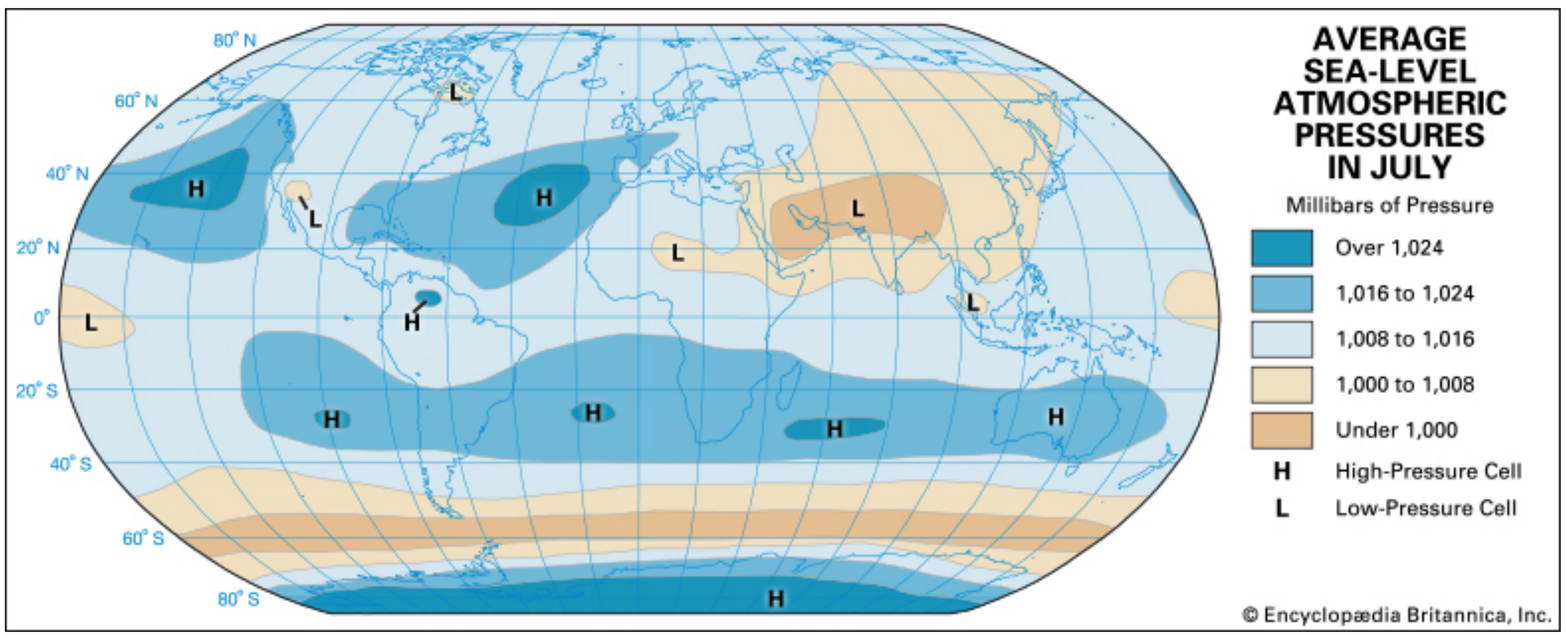
☑ ***Yes****:* the three-cell model explains reasonably well the surface wind distribution in the atmosphere.

☑ ***No****:* the three-cell model can not explain the circulation pattern accurately (Due to sea-land contrast and topography)

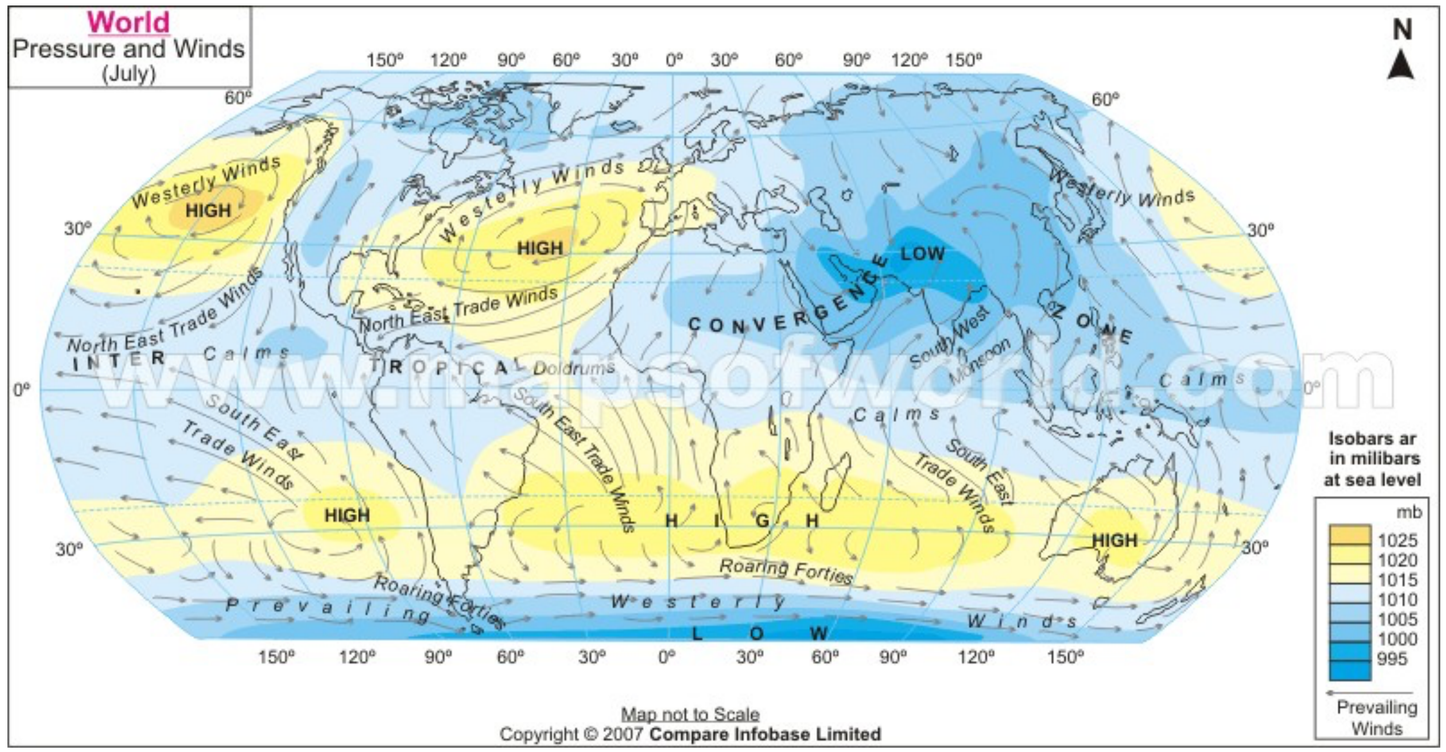
http://www.faculty.luther.edu/~bernatzr/Courses/ES185/Climate/climate.html

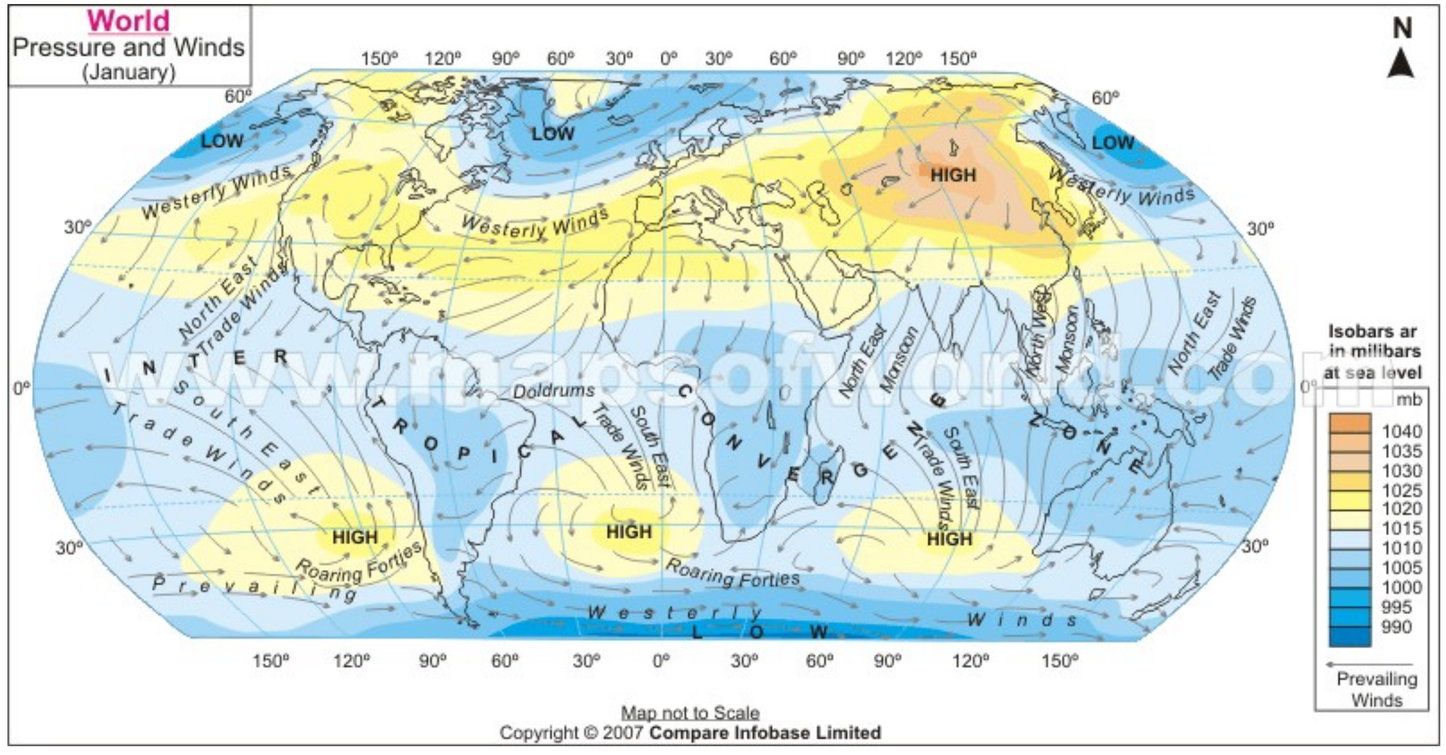
+Land-Ocean Temperature Contrast+ Seasonality

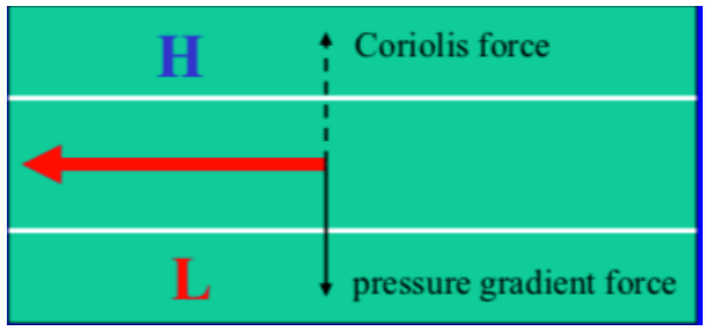




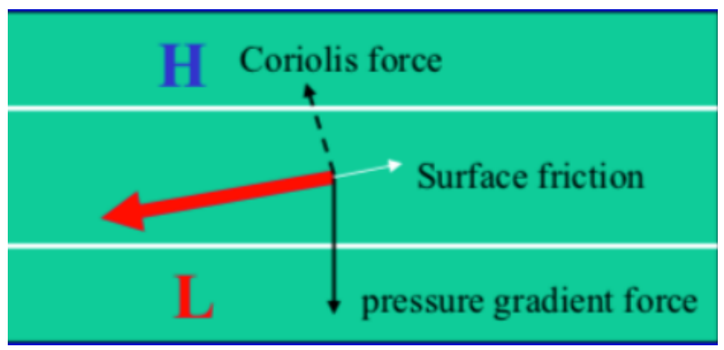
- https://en.wikipedia.org/wiki/Atmospheric_circulation#/media/File:MeanMonthlyP.gif



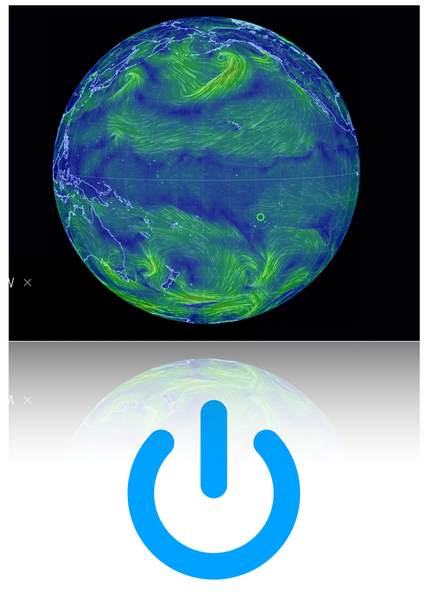




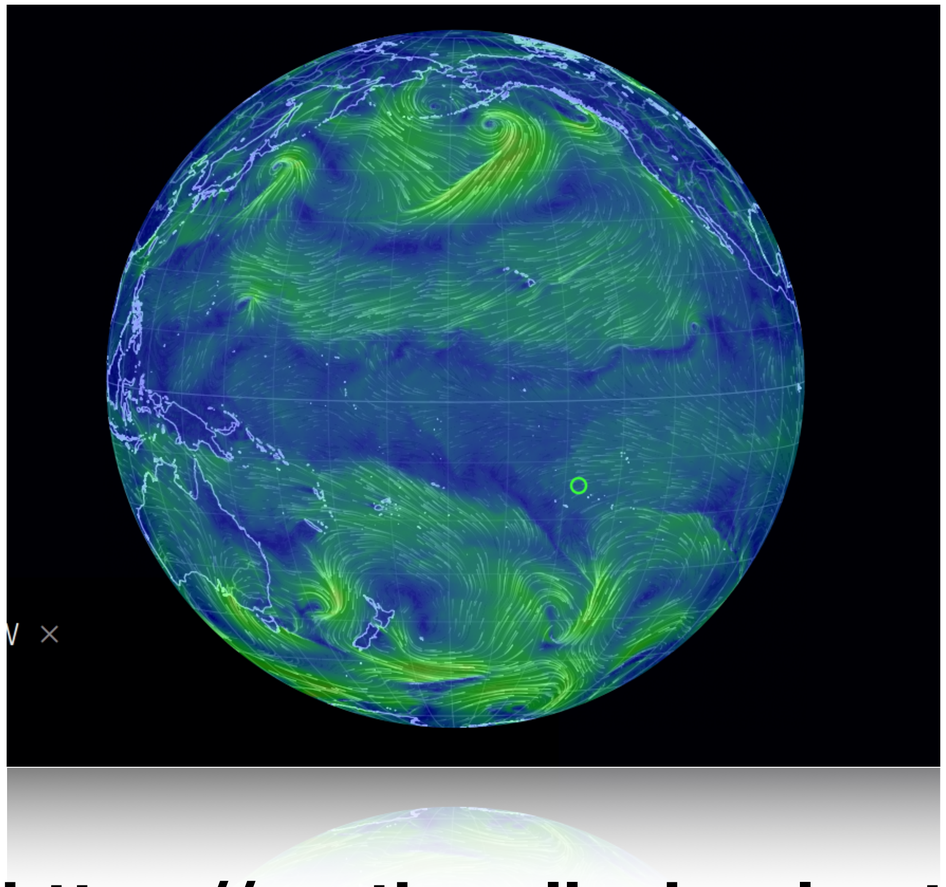
Geostrophic Balance



+ friction



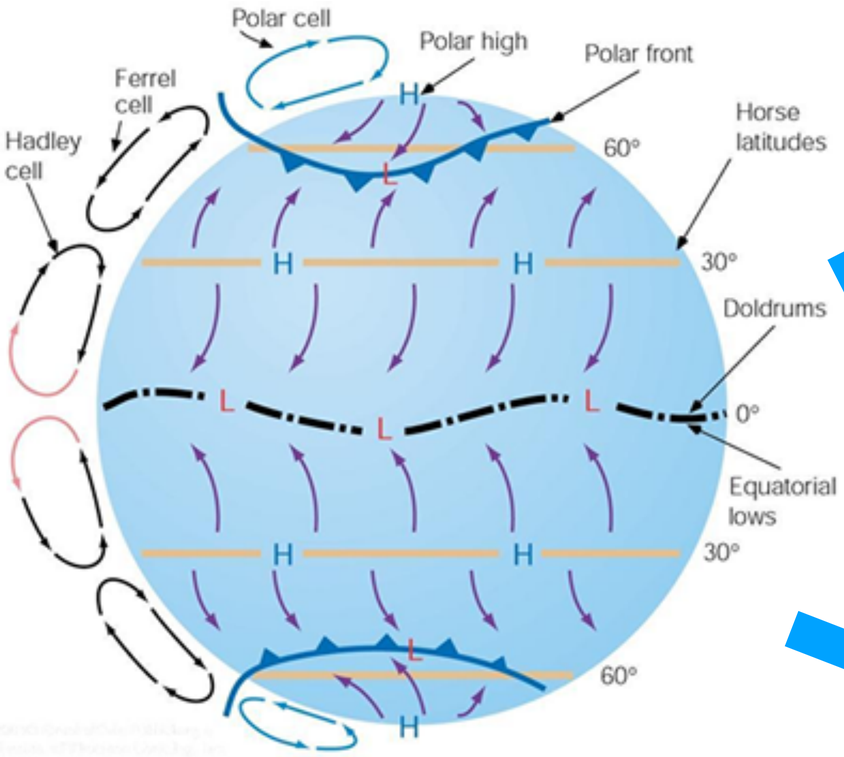
What is atmospheric circulation? Or Wind



https://earth.nullschool.net

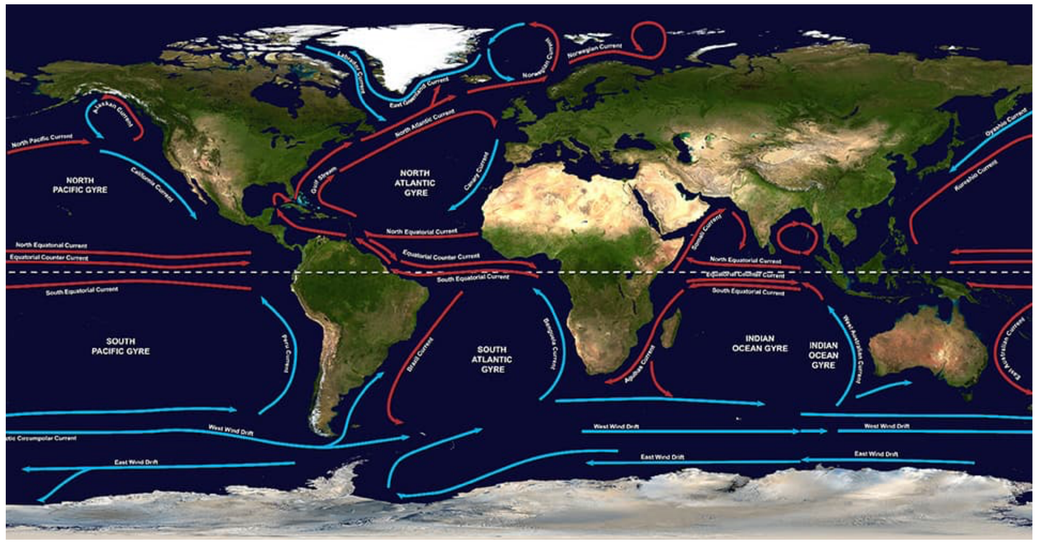
Atmosphere and Ocean

Q : How can the atmosphere affect the ocean circulation?



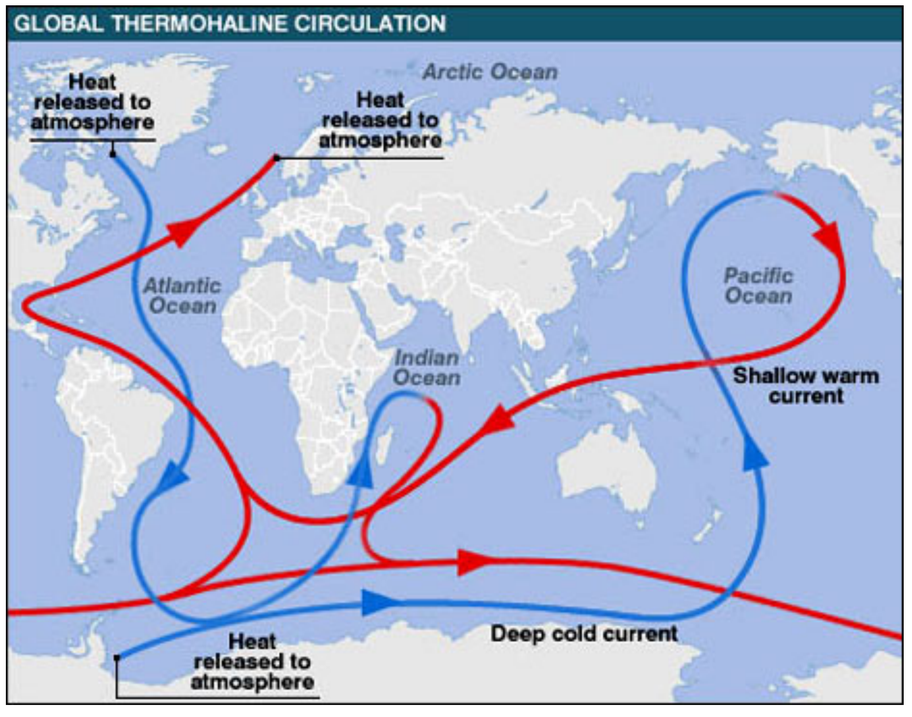
Wind

Wind-driven Circulation _Gyre



Salinity

Thermohaline Circulation



https://wattsupwiththat.com/2016/07/11/tol-on-gulf-stream-slowdown-cooling-is-probably-a-good-bit-more-harmful-than-warming/

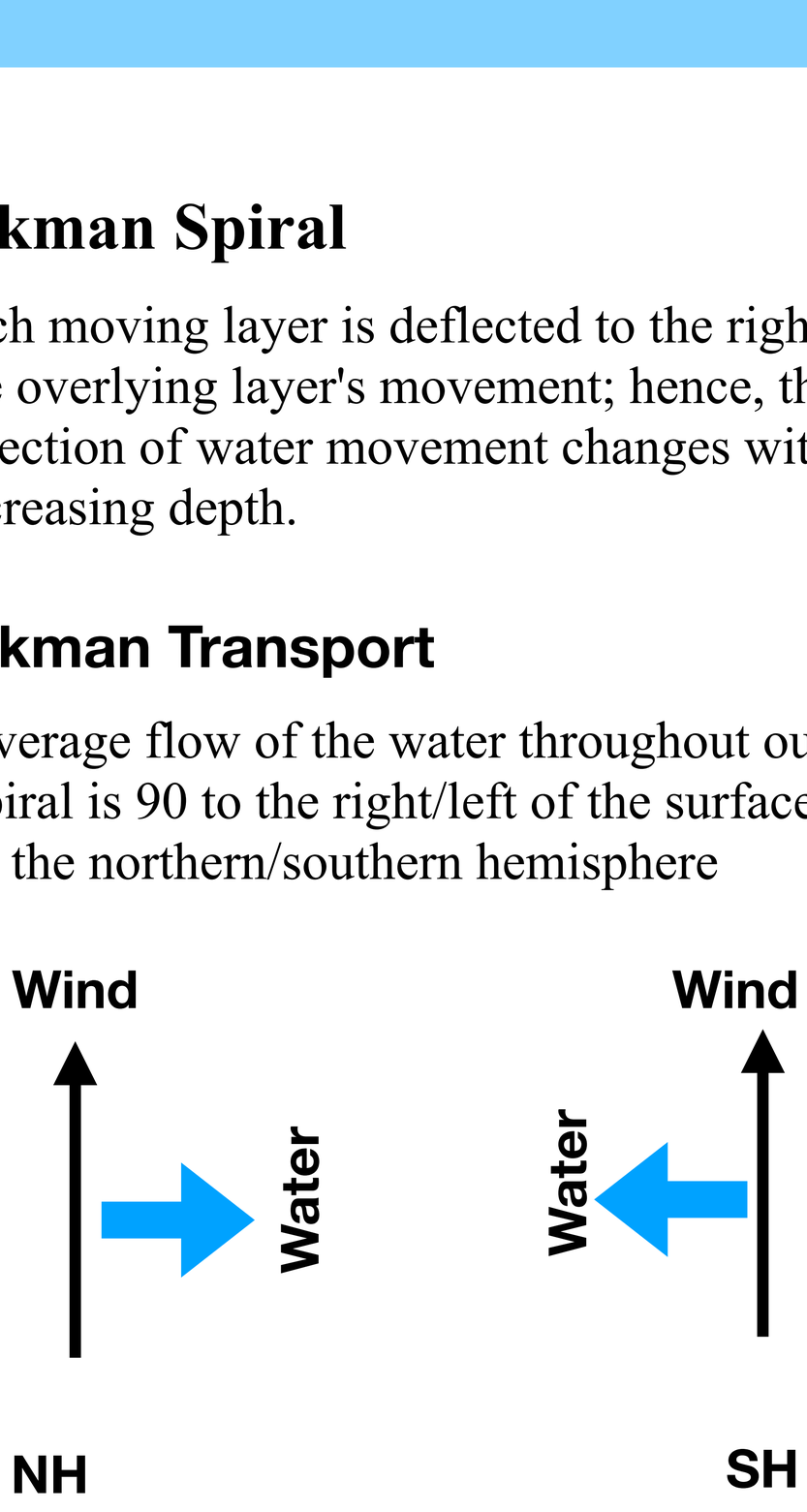
Wind —->Ekman Transport

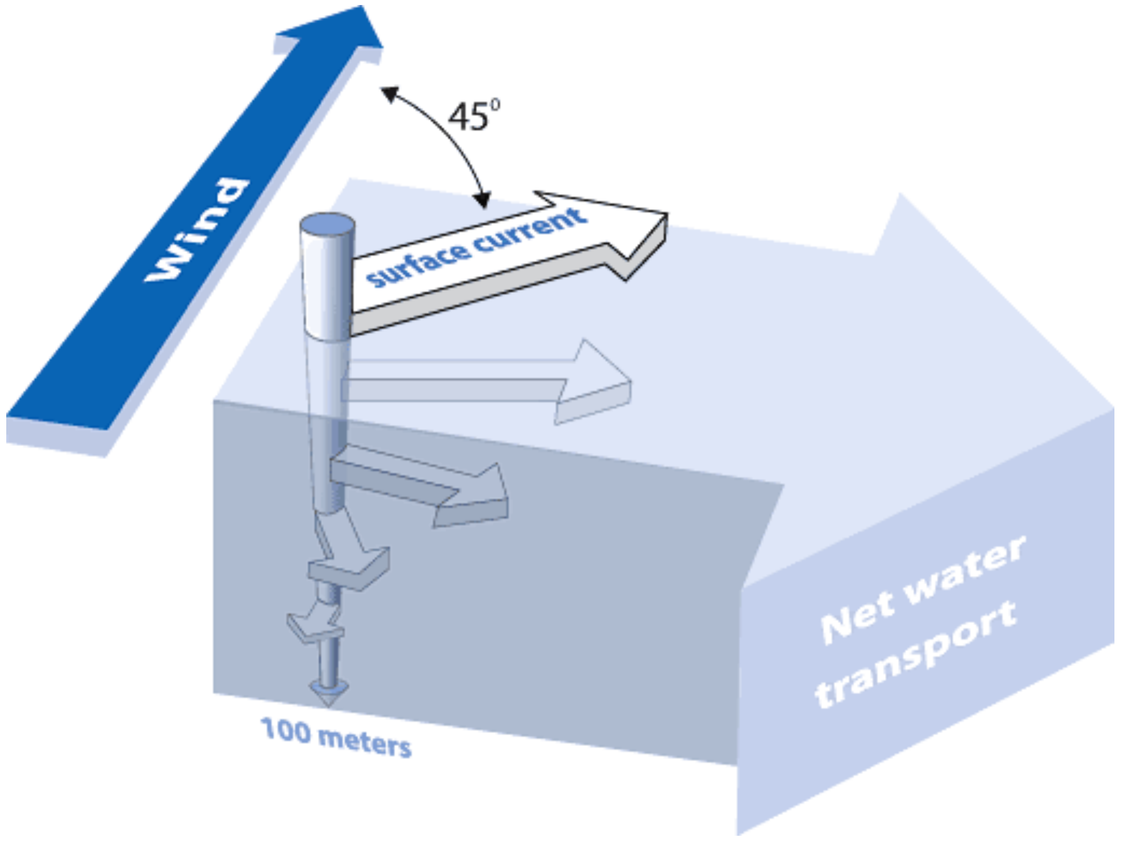
Ekman Spiral

each moving layer is deflected to the right of the overlying layer's movement; hence, the direction of water movement changes with increasing depth.

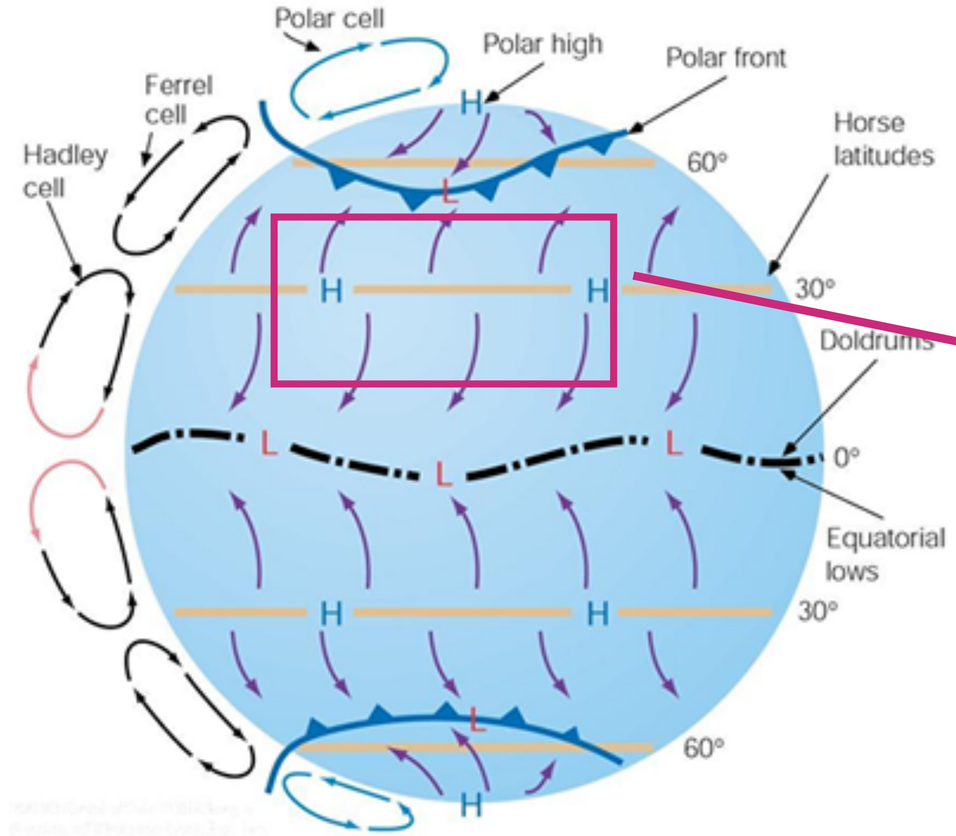
Ekman Transport

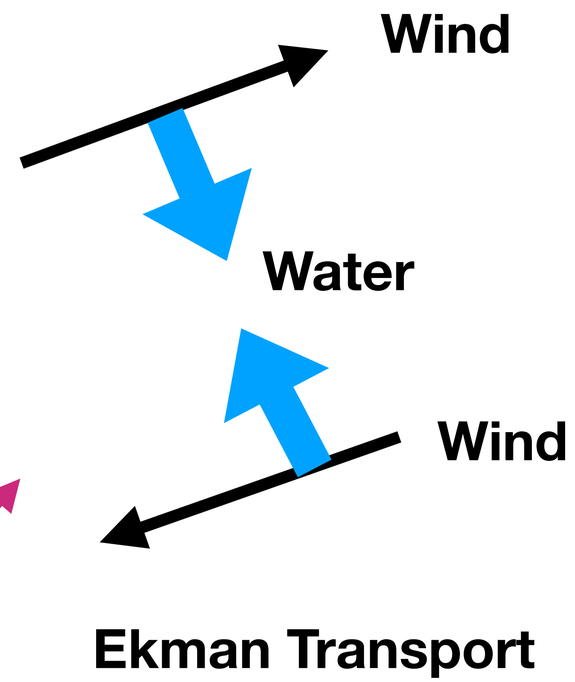
Average flow of the water throughout out the spiral is 90 to the right/left of the surface wind in the northern/southern hemisphere

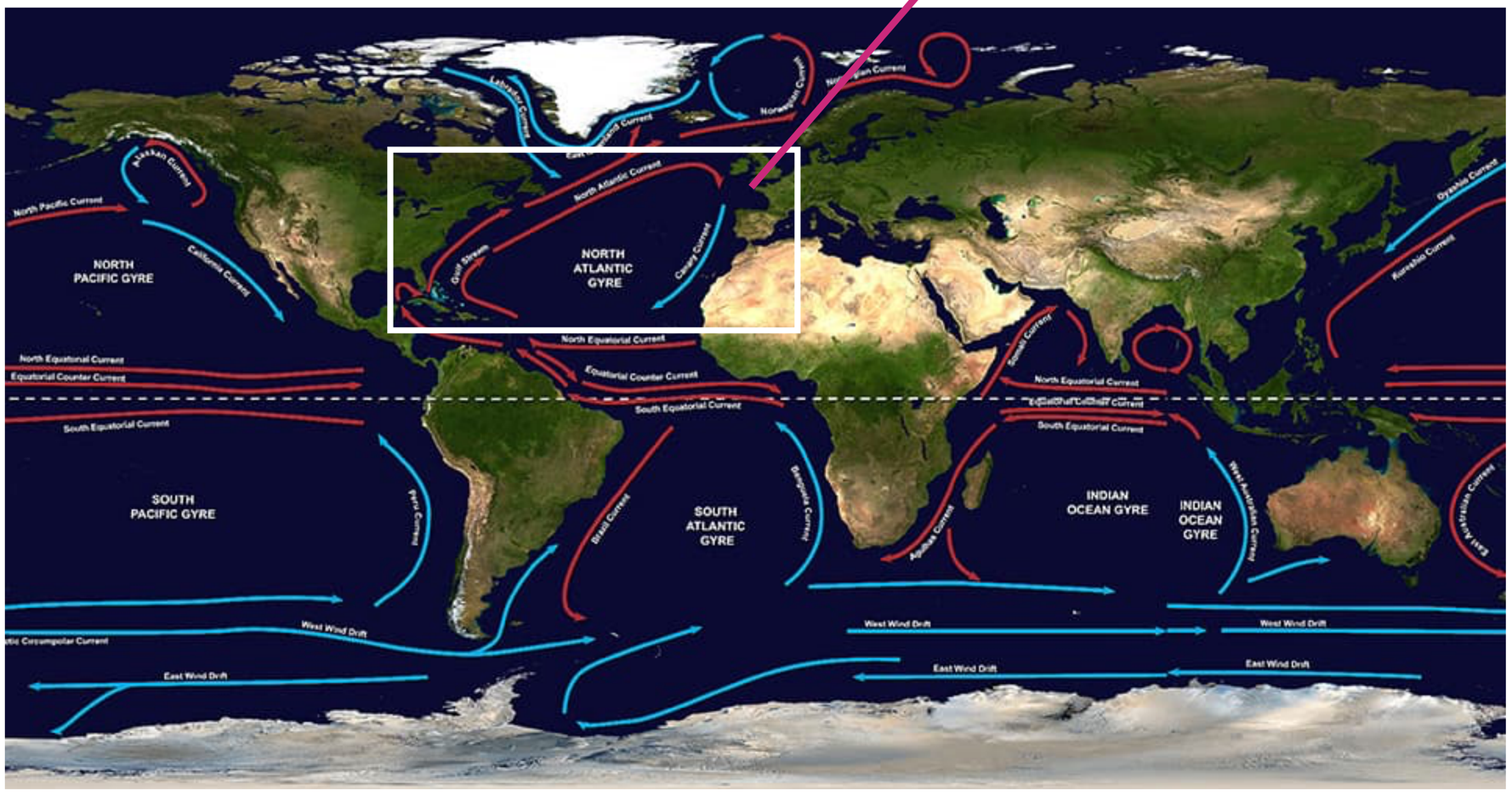




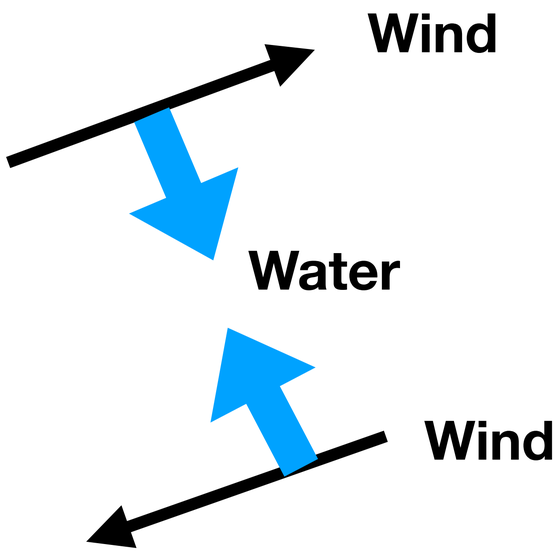
https://oceanservice.noaa.gov/education/kits/currents/05currents4.html


Polar cell
Polar high
Polar front
Ferrel cell
Hadley cell
Horse latitudes
60°
30°
Doldrums
0°
Equatorial lows
30°
60°
H
L


Wind
Water
Wind
Ekman Transport

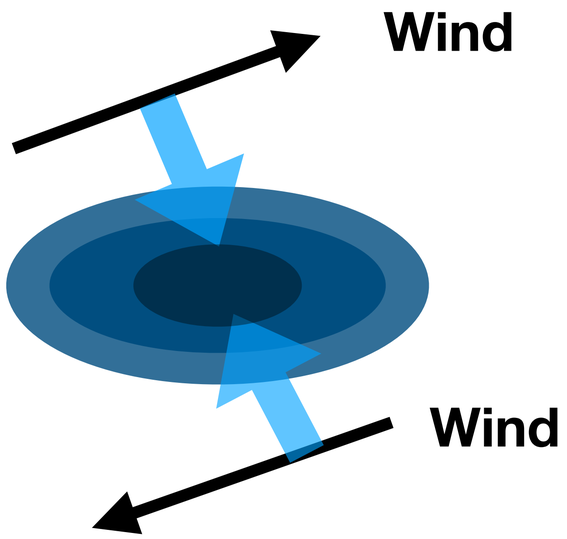

NORTH PACIFIC GYRE
SOUTH PACIFIC GYRE
NORTH ATLANTIC GYRE
SOUTH ATLANTIC GYRE
INDIAN OCEAN GYRE
INDIAN OCEAN GYRE
North Pacific Current
Kuroshio Current
California Current
Peru Current
North Equatorial Current
Equatorial Counter Current
South Equatorial Current
Brazil Current
Benguela Current
North Atlantic Current
Gulf Stream
Canary Current
Labrador Current
Norwegian Current
Somali Current
Agulhas Current
West Australian Current
Oyashio Current
East Australian Current
West Wind Drift
East Wind Drift

Step 1:

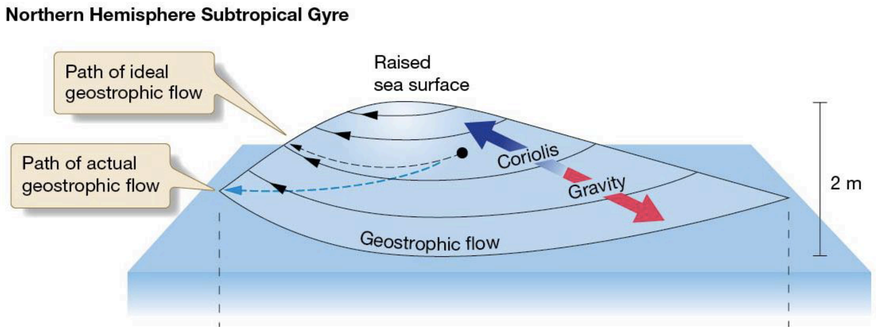


Ekman Transport

Step 2:



Ekman Transport

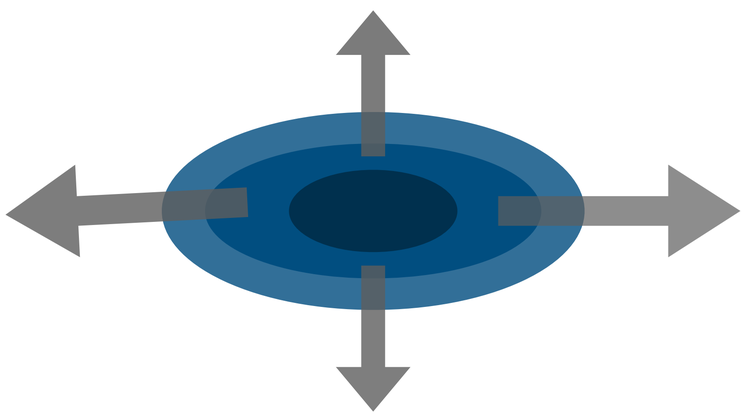


Pile up the water

High Pressure

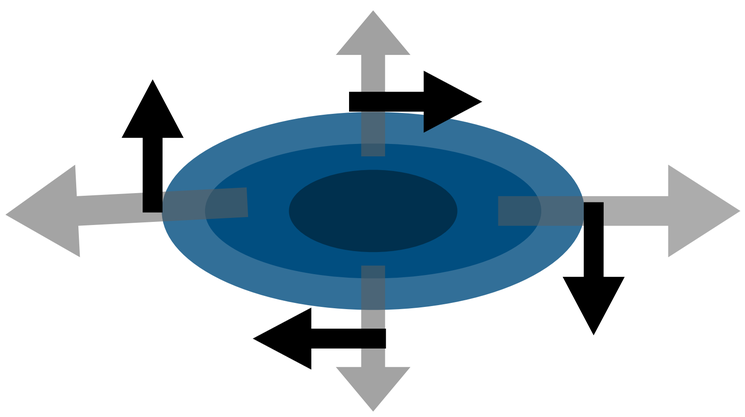
Step 3:

Pressure Gradient



Step 4:

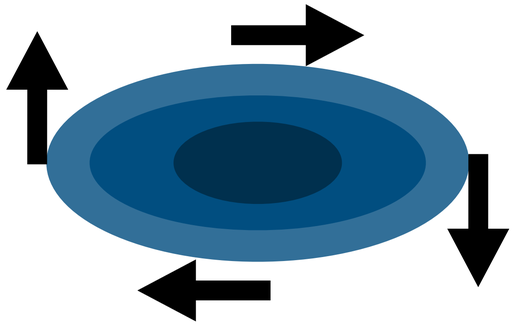
Pressure Gradient + Coriolis effect



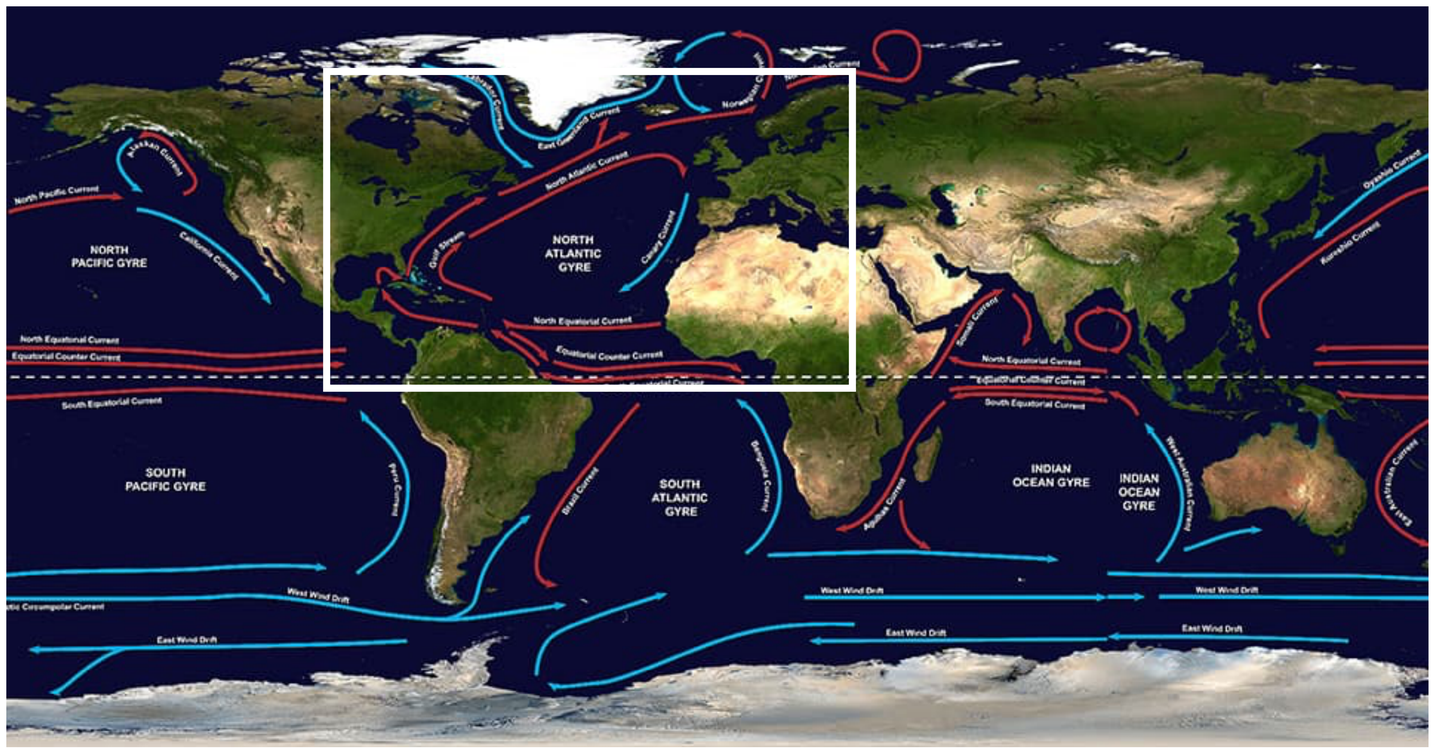
Clockwise

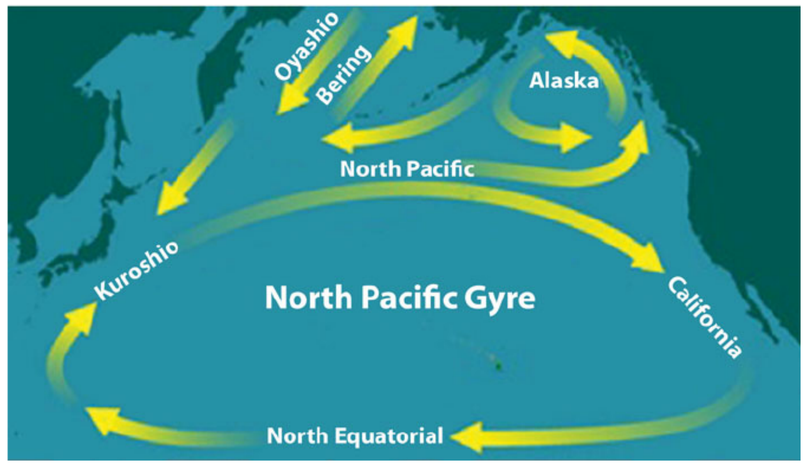
Northern Hemisphere

North Pacific Gyre



Clockwise

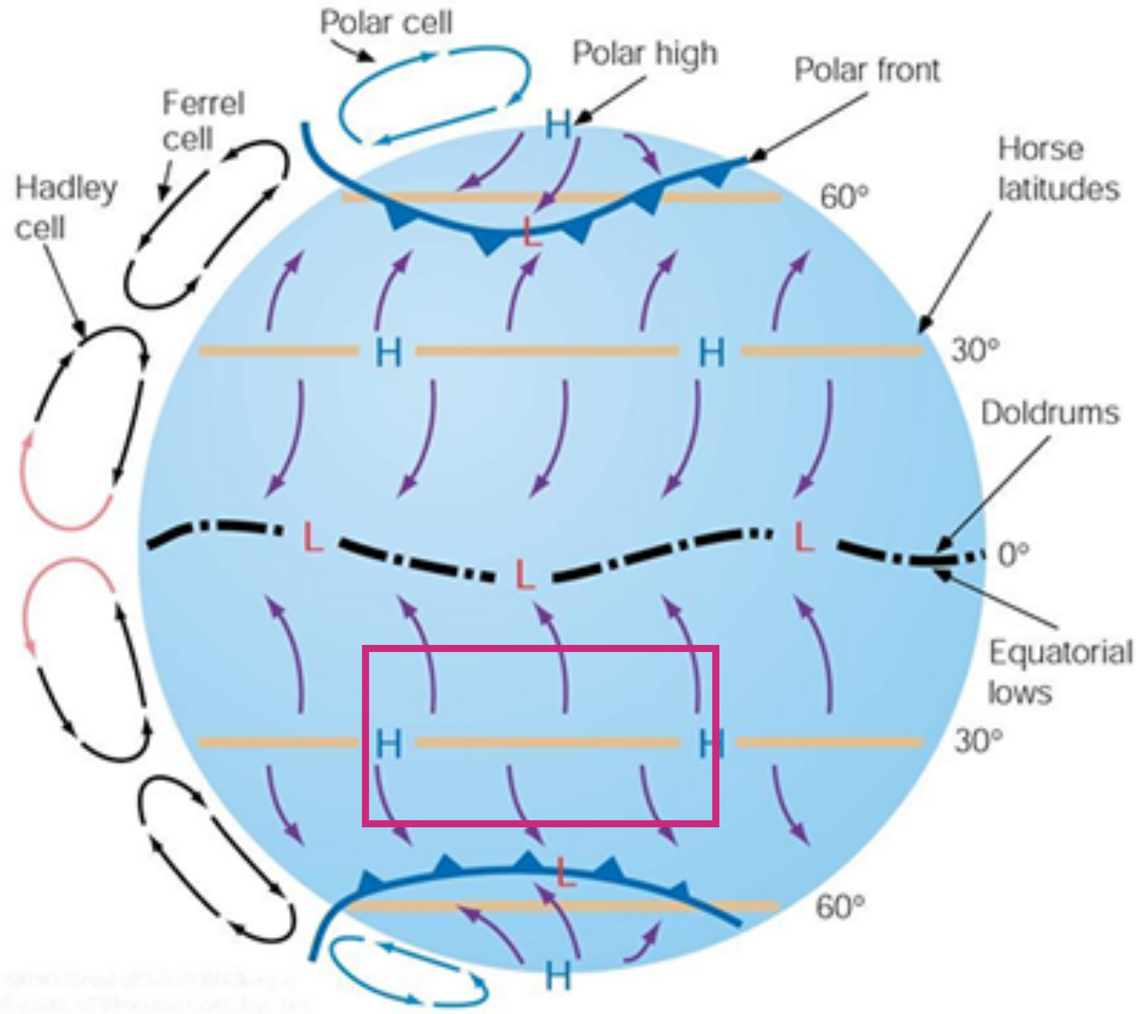




https://www.researchgate.net/figure/The-North-Pacific-Gyre-which-flows-clockwise-from-East-Asia-to-North-America-adapted_fig1_273509712

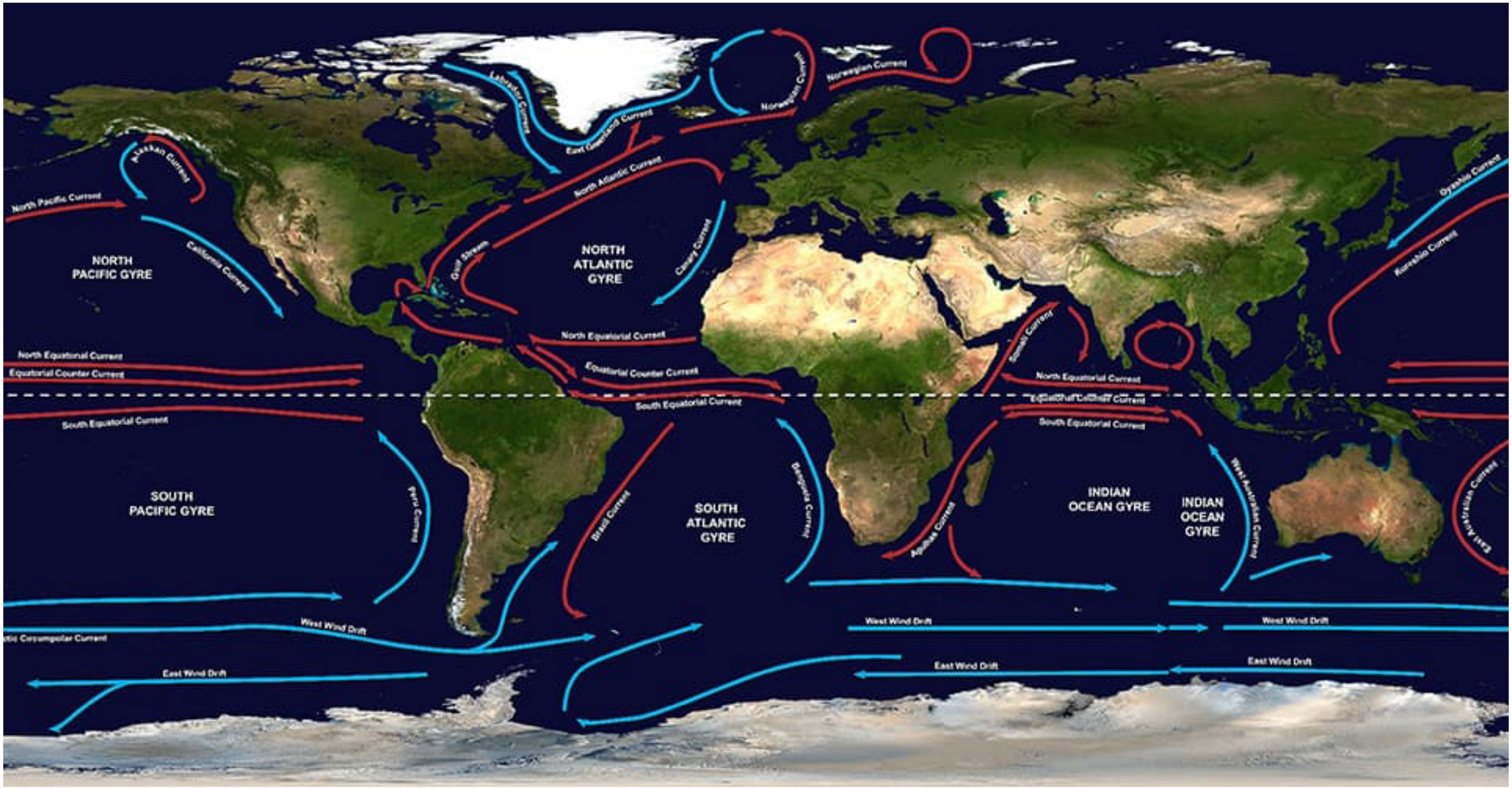
Iclick Question

How about the the sub-tropical gyre in South Hemisphere?



A. Clockwise
B. Counterclockwise

Heat transport by the gyre



NASA | Perpetual Ocean

https://www.youtube.com/watch?v=CCmTY0PKGDs

Thermohaline Circulation

- Thermo → temperature
- Haline → salinity

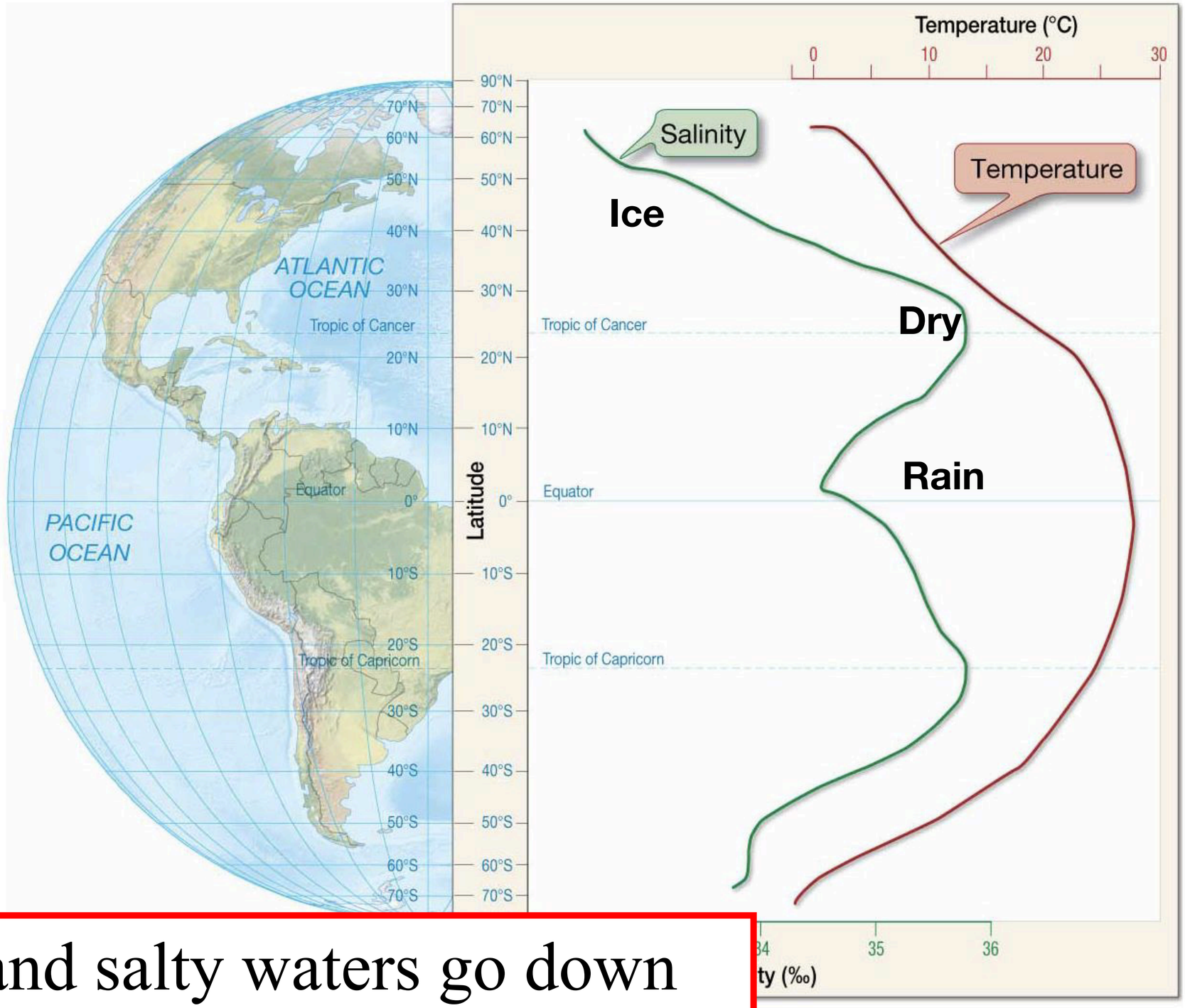
Density-Driven Circulation

Cold and salty waters go down

Warm and fresh waters go up

https://www.youtube.com/watch?v=EafneRiy1Is&index=18&t=0s&list=WL

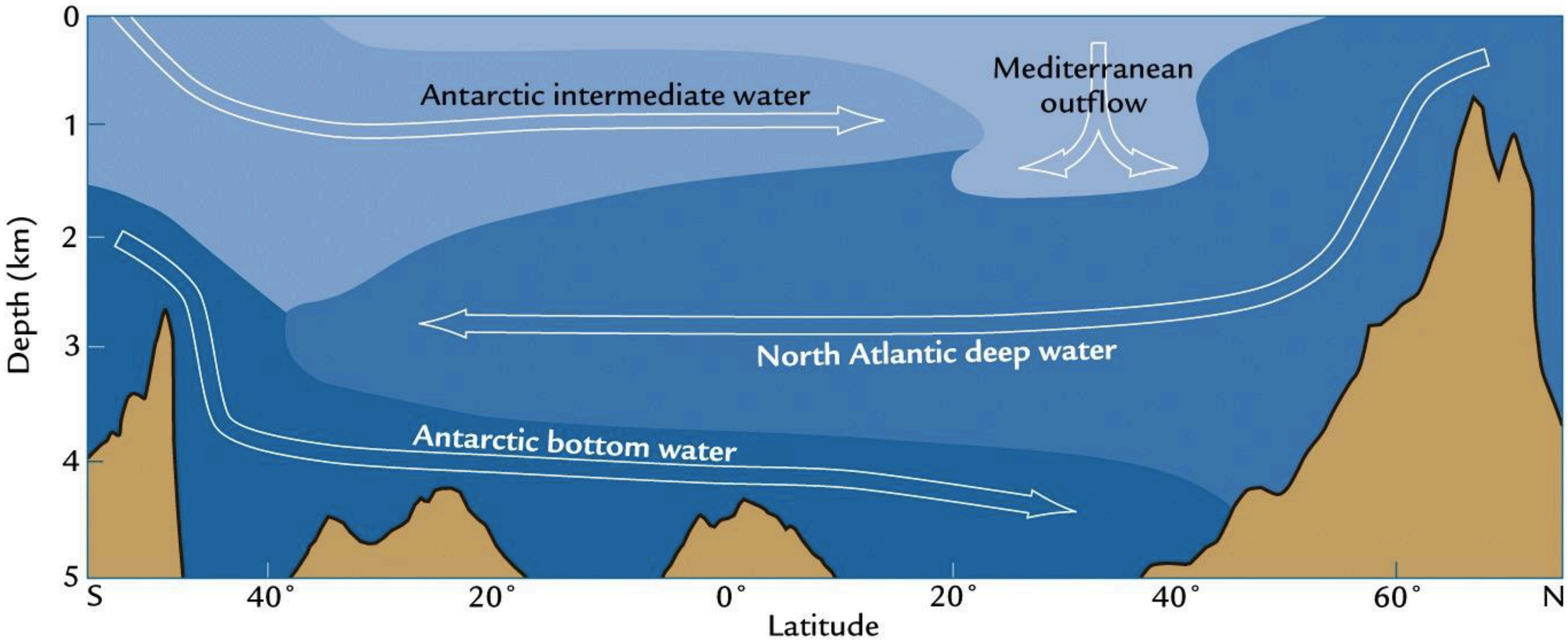
How did the 3 cell conceptual model affects the ocean salinity?



Cold and salty waters go down

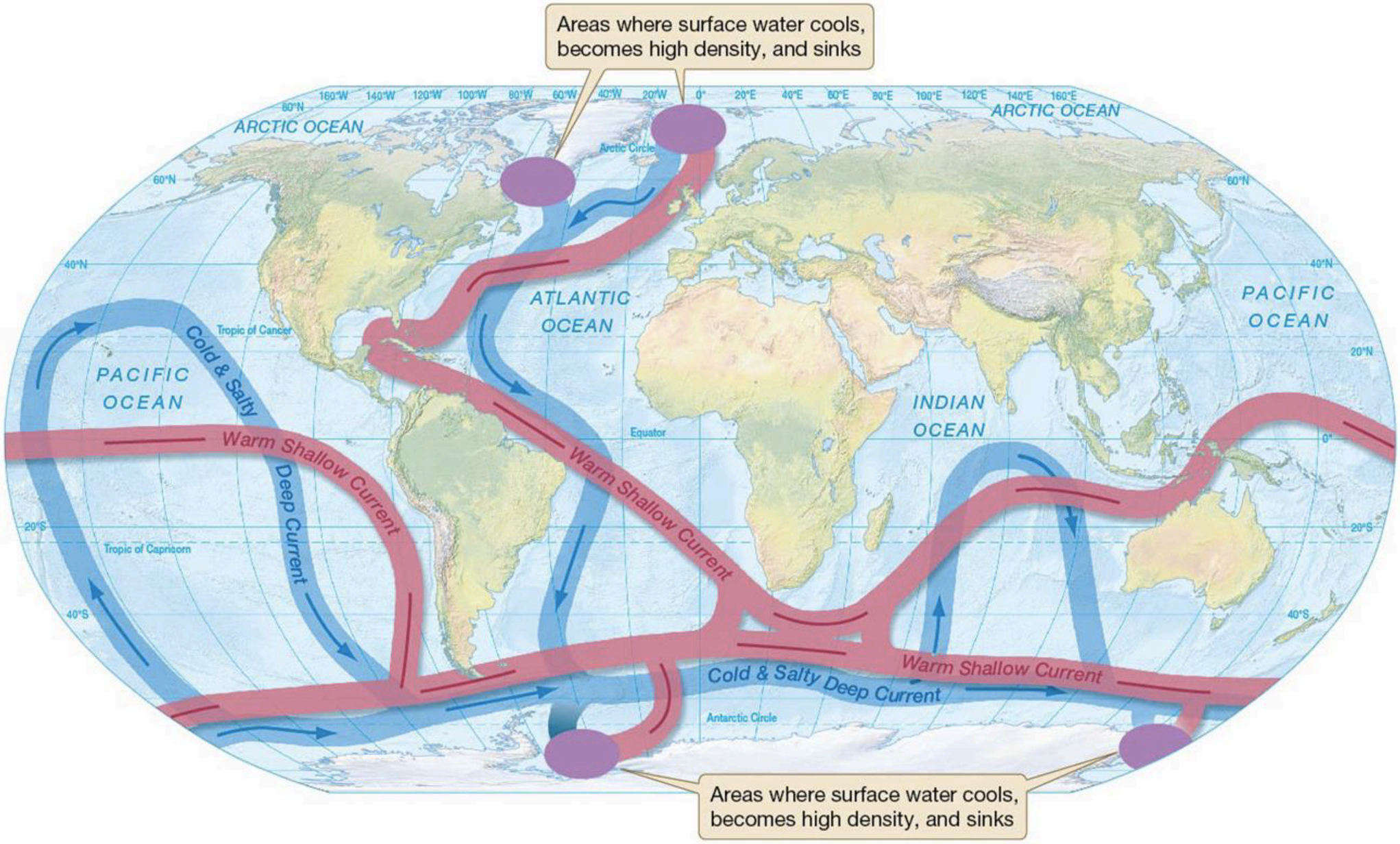
Warm and fresh waters go up

Ocean Water Mass: Stratification



https://www.youtube.com/watch?v=bN7E6FCuMbY

Thermohaline Conveyor Belt



- Typical speed for deep ocean current: 0.03-0.06 km/hour.
- Antarctic Bottom Water takes some 250-1000 years to travel to North Atlantic and Pacific.

https://svs.gsfc.nasa.gov/3658

It Takes ~1000 Years for Deep Ocean Waters to Travel Around…

- If we date a water parcel from the time that it leaves the surface and sink into the deep ocean.

➡Then the youngest water is in the deep north Atlantic, and the oldest water is in the deep northern Pacific, where its age is estimated to be 1000 year .

What will happen if we slow down the thermohaline circulation?

Thermohaline circulation: Changes

Iceberg armadas from icesheets!!

Release freshwater into the North Atlantic

↓

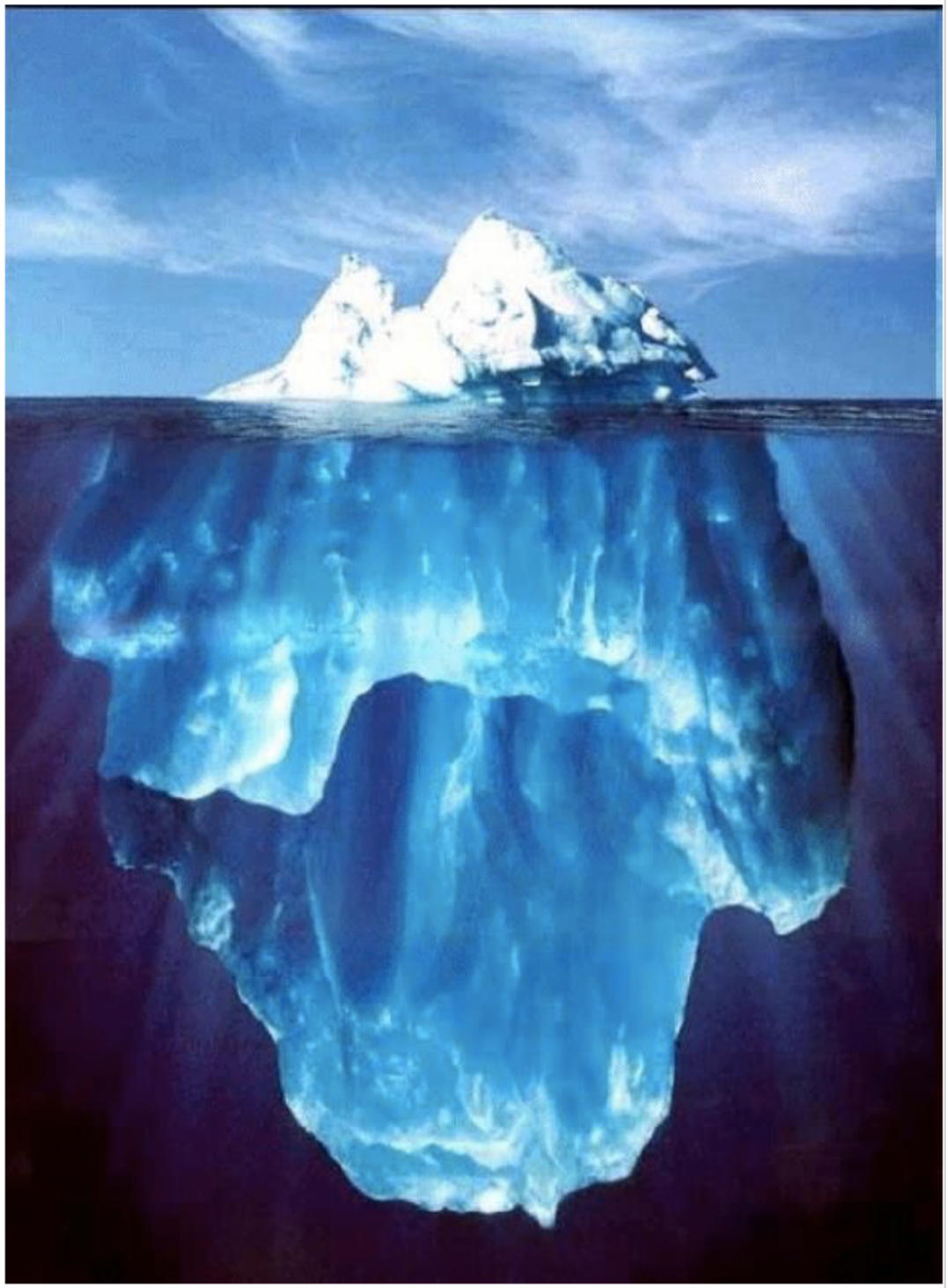
Reduces salinity of seawater

↓

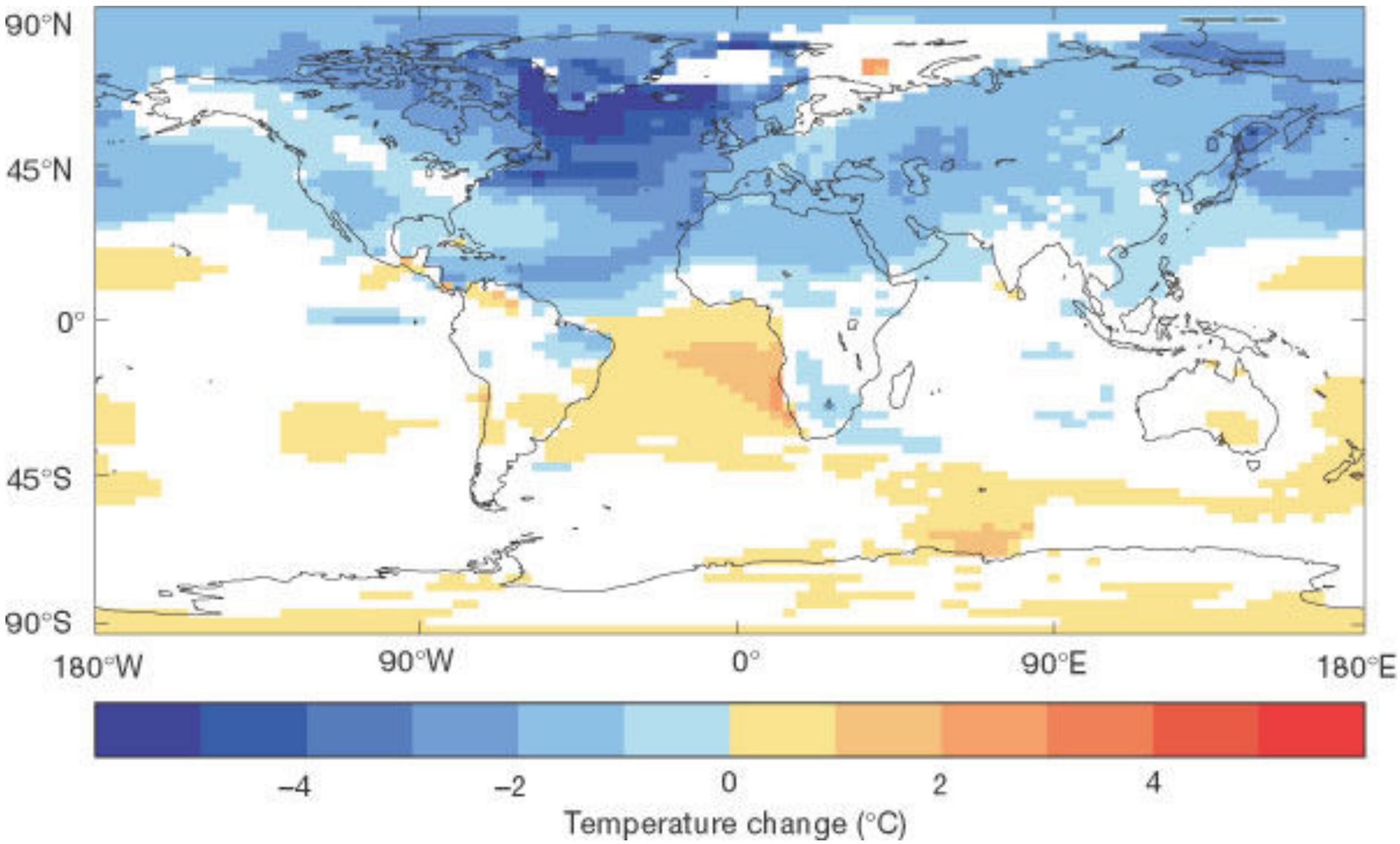
Reduces density so prevents water sinking

↓

Warm surface water not pulled so far north so temperatures fall around North Atlantic Ocean



The day after tomorrow



Rahmstorf 2002 Nature

Lecture 9: General circulation

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☑ **What is atmospheric circulation? Ocean gyre? Thermocline circulation?**

☑ **How it works?**

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