



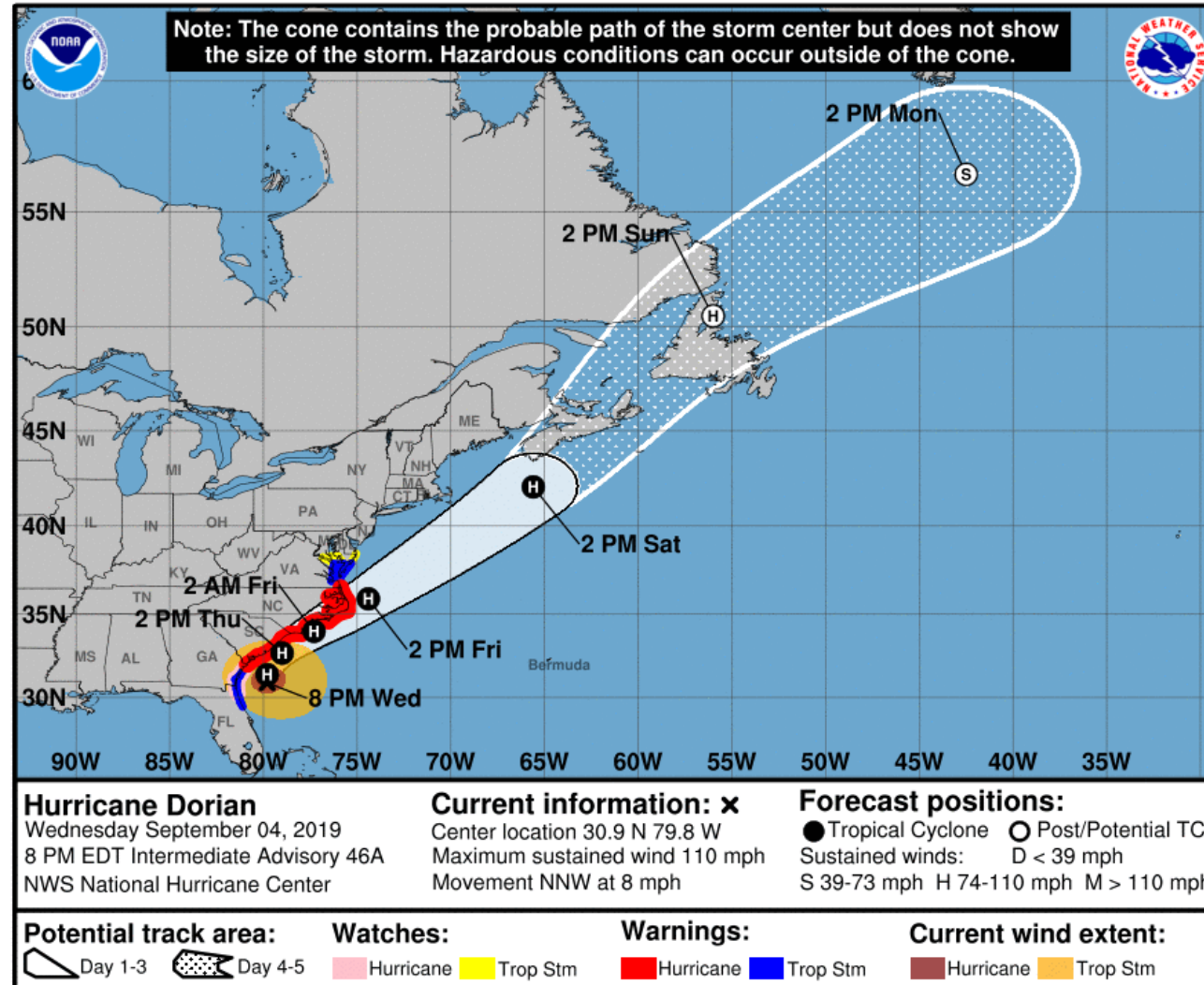
Class 4: The ocean's effect on climate

- How do ocean currents affect regional and global climate?
- How does the ocean impact temperature and carbon dioxide levels?

Learning Objectives

1. Draw a sketch of major ocean circulation patterns including overturning
2. Predict what would happen if ocean circulation were perturbed, specifically if overturning were to slow or cease
3. Explain how ocean currents result in the observed global distribution of climates
4. Describe how the ocean affects atmospheric carbon dioxide levels and temperature

Climate in the news



Webcam watching...storm live if the cams survive!

<http://surfchex.com/web-cams/>

<https://www.surflines.com/surf-report/cape-hatteras-lighthouse/5842041f4e65fad6a7708a38>

The screenshot shows a web browser window with the URL surfchex.com. The page features a dark blue navigation bar with the 'Surfchex' logo and menu items for WEATHER, CAMS, ABOUT, and CONTACT. Below the navigation bar is a promotional banner for 'Stand Up Putter - S7K Golf' with an 'OPEN' button. The main content area displays a Google Map of the Southeastern United States, including parts of North and South Carolina. Numerous red location markers are placed along the coast and inland, indicating the locations of SurfChex webcams. A legend at the bottom of the map states: 'Each marker is a SurfChex web cam. Click the marker for more info.'



NATIONAL HURRICANE CENTER and CENTRAL PACIFIC HURRICANE CENTER

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION



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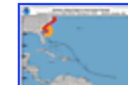
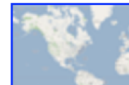
HURRICANE DORIAN

[Home](#) [Public Adv](#) [Fcst Adv](#) [Discussion](#) [Wind Probs](#) [Graphics](#) [Archive](#)

[U.S. Watch/Warning](#) [Local Products](#) **UPDATE**



Wind
Probs:



gs and
Wind



k
Mes

The initial motion is now 345/8. Dorian is moving around the western end of the subtropical ridge, and it should recurve northward and northeastward into the mid-latitude westerlies during the next 12-36 h. This motion should bring the center of Dorian near the coast of South Carolina in about 24 h and near or over the coast of North Carolina during the 36-48 h period. After that time, the cyclone is forecast to accelerate northeastward into the Atlantic toward the Canadian Maritimes, with a quick northeastward motion continuing through 120 h. The track guidance remains very tightly clustered, and the new forecast track is little changed from the previous forecast. It should be noted that the track is close to and almost parallel to the coast of the southeastern United State, and any deviation to the left of the track could bring the center onshore anywhere in the Carolinas.



DISASTER RELIEF

PROGRAMS

ABOUT

LATEST NEWS

GET INVOLVED

DONATE



SEPTEMBER 4, 2019

First meals served to families in the Northern Bahamas after Hurricane Dorian



José Andrés ✓

@chefjoseandres



We @WCKitchen are 80 miles from #HurricaneDorian eye & feeling this!! Imagine what the people of Abaco+Grand Bahamas will experience! Bahamas @opmthebahamas Government will need major help! @ClintonGlobal @RedCross @TeamRubicon ...Florida should also get ready for major winds!

<https://www.pbs.org/newshour/show/how-chef-jose-andres-is-working-to-feed-the-storm-stricken-bahamas>

Menu

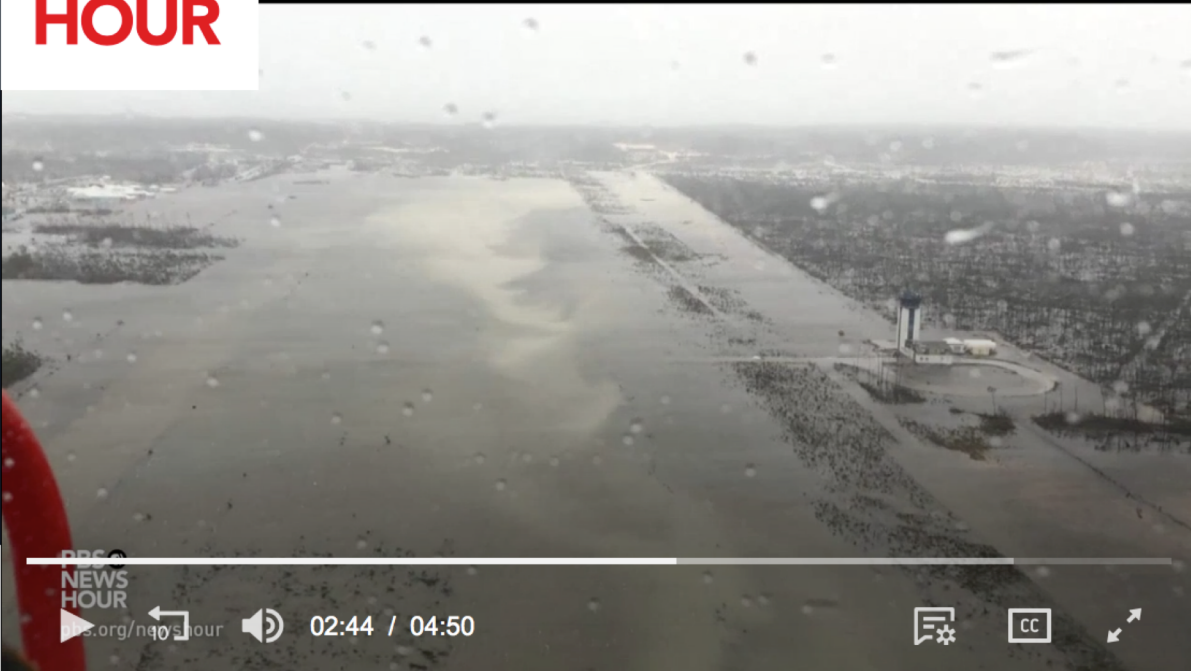
Full Episodes

Podcasts

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How chef José Andrés is working to feed the storm-stricken Bahamas

Sep 3, 2019 6:55 PM EDT

PBS
NEWS
HOUR

02:44 / 04:50



Related

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Reminder: Geo Dept BBQ, Today @ 4pm



Geology Department Fall BBQ

Thursday September 5th, 2019
4:00 to 5:00 p.m.

Gather on east-side lawn of Delehanty.

Enjoy delicious grilled food &
meet fellow students, faculty and staff.

RSVP to rhopps@uvm.edu by Wed., Sept 4th before 4pm and
indicate food allergies or food preferences if any.

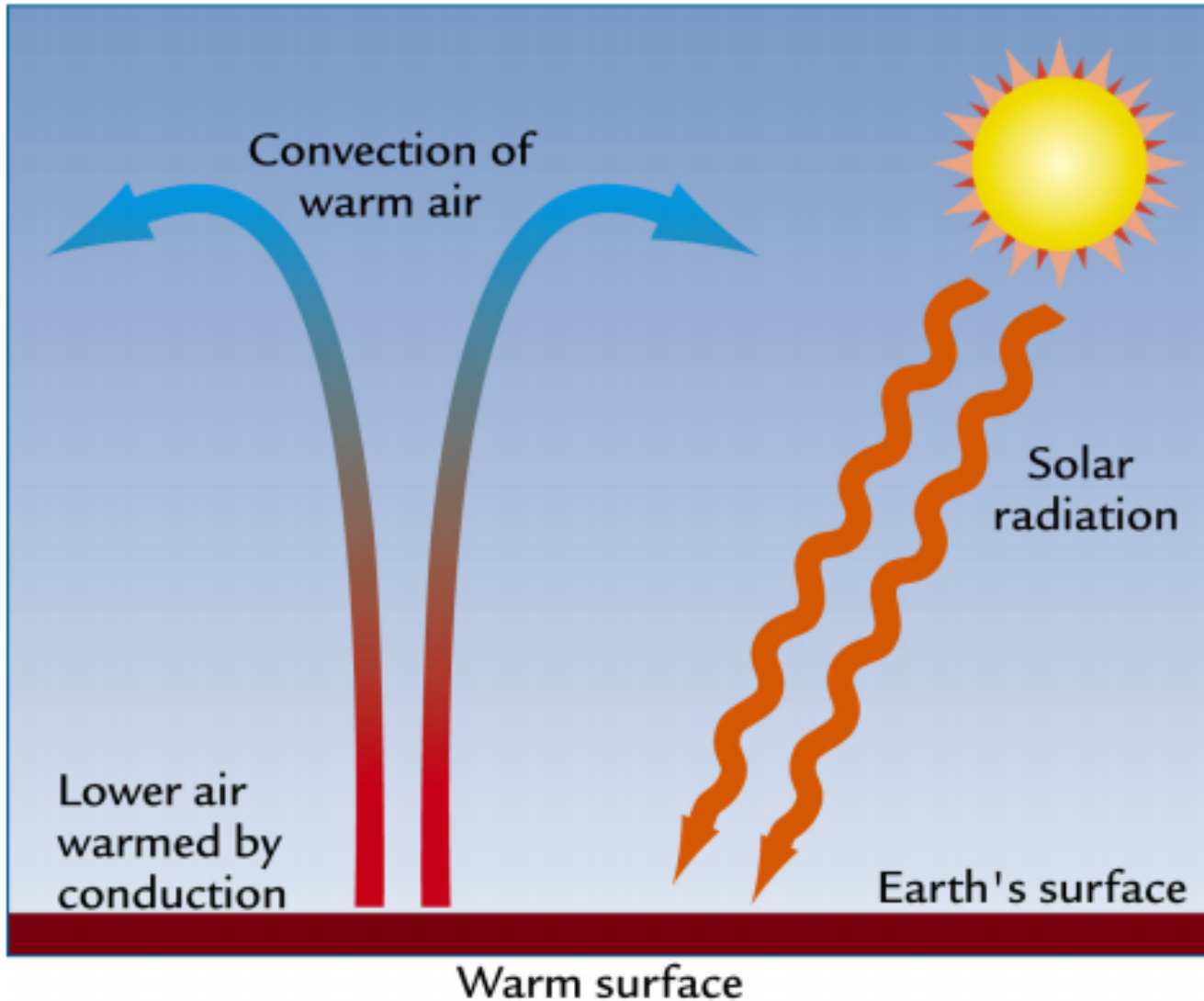


Class feedback blog – help us improve

- Questions about lecture
- Correct inaccuracies
- Questions about reading
- Ways we could improve teaching and learning
- One of us will check during class to see if there are questions we can address “live”

[https://blog.uvm.edu/pbierman-
improveclimateclass/](https://blog.uvm.edu/pbierman-improveclimateclass/)

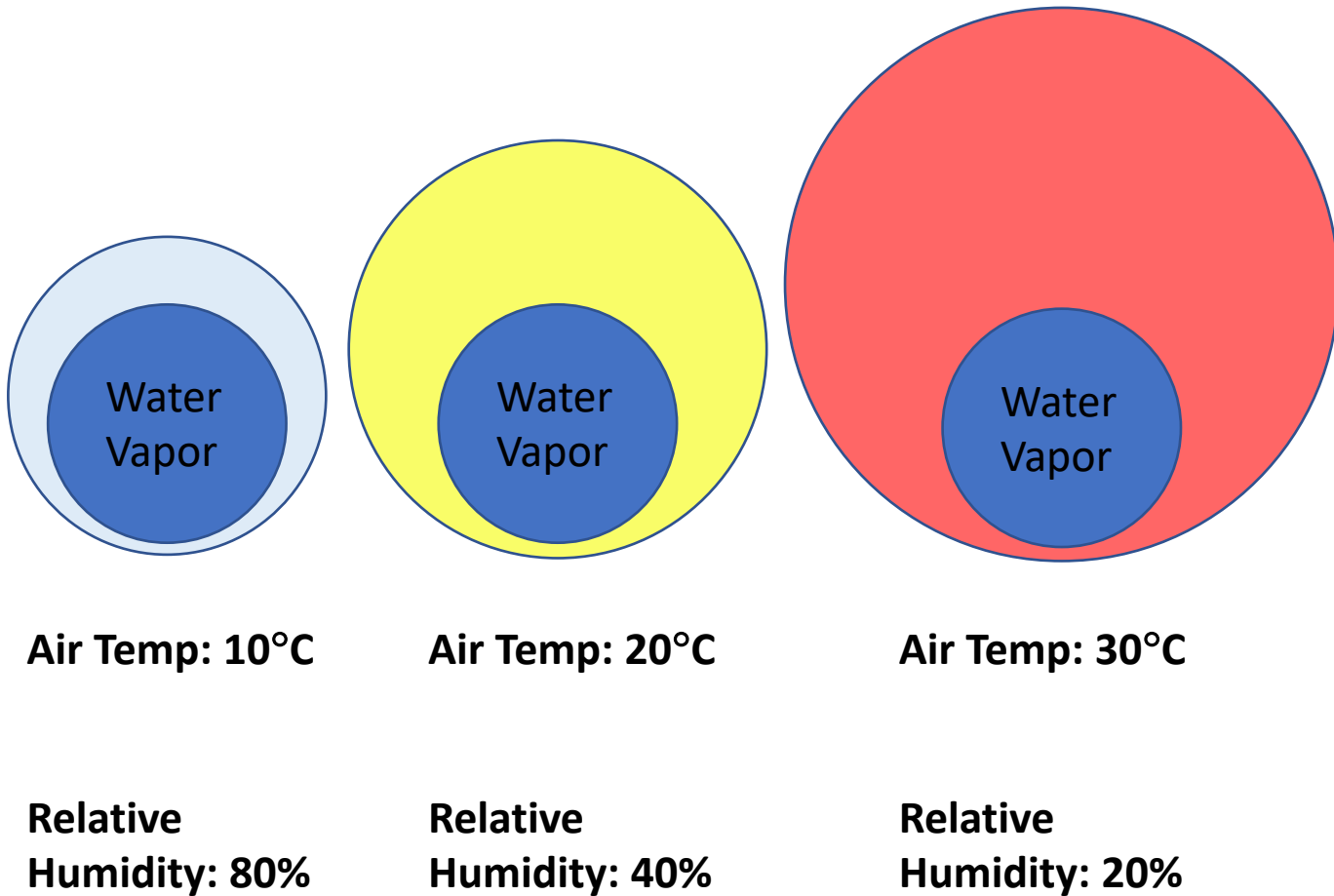
Revisiting Atmospheric Circulation



Important Dynamic #1:

1. Heated air becomes less dense and rises
2. Rising air expands and cools
3. Eventually, air cools and increases in density until it matches the surrounding air, stopping its rise

Revisiting Atmospheric Circulation

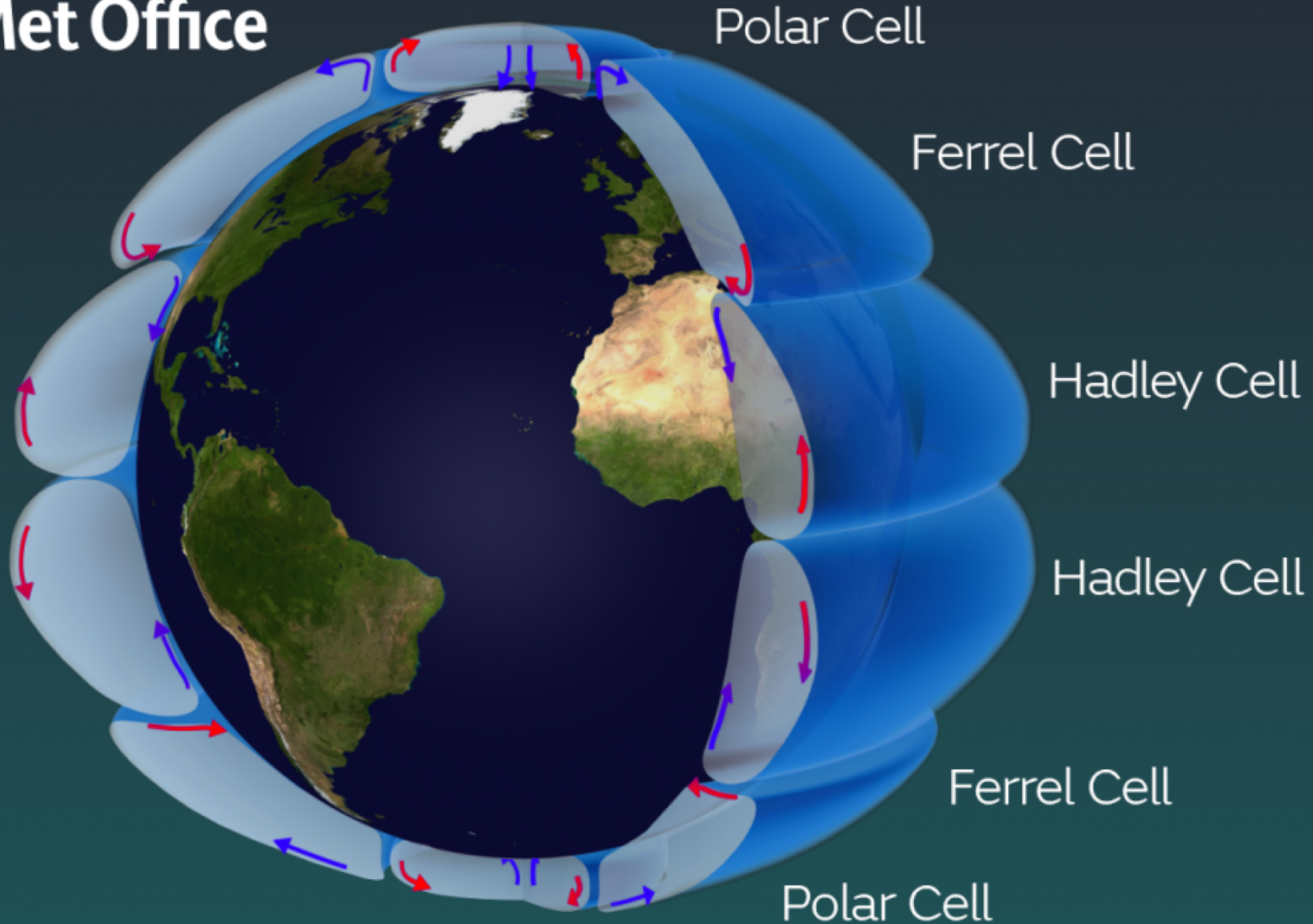


Important Dynamic #2:

1. Warm air can hold more water vapor
2. When air reaches its water carrying capacity, liquid water condenses

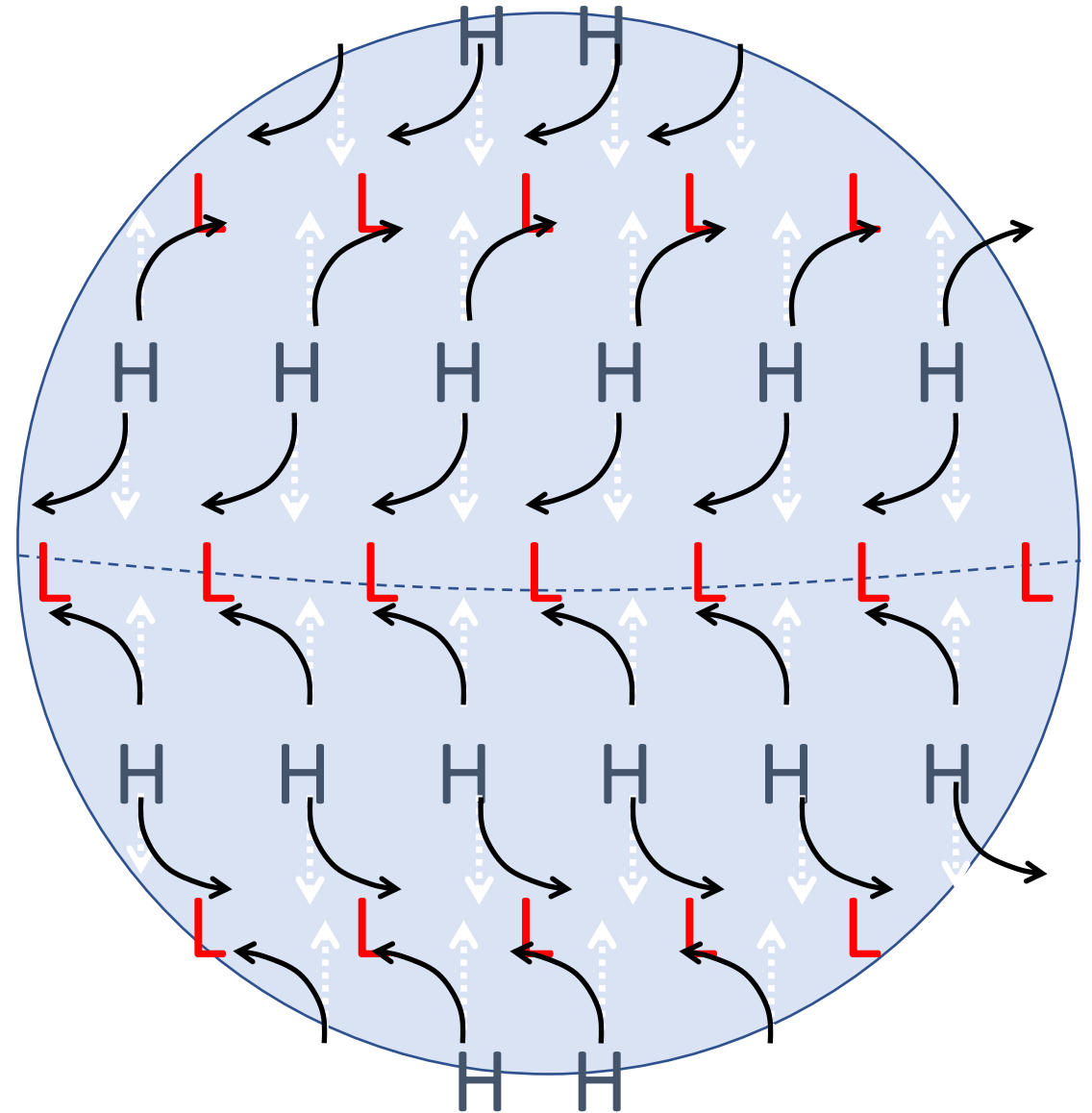
Revisiting Atmospheric Circulation

 **Met Office**

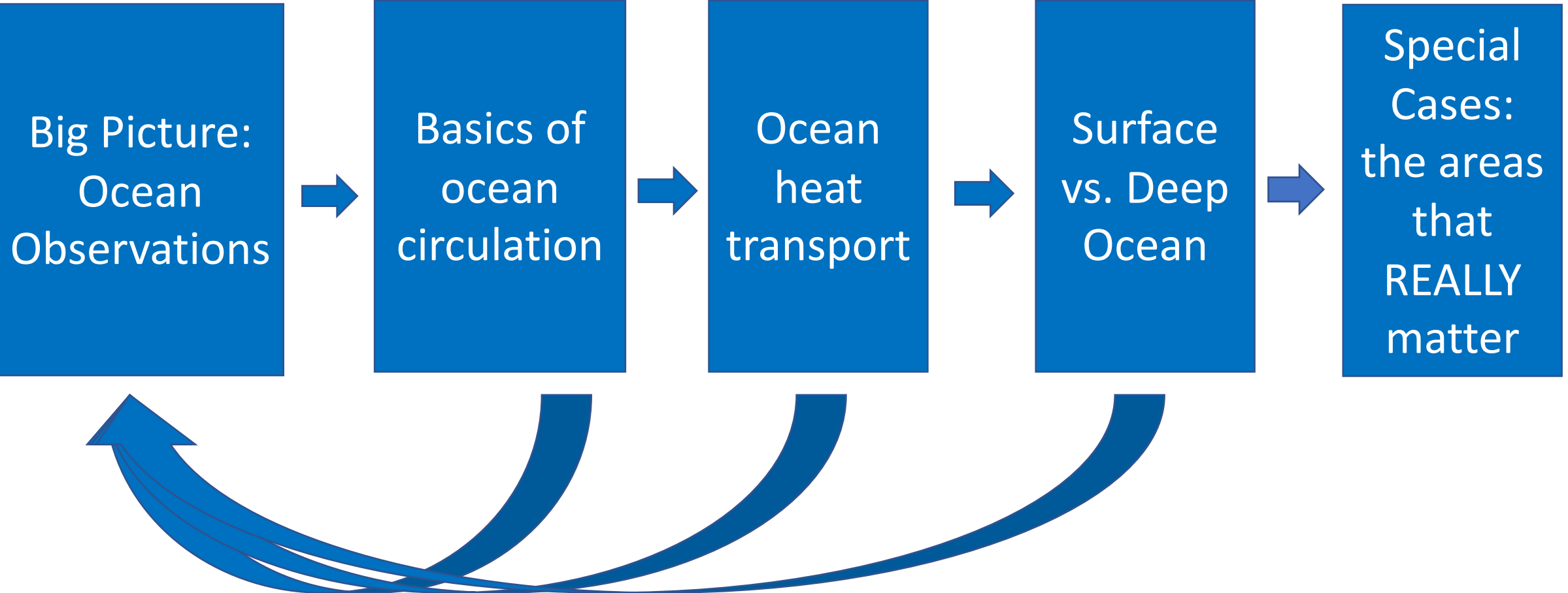


Revisiting Atmospheric Circulation

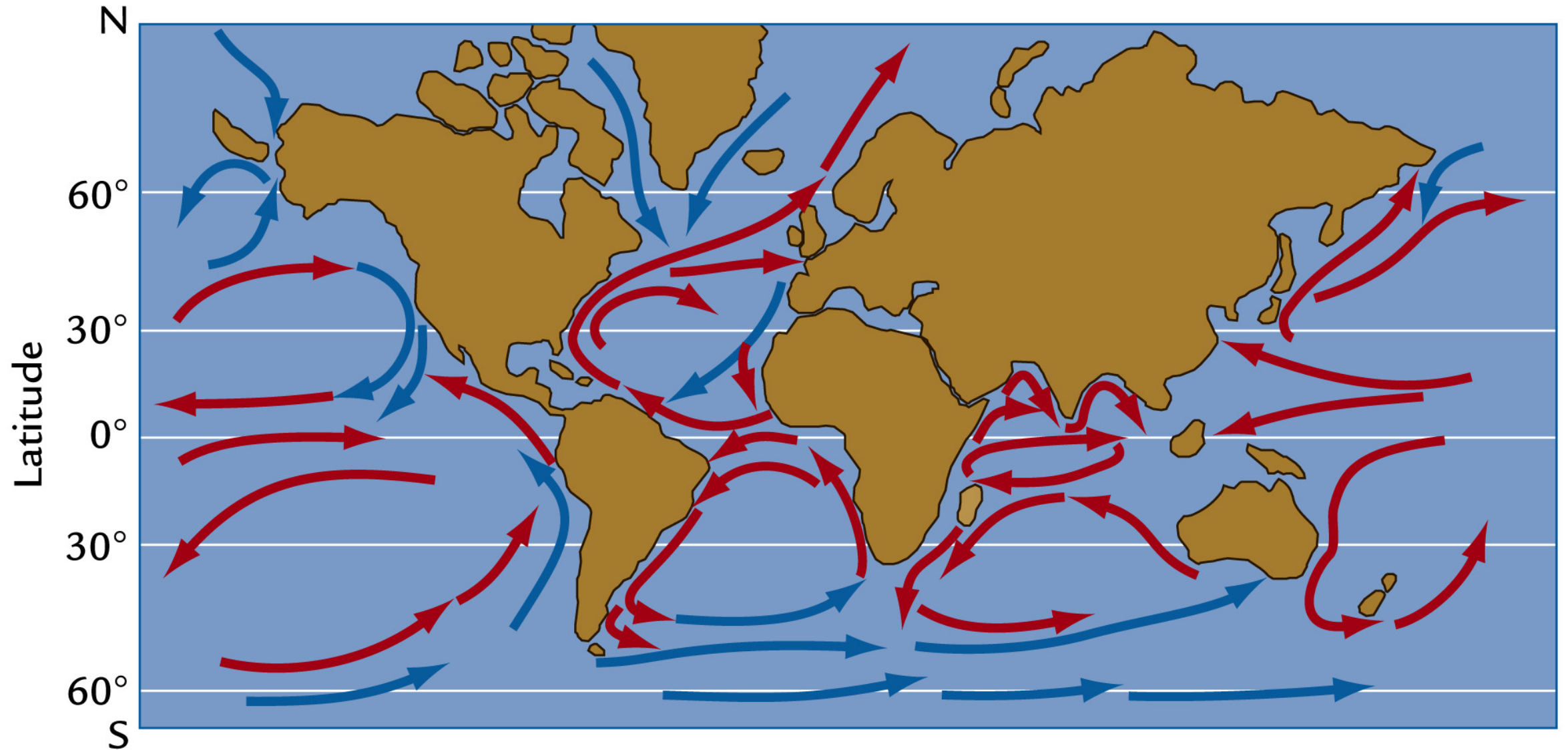
Coriolis effect causes wind to be deflected to the right in the NH, to the left in the SH



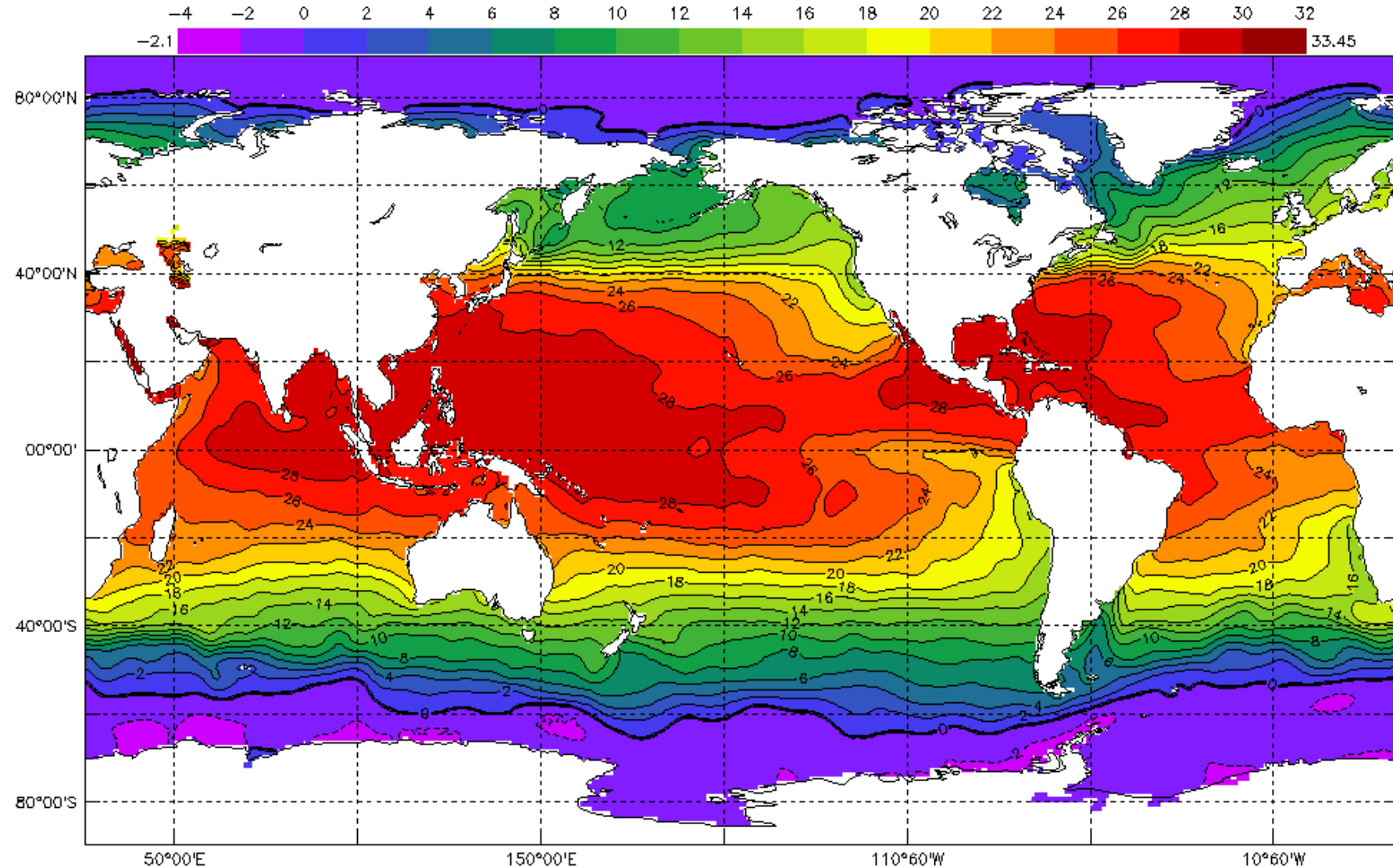
Check In



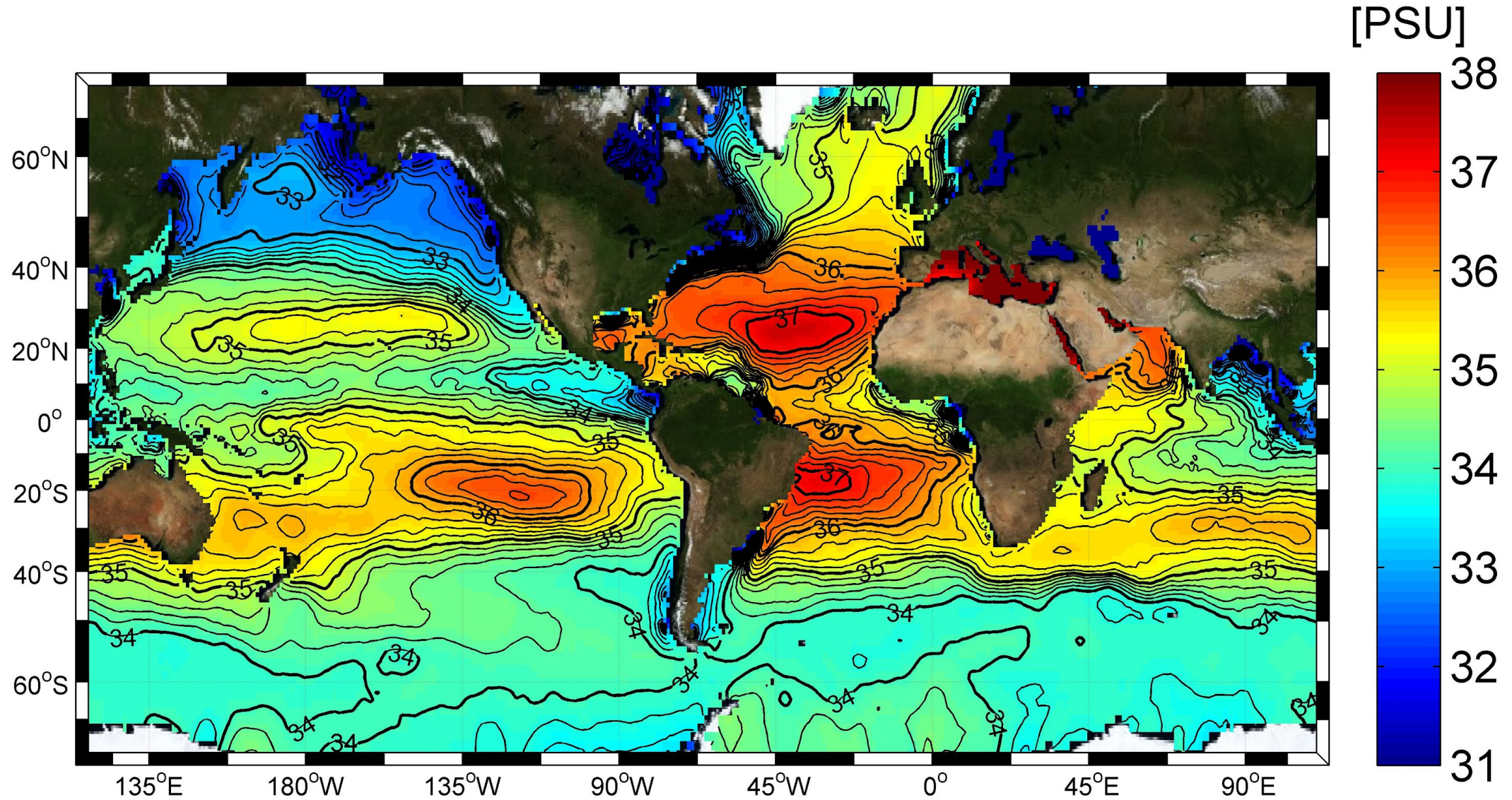
Big Picture: Ocean Observations (Currents)



Big Picture: Ocean Observations (Temperature)



Big Picture: Ocean Observations (Saltiness)

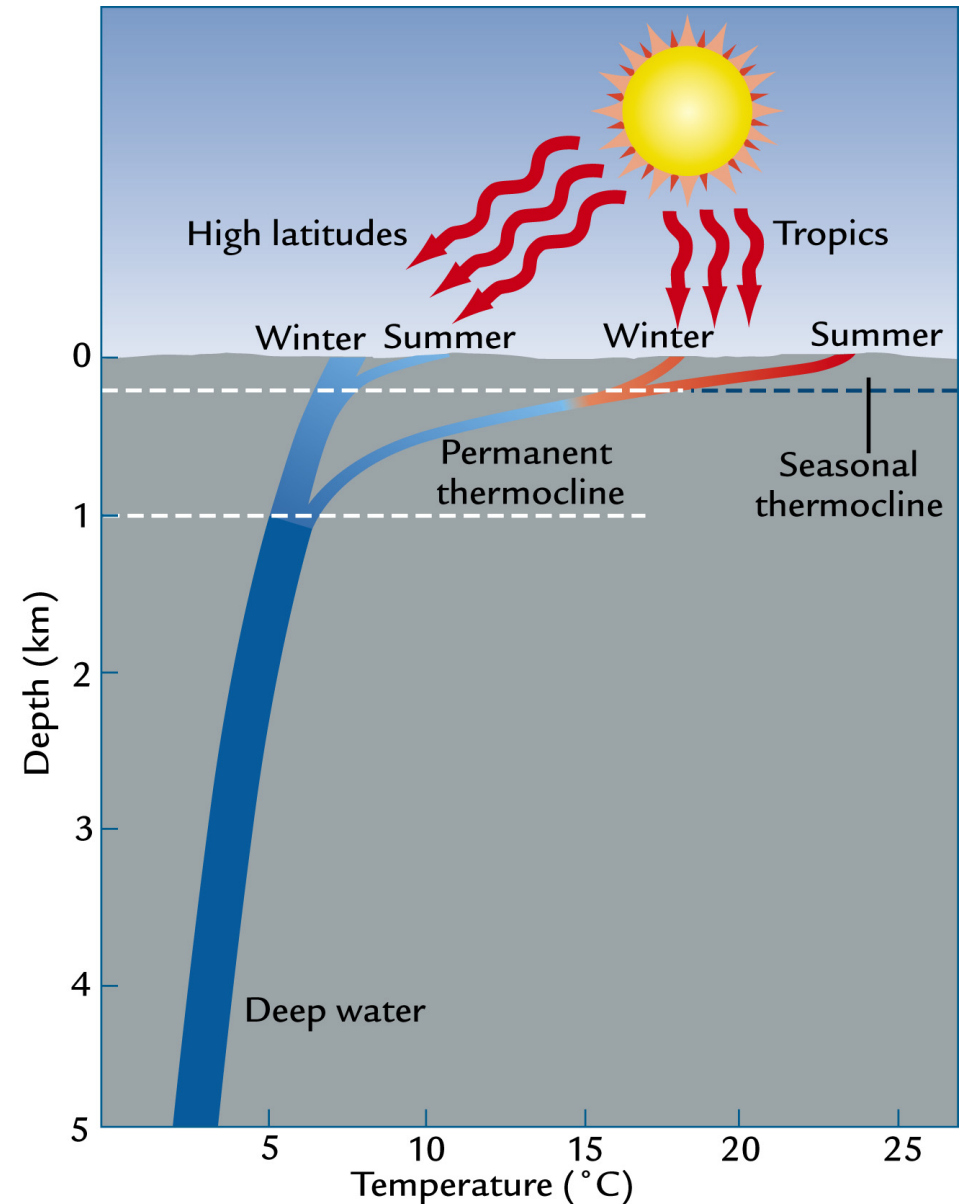


Fundamentals of the Oceans

Ocean Surface Heating

Important Dynamic #1:

- Surface ocean heated by sun, becomes less dense
- But surface water already on top of colder, denser water!
- No convection

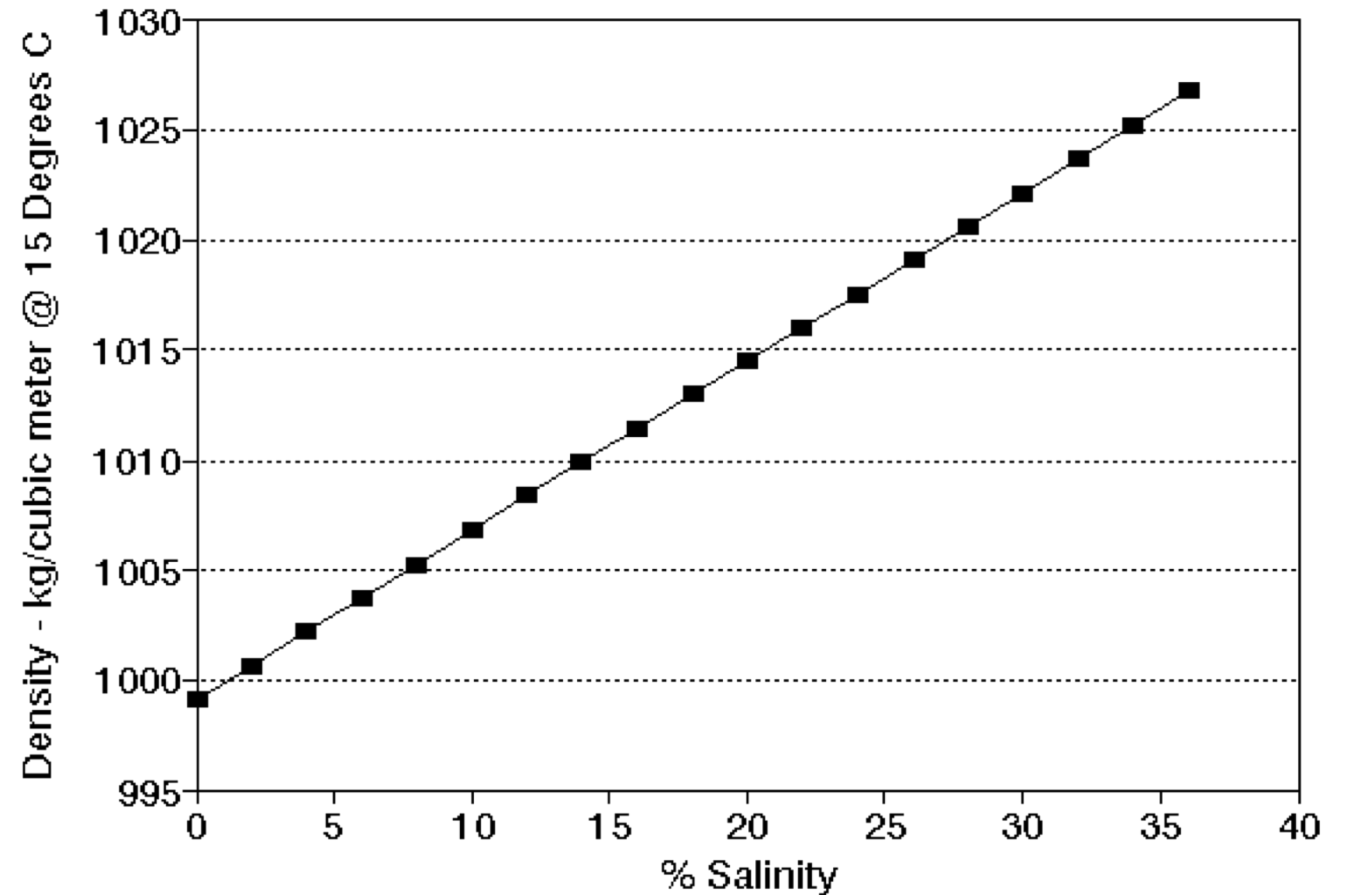


Ocean Water Contains Salt

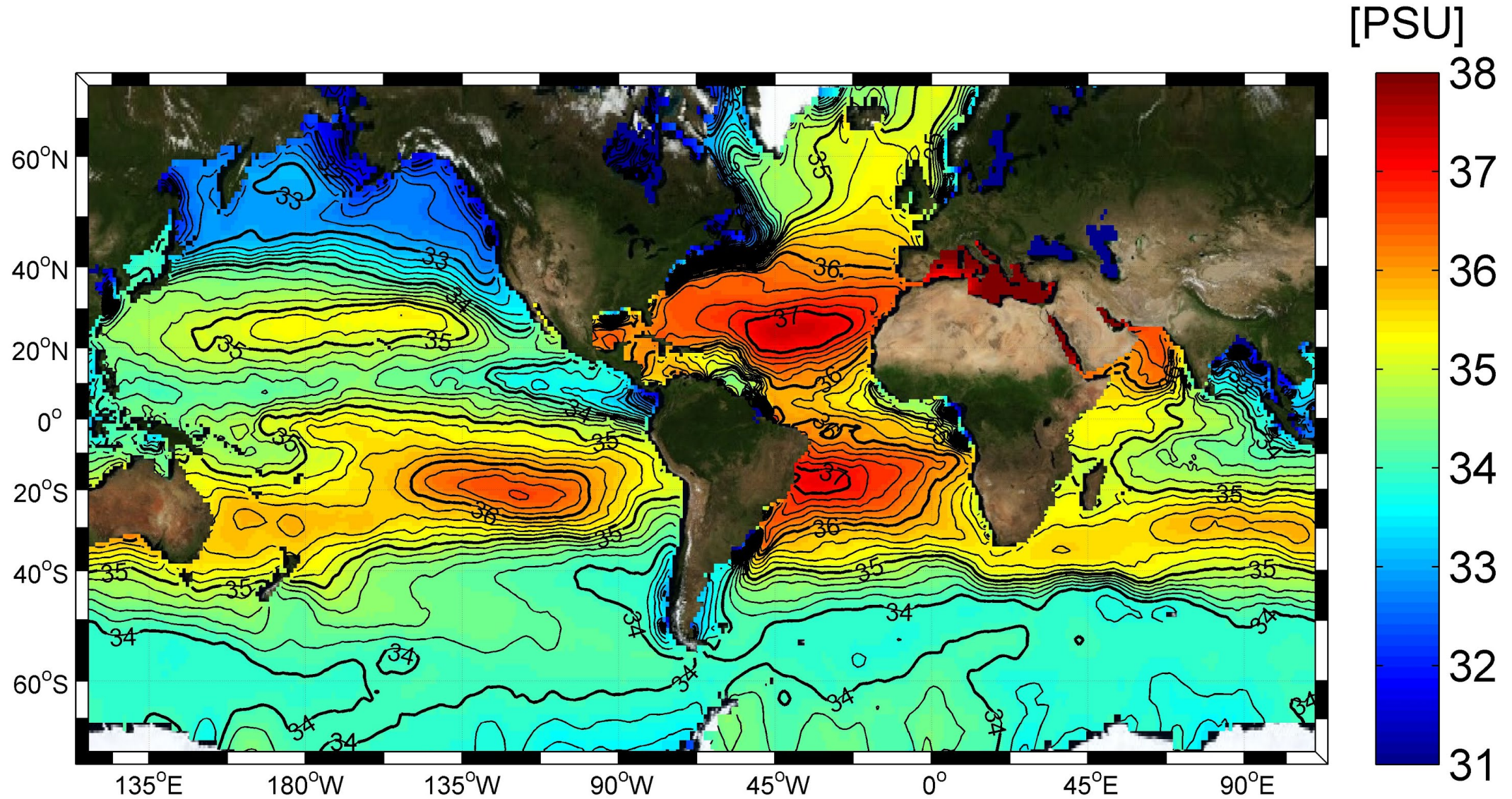
Important Dynamic #2:

- Ocean water density affected by both temperature *and* salt content
- More salt = more dense

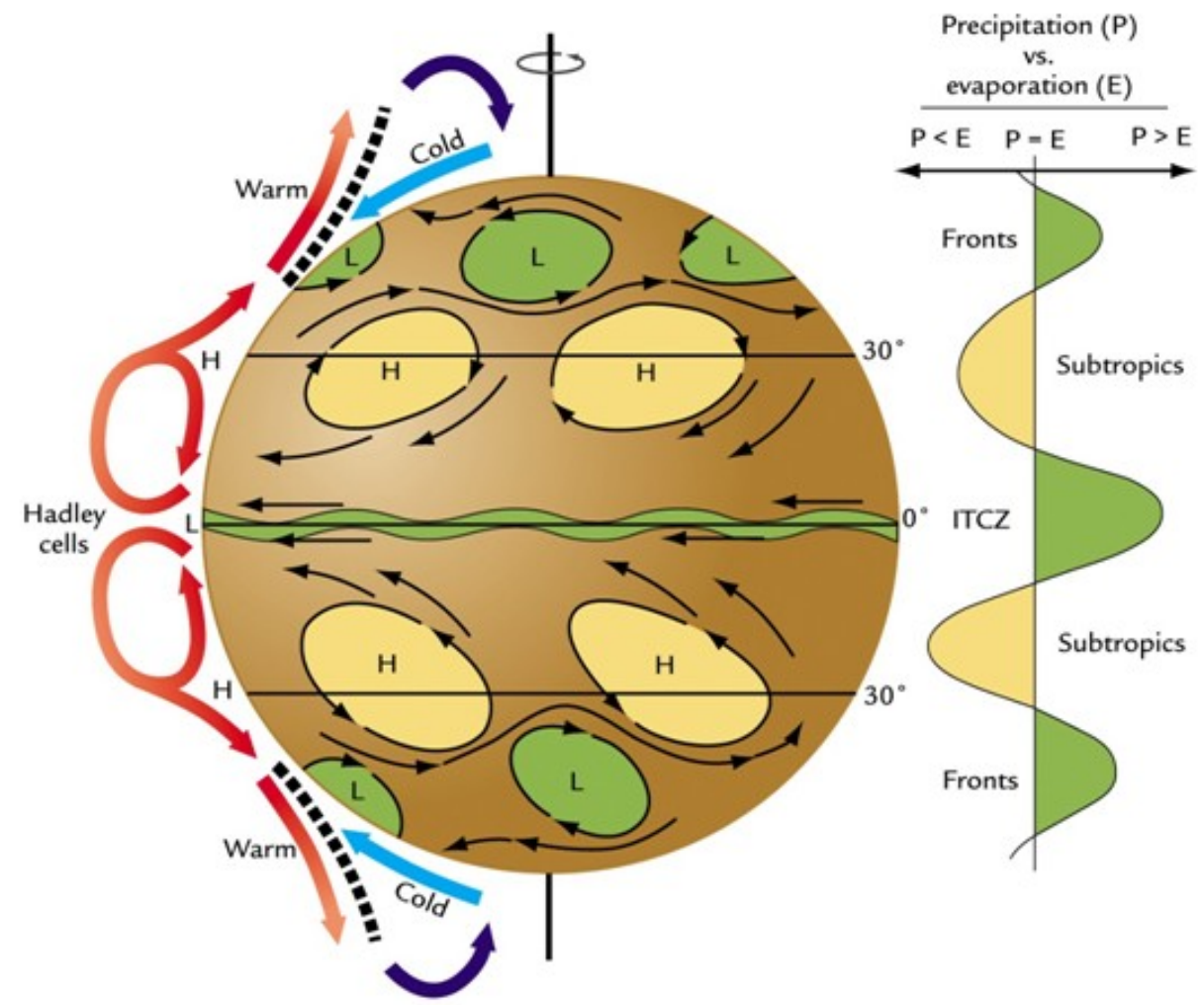
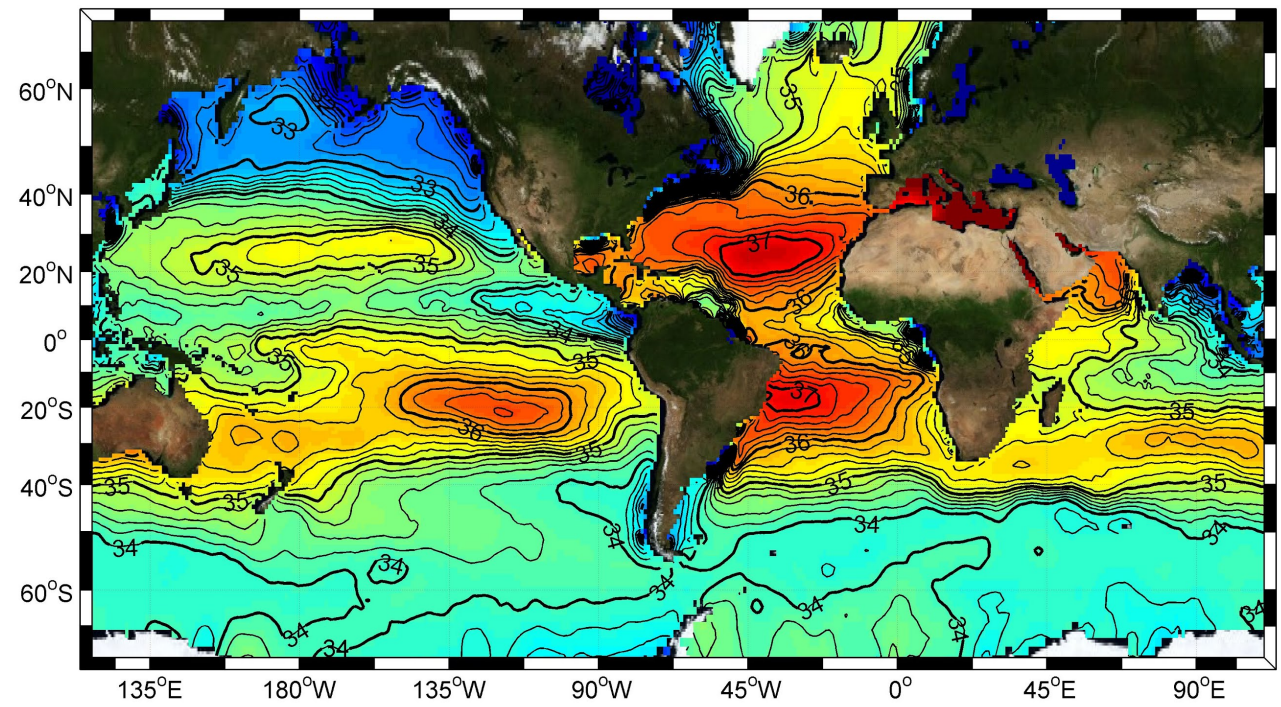
Effect of Salinity on Density



Ocean Water Contains Salt



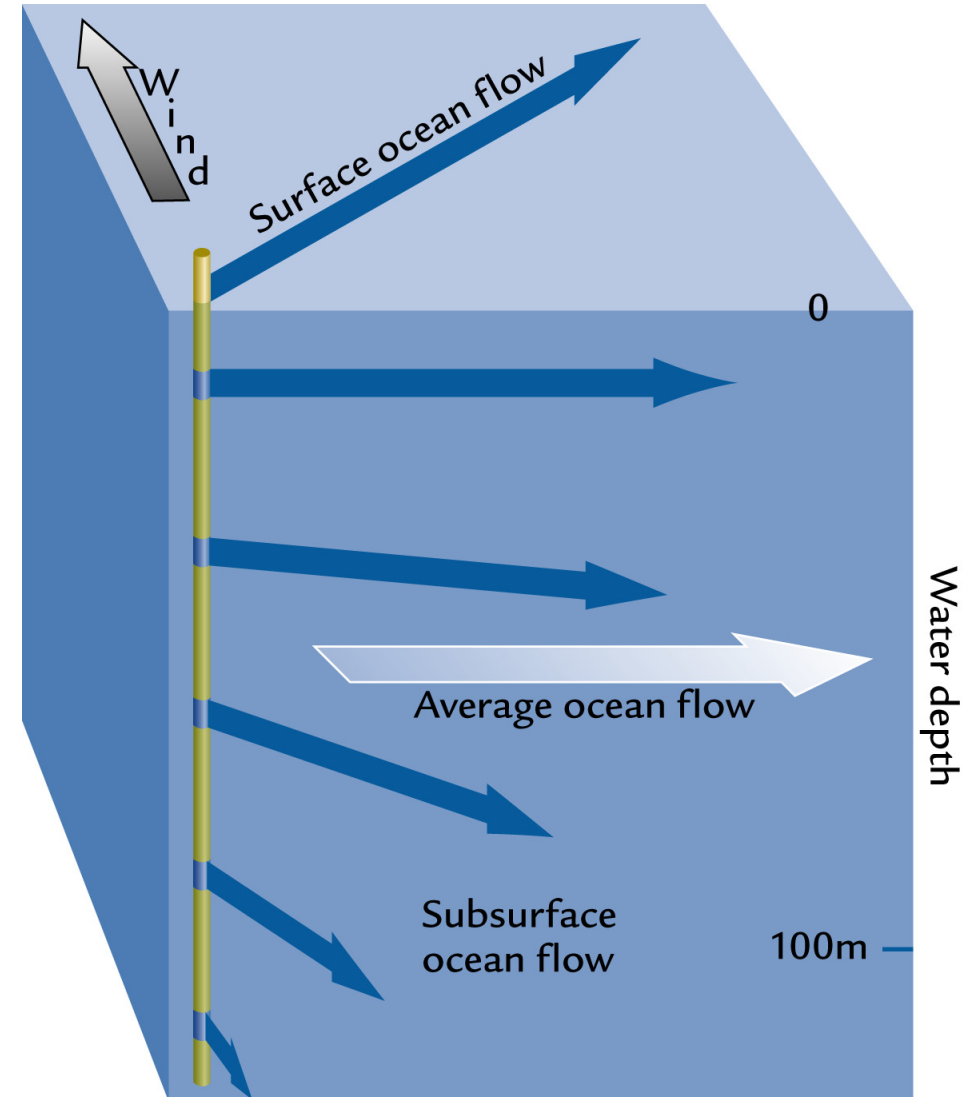
Ocean Water Contains Salt



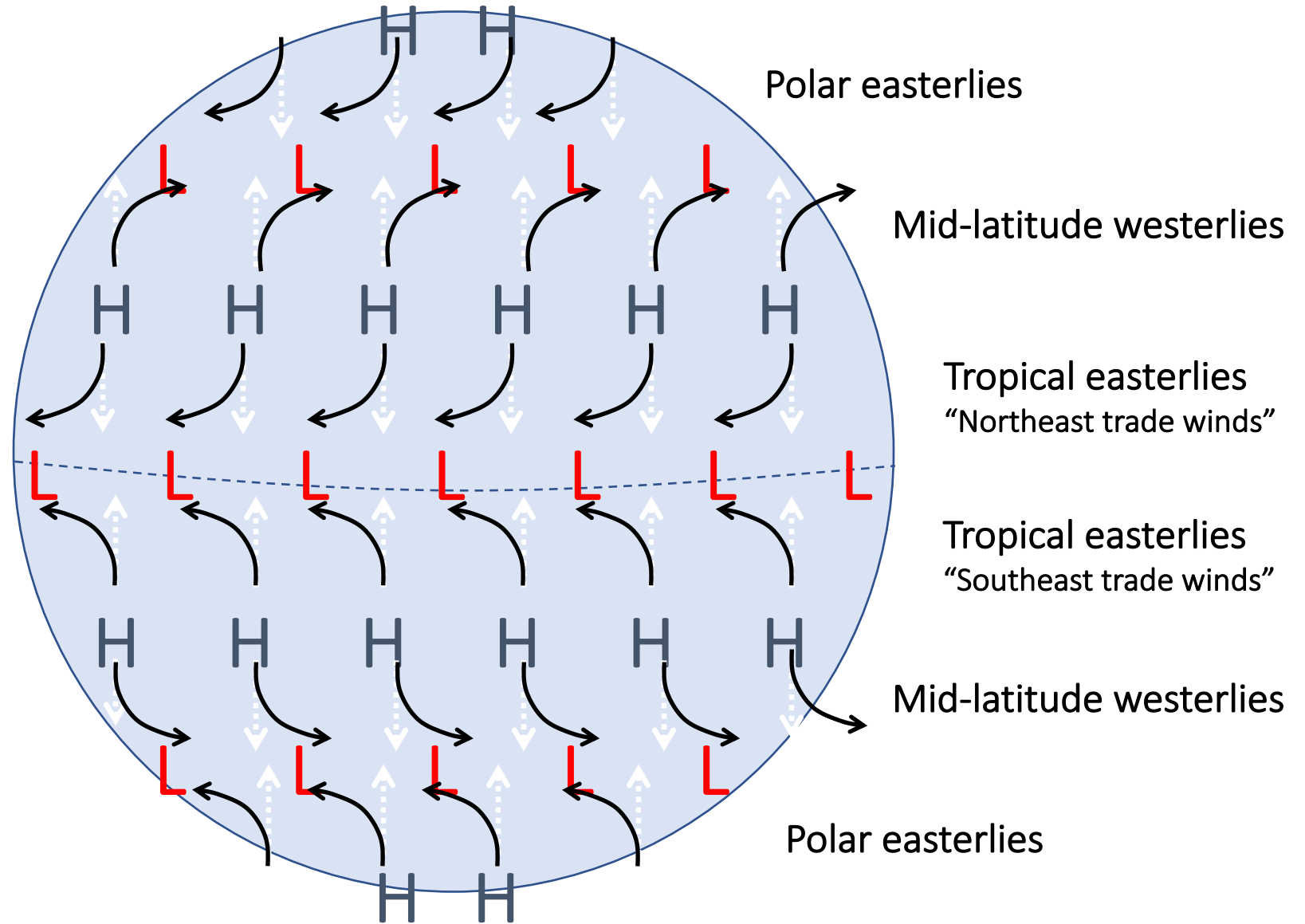
Wind Drives Ocean Currents

Important Dynamic #2:

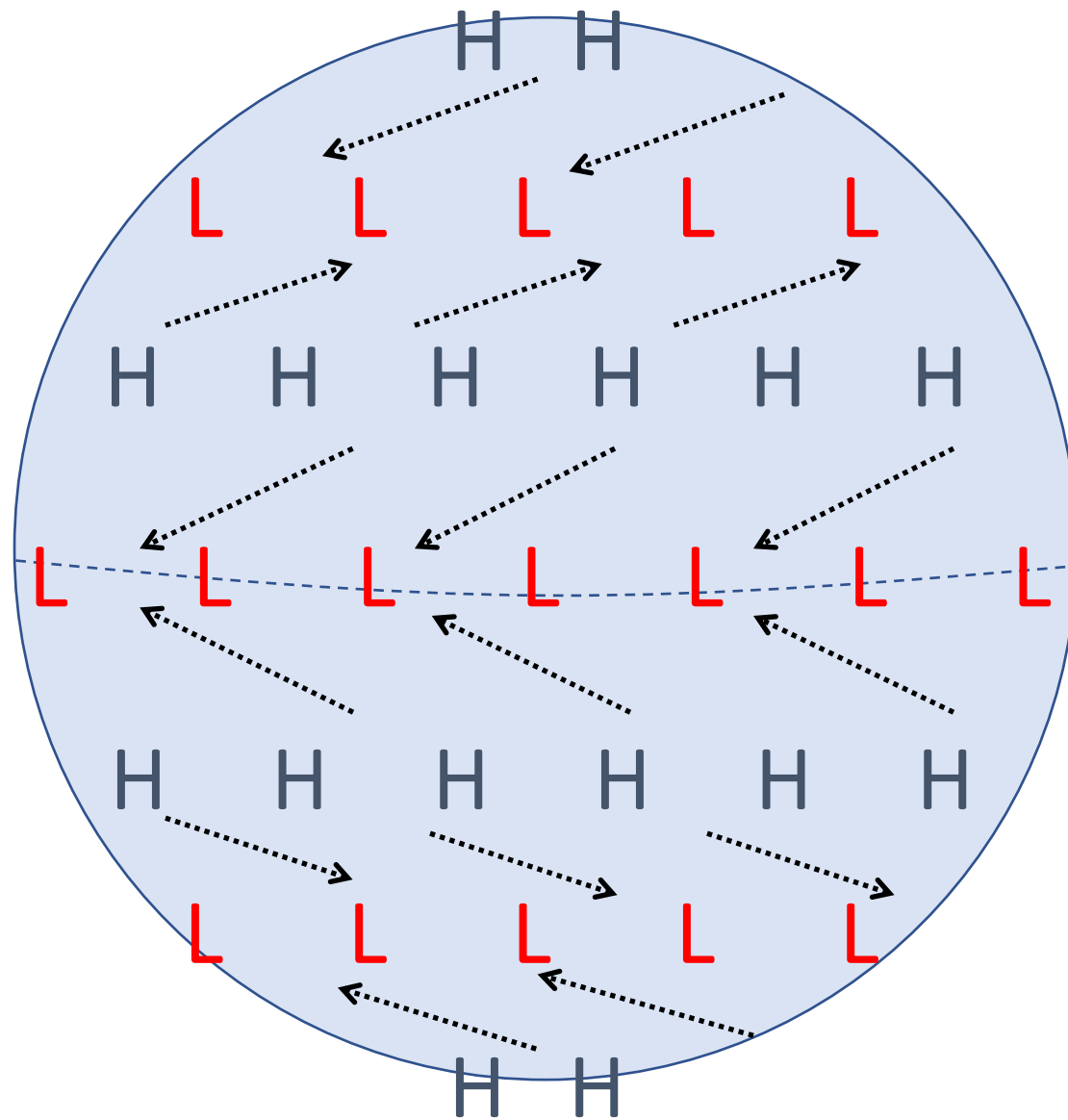
- Winds 'pull' at the ocean surface
- Coriolis effect deflects ocean flow at a 90° angle (right in NH, left in SH)



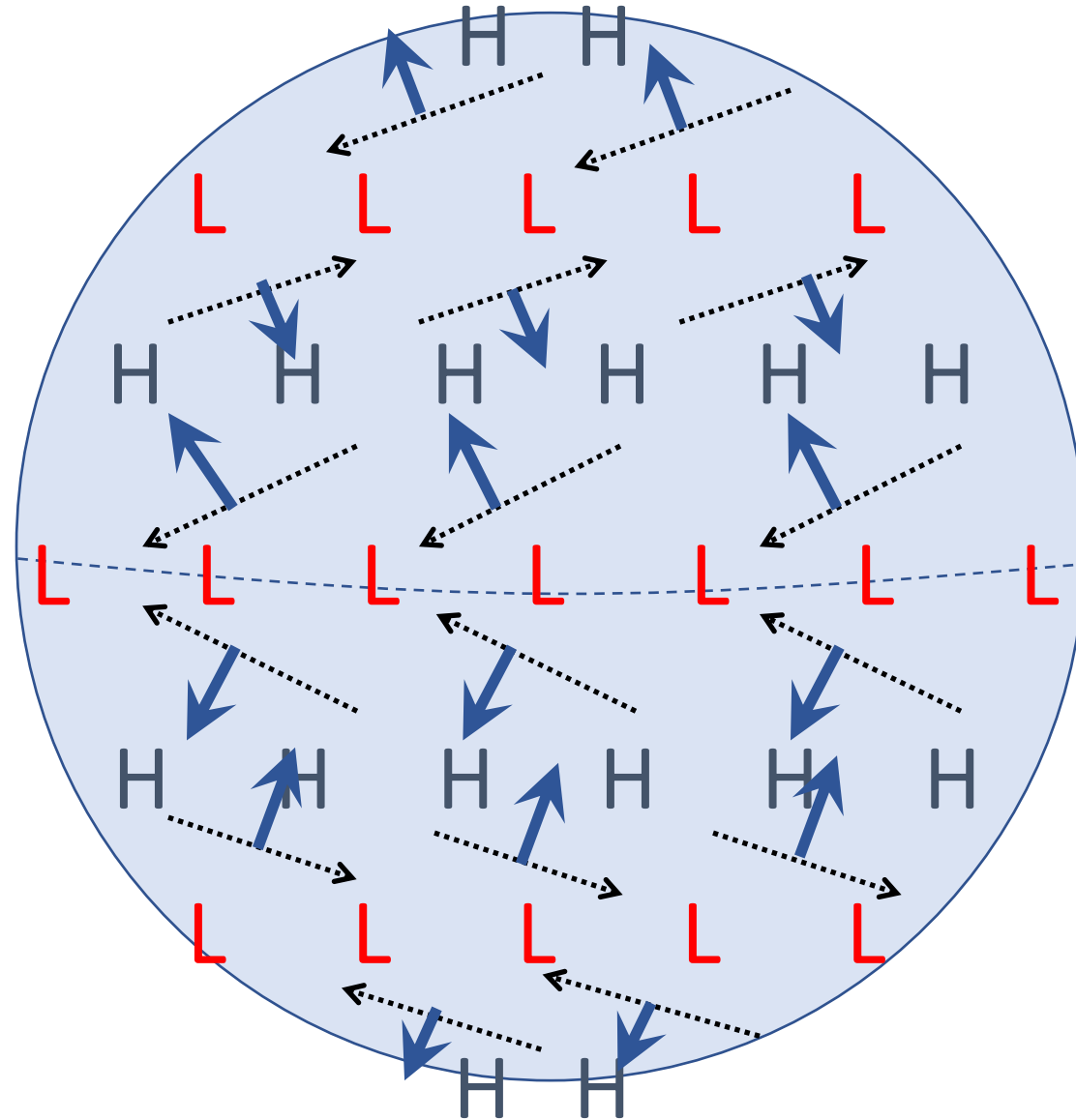
Wind Driven Ocean Currents



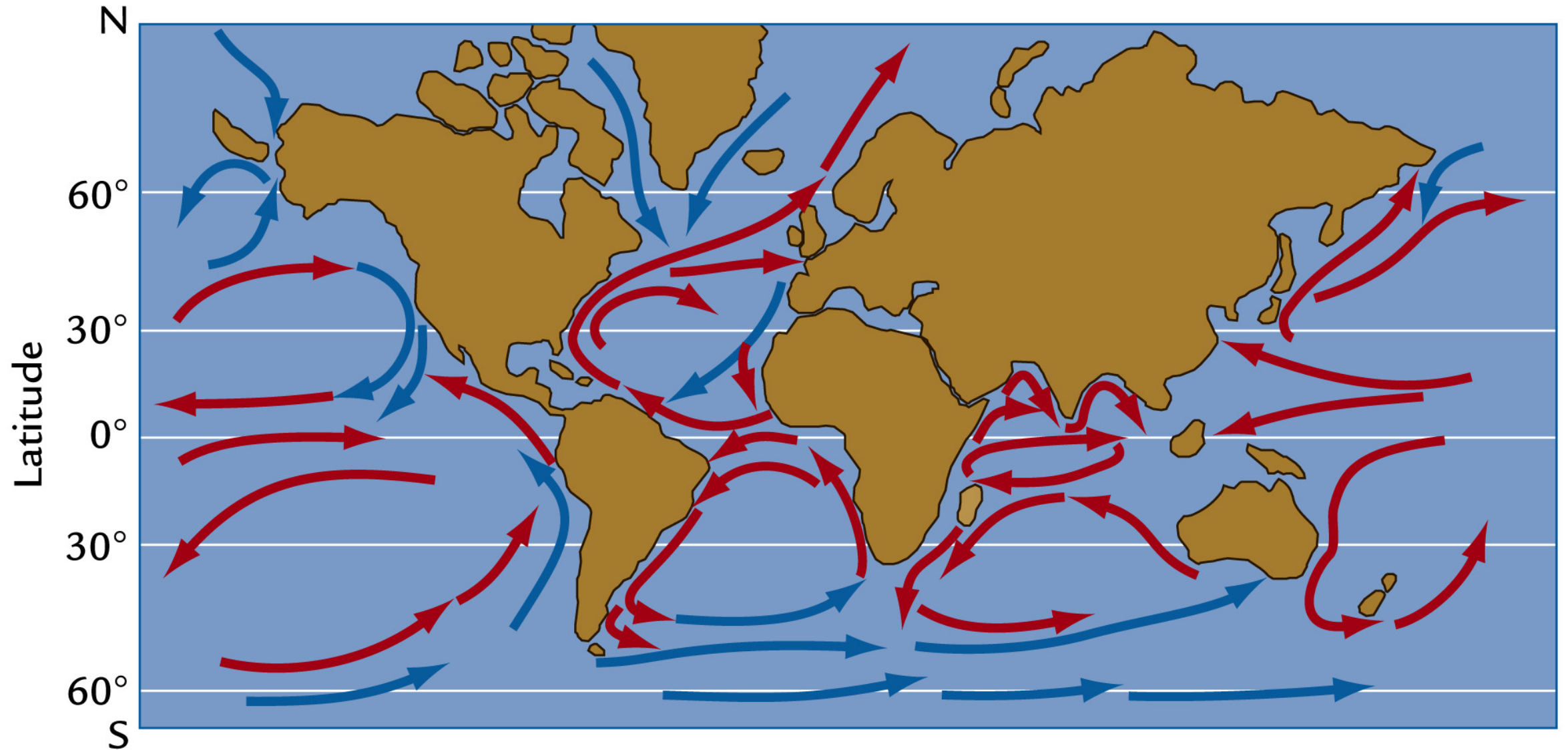
Wind-Driven Ocean Currents



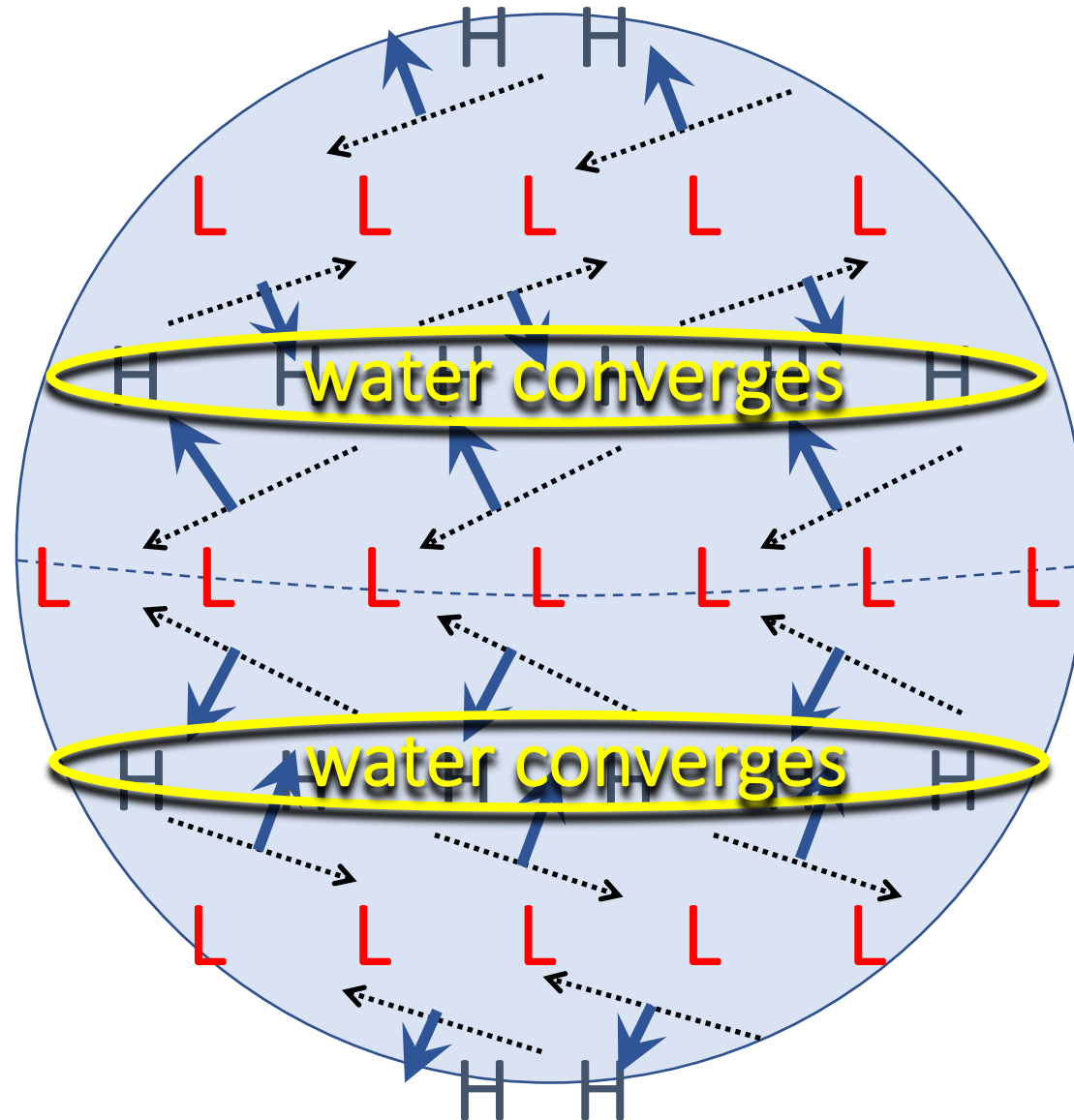
Wind-Driven Ocean Currents



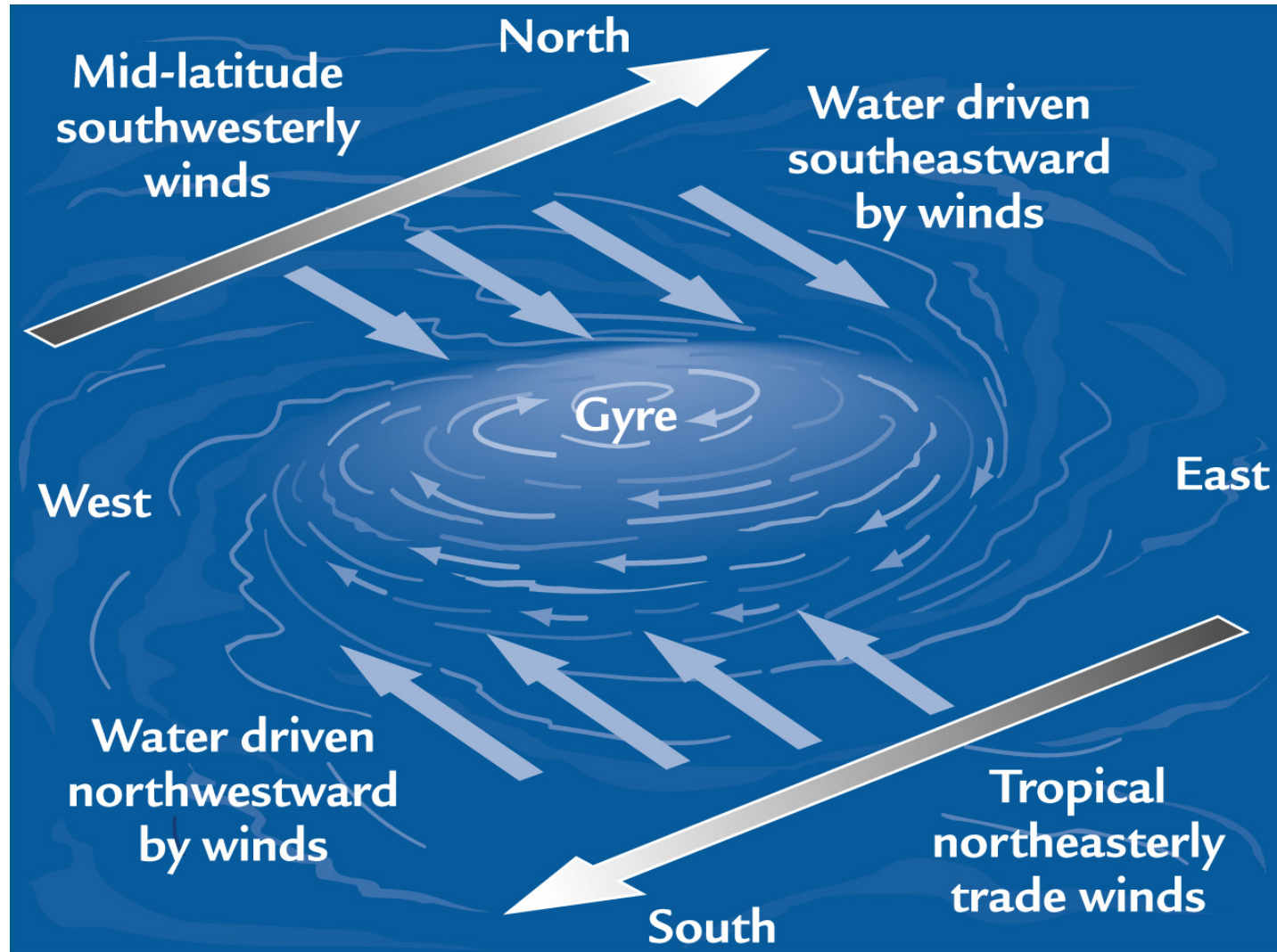
Revisiting Ocean Observations (Currents)



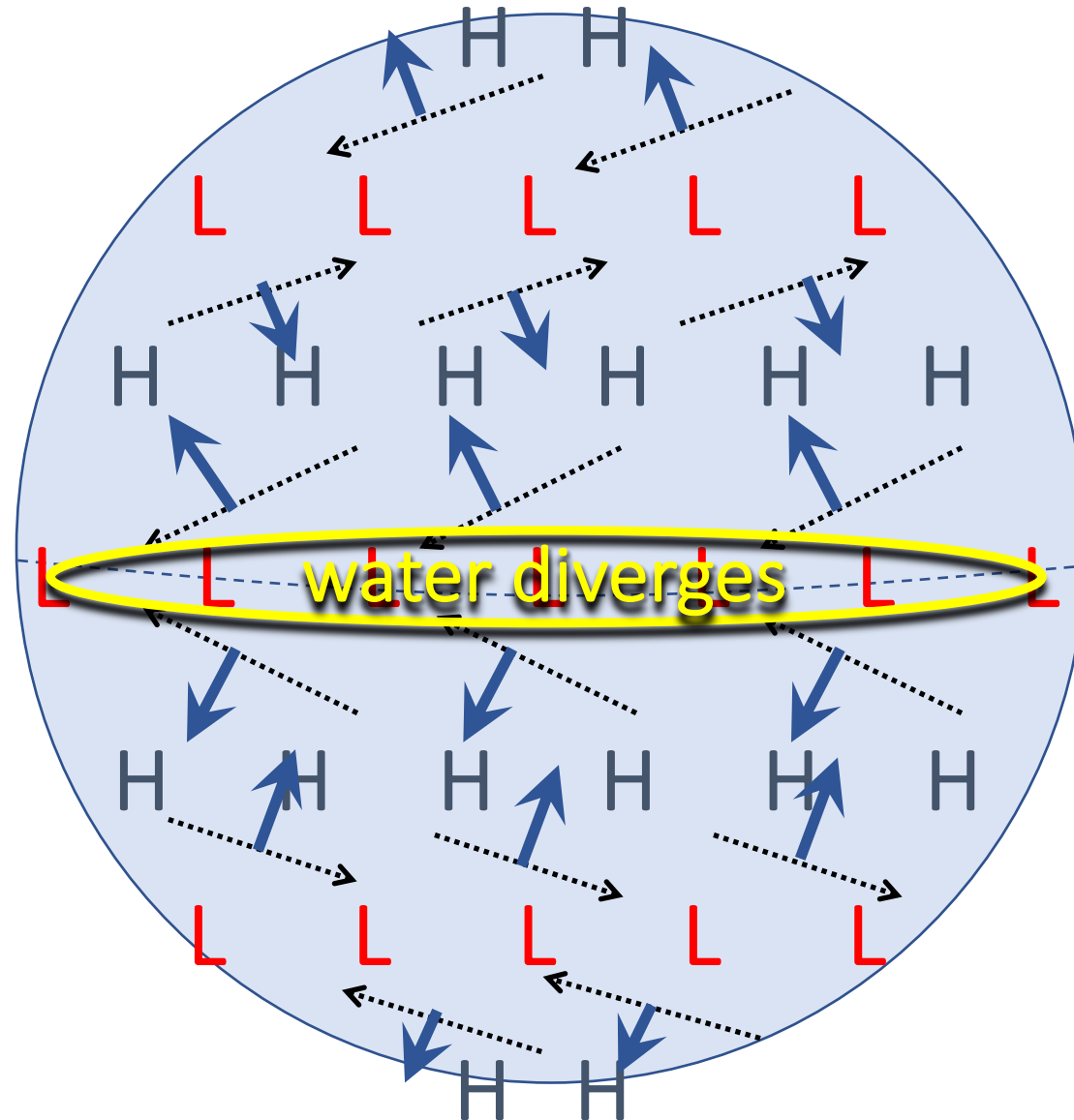
Wind-Driven Ocean Currents



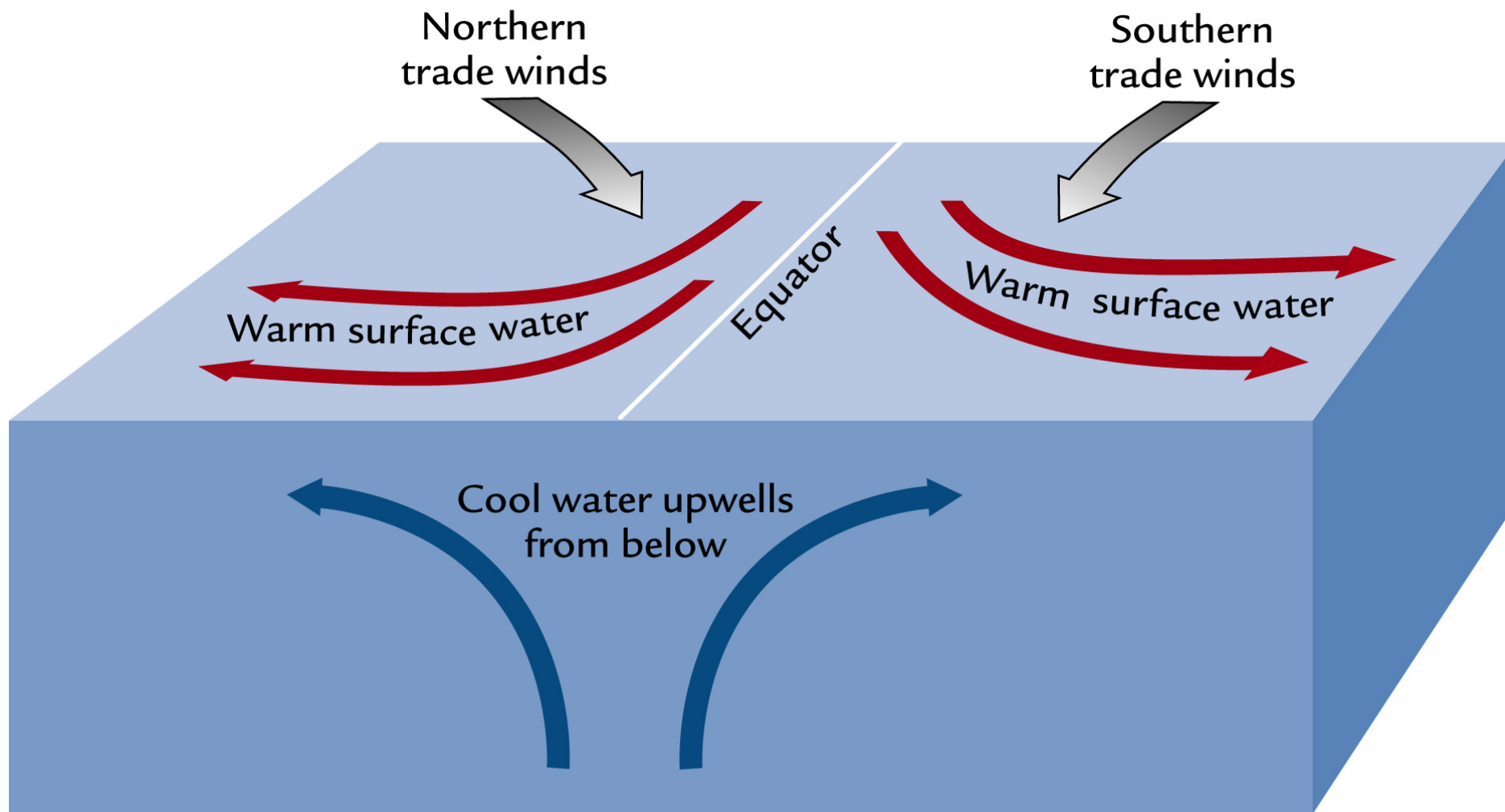
Wind-Driven Ocean Currents



Wind-Driven Ocean Currents

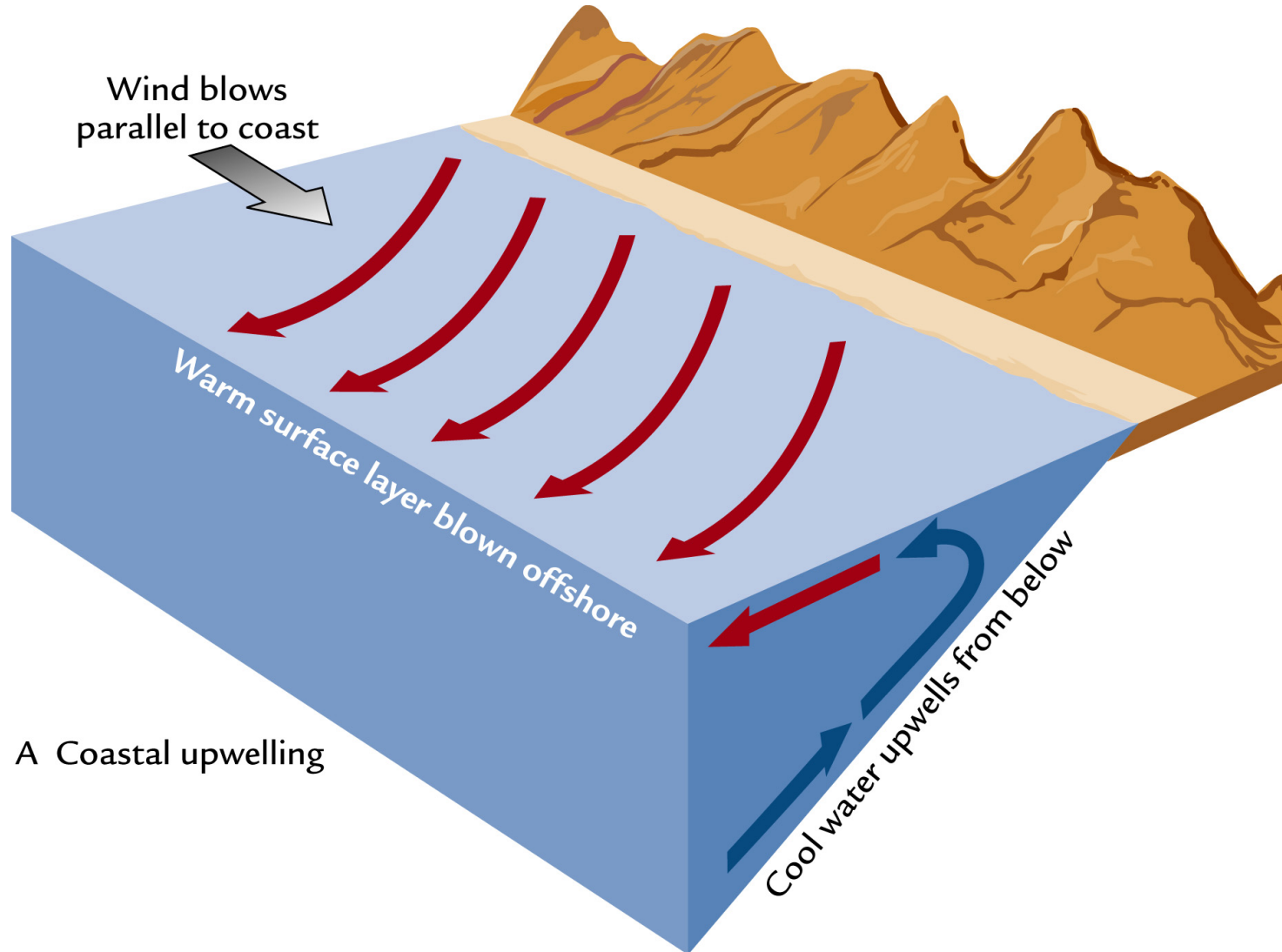


Wind-Driven Ocean Currents

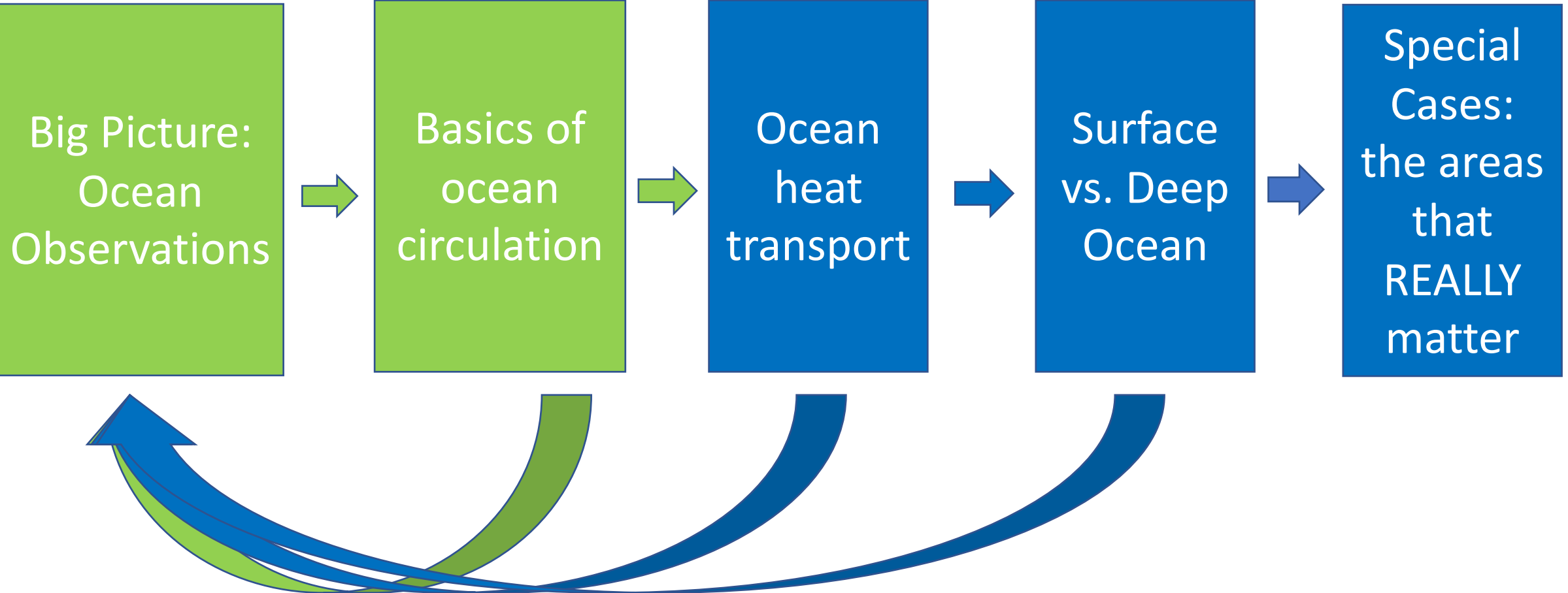


B Equatorial upwelling

Wind-Driven Ocean Currents



Check In



Comprehension Check

Ocean currents flow at 90° angles to the dominant wind direction because:

- A. The surface ocean is only pulled along by the right or left side of the wind column
- B. Gravity is pulling water down, which opposes the force of wind and causes it to flow at a 90° angle
- C. The Coriolis effect causes the top 100 m of surface ocean to flow to the right (left) of wind direction in the Northern (Southern) Hemisphere
- D. Surface waters are being 'pushed up' by less dense underlying water, causing a change in direction

How does all of this influence climate (and you)?

Ocean Heat Transport

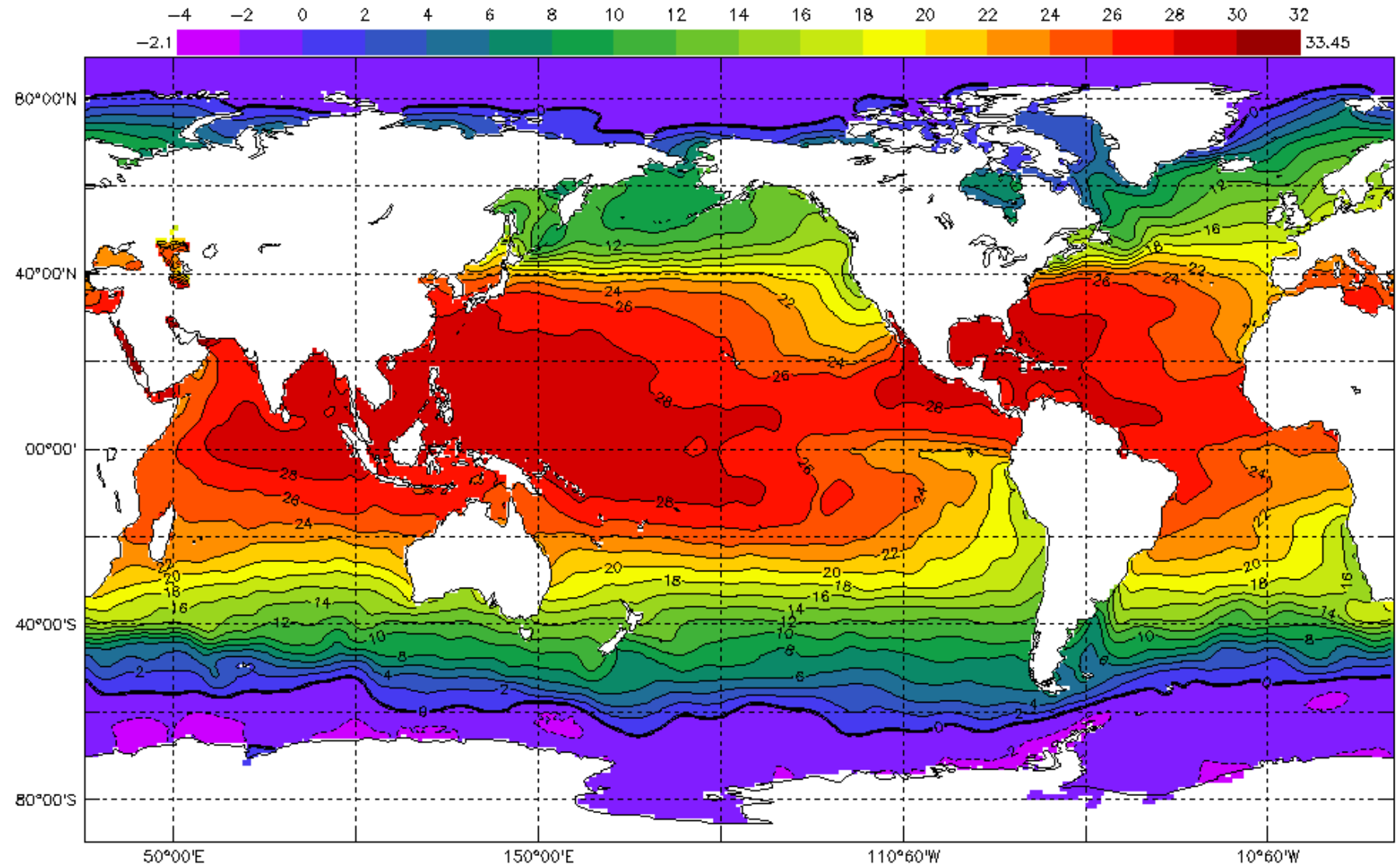


Image from NASA.gov

Ocean Heat Transport

Cold Eastern Boundary Currents

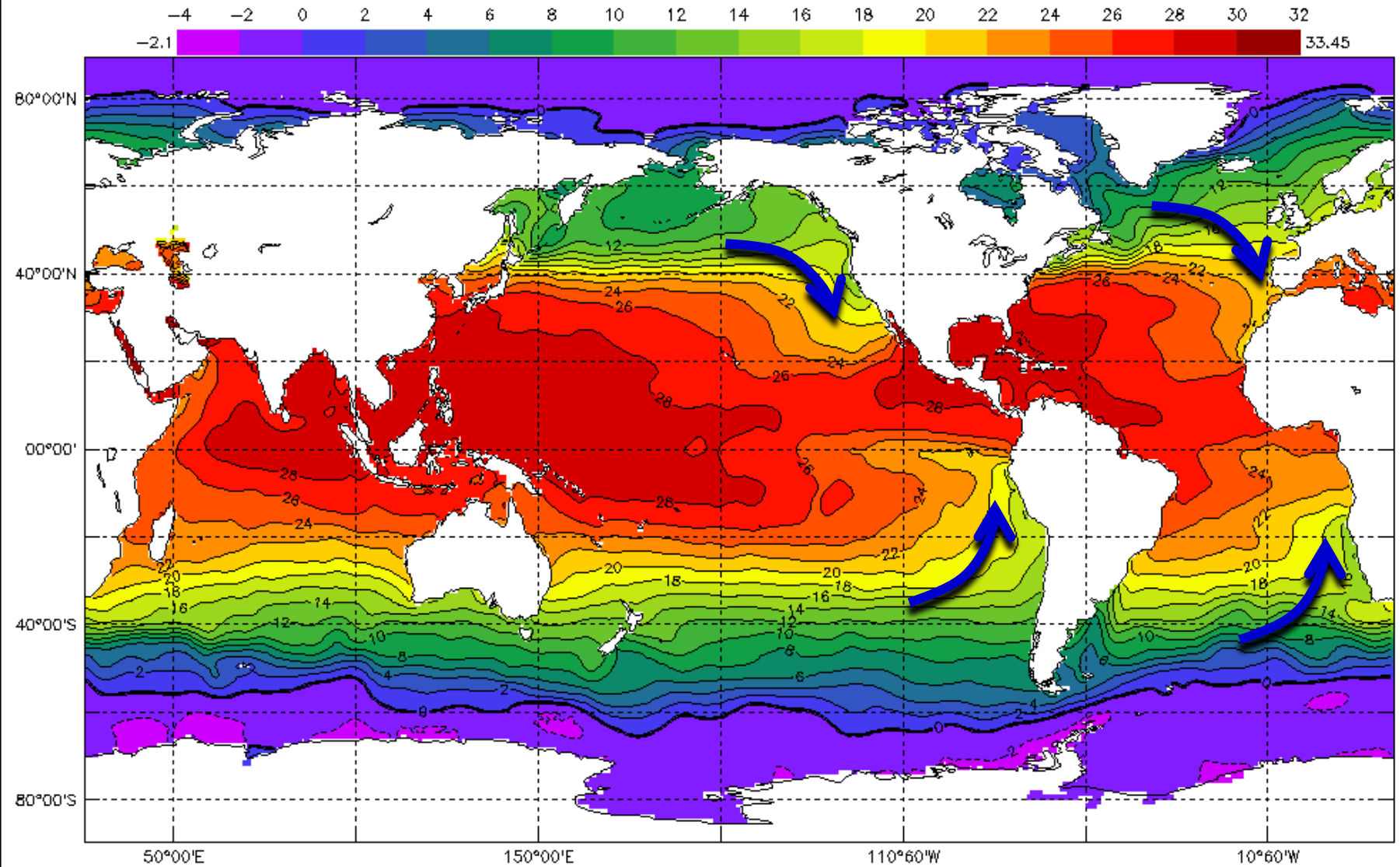


Image from NASA.gov

Ocean Heat Transport

**Cold Eastern
Boundary Currents**

**Warm Western
Boundary Currents**

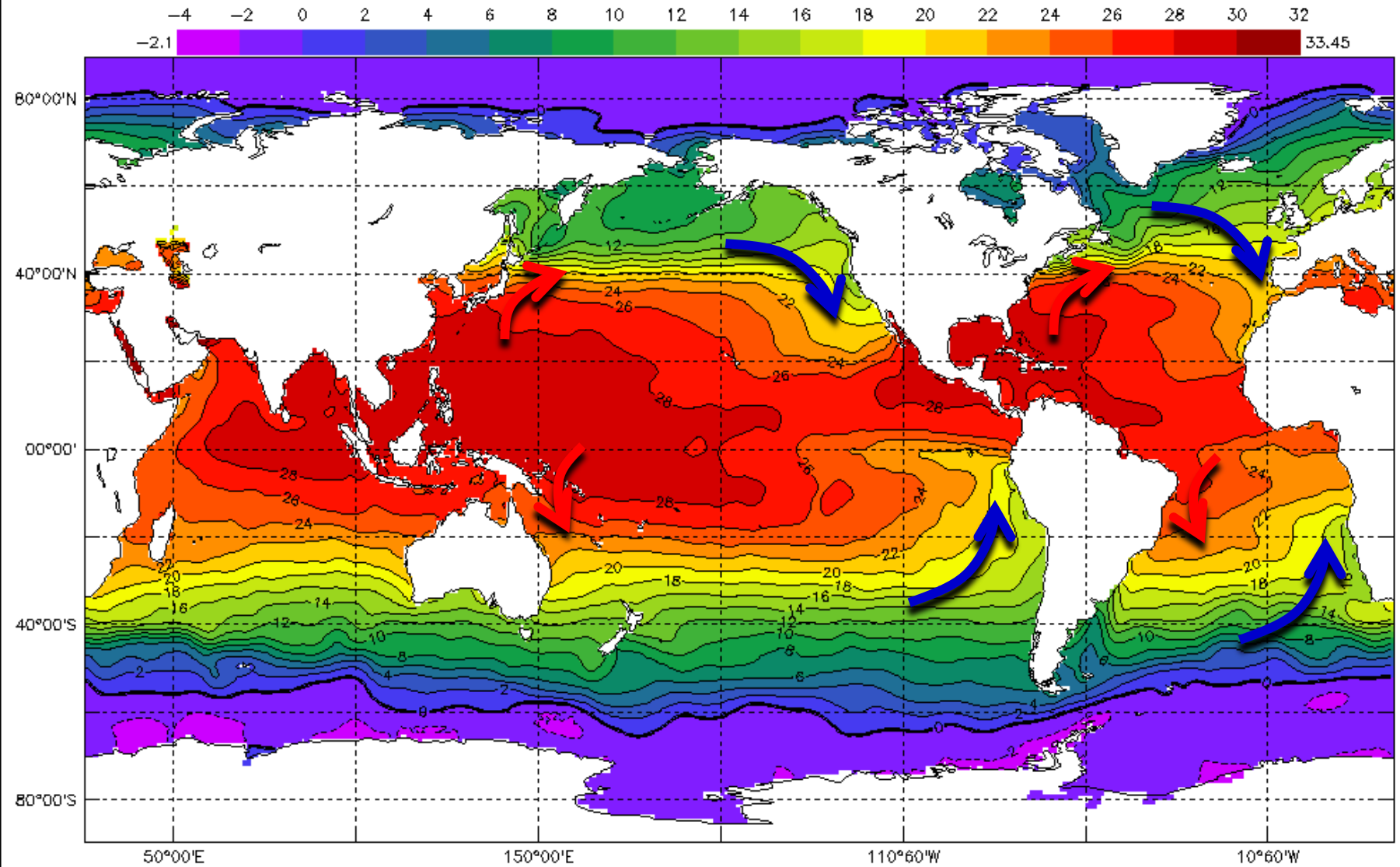


Image from NASA.gov

Ocean Heat Transport

**Cold Eastern
Boundary Currents**

**Warm Western
Boundary Currents**

**Equatorial &
Coastal Upwelling**

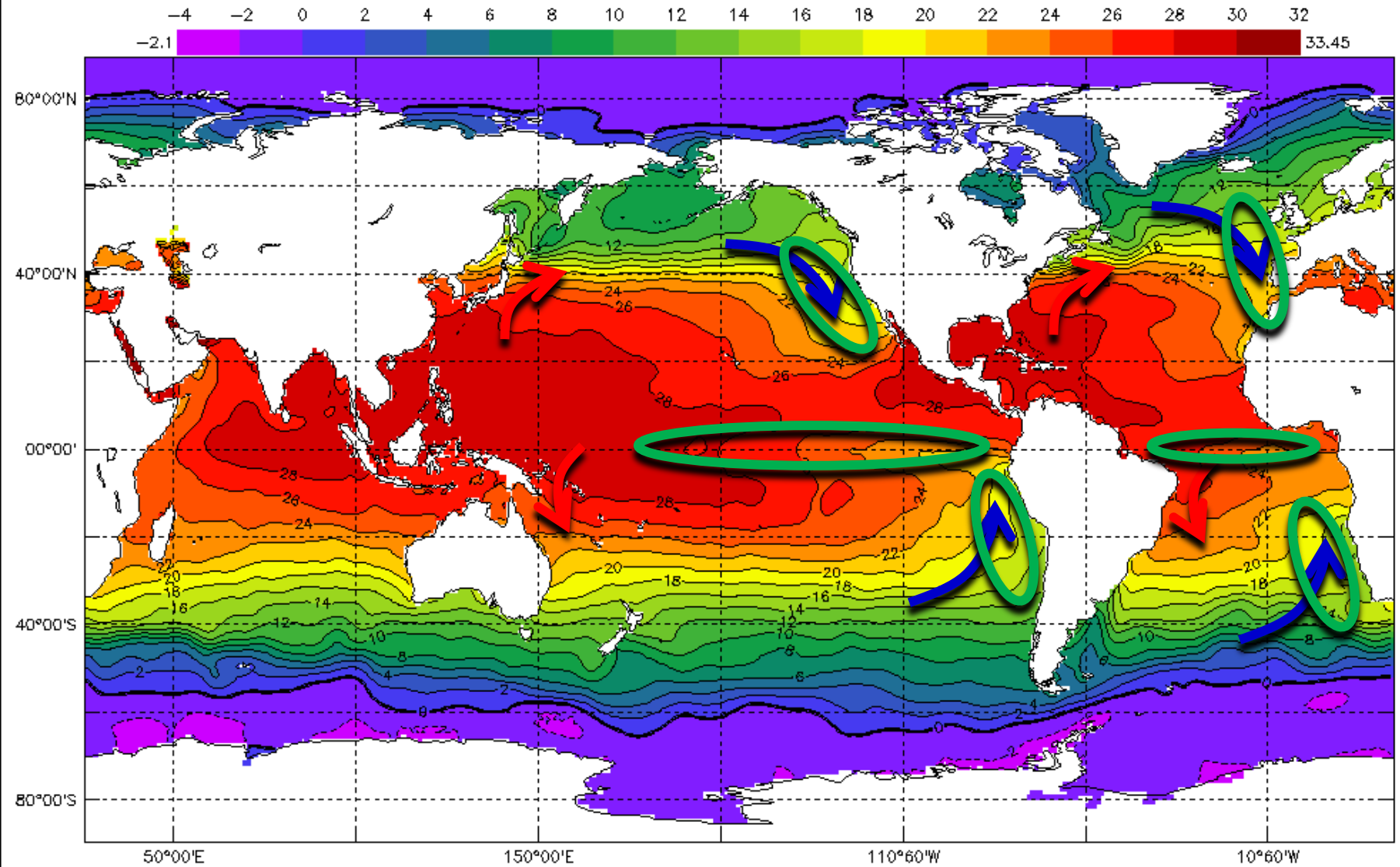


Image from NASA.gov

Ocean Heat Transport Example

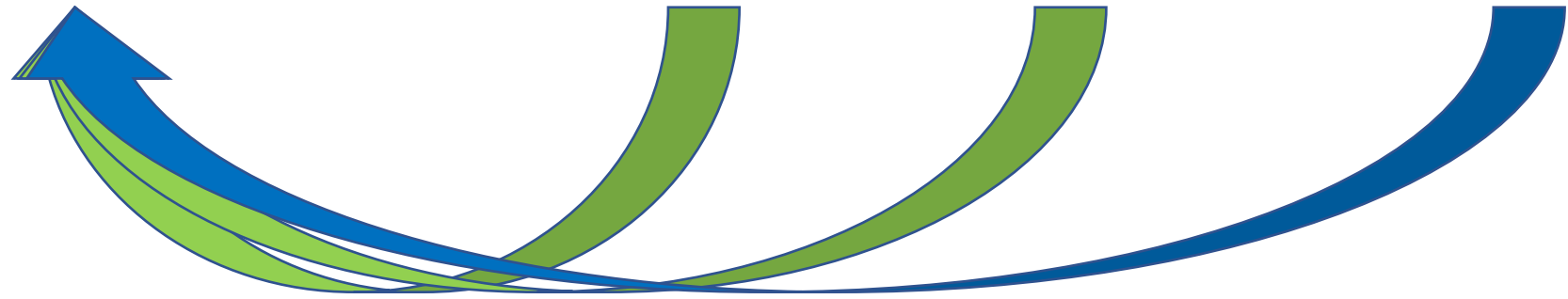
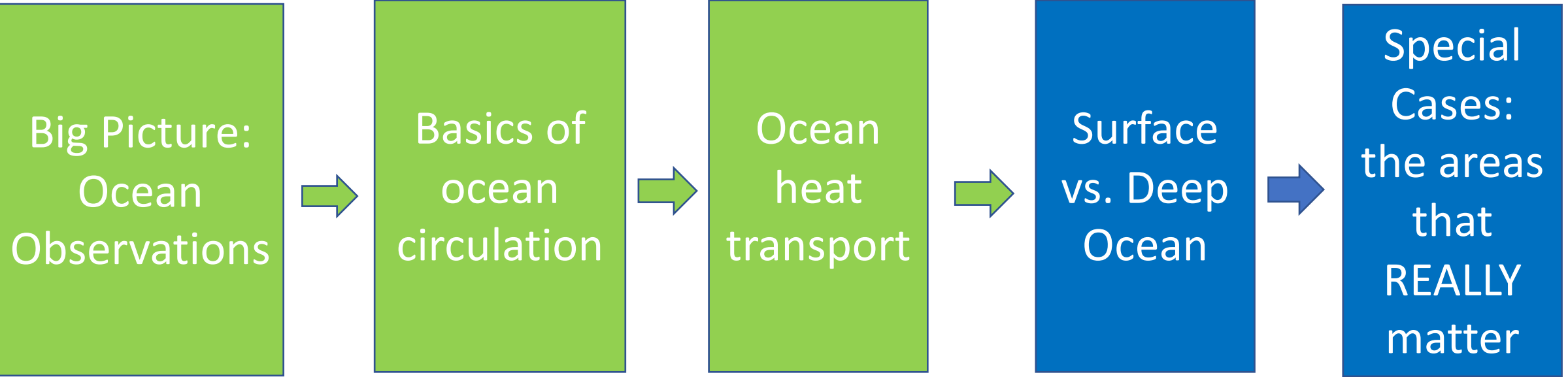


California: $\sim 35^{\circ}\text{N}$, 60°F Water Temp



North Carolina: $\sim 35^{\circ}\text{N}$, 75°F Water Temp

Check In



Comprehension Check

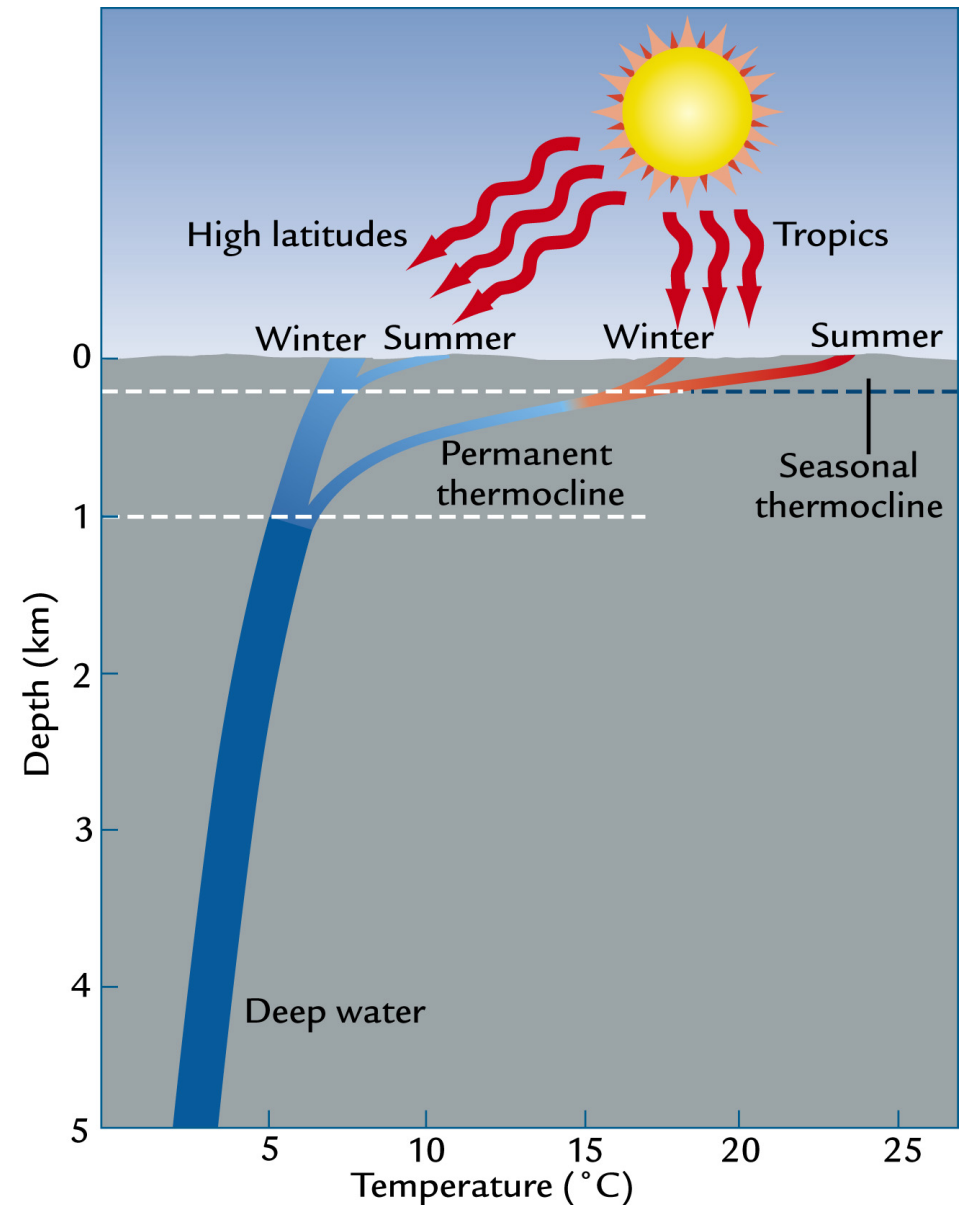
Some areas of ocean on the Equator have colder water temperatures than areas to the north or south. Why is this?

- A. Winds cause surface waters to move away from the equator, bringing cold, deep water up to the surface
- B. Lots of cloud cover cause the equator to be cooler than expected
- C. Heavy rains cause the equator to contain lots of cold, fresh water
- D. Strong winds cool the ocean surface near the equator

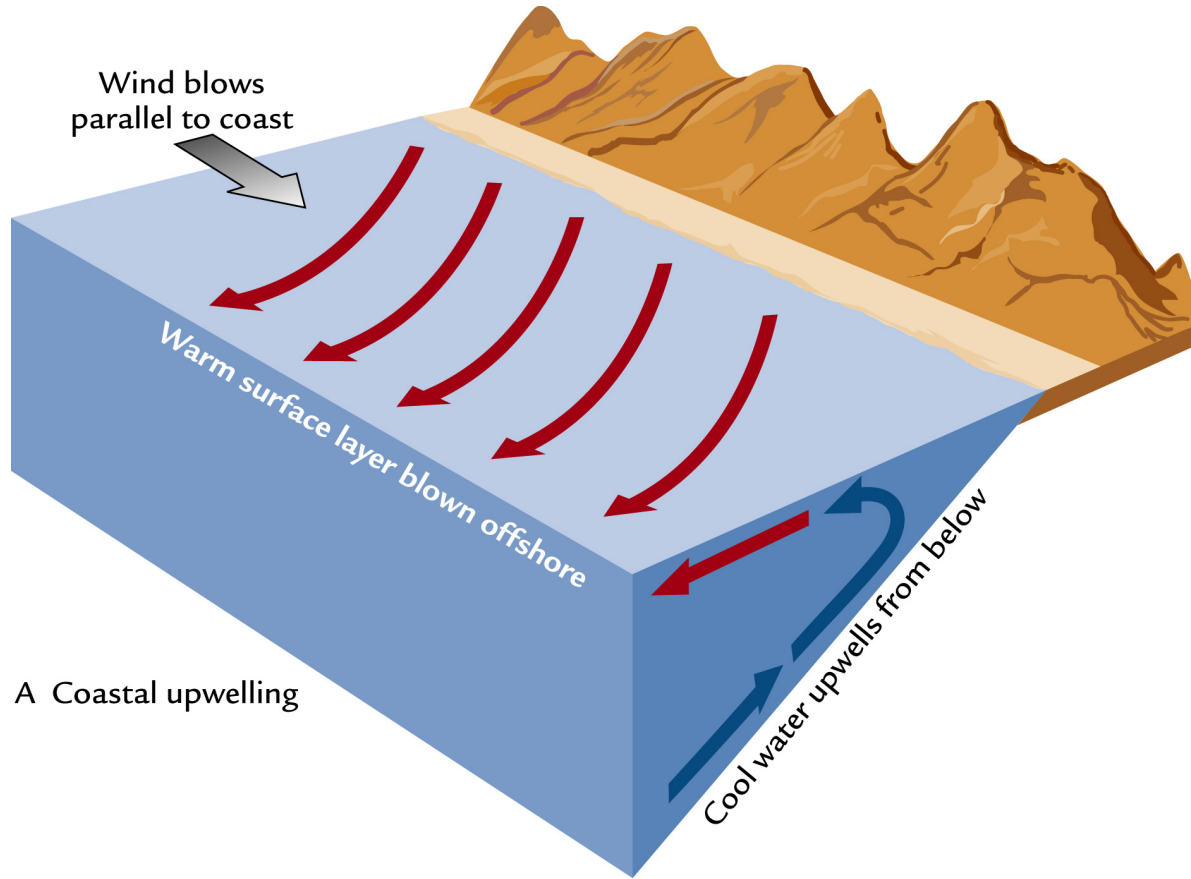
Surface vs. Deep Ocean

Surface vs. Deep Ocean

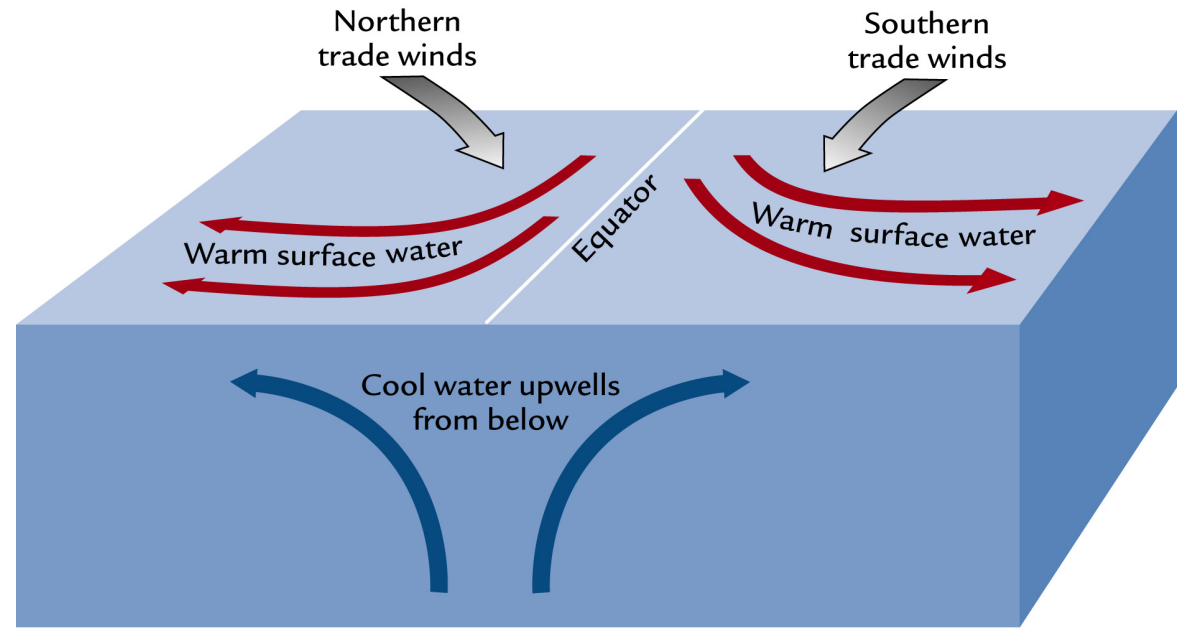
- Problem: warmer water on top of colder water.
- Can any convection happen in the oceans?



Deep Water Upwelling



A Coastal upwelling

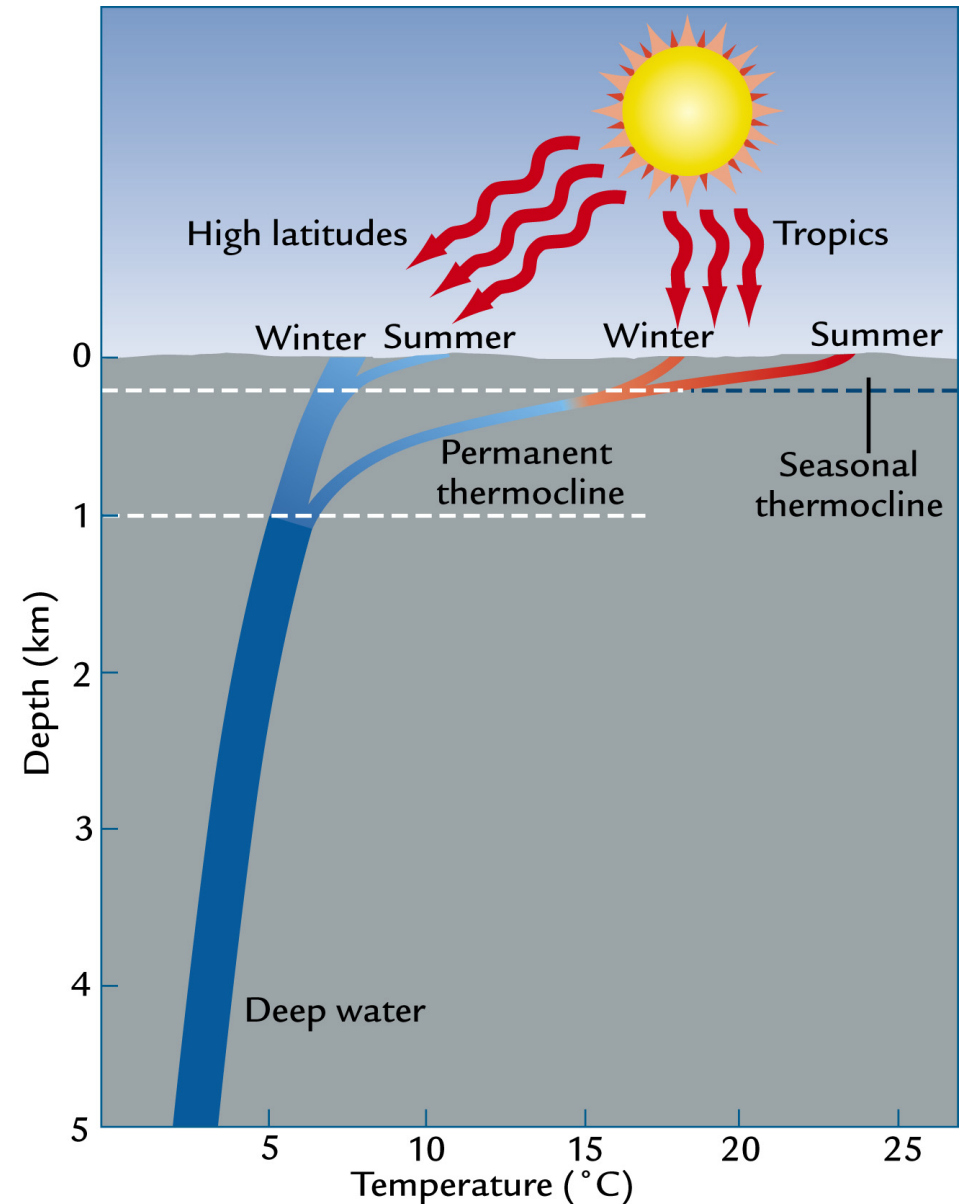


B Equatorial upwelling

Surface Water Sinking (Downwelling)

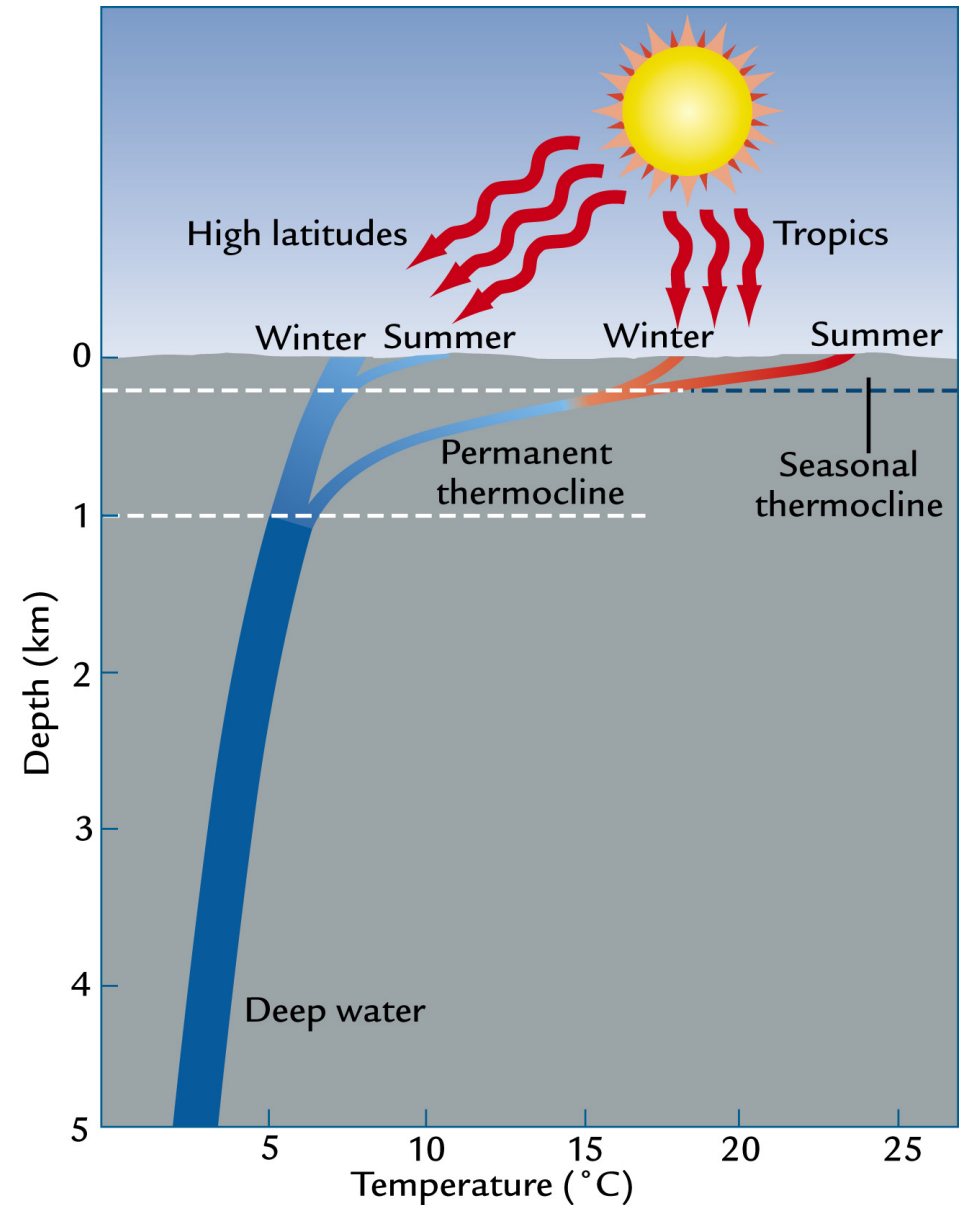
If deep water can rise to surface, surface water must sink somewhere, right?

How can this happen?



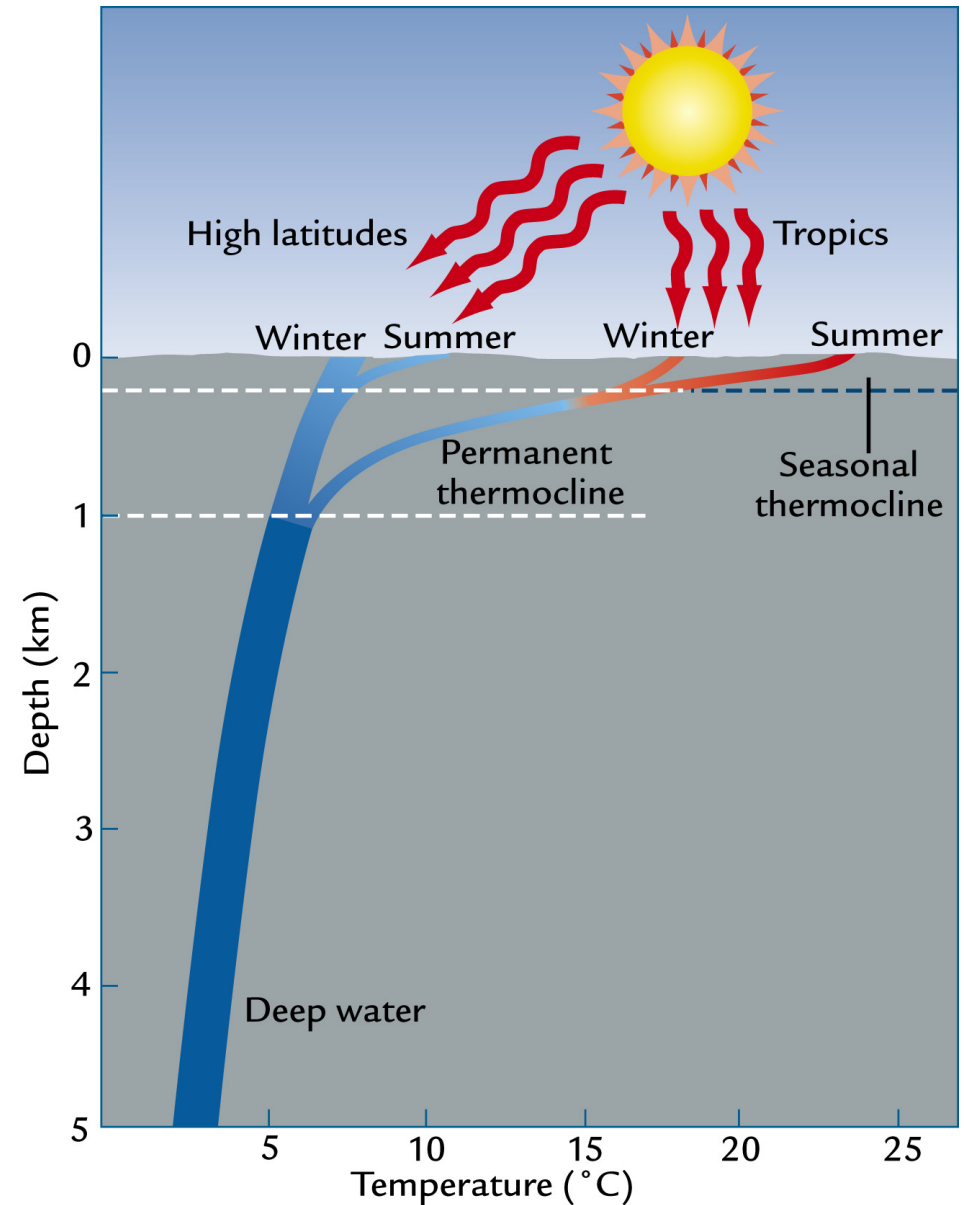
Surface Water Sinking (Downwelling)

- Surface waters need to be very dense to sink!
- Either:
 - Very Salty
 - Very Cold

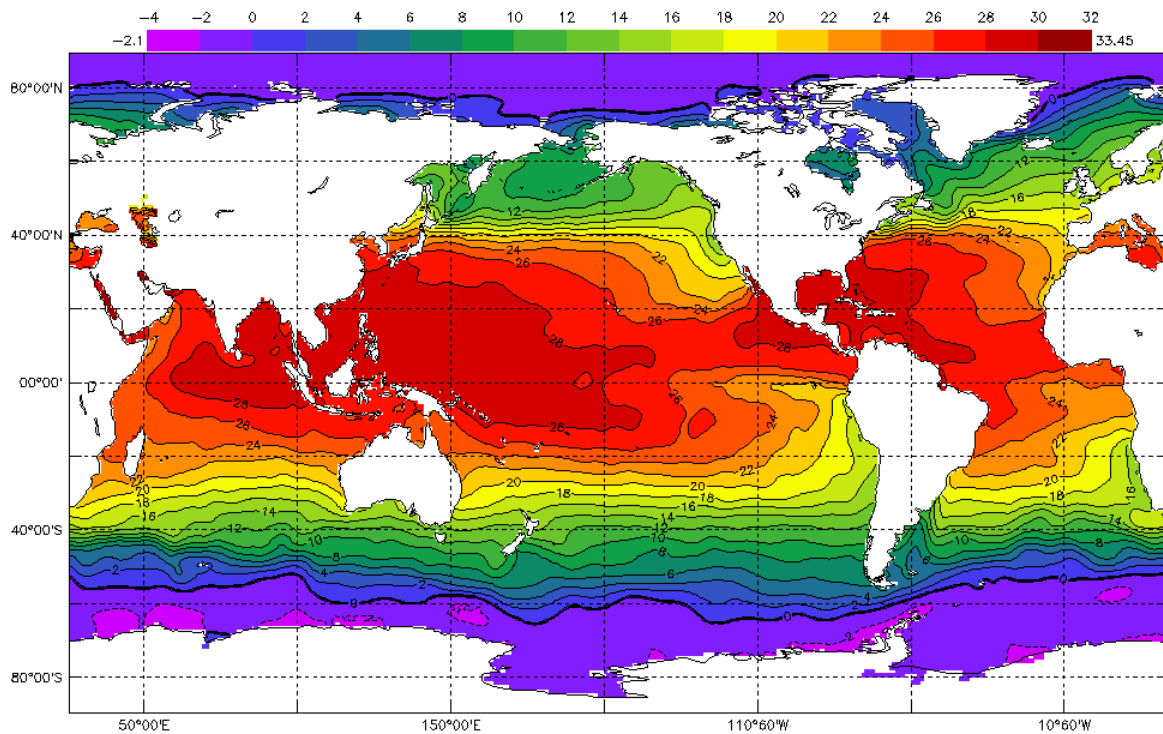


Surface Water Sinking (Downwelling)

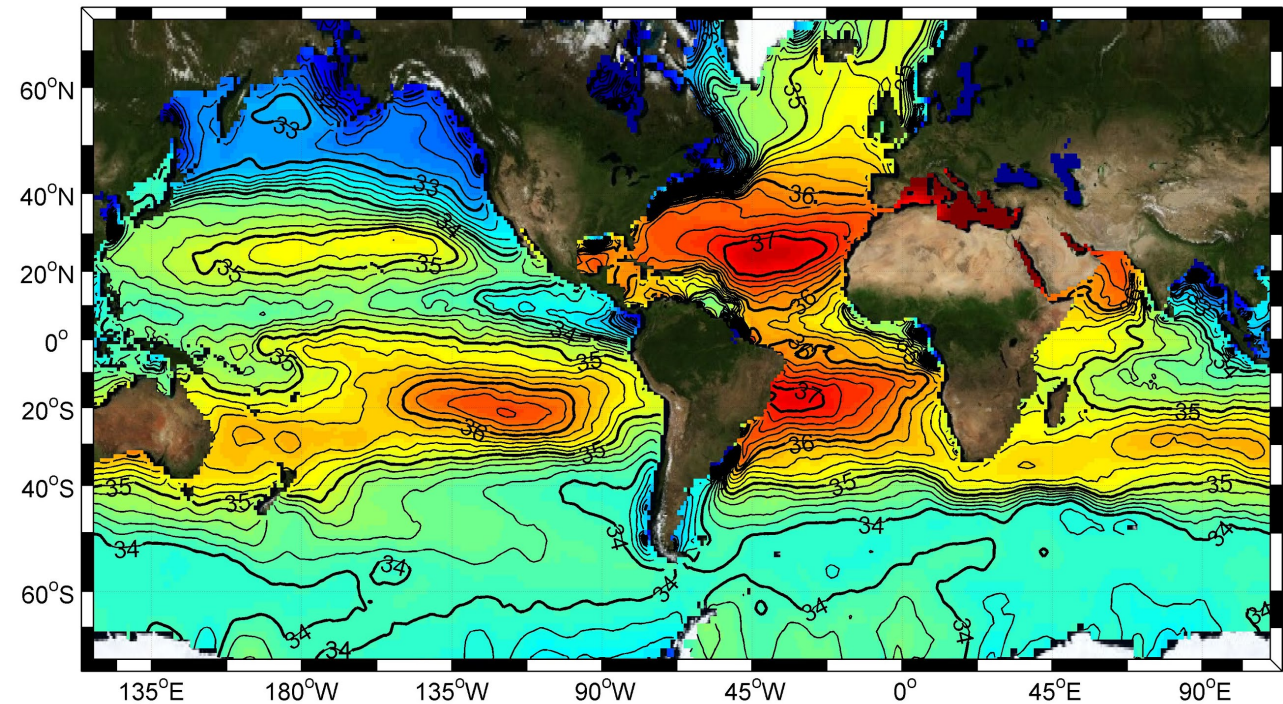
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 - Very Salty
 - Very Cold



Surface Water Sinking (Downwelling)

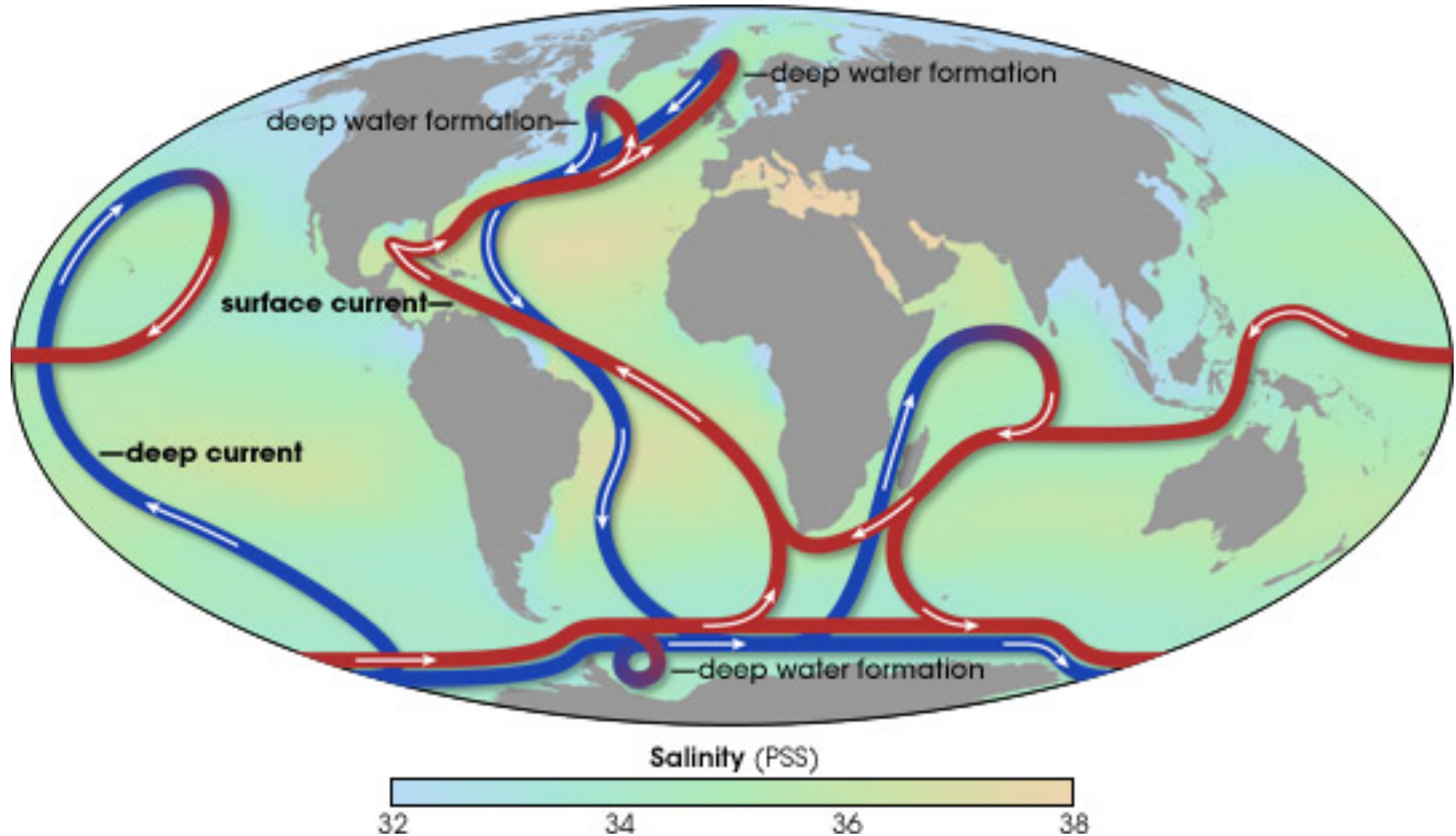


Temperature

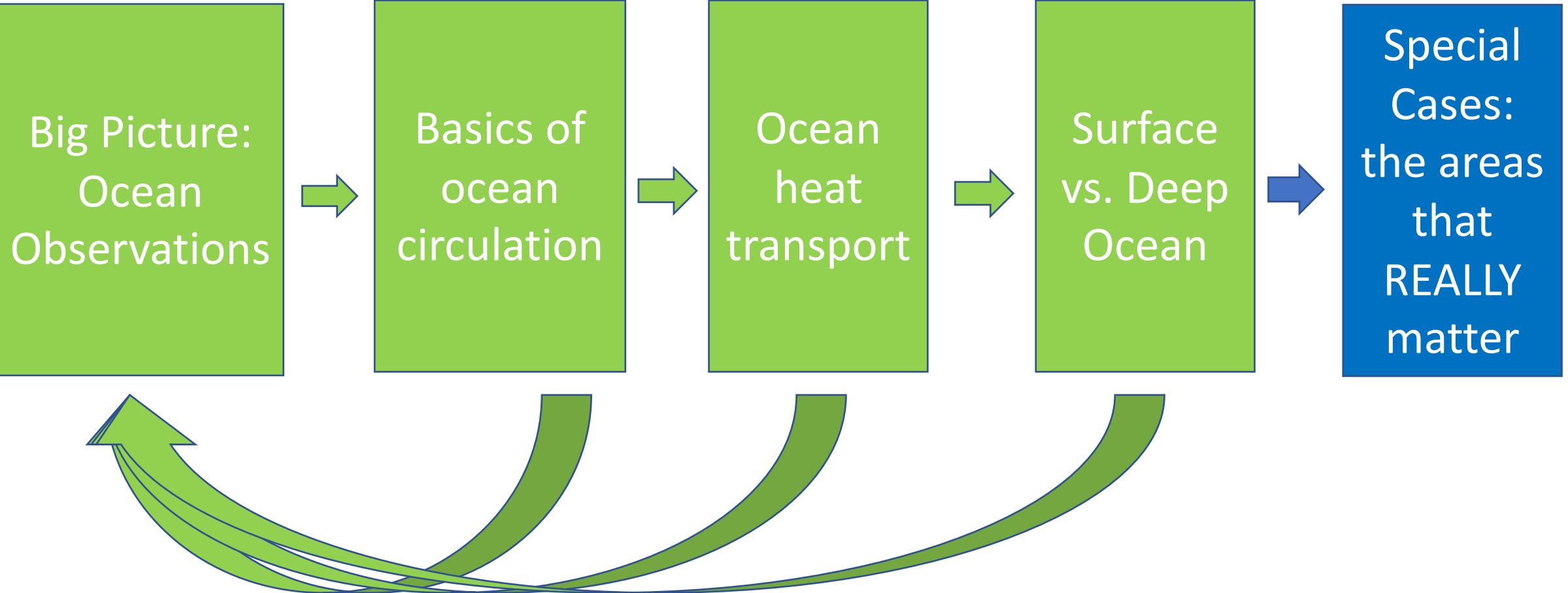


Salinity

Surface Water Sinking (Downwelling)



Check In



Think, Pair, Share

Think of any place(s) on Earth that have been affected by dominant ocean currents?

Think of areas that are warmer than makes sense based on their location alone (i.e., far north or south but are still warm).

Get ready to offer your ideas to the class.

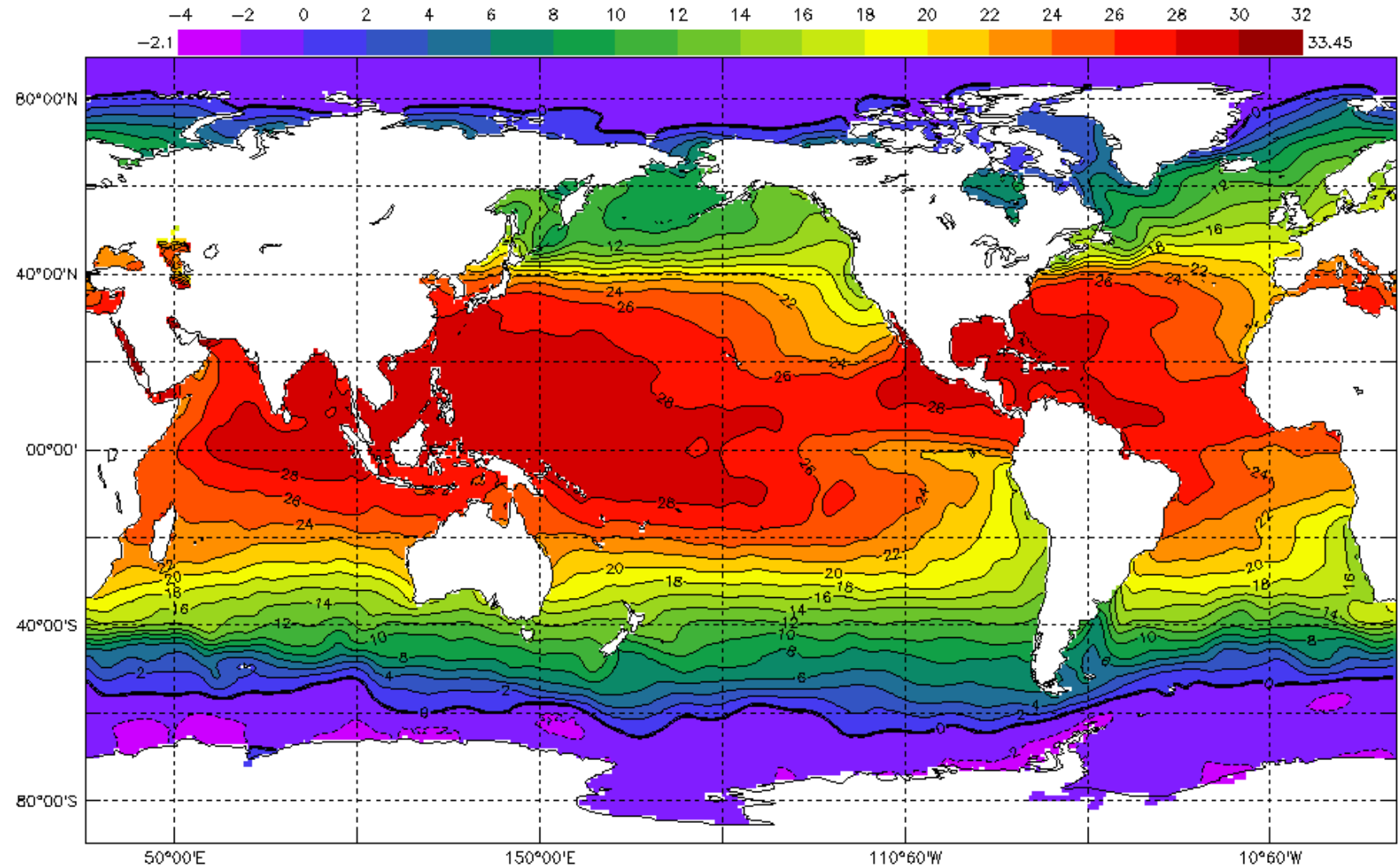
Special Cases: The places that really matter

Atlantic Meridional Overturning Circulation (AMOC)



Atlantic Meridional Overturning Circulation (AMOC)

North Atlantic is
~4°C warmer than
North Pacific



Atlantic Meridional Overturning Circulation (AMOC)

- Water cools down near Iceland and Greenland
- Very salty, more dense, sinks

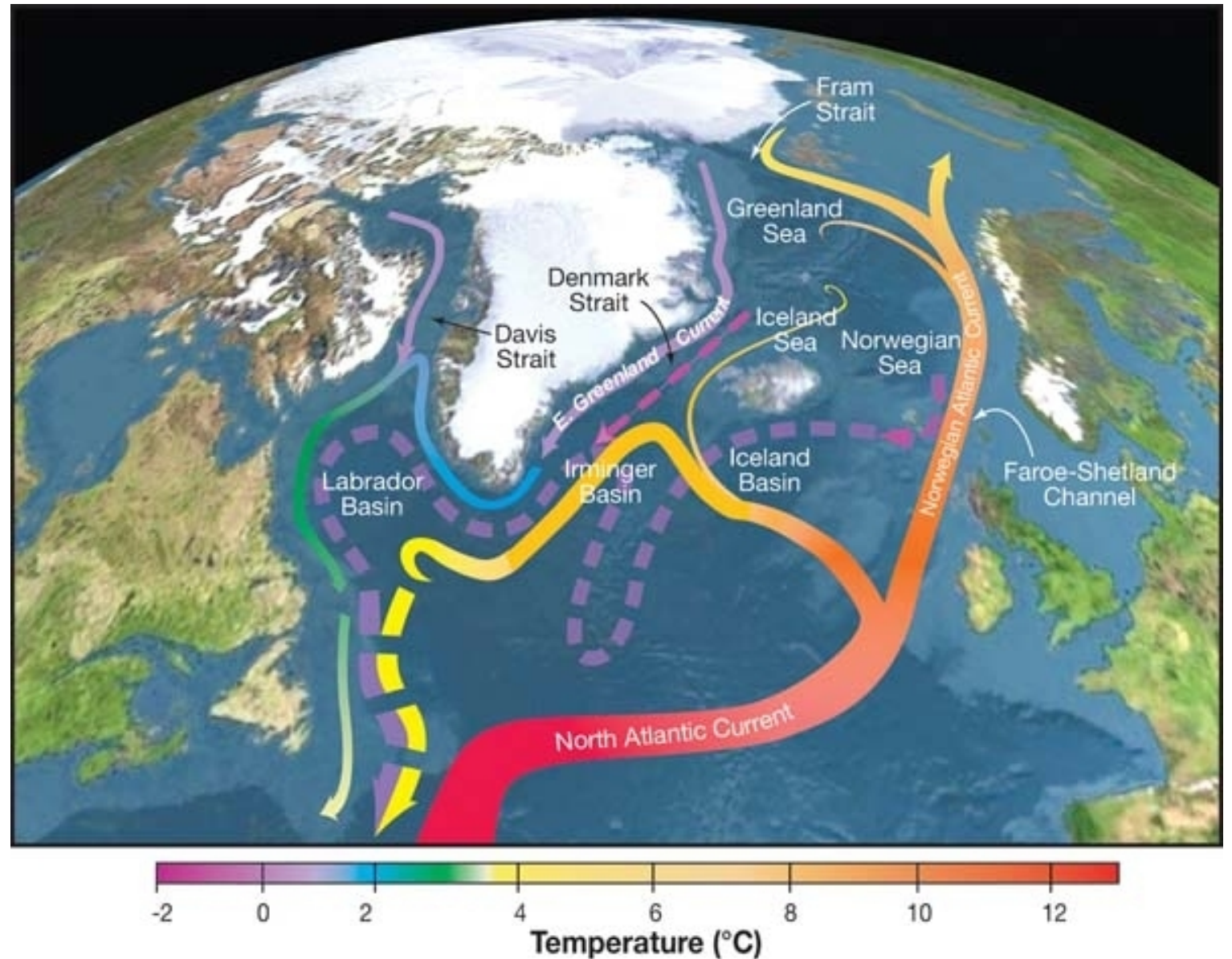


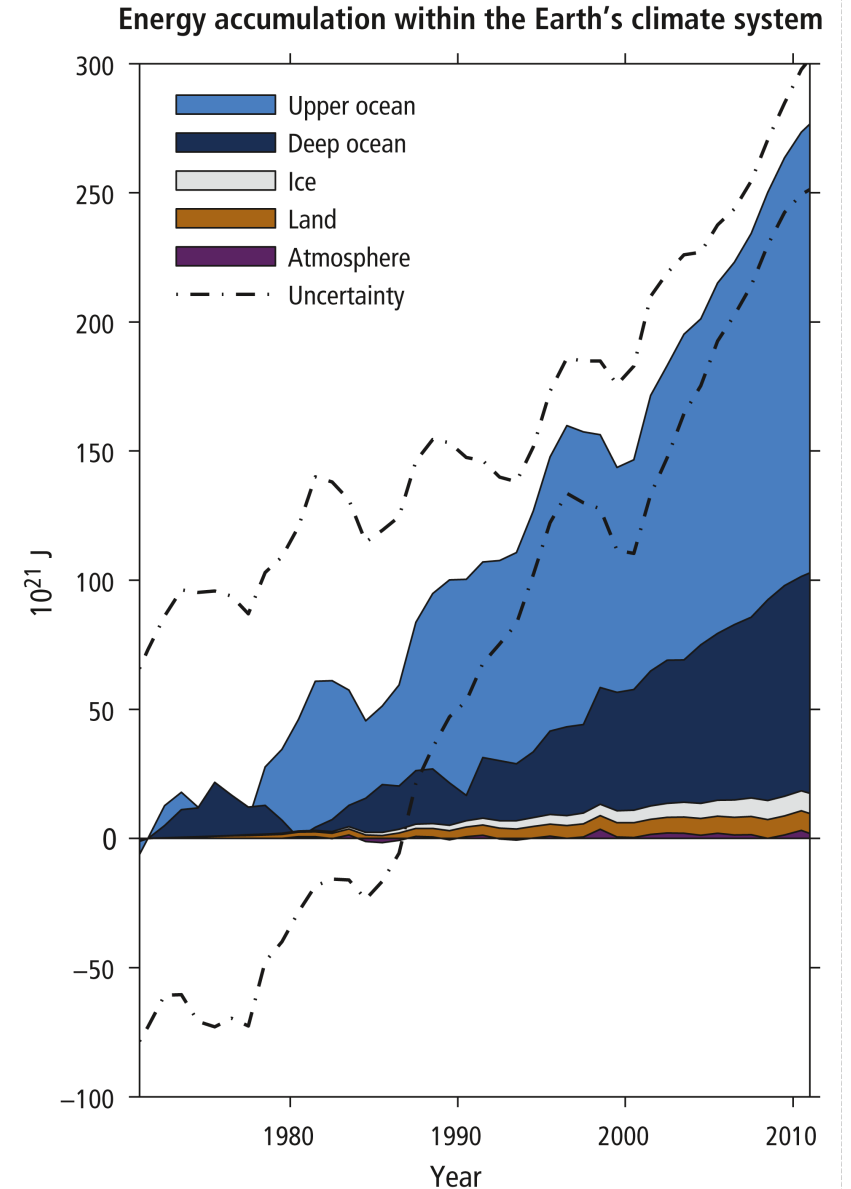
Figure from R. Curry, Woods Hole Oceanographic Institute

Atlantic Meridional Overturning Circulation (AMOC)

Why is this area important?

- Oceans absorb a lot of heat!
 - >90% of increased heat from human activities has been absorbed by oceans
- Surface ocean can exchange heat with atmosphere, deep ocean can not
- Deep ocean can “hide” heat

Figure from IPCC Fifth Assessment Report



Atlantic Meridional Overturning Circulation (AMOC)

Can this downwelling be slowed?

Depends on density, what if Greenland begins melting?

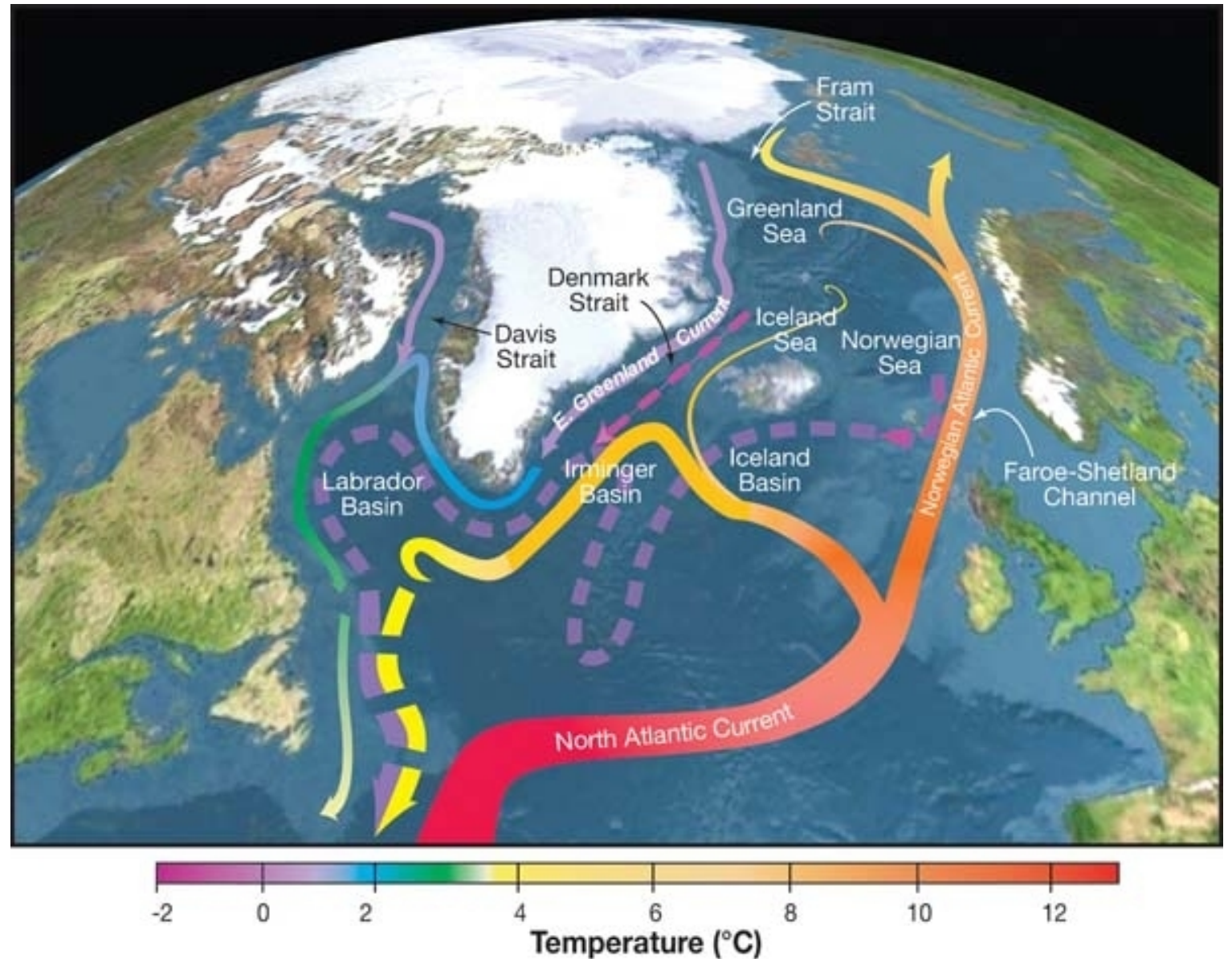


Figure from R. Curry, Woods Hole Oceanographic Institute

Dr. Wally Broecker – Legendary Climate Scientist



Climate is an angry beast and we are
poking at it with sticks

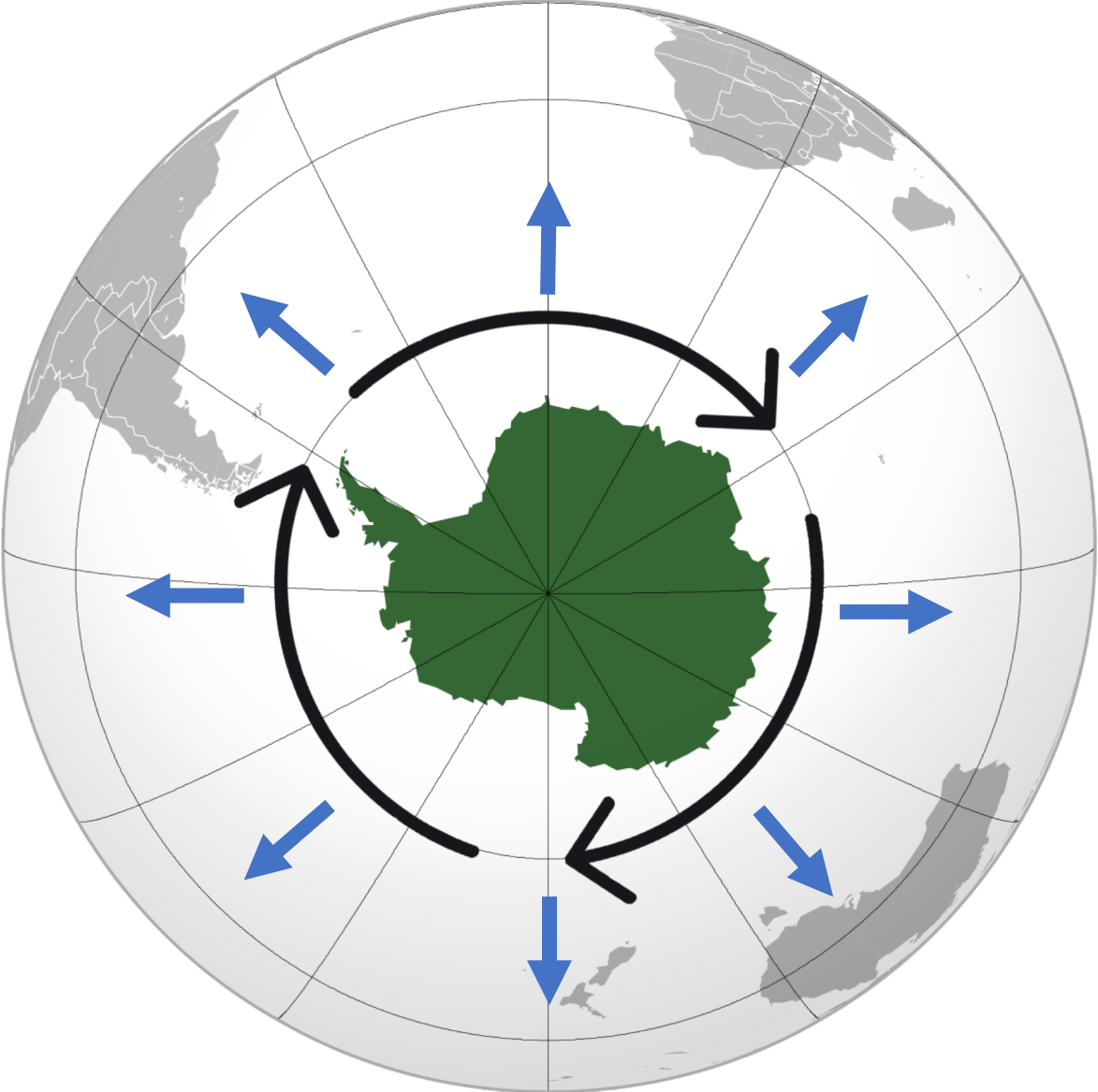
— *Wallace Smith Broecker* —

AZ QUOTES

Professor Wallace (Wally) Broecker was a geophysicist, oceanographer, and climate scientist based out of Columbia University. His work paved the way for our understanding of the AMOC and its influence on climate. He also predicted that past abrupt climate changes occurred because of changes to the AMOC, and the same could happen in our future. He died on Feb 18, 2019.

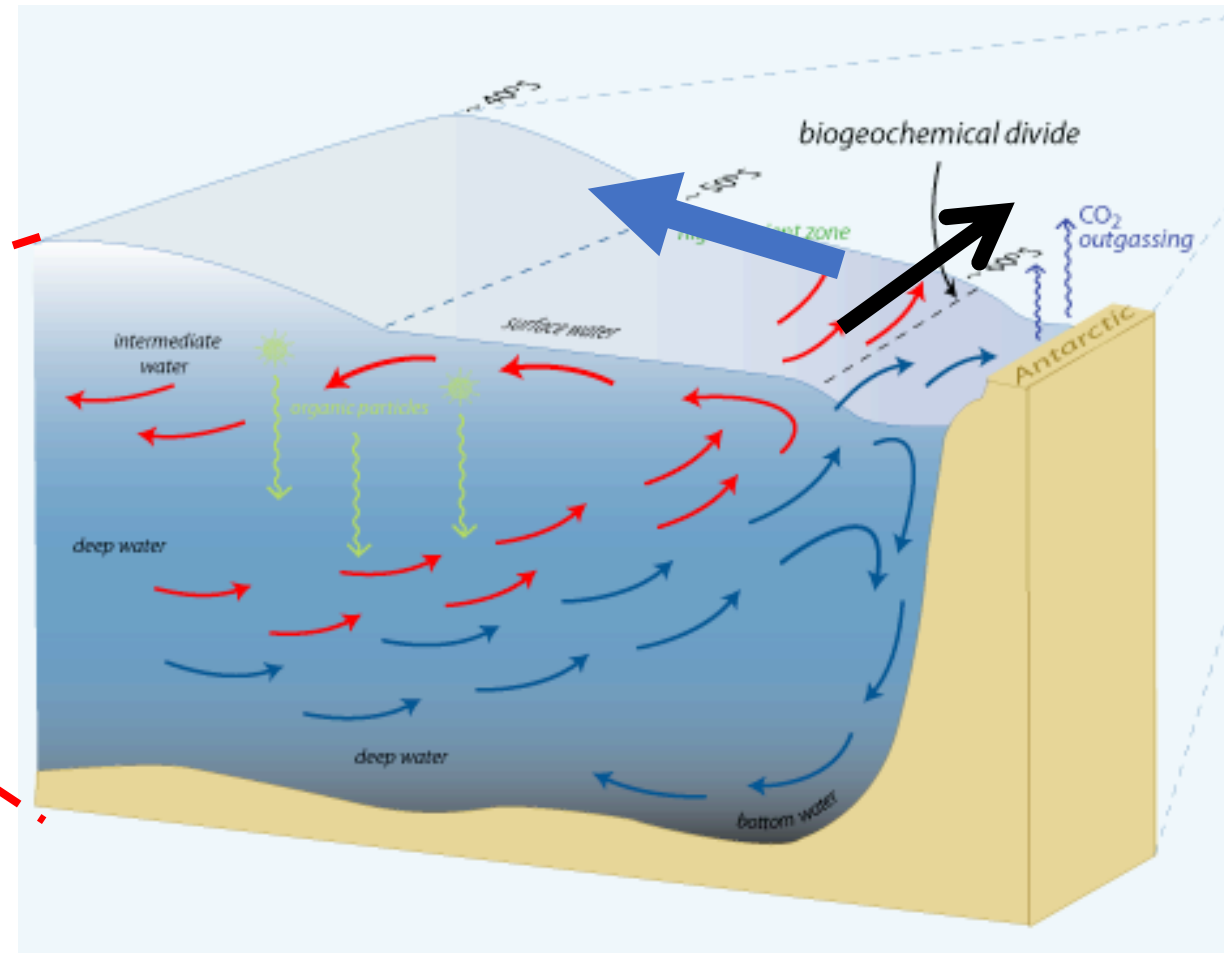
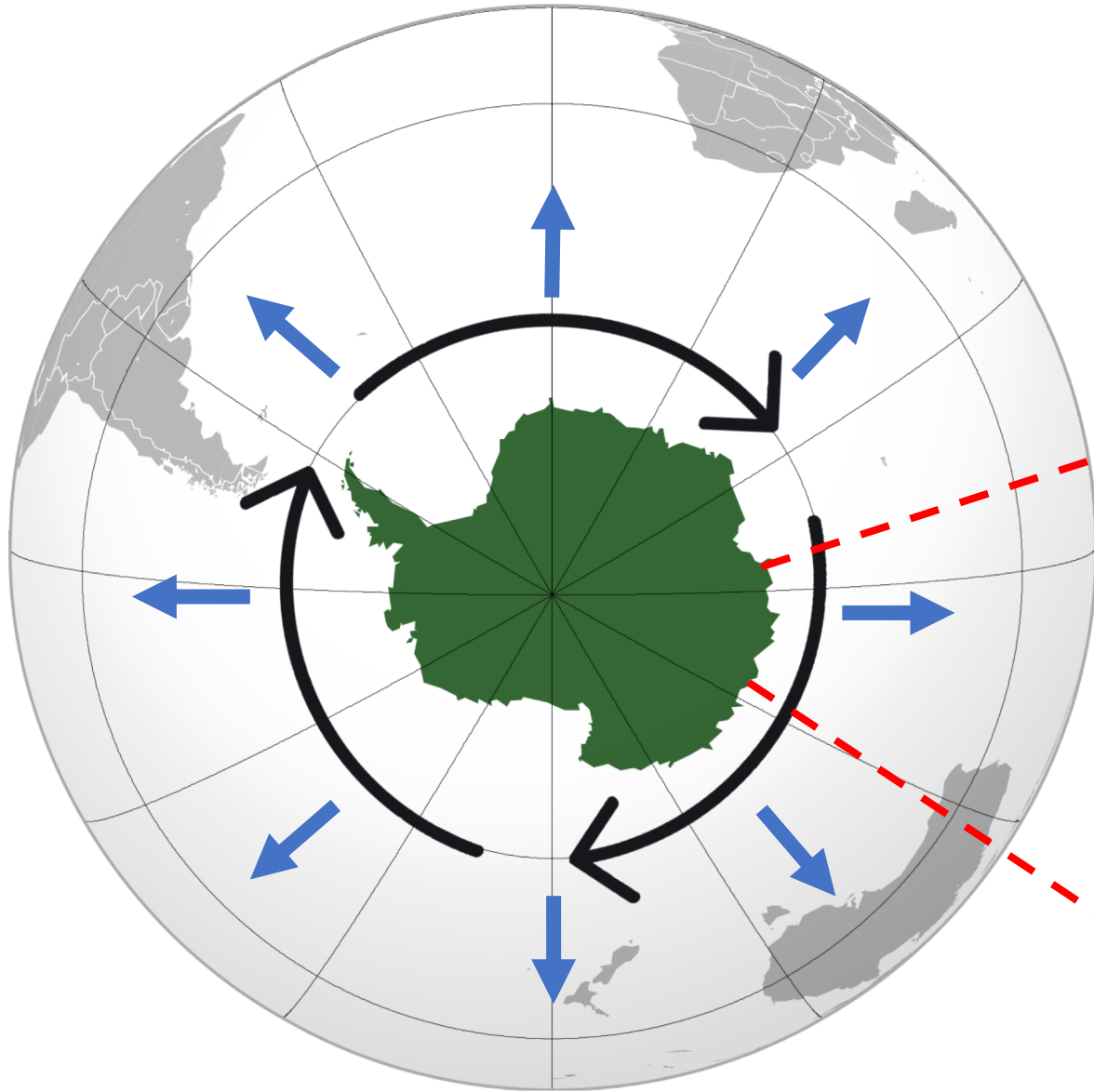
Southern Ocean Upwelling

Winds
↓
Ocean Currents
(Push Water
Offshore)



Southern Ocean Upwelling

Wind-driven currents cause upwelling off the coast of Antarctica



Southern Ocean Upwelling

Why does this matter to me?

- Upwelling brings heat and CO₂ stored in the deep ocean back into the surface ocean/atmosphere
- Understudied area, its impact/mitigation of climate change is still uncertain

