Fundamentals of Earth Sciences (ESO 213A)

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Oceans and winds

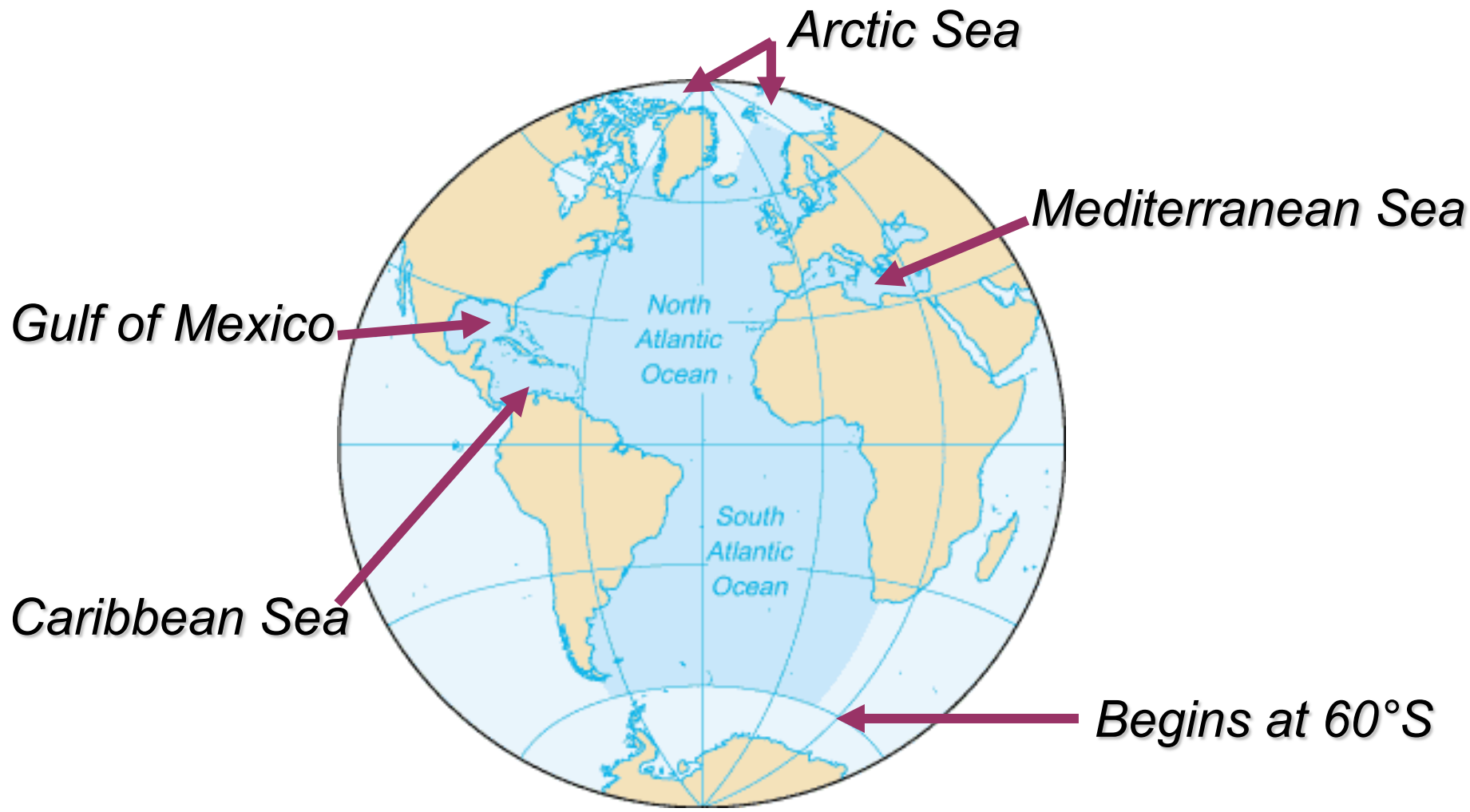
Previous Class: Soil

Why study major bodies of water?

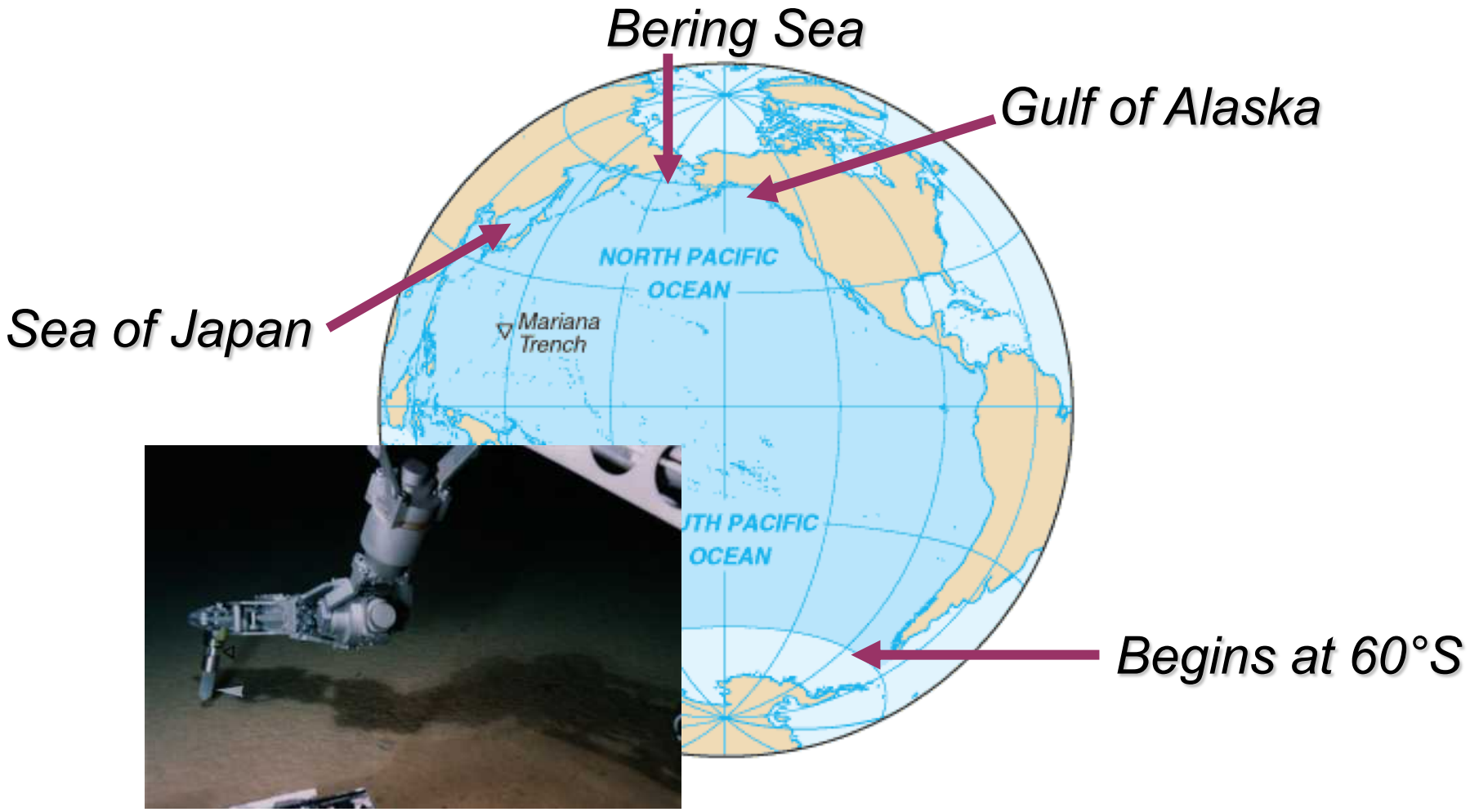
- Water covers nearly ¾ of the earth's surface
- More than 50% of the world's population lives within an hour of the coast
- Plays a role in both climate and day-to-day weather
- FOOD!
  - Cost of your food could depend on it

There are ***FOUR*** oceans

- ***ATLANTIC***
- ***PACIFIC***
- ***INDIAN***
- ***SOUTHERN***



The Atlantic Ocean encompasses pretty much everything on the map north of 60° South latitude. The Mediterranean, Caribbean, and Arctic Seas, as well as the Gulf of Mexico are all included in the Atlantic basin. It also provides some of the earth's most heavily trafficked routes.

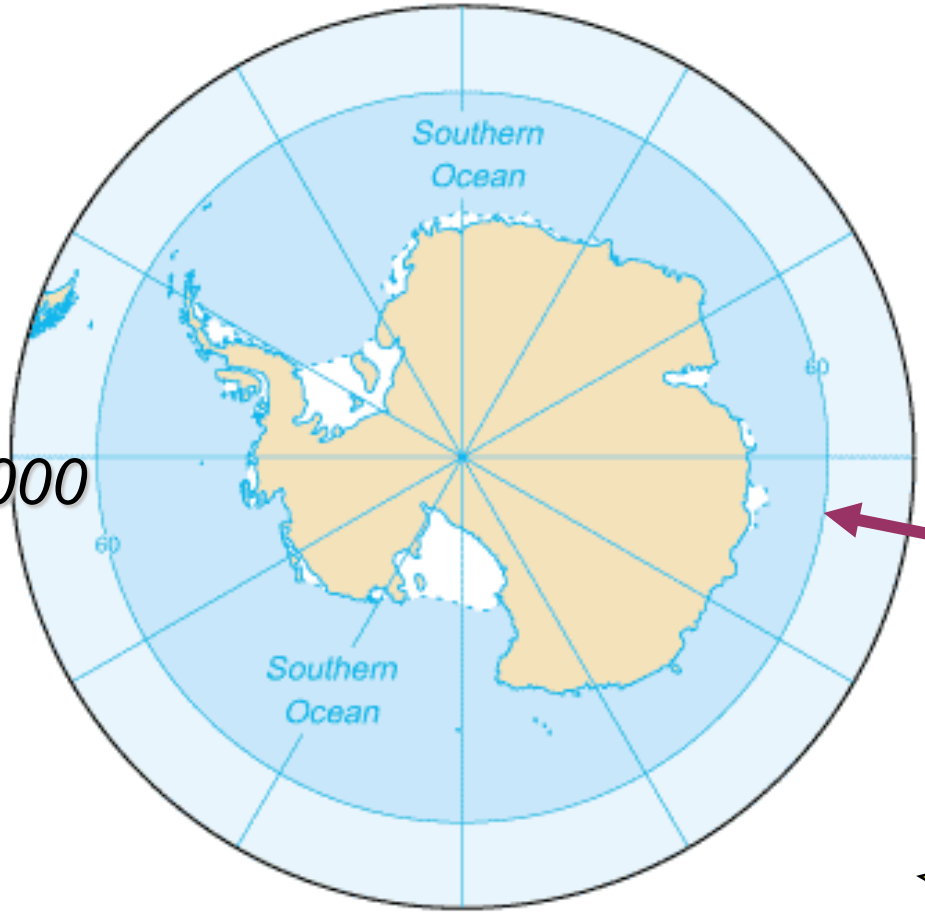


The Pacific Ocean encompasses pretty much everything on the map north of 60° South latitude. The Bering and Japan Seas, as well as the Gulf of Alaska are all included in the Pacific Basin. The Pacific Ocean covers 28% of the global surface and contributes more than half to the world's annual fish catch. Pacific Ocean also has the most coastline of the four oceans. The Mariana Trench is the deepest part of the earth's oceans. The deepest point is called Challenger Deep, named after the British exploration vessel HMS Challenger II. It has a depth of 10,911m or 35,798ft. The U.S. Navy bathyscaphe Trieste reached the bottom at 1:06 PM on January 23, 1960. At the bottom of the trench, the water exerts a pressure of 1086 bar or almost 16,000 psi. That's more than 1,000 times the standard atmospheric pressure at sea level (1013.25mb).

The Indian Ocean encompasses areas between the Indian subcontinent/Asia and 60° South latitude. The Arabian and Red Seas, as well as the Persian Gulf are all included in the Indian Ocean basin. Interesting side notes here – Estimated 40% of the world's offshore oil production comes from the Indian Ocean.

NEW!

NEW!



"Defined" in 2000

Begins at 60° S

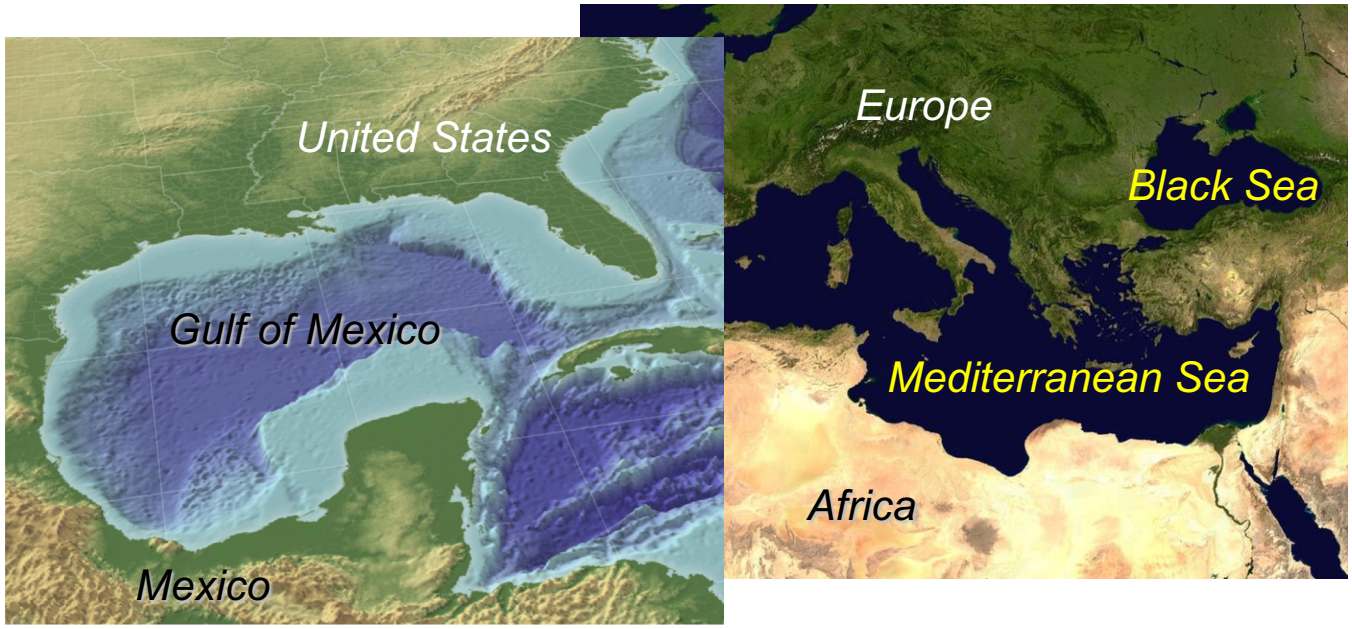
NEW!

NEW!

The Southern Ocean encompasses anything poleward of South latitude and is made of "parts" of the Atlantic, Pacific, and Indian Oceans. It is also the newest ocean, as it was defined in 2000.

Ocean or Sea, What's the Big Deal?

- SEAS
- Delineated by land masses
  - Doesn't matter if they're largely enclosed
- Also "communicate" with the ocean



Which ocean is the biggest?

OCEAN	SURFACE AREA [km^2]	OF ALL OCEANS…
Atlantic	90,818,000	27.1%
Indian	68,556,000	20.4%
Pacific	155,557,000	46.4%
Southern	20,327,000	6.1%

Which ocean has the most coastline?

OCEAN	COASTLINE LENGTH [km]
Atlantic	111,866
Indian	66,526
Pacific	135,663
Southern	17,968

FRESHWATER	SALTWATER
• Rivers	• Oceans
• Streams	• Gulfs
• Lakes	• Seas

QUESTION:

Is saltwater the same everywhere?

ANSWER:

No

- *There are areas of*
  - *HIGH salinity*
  - *LOW salinity*

In general, the Atlantic Ocean is the "saltiest."

So, where are these "highs" and "lows"?

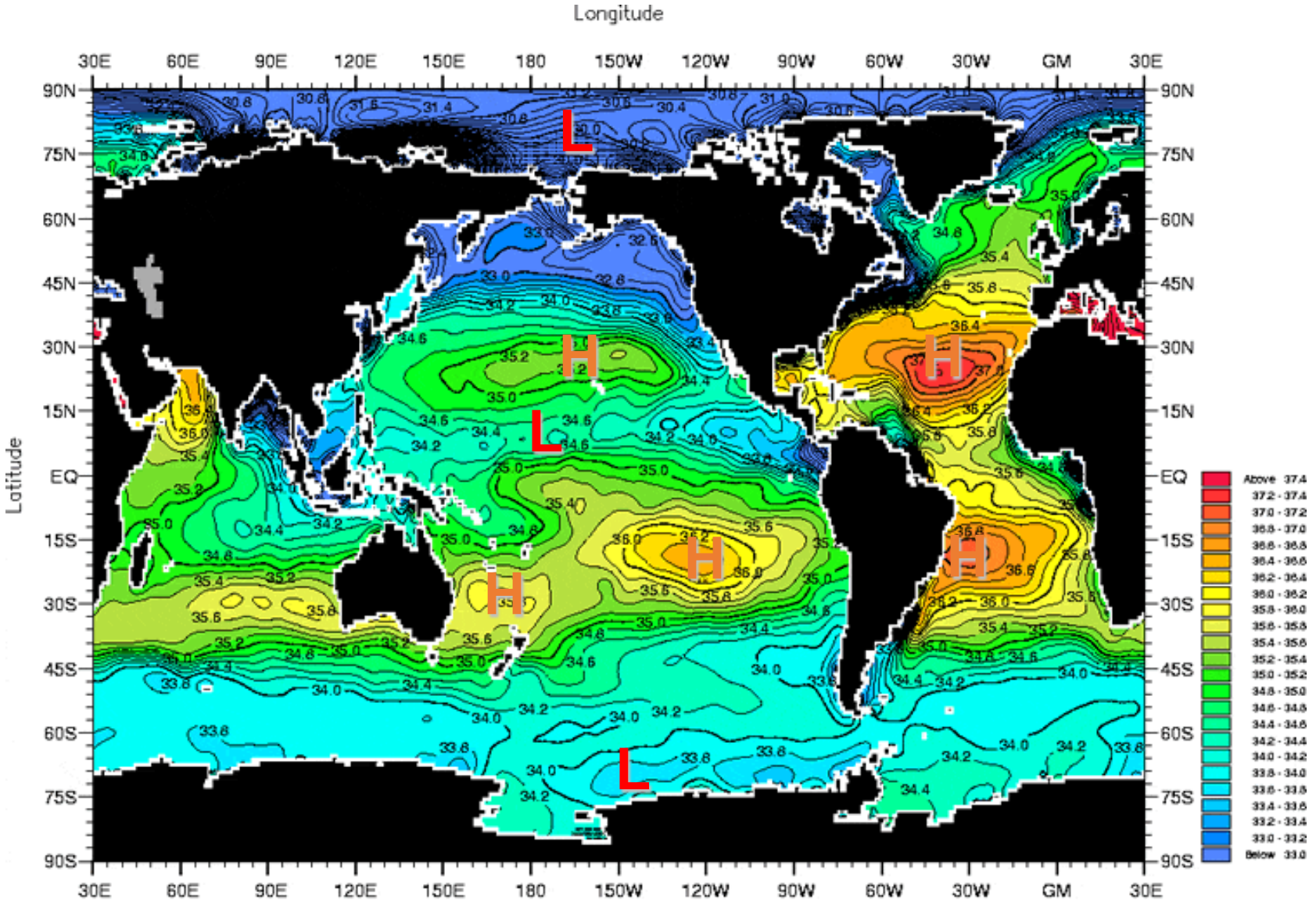


Fig. A2-1. Annual mean salinity (PSS) at the surface .

Minimum Value= 3.57 Maximum Value= 40.02 Contour Interval: 0.20

The first H is over the Persian Gulf/Red Sea area. With 40% salinity, this is the saltiest water on earth. Why? Primarily because there's no real "outlet" for fresh and ocean water to be exchanged. This is also a location of very high evaporation rates. When the water is evaporated, the salt is left behind. The "freshest" water is near the Arctic Circle due to melting ice. Note that there are mins near the equator. Persistent thunderstorm activity in this region keeps the water a little better fresher here.

The Dead Sea is actually a large lake, 47 miles long and about 11 miles wide. The intense evaporation leaves behind the salt, which precipitates onto the sea floor. In fact, the surface of the lake is the least salty. Other trivia facts – the surface of the Dead Sea is over 1300 ft. below sea level, with the very bottom part of the sea is over 2300 ft. below sea level.Christian Monks found no life in the body of water because of the high salinity.

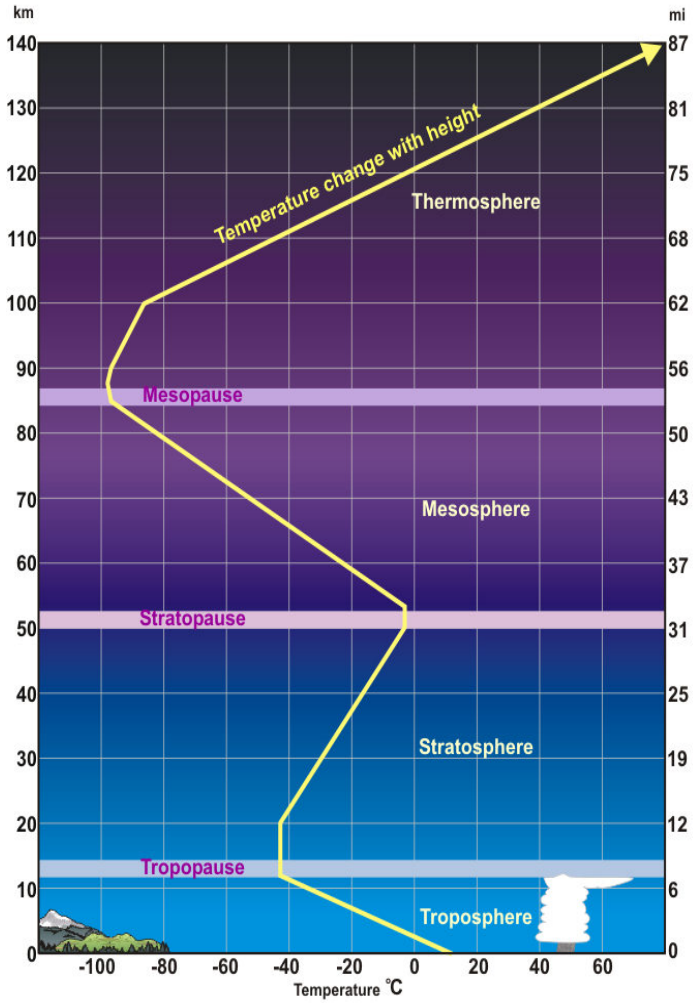
DEAD SEA FACTS:

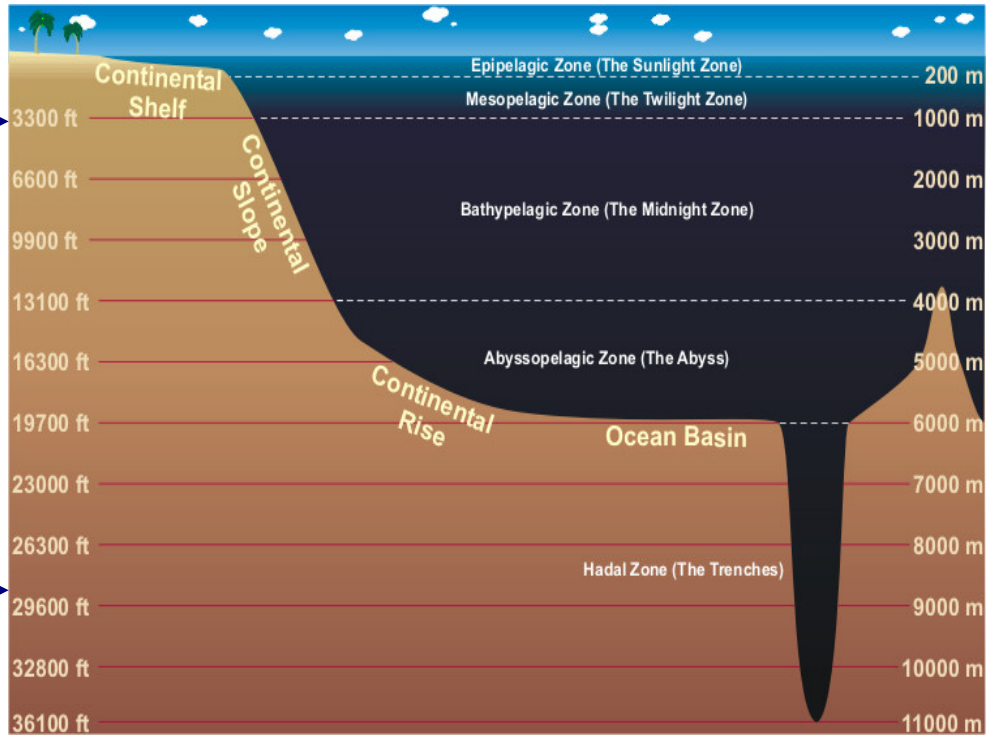
- Really a large lake
- Water gets in, but not out!
  - Fed by River Jordan
  - Evaporation only way out
- Has nearly 10 times the salinity of the oceans!
  - Leads to increased density

CAPT. OBVIOUS SAYS:

Dead Sea was named because it had no life!

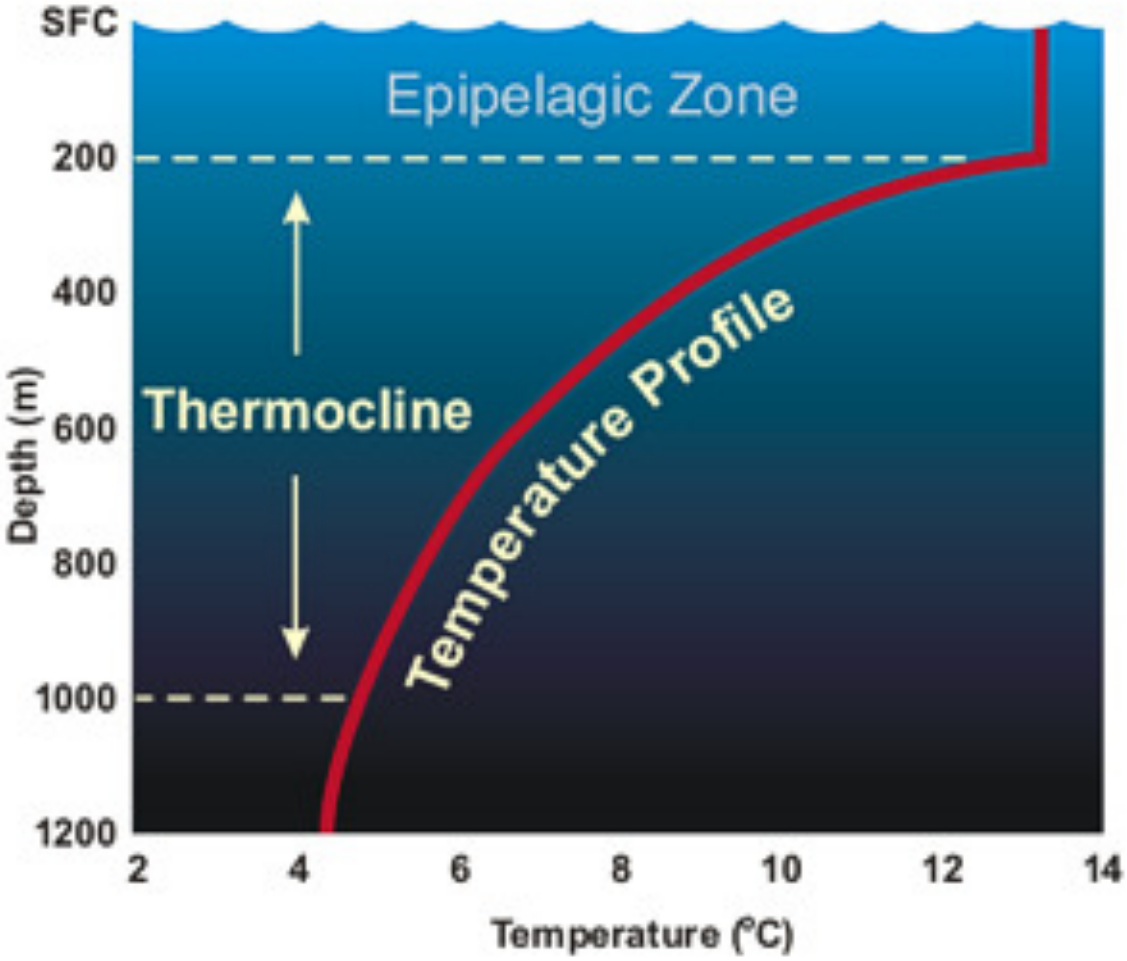
Layerings in ocean water:





Just like the atmosphere, the ocean has layers!

The Epipelagic Zone (Sunlight zone)

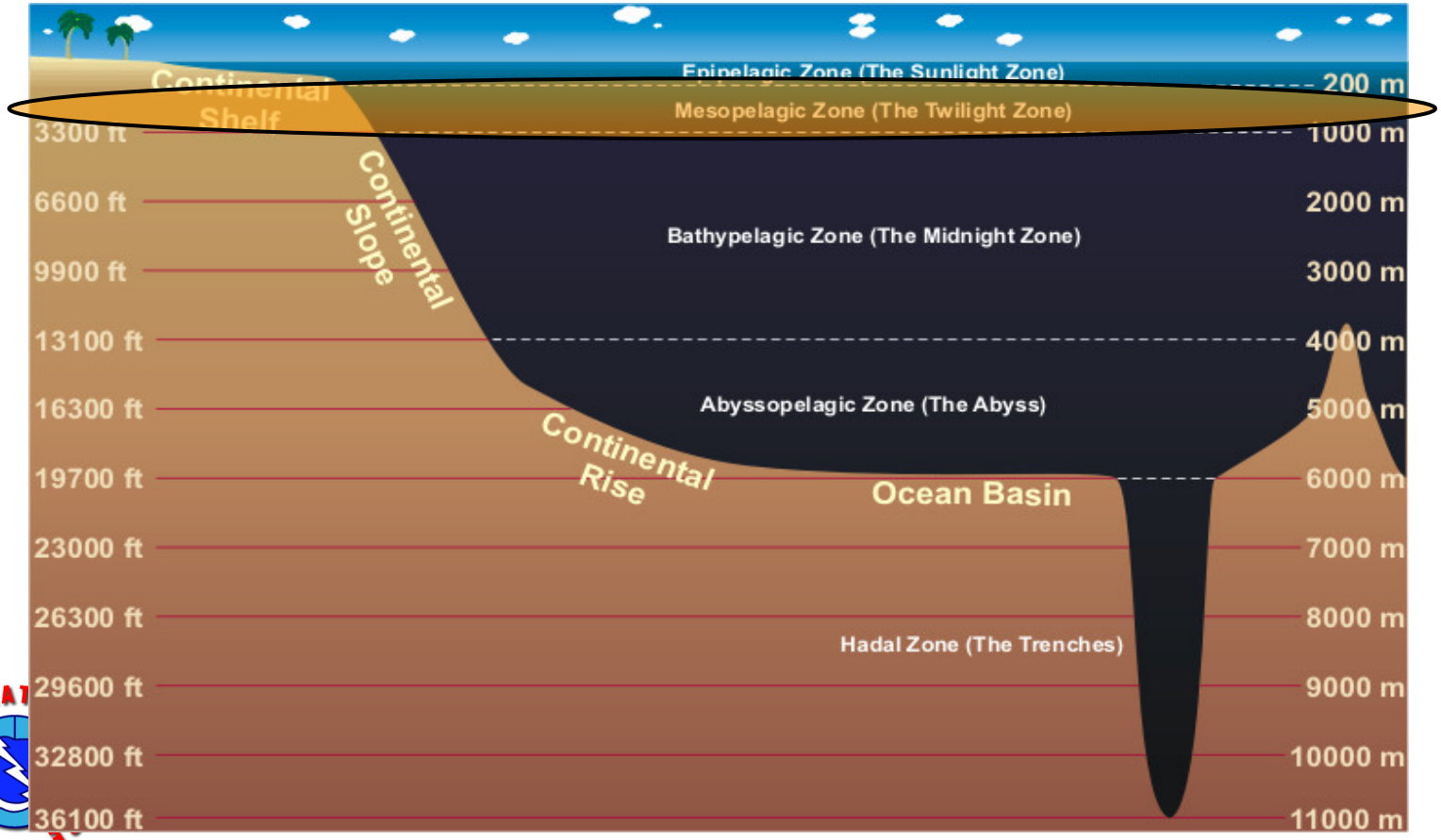


- A transition layer
- Temperature decreases rapidly
- Relevance to you?
  - oxygen is just right

The top layer of the ocean is the epipelagic zone, which receives the most heating from the sun. This results in a wide variation of temperature in a relatively short distance. This is also where the wind has the most influence, and results in mixing and heat distribution

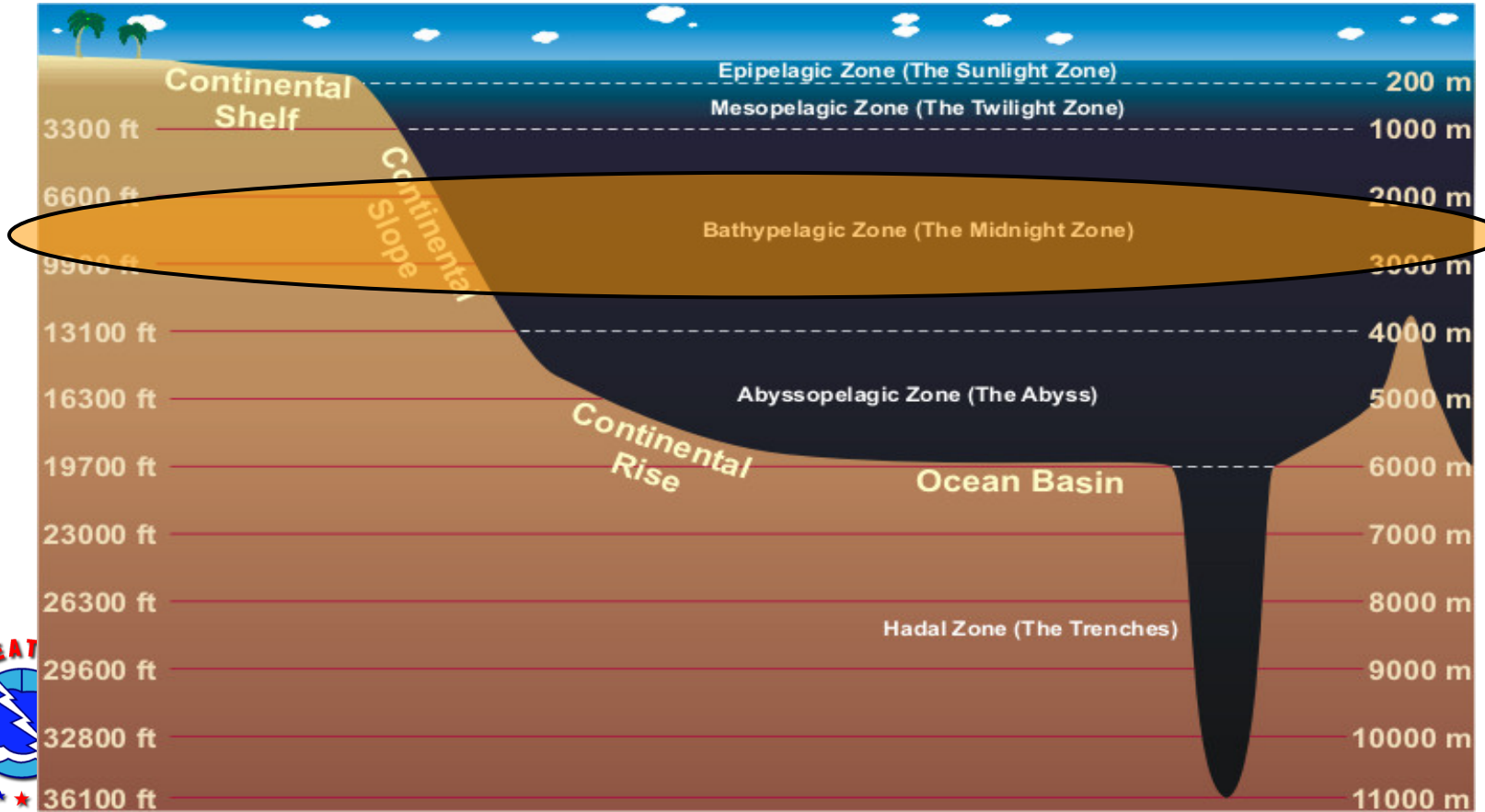
The Mesopelagic Zone

- "Twilight Zone" (sunlight is very faint)
  - Most temperature change near top of layer
- Between 200 and 1000m
- Animal characteristics begin to change (bioluminescent starts)



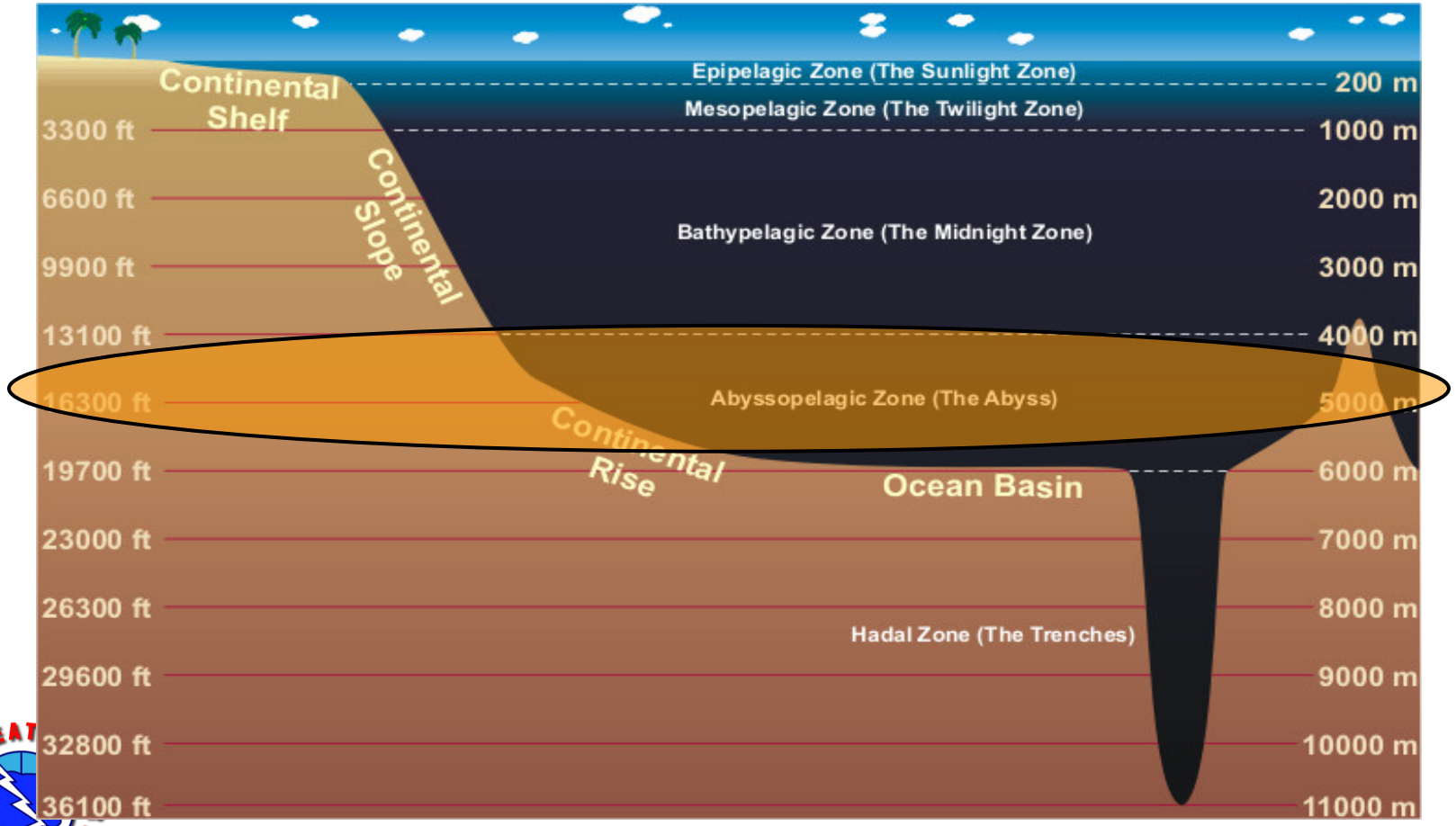
The Bathypelagic Zone

- "Midnight Zone"
  - No light *at all*
  - Only light comes from animals (bioluminescence)
- Very little temperature change
- Pressure reaches over 5800 p.s.i. (pressure at the earth's surface is 14.7 p.s.i.)



The Abyssopelagic Zone

- "The Abyss"
  - Greek word meaning "no bottom"
- Between 4000 and 6000m
- Water temperature near freezing

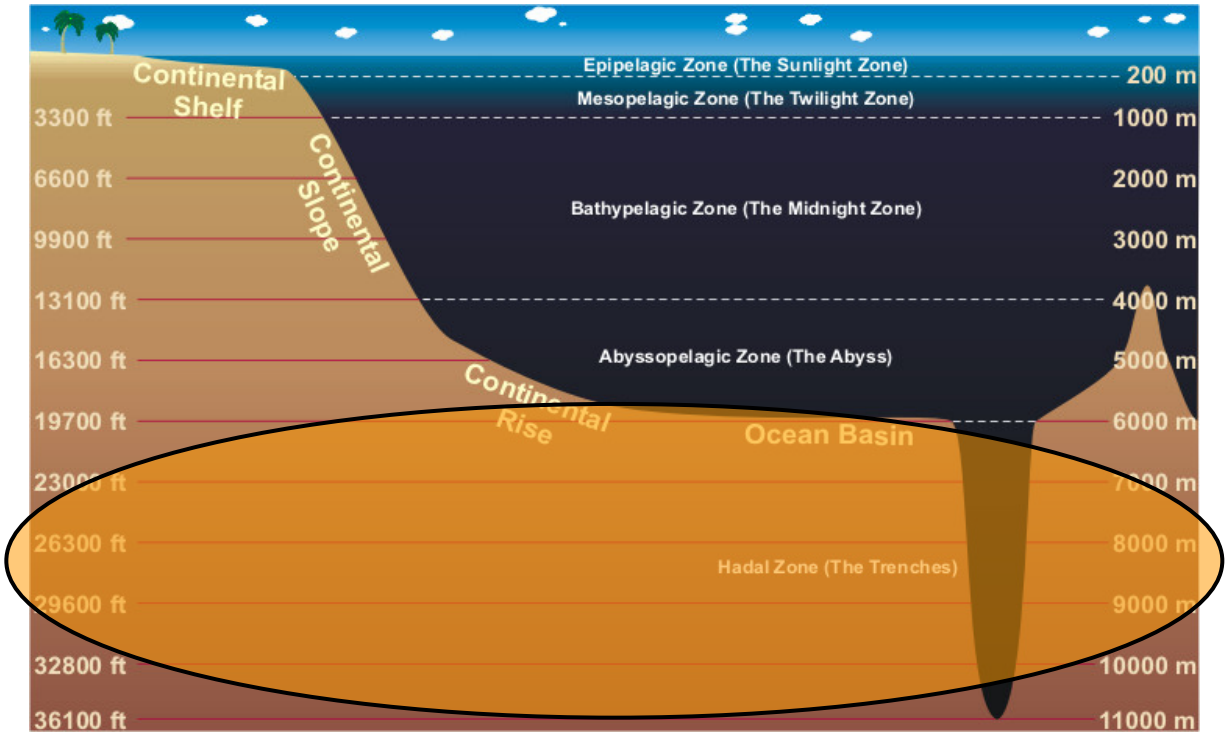


The Hadalpelagic Zone

- "The Trenches"
- Anything below 6000m
- Worth repeating:
  - Deepest trench is the Mariana Trench
  - "Weight": >8 t.s.i.

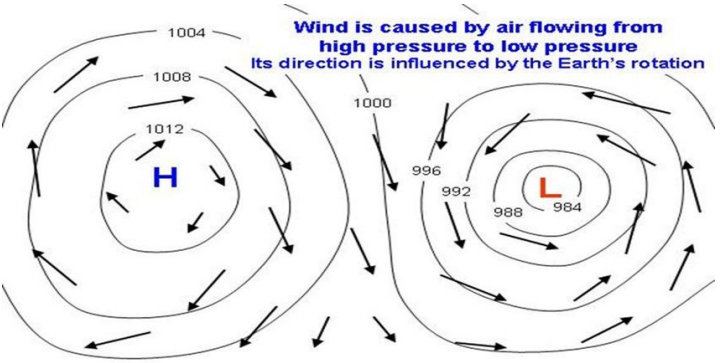
  (Tons per square inch)
- Life still exists here!

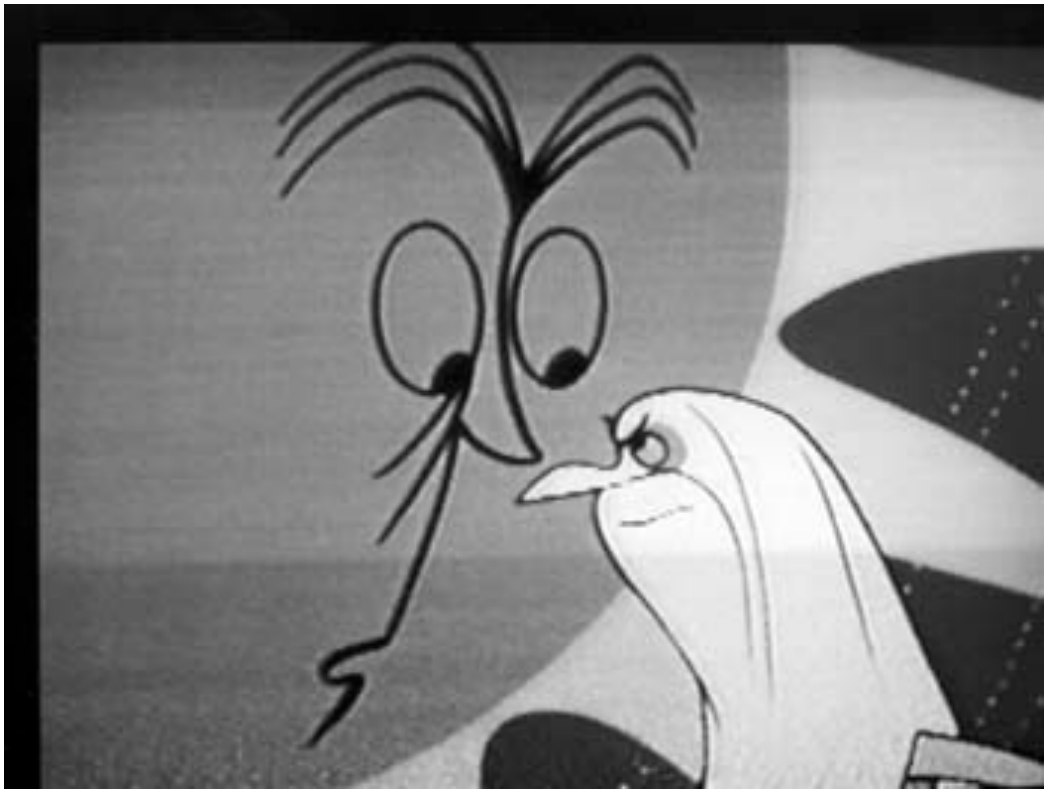
(in the form of plankton)



Ocean currents:

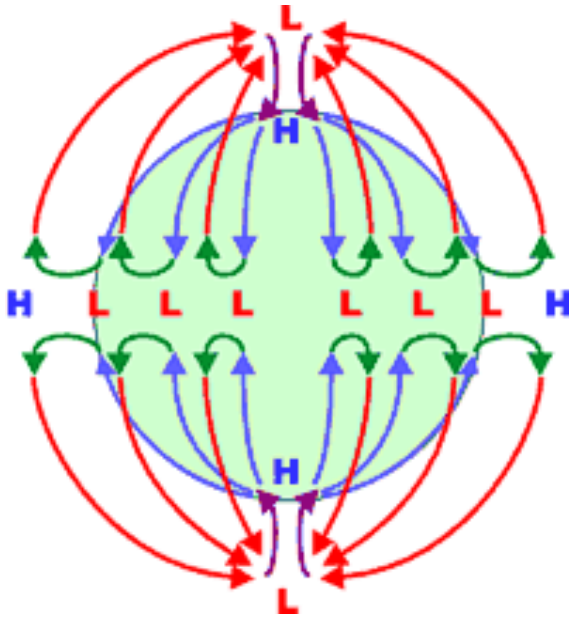
- Sun is the driving force
- Solar radiation affects the ocean differently. Incoming solar radiation (or insolation) is the ultimate cause of the weather on the earth. As solar insolation hits the earth's surface, it heats the atmosphere during the day and cools at night. When it heats the ocean, pretty much the same thing happens, only more slowly. As such, once the epipelagic zone is warmed, it stays warmer longer. These temperature differences cause wind.





Ocean Currents

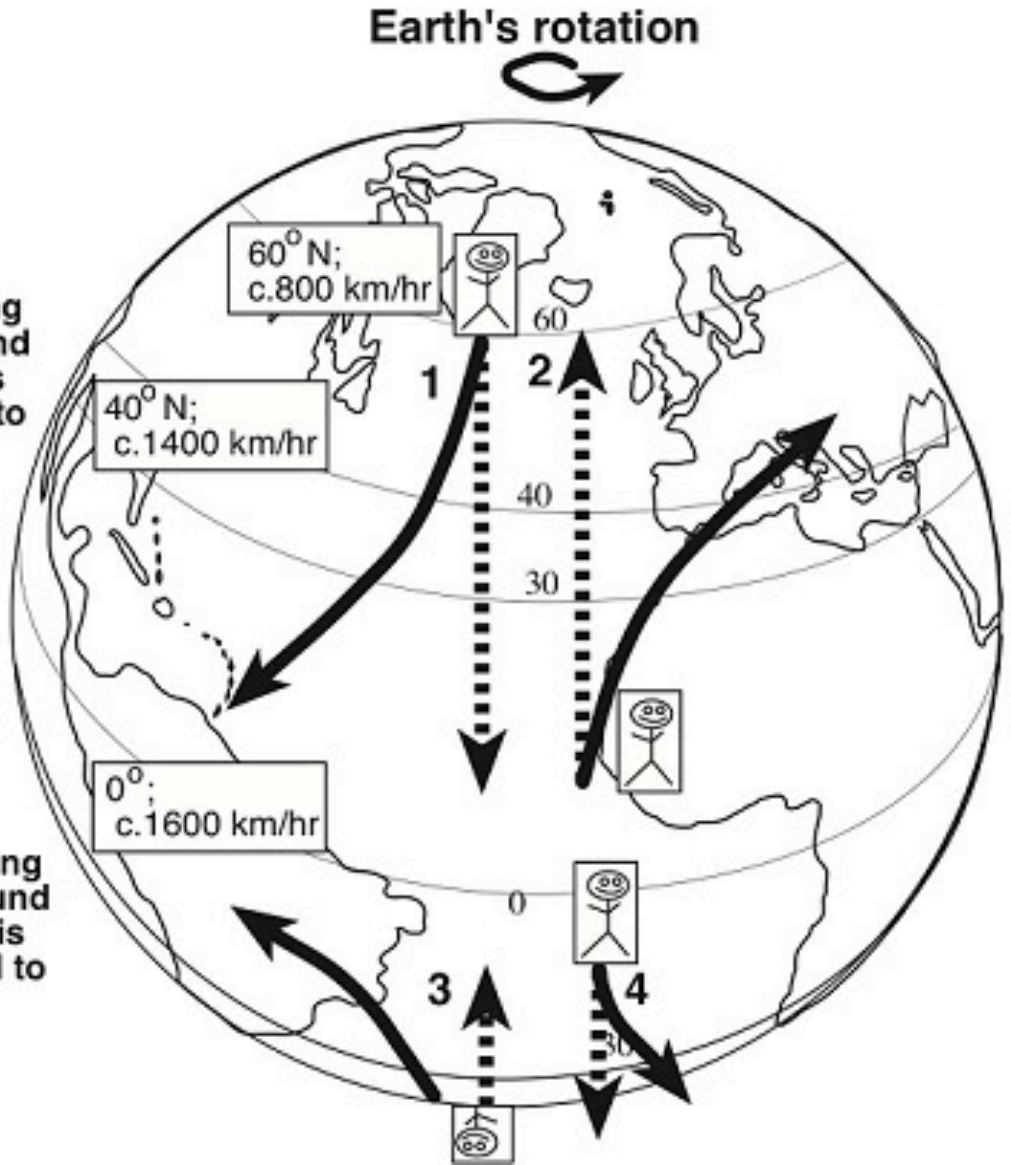
- Two types:
  - Wind-driven Currents
  - Deep Water Currents
- 40% of the global heat transport
- Move slower than surface winds
  - Kilometers per day vs. kilometers per hour
- Long-term climate impacts
  - Gulf Stream most important in our region



- Oceans near equator "heat up" more than the poles
- Sets up…
  - Temperature imbalance
  - Semi-permanent pressure areas
  - Constant push of wind on water

Coriolis force:

Objects moving in air and/or wateron the Earth's surface are decoupled from the solid earth, and move independently. Coriolis deflection is an apparent movement (to an observer), due to the fact that the Earth's speed of rotation is slower at the poles than at the equator. Coriolis deflection also affects air and water masses and governs atmospheric and ocean-surface circulation patterns.

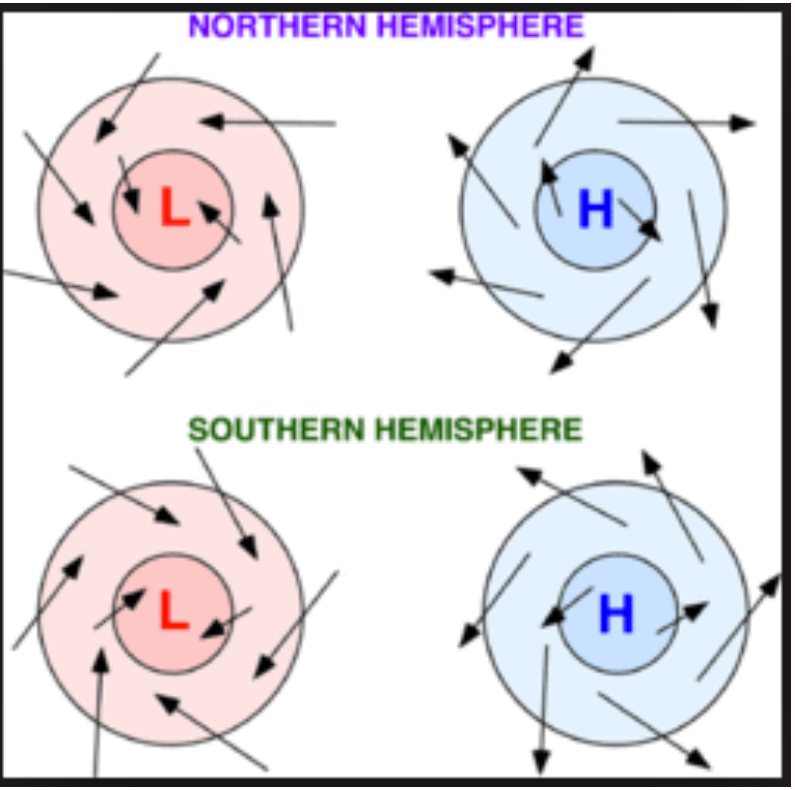


1). Object moving south in northern hemisphere is moving *slower* than the ground underneath, and so is apparently deflected to the *right*;

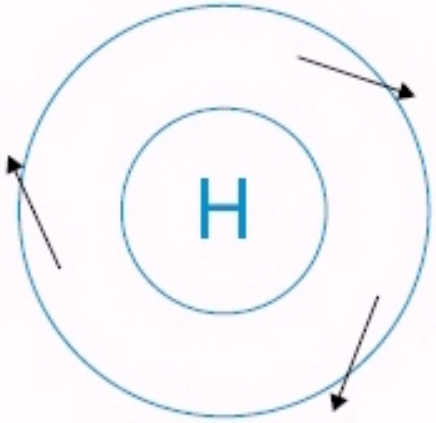
2). Object moving north in northern hemisphere is moving *faster* than the ground underneath, and so is apparently deflected to the *right*;

3). Object moving north in southern hemisphere is moving *slower* than the ground underneath, and so is apparently deflected to the *left*;

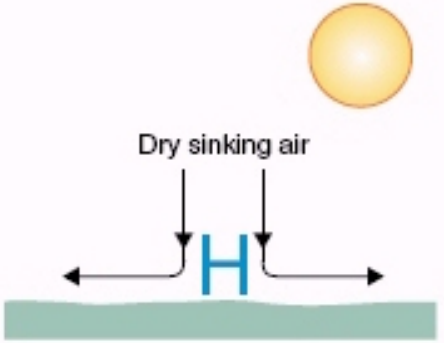
4). Object moving south in southern hemisphere is moving *faster* than the ground underneath, and so is apparently deflected to the *left*;



Surface winds blow clockwise around a high pressure and diverge.

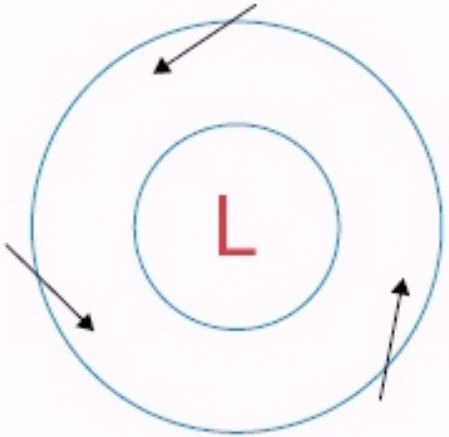


View from above

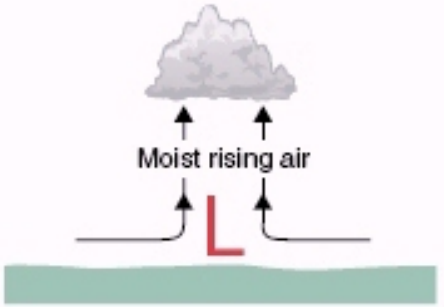


View from side

Surface winds blow counterclockwise around a low pressure and converge.

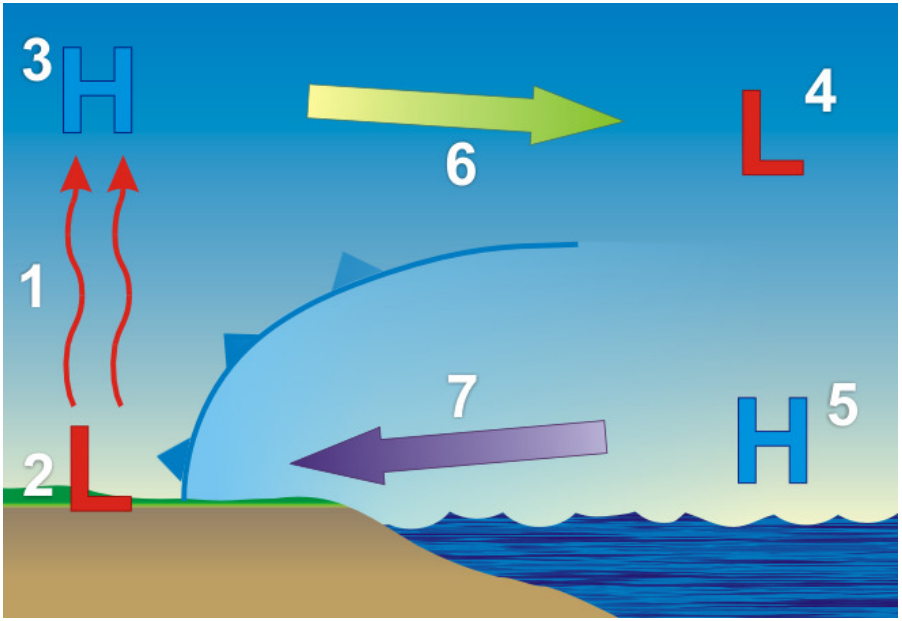


View from above



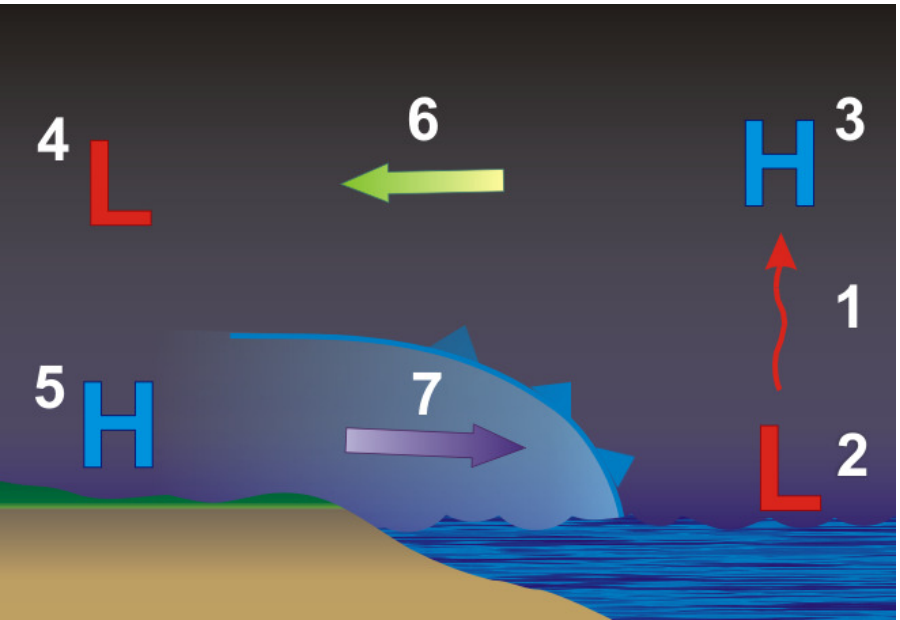
View from side

Seabreeze– During the Day

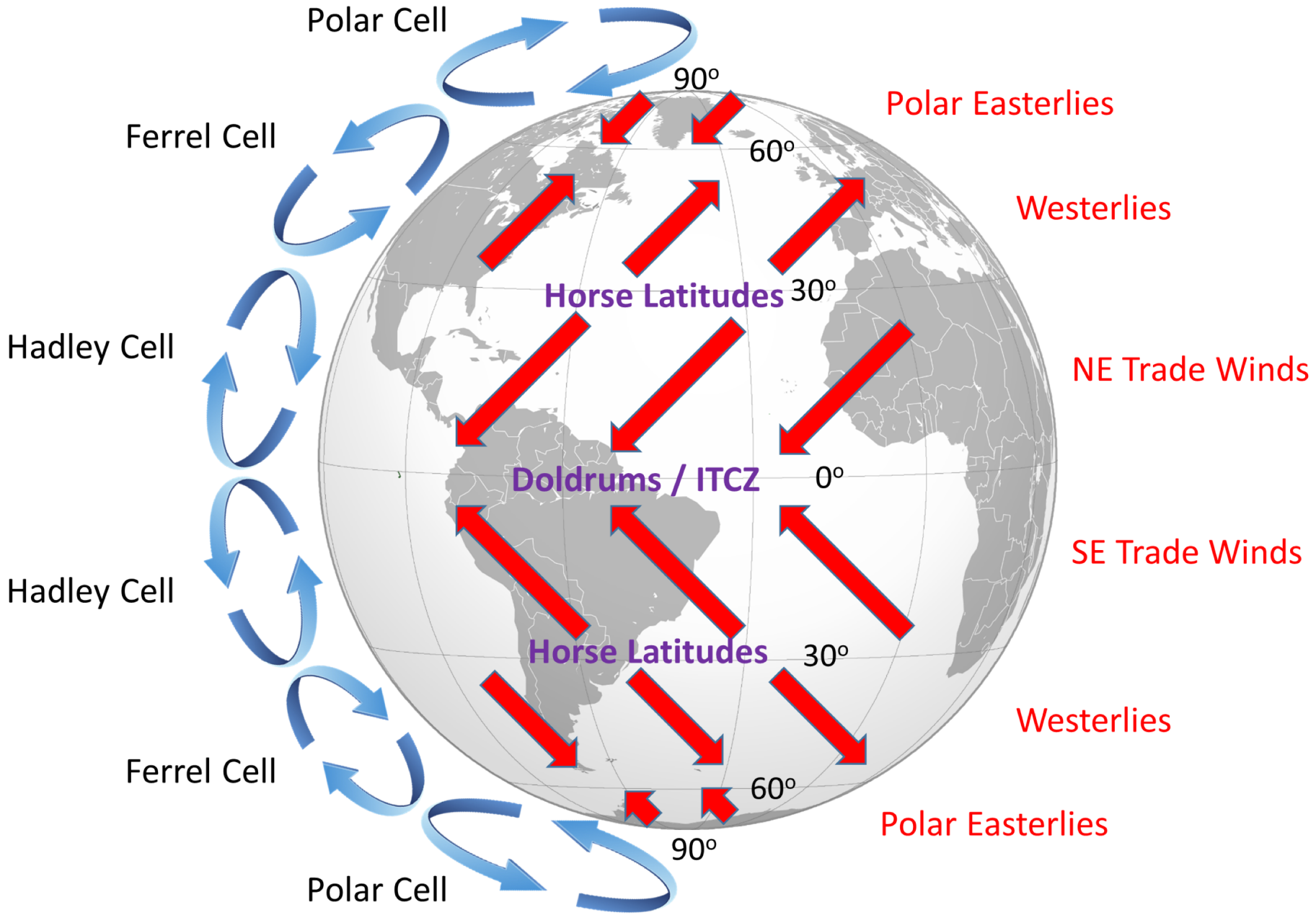


- Beach heats faster than ocean
- Air rises onshore
- Slightly cooler, denser air moves onshore to replace the “lost” air
- Results:
  - Onshore breeze
  - Possible storm development

Landbreeze– During night



- Beach cools faster than ocean
- Air rises offshore
- Slightly cooler, denser air moves offshore to replace the “lost” air
- Results:
  - Offshore breeze
  - Possible storm development


Polar Cell
Ferrel Cell
Hadley Cell
Hadley Cell
Ferrel Cell
Polar Cell
90°
60°
30°
0°
30°
60°
90°
Polar Easterlies
Westerlies
Horse Latitudes
NE Trade Winds
Doldrums / ITCZ
SE Trade Winds
Horse Latitudes
Westerlies
Polar Easterlies

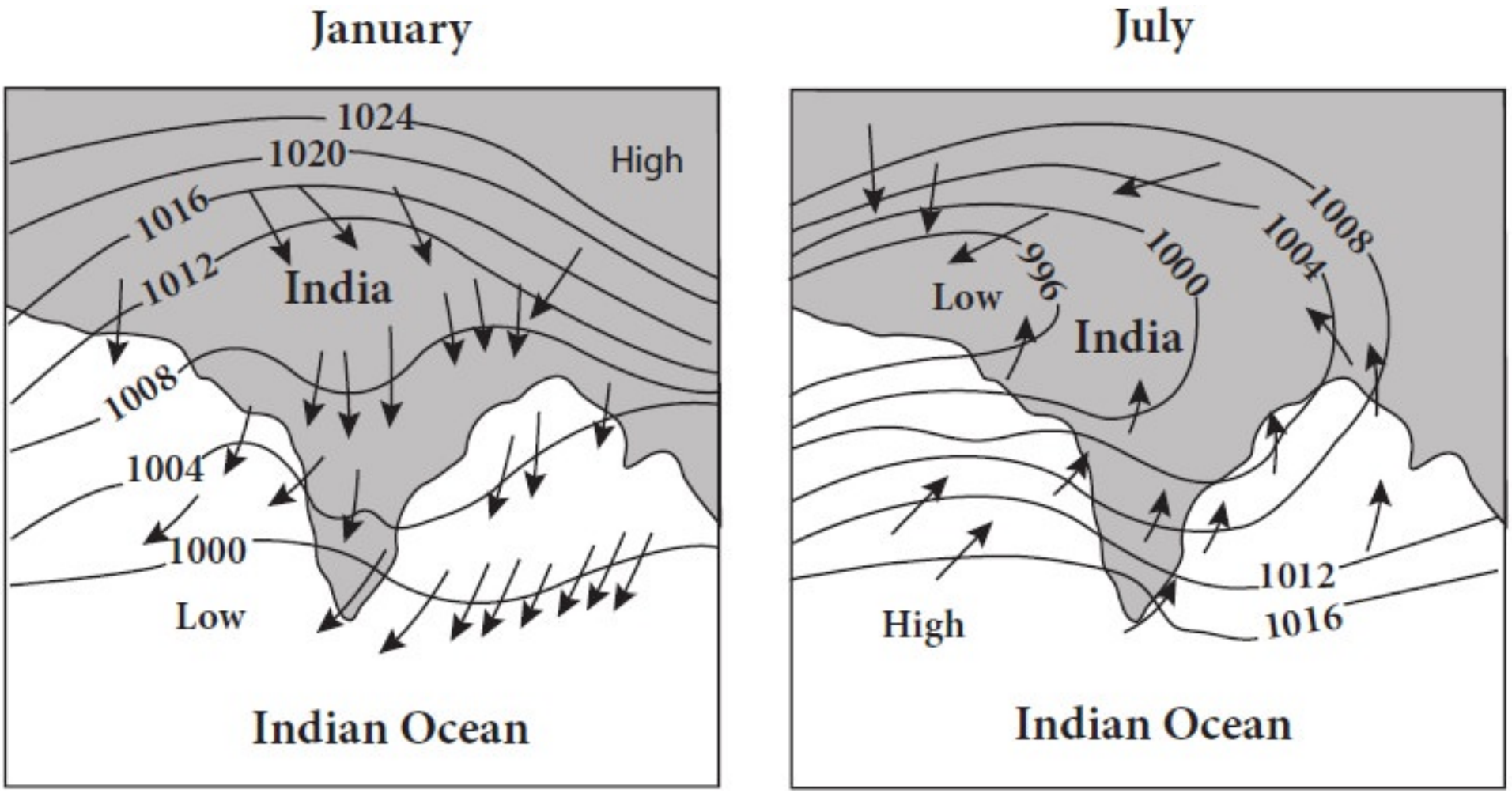
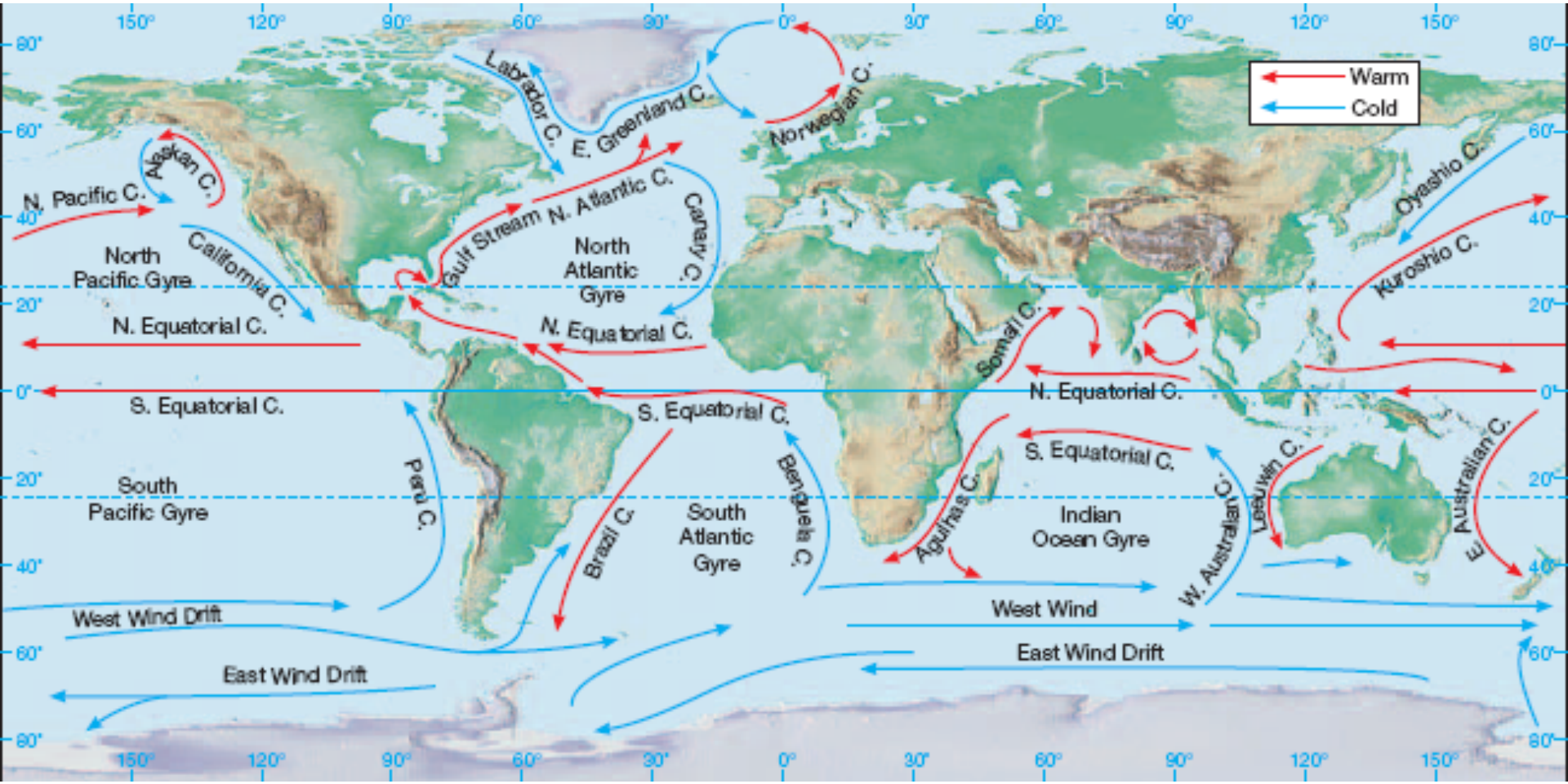


Figure 6.11 Location of High pressure and Low pressure in winter and summer

Wind driven currents

- **Surface Currents** – movements of water that flow horizontally in the upper part of the ocean's surface
- Surface currents develop from friction between the ocean and the wind that blows across its surface
- Some water movements are responses to local or seasonal influences, others are more permanent and extend over large portions of the ocean

Surface Ocean Currents and Gyres

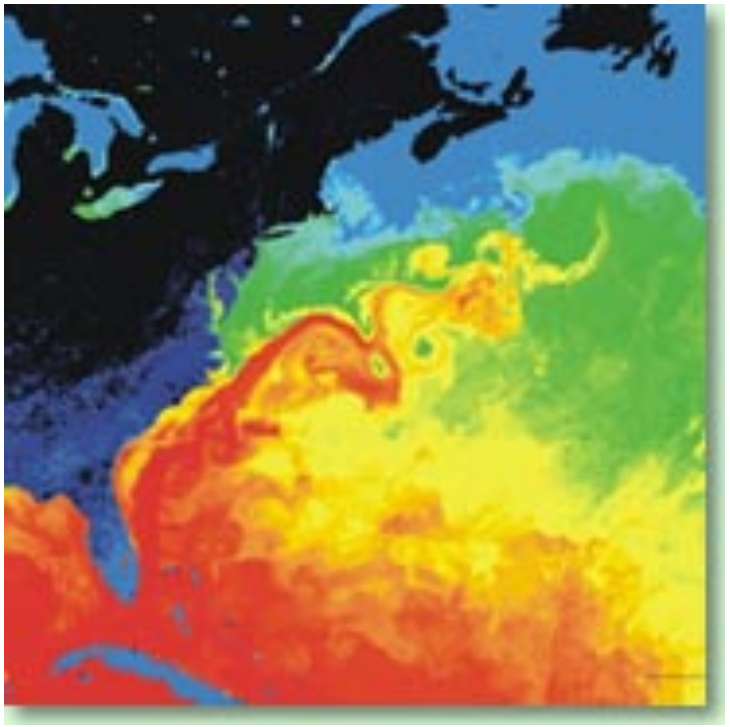


Gyres

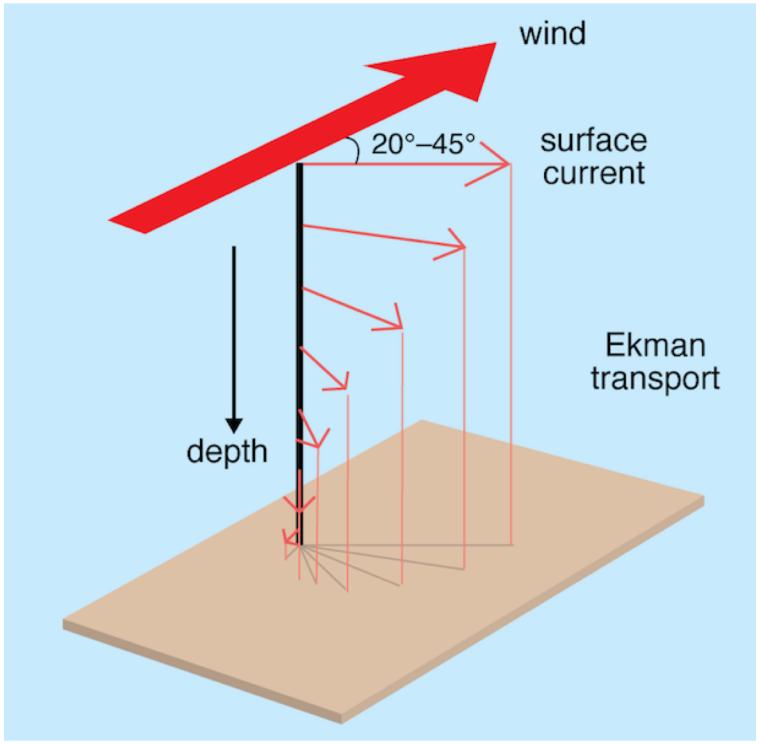
- **Gyre** – huge circular-moving current systems which dominate the surfaces of the oceans
- The 5 main ocean gyres: the North Pacific Gyre, the South Pacific Gyre, the North Atlantic Gyre, the South Atlantic Gyre, and the Indian Ocean Gyre
- **Coriolis Effect** – the deflection of currents away from their original course as a result of Earth's rotation
- Because of Earth's rotation, currents are deflected to the right in the Northern Hemisphere and to the left in the Southern Hemisphere
- Therefore, gyres flow in opposite directions in the two hemispheres

Ocean Currents and Climate

- When currents from low-latitude regions move into higher latitudes, they transfer heat from warmer to cooler areas of Earth
- The Gulf Stream, for example, brings warm water from the equator up to the North Atlantic Current (allowing Europe to be warmer in the winter than expected for those latitudes)
- As cold water currents move towards the equator, they help moderate the warm temperatures of adjacent land areas
- Ocean currents also play a major role in maintaining Earth's heat balance



Gulf Stream

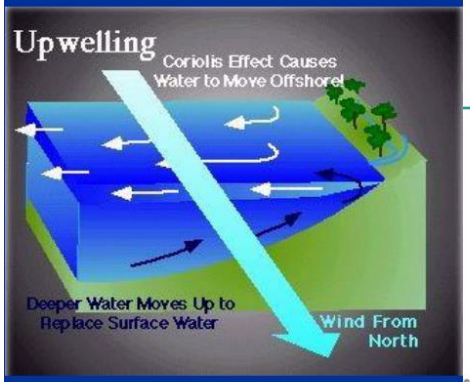


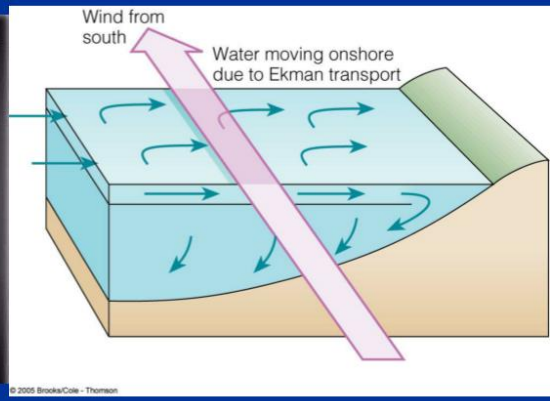
coastal upwelling

due to offshore Ekman transport along Oregon coast

summer upwelling (north winds)

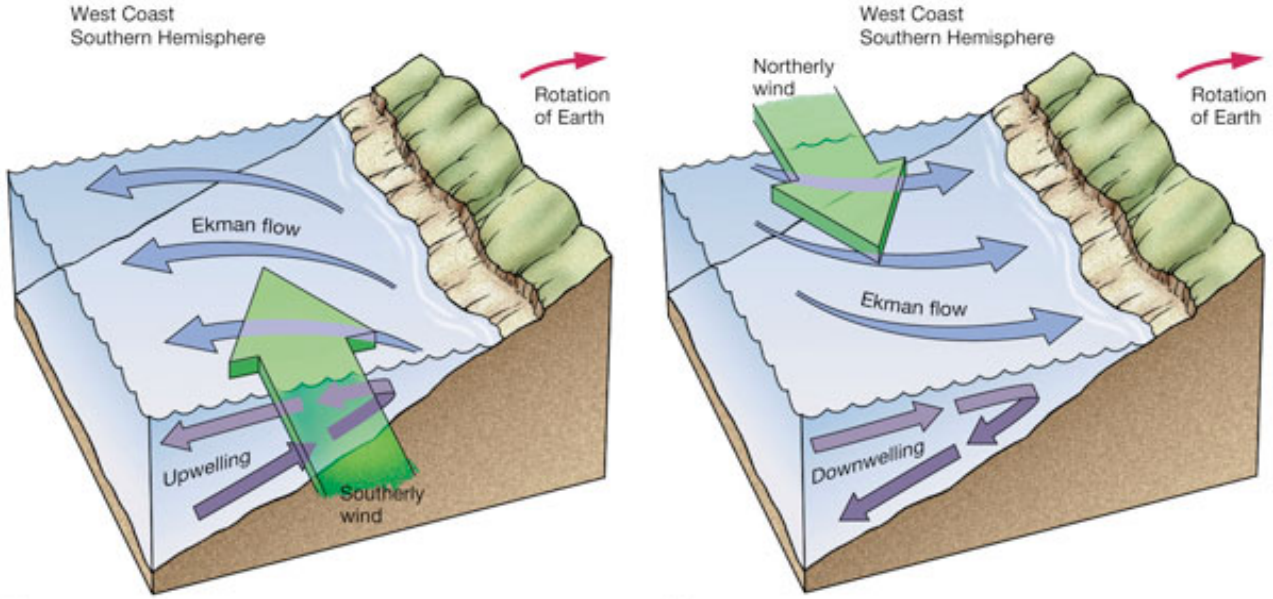
winter downwelling (south winds)





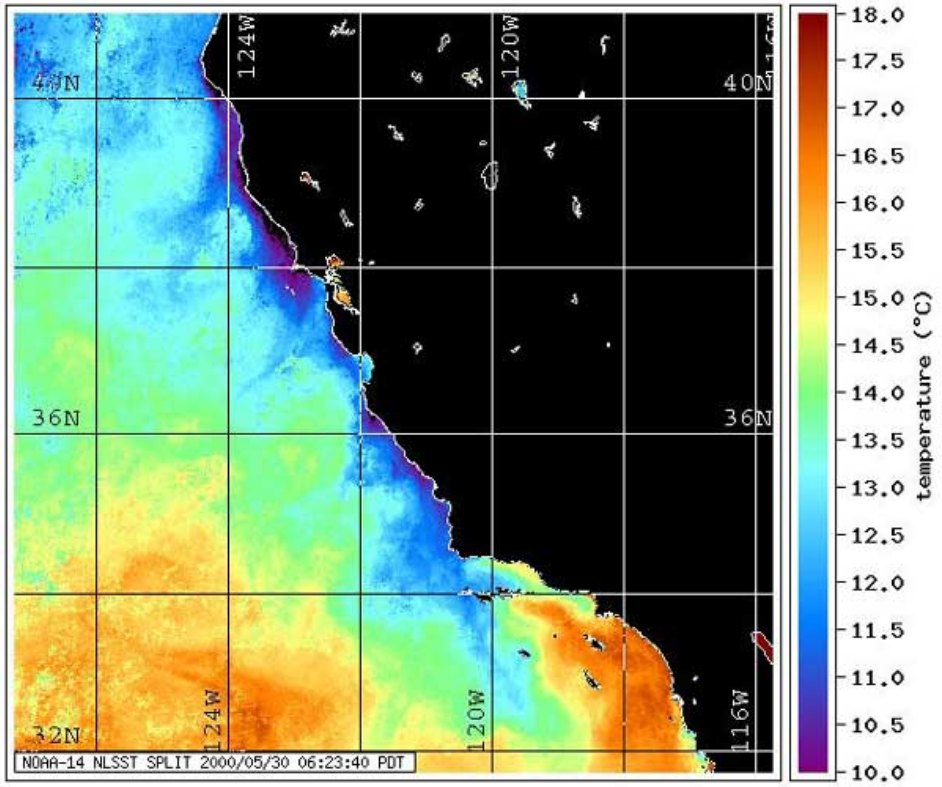
coriolis displacement to right in No. Hemisphere

Ekman transport

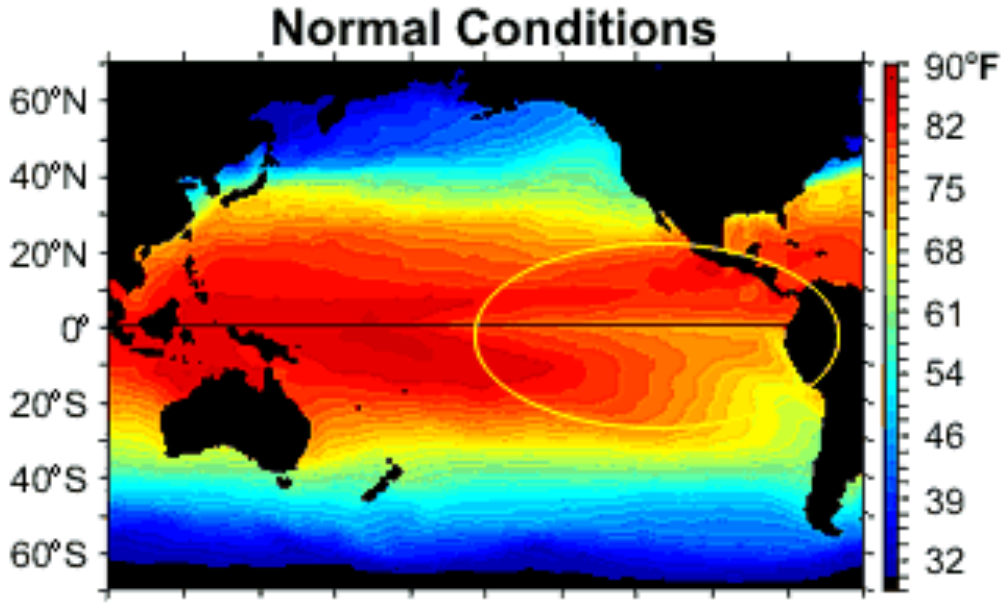


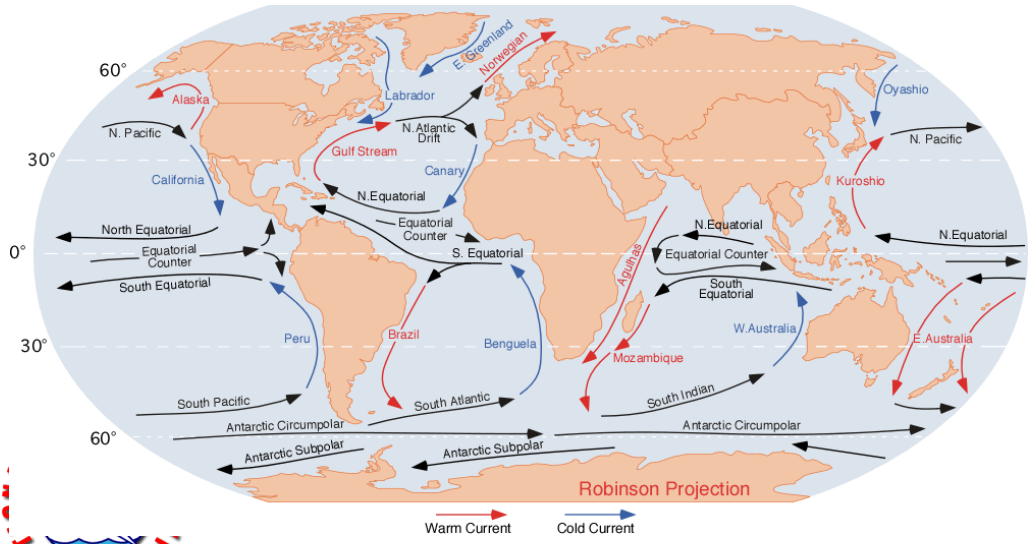
Upwelling

- **Upwelling** – the rising of cold water from deeper layers to replace warmer surface water
- Upwelling is a common wind-induced vertical movement
- Coastal upwelling occurs in areas when winds blow toward the equator and parallel to the coast, this combined with the Coriolis effect cause surface waters to move away from shore and be replaced by water from below the surface
- Upwelling brings greater concentrations of dissolved nutrients, such as nitrates and phosphates to the ocean surface



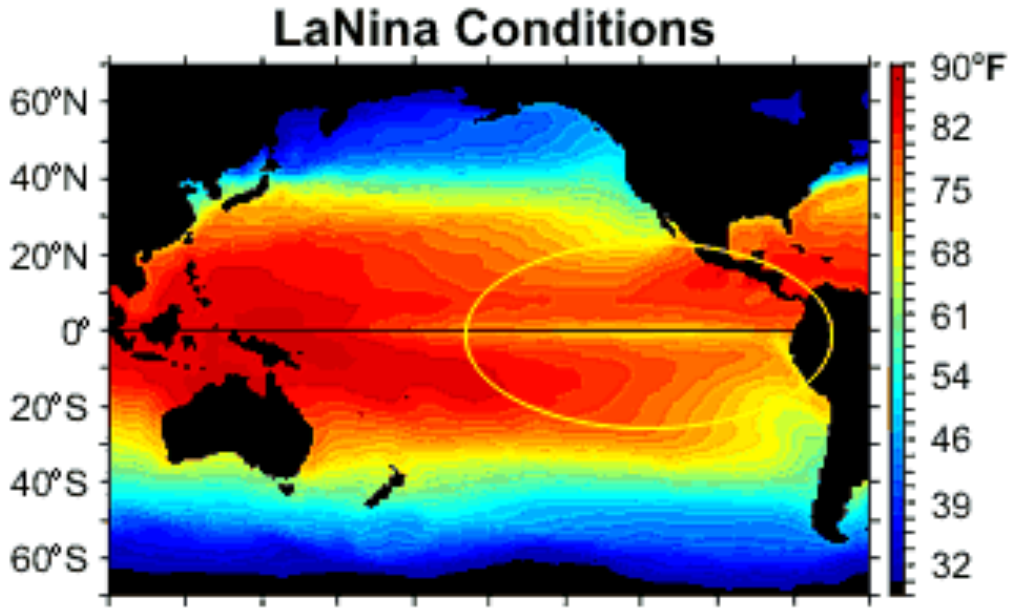
California Coastal Upwelling

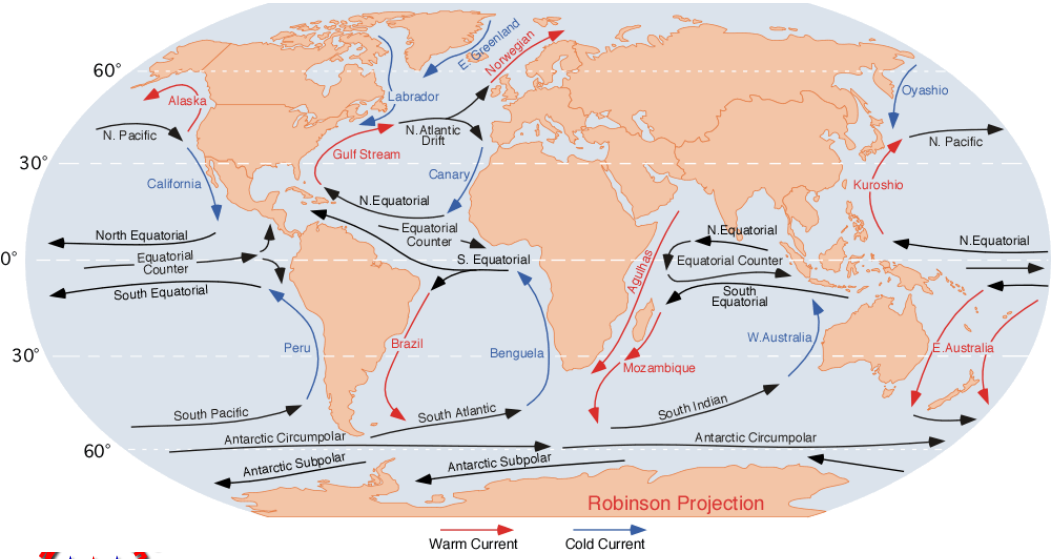




- Normally…
  - Warm waters over Central Pacific
  - Cooler waters off Peruvian coast
- Colder, nutrient-rich waters pulled up from western coast of South America

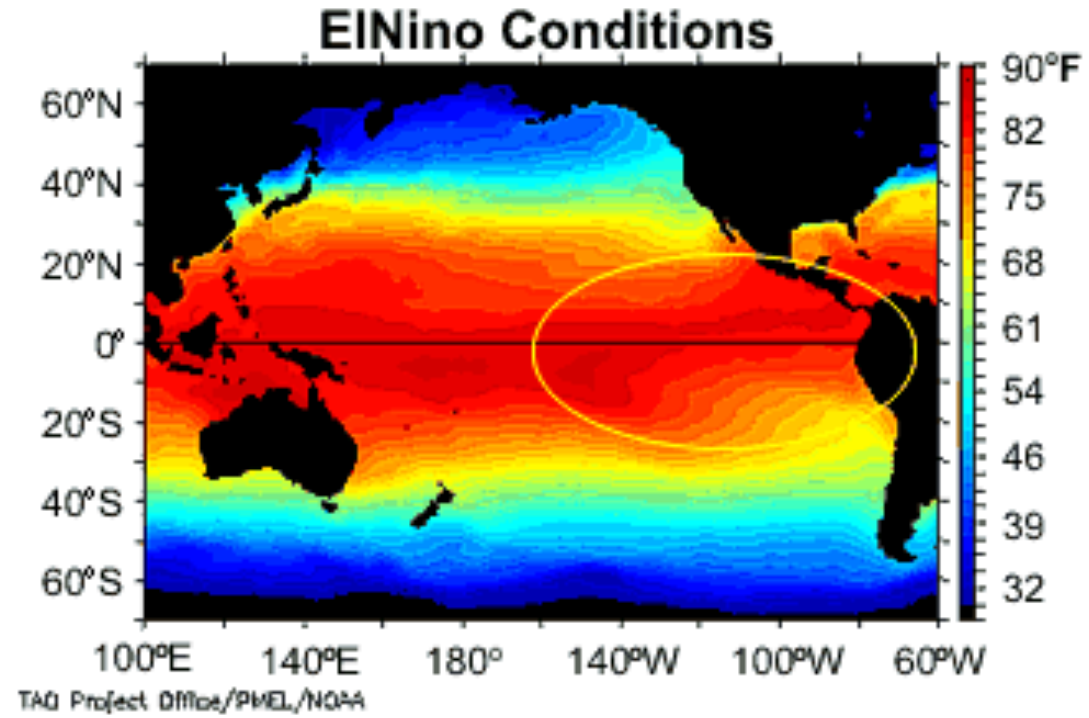
In a normal year, the Peruvian Current brings colder waters from the Southern Ocean northward along the coast of Peru. These waters are filled with lots of nutrients, which feed the fish living in the southern Pacific Ocean. Note also that the Equatorial Countercurrent tries to bring warmer water eastward toward the coast of South America.





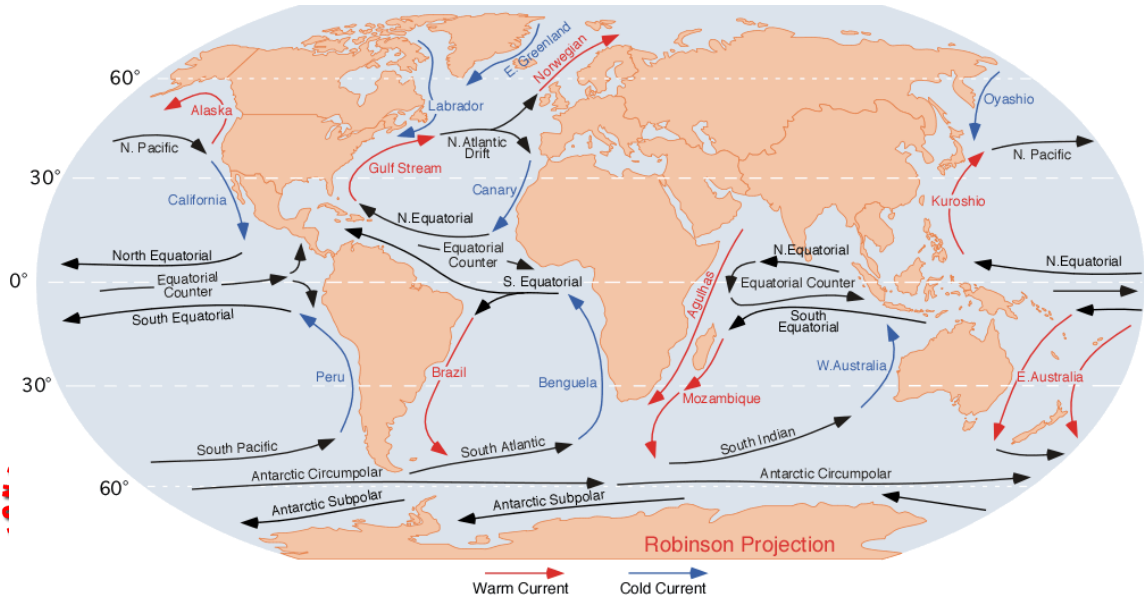
- La Nina:
  - Trade wind strengthens
  - Nutrient-rich water supply increases
- RESULT:
  - Warm waters "pile up" in the western Pacific

During a La Nina year, the Equatorial Countercurrent relaxes, allowing an "abundance" of cooler water to return to the region. When this takes place, the warmer waters will be pushed (so-to-speak) into the western Pacific. This is basically the opposite of El Nino conditions. Like El Nino, though, it can have major effects on the path major storm systems take.



- El Nino:
  - Trade wind weakens
  - Nutrient-rich water supply lessens
- RESULT:
  - Waters warm off Peruvian Coast

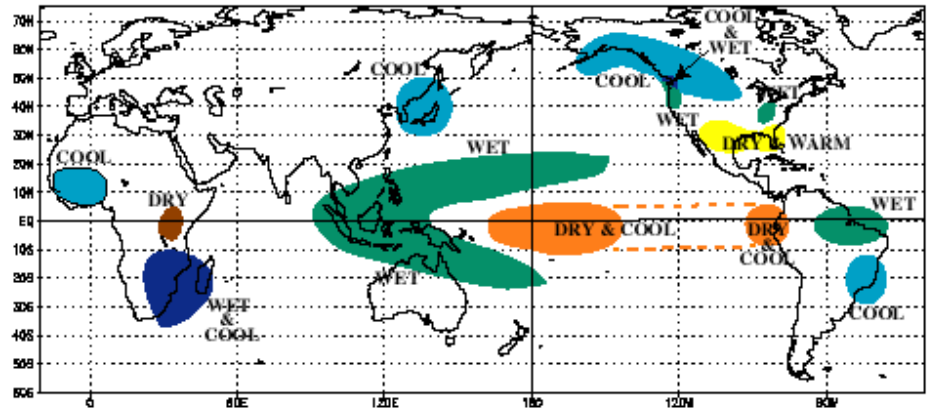
El Nino occurs each year. It is actually named for the Christ Child, since it takes place toward the end of December. Usually, we only hear about the bigger El Nino events. When these events occur, there can be a major shift of the warm waters with several effects, especially in regard to the track of major storm systems.



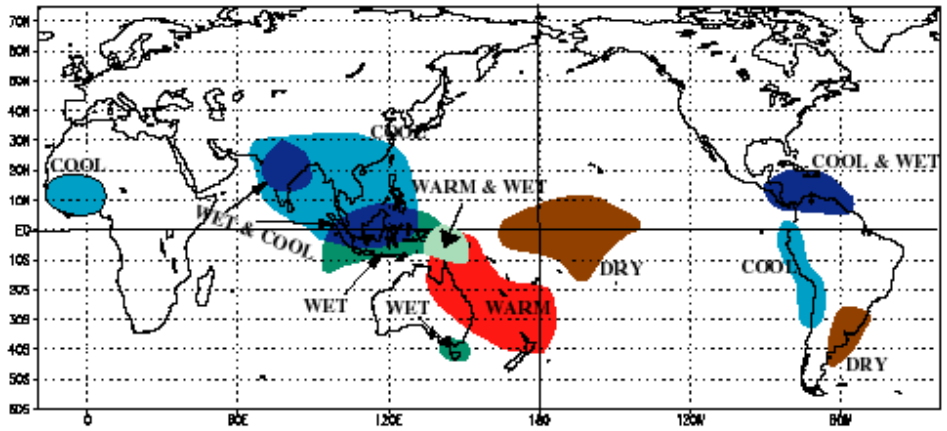
What Does This Mean Weather wise?

For La Nina Events –

COLD EPISODE RELATIONSHIPS DECEMBER - FEBRUARY



COLD EPISODE RELATIONSHIPS JUNE - AUGUST



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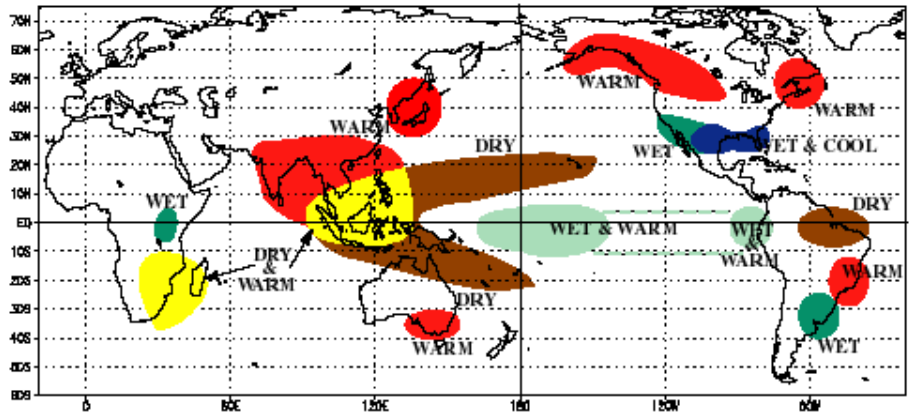
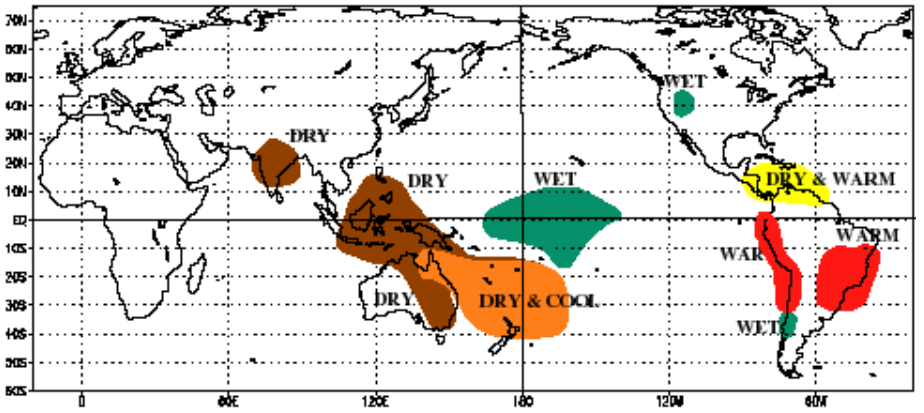
For El Nino Events –

WARM EPISODE RELATIONSHIPS DECEMBER - FEBRUARY



WARM EPISODE RELATIONSHIPS JUNE - AUGUST



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So???

- A lot of fishing takes place off the coast of Peru
- Anchovy fish thrive in the nutrient-rich waters of this area
- Anchovies are caught and used to make chicken feed

- **During big El Nino events:**
  - Waters are not full as nutrients
  - Not as many anchovies
  - Cost of chicken feed increases
  - Therefore, the cost of chicken increases

Wave Action

- Waves are byproduct of wind
- Size depends on *THREE* things:
  - Speed

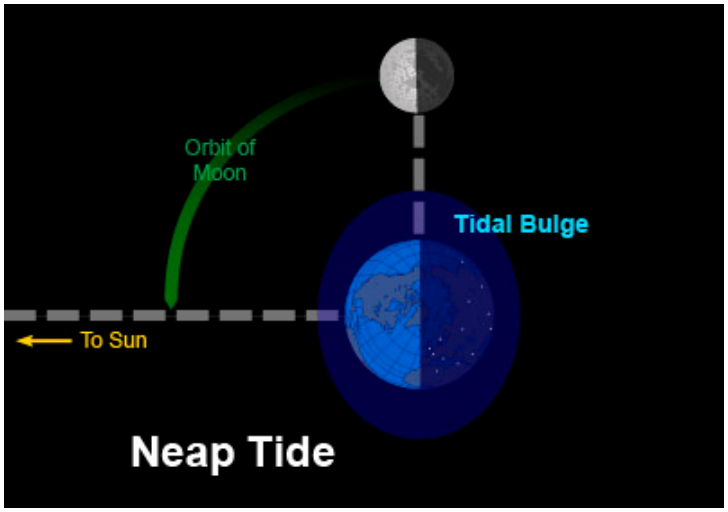
  – The wind has to be blowing faster than the tops of the waves. That meets the speed criteria. The longer that strong wind has been blowing, the better chance it has to generate large waves. The distance criteria is also known as the “fetch”. Basically, this is the uninterrupted distance over which the wind blows without a big change in direction.
  - Duration
  - Distance
- Longer the wave, the faster it moves
  - You can estimate the wind speed using the size of waves. Estimating the wind speed using this method is known as the Beaufort Scale.

- Tides are another type of wave action
- **Definition:**
  - A change in the ocean water level, which results from the gravitational pull of the moon

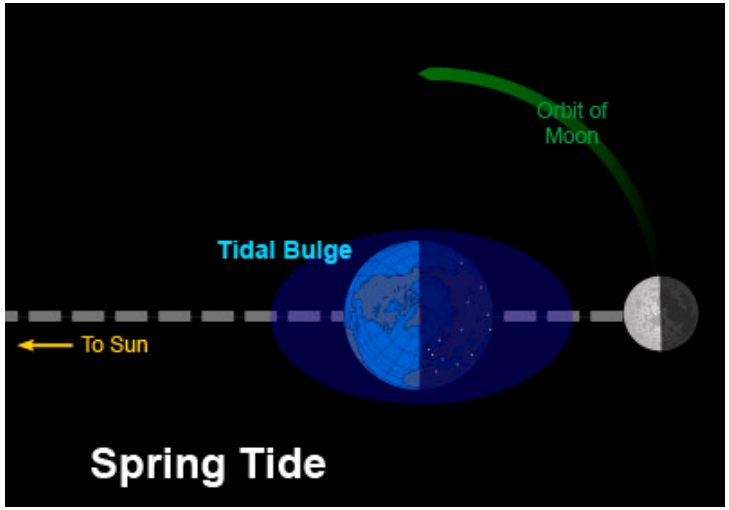
- Why the moon?
  - Sun's gravitational pull is greater
  - But the moon is closer
- Mariners have known for a long time that tides were related to the moon

Two tides? Four tides?

- Number of tides per day related to…
  - Shape of the coastline
  - Sea floor elevation
- Some places have one high/low tide cycle
  - Called a *diurnal tide*
  - Examples:
    - Lake Charles, LA
    - Gulfport, MS
    - Gulf Shores, AL
    - Pensacola, FL
- Other places have two high/low tide cycles
  - Called a *semi-diurnal tide*
  - Examples:
    - Galveston, TX
    - Apalachicola, FL



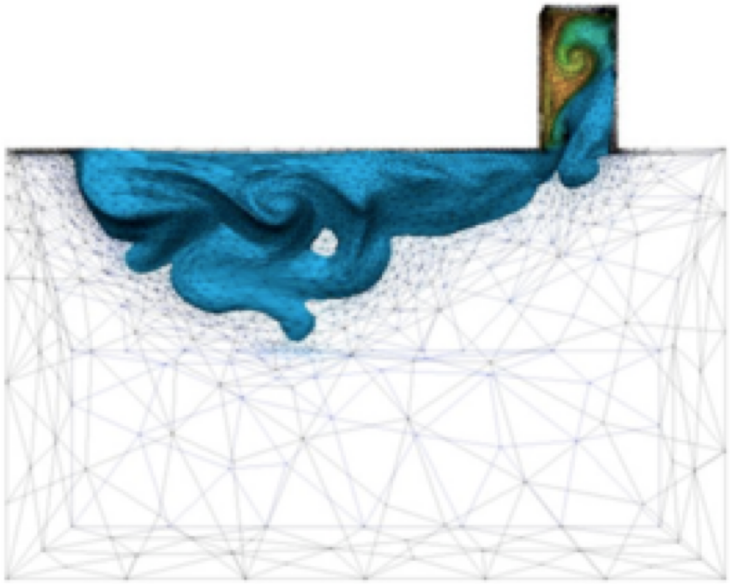
- Occur when the pull of the moon and sun partially cancel each other
- RESULT:
  - Very little change between high and low tides



- Occurs when the pull of the sun and moon act together
- RESULT:
  - Greater than normal tidal range experienced

Density Currents

- **Density Currents** – vertical currents of ocean water that result from density differences among water masses
- Denser water sinks and slowly spreads out beneath the surface
- An increase in seawater density can be caused by a decrease in temperature or an increase in salinity
- Density changes due to salinity variations are very important in the polar regions, where water temperature remains low and relatively constant



High Latitudes

- Most water involved in deep-ocean density currents begins in high latitudes at the surface
- The surface waters become cold, and its salinity increases as sea ice forms
- The water will than sink, initiating deep-ocean density currents
- The water's temperature and salinity will remain relatively unchanged while it is in the deep-ocean currents
- By knowing the temperature, salinity, and density of a water mass, scientists are able to map the slow circulation of water mass through the ocean

Sea Ice

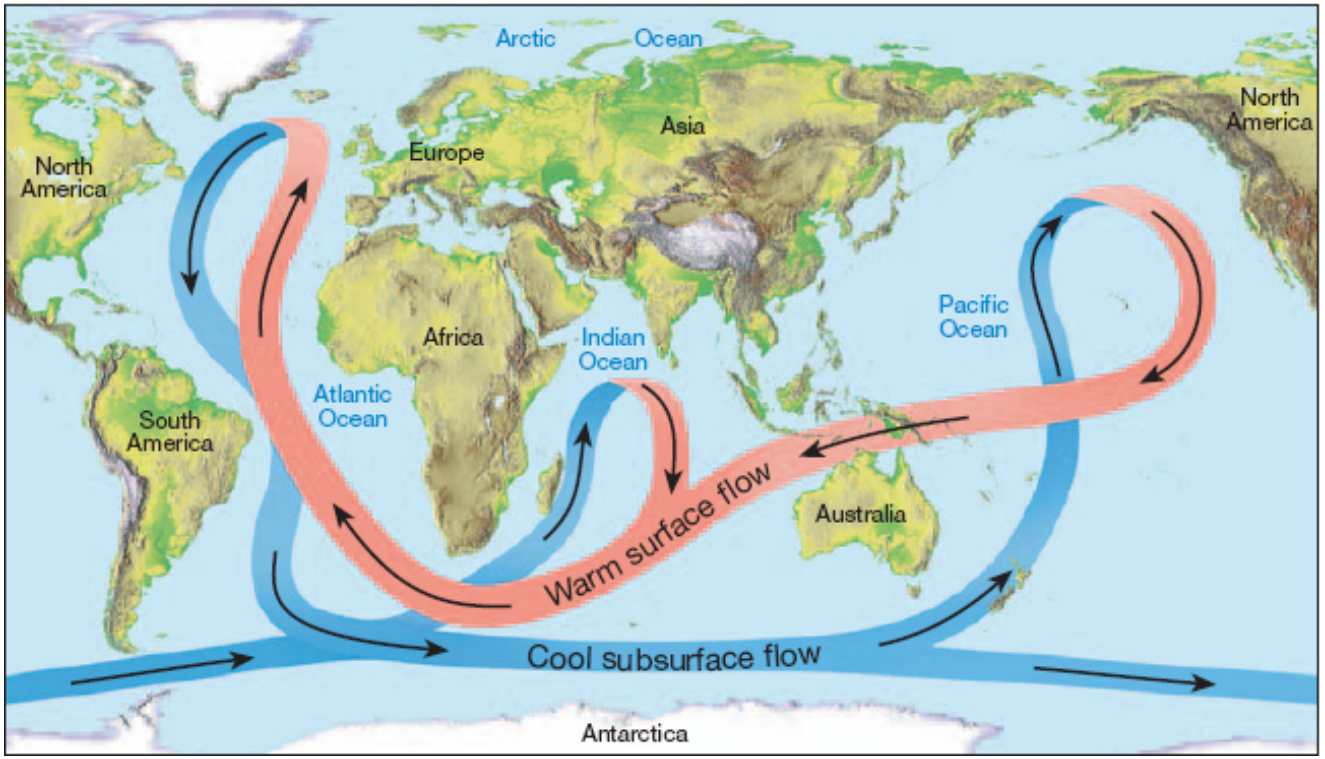
Evaporation

- Density currents can also result from increased salinity of ocean water due to evaporation
- In the Mediterranean Sea, conditions exist where a warm, high salinity water will sink and push its way out to the Atlantic Ocean
- This water has a salinity level of 38‰, compared to the Atlantic having a salinity of 35‰, making the Mediterranean water much more dense
- Scientists have tracked this water mass as far south as Antarctica

Mediterranean Sea

A Conveyor Belt

- A simplified model of ocean circulation is similar to a conveyor belt that travels from the Atlantic Ocean through the Indian and Pacific oceans and back again
- Warm water in the ocean's upper layers flow towards the poles
- When water reaches the poles its temperature drops and salinity increases, it sinks to the bottom and moves towards the equator
- The water will eventually upwells at warmer latitudes to complete the circuit



Global Conveyor Belt

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