Regional Online Training Course on the Relationship Between Ocean Environment Variability and Marine Resource Abundance and Oceanographic Sampling

Introduction to Physical Oceanography

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Introduction to Physical Oceanography

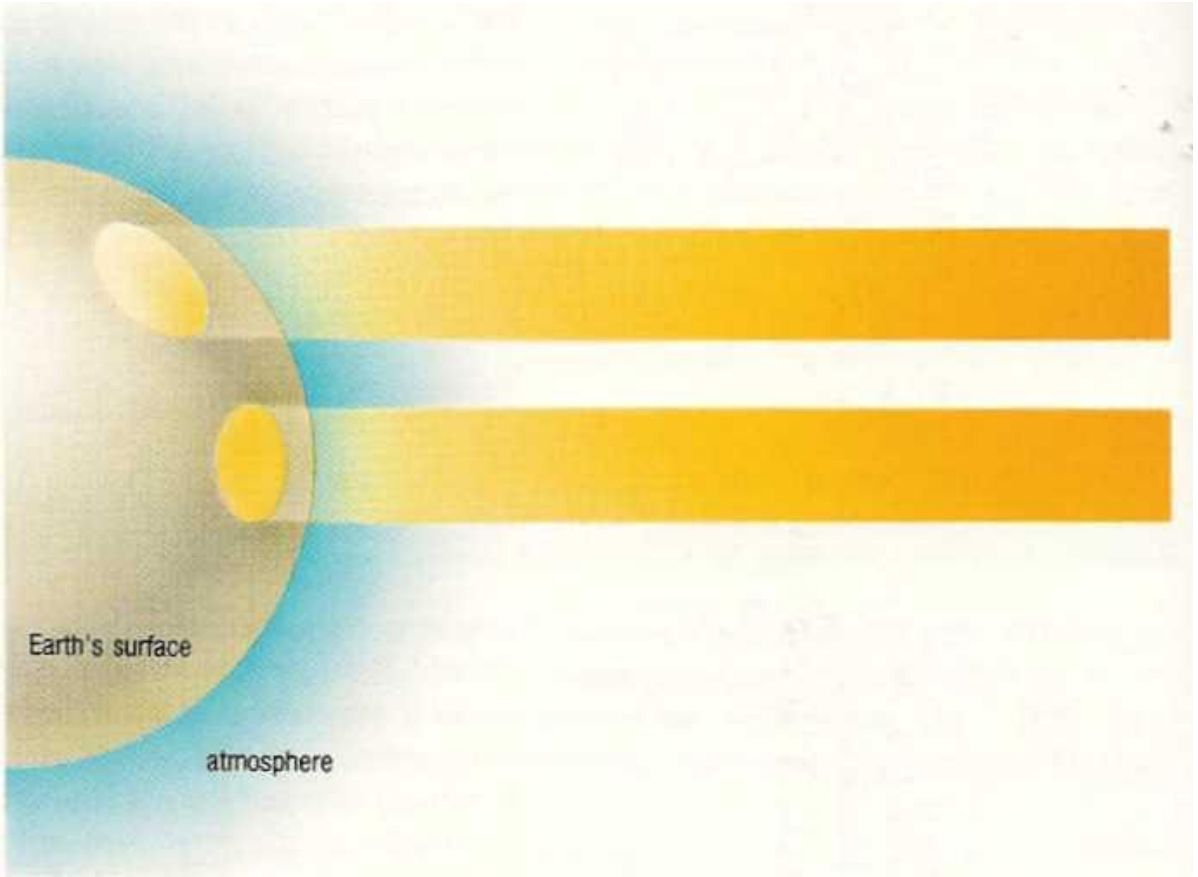
Two important topics to introduce:

- Physical properties and their distribution in the world ocean
    - Temperature, salinity and density
- Atmospheric and ocean circulation

Physical properties and their distribution in the world ocean

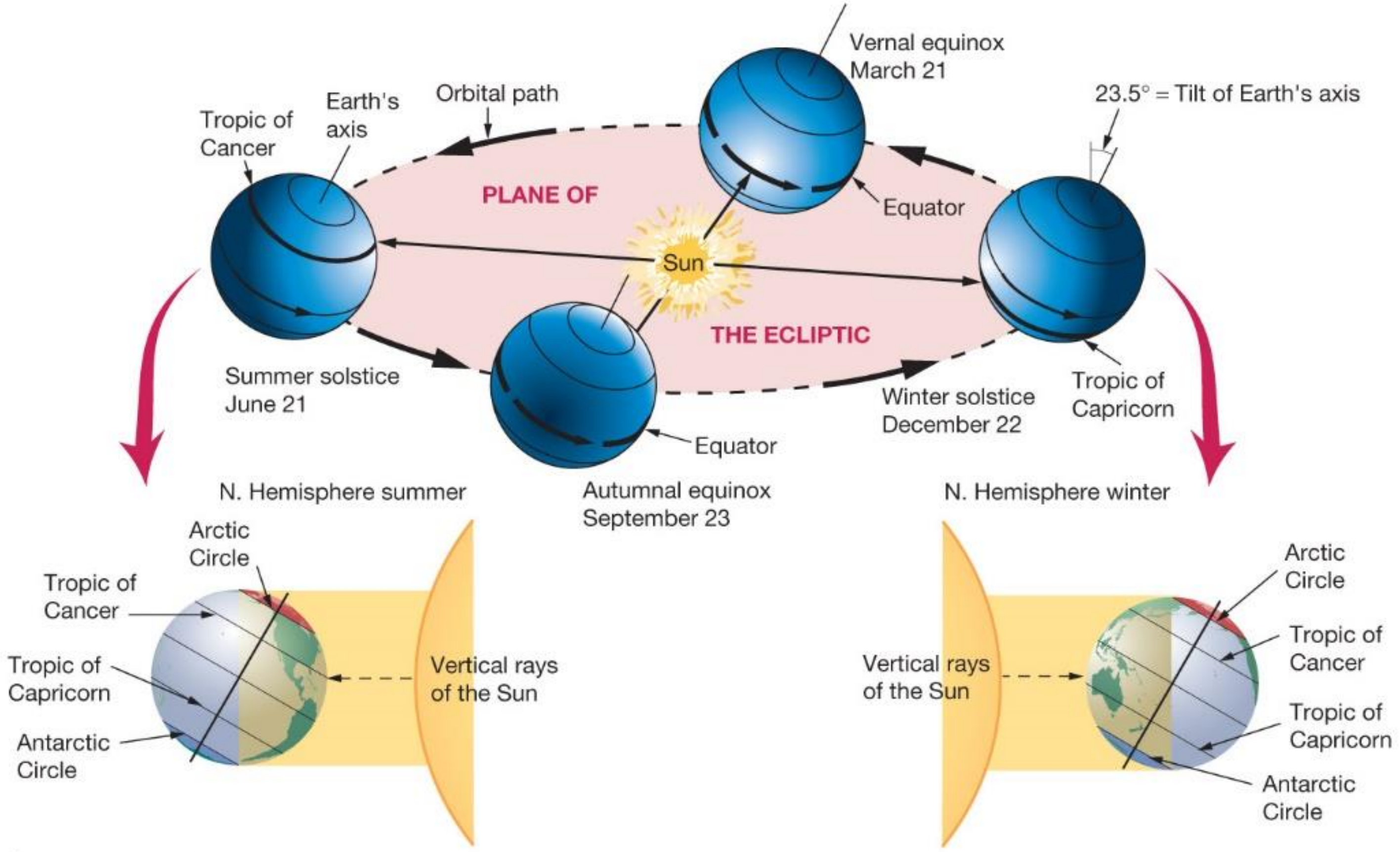
Distribution of Sea Surface Temperature

- Depend on different exposures from the sun at different latitudes.

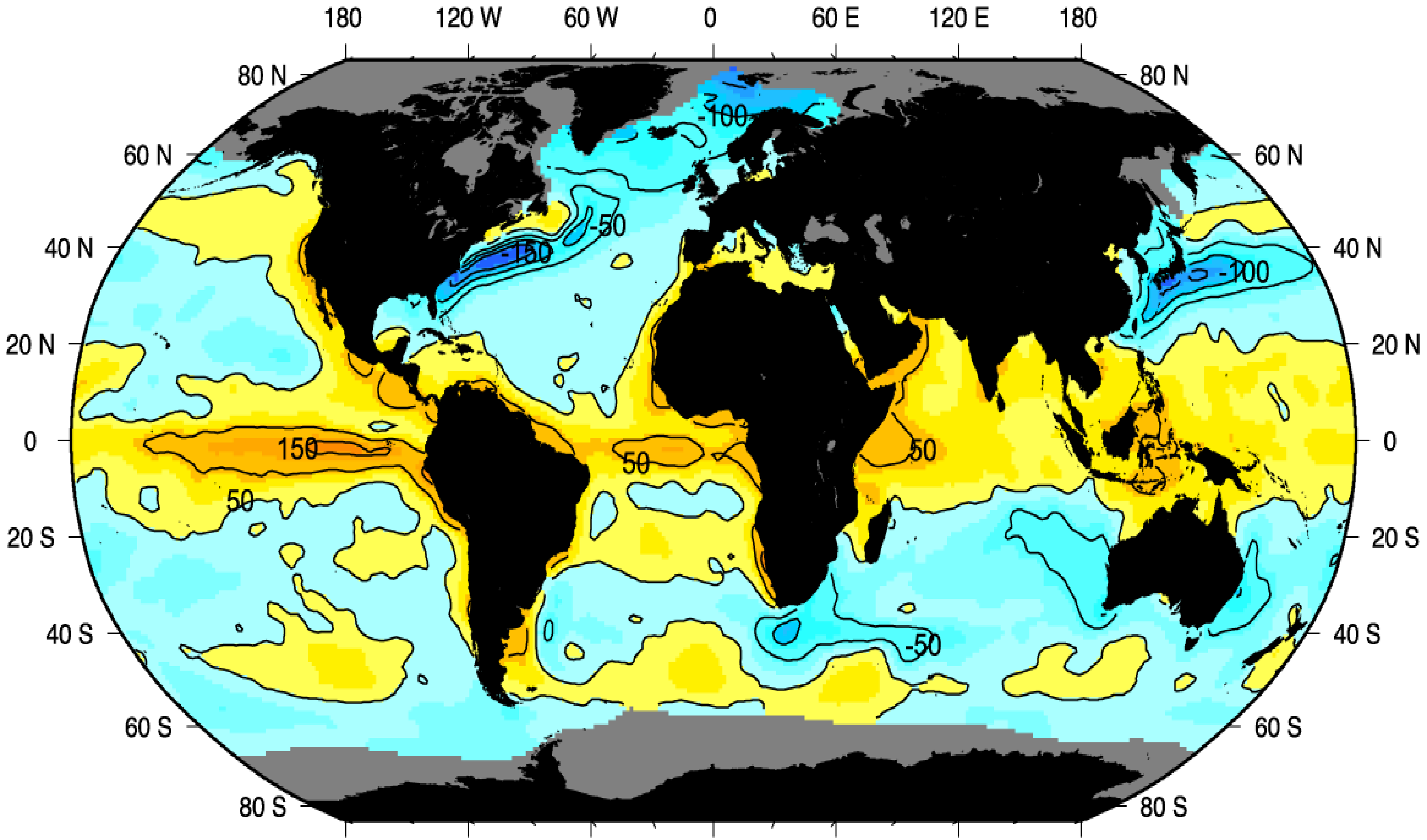


Seasonal variations are caused by the tilting of the Earth's axis and the Earth's orbit around the Sun.

- Solstices - The sun meets the Tropic of Cancer on June 21 (summer) and the Tropic of Capricorn on December 22 (winter).
- Equinoxes - day and night are equal on March 21 (spring) and September 23 (autumn) of every year



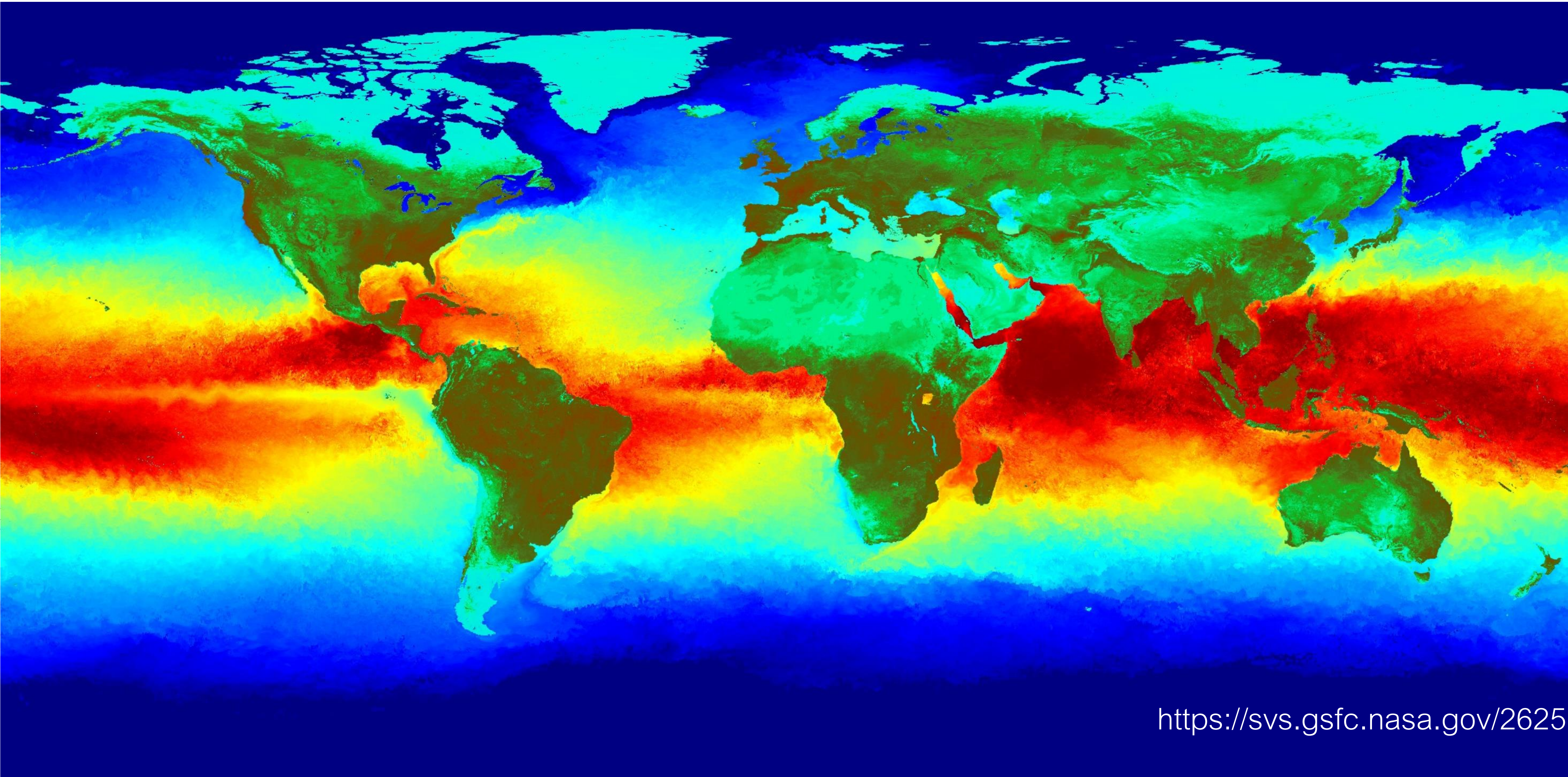
Surface heat flux (W/m^2) into ocean



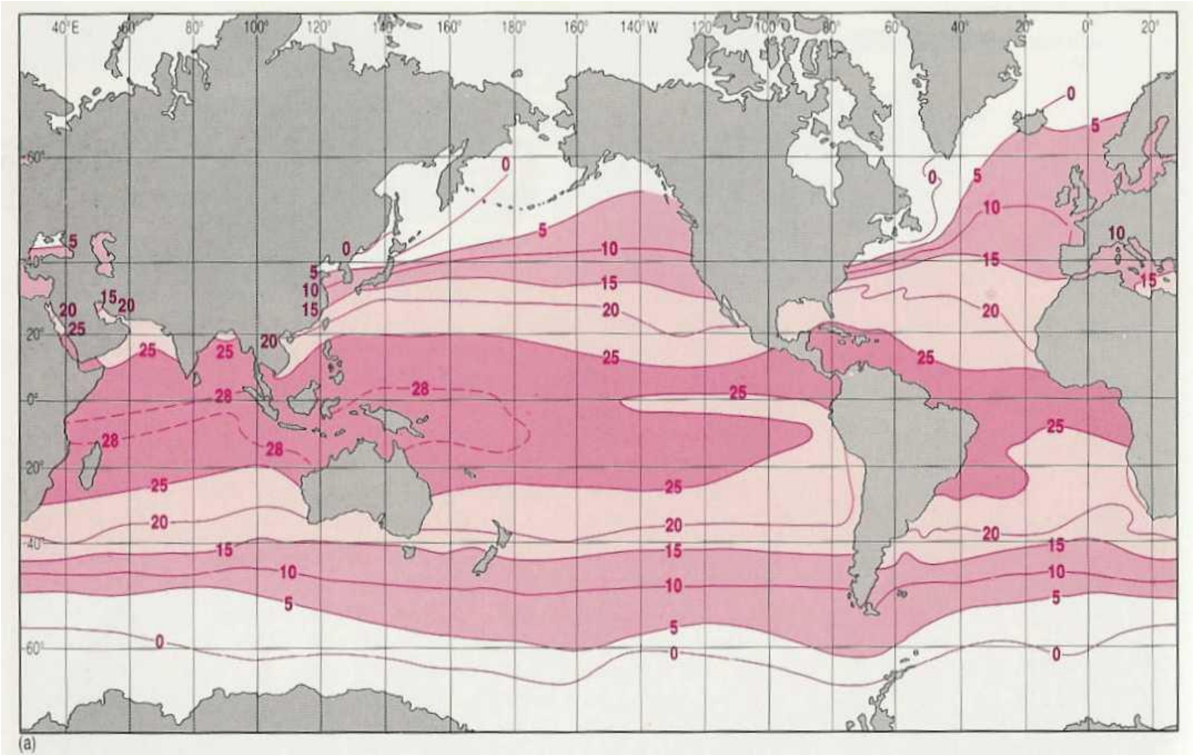
This is the annual mean (total for all seasons)

DPO Figure 5.16

Surface temperature (°C)



Horizontal distribution of sea surface temperature in different seasons



winter

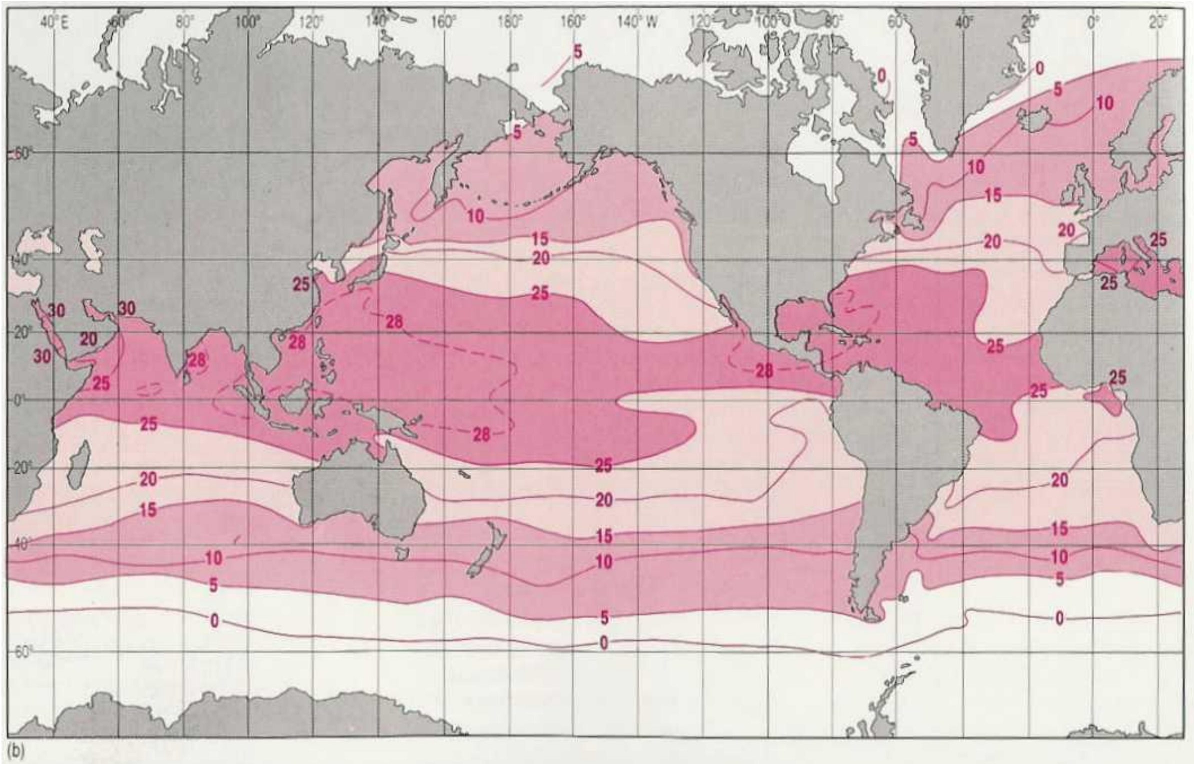
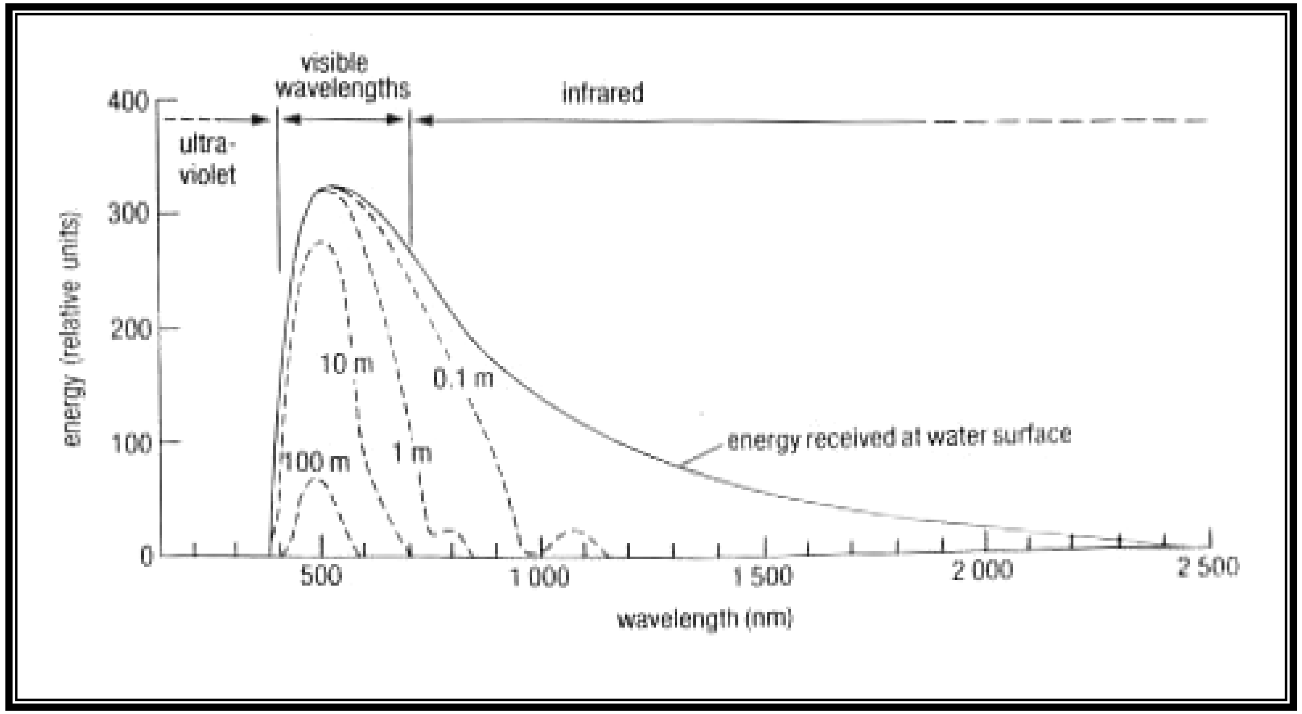


Figure 2.12 The global distribution of sea-surface temperature (°C) (a) in February, (b) in August.

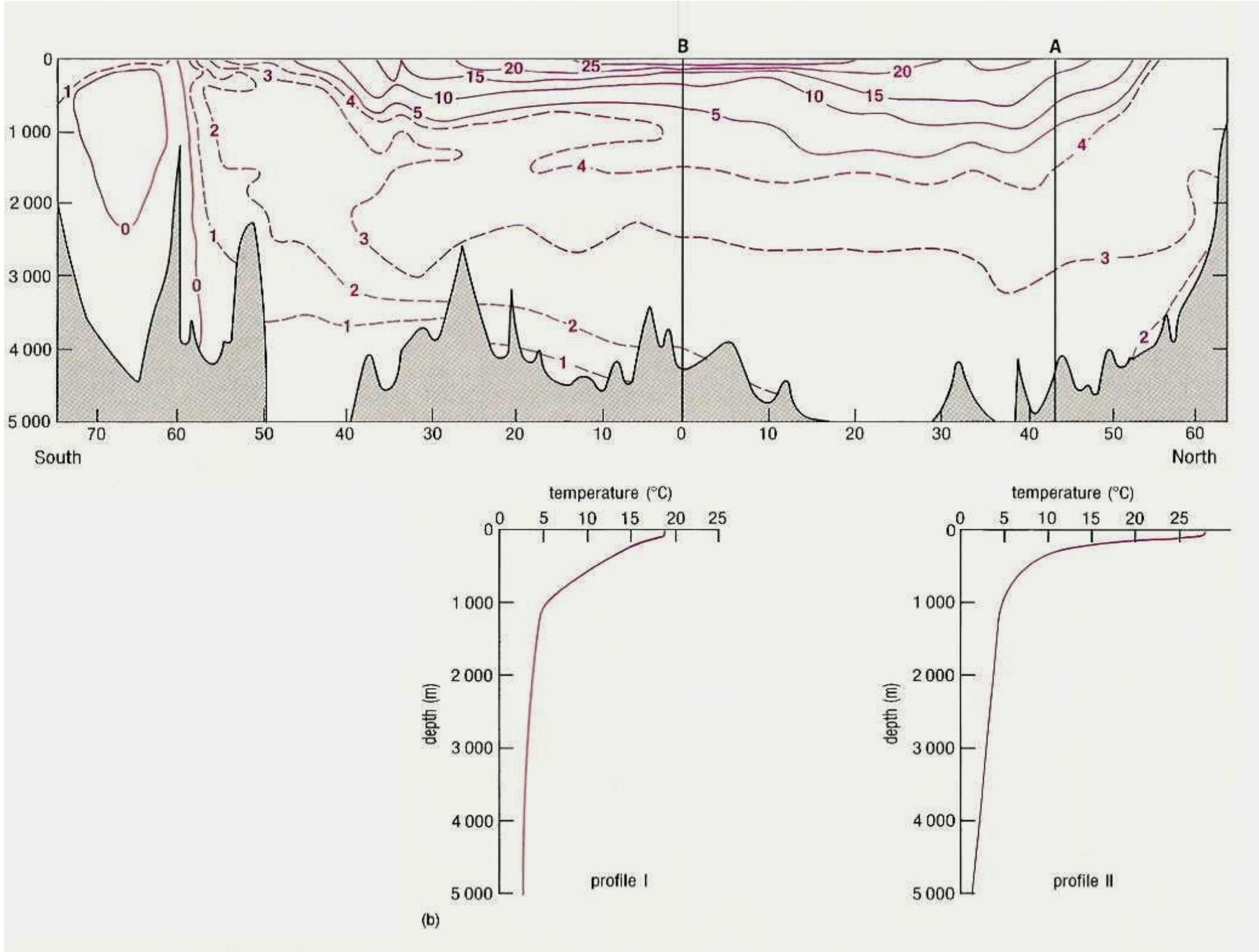
summer

Light absorption of sea water



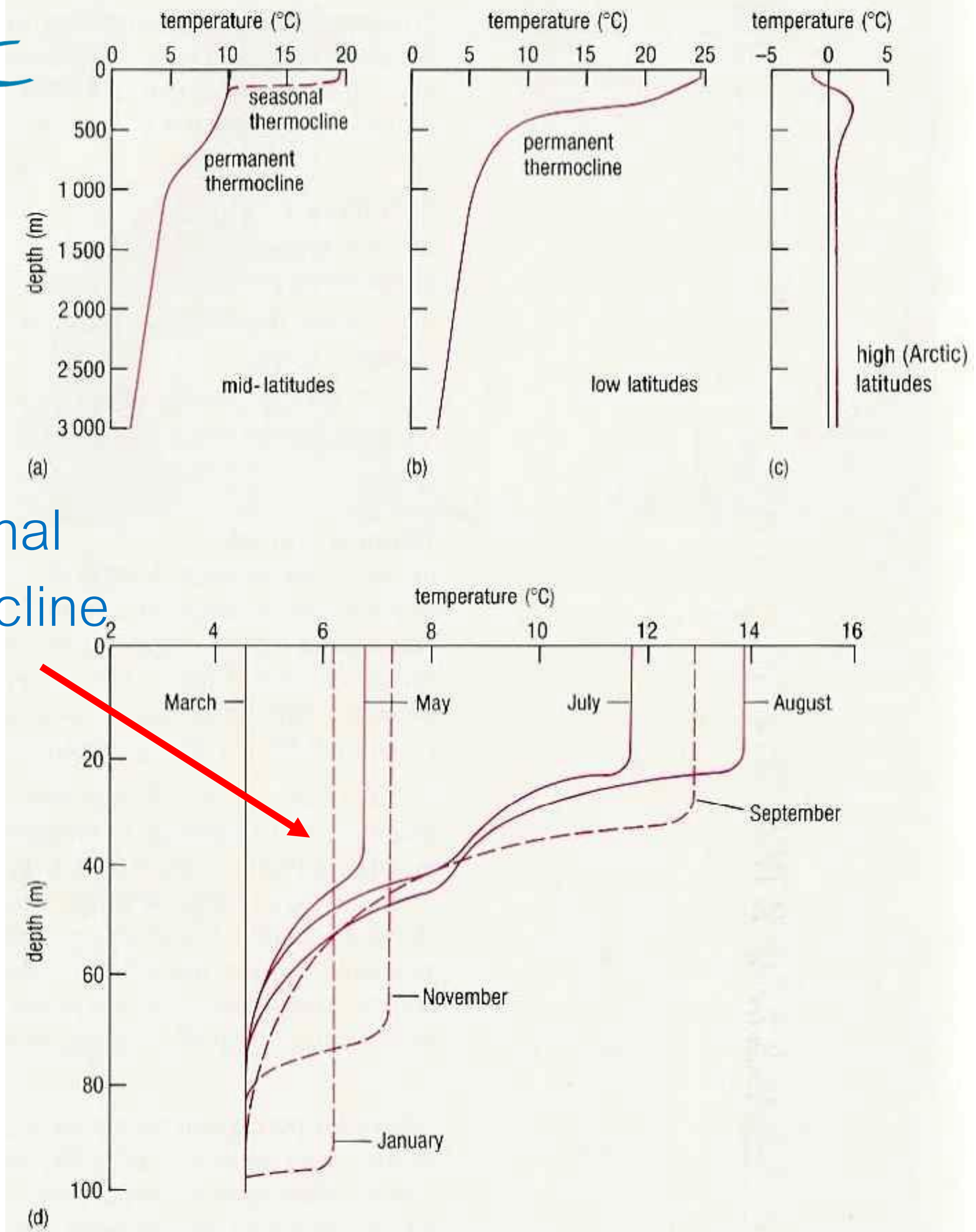
- The source of heat comes from solar energy.
- Light energy is absorbed in water at a small depth.
- 50% of energy is absorbed at a depth of 1 meters.
- 98% of energy is absorbed at a depth of 100 meters.
- At the surface, the temperature is higher than in the depths (in a lighted area).

Distribution of Temperature with Depth



Distribution of temperature with depth

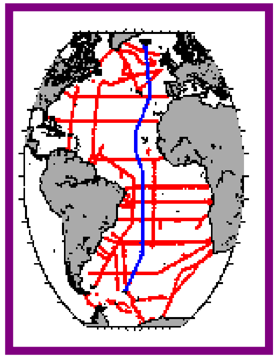
Seasonal Thermocline

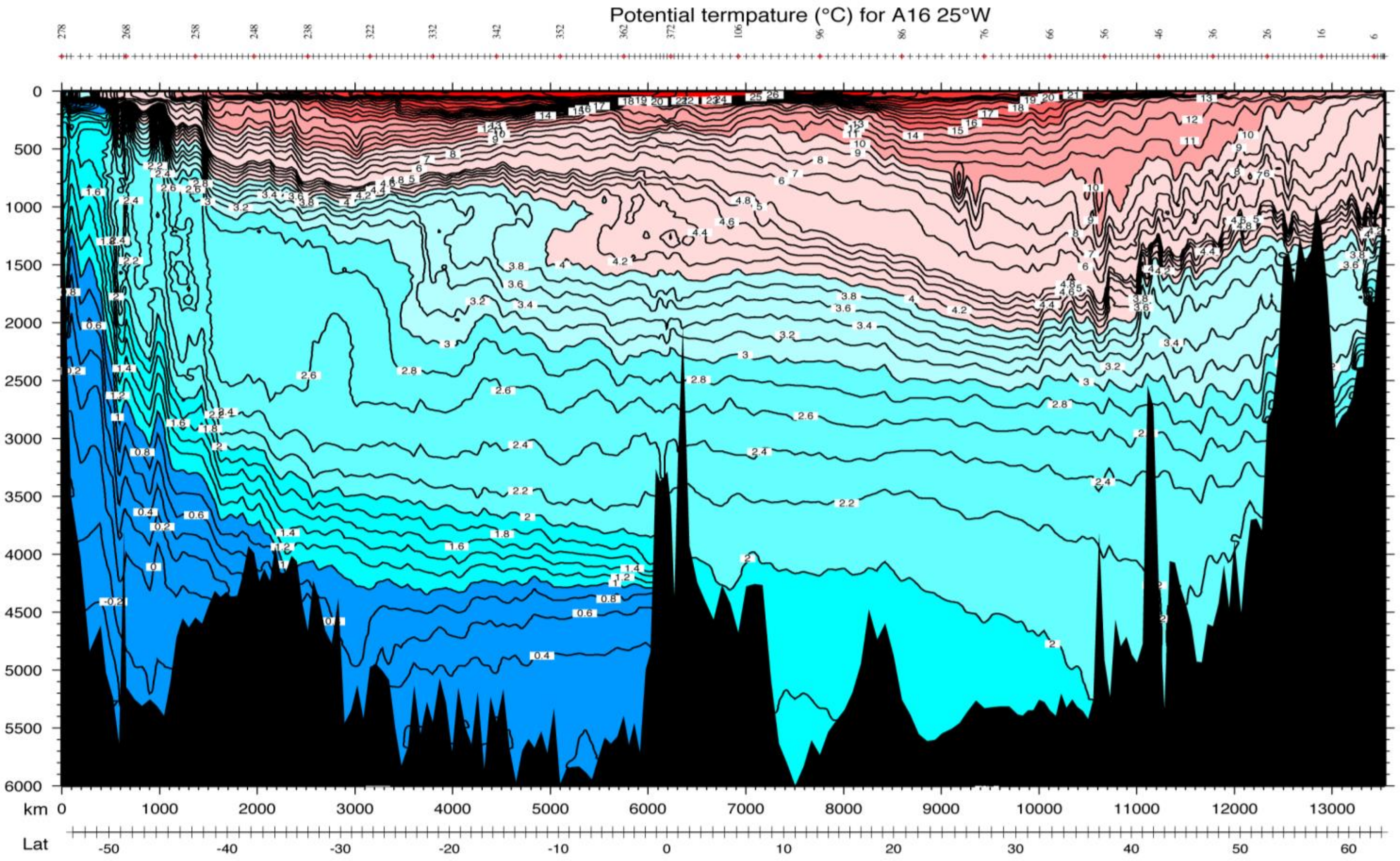


- **Mixing layer** ~ 200 - 300 m in winter at mid-latitudes
- **Seasonal thermocline** - developed in summer
- **Permanent thermocline**

  between 200 - 300 m and 1,000

Atlantic potential temperature section

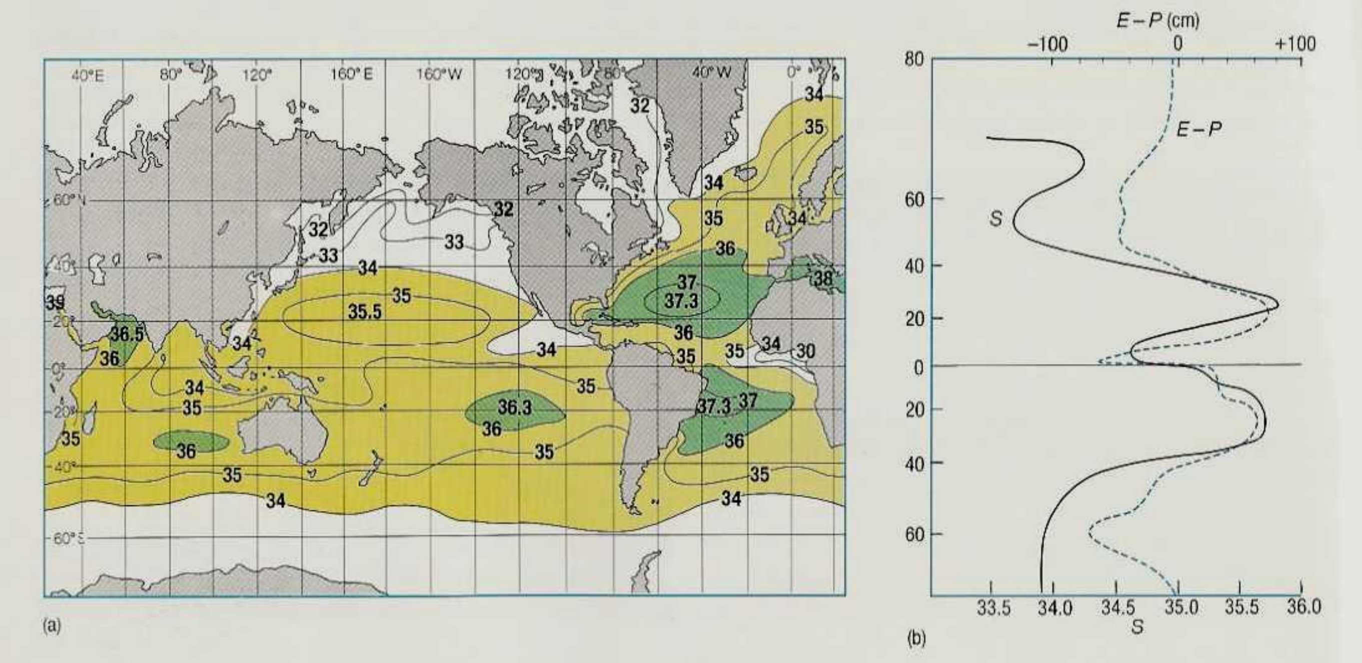


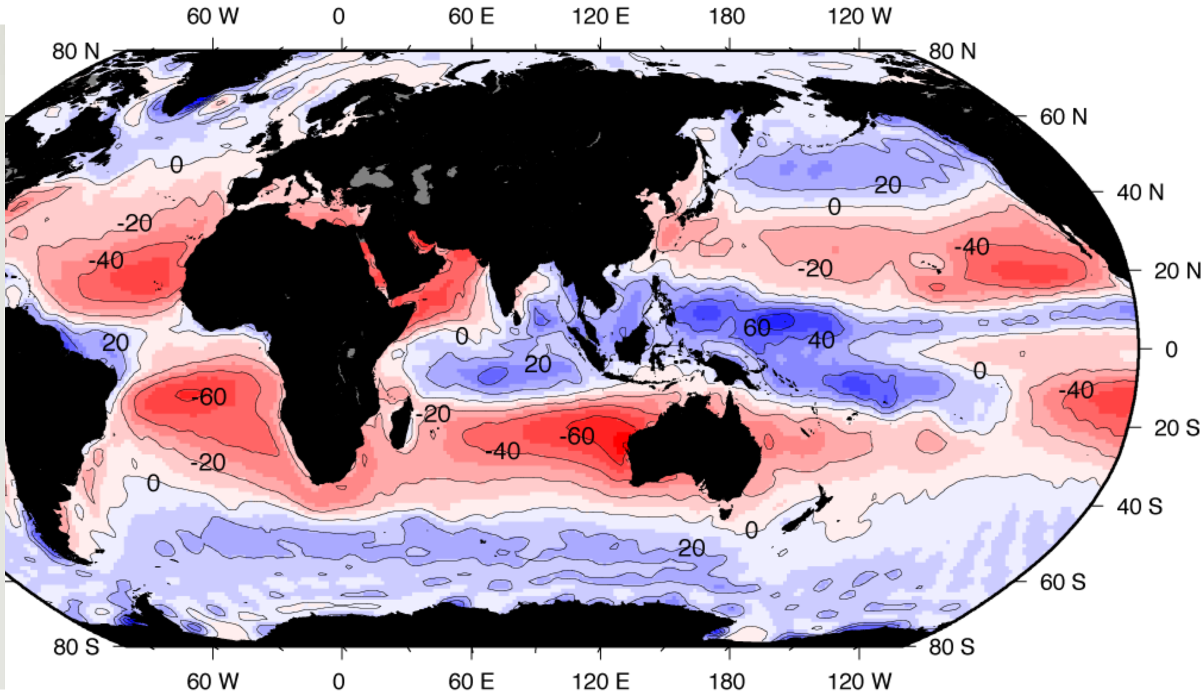


Unstable condition

- Cause vertical motion (Thermo-Haline circulation)
- at the poles caused by very low sea surface temperatures
- May cause from high salinity E >> P such as the Mediterranean Sea

Surface Salinity distribution



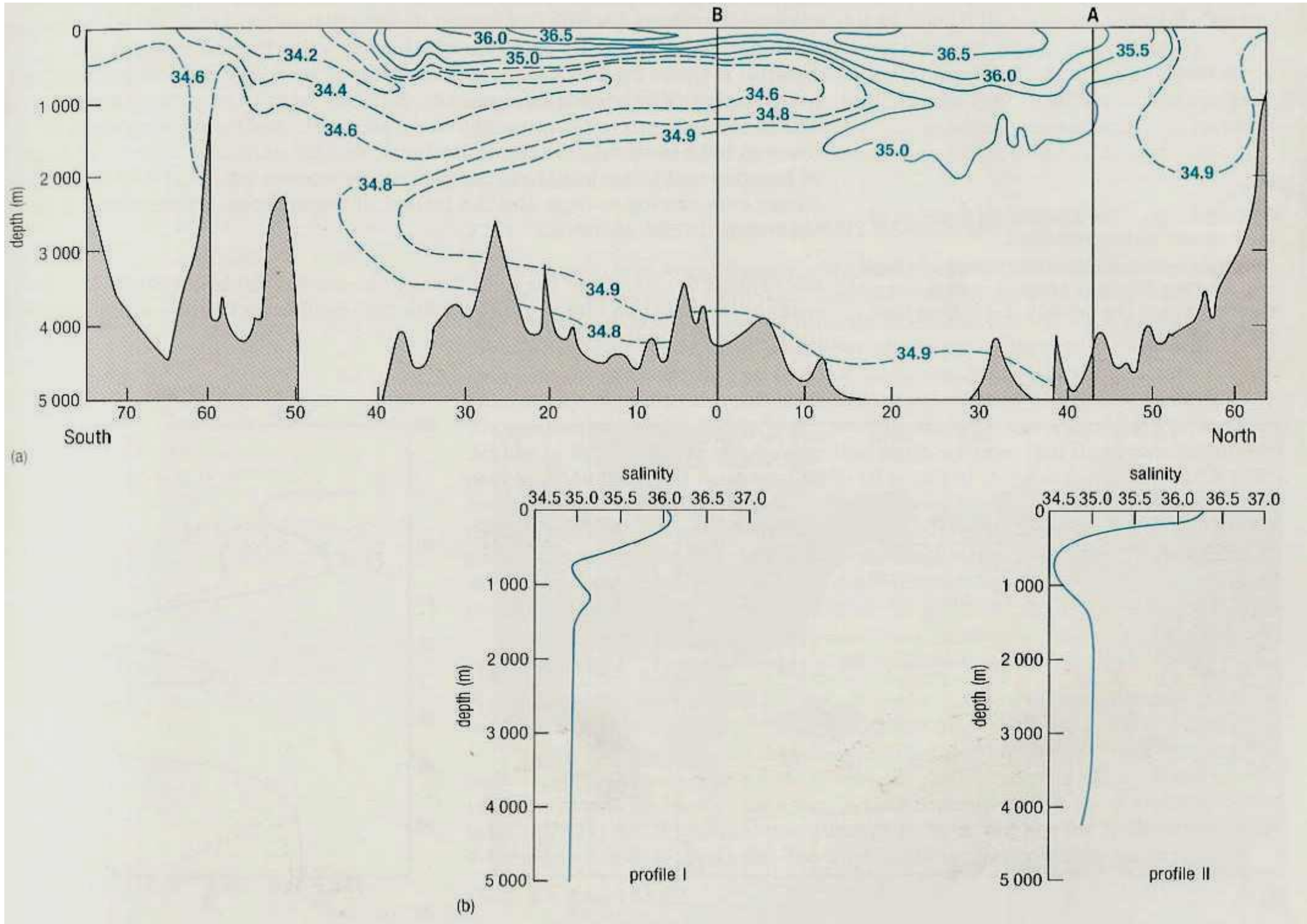


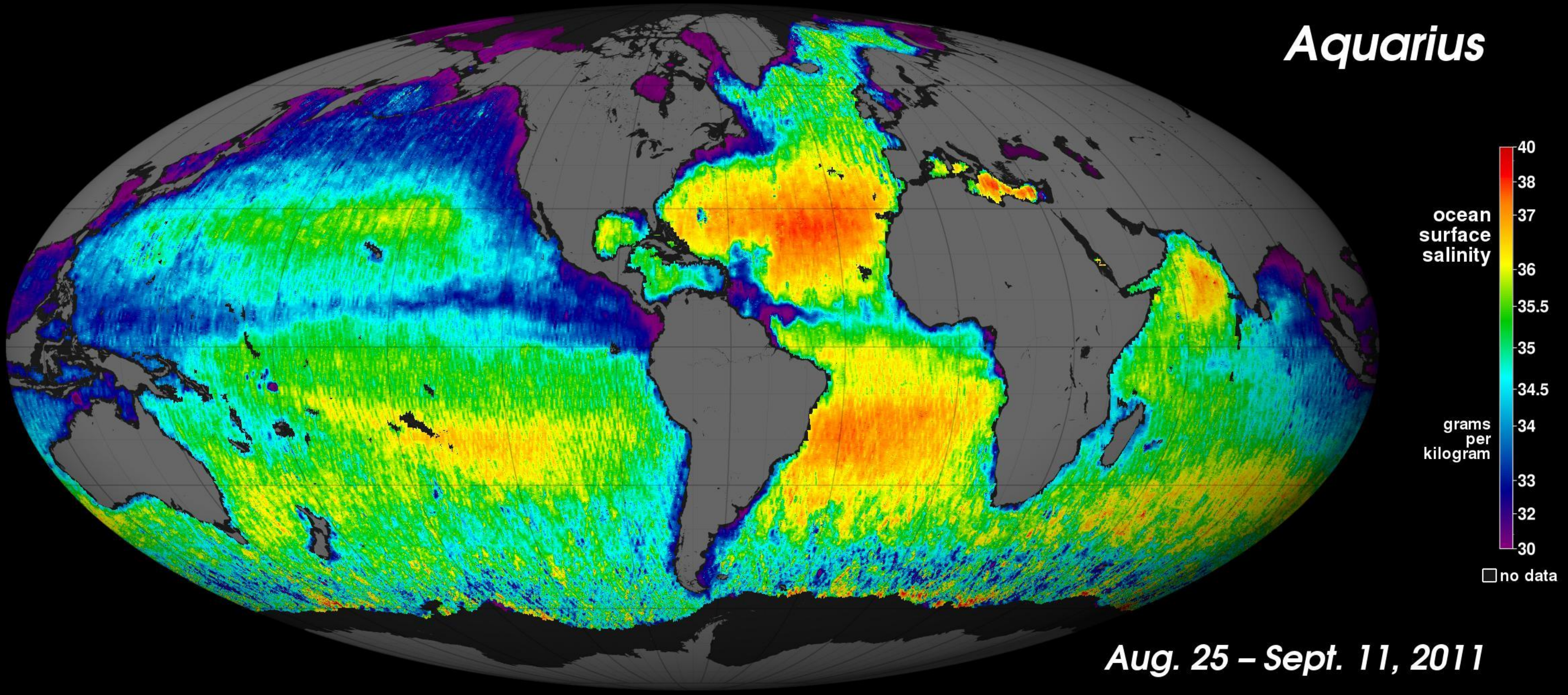
freshwater inputs and exports

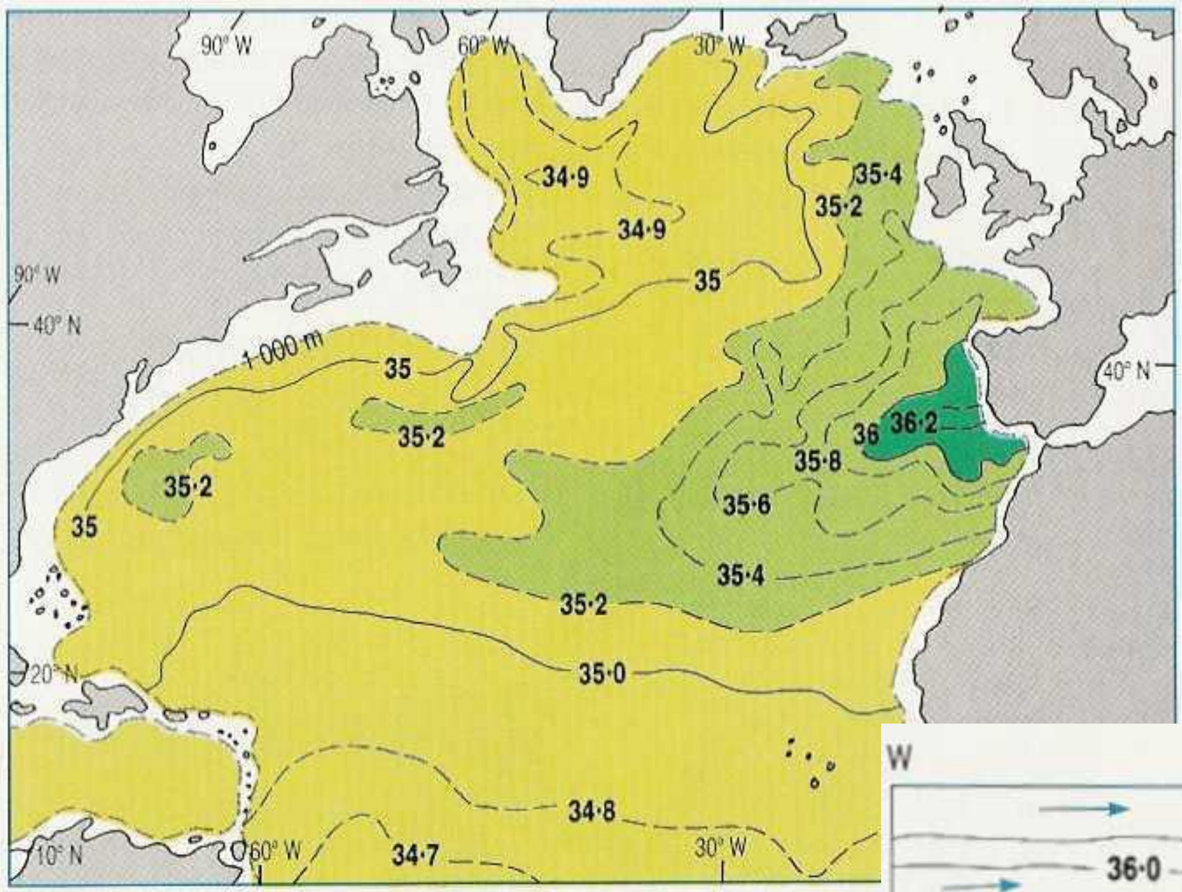
Salinity

- Vertical Distribution:

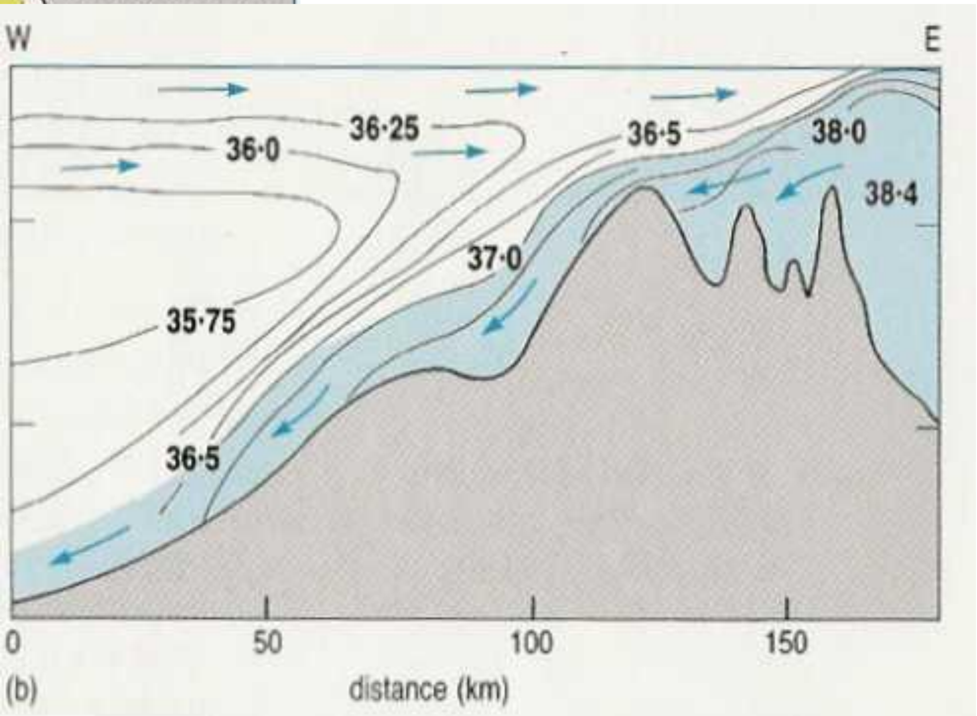
  Considering the stability of sea water, the salinity of the deep sea water should be higher than that at the sea surface. But…
- Why?




Aquarius
ocean surface salinity
grams per kilogram
40
38
37
36
35.5
35
34.5
34
33
32
30
no data
Aug. 25 – Sept. 11, 2011



Deepwater mass generated by high salinity water



Density

- Controlled by temperature, salinity and pressure
- The mean density of sea water is 1.03×10^3 kg m^{-3}
- Density in seawater generally deviates from this average by no more than 2%.
- The difference in the density of sea water in different places is very low in spite of the fact that the difference has a great effect on marine phenomena.

Sigma(σ)

- It is a quantity that is set up to make the difference in density in the seas in each area more clearly.

$$\sigma = \rho_{s,t,p} - 1000 \ \ kg\, m^{-3}$$

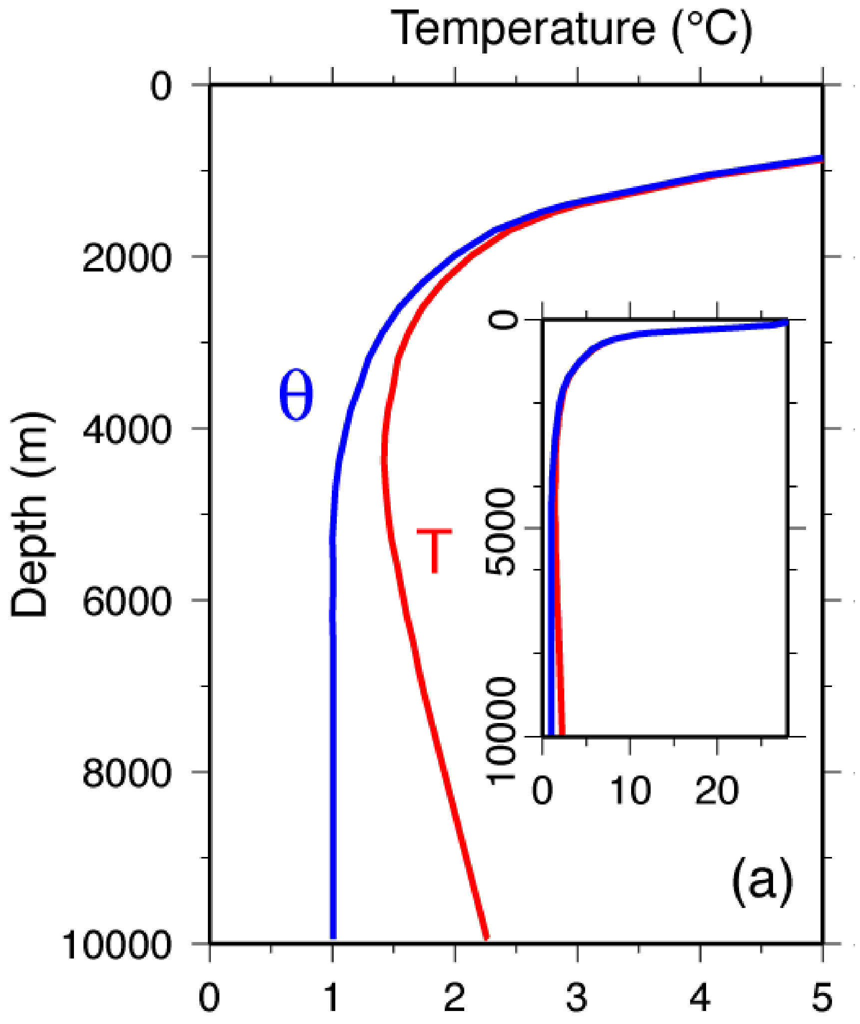
where $\rho_{s,t,p}$ is sea water density.

In situ Temperature and Potential Temperature

- In situ temperature is the temperature directly measured underwater using a CTD.
- When moving an adiabatic water mass from the depths to the surface, this water mass expands causing its temperature to decrease.
- The temperature measured after allowing the water mass to expand is called the Potential temperature.
- It is useful for tracking water masses as to where they come from.

Pressure effect on temperature:

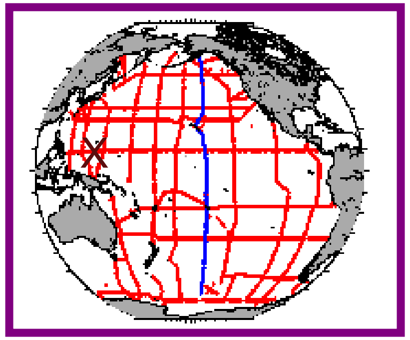
Mariana Trench (the most extreme example because of its depth)



Note the measured temperature has a minimum around 4,000 dbar and increases below that.

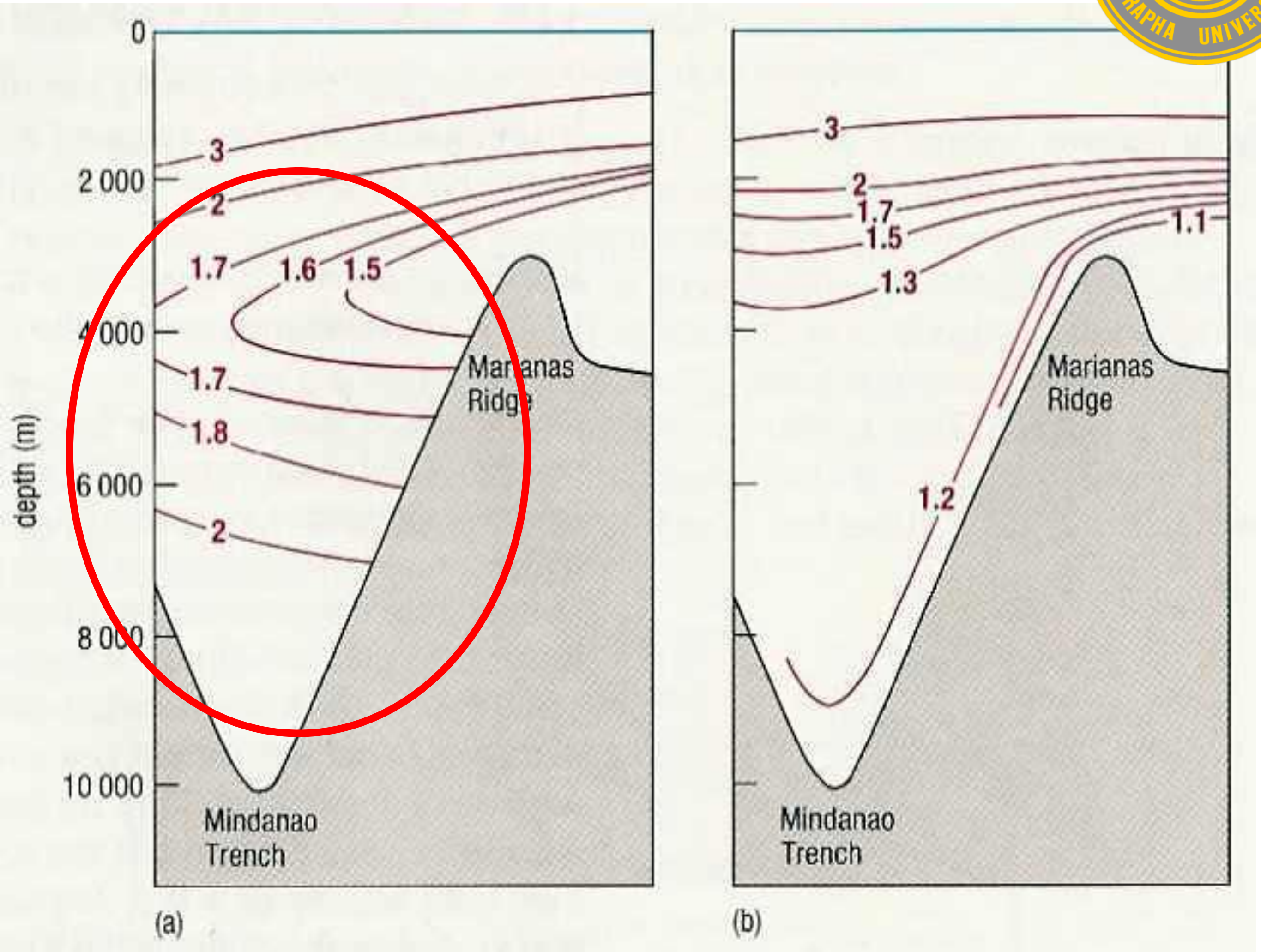
Potential temperature is almost exactly uniform below 5000 m. (This is because all of the water in this trench spilled into it over a sill that was at about 5000 m depth.)

DPO Figure 4.9



In situ and potential temperature

Abnormal high in situ temperature at great depth is generated by high pressure.



In situ temperature potential temperature

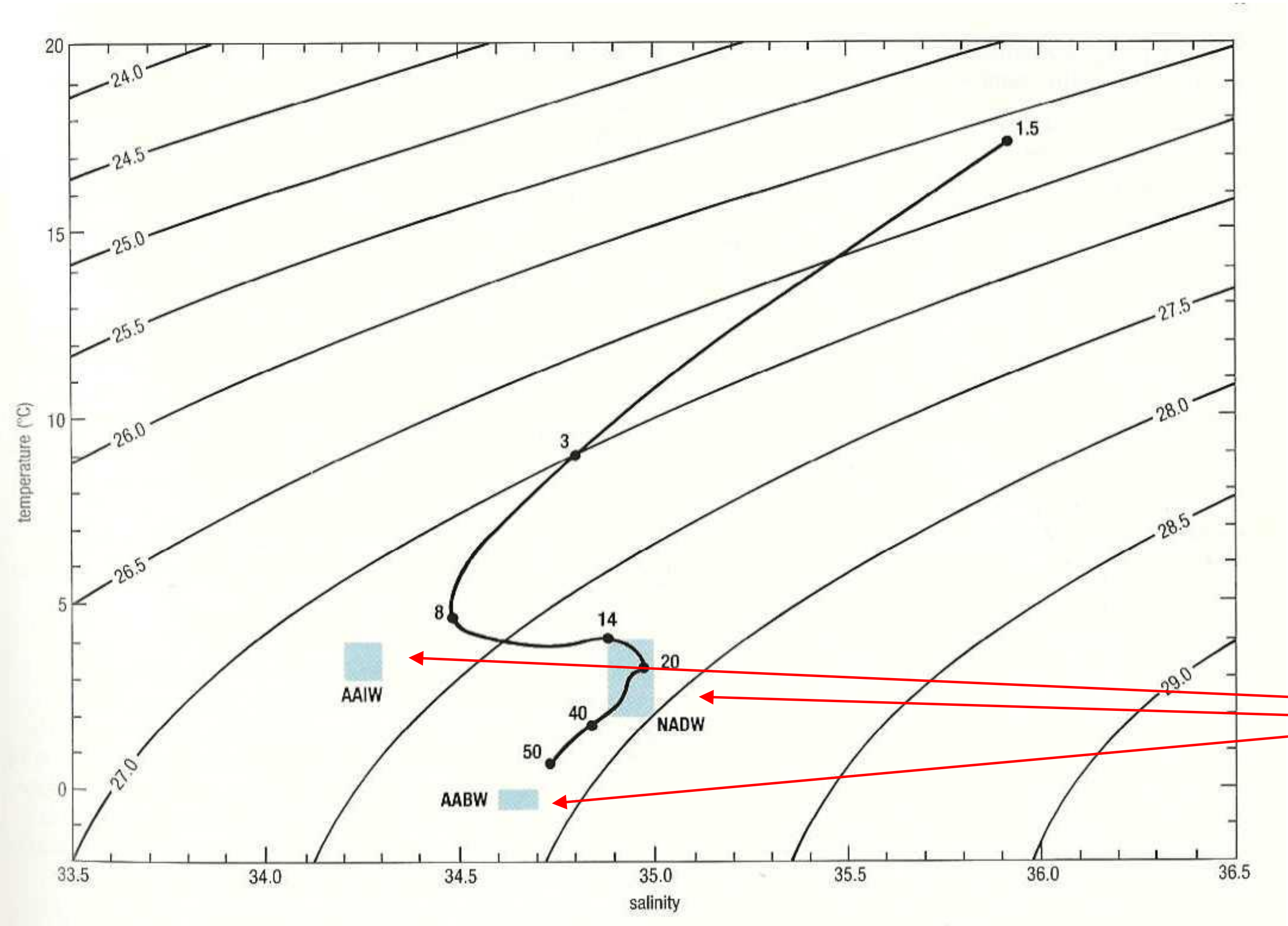
Sigma-t (σ_t)

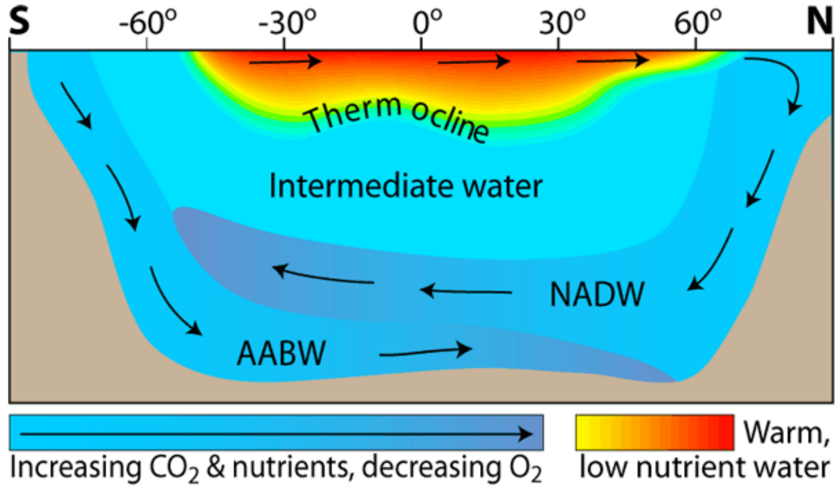
- Regardless of the effect of pressure
- Suitable for measuring the density of water at depths no grater than 1,000 meters.

$$\sigma_t = \rho_{s,t,0} - 1000 \ kg\, m^{-3}$$

where $\rho_{s,t,0}$ is density excluding the influence of pressure

Sigma estimation using TS-Diagram

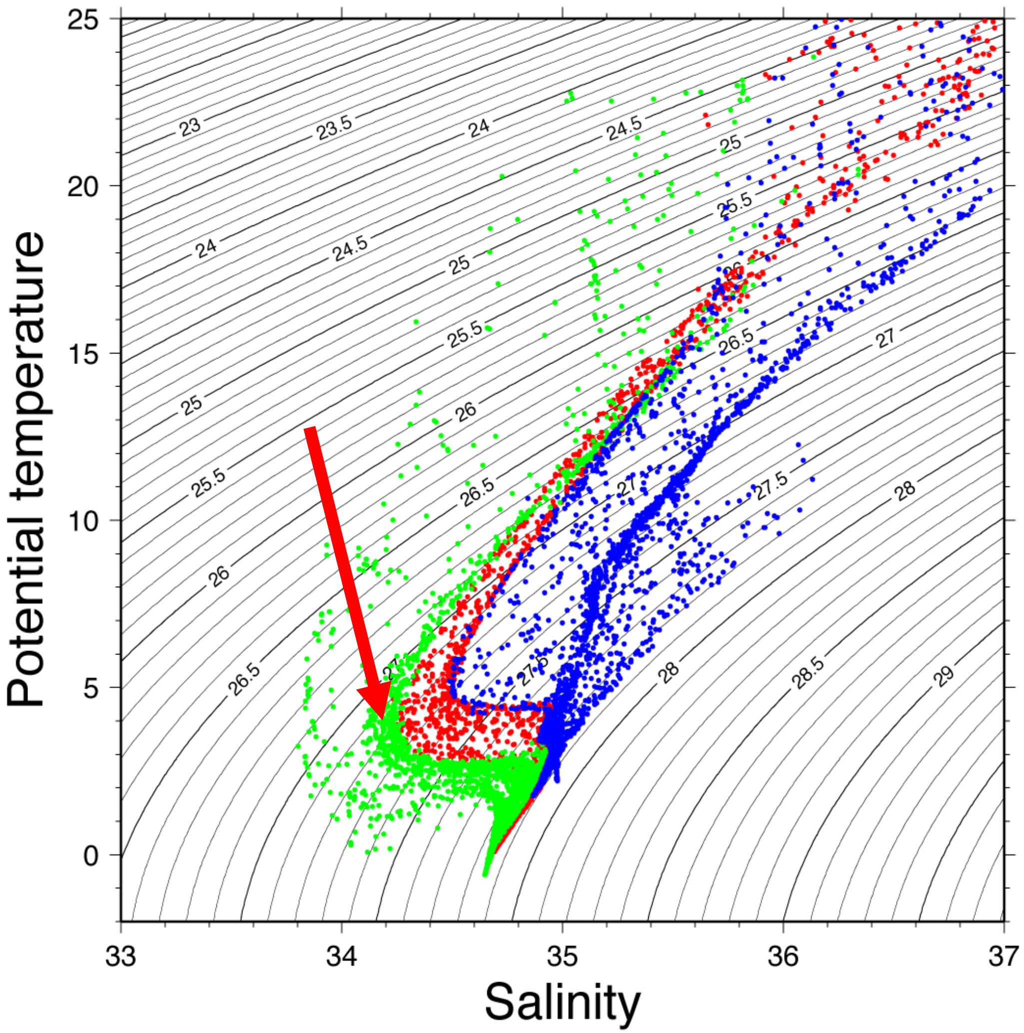


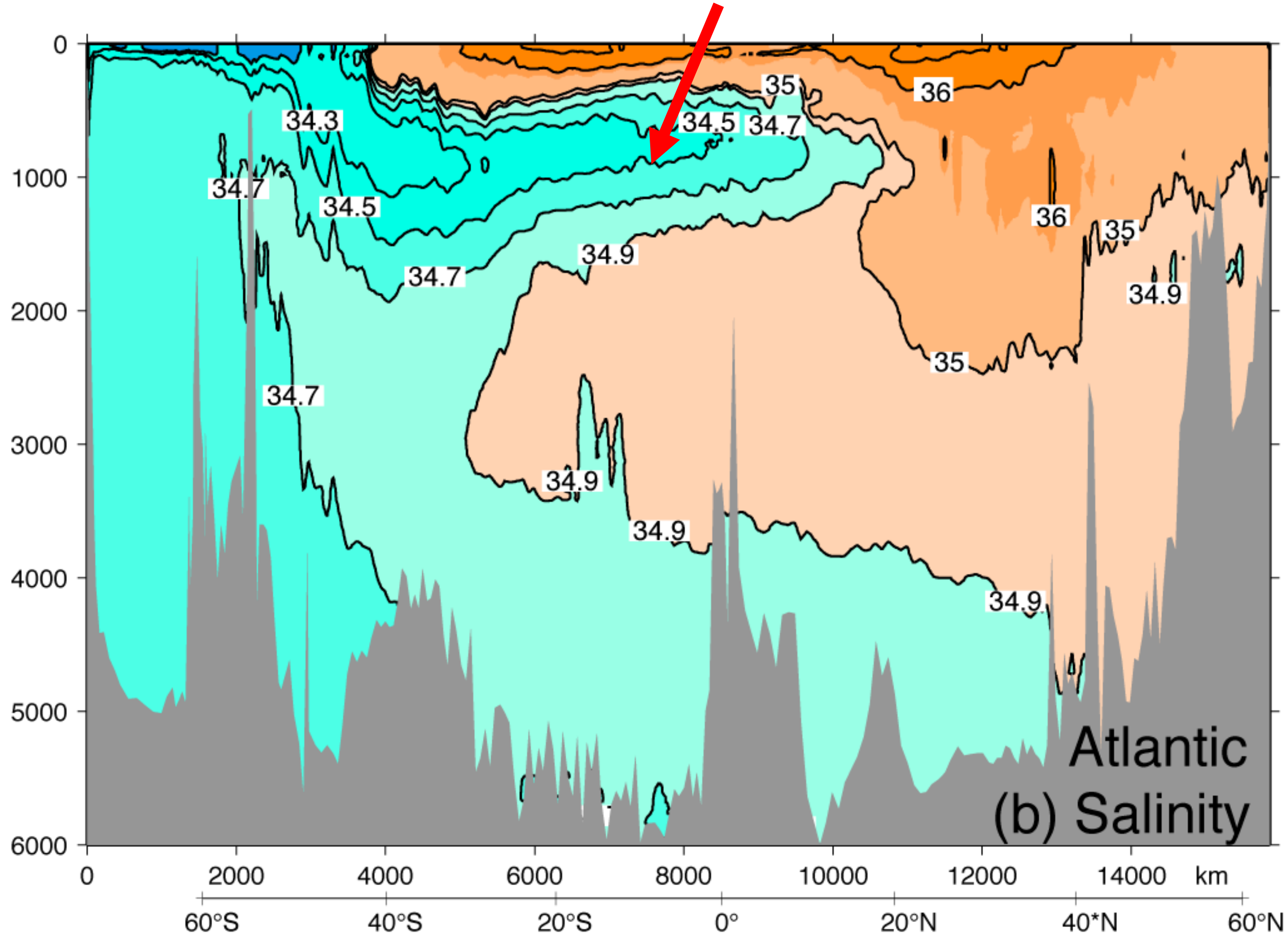


Reference water mass properties

Water mass

Example: Antarctic Intermediate Water - (a) low salinity layer, (b) originating in surface mixed layers near Antarctic Circumpolar Current

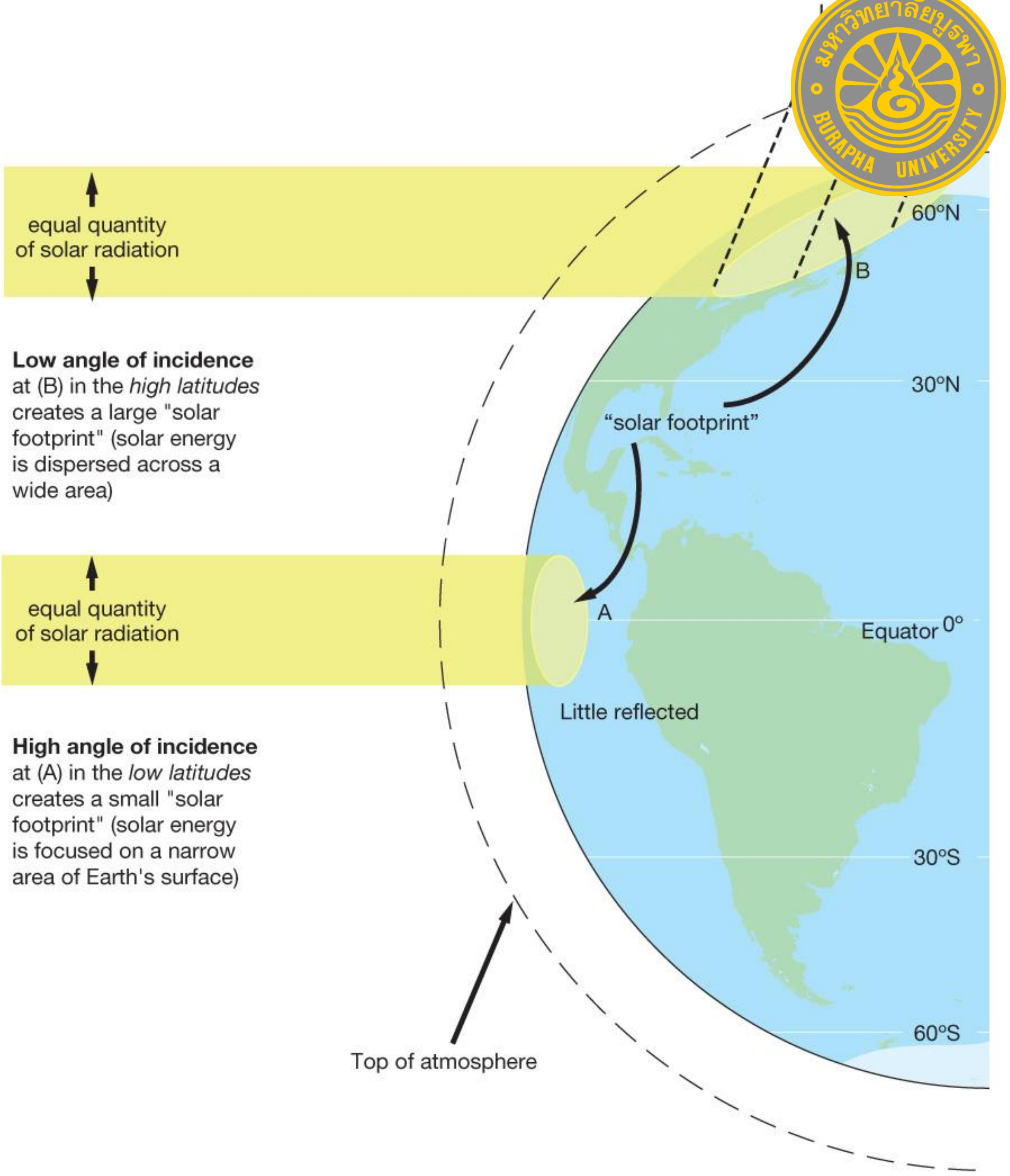




Atmosphere and Ocean Circulation

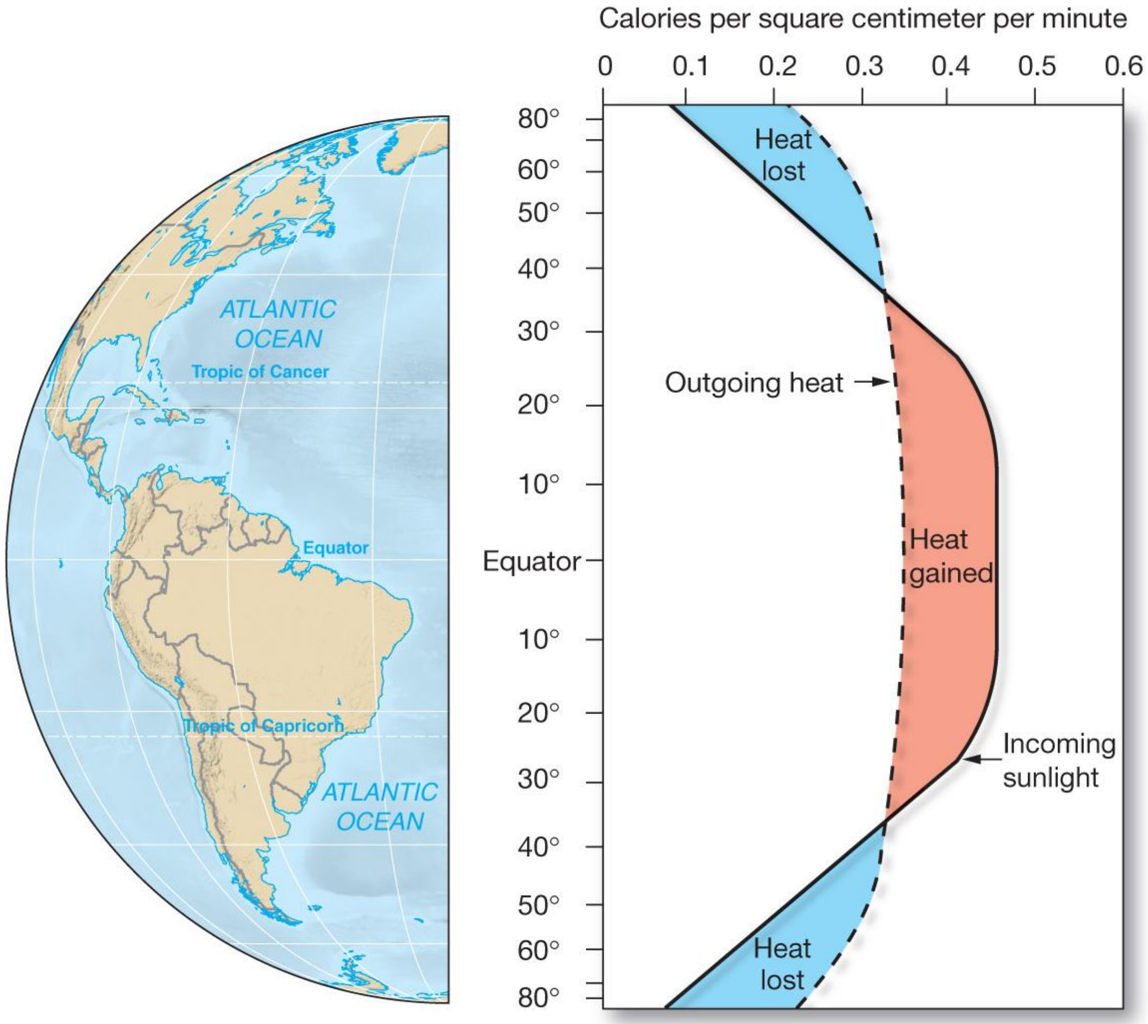
Distribution of Solar Energy

- The amount of sunlight received by the Earth in different latitudes is unequal.
- Because the angle of incidence of light above the Earth in each area is not the same.



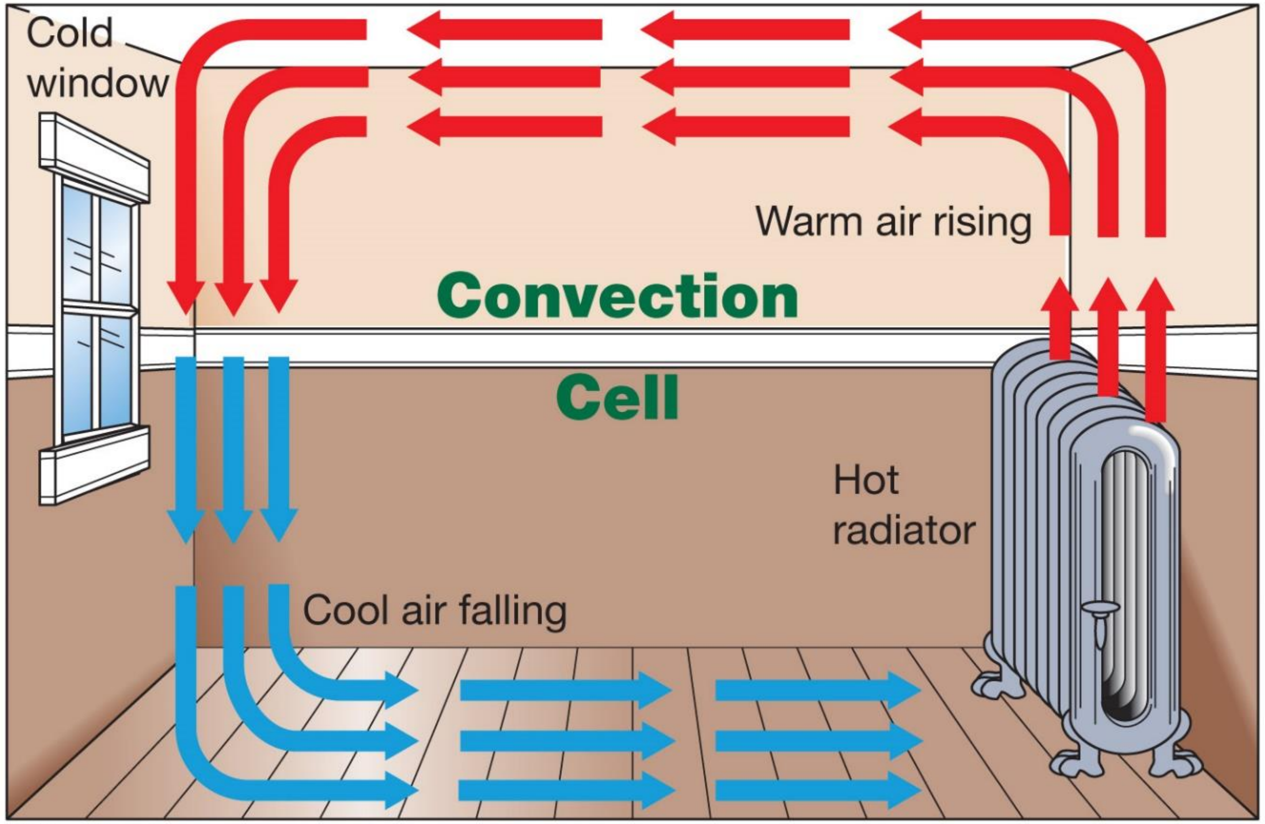
Atmospheric circulation

- This is due to the fact that the Earth receives unequal amounts of energy from the Sun in different latitudes.
- If the air does not circulate between the different latitudes, then the region that receives the most energy from the sun will be hotter.
- Conversely, regions that receive less solar energy are much cooler.



Atmospheric circulation

- based on the principle that “The hot air will rise to the height, and the cold air will sink to the ground.”

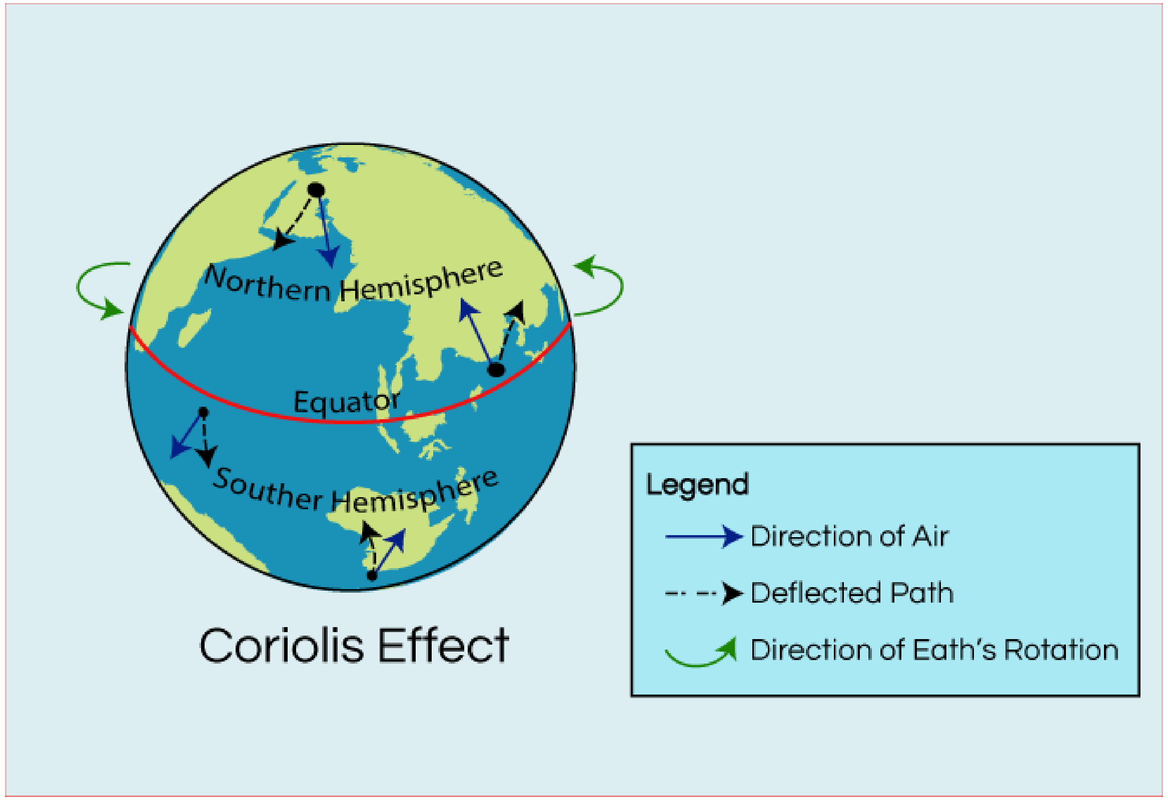


Important driving forces for atmospheric circulation

1. The difference in the amount of thermal energy the world receives in different latitudes.
2. Coriolis Force (or Coriolis Effect)
3. Gravity of the Earth

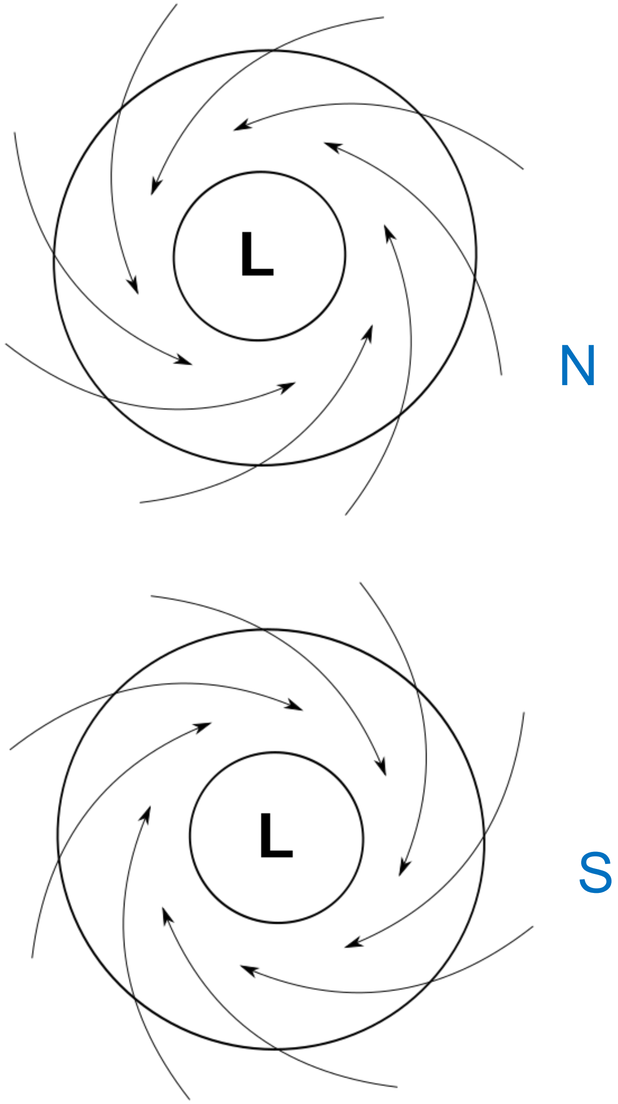
Coriolis Force (or Coriolis Effect)

- The force caused by the rotation of the Earth
- Moving objects on Earth, such as wind or current, are deflected to the right of motion in the northern hemisphere.
- And they are deflected to the left of the direction of movement in the southern hemisphere.



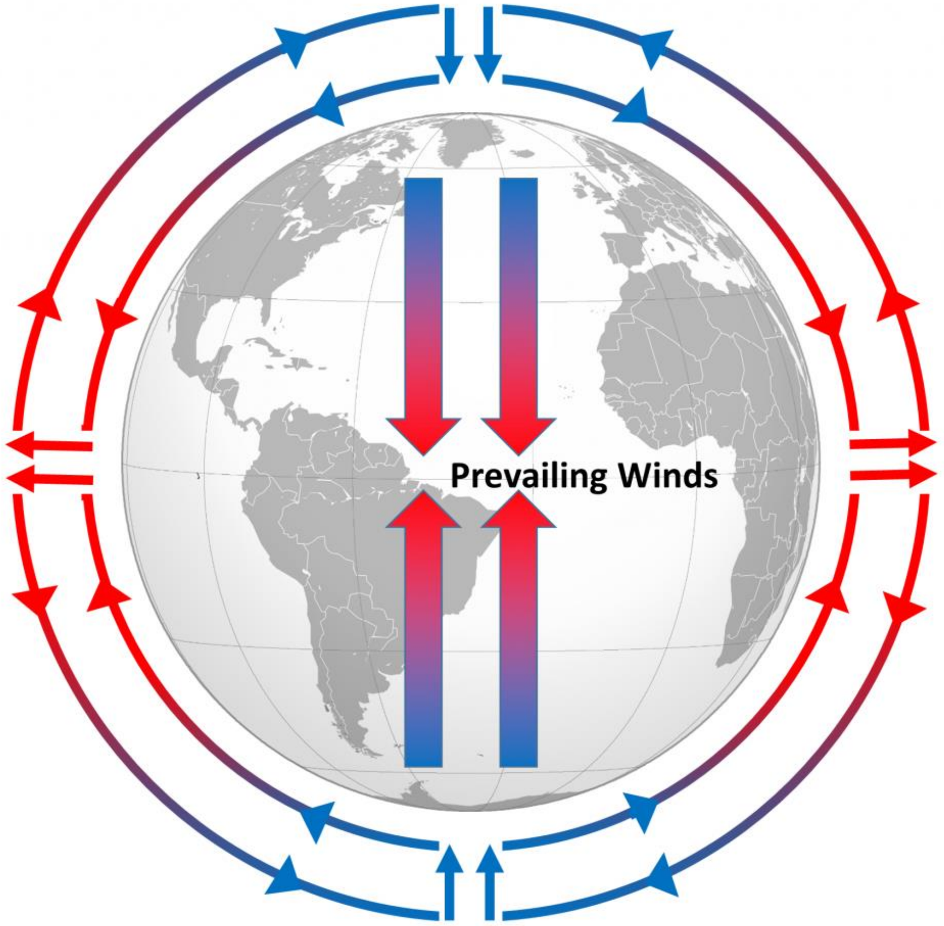
https://www.education.com/science-fair/article/determine-earth-rotation-affects-spin/

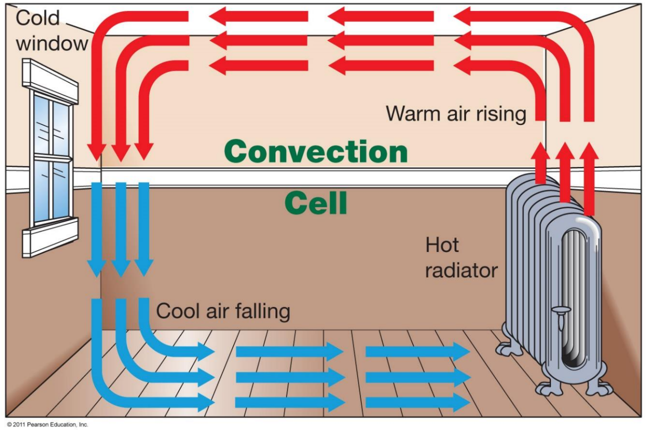
Coriolis Force (or Coriolis Effect)



- Coriolis is the force that causes the rotation of wind around the middle of a storm (low pressure) to rotate counter-clockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere.

Ideal atmospheric circulation

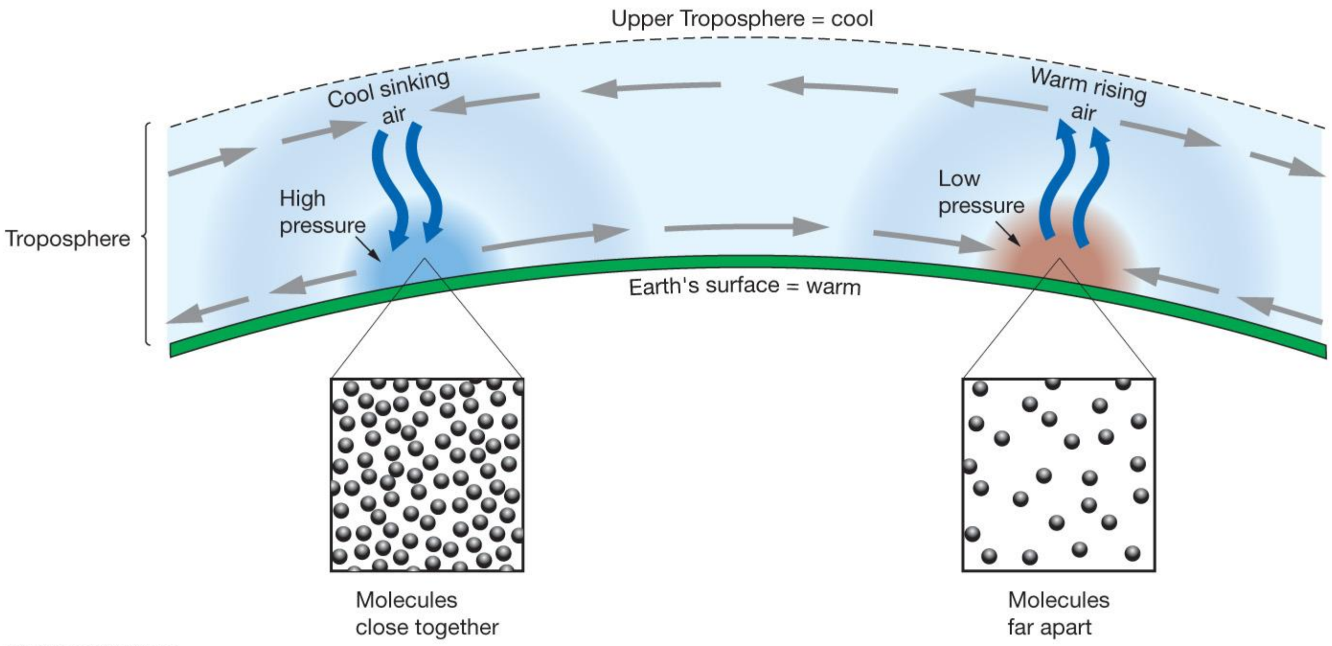


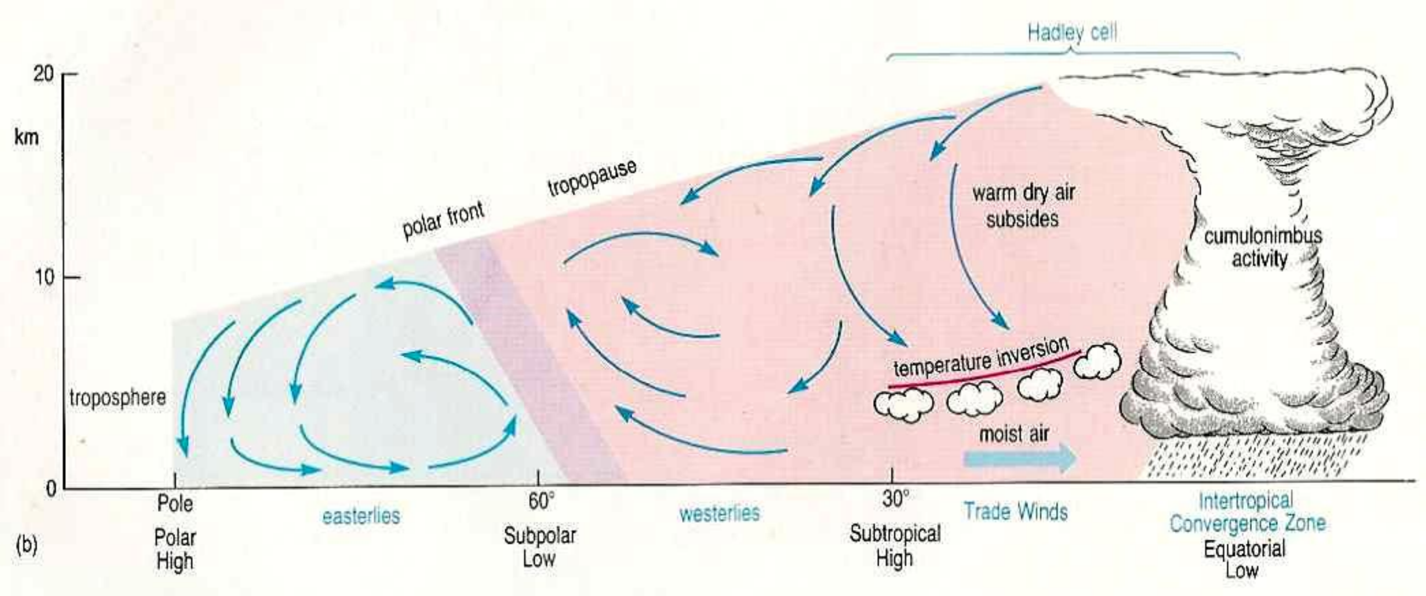


- Hypothetical atmospheric convection cells on a non-rotating Earth.
- Air rises at the equator and sinks at the poles, creating a single convection cell in each hemisphere.
- The prevailing winds moving over the Earth's surface blow from the poles towards the equator in both hemispheres

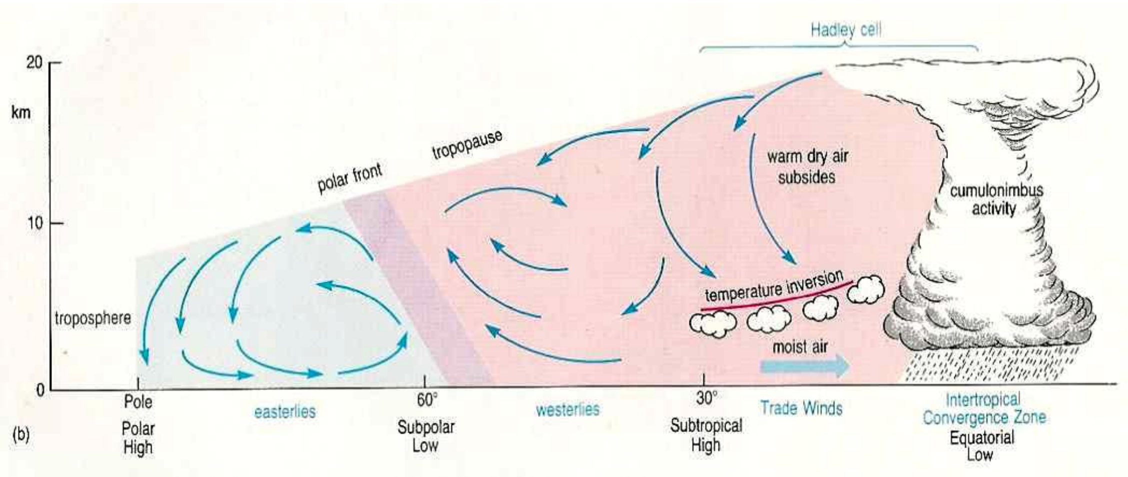
https://geo.libretexts.org/Courses/Diablo_Valley_College/Fundamentals_of_Oceanography_(Keddy)

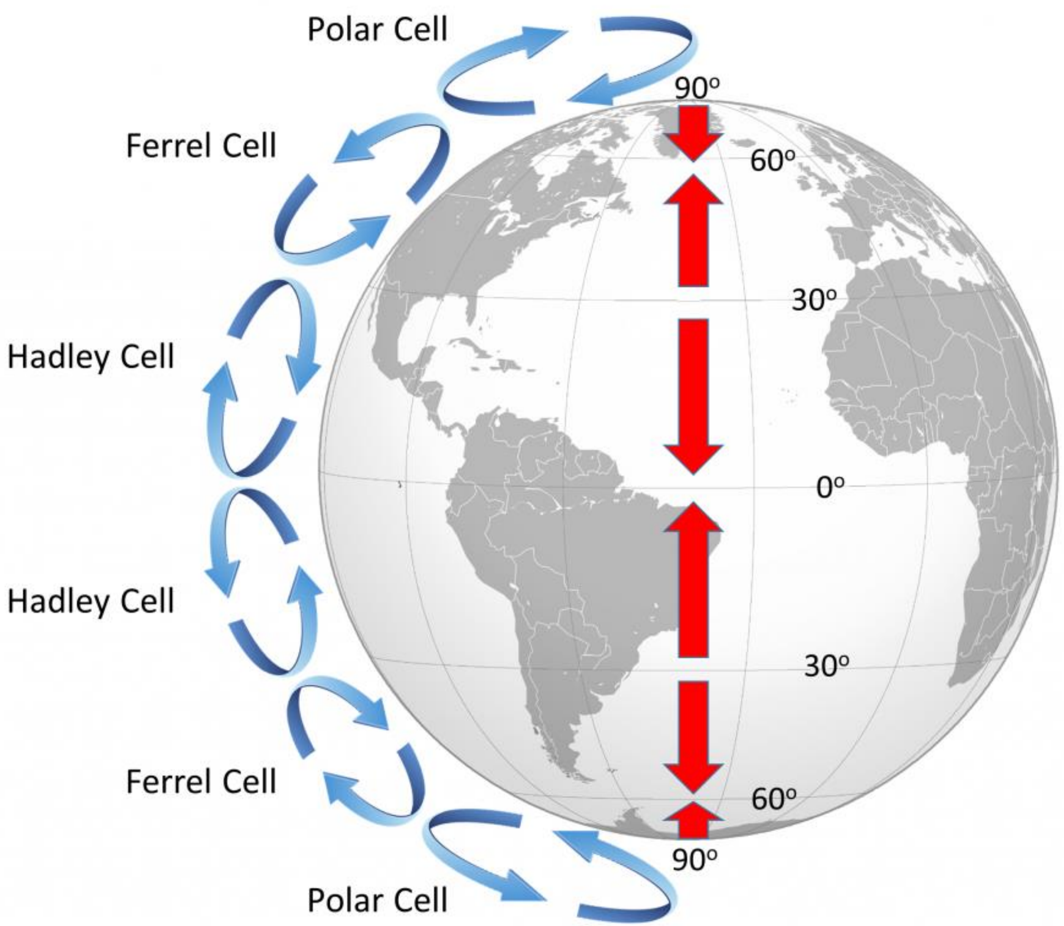
Vertical air movement





Atmospheric circulation with convection cells





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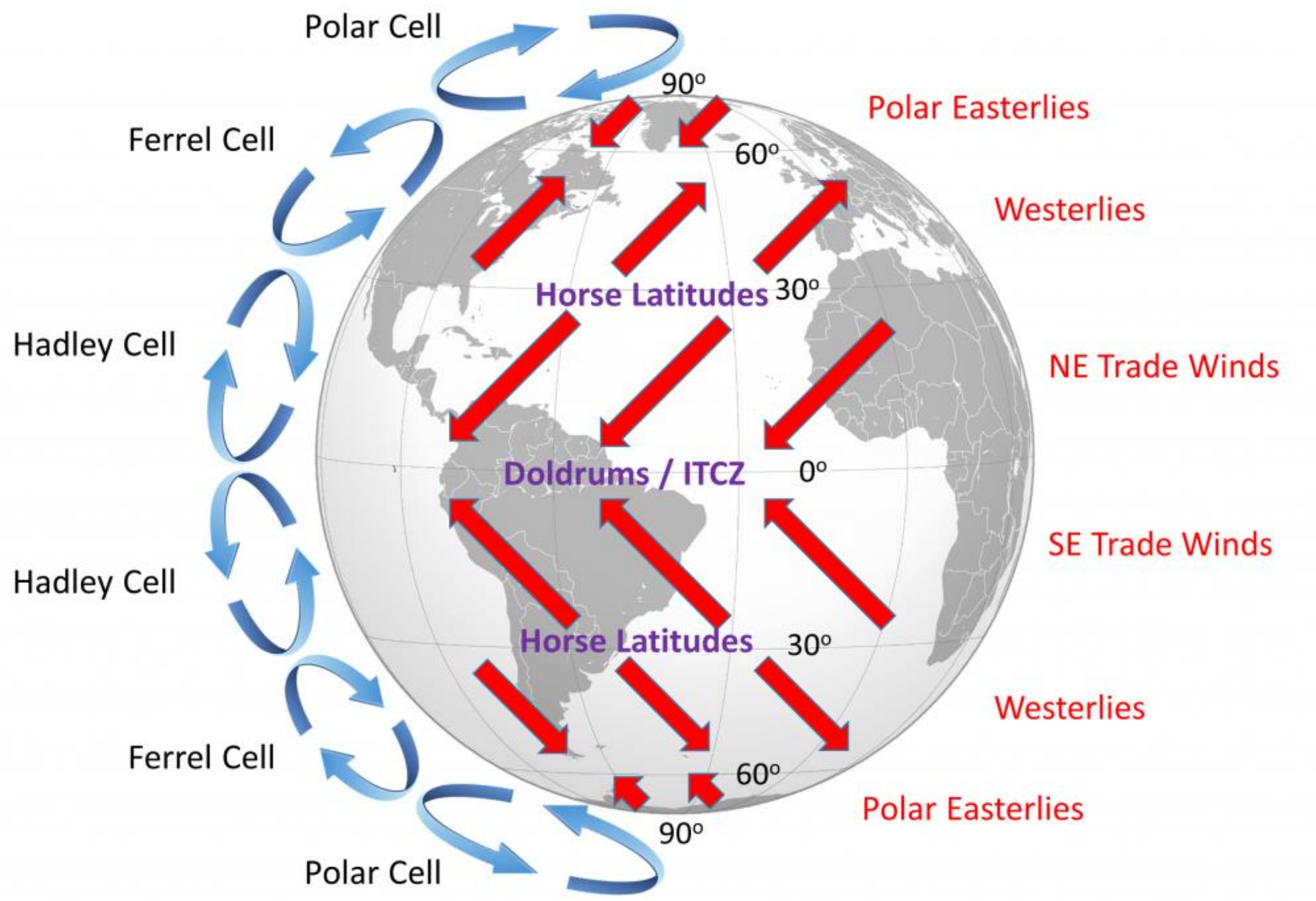
Wind patterns with Coriolis Effect



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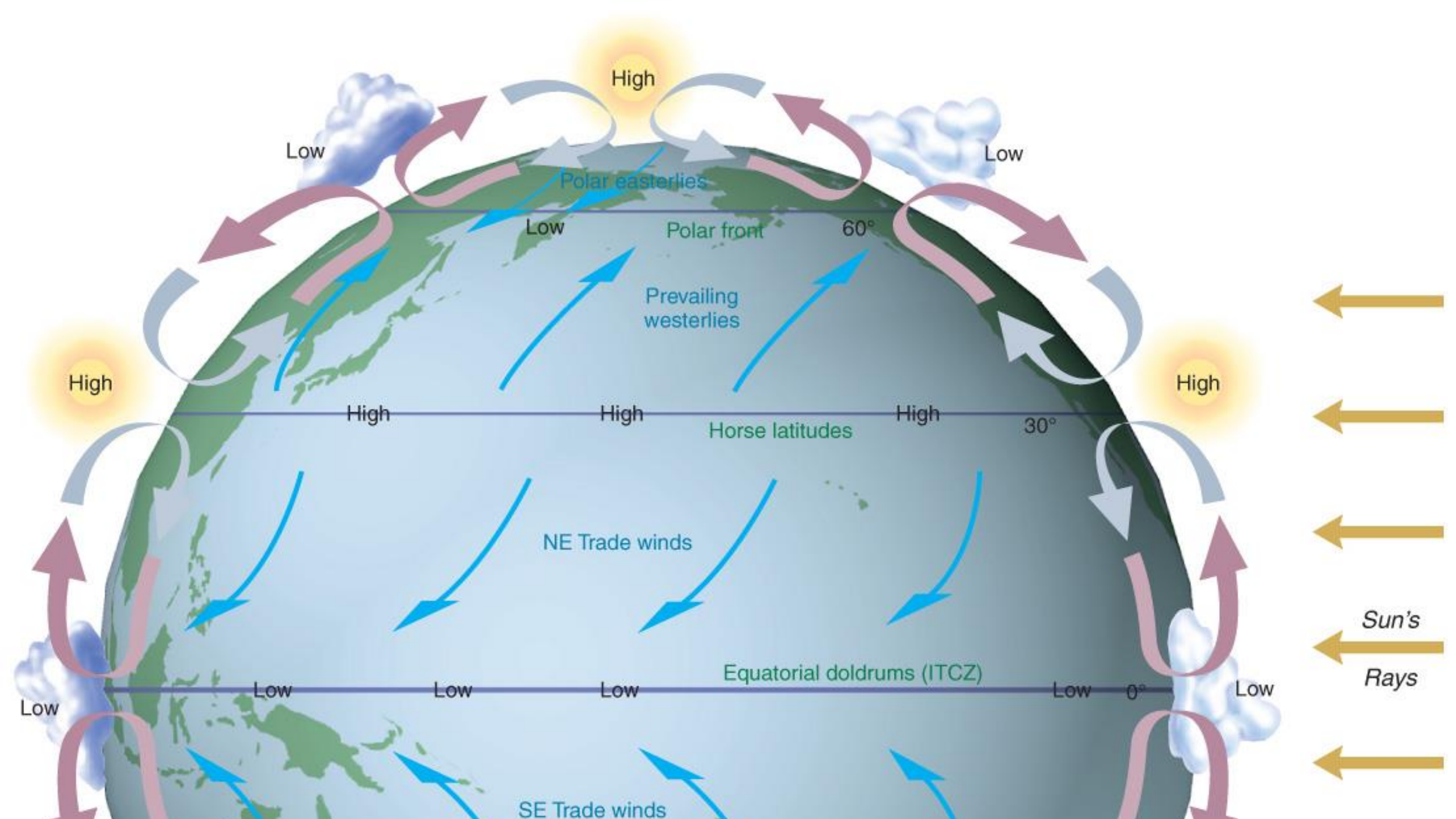
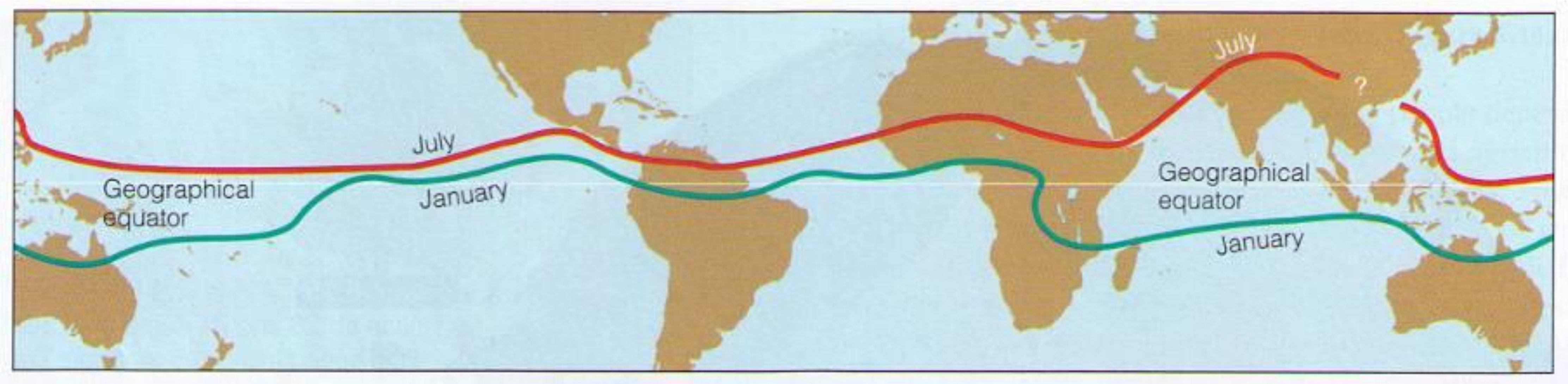


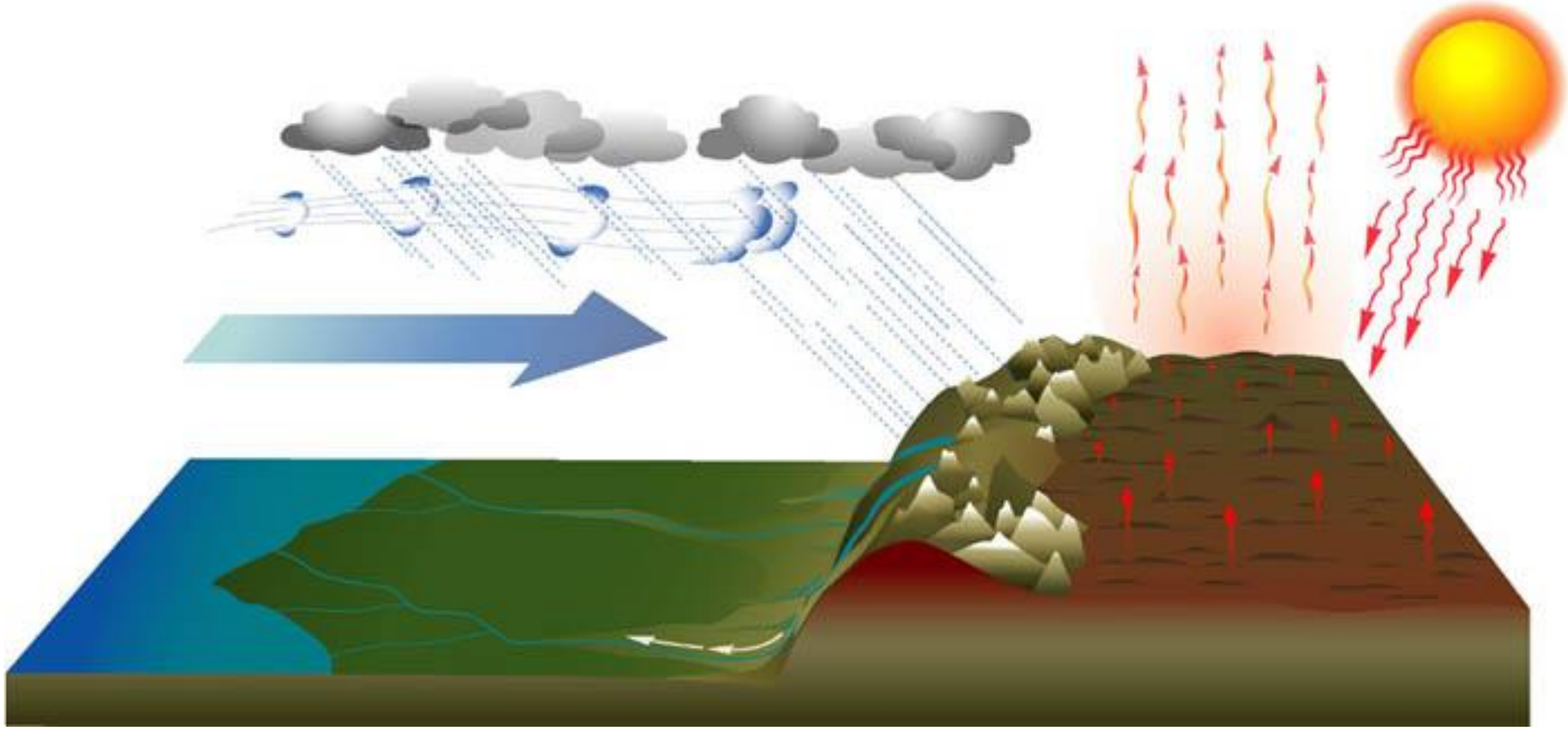
High
Low
Low
Polar easterlies
Low
Polar front
60°
Prevailing
westerlies
High
High
High
High
High
Horse latitudes
30°
NE Trade winds
Sun's
Rays
Equatorial doldrums (ITCZ)
Low
Low
Low
Low
Low
0°
Low
SE Trade winds

Seasonal changes of the wind patterns



Intertropical Convergence Zone (ITCZ)

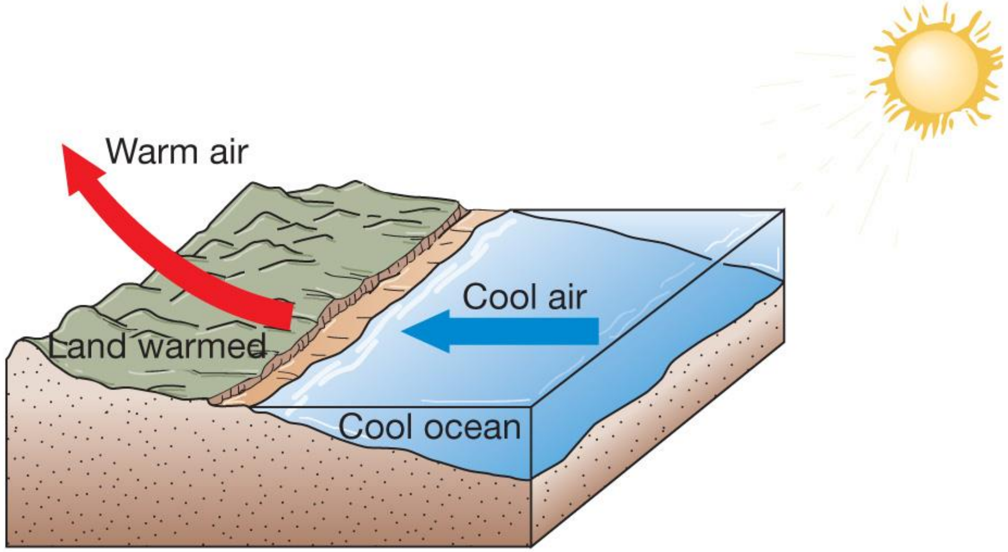
Monsoon System



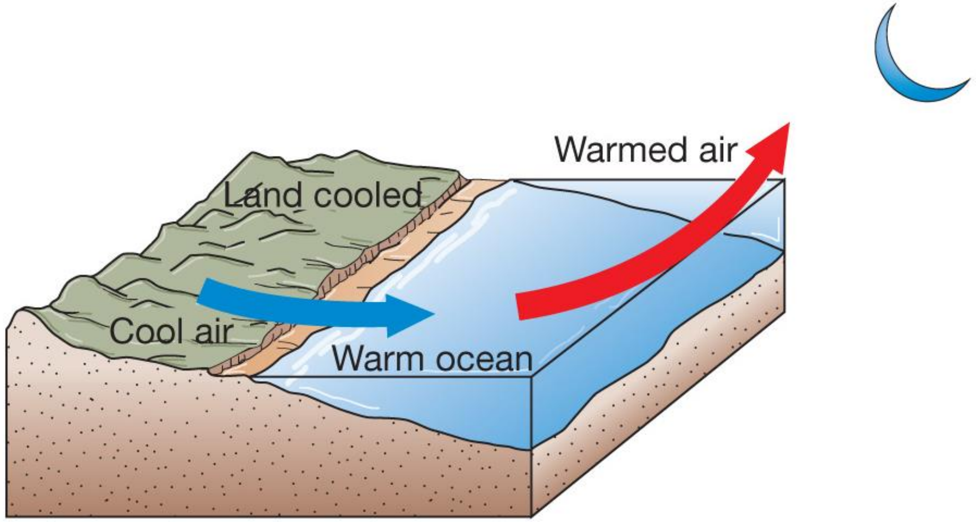
http://www.abdn.ac.uk/~wpg008/MonsoonCartoon.jpg

Sea breeze

Land breeze

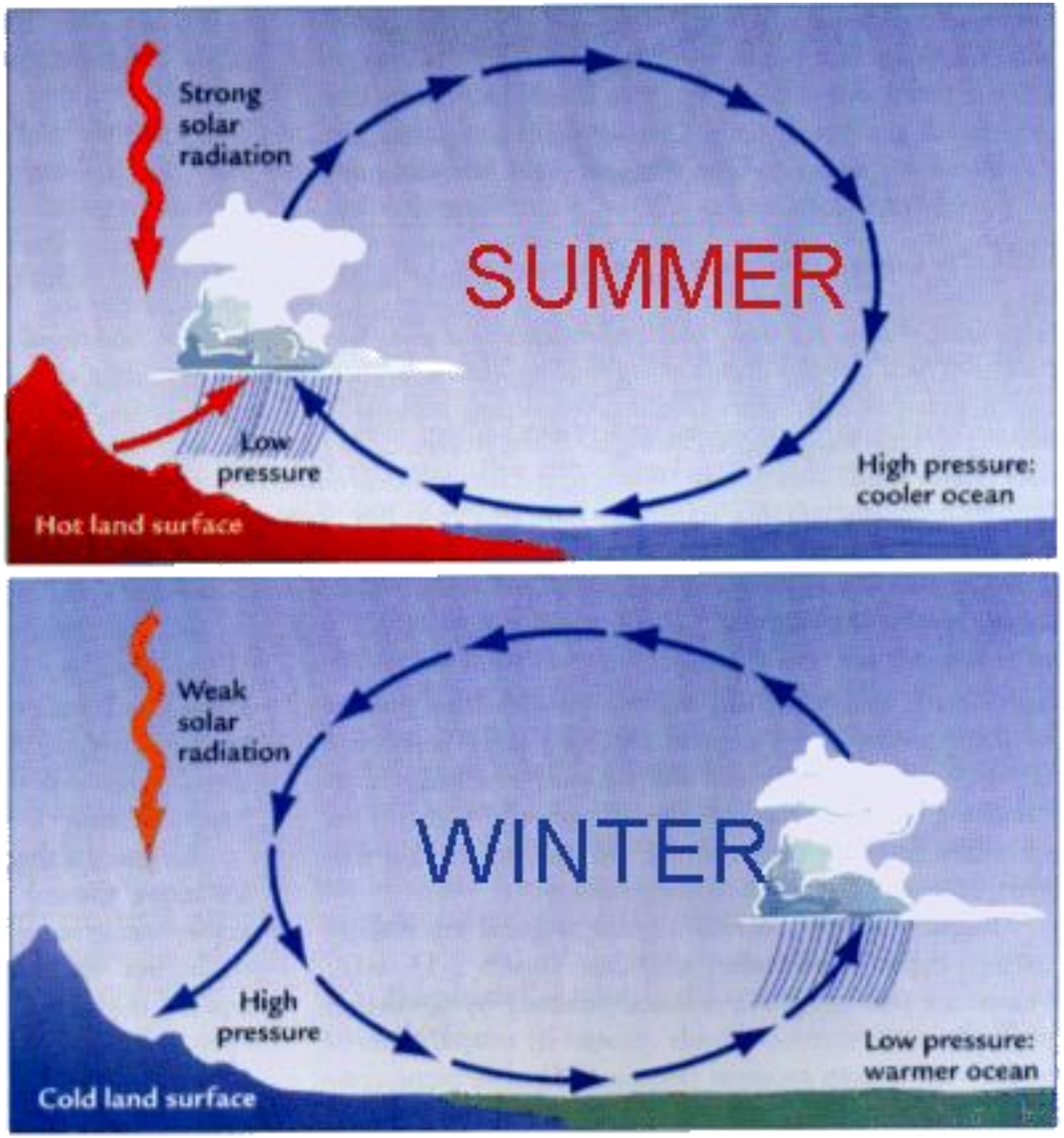


(a) Sea breeze



(b) Land breeze

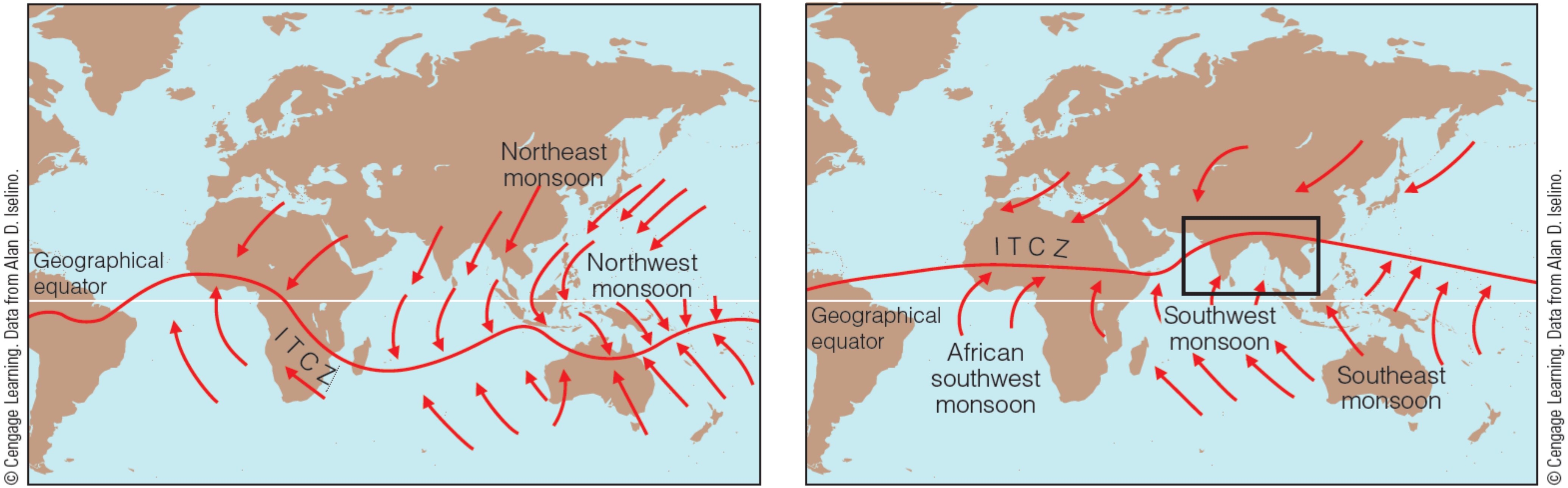
Monsoon System



Monsoon System

NE monsoon

SW monsoon



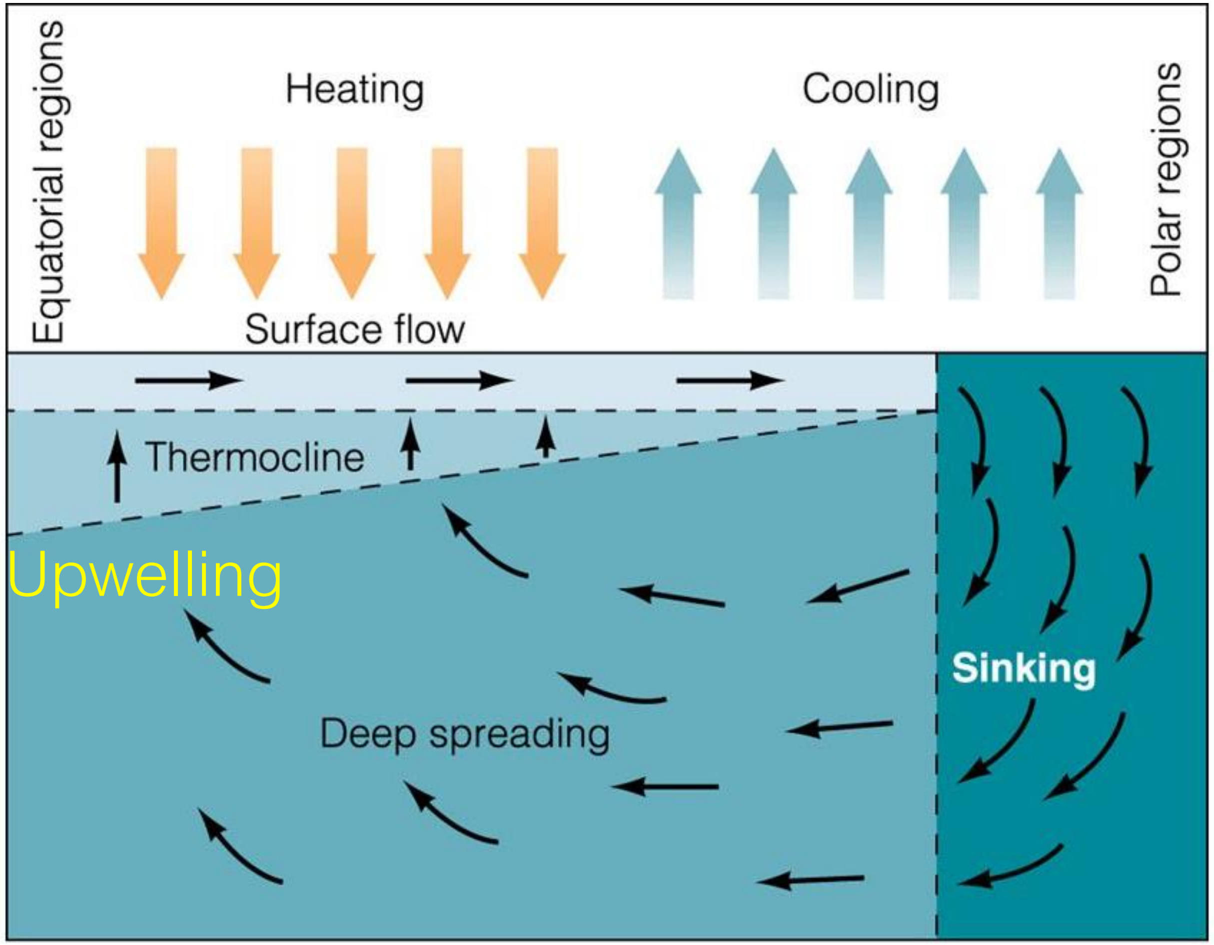
a January

b July

a During the monsoon circulations of January a and July b, surface winds are deflected to the right in the Northern Hemisphere and to the left in the Southern Hemisphere.

Ocean circulation

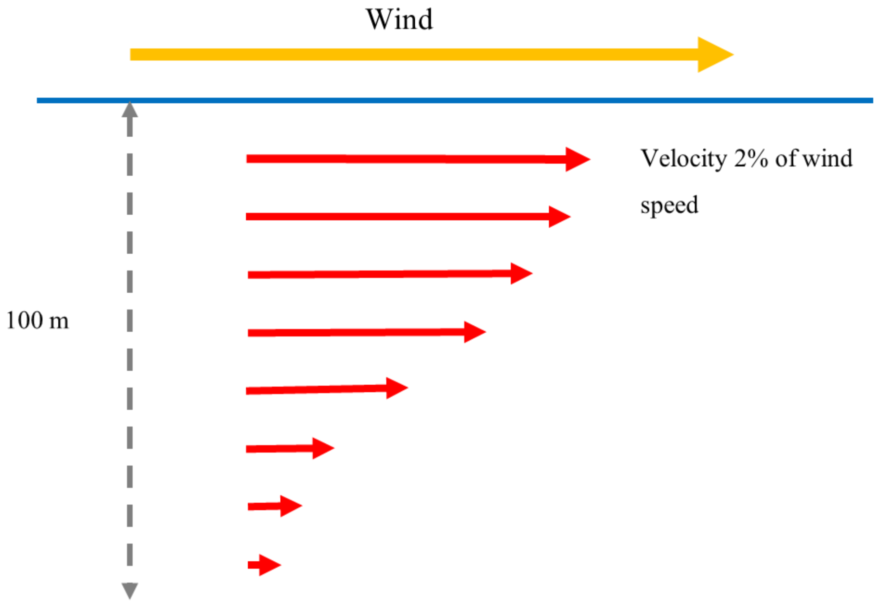
- Surface circulation is forced by wind.
- Thermohaline circulation or deep water formation is generated by instability condition

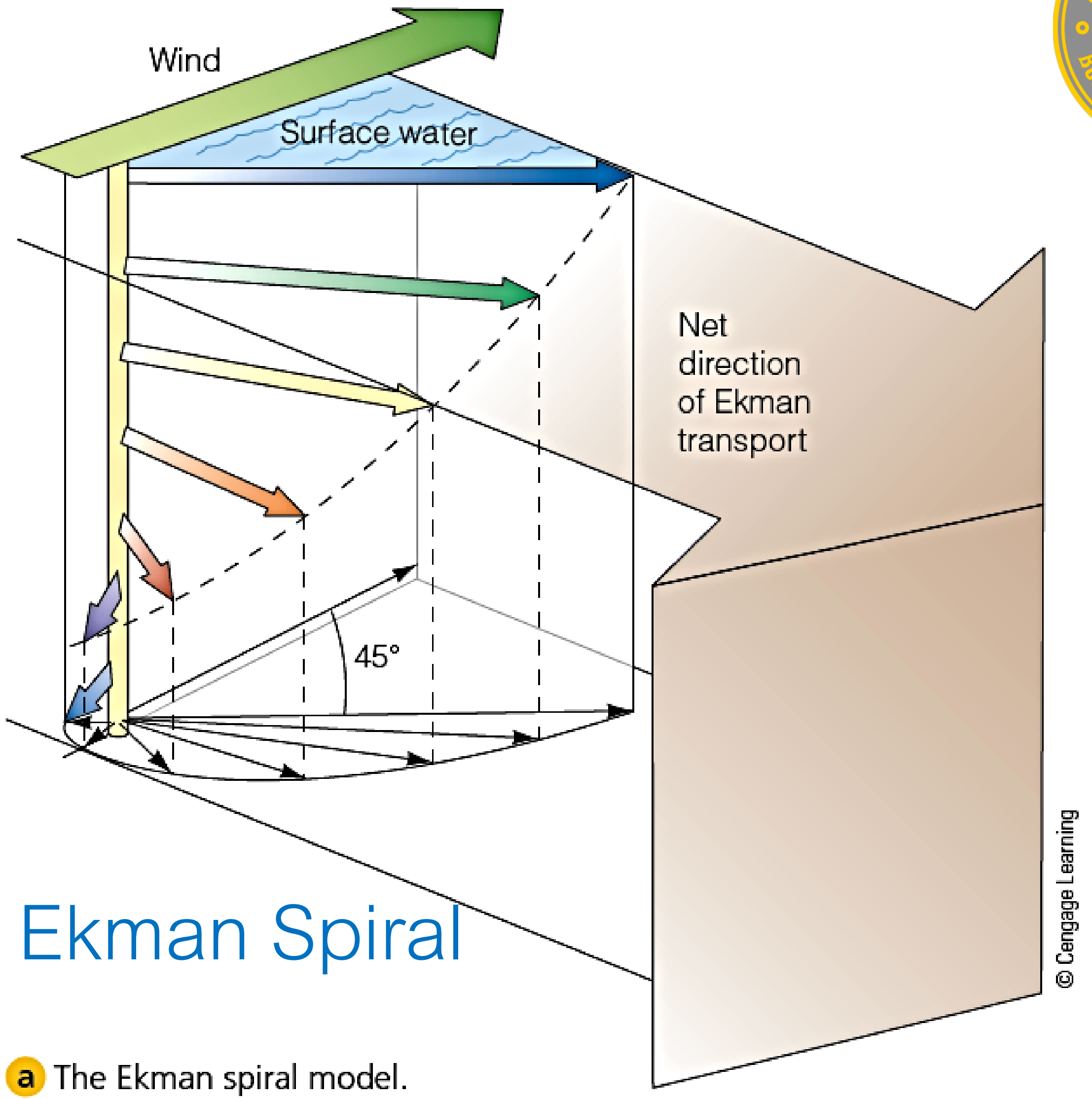


Classic thermohaline circulation

Surface current

- Caused by the action of friction between wind and sea surface water, and the Coriolis force.

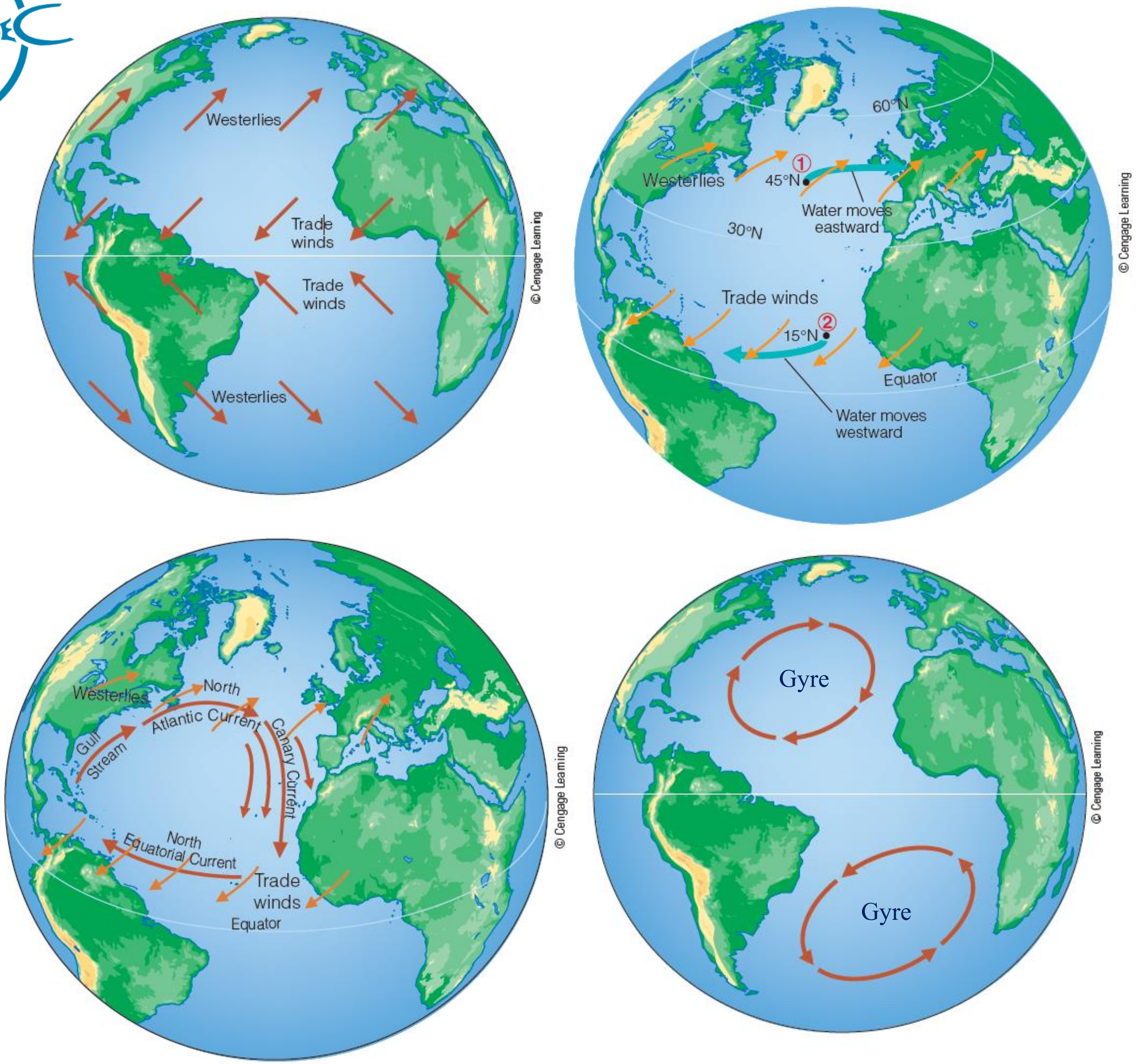




Ekman Spiral

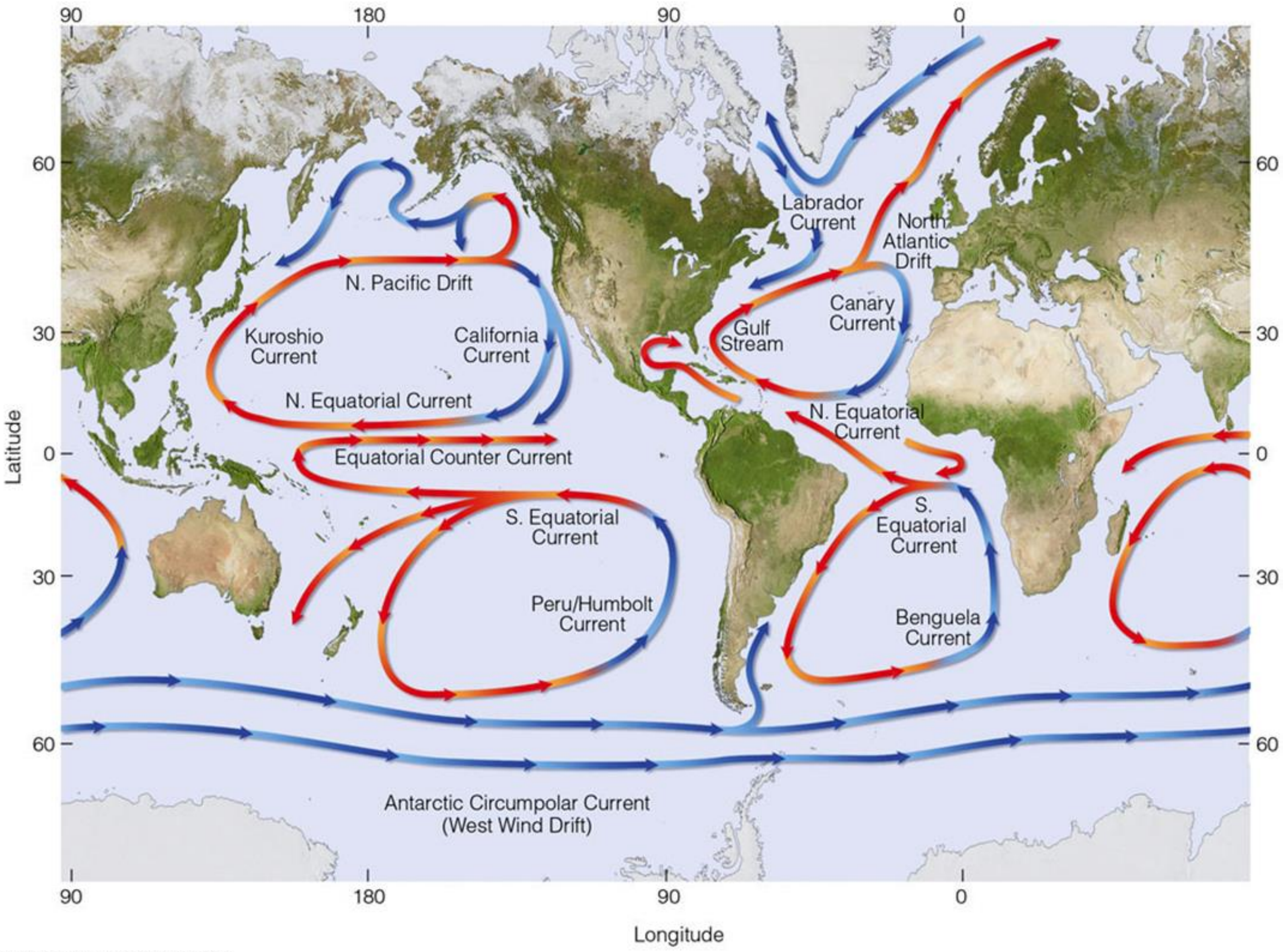
a The Ekman spiral model.

Figure 9.5 The Ekman spiral and the mechanism by which it operates. The length of the arrows in the diagrams is proportional to the speed of the current in each layer.

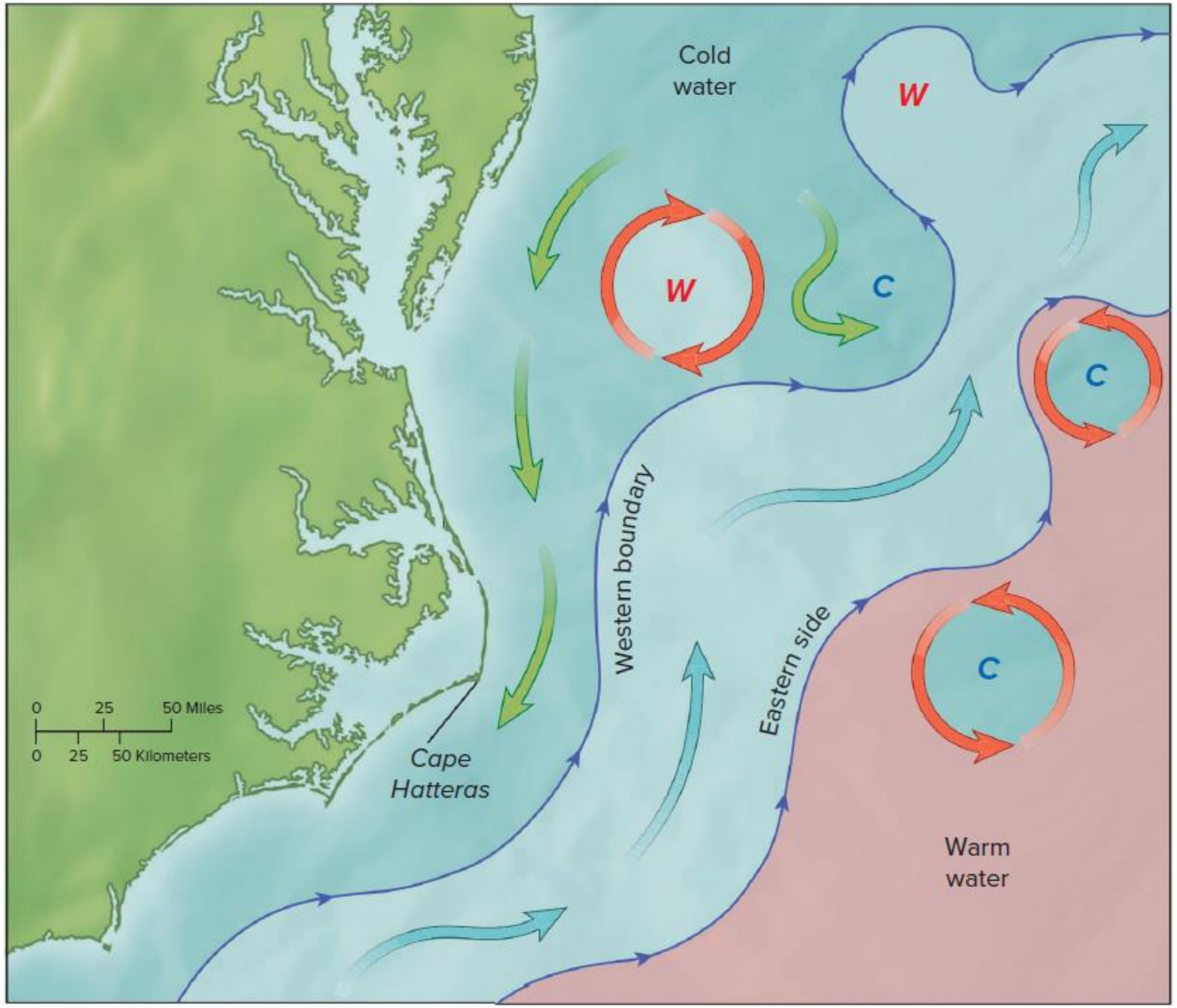


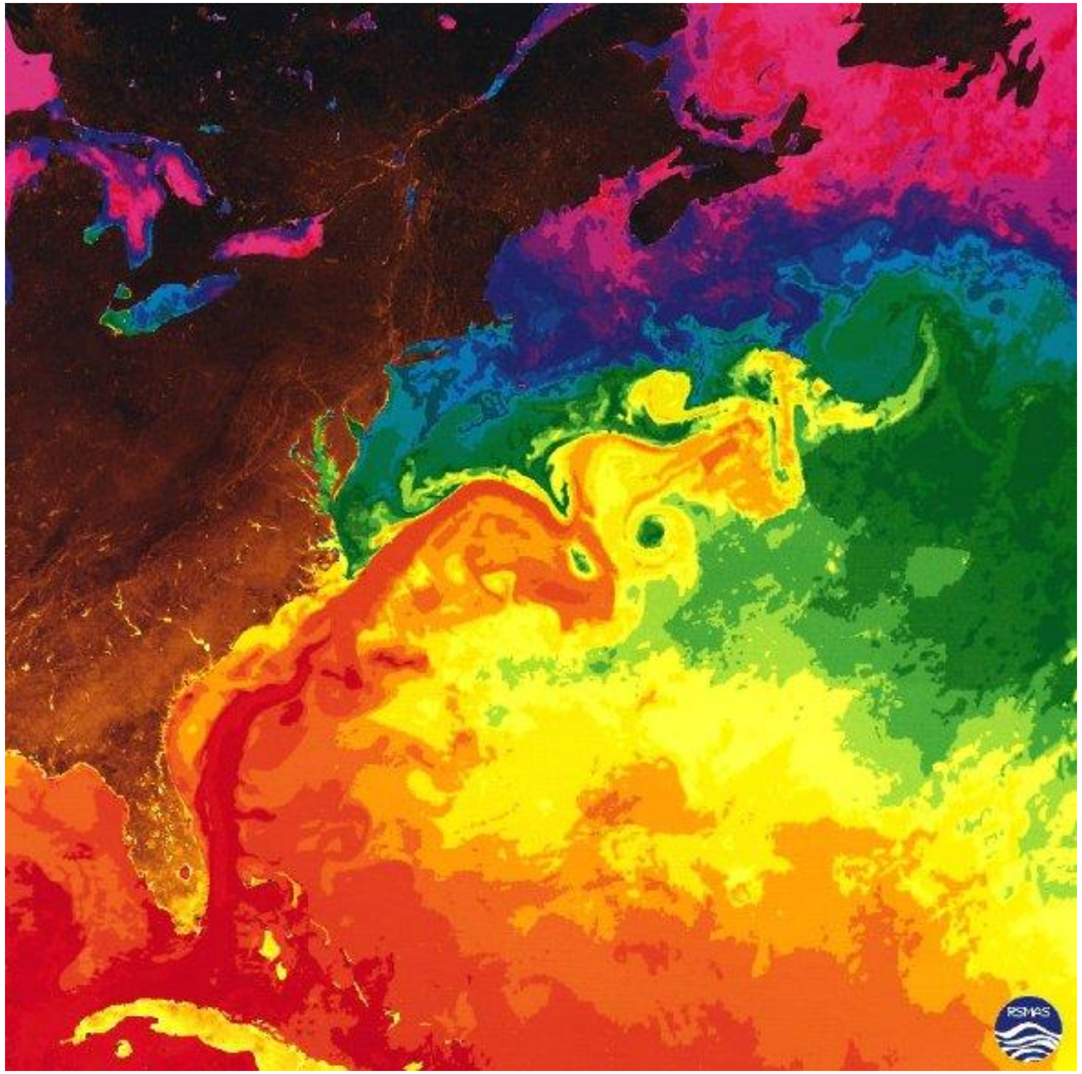
Wind and surface current pattern in the world ocean

Surface current of the world ocean

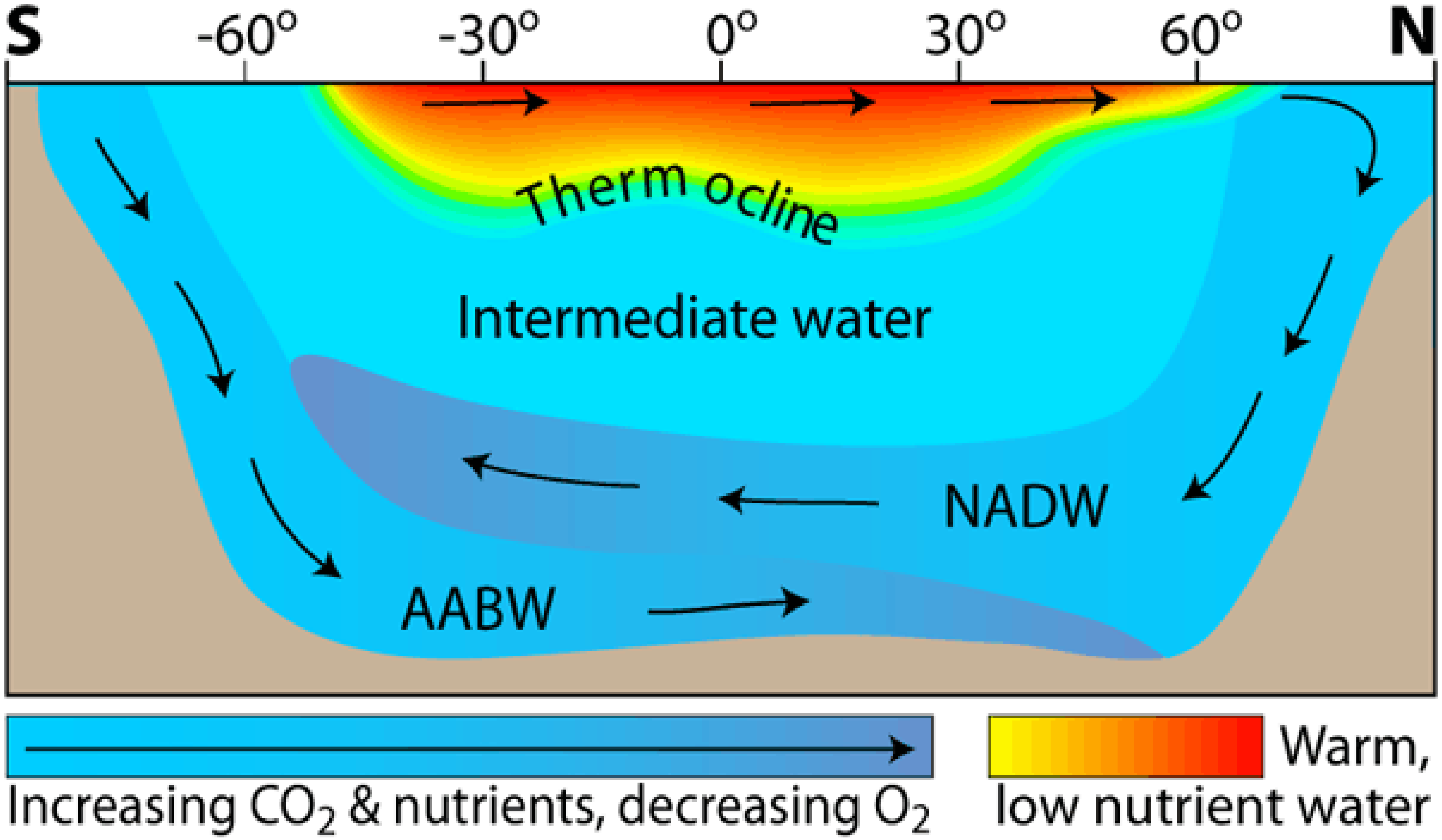


Cold and Warm Eddies

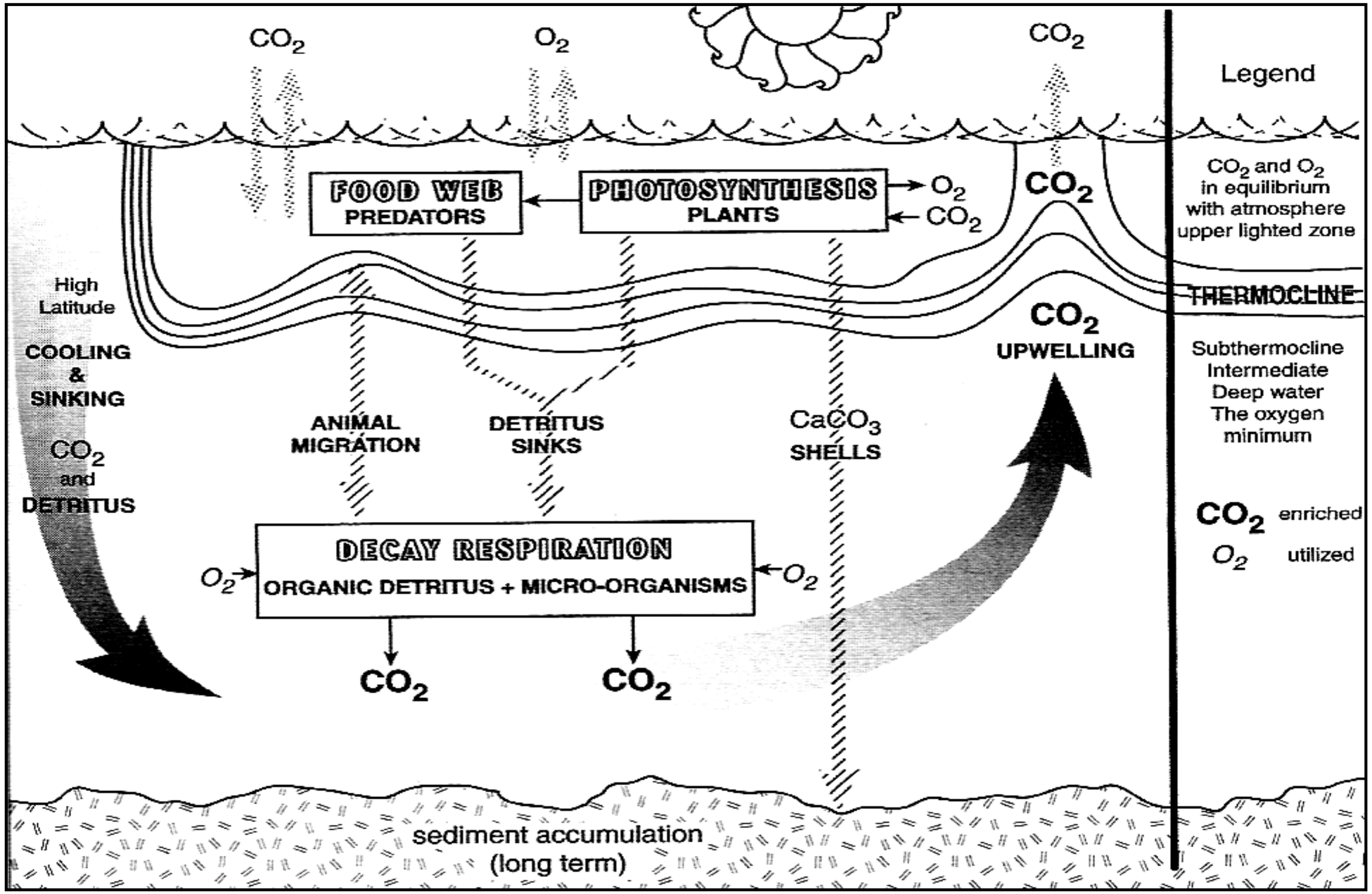




Thermohaline Circulation and Deep Water Masses

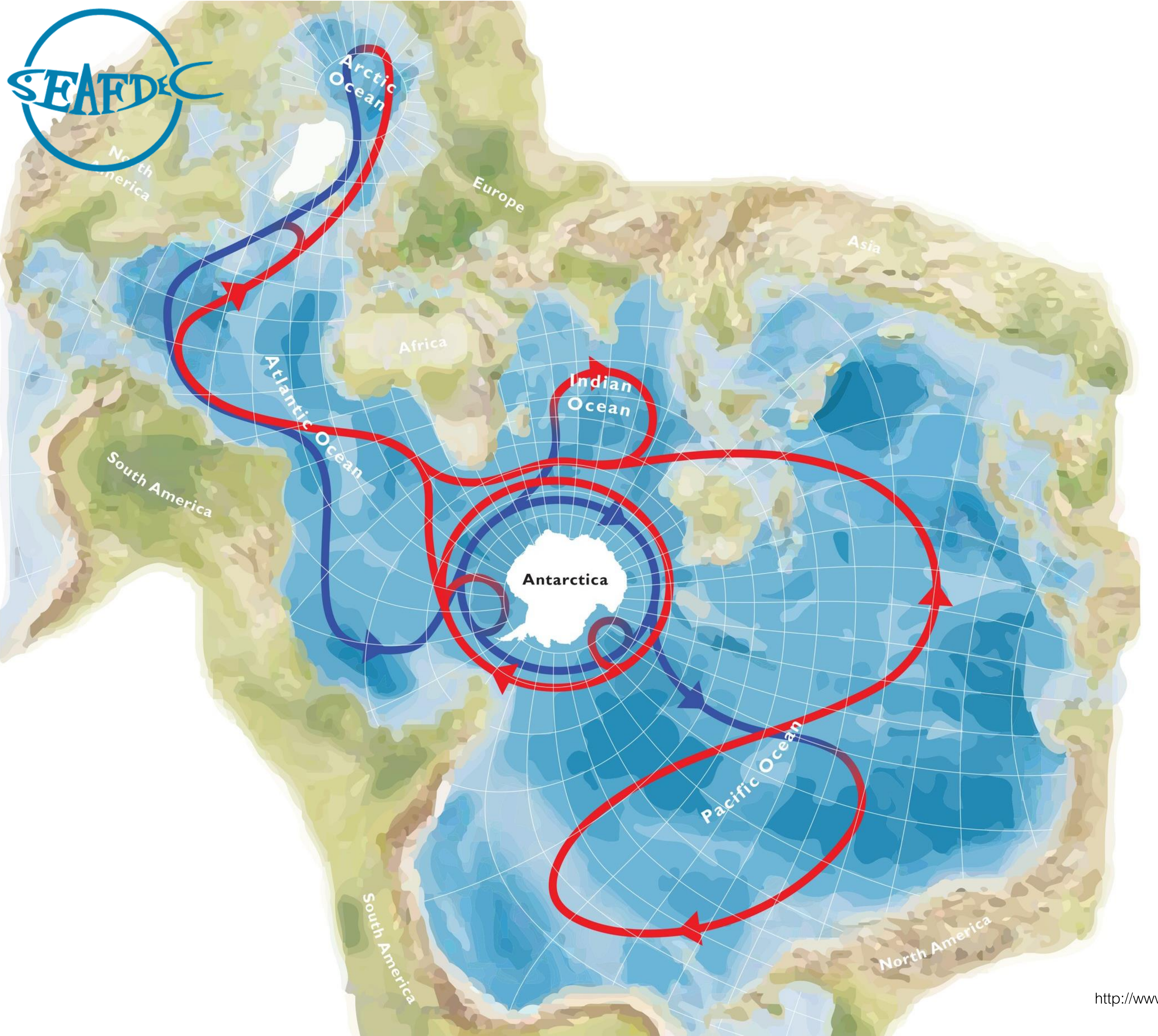


The ocean – atmosphere carbon cycle



Oceans 2020: Science, Trends, and the Challenge of Sustainability

by John G. Field (Editor), Gotthilf Hempel (Editor), Colin P. Summerhayes (Editor)



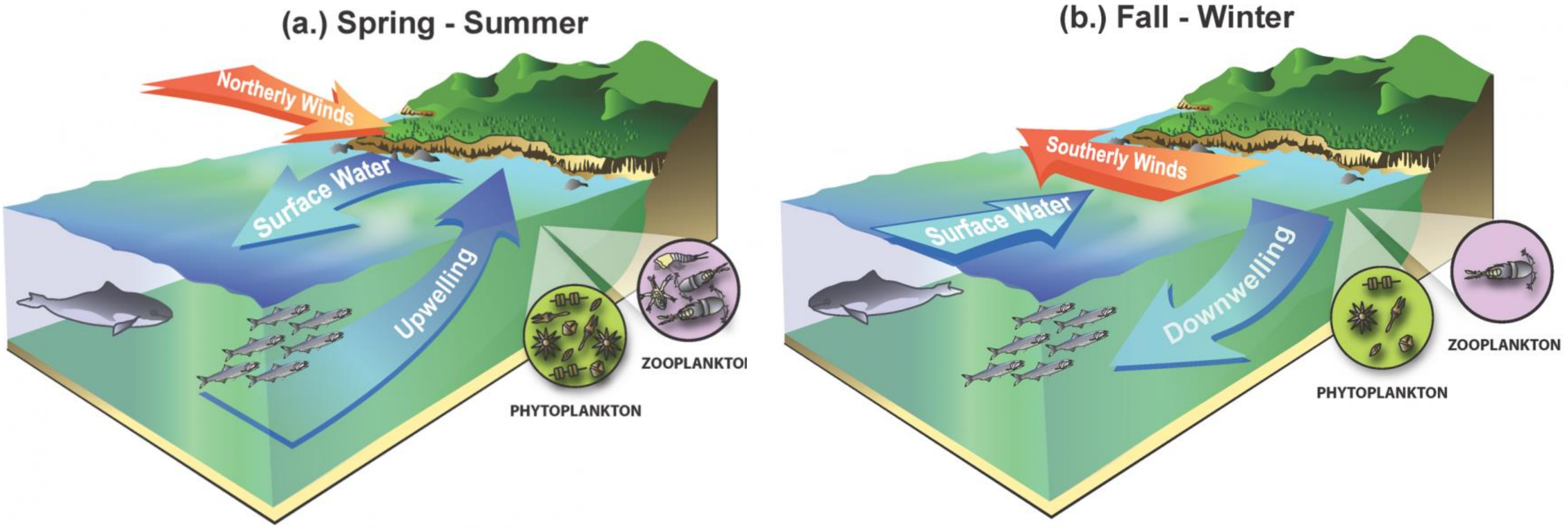
Conveyer Belt

Thermohaline Circulation and Deep Water Masses

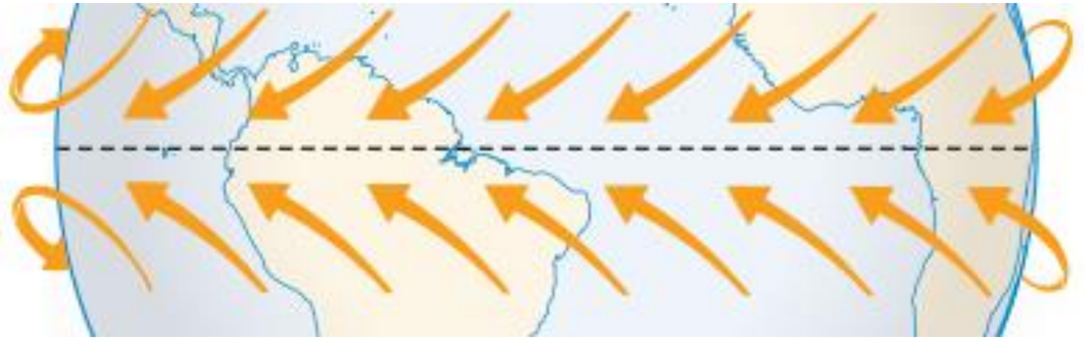
http://www.iau.gub.uy/wp-content/uploads/2019/08/circulacion-termohalina.jpg

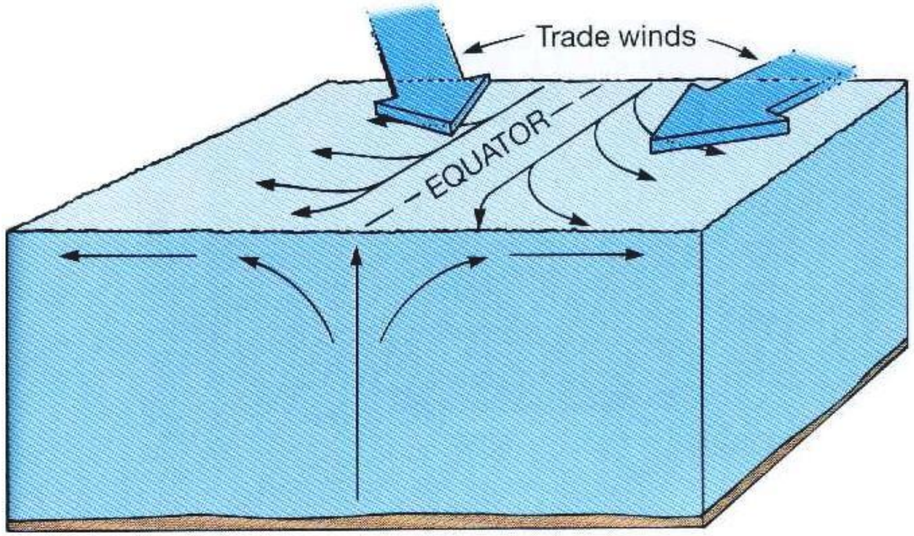
Upwelling and Down welling

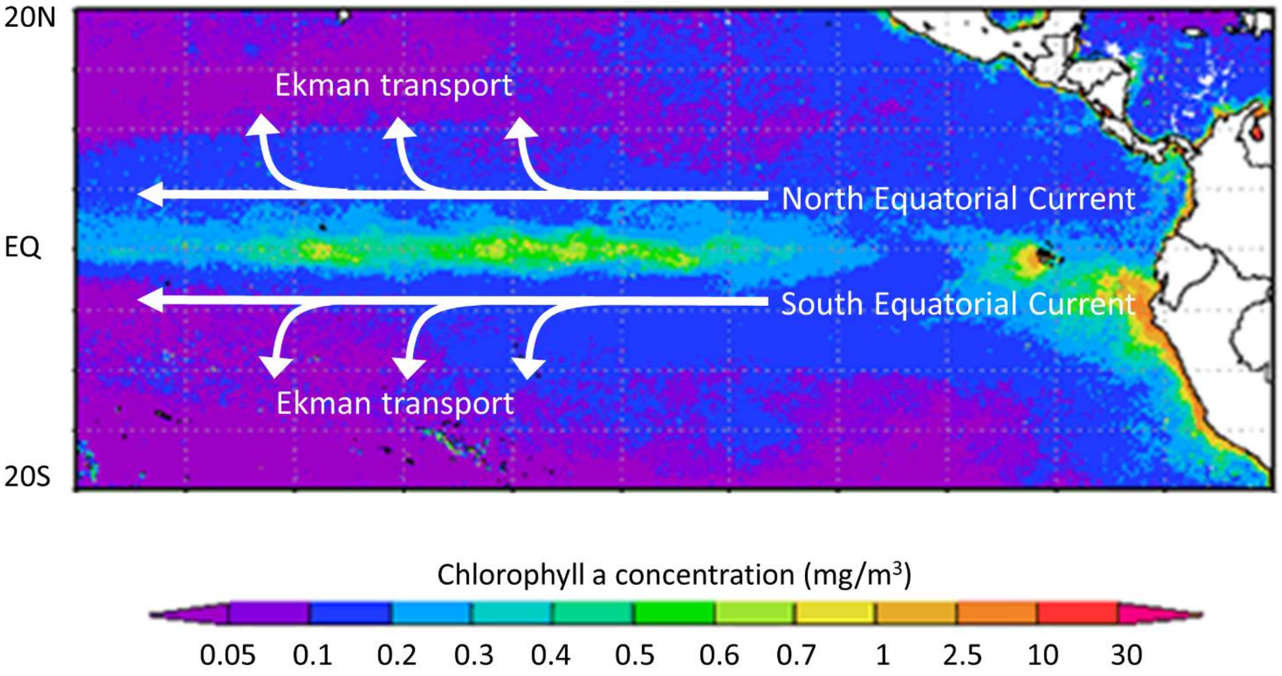
Northern Hemisphere



http://www.oregonconservationstrategy.org/oregon-nearshore-strategy/habitats/




Trade winds
EQUATOR


20N
EQ
20S
Ekman transport
North Equatorial Current
South Equatorial Current
Ekman transport
Chlorophyll a concentration (mg/m3)
0.05 0.1 0.2 0.3 0.4 0.5 0.6 0.7 1 2.5 10 30

Thank you