Océanos

Mundo Acuático

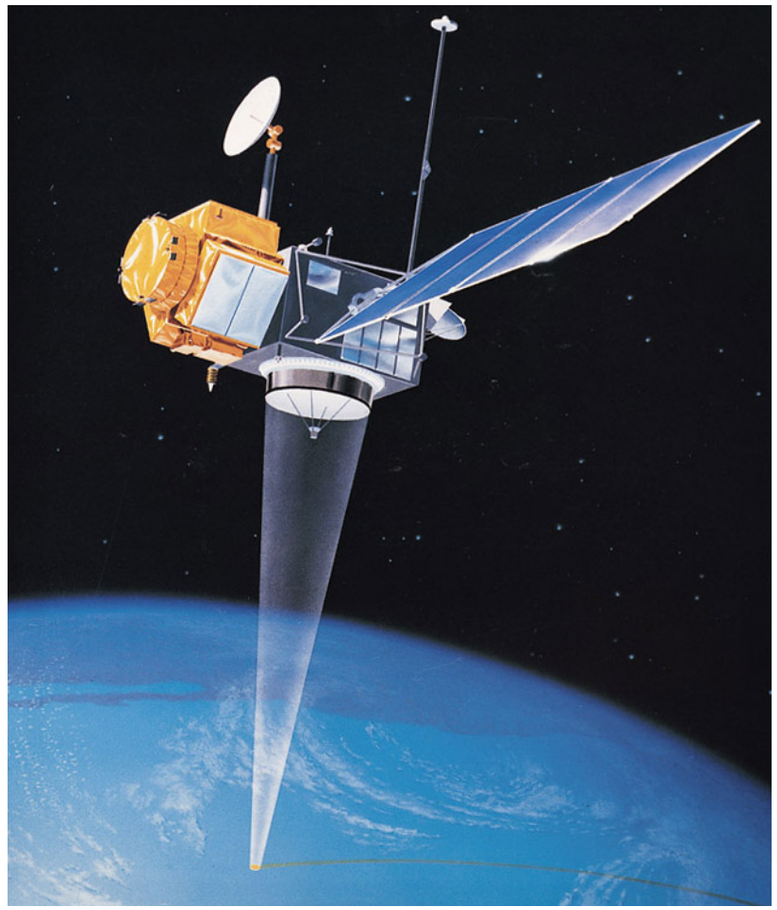
“Earth is a unique planet, possibly one of the few in the galaxy that has water.

Nearly 71% of it’s surface is ocean. From space, Earth is brilliantly blue, white in places with clouds and ice, sometimes swirling with storms.

Porqué estudiar el océano?

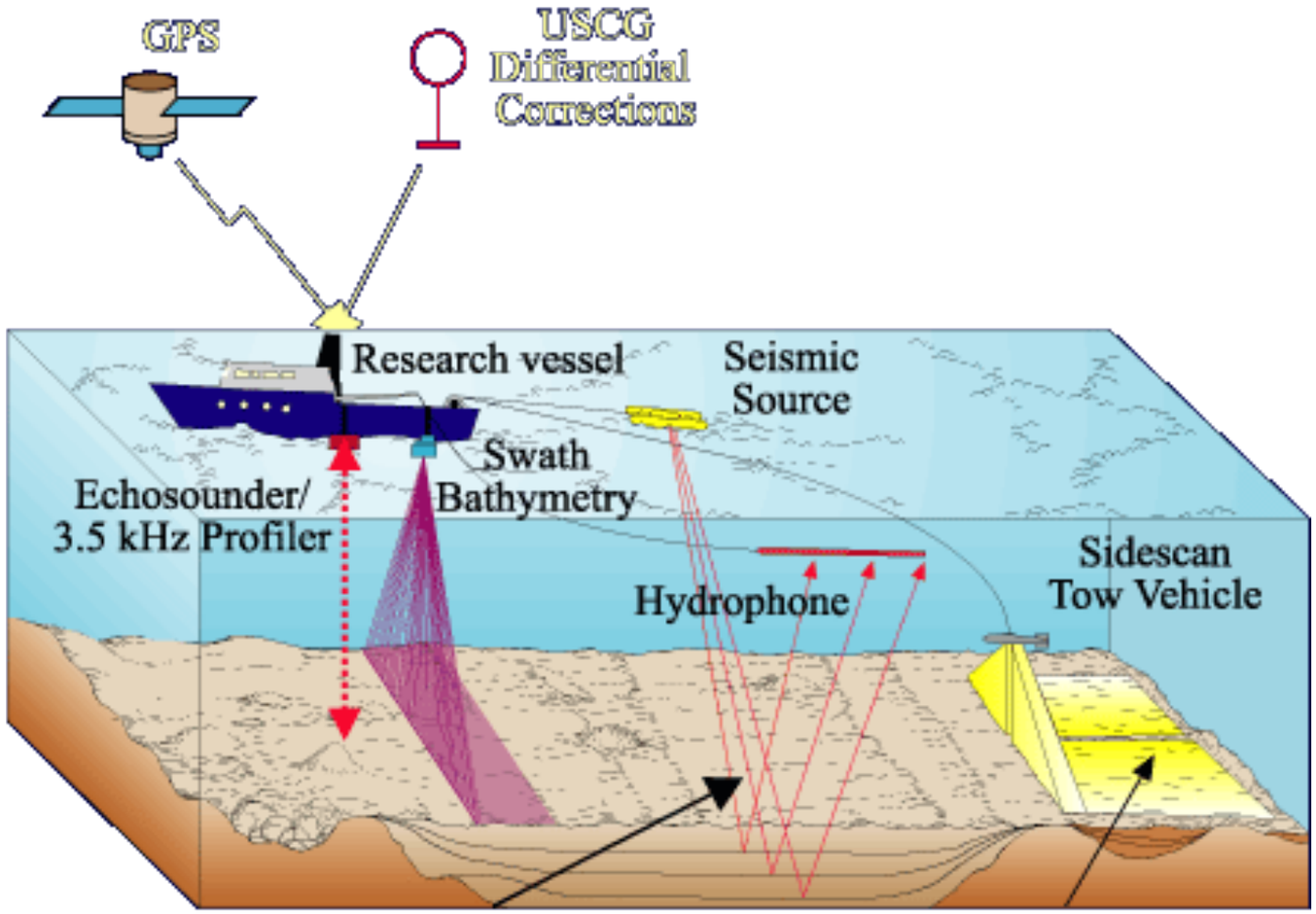
- Importante influencia en el clima y el tiempo
- Fuente de alimentos, energía, drogas, etc.
- Transporte
- Recreación
- Influencia en la salud del planeta
- Cultura e historia

Nuevas tecnologías



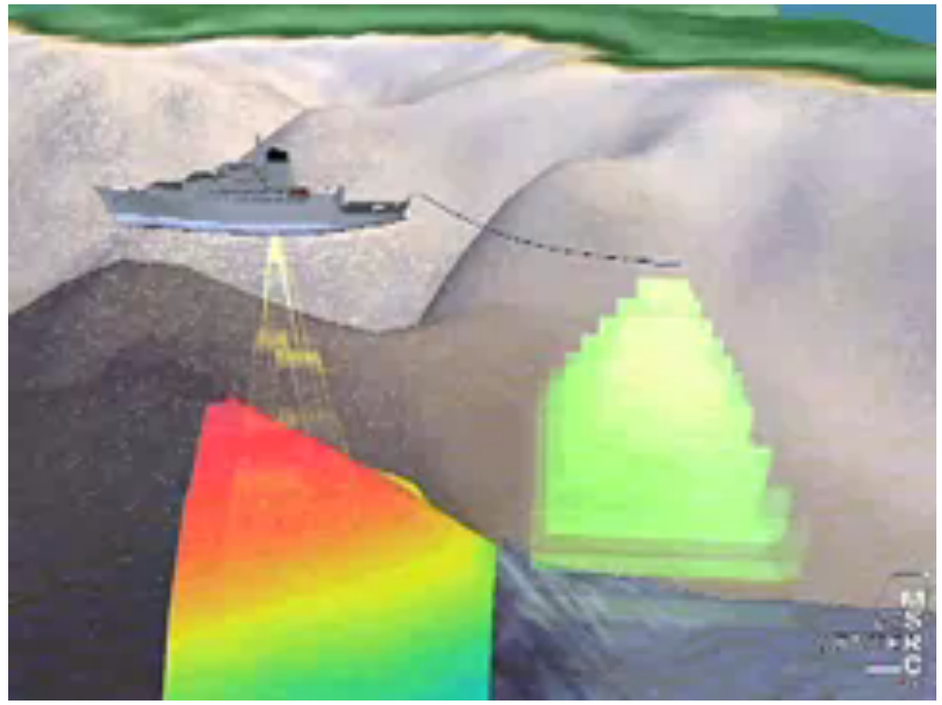
TOPEX/Poseidon satellite launched in 1992.

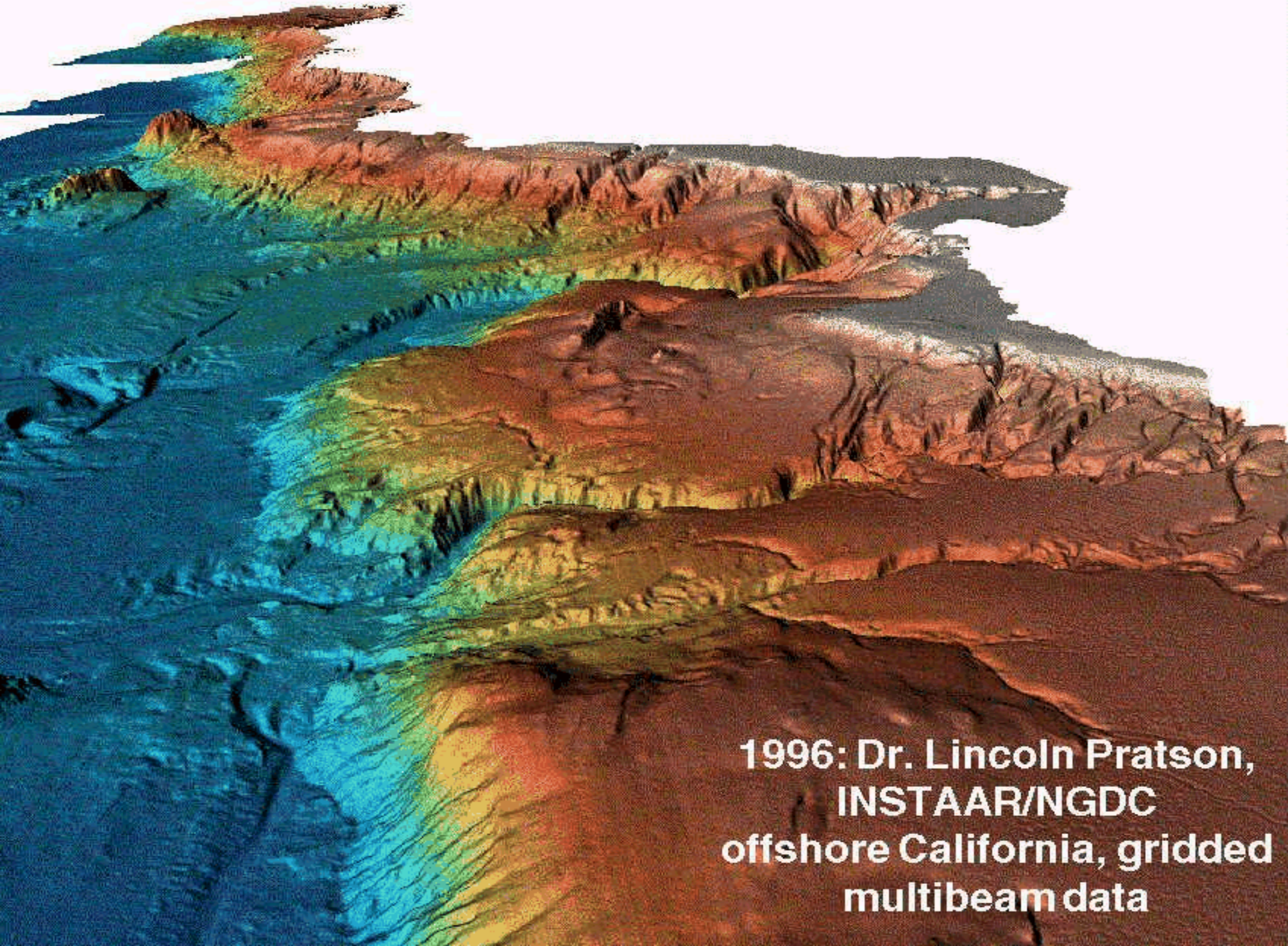
Nuevas tecnologías



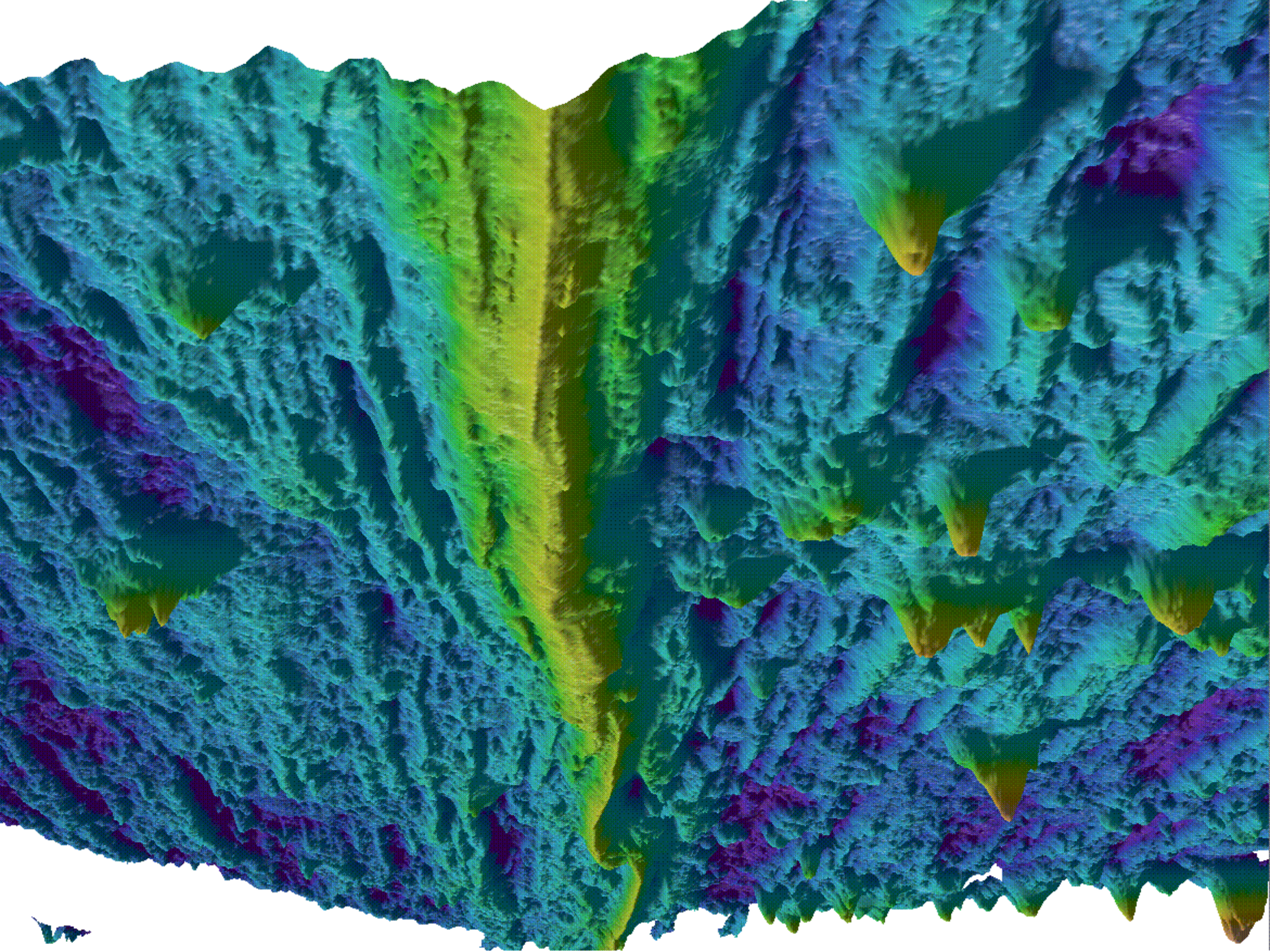
SEISMIC REFLECTION
(Subsurface Coverage)

SIDESCAN -SONAR
(Areal Coverage)





1996: Dr. Lincoln Pratson,
INSTAAR/NGDC
offshore California, gridded
multibeam data



USS San Francisco crashed into 2-km tall uncharted seamount

- Los Angeles class nuclear submarine ran aground enroute from Guam to Brisbane, Australia - 8 January, 2005
- One sailor killed, 115 injured
- 30-hour trip back to Guam, crew managed to keep the sub from sinking

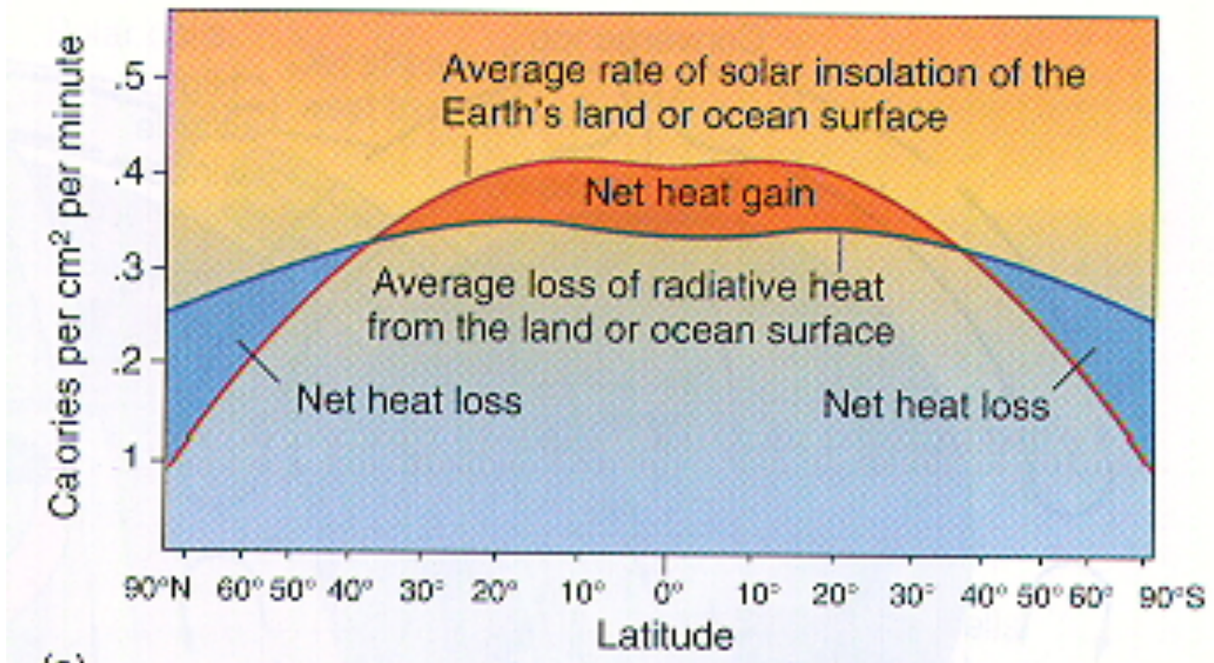
Courtesy of Dave Sandwell, Scripps Institution of Oceanography

De dónde provino el agua de los océanos?

- Degasificación (H_2O, CO_2) de la Tierra en volcanes, en la historia temprana de la misma, aunque continua hoy en día
- Rocas sedimentarias hasta de 3.8000 millones de años!
- Una pequeña parte viene de cometas.

Ocean Temperature
Solar Heating

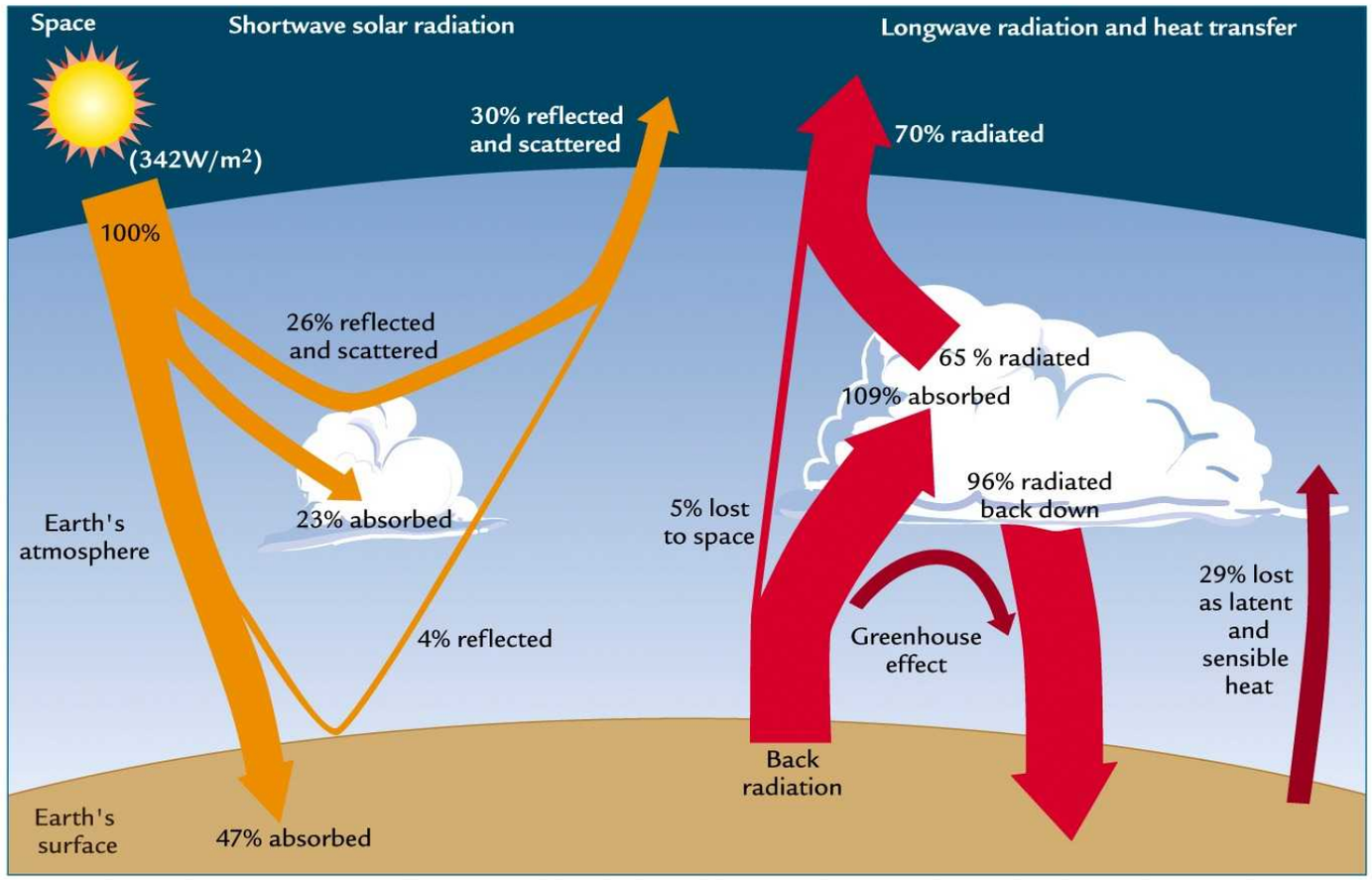
- Uneven heating of Earth's surface
- Release of heat as infrared radiation
- Requires flow of heat by oceans and atmosphere
- Surface circulation



Global Heat Budget

- **heat** at the Earth's surface (342 W/m^2) is supplied by absorption of 'short-wave' solar radiation from the sun.

- **heat** lost from Earth is through long-wave radiation back to space.



Propiedades especiales del agua

RECUERDE:

Punto de fusión y ebullición son muy altos

La más alta capacidad calórica entre líquidos comunes.

Mayor densidad en líquido que sólido!!!!

El Océano

La estructura básica del océano consiste en

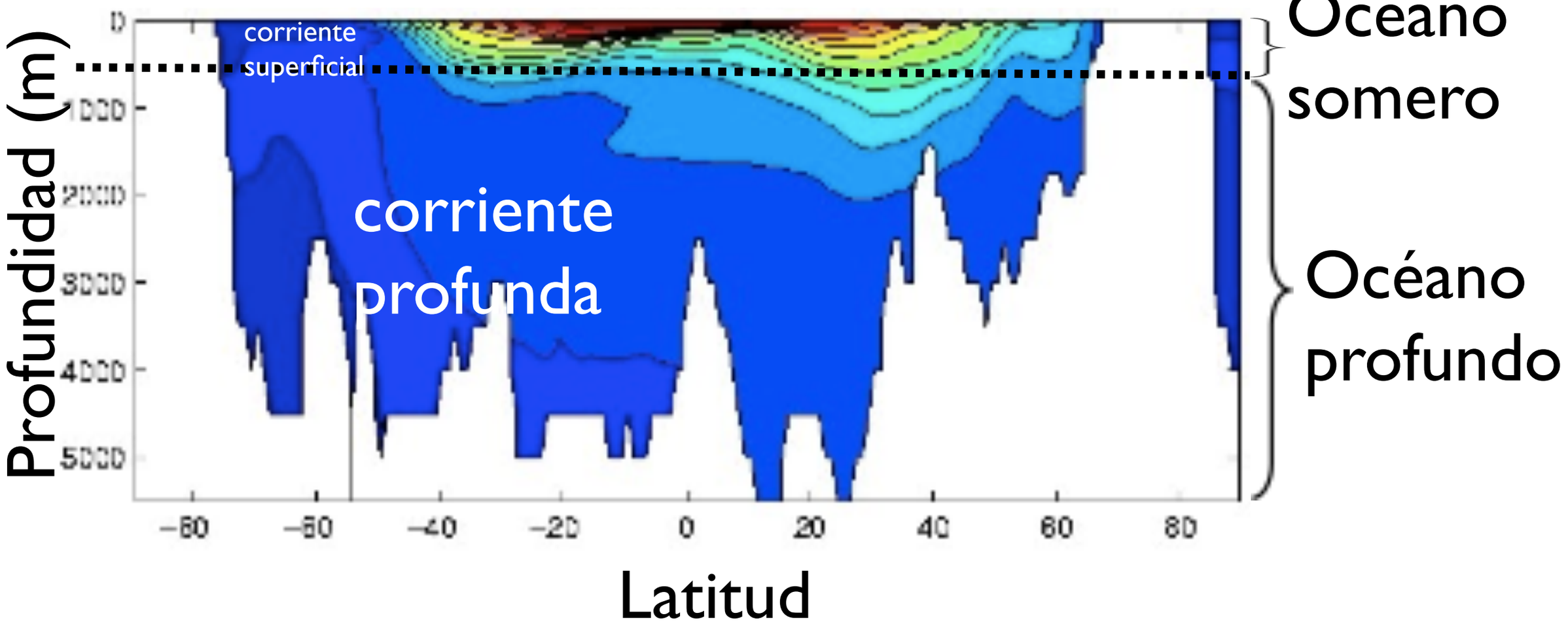
Océano superficial:

Es la parte superior que es más caliente y en donde la luz es abundante

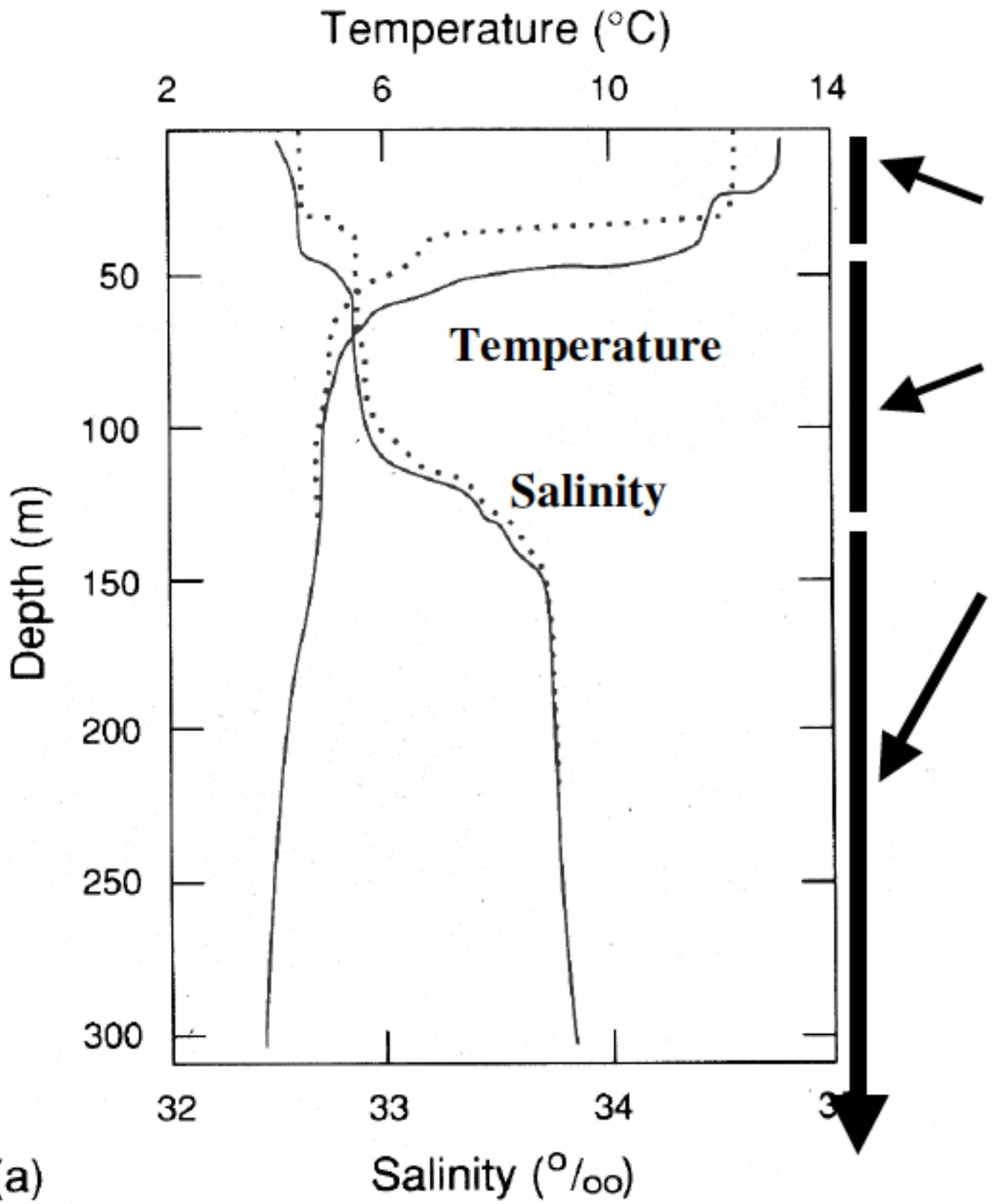
Océano profundo:

Es oscuro y frío y tiene gran cantidad de fuentes de nutrientes

Las corrientes



Salinidad y Temperatura

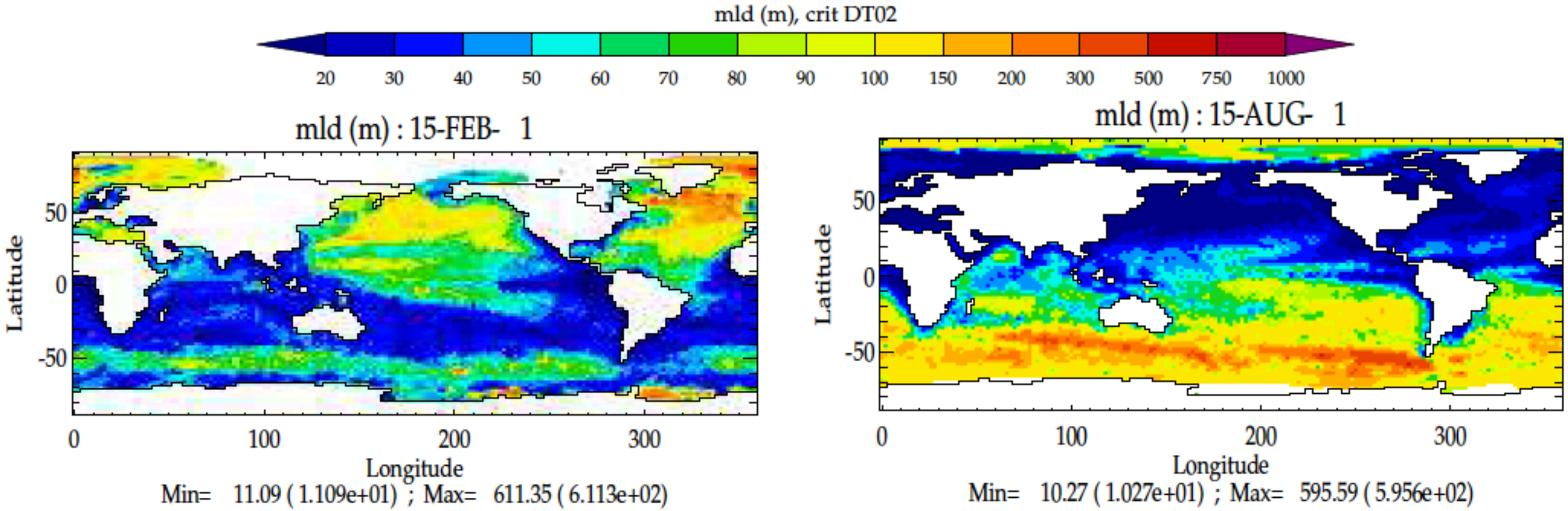


Capa de mezcla: T y S son homogéneos, mezclados por vientos

Termoclina: gradientes altos en T y S (es decir cambios muy grandes sobre distancias muy pequeñas)

Océano Profundo: T y S son independientes de la profundidad. Es frío, alta salinidad y un alto nivel de nutrientes

Capa mezclada

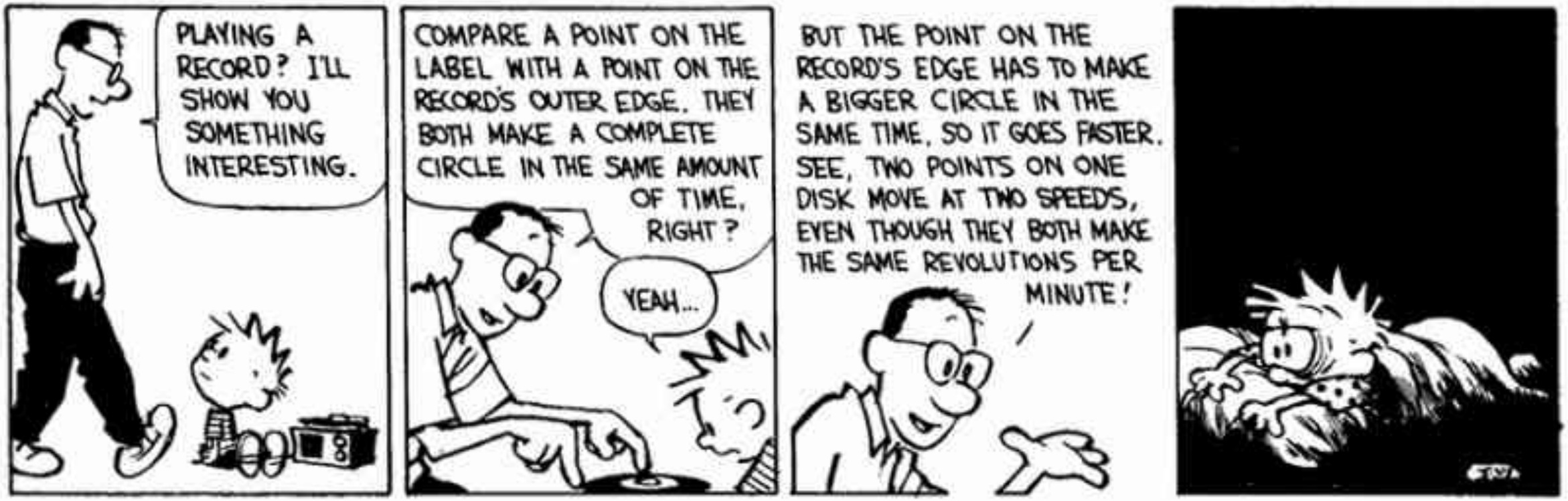


Verano: es caliente y delgada

Invierno: fria y profunda (~cientos de metros)

/home1/typhon/deboyer/IDL/PS/B_Mld_OceanProfiles/pp0_plot_pixcont_mldvars_2_28_mld_DT02_www.ps - Mon Mar 9 18:10:34 2009

Ocean Surface Circulation



NASA web site: http://oceanmotion.org

Two types of Ocean Circulation:

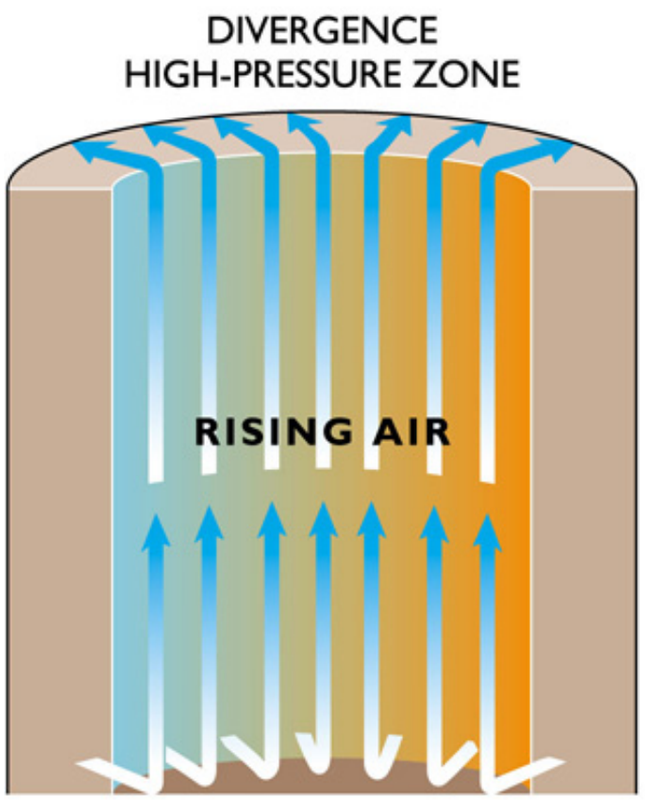
- Surface Circulation -- Wind-driven
- Deep Circulation – Density-driven

Density of water is influenced by Temperature and Salinity, so density- driven circulation is often called the

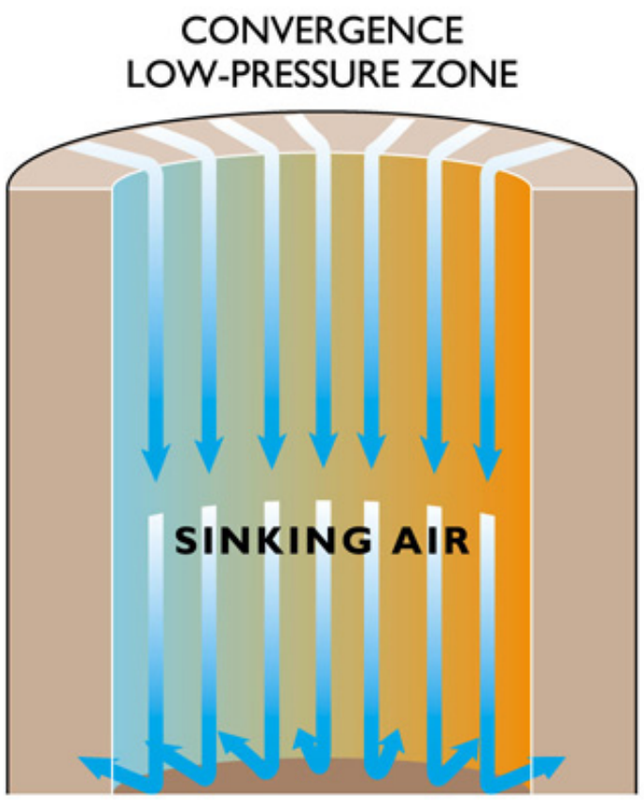
"Thermohaline" Circulation

Friday's lecture

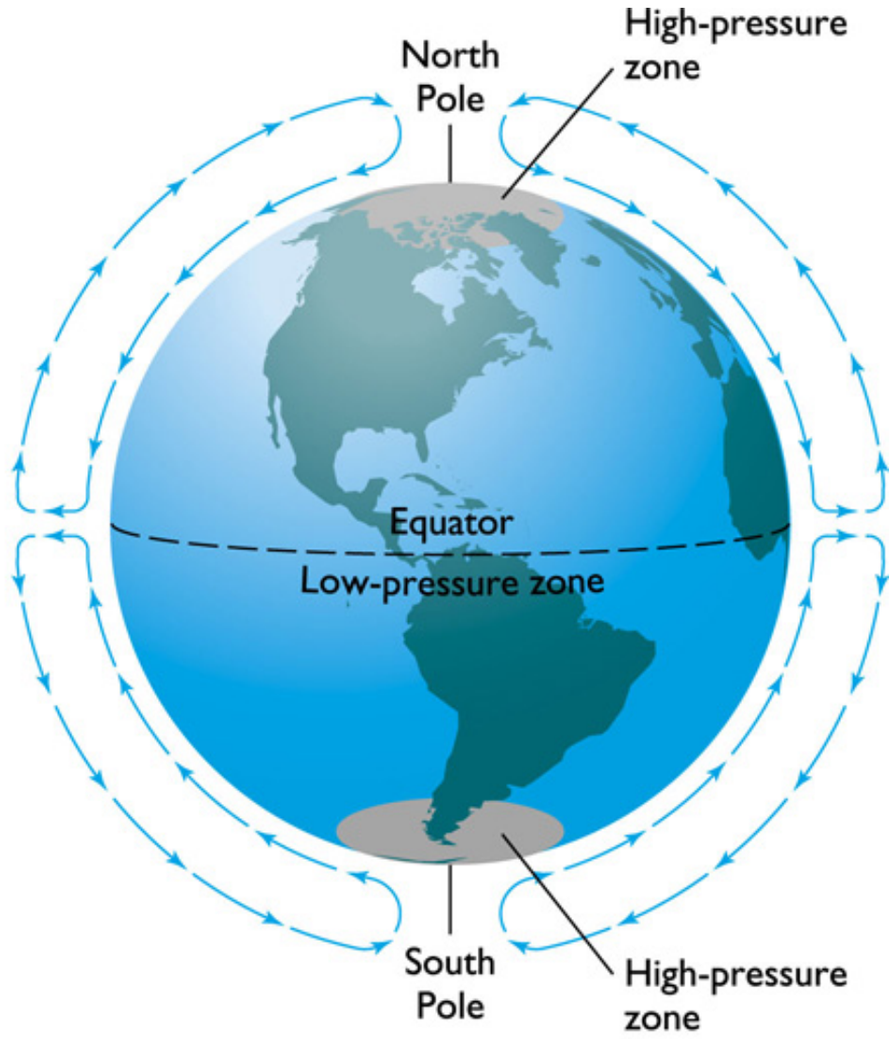
Atmospheric Circulation



(a) HEATING OF AIR



(b) COOLING OF AIR



(c) SIMPLE AIR CIRCULATION ON A NONROTATING EARTH

Temperature and Pressure

✨As the Earth's surface is heated, air is warmed, expands and rises (Low Pressure)

✨Warm air carries water vapor

✨In the upper atmosphere the air cools and sinks (High Pressure)

✨Surface winds blow from High Pressure to Low Pressure

✨This round-trip is called a "cell"

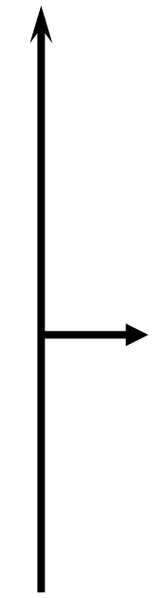
Things get interesting!

- On a rotating planet, moving objects appear to be deflected
- Why is this?

Coriolis Deflection

So, in the frame rotating CCW (like northern hemisphere), unforced particle in motion is deflected to the ***right***.

If frame rotates CW, motion of particle is to the ***left*** (reverse film).



Coriolis Force (northern hemisphere)

velocity

Coriolis Force (southern hemisphere)

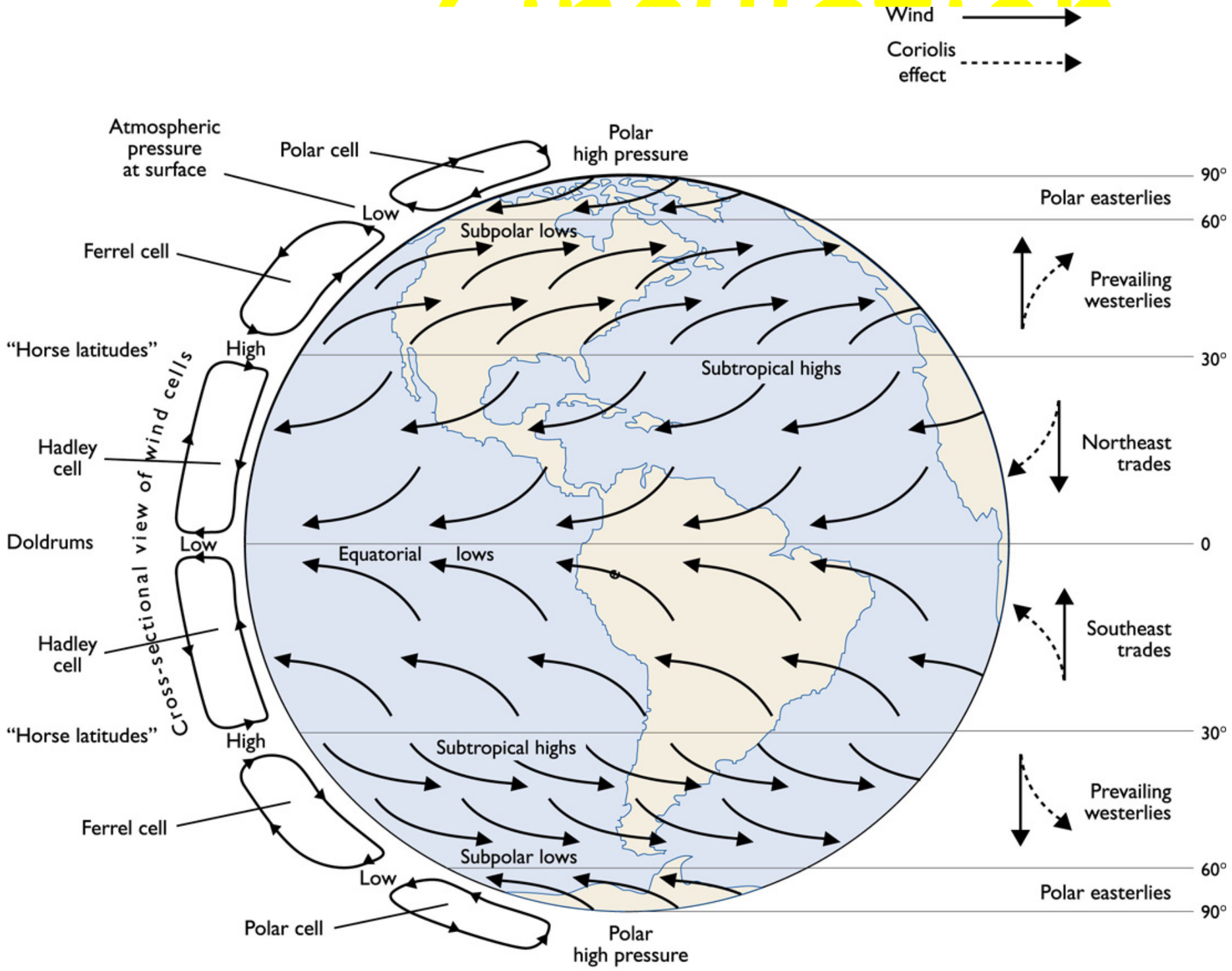
velocity

Consequences of Coriolis

✦Moving fluids (atmosphere and ocean) turn to the right in the Northern Hemisphere

✦Moving fluids (atmosphere and ocean) turn to the left in the Southern Hemisphere

Global Wind Circulation



(a) GLOBAL WIND PATTERN

westerlies

trades

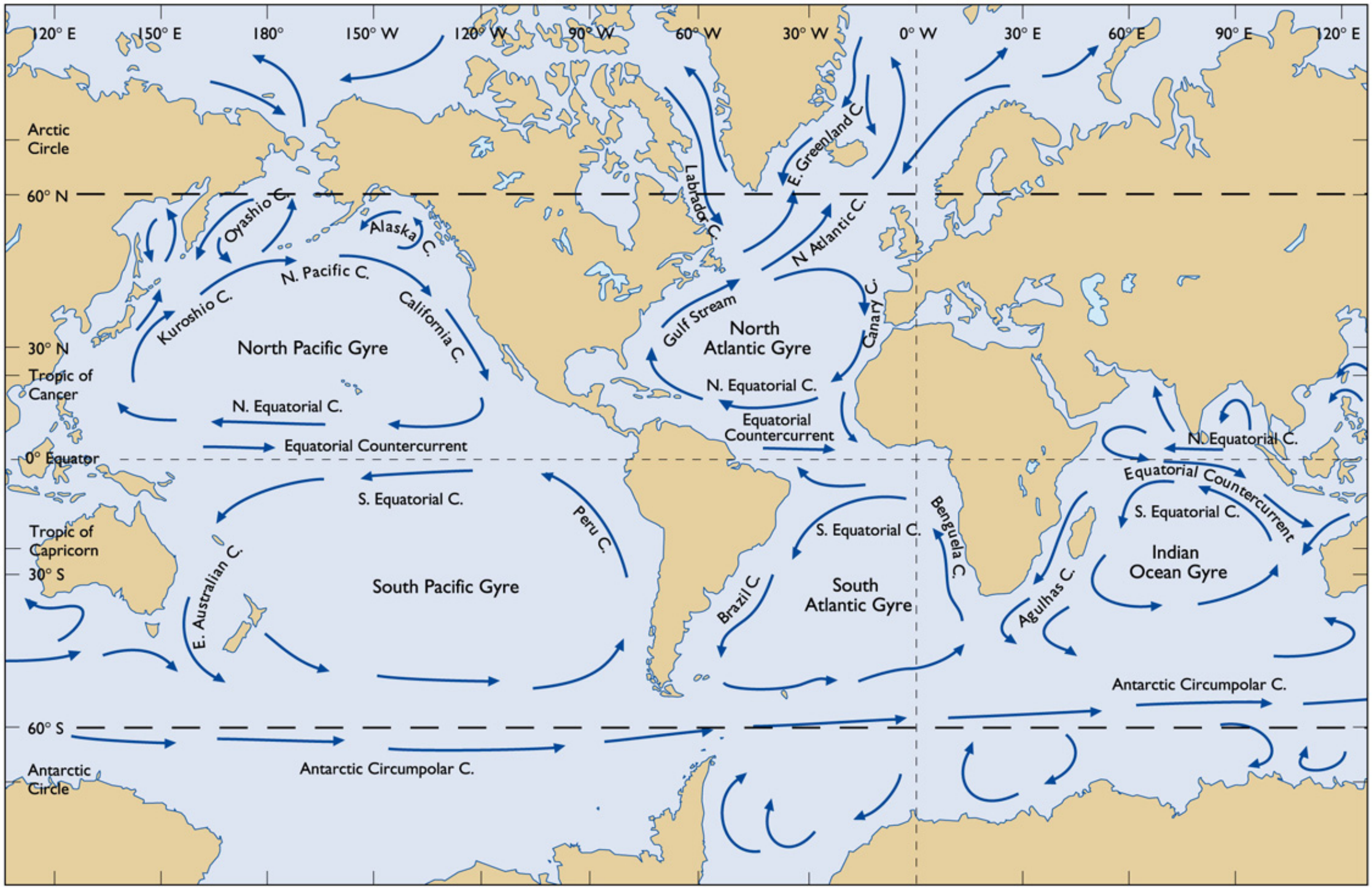
trades

westerlies

Wind-Driven Ocean Circulation

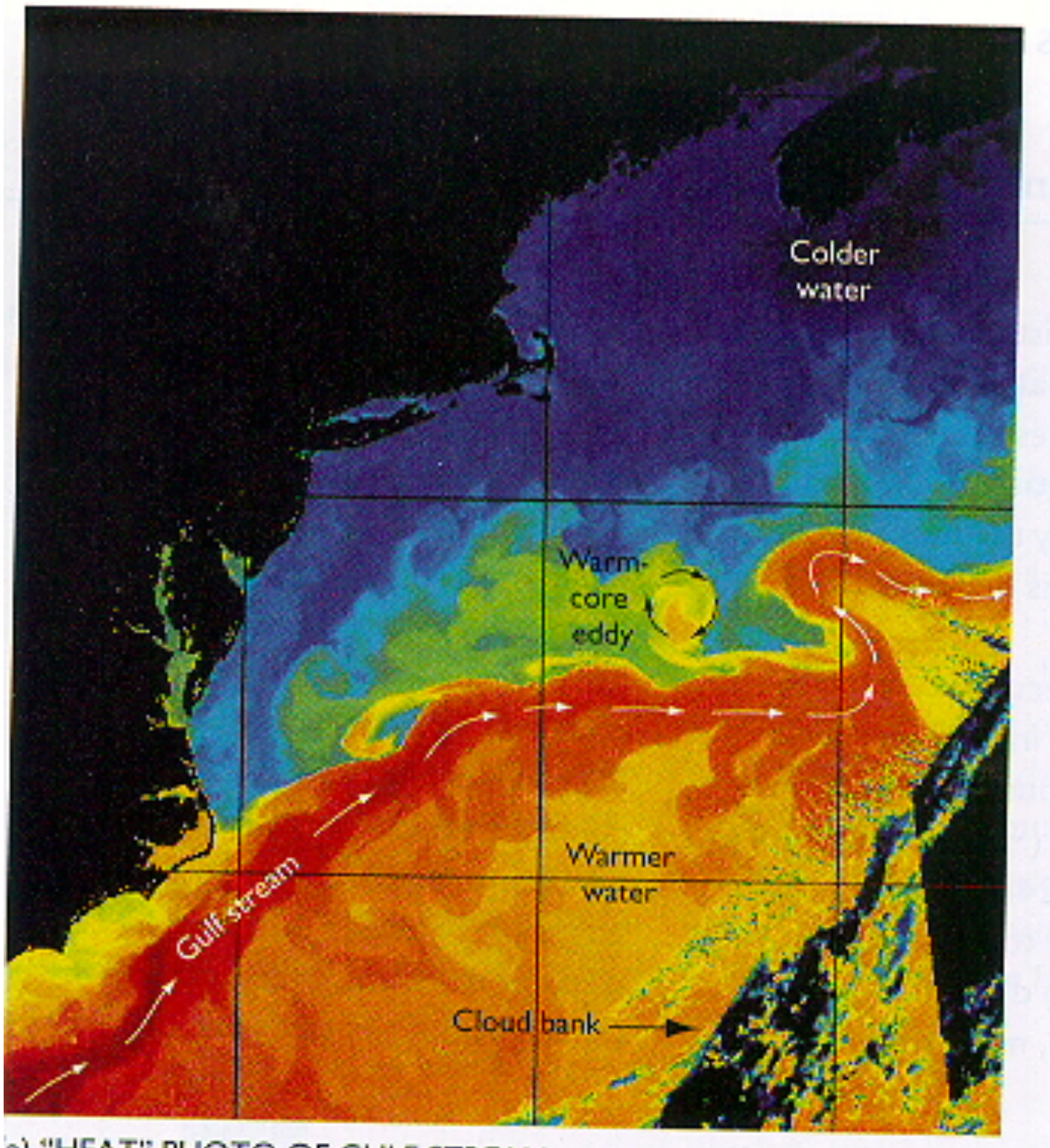
- Steady winds produce waves and set the surface water in motion
- Moving water is deflected to the right (N.Hemisphere) or left (S.Hemisphere)
- This starts the main “gyre” motion of the surface ocean

Surface Ocean Circulation



(b) GLOBAL SURFACE-WATER CURRENT PATTERN

Gulf Stream from satellite

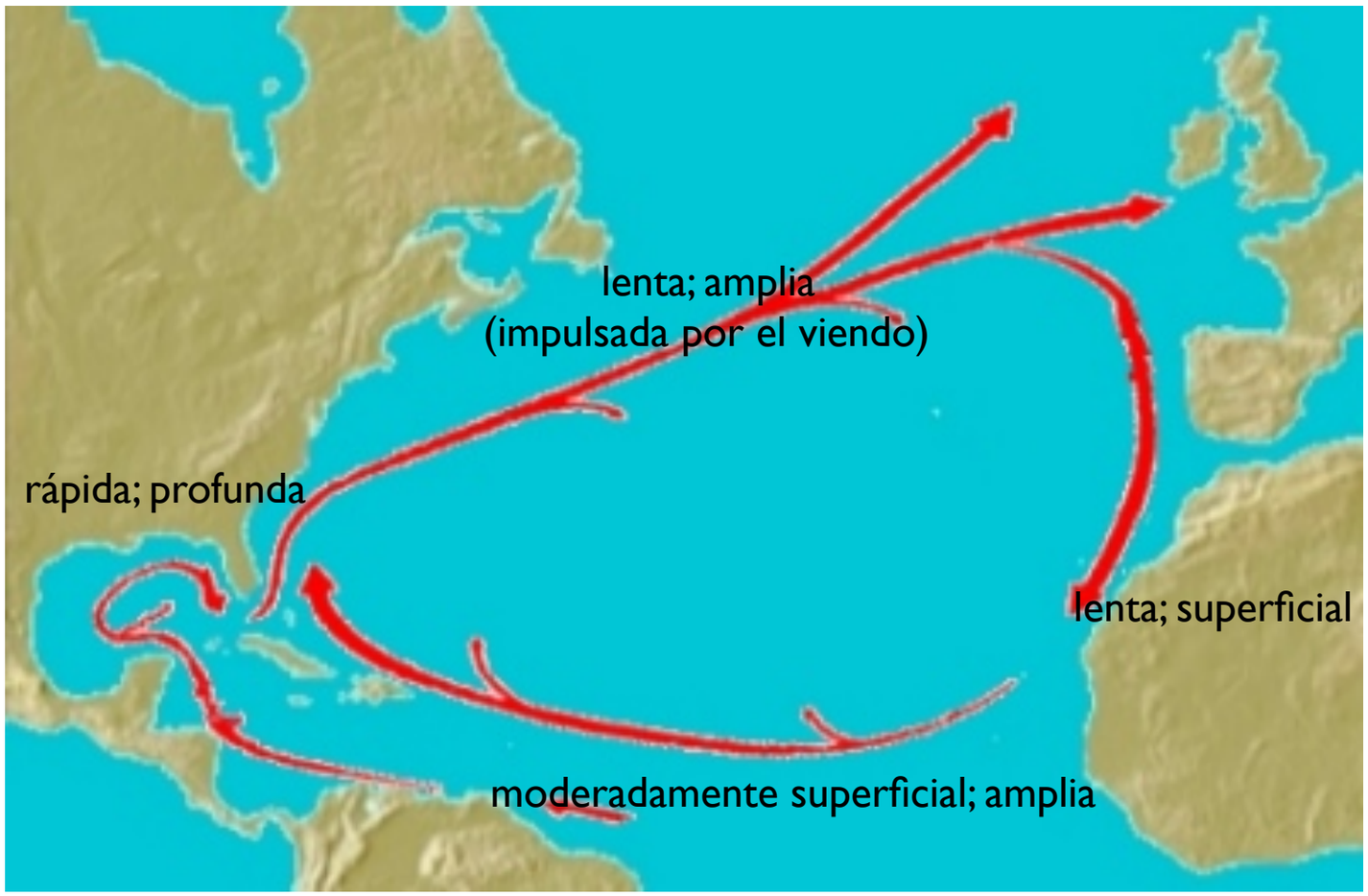


a) "HEAT" PHOTO OF GULF STREAM

Giros

Corrientes en balance geostrófico

4 componentes: dos corrientes de frontera (este y oeste), dos corrientes transversas (hacia el este y hacia el oeste).



1. Viento

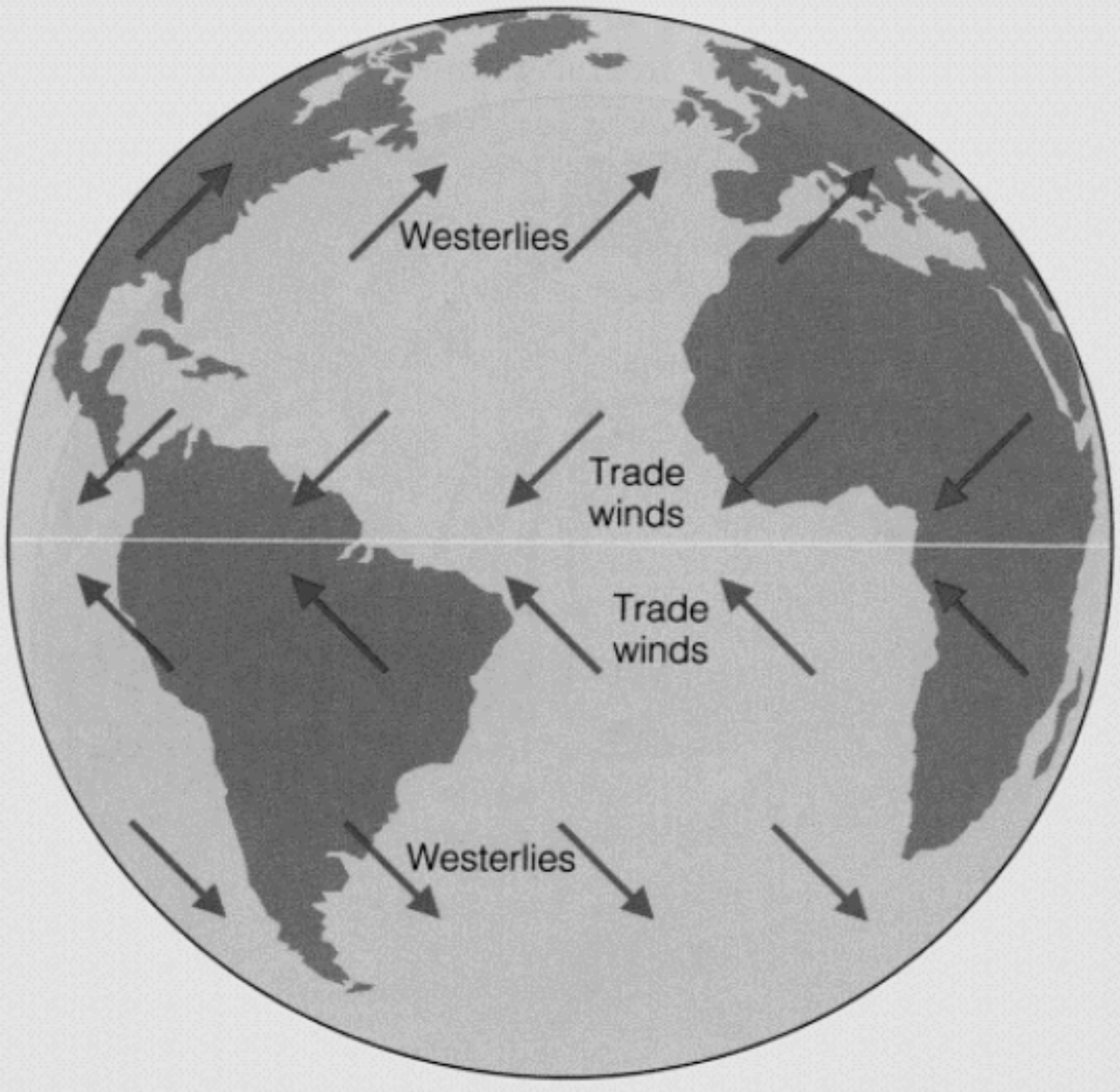


Figure 9.1 Winds, driven by uneven solar heating and Earth's spin, drive the movement of the ocean's surface currents. The prime movers are the powerful westerlies and the persistent trade winds (easterlies).

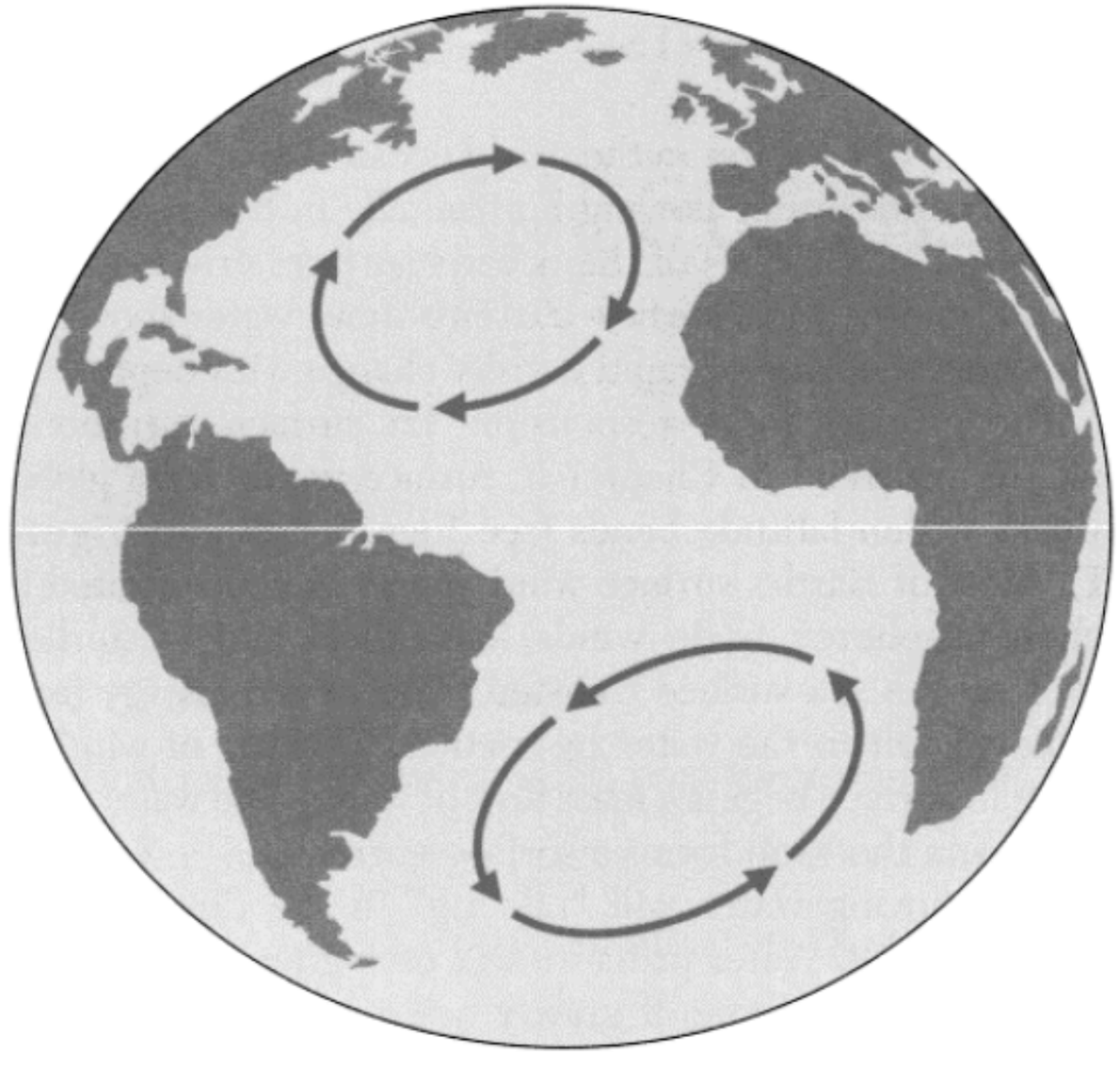


Figure 9.2 A combination of four forces—surface winds, the sun's heat, the Coriolis effect, and gravity—circulates the ocean surface clockwise in the Northern Hemisphere and counterclockwise in the Southern Hemisphere, forming gyres.

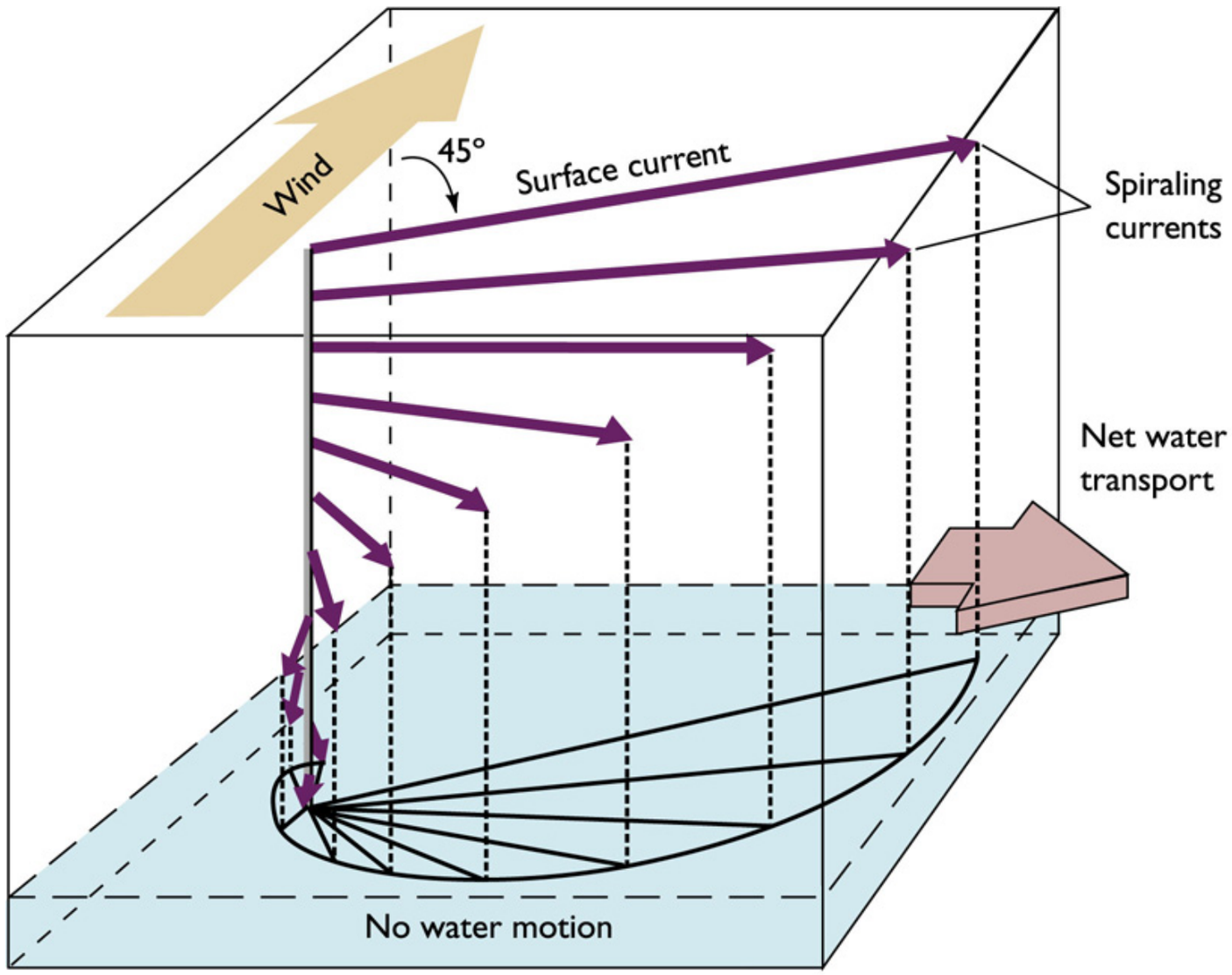
So, do the gyres just follow the winds?

✨Not exactly! But the winds get the motion in the ocean started

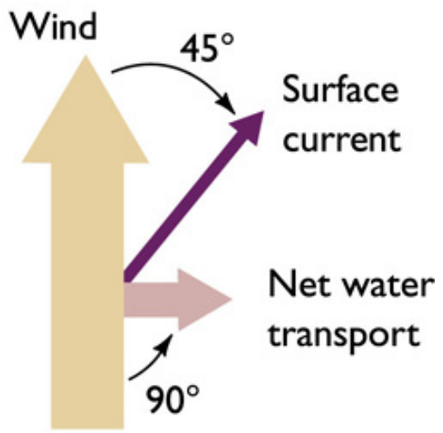
✨The oceans respond by flowing and turning

✨Water piles up in the center of gyres -- several meters high

Ekman Transport -- moves water 90°to the winds



(a) EKMAN SPIRAL IN THE NORTHERN HEMISPHERE

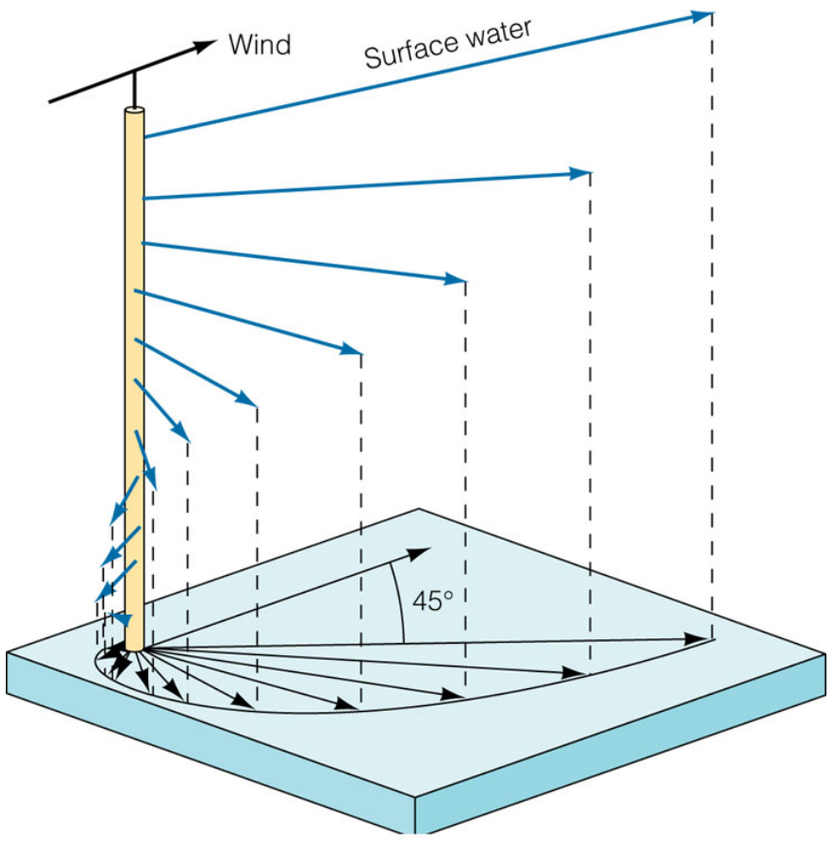


(b) MAP VIEW

Ekman (1905)

2. Coriolis + fricción

© 2005 Brooks/Cole - Thomson



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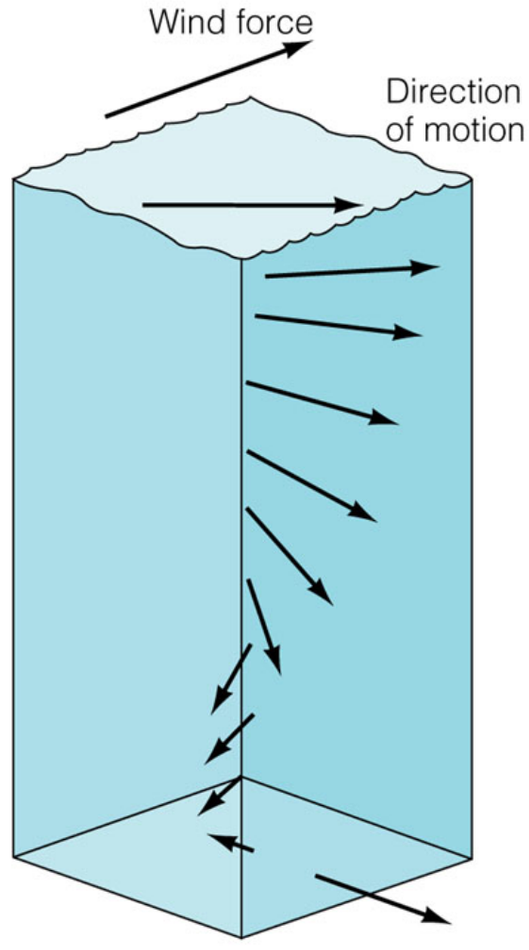

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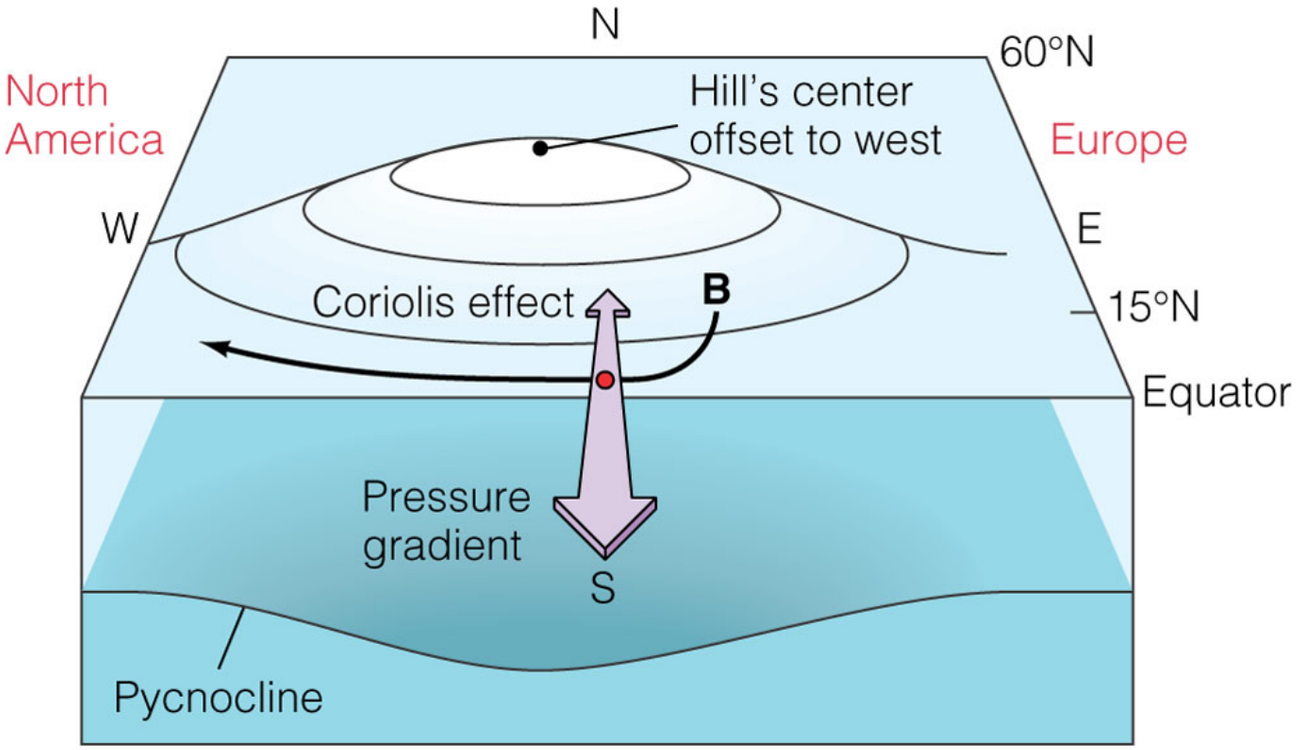
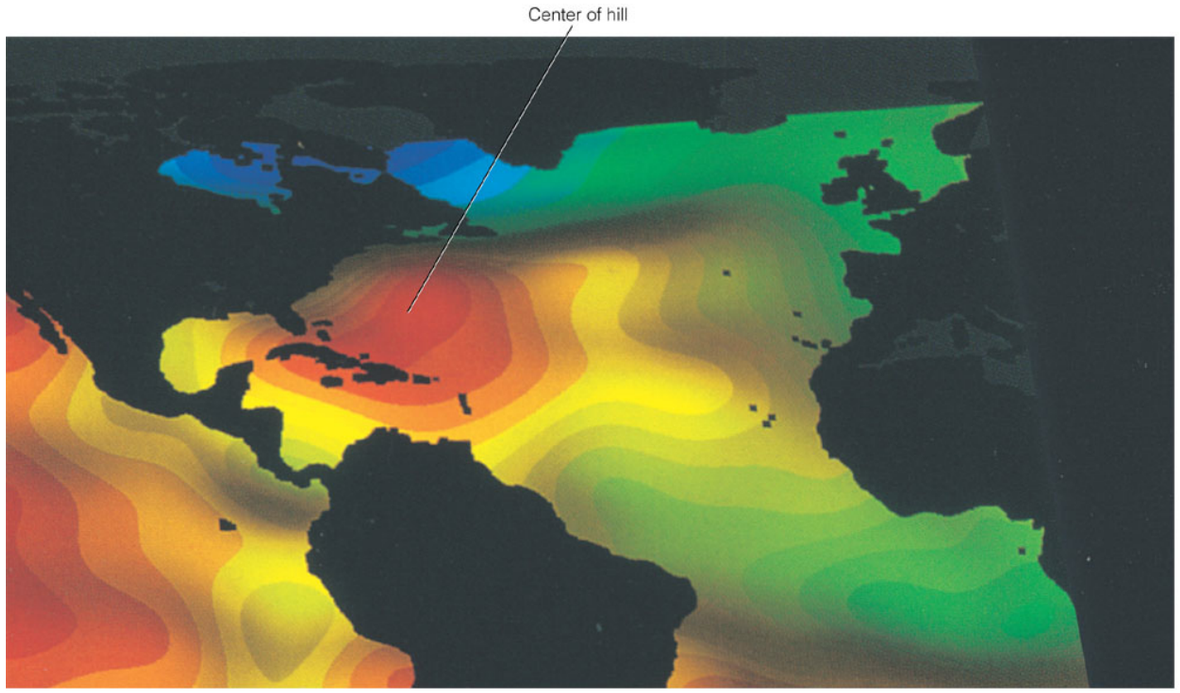
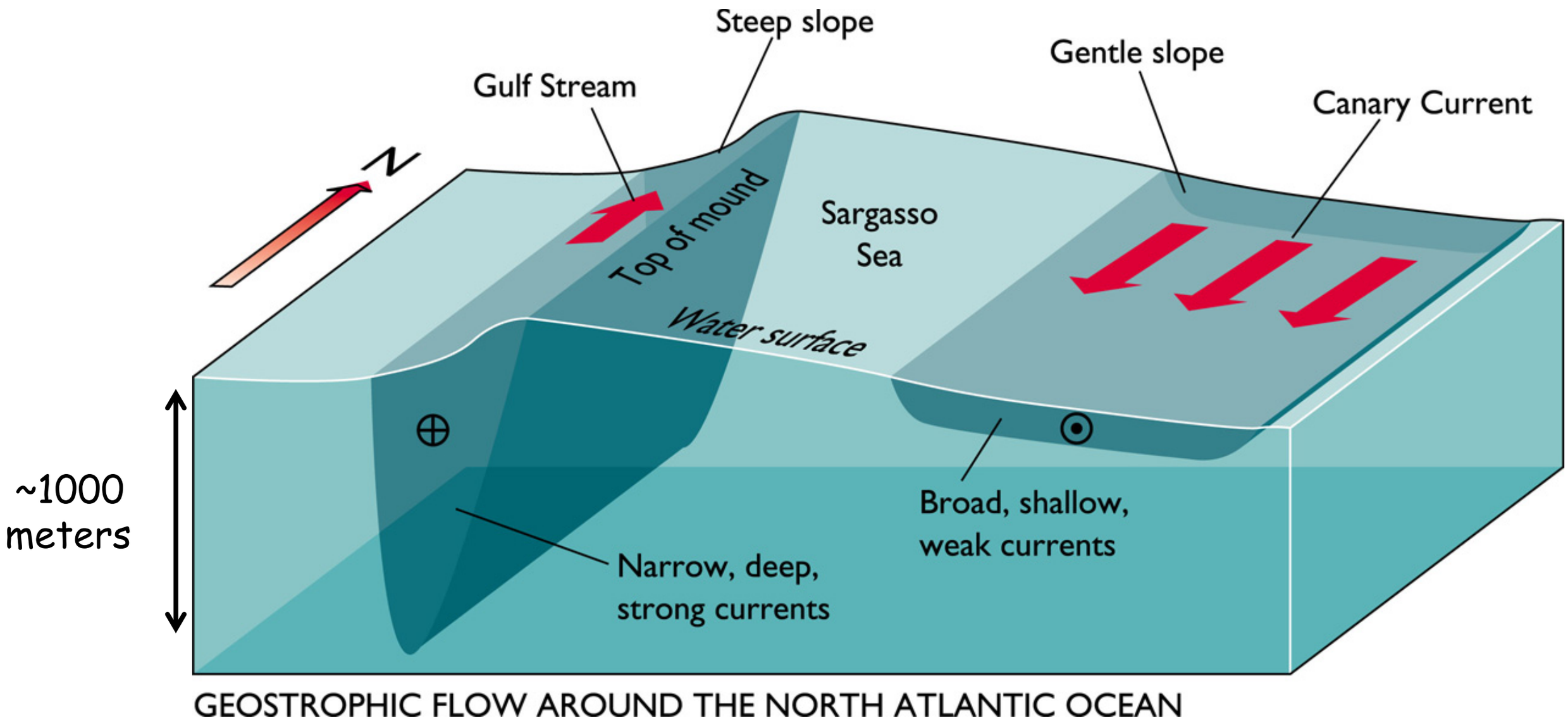
Transporte de Ekman



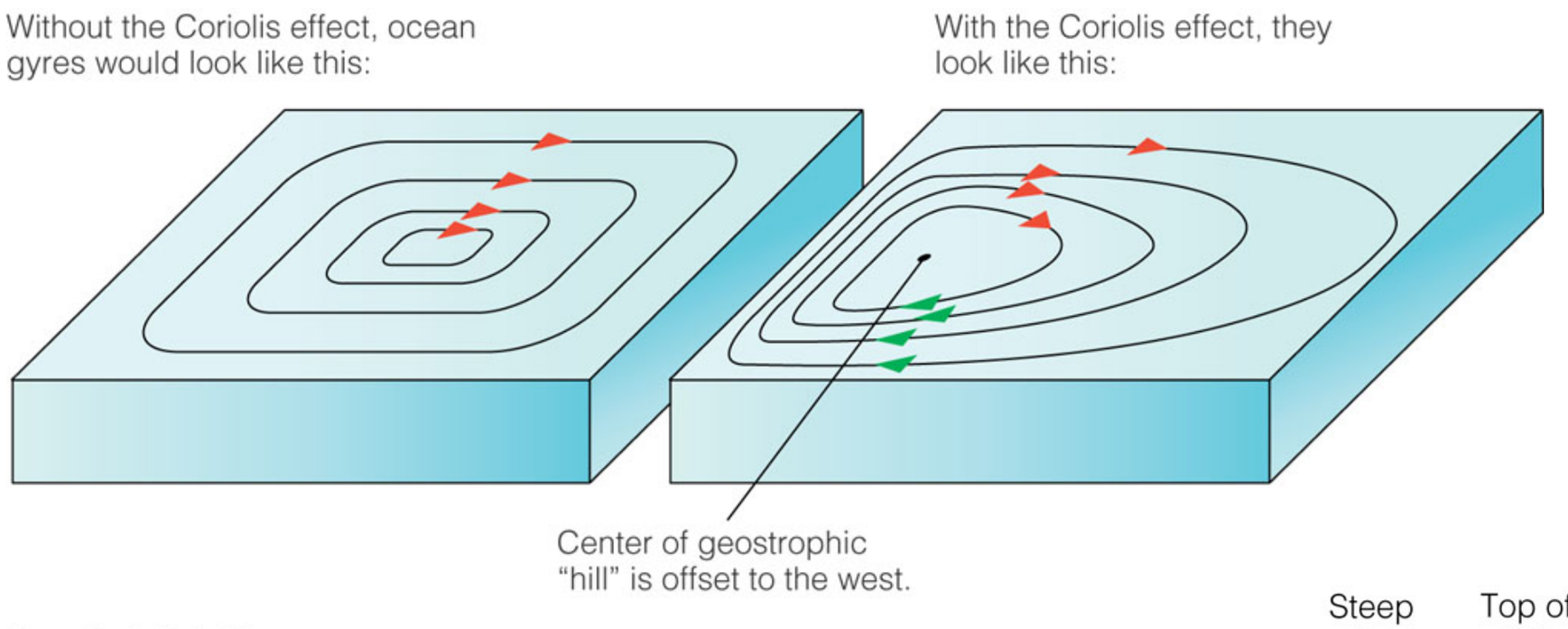


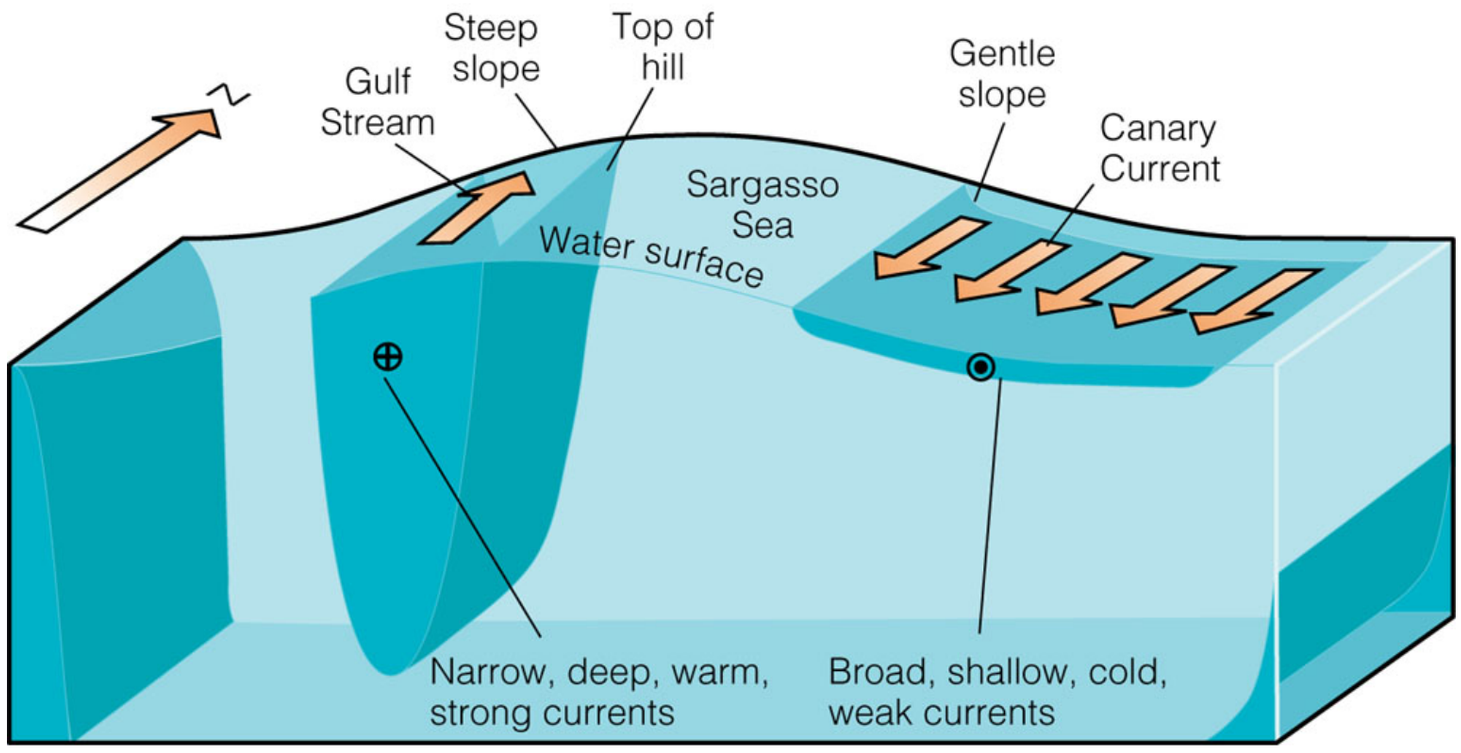
Northern Hemisphere Gyres
westward intensification



GEOSTROPHIC FLOW AROUND THE NORTH ATLANTIC OCEAN

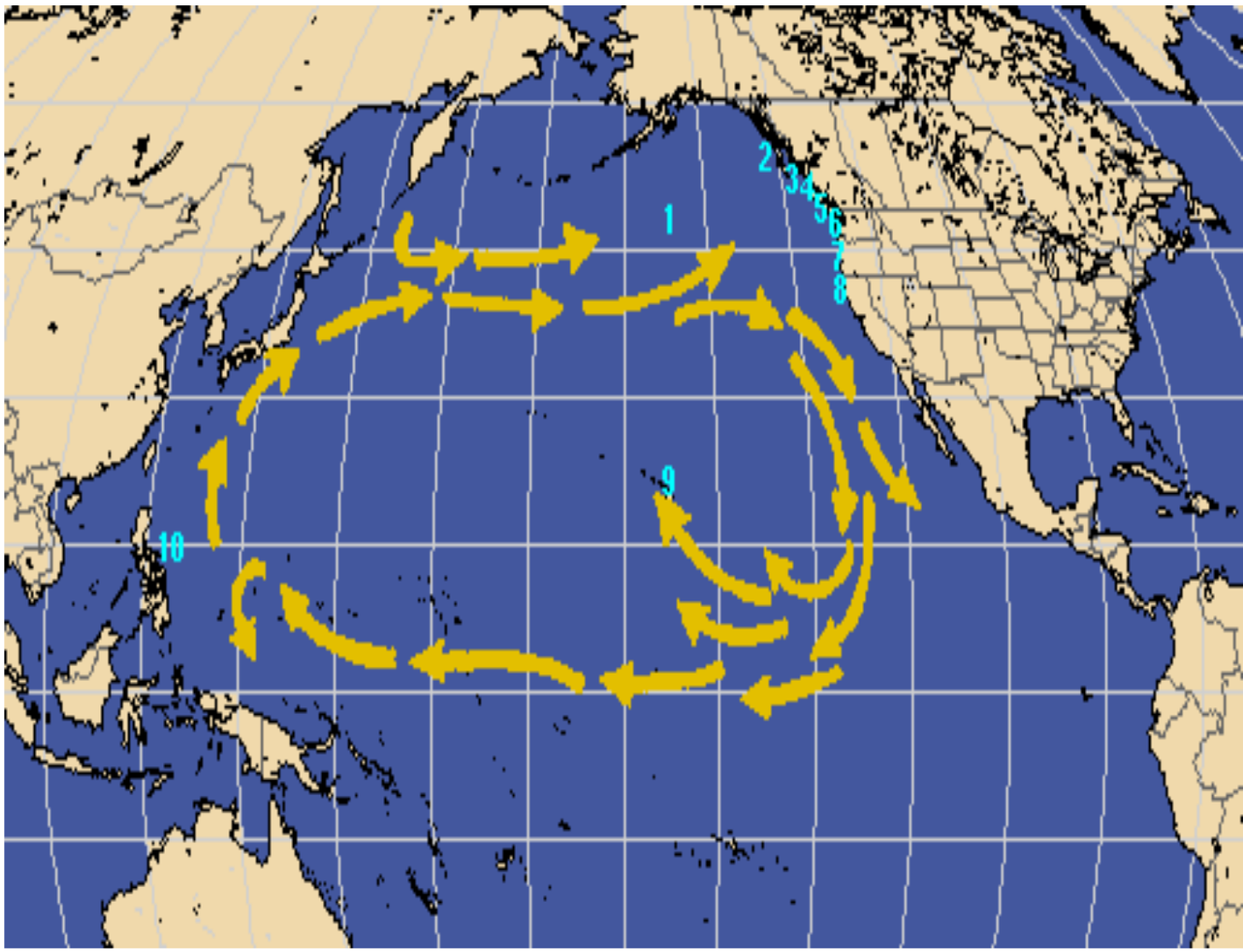
Giro del atlantico norte





Tracking Currents:
The Story of the Lost Nikes

- 1: 60,000 shoes spilled, May 1990
- 2-8: 1990-’91
- 9: 1993
- 10: 1994



Circulación superficial

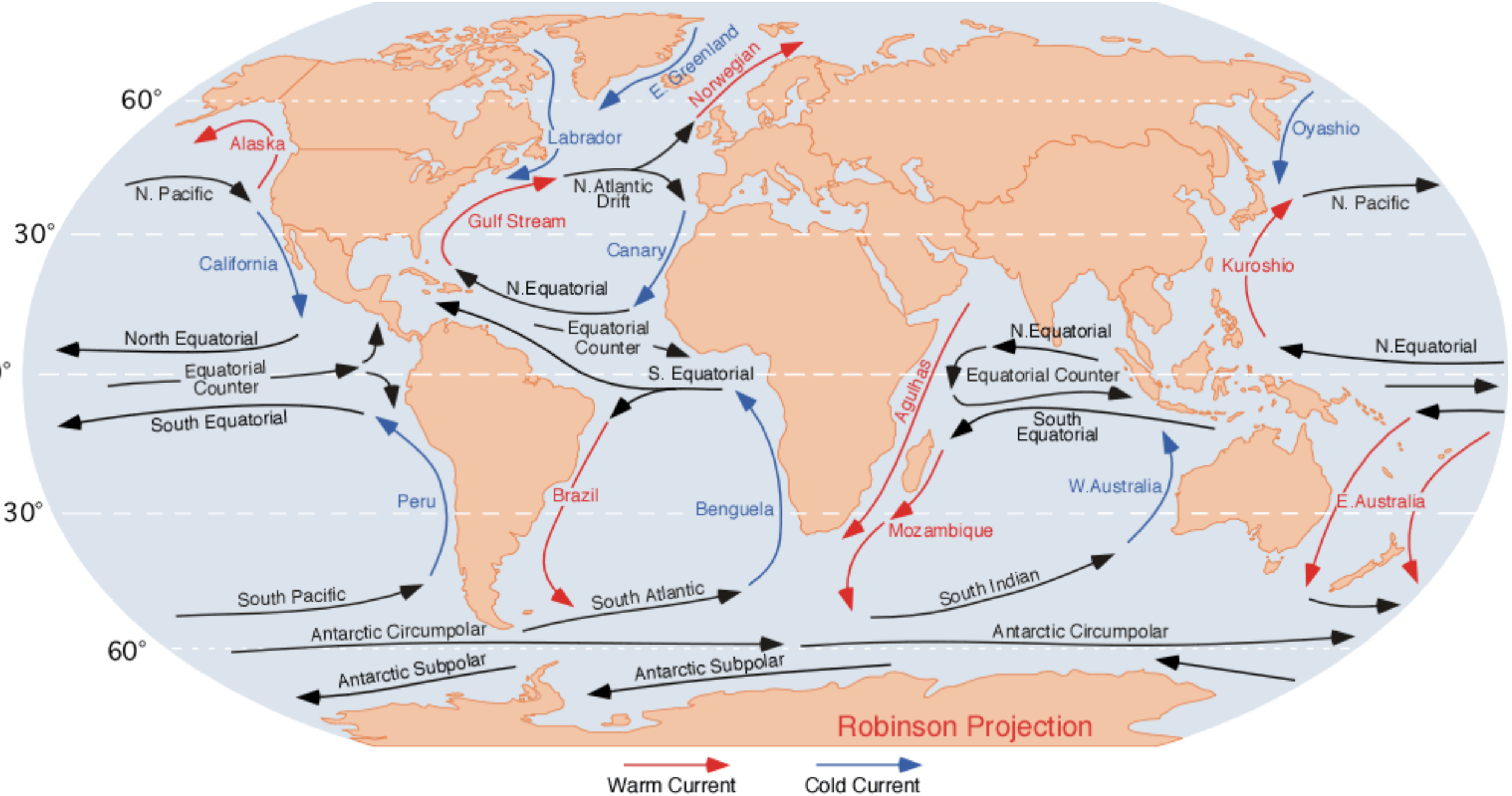
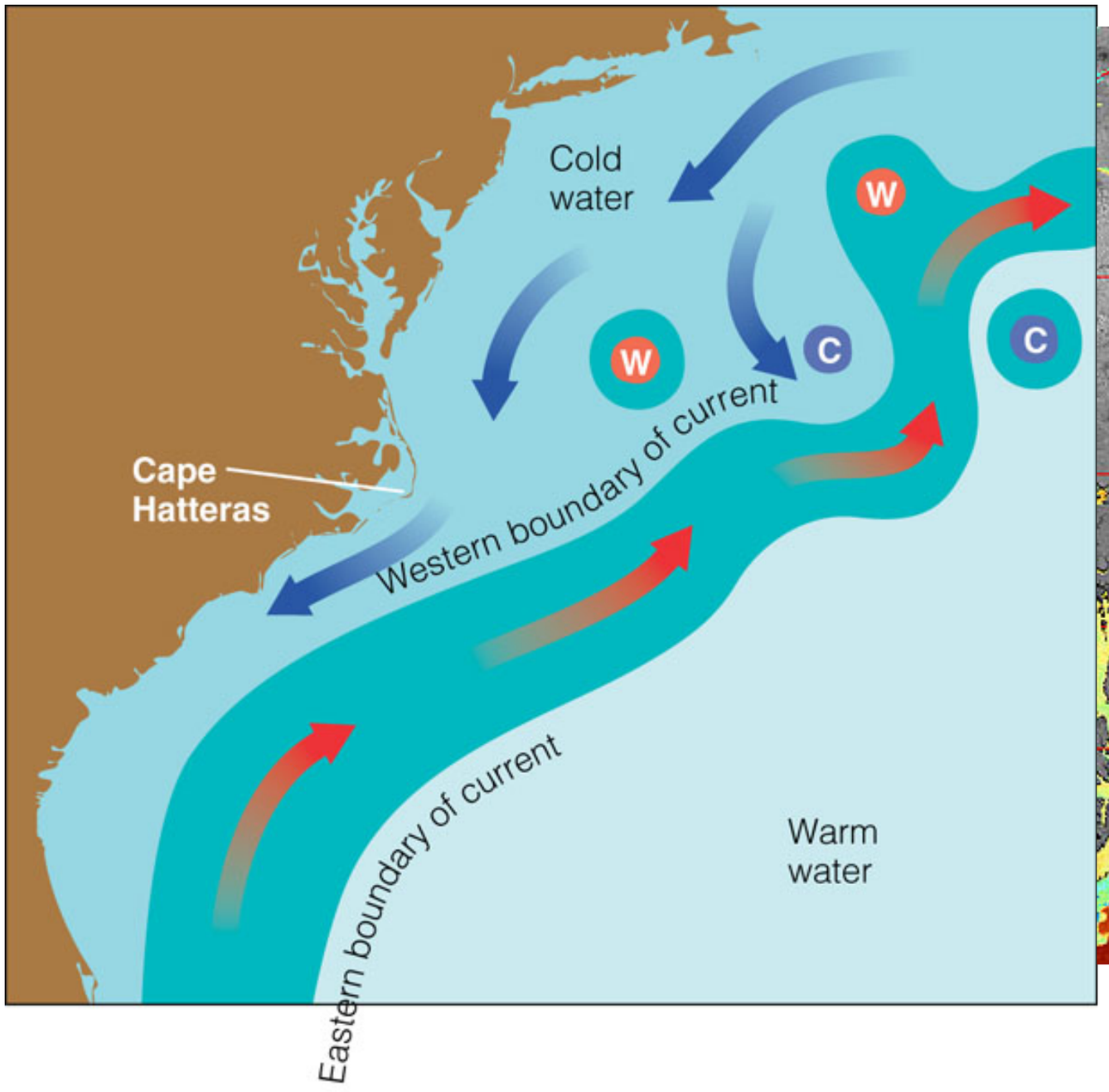
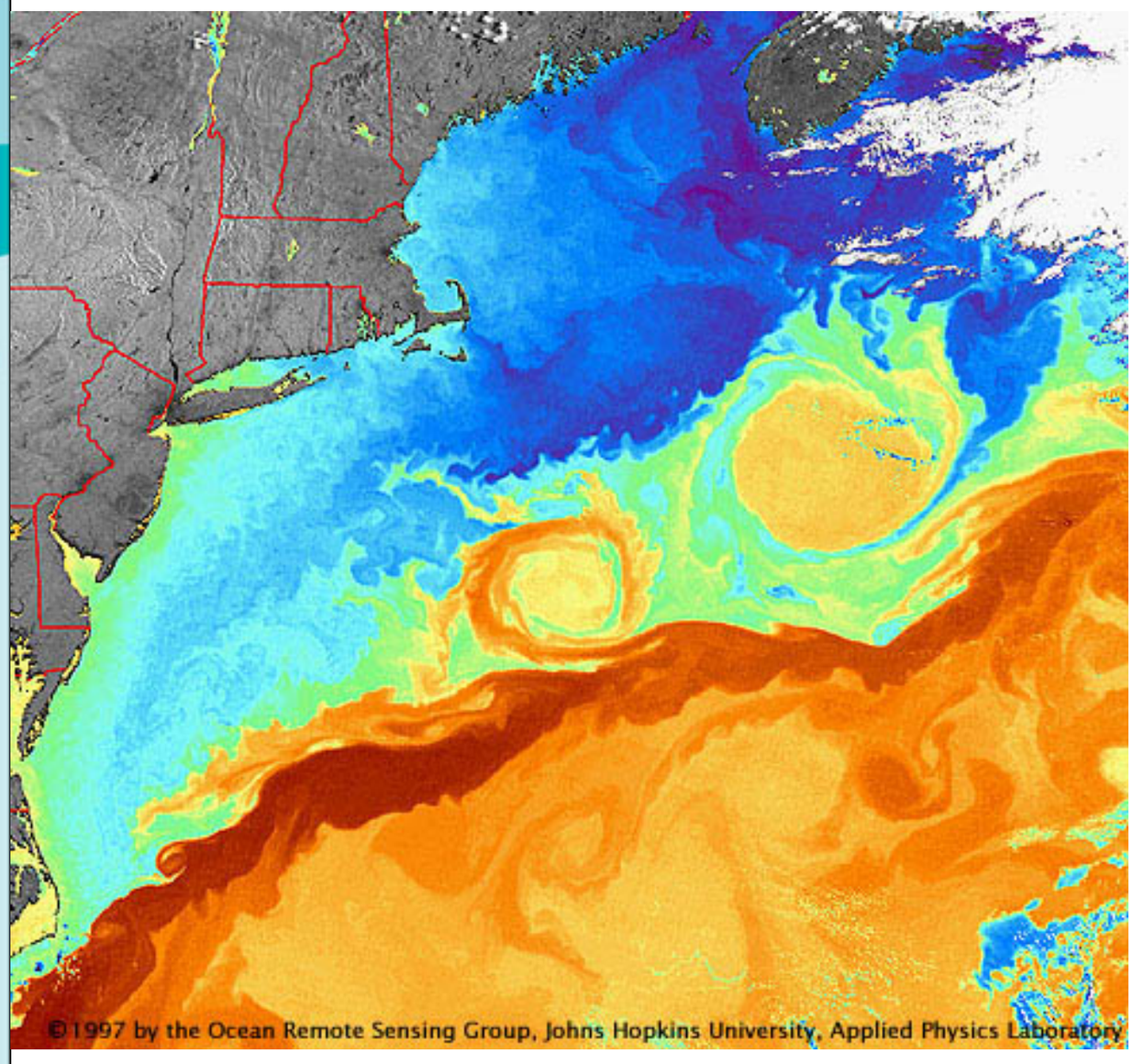


Figure 8q-1: Major ocean currents of the world. On this illustration **red** arrows indicate warm currents, while cold currents are displayed in **blue**. (http://www.physicalgeography.net/fundamentals/8q_1.html)

Giro del atlantico norte





Rapidez: 2 m/s
Profundidad: 450 m
Ancho= 70 km

Sea Surface Temperature (˚C)
-1 5 11 17 23

Corriente del golfo

NASA images courtesy Norman Kuring, MODIS Ocean Team.
http://earthobservatory.nasa.gov/IOTD/view.php?id=5432

Deep Ocean Circulation

How does the Deep Ocean respond to Surface Circulation?

- The main gyres move heat and salt
- Resulting DENSITY variations lead to vertical flow (sinking)
- Formation of “water masses”, characterized by Temperature + Salinity = Density

Density-Driven Water Flow

- Called "Thermohaline Circulation", because <u>temperature</u> and <u>salinity</u> together determine density of seawater
  "Thermo" = temperature
  "haline" = salt

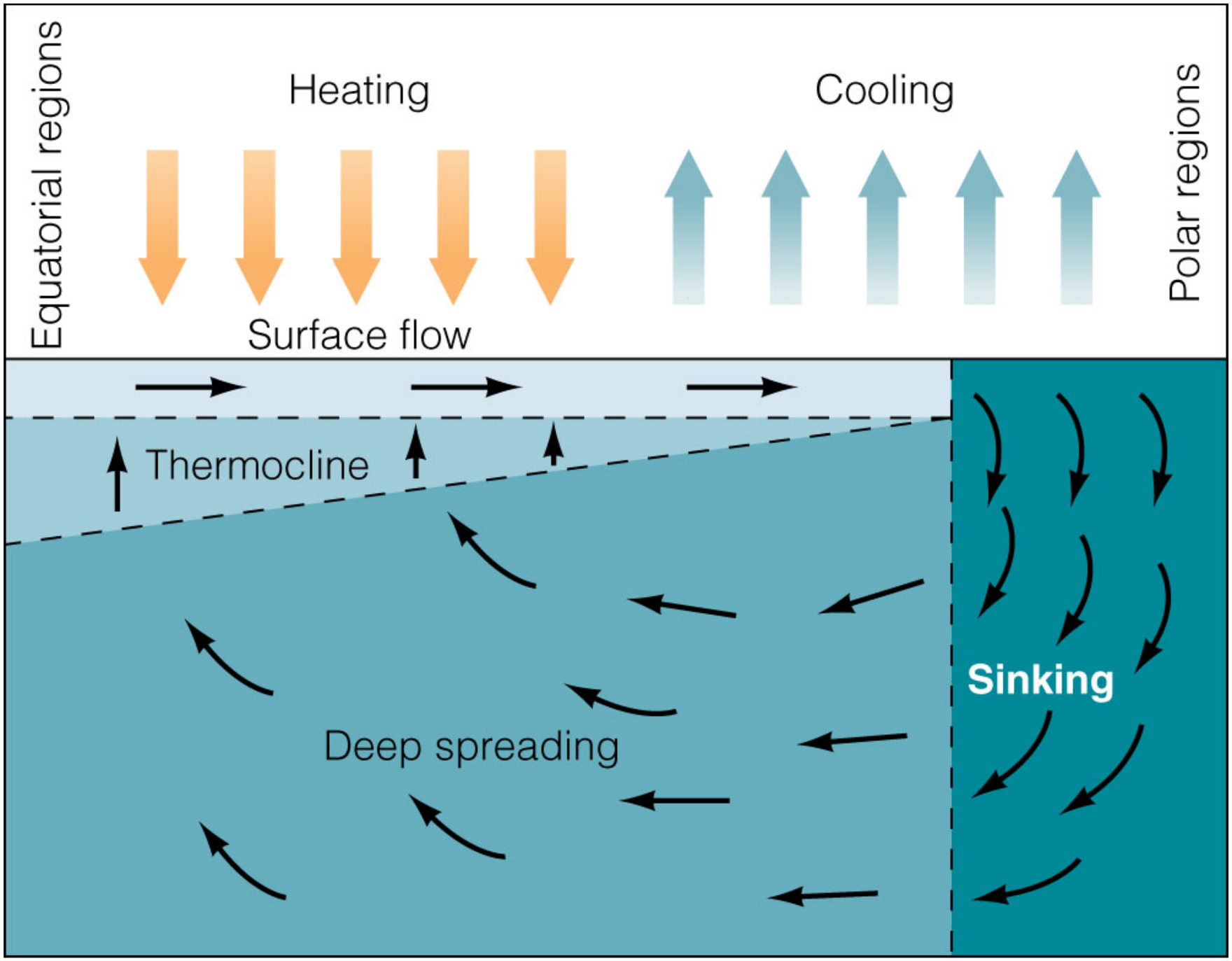
Where does the Ocean's Deepest Water Come From?

✨The densest seawater is <u>cold</u> and <u>salty</u>

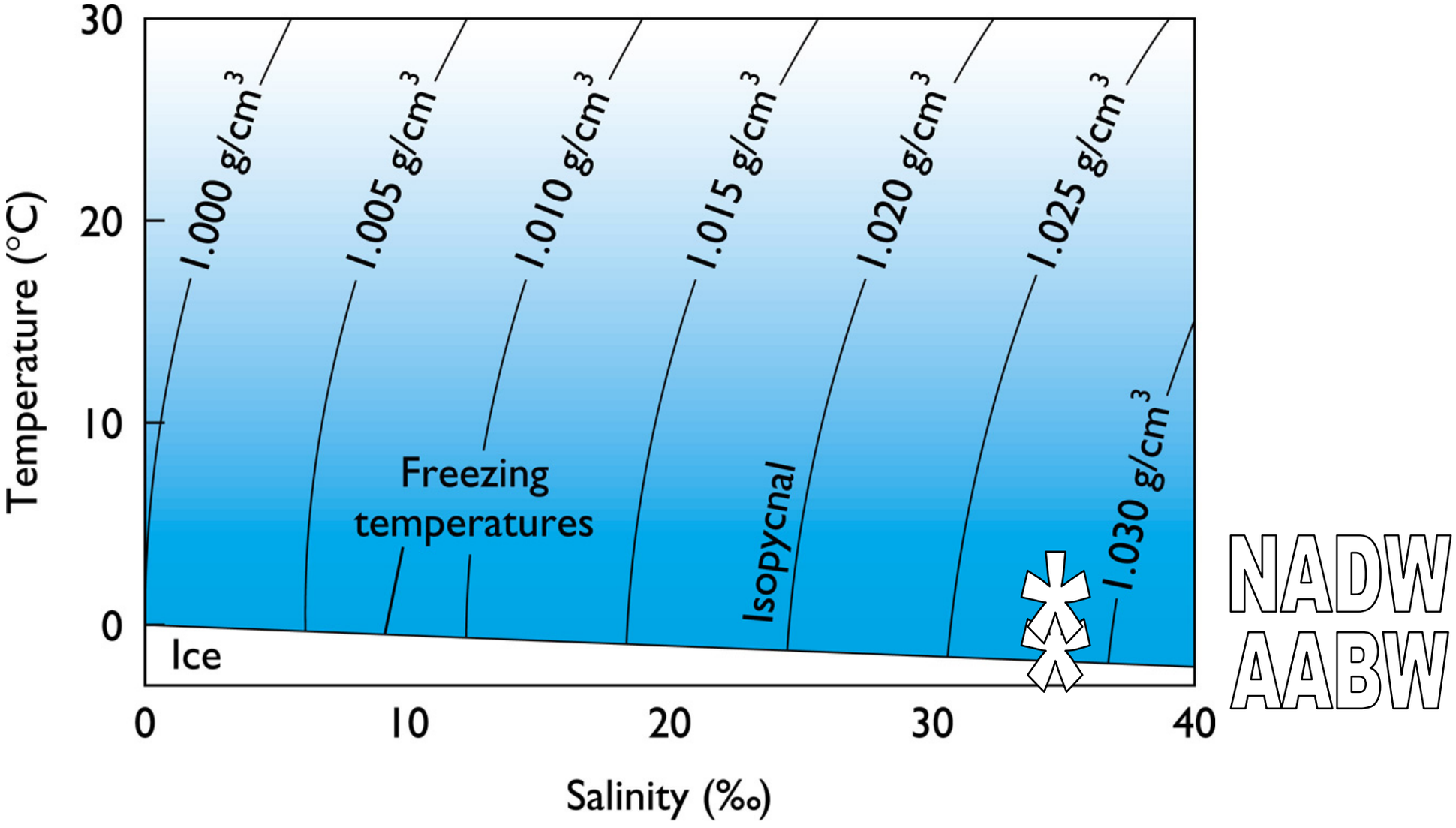
✨This is formed at high latitudes in the North and South Atlantic:

North Atlantic Deep Water (NADW)
Antarctic Bottom Water (AABW)

Corriente termohalina



Density of Sea Water

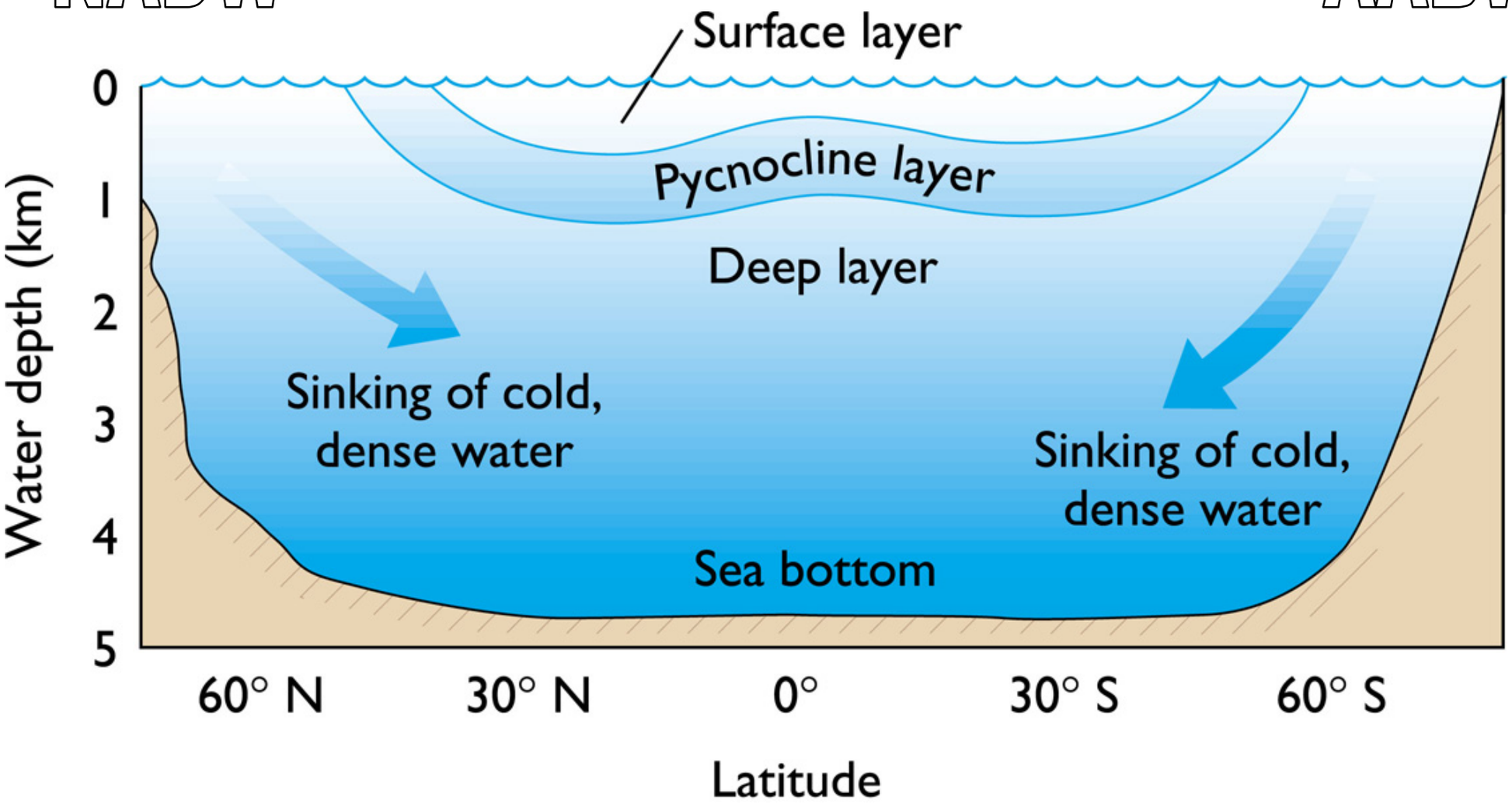


(a) SEAWATER DENSITY

Density Rules!

NADW

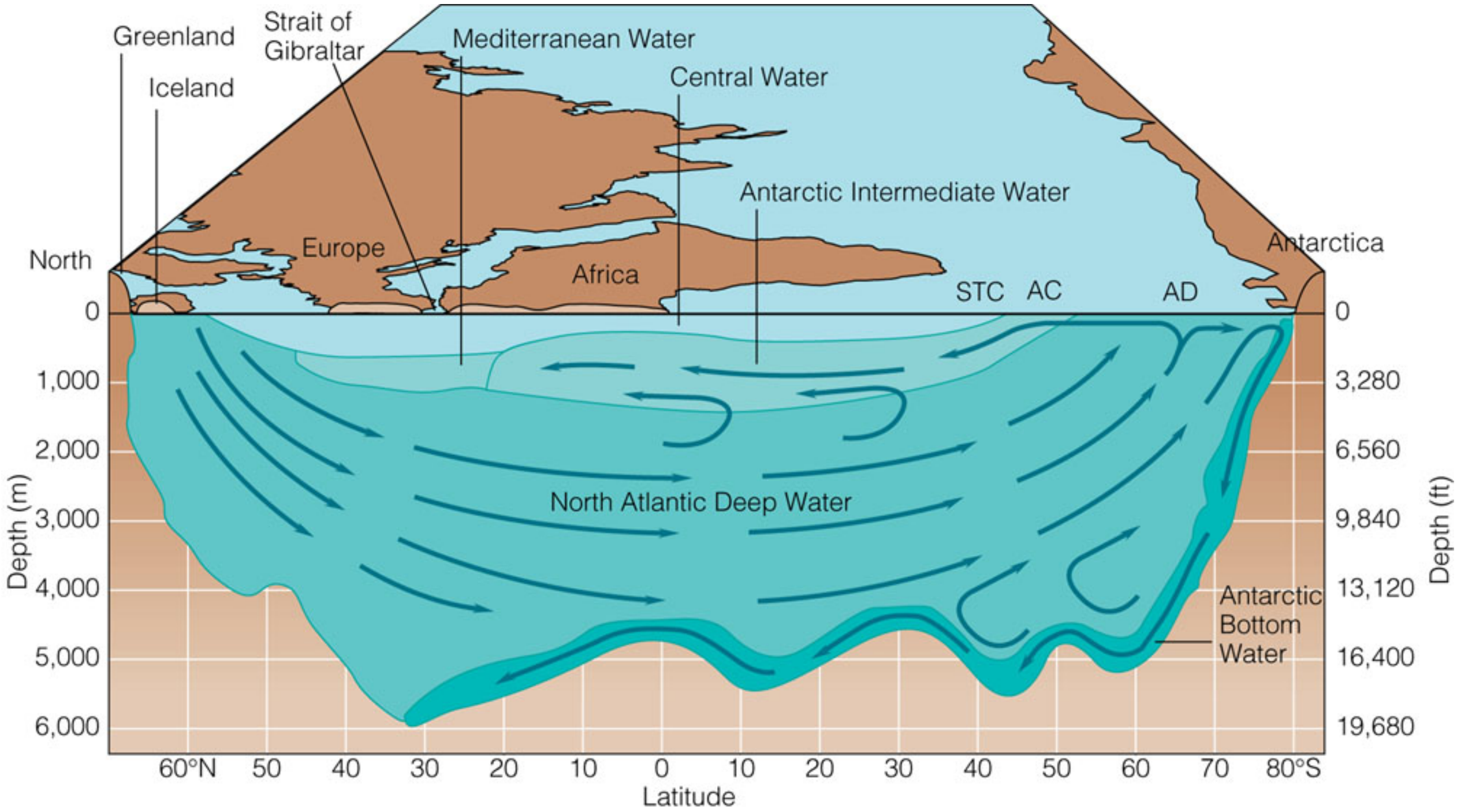
AABW



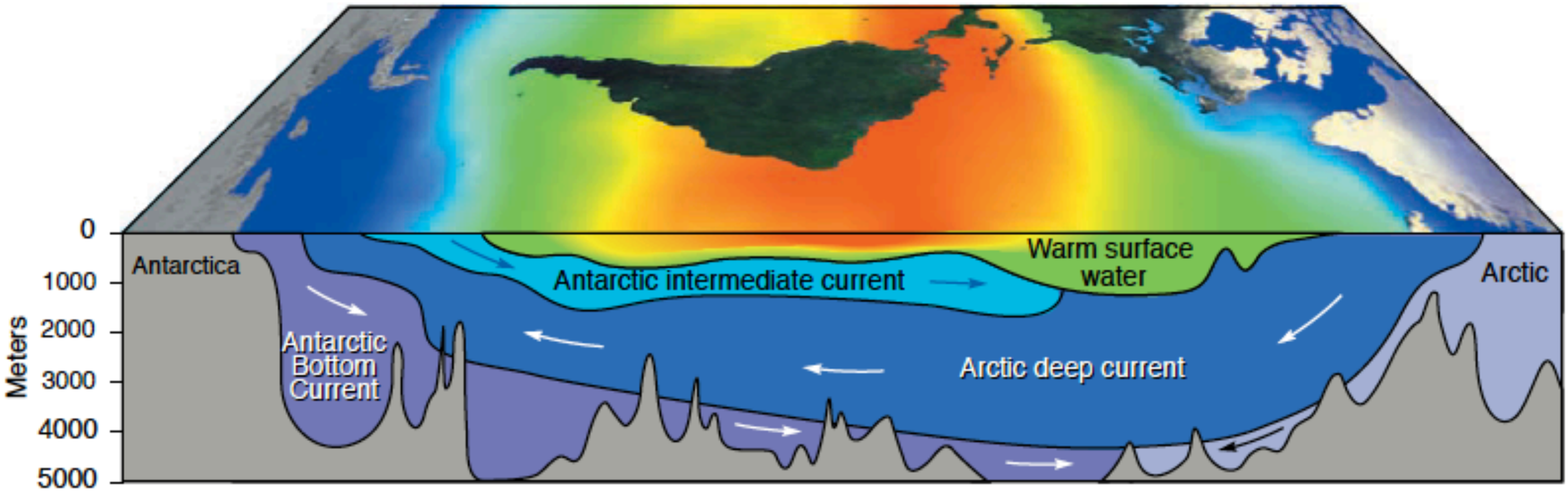
(c) DENSITY STRUCTURE OF THE OCEANS

Water Masses and ocean mixing determined by CTD (conductivity, temperature, depth) measurements

Corriente termohalina



Corriente termohalina



Ocean Circulation:
The Great Conveyor Belt

Surface water at high latitudes forms deep water

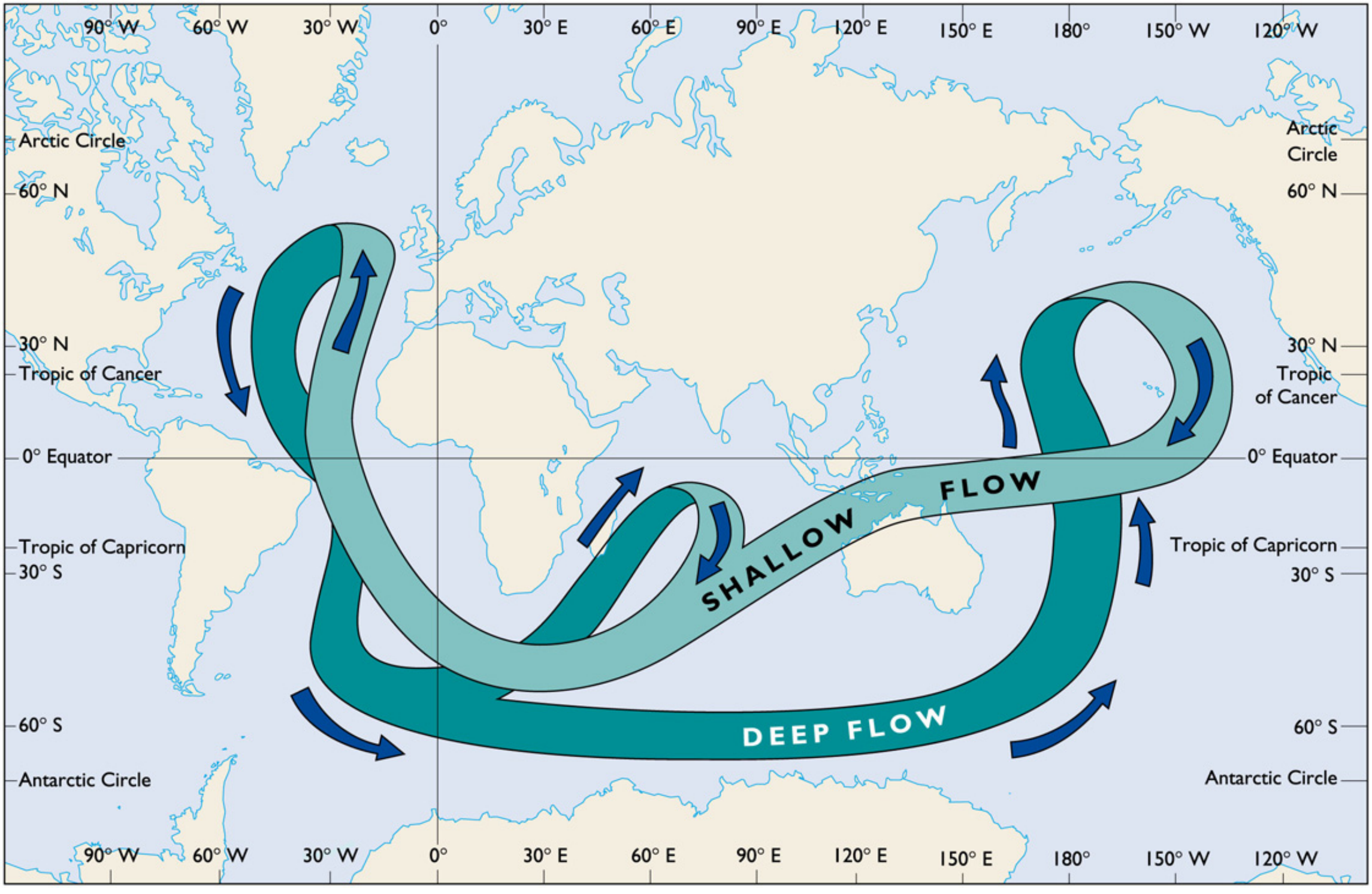
Deep water sinks and flows at depth throughout the major ocean basins

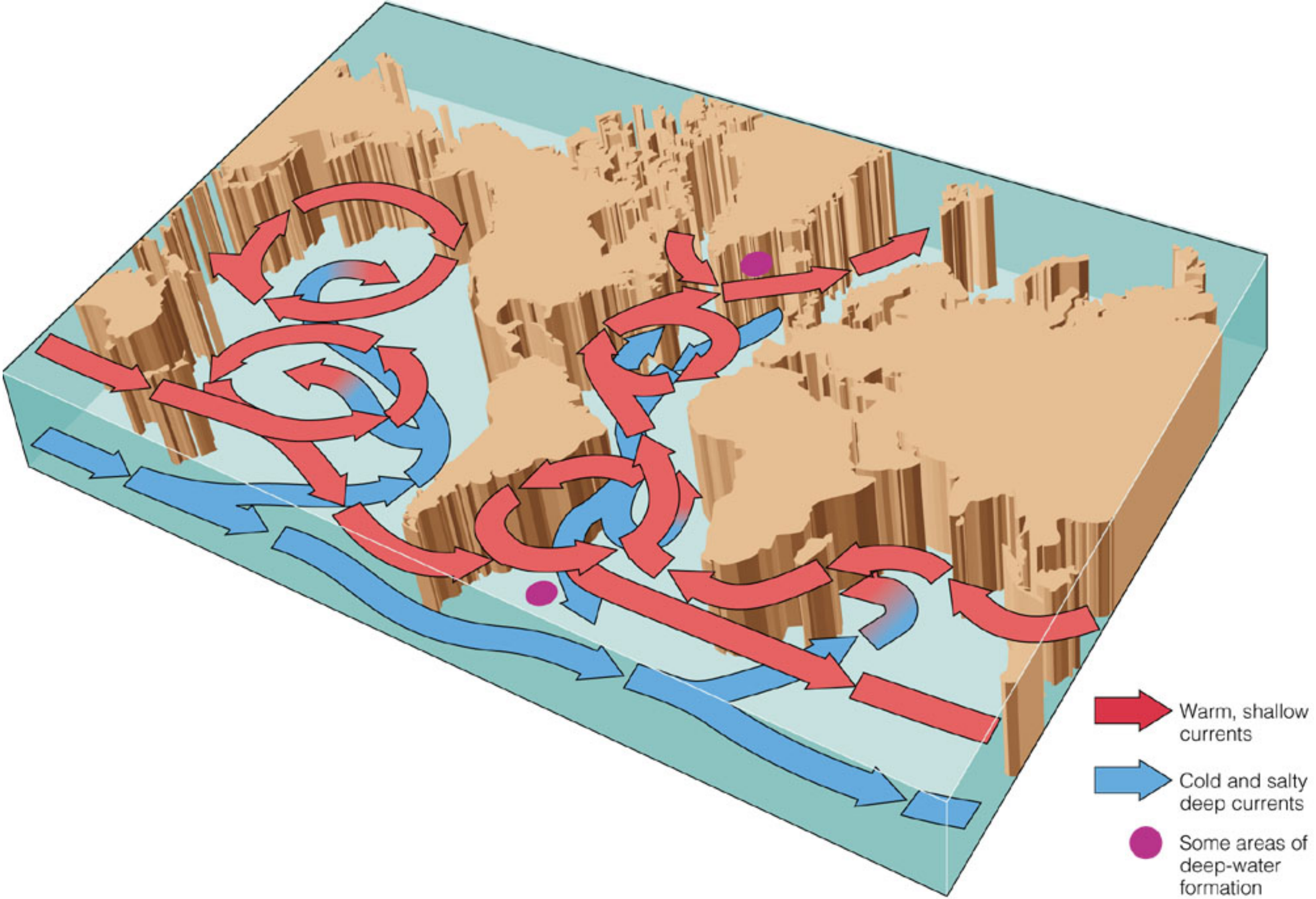
Deep water upwells to replace the surface water that sinks in polar regions

Surface waters must flow to high latitudes to replace water sinking in polar regions

This Idealized circulation is called the “Great (Thermohaline) Conveyer Belt”

The Great Conveyor Belt





Ocean Circulation and Climate

On long timescales, average ocean temperature affects climate

Most water is in deep ocean

Average temperature of ocean is a function of

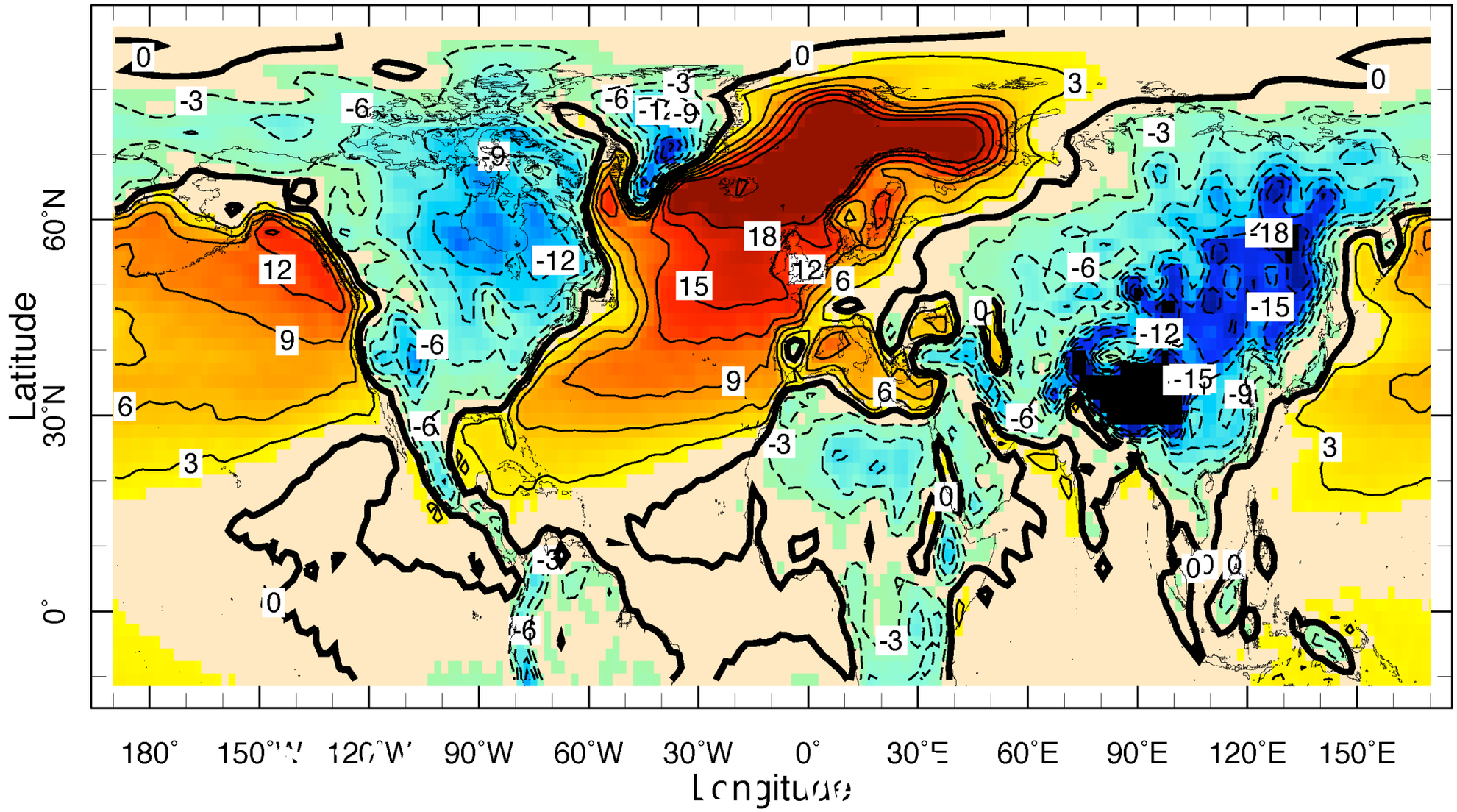
process of bottom-water formation

transport of water around ocean basins

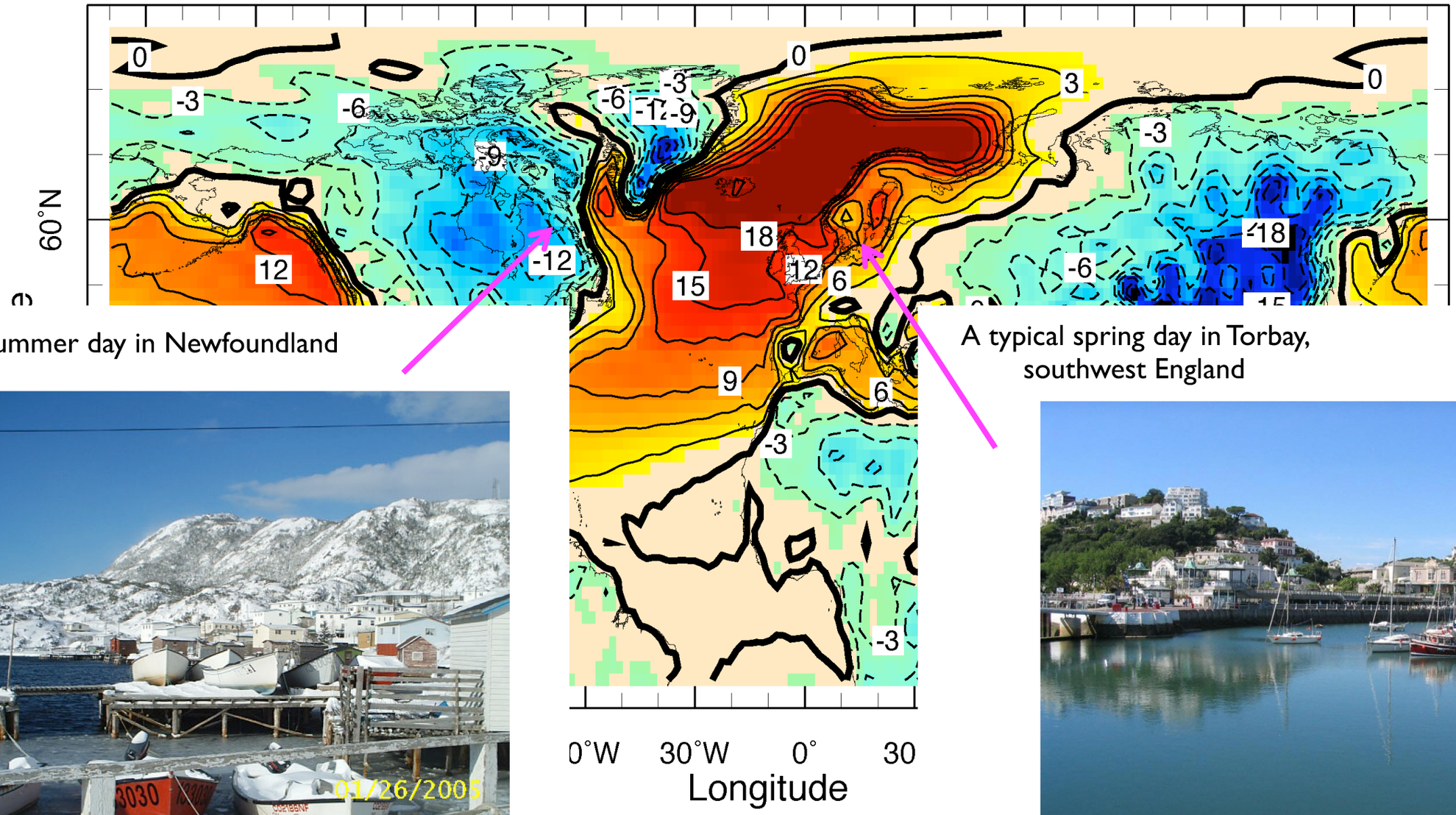
Deep water recycle times is ~1000 years

Thermohaline circulation moderates climate over time periods of ~ 1000 years

The oceans are responsible for warmer temperatures on west coasts of continents compared with east coasts



The oceans are responsible for warmer temperatures on west coasts of continents compared with east coasts



A typical summer day in Newfoundland

A typical spring day in Torbay, southwest England

Carbon Cycle and Global Warming

✦The temperature of bottom water formation determines how much CO_2 is dissolved in deep ocean water

✦The rate of overturn of the oceans determines the "burial rate" of *C* from the atmosphere

✦*Organic C* accumulates in sediments, depending on the O_2 content of deep ocean

Carbon Cycle and Global Warming

- Organic C in sediments is reduced to CH_4 (methane gas)
- Methane gas migrates upward and can be trapped as frozen "gas hydrates" near the ocean floor

Climate Change Concerns

✦What happens when sea level falls?
(negative feed-back – polar ice forming)

✦What happens when deep water warms?
(positive feed-back – less CO_2 in water)

✦Both effects liberate gas hydrates (CH_4), which combines with O_2 to form CO_2, ultimately reaching the atmosphere

Deep Ocean Circulation

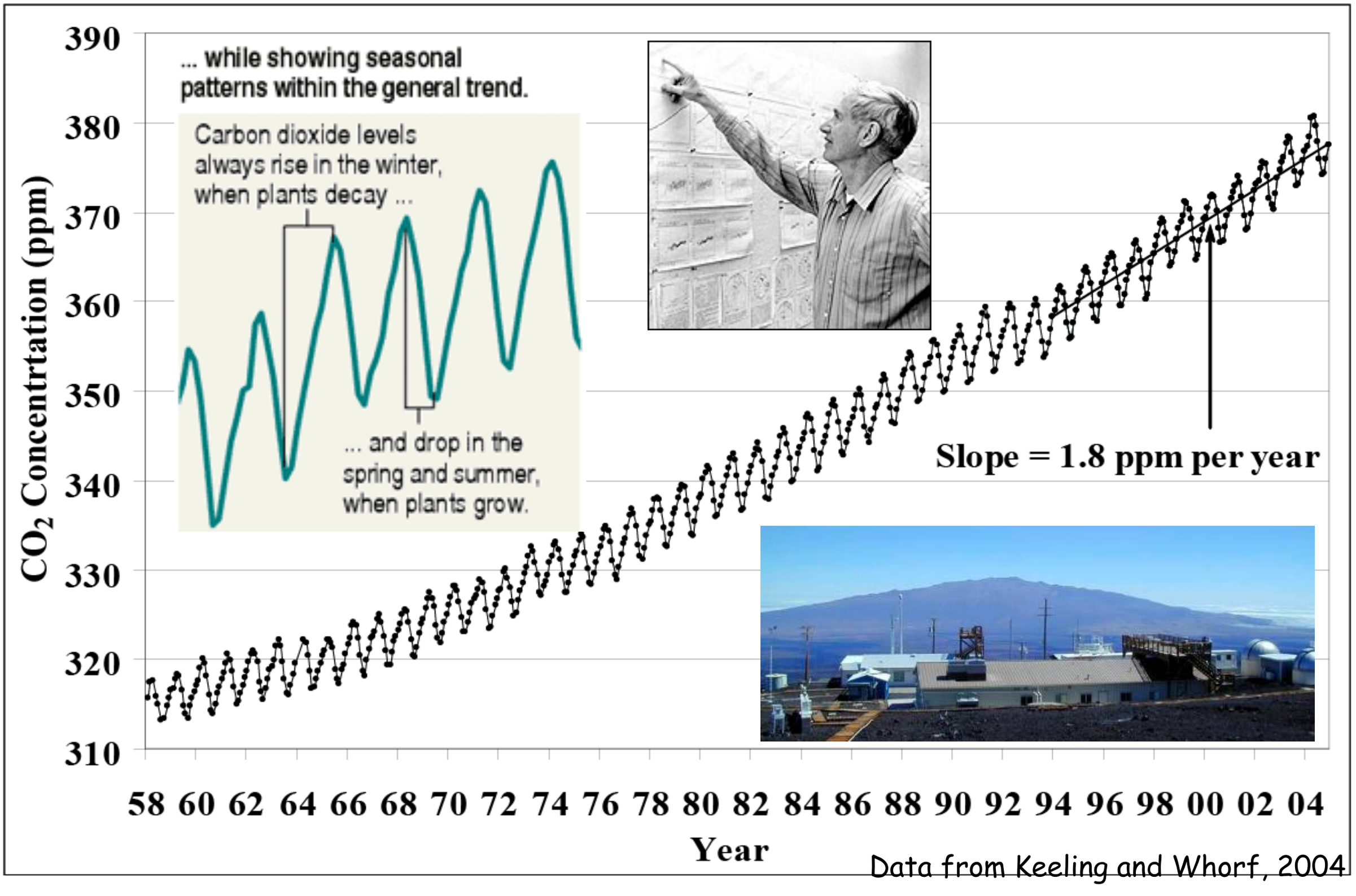
- Deep ocean water properties and circulation play critical roles in earth's climate system
- Modulates climate on long time scales (~100s-1000s years)
- The ocean has an enormous capacity to absorb and release greenhouse gases
- So, the rate, temperature and composition of seawater circulating through the deep ocean is vitally important in assessing long term climate change

Ocean Acidification and the Future Global Carbon Cycle

- Rising atmospheric CO_2
- Ocean's role in uptake of atmospheric CO_2
- Resulting changes in ocean chemistry
- Possible outcomes for future oceans
- What can we can do to help improve the future?

for further info: "The Future of Ocean Biogeochemistry in a High CO2 World," Oceanography magazine (Dec. 2009)
http://www.tos.org/oceanography/issues/issue_archive/22_4.html

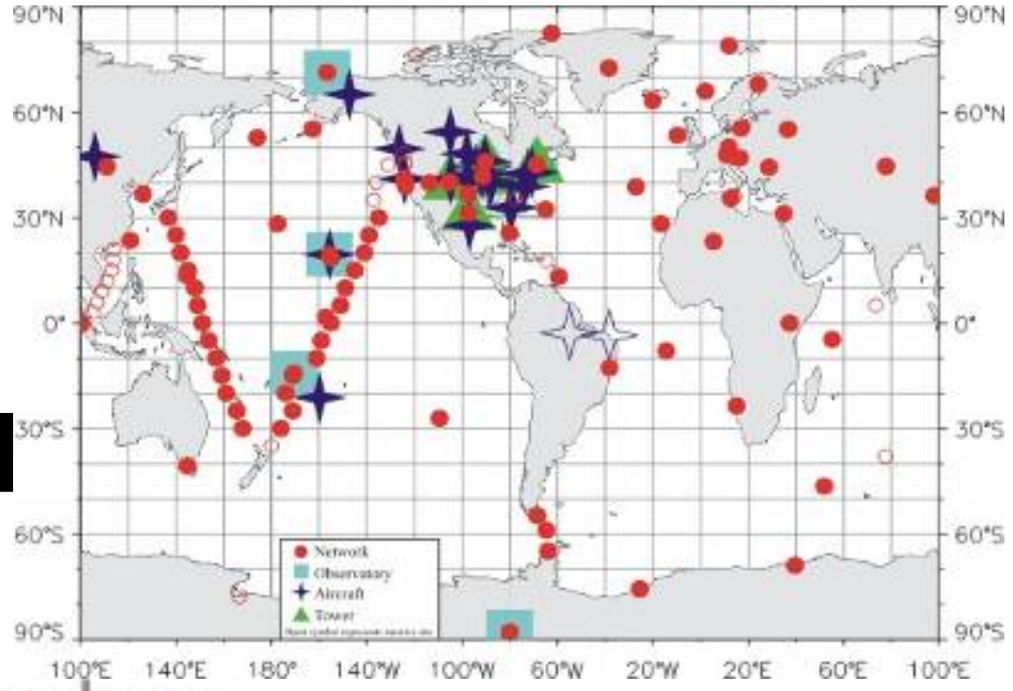
Rising Atmospheric CO_2 was first discovered by Dr. David Keeling in the mid 1900s.

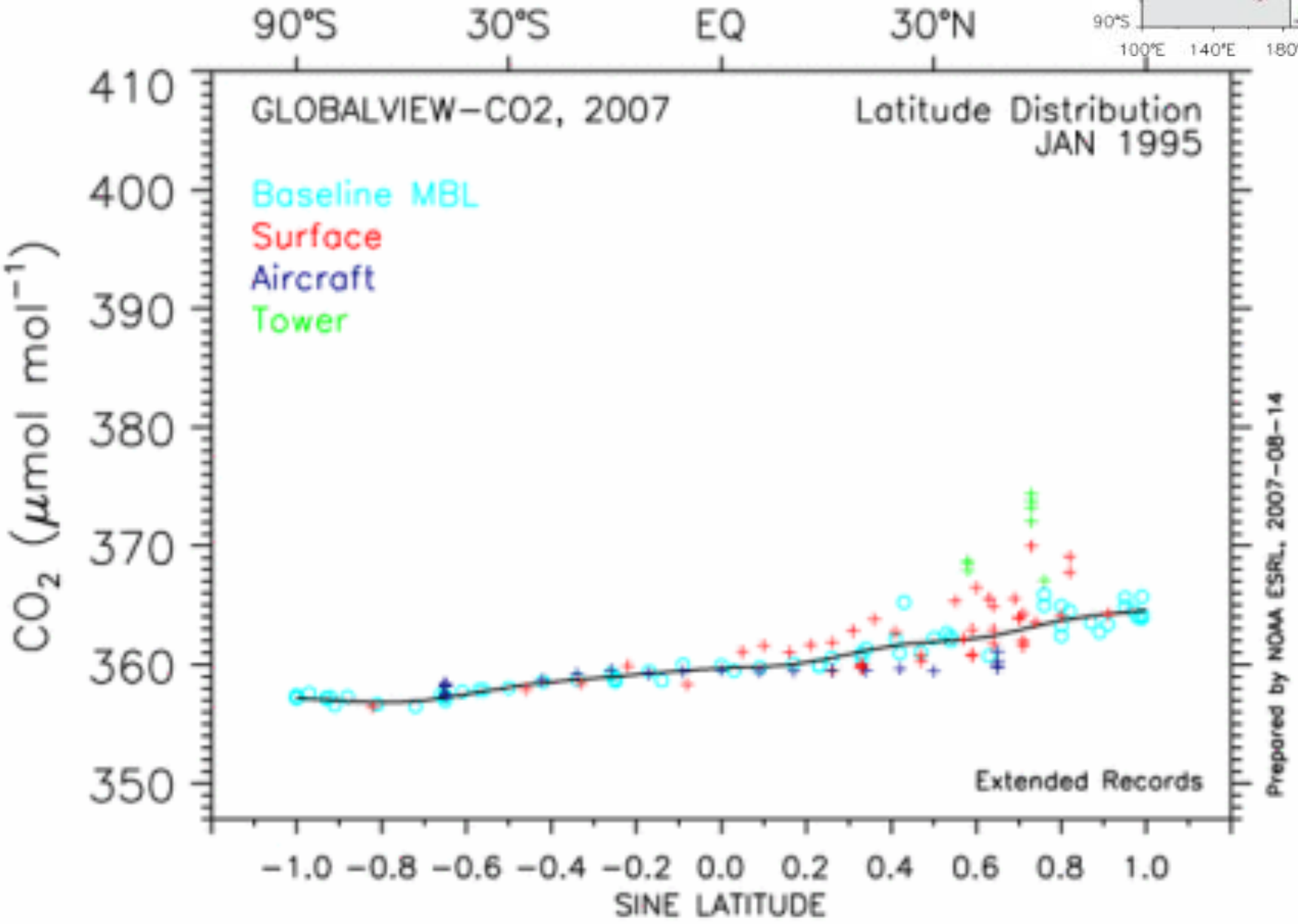


Data from Keeling and Whorf, 2004

Atmospheric CO_2 Record

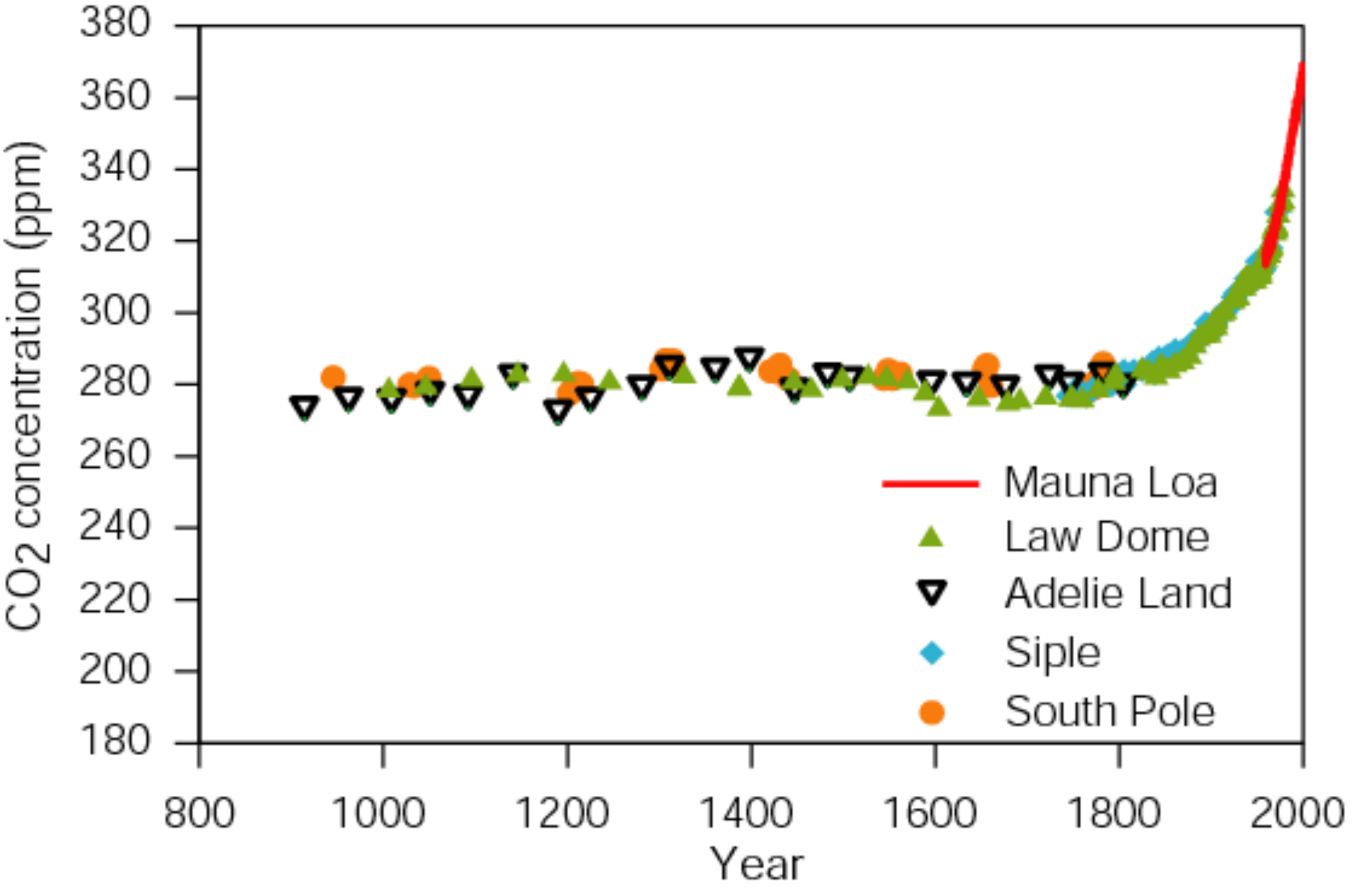
Atmospheric CO_2 levels are rising everywhere in the world. This can easily





Northern Hemisphere has larger seasonal variability than southern hemisphere

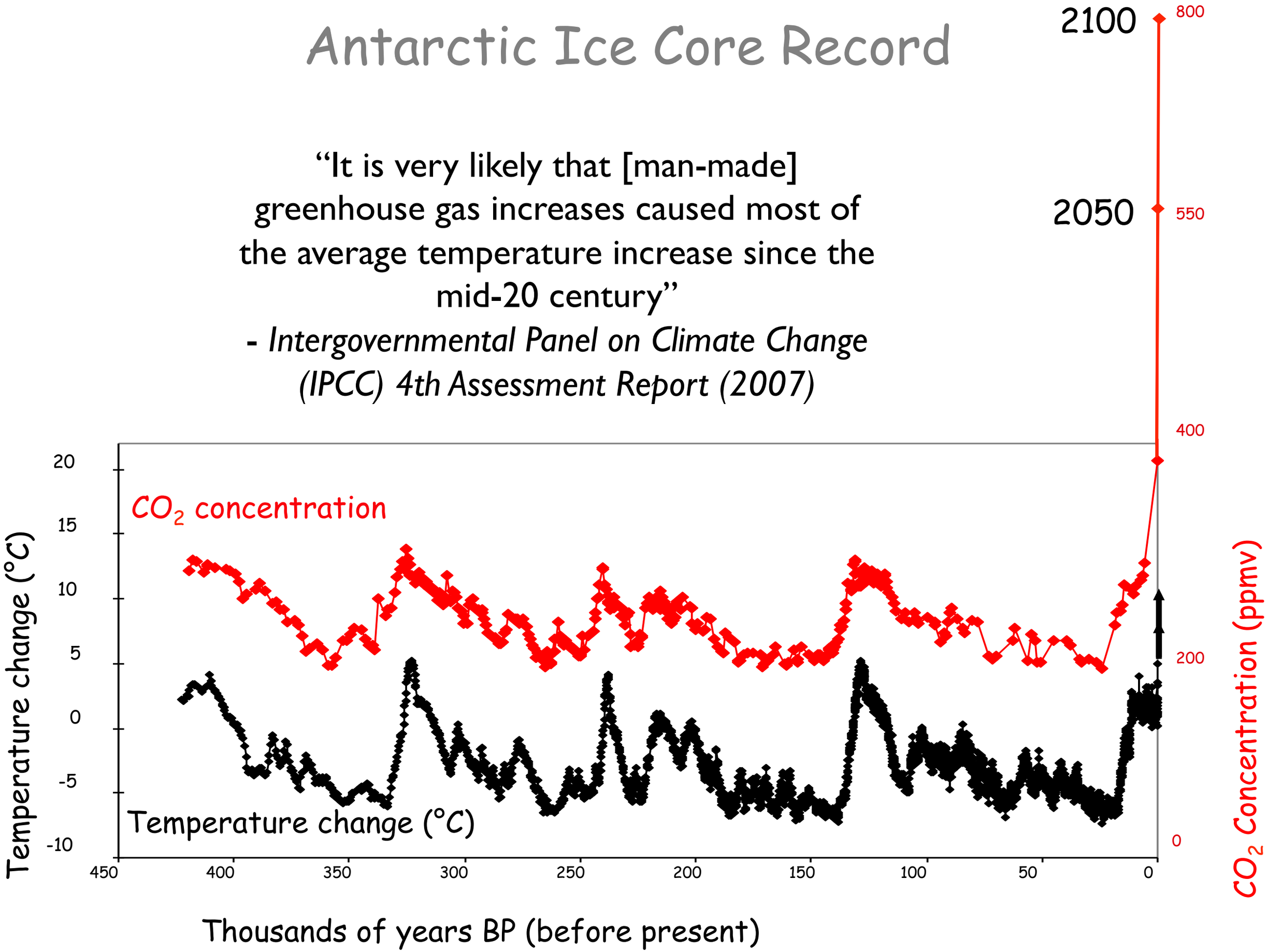
Atmospheric CO_2 was steady for at least 1,000 years before the industrial revolution.



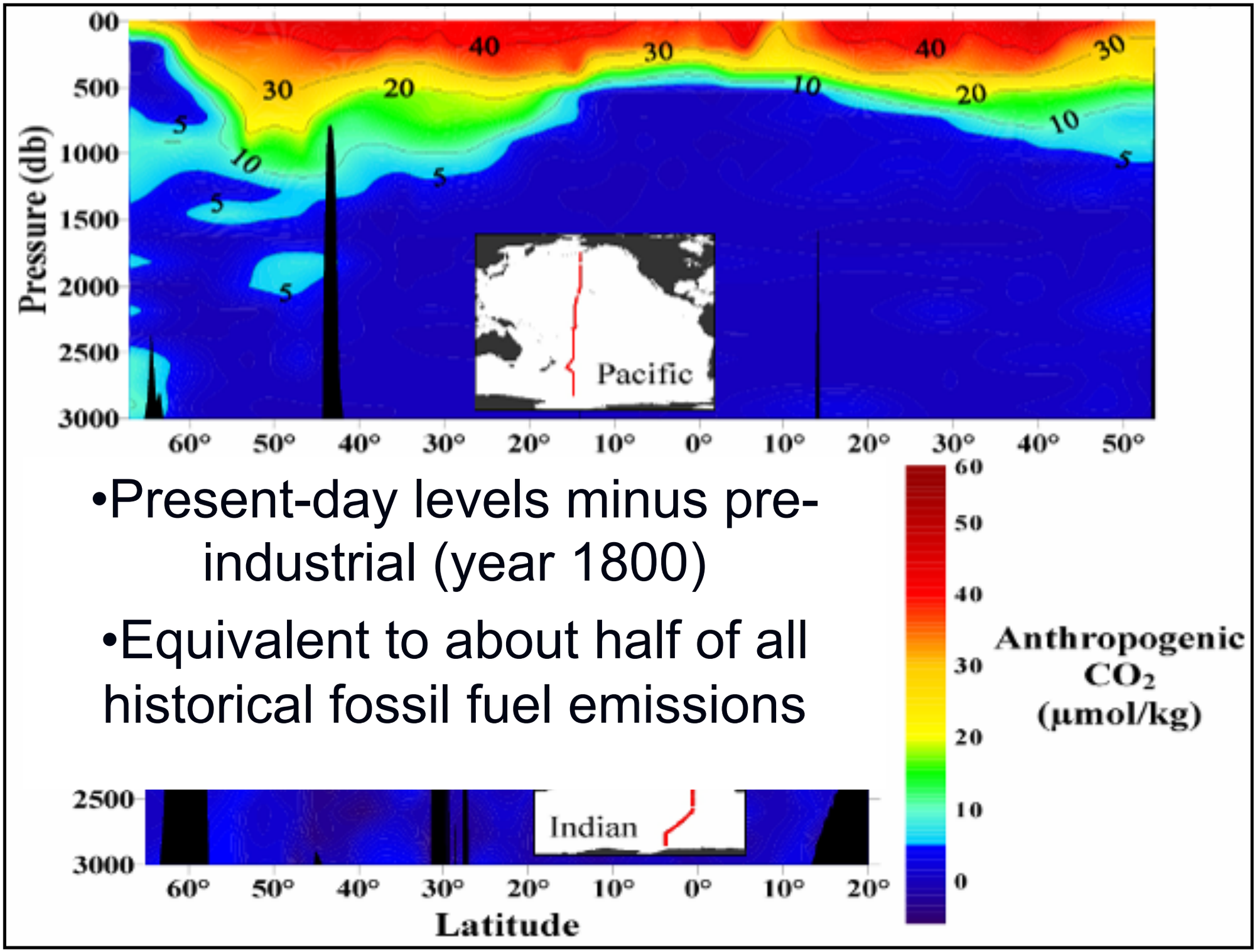
Antarctic Ice Core Record

"It is very likely that [man-made] greenhouse gas increases caused most of the average temperature increase since the mid-20 century"

- *Intergovernmental Panel on Climate Change (IPCC) 4th Assessment Report (2007)*



Penetration of human-caused CO_2 into Ocean



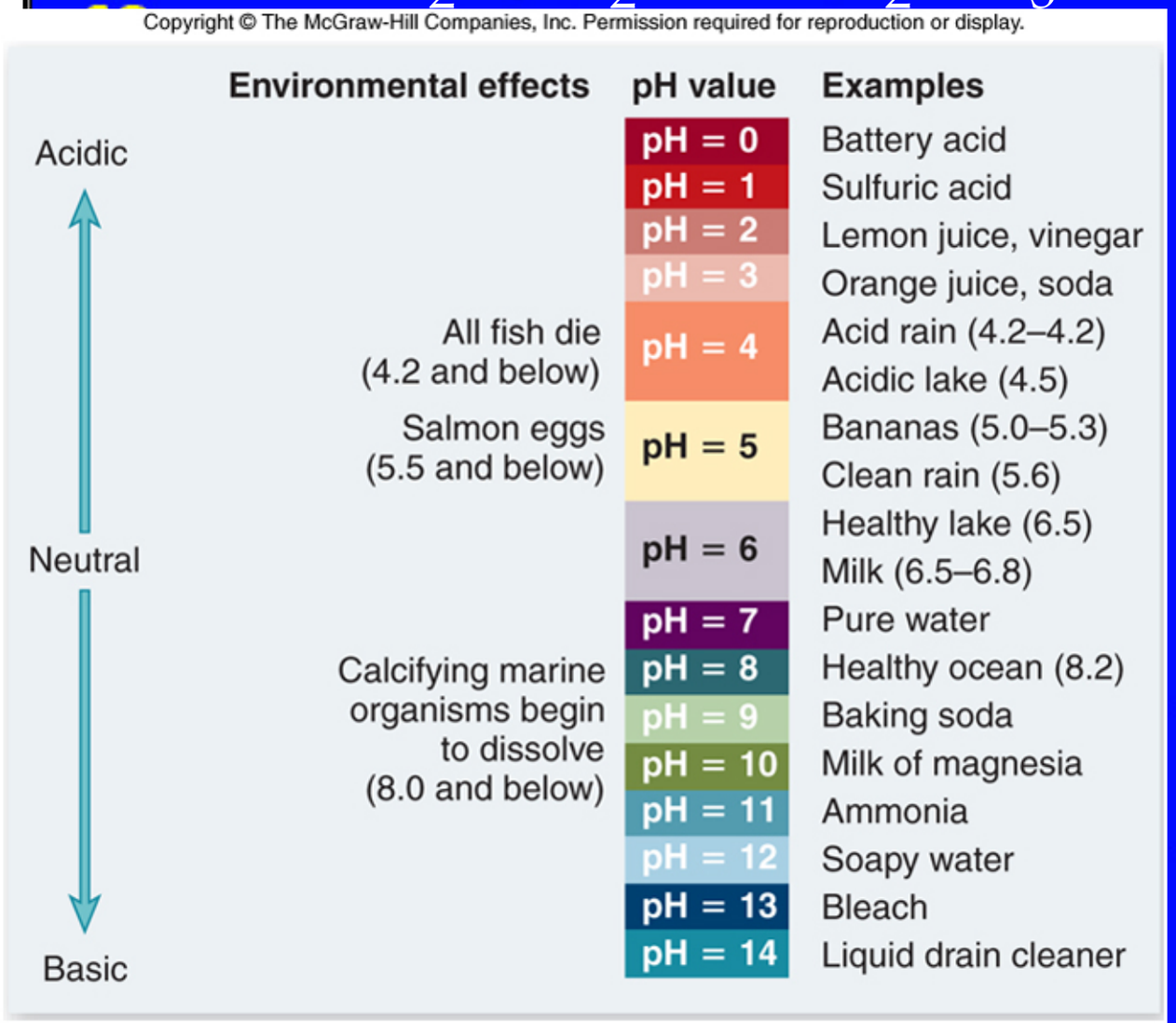
- Present-day levels minus pre-industrial (year 1800)
- Equivalent to about half of all historical fossil fuel emissions

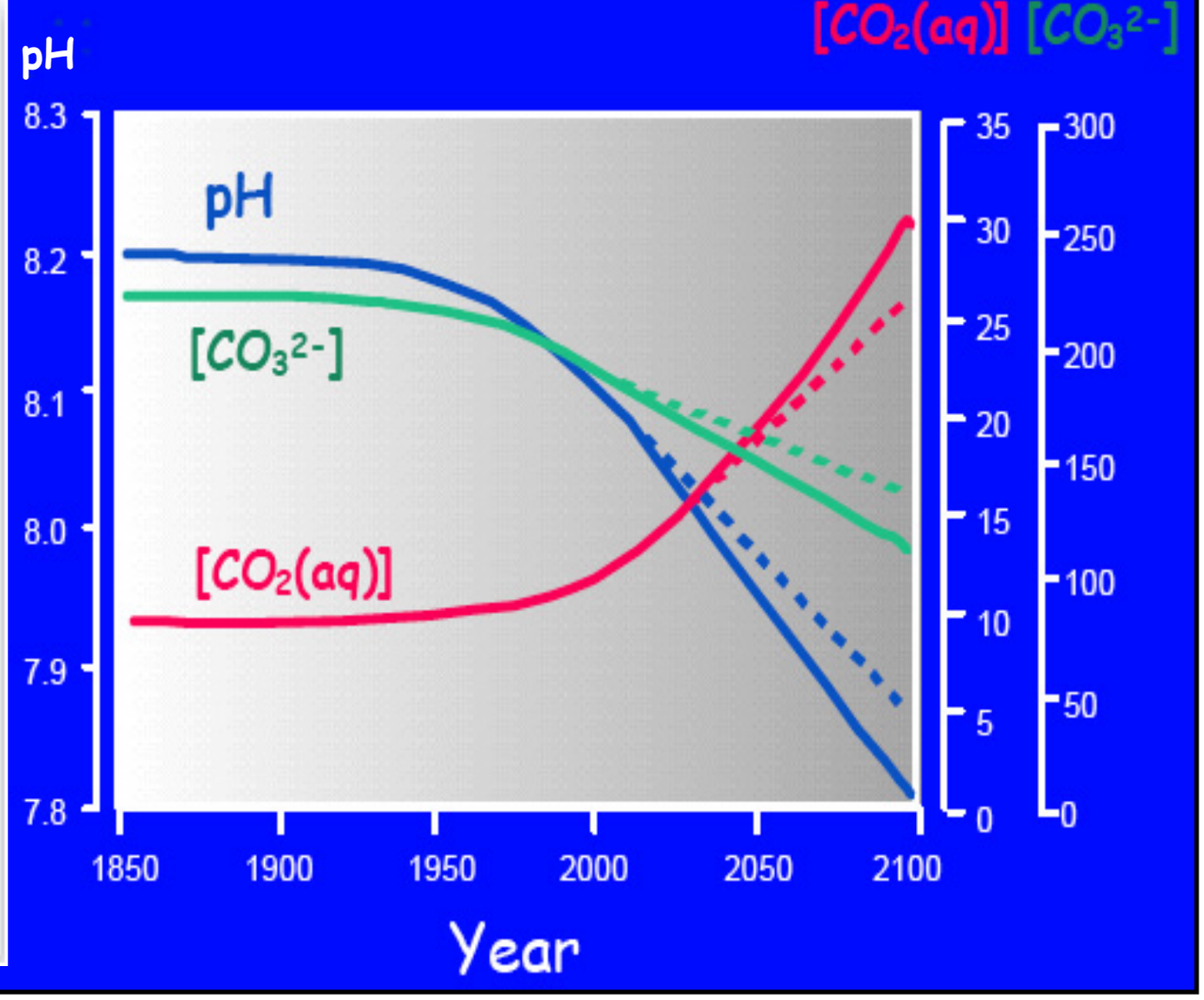
Sabine et al. (*Science*, 2004)

Rising atmospheric CO_2 is changing the chemistry of the ocean

CO_2 is an acid gas so the addition of 22 million tons of carbon dioxide to the ocean every day is acidifying the seawater…we call this process "ocean acidification"

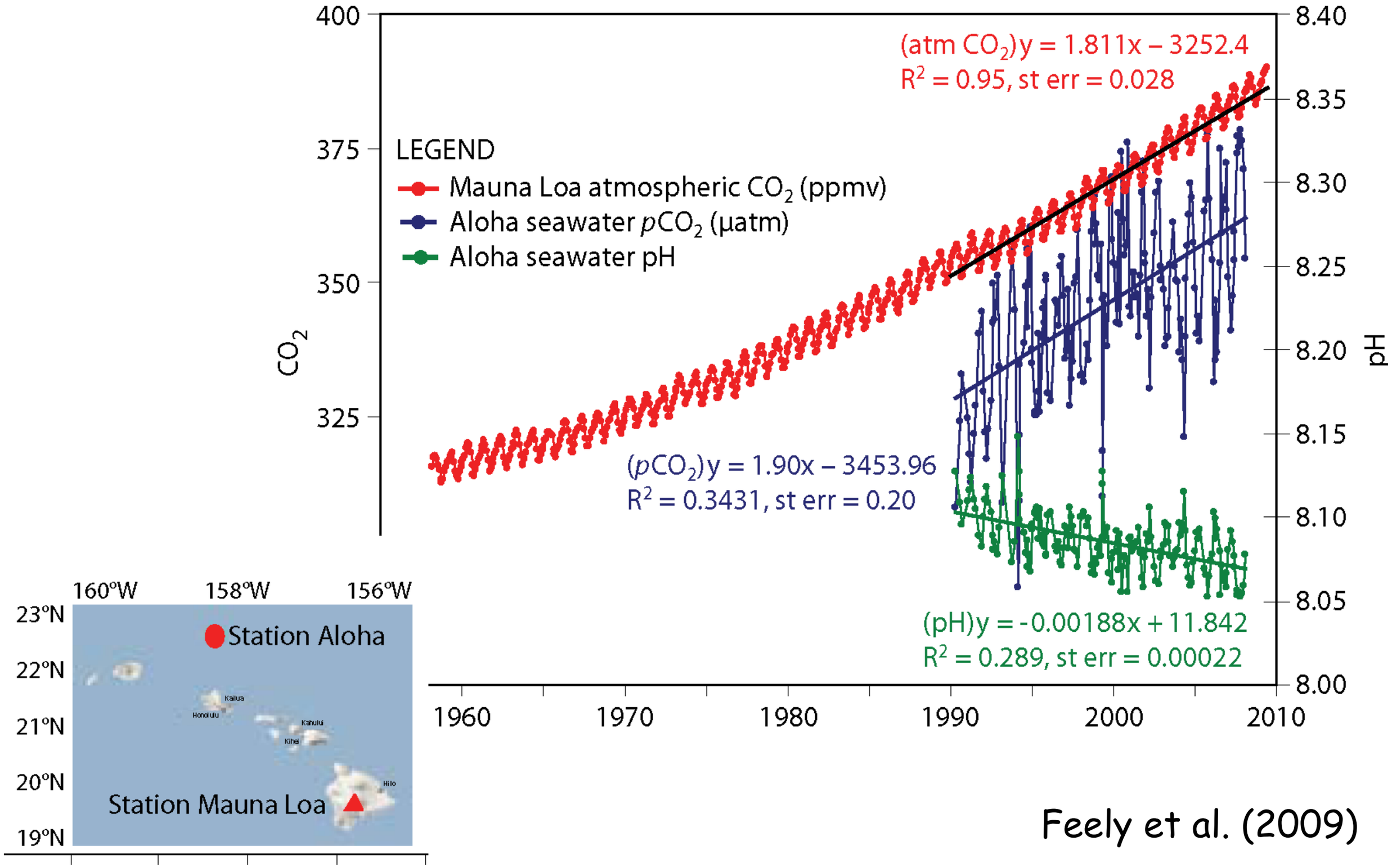
$$CO_2 + H_2O \leftrightarrows H_2CO_3 \leftrightarrows HCO_3^{2-} + H^+ \leftrightarrows CO_3^{-} + H^+$$





After Turley et al., 2005

Ocean Measurements of pCO_2 and pH



Feely et al. (2009)

Ocean Acidification

$$CO_2 + CO_3^{2-} + H_2O \Leftrightarrow 2HCO_3^-$$

$$\text{Saturation State} = \Omega_{phase} = \frac{[Ca^{2+}]\,[CO_3^{2-}]}{K^*_{sp,\,phase}}$$

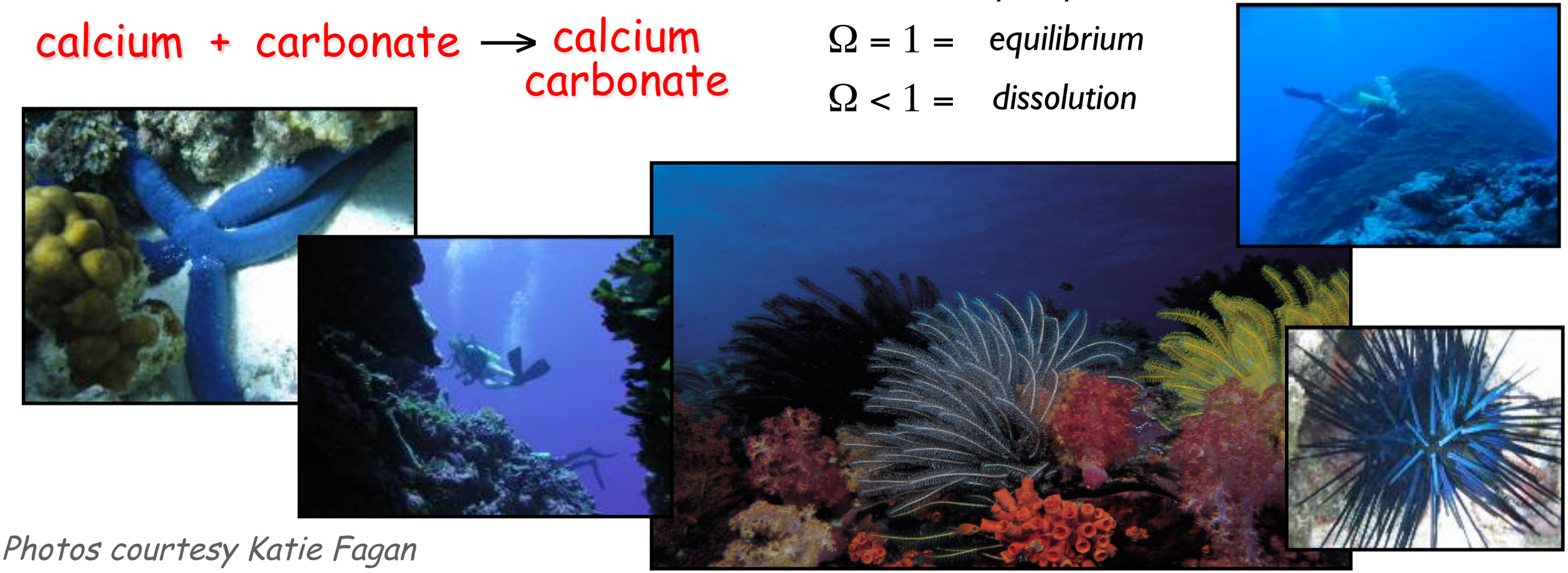
$$Ca^{2+} + CO_3^{2-} \longrightarrow CaCO_3$$

calcium + carbonate → calcium carbonate

$\Omega > 1 =$ *precipitation*

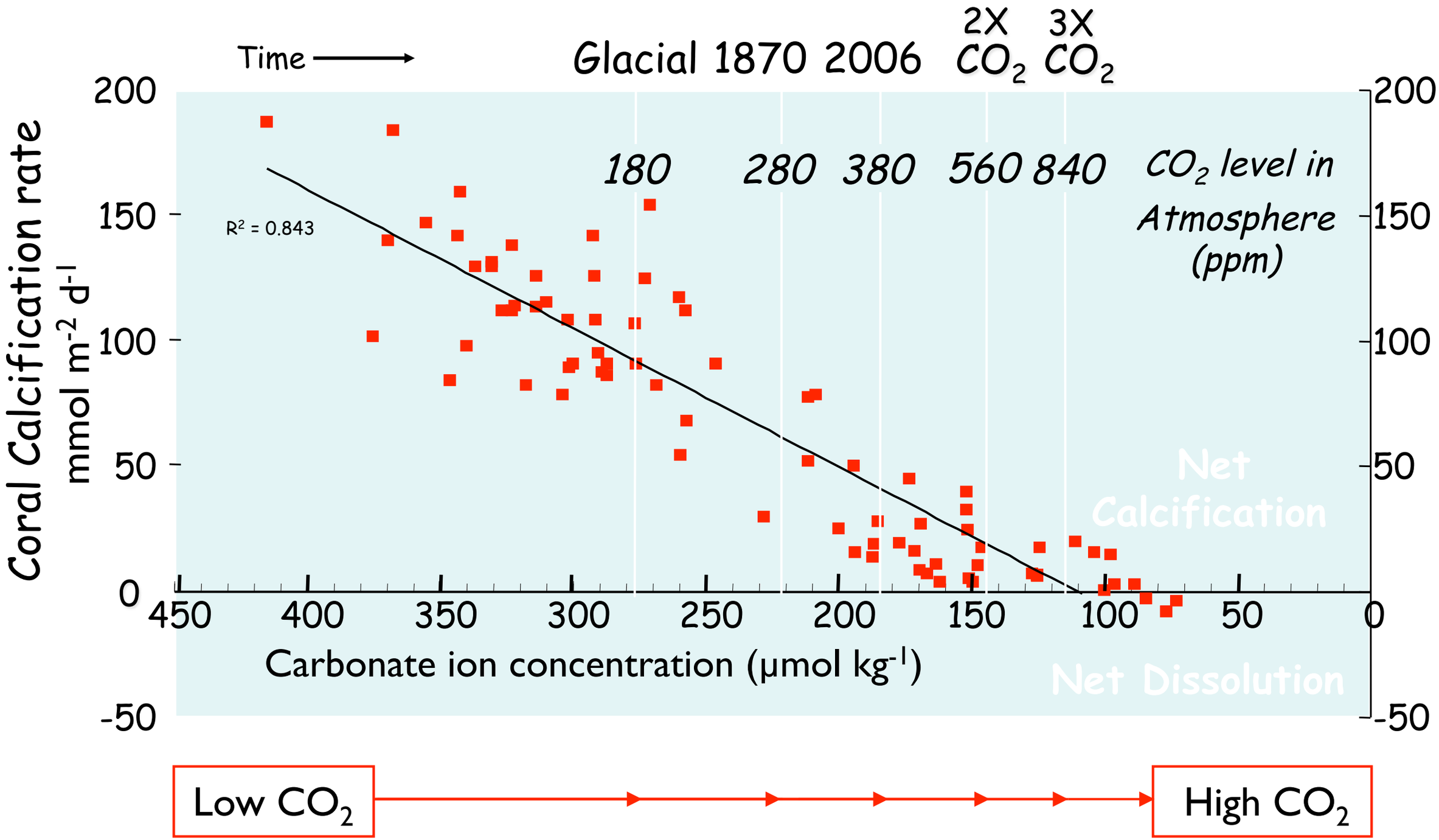
$\Omega = 1 =$ *equilibrium*

$\Omega < 1 =$ *dissolution*



Photos courtesy Katie Fagan

There appears to be a linear decrease in the calcification rate of coral reef systems with decreasing carbonate ion concentrations in Biosphere 2 Corals



Langdon & Atkinson, (2005)