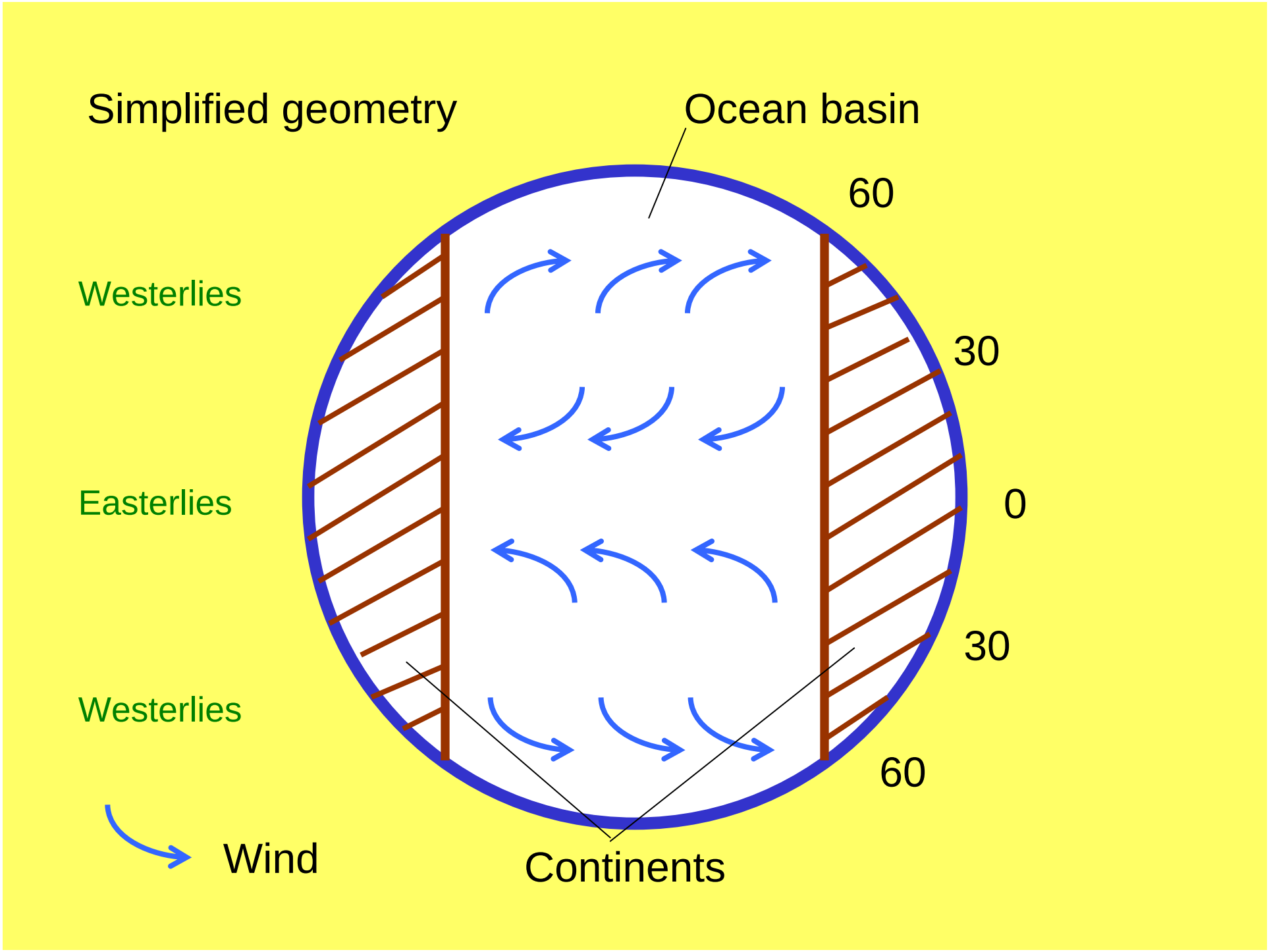
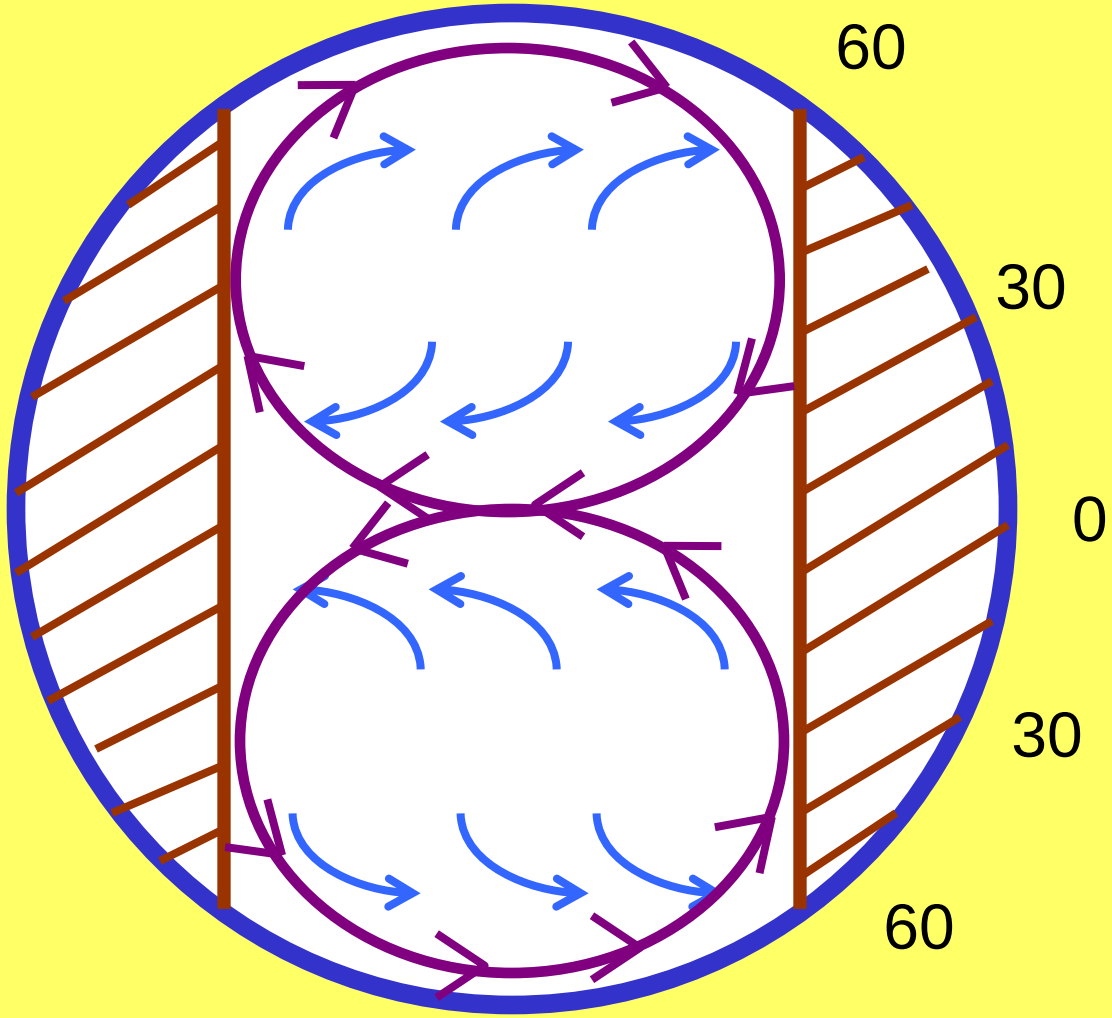
Chapter 5

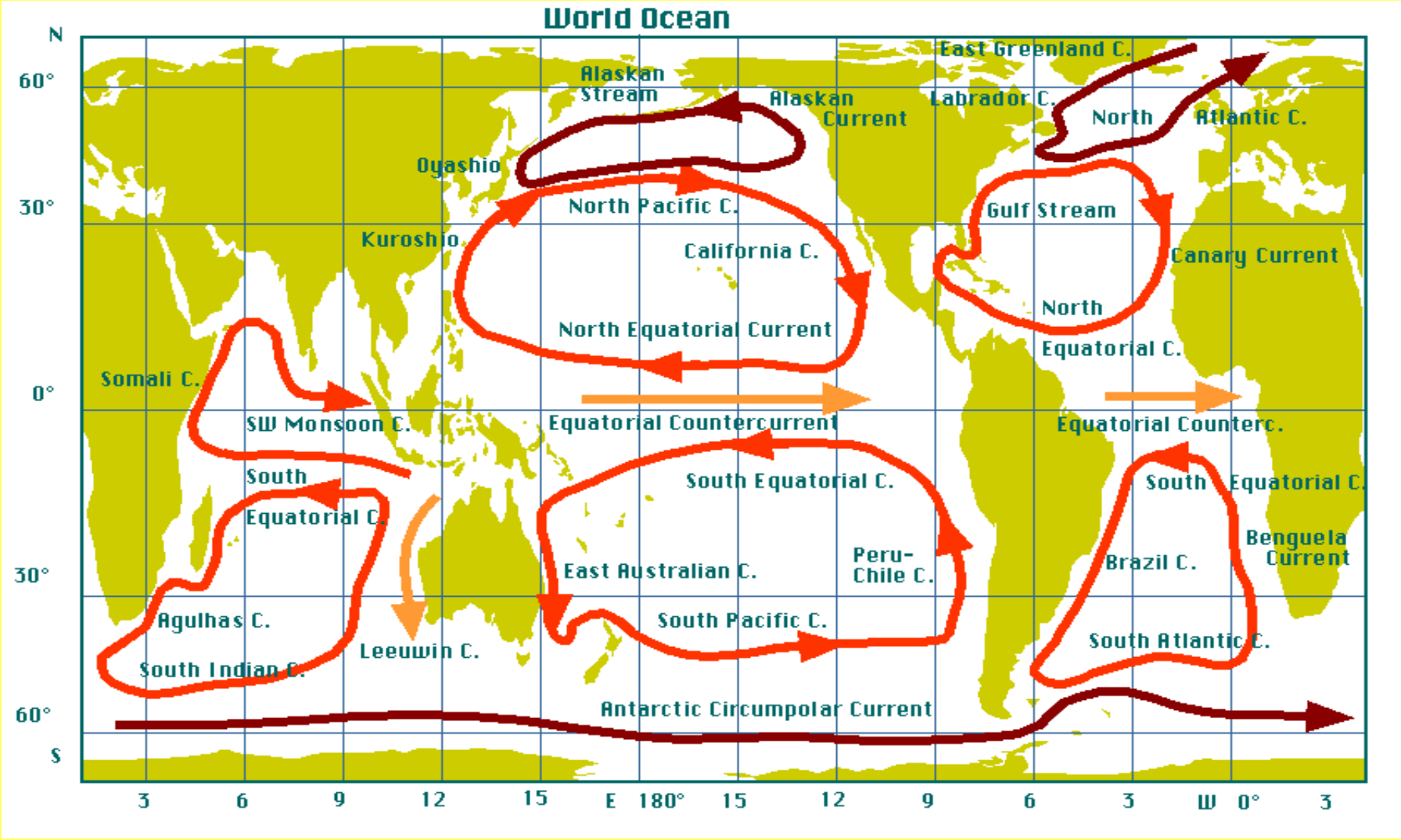
Surface Ocean/
Deep Ocean Circulation

Winds also cause large gyres (circular patterns) in the surface ocean…


Simplified geometry
Ocean basin
60
Westerlies
30
Easterlies
0
30
Westerlies
60
Wind
Continents

Ocean currents form large GYRES

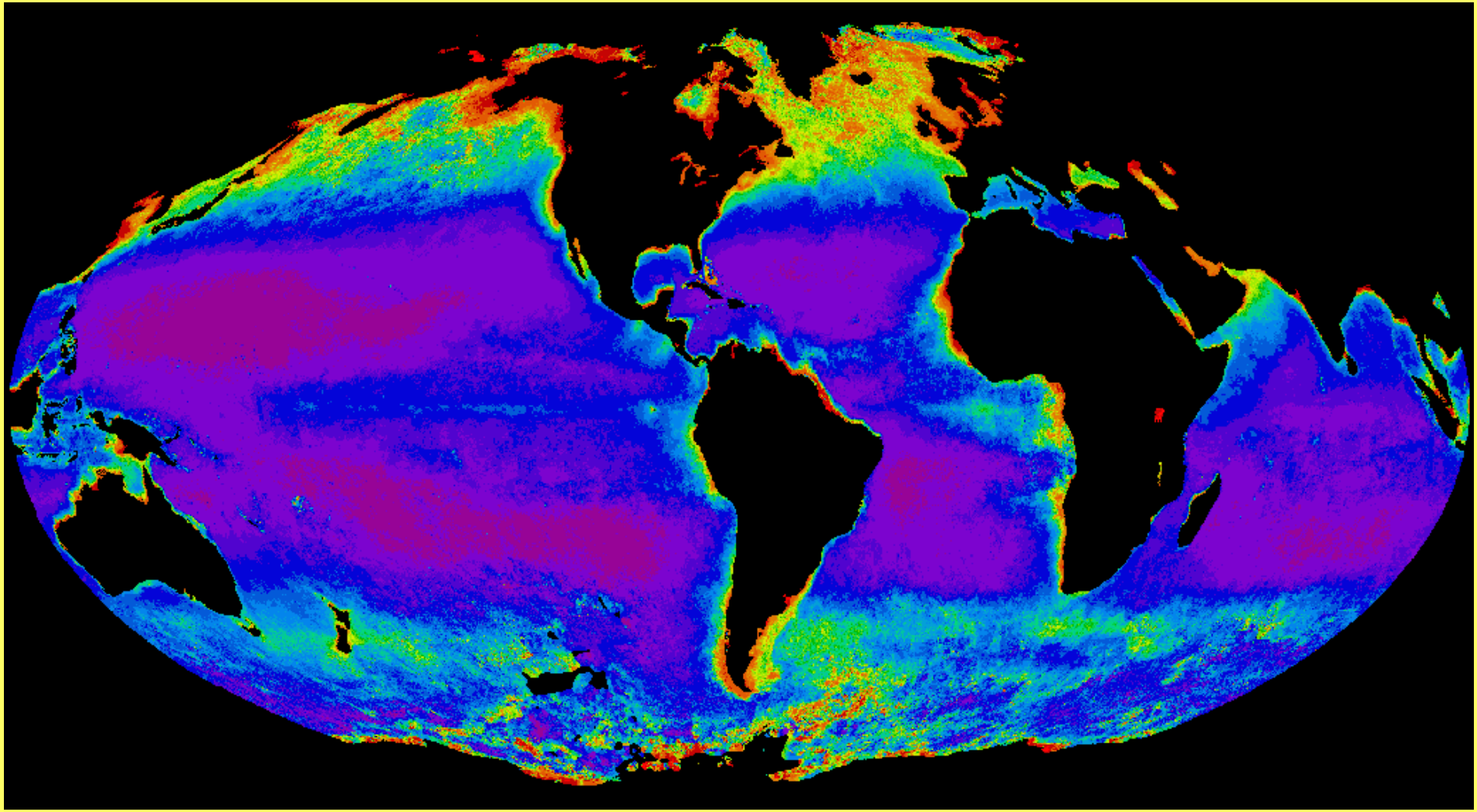




http://www.es.flinders.edu.au/~mattom/IntroOc/notes/figures/fig2a2.html

Get downwelling at the centers of gyres

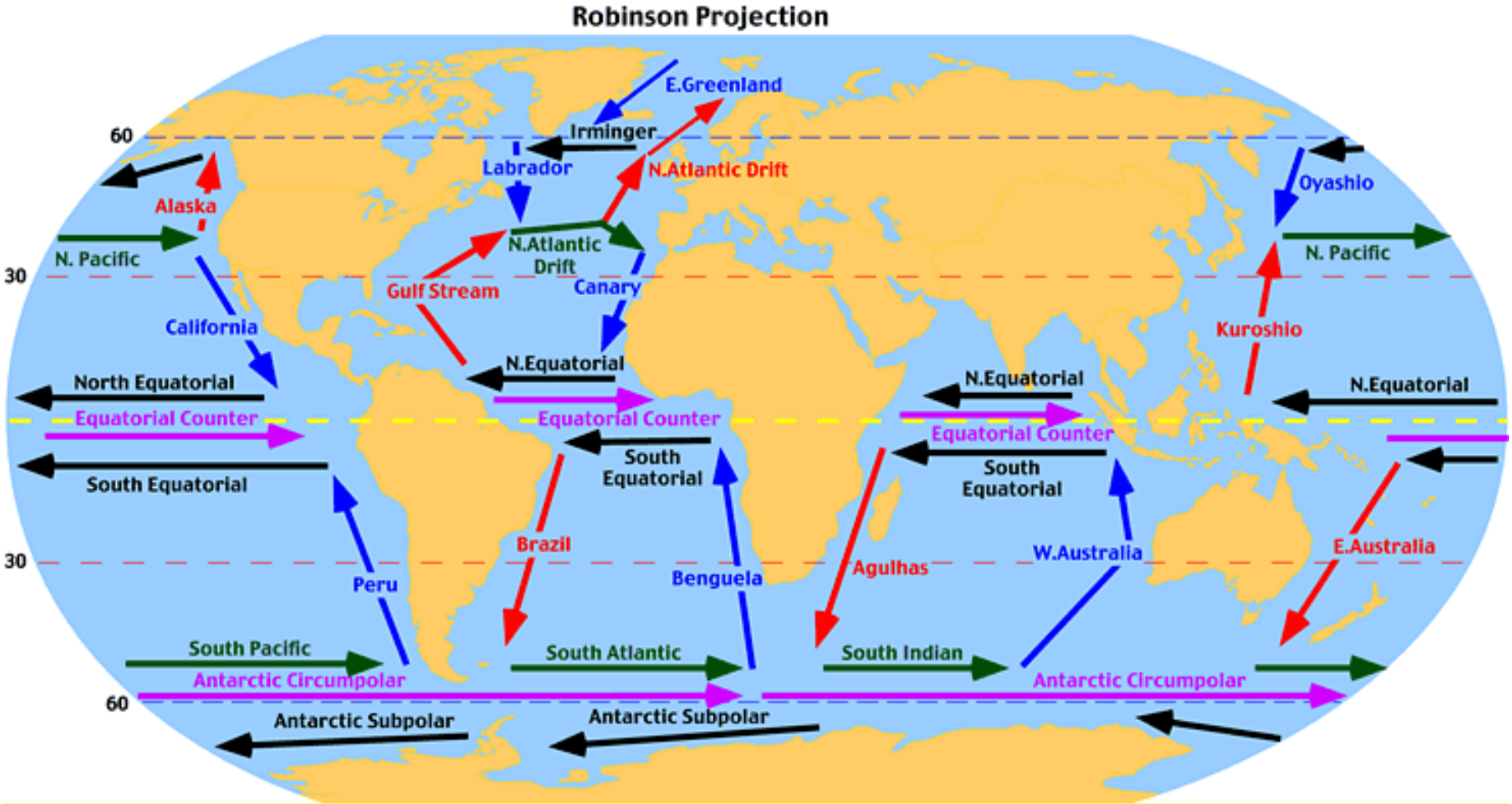
$\Rightarrow$ low productivity



Phytoplankton patterns reveal circulation patterns:
(Note the large gyres in Pacific Ocean)

http://www.ccpo.odu.edu/~arnoldo/ocean405/globalcolor.gif

Major Ocean Surface Currents



http://www.geog.ouc.bc.ca/physgeog/contents/images/oceancurrents.gif

Gulf Stream

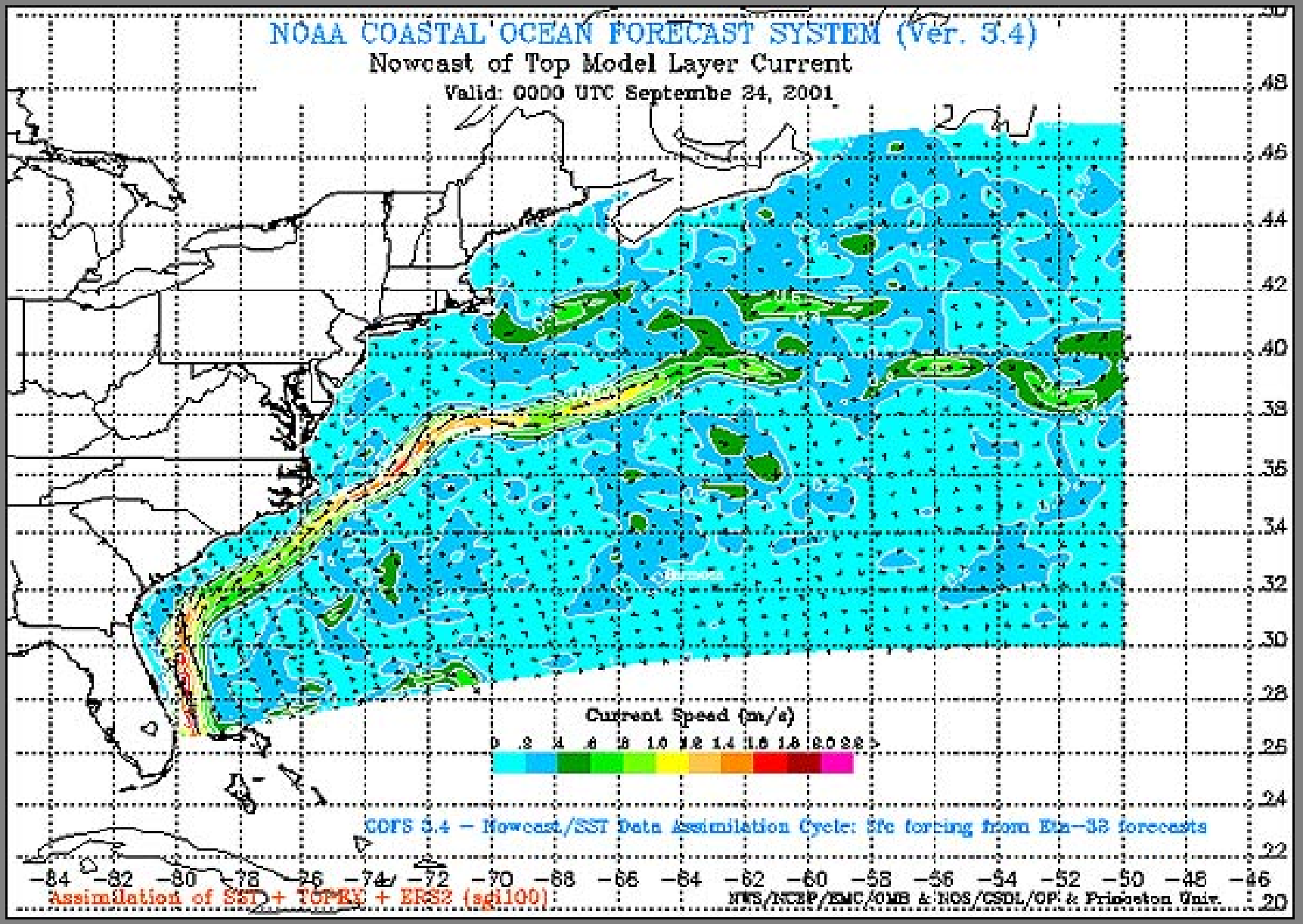
Western edge of North Atlantic gyre

Brings warm tropical waters north

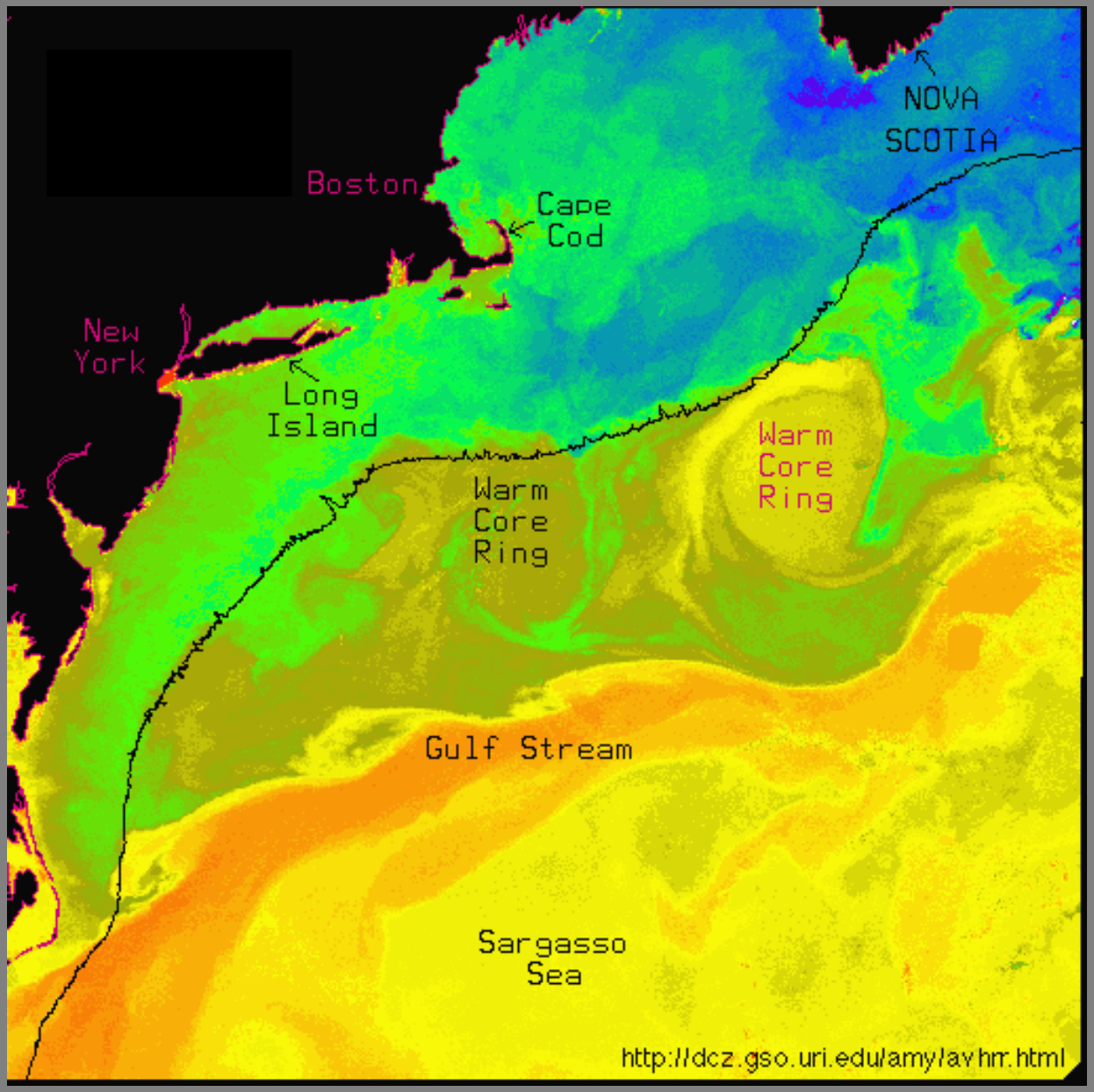
Transfers heat to Northern Europe

Waters in the Gulf Stream are salty

(because of evaporation)



http://oceanexplorer.noaa.gov/explorations/islands01/log/sep22/media/atlantic_currents_600.jpg


NOVA
SCOTIA
Boston
Cape
Cod
New
York
Long
Island
Warm
Core
Ring
Warm
Core
Ring
Gulf Stream
Sargasso
Sea
http://dcz.gso.uri.edu/amy/avhrr.html

What causes deep ocean circulation?

- Surface ocean circulation can lead to density differences in surface water

- What makes water dense?

  (Hint: 2 factors)

What makes water dense?

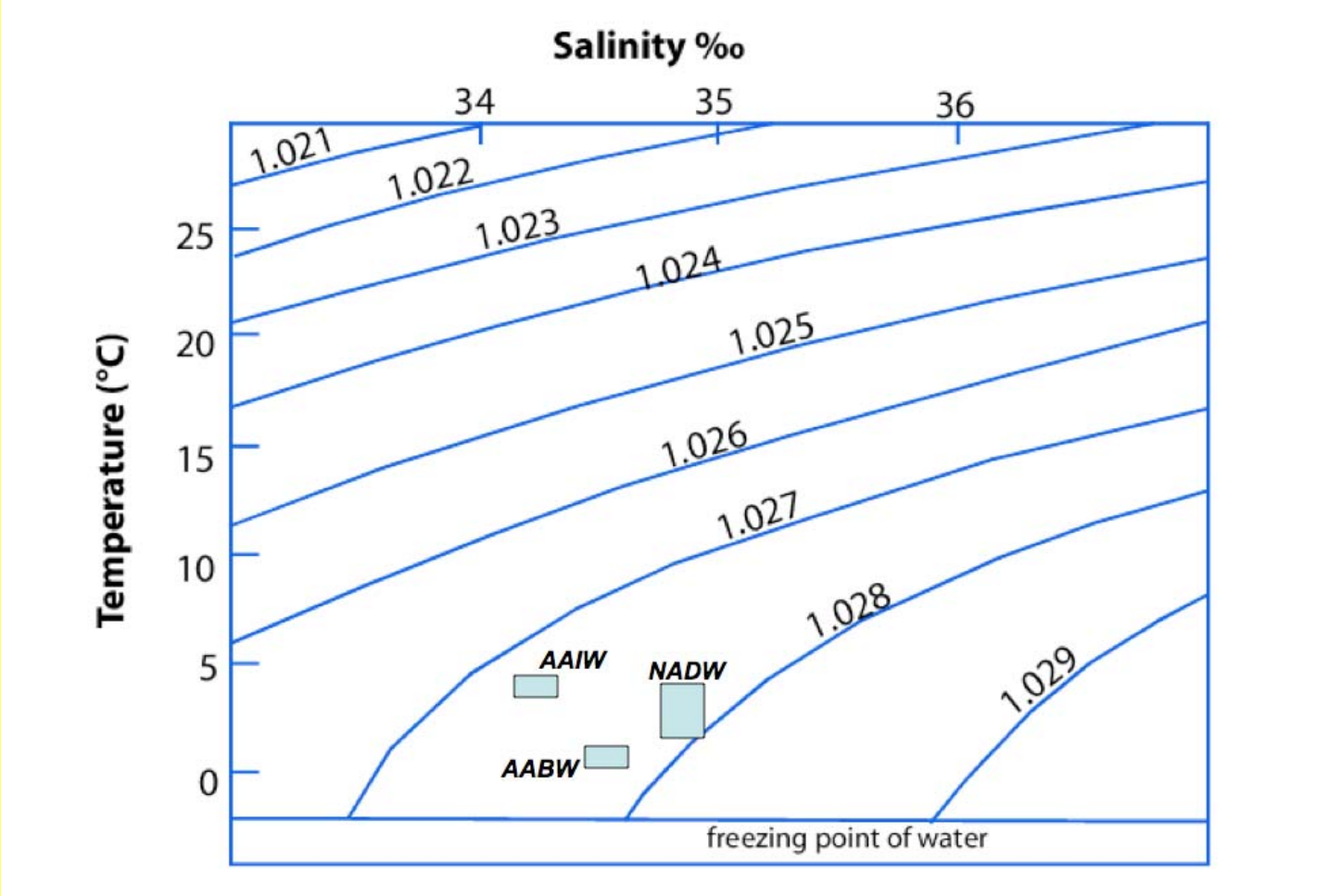
- Cold temperatures*
- High salt content

Cold, salty waters sink below warm or fresher waters

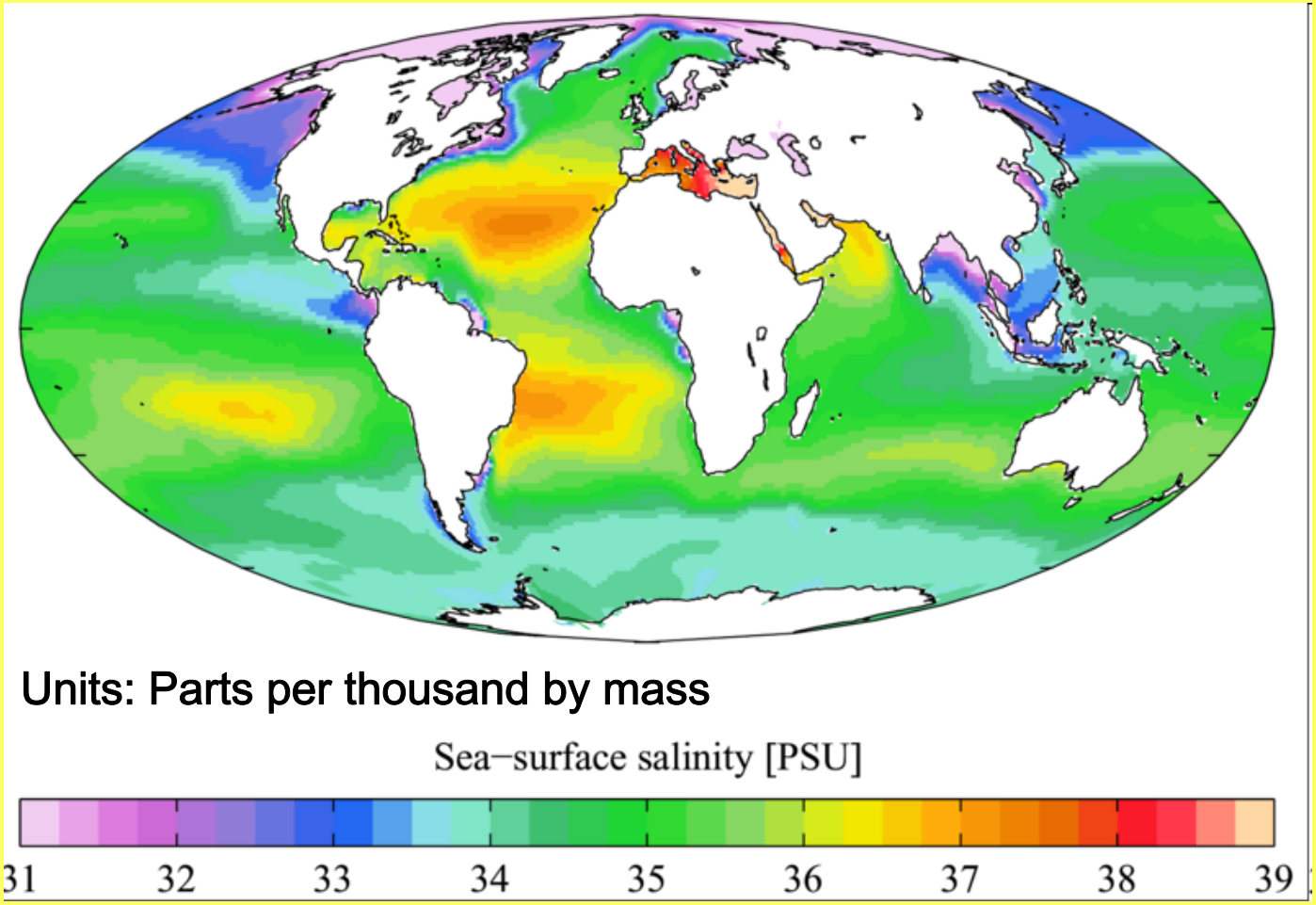
This drives circulation in deep waters

*Except, curiously, below 4°C

Seawater density vs. T and S



Annual mean surface water salinity

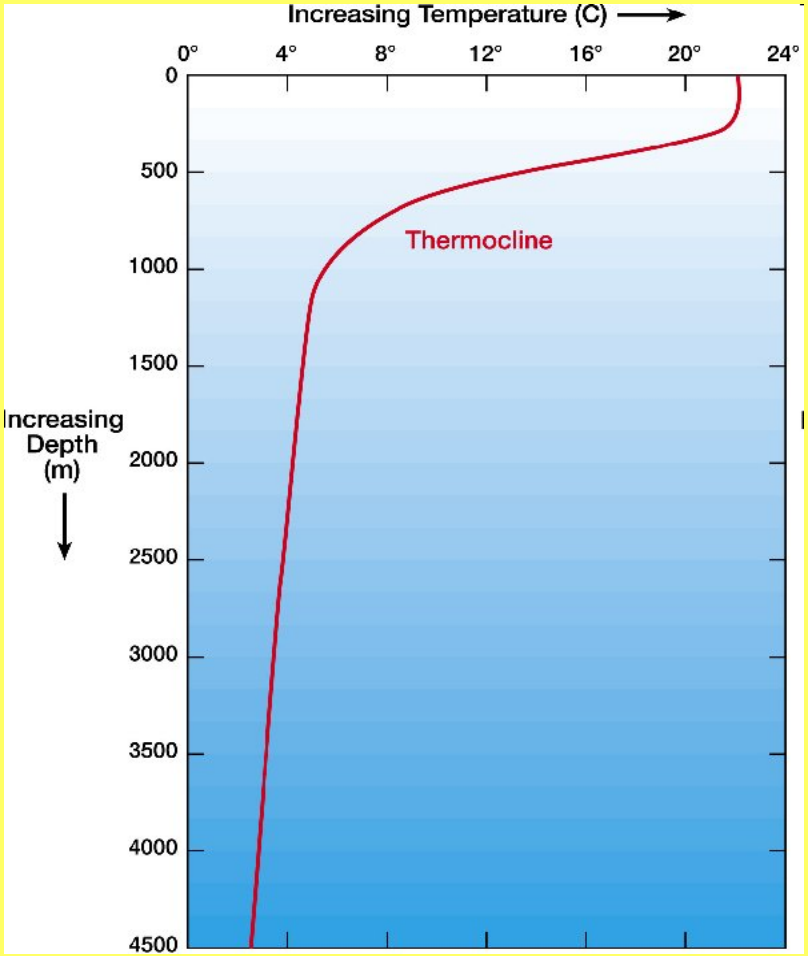


Units: Parts per thousand by mass

http://en.wikipedia.org/wiki/Seawater#Salinity

Seawater temperature vs. depth

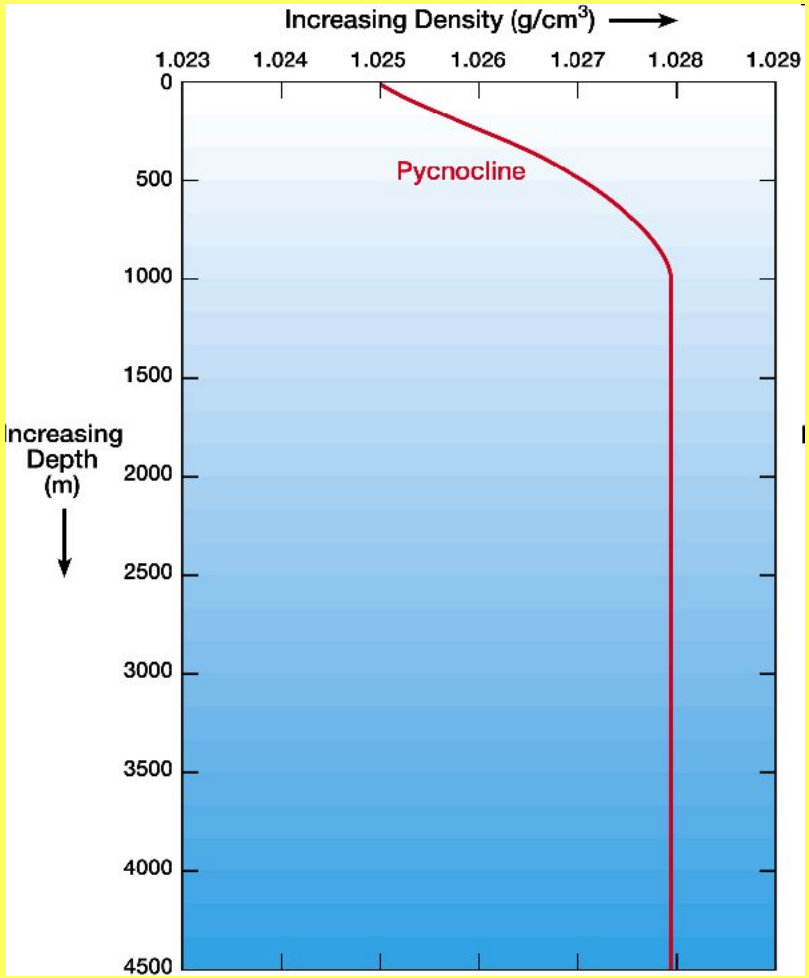
- On average, seawater temperature *decreases* with depth
- This difference is less pronounced, though, at high latitudes



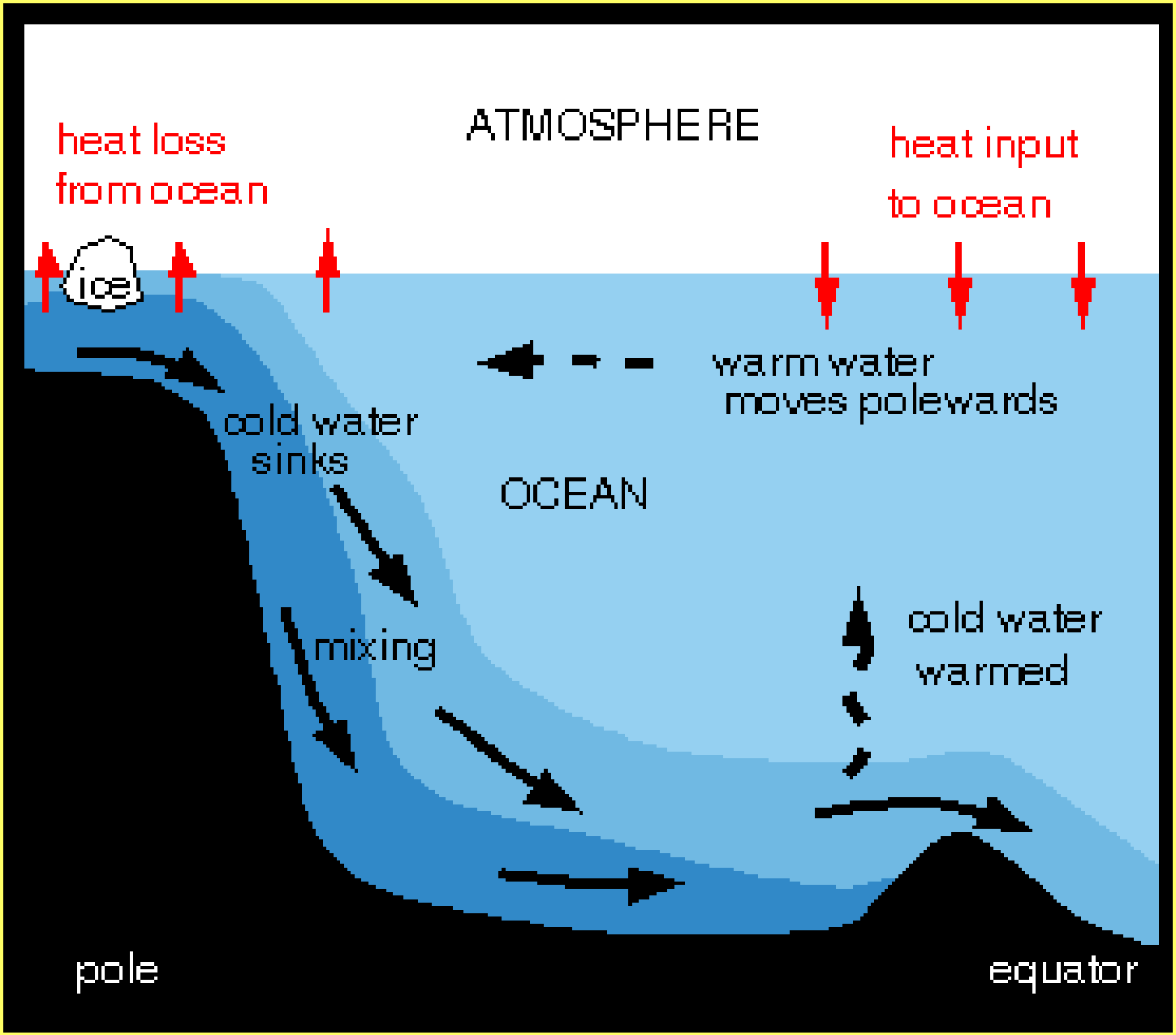
http://www.windows.ucar.edu/tour/link=/earth/Water/temp.html&edu=high

Seawater density vs. depth

- On average, seawater density *increases* smoothly with depth
- Slight differences exist, though, between different ocean basins

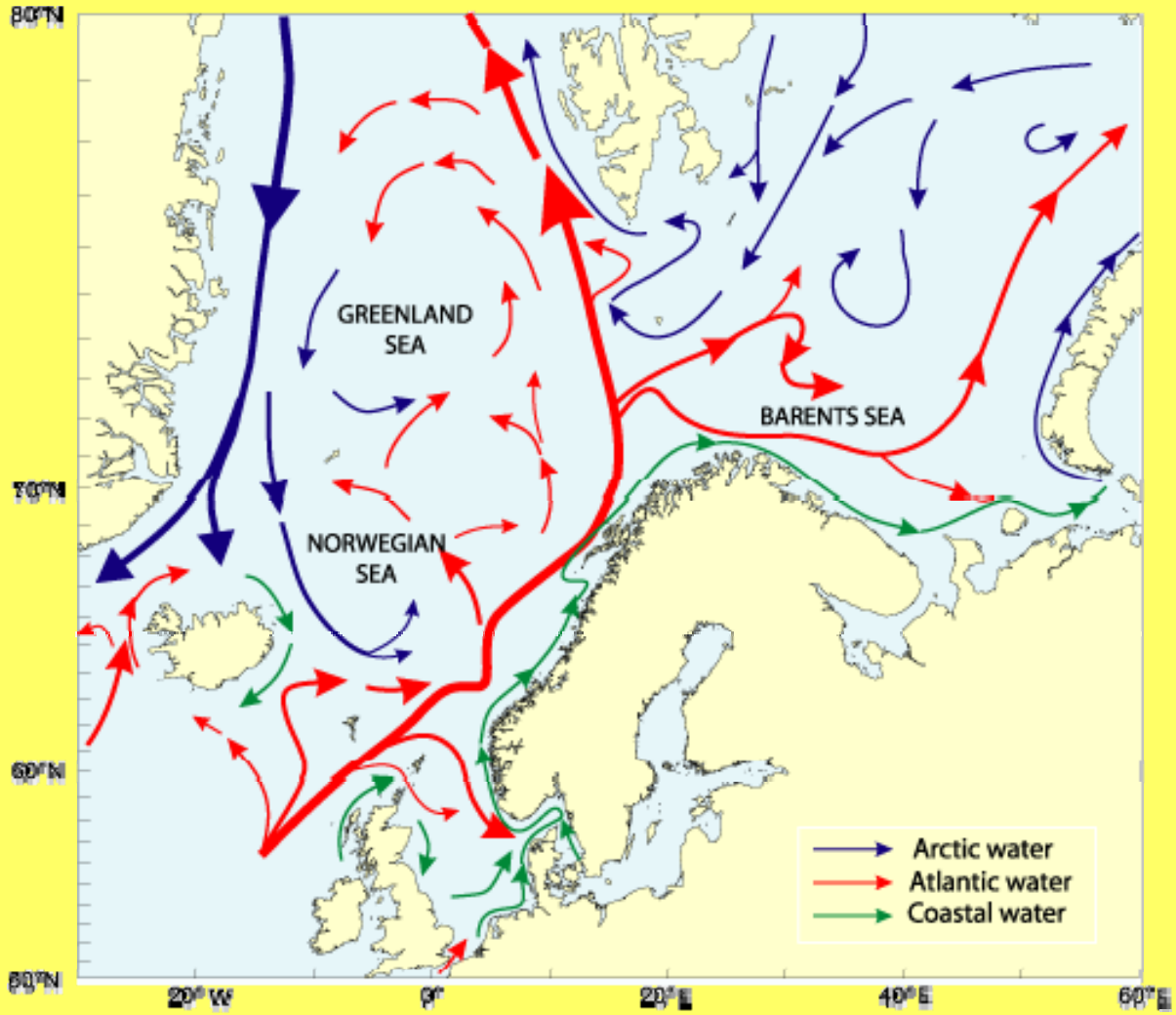


http://www.windows.ucar.edu/tour/link=/earth/Water/density.html



http://www.liv.ac.uk/~ric/

Salty waters from the Gulf Stream mix with cold waters in the North Atlantic


80°N
70°N
60°N
50°N
20° W
0°
20° E
40° E
60° E
GREENLAND SEA
NORWEGIAN SEA
BARENTS SEA
Arctic water
Atlantic water
Coastal water

Salty waters from the Gulf Stream mix with cold waters in the North Atlantic

→ The result is very **cold** and very **salty** water.

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The result is very **cold** and very **salty** water.

This North Atlantic water sinks, and begins to move along the bottom of the Atlantic Ocean.

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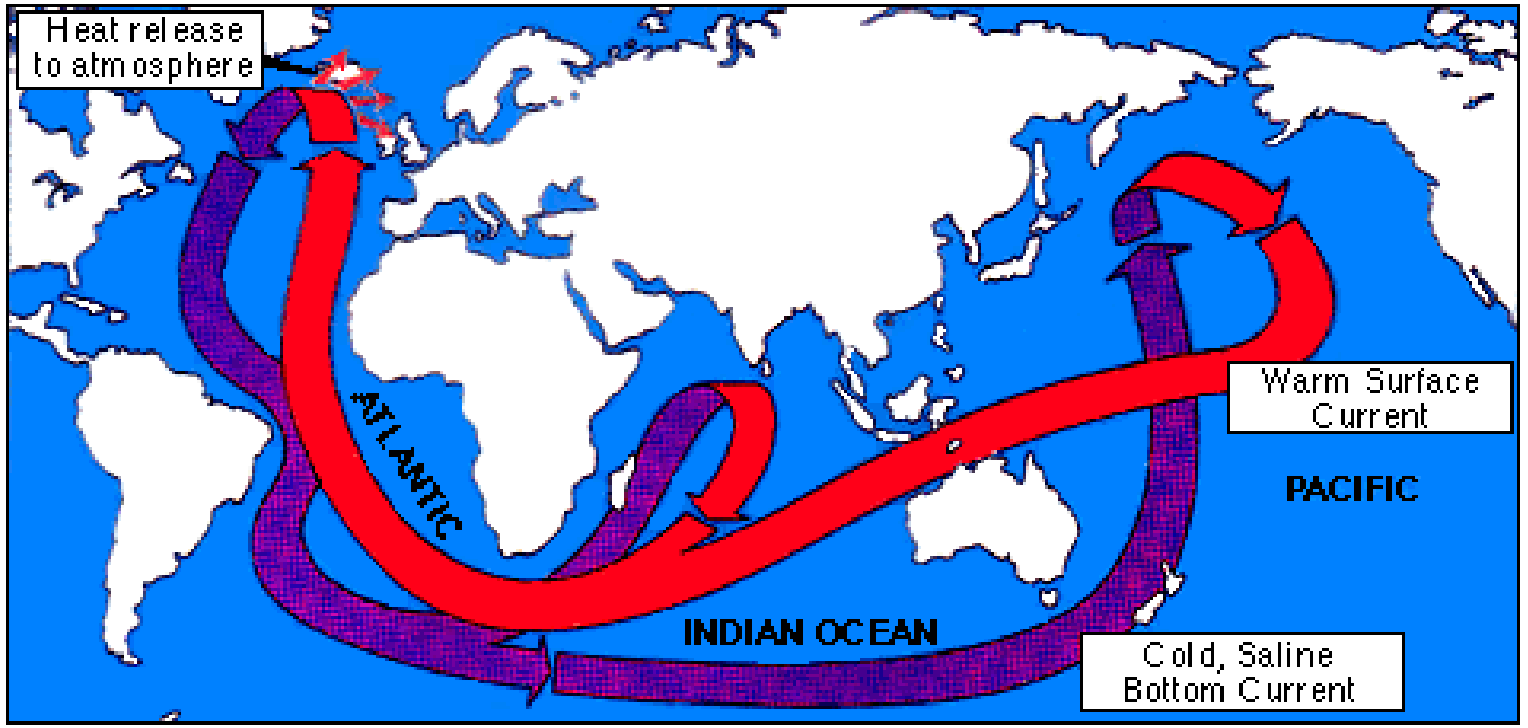
This North Atlantic water sinks, and begins to move along the bottom of the Atlantic Ocean.

→ Eventually it warms, and returns to the surface, creating a return flow.

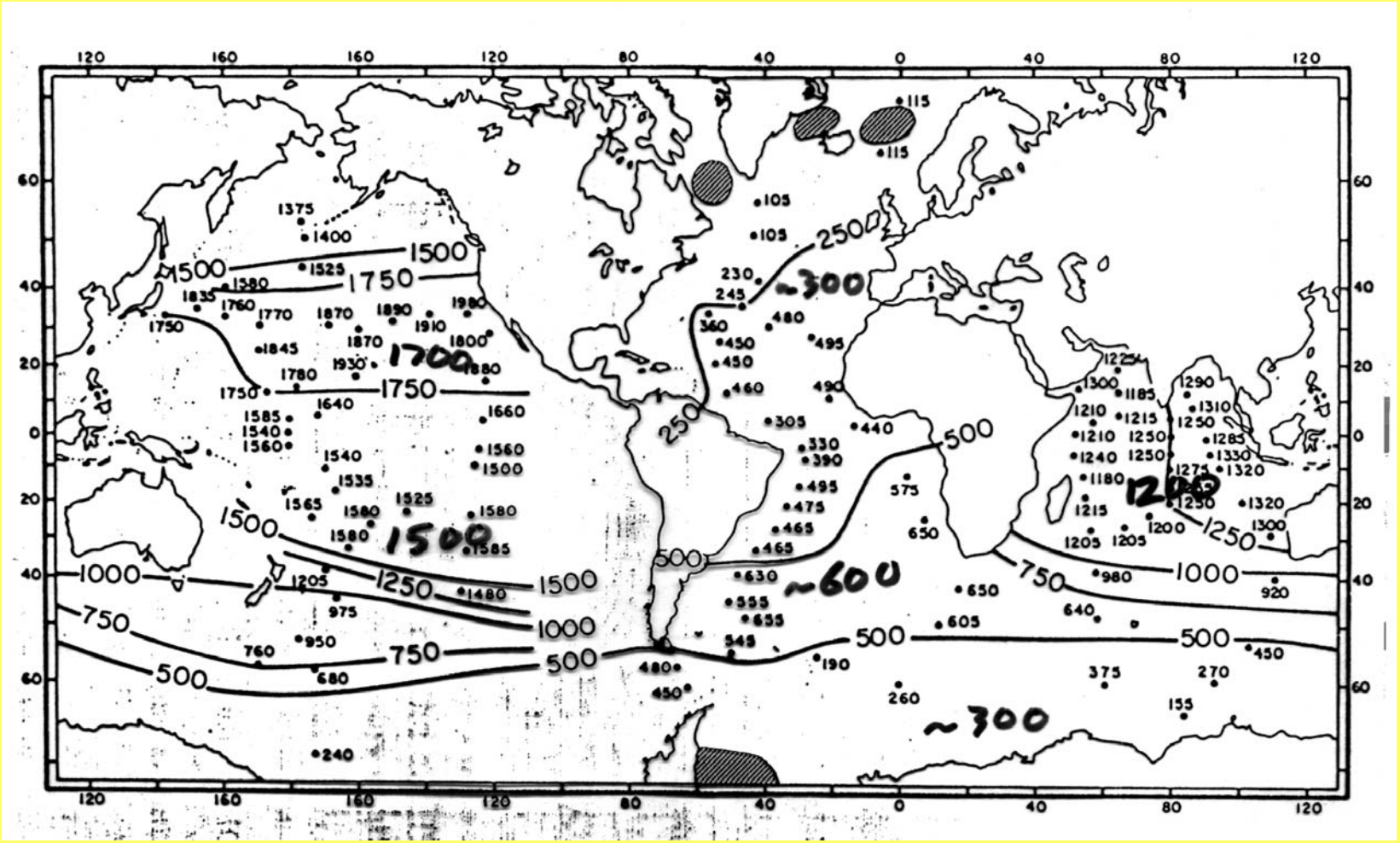
The Atlantic Conveyor



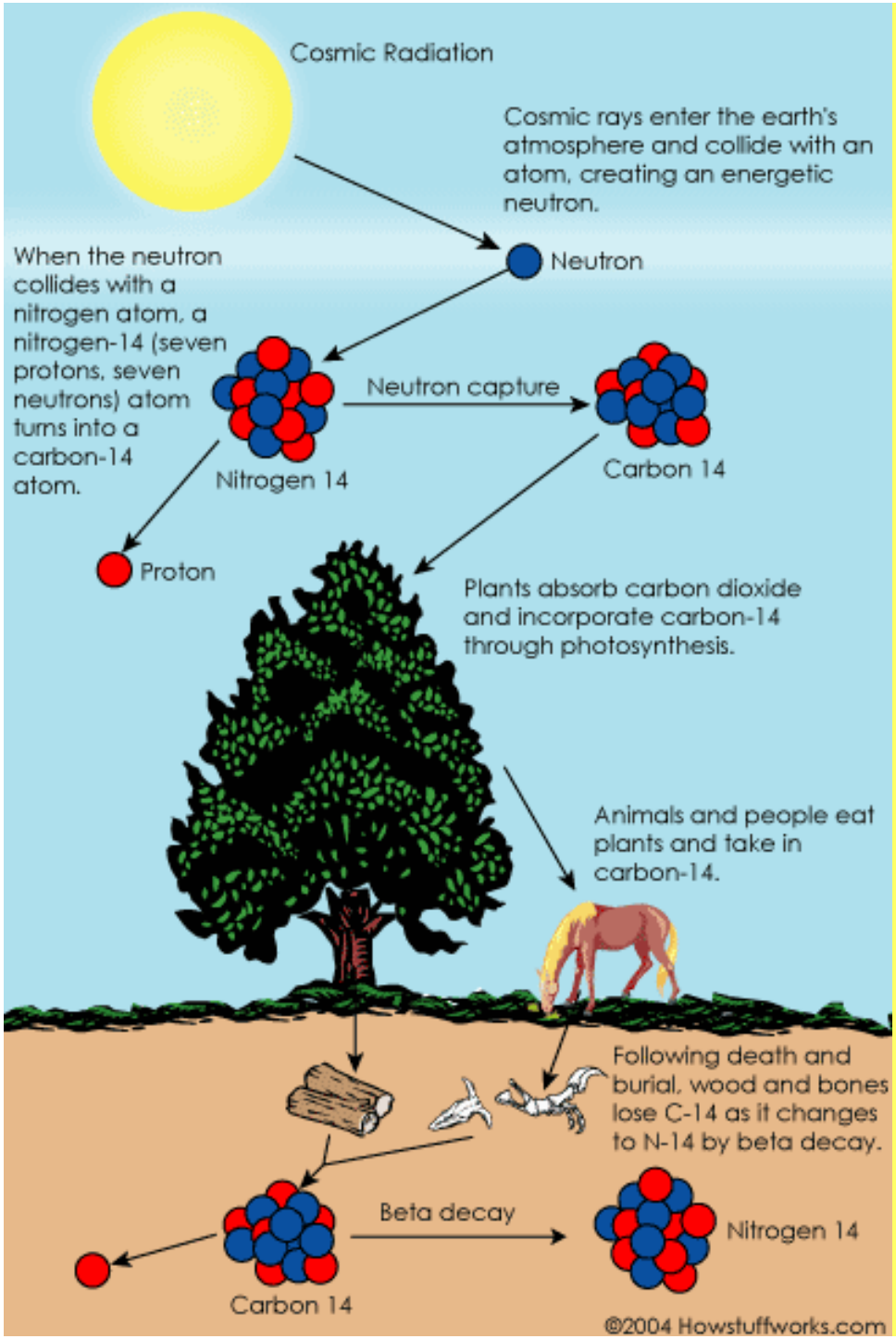
The present large-scale ocean current system determines climate to a great extent. The huge "conveyor belt" reacts extremely sensitively to global temperature changes accompanying each increase and decrease in the content of carbon dioxide in the atmosphere. - Broecker

- Because it is driven by differences in temperature and salinity, this is termed the thermohaline circulation

Radiocarbon Age of Deep Water



Ref: Broecker and Peng, *Tracers in the Sea* (1982), p. 269



How Carbon-14 is made

- ^{14}N: 7 p, 7 n
- ^{14}C: 6 p, 8 n

- C-14 production:

$$^{14}N + n \rightarrow {}^{14}C + p$$

- C-14 decay:

$$^{14}C \rightarrow {}^{14}N + e^-$$

(Beta decay)

http://science.howstuffworks.com/carbon-141.htm

Preview of global warming/effect on thermohaline circulation

- Question: Has the Atlantic Conveyor Belt ever shut down?
  - Answer: We think it did shut down for almost 1000 years at the end of the last Ice Age. This is called the Younger Dryas Period

- Question 2: Could this happen again in the relatively near future?
  - Answer: Maybe! Global warming causes increase in rainfall in the N. Atlantic $\Rightarrow$ surface water becomes fresher and, hence, less dense
  - This effect is augmented by runoff of glacial meltwater from Greenland
  - Thermohaline circulation shuts down about 75 years from now in some climate model simulations!