Geography of the world's oceans and major current systems

Lecture 2

WHY is the GEOMORPHOLOGY OF THE OCEAN FLOOR important?

(in the context of Oceanography)

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- Ocean circulation, tides, and mixing on regional and basin scales are heavily controlled by the topography of the ocean.
- The nature of the earth, its origin, and its characteristics have a profound effect on the properties and the composition of the biota that are contained in the ocean.
- The structure and distribution of sediments can be understood based on the geomorphology of the ocean floor. These sediments are important because they tell us about the geochemistry of the ocean floor. Also they can be used to reconstruct ocean circulation of the past and improve our understanding of the climate system.

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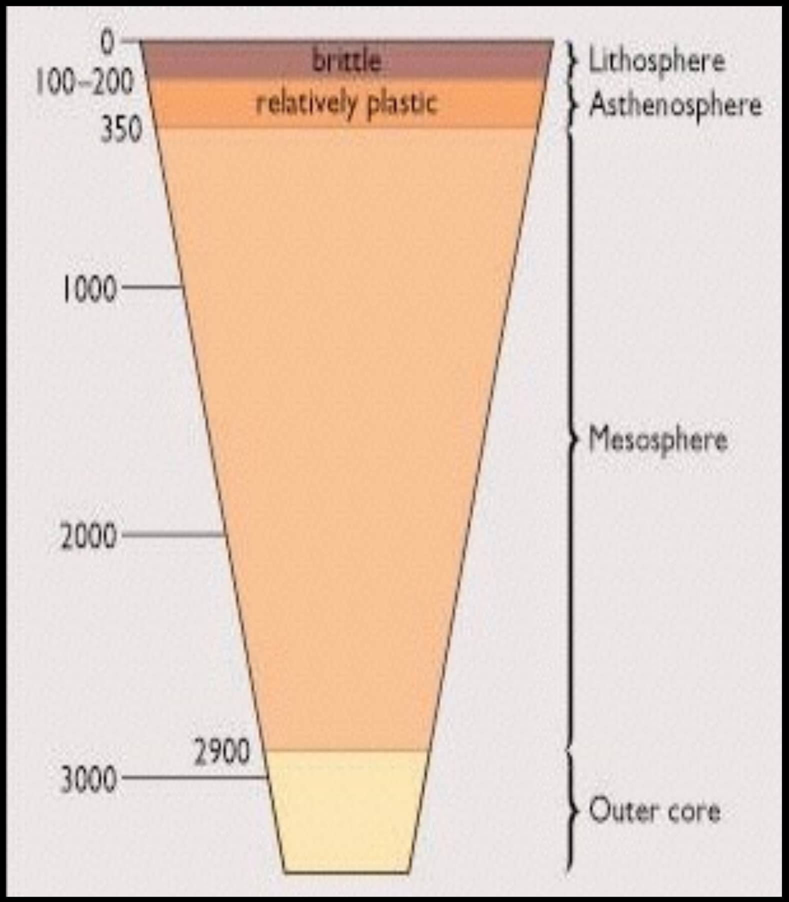
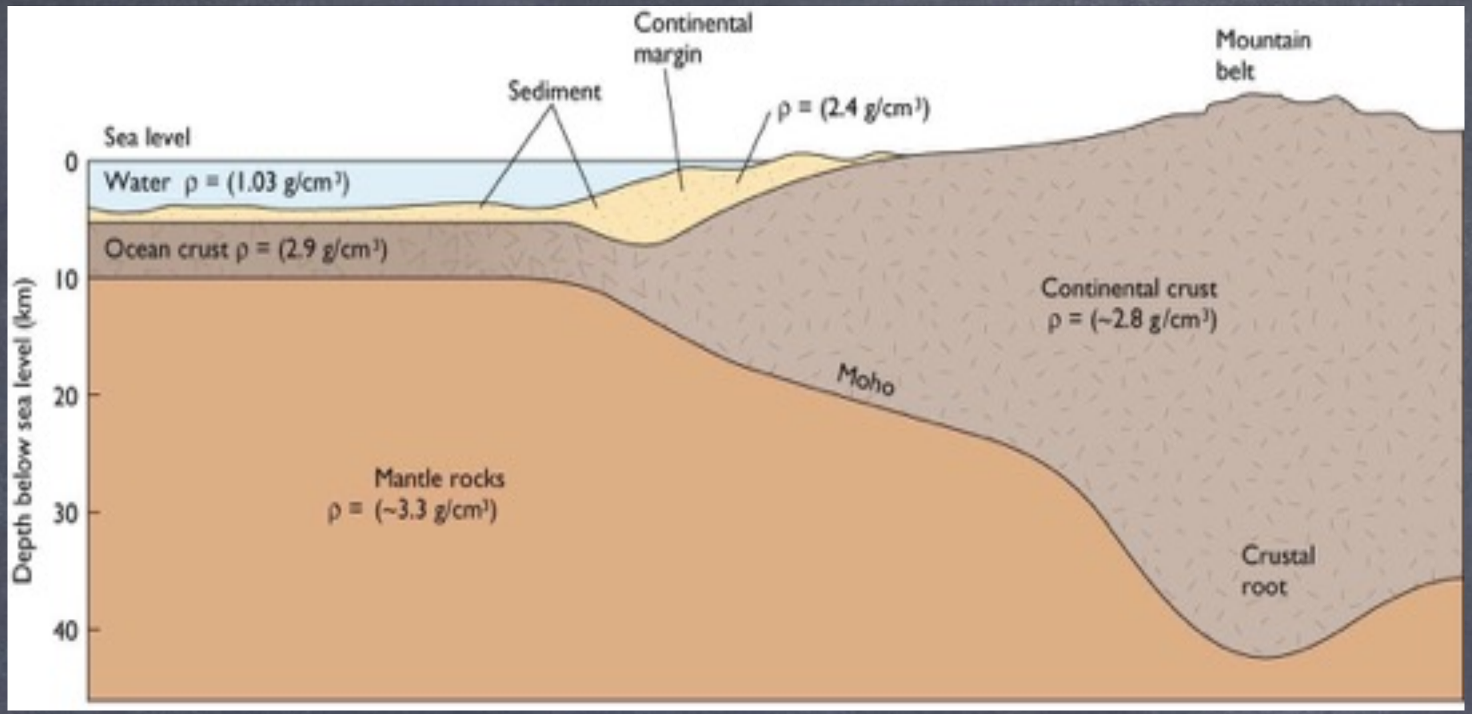
Divisions of the Earth based upon physical state are:

- Lithosphere or crust (hard rock: pressure effect dominates)
- Asthenosphere (mantle, <1% of rock melted, similar to tar or asphalt: temperature effect significant)
- Mesosphere (more rigid part of deeper Mantle: pressure effect dominates)
- Outer and inner core (molten and solid, both made up of iron and nickel alloy)



Geologic Differences between Continents and Ocean Basins



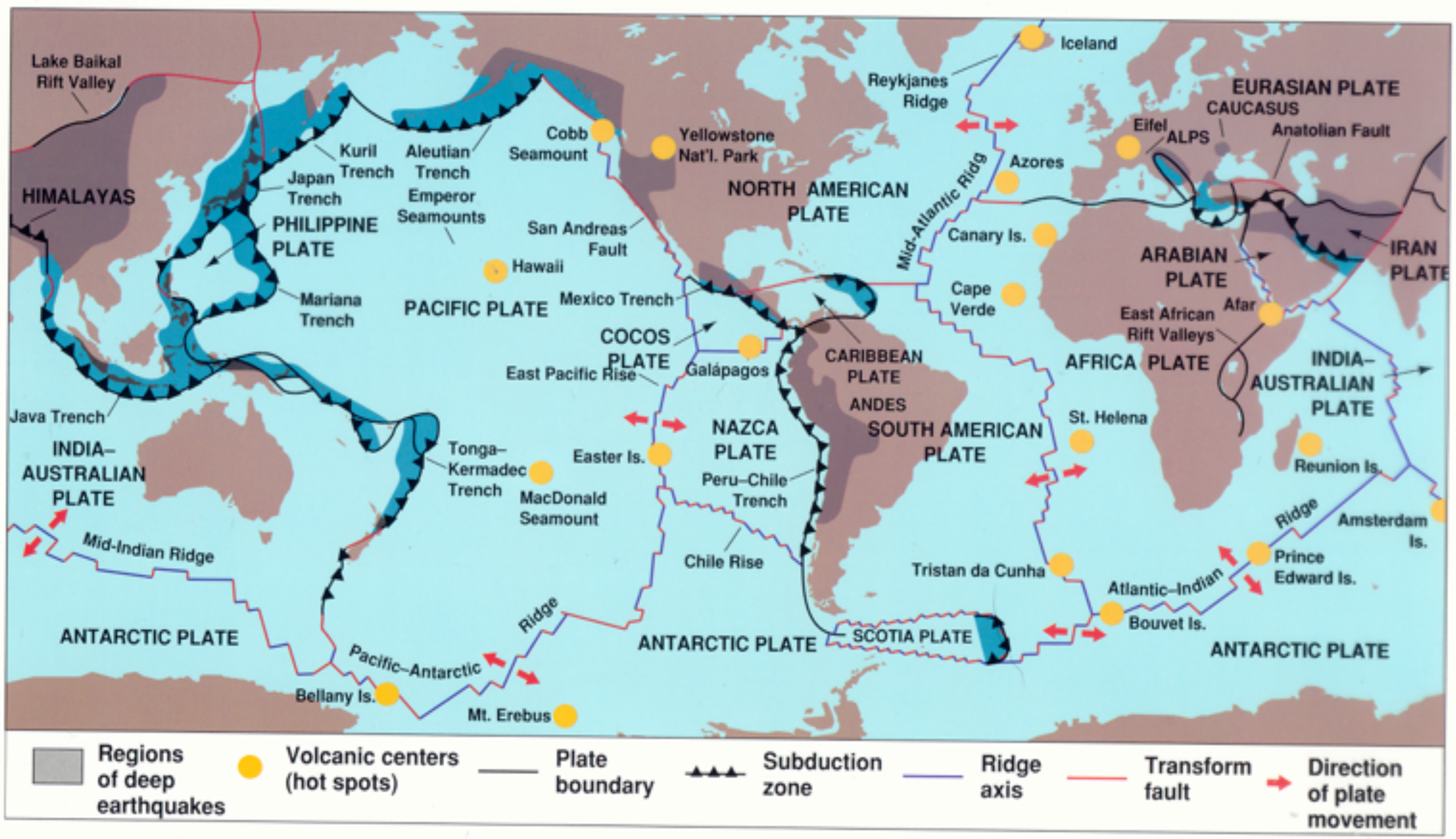
- Continental crust is mainly composed of granite, a light colored, lower density (2.8 gm/cm3) igneous rock rich in aluminum, silicon and oxygen.

- Oceanic crust is composed of basalt, a dark colored, higher density (2.9 gm/cm3) volcanic rock rich in silicon, oxygen and magnesium.

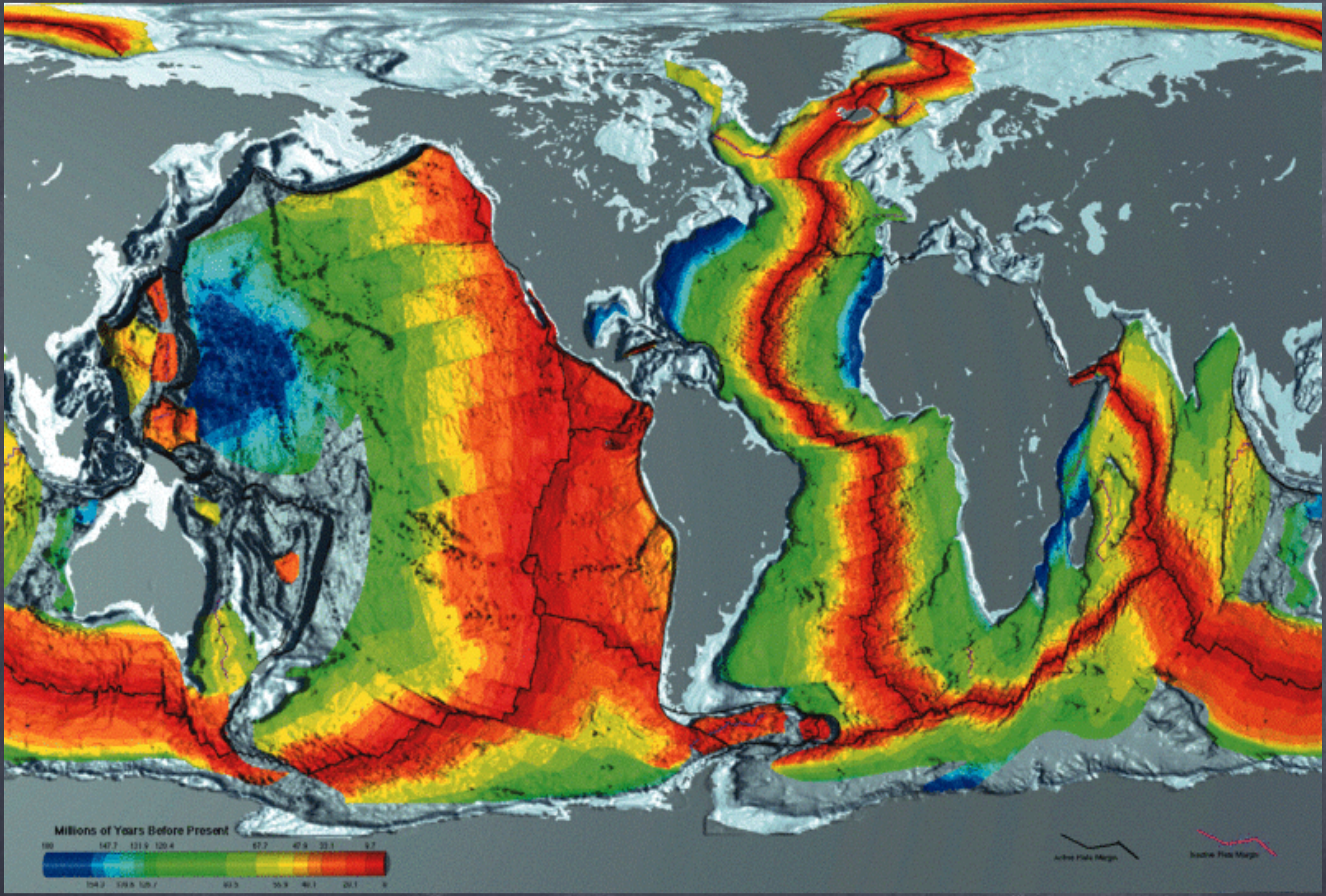
- Oceanic crust is thin and dense. Continental crust is thick and light.

Isostasy is a term used in Geology to refer to the state of gravitational equilibrium between the Earth's lithosphere and asthenosphere such that the tectonic plates (continental and ocean crusts) "float" at an elevation which depends on their thickness and density. (similar to ice floating in water).

In the 1960's there was a geological revolution: the realization that the surface of the earth is in motion, slowly recycling the material that makes up our environment and shapes the ocean basins and seafloors.



The major lithospheric plates



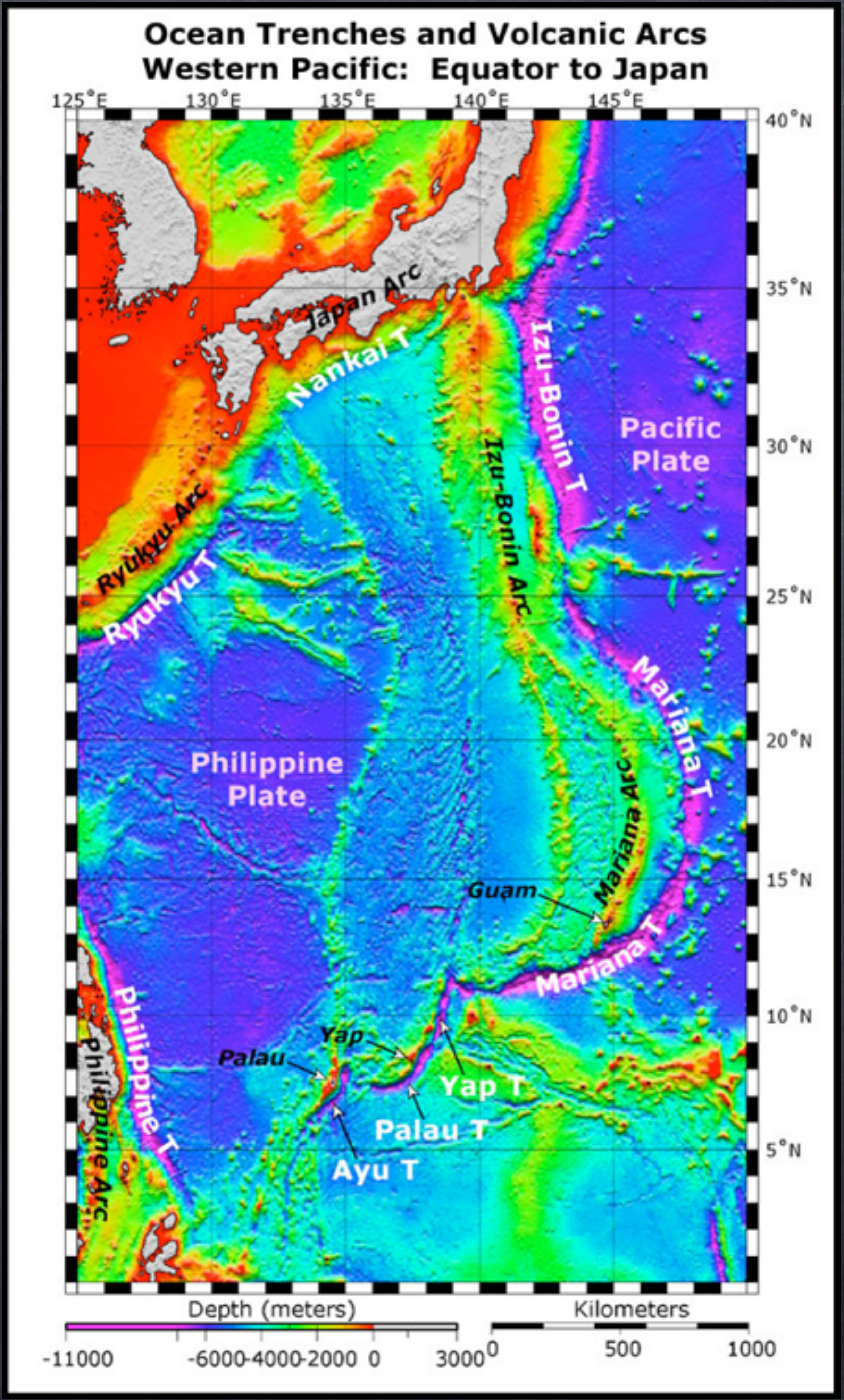
Age of oceanic crust.

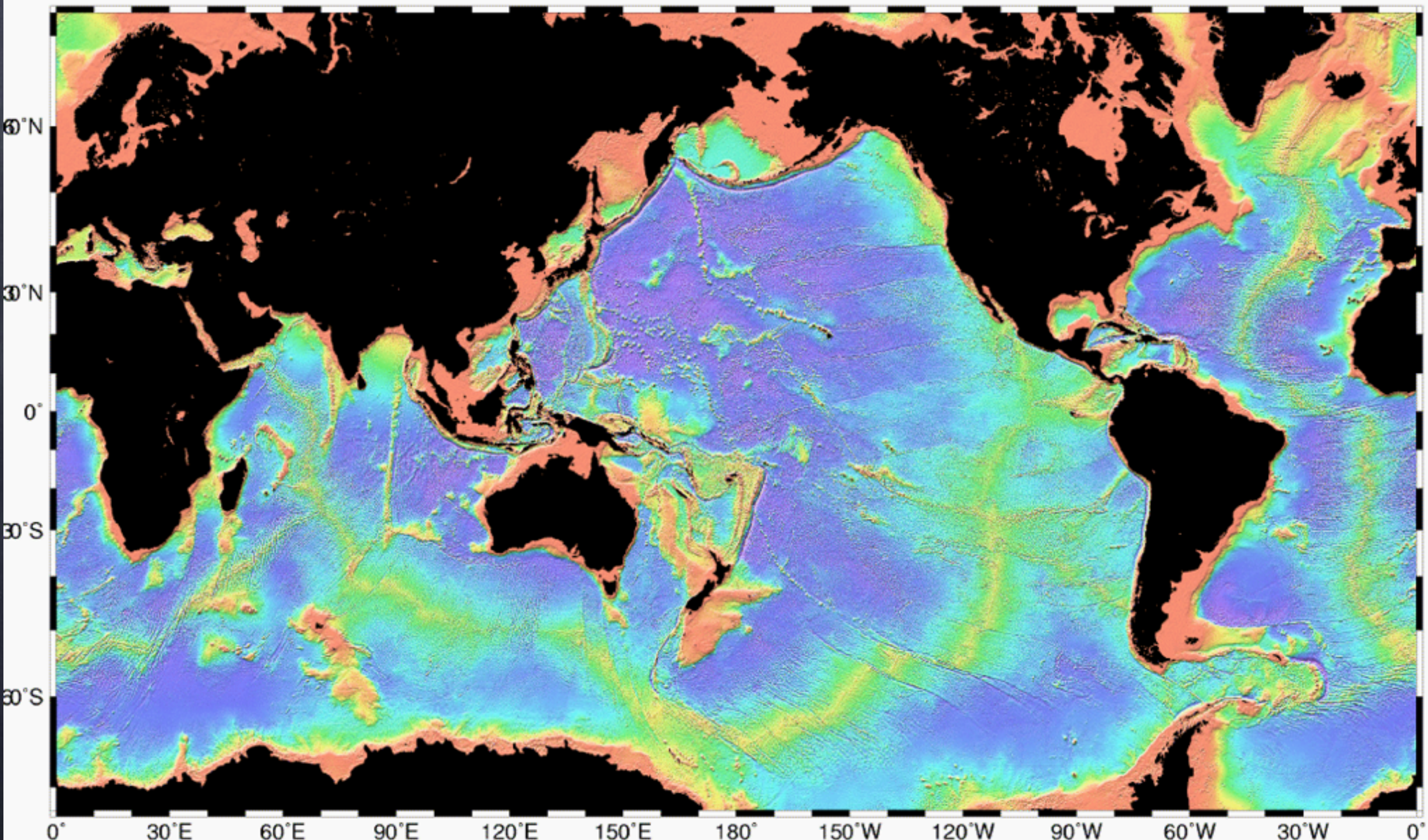
Youngest crust is along spreading centers (in red) - these are the mid-ocean ridges

Satellite altimetry data of the western Pacific from the equator to Japan. Submarine trenches are magenta. Volcanic Arcs are indicated by italicized text.

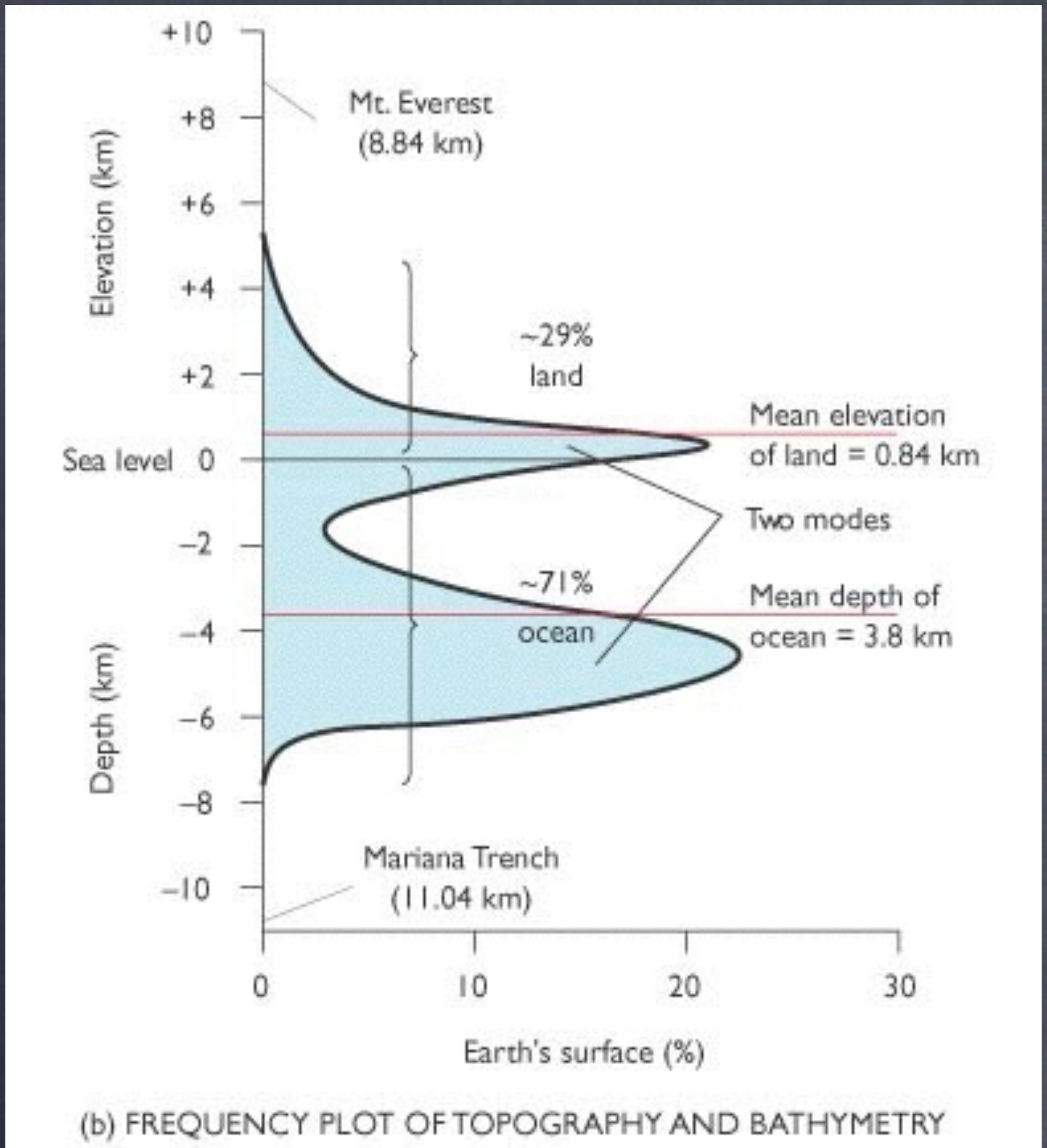
In the western Pacific the volcanic arcs (island and submarine) are west of the **deep ocean trenches**, due to the western migration and subduction of the Pacific plate under the Philippine plate. Volcanic arcs form when the subducting plate melts at depth and magma is produced, which rises buoyantly and forms volcanic arc lavas.

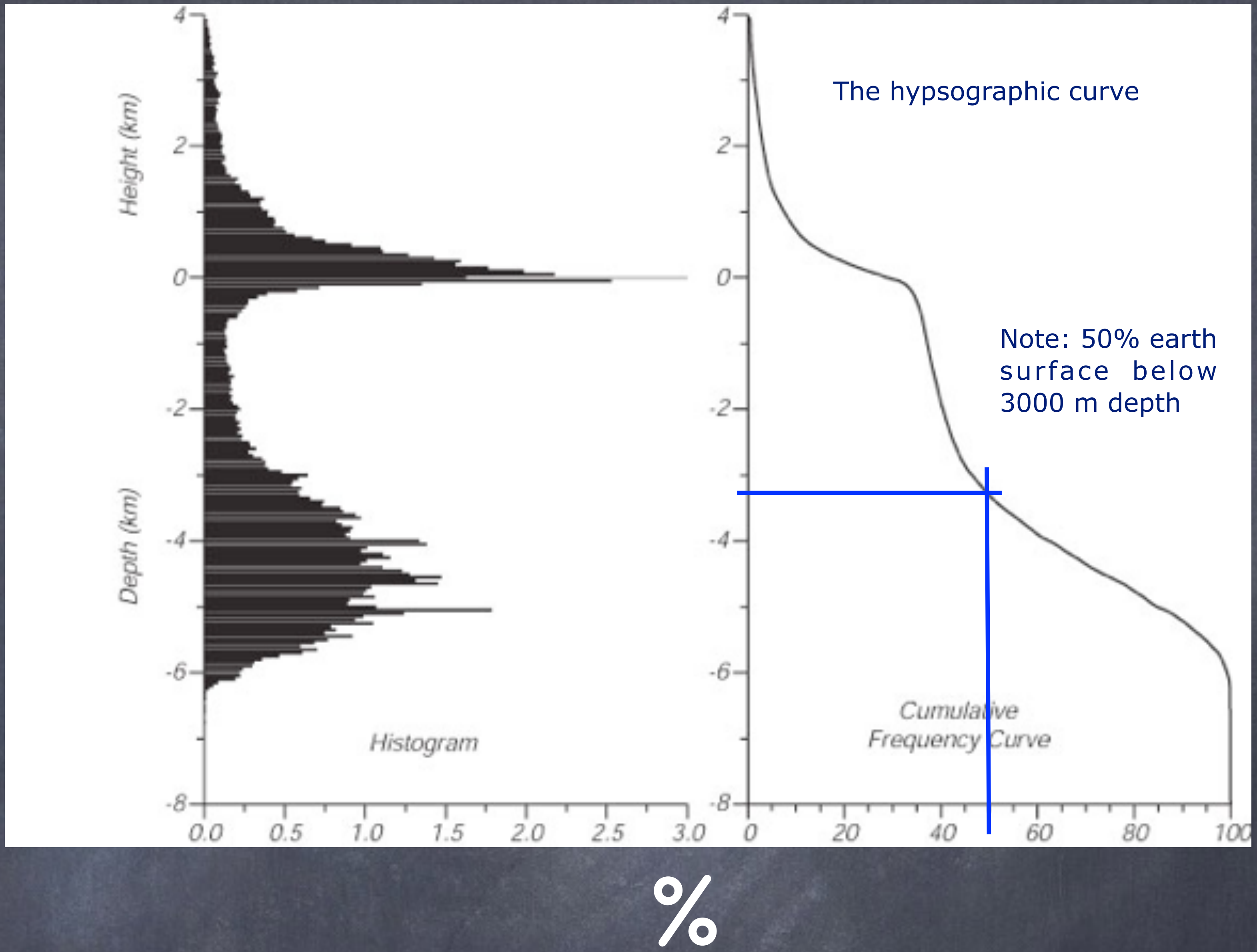
Satellite data courtesy of Smith and Sandwell, 1997. Image courtesy of the NOAA Vents Program.





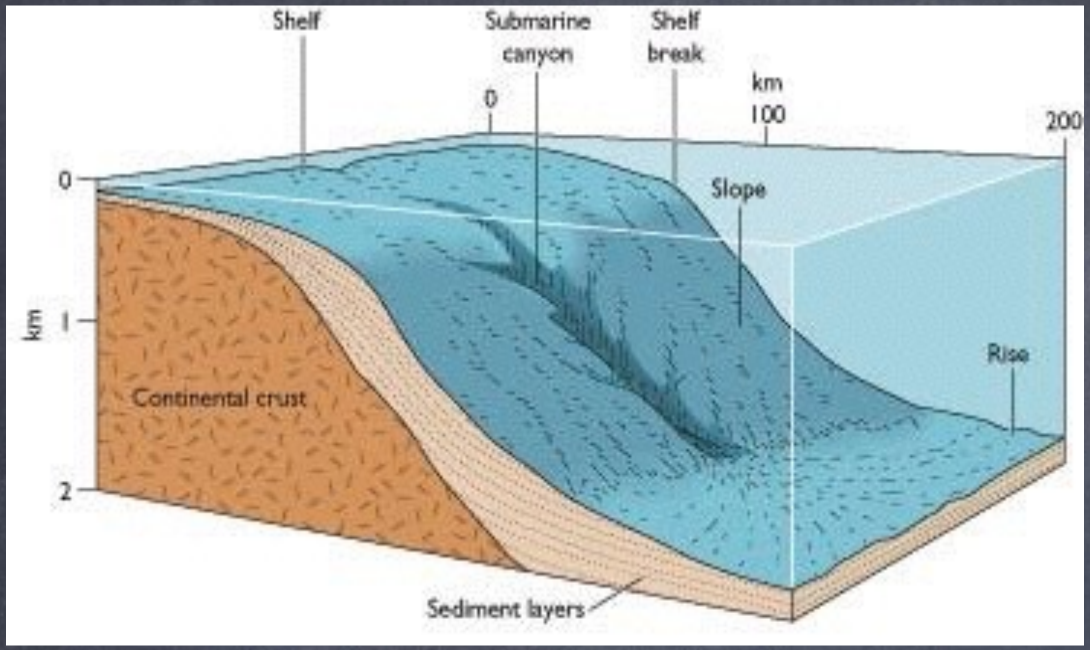
Walter H. F. Smith and David T. Sandwell, Seafloor Topography Version 4.0, SIO, September 26, 1996



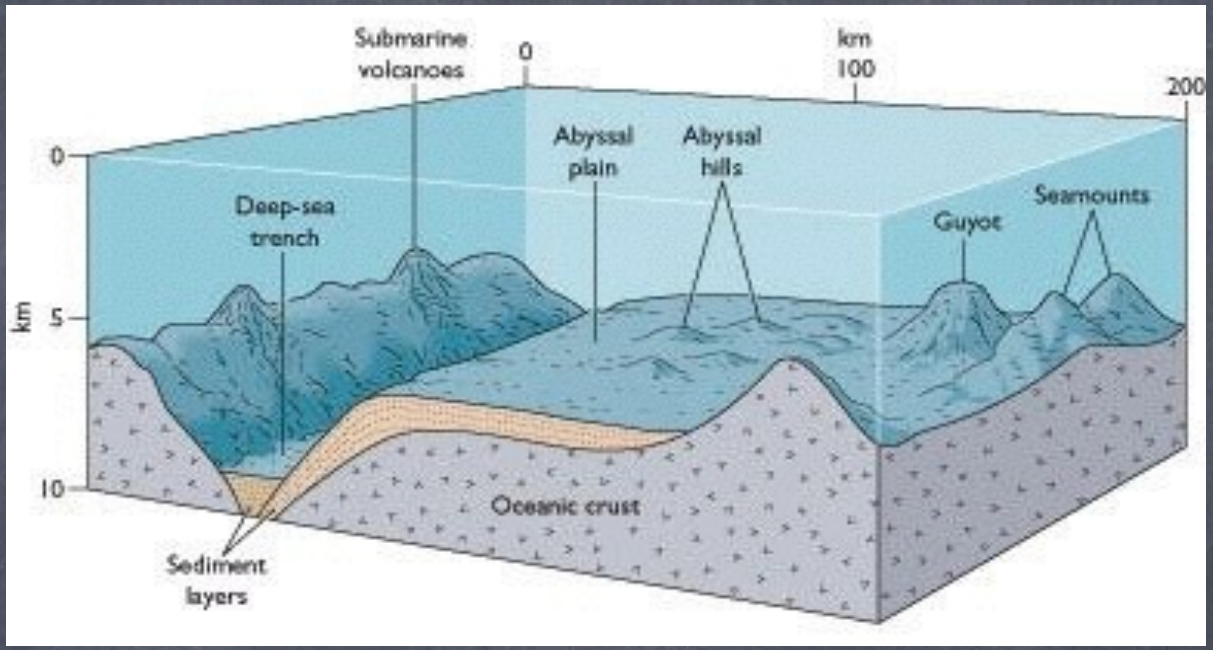


Elevation of Earth's surface displays a bimodal distribution with about 29% above sea level and much of the remainder at a depth of 4 to 5 kilometers below sea level.

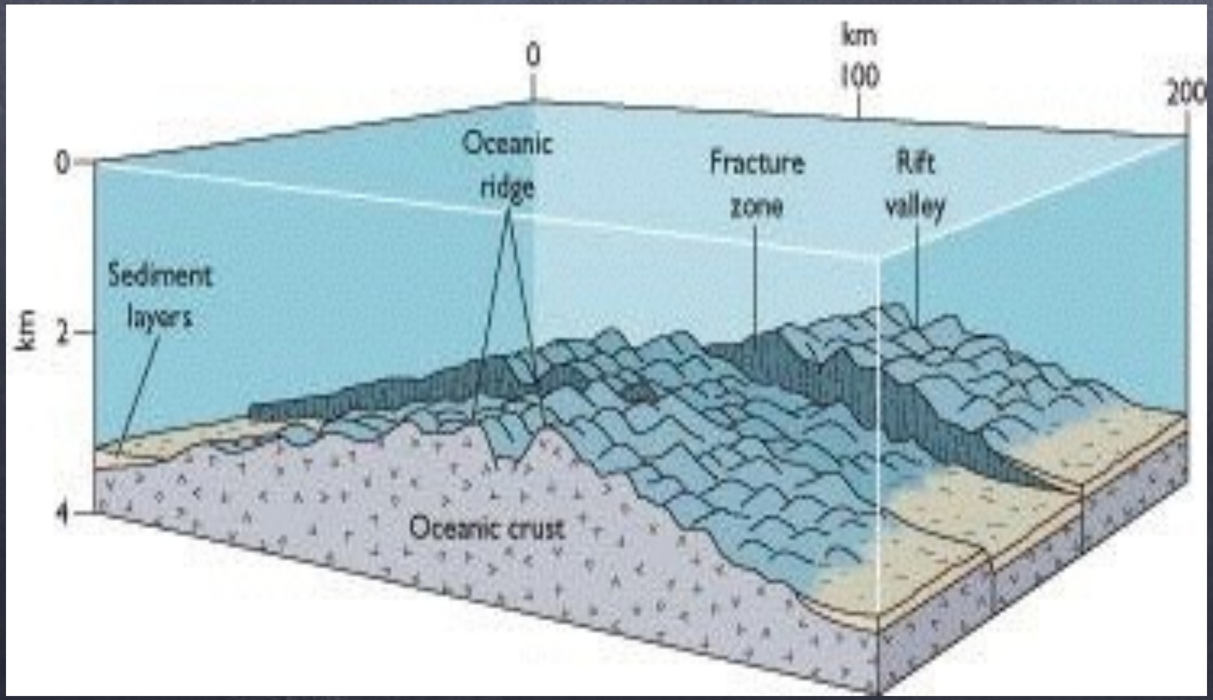
Continental margin

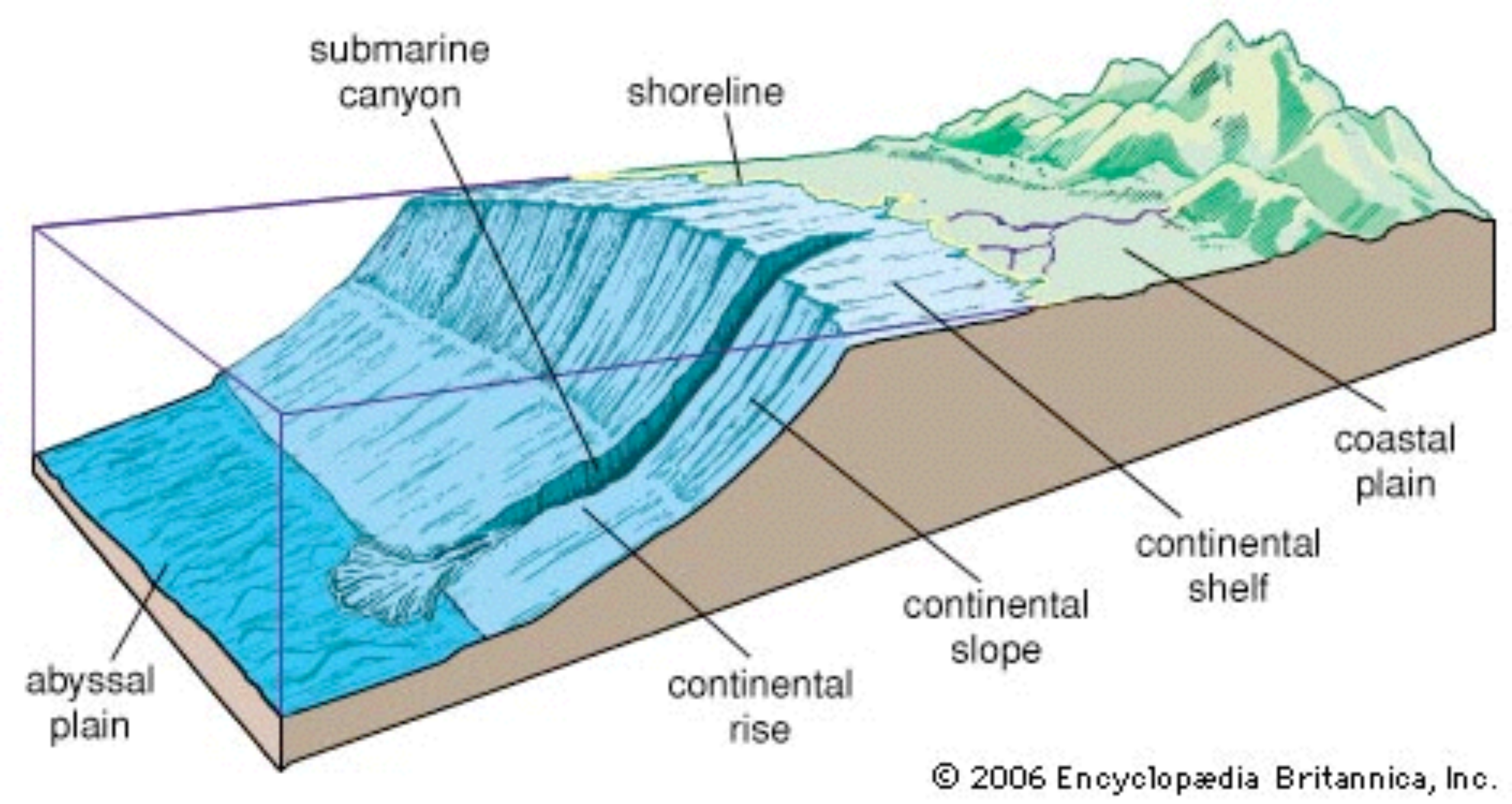


Ocean basin



Mid-ocean ridge



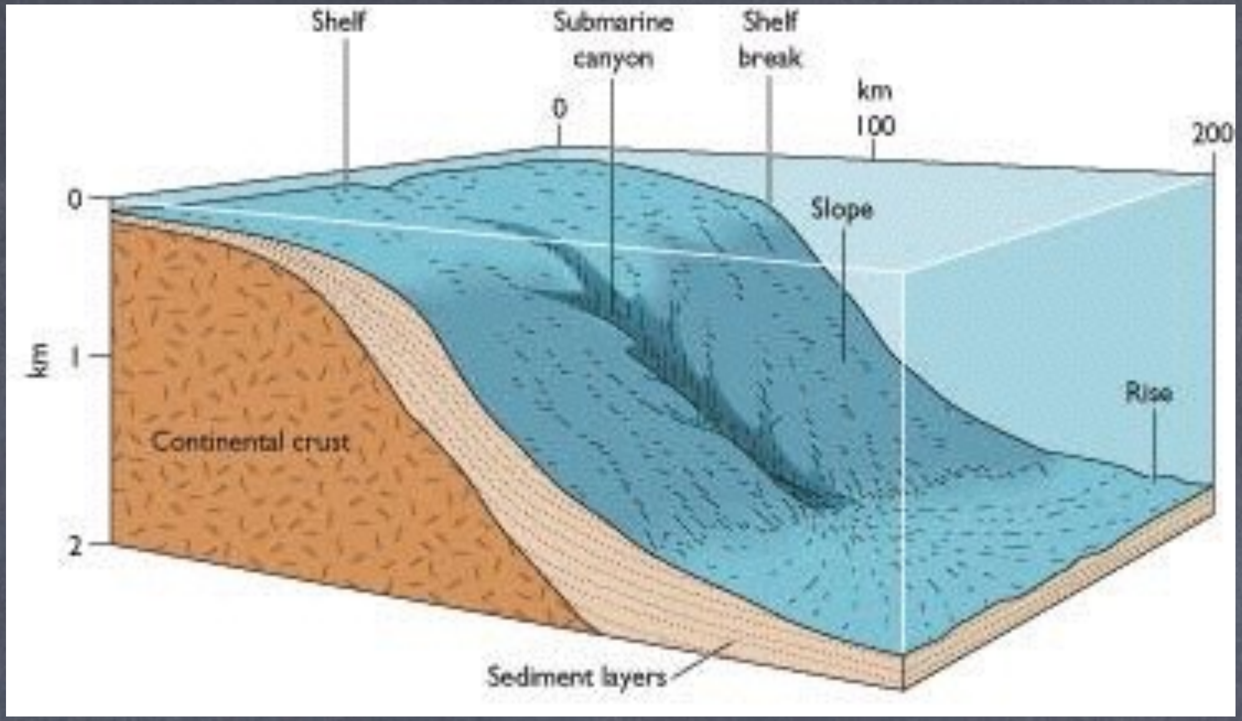


Continental margins are the submerged edges of the continents and consist of massive wedges of sediment eroded from the land and deposited along the continental edge. The continental margin can be divided into three parts:

Continental shelf,

Continental slope,

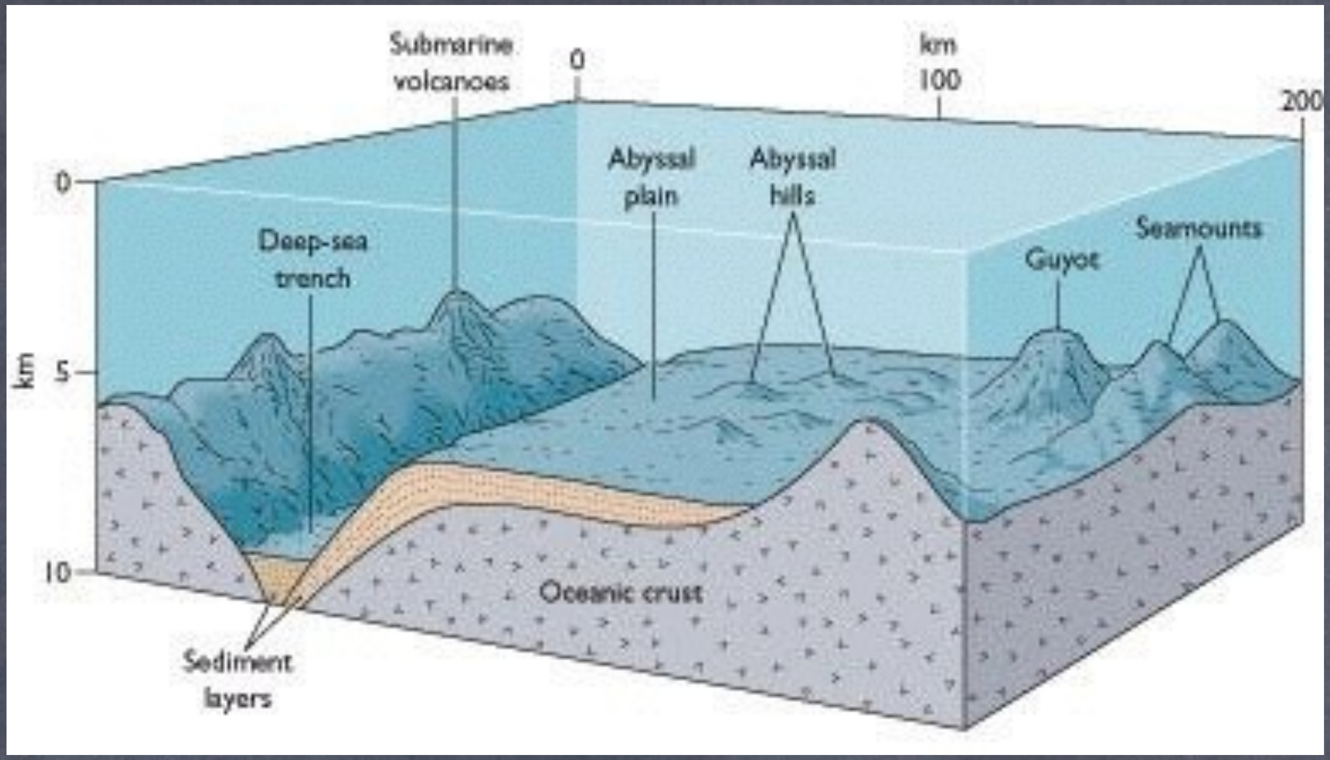
Continental rise.



Feature	Width	Water Depth	Bottom Gradient
Shelf	1-1000km	<150m	<1:1000 (~0.5°)
Slope	10-200km	100m to several km	~1:40 (4°-6°)
Rise	100-500km	3000-4000km	~1:700 (0.5°-1°)

20,000 years ago the continental shelves were above sea level.
Submarine canyons may have been carved by rivers or by gravity/turbidity currents.

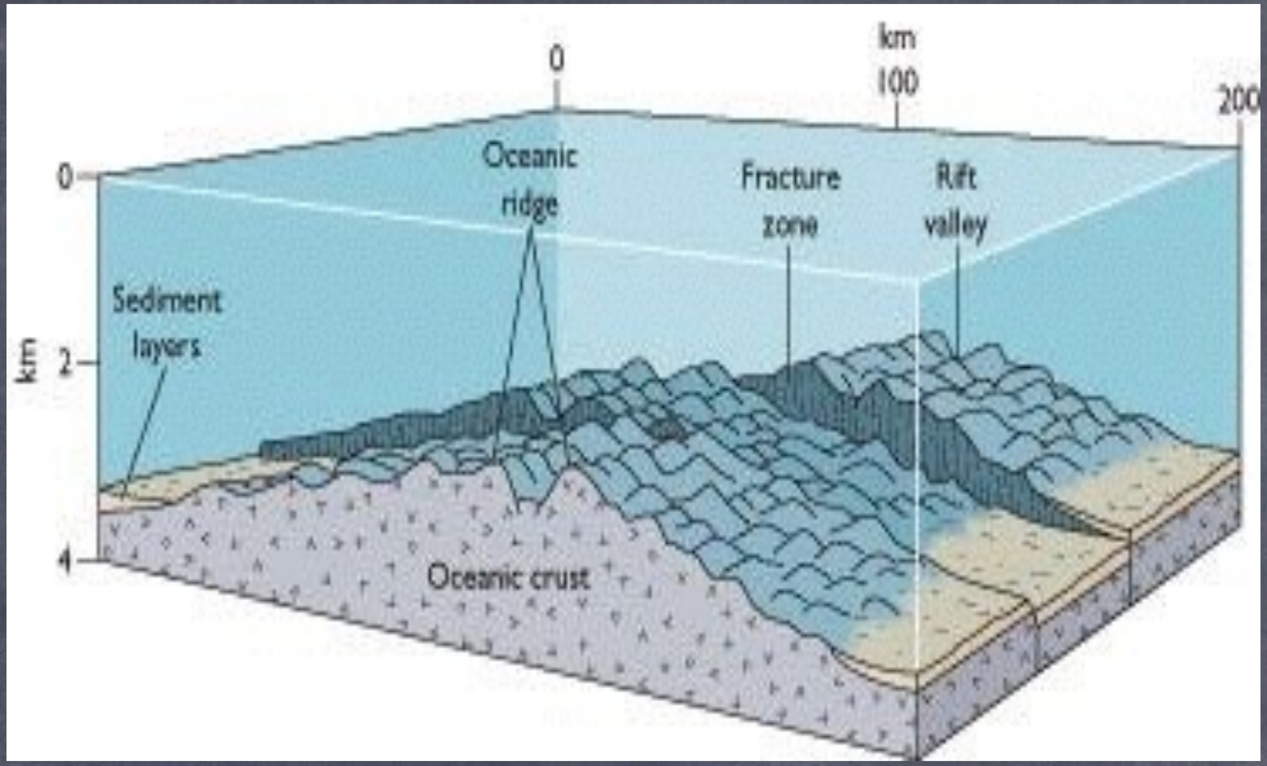
Ocean basin



Feature	Width	Water Depth	Bottom Gradient
Abyssal plains	1-1000km	> 3km	<1:1000 (<0.5°)
Abyssal hills	0.1-100km	variable	
Seamounts	2-100km	variable	
Deep-sea trench	30-100km	5-12km	

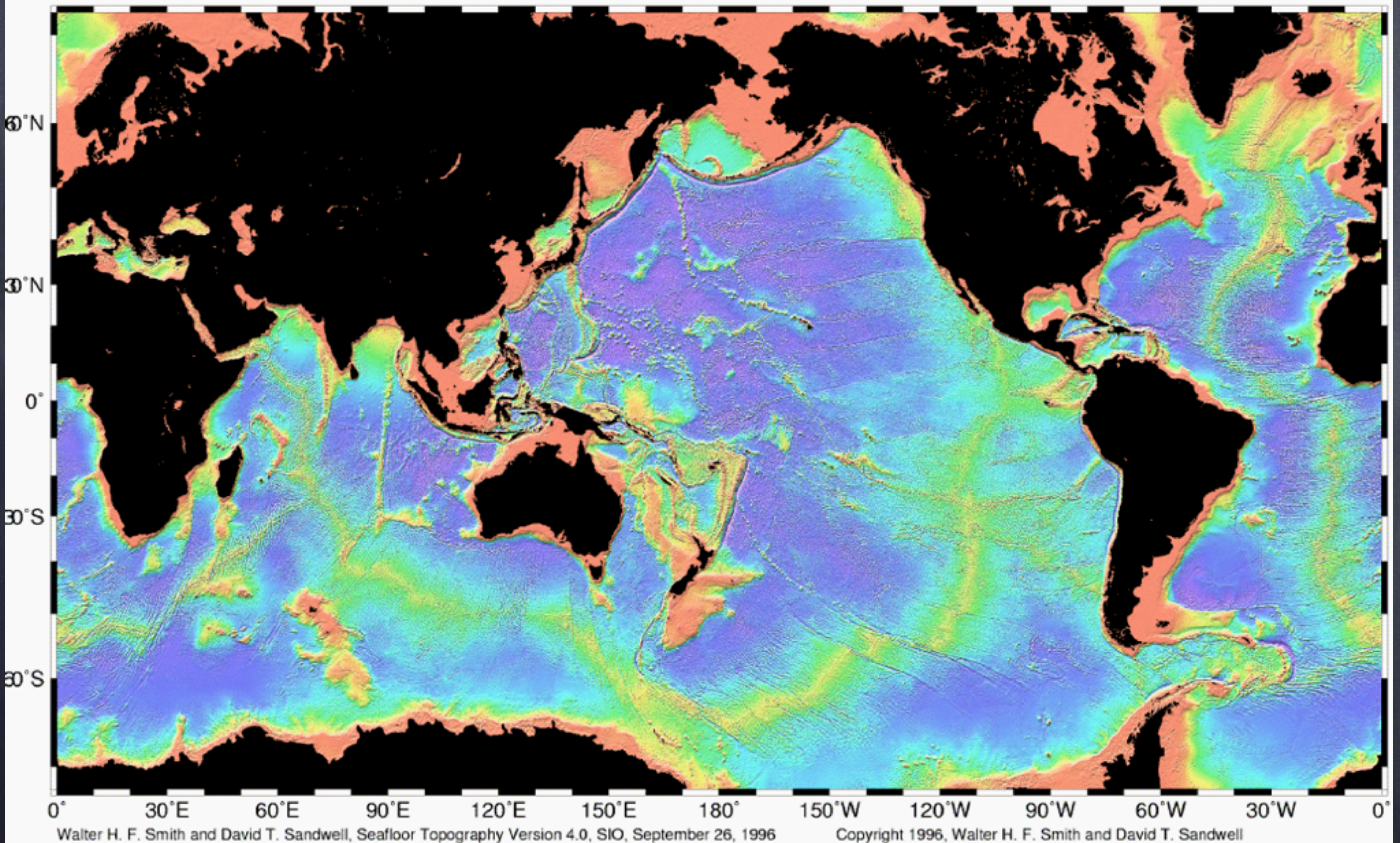
Seamounts can reach to within a few hundred meters of the surface and support vibrant ecosystems, fed by upwelling waters

Mid-ocean ridge



Feature	Width	Water Depth
Midocean ridge flanks	500-1500km	> 3km
Midocean ridge crest	500-1000km	2-4km

The mid-ocean ridge system is a continuous submarine mountain range covering about one third of the deep ocean and extending for 60,000 km around the Earth (almost 10X radius of earth).


60°N
30°N
0°
30°S
60°S
0°
30°E
60°E
90°E
120°E
150°E
180°
150°W
120°W
90°W
60°W
30°W
0°
Walter H. F. Smith and David T. Sandwell, Seafloor Topography Version 4.0, SIO, September 26, 1996
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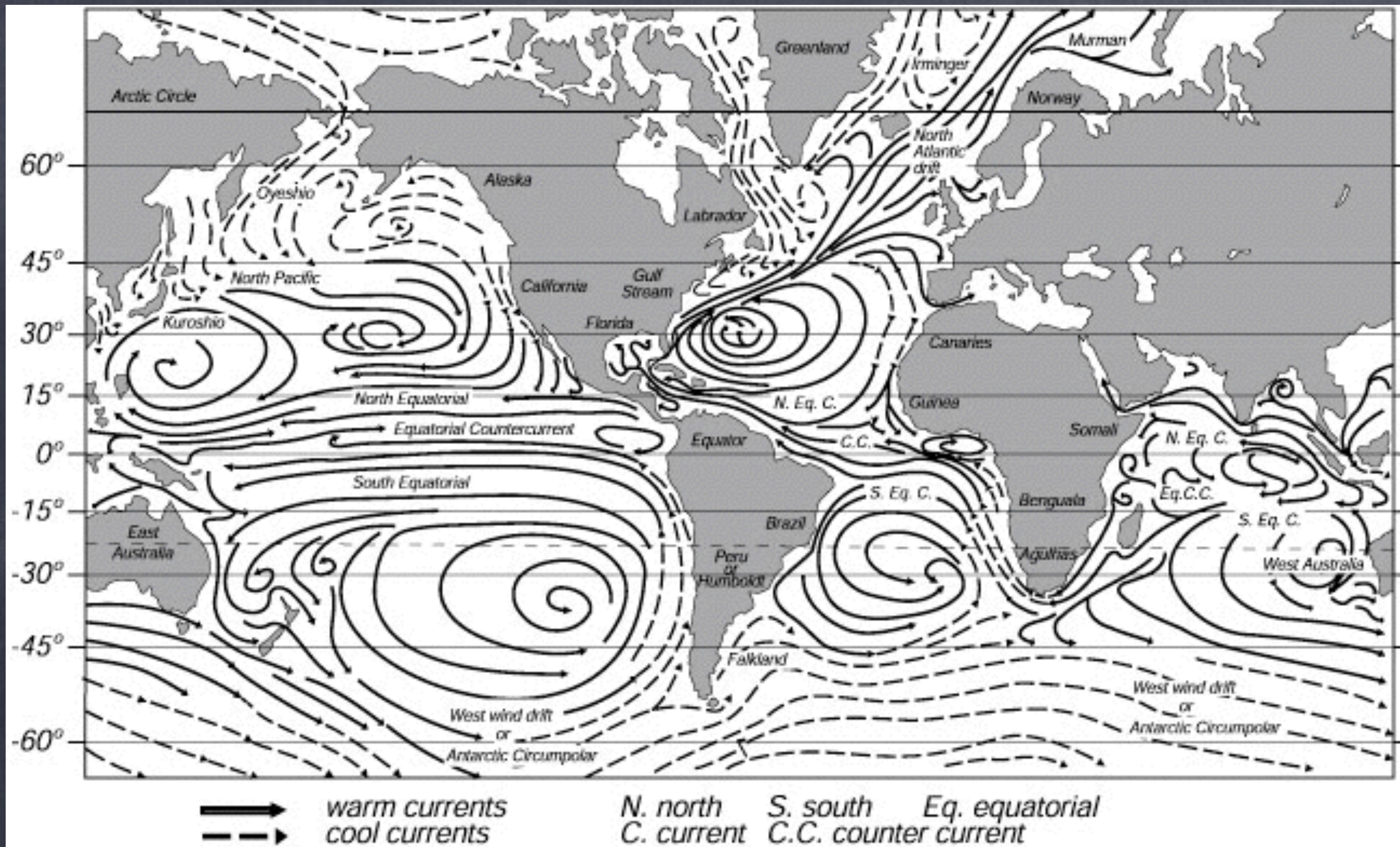
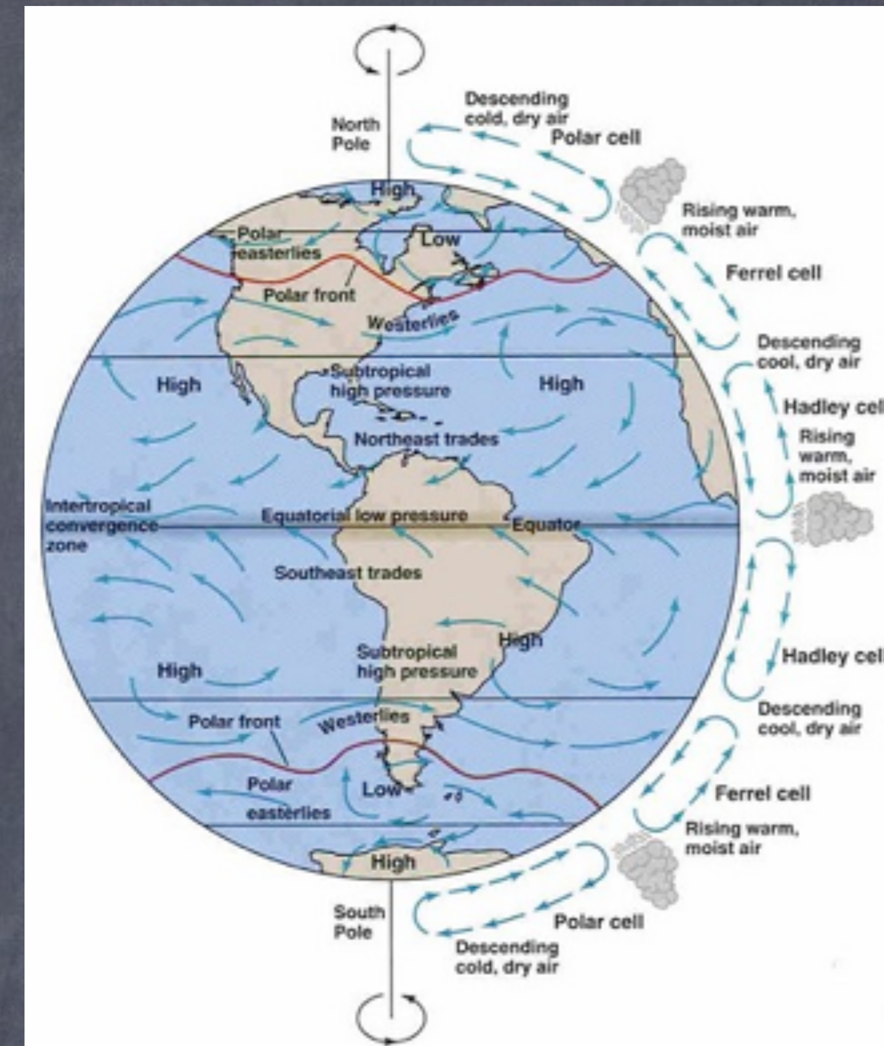
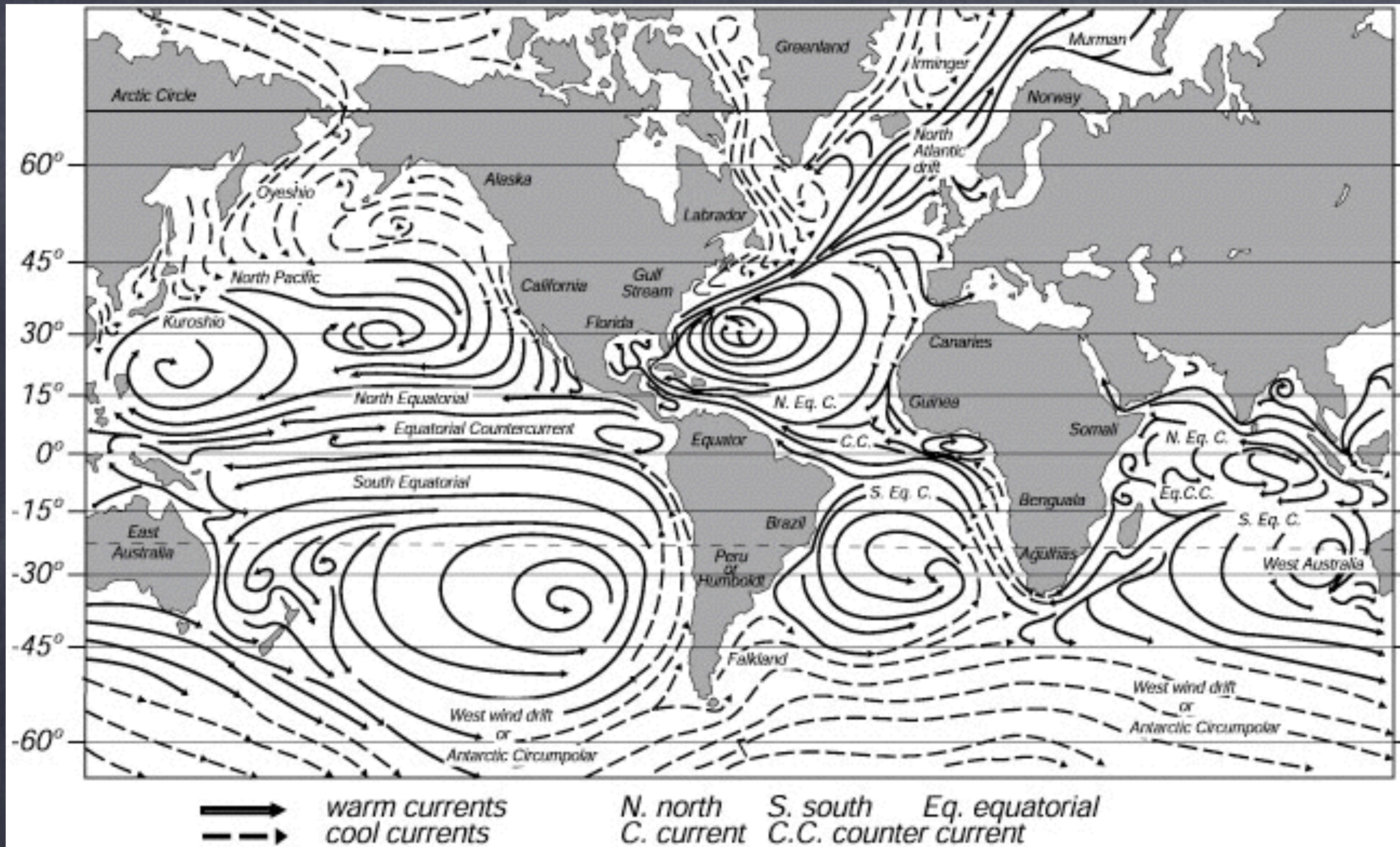
Major current systems

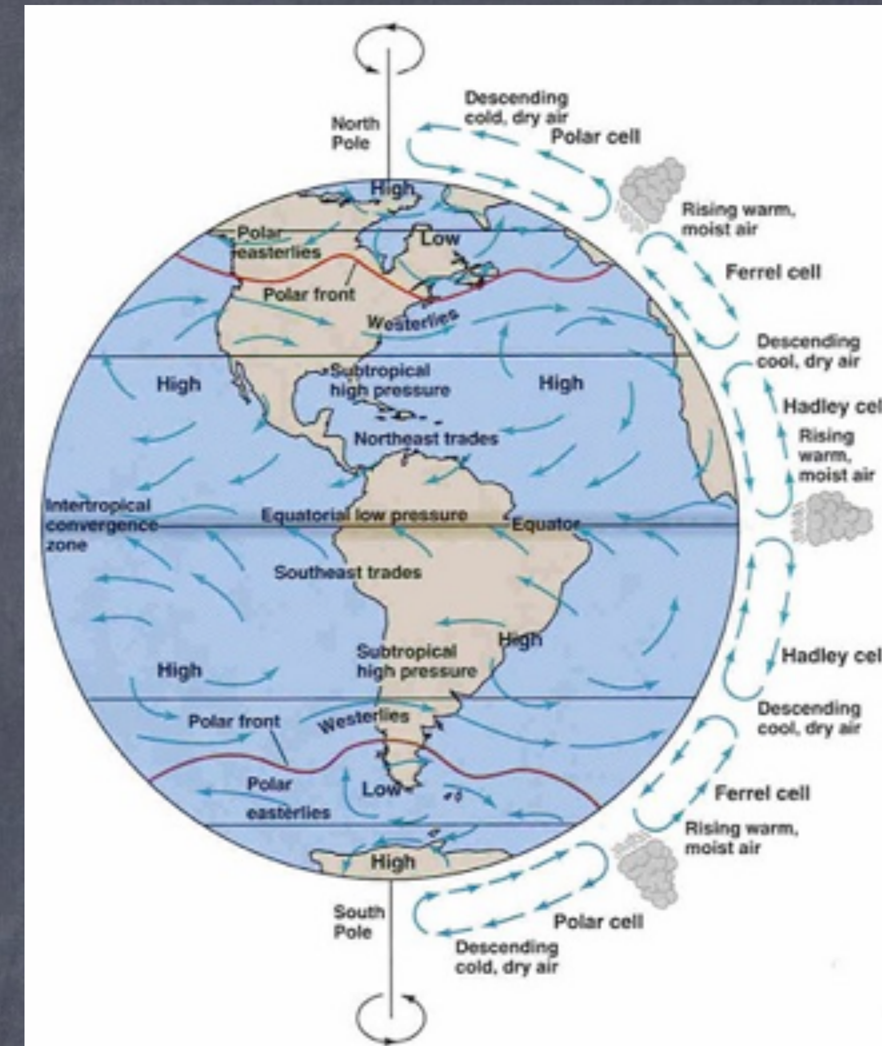
You see gyres separated by zonal flow at equator



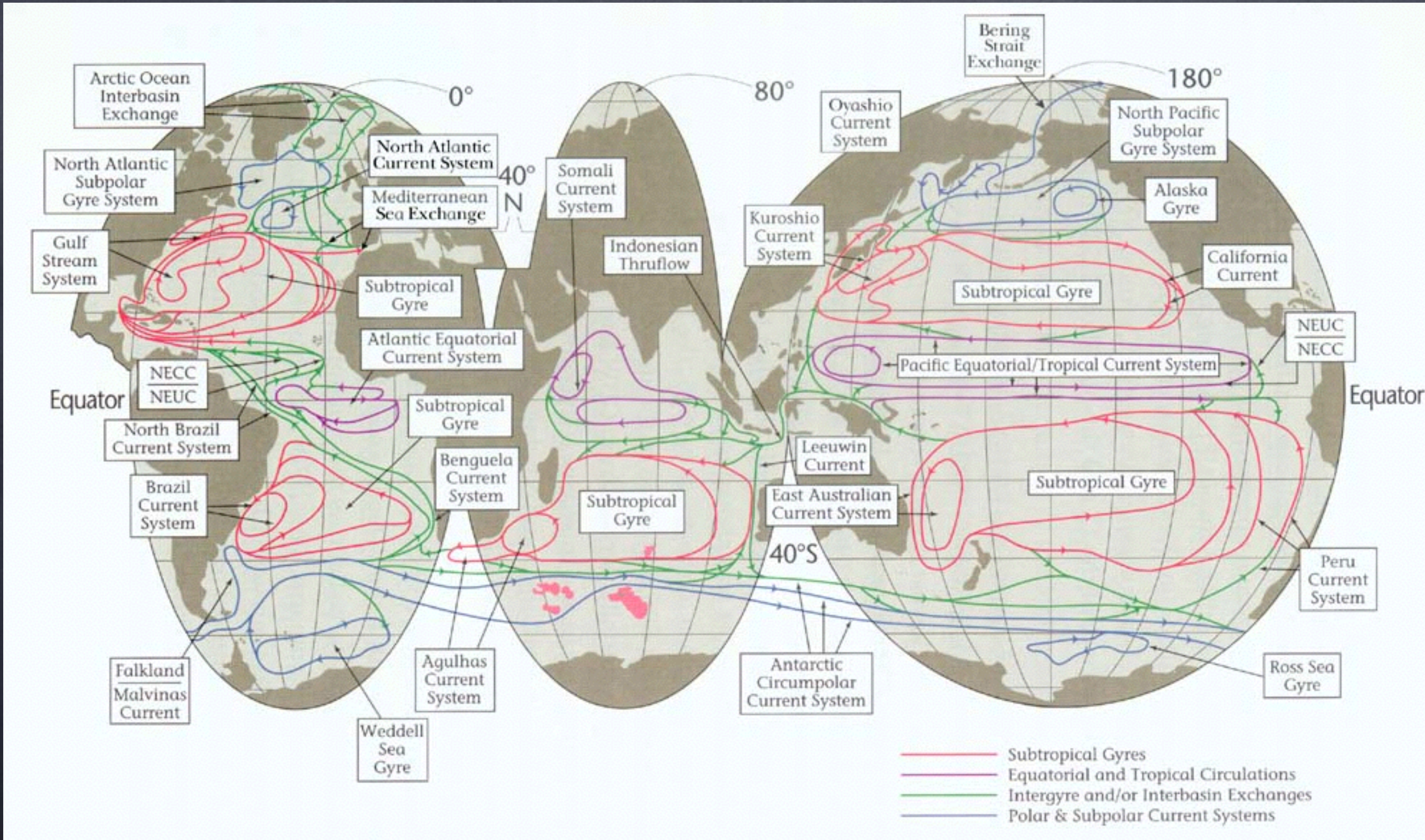


Now see gyres offset to west and zonal currents and countercurrents on equator, plus subpolar gyres in northern hemisphere, and north-south excursion of ACC in Southern Ocean

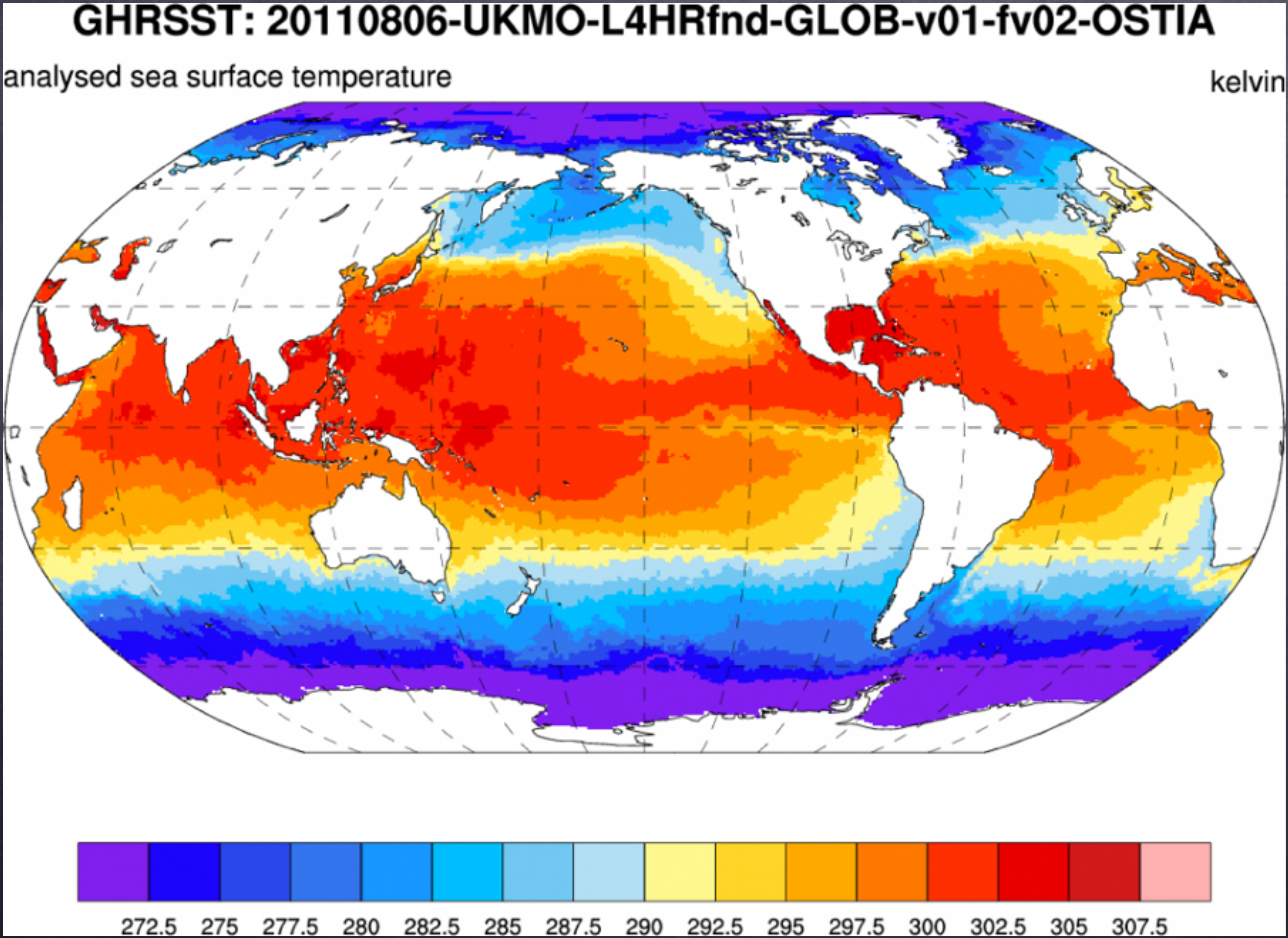




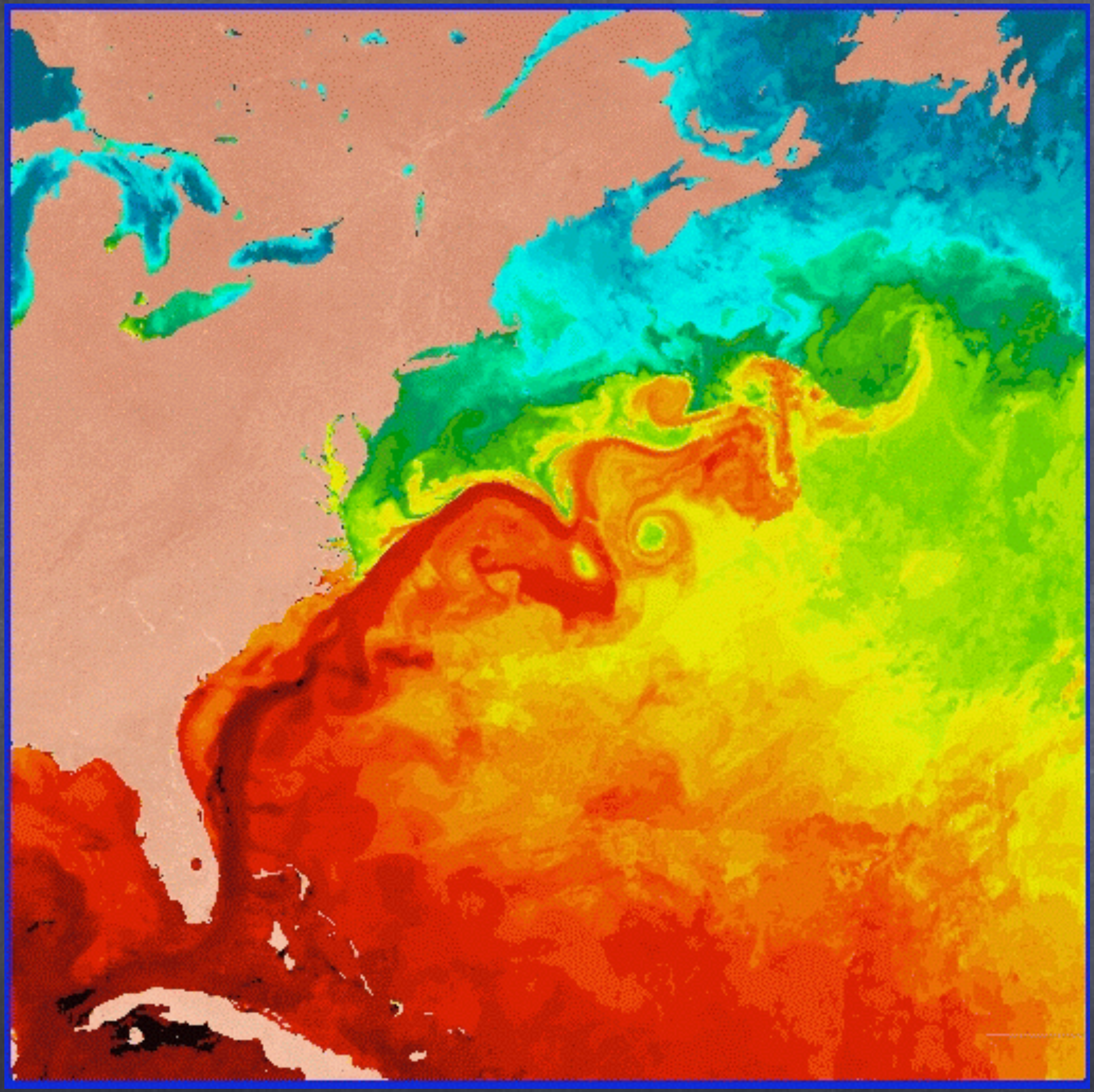
Wind systems look somewhat similar to ocean gyres, but not asymmetric... and ECC in opposite direction!
Notice: subtropical gyre centers at latitude 30 - where air descends (high P). Gyre boundaries at 45 - rising air (low P)

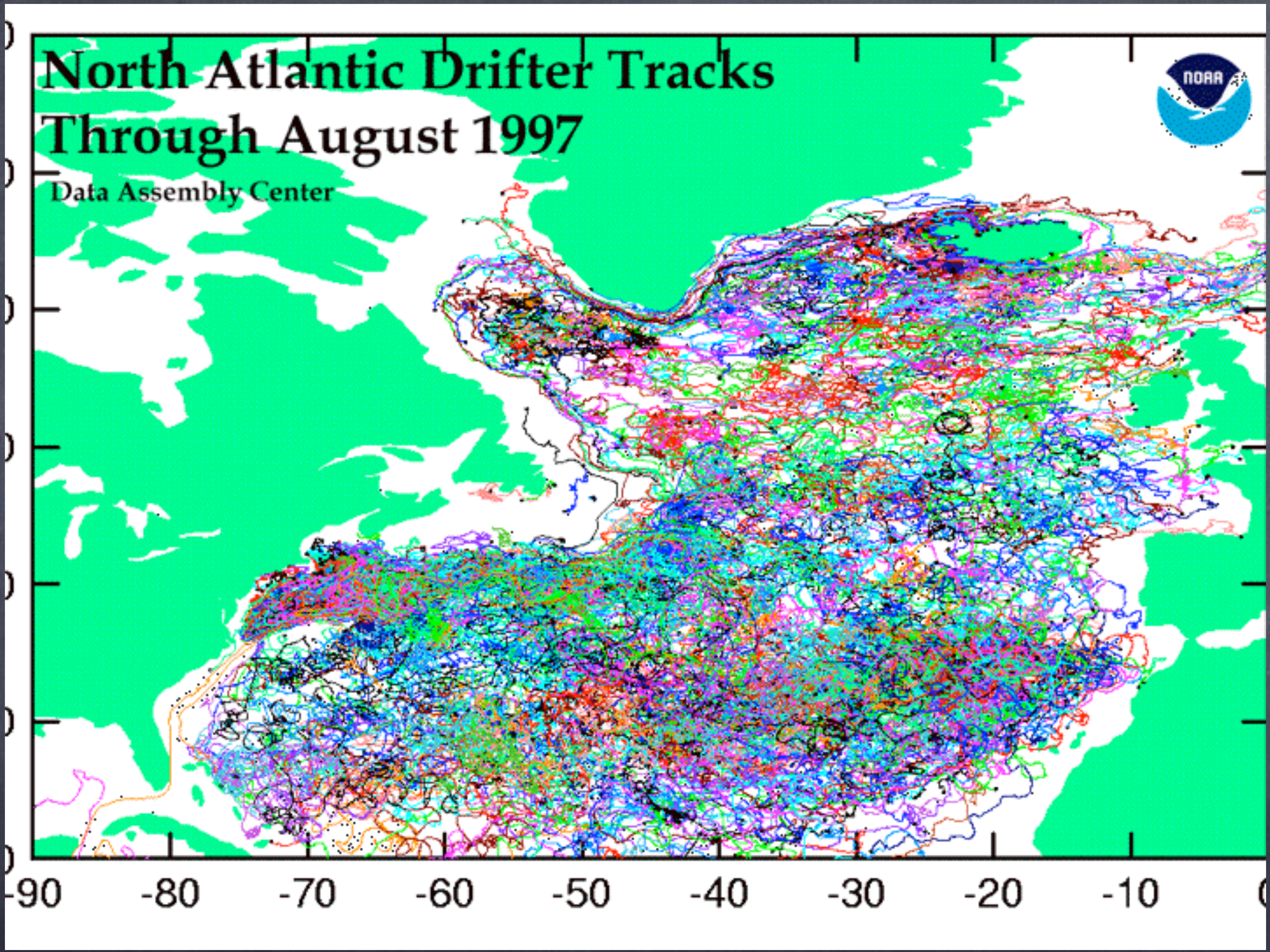

Arctic Ocean Interbasin Exchange
North Atlantic Subpolar Gyre System
North Atlantic Current System
Mediterranean Sea Exchange
Gulf Stream System
Subtropical Gyre
Atlantic Equatorial Current System
NECC
NEUC
Equator
North Brazil Current System
Subtropical Gyre
Benguela Current System
Brazil Current System
Falkland Malvinas Current
Weddell Sea Gyre
Agulhas Current System
0°
40° N
80°
Somali Current System
Indonesian Thruflow
Subtropical Gyre
Leeuwin Current
East Australian Current System
40°S
Antarctic Circumpolar Current System
Bering Strait Exchange
180°
Oyashio Current System
North Pacific Subpolar Gyre System
Alaska Gyre
Kuroshio Current System
Subtropical Gyre
California Current
NEUC
NECC
Pacific Equatorial/Tropical Current System
Equator
Subtropical Gyre
Peru Current System
Ross Sea Gyre
Subtropical Gyres
Equatorial and Tropical Circulations
Intergyre and/or Interbasin Exchanges
Polar & Subpolar Current Systems

Sea Surface Temperature

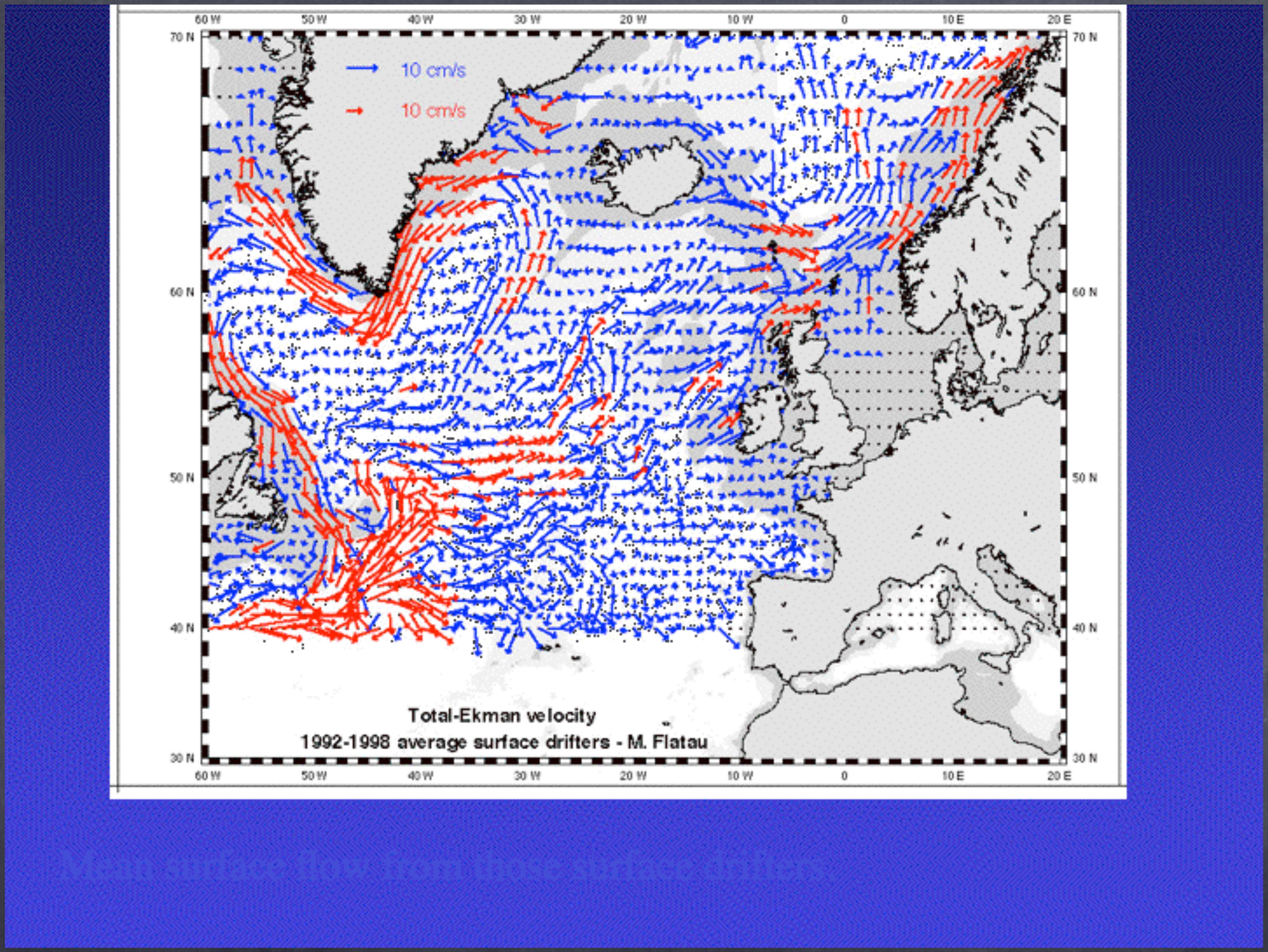


Sea Surface Temperature



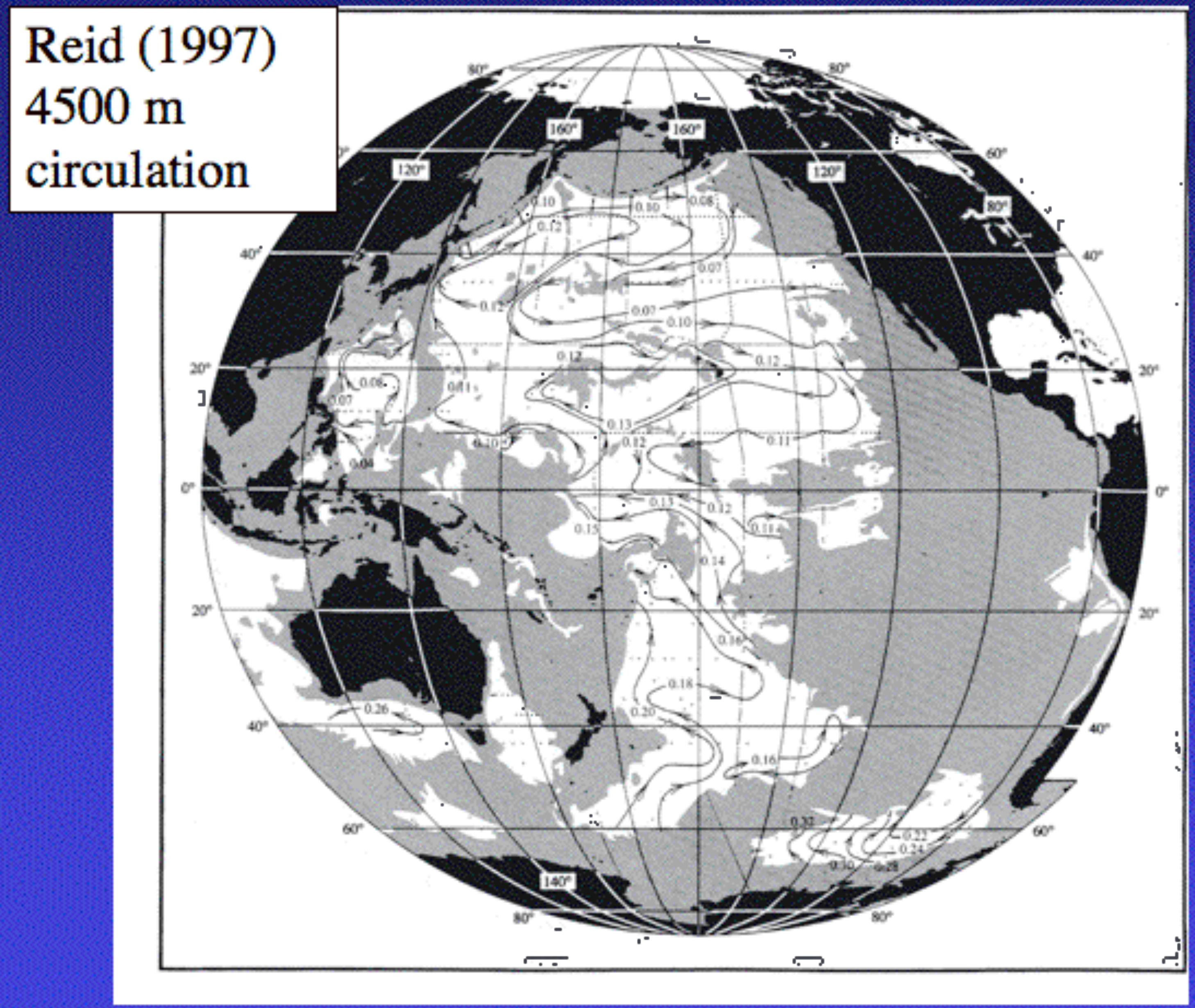


North Atlantic Drifter Tracks
Through August 1997
Data Assembly Center
NOAA
-90
-80
-70
-60
-50
-40
-30
-20
-10

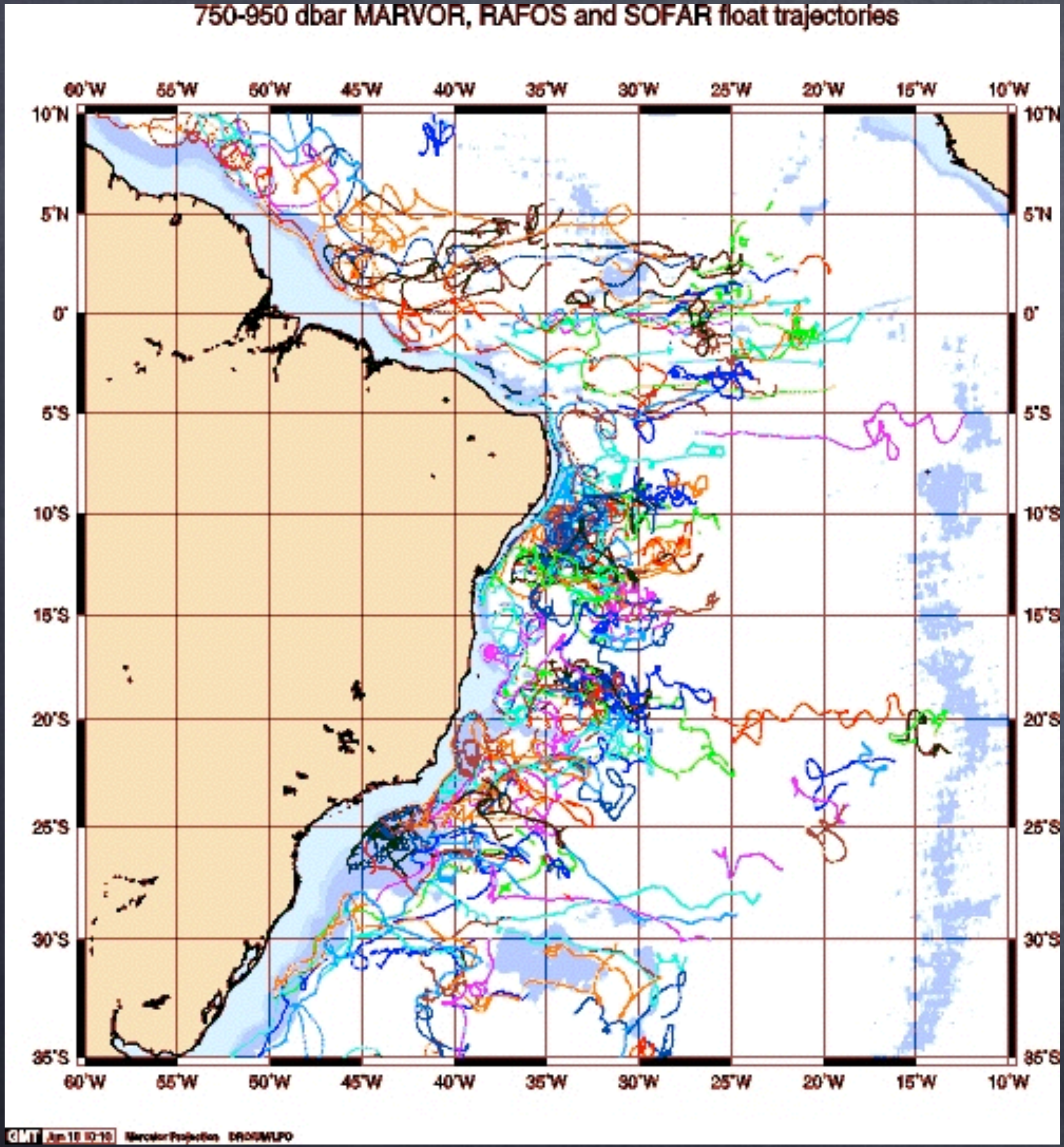


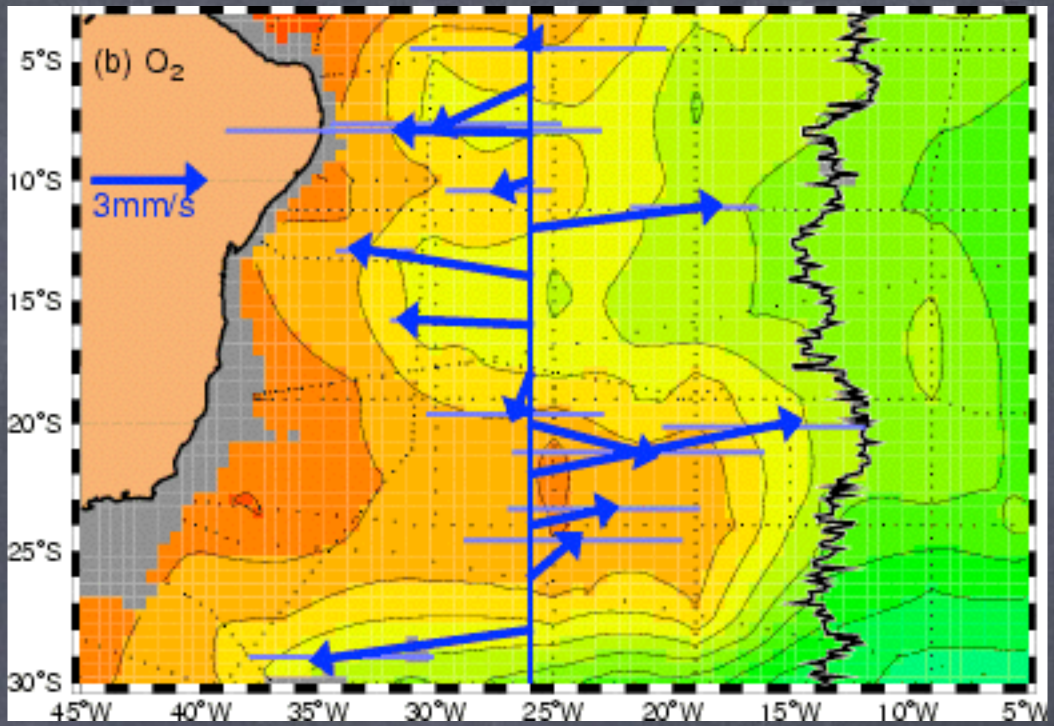
Drifter tracks averaged over six years

Pacific 4500 dbar circulation



Deep circulation steered by bathymetry of ocean floor

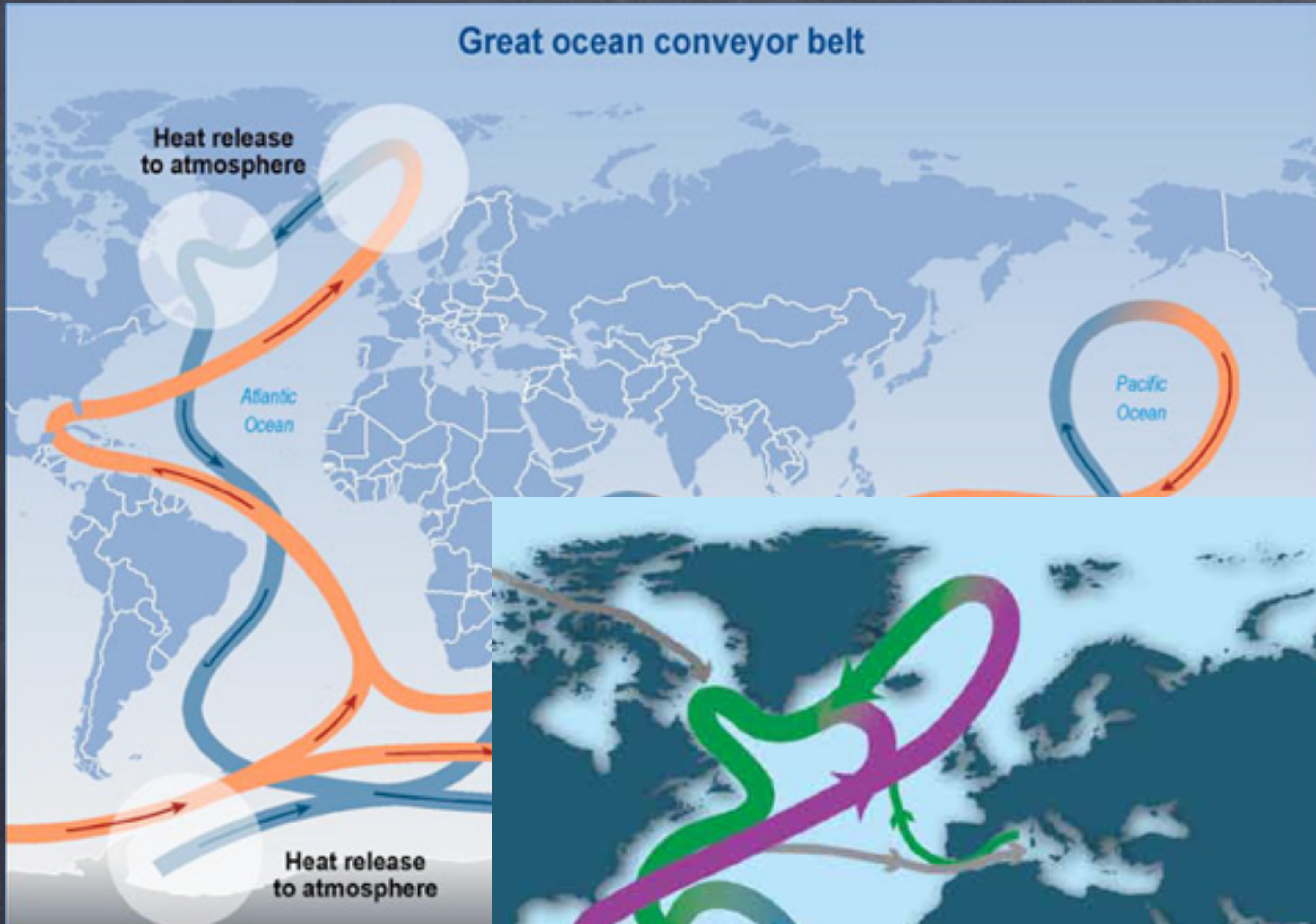


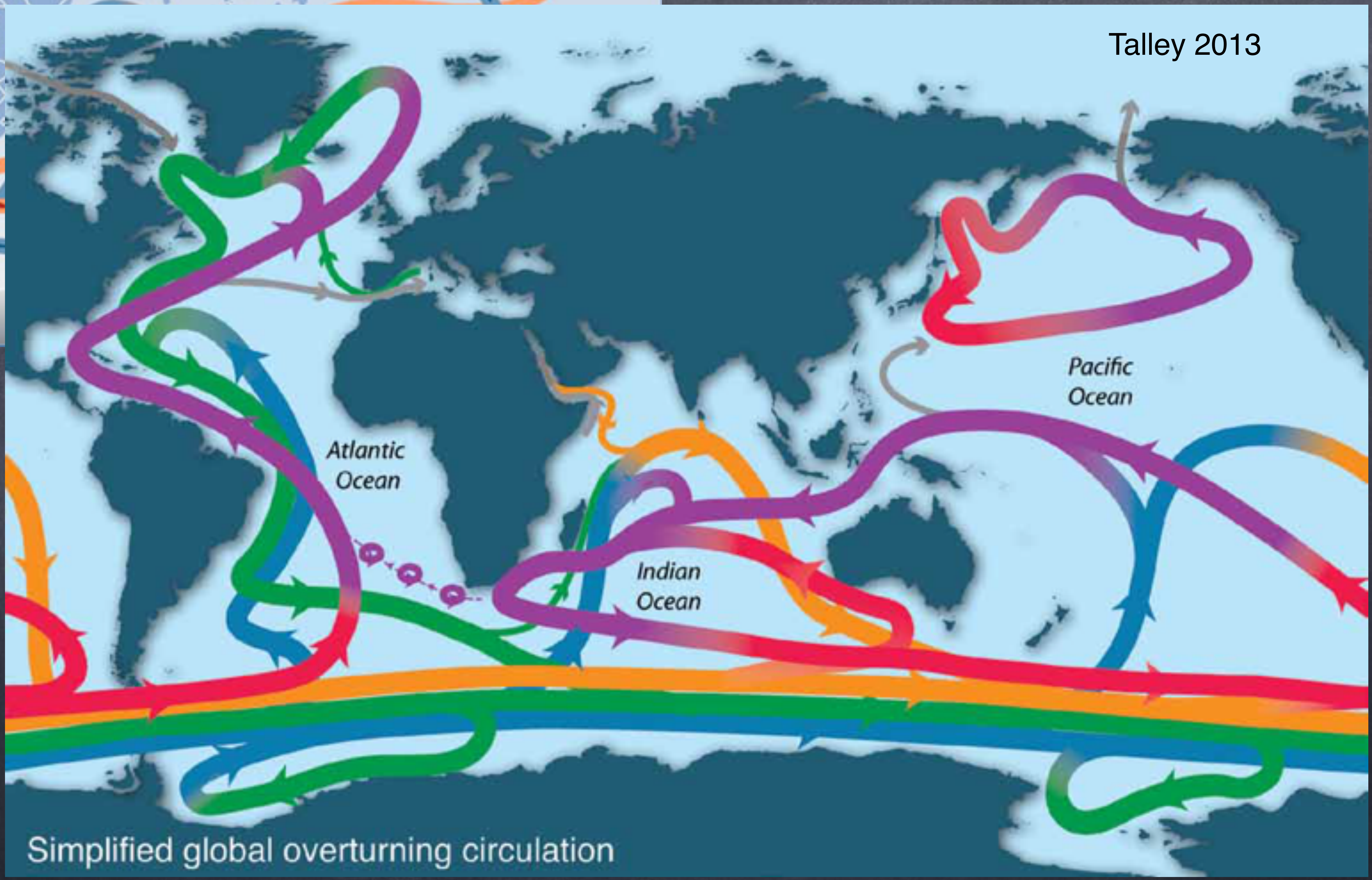


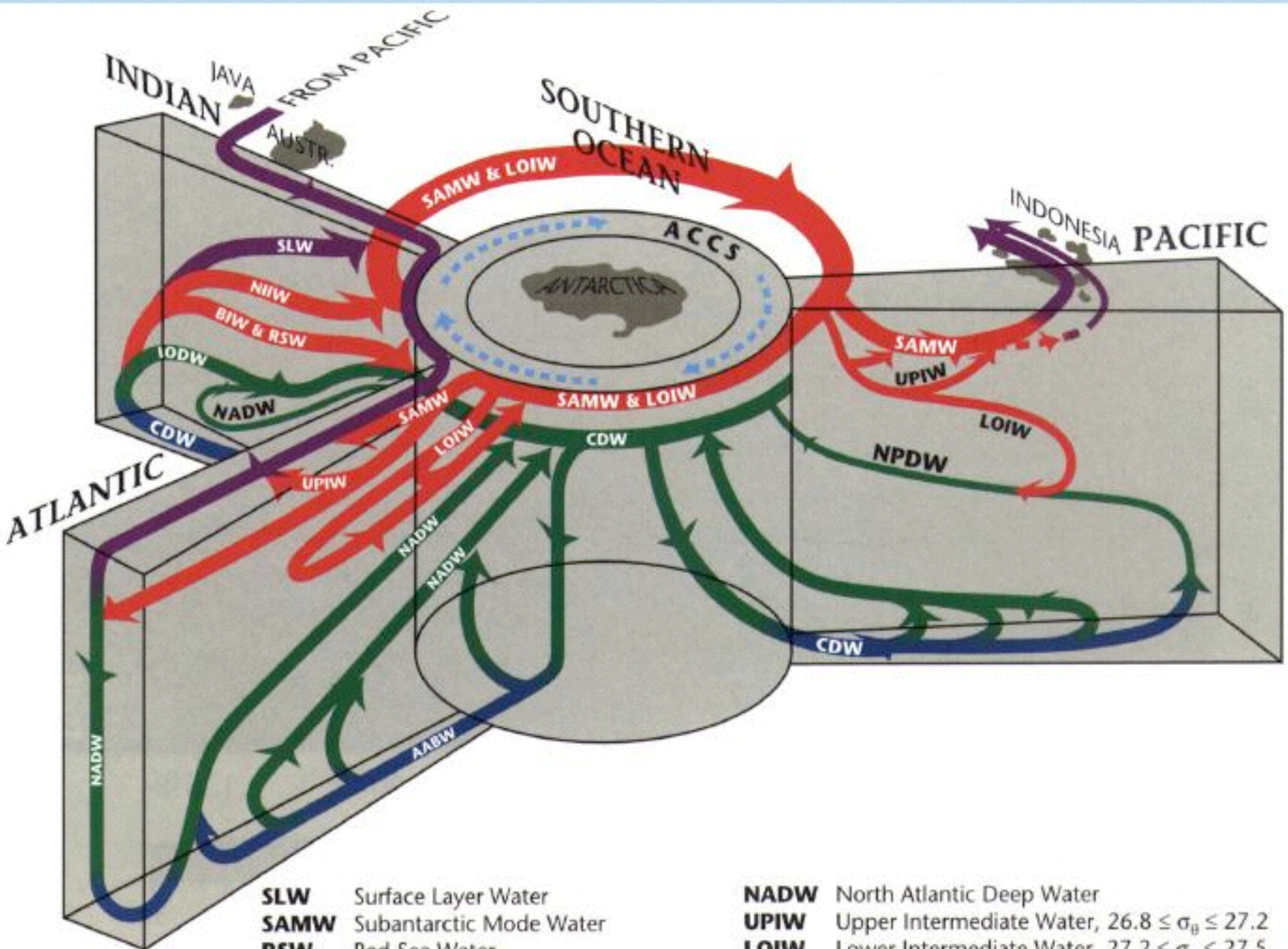
Intermediate and Deep circulation more complex and energetic than previously thought

Global thermohaline circulation

Meridional overturning circulation

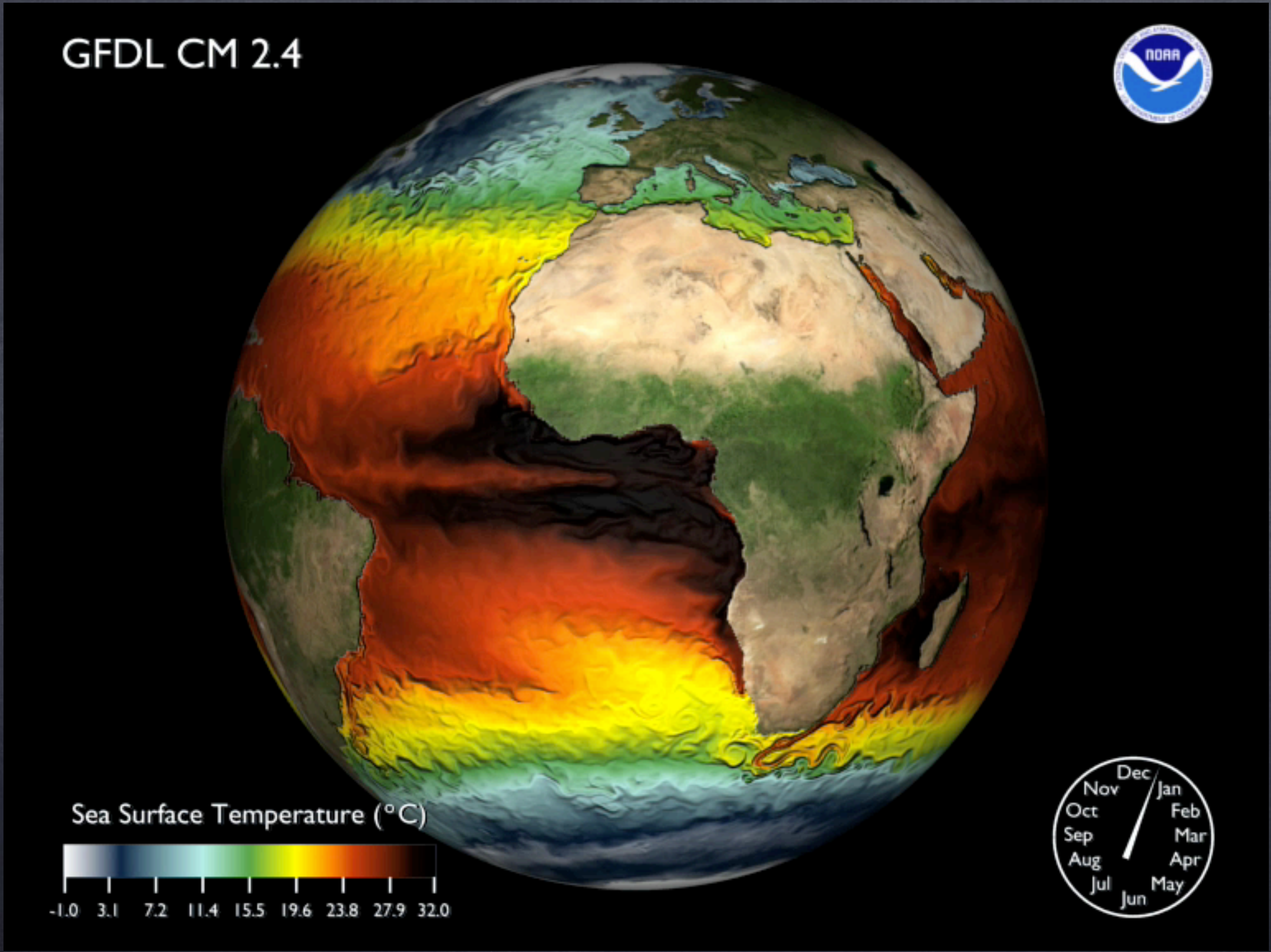






SLW Surface Layer Water
SAMW Subantarctic Mode Water
RSW Red Sea Water
AABW Antarctic Bottom Water
NPDW North Pacific Deep Water
ACCS Antarctic Circumpolar Current System
CDW Circumpolar Deep Water

NADW North Atlantic Deep Water
UPIW Upper Intermediate Water, $26.8 \le \sigma_\theta \le 27.2$
LOIW Lower Intermediate Water, $27.2 \le \sigma_\theta \le 27.5$
IODW Indian Ocean Deep Water
BIW Banda Intermediate Water
NIIW Northwest Indian Intermediate Water


GFDL CM 2.4
Sea Surface Temperature (°C)
-1.0 3.1 7.2 11.4 15.5 19.6 23.8 27.9 32.0
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov