2.011 Intro. to Ocean Science and Engineering

Prof. Alexandra Techet

Spring 2006

2.011 Course Organization

- 3-2-4 U Spring 2006 T/R 11-12:30p
- Instructor: Prof. Techet
- TA
- Laboratory Session 3-5p;
  First lab meeting will be held first week of class.
- 2 In-Class Exams: 40% Grade
- Labs/Projects: 40% Grade
- HW: 20% Grade

HOMEWORK

- Portions of the HW will preview upcoming lecture materials. The necessary knowledge will come from the text or selected readings (on-line or class handouts). These will typically cover basic concepts that will not necessarily be covered in-depth in lecture. <u>This material *will* be covered on the exams however</u>.
- The remainder of the HW assignments will take the material one step further and may on occasion not have a definite or single correct solution.

Laboratories

- Labs will meet in Ocean Engineering Teaching Laboratory
- Safety FIRST!
- Labs will be a combination of experimentation and design for the ocean environment.
- You will design, build, and test your instruments and report your findings back to the class.

INTRO TO OCEAN SCIENCE AND ENGINEERING

- TOPICS INCLUDE
  - Physical Oceanography
  - Oceangoing vehicles
  - Hydrostatics
  - Measuring the ocean
  - Sound propagation in the Ocean

THIS WEEK

- Lectures T/R 11-12:30 – No Lab this week
- Readings: Chapters 1-4 in Stewart.
- HW #1
  - DUE NEXT WEDNESDAY IN LAB (2/15)
  - Research ONE underwater vehicle (see list next slide)
  - Prepare 5 minutes (2-3max powerpoint slides) about it's main mission, any special design considerations (pros/cons), history, any suggestions for making it a better vehicle… You will present your slides to the class in the first lab on 2/15. SEE MIT Server FOR MORE DETAILS.
- Next Week:
  - HW #2 out Tuesday
  - Lab Wednesday, UPLOAD PPT files to MIT Server.
  - Readings: Stewart CH 4-5.

Vehicle List Assignment #1

- Choose from this list of vehicles. Only one student per vehicle.
  - Alvin I (WHOI)
  - ABE (WHOI)
  - Remus (WHOI)
  - Odessey II b/c/ or d (MIT SeaGrant)
  - Ventana (MBARI)
  - Tiburon (MBARI)
  - Millenium ROV (Oceaneering)
  - Hydra Magnum (Oceaneering)
  - Bluefin-21 BPAUV ((Bluefin Robotics)
  - Bluefin Glider - SPRAY (Bluefin Robotics/Scripps/WHOI)
  - Slocum Glider (Webb Research Corp.)
  - Theseus AUV (International Submarine Engineering Ltd. (ISE))
  - Dorado AUV International Submarine Engineering Ltd. (ISE)

- Websites:
  - WHOI
  - MBARI
  - Webb Research Corp.
  - OCEANEERING
  - International Submarine Engineering Ltd. (ISE)
  - MIT SeaGrant
  - Bluefin Robotics

I.

WHAT’S SO COOL ABOUT THE OCEAN?

Water covers 71% of the earth

The Oceans represent 97% of the total water on earth

Why study Ocean Science and Engineering?

- It's cool... ☺
- Food, Water, Global Warming, Pollution control, environment/weather, fuel (gas, oil, alternate energy)
- To operate in the marine environment we need to understand it through
  - Measurements (instruments, data)
  - Modeling (math, theory)
  - Simulations (numerical, computational)
  - To do all this we need actual DATA about the oceans, so *MEASUREMENTS are a priority*!

Cool Creatures in the Ocean

Photos removed for copyright reasons.

Historically Speaking...

- Ocean Observations and measurements
  - First Recorded Depth Soundings and Sea Floor Samples?
  - First submarine?
  - HMS *Challenger* discovered more than 4,700 new species of marine life, including deep-sea organisms (1872-1876)
  - Bathyspheres

Photo of Trieste II (DSV-1) removed for copyright reasons.

» History of the Trieste (http://www.bathyscaphtrieste.com/)

Want more? http://www.ocean.udel.edu/deepsea/level-2/tools/history.html
http://www.ocean.udel.edu/deepsea/Resources/8pg%20for%20print--Final.pdf

AUV, ROV, or UUV?

New ALVIN concept drawing

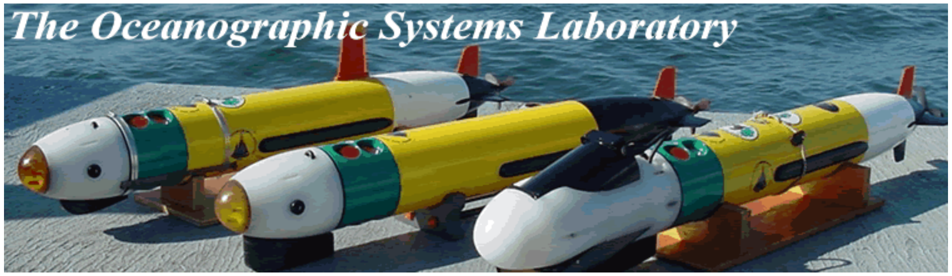
New Alvin illustration by E. Paul Oberlander, Woods Hole Oceanographic Institution.

JASON

http://www.whoi.edu/marine/ndsf/vehicles/jason/index.html

Jason photo by Dan Fornari, Woods Hole Oceanographic Institution.

REMUS



http://www.whoi.edu/science/AOPE/dept/OSL/remus.html

Remus photo by Tom Kleindinst, Woods Hole Oceanographic Institution.

II.

WHAT LIMITS OUR DESCENT TO THE DEPTHS OF THE OCEAN?

Humans in the Sea

- **How deep can we go?**
  - The deepest recorded dive by a skin diver is 127 meters (417 ft).
  - The deepest recorded dive by a scuba diver is 145 meters (475 ft).
  - Revolutionary diving suits, such as the "jimsuit," enable divers to reach depths up to about 600 meters (2,000 ft). Some suits feature thruster packs that can boost a diver to different locations underwater.

Challenge:

- What is the best shape for an AUV Design?

- Consider:
  - How does your choice depend on what the mission/purpose/use of the AUV is?
  - How does depth play a role?
  - Other design issues?

Feeling the *Pressure* Yet?

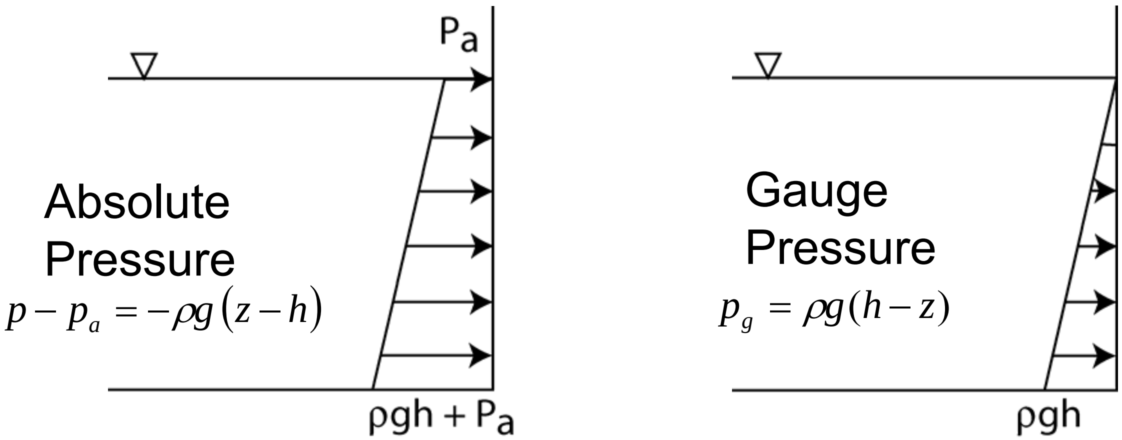
- Why do my ears pop when I dive deep?

Pressure increases with depth

- Hydrostatic Pressure

$$\frac{dp}{dz} = -\rho g$$

- Pressure on a vertical wall:

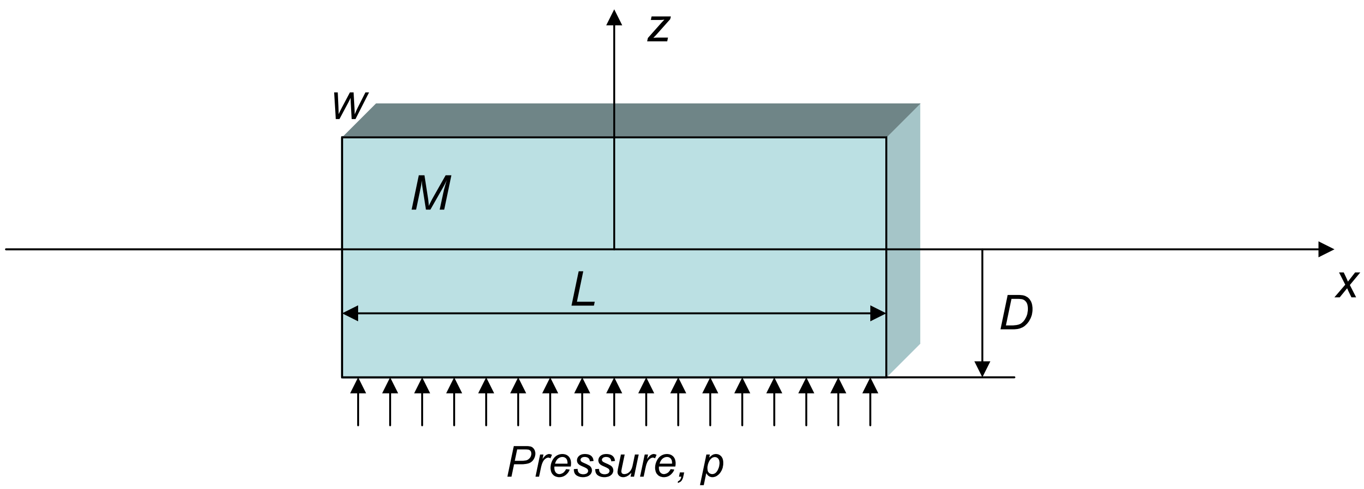


Pressure is *isotropic.*

FOR MORE DETAILS WITH THE DERIVATION OF THE HYDROSTATIC EQUATION, SEE THE READING ON PRESSURE POSTED ON THE CLASS WEBPAGE

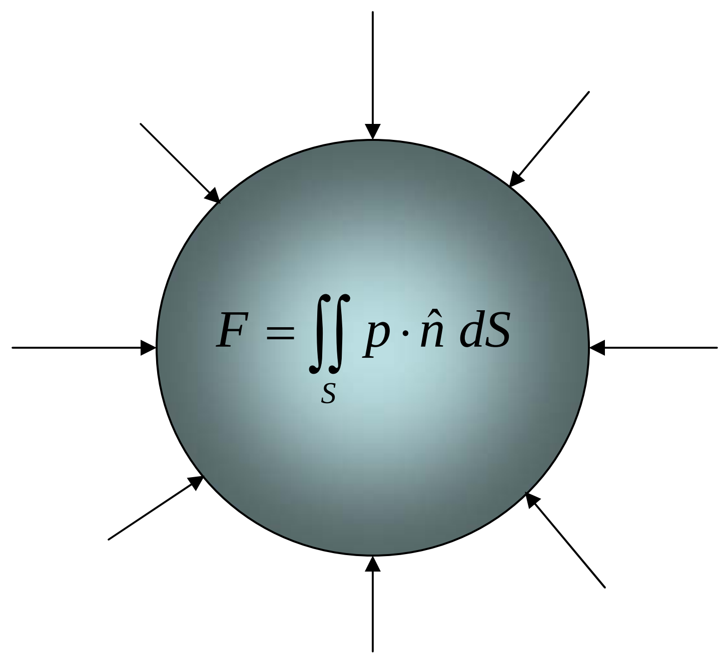
Archimedes' Principle

- *The buoyant force is equal to the weight of the displaced fluid.*



$$F_z = \rho * L * D * W = \rho * Volume$$

Pressure on a sphere at depth?



Pressure acts normal to the surface. By convention pressure is positive in compression. The *total force* is the integration of the ambient pressure over the surface area of the sphere.

Bulk Modulus

- If you are designing things that will go underwater or into the air, where the water pressure, or the air pressure will acts on them from all sides, you have to worry about changes in length in all three dimensions, which is actually a change in volume.
- Here, we define a bulk modulus, B, such that

$$\Delta V = -\frac{1}{B}\Delta P V_o$$

$$\frac{\Delta V}{V_o} = -\frac{1}{B}\Delta P$$

Material Properties

Material	Elastic Modulus E (N / m²)	Shear Modulus G (N / m²)	Bulk Modulus B (N / m²)
Solids			
Iron, cast	100×10^9	40×10^9	90×10^9
Steel	200×10^9	80×10^9	140×10^9
Brass	100×10^9	35×10^9	80×10^9
Aluminum	70×10^9	25×10^9	70×10^9
Concrete	20×10^9		
Brick	14×10^9		
Marble	50×10^9		70×10^9
Granite	45×10^9		45×10^9
Wood (pine)			
(parallel to grain)	10×10^9		
(perpendicular to grain)	1×10^9		
Nylon	5×10^9		
Bone (limb)	15×10^9	80×10^9	
Liquids			
Water			2.0×10^9
Alcohol (ethyl)			1.0×10^9
Mercury			2.5×10^9
Gases			
Air, He, H_2, CO_2			1.01×10^5

Compression at Depth

- The Mariana trench is located in the Pacific Ocean, and at one place it is nearly seven miles beneath the surface of the water. The water pressure at the bottom of the trench is enormous, being about $\Delta P = 1.1 \times 10^8$ Pa greater than the pressure at the surface of the ocean. A solid steel ball of volume $V_0 = 0.20 \text{ m}^3$ is dropped into the ocean and falls to the bottom of the trench. What is the change ΔV in the volume of the ball when it reaches the bottom?

Bathysphere Physics

- The American naturalist Charles William Beebe (1877–1962) set a world record in 1934 when he made a dive to a depth of 923 m below the surface of the ocean. The dive was made in a device known as the bathysphere, which was basically a steel sphere 4.75 ft in diameter. How much did the volume of the sphere change as it was lowered to its record depth? $(B = 1.6 \text{x} 10^{11}\ \text{N/m}^2)$

Photo removed for copyright reasons.
Engineer Otis Barton with a replica of his steel bathysphere.

Deepest Depths?

- Mariana Trench

It is located east of the Mariana Islands at *11°21'N, 142°12'E*, near Guam.

The trench has a maximum depth of 10,911 *m* (35,798 *feet*) below sea level, called *Challenger Deep.*

On 23 January 1960, the US Navy Bathyscaphe Trieste descended to the ocean floor in the trench.

Photo # NH 96797 Trieste just before record Marianas Trench dive, Jan. 1960

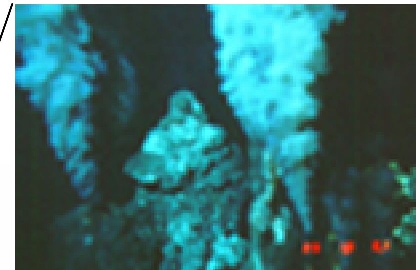
Map showing location of Mariana Trench removed for copyright reasons.

Courtesy of U. S. Navy.

Seafloor Topology

Credit: NOAA Pacific Marine Environmental Laboratory's Vents Program.

Please see: http://www.pmel.noaa.gov/vents/multimedia.html



Hydrothermal vents are found along mid-ocean ridges

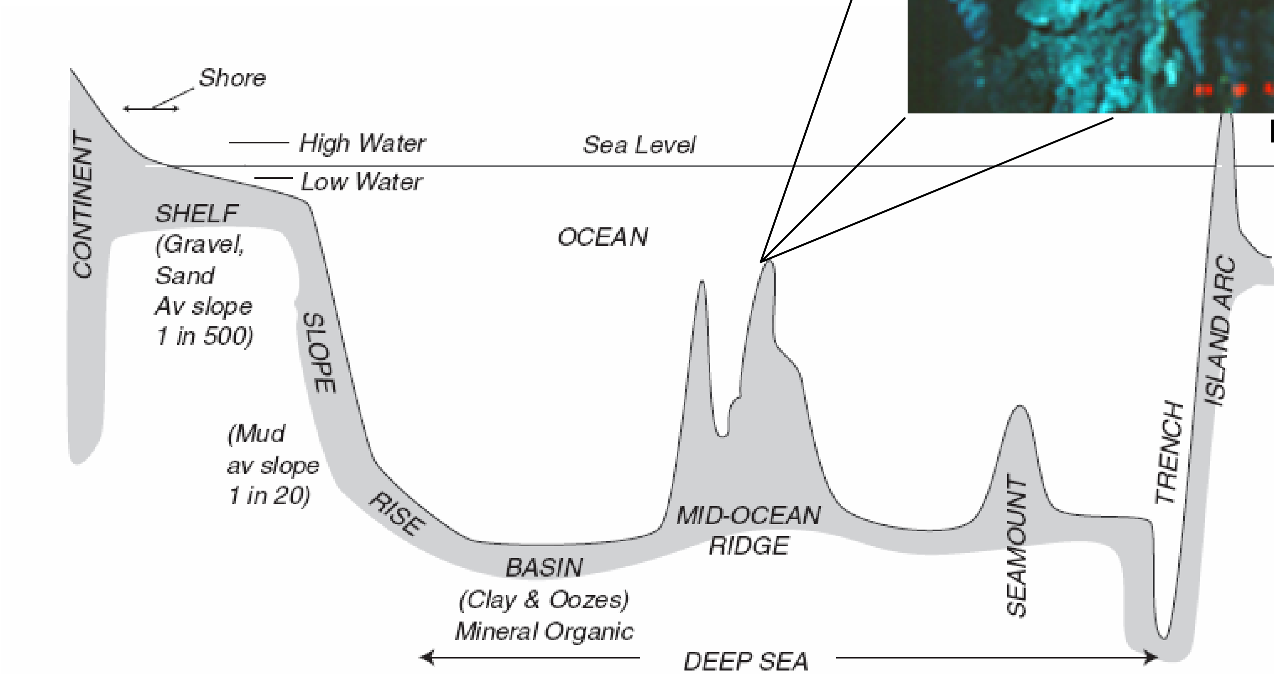


Figure 3.6 Schematic section through the ocean showing principal features of the sea floor. Note that the slope of the sea floor is greatly exaggerated in the figure.

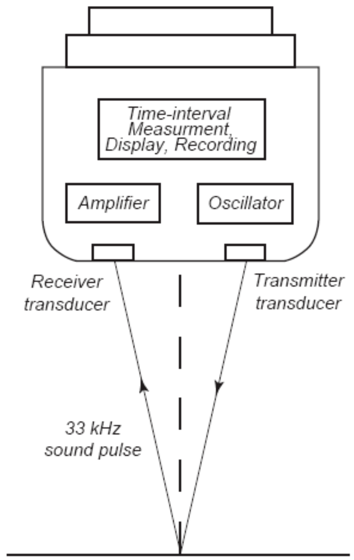
Courtesy of Prof. Robert Stewart. Used with permission.

Source: Introduction to Physical Oceanography, http://oceanworld.tamu.edu/home/course_book.htm

Ocean Floor

- Geological formations on the ocean floor require mapping for navigation and ocean modeling

- How do we map the sea floor?
  - Satellite Altimetry Data
  - Acoustic scattering off the sea floor
  - Depth Sounding



Courtesy of Prof. Robert Stewart. Used with permission.

Source: Introduction to Physical Oceanography, http://oceanworld.tamu.edu/home/course_book.htm

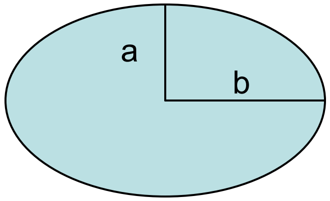
Satellite Altimetry Data of the Sea Floor

Image removed for copyright reasons.

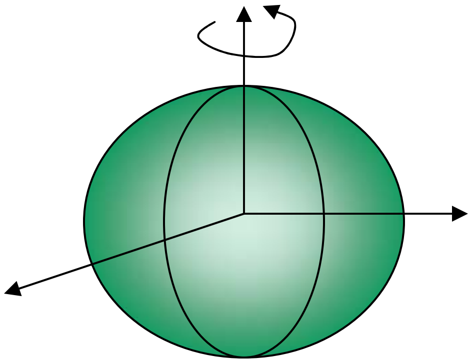
Smith, Walter H.F., and David T. Sandwell, "Global Sea Floor Topography from Satellite Altimetry and Ship Depth Soundings", Science, 277, 1956-1962, 1997.

The Earth and The Ocean

- The earth is an oblate ellipsoid
- Ellipse: minor/major axes (a/b)

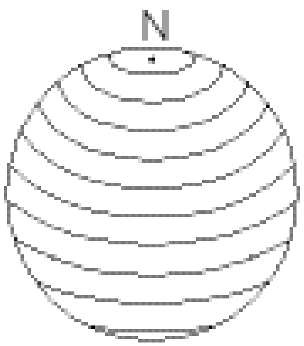


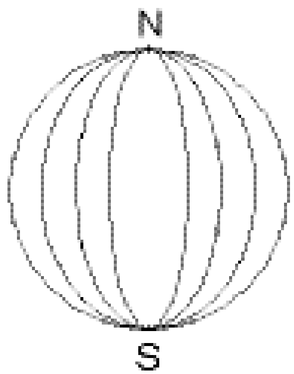
- Oblate ellipsoid: ellipse rotated about minor axis.
- $R_{equator}$ = 6,378.1349 km
- R_{polar} = 6,356.7497 km
- $R_{eq} > R_p$



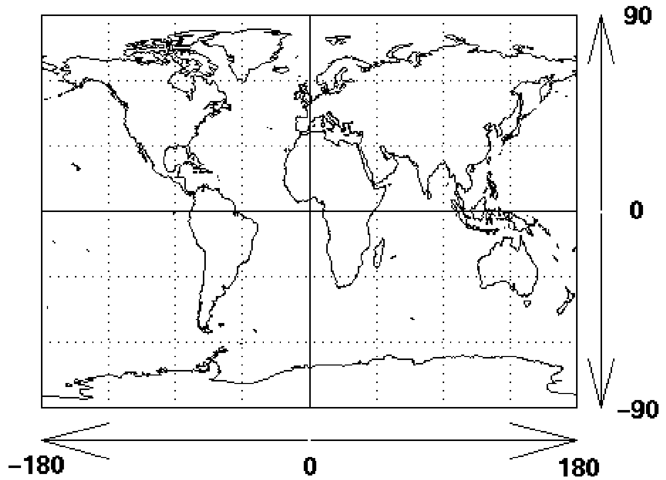
Latitude and Longitude

- Latitude (equator)
- Longitude (N-S)



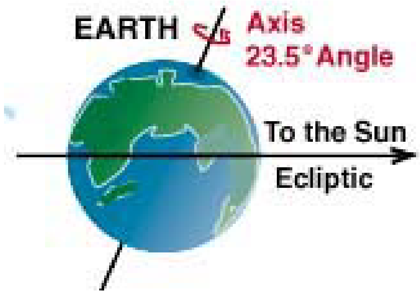


- 1 degree Latitude = 111 km
- 1 degree Longitude = 111*cos ϕ
- ϕ = degrees latitude



Courtesy of NASA.

Earth’s Rotation



- The Earth rotates once in a few minutes under a day (23 hours 56 minutes 04. 09053 seconds).
  - This is called the *sidereal period* (which means the period relative to stars). The sidereal period is not exactly equal to a day because by the time the Earth has rotated once, it has also moved a little in its orbit around the Sun, so it has to keep rotating for about another 4 minutes before the Sun seems to be back in the same place in the sky that it was in exactly a day before.
- An object on the Earth's equator will travel once around the Earth's circumference (~40,075.036 kilometers) each sidereal day.
- The speed due to rotation at any other point on the Earth can be calculated by multiplying the speed at the equator by the cosine of the latitude of the point.

Is the Rotation Slowing?

- The earth's rotation is slowing at a rate of about 0.005 seconds per year per year. This extrapolates to the earth having a fourteen-hour day 4.6 billion years ago, which is entirely possible.
- The rate at which the earth is slowing today is higher than average because the present rate of spin is in resonance with the back-and-forth movement of the oceans.
- Weather events can affect the earth’s rotation (e.g. El Nino)

http://www.talkorigins.org/indexcc/CE/CE011.html

Do winds affect the earth's spin rate?

- To understand how air currents can affect earth rotation, you have to consider the ice skater on the ice doing a spin. If she changes how far our she holds her hands by just a little, it affects how rapidly she spins.

- Air currents change their location on the earth, and their distance from the earth's center by a few miles, and they also carry thousands or even millions of tons of air in clouds.

- It is easy to understand from this how, with *conservation of angular momentum*, the earth's spin is constantly changing.

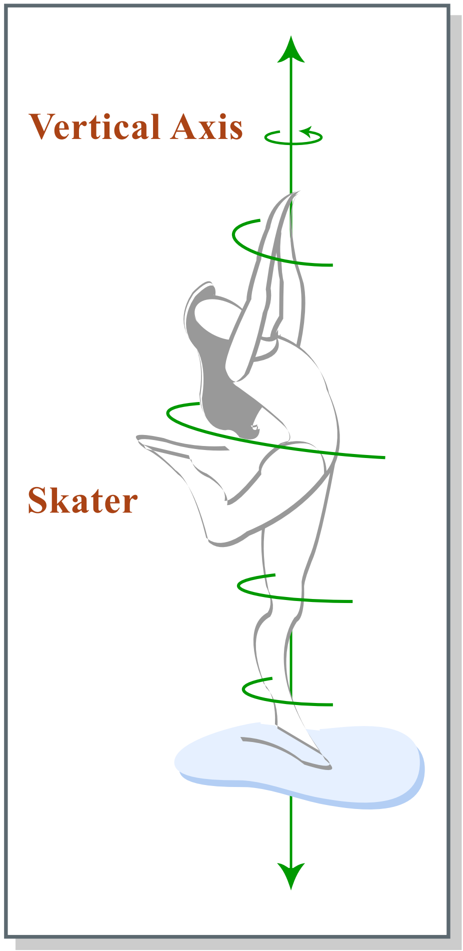


Figure by MIT OCW.

Three Major Oceans

- Atlantic, Pacific, Indian
- Rest are seas, e.g.
  - Mediteranean Sea
  - Marginal Seas (Arabian Sea, S. China Sea)
  - Black Sea
- Aspect Ratio (width to depth) is large & oceans are considerably "thin"
- Vertical velocity can be < 1% of horizontal velocity
- SCALING!!

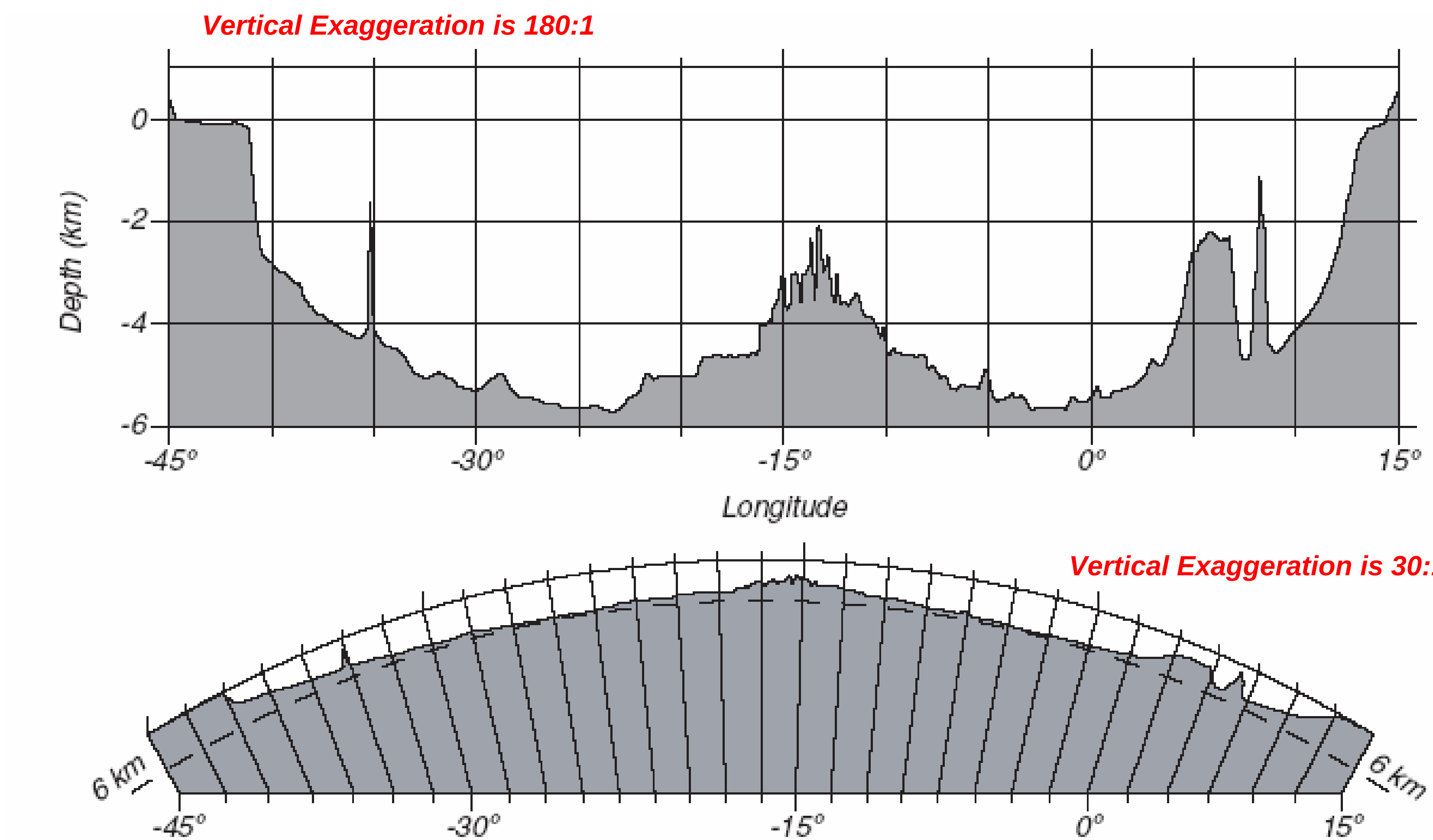
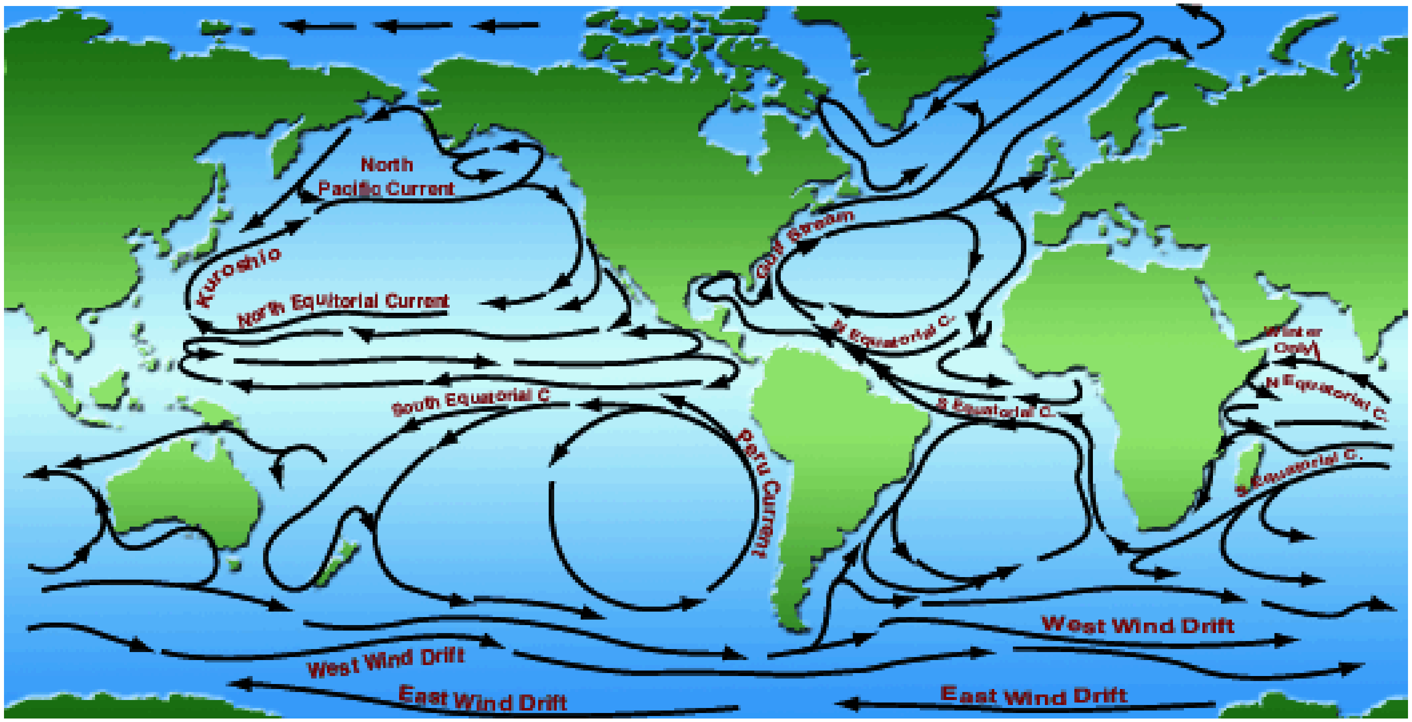


Figure 3.4 Cross-section of the South Atlantic along 25°S showing the continental shelf offshore of South America, a seamount near 35°W, the mid-Atlantic Ridge near 14°W, the Walvis Ridge near 6°E, and the narrow continental shelf off South Africa. **Upper** Vertical exaggeration of 180:1. **Lower** Vertical exaggeration of 30:1. If shown with true aspect ratio, the plot would be the thickness of the line at the sea surface in the lower plot.

Source: Introduction to Physical Oceanography, http://oceanworld.tamu.edu/home/course_book.htm

Major Currents



Courtesy of U.S. Navy.

Interesting Articles and Websites

- UNDERSEA TECHNOLOGIES HELP NOAA "GET TO THE BOTTOM OF THINGS" http://www.magazine.noaa.gov/stories/mag187.htm 01/06
- THE GLOBAL EARTH OBSERVATION SYSTEM REVOLUTIONIZING OUR UNDERSTANDING OF HOW EARTH WORKS http://www.noaa.gov/eos.html
- EARTH OBSERVATION SUMMIT http://www.earthobservationsummit.gov/
- NOAA SATTELITE AND INFORMATION SERVICE http://www.nesdis.noaa.gov/