Chapter 6: Water and Ocean Structure

Water is a compound, a substance that contains two or more different elements in a fixed proportion.

An element: composed of atoms, is a substance that can not be broken down into simpler substances.

Water is a molecule: or a group of atoms held together by chemical bonds.

Chemical Bonds

1) Covalent Bonds-form in atoms which share electrons.
   *Including Polar Covalent
2) Ionic Bonds-form in atoms which transfer electrons.
3) Hydrogen Bonds-occur between opposite end of many polar molecules.
   (about 5-10% as strong as the covalent bond)
   (allow for cohesion-water molecules can stick to each other: can support needles, razor blades or bugs; or adhesion-water molecules stick to other things-makes them wet)-cohesion and adhesion are responsible capillary action

Hydrogen bonds are also responsible for giving water its pale blue color. When water molecules vibrate, adjacent molecules push against their neighbors. This action absorbs a small amount of red light, leaving proportionally more blue light to scatter back to our eyes.

If Hydrogen bonds did not hold water together, it would form a gas. Example: H_2S

Water and Heat

Water's behavior with gaining and losing heat is responsible for much of the atmospheric and oceanographic behaviors.

Heat and Temperature

Heat: energy produced by the random vibrations of atoms and molecules.
(accounts for how many molecules are vibrating as well as how rapidly)
Temperature: only records how rapidly the molecules of a substance are moving, and is the object's response to an input (or removal) of heat.
Bathtub (more heat) Vs. Flame (more temperature)

Temperature is measured in: Celsius, Fahrenheit, and Kelvin

Heat Capacity is a measure of the heat required to raise the temperature of 1 gram (0.035 oz) of a substance by 1 degree Celsius.

*Measured in calories per gram.
*Water's heat capacity is among the highest of all known substances.

(Result: Water can absorb (or release) large amounts of heat while changing relatively little in temperature.)

>Comparison: Ethyl alcohol (beer) 3x faster, beach sand

Calorie: the amount of heat required to raise the temperature of 1 gram of pure water by 1 degree Celsius.

Water Temperature and Density
D=m/v
Most substances become progressively denser as they cool.
Water's density curve: Figure 6.3

Water Freezes Over: as a floating layer rather than under, like most liquids.

During the transition to freezing, the bond angle of water increases to 109 degrees. This allows ice to form a crystal lattice.

*The space taken by 27 water molecules in the liquid state will be occupied by only 24 ice molecules (therefore a 9% expansion).

M_{ice}=0.917 g
M_{water}=0.999 g

Freezing Water

Point C-Temperature stops going down

Sensible Heat Loss- detectable decrease in heat 80 additional calories of energy must be removed per gram of water to freeze it. › Latent Heat of Fusion

Latent Heat of Fusion is also a factor during thawing.

- When ice melts, it absorbs 80 cal/g -»this is why ice is so effective in cooling drinks.

Evaporating Water
Figure 6.6 – Reproduce on board

1. At 100 º C – water begins to boil.
2. 540 cal/g of energy needed to break the hydrogen bonds in order for the water to evaporate »Latent Heat of Vaporization
3. No temperature change occurs (At 540 cal/g @ 20ºC, water has the highest LHV of any known substance)
4. Every year 1 meter (3.3 feet) of water evaporates from the ocean
5. When this water vapor condenses back into liquid water, the same 540 cal/g is again available to do work (Things such as winds, storms, ocean currents and wind waves are powered by that heat)

Why the big difference between Latent Heat of Fusion and LHE?
ALL of the bonds need to be broken.

Seawater and Pure water
Seawater is 96.5% pure water and 3.5% dissolved solids and gasses.

Dissolved solids lower the thermal characteristics:

- Latent Heat of Fusion – 4% lower, 0.96 cal/g needed to raise water 1ºC
- Saltier water – lowers freezing point
  - >24.7‰ - Temp of Max Density, - 1.33ºC or 29.61º F
  - >Typical Seawater: 35‰, freezes at – 1.91 ºC (or 28.6º F)
- Latent Heat of Vaporization – does not change much with salinity changes, etc.

Global Thermostatic Effects
Thermal Inertia - tendency of a substance to resist a change in temperature with the gain or loss of heat energy.

- Much greater for water

T Ranges: Land 50ºC (122ºF)
-90ºC (-129ºF)
Difference___

Practical Example : S.F. vs. Norfolk VA

Water 32 ºC (90ºF)
-2 ºC (29ºF)
Difference___

Heat Capacity of Solid Ice is half that of water.

Both Ocean currents and atmospheric moistures take warm air and water toward the poles and vice versa.

Density Structure of the Ocean
The structure of the ocean is mainly a function of its temperature and salinity.

Seawater is 2-3% more dense (1.020 to 1.03 g/cc)

Density Zones

1. Surface Zone	2. Pycnocline	3. Deep Zone
T& Salinity are relatively Constant, due to:	Density increases w/depth	greater than 1000 m
Contact with atmosphere	18% of all ocean water	(3300 ft – in mid-latitudes)
Exposure to sunlight	isolates surface from deep	80% ocean water
2% total ocean volume		
Typically 50m (~ 500 ft)		

Thermocline – temperature changes with depth (Figure 6.14)
Halocline – Salinity changes with depth

Pycnocline is due mainly to decreases in water temperature.

Pycnocline also corresponds with the thermocline, and can also be a halocline.

- Tropical thermocline is deeper than thermoclines at higher latitudes. It is also more abrupt.

(Polar waters, which receive relatively little solar warmth, are not stratified by temperature, and generally lack a thermo cline.) – Figure 6.15

Average Temperature is chilly: 3.9°C (39° F)

Wherever precipitation exceeds evaporation, salinity will be lower, and a halo cline will be produced. (Halos = Salt)

The halocline often coincides with the thermocline, and the condensation produces a pronounced pycnocline.
Layers produced are referred to as water masses.

- Salty, cold water sinks to the bottom

Layering by density traps dense water masses at great depths, where they are not exposed to daily heating and cooling.

- The pycnocline isolates 80% of the world's ocean water from the 20% involved in the circulation.
- Waters are stratified and tend not to mix.

Configuration of continents can make a difference:

1. Salinity in Arctic – receives large volume of runoff from Siberia/Canada.
2. Antarctic has almost no thermocline in Polar water
   (why?: effectiveness of southern water mixing)

Variations in temperature, salinity and density are usually configured to the uppermost 2000 meters (6500 feet). Fig. 6.16/6.17

- Below this, its all the same

Refraction, Light and Sound

Refraction – the beading of waves
Fig 6.18 in text

Refractive Index – degree to which light is refracted from one medium to another

Light in the Ocean

Light is a form of EM radiation.

Except for very long radio waves, water rapidly absorbs nearly all EM radiation

- Only blue and green wave lengths pass through or into water in an appreciable quantity or distance.

Scattering occurs as light is bounced between air or water molecules, dust, etc.

When light is absorbed, molecules vibrate and the energy is converted to heat.

Photic Zone – film of lighted water at the top of the surface zone.

Typical – 100 M (330 feet)

- Clearest 600M (2000 ft) – tropics

Photosynthesis takes place here! (Cyanobacteria)

Below-Aphotic Zone (without light)

Water Color

- From above, clear ocean water looks blue because blue light can travel through water for enough to be scattered back through the surface to our eyes. (Figure 6.20)
  - Nearly all red wave lengths are converted to heat in the first few feet

- Red Sea – Cyanobacteria

Sound

Sound- a form of energy transmitted by rapid pressure changes in an elastic medium.

Scattering occurs here too- by bubbles, critters

Sound waves travel much further – many critters use this as their “eye”

Speed of sound – 1500 m/s (3345 miles hr)
(5x the speed of sound in air)

- Increases as T & P increase
- Speed decreases with depth to 1000M (3300 ft) but then increases again.

SOFAR LAYERS AND SHADOW ZONES

Sofar Layer- travels at minimum speed, but refraction keeps the sound within this layer, which allows the sound to travel for thousands of km.

- Named for sound fixing and ranging

The Shadow Zone – Figure 6.23

SONAR

Sound Navigation and Ranging

High Frequency- Pings before

- Now real high – above our ear level (Active Sonar)

Side Sound Sonar (a Type of Active)

- Great resolution – 60 transmitter/received

Deeper Soundings – Seismic Reflection Profile

- Use sparks, explosive or compressed air.

Passive Sonar – Listening devices