Physical Properties of Seawater

- Water: An Unusual Substance
- Temperature and Density
- Thermal Structure of the Ocean
- Light and Sound in the Ocean
- The Ocean as a Physical-Chemical System

Water: An Unusual Substance

- Density (highest as liquid above freezing)
- Melting and Boiling Points (unusually high for molecular weight)
- Heat Capacity (very high)
- Surface Tension (very high)
- Absorption of radiation (very high)
- Solvent Properties (excellent)

Heat vs. Temperature

- Temperature: how fast molecules vibrate
  - A form of kinetic energy
- Heat is total amount of thermal energy
  - Proportional to temperature times heat capacity times volume

Heat Capacity

- Amount of energy needed to raise temperature of 1gm of substance by 1° C
- Water has one of highest heat capacities known
- Higher than air…
  - Entire atmosphere heat capacity equivalent to top 3.2m of ocean!
  - Adds “memory” to climate (e.g. lagged seasonal cycles; delays global warming; creates monsoons)
  - Makes excellent heat transfer material, allowing currents to moderate climate

<table>
<thead>
<tr>
<th>Material</th>
<th>Heat capacity (calories/g°C)</th>
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<tbody>
<tr>
<td>Acetone</td>
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<tr>
<td>Aluminium</td>
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<td>Ammonia</td>
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<td>Grain alcohol</td>
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<td>Lead</td>
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<tr>
<td>Mercury</td>
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<td>Silver</td>
<td>0.06</td>
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<tr>
<td>Water</td>
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</tbody>
</table>
Heat transfer by currents

- Currents retain temperature of source regions, influence climate

Temperature vs. density - pure water

- Pure water is most dense at 3.98°C above freezing point
- Can relate to lake processes (but not ocean)

Temperature vs. density - seawater

- Salt water behaves slightly differently
  - Densest at freezing point (for more than 24‰ salt)
  - When seawater "freezes" it forms fresh water ice
  - Bottom water in oceans is -2°C
Ice is less dense than water

- When water molecules bond, structure is less compact

Ice is less dense than water

- Water expands as it freezes

Density vs. Temperature for Pure Water

- Latent heat = energy absorbed or released as water changed phase (gas, liquid, solid)
- Energy transitions occur without temperature change as phase changes

How different would Earth be if ice sank?
Latent heat

- Largest latent heat changes occur on liquid-gas transition
- Latent heat release/absorption are key to climate (atmospheric) processes

Latent Heats for Water Transitions

- Large release of heat during rainfall (especially tropical storms) or freezing
- Large absorption of heat during melting and evaporation

Ocean temperatures

- Reflect energy input from Sun and surface circulation patterns (next week)

Temperature layering

- Tropical and subtropical oceans are permanently layered
  - Warm, less dense surface water separated from cold, dense deep water by a thermocline (layer in which water temperature and density change rapidly)
- Temperate regions have a seasonal thermocline and polar regions have none.
Salinity layering

- Highest ocean salinity is between 20-30° and the equator (evaporation > precipitation).
- Salinity at the equator and > 30° is low (evaporation < precipitation).

Salinity layering

- In some places surface water and deep water are separated by a **halocline** (a zone of rapid change of salinity with water depth)

Density structure of the ocean

- **thermocline**, **halocline**, **pycnocline**
- Ocean is strongly layered
  - Densest water is on the bottom
- Density is acquired at surface
  - Temperature, Salinity

Surface mixed layer

- Mixed by waves and currents
- Light penetration ("photic zone" - top 100m or so depending on clarity)
  - Zone of biological productivity
- Temperature and salinity relatively constant with depth
Depth stratification

- Ocean water column:
  - Surface layer (2%)
  - Pycnocline (18%)
  - Deep layer (80%)

Light in the ocean

- What happens when light enters water?
  - Refraction (bending of light waves)
  - Scattering
  - Absorption (converts light energy to heat)

- Light only penetrates top ~100m
  - Less in coastal waters where more scattering due to particles
  - Photic zone: photosynthesis occurs here - base of marine food chain

- Absorption is wavelength-specific

Variable transmission of visible light

- Light is absorbed at increasing depths
- Some wavelengths absorbed more than others
  - Blue light penetrates further
  - Red light absorbed near surface

Variable transmission of visible light

- Different absorption for nearshore and open ocean waters
- Nearshore absorption is greater for green and yellow due to particulate matter
Sound in the ocean

- Sound intensity in water decreases because of spreading, scattering, and absorption: higher frequencies absorbed sooner.
- Sound travels farther in water than light does.
- Many marine animals use sound to locate prey, communicate, navigate.
- Effective oceanographic and naval tool (sonar).

Speed of sound in the ocean

- 1500 m/sec in water; only 300 m/sec in air.
- Speed increases with increasing temperature and pressure (and secondarily, with salinity).
- Fast at surface (high T) and in very deep (high P).

Minimum velocity layer (SOFAR)

- Lowest P and cool T at about 1000m.
- Focuses sound waves and transmits sound over long distances.
Acoustic thermometry of the ocean

- Sound travels faster in warm water
- Can measure sound wave travel times very precisely
- Acoustic source + network of receivers = sophisticated detection of ocean temperature change

Proof of concept

- Heard island experiment
- Sound detected at receivers far from source

Other sources of ocean noise

- Geophysical prospecting
- Sonar
- Military (submarine detection) - LWAD
- Geologic events (EQs, volcanoes)
- Scientific research
- Shipping
Marine mammal impacts

- Marine mammals depend on sound; sensitive to sound
- Beachings/strandings reported following large acoustic experiments
  - Ear damages
  - Bahamas 2000: 16 whales beach during Navy tests
- NRDC successful on occasion in blocking tests; ongoing struggle
  - Common-sense measures to reduce harm: avoid sensitive areas, listen before deploying; turn up volume gradually
- Main problem - military tests

The noisy ocean!

- http://oceanexplorer.noaa.gov/gallery/sound/sound.html