Water Properties and Seawater Constituents

ES 383

Colby at Bigelow, September 2019

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(Sea)Water is Amazing

Avatar wiki

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Water has special properties that allow it to:

- Maintain a stable atmospheric climate
- Enable transport of molecules to and within organisms
- Be present in all three physical phases in earth's surface temperature range
- Ultimately produce ocean currents

Location	Percentage of Total 1.4×10^9 km^3
Oceans	**97.2**
Freshwater	
Ice caps and glaciers	2.38
Surface waters (lakes, rivers, streams)	0.022
Air and soil moisture	0.001
Groundwater	0.40
Total freshwater	**2.8**

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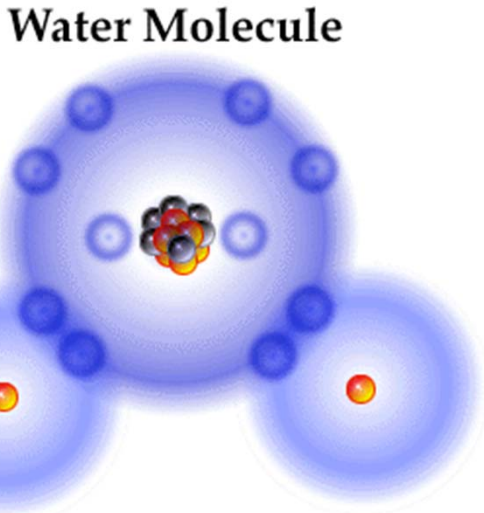
Properties: structure of the molecule

Review of atoms:

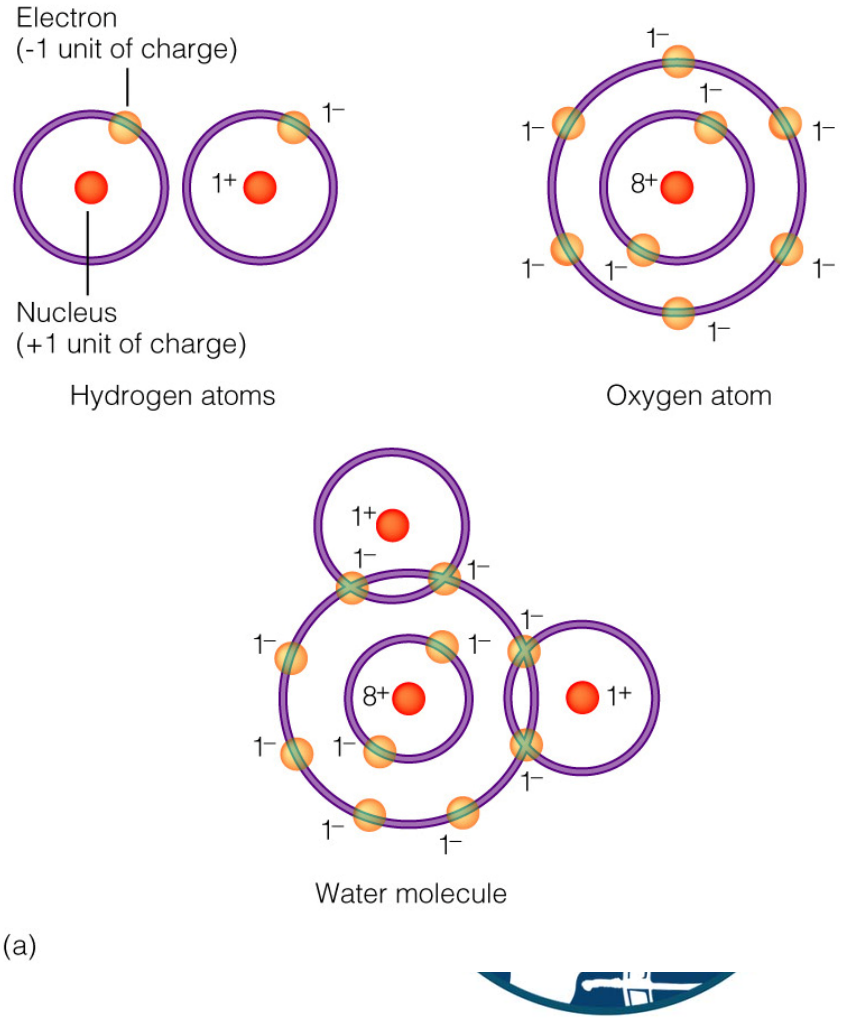
electrons –
protons +
neutrons 0

Covalent Bonds

- strongest bonds
- shared electrons to fill shells
- water has 2 covalent bonds



Water molecule like a magnet

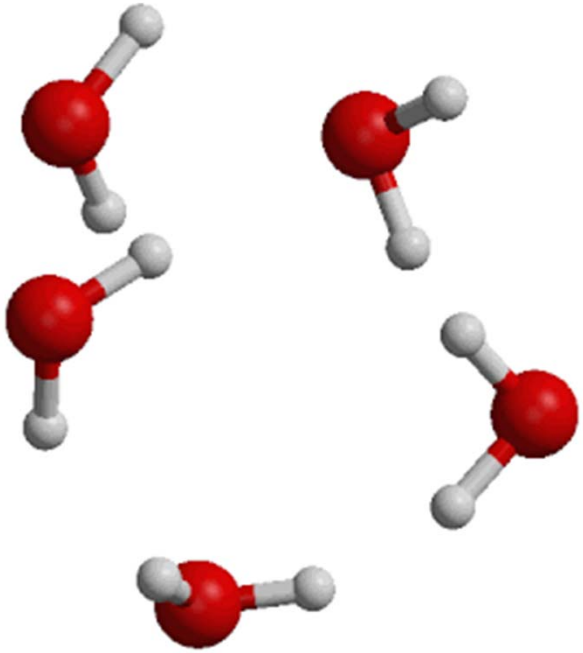


Properties: structure of the molecule

Hydrogen Bond

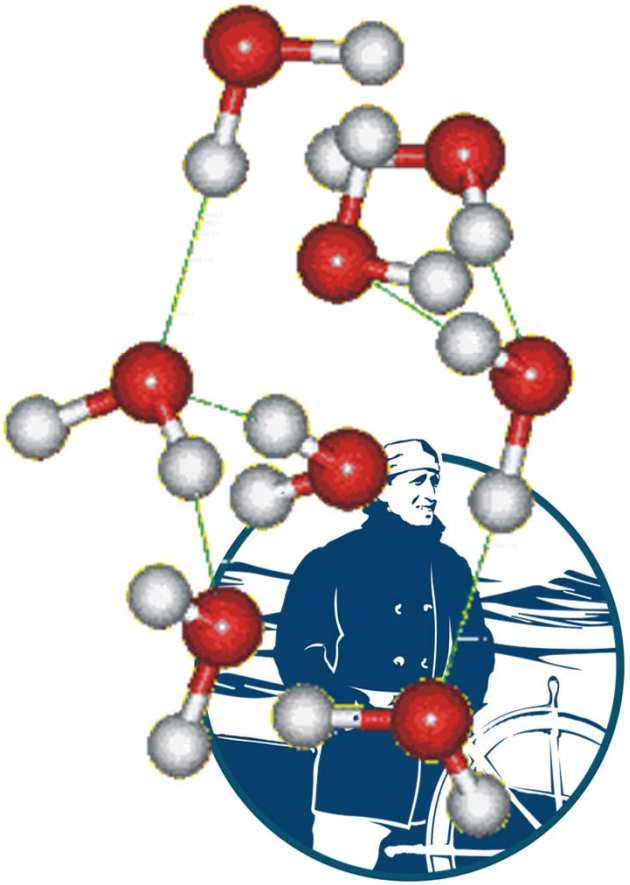
- attractive force between the negatively charged side of one water molecule and the positively charged side of another water molecule

~ 100 times weaker than covalent bonds

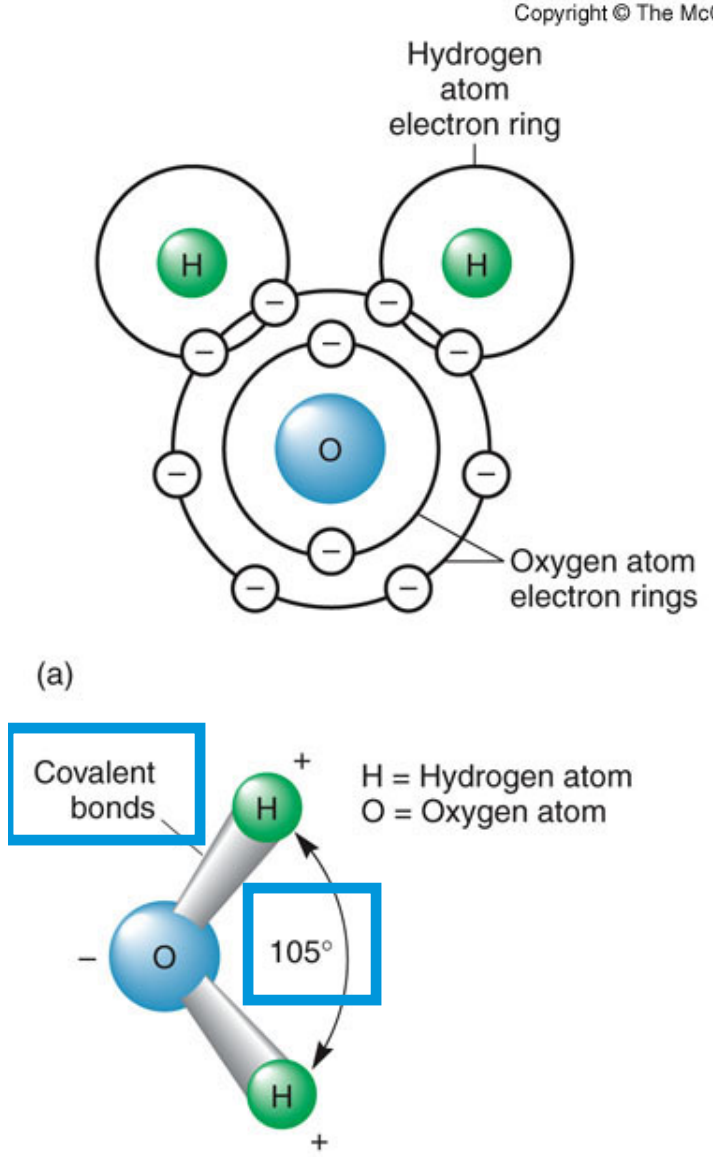


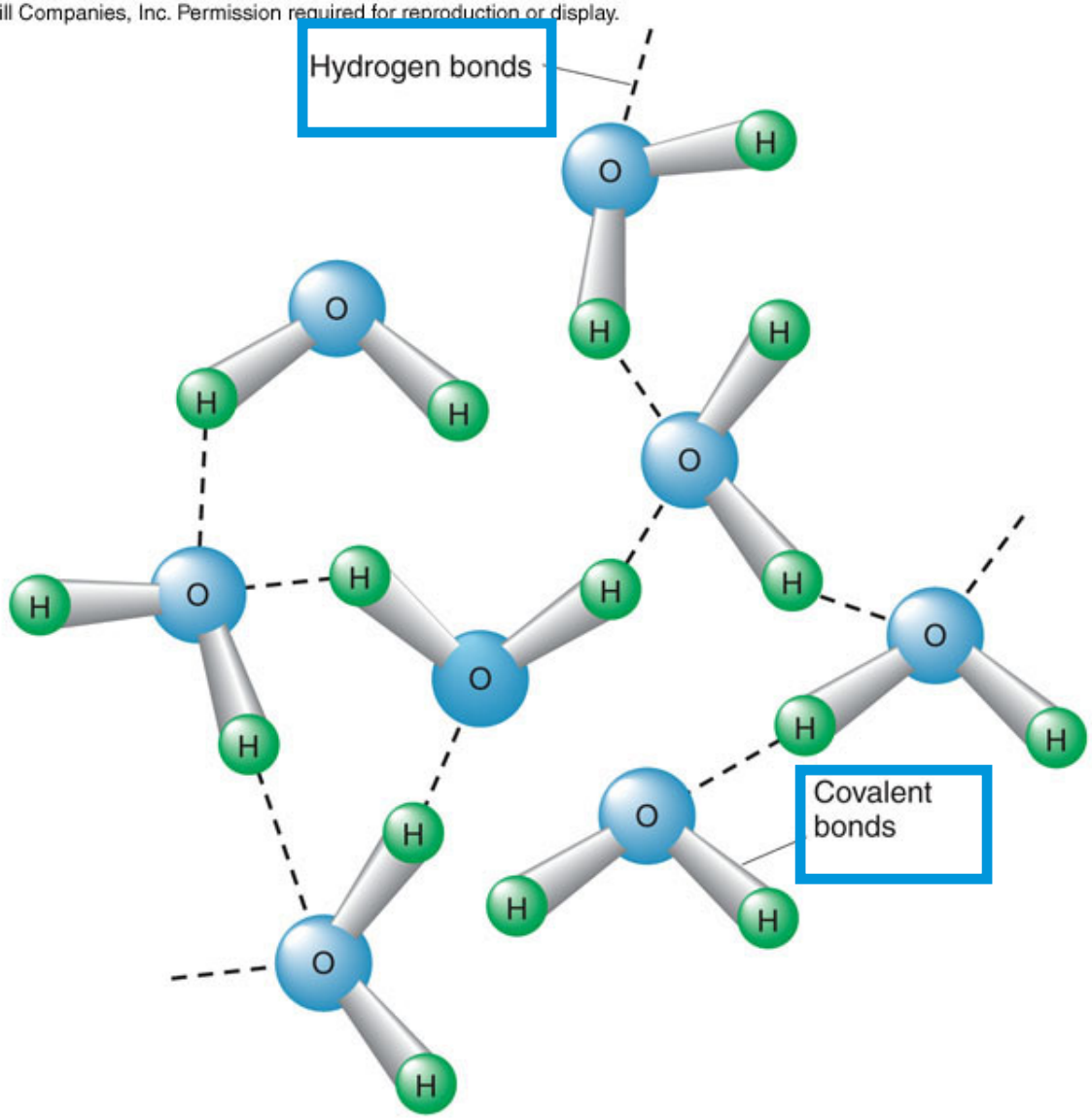
Water molecule like a magnet:

- it's polar
- it can join with 4 others



Neutral but polar





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Dissolving Power

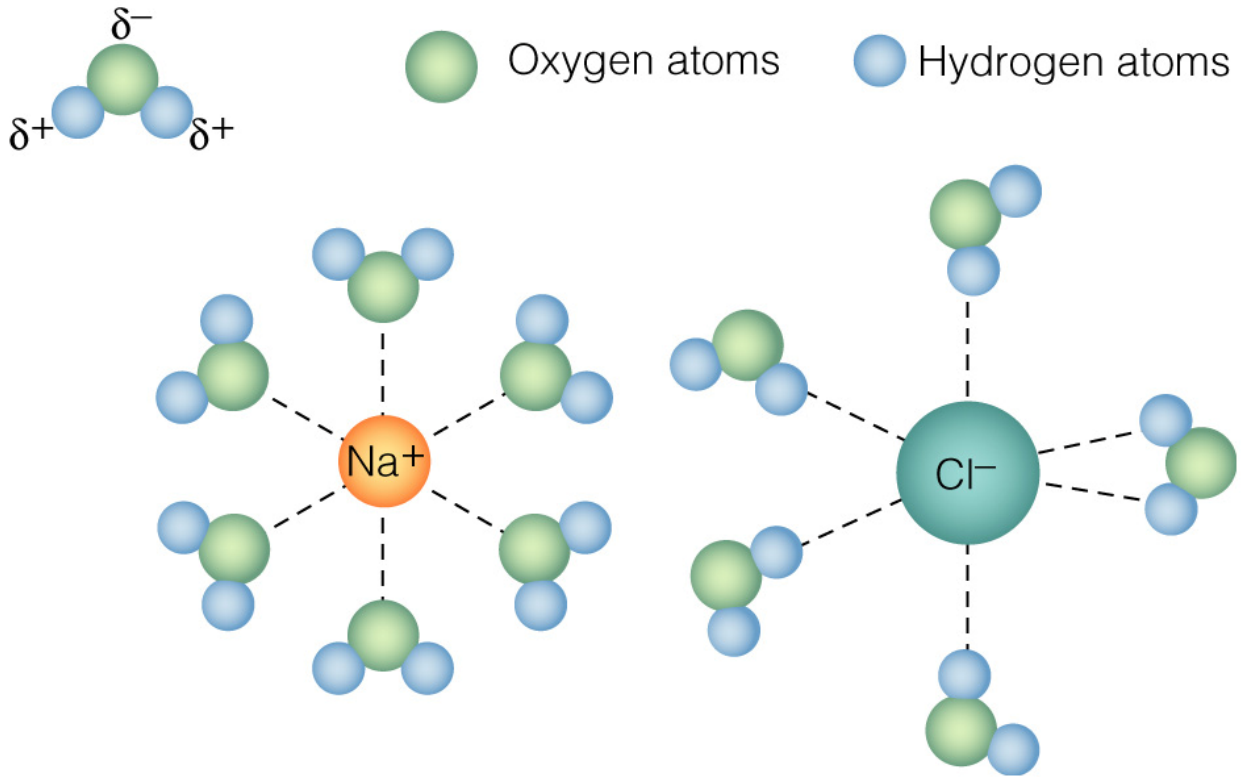
Can dissolve more substances / greater quantities than any other liquid

Hydration – ion surrounded by water molecules

→Weathering of rocks

→ Sedimentation

→Facilitates chemical reactions necessary for life



Thermal expansion

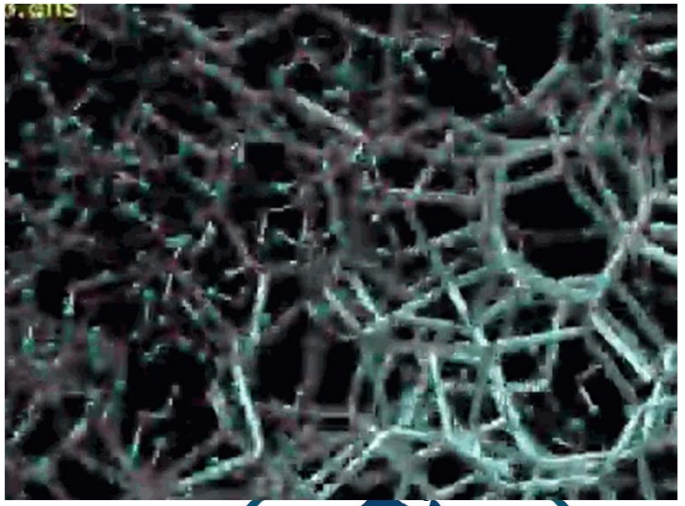
Most substances get denser as they cool
So does water, down to about 4 °C
Then it starts to become less dense

http://www.youtube.com/watch?v=gmjLXrMaFTg

http://www.youtube.com/watch?v=RIW65QLWsjE

http://www.youtube.com/watch?v=PcoiLAsUvqc

http://www.youtube.com/watch?v=Vlqgih0Rpag



→Allows water to stay unfrozen under ice
→Produces <u>global thermo-haline circulation</u>
(dominant circulation pattern in oceans)

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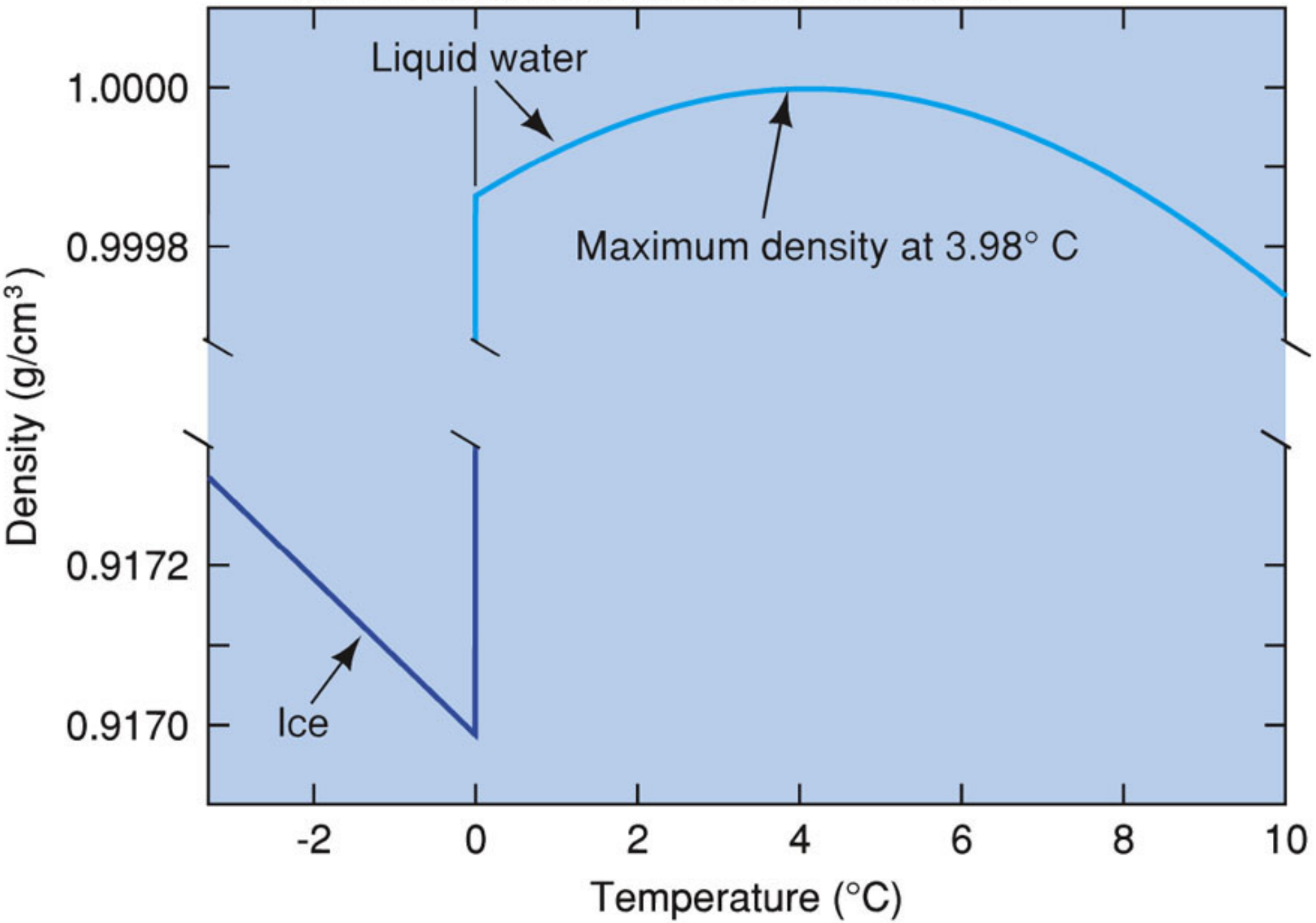

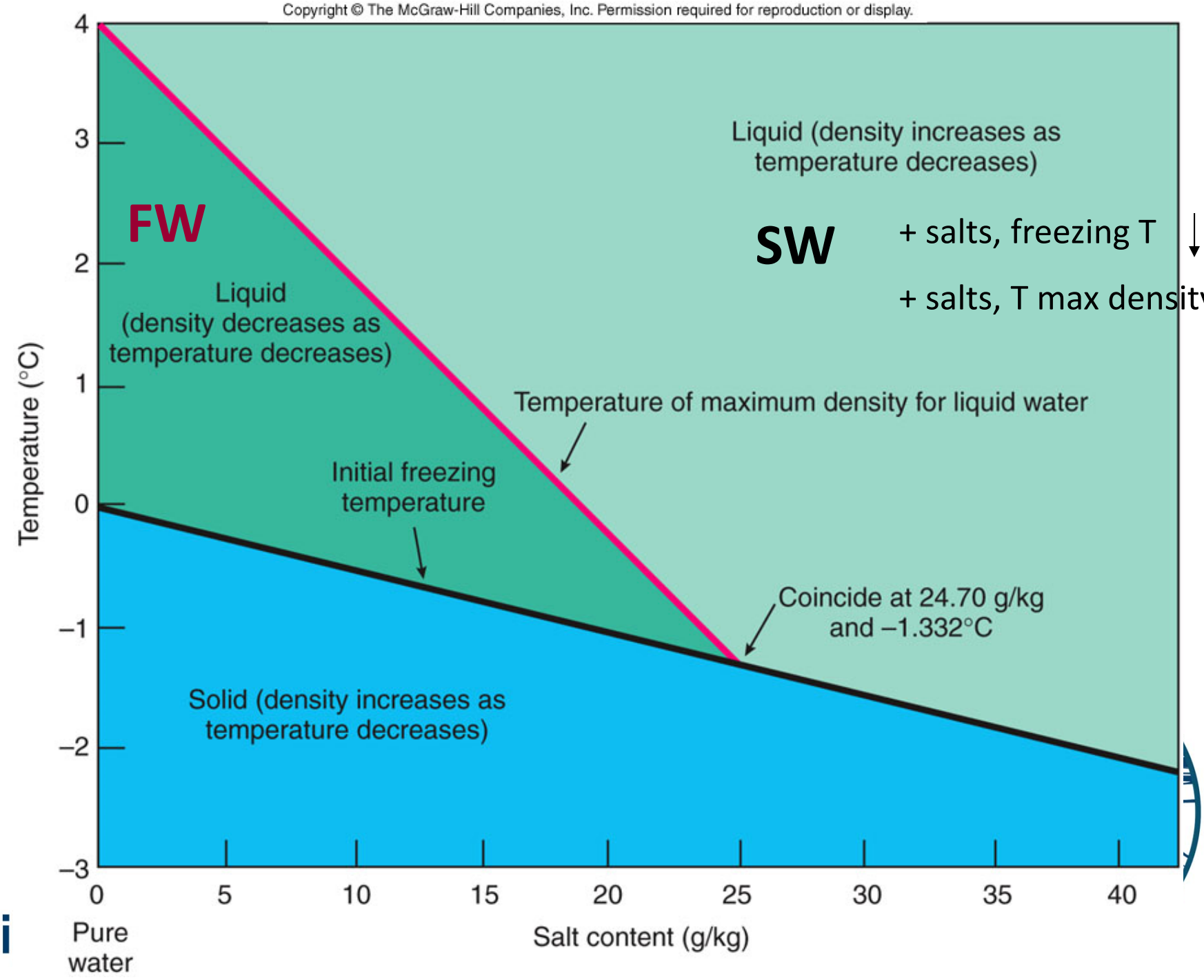

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Heat Capacity

- Amount of heat required to increase temperature
- Very high in water
-It takes roughly 100 times as much heat to warm water 1 degree,
as compared to air

→Oceans absorb and “buffer” atmospheric temperature changes

Note: Specific heat = heat capacity of a material / heat capacity of water

Material	Heat Capacity (calories/g/°C)
Acetone	0.51
Aluminum	0.22
Ammonia	1.13
Copper	0.09
Grain alcohol	0.23
Lead	0.03
Mercury	0.03
Silver	0.06
Water	1.00

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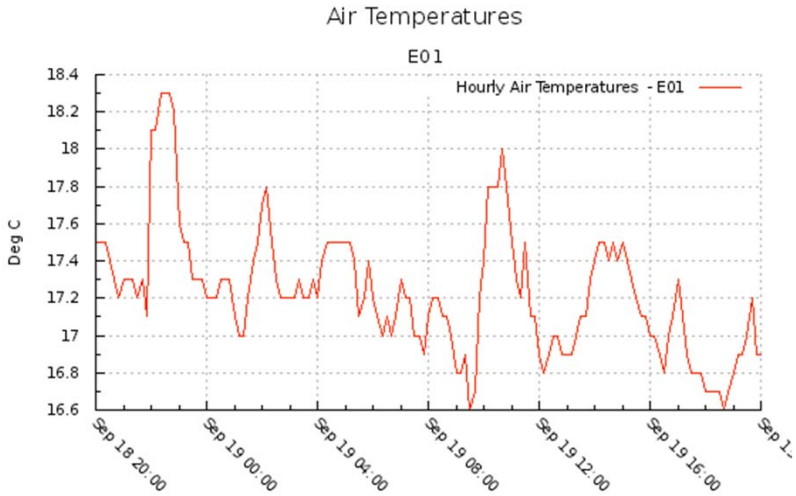
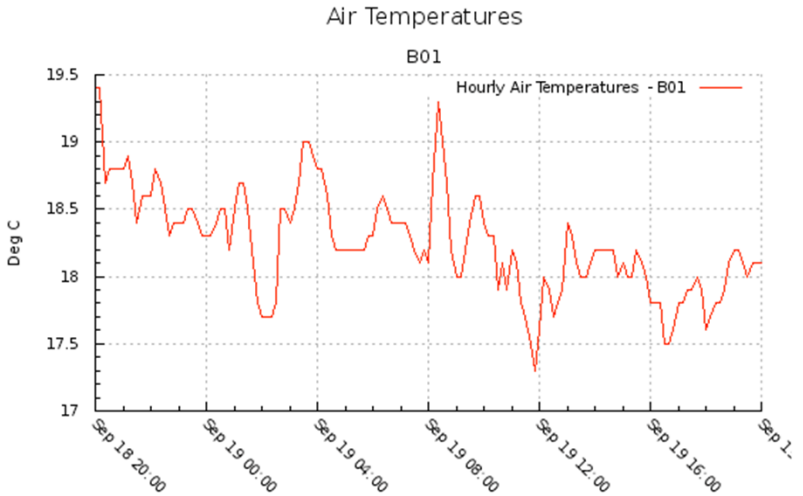
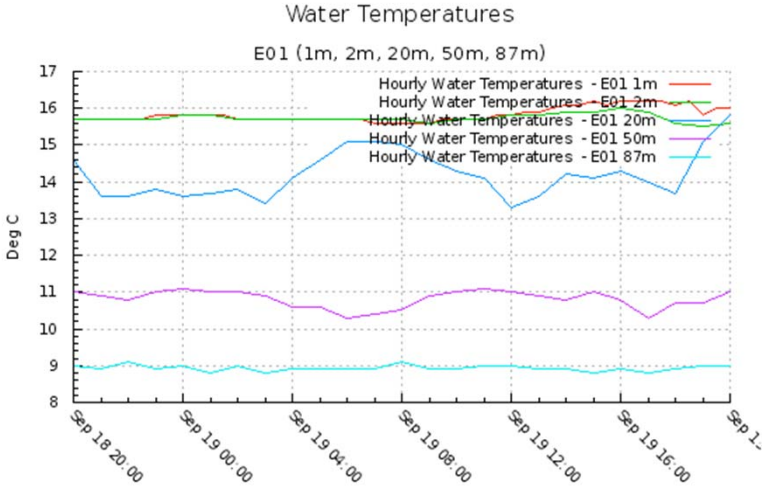
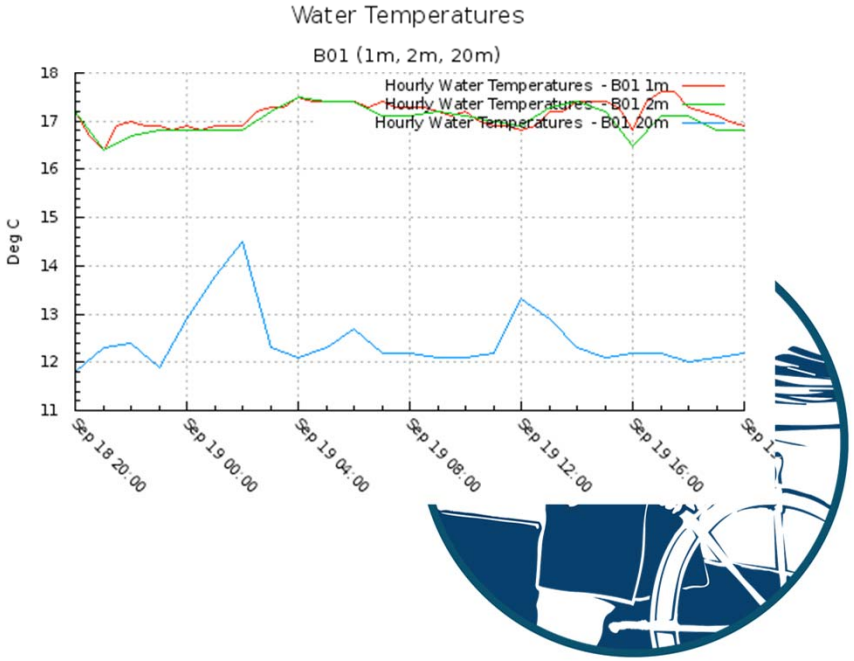
Temperature fluctuations very different between land and ocean









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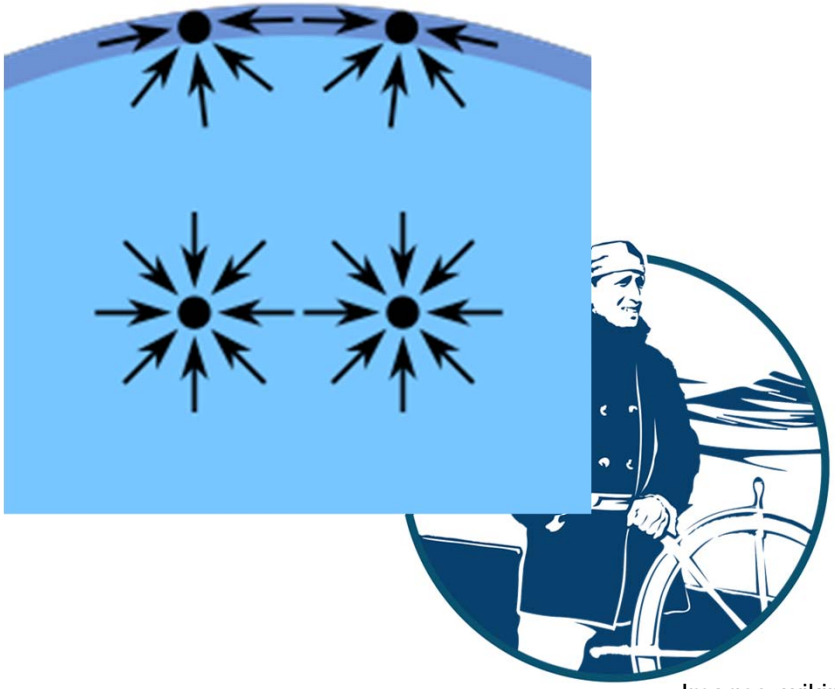
Surface Tension

Very high compared to other liquids
Allows droplets to form in the atmosphere → precipitation
Allows bubbles to form in the water
Determines many wave and surface properties

Water + salt: surface tension up
Water + T : surface tension down
Water - T : surface tension up



Images: wikipedia

Viscosity

Water has a low viscosity

Water + salt: viscosity up (small amount)	Poles
Water + T : viscosity down	Poles
Water - T : viscosity up	Tropics

Images: wikipedia

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Summary

Properties are a result of its molecular structure: $H^{+}_{2}O^{2-}$

- Covalent bonds => link 3 atoms; 2 e- are shared
- Polar molecule => unequal spatial distribution of charges
- Hydrogen bonds => ea. H_2O molecule can join w/ 4 others

Changes of physical state:

- Solid or ice (less dense); liquid or water; gas or vapor (moisture, humidity)
- pure water = fresh water w/o suspended particles, dissolved substances or gases
- energy required to break H-bonds to form water and vapor => 1 calorie = amount of heat needed to raise temperature of 1g water by $1^{o}C$

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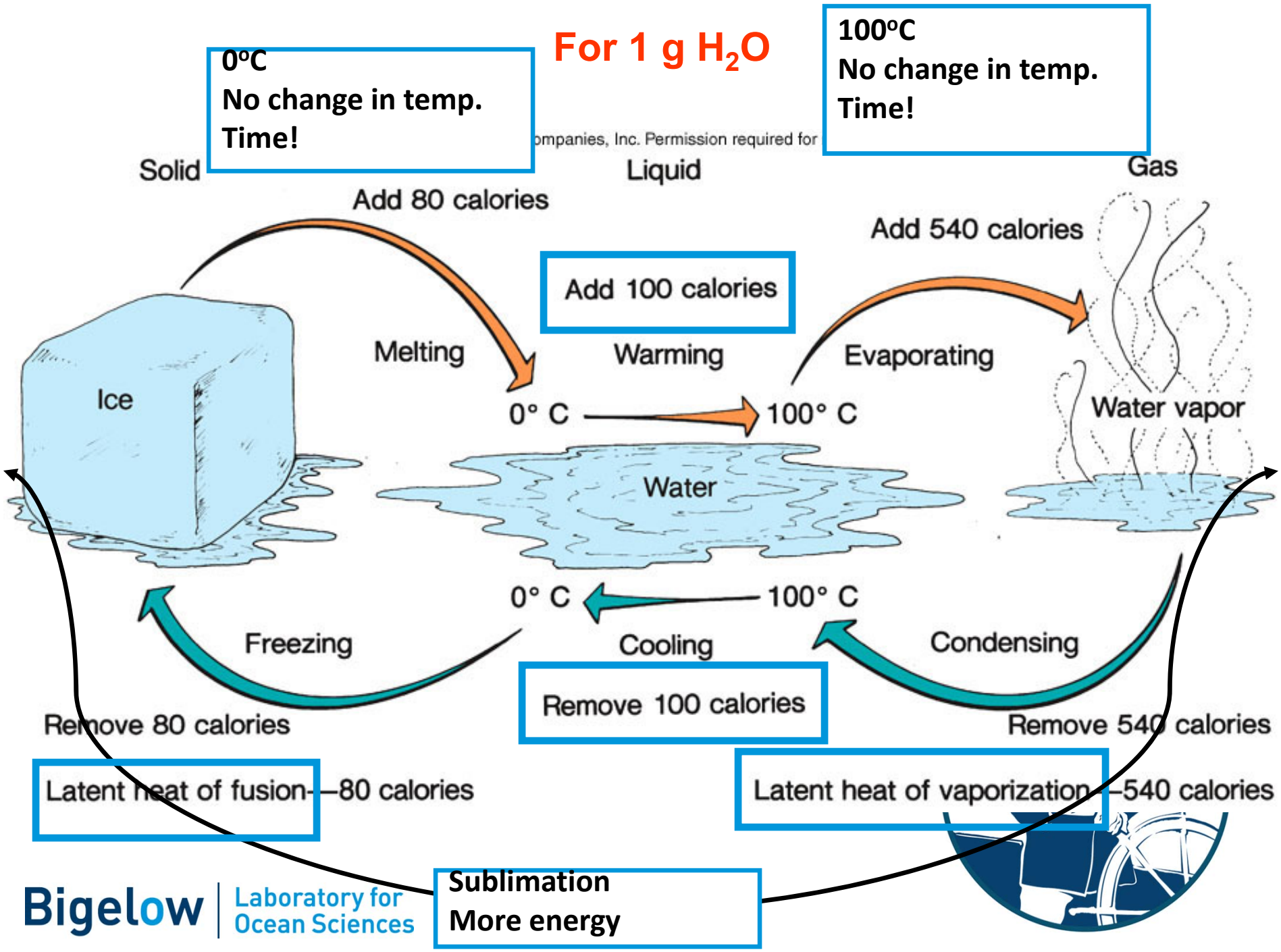
For 1 g H_2O
0°C
No change in temp.
Time!
100°C
No change in temp.
Time!
Solid
Liquid
Gas
Add 80 calories
Add 100 calories
Add 540 calories
Melting
Warming
Evaporating
Ice
0° C
100° C
Water vapor
Water
0° C
100° C
Freezing
Cooling
Condensing
Remove 80 calories
Remove 100 calories
Remove 540 calories
Latent heat of fusion—80 calories
Latent heat of vaporization—540 calories
Sublimation
More energy
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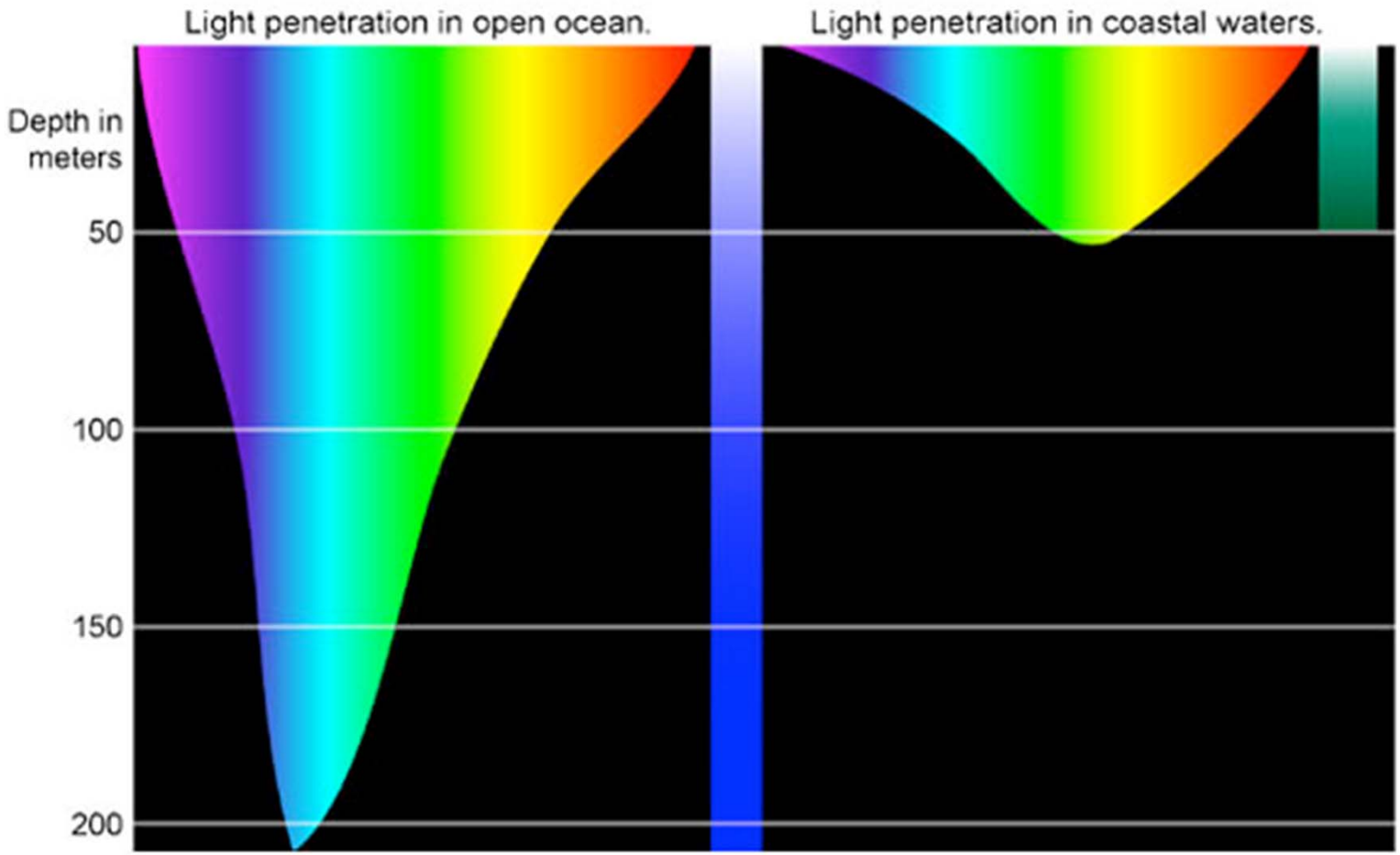
Other properties of water: **light**



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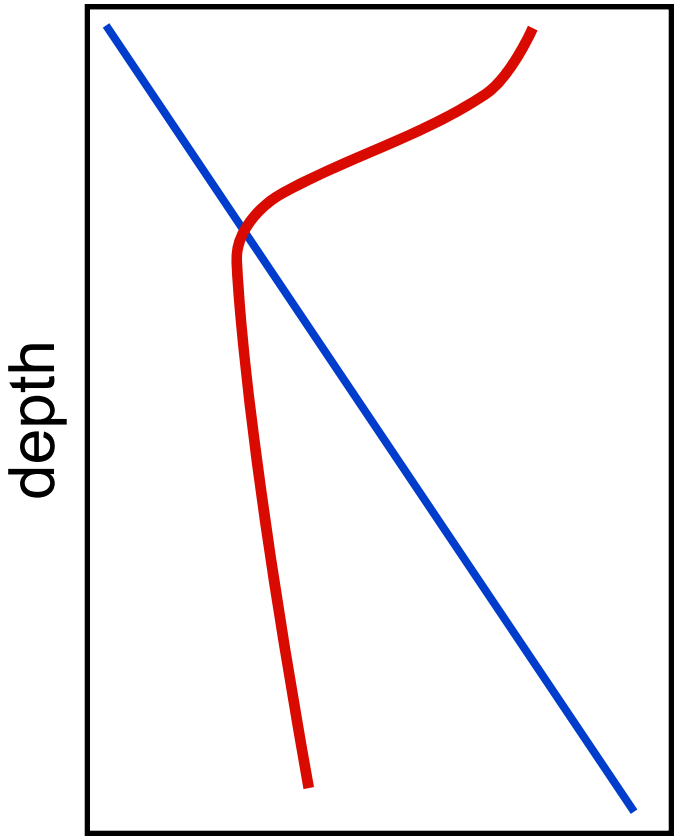
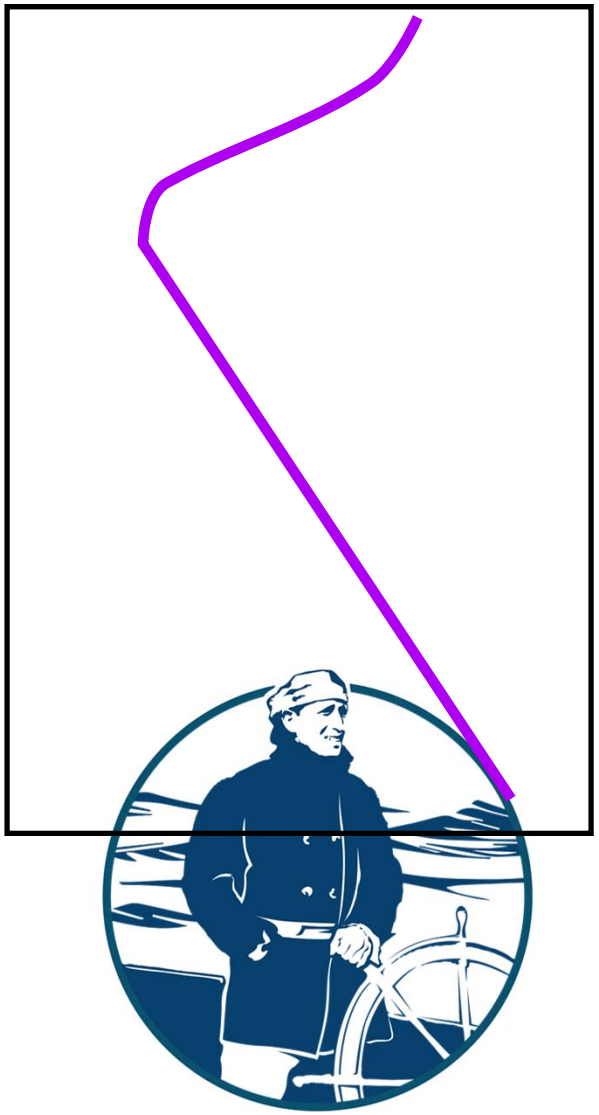
Other properties of water: **sound**



Sound speed increases w/ temp

Sound speed increases w/ pressure



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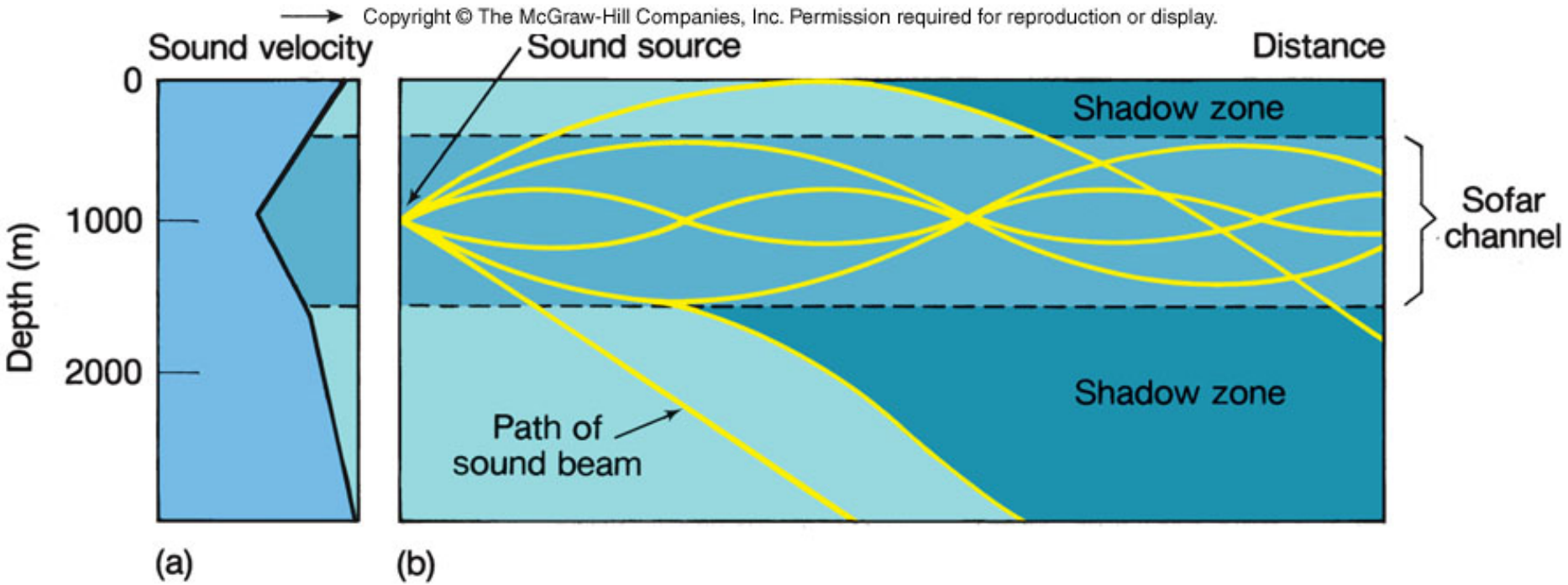
Other properties of water: sound

Sound speed
increases w/ temp



Sound speed
increases w/
pressure

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Table 4.1 Properties of Water

Definition	Comparison	Effects
Physical States Gas, liquid, solid Addition or loss of heat breaks or forms bonds between molecules to change from one state to another.	The only substance that occurs naturally in three states on the Earth's surface.	Important for the hydrologic cycle and the transfer of heat between the oceans and atmosphere.
Heat Capacity One calorie per gram of water per °C.	Highest of all common solids and liquids.	Prevents large variations of surface temperature in the oceans and atmosphere.
Surface Tension Elastic property of water surface.	Highest of all common liquids.	Important in cell physiology, water surface processes, and drop formation.
Latent Heat of Fusion Heat required to change a unit mass from a solid to a liquid without changing temperature.	Highest of all common liquids and most solids.	Results in the release of heat during freezing and the absorption of heat during melting. Moderates temperature of polar seas.
Latent Heat of Vaporization Heat required to change a unit mass from a liquid to a gas without changing temperature.	Highest of all common substances.	Results in the release of heat during condensation and the absorption of heat during vaporization. Important in controlling sea surface temperature and the transfer of heat to air.
Compressibility Average pressure on total ocean volume 200 atmospheres; ocean depth decreased by 37 m (121 ft).	Seawater is only slightly compressible, $4–4.6 \times 10^{-5}$ cm^3/g for an increase of 1 atmosphere of pressure.	Density changes only slightly with pressure. Sinking water can warm slightly due to its compressibility.
Density Mass per unit volume: grams per cubic centimeter, g/cm^3.	Density of seawater is controlled by temperature, salinity, and pressure.	Controls the ocean's vertical circulation and layering. Affects ocean temperature distribution.

Viscosity Liquid property that resists flow. Internal friction of a fluid.	Decreases with increasing temperature. Salt and pressure have little effect. Water has a low viscosity.	Some motions of water are considered friction free. Low friction dampens motion; retards sinking rate of single-celled organisms.
Dissolving Ability Dissolves solids, gases, and liquids.	Dissolves more substances than any other solvent.	Determines the physical and chemical properties of seawater and the biological processes of life forms.
Heat Transmission Heat energy transmitted by conduction, convection, and radiation.	Molecular conduction slow; convection effective. Transparency to light allows radiant energy to penetrate seawater.	Affects density; related to vertical circulation and layering.
Light Transparency Transmits light energy.	Relatively transparent for visible wavelength light.	Allows plant life of grow in the upper layer of the sea.
Sound Transmission Transmits sound waves.	Transmits sound very well compared to other fluids and gases.	Used to determine water depth and to locate targets.
Refraction The bending of light and sound waves by density changes that affect the speed of light and sound.	Refraction increases with increasing salt content and decreases with increasing temperature.	Makes objects appear displaced when viewed by light and sound.

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Sea Water Constituents

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Salinity

The amount of dissolved salts in seawater

Mix of types of salts:

90% NaCl

9% $MgSO_4$

Ca

K

table salt

bath salt (epsom)

Traditionally measured in grams-of-salt per kilogram-of-water:

35 g of salt in 1 kg of water = 35‰

Now measured using electrical conductivity

35 PSU

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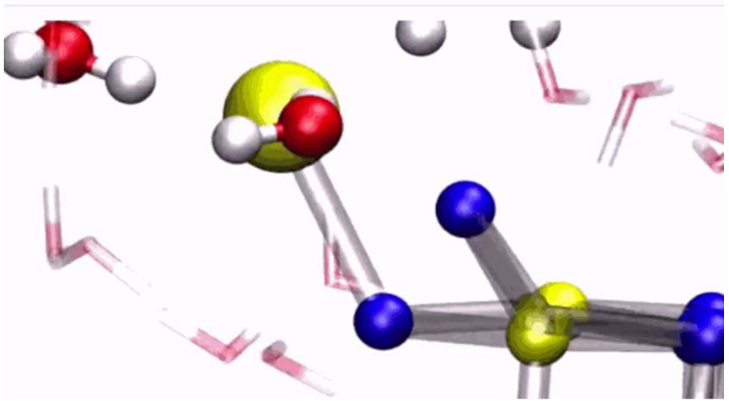
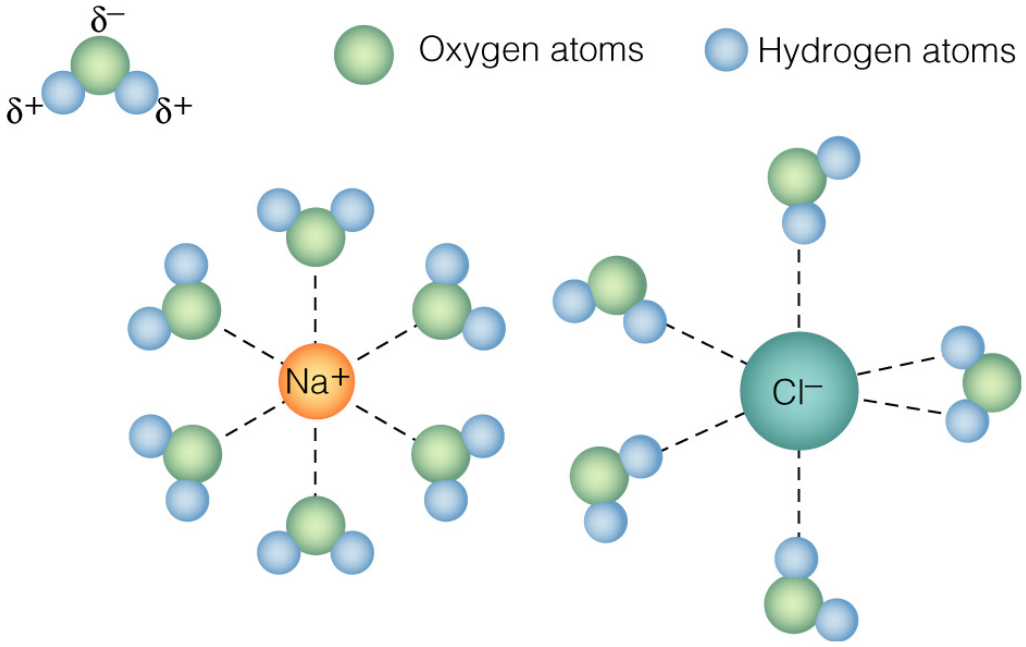
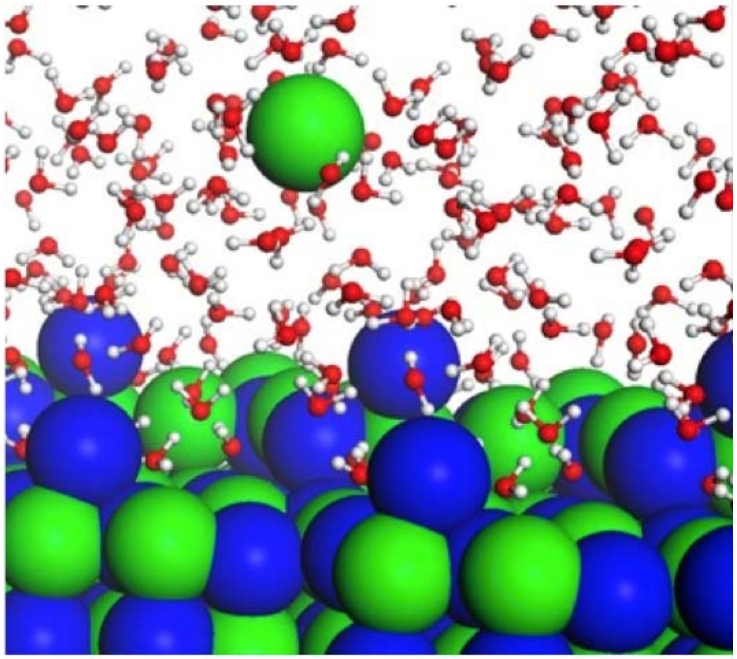
Salinity

These elements easily form ions
→ salt is dissolved







Water dissolving salt, Liu and Michaelides, London Centre for Nanotechnology, UCL, http://www.ucl.ac.uk/news/ucl-views/0803/salt500

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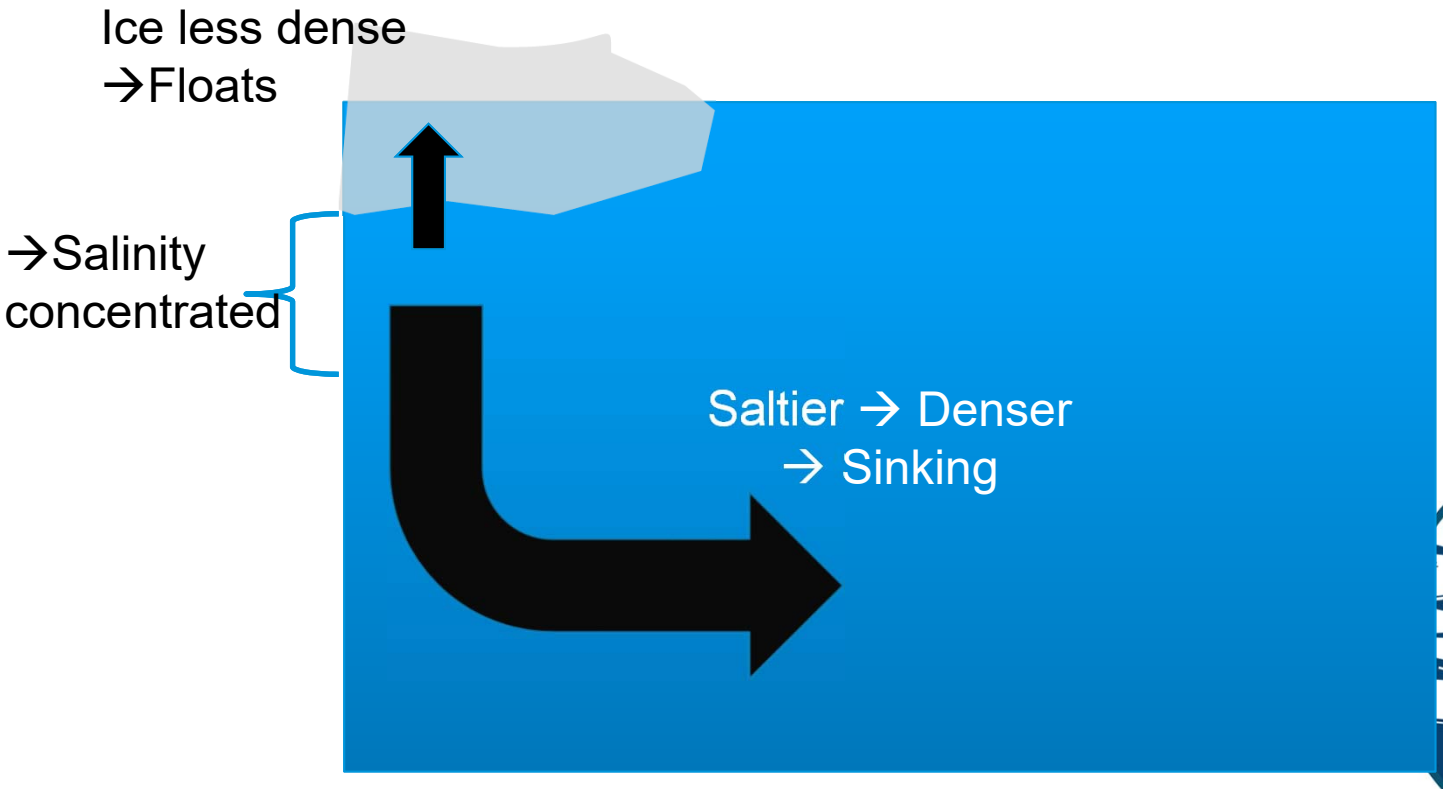
Salinity

Salinity has a major effect on density
Density has a major effect on currents
→ Try to measure salinity to ±0.001



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Seawater: other constituents

Minor constituents:
•Bromine
•Carbon
•Strontium
•Boron
•Silicon
•Fluorine
-1-100 parts per million

Trace elements:
-All other elements
- less than 1 part per million
- Some are important (Fe = nutrient, Hg = toxin)

Radionuclides:
-Most are natural
-Tritium from nuclear testing (1950-1962) can be used to trace water movement

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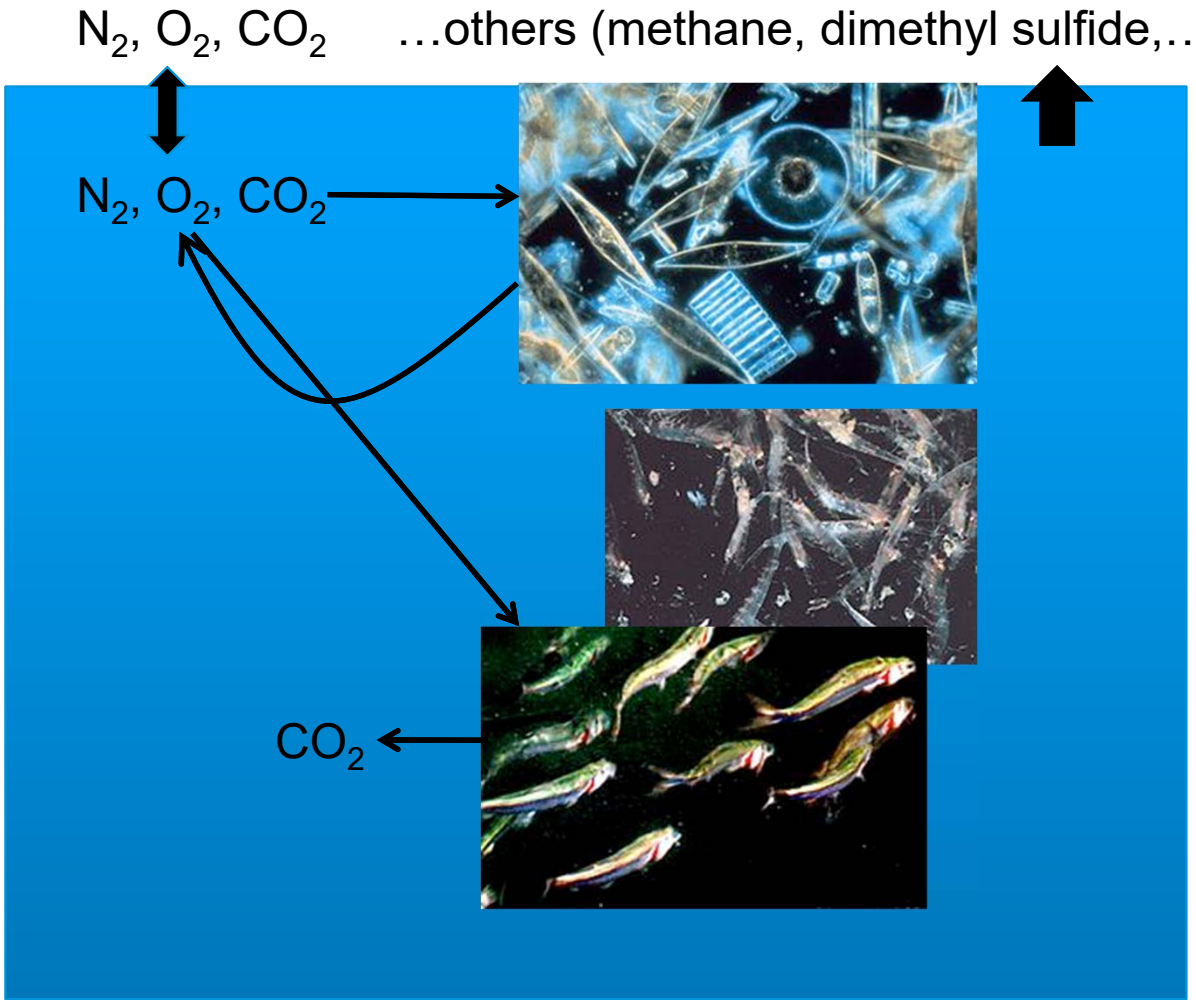
Seawater: other constituents

- Dissolved Gasses

- Hydrogen ions (H^+)
  i.e. pH



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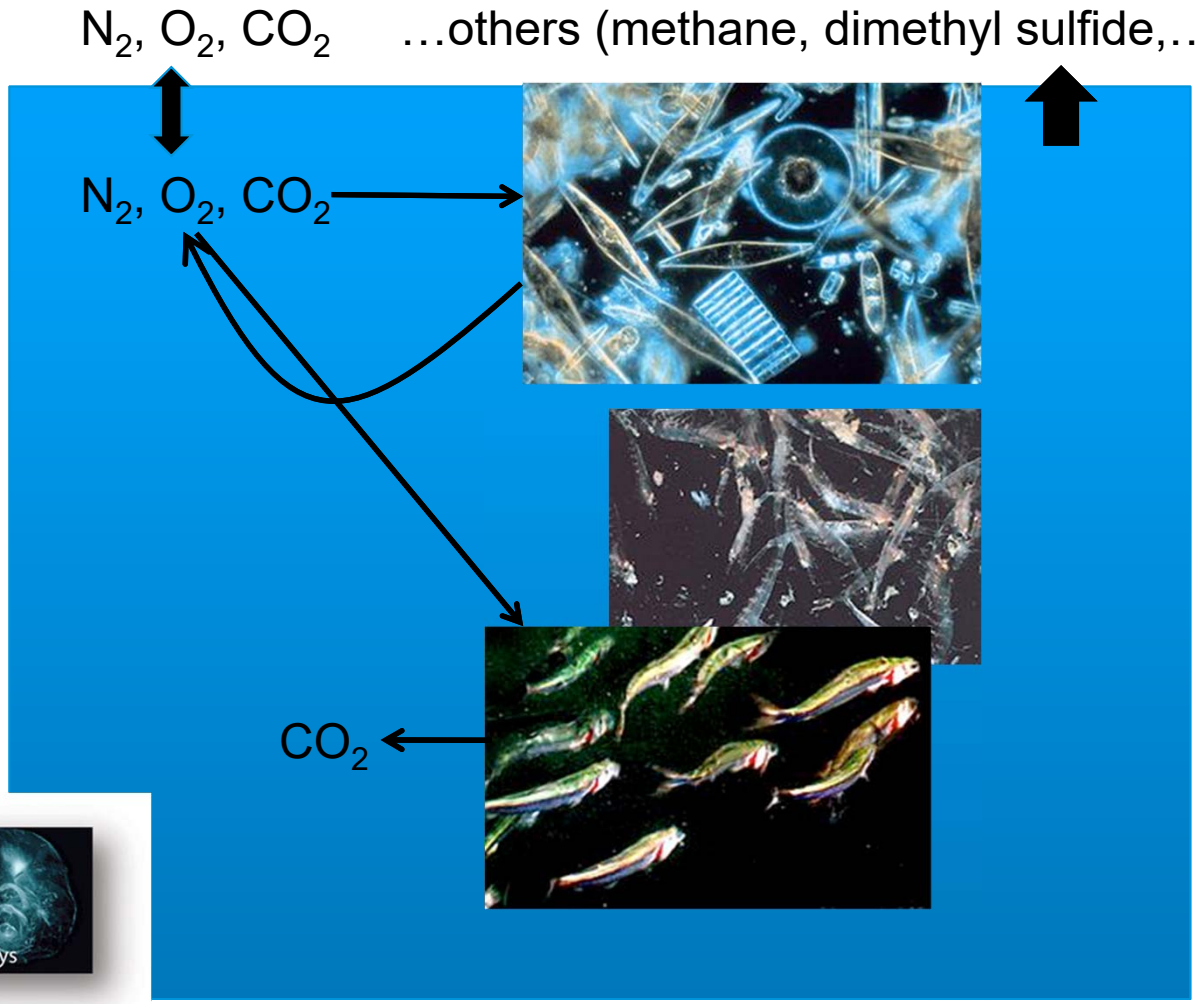
Seawater: other constituents

- Dissolved Gasses

- Hydrogen ions (H^+) i.e. pH

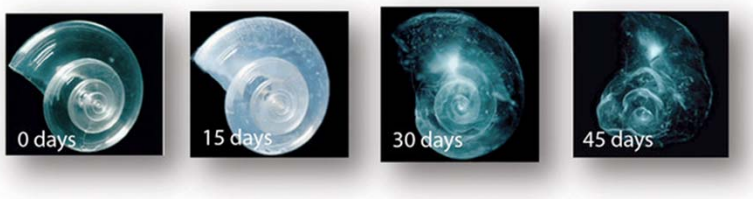


Acidification Problem

$$CO_2 + H_2O \leftrightarrow H_2CO_3$$

$$H_2CO_3 \leftrightarrow H^+ + HCO_3^-$$

$$H^+ + CO_3^{2-} \leftrightarrow HCO_3^-$$



Seawater: Density

Determines structure/currents in the ocean

Measured in : g / cm^3

or g/mL

or, because pure water has a density of 1000 kg/m^3,
… measured in (kg/m^3 – 1000 kg/m^3)
i.e. 1021.2 kg/m^3 → 21.2

Determined by:
1) Temperature
2) Salinity
3) Pressure

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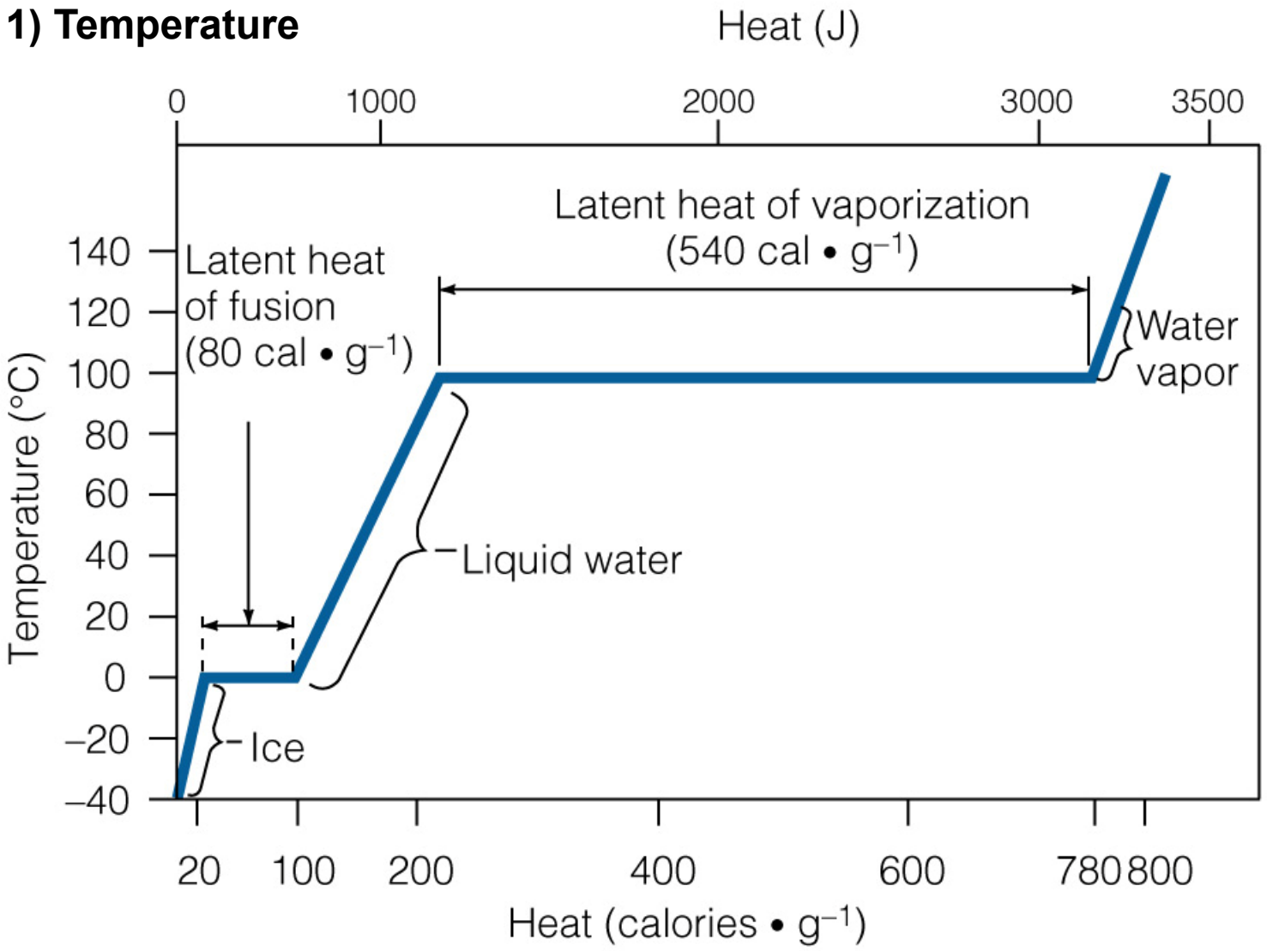
1) Temperature



Sensible Heat: measurable change in temperature when heat is added or subtracted (sloping lines).

Latent Heat: no temperature change with added/subtracted heat (flat lines).

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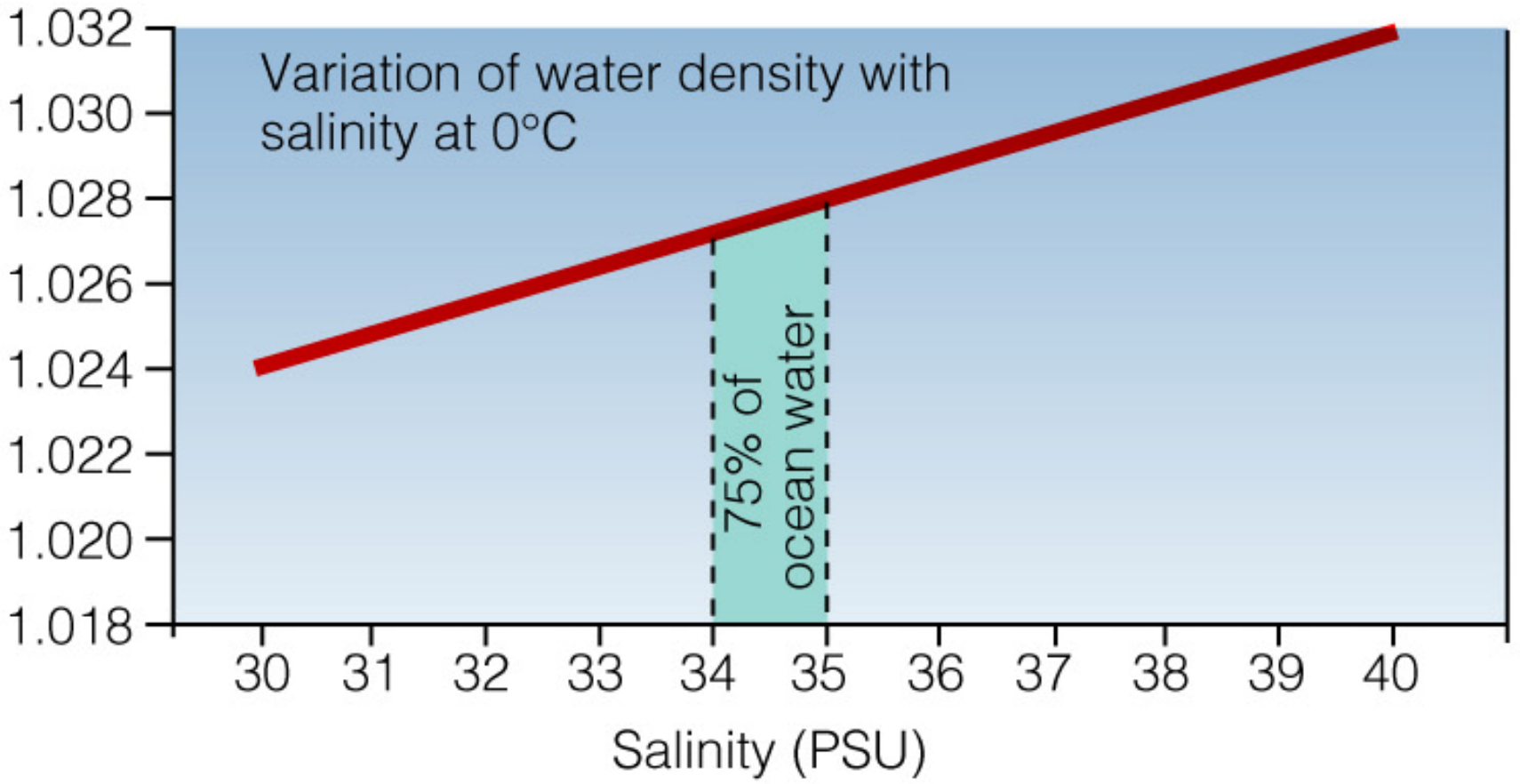
2) Salinity



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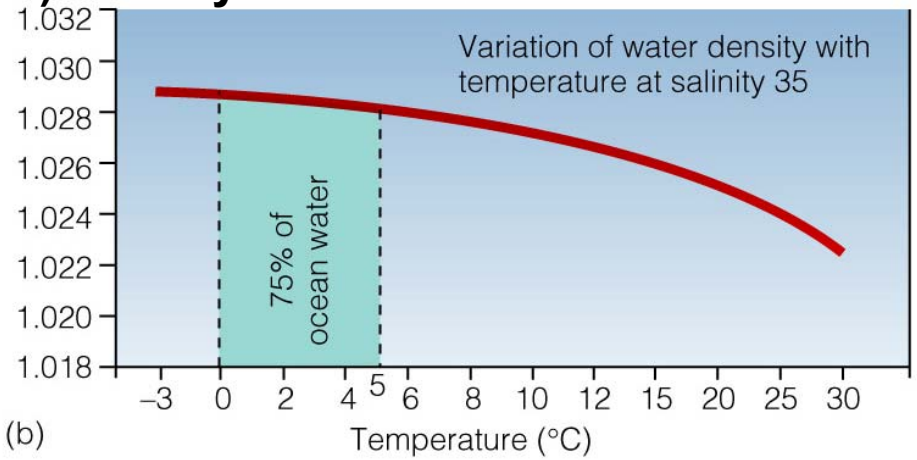
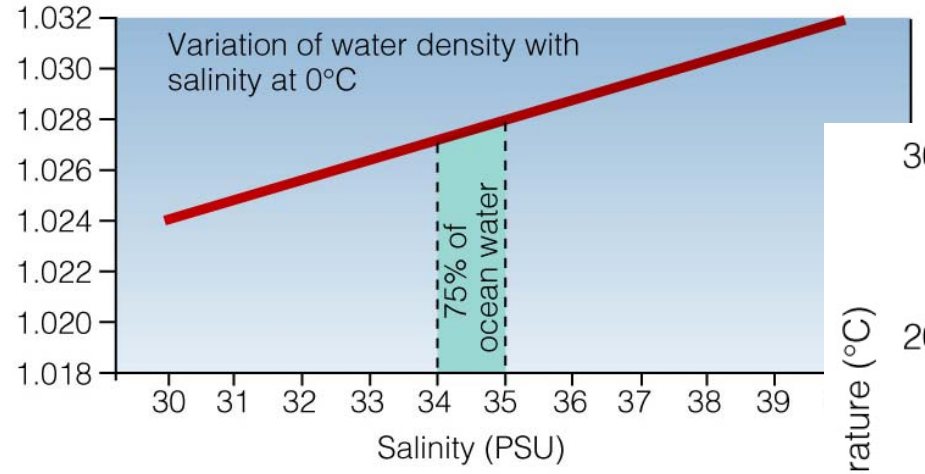
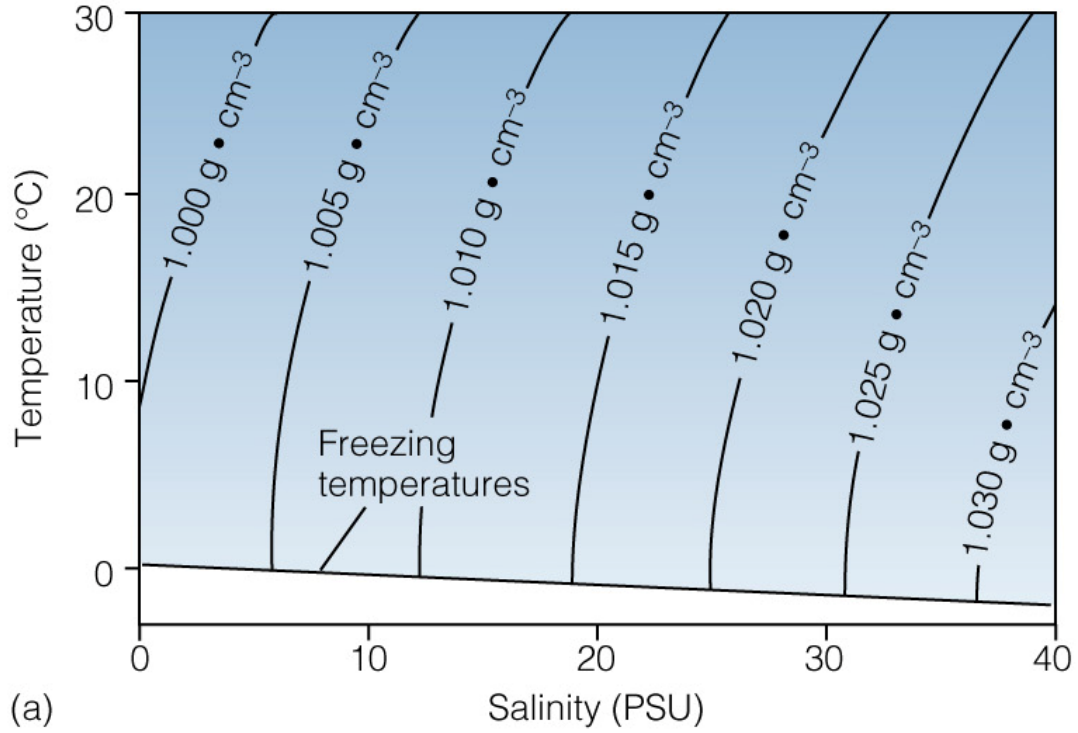
2) Salinity



(b)



(c)



(a)

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3) Pressure

Pressure compresses materials to make them more dense

Water is almost completely incompressible

Only matters in the very deepest part of the ocean

Only increases density by about 2%

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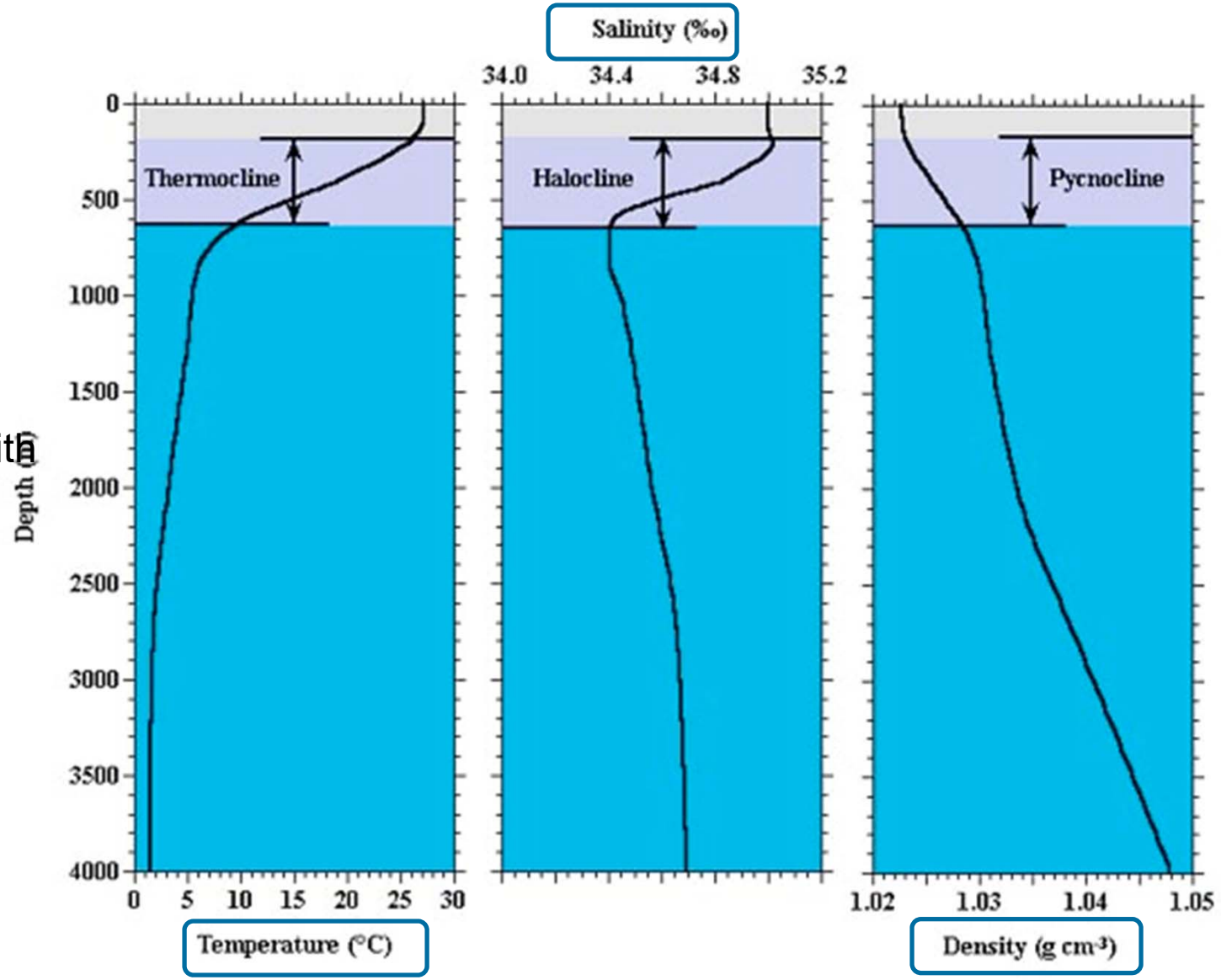
Typical ocean layering

Mixed layer

-wind-mixed
-nearly uniform
-100m – 1000m
-~ 2% of ocean
-Sunlit ➔ photosynthesis
-gas exchange with atmosphere



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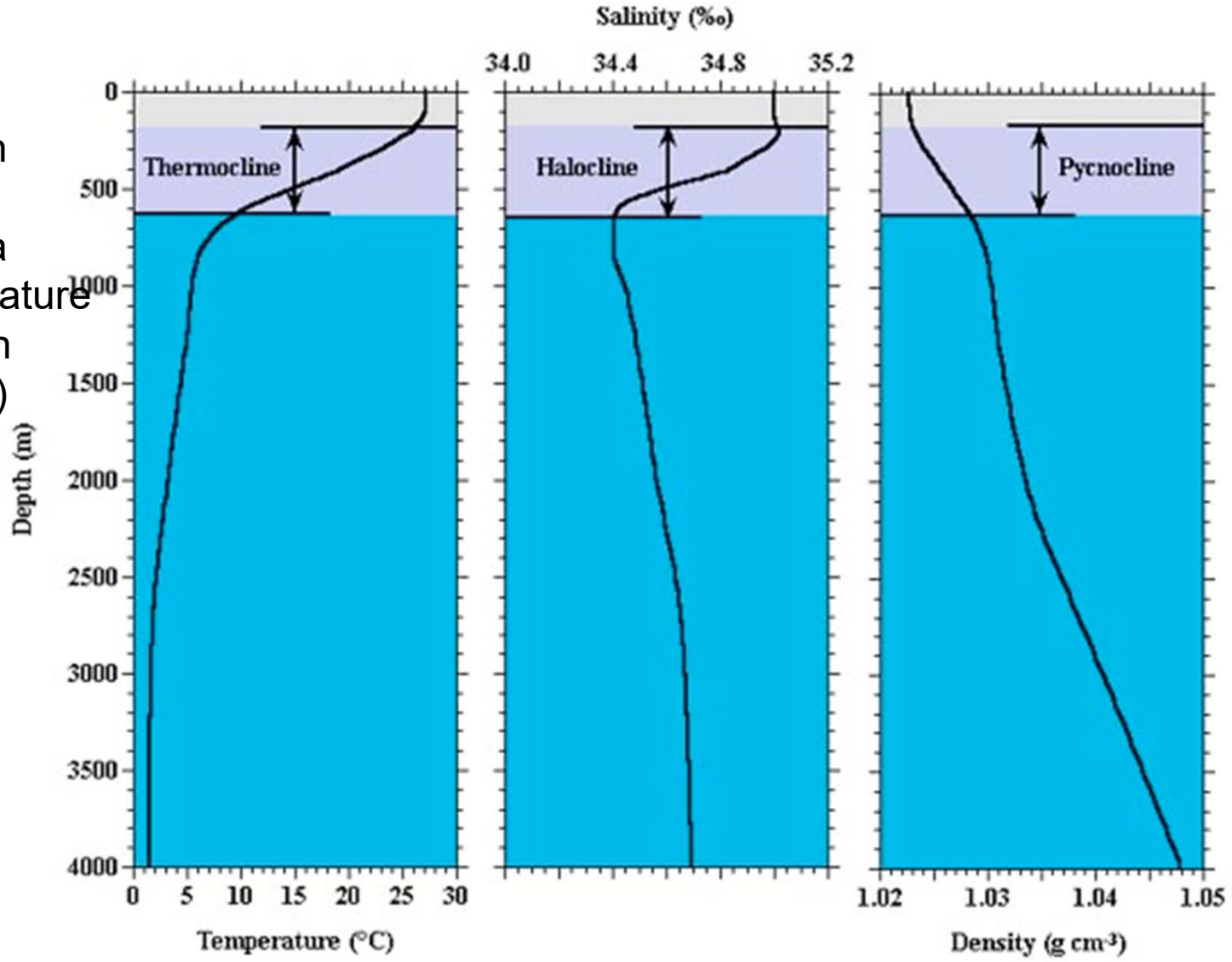
Typical ocean layering

<u>Pycnocline</u>

-Sharp gradient in density
-Could be either a change in temperature (thermocline) or in salinity (halocline)
-~18% of ocean



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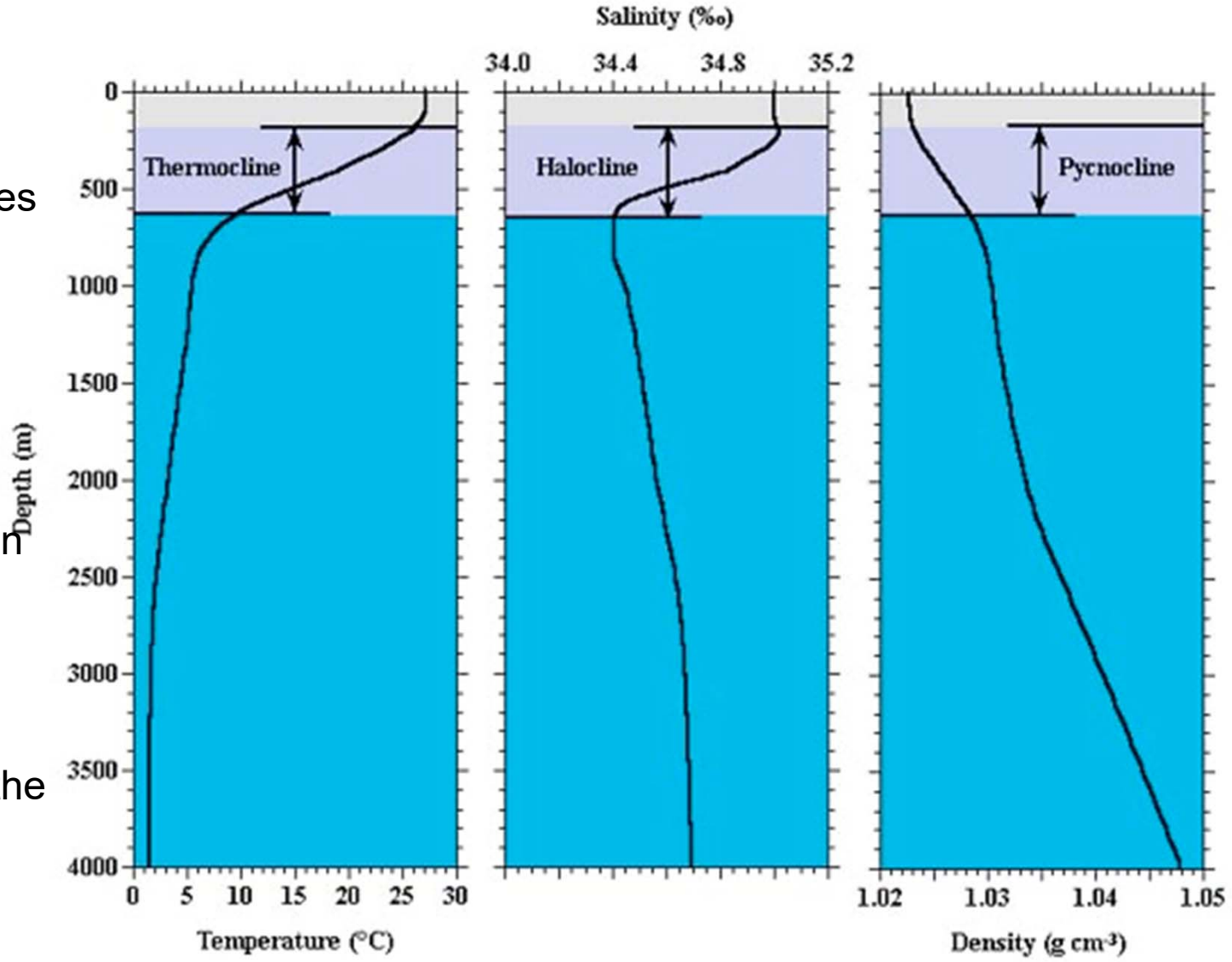
Typical ocean layering

<u>Deep layer</u>

-Cold (<4 deg)
-Originates at poles
-Dark (no photosynthesis)
-Not much effect from surface processes
-~80% of ocean
-Largest habitat on earth*

*except possibly the deep biosphere



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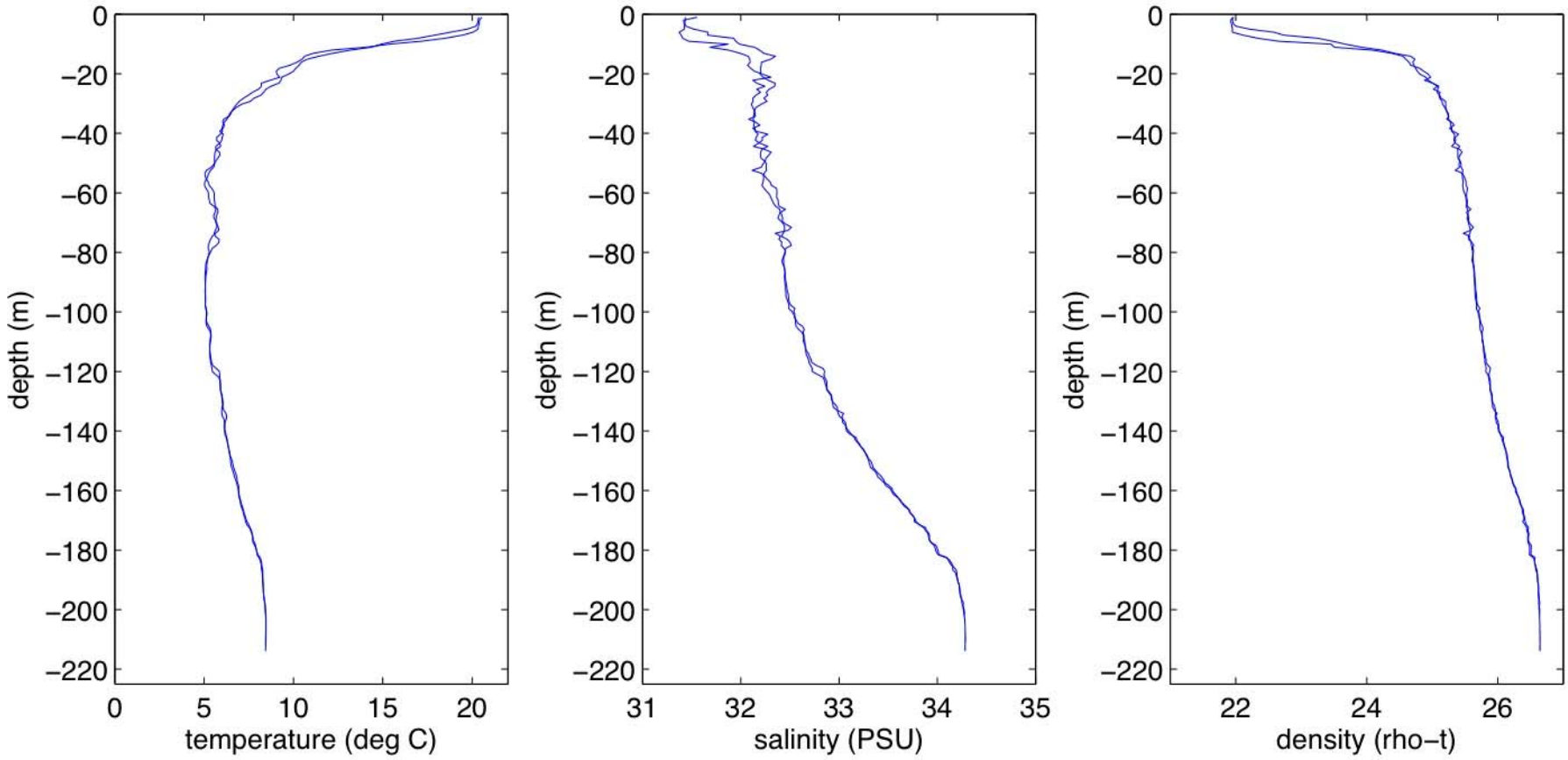
Tracing water masses

Wilkinson Basin



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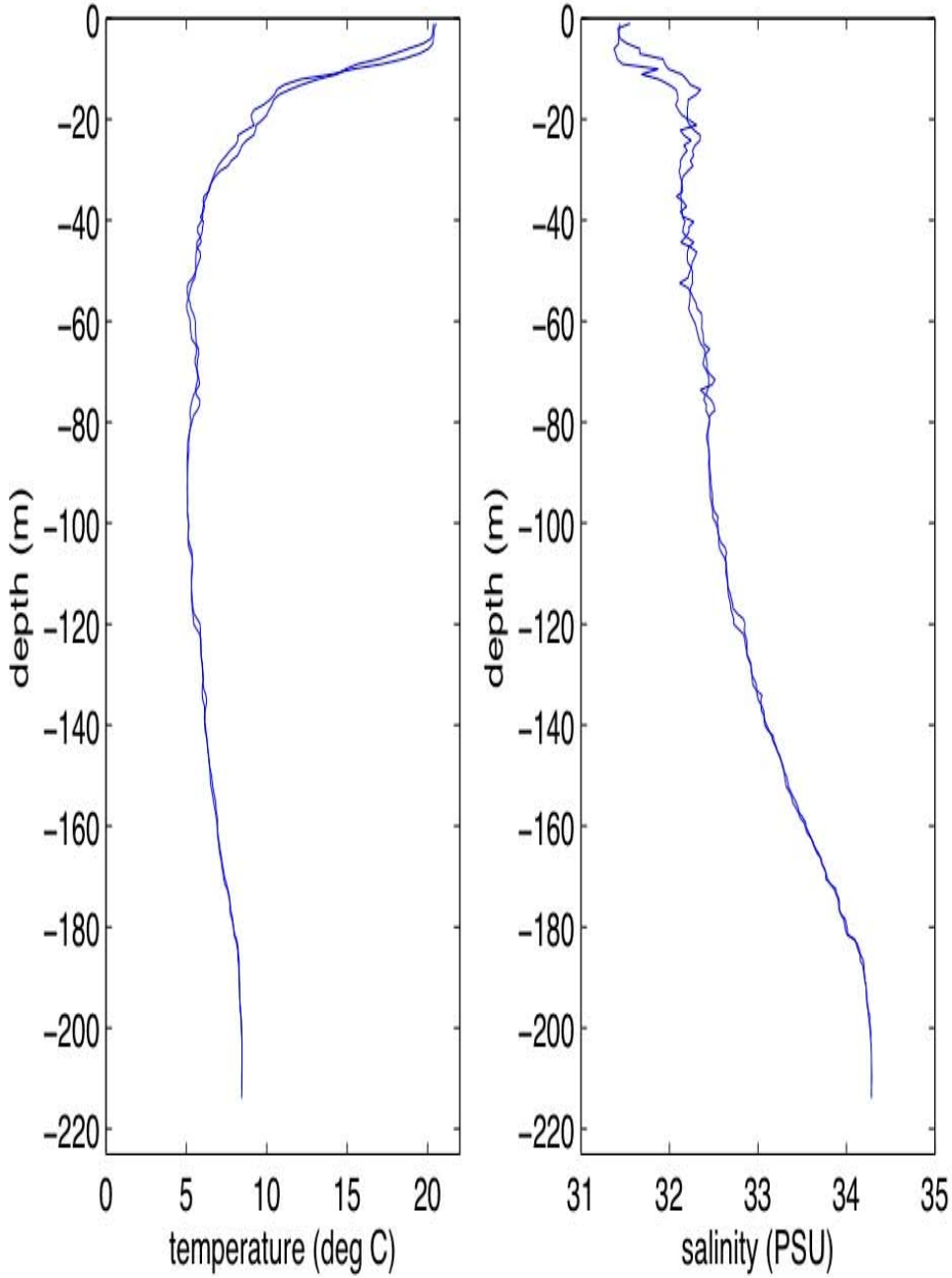
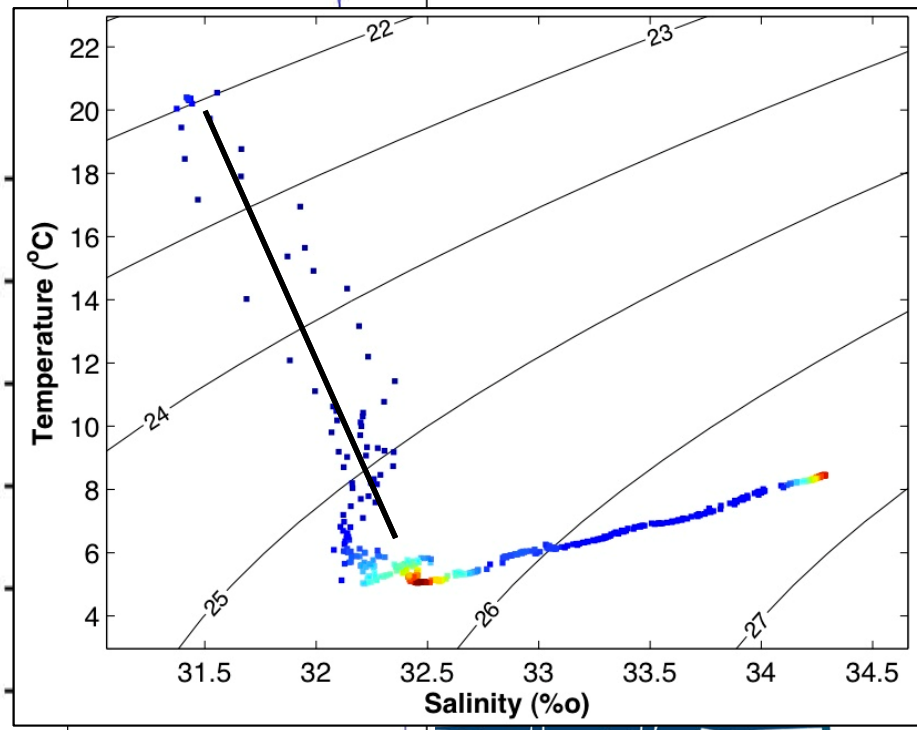
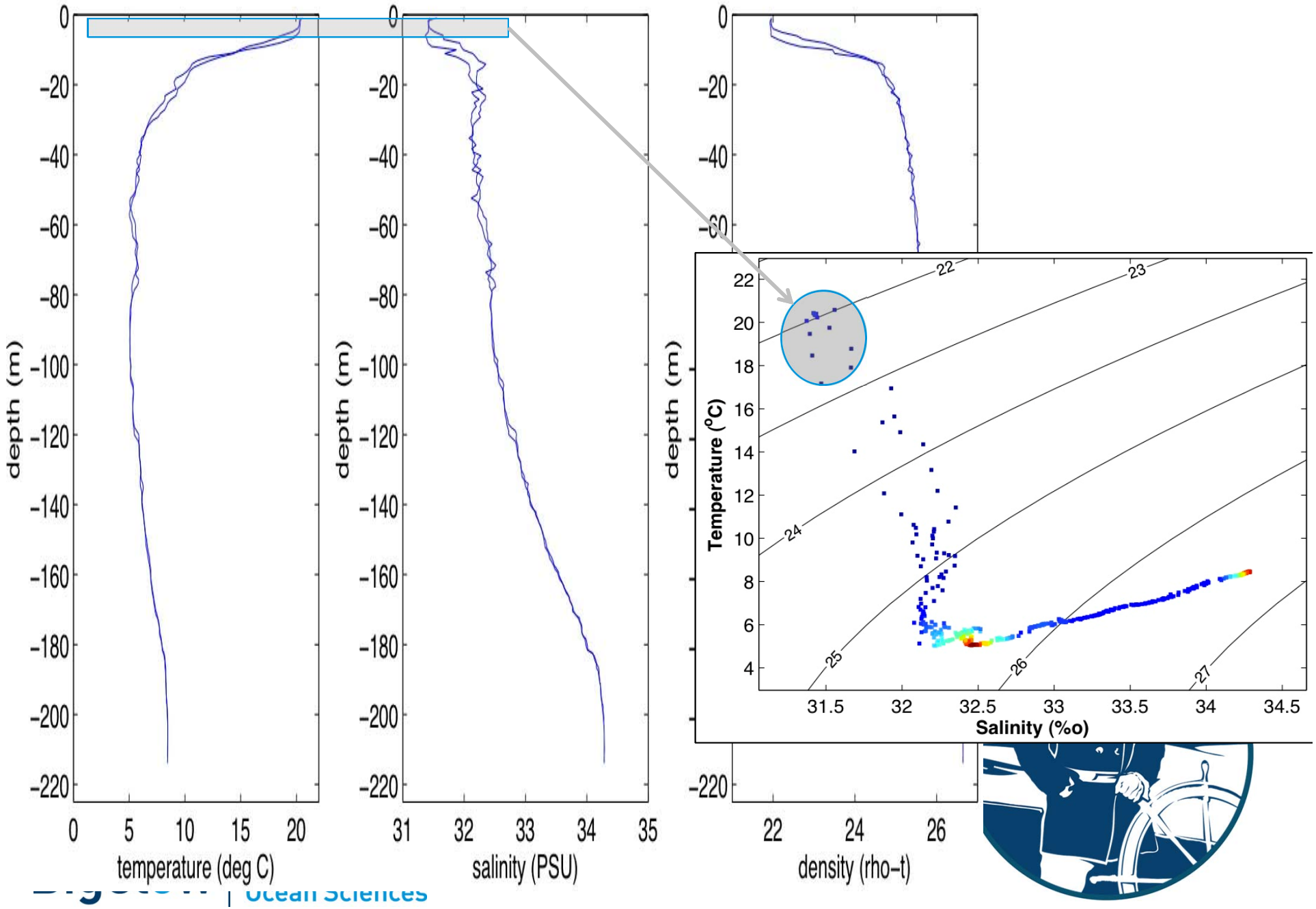


Mixing occurs on a straight line on this plot



Note: T, S are conservative (only changed through mixing)


depth (m)
temperature (deg C)
salinity (PSU)
density (rho-t)
Temperature (°C)
Salinity (‰o)
22
23
24
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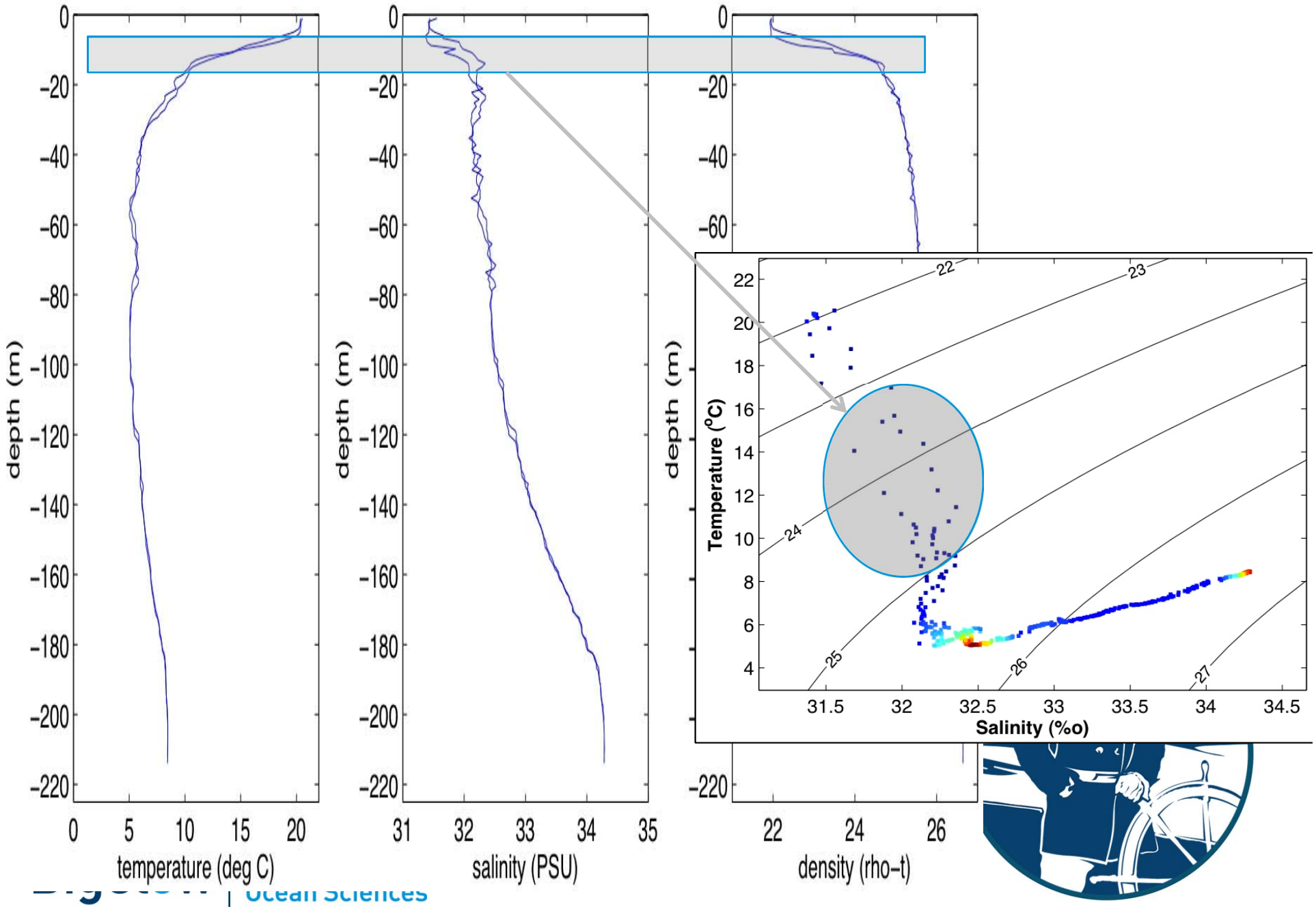
26
27


depth (m)
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Temperature (°C)
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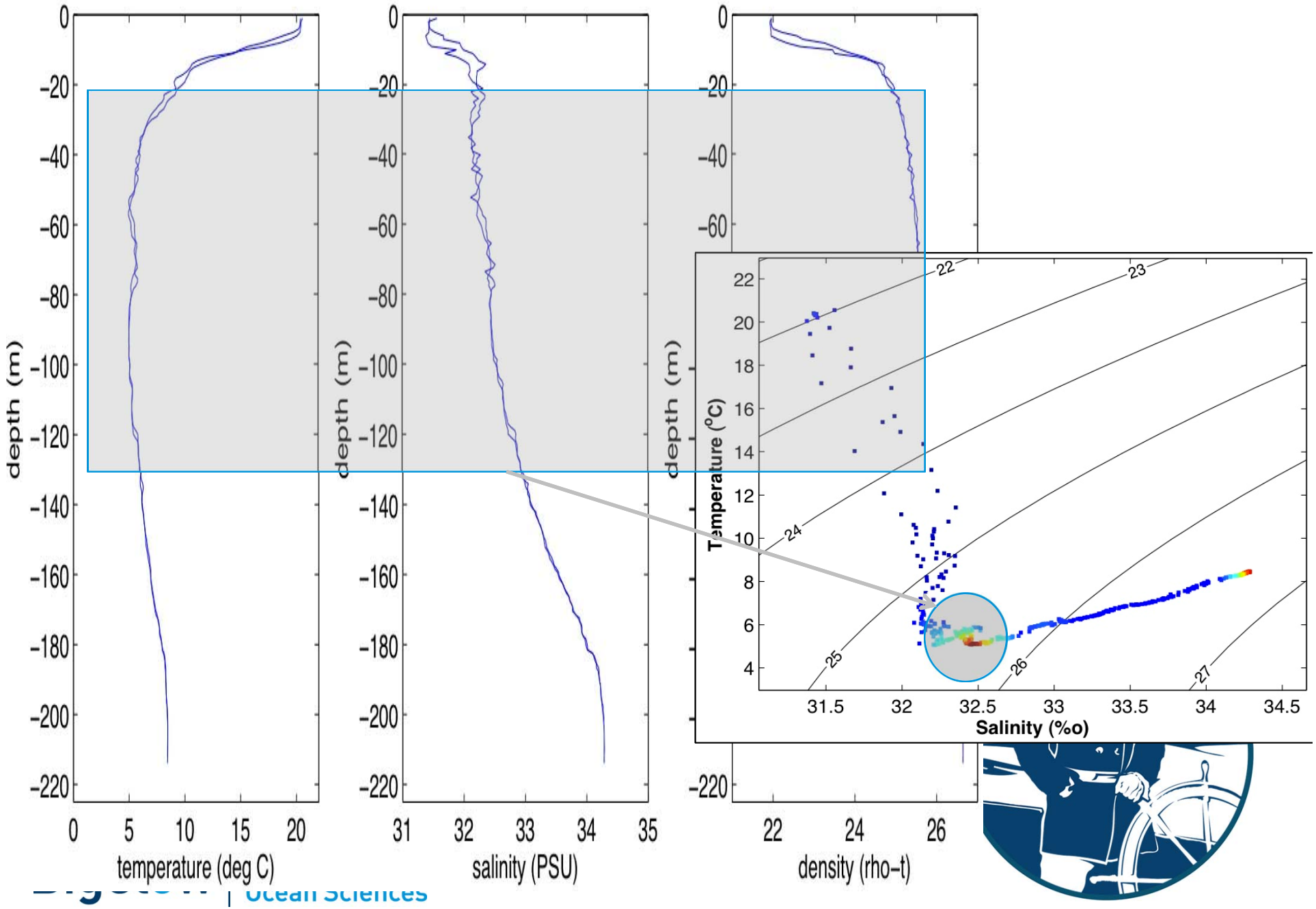
depth (m)
temperature (deg C)
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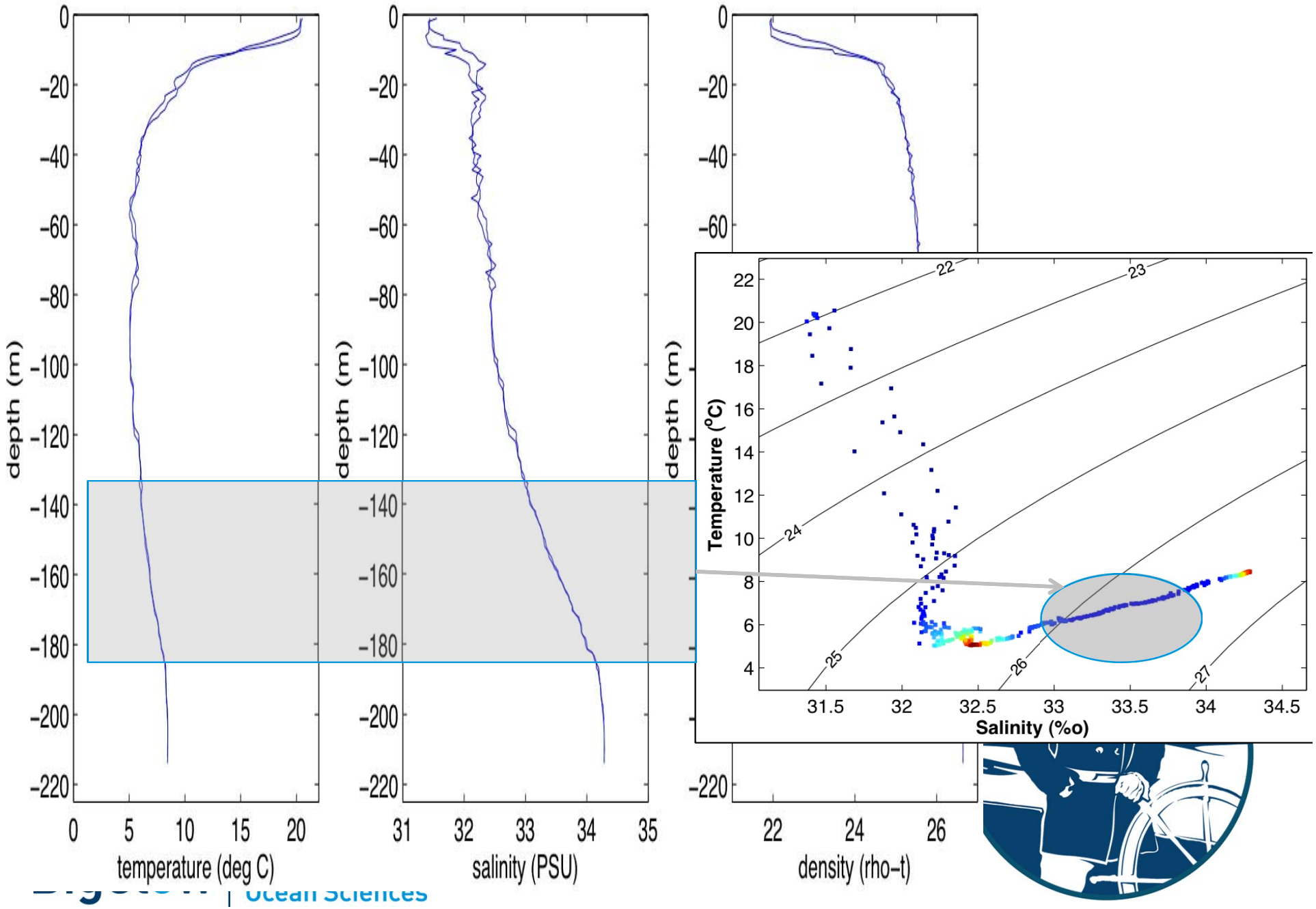
Temperature (°C)
Salinity (‰)


depth (m)
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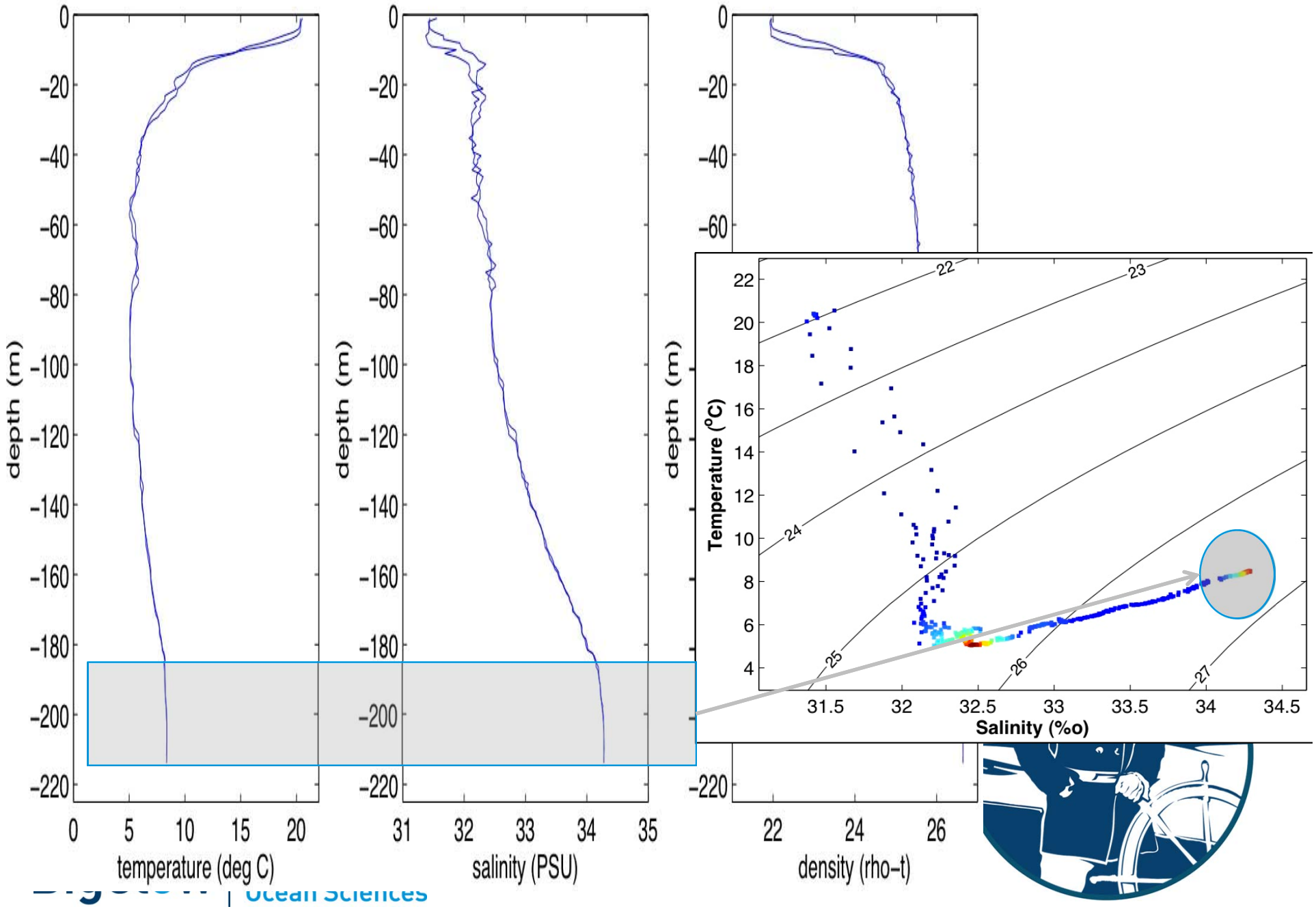
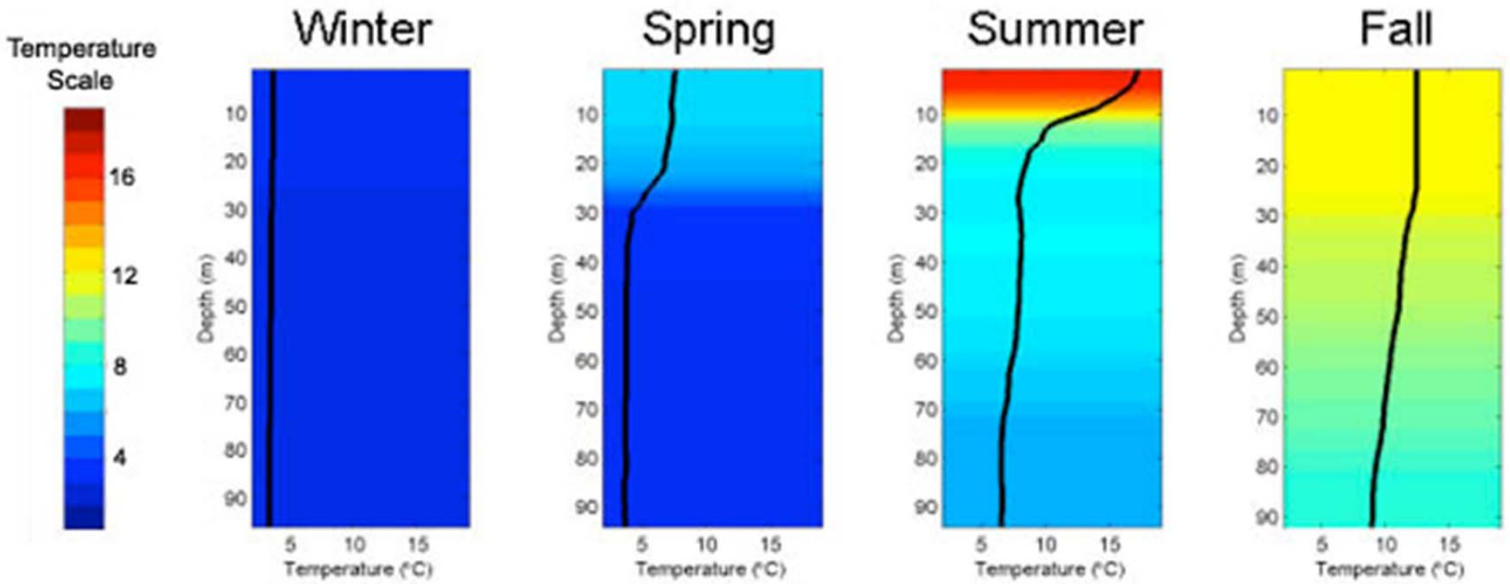

depth (m)
temperature (deg C)
salinity (PSU)
density (rho-t)
Temperature (°C)
Salinity (‰)



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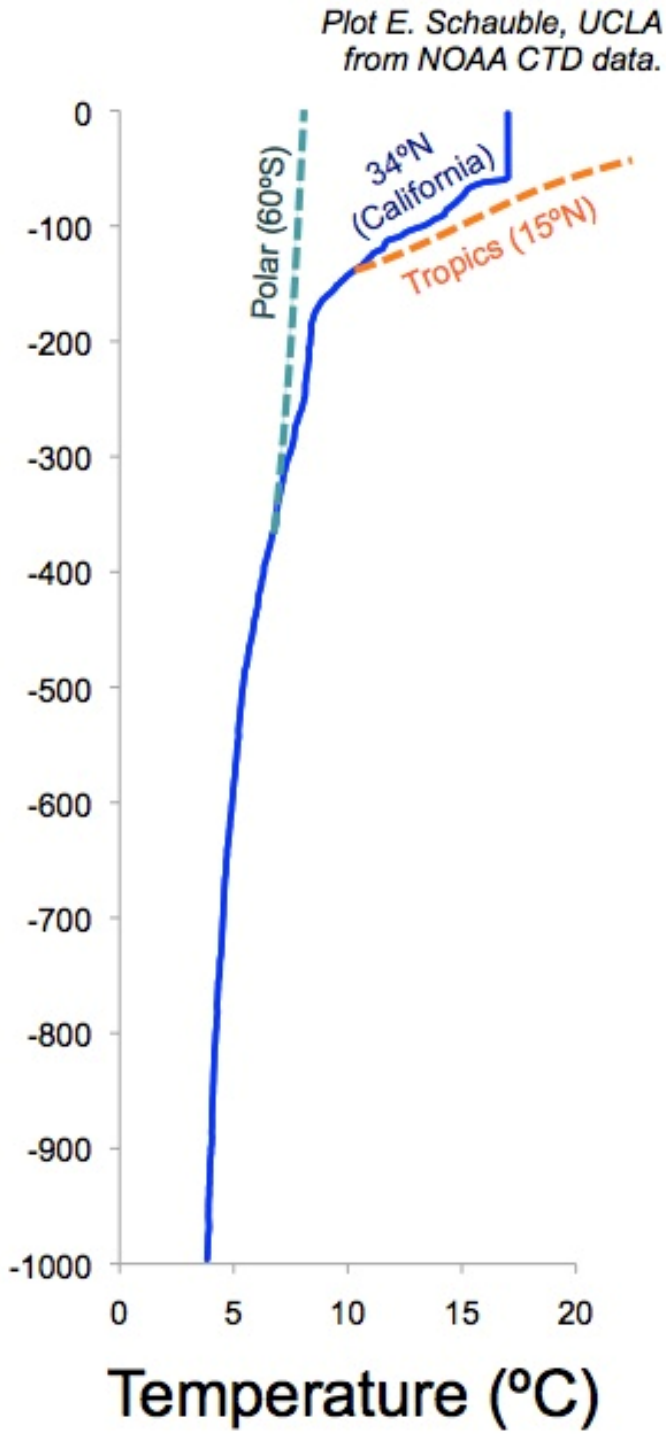

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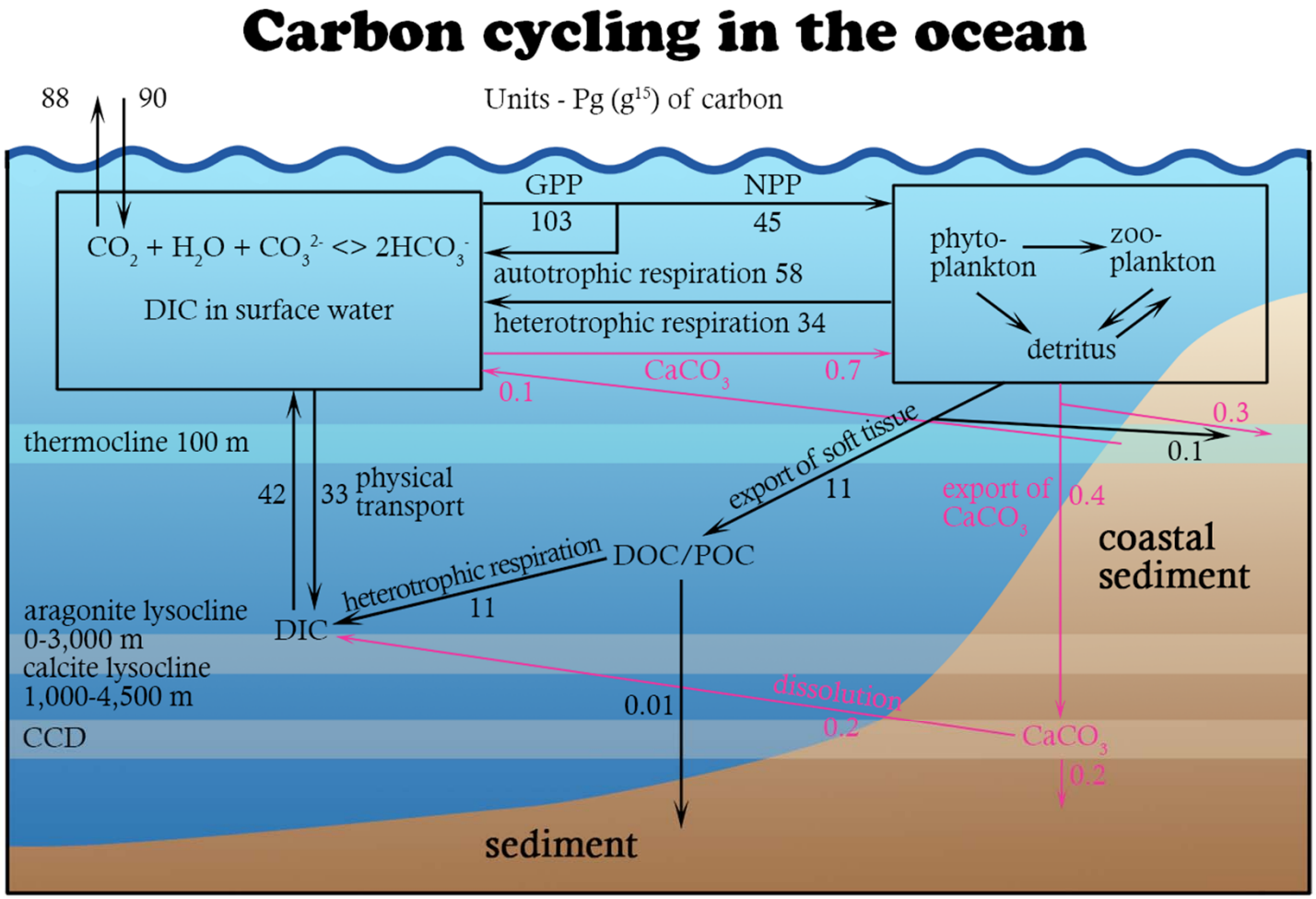
Element cycles



DIC - Dissolved Inorganic Carbon
DOC - Dissolved Organic Carbon
POC - Particulate Organic Carbon

GPP - Gross Primary Productivity
NPP - Net Primary Productivity
CCD - Carbonate Compensation Depth (a sediment property, where carbonate rain is balanced by carbonate dissolution)

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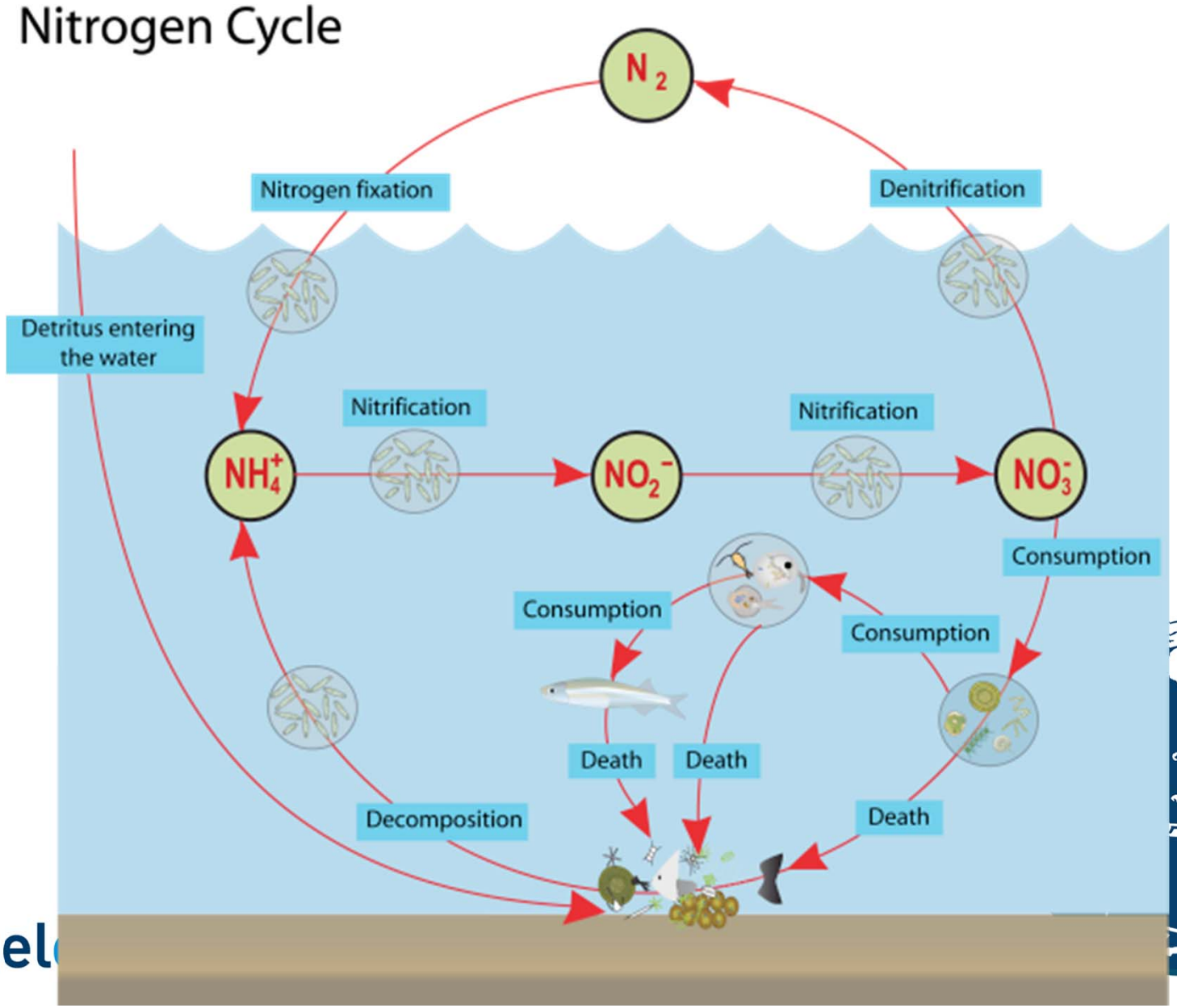
Element cycles



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