Salinity

- A measure of the dissolved solids in seawater, usually expressed in grams per kilogram or parts per thousand by weight.

- **Average** Salinity: standard seawater has a salinity of **35‰** at 0˚C (32˚F).
  - **34.72** (34.72 is a number, you really don't need the ppt,ssu, etc.)
  -
- **Absolute** Salinity: ratio of the mass of dissolved material in a sample of seawater to the mass of the sample of seawater

How did the Ocean get Salty?

- In order to understand how salts get into the world ocean, you have to know something about the composition of Earth's crust & something about the **hydrologic cycle***,* the movement of water through the various reservoirs of Earth
- Interactions between the **geosphere** & the **hydrosphere** govern the salinity of the world ocean over geologic time scales
- Earth's crust & volcanoes are the **major *sources*** of the substances dissolved in seawater
- The early ocean (4.6-2 BYA) may have been twice as salty as today
- Today the **sources** of salts & **sinks** for salts appear to be in balance

Sources & Sinks

Component	Sources	Sinks
Chloride (Cl^-)	Volcanos River Influx	Evaporite Deposition (NaCl)
Sodium (Na^+)	River Influx	Evaporite Deposition (NaCl)
Potassium (K^+)	River Influx Volcanic-seawater Reactions (High Temp)	Uptake by Clays Volcanic-seawater Reactions (Low Temp)
Calcium (Ca^{++})	River Influx Volcanic-seawater Reactions	Biogenic Shells Evaporites – gypsum Calcite Precipitation
Silica	River Influx Basalt-seawater Reactions	Biogenic Shells

- NOT from River runoff (because river runoff is dominated by HCO_3^-, SiO_2, & Ca^{2+})
- Ocean formed 4 x 10^9 years ago
- Atmospheric gases from Volcanoes (Cl SO_2 CO_2)
- In Rainwater these gases form Acids (HCl H_2SO_4 HCO_3)
- Acids dissolve minerals from rocks
- The **dissolved minerals** made the Ocean Salty

Why isn't the Ocean Saltier?

- After volcanic activity decreased, the rate of addition of dissolved material to the ocean came into balance with the rate at which the dissolved material is removed by processes such as precipitation & uptake by marine organisms.

➢ What makes the ocean Salty?

1. Major Constituents

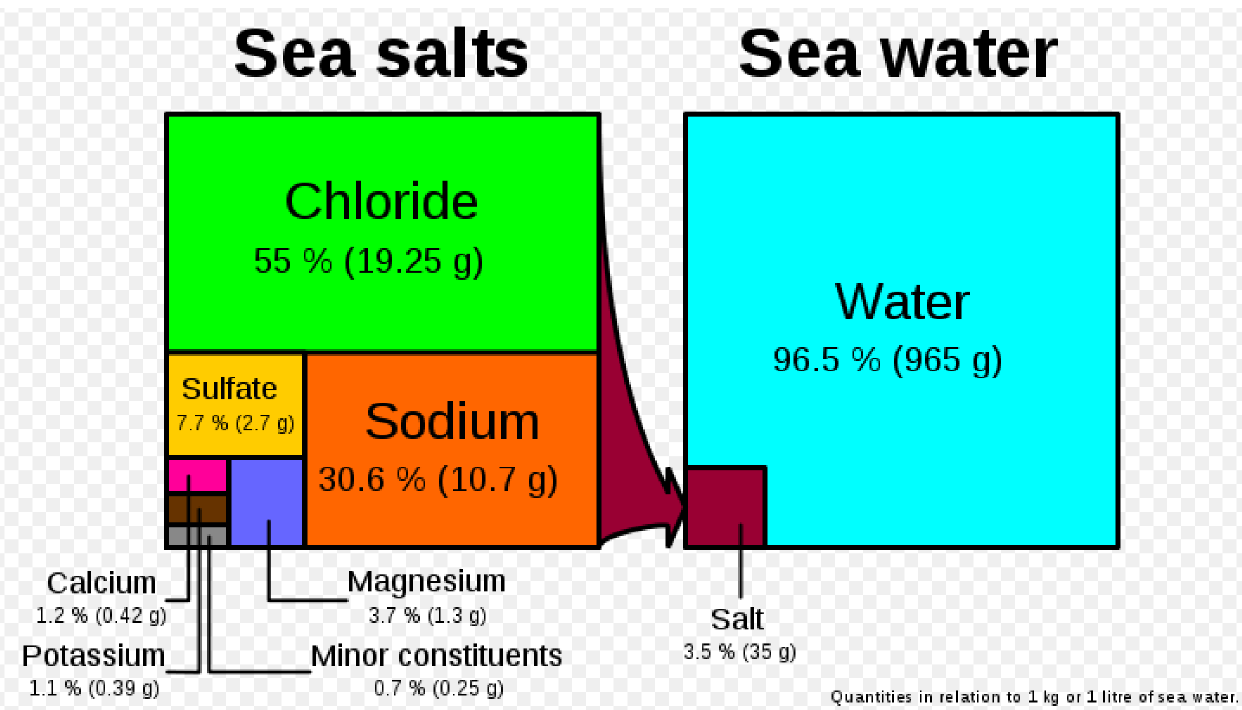
- The 6 most abundant (by weight) ions in sea salts are:
  - **Chloride (Cl^-)**
  - **Sulfate (SO_4^-)**
  - **Calcium (Ca^{++})**
  - **Sodium (Na^+)**
  - **Magnesium (Mg^{++})**
  - **Potassium (K^+)**
- The most abundant constituent of seawater is the *anion* **chloride (CL^-)**, which is the ionic form of **chlorine**
- The 2nd most abundant constituent of seawater is the *cation* **sodium (NA^+)**
- In solid form, they make **Table Salt** (**NaCl**)
- When dissolved in seawater they form NA^+ & Cl^-

2. Minor Constituents

3. Biologically important Nutrients

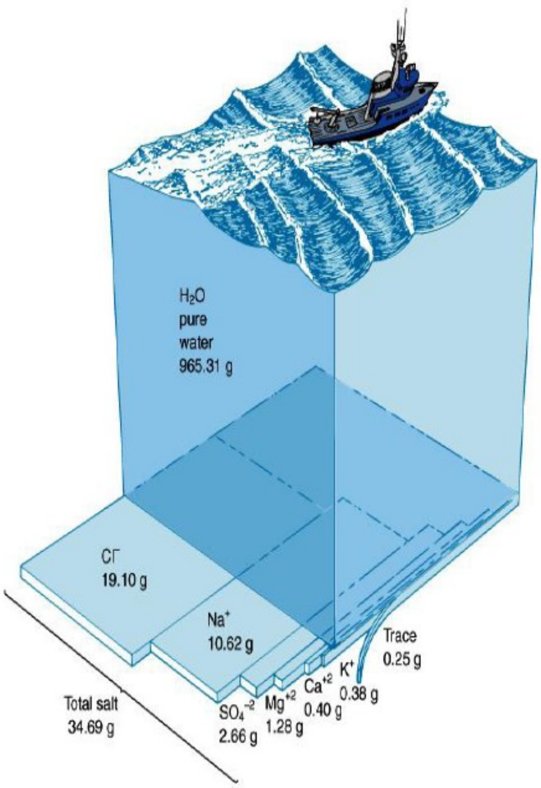
4. Dissolved Organic Matter

5. Dissolved Gases



Salinity

Average Ocean Water



Dissolved Material in Seawater		
ION	Gram weight per kg	% by weight
★ **Chloride – Cl^-**	19.111	55.04
★ **Sodium - Na^+**	10.629	30.61
Sulfate – SO_4^{2-}	2.667	7.68
Magnesium - Mg^{2+}	1.281	3.96
Calcium - Ca^{2+}	0.403	1.16
Potassium- K^+	0.383	1.10
Bicarbonate - HCO_3^-	0.141	0.41
Bromide - Br^-	0.065	0.19
Boric Acid – $H_2BO_3^-$	0.026	0.07
Strontium - Sr^{2+}	0.013	0.04
Fluoride - F^-	0.001	0.00

S = 34.72

These First 7 Ions sum to 99.69%, all 11 Ions sum to 99.9%
(any variation in these numbers occurs in the 4 or 5th significant digit)

This concept is called the "**Law of Constant Proportions,**"
the ocean is well mixed & only really changes at the sources and sinks

Some Minor Constituents	
Lithium	170 parts per billion
Iodine	60
Molybdenum	10
Zinc	10
Iron	2
Aluminum	2
Copper	2
Manganes	2
Lead	0.003
Mercury	0.003
Gold	0.005

The Most Common Dissolved Gases in the Ocean			
	% in Atmosphere	% in Surface Water	Ratio
N_2	78.1	47.5	0.6
O_2	20.9	36.0	1.7
★ CO_2	0.03	15.1	503.3
Ar, H, He, …	0.97	1.4	1.5

pH of Seawater

pH – measure of the concentration of H+ ions

0	7	14
Acid	Neutral	Basic

pH of seawater = 7.5 to 8.1

The pH of seawater is buffered by dissolved CO_2

- Seawater acts to **buffer,** preventing large pH changes when acids or bases are added

Physical Properties of Seawater

Increase with Increasing Salinity	Decrease with Increasing Salinity
Density	★ Freezing Point
Refractive Index	★ Temperature of Maximum Density
Electrical Conductivity	★ Compressibility (pure H_2O can't be compressed much)
- Speed of Sound	- Solubility of Non-Reacting Gases
- Surface Tension (wake lasts longer in seawater than in freshwater)	- Specific Heat

➢ Measuring Salinity

○ Principle of Constant Proportions

- Regardless of the salinity, the percentage of each major constituent stays the same
- For example, if you evaporate a high salinity sample & a low salinity sample, while the total amount of salt will be less for the low salinity sample, ~ ½ (55%) of each of the piles of dried salts will be chlorine
- This allowed oceanographers to measure just one constituent (such as chlorine) in order to determine the rest of the constituents

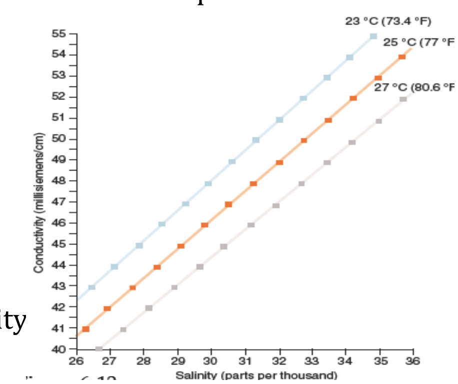
- **Chlorinity**
  - A measure of the content of chloride, bromine, & iodide ions in seawater.
  - We derive **salinity** from chlorinity by multiplying by **1.80655**, i.e. S = 1.80655 Cl
- **Refractometer**
  - A compact optical device that determines the salinity of a water sample by comparing the refractive index of the sample to the refractive index of water of known salinity.

○ Measuring the Conductivity

- Presence of ions in seawater provides a means for the conductance of electricity
- The ability of seawater to transmit an electrical charge is called **electrical conductivity**
- **Conductivity** is much **easier** to measure than the individual constituents of seawater
- Absolutely **pure water** has almost **zero electrical conductivity**
- **Water with salts dissolved in it** like seawater have a **high electrical conductivity**.
- **Electrical conductivity** (EC) of a **solution** ↑ **as the amount of dissolved ions** ↑

  Thus dissolving table salt ($NaCl + H_2O \rightarrow Na^+ + Cl^- + H_2O$) will increase the electrical conductivity of water because ions of sodium & chloride are formed.

- **Conductivity Meter:** An electronic probe used to measure electrical conductance
  - The higher the conductance, the greater the salinity
- **Salinometer :** measures the **electrical conductivity** of a seawater sample



○ Determining the Exact Salinity of a sample

1) measure the conductance of a seawater sample with a known salinity (**standard seawater**)
2) calibrate your instruments until the reading is correct
3) use these calibrated instruments to measure the conductivity of your unknown sample
4) use the **Practical Salinity Scale** to find what the salinity is at the given temperature

○ Reporting Salinity

- **Practical Salinity Units** (**psu**)
- **Parts per Thousand** (**ppt**)

Water salinity			
Fresh water	Brackish water	Saline water	Brine
< 0.05 %	0.05 – 3 %	3 – 5 %	> 5 %
< 0.5 ‰	0.5 – 30 ‰	30 – 50 ‰	> 50 ‰

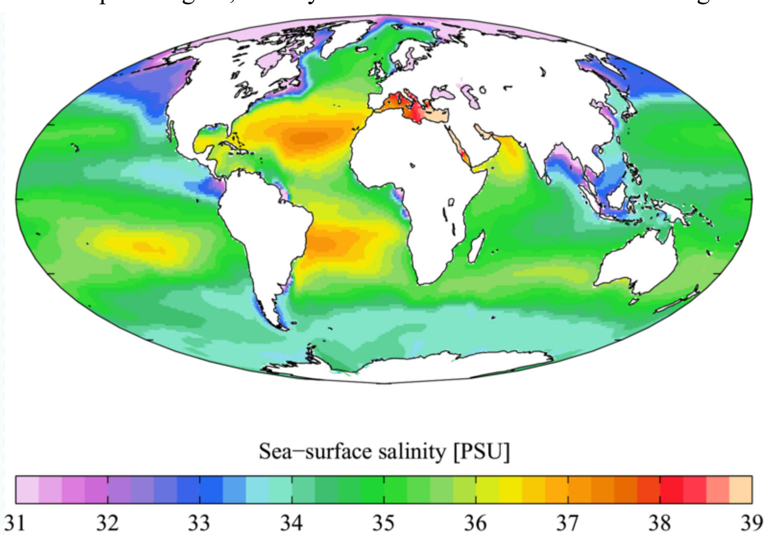
Measuring Salinity Remotely

Advantages and disadvantages for SST and salinity quantification

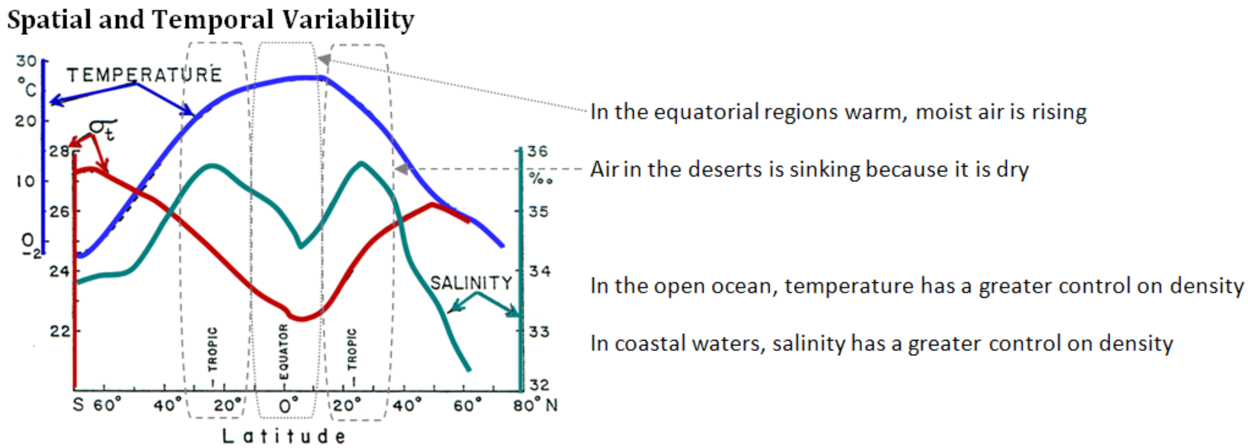
	SST quantification	Salinity (SSS) quantification
Advantages	- No scattering by the atmosphere or aerosols, haze, dust, etc in clouds - Its effectively an "all weather" system (meaning its not affected by clouds)	- Salinity controls density in coastal regions, especially where there's river discharge - Changes in salinity are caused by events occurring at the surface, such as evaporation, precipitation, ice melting, and river discharge - Understanding salinity is the first step in understanding the effects on ocean density and circulation
Disadvantages	- Thermal emission is very weak at these longer wavelengths (emissivity = 0.3-0.5, not 1) - a large field of view must be used to overcome noise levels → low spatial resolution - the emissivity varies with dielectric properties of sea water and surface roughness - dielectric constant varies with temperature, salinity, and e.m. frequency → must know SSS to get SST -	- Precise knowledge of the incidence angle of radiation beam is needed - Thus aircraft orientation information is needed - Galactric background radiation must be included into the retrieval algorithm - There's large uncertainties with retrieval: • Surface roughness effects • Wind speed • Fetch • Surfactants - dielectric constant varies with temperature, salinity, and e.m. frequency → must know SST to get SSS

- **Sea surface salinity distribution**

  - At the **ITCZ (Inter Tropical Convergence Zone)** near the equator (see chapter on atmosphere), due to the prevailing rainfall, salinity tends to be **low**.
  - Near the mouths of large rivers, salinity is low.
  - In the tropics (middle of the ocean basins), due to the steady prevailing trade wind and low rainfall, there is a net evaporation (high salinity).
  - In the polar region, salinity tends to be lower due to the melting of sea ice.

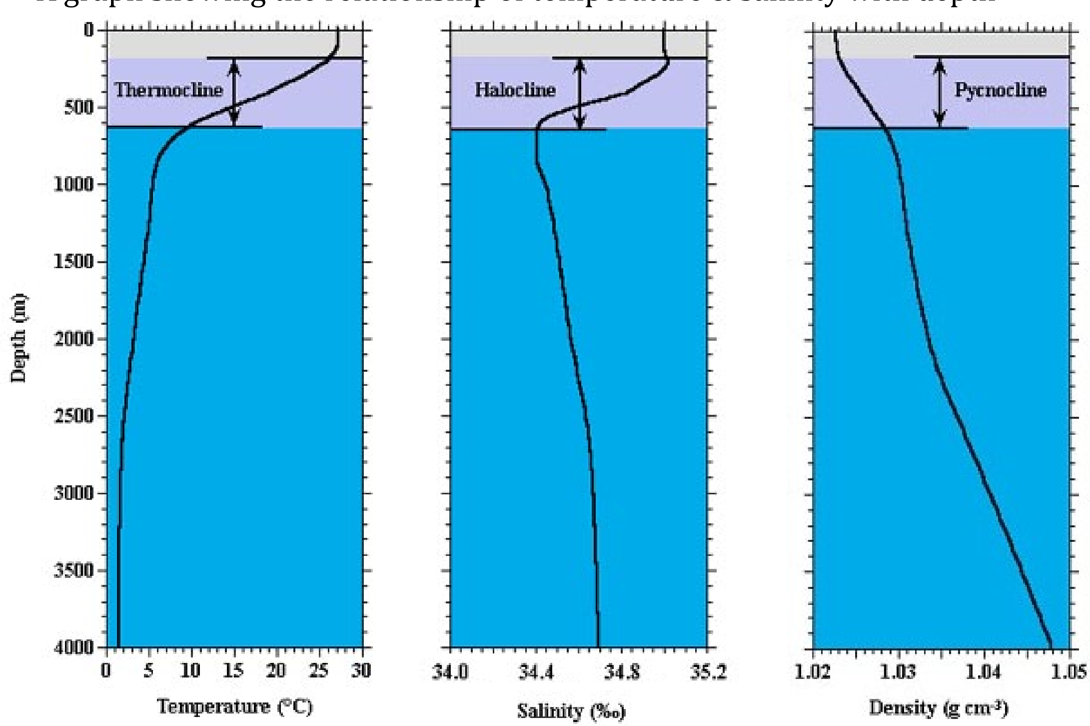


➢ Relationship between Temperature, Salinity, Depth, & Density



- ### Density
  - Density is a function of **Salinity, Temperature,** & **Pressure** (a.k.a. depth)
  - Density is controlled primarily by **temperature** in the **open ocean**
  - Density is controlled primarily by **salinity** in the **coastal ocean**
  - **Density** ↑ with ↑ **Salinity** , ↑ **Pressure**, & ↓ **Temperature**
  - ↑ **Temperature** causes seawater to **expand** (↑ volume), & ↓ temperature → ↓ volume

- ### Temperature-Salinity (T-S) Diagram
  - A graph showing the relationship of temperature & salinity with depth



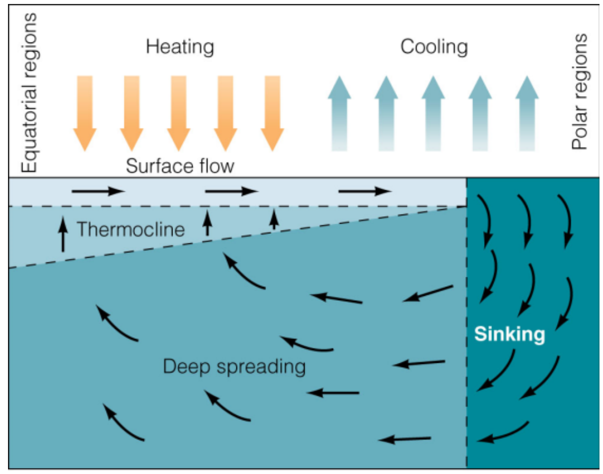
➢ Thermohaline Circulation

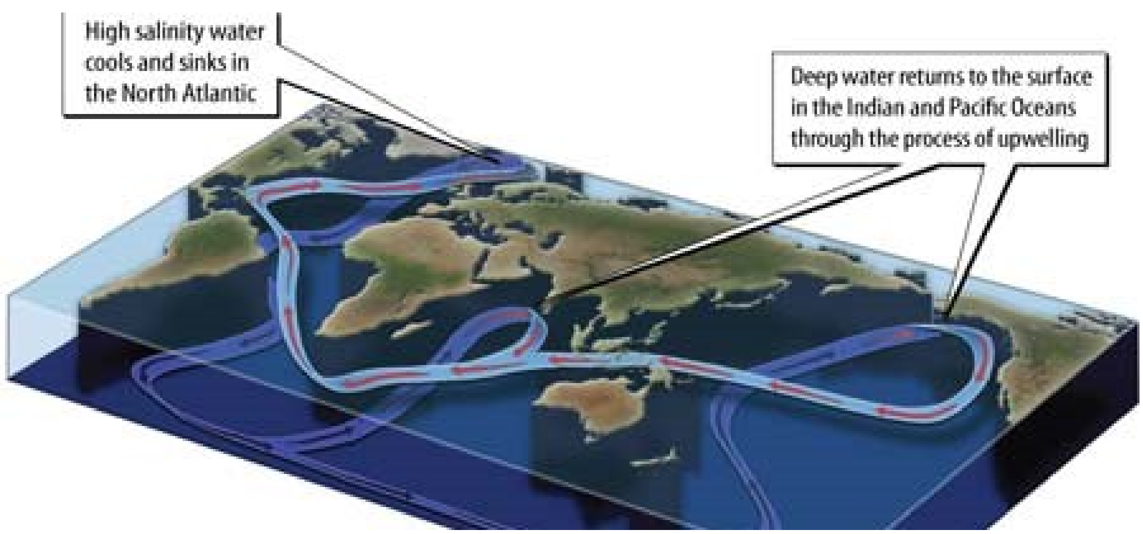
- Water circulation is driven by density gradients (due to changes in temperature & salinity)
- It is present at all ocean depths, but is the most dominant below ~2km in all of the oceans

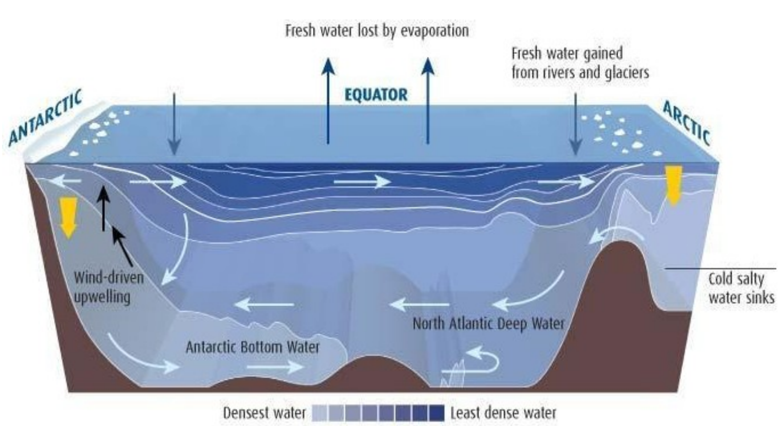
- **Ocean-Atmosphere Interaction Drives Deep Circulation**
  - Water is driven by density gradients & steered by Coriolis

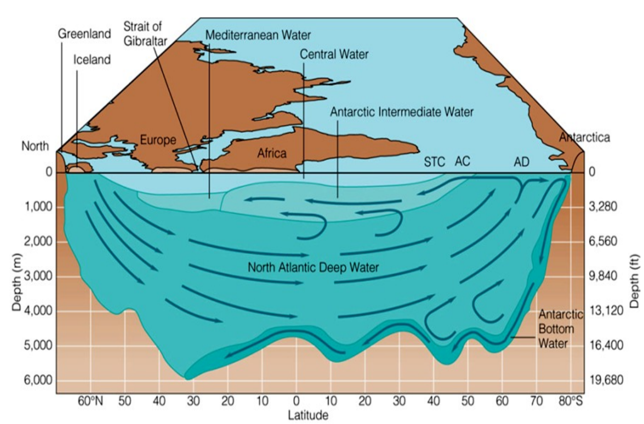
    → more intense flow on western margins of ocean basins

  1) Warm, salty waters move from the tropics to high latitudes
  2) cools under high latitude winds
  3) becomes saltier where fresh water is removed as sea ice (sea ice is NOT salty)
  4) ↑ density & gravity cause the water to sink









➢ Global Salinity Patterns

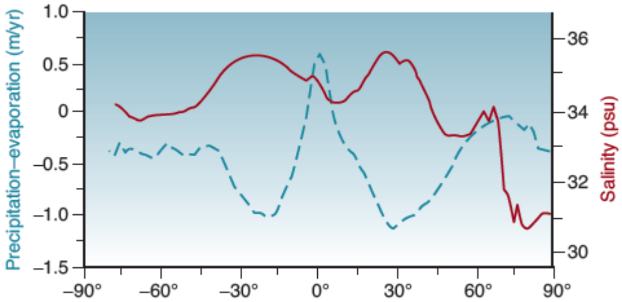
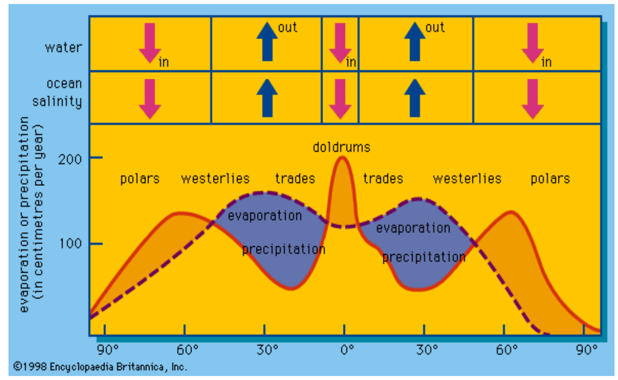
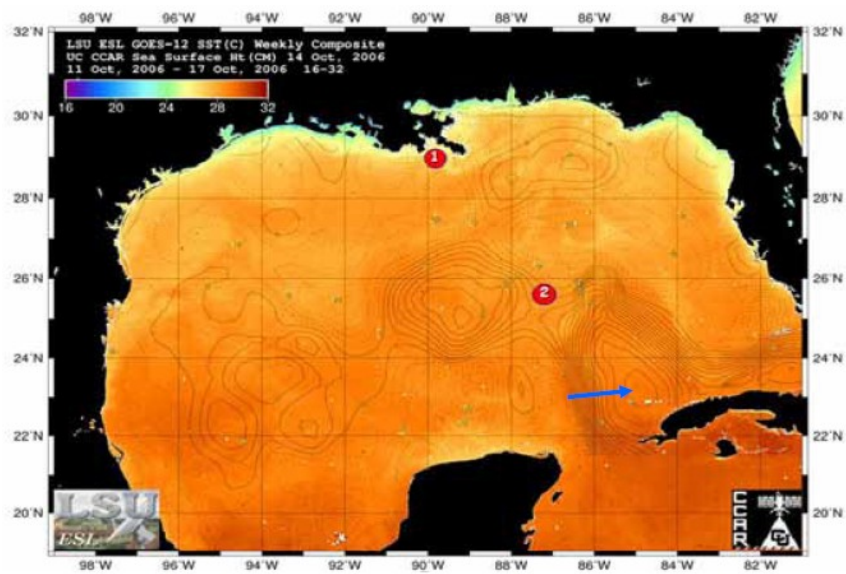


Figure 8-25

Broadly speaking, P-E and SSS exhibit an inverse relationship over a longitudinal section of the world ocean. Sea ice and riverine processes also modify SSS.



➢ Gulf of Mexico Salinity Patterns

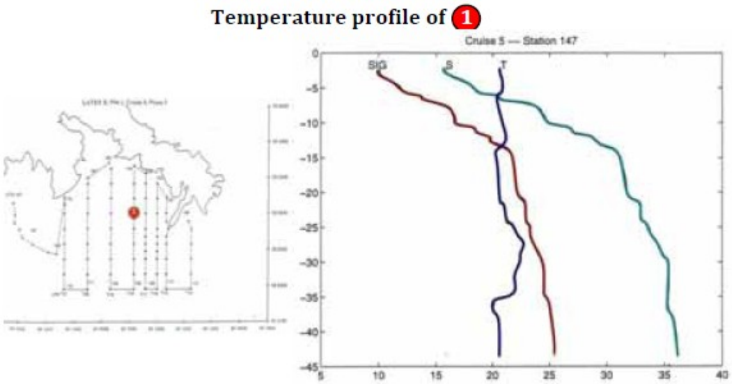


SST in the Gulf of Mexico

The lines are of constant elevation, they indicate that warmer (less dense) waters float on the colder (more dense) water

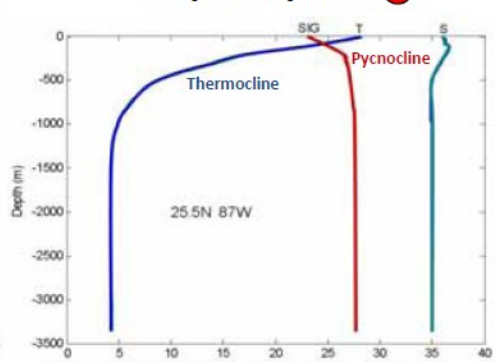
Note: the **blue arrow** indicates an elevation change of $^{7}/_{10}$ m

Temperature profile of ❶



Temperature is fairly constant, salinity is decreasing in steps, overall this shows that coastal water density looks more like salinity than temperature

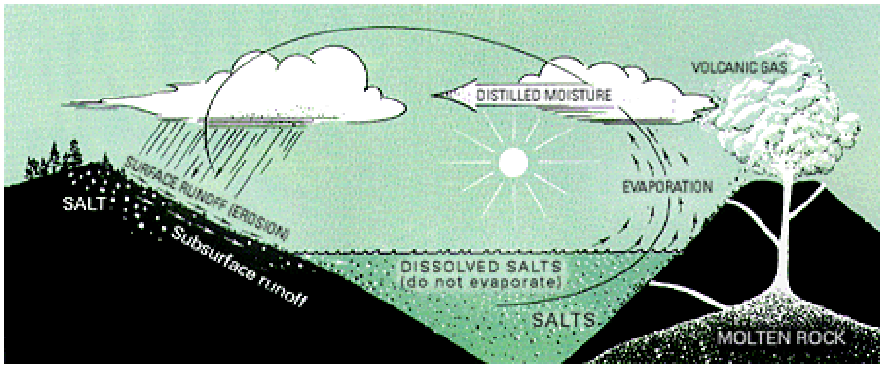
Temperature profile of ❷



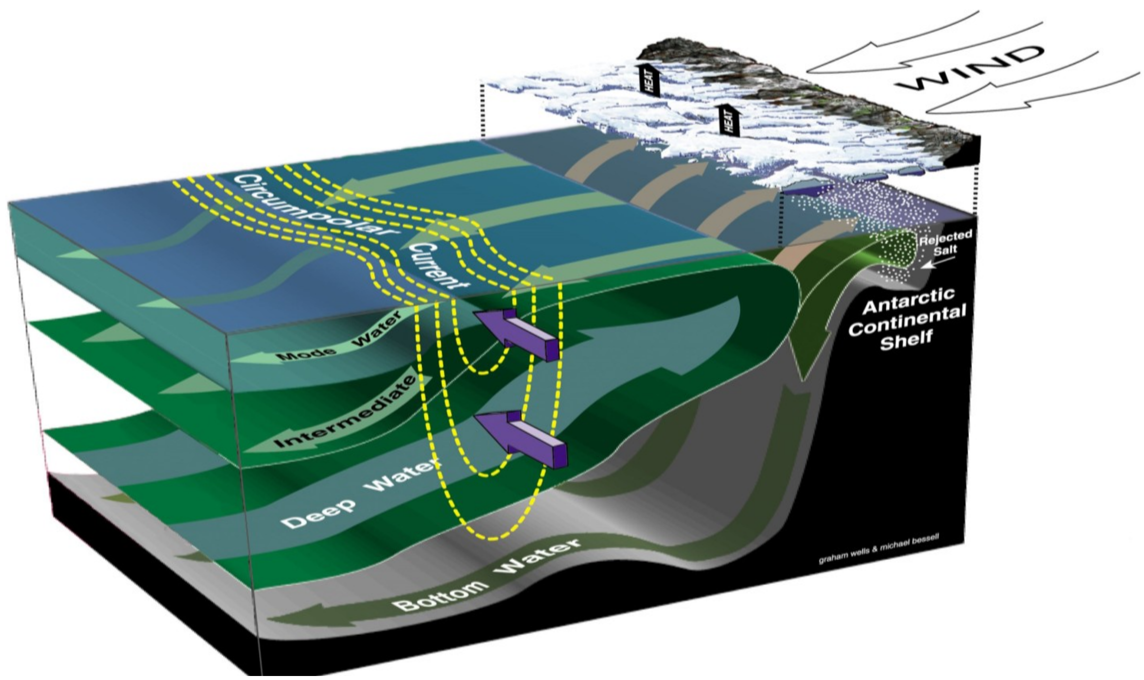
whereas, this shows that non-coastal ocean water density more closely resembles temperature

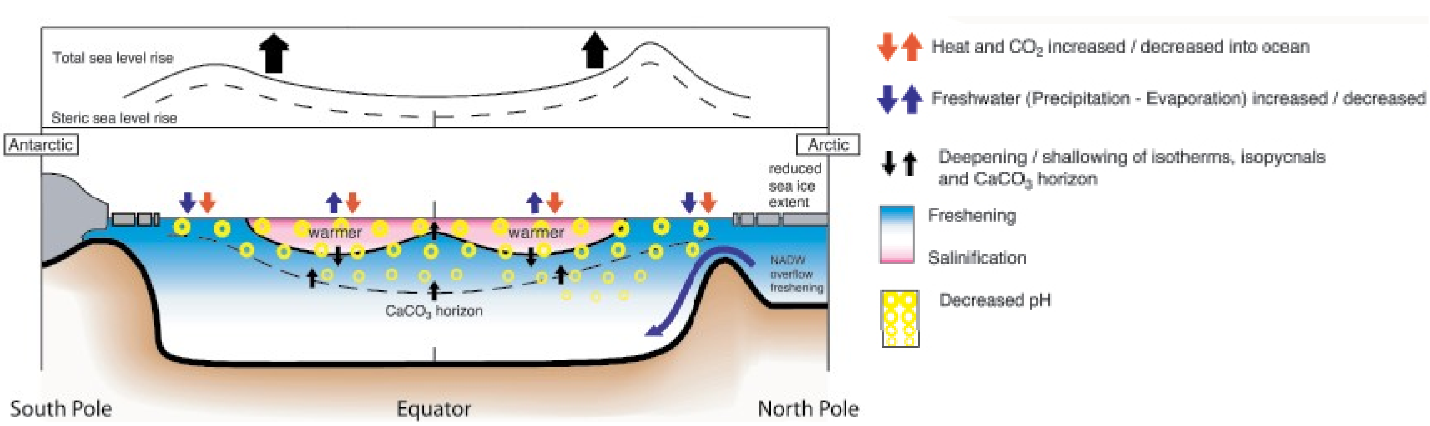
Why is studying Salinity important?

- Changes in the Earth's Hydrological Cycle & its Footprint on Ocean Salinity Fields



- Salinity measurements are especially important in coastal research because changes in river discharge & wind direction/speed control the salinity at the coast & on the shelf
- thus, by understanding salinity we can better understand the coastal ocean density & circulation patterns





Other Terminology relating to Salinity

-
    - **Conservative Properties**
        - Properties that change only by **mixing**
        - **Salinity** & **potential temperature** are Conservative Properties, as they can only be change through mixing
        - whereas, Temperature & Dissolved Oxygen can be influenced by various other properties & thus aren't conservative
        -
- **Measures** of Salinity
    - **Chlorinity**
        - A measure of the content of chloride, bromine, & iodide ions in seawater.
        - We derive **salinity** from chlorinity by multiplying by **1.80655**.
    - **Refractometer**
        - A compact optical device that determines the salinity of a water sample by comparing the refractive index of the sample to the refractive index of water of known salinity.
    - **Salinometer**
        - An electronic device that determines **salinity** by measuring the **electrical conductivity** of a seawater sample.

- **Seawater** & Salinity
    - **Brackish**
        - Describing water intermediate in **salinity** between seawater & fresh water
    - **Caballing**
        - Mixing of two water masses of identical densities but different temperatures & **salinities**, such that the resulting mixture is denser than its components.
    - **Chemical equilibrium**
        - In seawater, the condition in which the proportion & amounts of dissolved salts per unit volume of ocean are nearly constant
    - **Halocline**
        - The zone of the ocean in which **salinity** increases rapidly with depth.
    - **Pycnocline**
        - The middle zone of the ocean in which **density** increases rapidly with depth.
        - Temperature falls & **salinity** rises in this zone
    - **Water Mass**
        - A body of water identifiable by its salinity & temperature (& therefore its density) or by its gas content or another indicator.
        -
    -
        -

- **Solutions** & Salinity
  - **Colligative Properties**
    - Those characteristics of a solution that differ from those of pure water because of material held in solution.
  - **Isohaline**
    - Constant salinity
  - **Hypertonic**
    - Referring to a solution having a **higher concentration** of dissolved substances than the solution that surrounds it.
  - **Hypotonic**
    - Referring to a solution having a **lower concentration** of dissolved substances than the solution that surrounds it.
  - **Isotonic**
    - Referring to a solution having the **same concentration** of dissolved substances as the solution that surrounds it.
  - **Mixture**
    - A close intermingling of different substances that still retain separate identities.
    - The properties of a mixture are **heterogeneous**; they may vary within the mixture
  - **Solution**
    - A **homogeneous** substance made of two components, the **solvent** & the **solute**
  - **Solvent**
    - A substance able to dissolve other substances
  - **Solute**
    - A substance dissolved in a solvent
  -
    -
    -

-
  - **desalination**
    - the process of removing salt from seawater or brackish water
  - **evaporite**
    - deposit formed by the evaporation of ocean water
  - **Hydrogenous sediment**
    - A sediment formed directly by precipitation from seawater
    - also called *authigenic sediment*
  -
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- **Organisms** & Salinity
  - **Osmoregulation**
    - The ability of an organism to adjust internal salt concentration.
  - **Euryhaline**
    - Describing an organism able to tolerate a **wide** range in salinity
  - **Stenohaline**
    - Describing an organism unable to tolerate a wide range in **salinity.**
  - **extremophile**
    - an organism capable of tolerating extreme environmental conditions, especially temperature or pH level
  - **Osmosis**
    - The diffusion of water from a region of high water concentration to a region of lower water concentration through a semipermeable membrane.
  - **Physical Factor**
    - An aspect of the physical environment that affects living organisms, such as light, **salinity**, or temperature.
  - **Salt Gland**
    - Specialized tissue responsible for concentration & excretion of excess salt from blood & other body fluids
    -
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