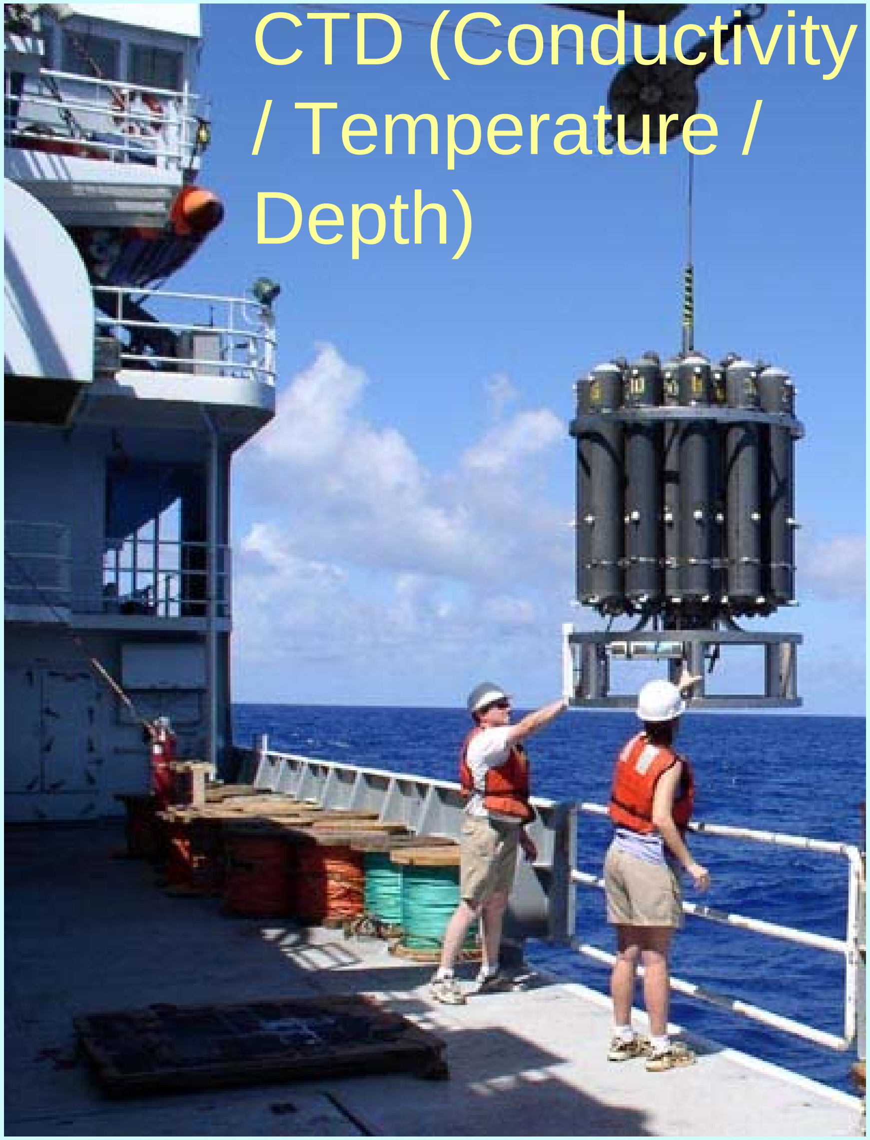
AdOc 4060 / 5060
Seawater Salinity

2013 Spring
Chris Jenkins



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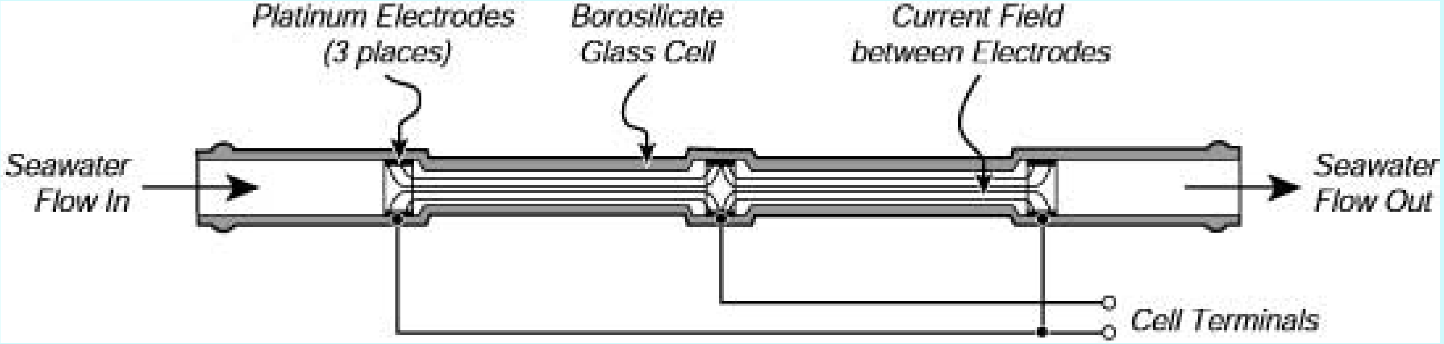
Conductivity measurement



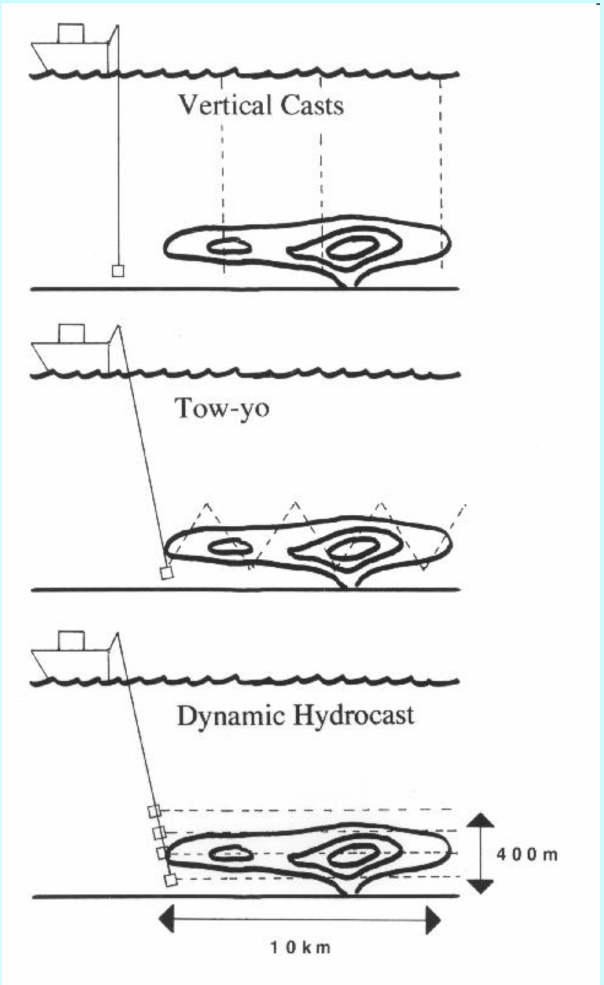
- Accuracy: 0.75 psu (practical salinity unit)
- Ocean water: 35 psu = 35,000 ppm (by weight) of salt in water

Temperature measurement

- Thermistor (Pt)
- Range: -1 to 40 deg C
- Accuracy: +/- 0.1deg C

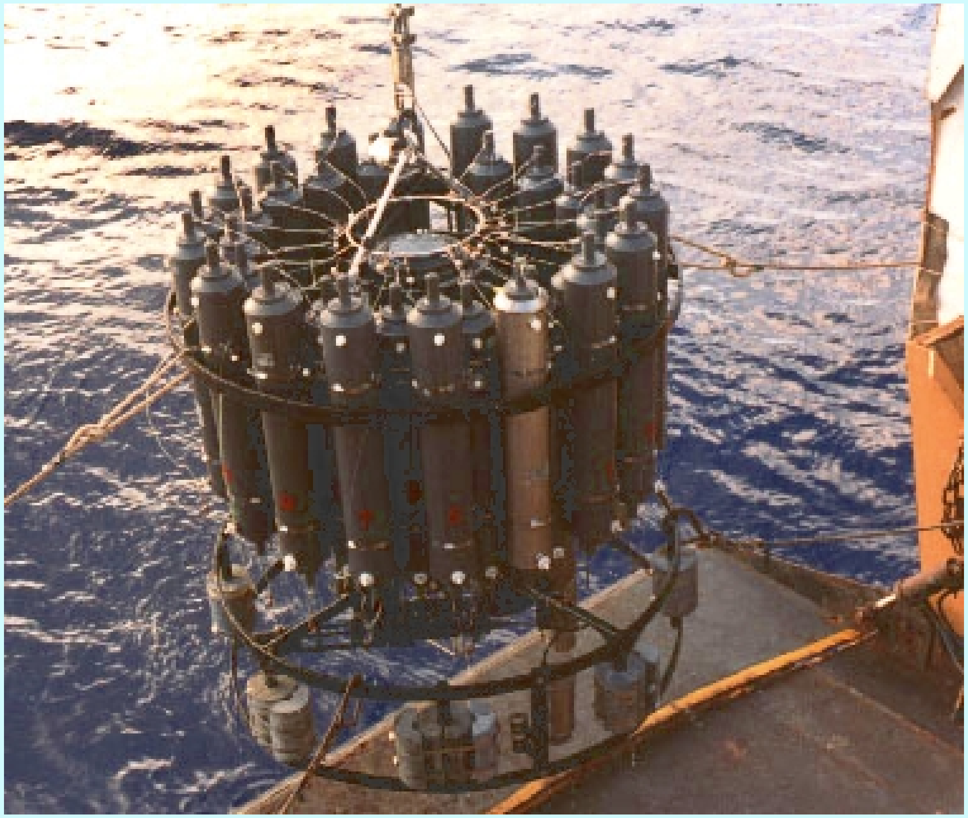
http://ad4.doubleclicker.net/c.php?url=http%3A%2F%2Fwww.seas.harvard.edu%2Fclimate%2Feli%2FCourses%2FEPS131%2F2005fall_a%2Fstudent-presentations%2FBen-Lee-2.ppt&p=0&rf=http%3A%2F%2Fctd.feedtrade.com%2Findex.php

Profiling



http://www.chelsea.co.uk/Vehicles%20SeaSoar.htm

Niskin bottles



- Bottles can be closed when desired by researchers on the ship
- Water samples can be obtained to calibrate the CTD and to investigate properties not measured by the CTD such as dissolved nutrient content, carbon dioxide, chlorofluorocarbons, and others tracers.

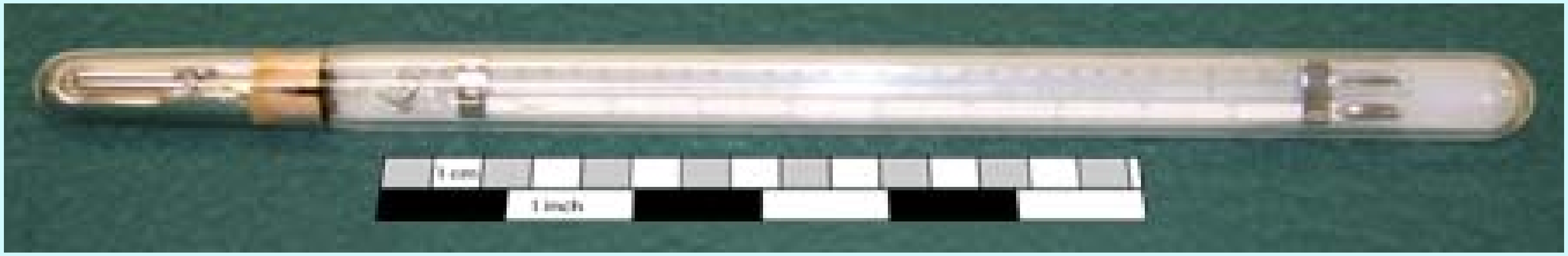
http://ad4.doubleclicker.net/c.php?url=http%3A%2F%2Fwww.seas.harvard.edu%2Fclimate%2Feli%2FCourses%2FEPS131%2F2005fall_a%2Fstudent-presentations%2FBen-Lee-2.ppt&p=0&rf=http%3A%2F%2Fctd.feedtrade.com%2Findex.php

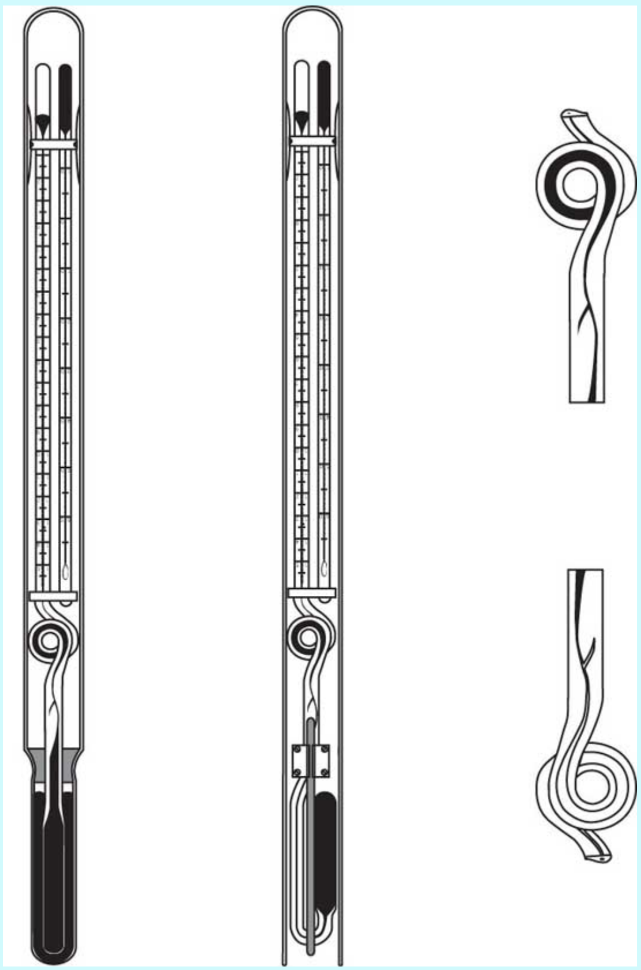
Nansen bottles

Nansen water bottles before (I), during (II), and after (III) reversing. (From Dietrich et al. 1980)

- Approximately 12 to 24 Nansen bottles are attached in series at predetermined intervals along a cable
- Deployed with both ends open
- Closes as the bottles are reversed
- Used in conjunction with inverting or reversing thermometers

http://ad4.doubleclicker.net/c.php?url=http%3A%2F%2Fwww.seas.harvard.edu%2Fclimate%2Feli%2FCourses%2FEPS131%2F2005fall_a%2Fstudent-presentations%2FBen-Lee-2.ppt&p=0&rf=http%3A%2F%2Fctd.feedtrade.com%2Findex.php





Inverting thermometers

- Has a constriction in the capillary that allows it to retain its reading upon being inverted
- Deployed in pairs, one protected and the other unprotected from high pressures. Combination of the two gives temperature and pressure at the depth where reversal took place

http://ad4.doubleclicker.net/c.php?url=http%3A%2F%2Fwww.seas.harvard.edu%2Fclimate%2Feli%2FCourses%2FEPS131%2F2005fall_a%2Fstudent-presentations%2FBen-Lee-2.ppt&p=0&rf=http%3A%2F%2Fctd.feedtrade.com%2Findex.php

Salinity

- The total amount of solid material dissolved in water.
- Concentration, often described as parts per thousand
- Average ocean salinity is 35 parts per thousand (or about 3.5%)

- By evaporation of seawater (inaccurate)
- By chlorinity method (via titration)

  $S = 1.80655 \; Cl$
- By electrical conductivity

  conductivity is proportional to salinity

Main constituents of seawater (ions)

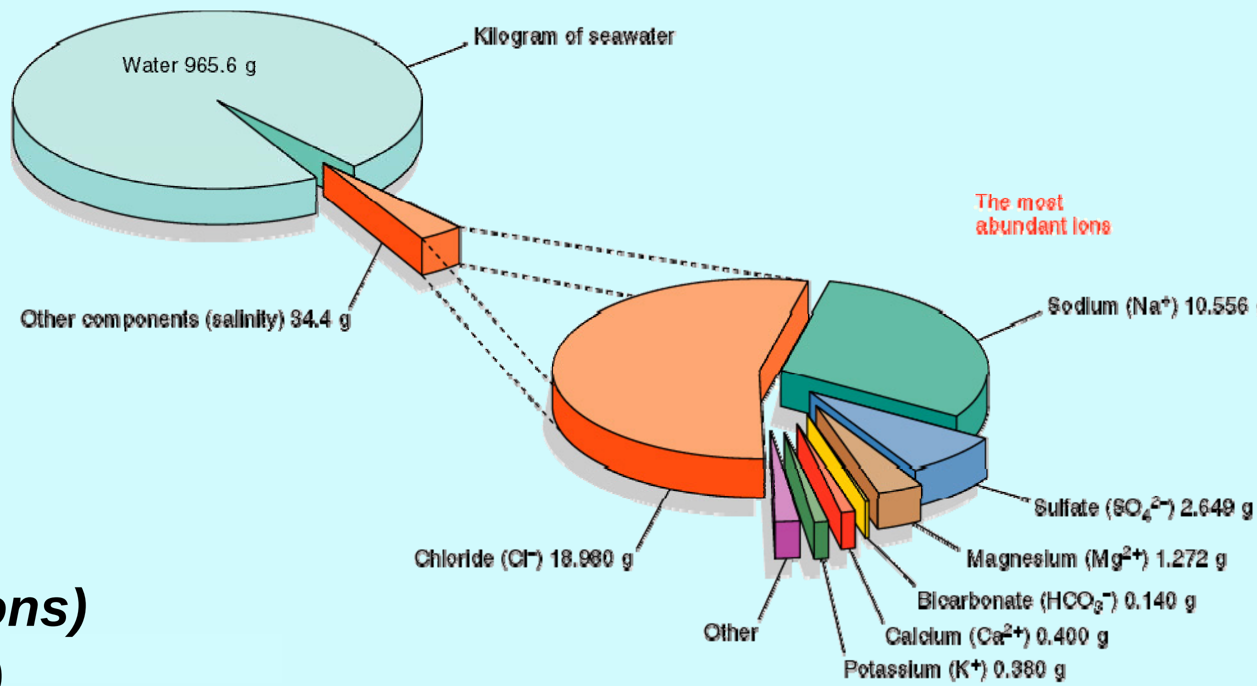
Main constituents of seawater (> 1ppm):

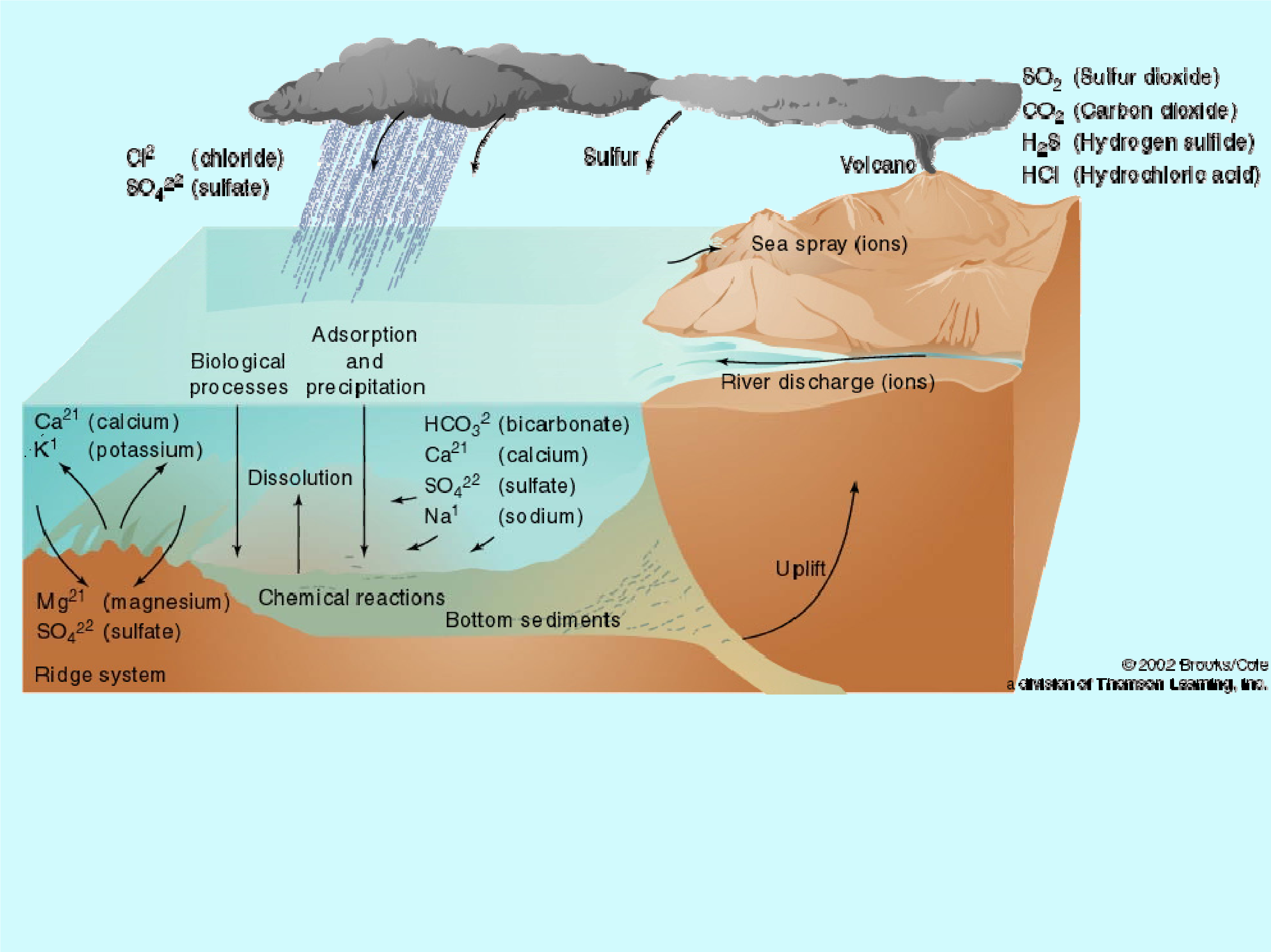
anions (-ve ions)

- Chloride
- Sulphate (SO_4^{2-})
- Bicarbonate
- Bromide,
- Borate & Fluoride

cations (positive ions)

- Sodium (Na^+, cation)
- Magnesium (Mg^{2+})
- Calcium
- Potassium
- Strontium





SO2 (Sulfur dioxide)
CO2 (Carbon dioxide)
H2S (Hydrogen sulfide)
HCl (Hydrochloric acid)
Cl2 (chloride)
SO422 (sulfate)
Sulfur
Volcano
Sea spray (ions)
Adsorption and precipitation
Biological processes
River discharge (ions)
Ca21 (calcium)
K1 (potassium)
HCO32 (bicarbonate)
Ca21 (calcium)
SO422 (sulfate)
Na1 (sodium)
Dissolution
Uplift
Chemical reactions
Bottom sediments
Mg21 (magnesium)
SO422 (sulfate)
Ridge system
© 2002 Brooks/Cole
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Table 7.3 Approximate Residence Times for Constituents of Seawater

Constituent	Residence Time (years)
Chloride (Cl^{2})	100,000,000
Sodium (Na^{1})	68,000,000
Magnesium (Mg^{21})	13,000,000
Potassium (K^{1})	12,000,000
Sulfate (SO_4^{22})	11,000,000
Calcium (Ca^{21})	1,000,000
Carbonate (CO_3^{22})	110,000
Silicon (Si)	20,000
Water (H_2O)	4,100
Manganese (Mn)	1,300
Aluminum (Al)	600
Iron (Fe)	200

Sources: Data from Broecker and Peng, 1982; Bruland, 1983; Riley and Skirrow, 1975.

Forchammer, Dittmar and the law of constant proportions

- Regardless of salinity, the major ions are found in the same proportions throughout the world ocean (chemical equilibrium)
- This means that if you measure one, you have them all.
- Oceanographic insights can be found in the exception to this rule.

Example: Law of constant proportions

Suppose you are given a sea water sample and you are told that it has 12.1 ppt of Sodium.

What is the overall salinity of this sample ?

Table 3.1 (p. 29) shows that standard seawater has:

Sodium (ppt) / Salinity (ppt) = 10.556 / 34.482

= 0.306

Our sample must have this same ratio, so we have:

12.1 (ppt) / Salinity = 0.306

With a little algebra we find: Salinity = 39.54 (ppt)

Practical Salinity Scale PSS 1978

CONCLUSIONS

Using Newly generated data, a fit has been made giving the following algorithm for the calculation of salinity from data of the form:

$$R = \frac{C(S, T, P)}{C(35, 15, 0)}$$

T in °C (IPTS '68), P in decibars.

$$R_T = \frac{R}{R_P r_T}; R_P = 1 + \frac{P \times (A_1 + A_2 P + A_3 P^2)}{1 + B_1 T + B_2 T^2 + B_3 R + B_4 R T}$$

$$r_T = c_0 + c_1 T + c_2 T^2 + c_3 T^3 + c_4 T^4$$

$A_1 = 2.070 \times 10^{-5}$ $B_1 = 3.426 \times 10^{-2}$

$A_2 = -6.370 \times 10^{-10}$ $B_2 = 4.464 \times 10^{-4}$

$A_3 = 3.989 \times 10^{-15}$ $B_3 = 4.215 \times 10^{-1}$

$B_4 = -3.107 \times 10^{-3}$

$c_0 = 6.766097 \times 10^{-1}$

$c_1 = 2.00564 \times 10^{-2}$

$c_2 = 1.104259 \times 10^{-4}$

$c_3 = -6.9698 \times 10^{-7}$

$c_4 = 1.0031 \times 10^{-9}$

$$S = \sum_{j=0}^{5} a_j R_T^{j/2} + \frac{(T-15)}{1 + k(T-15)} \sum_{j=0}^{5} b_j R_T^{j/2}$$

$a_0 = 0.0080$ $b_0 = 0.0005$ $k = 0.0162.$

$a_1 = -0.1692$ $b_1 = -0.0056$

$a_2 = 25.3851$ $b_2 = -0.0066$

$a_3 = 14.0941$ $b_3 = -0.0375$

$a_4 = -7.0261$ $b_4 = 0.0636$

$a_5 = 2.7081$ $b_5 = -0.0144$

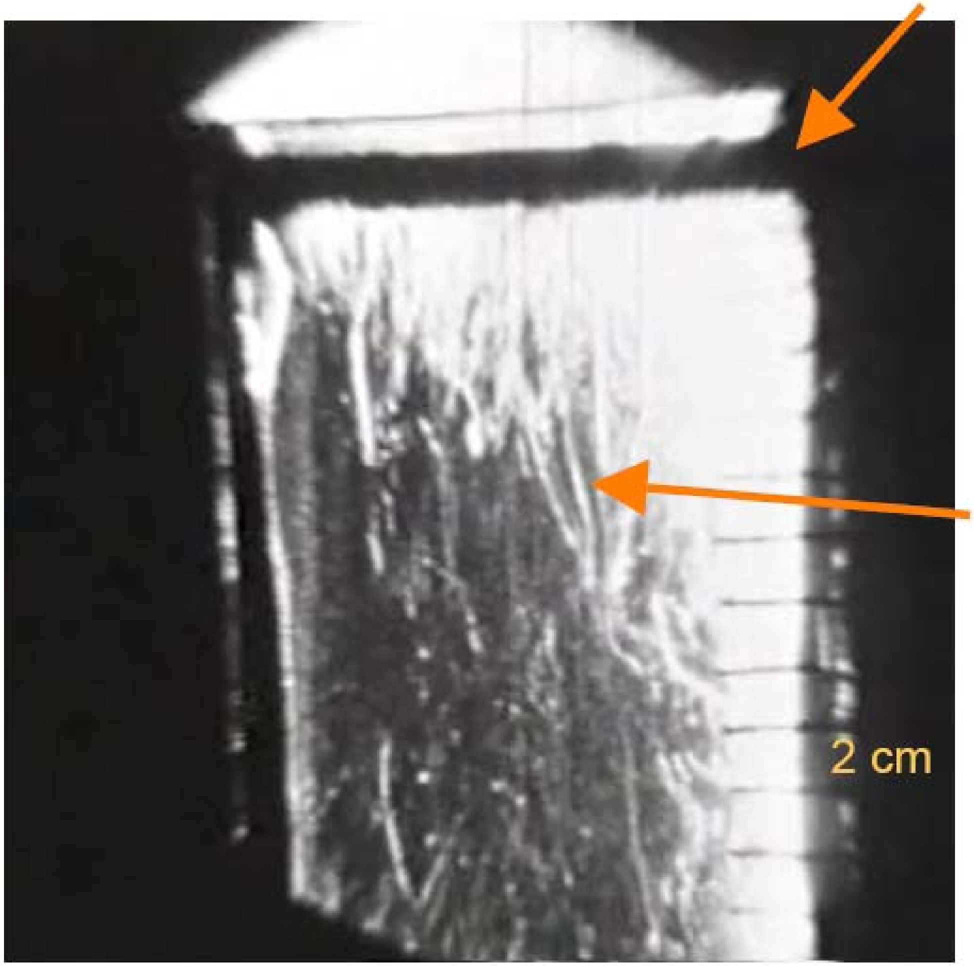
http://www.iode.org/oceanportal/detail.php?id=3540

Salinity variations

Location/type	Salinity
Normal open ocean	33-38 ‰
Baltic Sea	10 ‰ (brackish)
Red Sea	42 ‰ (hypersaline)
Great Salt Lake	280 ‰
Dead Sea	330 ‰
Tap water	0.8 ‰ or less
Premium bottled water	0.3‰
Human tears	9 ‰

Rejected Brine and Brine Plumes

Shadowgraph



Movie of Wakatsuchi, 1974 / 1983

JGR, Vol.88, No.C5, 2943-2951, 1983

http://www.gi.alaska.edu/~eicken/he_teach/ppt/G615_Petrich.pdf

Processes affecting seawater salinity

- Processes that <u>decrease</u> seawater salinity:
  - Precipitation
  - Runoff
  - Icebergs melting
  - Sea ice melting
- Processes that <u>increase</u> seawater salinity:
  - Sea ice forming
  - Evaporation

Precipitation and evaporation are most important overall.

Surface salinity variation

- Pattern of surface salinity:
  - Lowest in high latitudes
  - Highest in the tropics
  - Dips at the Equator
- Surface processes help explain pattern

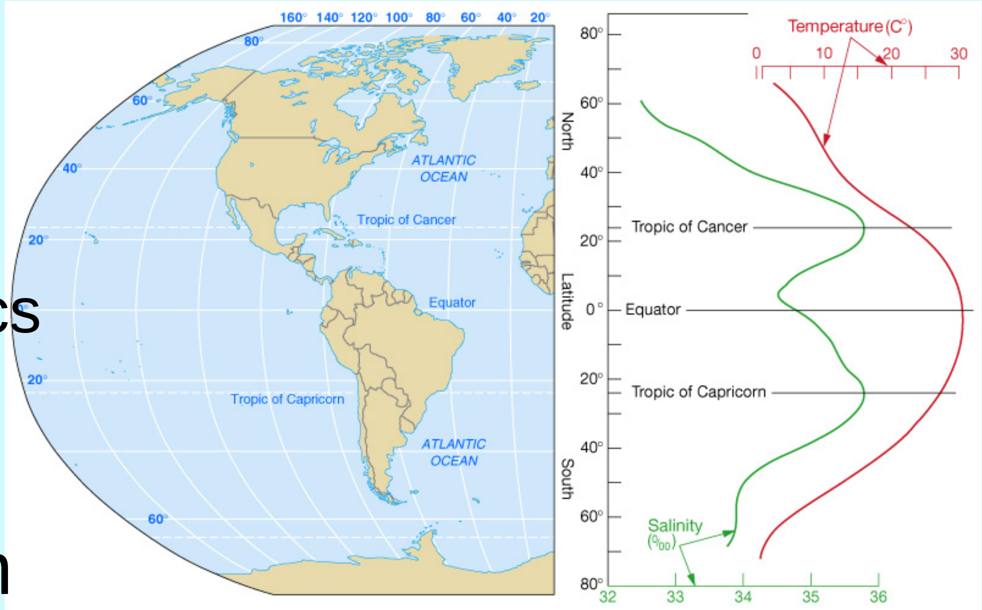
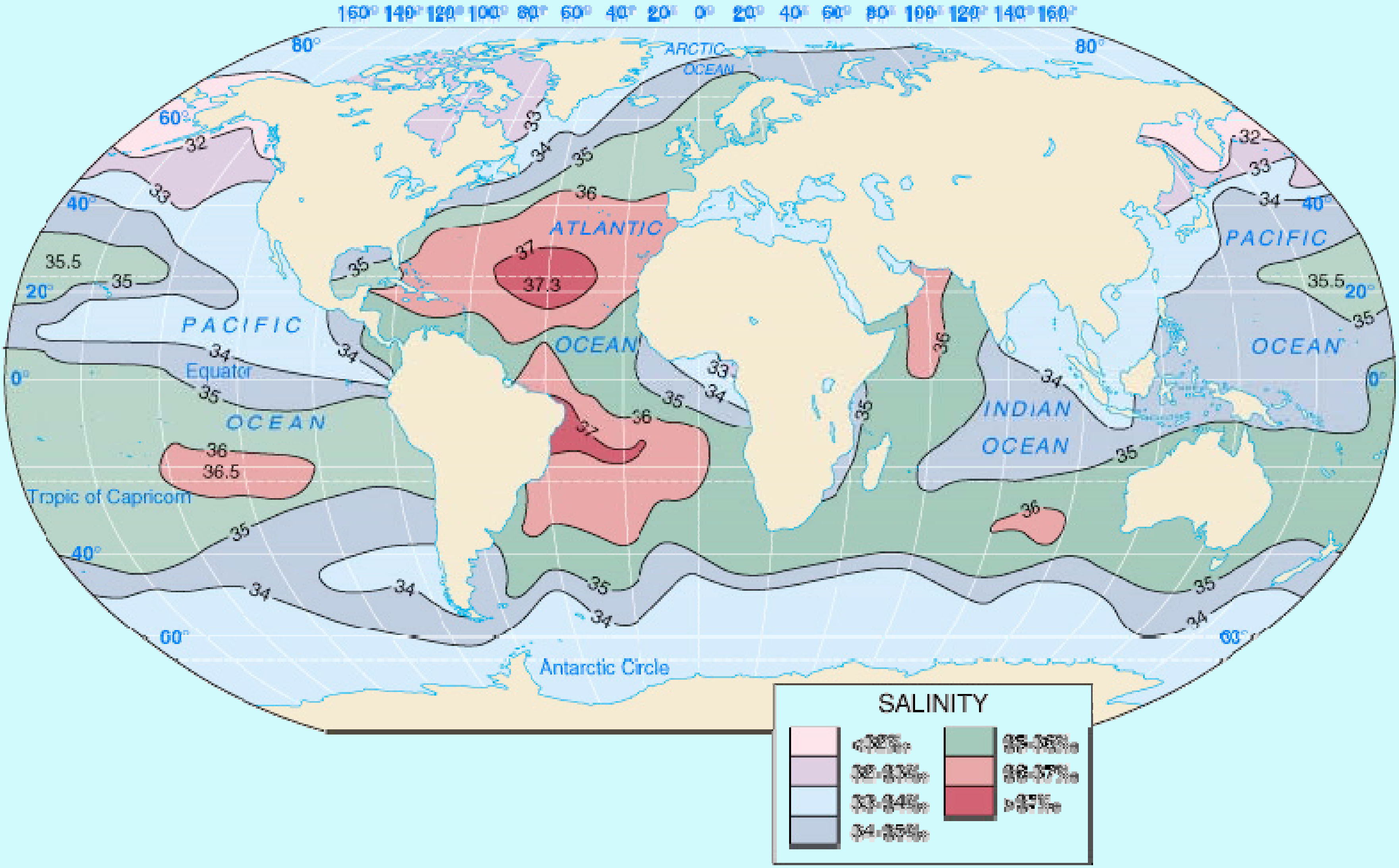


Figure 5-20

Surface salinity variation

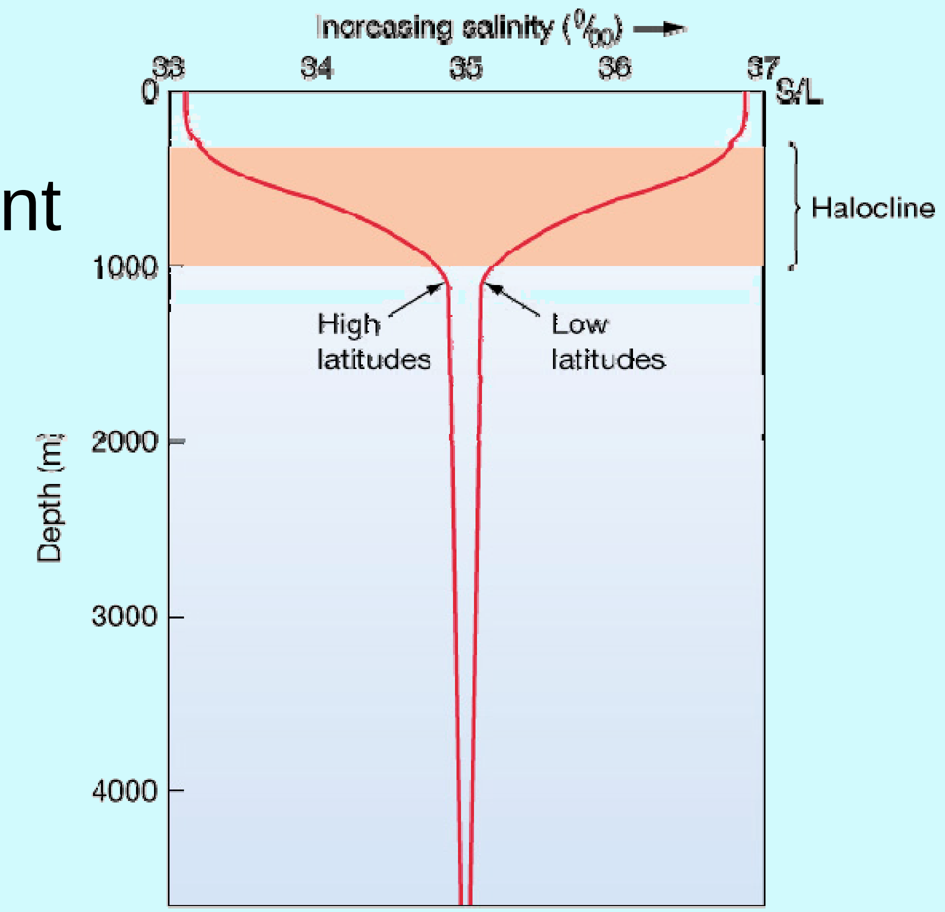
- High latitudes have low surface salinity
  - High precipitation and runoff
  - Low evaporation
- Tropics have high surface salinity
  - High evaporation
  - Low precipitation
- Equator has a dip in surface salinity
  - High precipitation partially offsets high evaporation

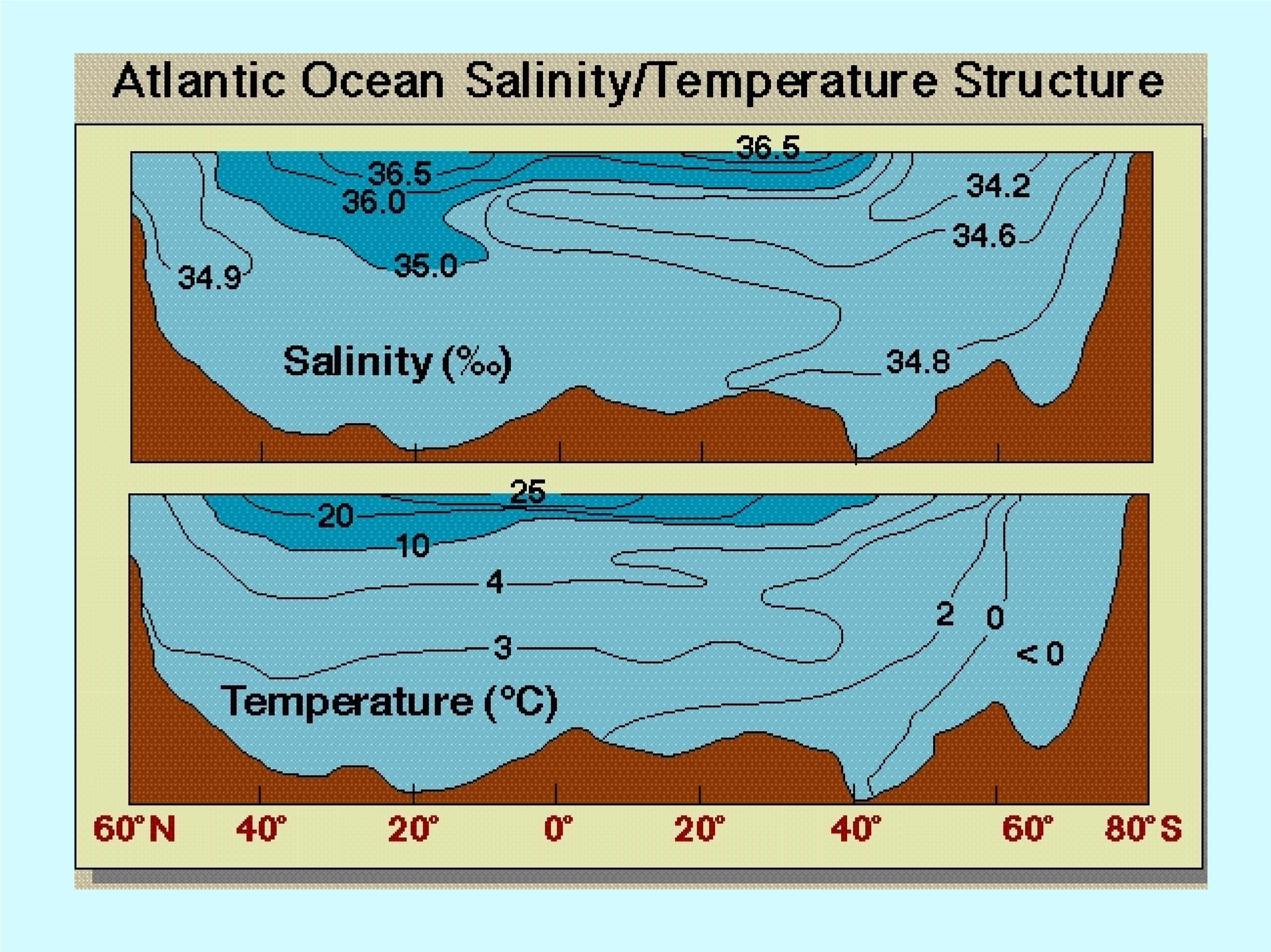
Global surface salinity



Salinity variation with depth

- Curves for high and low latitudes begin at different surface salinities
- **Halocline** = layer of rapidly changing salinity
- At depth, salinity is uniform




Atlantic Ocean Salinity/Temperature Structure
36.5
36.5
36.0
35.0
34.9
34.2
34.6
34.8
Salinity (‰)
25
20
10
4
3
2
0
< 0
Temperature (°C)
60°N
40°
20°
0°
20°
40°
60°
80°S

Summary

- SW salinity is on average 35 ppt by weight
- 11 major ions make up 99.9% of the dissolved constituents
- Constituents differ greatly from crustal rock due to differences in their solubilities
- Salinity varies with depth and latitude but the constituent ratios remain virtually constant: evaporation and precipitation change the total salinity but not the composition
- Minor departures are a result of biological processes affecting Ca^{++} and HCO_3^-
- Major departures occur only locally (anoxic conditions, hydrothermal vents)
- Surface salinities are largest in the tropical and subtropical latitudes where evaporation is greater than precipitation; and smallest in higher latitudes where precipitation and runoff is greater than evaporation
- Electrical conductivity is the modern means of measurement

Salinity clock ?