Ocean Regions

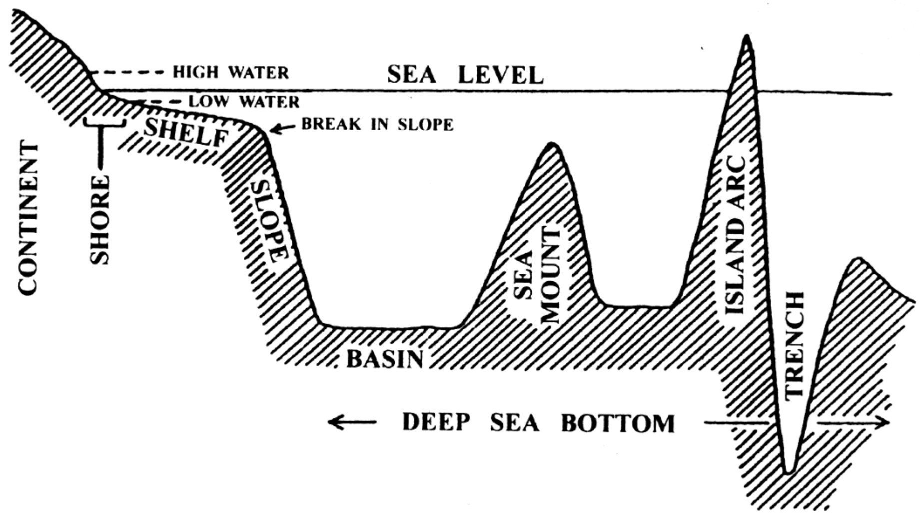
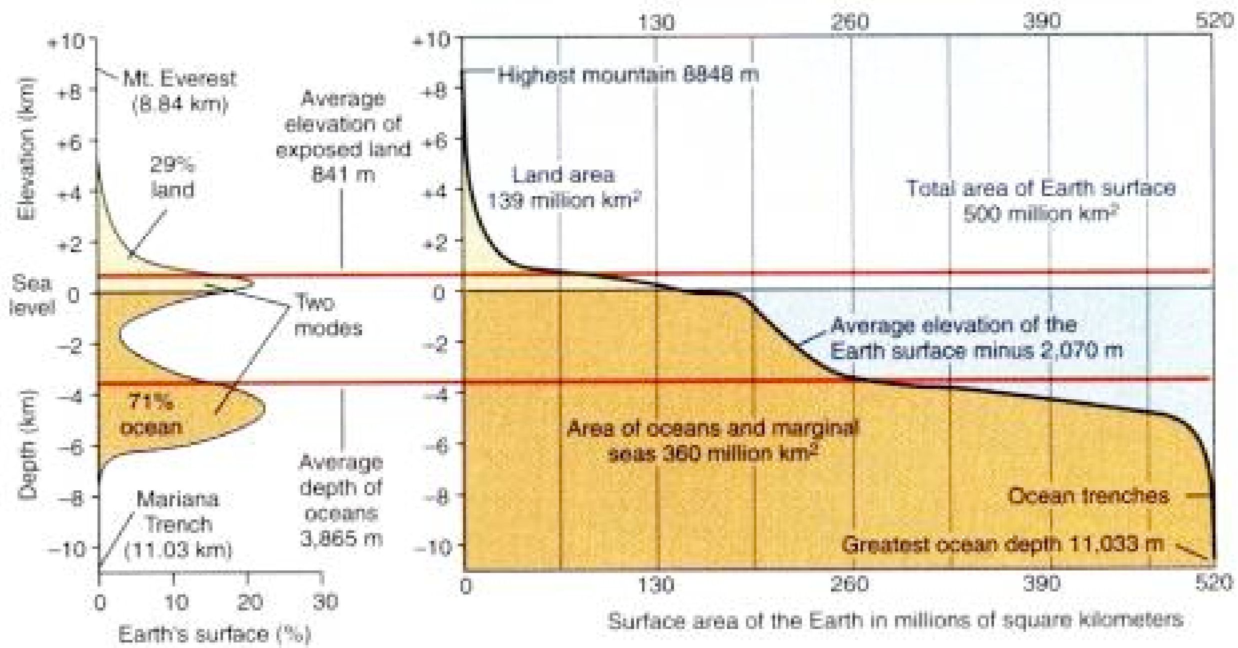
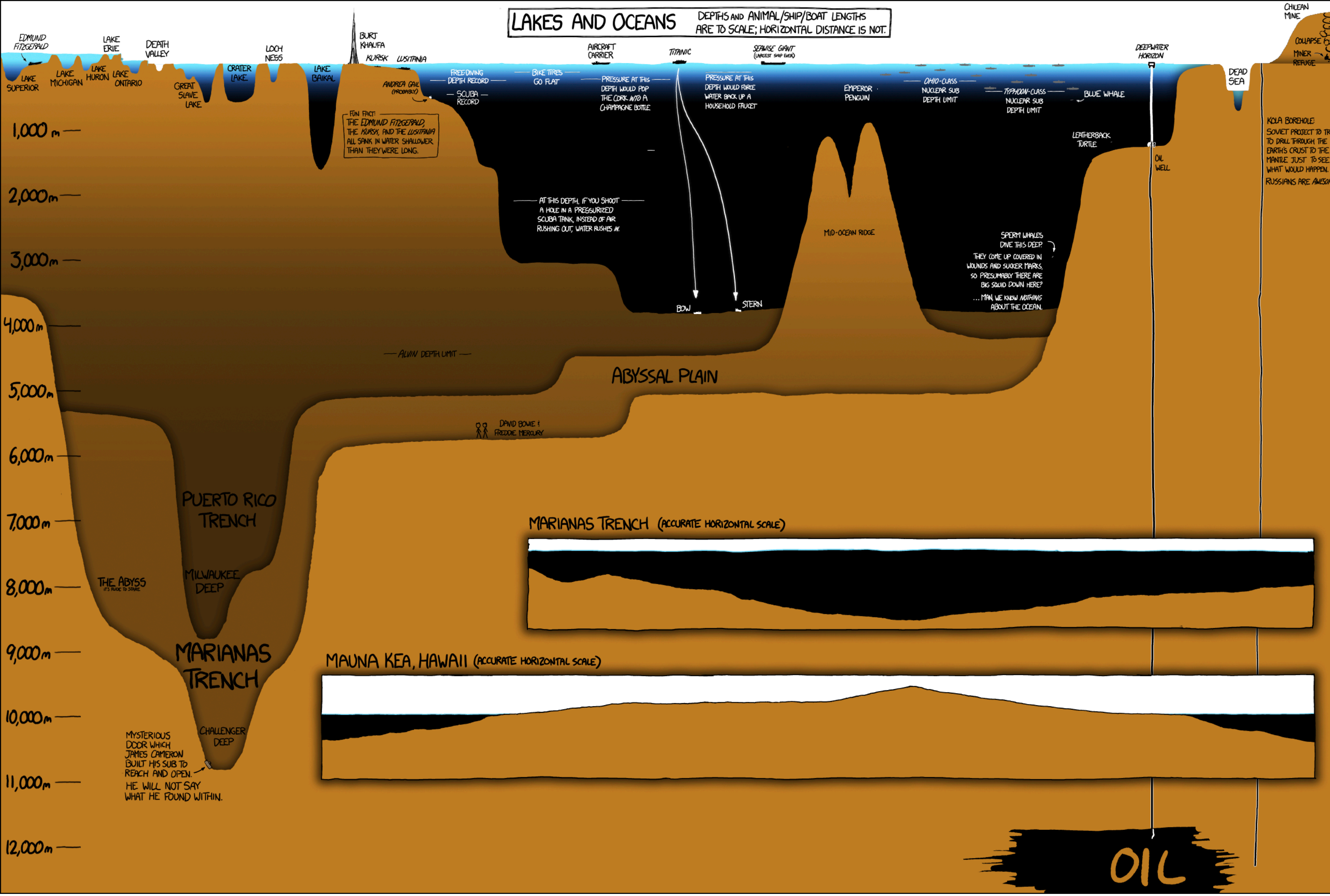


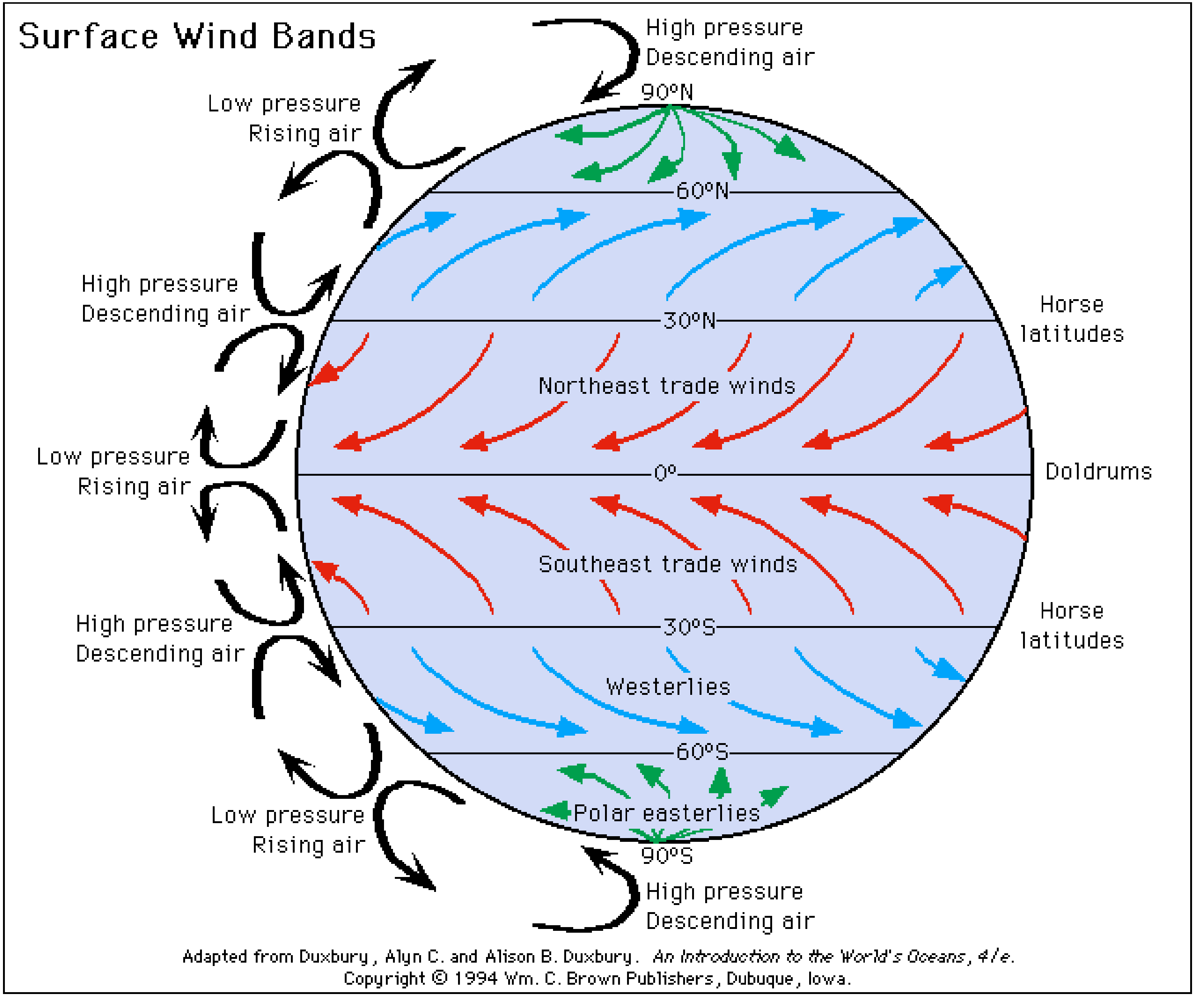
FIGURE 1.2. Structure of the ocean bottom.

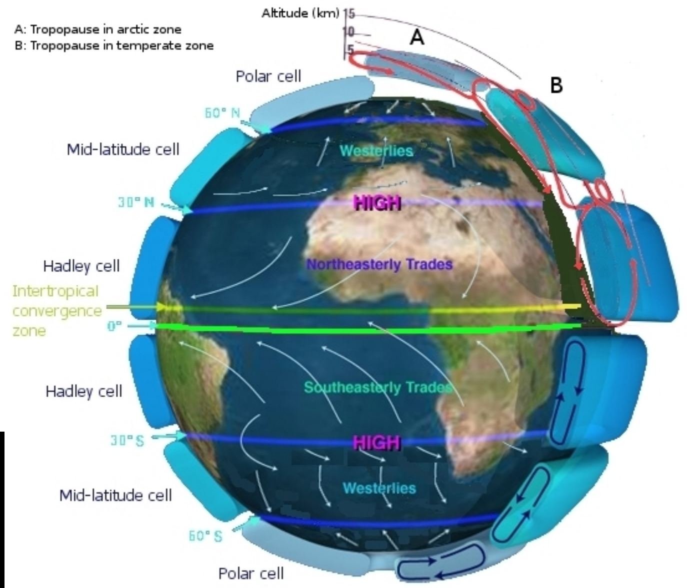


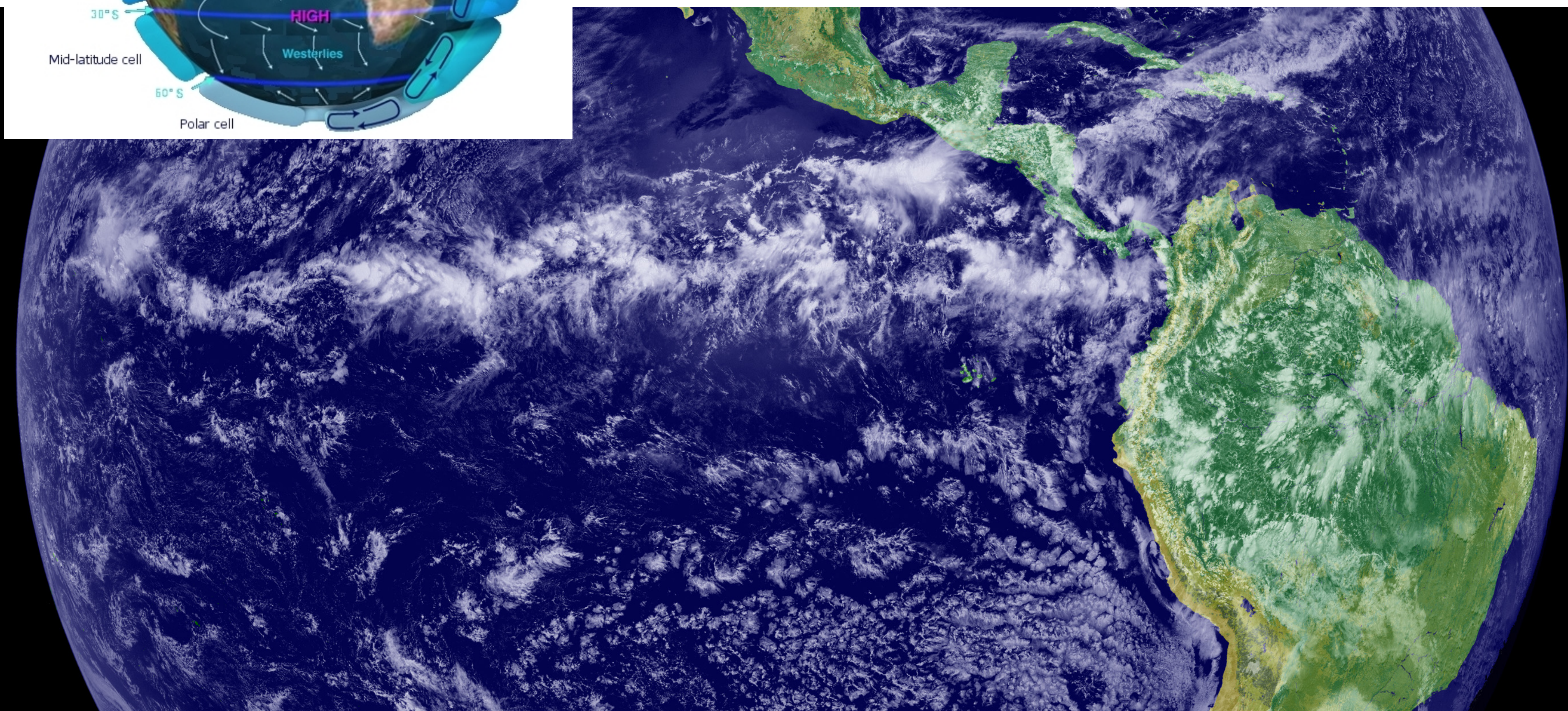


LAKES AND OCEANS
DEPTHS AND ANIMAL/SHIP/BOAT LENGTHS ARE TO SCALE; HORIZONTAL DISTANCE IS NOT.
EDMUND FITZGERALD
LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
LAKE ERIE
LAKE ONTARIO
DEATH VALLEY
GREAT SLAVE LAKE
CRATER LAKE
LOCH NESS
LAKE BAIKAL
BURJ KHALIFA
KURSK
LUSITANIA
ANDREA GAIL (PROBABLY)
FUN FACT: THE EDMUND FITZGERALD, THE KURSK, AND THE LUSITANIA ALL SANK IN WATER SHALLOWER THAN THEY WERE LONG.
FREE-DIVING DEPTH RECORD
SCUBA RECORD
BIKE TIRES GO FLAT
AIRCRAFT CARRIER
PRESSURE AT THIS DEPTH WOULD POP THE CORK INTO A CHAMPAGNE BOTTLE
TITANIC
PRESSURE AT THIS DEPTH WOULD FORCE WATER BACK UP A HOUSEHOLD FAUCET
SEAWISE GIANT (LARGEST SHIP EVER)
EMPEROR PENGUIN
OHIO-CLASS NUCLEAR SUB DEPTH LIMIT
TYPHOON-CLASS NUCLEAR SUB DEPTH LIMIT
BLUE WHALE
LEATHERBACK TURTLE
DEEPWATER HORIZON
OIL WELL
DEAD SEA
CHILEAN MINE
COLLAPSE
MINER REFUGE
KOLA BOREHOLE: SOVIET PROJECT TO TRY TO DRILL THROUGH THE EARTH'S CRUST TO THE MANTLE JUST TO SEE WHAT WOULD HAPPEN. RUSSIANS ARE AWESOME.
AT THIS DEPTH, IF YOU SHOOT A HOLE IN A PRESSURIZED SCUBA TANK, INSTEAD OF AIR RUSHING OUT, WATER RUSHES IN.
MID-OCEAN RIDGE
SPERM WHALES DIVE THIS DEEP.
THEY COME UP COVERED IN WOUNDS AND SUCKER MARKS, SO PRESUMABLY THERE ARE BIG SQUID DOWN HERE?
...MAN, WE KNOW NOTHING ABOUT THE OCEAN.
BOW
STERN
ALVIN DEPTH LIMIT
ABYSSAL PLAIN
DAVID BOWIE & FREDDIE MERCURY
1,000 m
2,000 m
3,000 m
4,000 m
5,000 m
6,000 m
7,000 m
8,000 m
9,000 m
10,000 m
11,000 m
12,000 m
PUERTO RICO TRENCH
MILWAUKEE DEEP
THE ABYSS
IT'S RUDE TO STARE
MARIANAS TRENCH
CHALLENGER DEEP
MYSTERIOUS DOOR WHICH JAMES CAMERON BUILT HIS SUB TO REACH AND OPEN.
HE WILL NOT SAY WHAT HE FOUND WITHIN.
MARIANAS TRENCH (ACCURATE HORIZONTAL SCALE)
MAUNA KEA, HAWAII (ACCURATE HORIZONTAL SCALE)
OIL

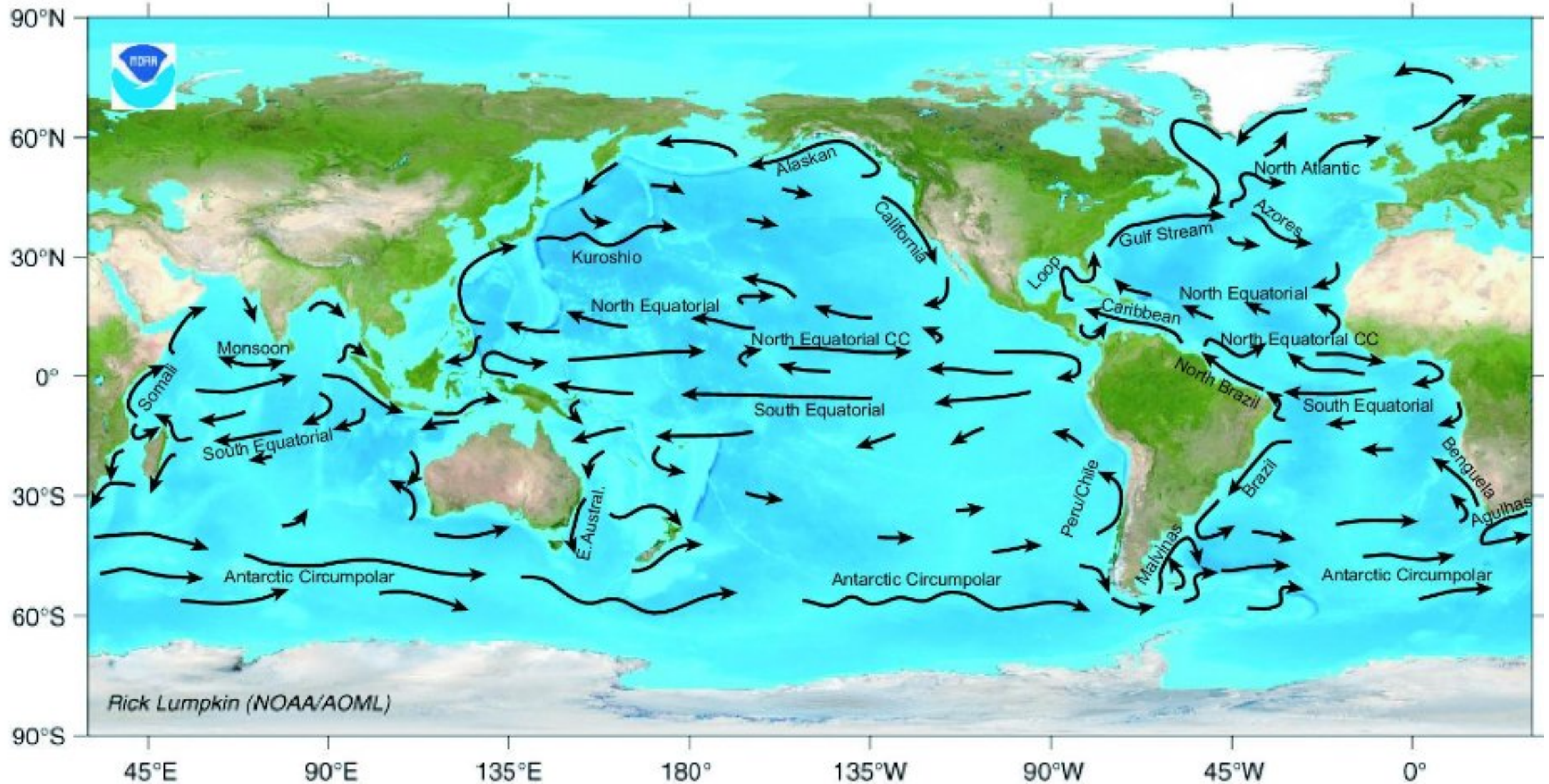
Winds

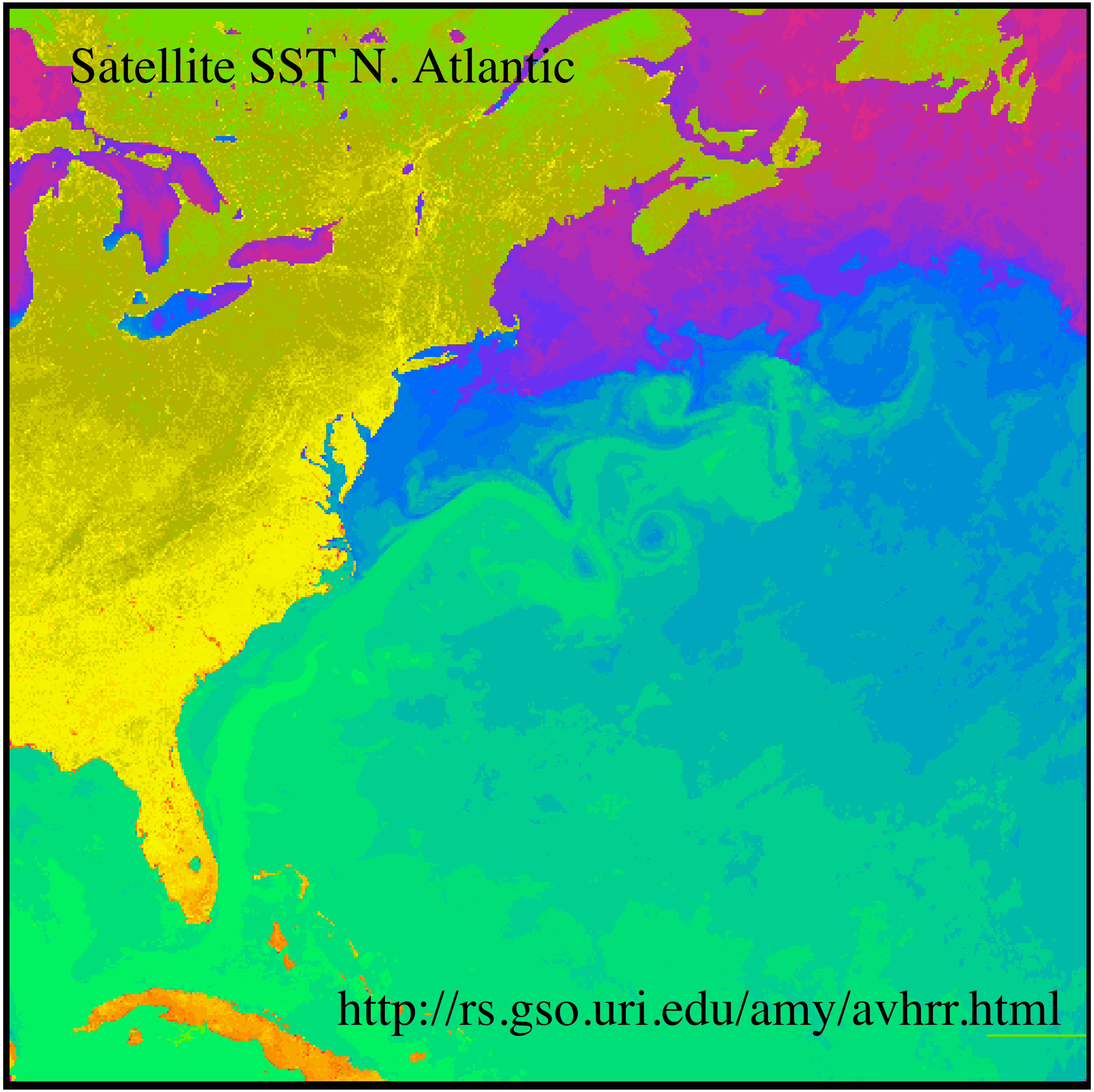

Surface Wind Bands
High pressure
Descending air
90°N
Low pressure
Rising air
60°N
High pressure
Descending air
30°N
Horse
latitudes
Northeast trade winds
Low pressure
Rising air
0°
Doldrums
Southeast trade winds
High pressure
Descending air
30°S
Horse
latitudes
Westerlies
60°S
Low pressure
Rising air
Polar easterlies
90°S
High pressure
Descending air
Adapted from Duxbury, Alyn C. and Alison B. Duxbury. *An Introduction to the World's Oceans, 4/e.*
Copyright © 1994 Wm. C. Brown Publishers, Dubuque, Iowa.


A: Tropopause in arctic zone
B: Tropopause in temperate zone
Altitude (km) 15
10
5
A
B
Polar cell
60° N
Mid-latitude cell
Westerlies
30° N
HIGH
Hadley cell
Northeasterly Trades
Intertropical convergence zone
0°
Hadley cell
Southeasterly Trades
30° S
HIGH
Mid-latitude cell
Westerlies
60° S
Polar cell

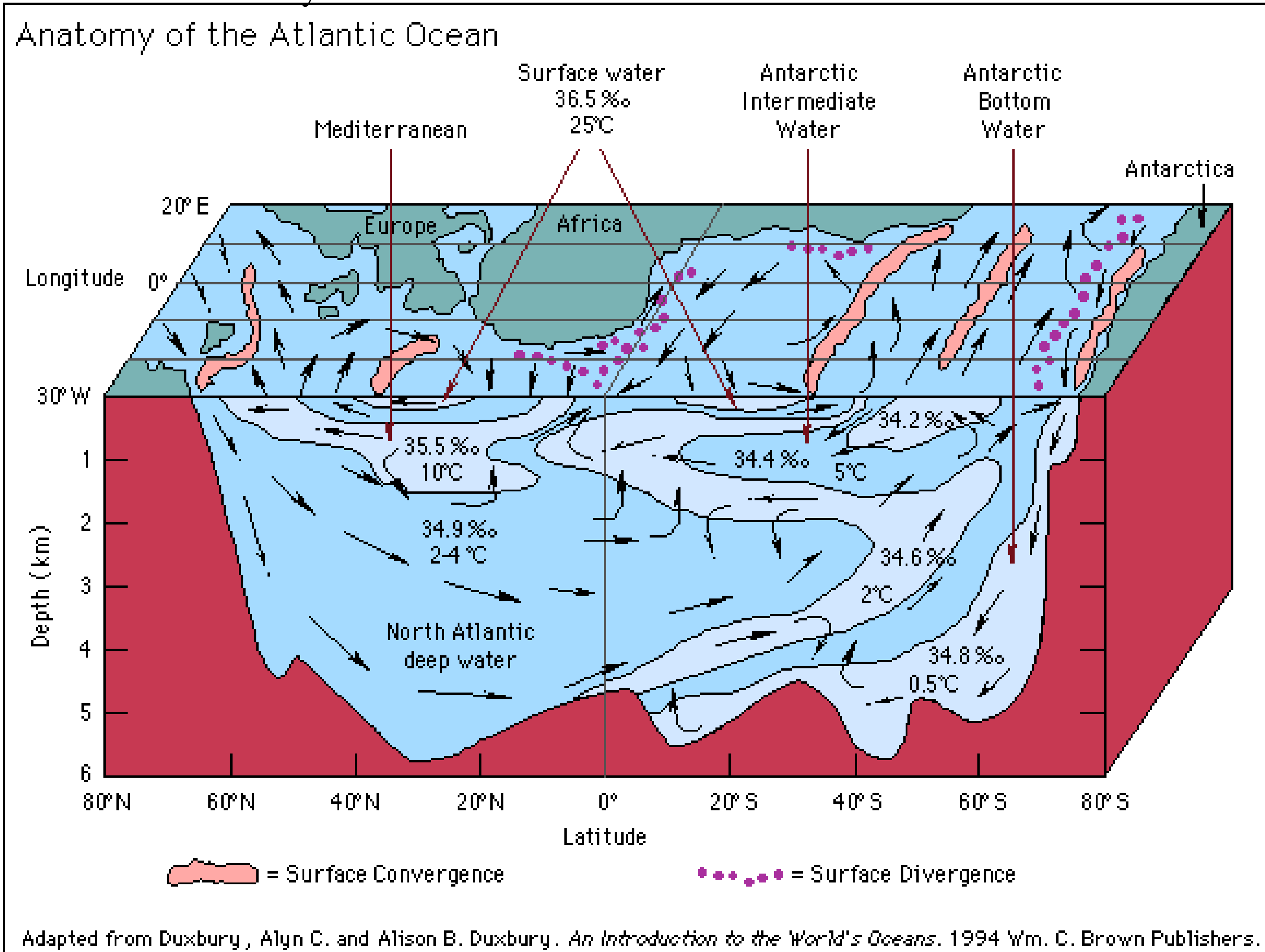


Major Surface Currents

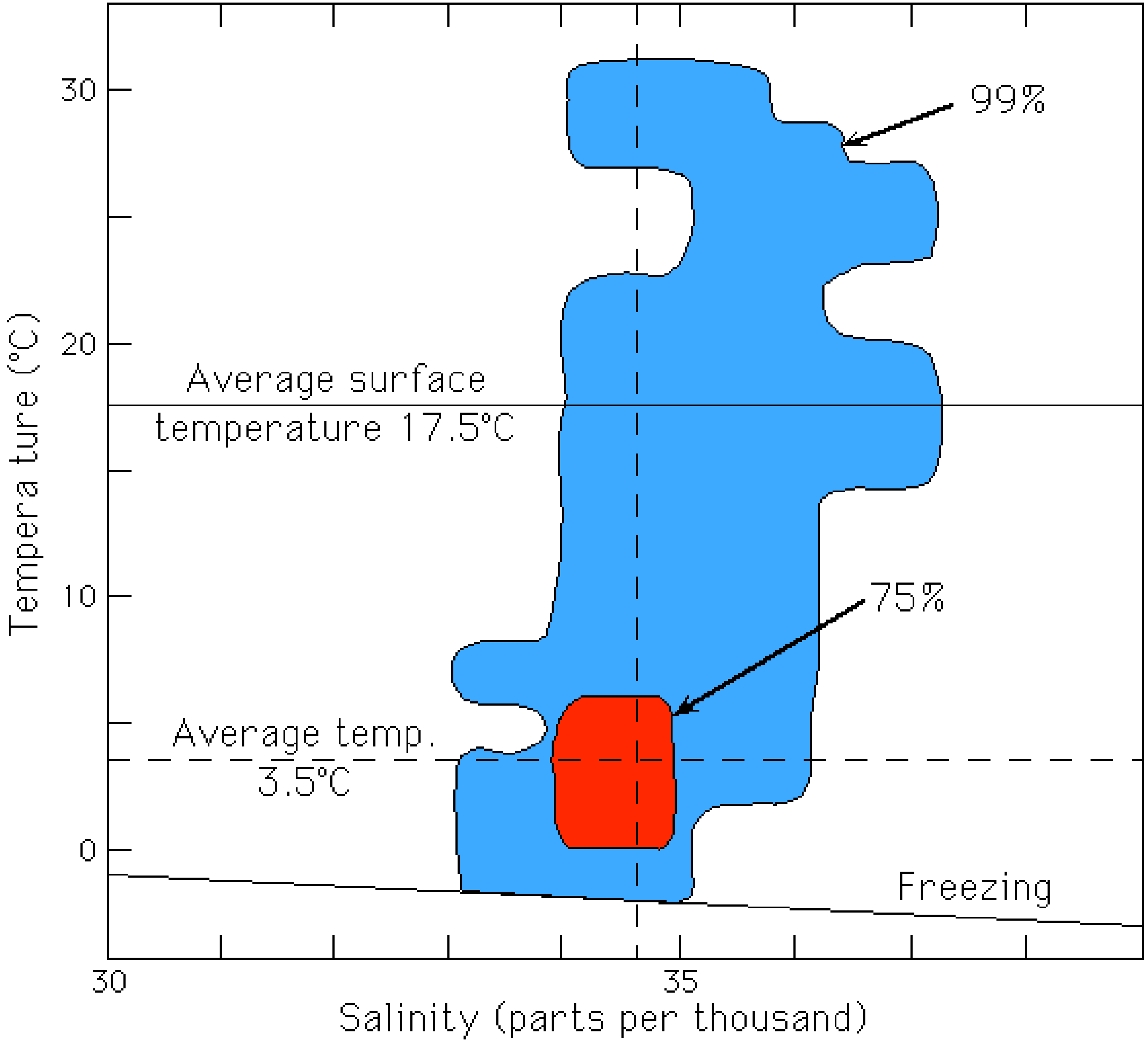



Satellite SST N. Atlantic
http://rs.gso.uri.edu/amy/avhrr.html

N. Atlantic cut-away



Global T-S



Temperature and salinity of 99% (75%) of the ocean water are represented by points within the blue (red) area. (After Gross, 1993).

Temperature Variations

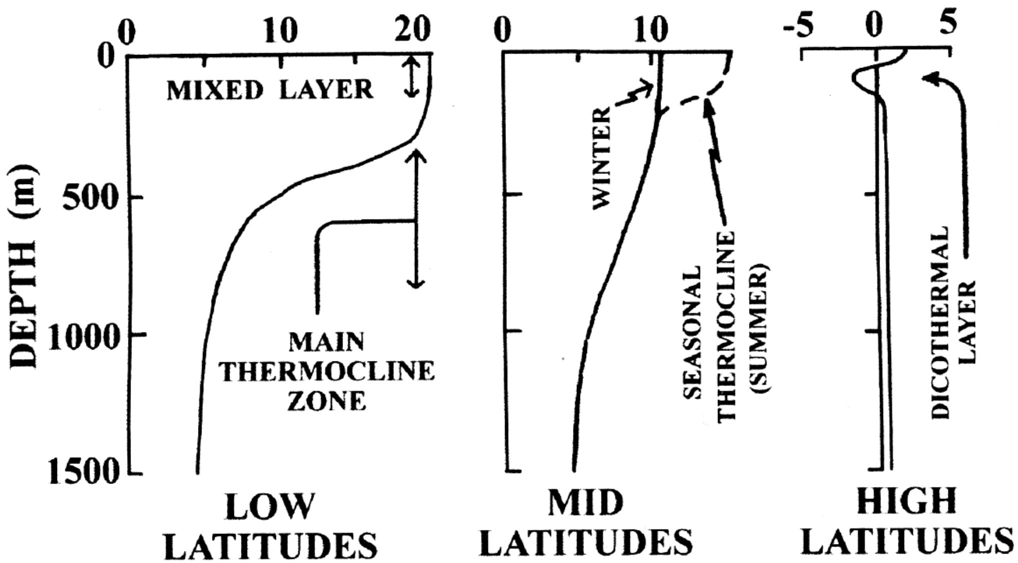


FIGURE 1.7. Typical temperature profiles in the ocean.

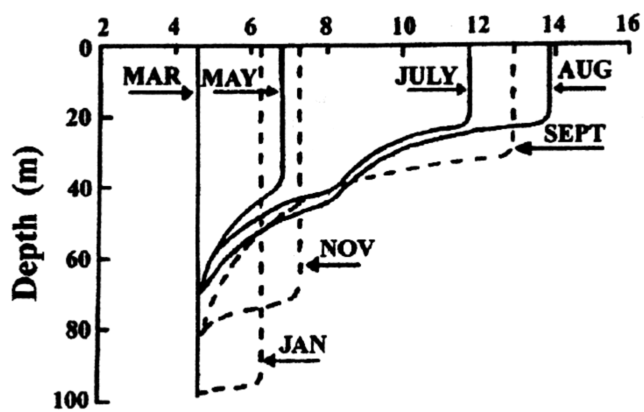


FIGURE 1.8. Growth and decay of the thermocline.

Potential Temperature

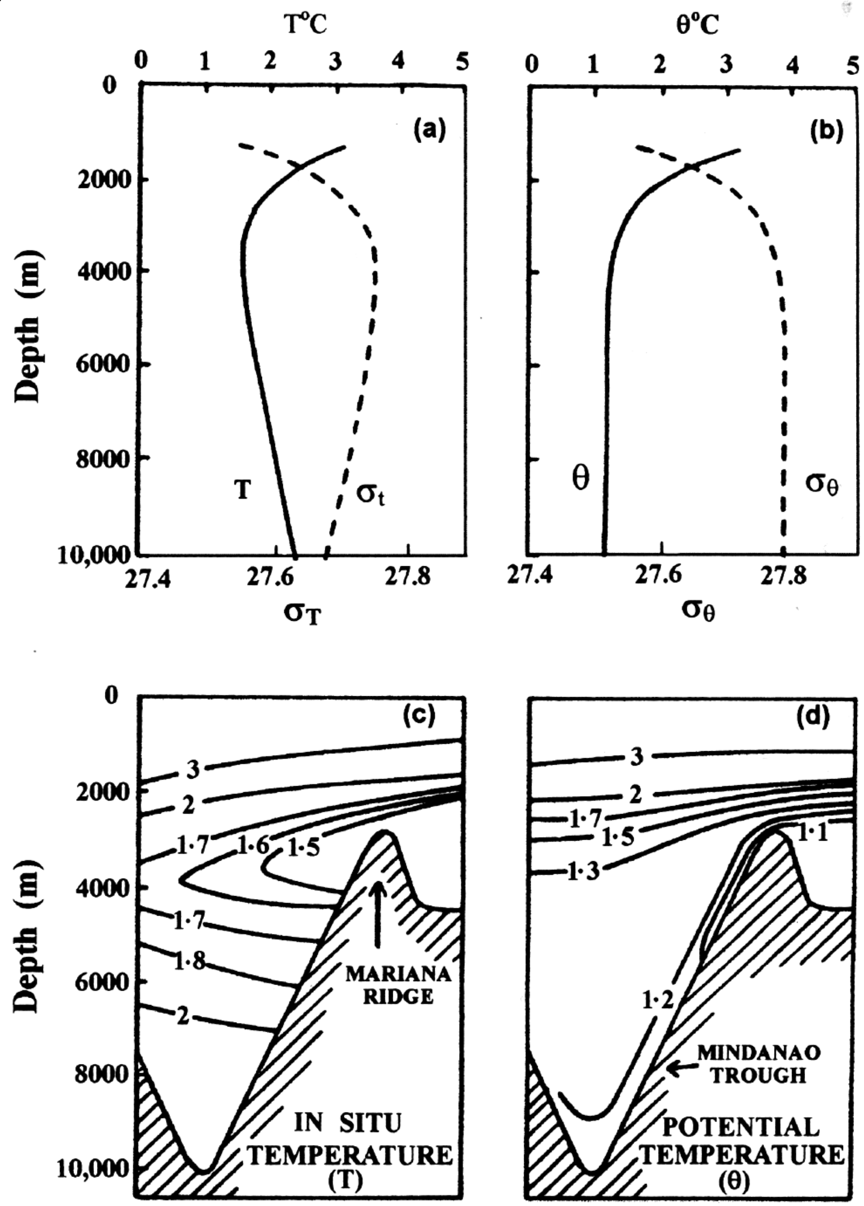
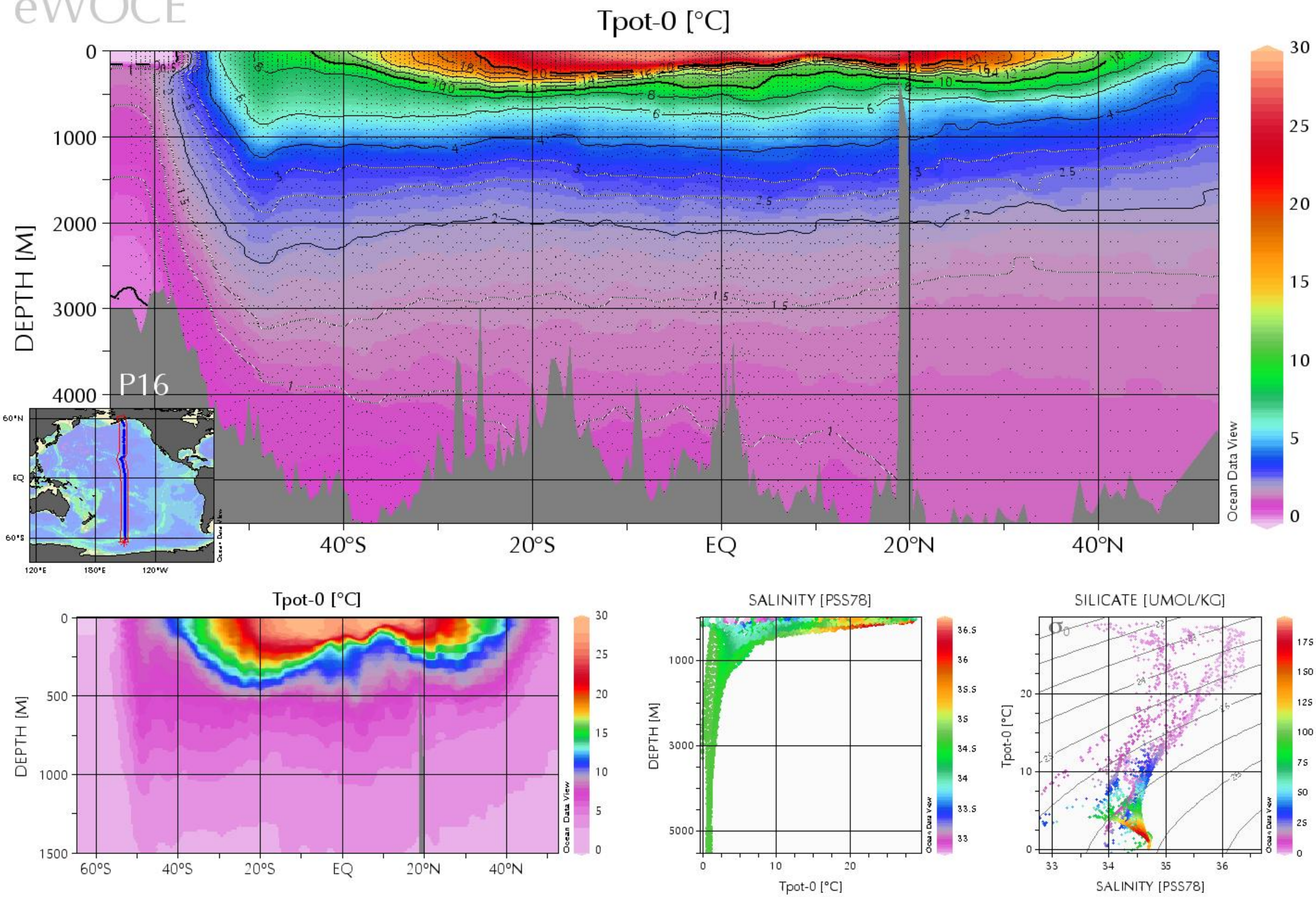


FIGURE 1.9. *In situ* and potential temperature in deep sea trench.

eWOCE



Tpot-0 [°C]
DEPTH [M]
0
1000
2000
3000
4000
40°S
20°S
EQ
20°N
40°N
P16
Ocean Data View
30
25
20
15
10
5
0
Tpot-0 [°C]
60°S
40°S
20°S
EQ
20°N
40°N
SALINITY [PSS78]
Tpot-0 [°C]
SILICATE [UMOL/KG]
SALINITY [PSS78]
Tpot-0 [°C]

Salinity Variations

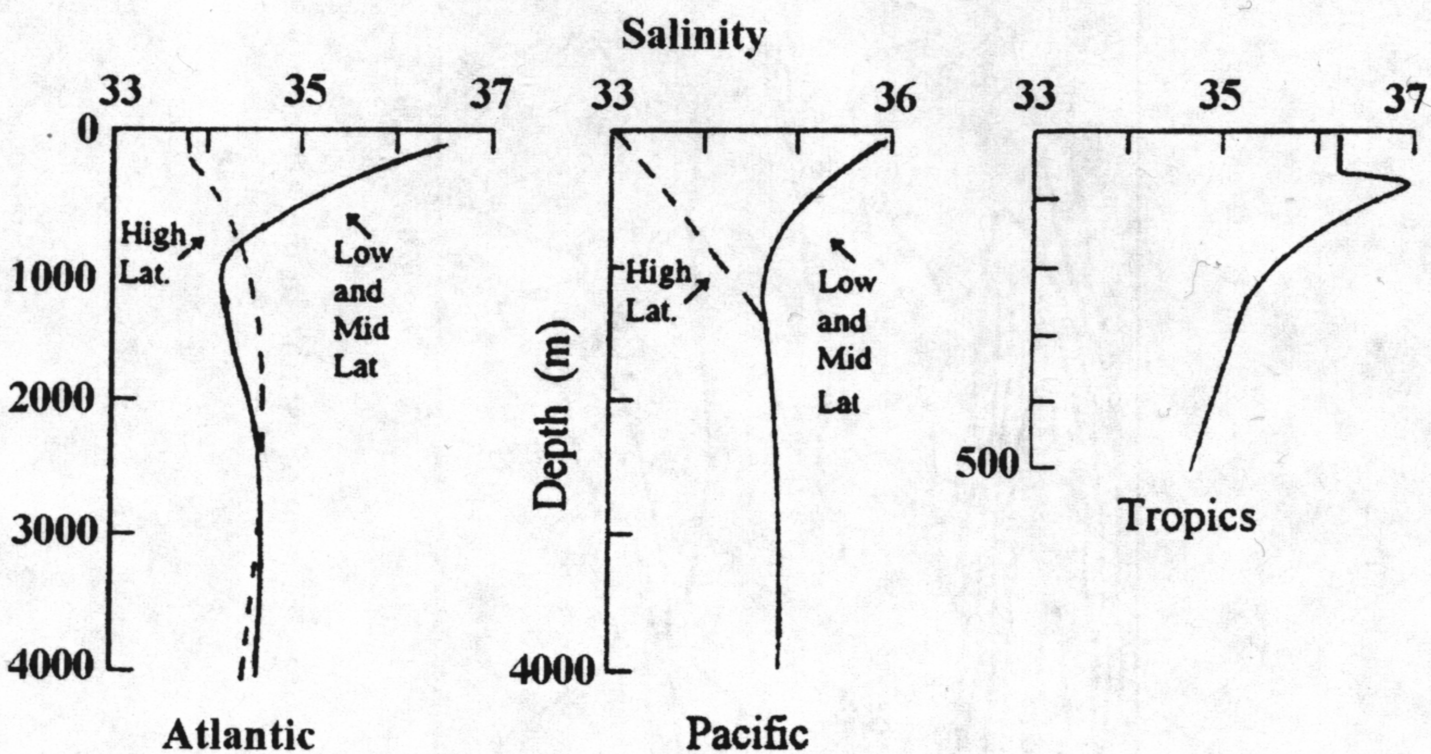
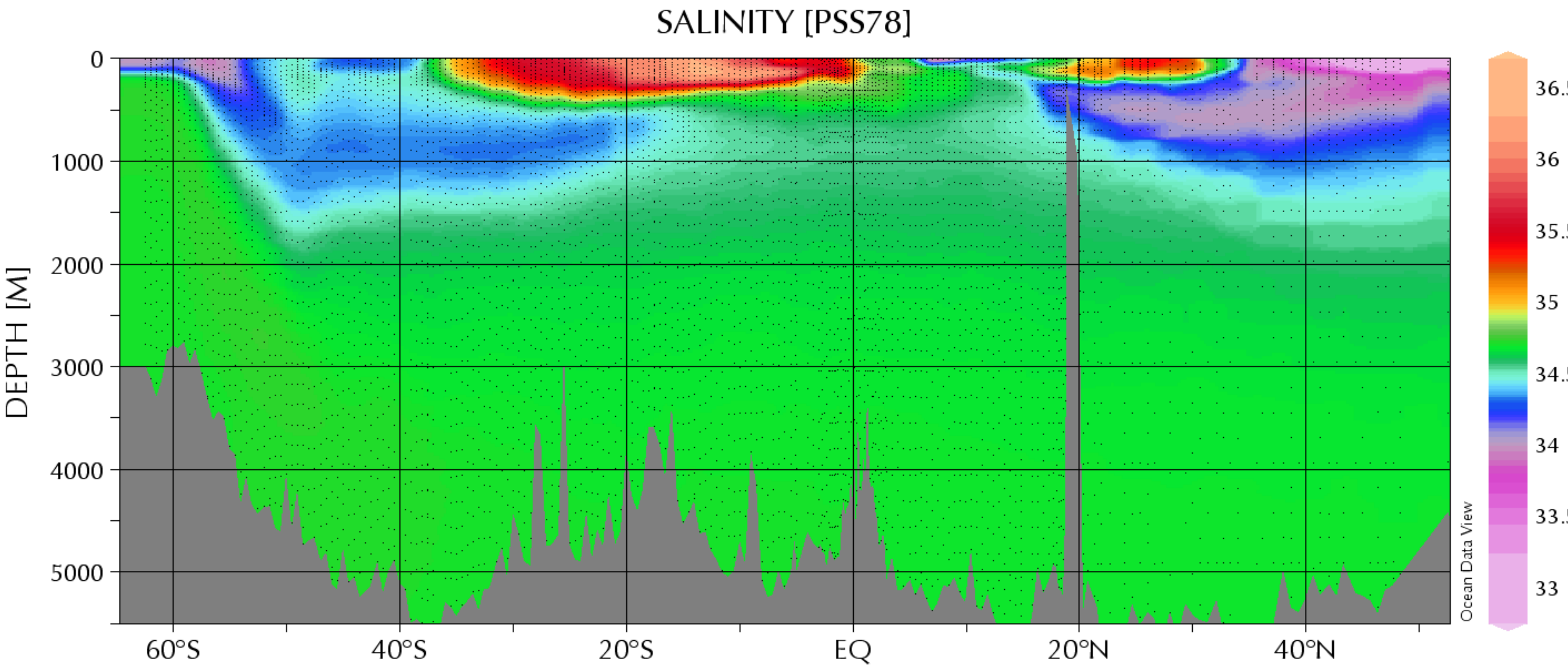


FIGURE 1.15. Typical salinity profiles in the oceans.


SALINITY [PSS78]
DEPTH [M]
0
1000
2000
3000
4000
5000
60°S
40°S
20°S
EQ
20°N
40°N
Ocean Data View
36.5
36
35.5
35
34.5
34
33.5
33

Major Water Mass Characteristics

TABLE 4.1
Major Water Masses of the World Ocean

Water mass	*Temperature (°C)*	*Salinity (‰)*
Central water masses		
N. Atlantic water (NAC)	8–19	35.1–36.5
S. Atlantic water (SAC)	6–17	34.7–36.0
W. North Pacific water (NPC)	6–18	34.0–34.9
W. South Pacific water (SPC)	10–17	34.5–35.6
Indian water (IC)	7–16	34.5–35.6
High-latitude surface water masses		
Atlantic subarctic water	4–5	34.6–34.7
Pacific subarctic water	3–6	33.5–34.4
Subantartic water	3–10	33.9–34.7
Antarctic circumpolar water	0–2	34.6–34.7
Intermediate water masses		
Arctic intermediate water (NAI)	3–5	34.7–34.9
N. Pacific intermediate water (NPI)	4–10	34.0–34.5
Antarctic intermediate water (AI)	3–7	33.8–34.7
Mediterranean intermediate water (MI)	6–12	35.3–36.5
Red Sea intermediate water (RSI)	8–12	35.1–35.7
Deep and bottom water masses		
N. Atlantic deep and bottom water (NAD and B)	2–4	34.8–35.1
Antarctic bottom water (AB)	−0.4	34.7

Source: From *The World Ocean: An Introduction to Oceanography*, W. A. Anikouchine and R. W. Sternberg, copyright © 1981 by Prentice Hall, Inc., Englewood Cliffs, NJ, p. 219. Reprinted by permission. After *The Oceans*, H. U. Sverdrup, M. W. Johnson, and R. H. Fleming, copyright © 1941 by Prentice Hall, Inc., Englewood Cliffs, NJ, p. 741. Reprinted by permission.

TS mixing

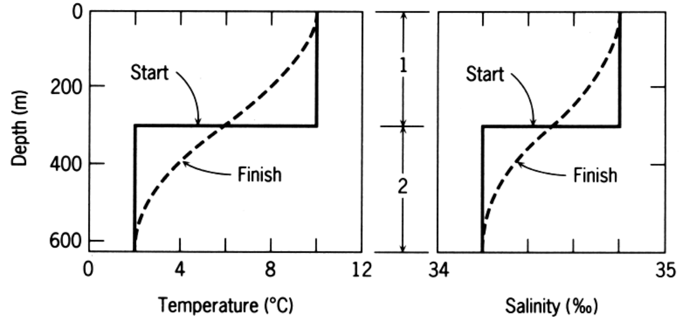


FIGURE 4.10. Conservative mixing of water masses. *Source:* From *Oceanography: A View of the Earth*, 4th ed., M. G. Gross, copyright © 1987 by Prentice Hall, Inc., Englewood Cliffs, NJ, p. 169. Reprinted by permission.

The rate of change in concentration of a conservative solute, C, at some fixed point, x, which is caused by turbulent mixing is given by Fick's Second Law:

$$\frac{\partial[C]}{\partial t} = D_x\left[\frac{\partial}{\partial x}\left(\frac{\partial[C]}{\partial x}\right)\right] = D_x\left[\frac{\partial^2[C]}{\partial x^2}\right] \tag{4.1}$$

where D_x is the turbulent mixing coefficient for water motion in the x direction.

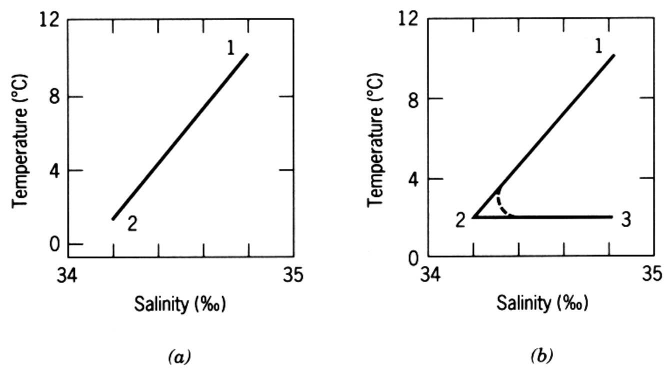
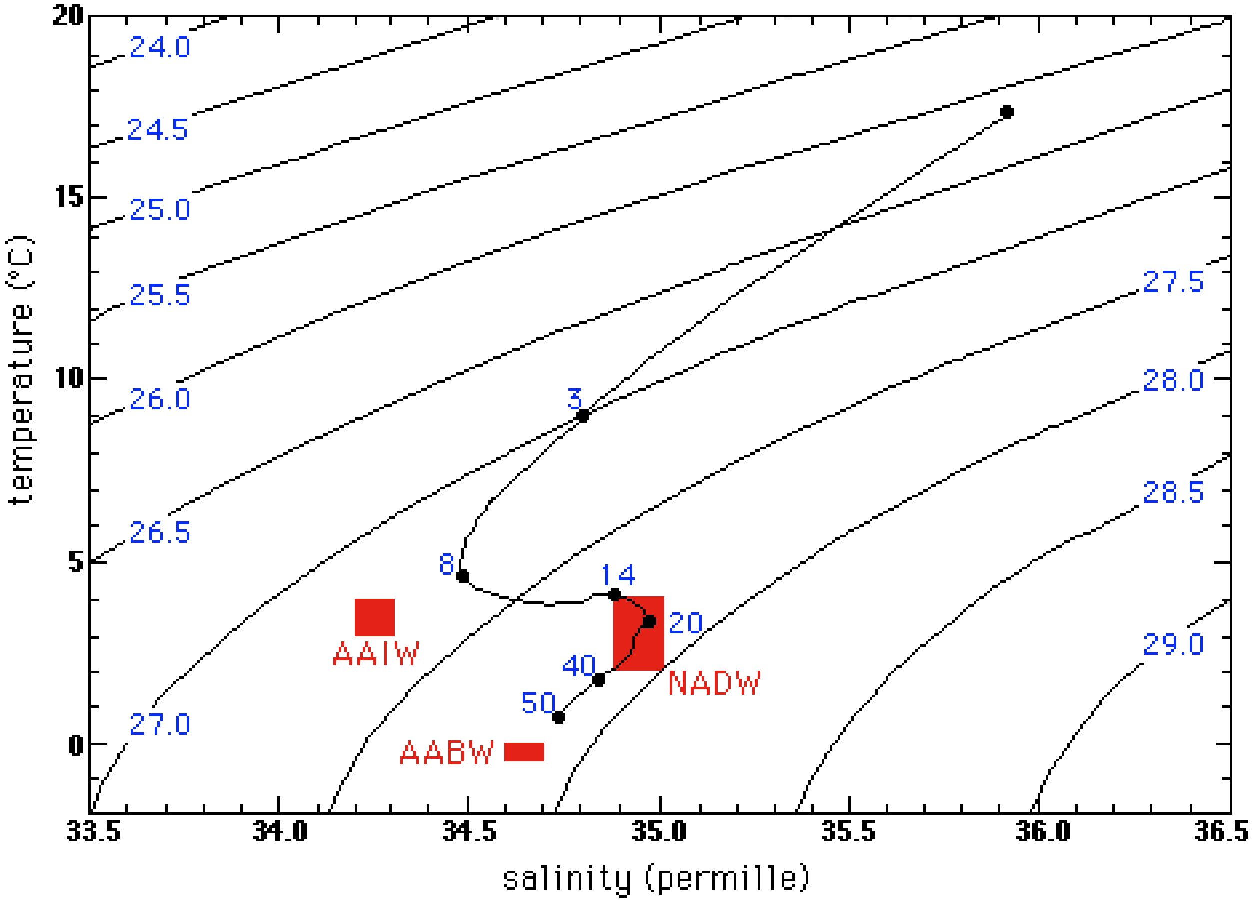


FIGURE 4.11. T–S Diagram indicating the presence of (*a*) two water masses and (*b*) multiple water masses. From *Oceanography: A View of the Earth*, 4th ed., M. G. Gross, copyright © 1987 by Prentice Hall, Inc., Englewood Cliffs, NJ, p. 169. Reprinted by permission.

Typical T-S diagram



An example of a T-S diagram for observations at depths from 150 m to 5,000 m at 9°S latitude in the Atlantic Ocean. Dots represent individual seawater samples; numbers indicate depths in hundreds of meters. Red boxes represent the major subsurface Atlantic water masses. AABW = Antarctic Bottom Water; NADW = North Atlantic Deep Water; AAIW = Antarctic Intermediate Water.

Sigma-T Calculation

Kg/m³

TABLE 1.4
The International Equation of State for Seawater (m³[redacted])[a]

$$v^P = v^0(1 - P/K)$$
$$\rho^P = \rho^0[1/(1 - P/K)]$$

where:

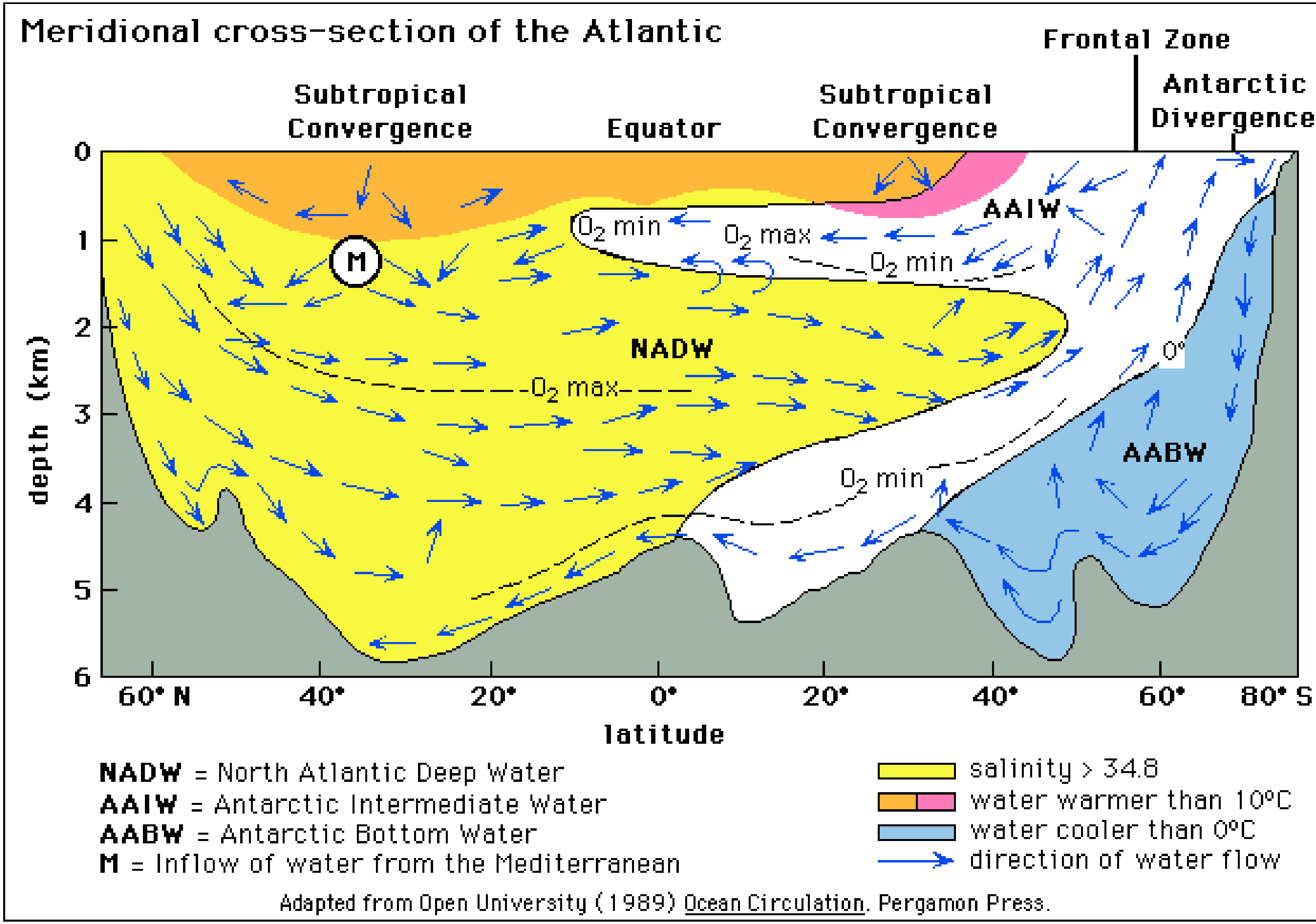
$$\begin{aligned}
\rho^0 = {} & 999.842594 + 6.793952 \times 10^{-2}\,t - 9.095290 \times 10^{-3}\,t^2 \\
& + 1.001685 \times 10^{-4}\,t^3 - 1.120083 \times 10^{-6}\,t^4 \\
& + 6.536336 \times 10^{-9}\,t^5 + (8.24493 \times 10^{-1} \\
& - 4.0899 \times 10^{-3}\,t + 7.6438 \times 10^{-5}\,t^2 \\
& - 8.2467 \times 10^{-7}\,t^3 + 5.3875 \times 10^{-9}\,t^4)\,S \\
& + (-5.72466 \times 10^{-3} + 1.0227 \times 10^{-4}\,t \\
& - 1.6546 \times 10^{-6}\,t^2)S^{3/2} + 4.8314 \times 10^{-4}\,S^2
\end{aligned}$$

$$\begin{aligned}
K = {} & 19652.21 + 148.4206\,t - 2.327105t^2 + 1.360477 \times 10^{-2}\,t^3 \\
& - 5.155288 \times 10^{-5}\,t^4 + S(54.6746 - 0.603459t \\
& + 1.09987 \times 10^{-2}\,t^2 - 6.1670 \times 10^{-5}\,t^3) - S^{3/2}(7.944 \times 10^{-2} \\
& + 1.6483 \times 10^{-2}\,t - 5.3009 \times 10^{-4}\,t^2) + P[3.239908 \\
& + 1.43713 \times 10^{-3}\,t + 1.16082 \times 10^{-4}\,t^2 - 5.77905 \times 10^{-7}\,t^3 \\
& + S(2.2838 \times 10^{-3} - 1.0981 \times 10^{-5}\,t - 1.6078 \times 10^{-6}\,t^2) \\
& + S^{3/2}\,(1.91075 \times 10^{-4})] + P2[8.50935 \times 10^{-5} - 6.12293 \times 10^{-6}\,t \\
& + 5.2787 \times 10^{-8}\,t^2 + S(-9.9348 \times 10^{-7} \\
& + 2.0816 \times 10^{-8}\,t + 9.1697 \times 10^{-10}\,t^2)]
\end{aligned}$$

Kg/m³

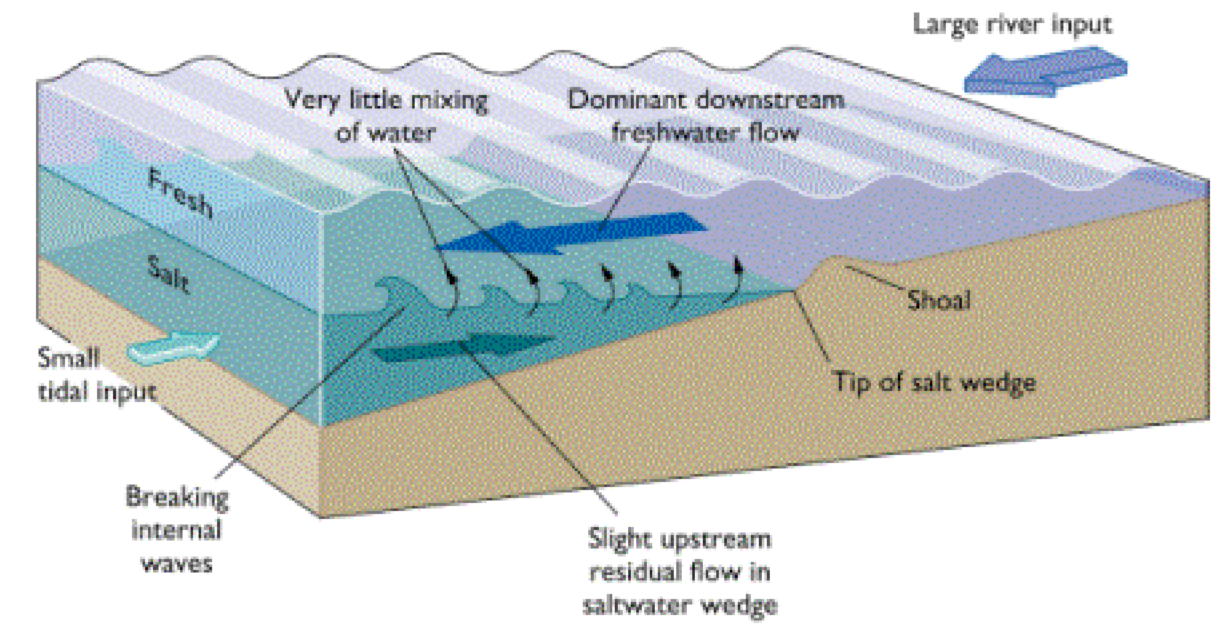
Check values:	S	t	P	v(~~m³ kg⁻¹~~)	K(b)
	35	5°C	0 b	1027.67547	22185.93358
			1000	1069.48914	25577.49819

[a] Millero et al., *Deep-Sea Res.*, **27**, 255, 1980; Millero and Poisson, *Deep-Sea Res.*, **28**, 625, 1981.

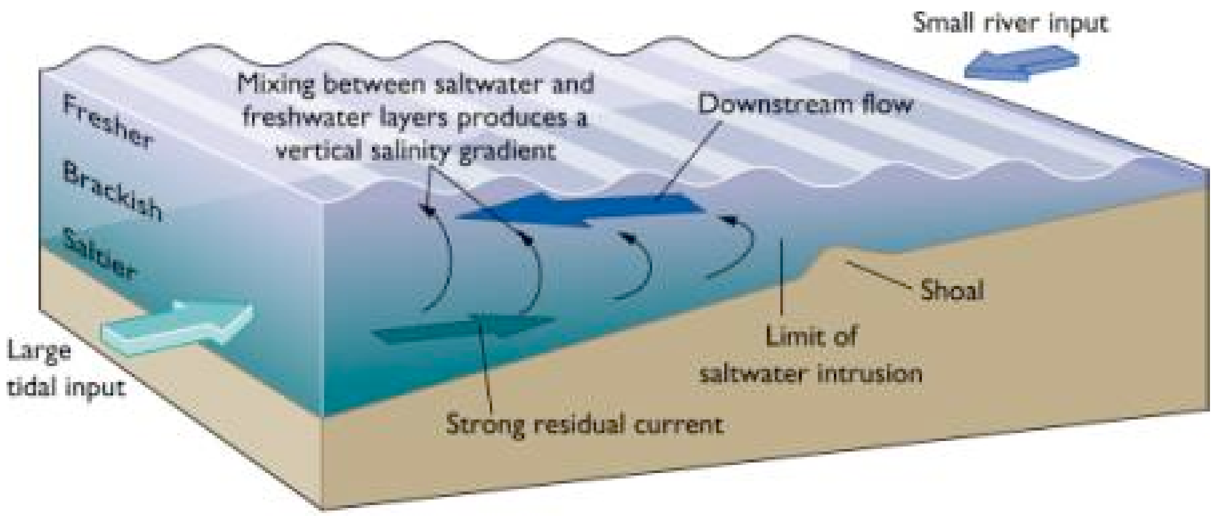


Atlantic water masses

Estuarine Circulation

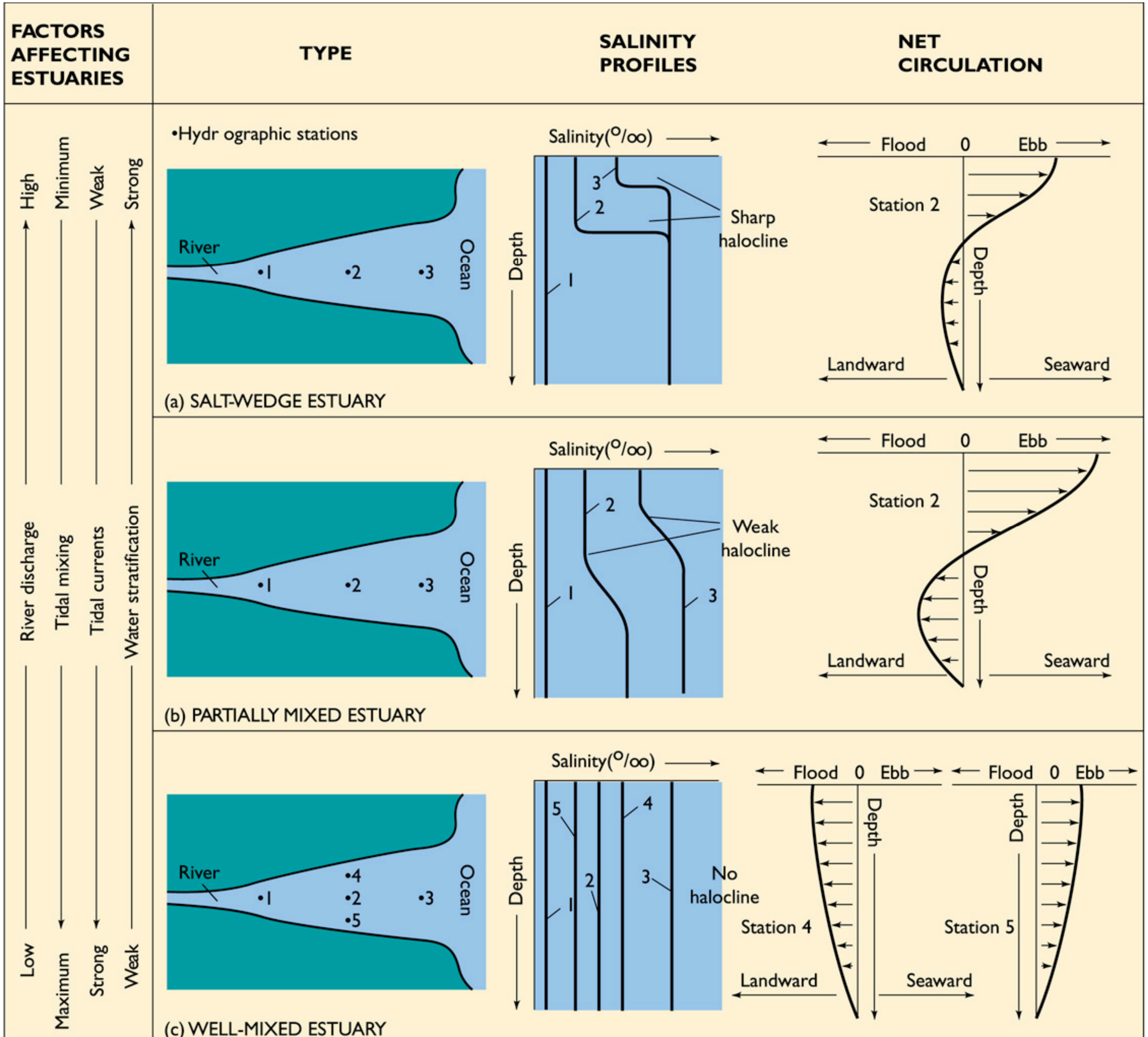


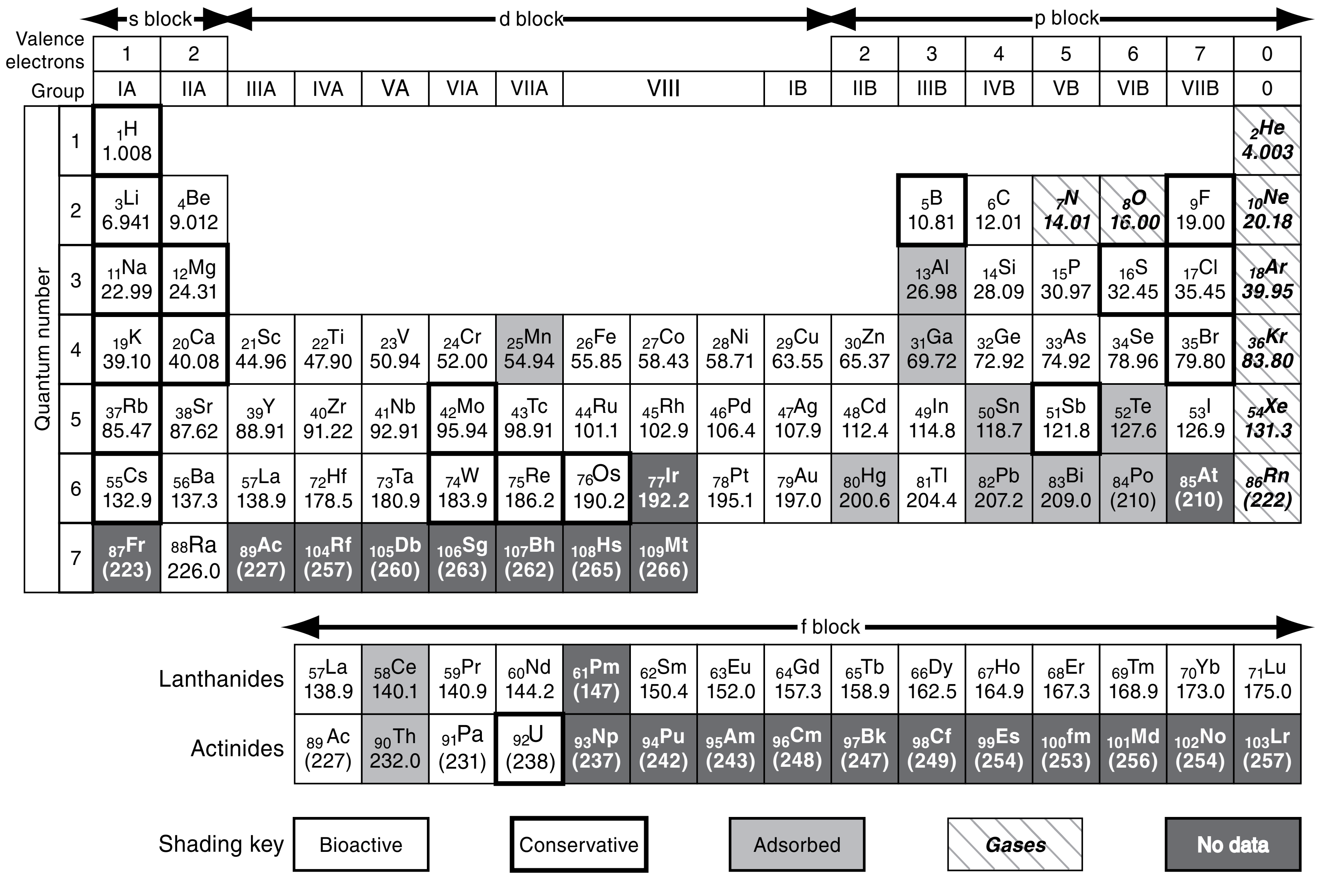
(a) SALT-WEDGE ESTUARY



(b) PARTIALLY MIXED ESTUARY

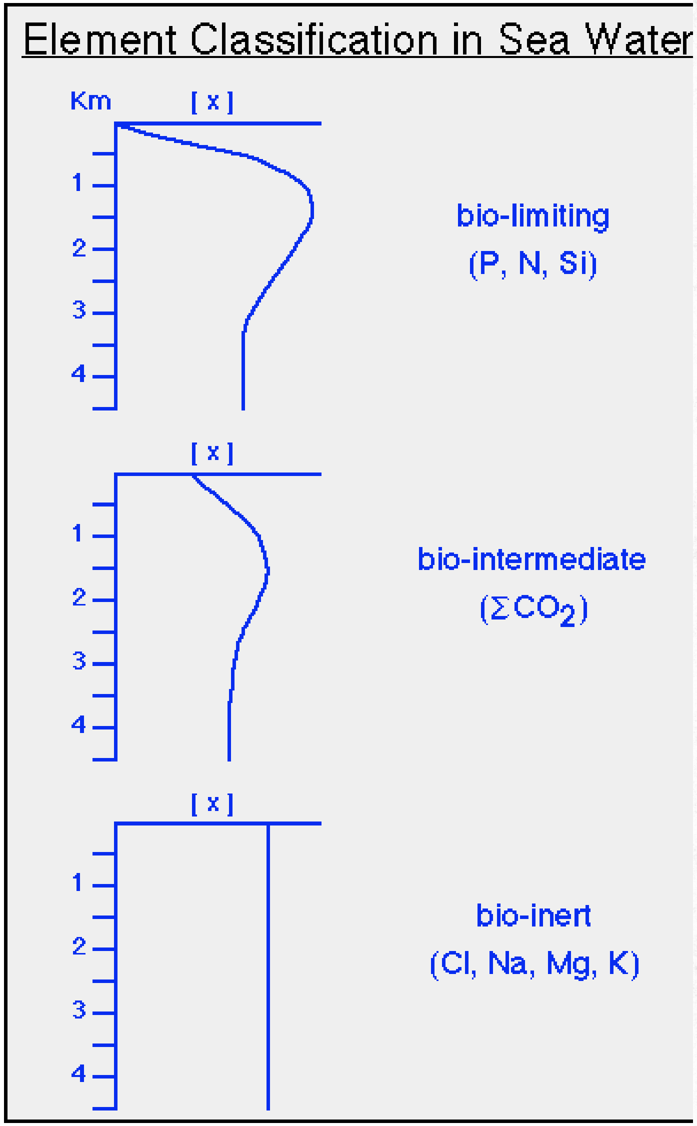
Estuary Types





s block
d block
p block
Valence electrons
1
2
2
3
4
5
6
7
0
Group
IA
IIA
IIIA
IVA
VA
VIA
VIIA
VIII
IB
IIB
IIIB
IVB
VB
VIB
VIIB
0
Quantum number
1
1H 1.008
2He 4.003
2
3Li 6.941
4Be 9.012
5B 10.81
6C 12.01
7N 14.01
8O 16.00
9F 19.00
10Ne 20.18
3
11Na 22.99
12Mg 24.31
13Al 26.98
14Si 28.09
15P 30.97
16S 32.45
17Cl 35.45
18Ar 39.95
4
19K 39.10
20Ca 40.08
21Sc 44.96
22Ti 47.90
23V 50.94
24Cr 52.00
25Mn 54.94
26Fe 55.85
27Co 58.43
28Ni 58.71
29Cu 63.55
30Zn 65.37
31Ga 69.72
32Ge 72.92
33As 74.92
34Se 78.96
35Br 79.80
36Kr 83.80
5
37Rb 85.47
38Sr 87.62
39Y 88.91
40Zr 91.22
41Nb 92.91
42Mo 95.94
43Tc 98.91
44Ru 101.1
45Rh 102.9
46Pd 106.4
47Ag 107.9
48Cd 112.4
49In 114.8
50Sn 118.7
51Sb 121.8
52Te 127.6
53I 126.9
54Xe 131.3
6
55Cs 132.9
56Ba 137.3
57La 138.9
72Hf 178.5
73Ta 180.9
74W 183.9
75Re 186.2
76Os 190.2
77Ir 192.2
78Pt 195.1
79Au 197.0
80Hg 200.6
81Tl 204.4
82Pb 207.2
83Bi 209.0
84Po (210)
85At (210)
86Rn (222)
7
87Fr (223)
88Ra 226.0
89Ac (227)
104Rf (257)
105Db (260)
106Sg (263)
107Bh (262)
108Hs (265)
109Mt (266)
f block
Lanthanides
57La 138.9
58Ce 140.1
59Pr 140.9
60Nd 144.2
61Pm (147)
62Sm 150.4
63Eu 152.0
64Gd 157.3
65Tb 158.9
66Dy 162.5
67Ho 164.9
68Er 167.3
69Tm 168.9
70Yb 173.0
71Lu 175.0
Actinides
89Ac (227)
90Th 232.0
91Pa (231)
92U (238)
93Np (237)
94Pu (242)
95Am (243)
96Cm (248)
97Bk (247)
98Cf (249)
99Es (254)
100fm (253)
101Md (256)
102No (254)
103Lr (257)
Shading key
Bioactive
Conservative
Adsorbed
Gases
No data

Element Dist Types



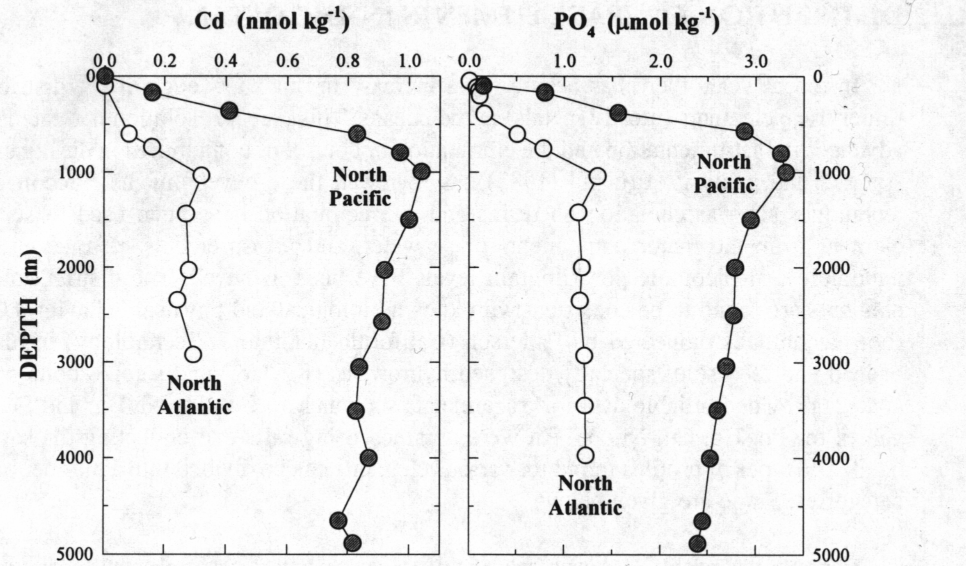
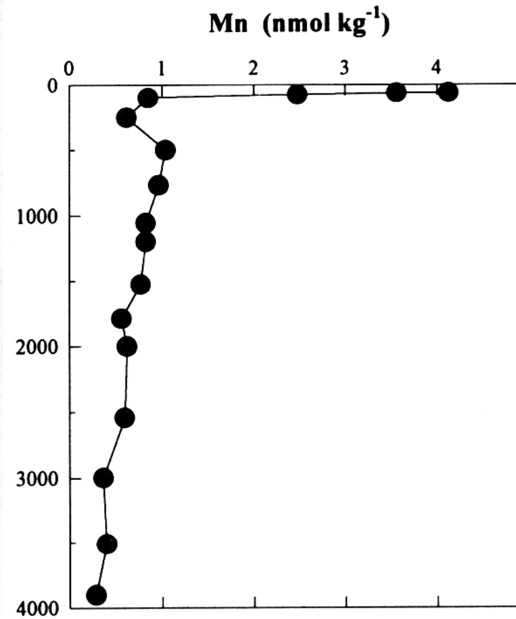
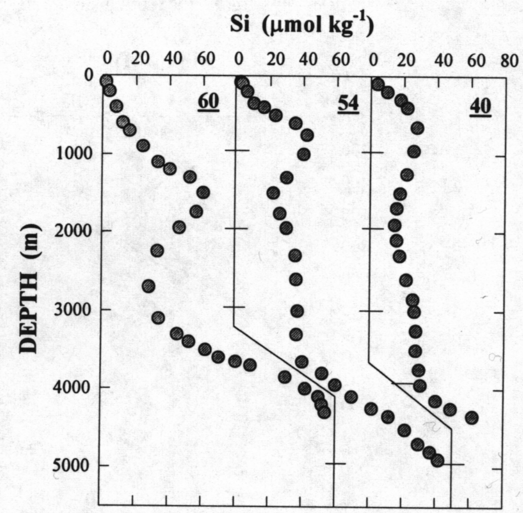


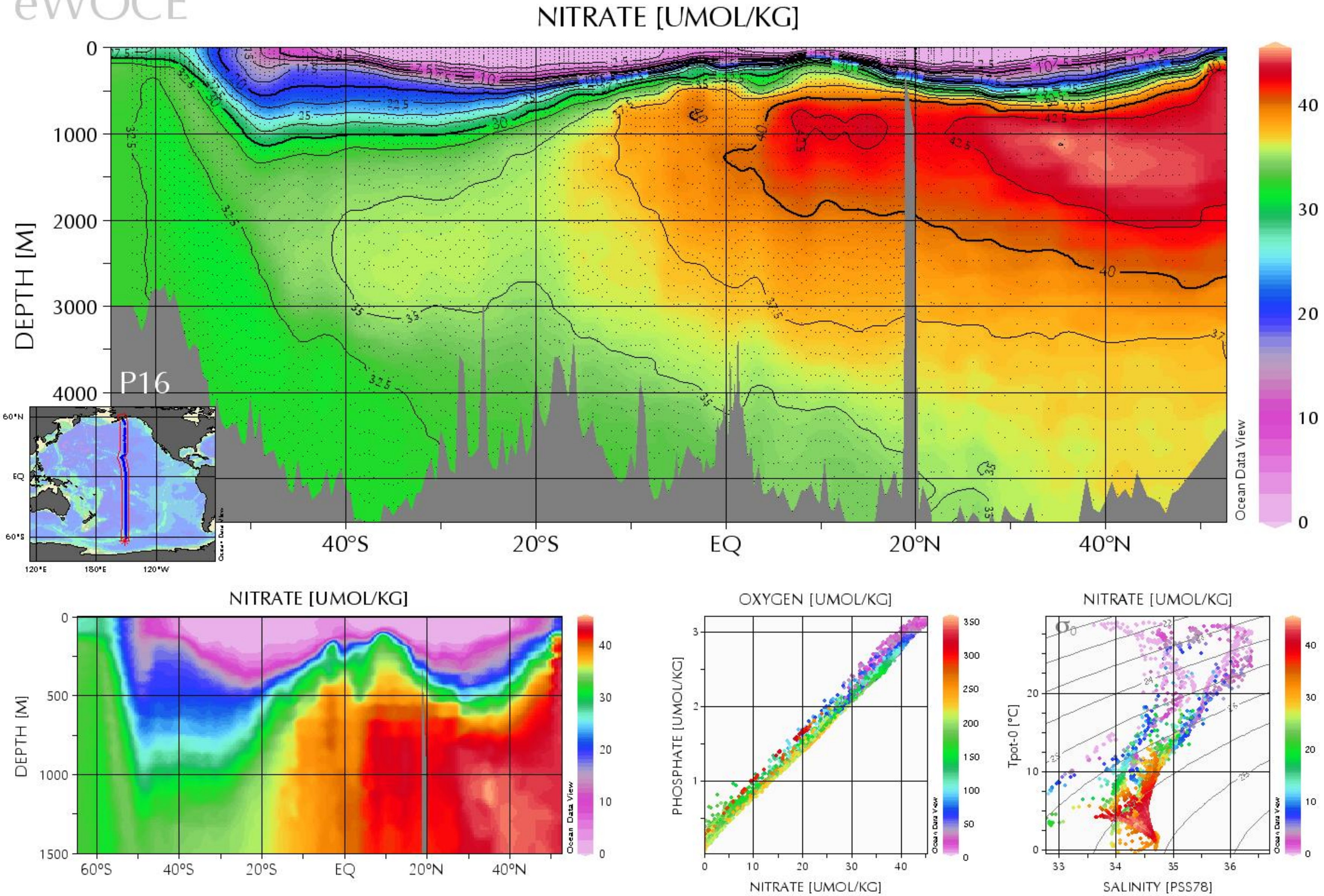
FIGURE 3.6. Profiles of cadmium (Cd) and phosphate (PO_4) in the Atlantic and Pacific Oceans.





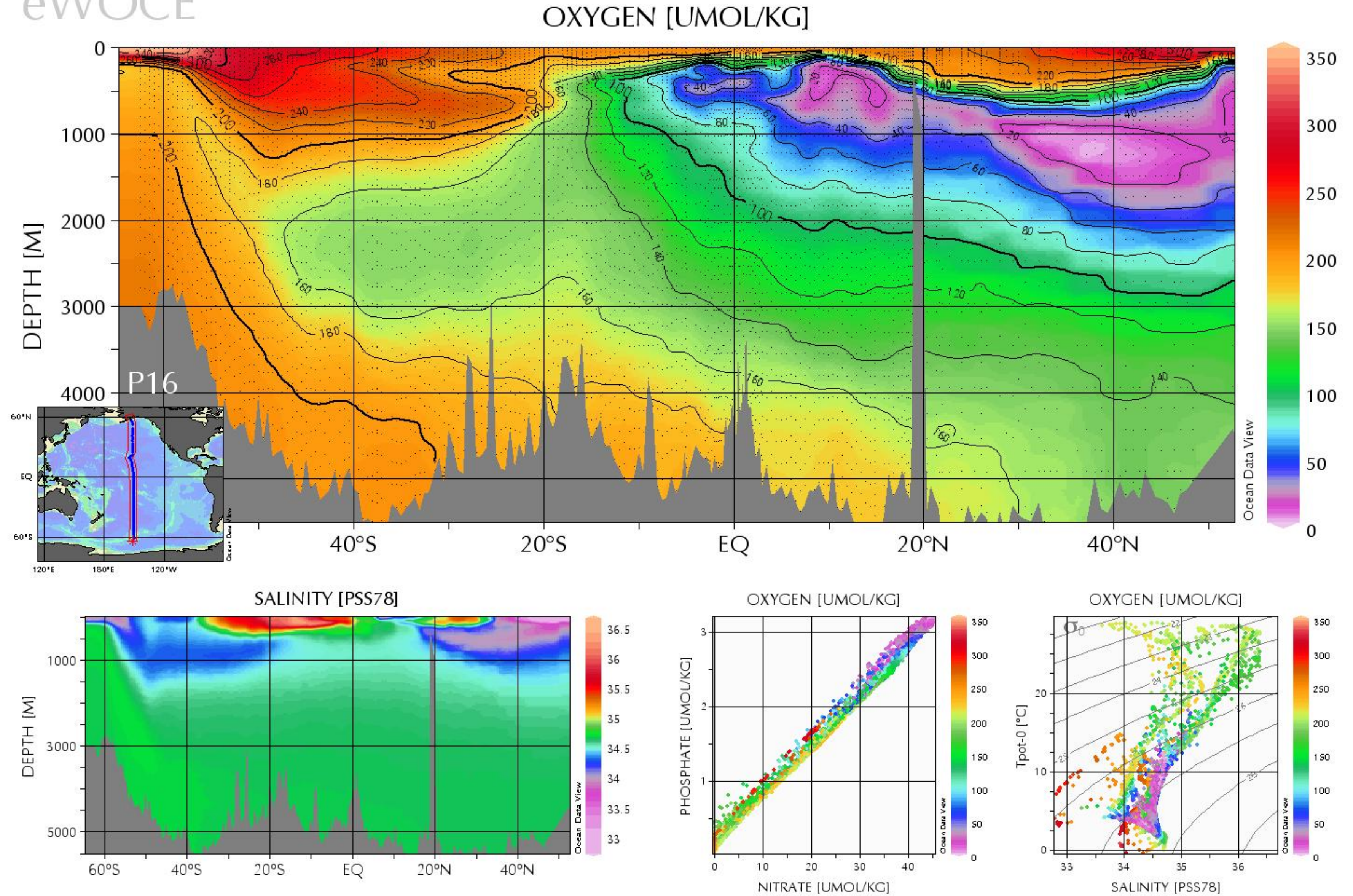
ı) and silica (Si) (b) profiles in the South Atlantic.

eWOCE

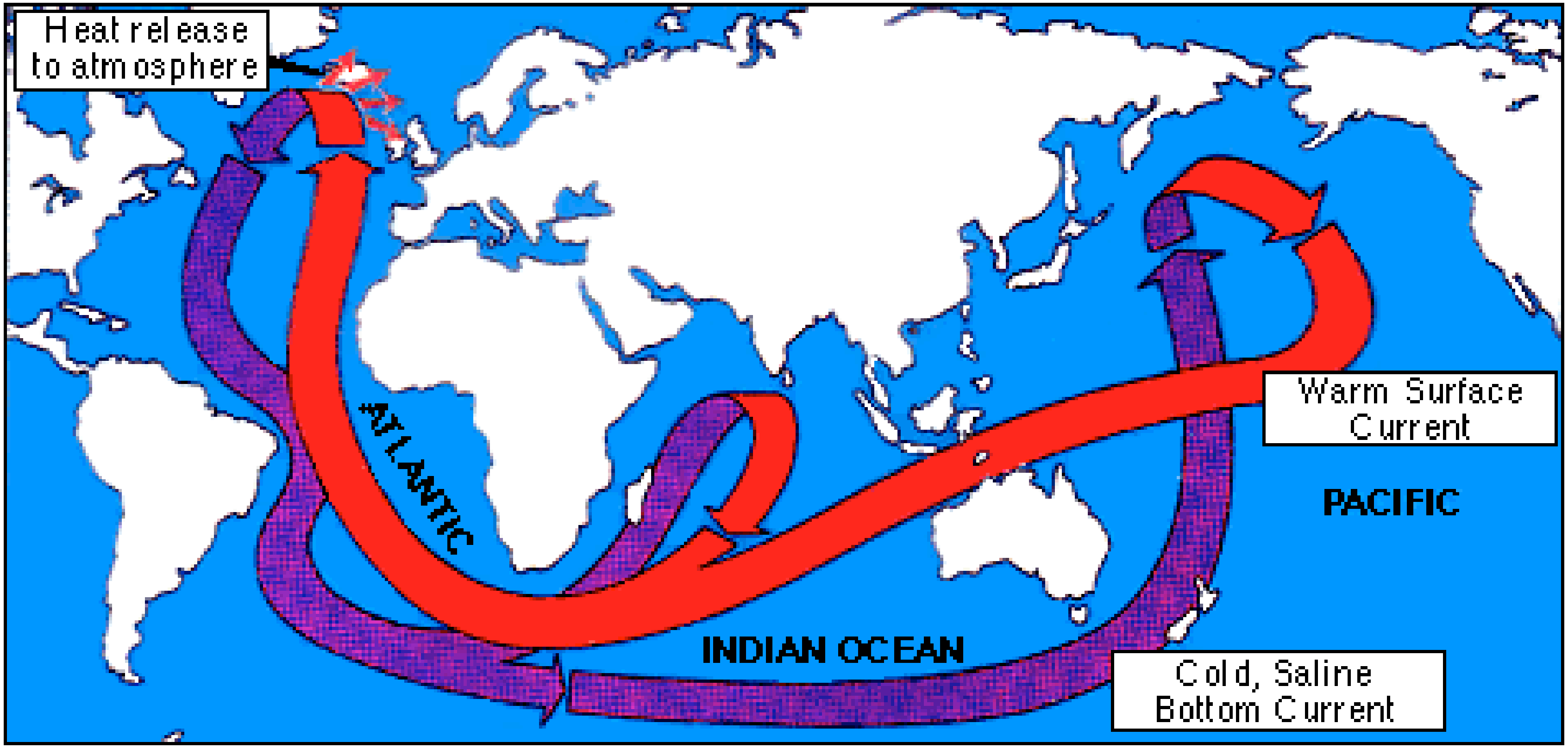


NITRATE [UMOL/KG]
DEPTH [M]
0
1000
2000
3000
4000
40°S
20°S
EQ
20°N
40°N
P16
60°N
EQ
60°S
120°E
180°E
120°W
Ocean Data View
0
10
20
30
40
NITRATE [UMOL/KG]
DEPTH [M]
500
1000
1500
60°S
OXYGEN [UMOL/KG]
PHOSPHATE [UMOL/KG]
NITRATE [UMOL/KG]
50
100
150
200
250
300
350
NITRATE [UMOL/KG]
Tpot-0 [°C]
SALINITY [PSS78]
33
34
35
36

eWOCE

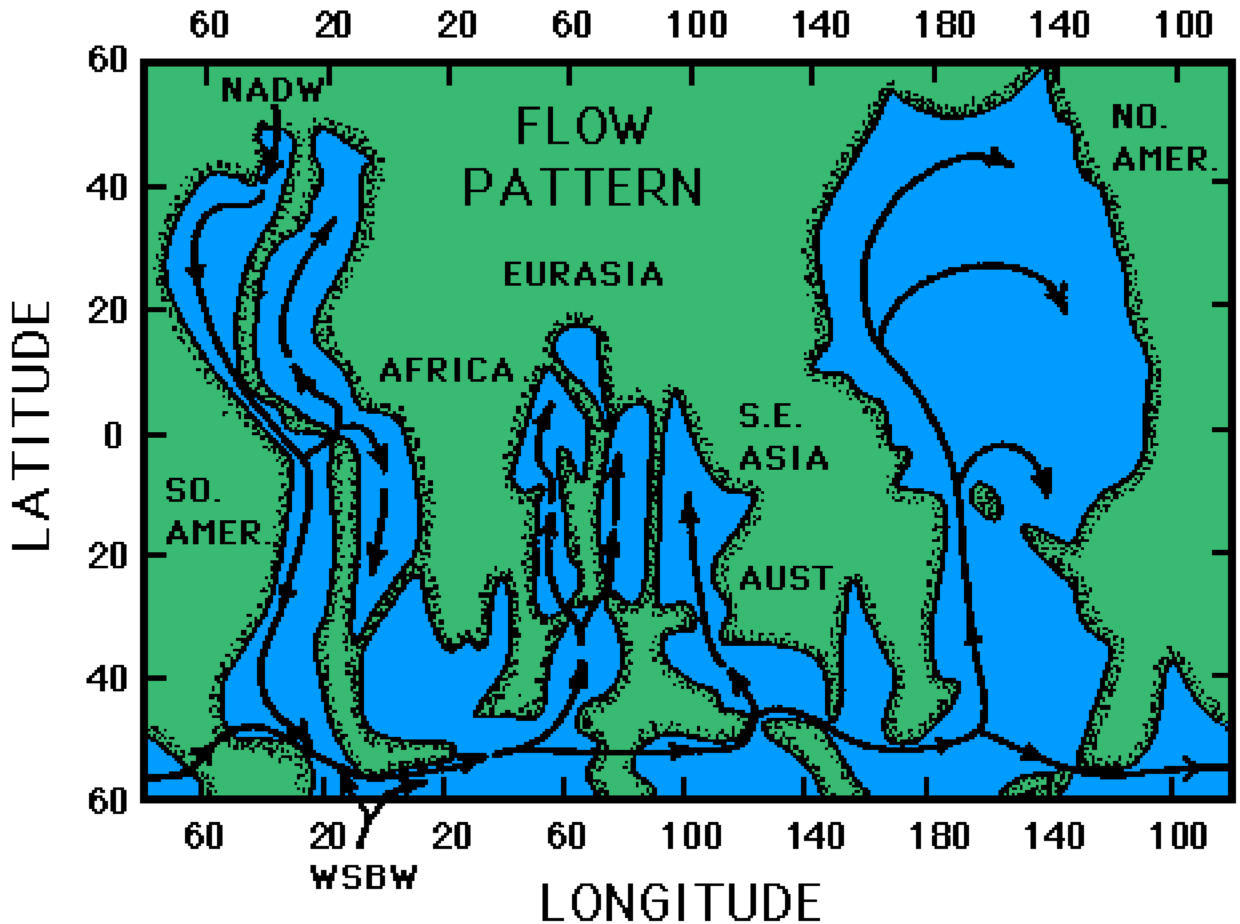

OXYGEN [UMOL/KG]
DEPTH [M]
P16
40°S
20°S
EQ
20°N
40°N
Ocean Data View
SALINITY [PSS78]
DEPTH [M]
60°S
40°S
20°S
EQ
20°N
40°N
OXYGEN [UMOL/KG]
PHOSPHATE [UMOL/KG]
NITRATE [UMOL/KG]
OXYGEN [UMOL/KG]
Tpot-0 [°C]
SALINITY [PSS78]

Ocean Conveyer Belt



The present large-scale ocean current system determines climate to a great extent. The huge "conveyor belt" reacts extremely sensitively to global temperature changes accompanying each increase and decrease in the content of carbon dioxide in the atmosphere. - Broecker

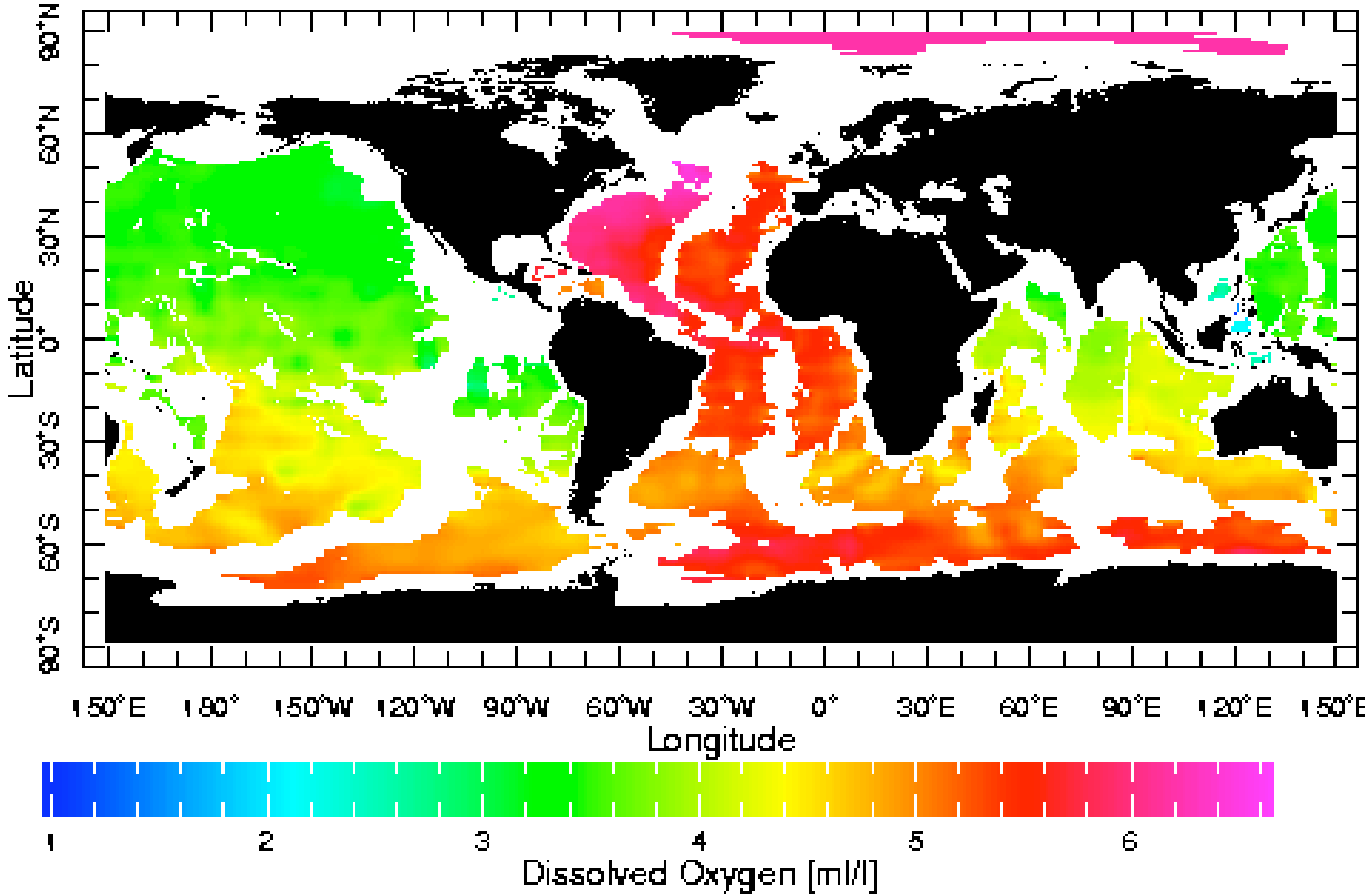
Abyssal Circulation



Flow pattern at a depth of 4000 meters. The major inputs to this horizon are North Atlantic Deep Water (NADW) which enters at the northern end of the western basin of the Atlantic and Weddell Sea Bottom Water (WSBW) which enters from the margin of the Antarctic continent adjacent to the South Atlantic.

From: Broecker, Wallace S. and Tsung-Hung Peng. Tracers in the Sea,

Deep
O2



80°N
60°N
30°N
0°
30°S
60°S
80°S
Latitude
150°E
180°
150°W
120°W
90°W
60°W
30°W
0°
30°E
60°E
90°E
120°E
150°E
Longitude
1
2
3
4
5
6
Dissolved Oxygen [ml/l]

Deep
Phosphate