



Edward Butler, AIMS-NT



Australian Government



AUSTRALIAN INSTITUTE
OF MARINE SCIENCE



AIMS: Australia's tropical marine research agency.



V

- Oceans cover >70% of planet
- Life began in the oceans
- Still an unexplored frontier
- It's interesting and gets you places others don't...!



Halifax -vs- Bergen

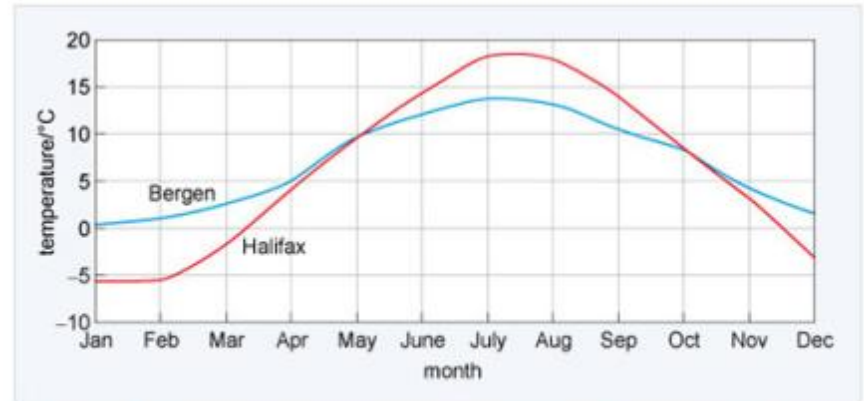
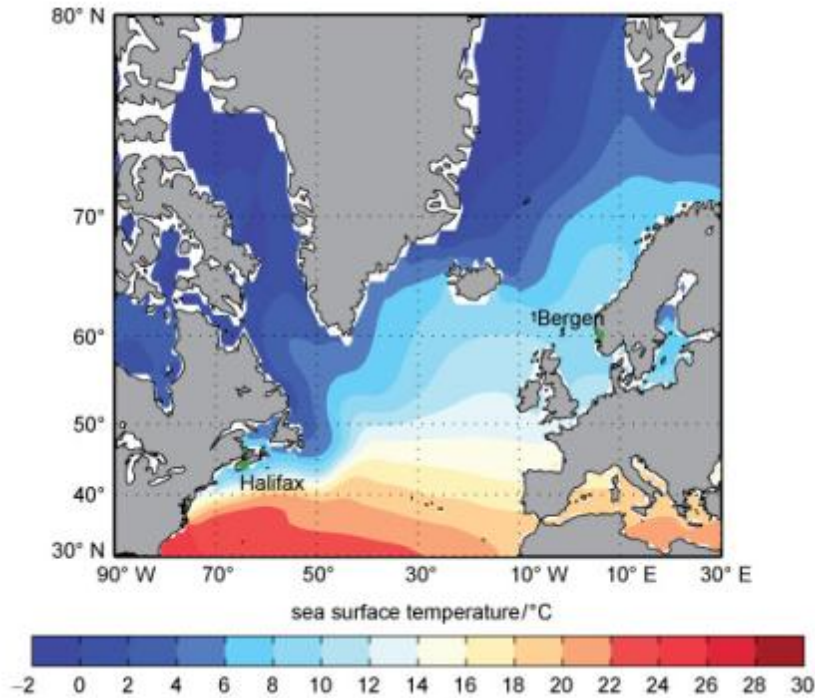
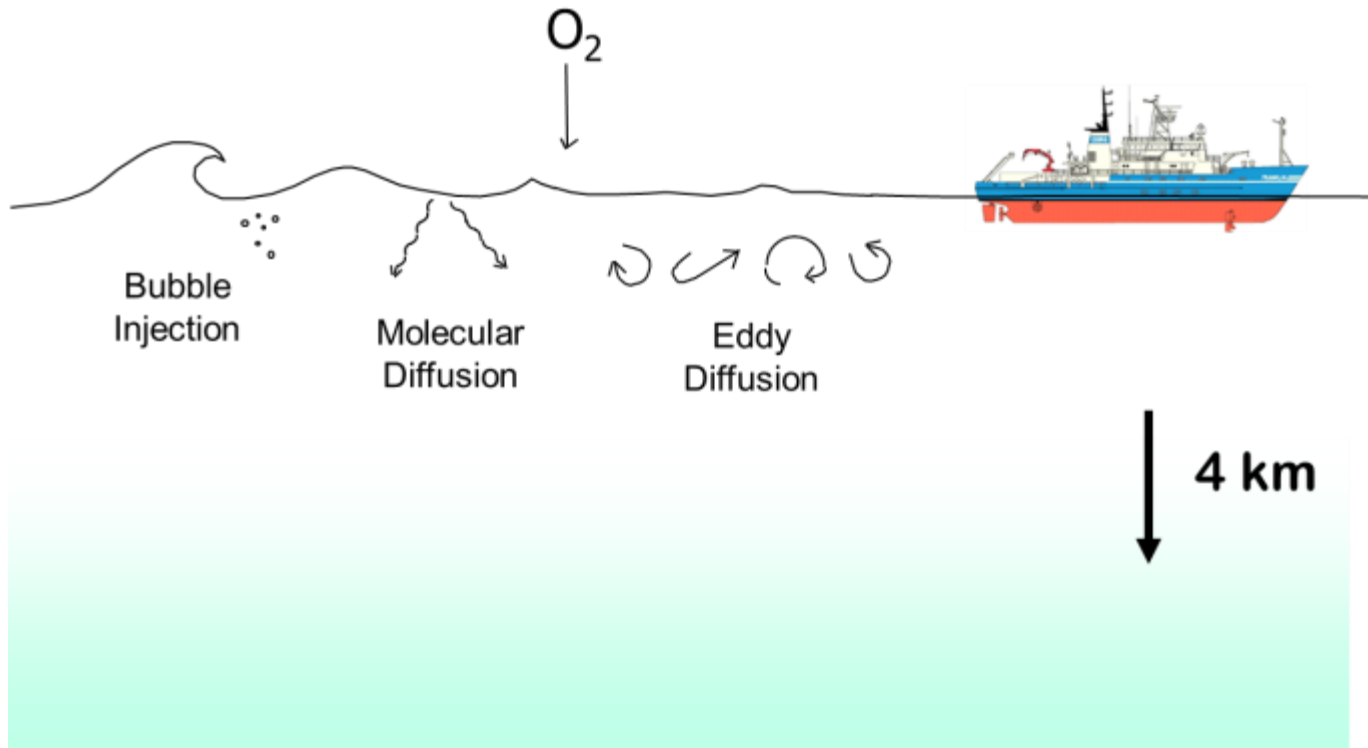


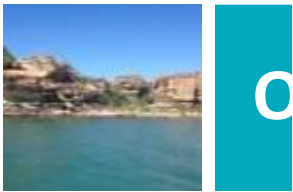
Figure 2 Monthly mean atmospheric temperatures for Bergen, Norway and Halifax, Nova Scotia.

'The Gulf Stream'



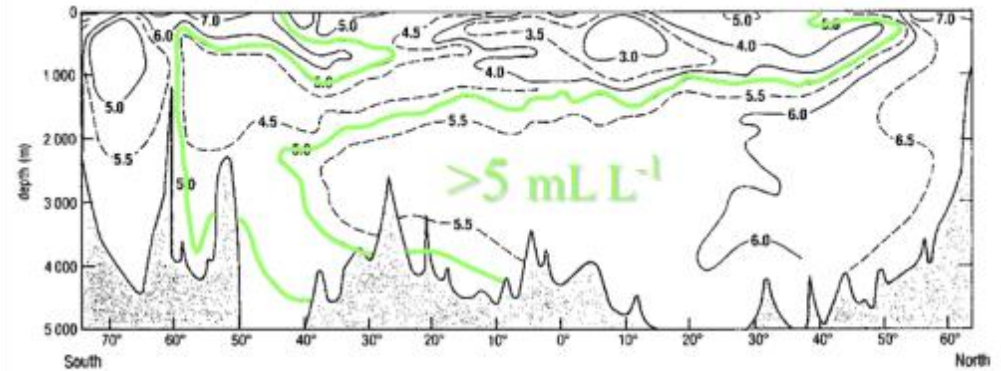
How to get oxygen to the bottom?



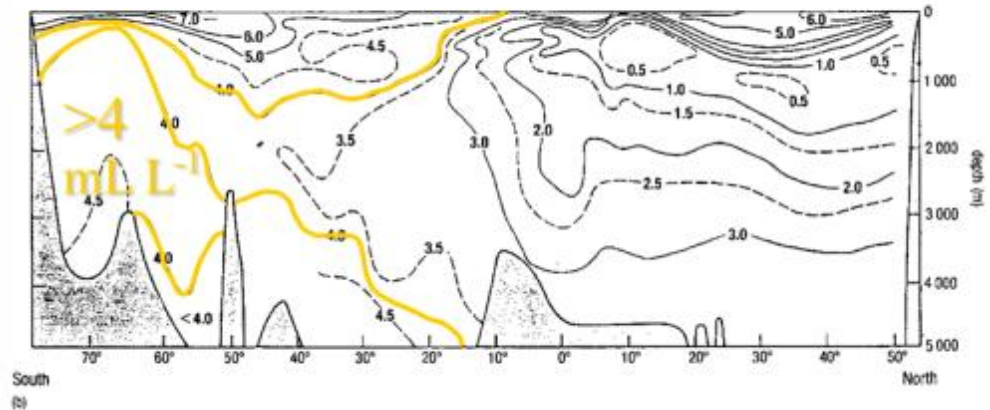


Sections showing dissolved oxygen (mL L^{-1}) in (a) western Atlantic and (b) Pacific ($\sim 170^\circ \text{W}$)

a)



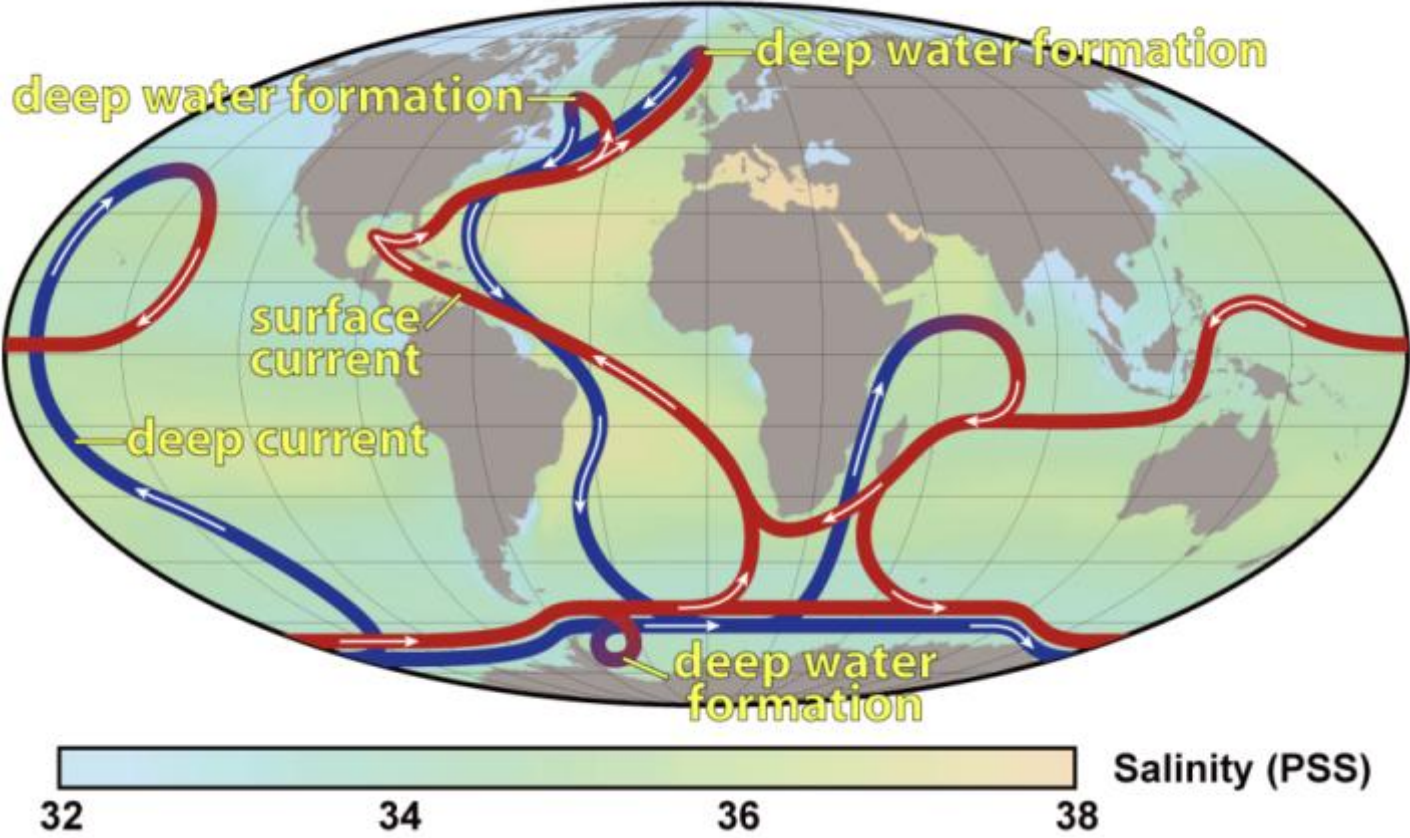
b)





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Thermohaline Circulation



Robert Simmon / Robert A. Rohde NASA.



- Currents are generated by winds, density differences (S & T), etc., and influenced by tides, Coriolis effect, bathymetry and possibly biodynamics, ...

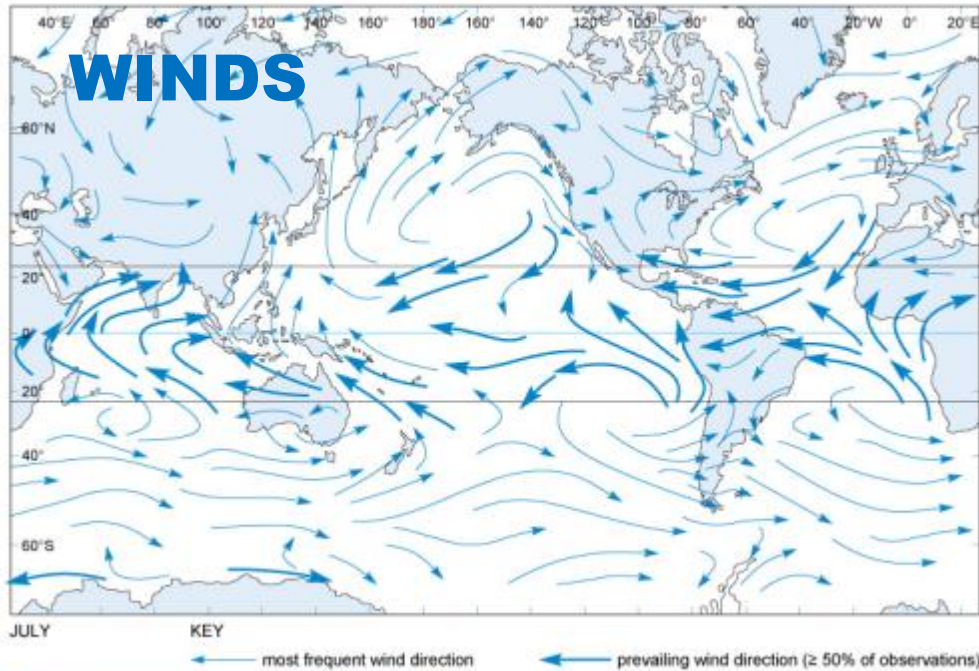
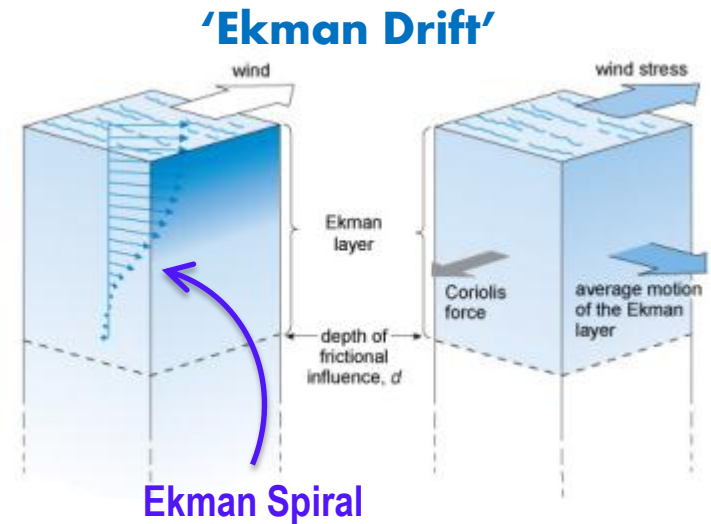


Figure 18 The mean global surface wind pattern in July.





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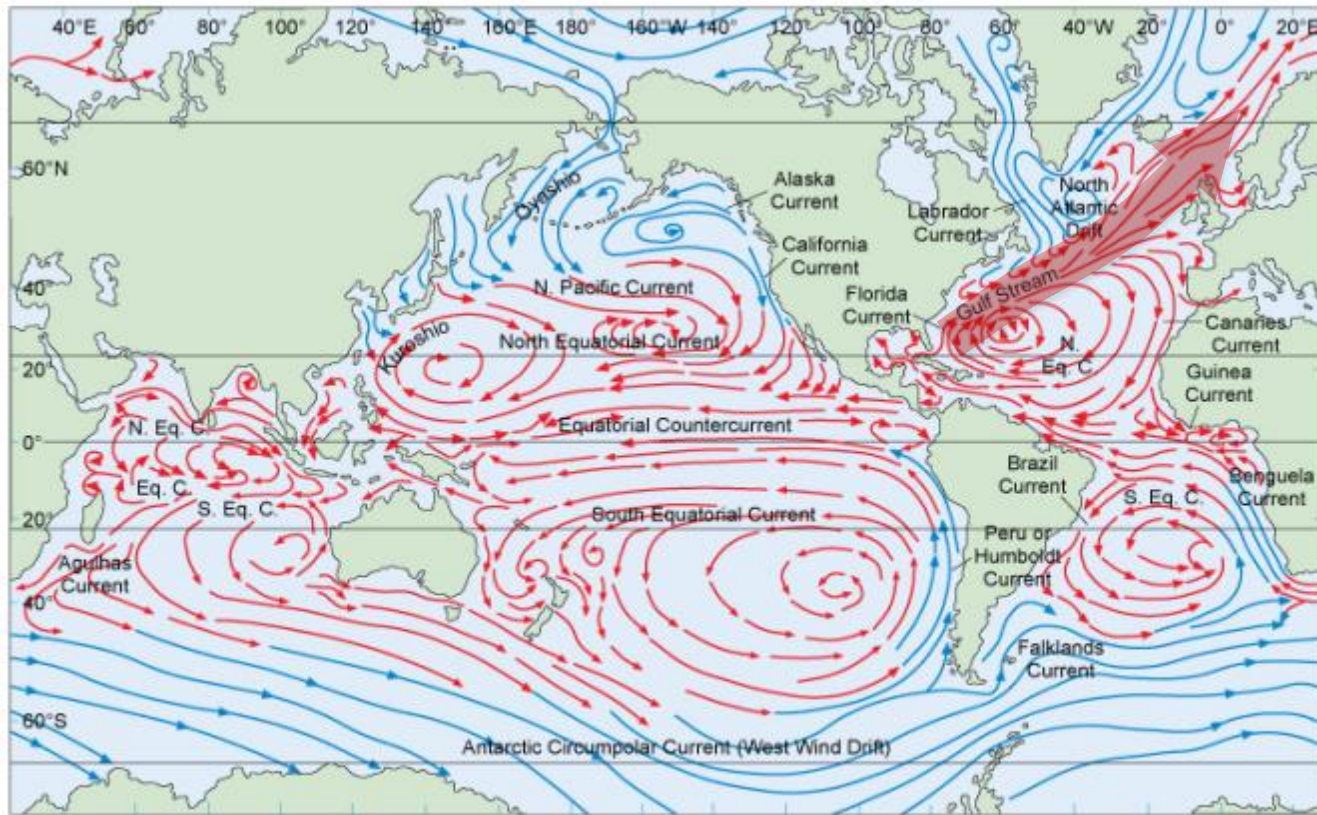


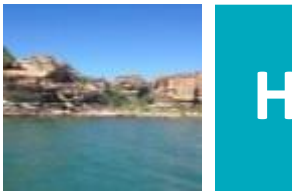
Figure 15 A schematic diagram of the surface currents of the Earth in the northern winter. Red arrows represent warm ocean currents; blue arrows represent cool currents. In some regions there are large seasonal differences.



S

Table 2 Major ionic constituents dissolved in seawater.

Ion	% by mass of 34.482 g	Weight/g kg⁻¹
Chloride Cl ⁻	55.04	18.980
Sulfate SO ₄ ²⁻	7.68	2.649
Hydrogen carbonate, HCO ₃ ⁻	0.41	0.140
Bromide, Br ⁻	0.19	0.065
Borate, H ₂ BO ₃ ⁻	0.07	0.026
Fluoride, F ⁻	0.003	0.001
Sodium, Na ⁺	30.61	10.556
Magnesium, Mg ²⁺	3.69	1.272
Calcium, Ca ²⁺	1.16	0.400
Potassium, K ⁺	1.10	0.380
Strontium, Sr ²⁺	0.04	0.013



1. Gravimetry (weighing after drying)
2. Analyse all the ions and sum
3. Titration, relative to halogens ($\text{Cl}^- + \text{Br}^- + \text{I}^-$)
using Knudsen equation from 1911 (n = 9 samples);
$$S \text{ ‰} = 0.030 + 1.8059 \text{ Cl ‰} * \text{ (or gms per kg)}$$
4. Conductivity (UNESCO, 1981);
Defined Practical Salinity Scale (PSS)
Determined to 0.001 units

* now $S \text{ ‰} = 1.8065 \text{ Cl ‰}$

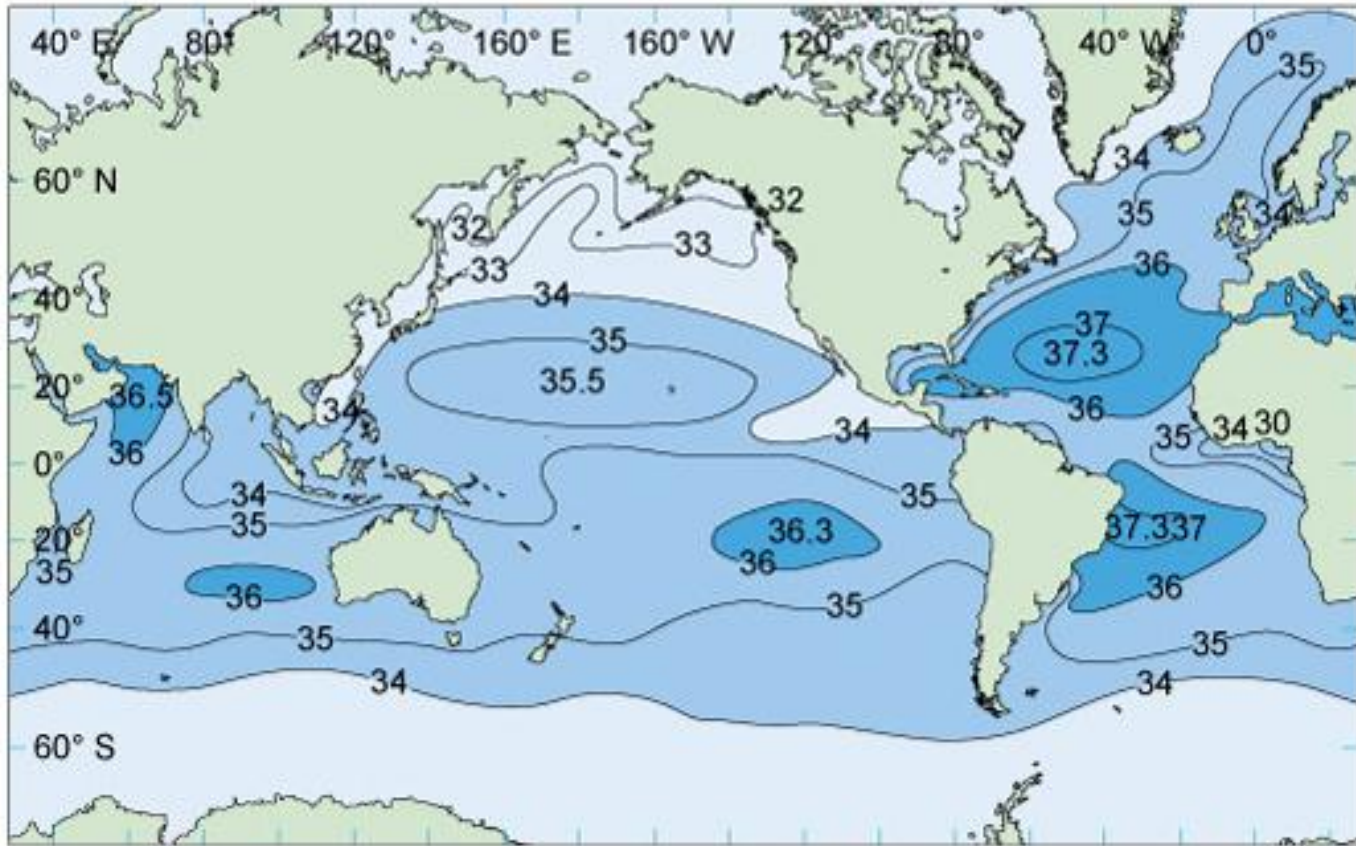
CTD



Photo: Stella Rintoul, CSIRO



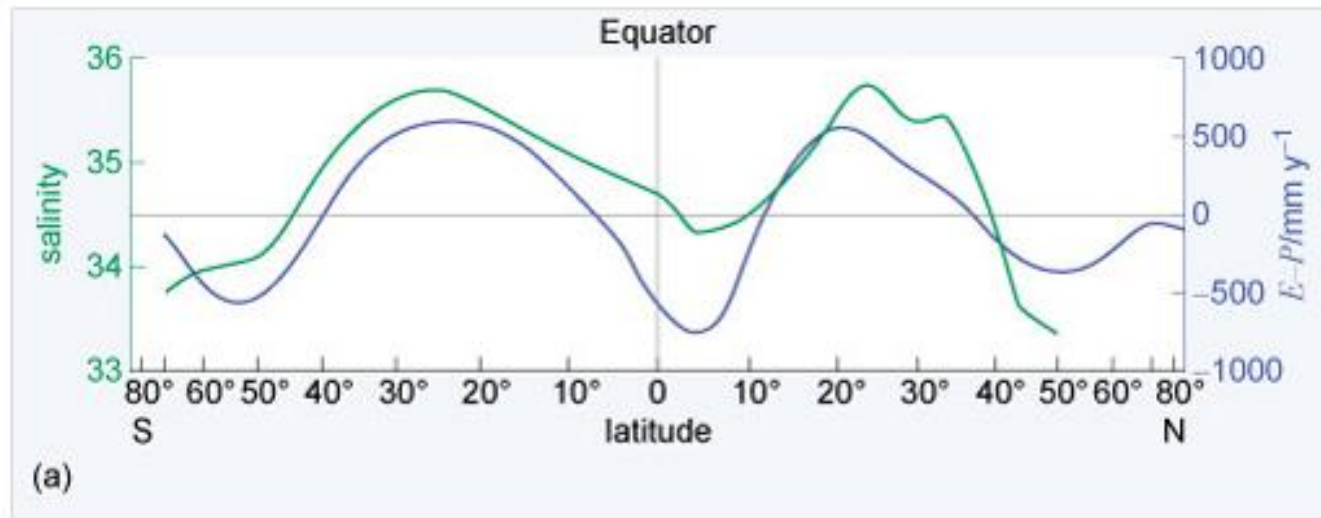
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UK Open University – The Oceans



E



Precipitation (P)—including rain and river flow—reduces the salinity of the sea surface while evaporation (E) increases surface salinity by the removal of water.

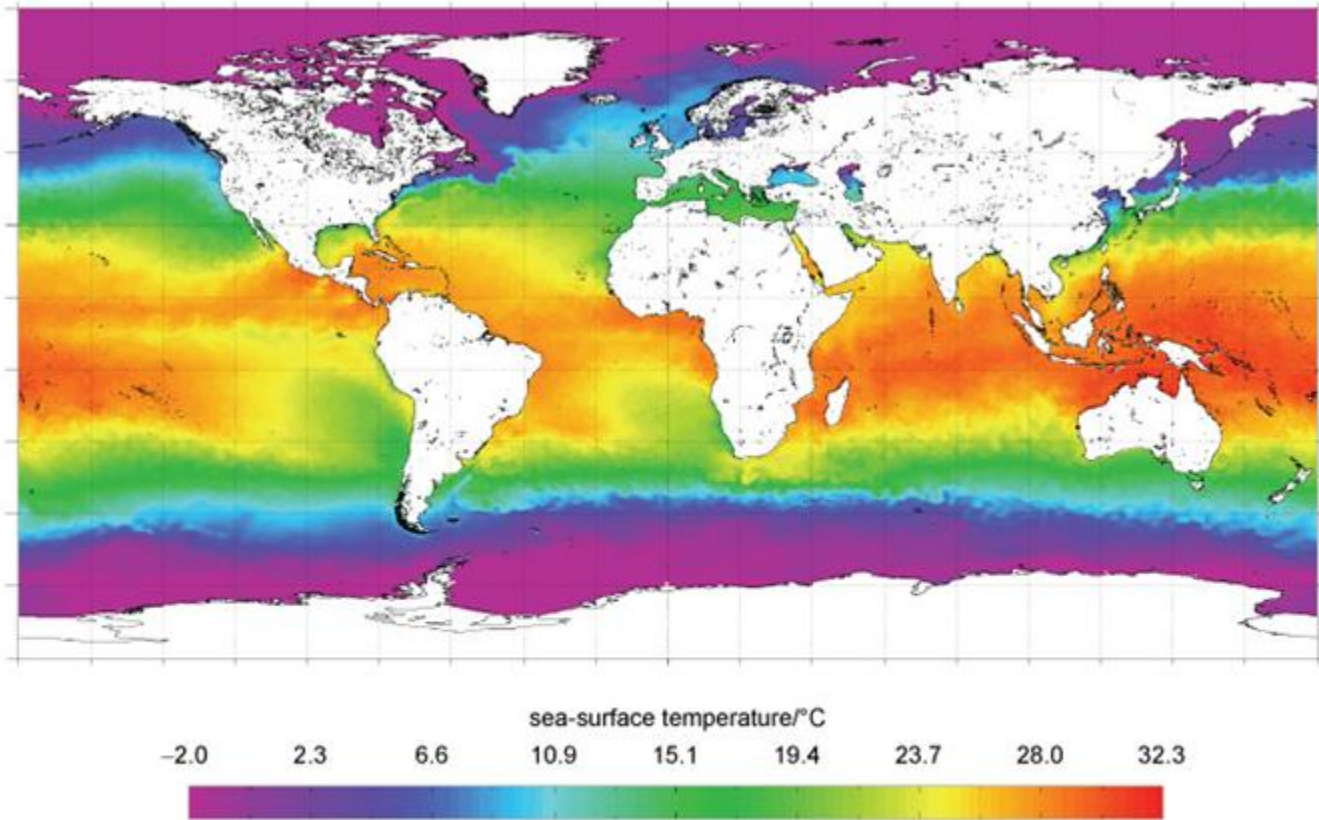


Figure 9 The global sea-surface temperature in January 2014 recorded by satellite. Areas of uniform sea-surface temperature are the same colour and the scale is in °C.

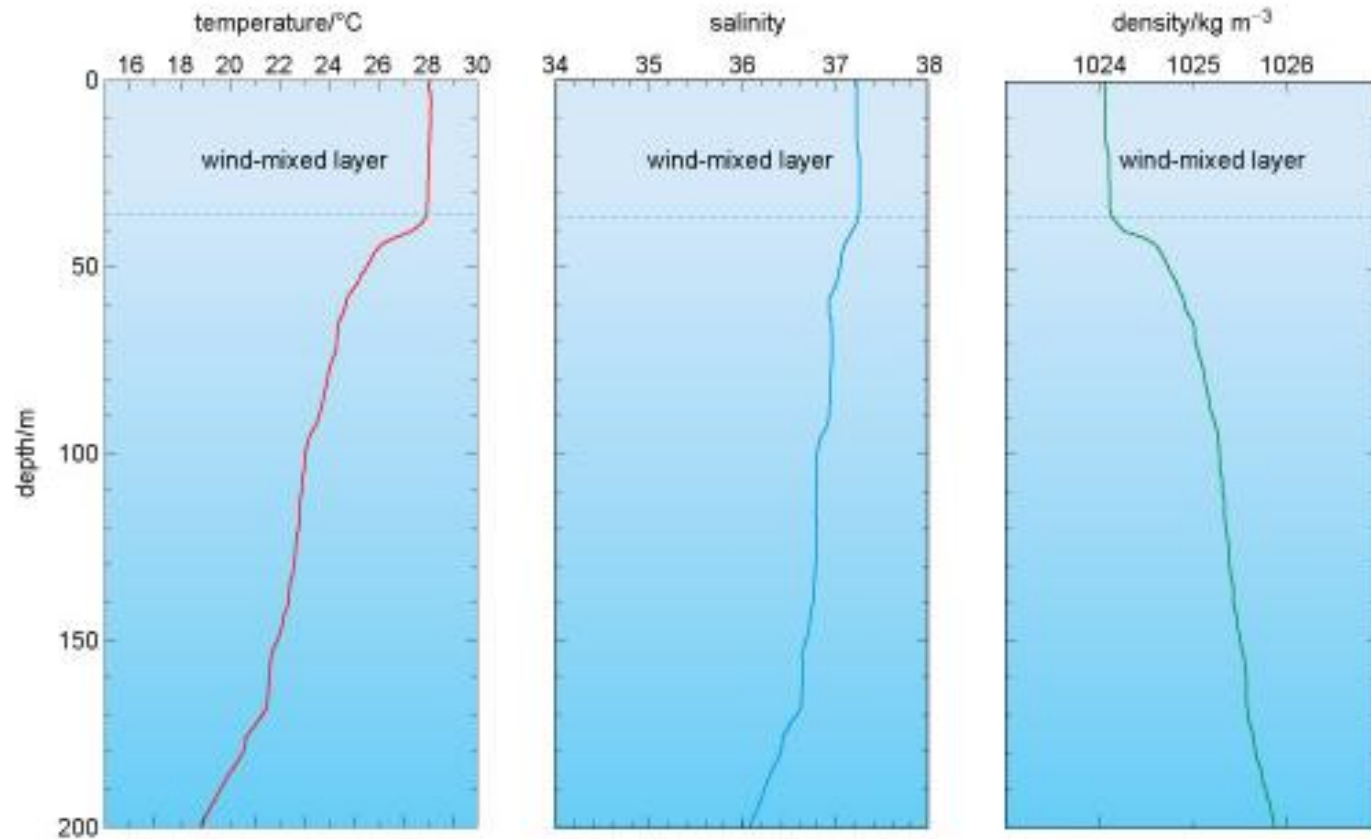
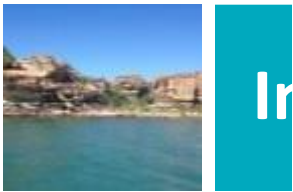


Figure 7 The physical properties of seawater at 20° S in the Atlantic Ocean against depth. (a) Temperature; (b) salinity; (c) density.



$$\sigma(s, t, p) = \rho(s, t, p) - 1000 \text{ kg/m}^3$$

where ρ = density

ρ_θ - potential density

(allowing for compressibility at depth, using potential temperature)

[Recent refinement to neutral density γ^n , and isopycnals have become neutral surfaces]

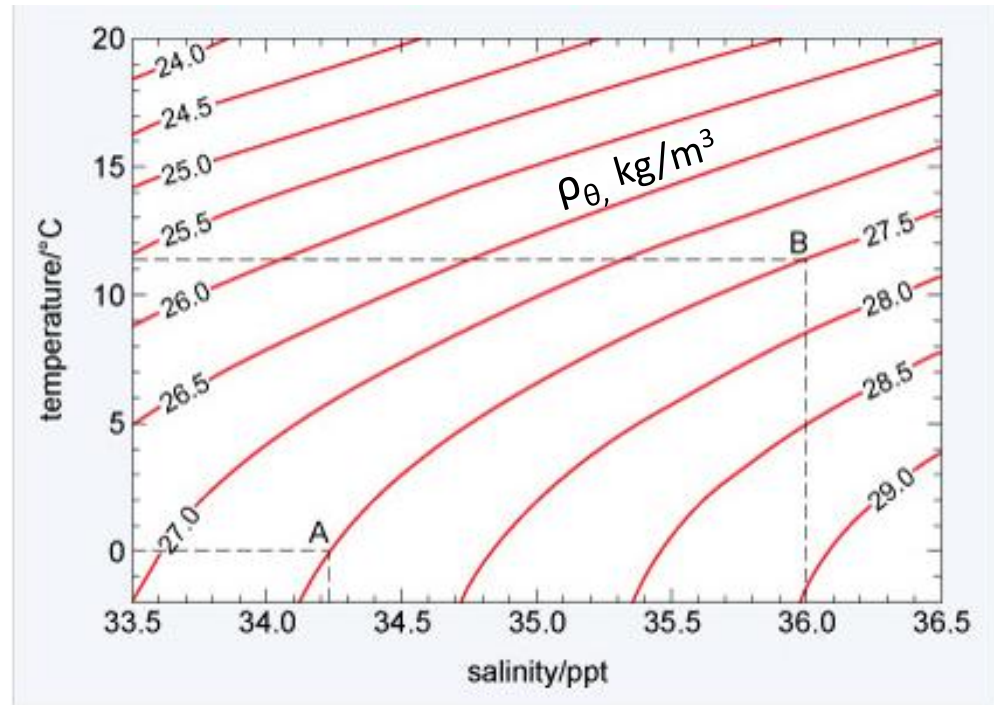
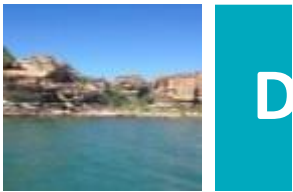
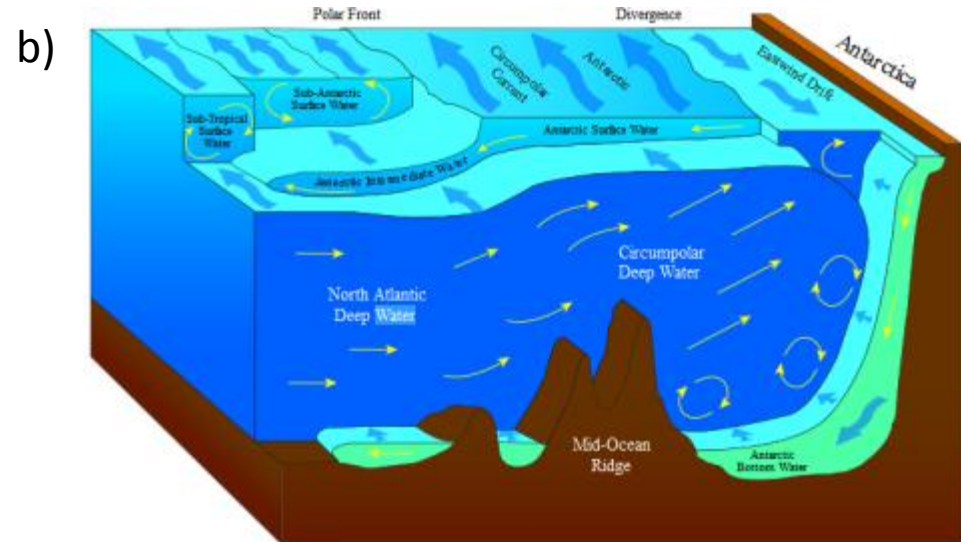
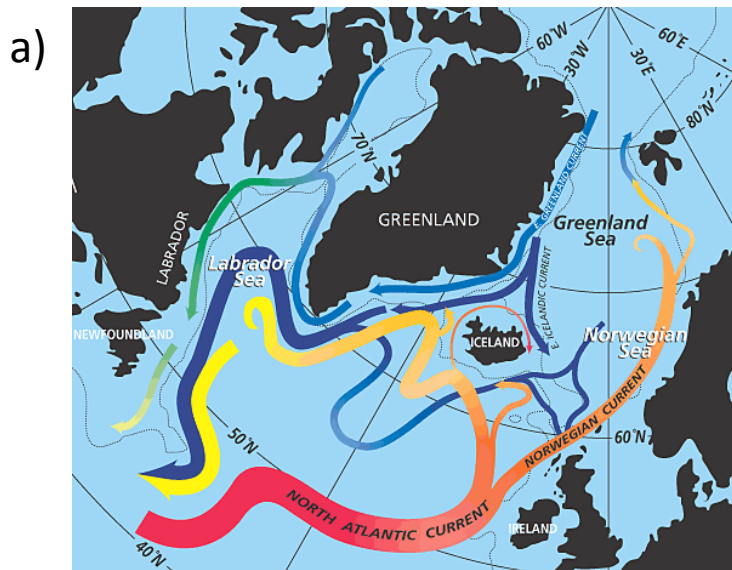


Figure 12 A temperature–salinity plot showing the range of typical temperatures and salinities and selected density anomalies found in the oceans. The two points, A and B, have the same density anomalies despite having different properties.



Formation of deep waters: a) North Atlantic Deep Water (NADW), and b) Antarctic Bottom Water (AABW)



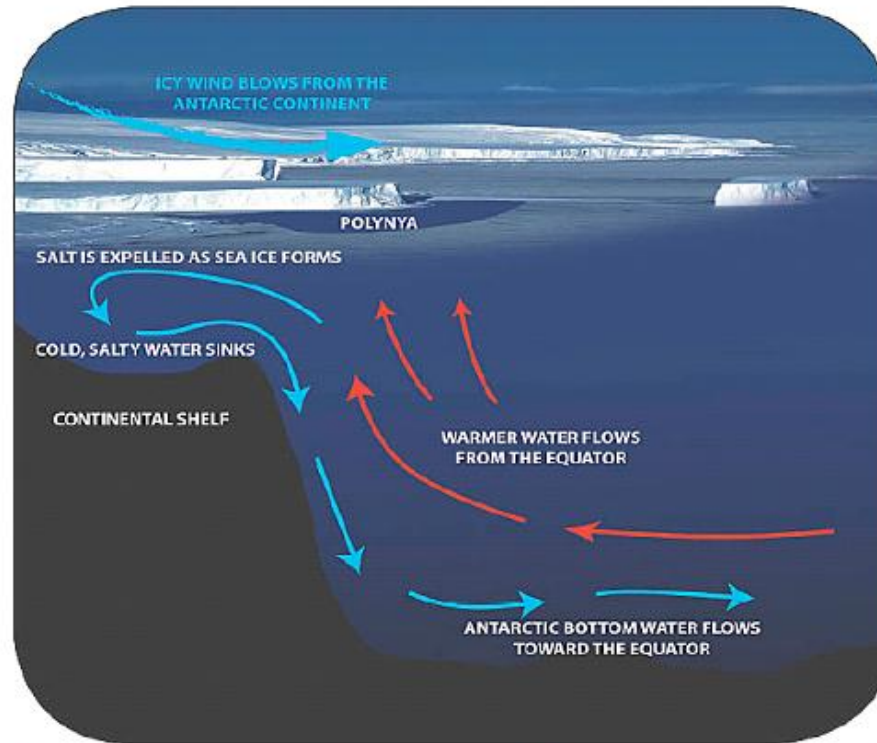
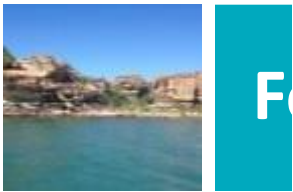


Figure 2. Schematic diagram showing the formation mechanism for Antarctic Bottom Water. Cold dry air blows off the Antarctic continent, cooling the ocean to sub-freezing temperatures. When seawater freezes to form sea-ice, salt is rejected so that the surface waters become highly saline. This dense salty water sinks over the Antarctic continental shelf and eventually becomes Antarctic Bottom Water, which flows into the abyssal Atlantic, Indian, and Pacific Oceans.

Matthew England, CCRC / UNSW



T

EXPLORING the Ocean Floor

Earth's oceans are thousands of kilometers wide. To show the width of the ocean floor in this illustration, the vertical and horizontal scales are not the same. The vertical scale, showing depth, has been stretched. The horizontal scale, showing distances, has been squeezed.

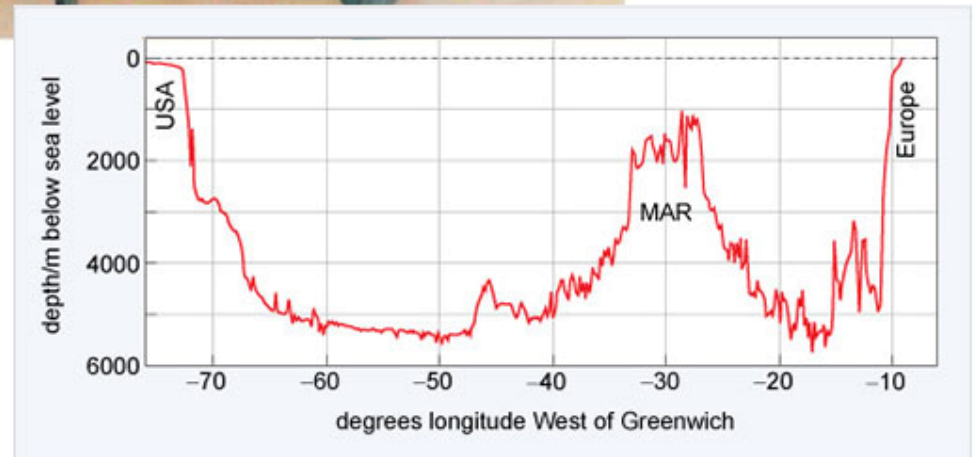
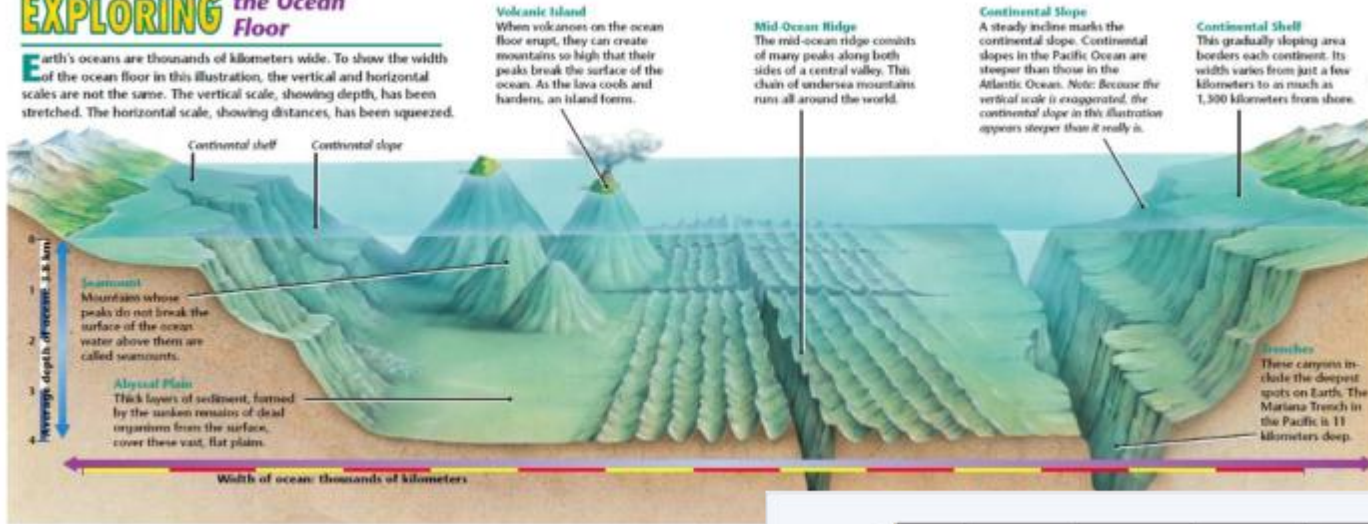
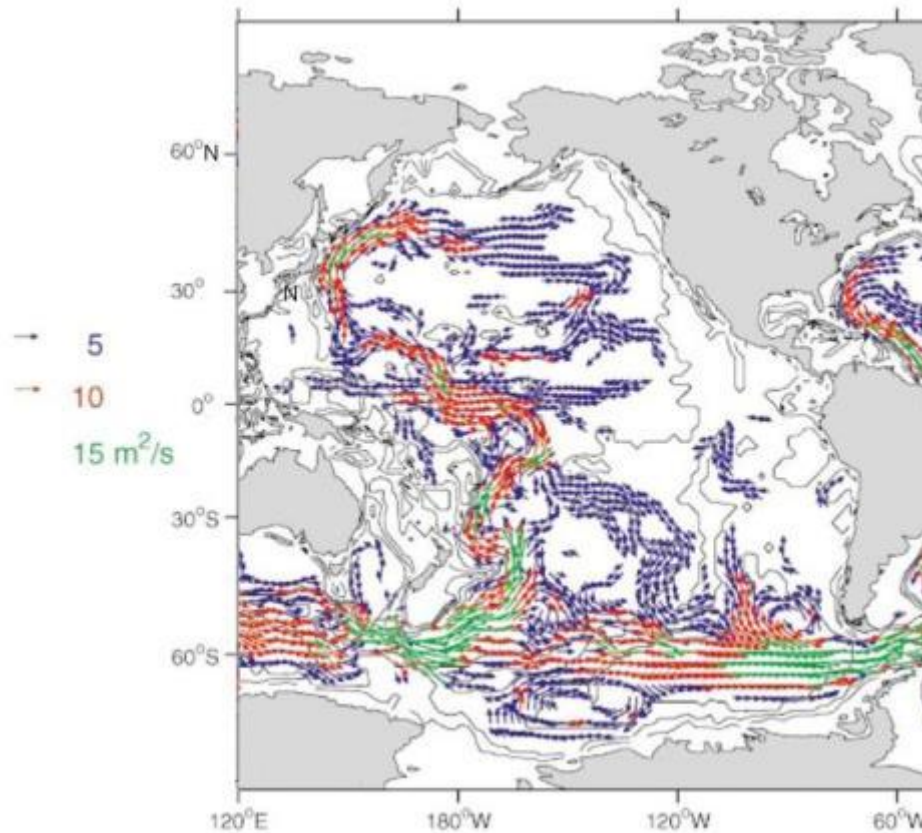


Figure 3 Bathymetry along latitude close to 39° N. Sea level is shown as a dashed line.



...topographically steered

Fig. 4. Deepwater (>2000 m) circulation in the Pacific Basin depicted by current vectors. Courtesy of ECCO 'Estimating the Circulation & Climate of the Ocean' Consortium.

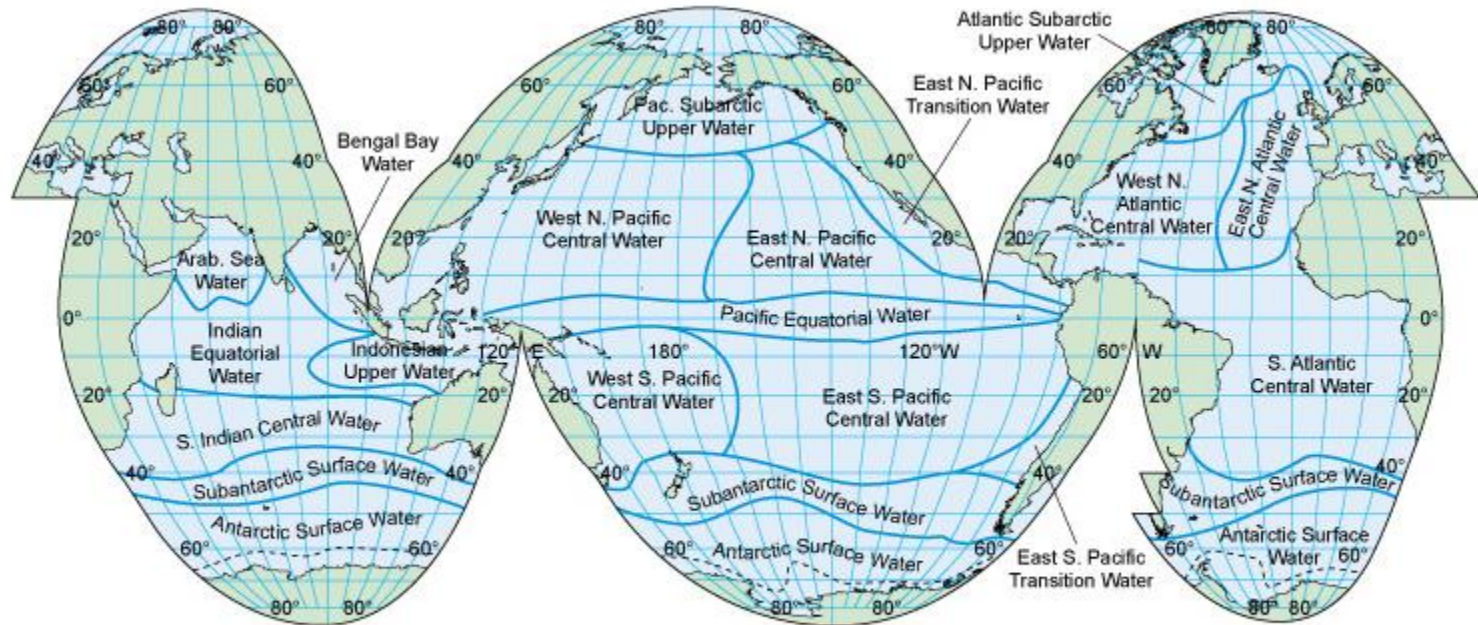


Figure 20 The global distribution of the most common upper ocean water masses. The boundaries between the different water masses are diffuse as properties gradually change.



Chemical Oceanography



E

Elements

Conservative

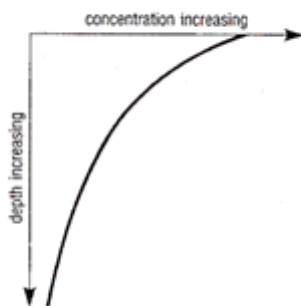
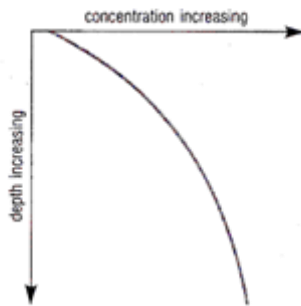
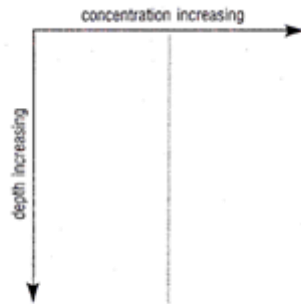
B	K	Rb
Br	Li	S
Cl	Mg	Tl
Cs	Mo	U
F	Na	

Recycled

Ag	Fe	Ra
As	Ge	Sc
Ba	I	Se
Be	N	Si
Ca	Ni	Sr
Cd	P	V
Cr	Pd	Zn
Cu	Pt	REEs

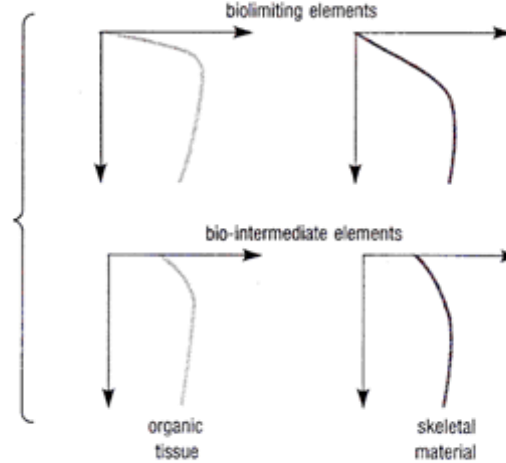
Scavenged

Al	Mn
Bi	Pb
Ce	Sn
Co	Te
Hg	Th



[Deep Pac Oc]
[Deep Atl Oc]

1

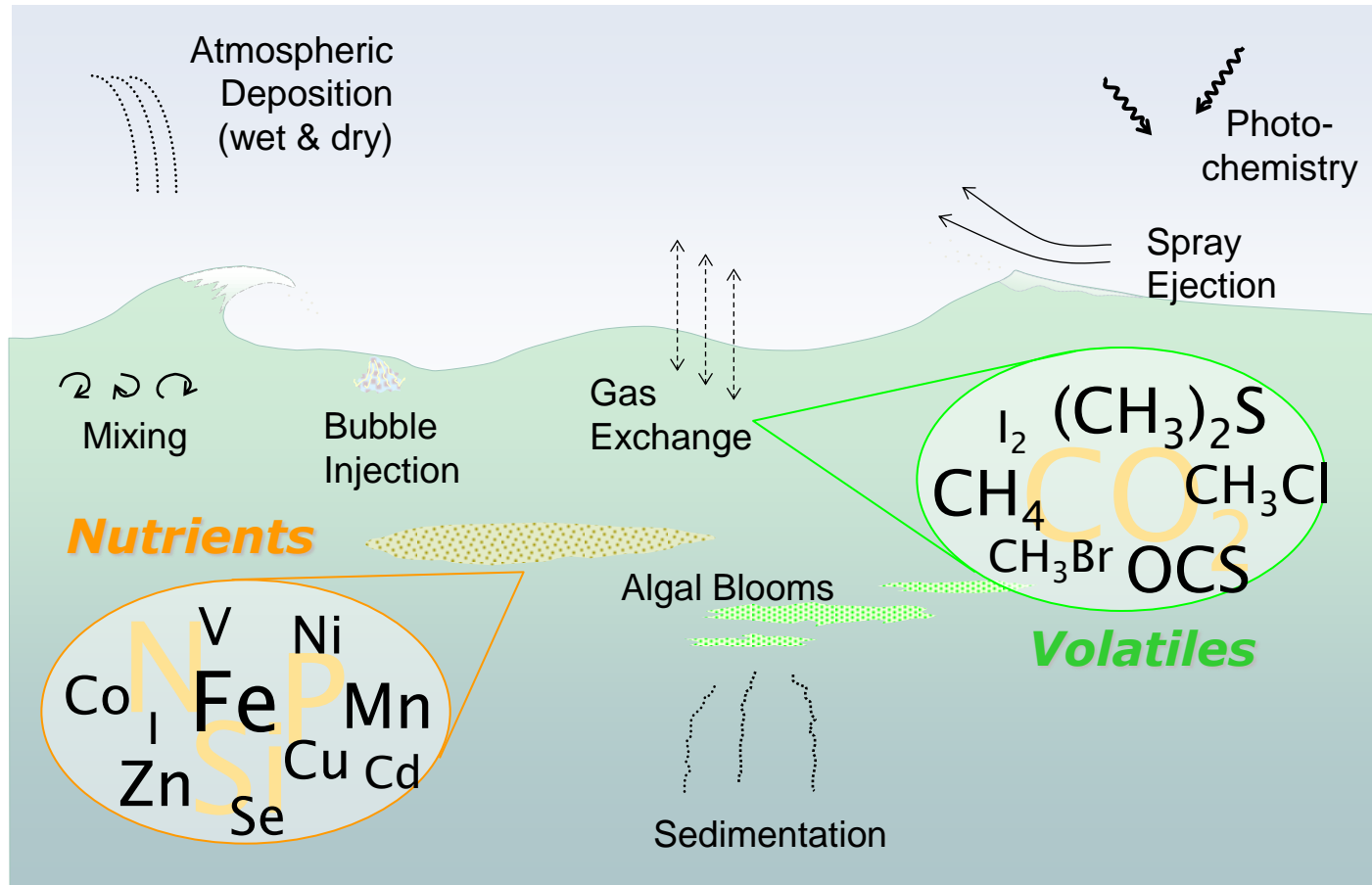


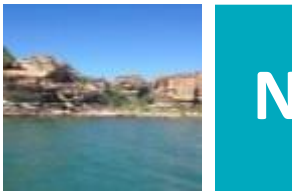
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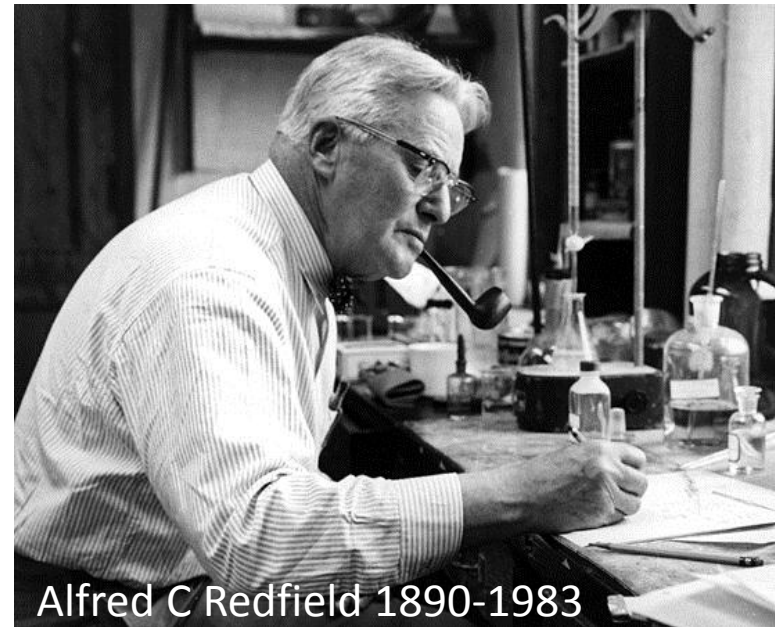


Trace elements that are required for life forms to be viable





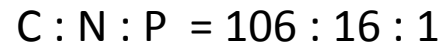
- ▶ **Nutrient ratios** ('ecological stoichiometry') are pivotal in determining what nutrients are limiting to primary production
- ▶ Redfield ratio:
 $C_{106}H_{263}O_{110}N_{16}P_1S_{0.7}Si_yMe_z$
- ▶ Marine macronutrients:
N, P and Si
(c.f. terrestrial: N, P, K)
- ▶ Estuaries are often N-limited, i.e. $N:P < 16$



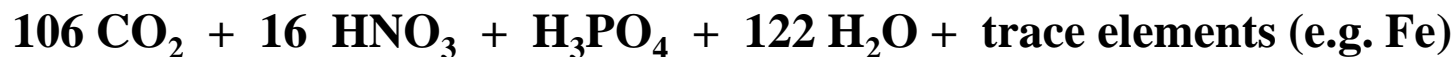
Alfred C Redfield 1890-1983



The mean elemental ratio of marine organic particles is given as:



Average oceanic photosynthesis is written as,

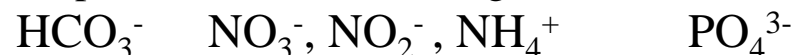


or



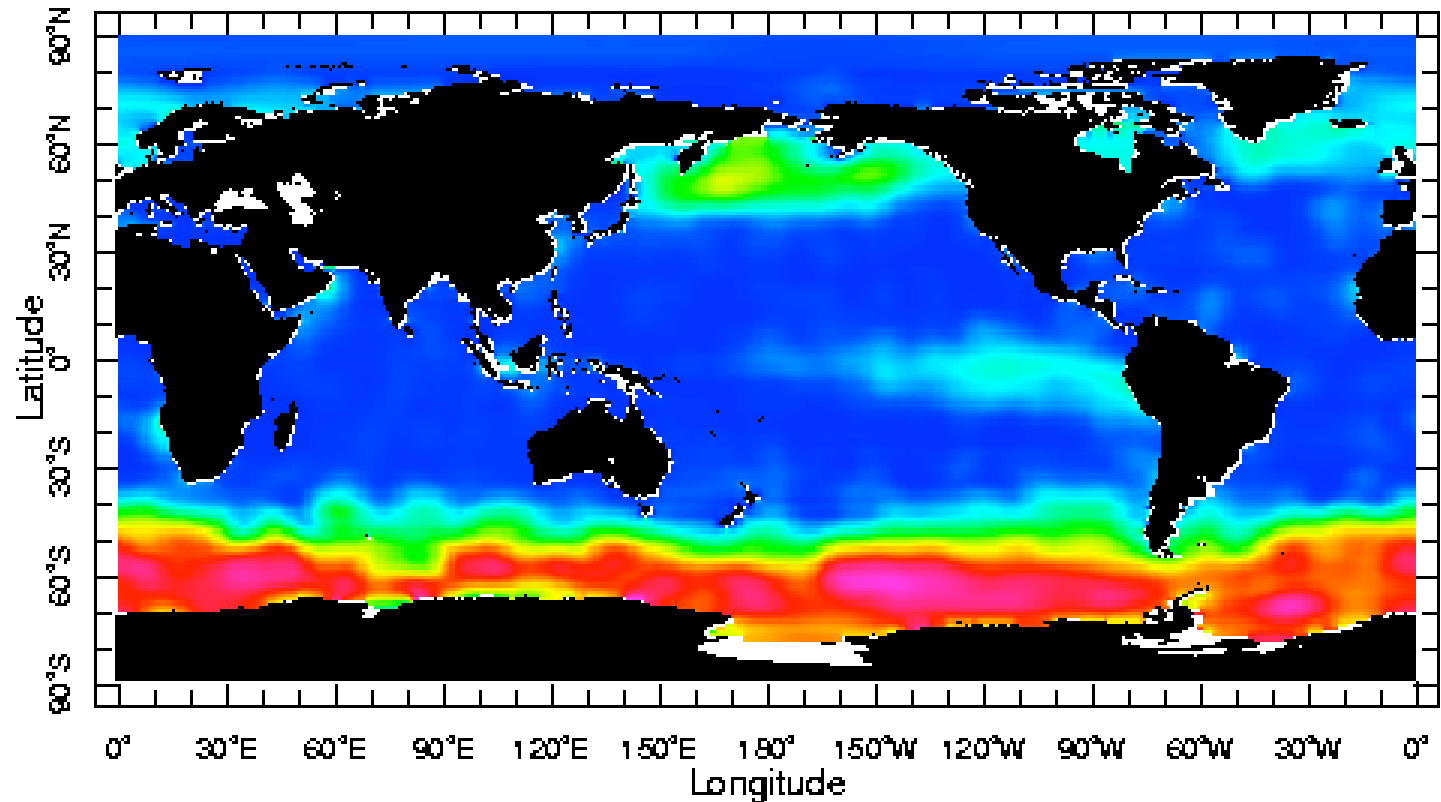
Notes

1. The reverse reaction of photosynthesis is aerobic respiration (or 'rem mineralisation')
2. The actual chemical species assimilated during this reaction are:

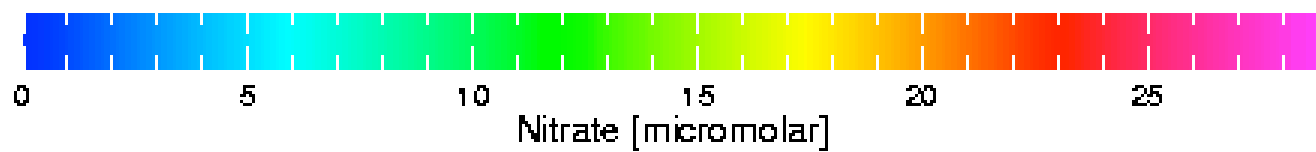




Su

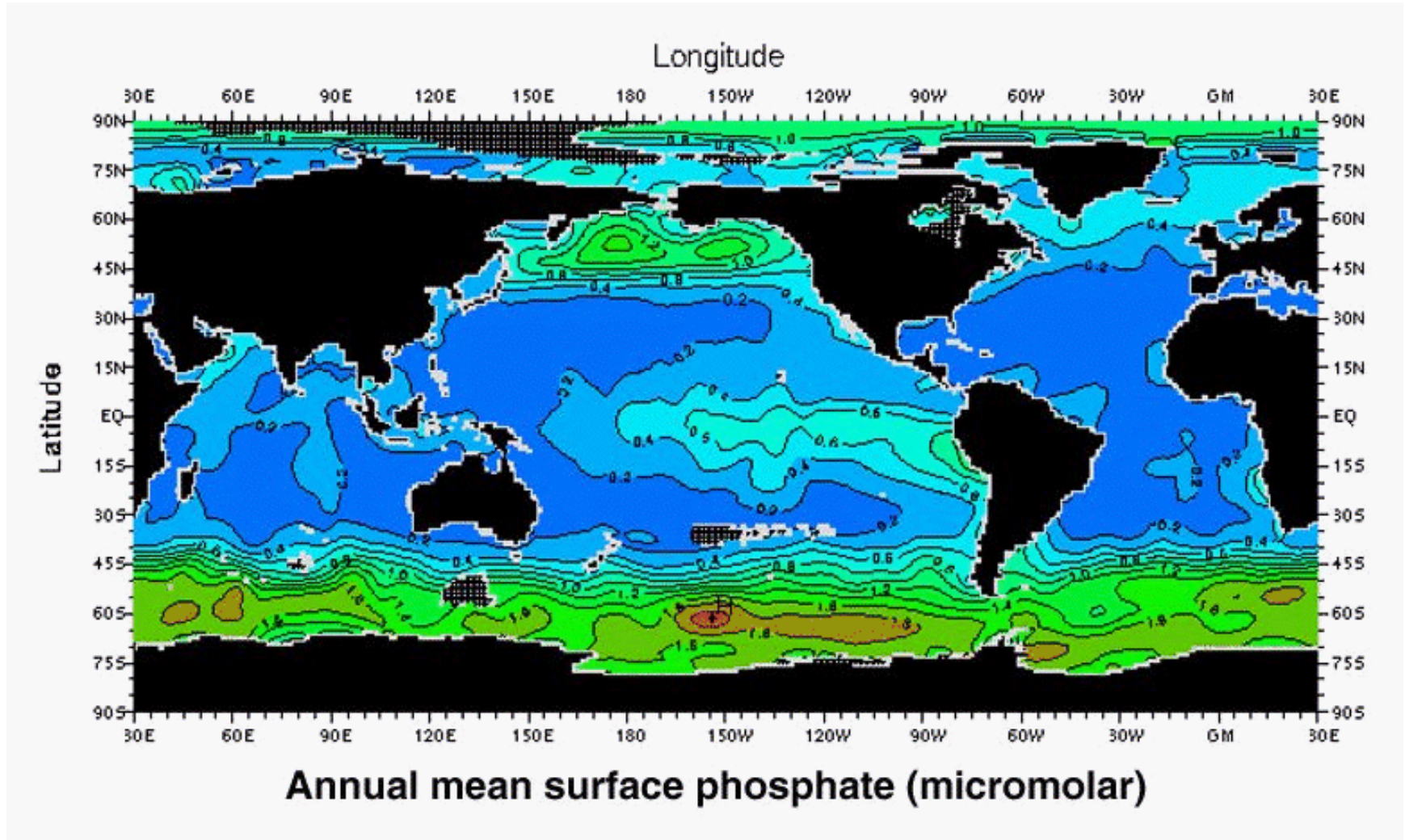


0.0 m





S





Definition: All elements less than 1 mg kg^{-1} (<1 ppm) — not contributing to salinity

Why are they important?

1. many are micronutrients (e.g. Fe, Cu, Se) – speciation is important
2. others are toxic (e.g. Cu, Hg)
3. some are tracers for redox conditions (Mn, Fe, Cr, I, Re, Mo, V, U)
4. some are enriched in economic deposits, e.g. manganese nodules (e.g. Cu, Co, Ni)
5. some have man made sources and are tracers of pollution (e.g. Pb, Pu, Ag)



R
in

redox element

possible redox element

1 H																	2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	57 La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	89 Ac	104 Rf	105 Ha	106 Sg	107 Ns	108 Hs	109 Mt	110	111	112	(113)	(114)	(115)	(116)	(117)	(118)

LANTHANIDES

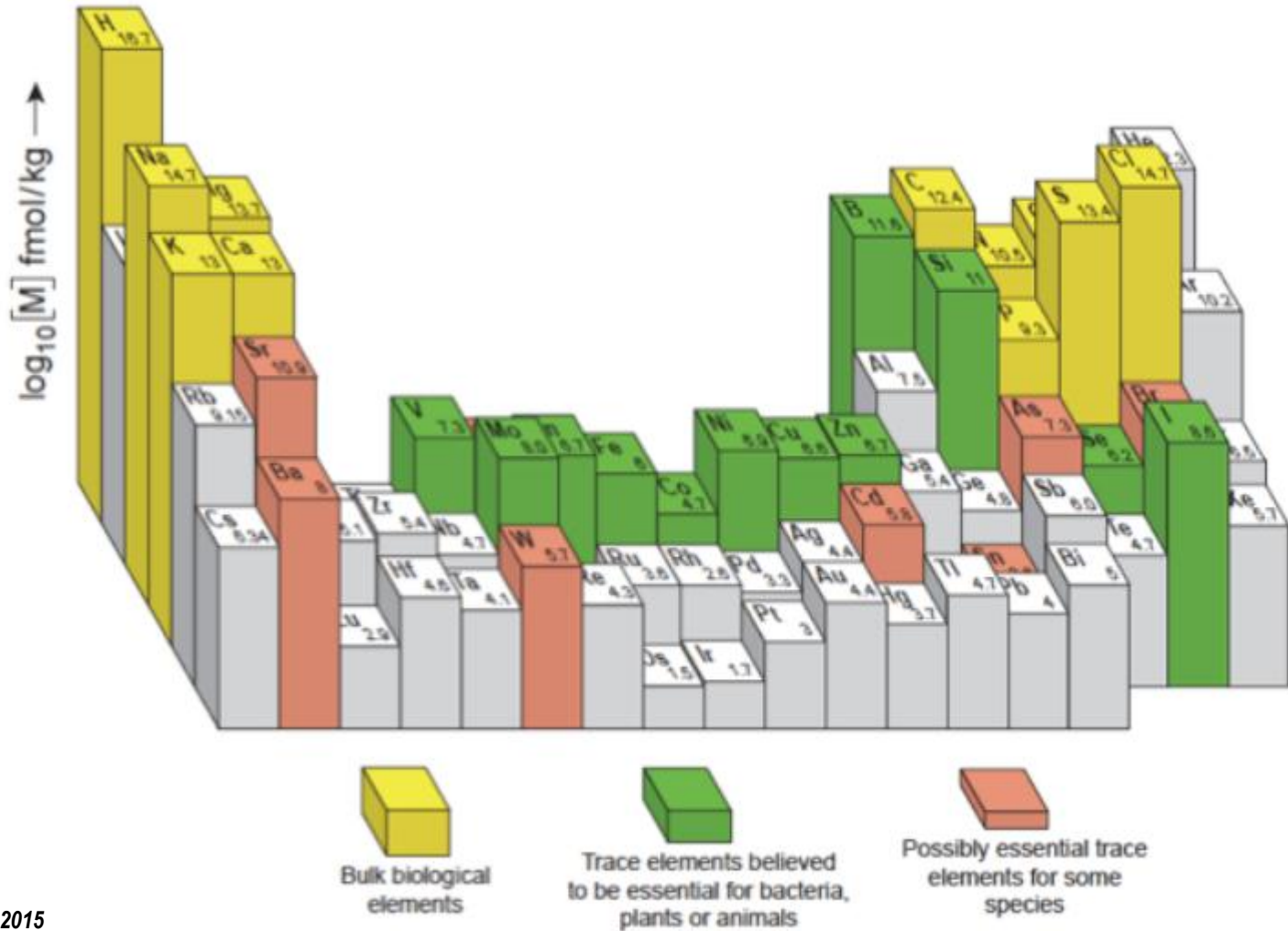
58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
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ACTINIDES

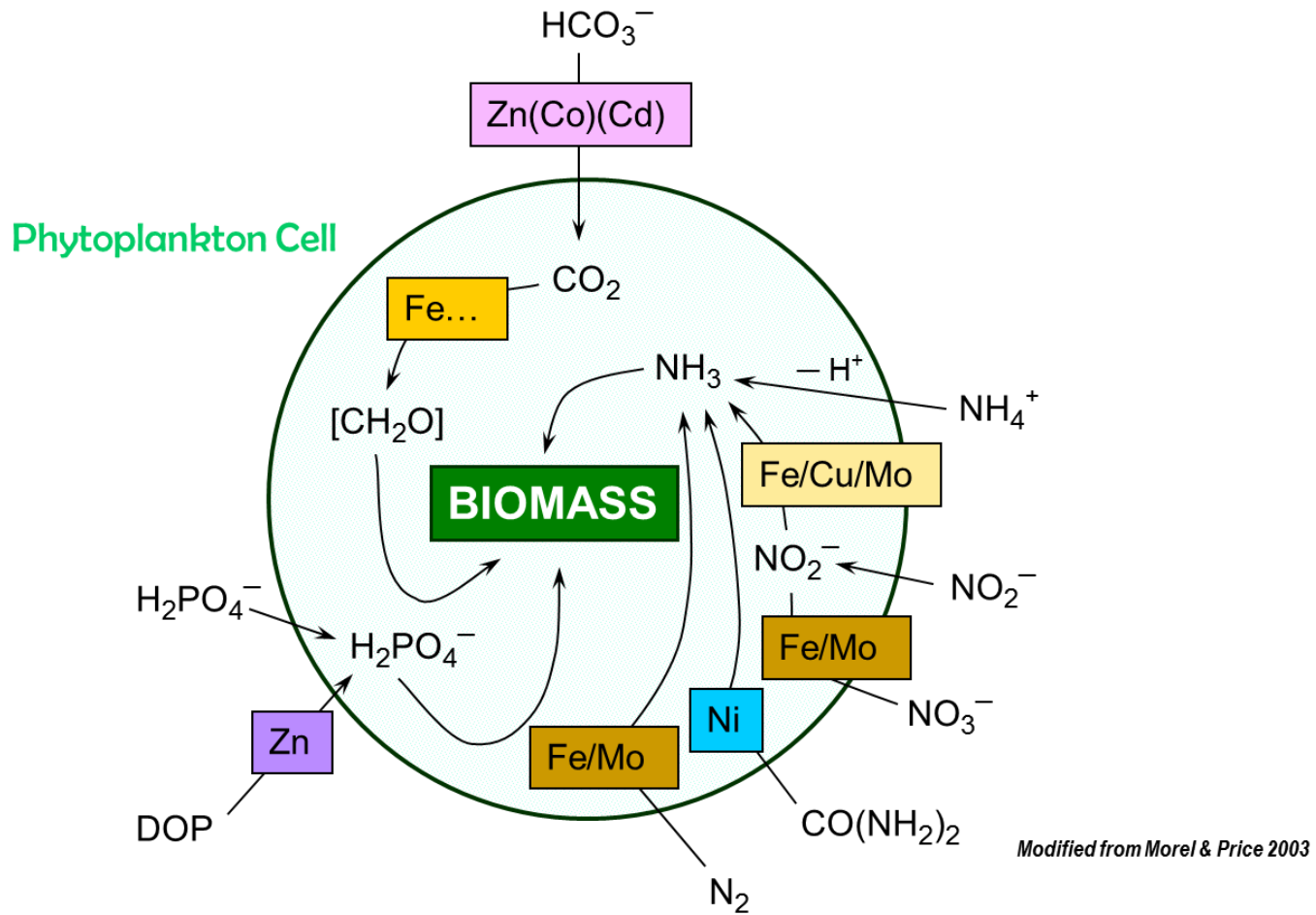
90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr
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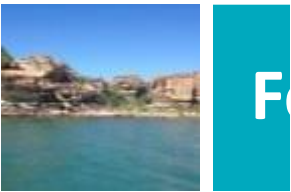


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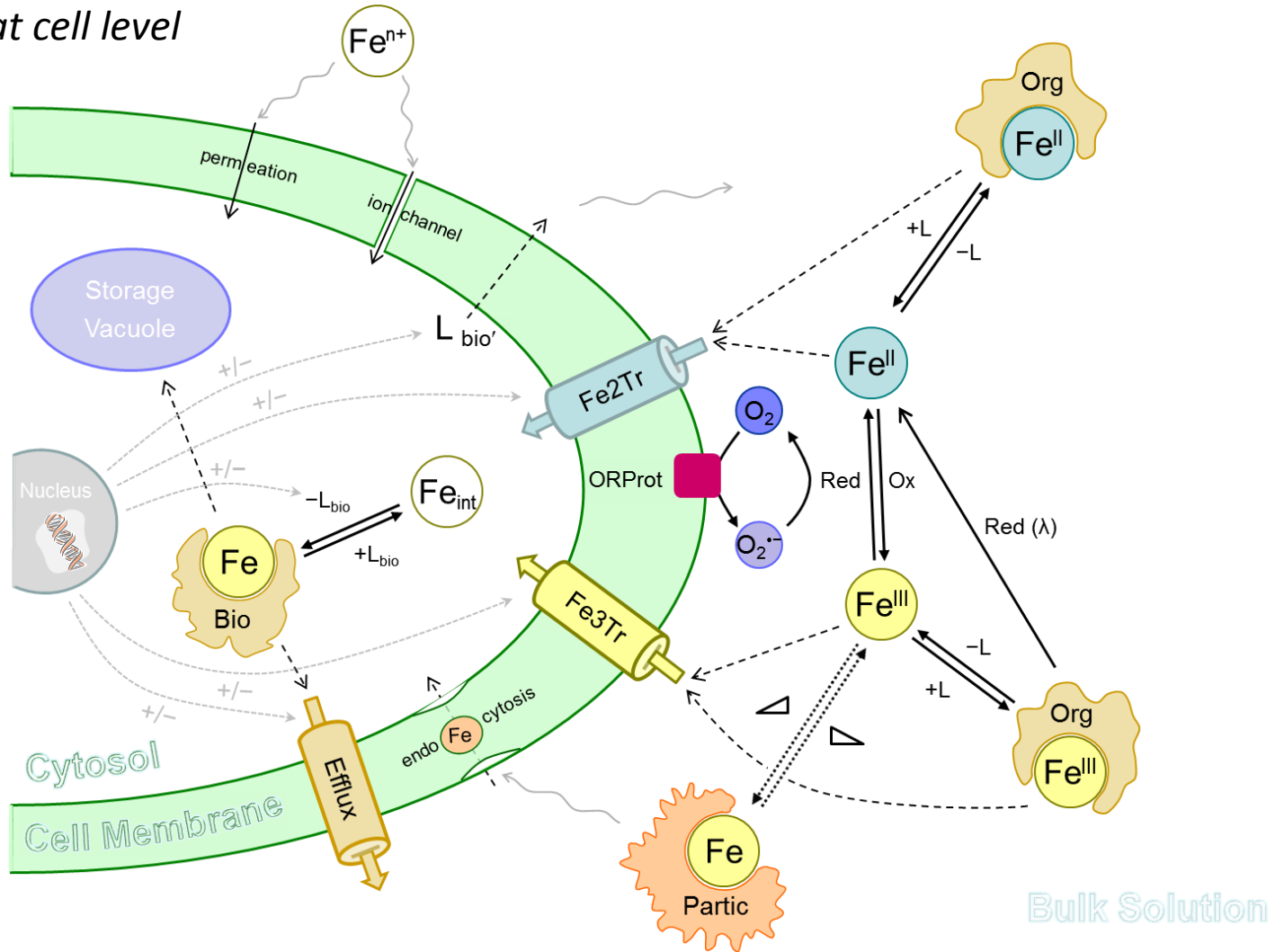


Rickaby 2015





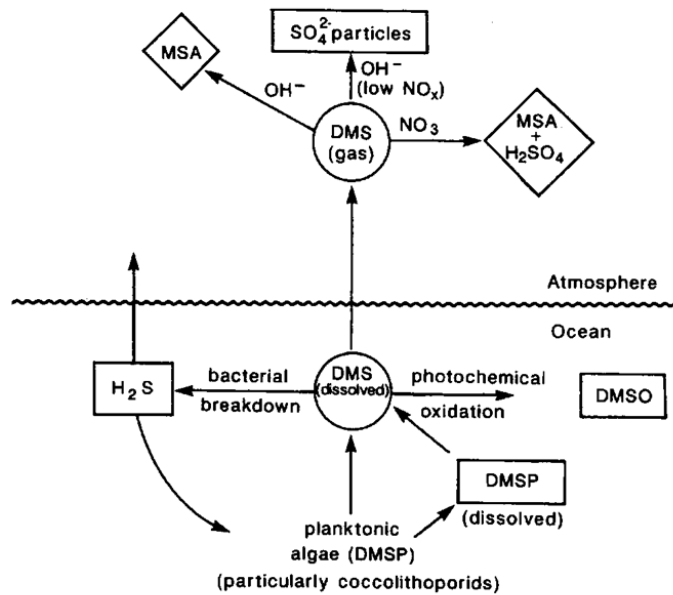
Processes at cell level



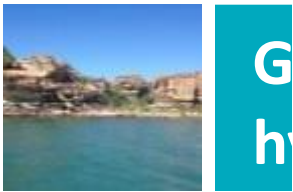


Sources and fate of DMS in the surface ocean

G. R. Bigg



Ref: Hester RE, Harrison RM (eds) 2000 *Chemistry in the Marine Environment*
Roy. Soc. Chem. pp. 25-30.



Oceanic phytoplankton, atmospheric sulphur, cloud albedo and climate

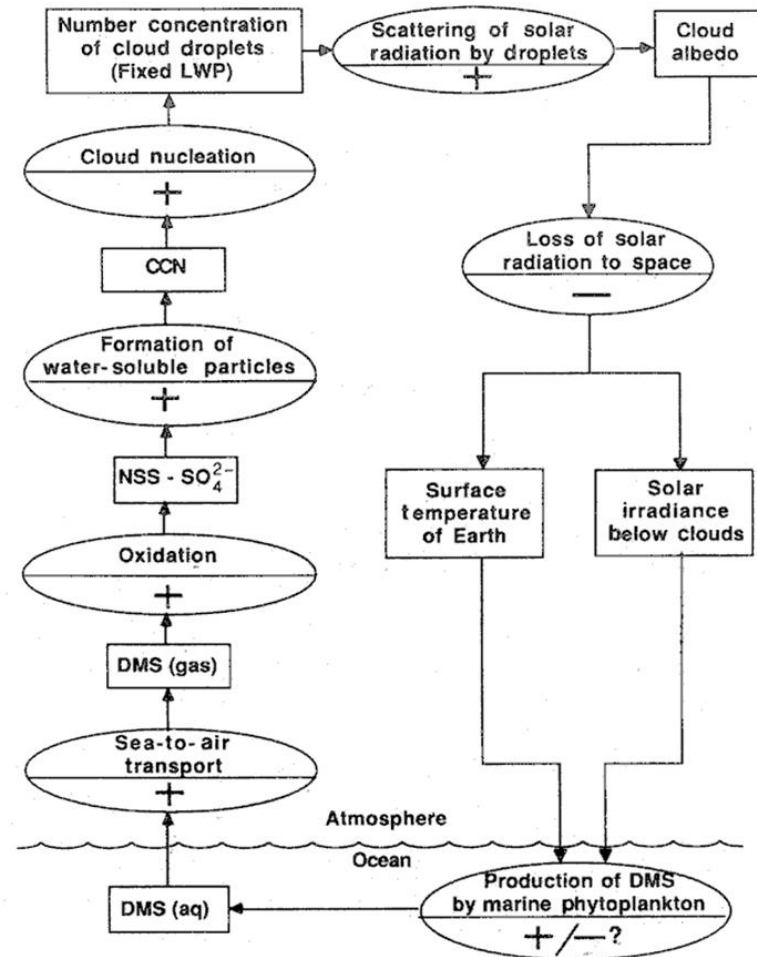
Robert J. Charlson*, James E. Lovelock†, Meinrat O. Andreae‡ & Stephen G. Warren*

* Department of Atmospheric Sciences AK-40, University of Washington, Seattle, Washington 98195, USA

† Coombe Mill Experimental Station, Launceston, Cornwall PL15 9RY, UK

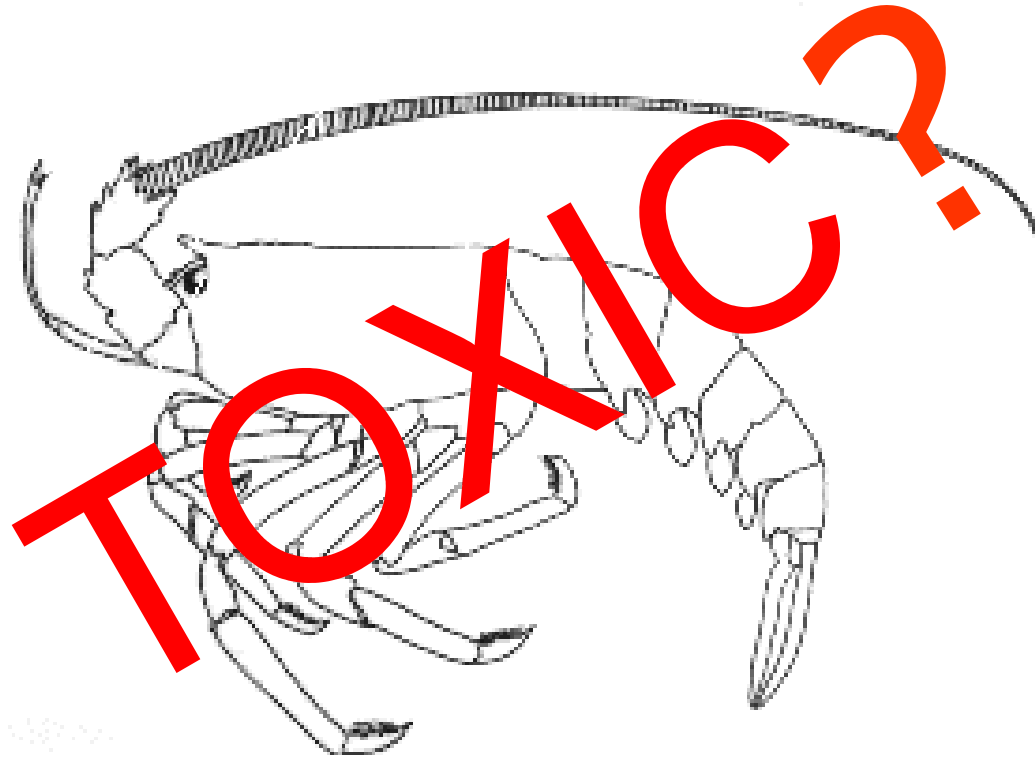
‡ Department of Oceanography, Florida State University, Tallahassee, Florida 32306, USA

Nature 326 (1987) 655





C





F

$$\text{As}_T = 13\text{--}27 \text{ nM} \quad (1\text{--}2 \text{ } \mu\text{g As/L})$$



...

...

Other As species in marine biota



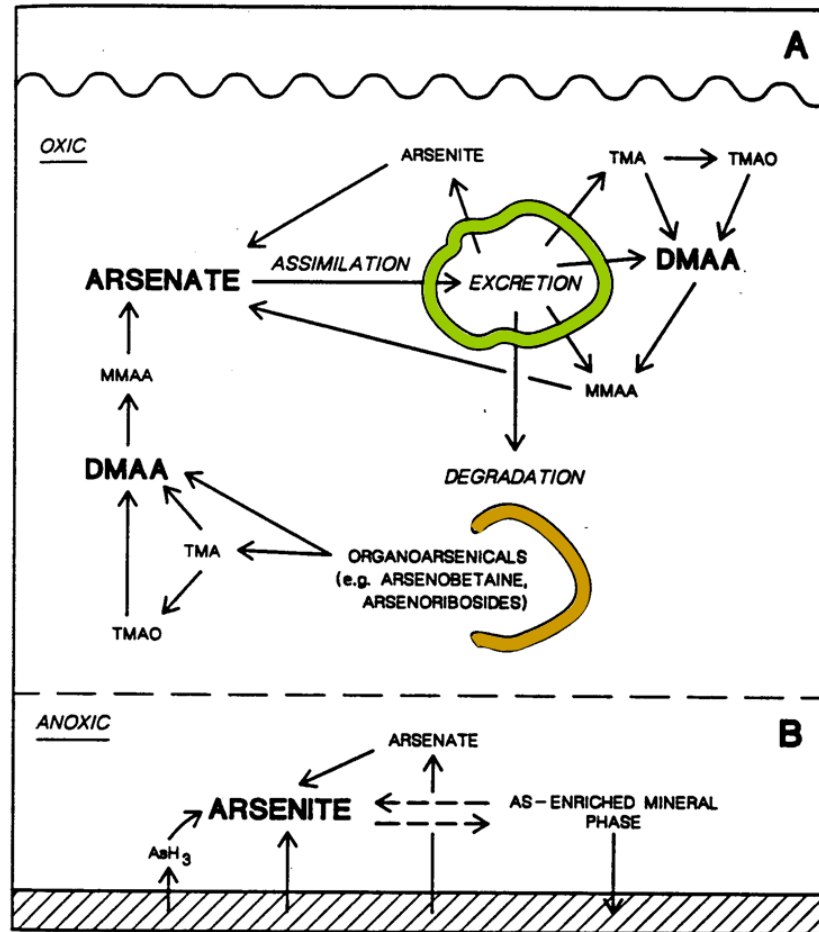
arsenobetaine

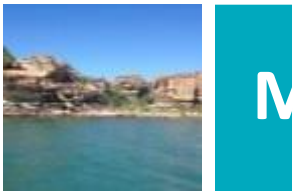
arsenocholine

trimethylarsine



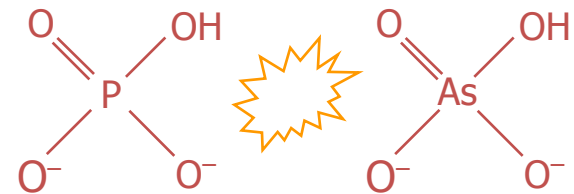
B





A) methyl arsenicals (MMA, DMA, etc.)

phospate vs. arsenate



For marine biota (phytoplankton, etc.), methylation of arsenic is a **detoxification** mechanism to protect phosphorus biochemical pathways (and also sulfur-containing enzymes).

B) other org-As compounds (arsenobetaine, arseno-sugars, etc.)

– critical compound in biosynthetic pathway is said to be

arsenocholine:



OH^-

OH^- choline

In this instance, arsenic is “mimicking” nitrogen in its intracellular pathways.

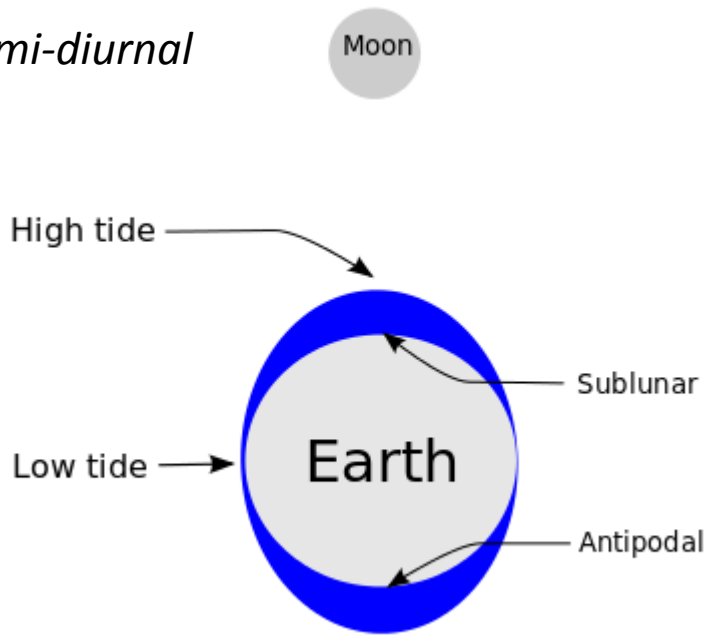


Land-Sea Interactions (Coastal Processes)

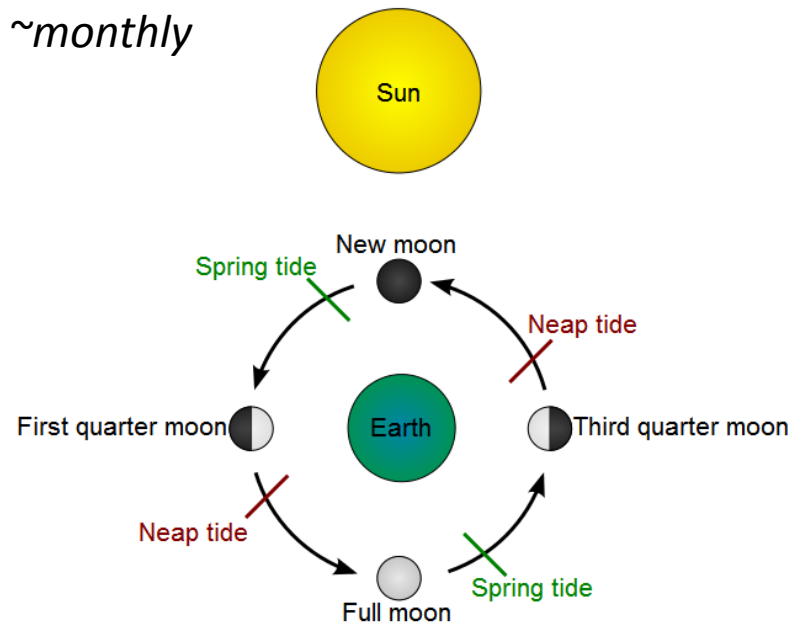


Tides are generated by gravitational pull of the moon and sun, and modified by water depth, bottom topography, coastal landforms, etc. as a series of harmonics

semi-diurnal



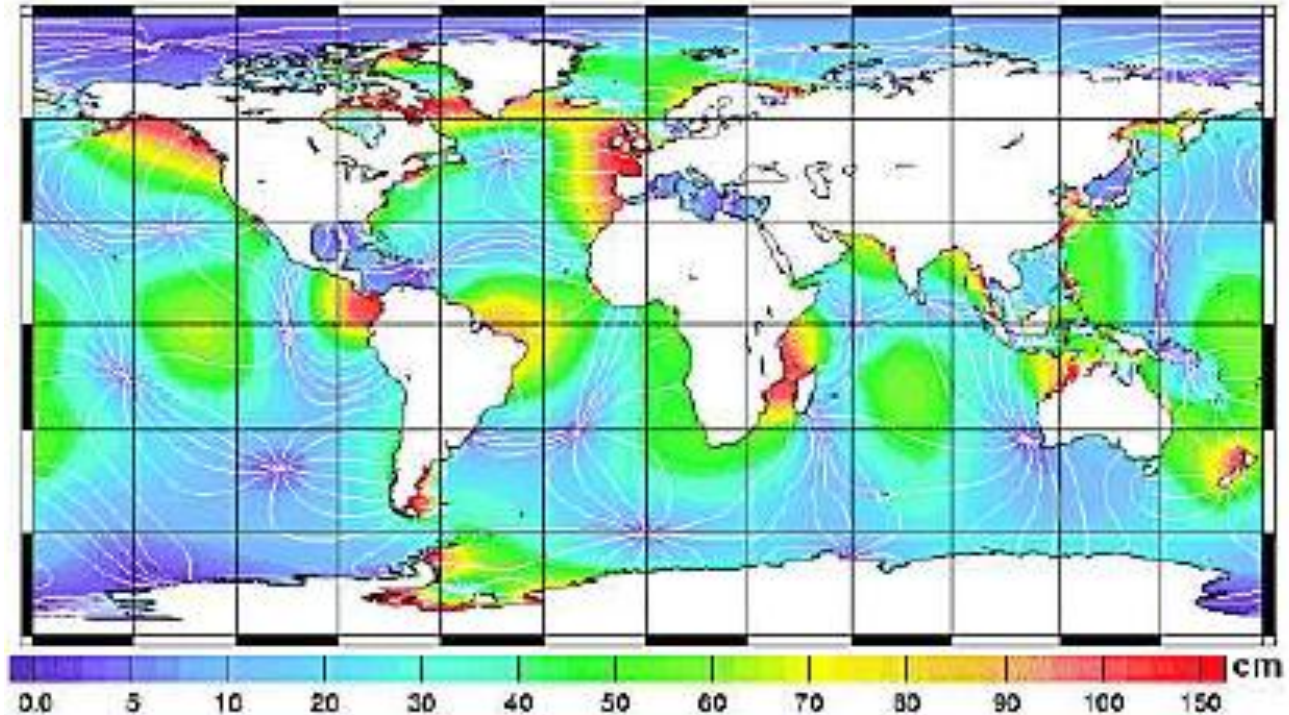
~monthly



Wikipedia



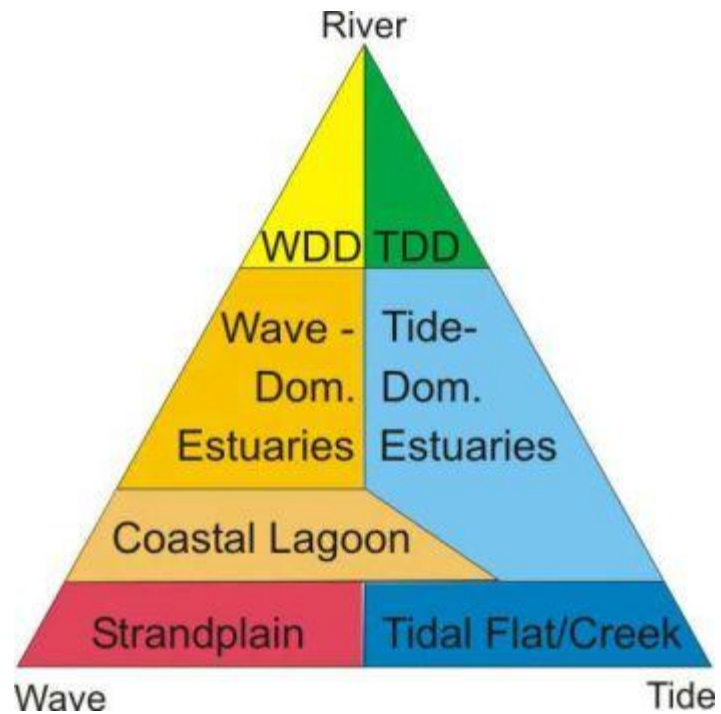
G



Amplitude of the M2 tidal constituent (in centimetres) derived from the FES99 model. Cotidal lines indicating the phase every 30 degrees originate at amphidromic points where the tidal range is zero. (Credits Legos/CNRS)



E

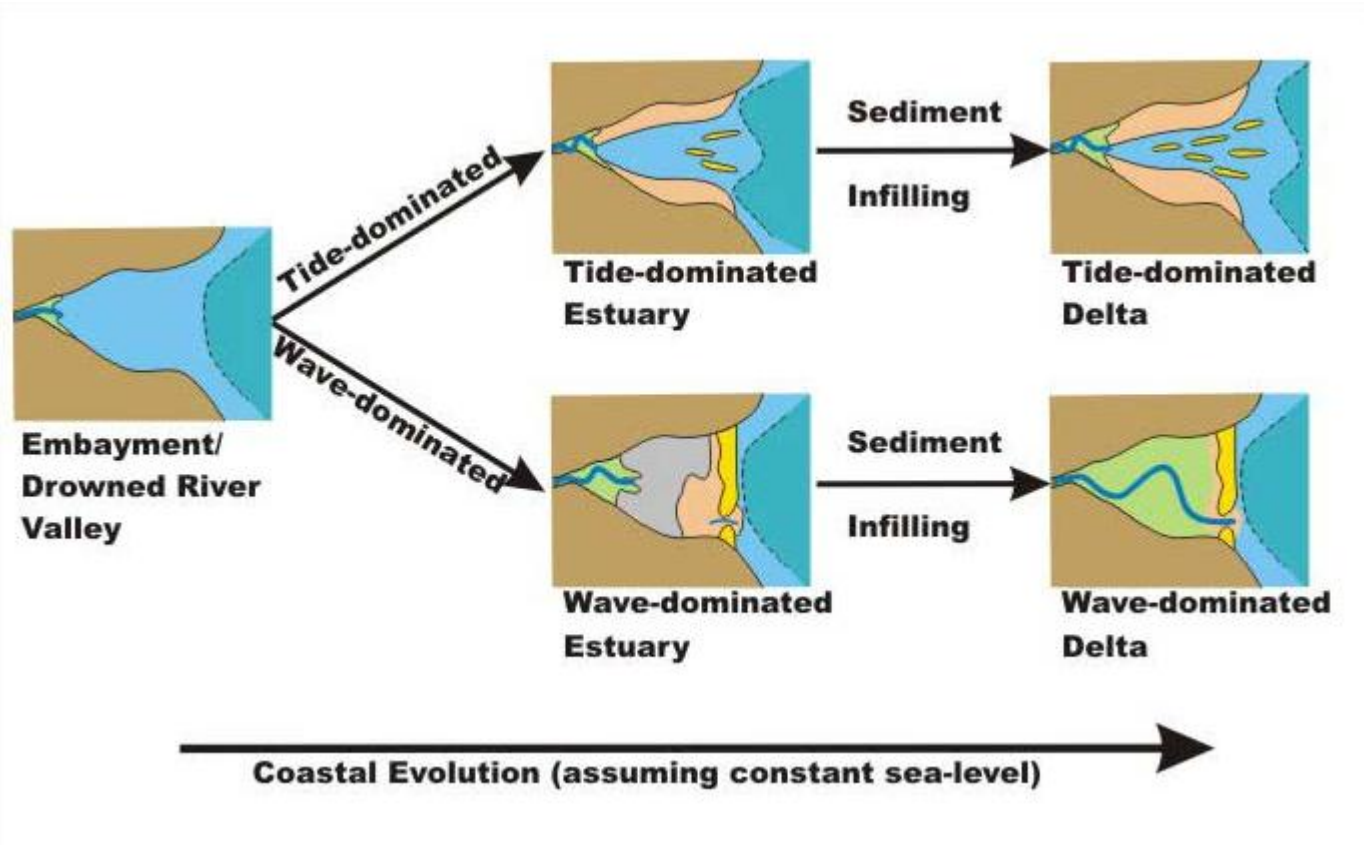


Notes

WDD – wave dominated deltas; TDD – tide-dominated deltas



E





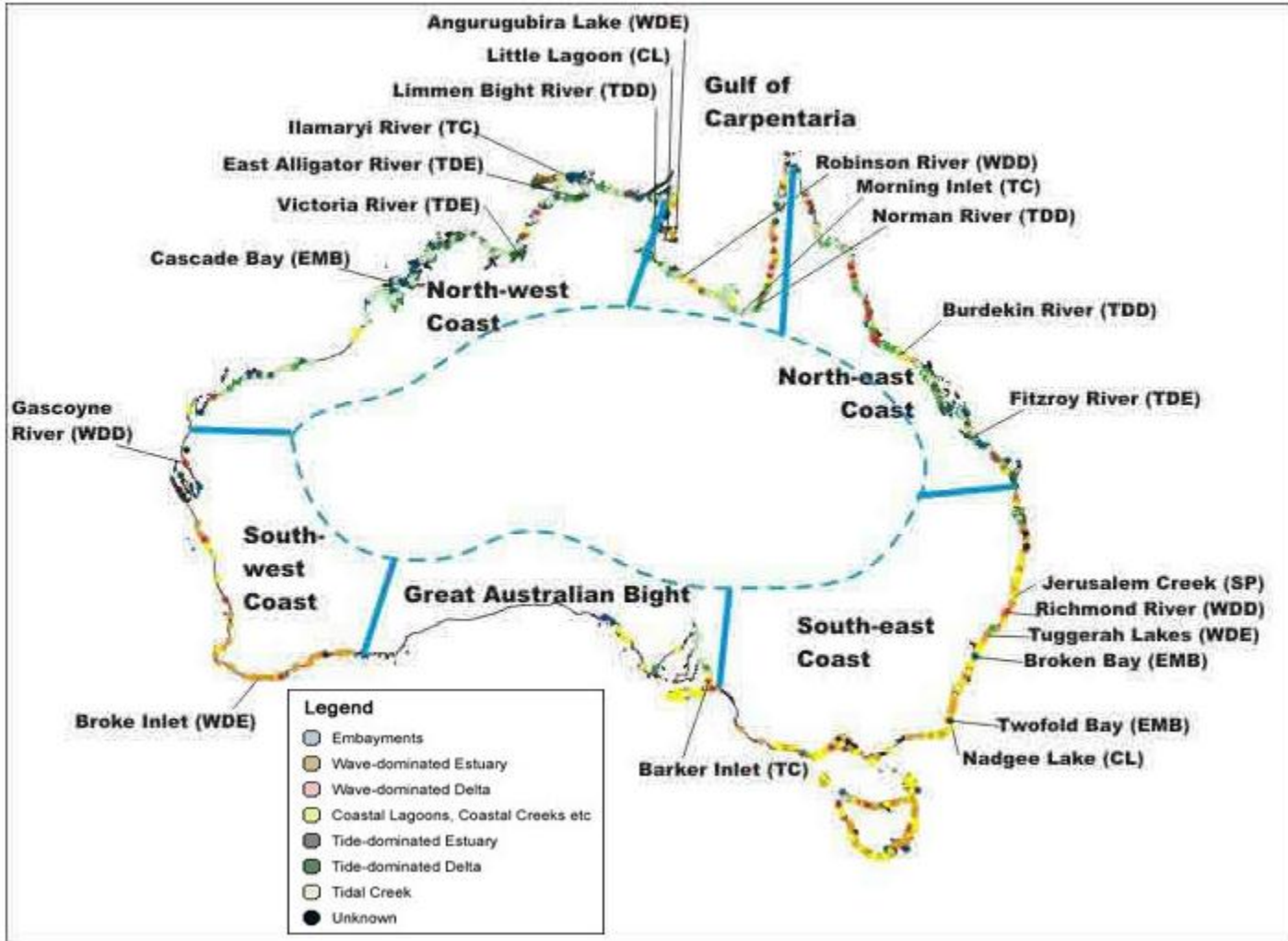
T

	Type of Coastal Waterway	Mixing
	Tide-dominated Delta	High
	Wave-dominated Delta	Low
	Tide-dominated Estuary	High
	Wave-dominated Estuary	Low
	Tidal Creeks	High
	Strandplains/Coastal Lagoons	Low
	Embayments/Drowned River Valleys	Low

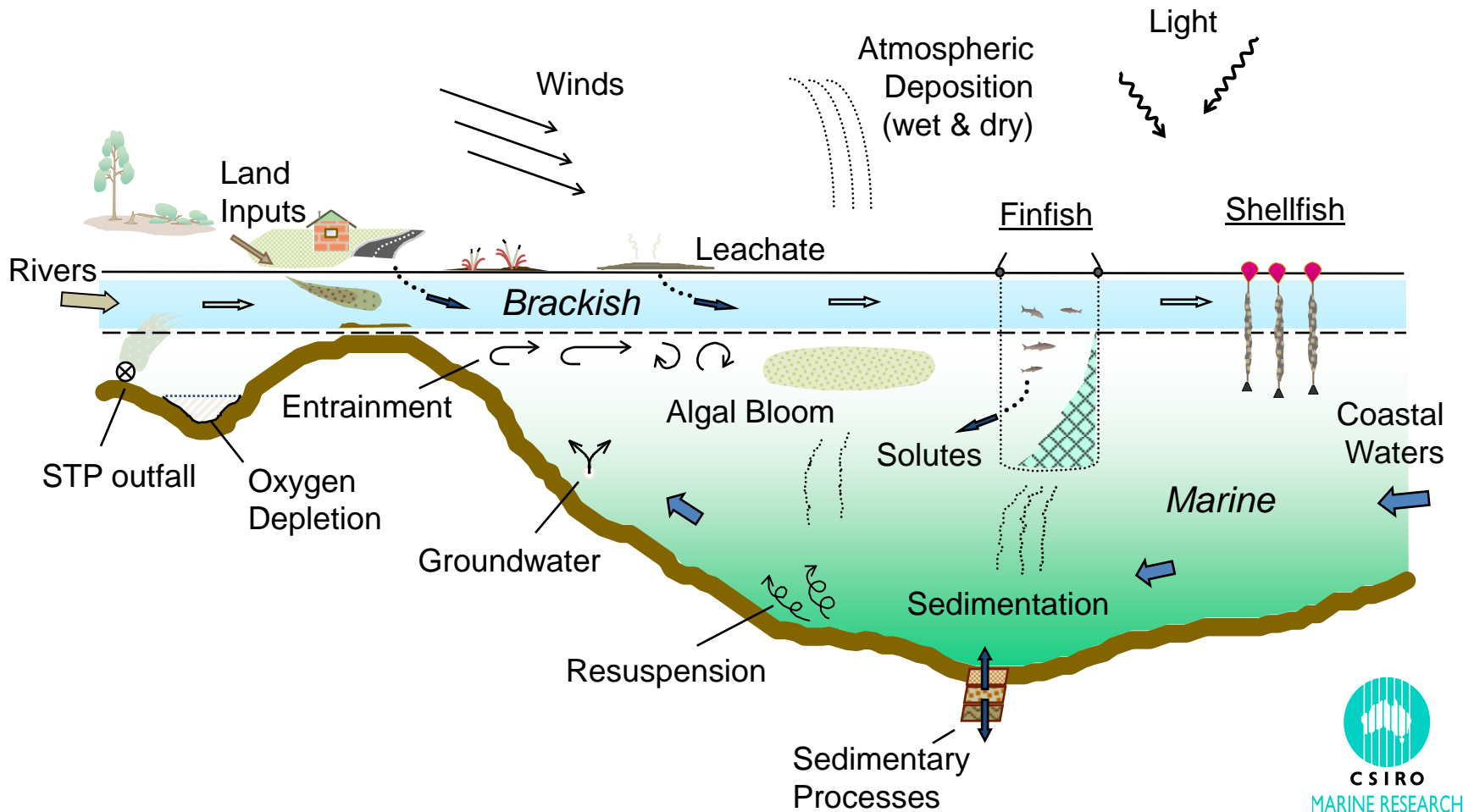
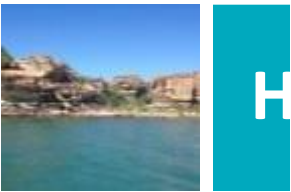
Ozcoasts



A

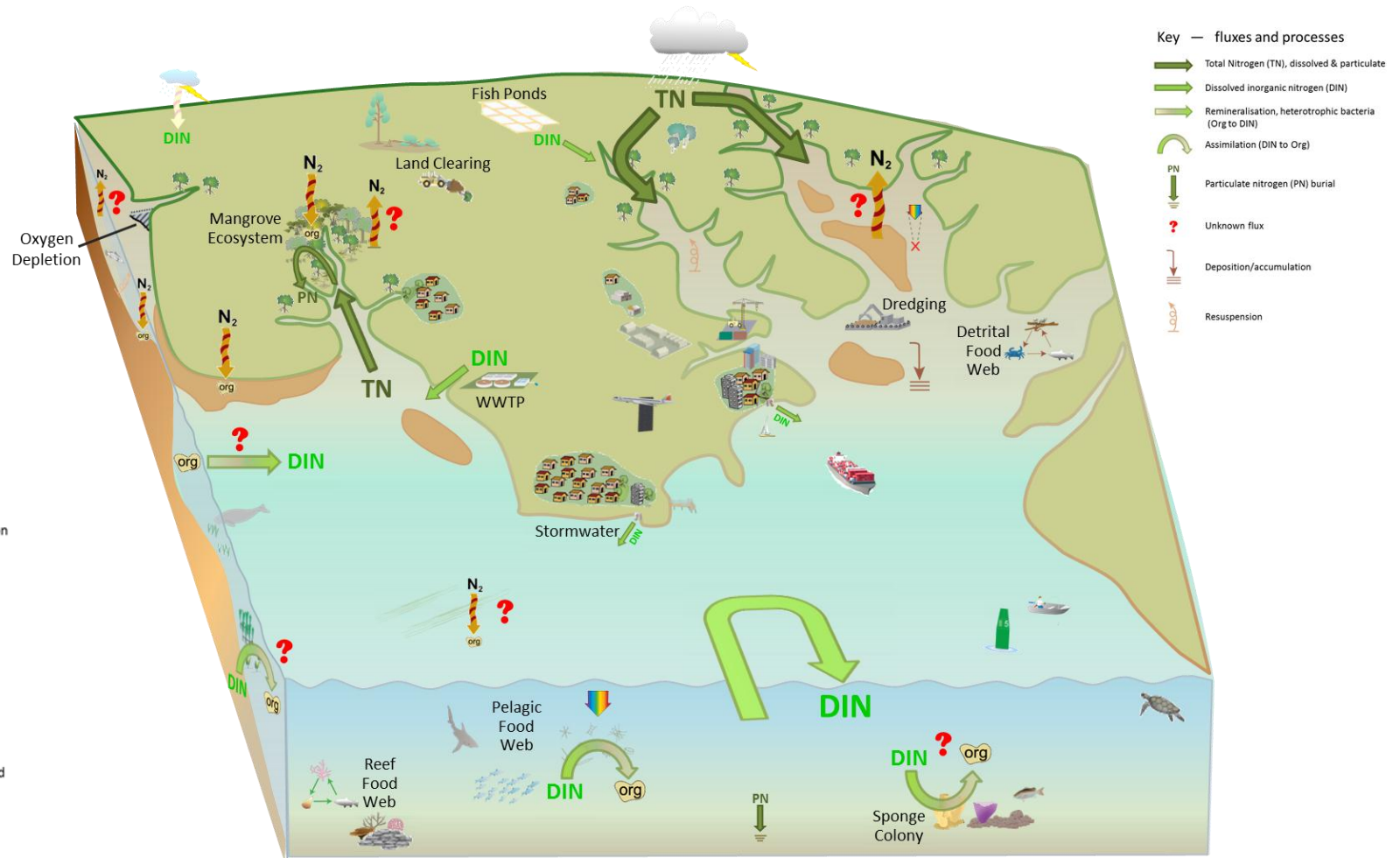


Ozcoasts





D





- Climate science
- Air-sea interactions
- Coral reefs
- Seagrass and dugongs
- Charismatic megafauna: sharks, whales, turtles, ...
- Marine microbiology: bacteria and viruses
- Coastal geomorphology
- Sedimentology
- Environmental modelling
- Pollution
- Polar regions
- ...



