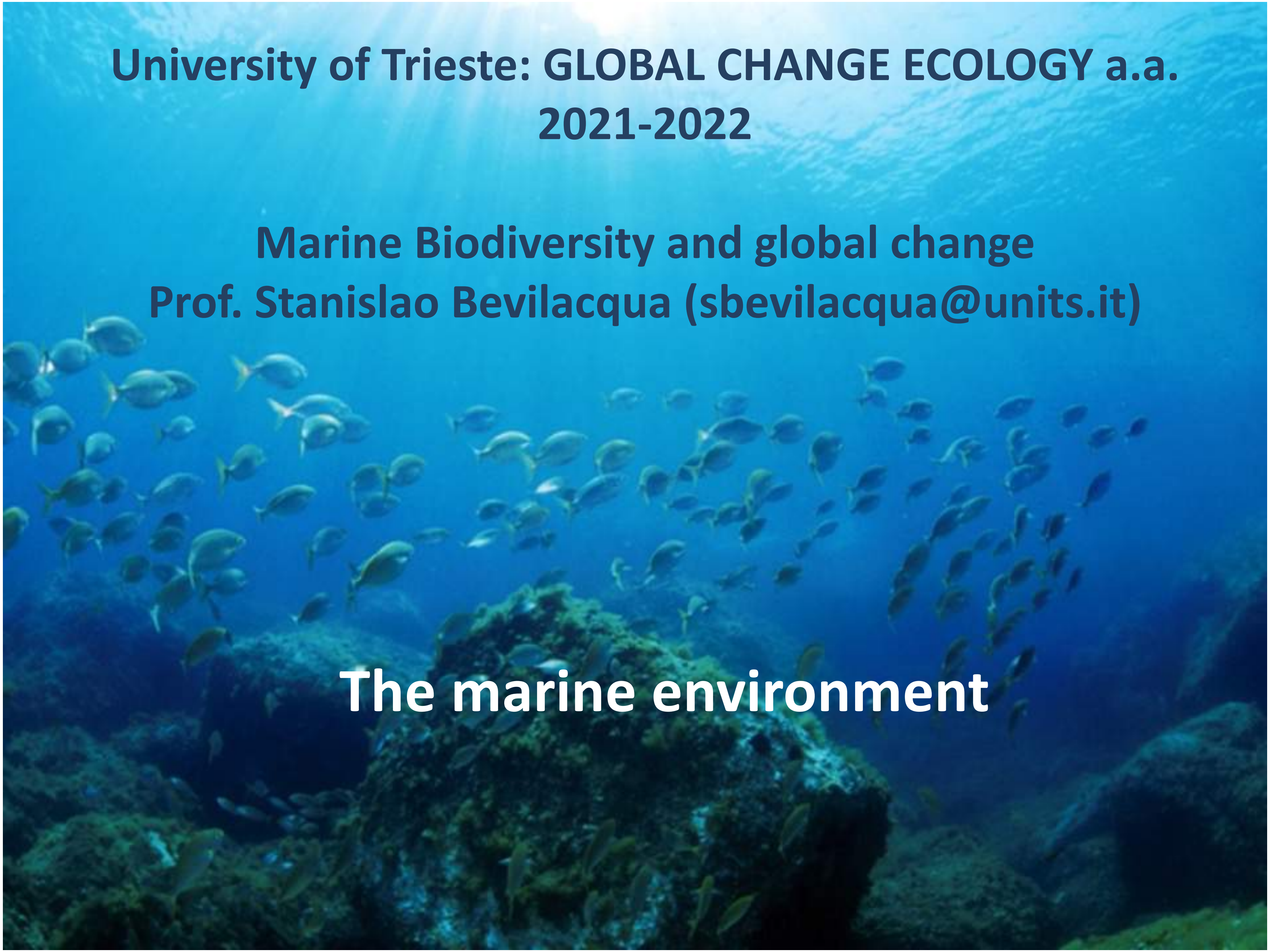


University of Trieste: GLOBAL CHANGE ECOLOGY a.a. 2021-2022

Marine Biodiversity and global change

Prof. Stanislao Bevilacqua (sbevilacqua@units.it)

The marine environment

The importance of oceans

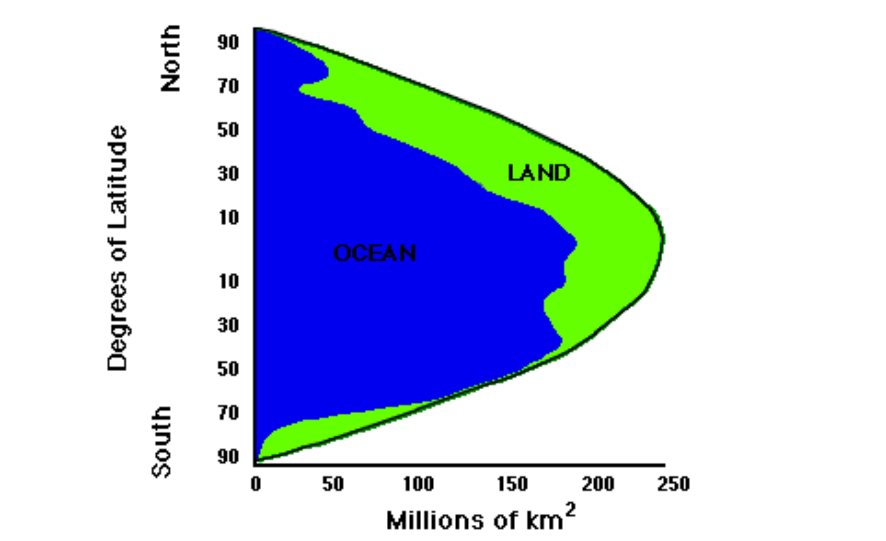
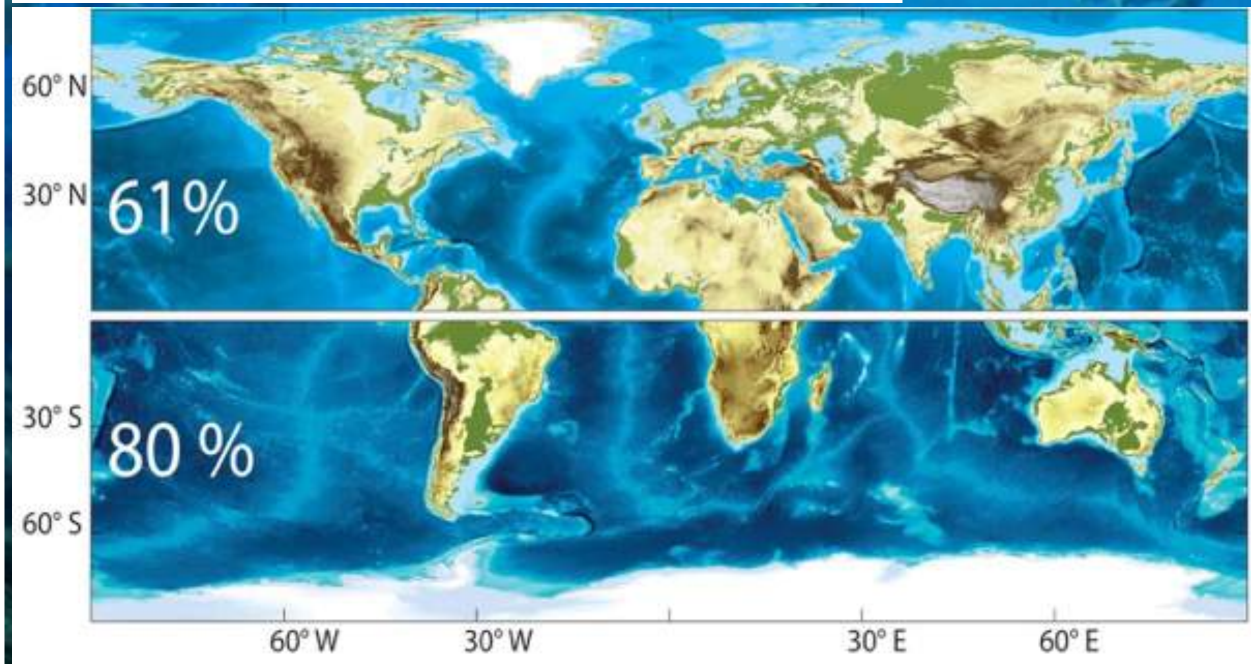


Diagram showing the distribution of land and water with latitude. The shaded portion is land and the area to the left of that is ocean. Note the large percentage of land in the Northern hemisphere as compared with the southern hemisphere.



More than 70% of surface on Earth is covered by seawater, with 1300 billion km^3 in volume

1. **80% of international trade is carried by the sea**
2. **By the year 2020, 75% of world's population will live within 60 km from the sea shore**
3. **The world fish catch amounts to about 20% of total human consumption of animal proteins**
4. **The offshore production of oil and gas accounted for about 30% of world's total and is increasing**
5. **Coastal marine environments and wetlands may provide as much as 43% of the estimated value of the world's ecosystem services, and yet over 65% of such areas have been already undergone severe environmental degradation**

The importance of oceans

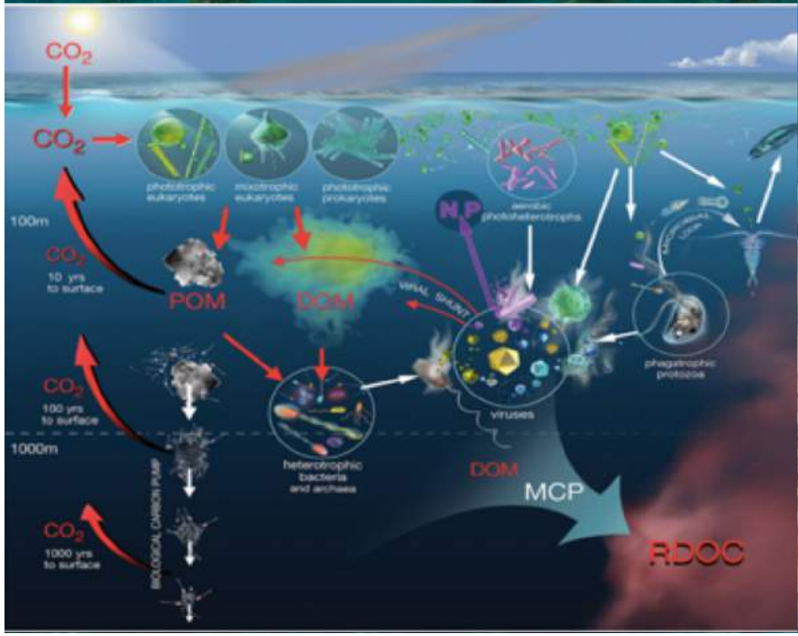
1. **We do not know the impact of most activities on our seas**
   - Increasing impact from old (e.g., oil) and new chemicals
   - Overexploitation of marine resources
   - New pollution sources

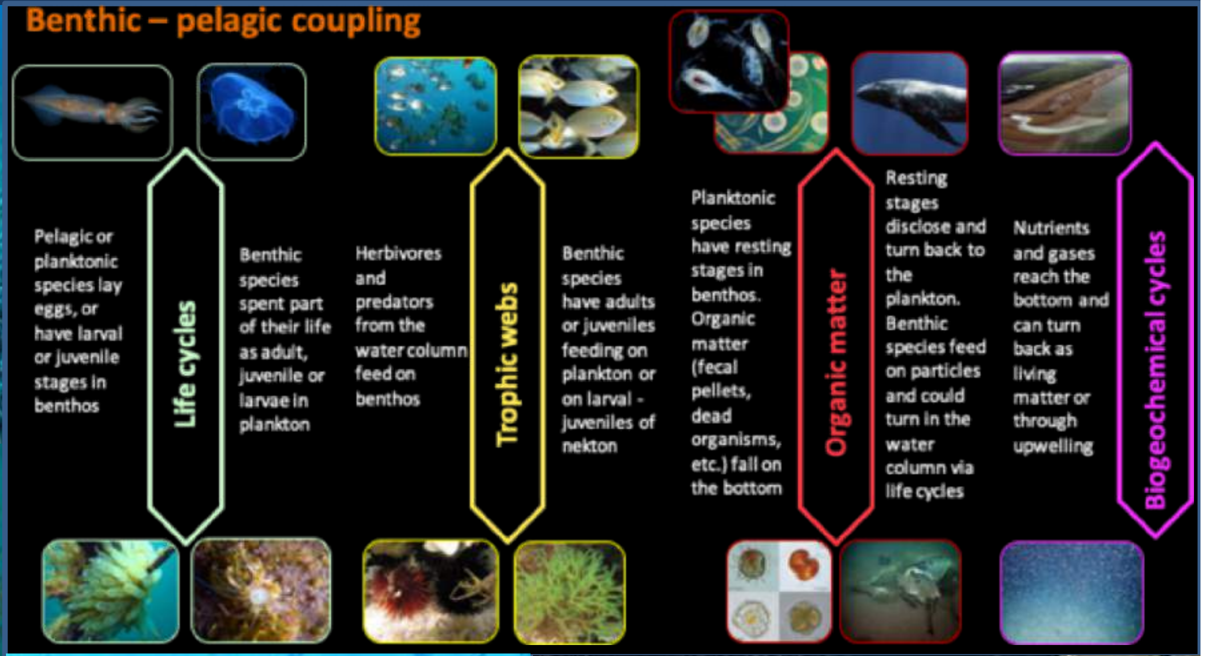
2. **Systematic underestimation of marine ecosystems and their economical functions**
   - Europe has 89,000 km of coastline with a very high coast to surface ratio
   - Europe and italian economy increasingly dependent upon resources from the sea

3. **Increasing turism impact:**
   - 75,000,000 international tourists
   - 60,000,000 domestic tourists every year

4. **Increasing economical and societal role:**
   - >600,000 persons in Europe work in the fields of mariculture, fisheries, and related industries

Carbon storage





Regulation

	Functions	Ecosystem processes and components	Goods and services (examples)
	Regulation Functions	*Maintenance of essential ecological processes and life support systems*	
1	Gas regulation	Role of ecosystems in bio-geochemical cycles (e.g. CO_2/O_2 balance, ozone layer, etc.)	1.1 UVb-protection by O_3 (preventing disease). 1.2 Maintenance of (good) air quality.
2	Climate regulation	Influence of land cover and biol. mediated processes (e.g. DMS-production) on climate	Maintenance of a favorable climate (temp., precipitation, etc) for, for example, human habitation, health, cultivation
3	Disturbance prevention	Influence of ecosystem structure on dampening env. disturbances	3.1 Storm protection (e.g. by coral reefs). 3.2 Flood prevention (e.g. by wetlands and forests)
6	Soil retention	Role of vegetation root matrix and soil biota in soil retention	6.1 Maintenance of arable land. 6.2 Prevention of damage from erosion/siltation
7	Soil formation	Weathering of rock, accumulation of organic matter	7.1 Maintenance of productivity on arable land.

Habitat provision

	Habitat Functions	*Providing habitat (suitable living space) for wild plant and animal species*	Maintenance of biological & genetic diversity (and thus the basis for most other functions)
12	Refugium function	Suitable living space for wild plants and animals	Maintenance of commercially harvested specie
13	Nursery function	Suitable reproduction habitat	13.1 Hunting, gathering of fish, game, fruits,

Habitat and production functions

14	Food	Conversion of solar energy into edible plants and animals	14.1 Building & Manufacturing (e.g. lumber, skins). 14.2 Fuel and energy (e.g. fuel wood, organic matter). 14.3 Fodder and fertilizer (e.g. krill, leaves, litter).

1/3 of world human population based based its diet basically on seafood (FAO, 2018)

Cultural and spiritual

	Functions	Ecosystem processes and components	Goods and services (examples)
19	Aesthetic information	Attractive landscape features	Enjoyment of scenery (scenic roads, housing, etc.)
20	Recreation	Variety in landscapes with (potential) recreational uses	Travel to natural ecosystems for eco-tourism, outdoor sports, etc.
21	Cultural and artistic information	Variety in natural features with cultural and artistic value	Use of nature as motive in books, film, painting, folklore, national symbols, architect., advertising, etc.
22	Spiritual and historic information	Variety in natural features with spiritual and historic value	Use of nature for religious or historic purposes (i.e. heritage value of natural ecosystems and features)
23	Science and education	Variety in nature with scientific and educational value	Use of natural systems for school excursions, etc. Use of nature for scientific research

(V. Van Gogh 1888, E. Hemingway 1952, Iron Maiden 1984, J. Cameron 1989)

The importance of oceans

Managing the oceans means:

1. Scientific and socio-economic bases for sustainable development of Mediterranean and European seas and their resources

2. Understanding and predicting impacts due to human exploitation of natural resources, pollution and climate changes

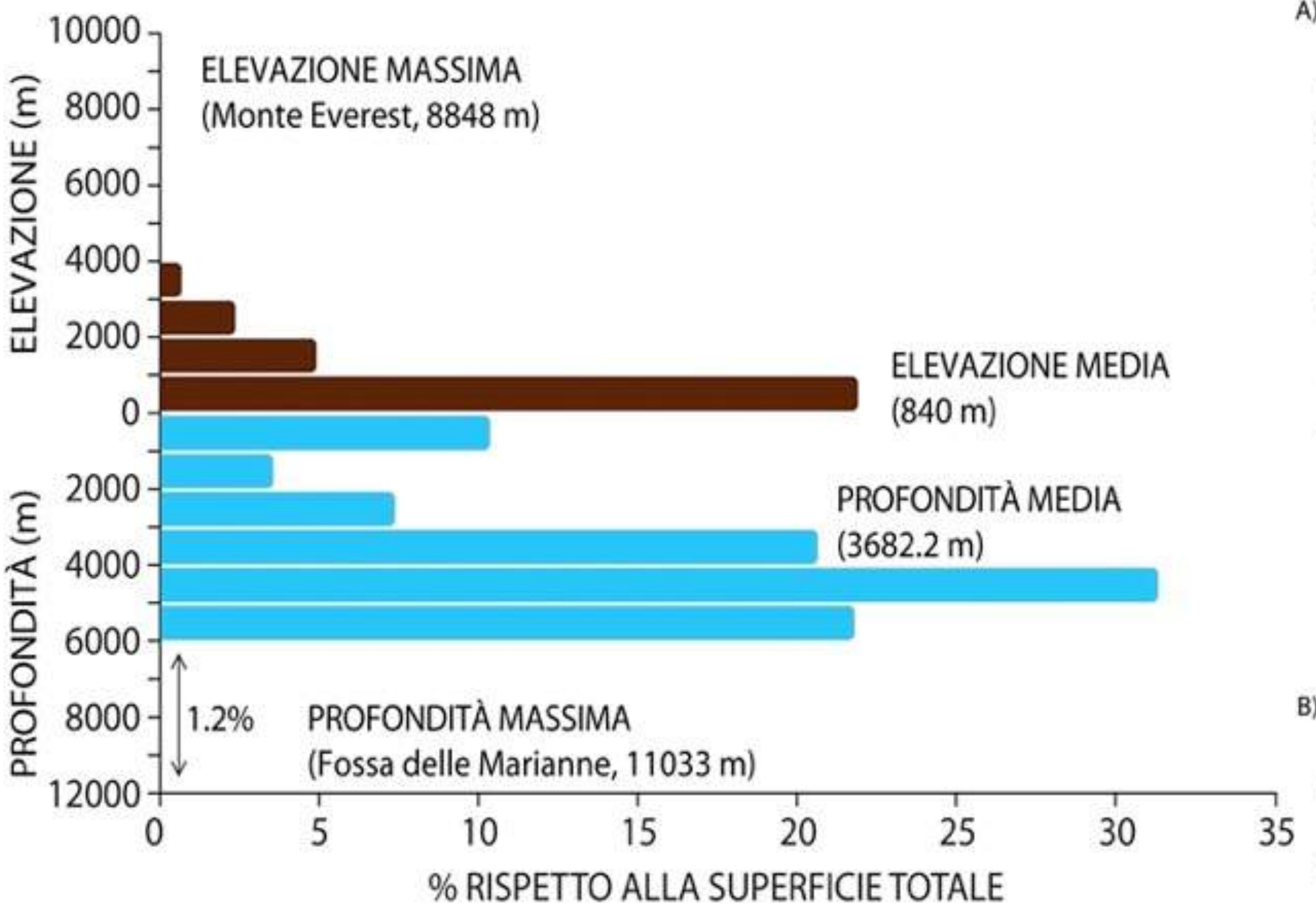
3. New frontiers in research and technologies

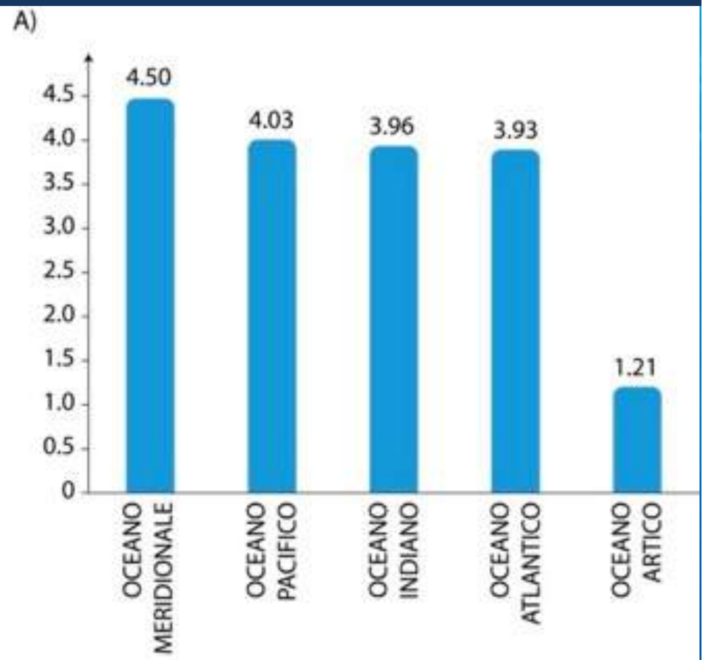
The importance of oceans

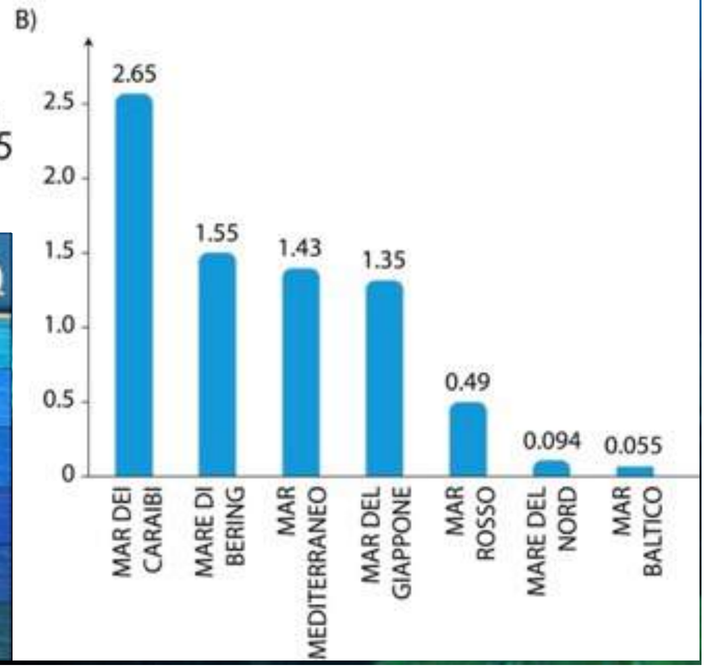
Main threats

1. Hydrocarbons and other contaminants
   - New forms of chemical pollution (micropollutants and secondary metabolites)
2. Habitat destruction
3. Eutrophication
4. Pathogenic forms and sanitary problems
5. Overfishing
6. Introduction of alien species
7. Climate changes and potential consequences on marine biodiversity

Depth



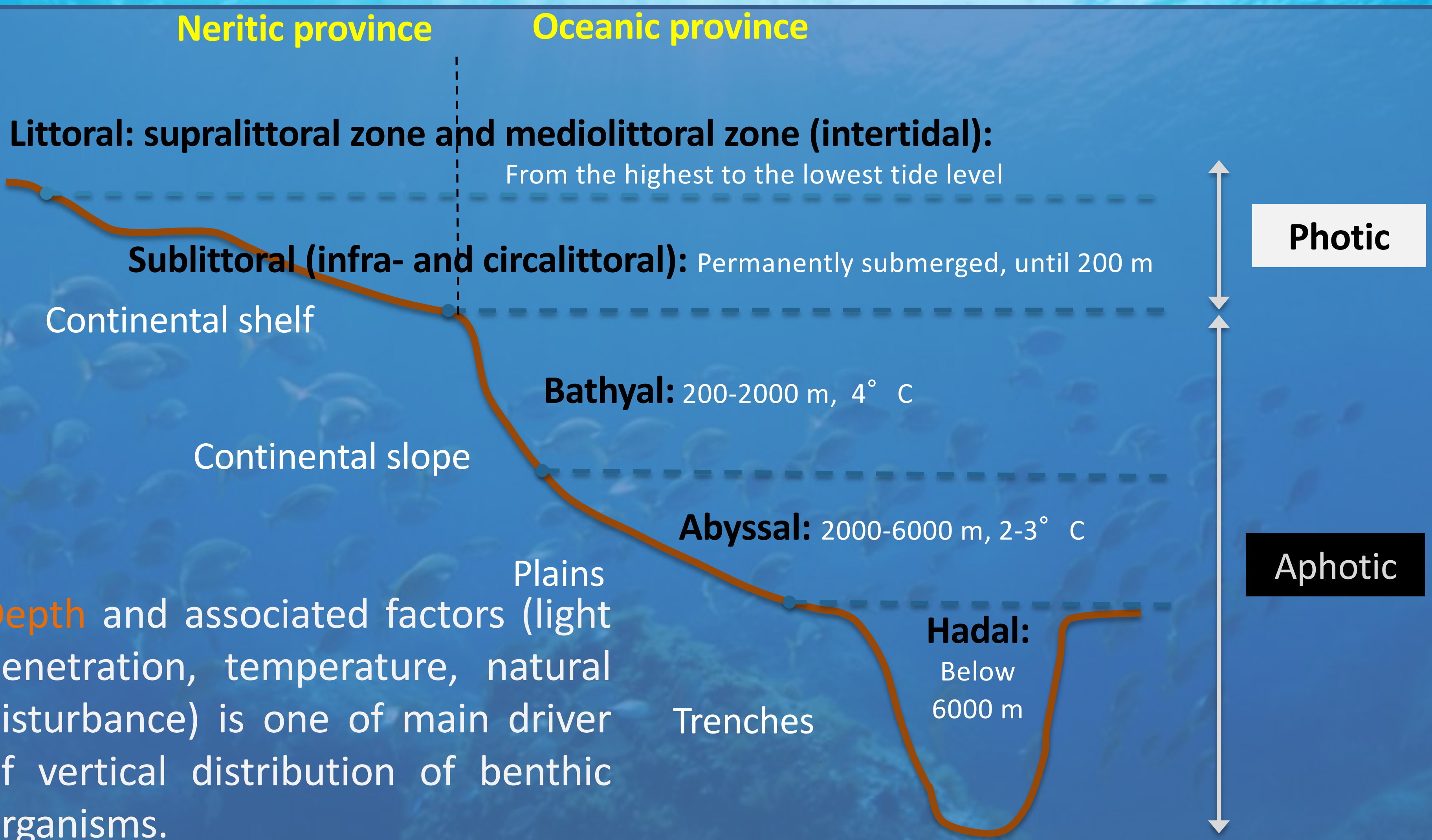




>80% of the seafloor (and therefore of the Earth's surface) and 98% of volume are 2 km under the surface

Depth (m)	Pressure (bar)
(surface) 0	1
10	2
20	3
30	4
40	5
50	6

The benthic domain

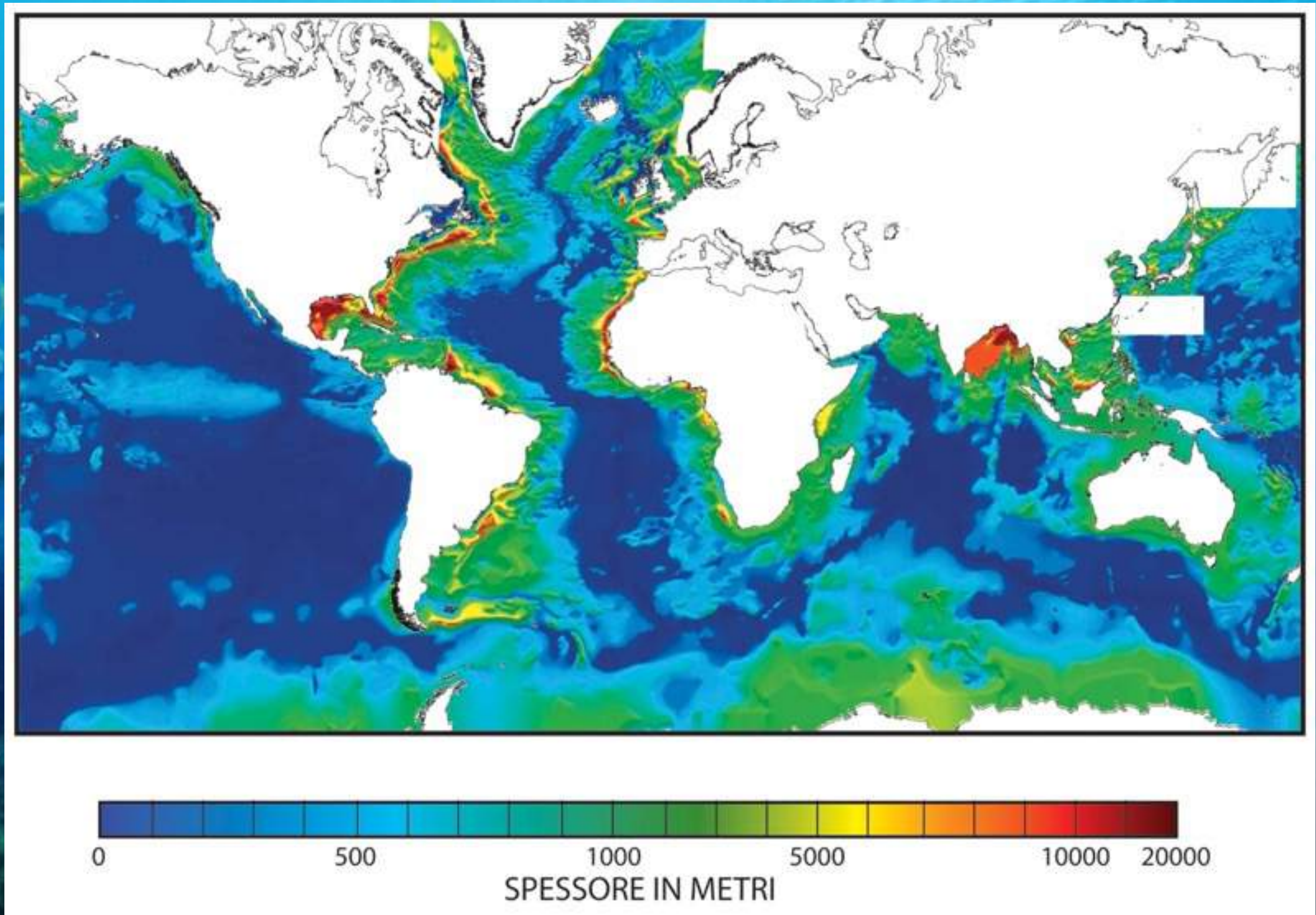


Depth and associated factors (light penetration, temperature, natural disturbance) is one of main driver of vertical distribution of benthic organisms.

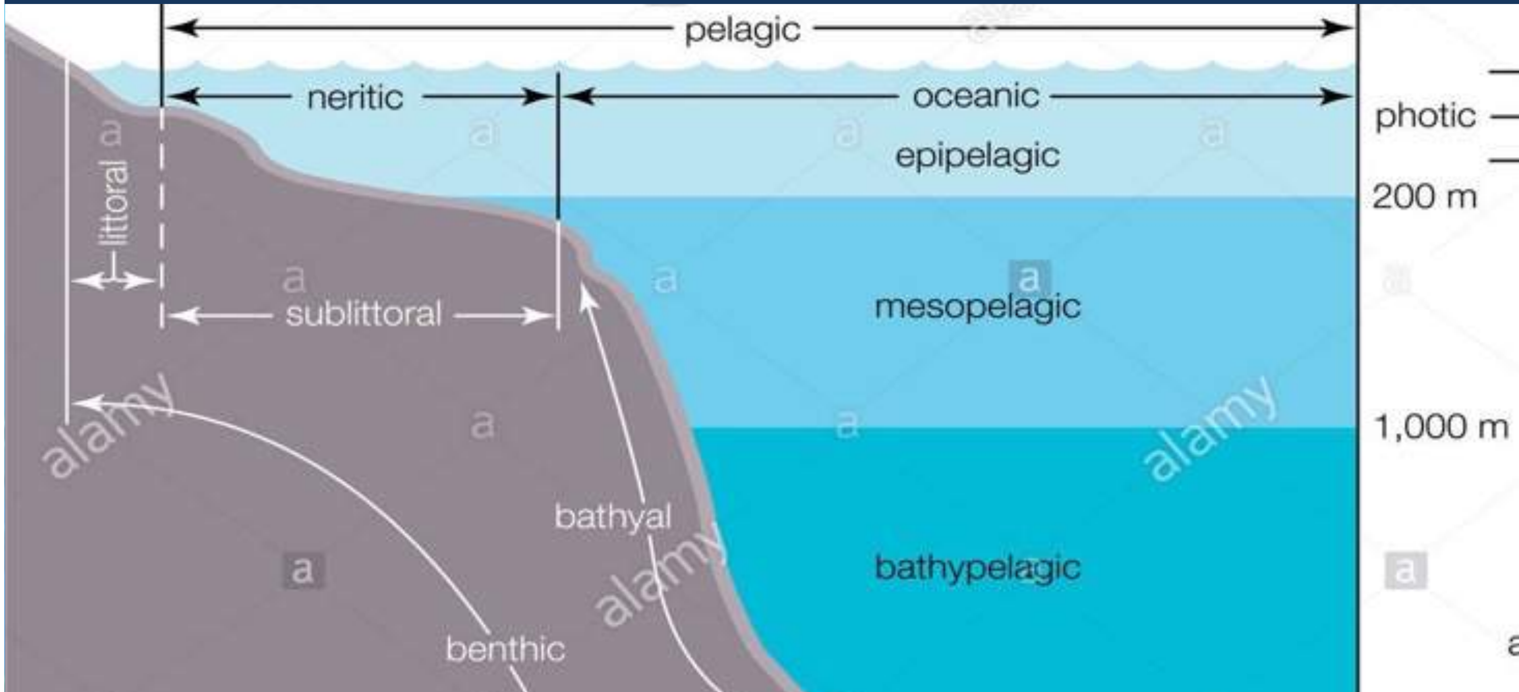
Higher diversity in shallow waters, where light allows primary production. Deep waters depend on secondary production. Harsh conditions (low temperature, pressure, absence of light) limit diversity in deeper waters. However, hot spots due to chemosynthesis. Infaunal diversity can be very high

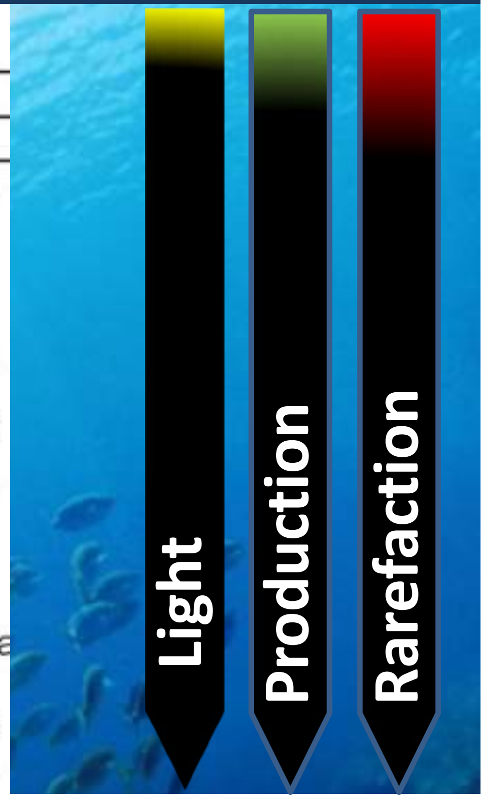
Sediments

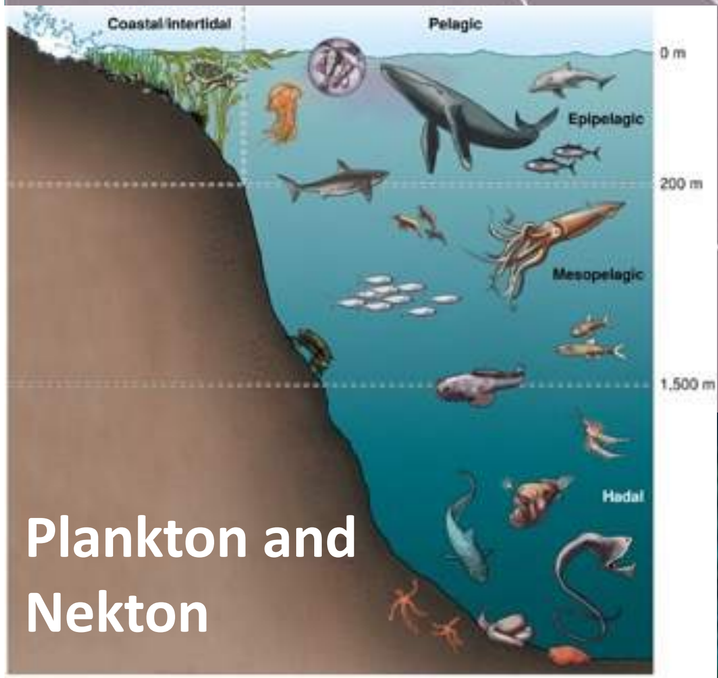
Thickness of sediments in the ocean margin



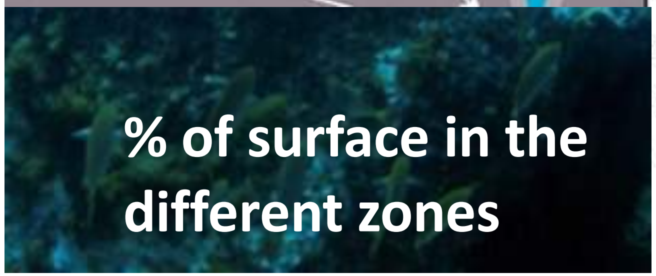
The pelagic domain



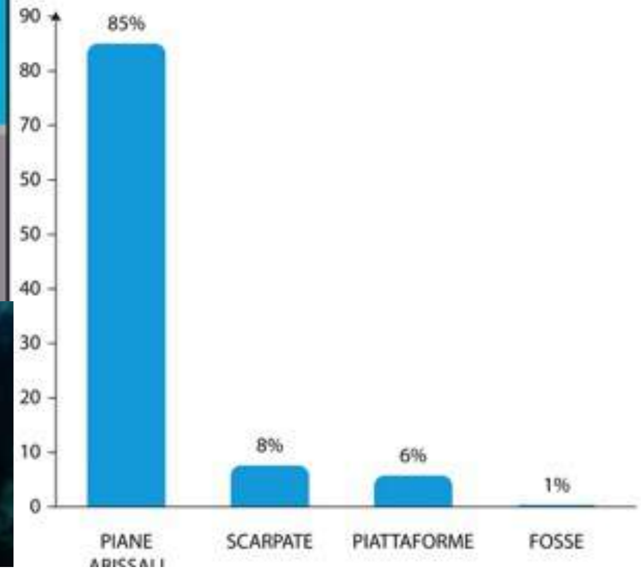




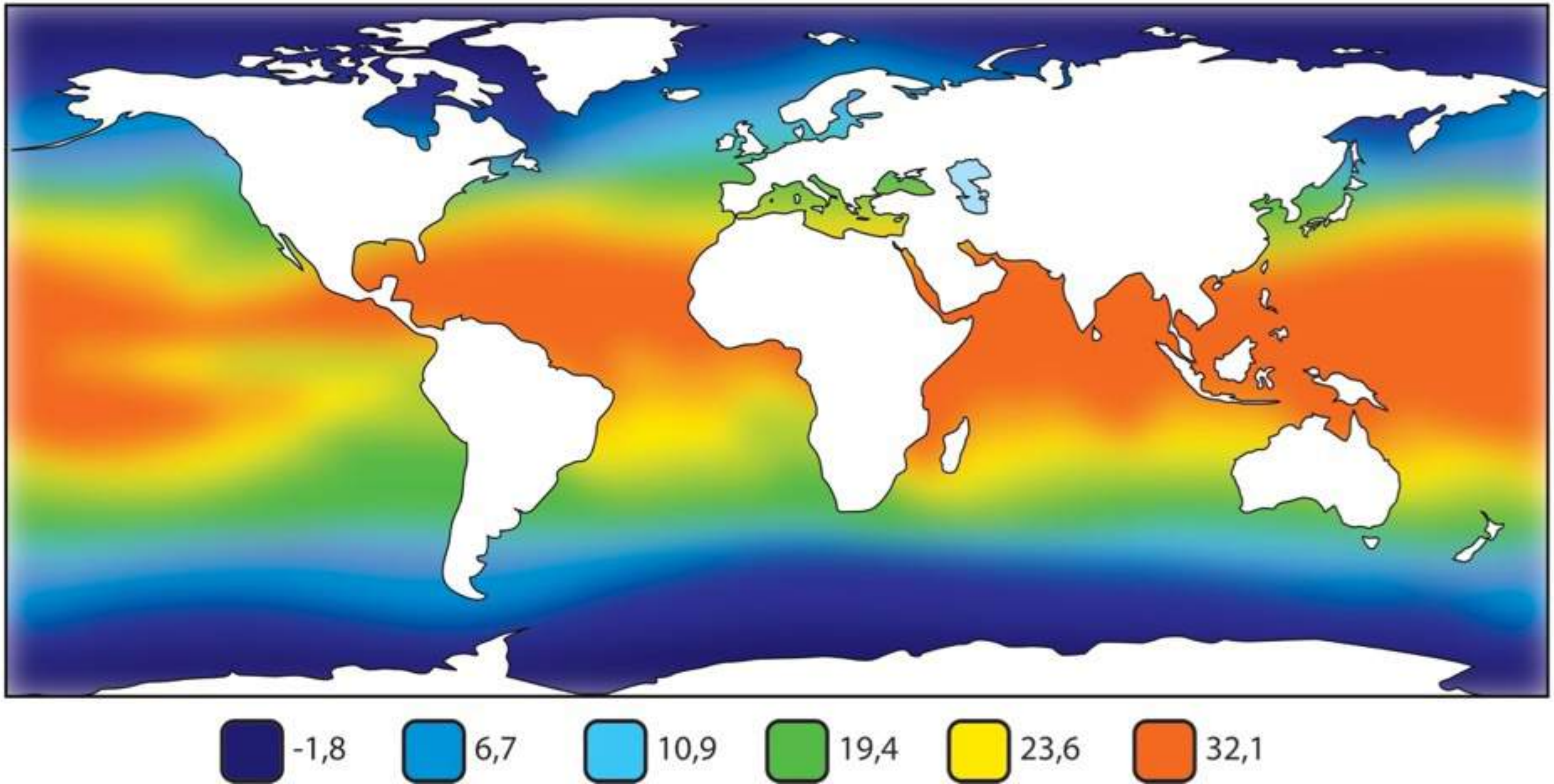
Plankton and Nekton



% of surface in the different zones

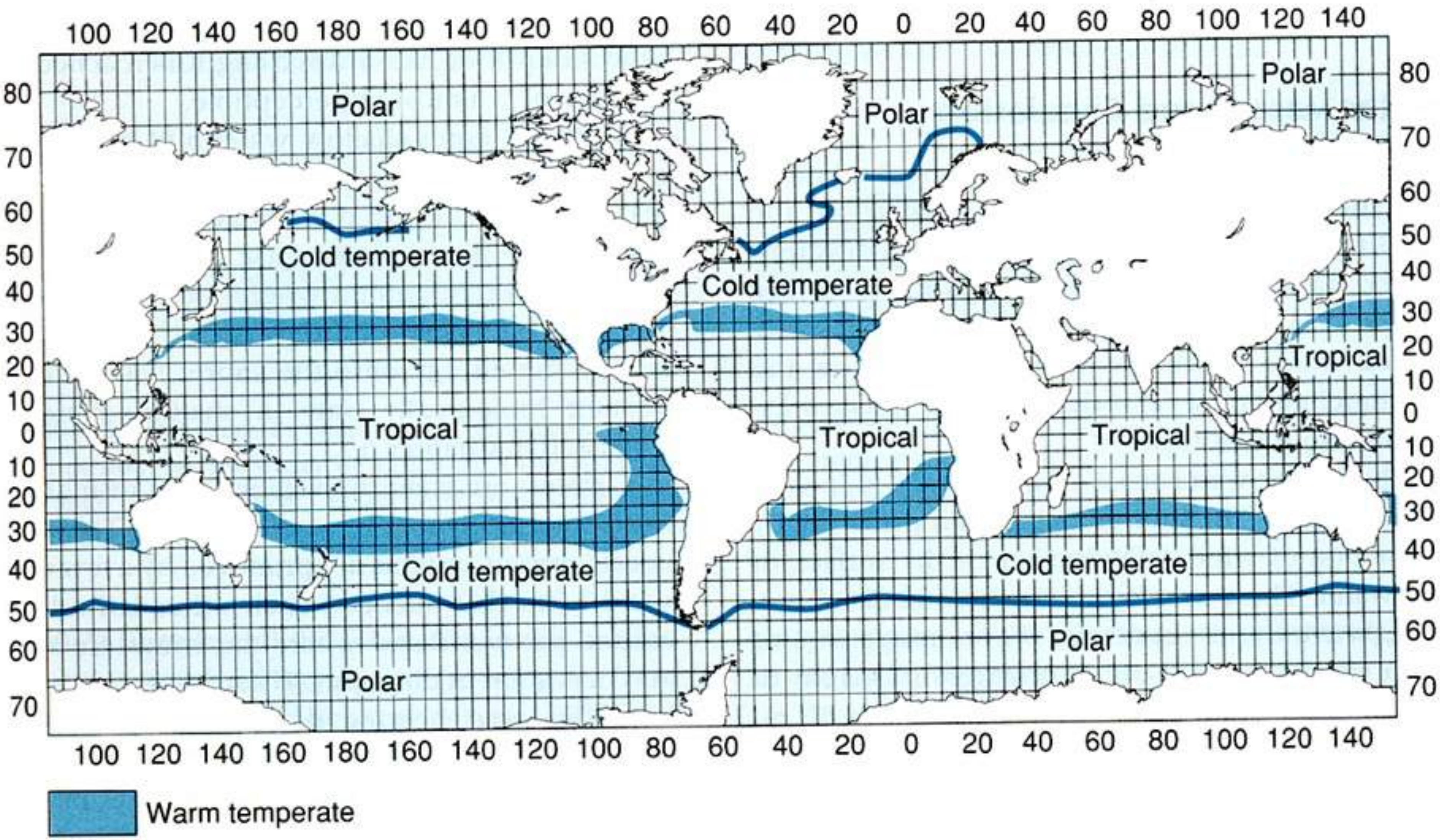


Temperature

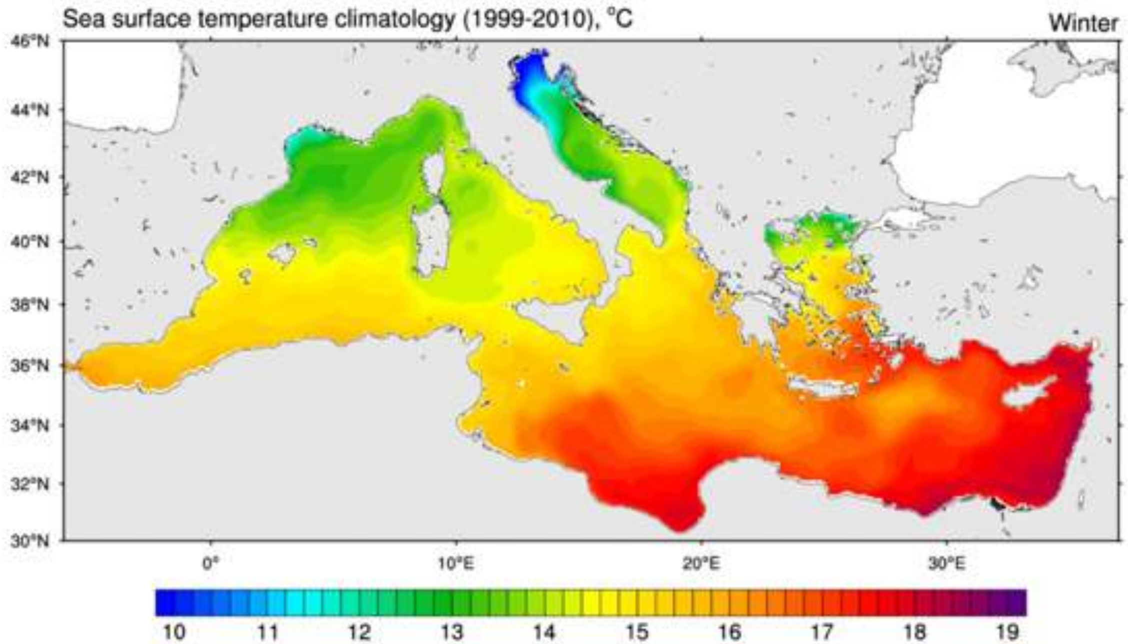


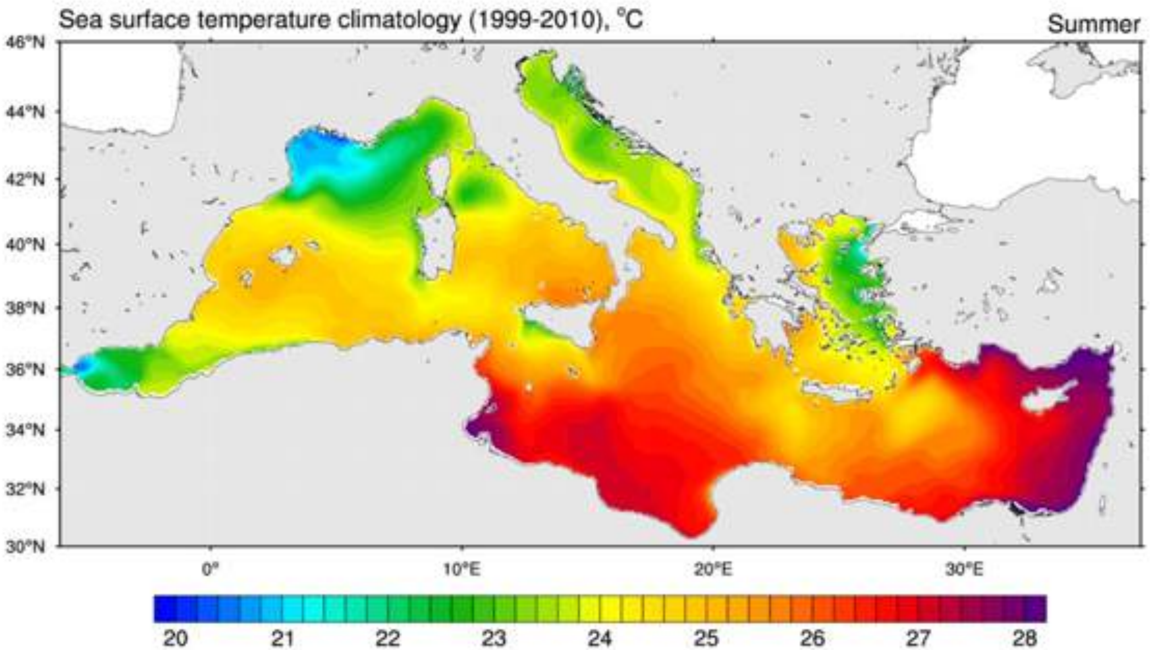
Average SST range from about – 2 ° C a the poles to 28 ° C in tropical areas. Seasonal variations in superficial water are typical of temperate areas and depend also on geomorphology and other characteristics of the basin

Temperature



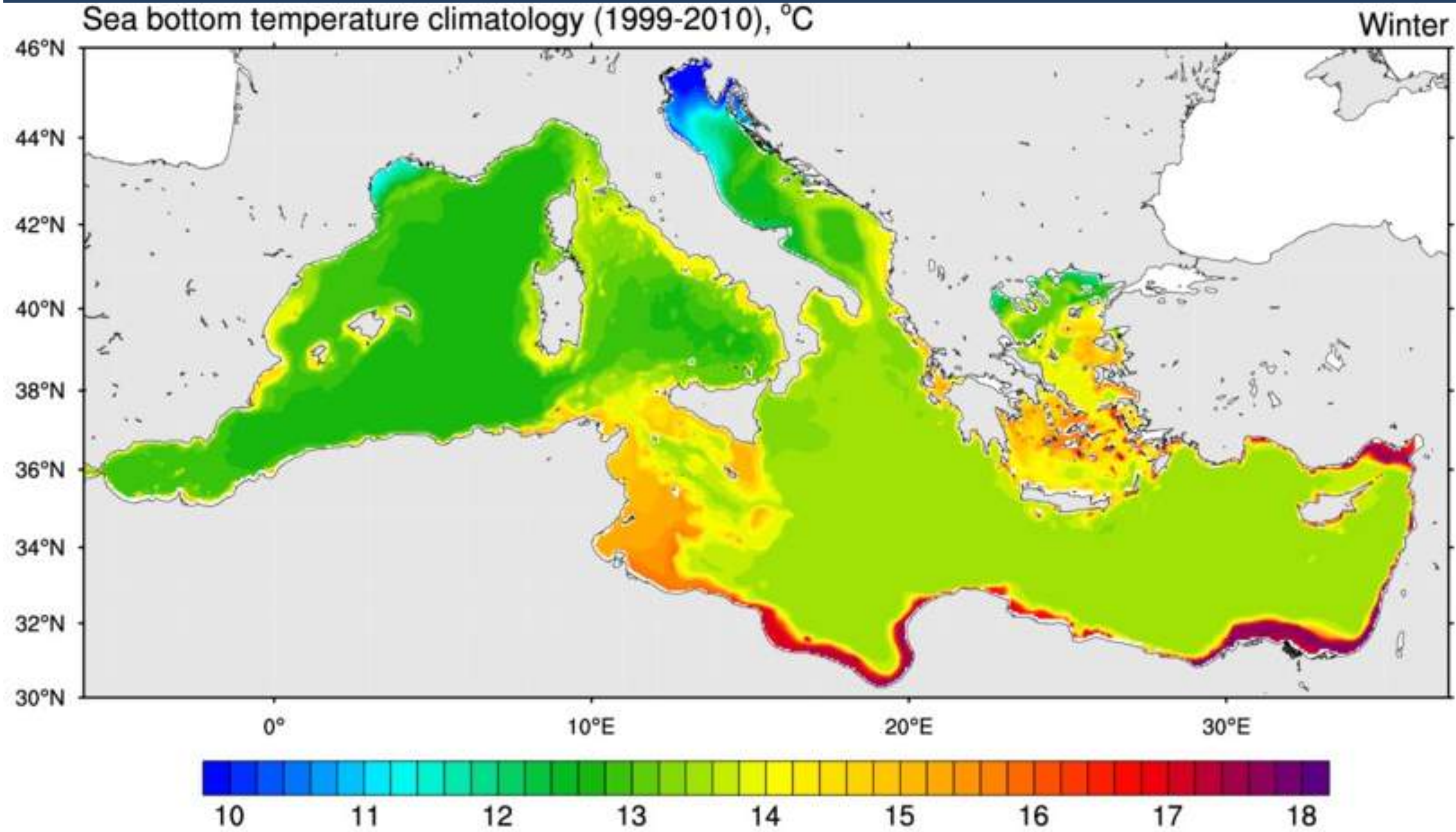
Temperature





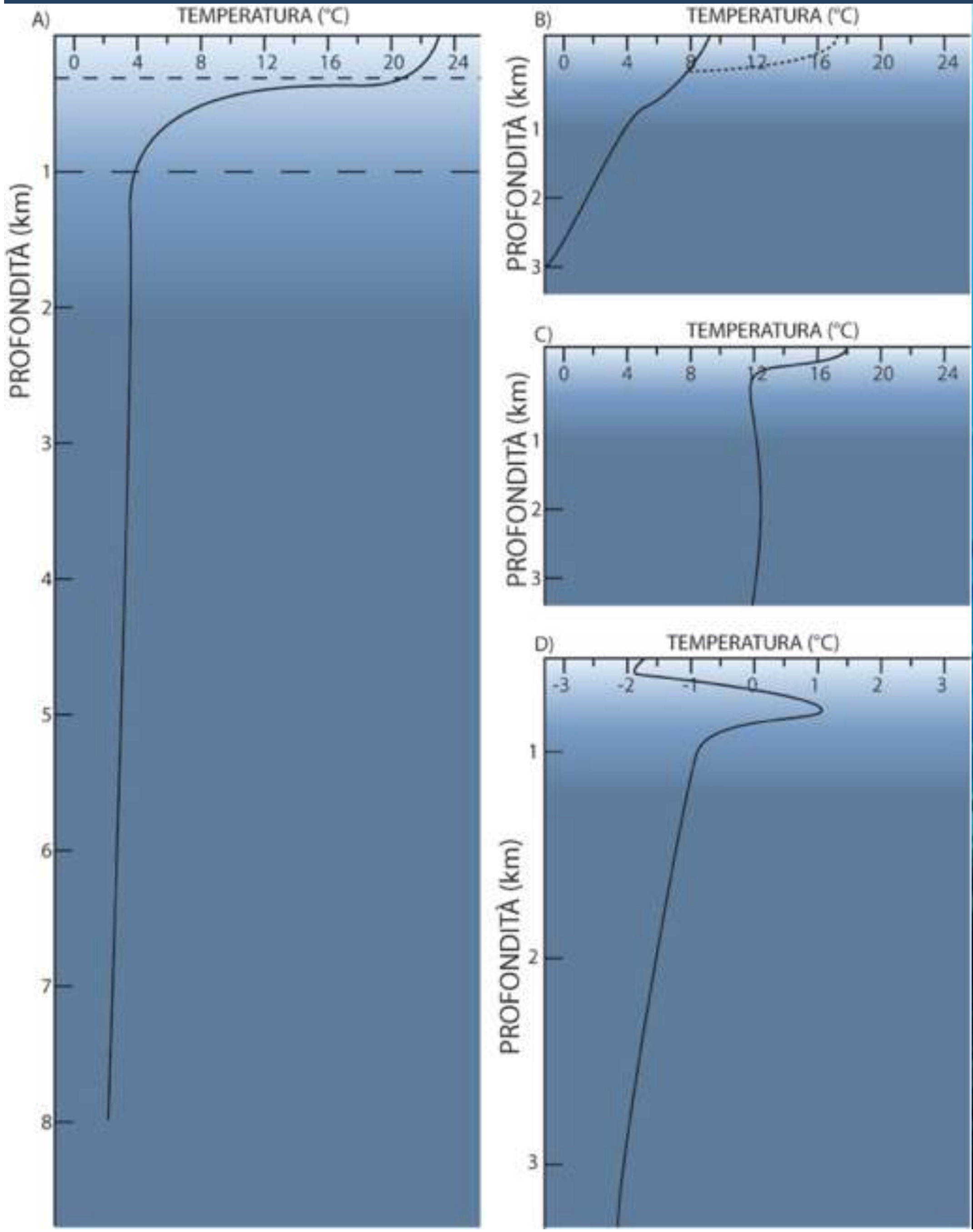
The Mediterranean Sea has a dual nature as far as temperature. It is close to a subtropical sea, in the southeast basin, and a temperate sea in the western basin. The seasonal variability in temperature, light availability and dissolved nutrient concentrations are similar to temperate seas, but the average values are closer to subtropical seas.

Temperature



Temperature of deep waters is constant and around 12° C

Thermocline

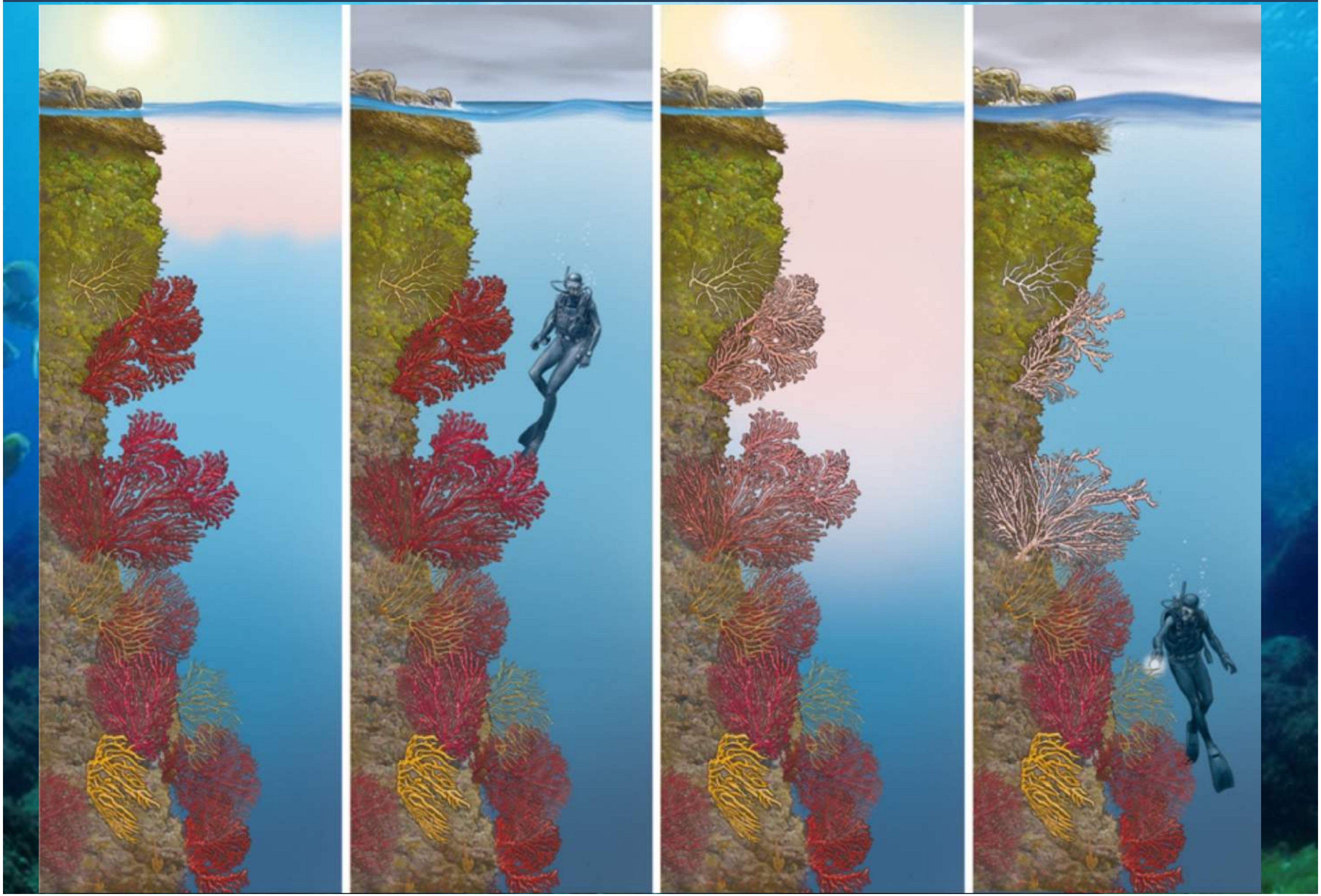


Thermocline is a water layer where a sharp variation of water temperature occurs (0.1 ° C or more each m depth).

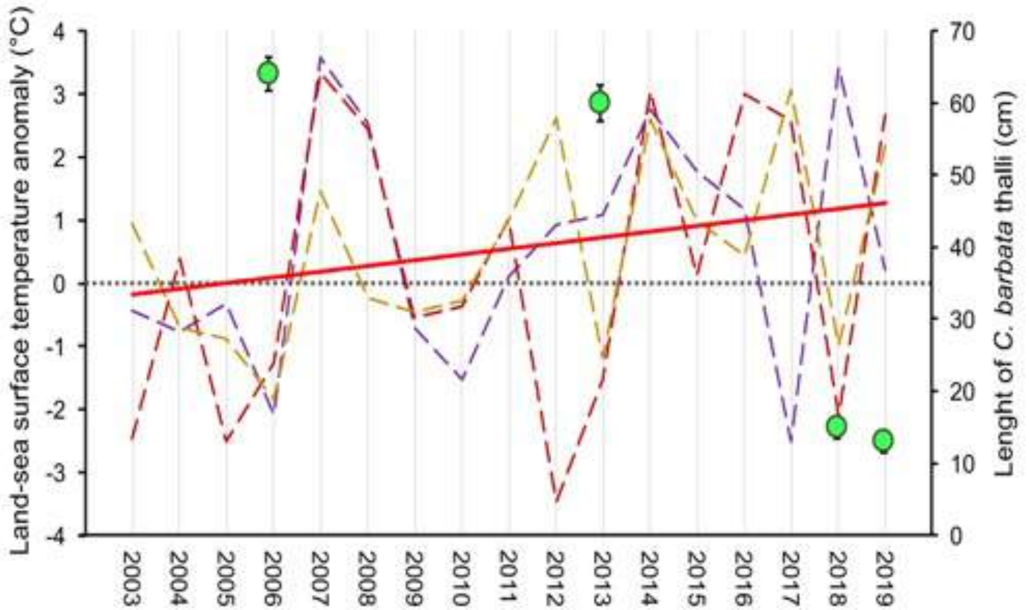
Thermocline pattern changes with latitude. At low latiitude, in tropical areas, the thermocline is stable all year round, at about 500 m depth (a, c).
In temperate seas and low latitudes, the thermocline is less sharp and deeper in the cold season, whereas in the warm season it becomes sharper and shallower. In the Mediterranean Sea, for example, it is at about 400 m depth in winter and at 15-40 m in summer.

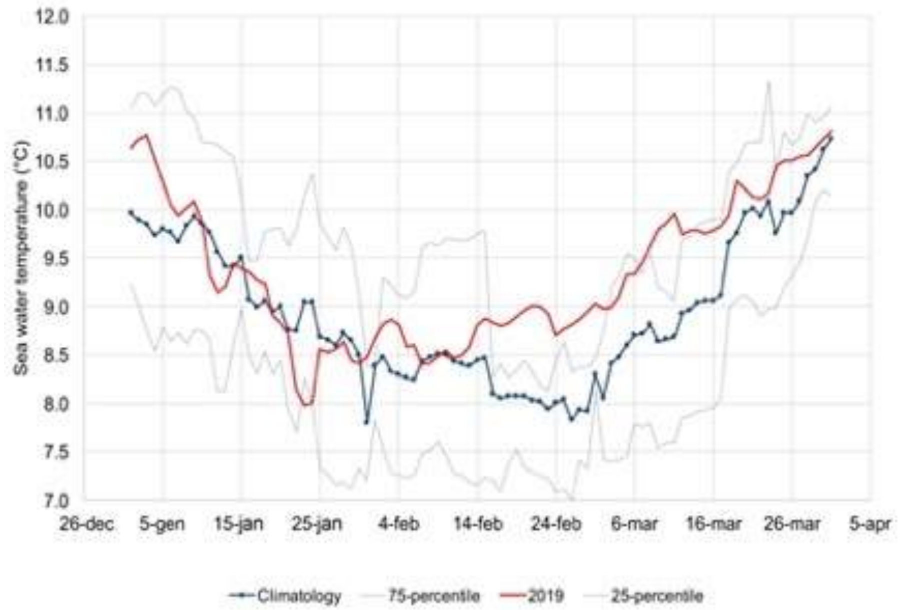
At high latitudes, the thermocline could be inverted or there could be two thermoclines, due to different layers (d).

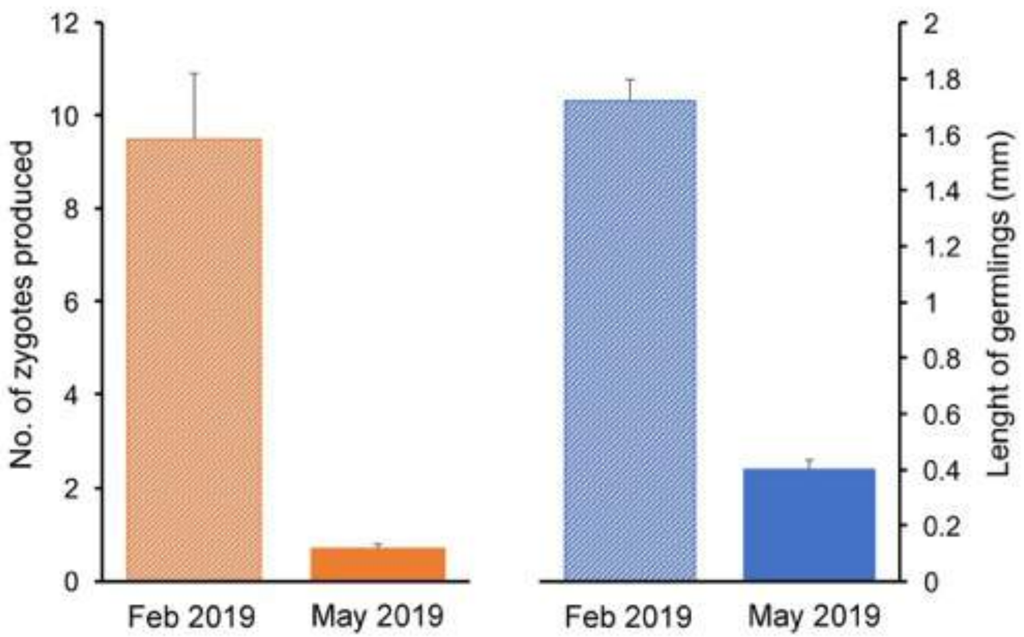
Thermal anomalies and mass mortalities



Marine heat waves





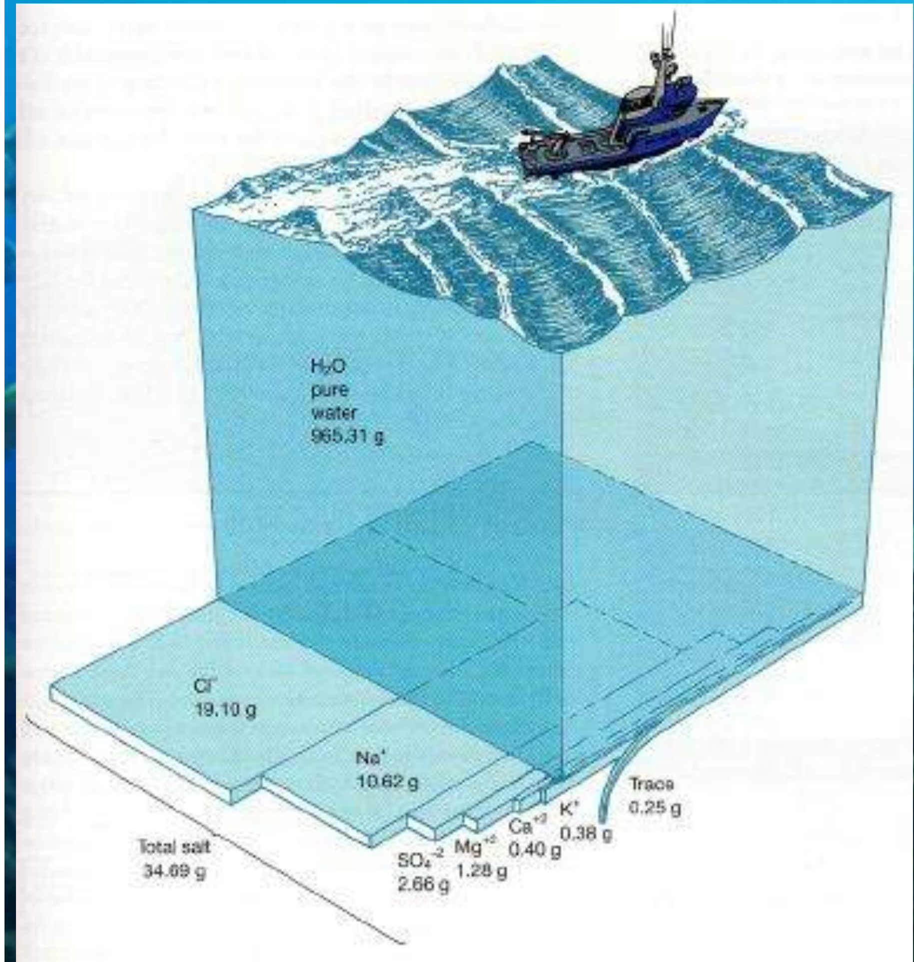


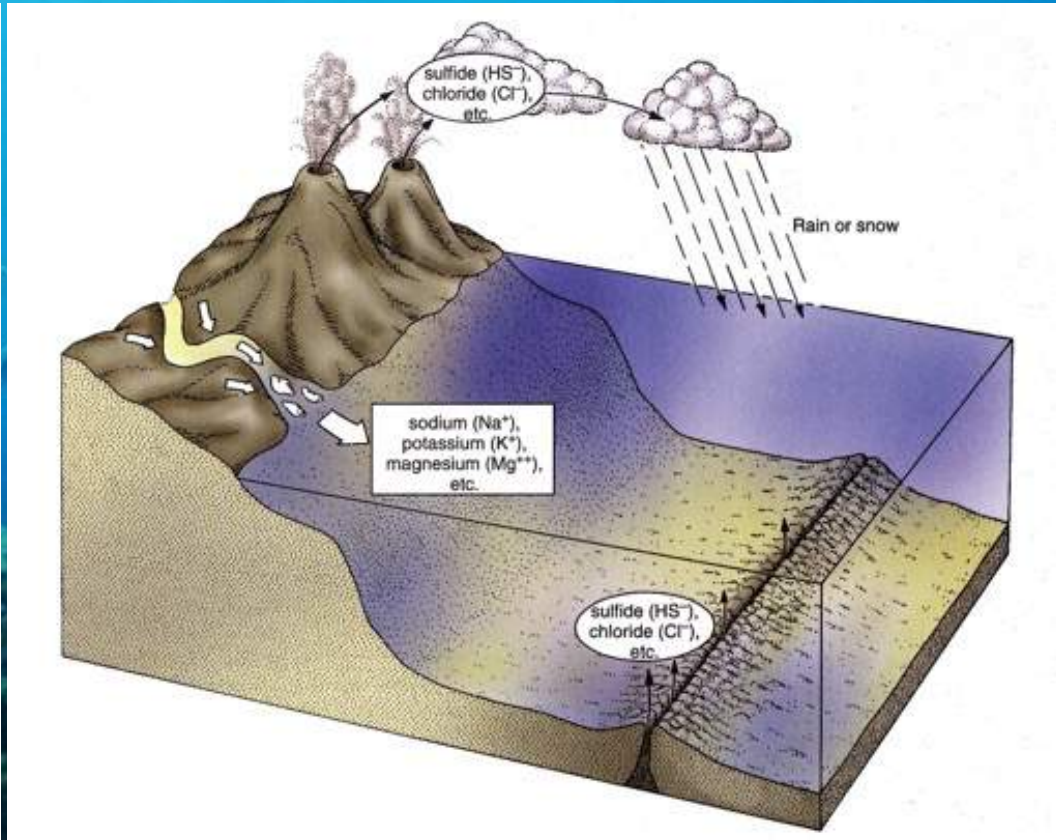
Salinity

Average salinity: 35‰ (0.5-40 ‰)

Freshwater inputs, evaporation, morphology, depth determine the salinity range

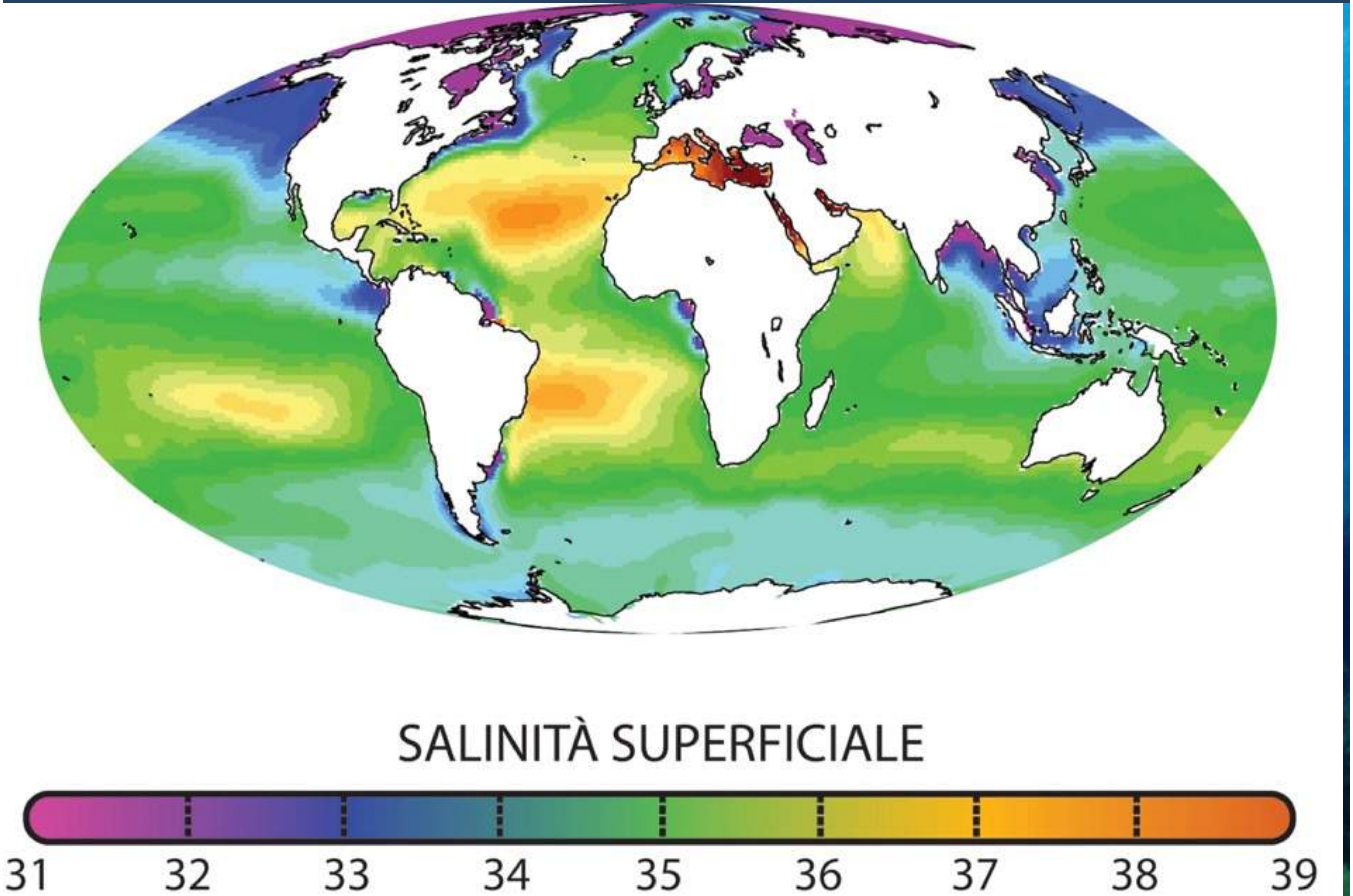
Elements derive from erosion on mainland, rivers transport and volcanic activity





Sodium chloride, magnesium chloride, magnesium, calcium and potassium sulfate, calcium carbonate

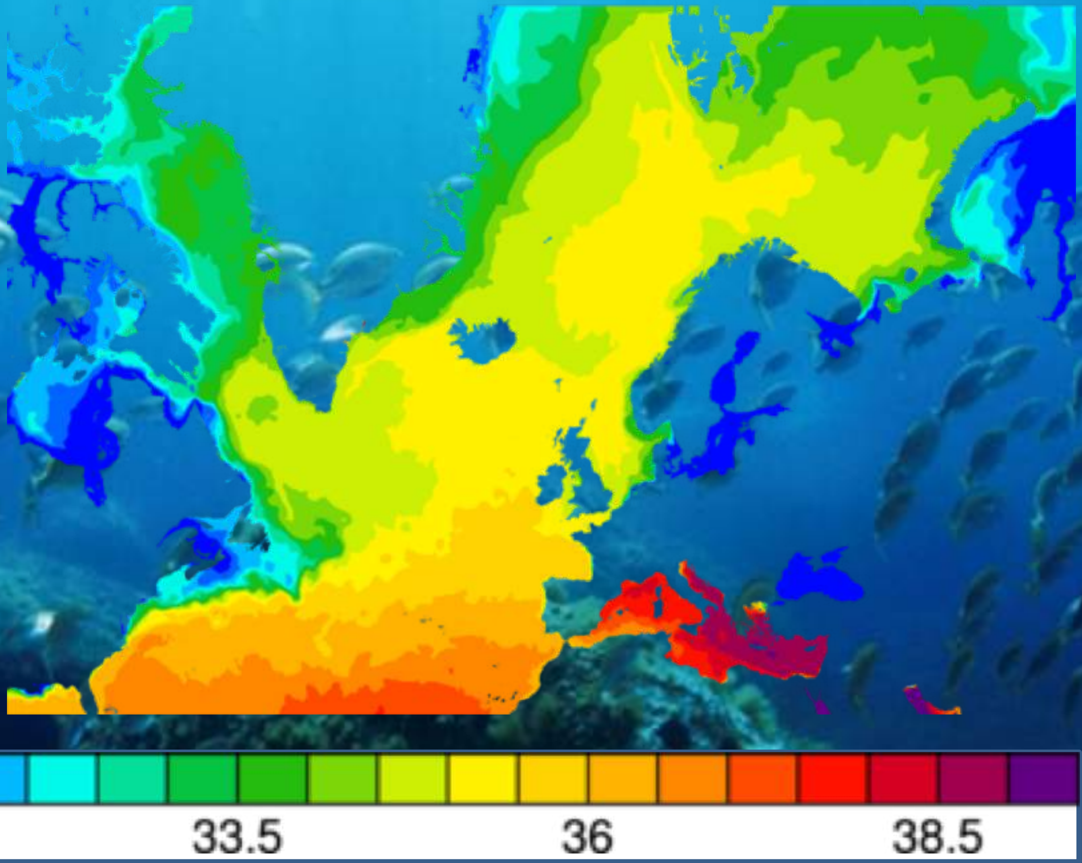
Salinity: global average



Salinity: N Atlantic

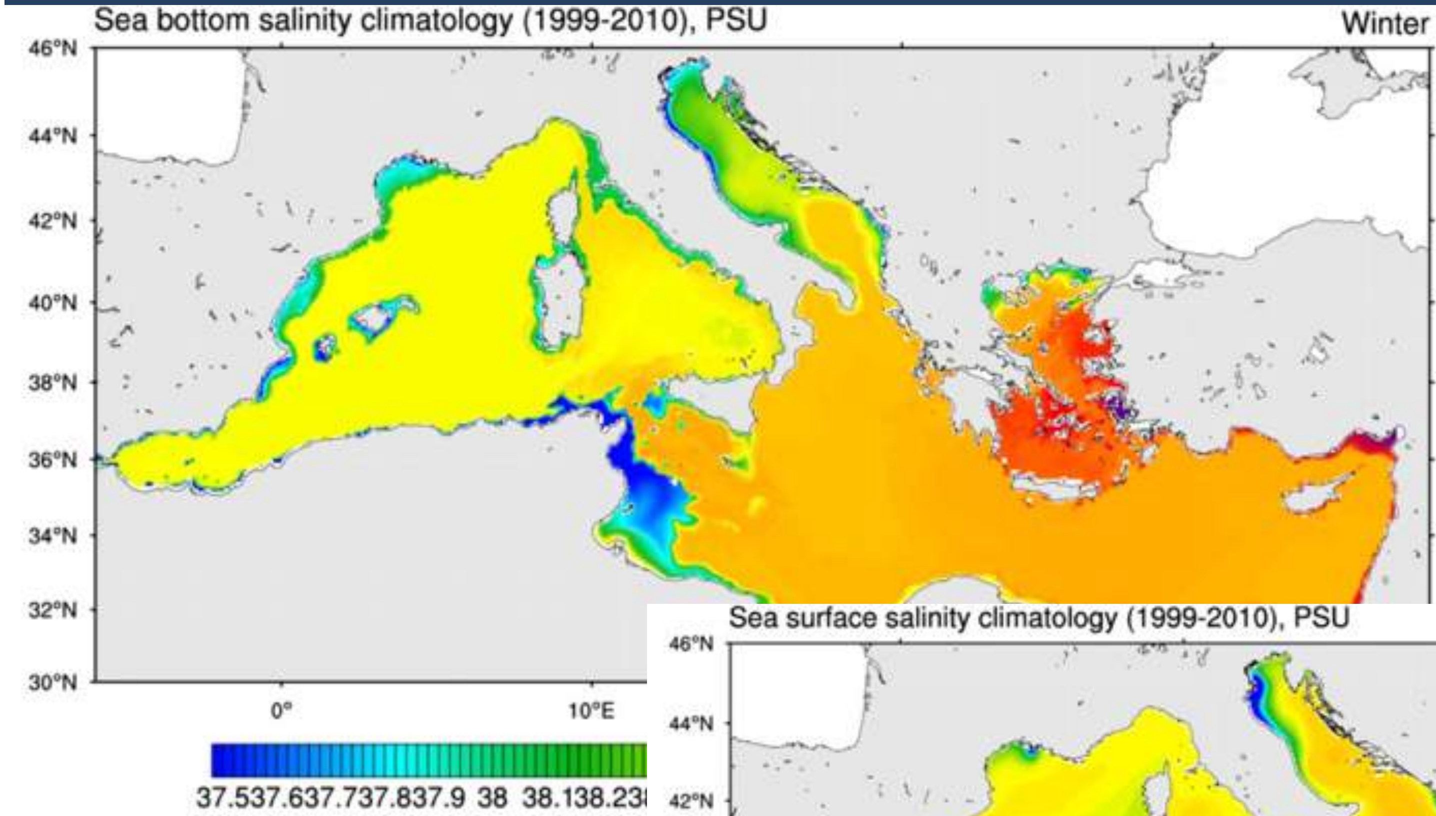
European Commission

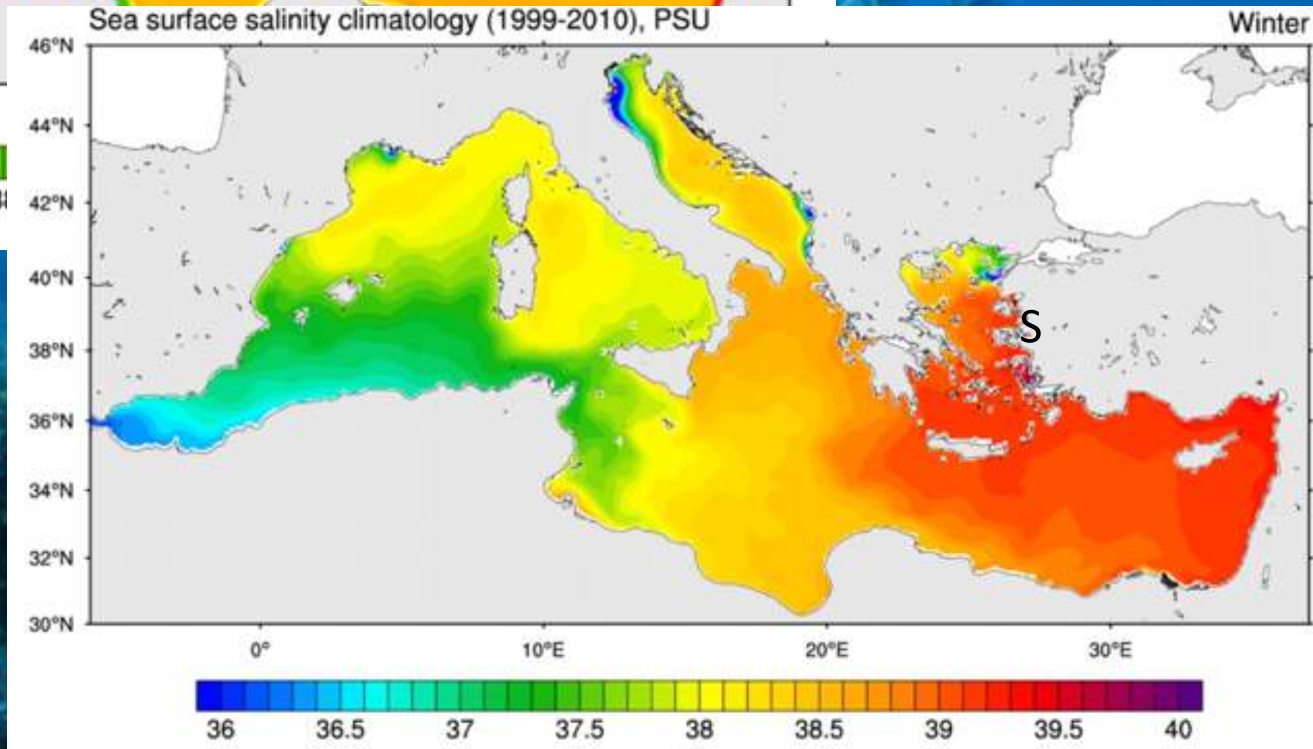
North Atlantic: sea-surface salinity - Autumn 2012 (PSU)



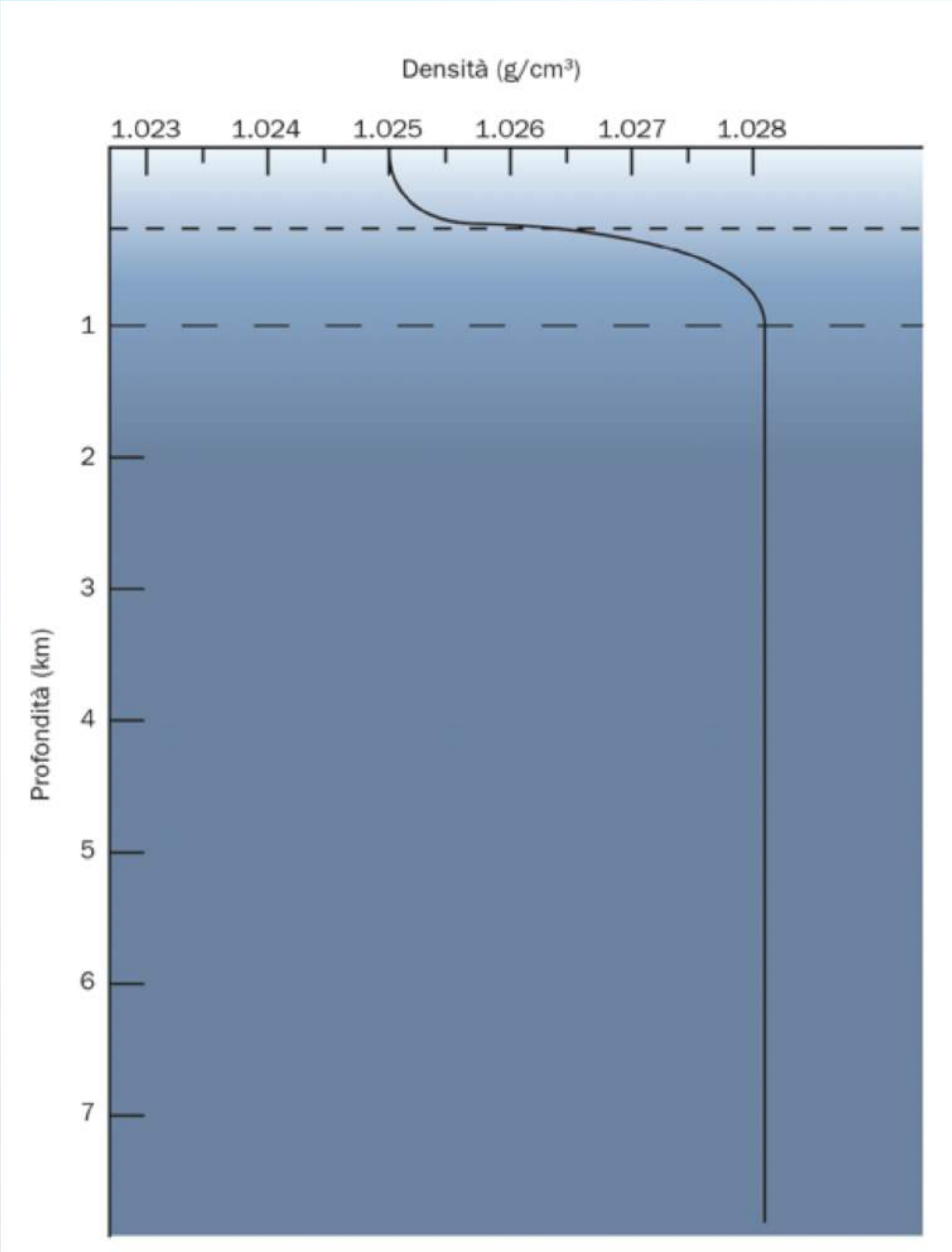
Note in dark blue areas (below 31) salinity values can equate to anything between 0-31psu

The Mediterranean Sea





Density



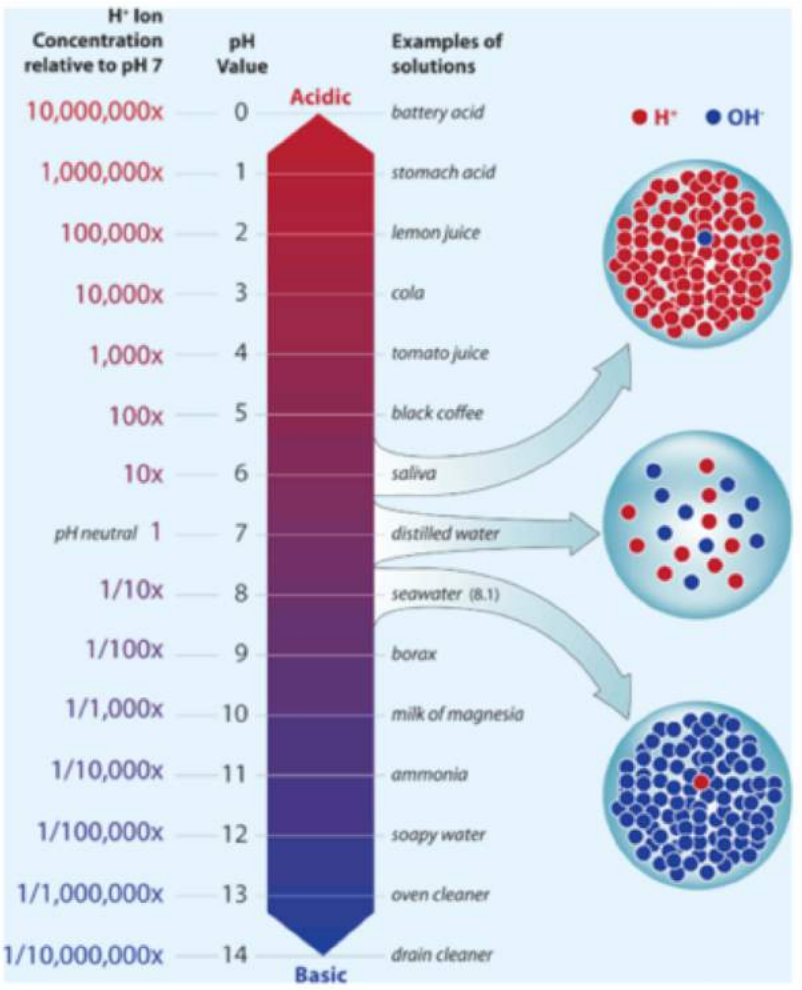
Density changes depending on temperature, pressure, and salinity.

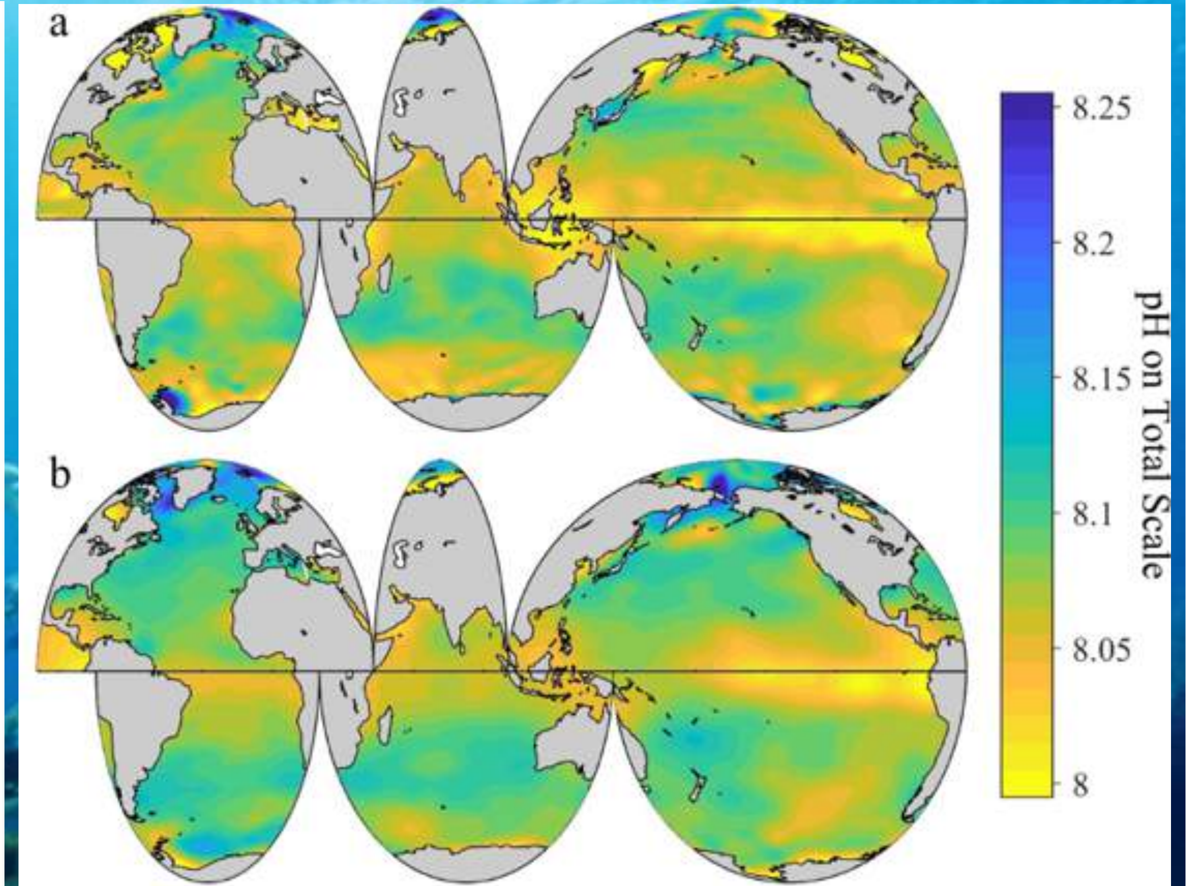
Warm waters are less dense than cold waters.
Increased salinity increases sea water density

The contribution of temperature to density is stronger than that one of salinity

Genereally, superficial waters are less dense than deep waters. Density increases with depth until the *pycnocline* and then becomes more stable and virtually constant at increasing depth.

pH



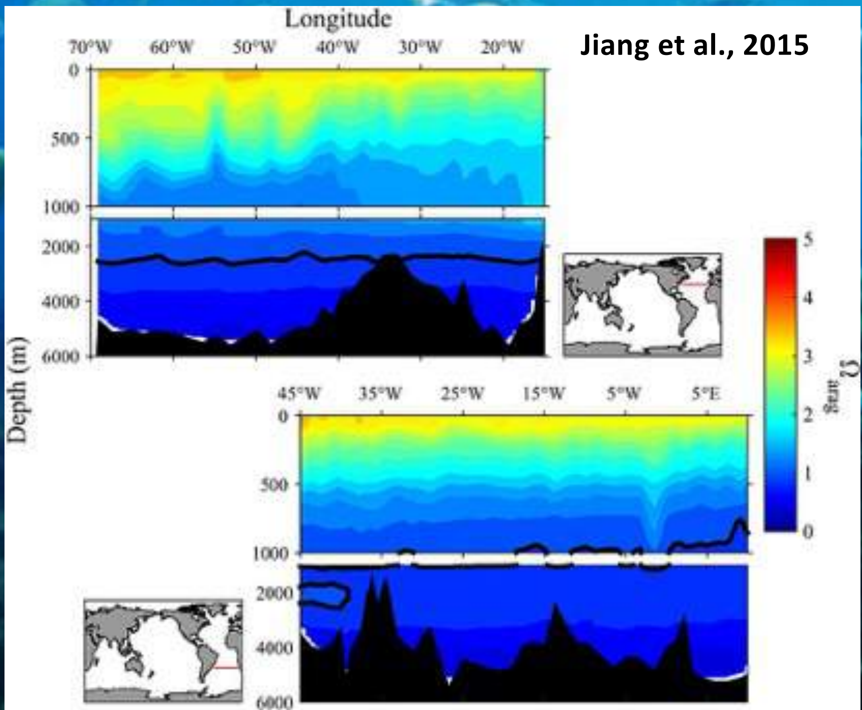


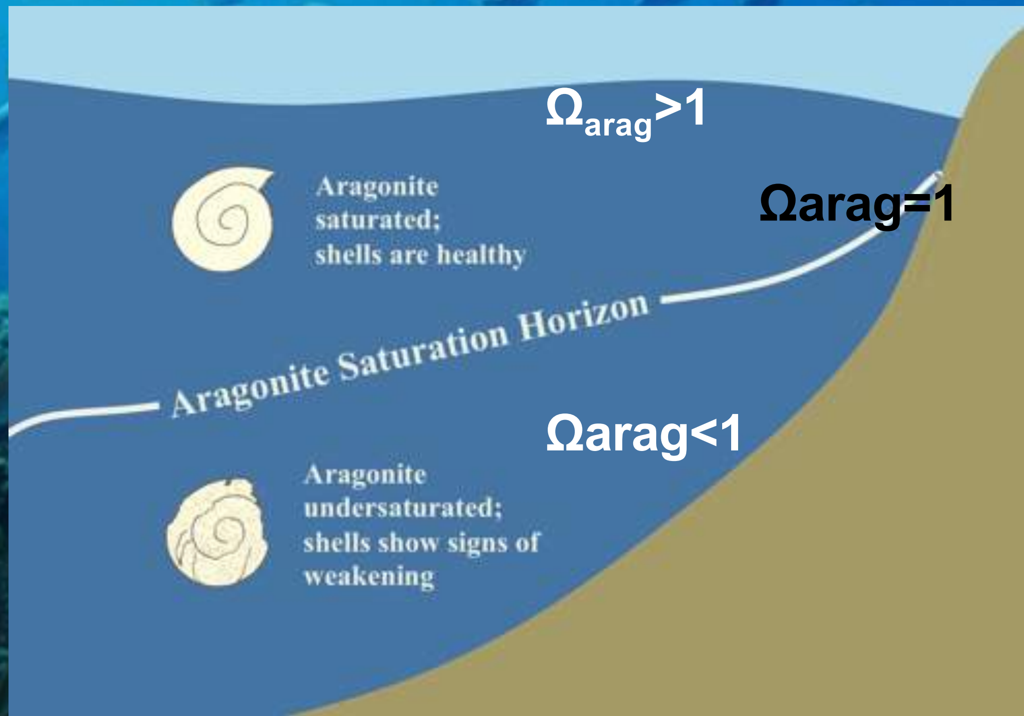
Average pH = 8.1

Mostly depend on CO_2 diffusion in seawater (where it is 15% of dissolved gases).Changes in pH could strongly affect marine organisms

pH

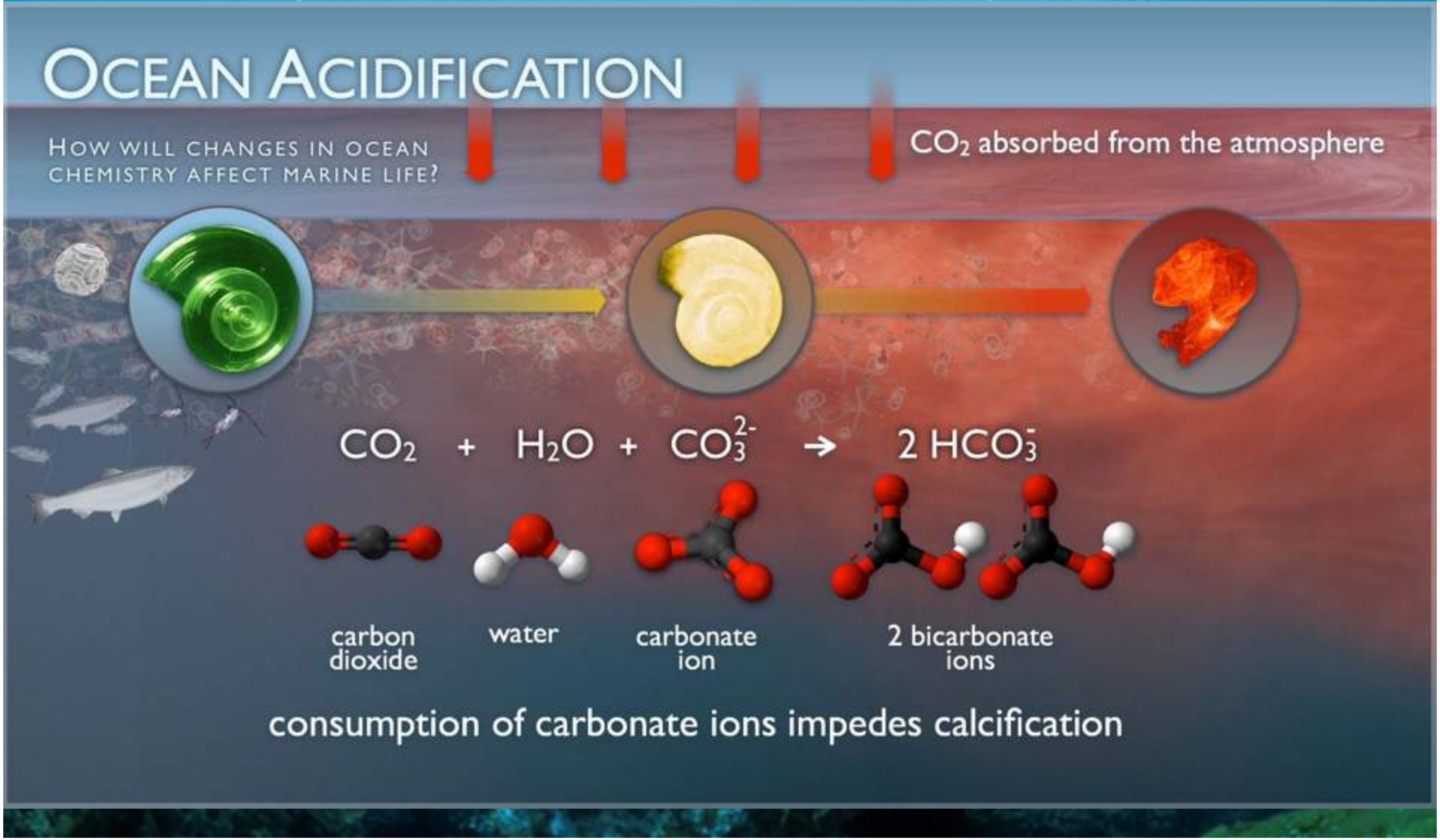
Aragonite and calcite are the two cristalline forms of calcium carbonate, used by most of marine organisms with calcified structures (corals, molluscs, crustaceans, coralline algae, etc.). Ω_{arag} was highest in the surface mixed layer. Higher hydrostatic pressure, lower water temperature, and more CO_2 buildup from biological activity in the absence of air-sea gas exchange helped maintain lower Ω_{arag} in the deep ocean.





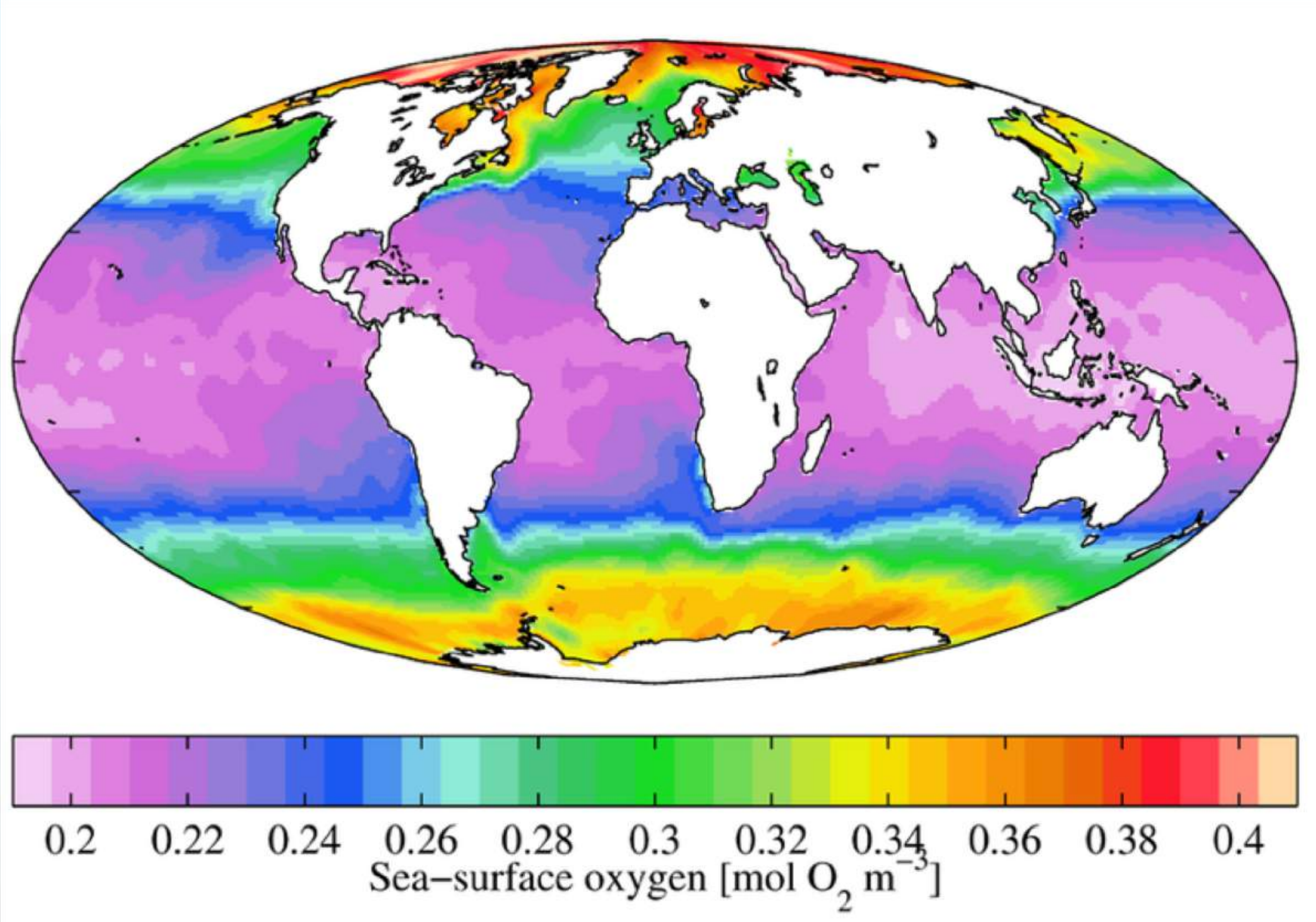
pH

Oceans absorb about one third of atmospheric CO_2. So, increasing level of carbon dioxide in the air results in increasing levels in sea water. **This lead to increase in carbonic acid, and H^+ ions that decrease ocean pH, which is generally slightly basi**c.



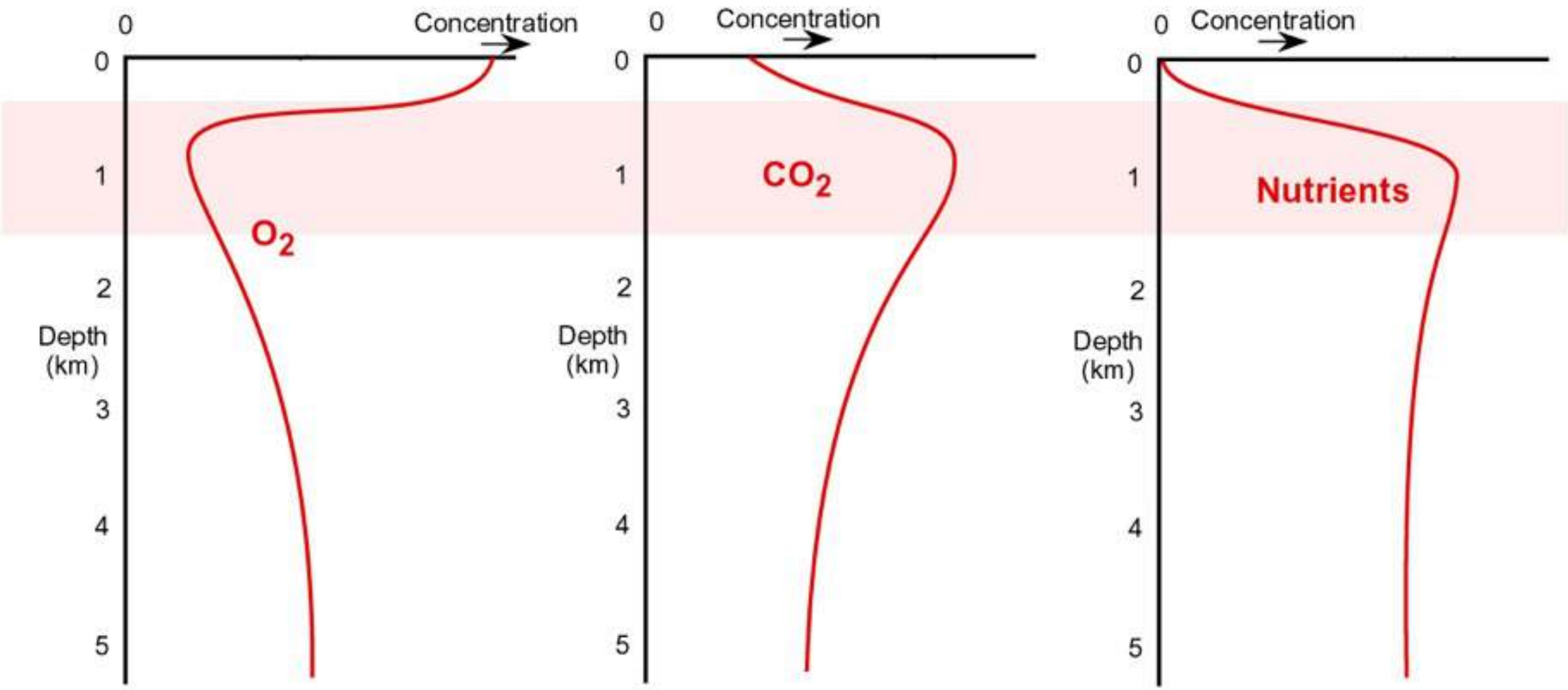
Oxygen

Absent on Earth 4 billions years ago
On Earth constant concentration (21%)
In seawater variable concentration, from 0 to 8 ml/l)



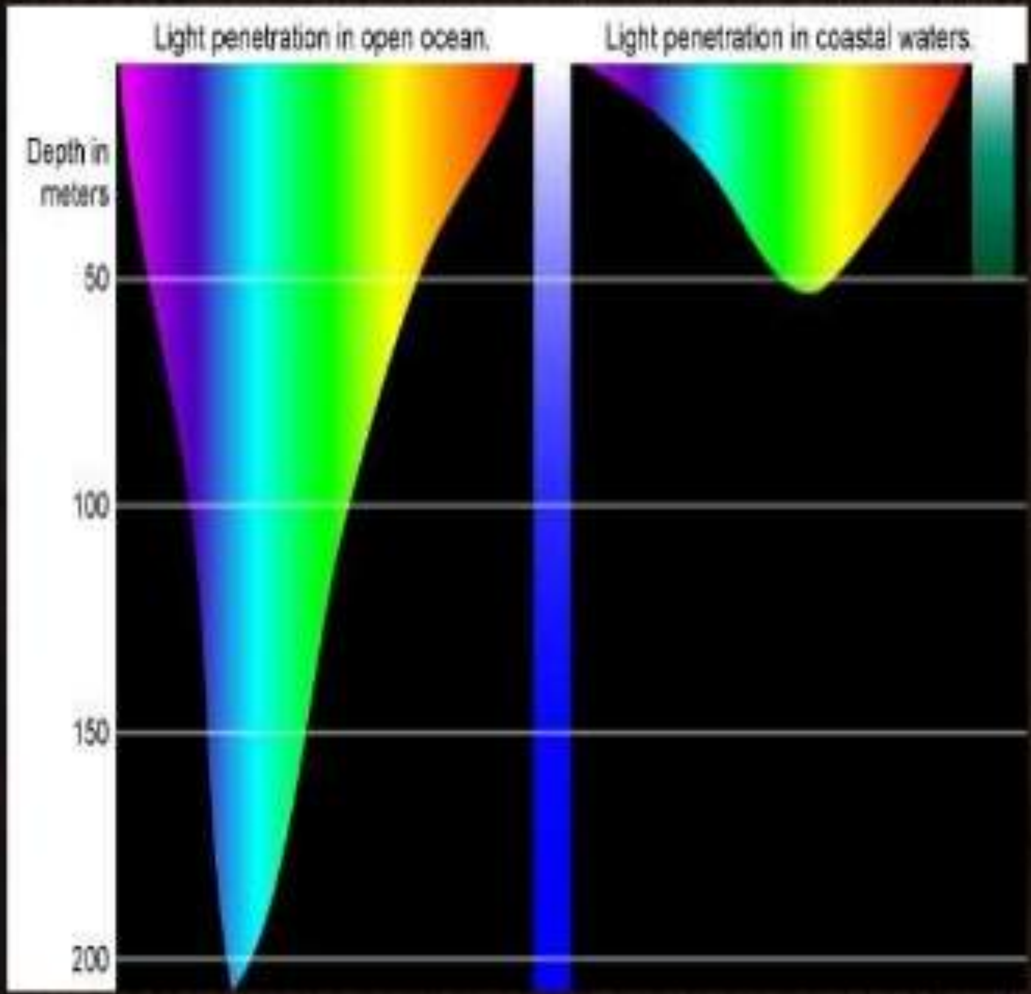
Main environmental features

In the photic zones oxygen is produced by macroalgae and plants, that consume carbon dioxide and nutrients. O_2 decreases with depth due to decline of photosynthetic activity and oxidation of organic matter, whereas CO_2 and nutrients increase due to respiration and increased solubility (high P and low T). Min of O_2 and max of CO_2 and nutrients is achieved at about 1000 m. Below this threshold, nutrients remain stable, O_2 slightly increases due to oxygenation from the surface through currents, and CO_2 slightly decreases due to reduced respiration rates (rarefaction of organisms)



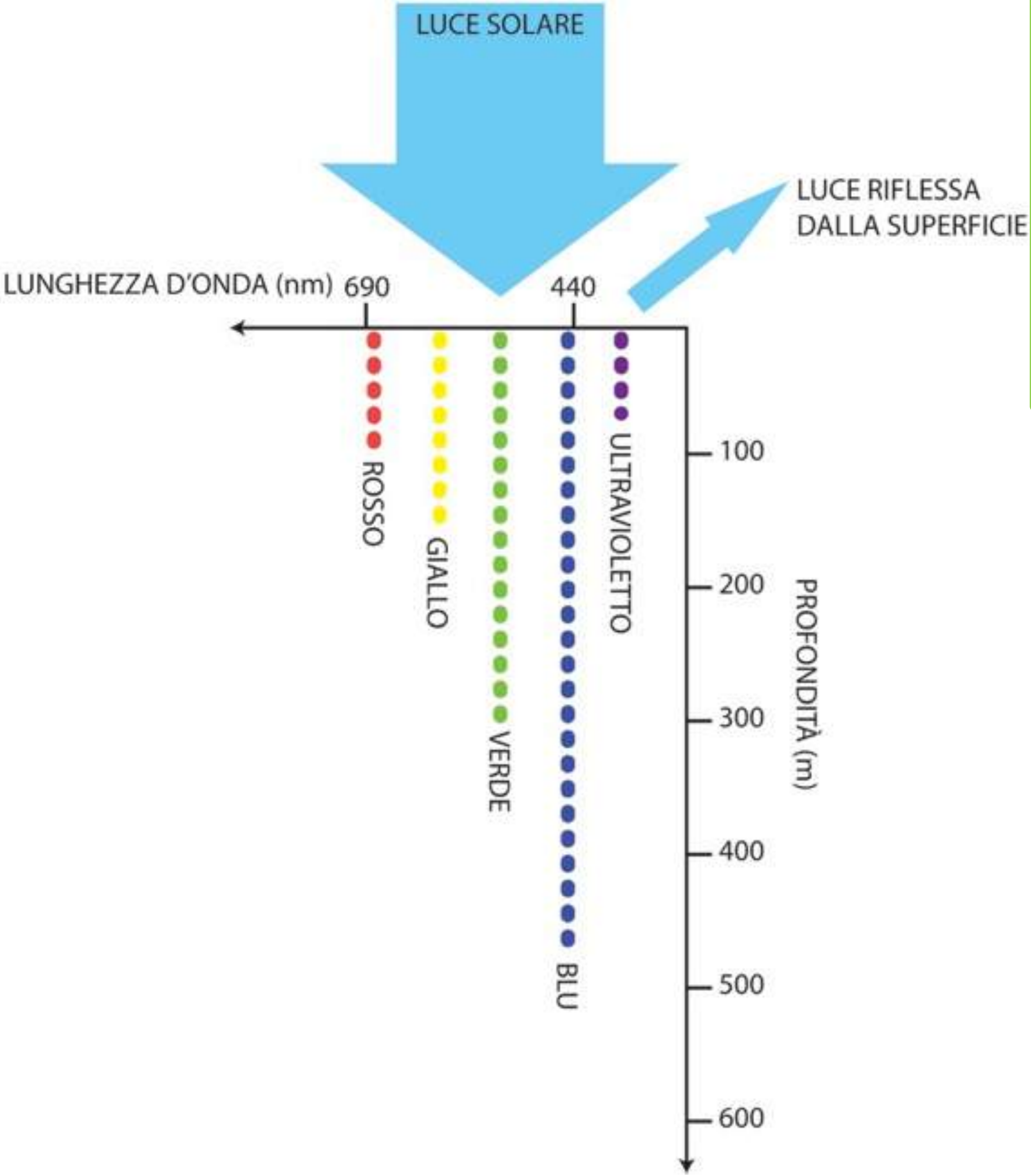
Light

Visible light penetration



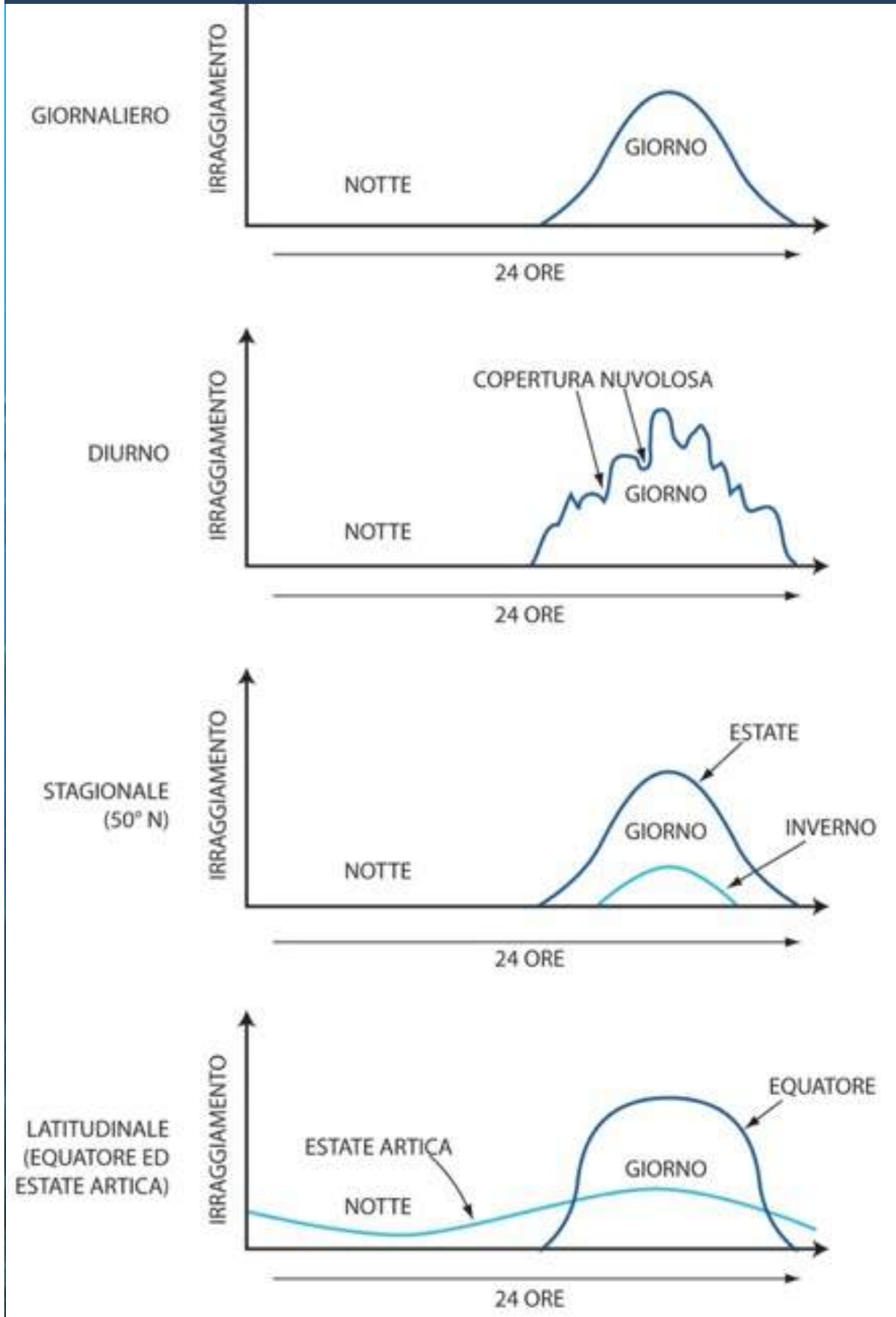
Visible light penetrates into the ocean, but once past the sea surface, light is rapidly weakened by scattering and absorption (coastal water). The more particles that are in the water, the more the light is scattered. This means that light travels farther in clear water (open ocean).

Light

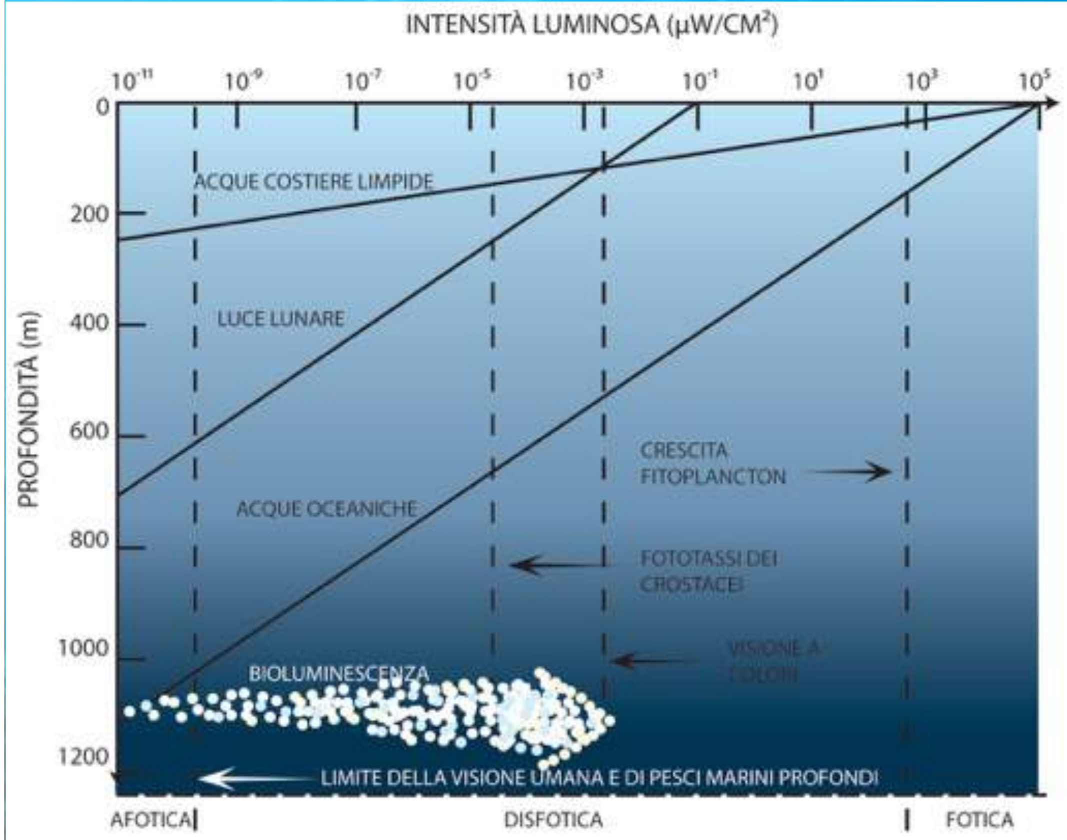


LUCE SOLARE
LUCE RIFLESSA
DALLA SUPERFICIE
LUNGHEZZA D'ONDA (nm)
690
440
ROSSO
GIALLO
VERDE
BLU
ULTRAVIOLETTO
100
200
300
400
500
600
PROFONDITÀ (m)

Light

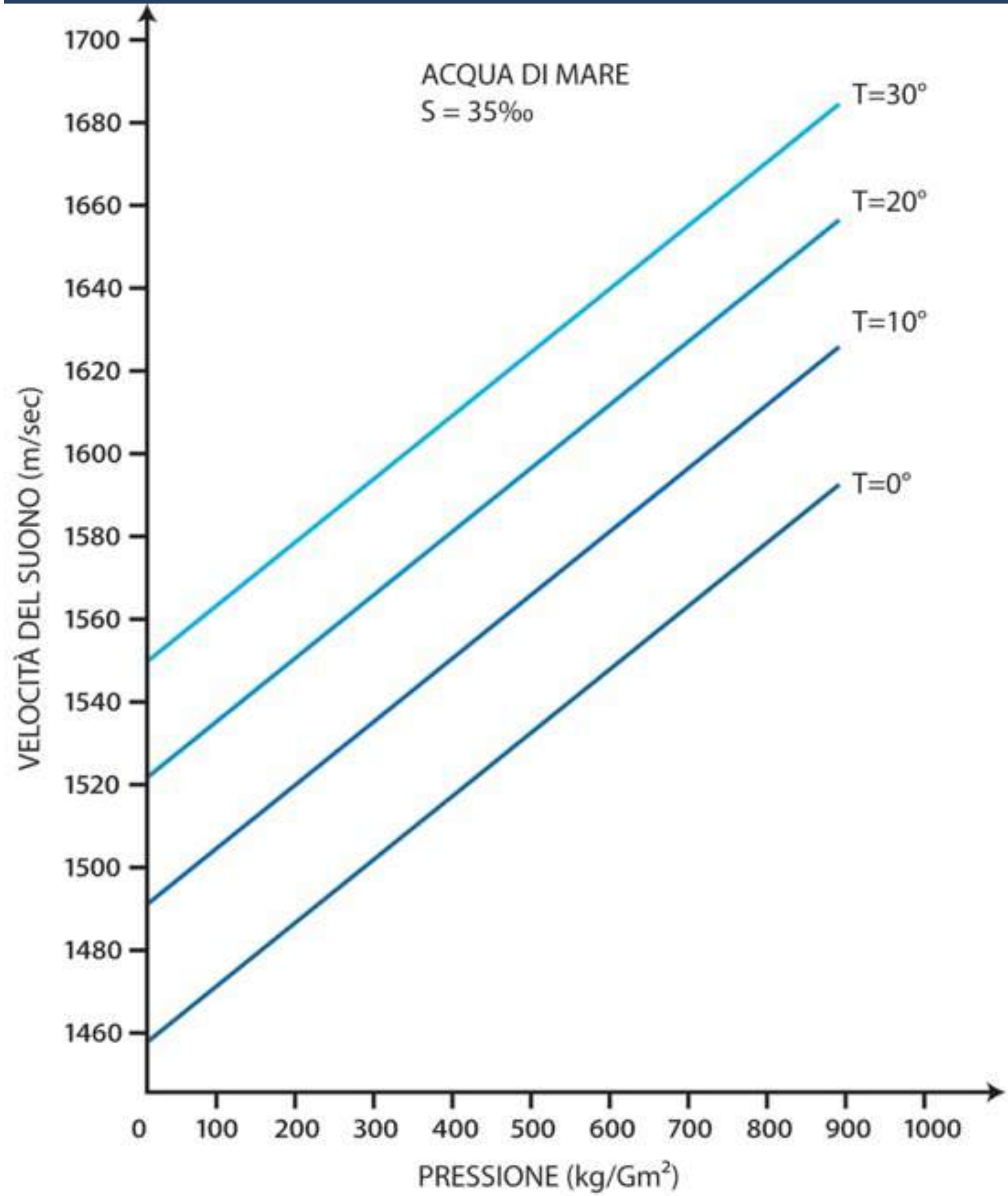


Light varies during the day and with seasons in temperate areas.



Light intensity decrease with depth: (in open waters) photic zone (0-200 m), disphotic (200-1000 m), aphotic zone (below 1000 m).
Primary photosynthetic production occurs only in the photic zone.

Sound



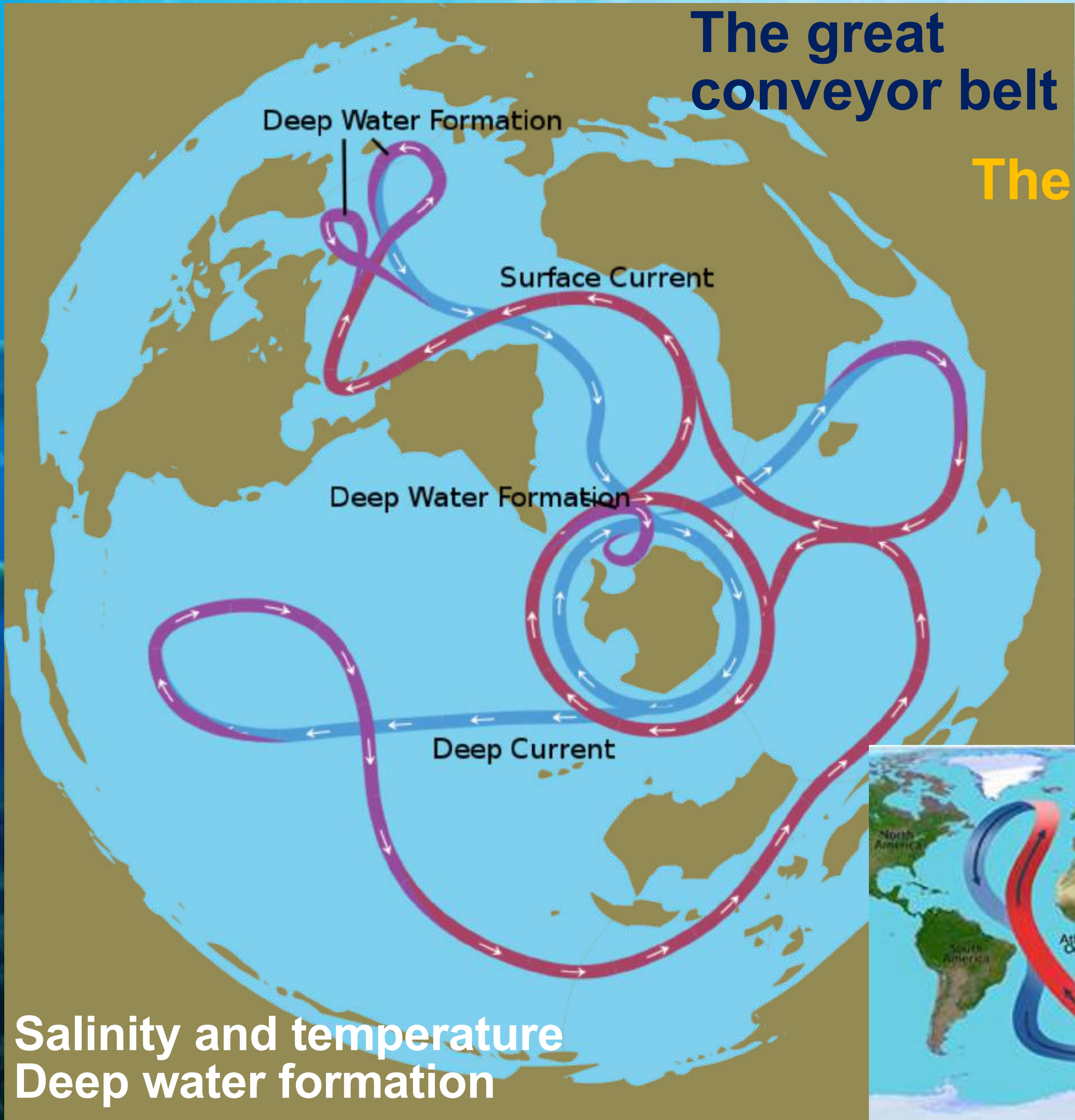
Sound propagate more quickly in water than in the air (340 ms^{-1}). Typically, sound speed in the sea water is around 1500 ms^{-1}

Sound speed increase with temperature, pressure (depth) and also salinity

Sound is crucial for marine organisms, more than one could imagine, since it is involved in their communication, predation, mating and many other aspects of their life

Deep sea circulation

The great conveyor belt



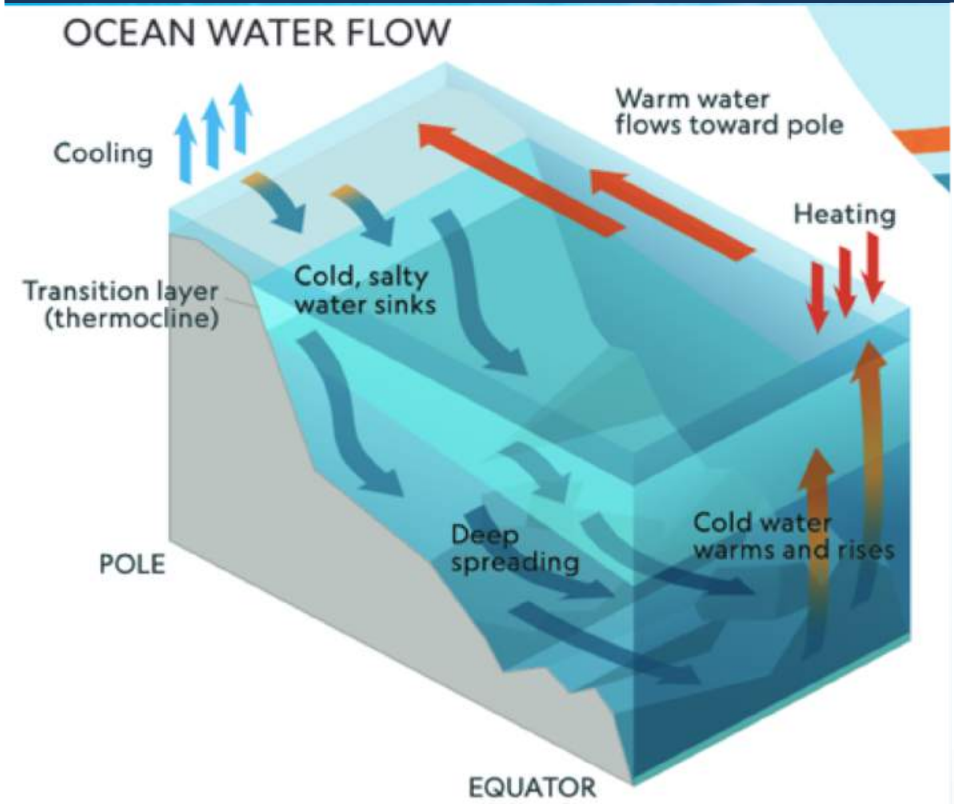
Thermohaline circulation

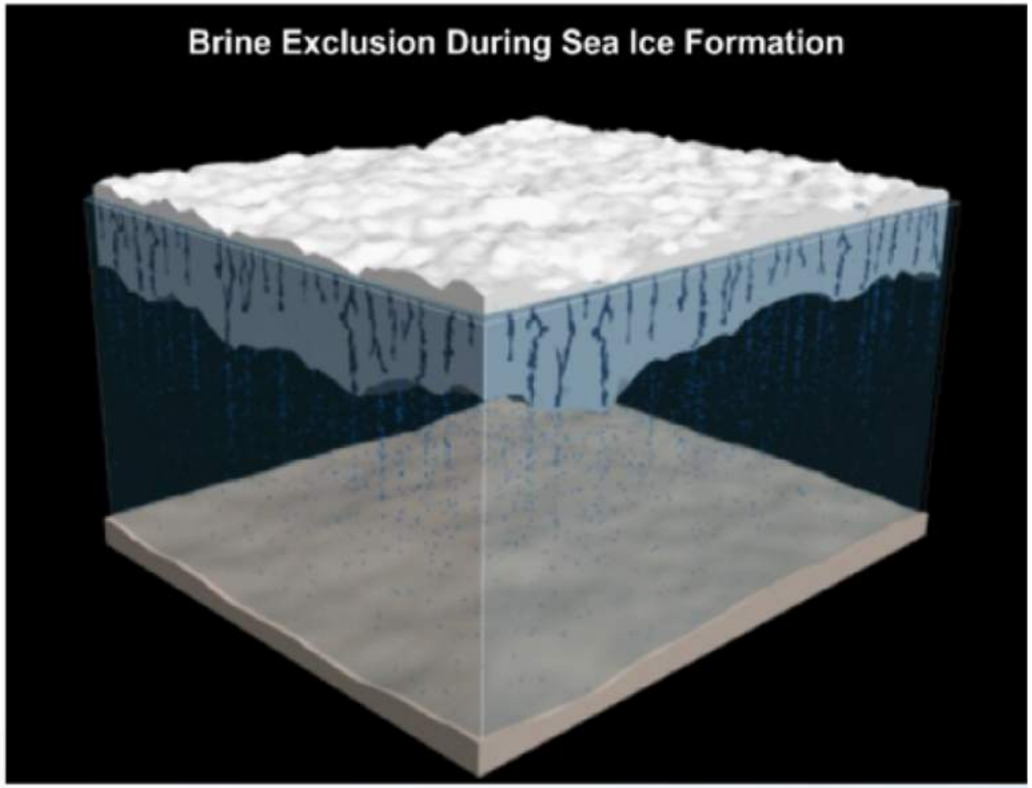
(few cm s^{-1})

In the Atlantic ocean higher mixing between the surface and the deep waters with respect to the Pacific Ocean, where deep water formation lacks. This lead to lower oxigenation and exchange

Salinity and temperature
Deep water formation

Deep water formation



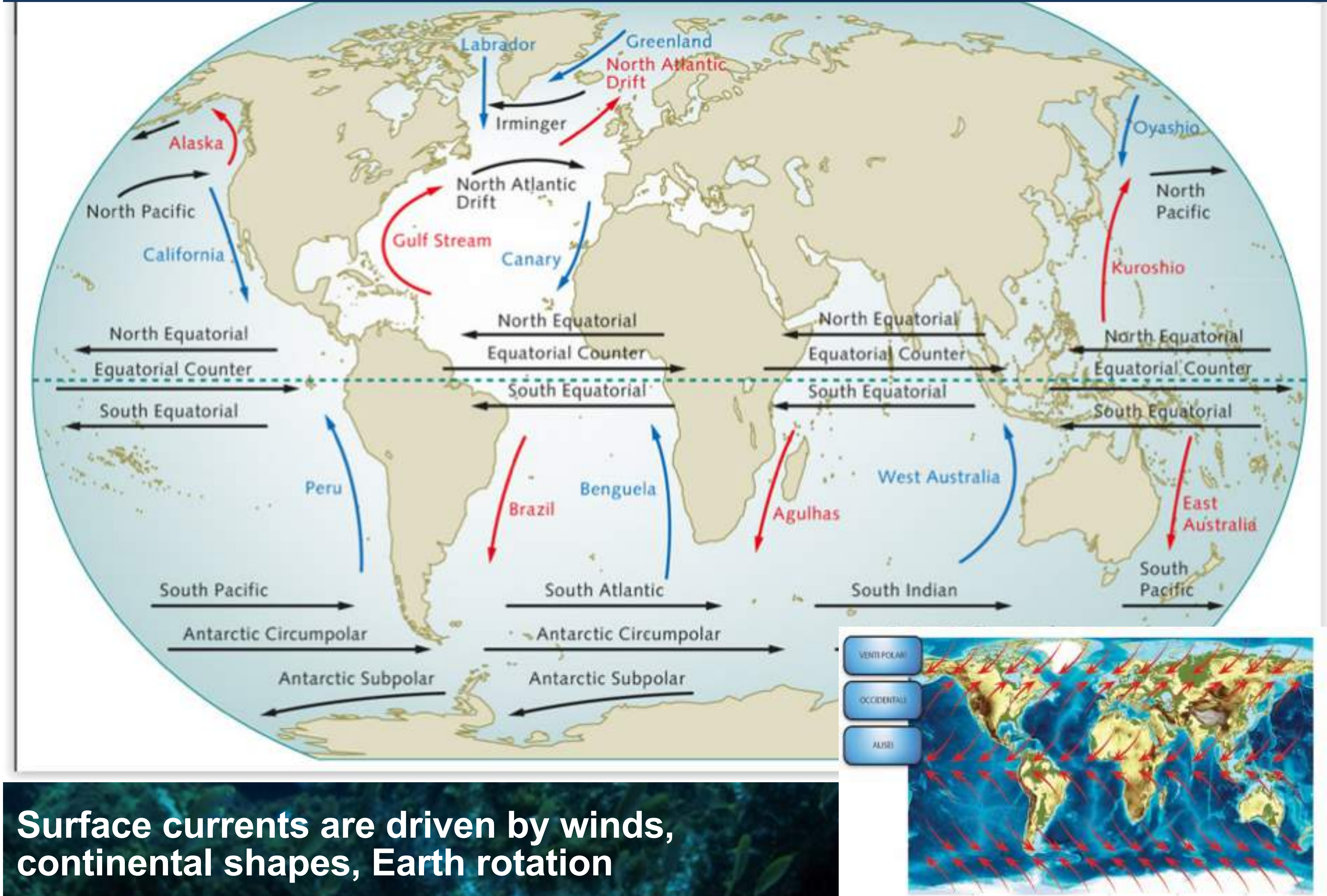


Cold polar winds cause evaporative cooling of seawater, and increase of salinity

Ice formation further increase salinity through brine exclusion

Increased salinity and cooling of waters lead to dense water masses that sink, moving towards the deep ocean, representing the cold engine of the ocean circulation

Main surface currents

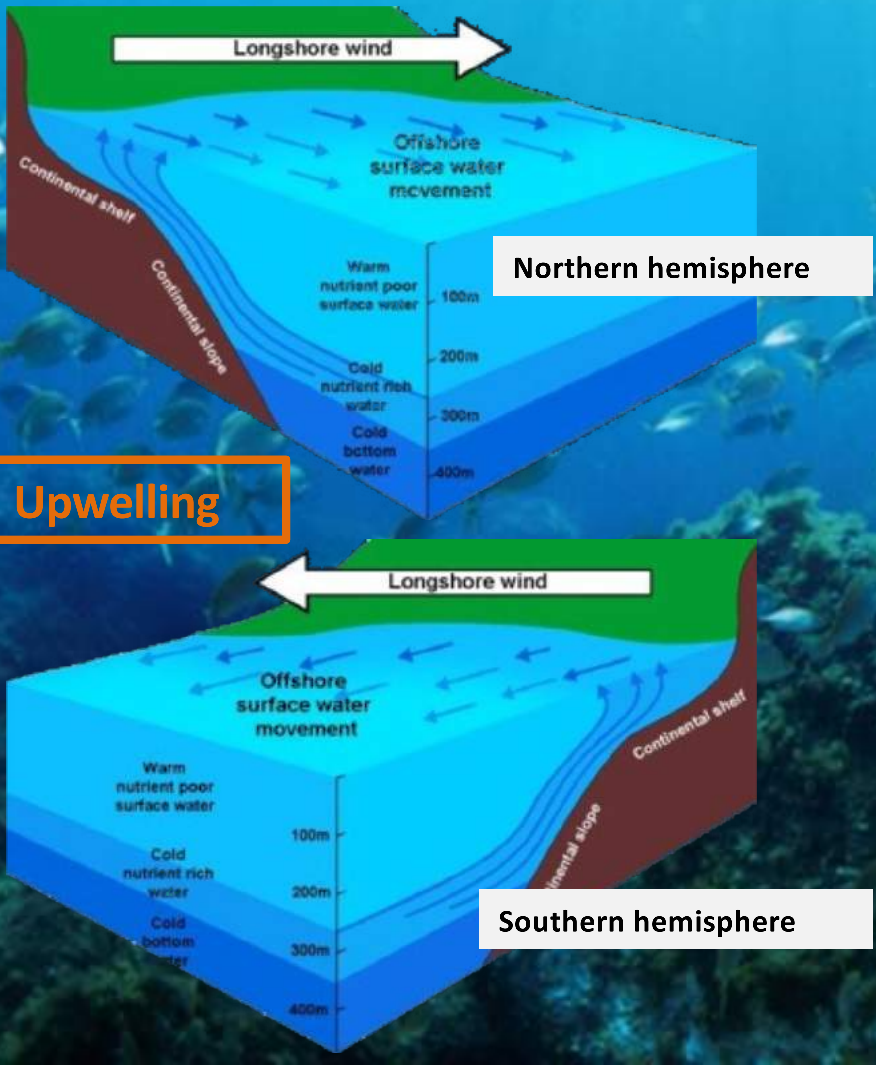


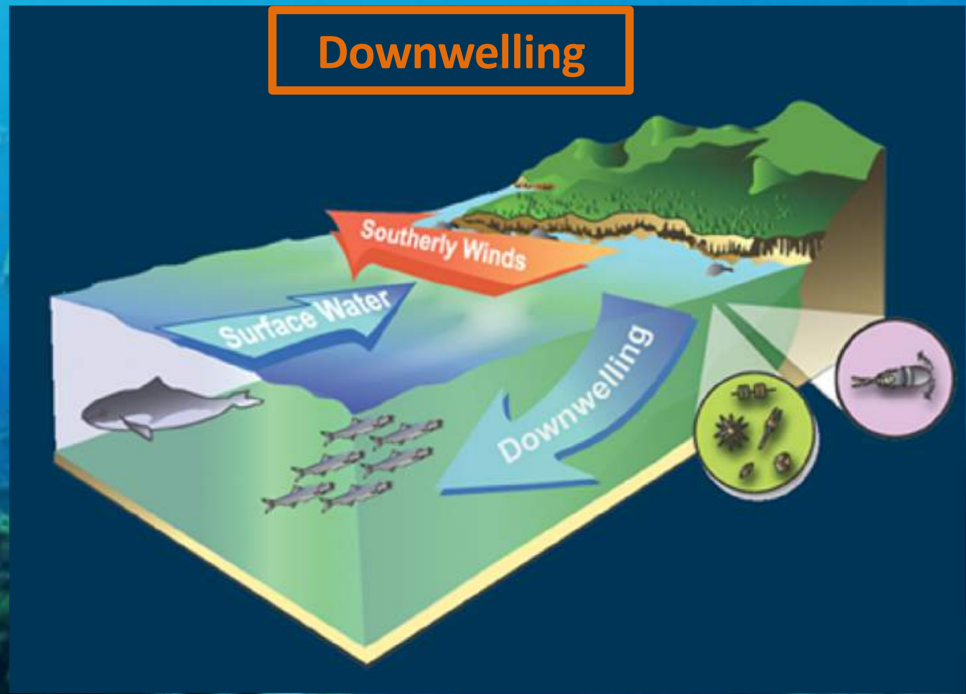
Surface currents are driven by winds, continental shapes, Earth rotation

Vertical circulation

Vertical circulation is also important for the functioning of marine ecosystems. It allows replacing warm and nutrient-poor surface waters with cold and nutrient-rich waters from the bottom, and to transport oxygen towards the bottom

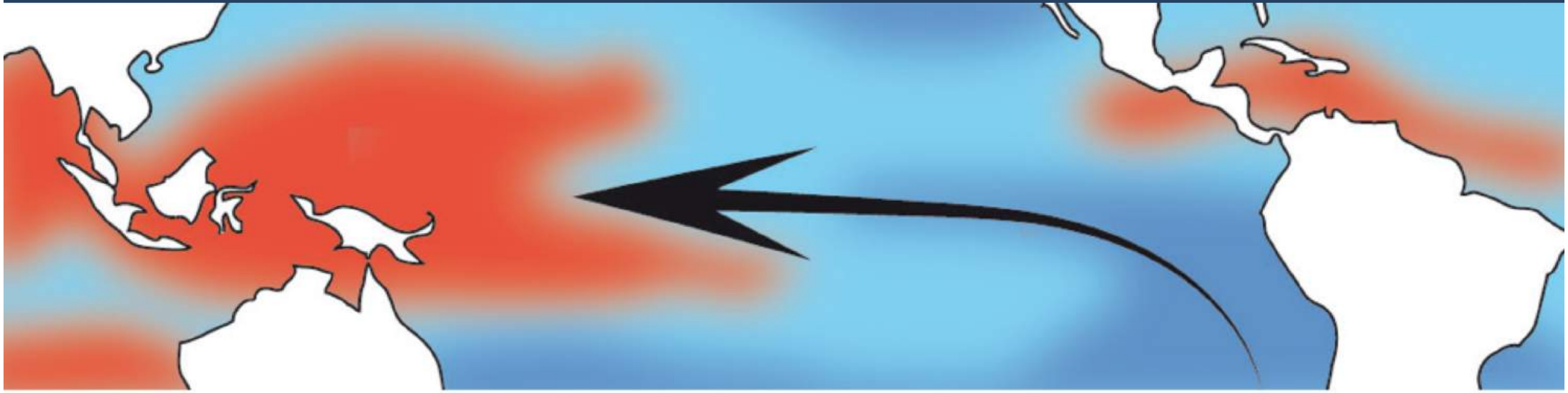
Upwelling





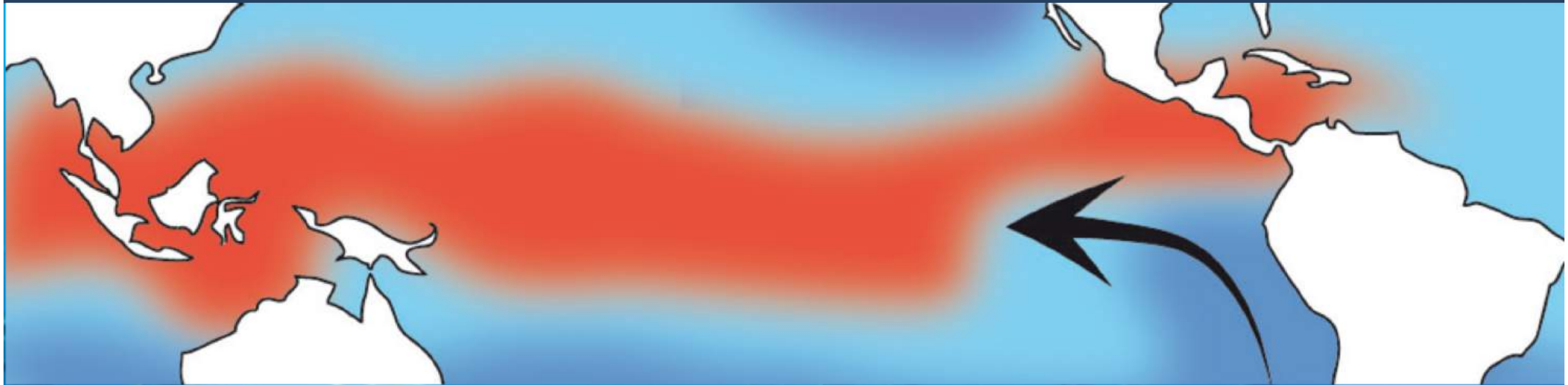
Winds and Earth's rotation generate water movements from the surface to the bottom and vice versa along the coast, but also in open waters

ENSO (El Nino Southern Oscillation)



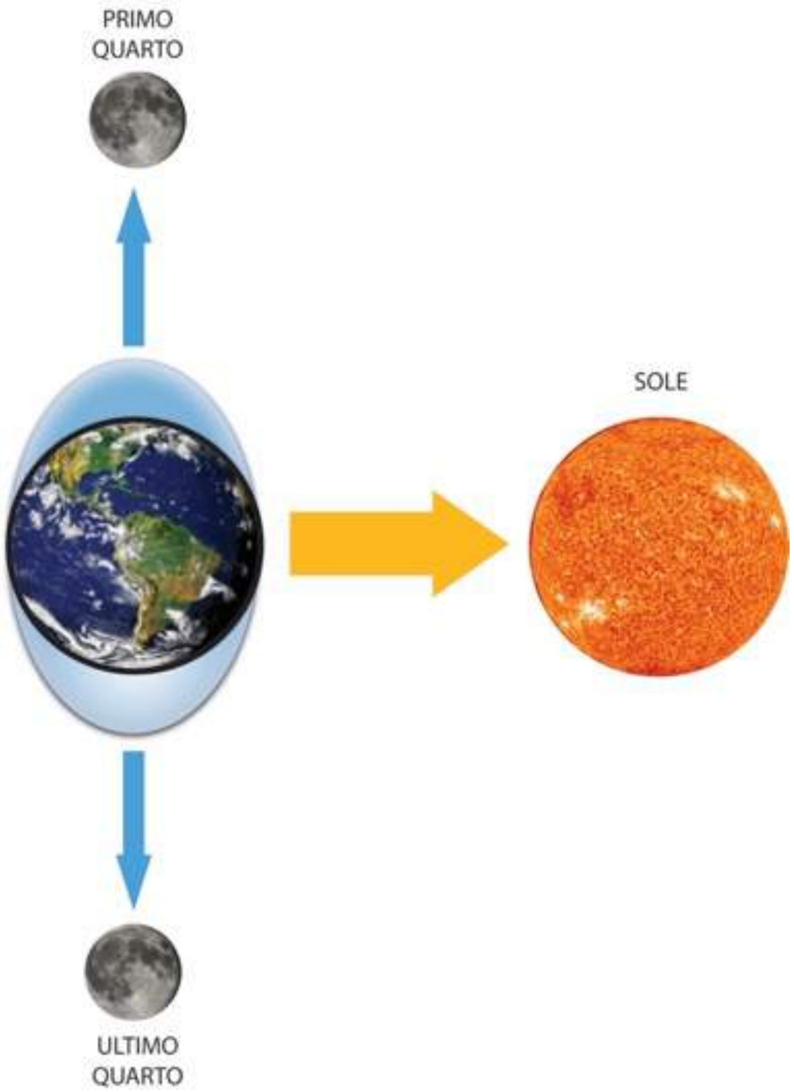
Normal conditions: wind trades blow strong, the Humboldt current is strong, upwelling occurs on the S America coasts (Chile and Ecuador), high pressure is on S-central Pacific and low pressure (wet, warm) on the Australian and Indonesian coasts. Superficial waters in the east Pacific are cold. When T is 0.5 ° C or more below the seasonal average, we have **la Nina**.

ENSO (El Nino Southern Oscillation)



El Nino: cyclic but irregular, every 2-7 years (5 on average) with max during winter (december). It is an increase in superficial water temperature in the central-SE Pacific of at least 0.5 ° C above the average T for at least 5 months. Wind trades are weak, the Humboldt current is weak, upwelling on the S America coasts (Chile and Ecuador) is strongly reduced or absent, high pressure is on the Australian and Indonesian coasts and low pressure (wet, warm) on the S-central Pacific coasts. Superficial waters in the east Pacific are warm.

Tides



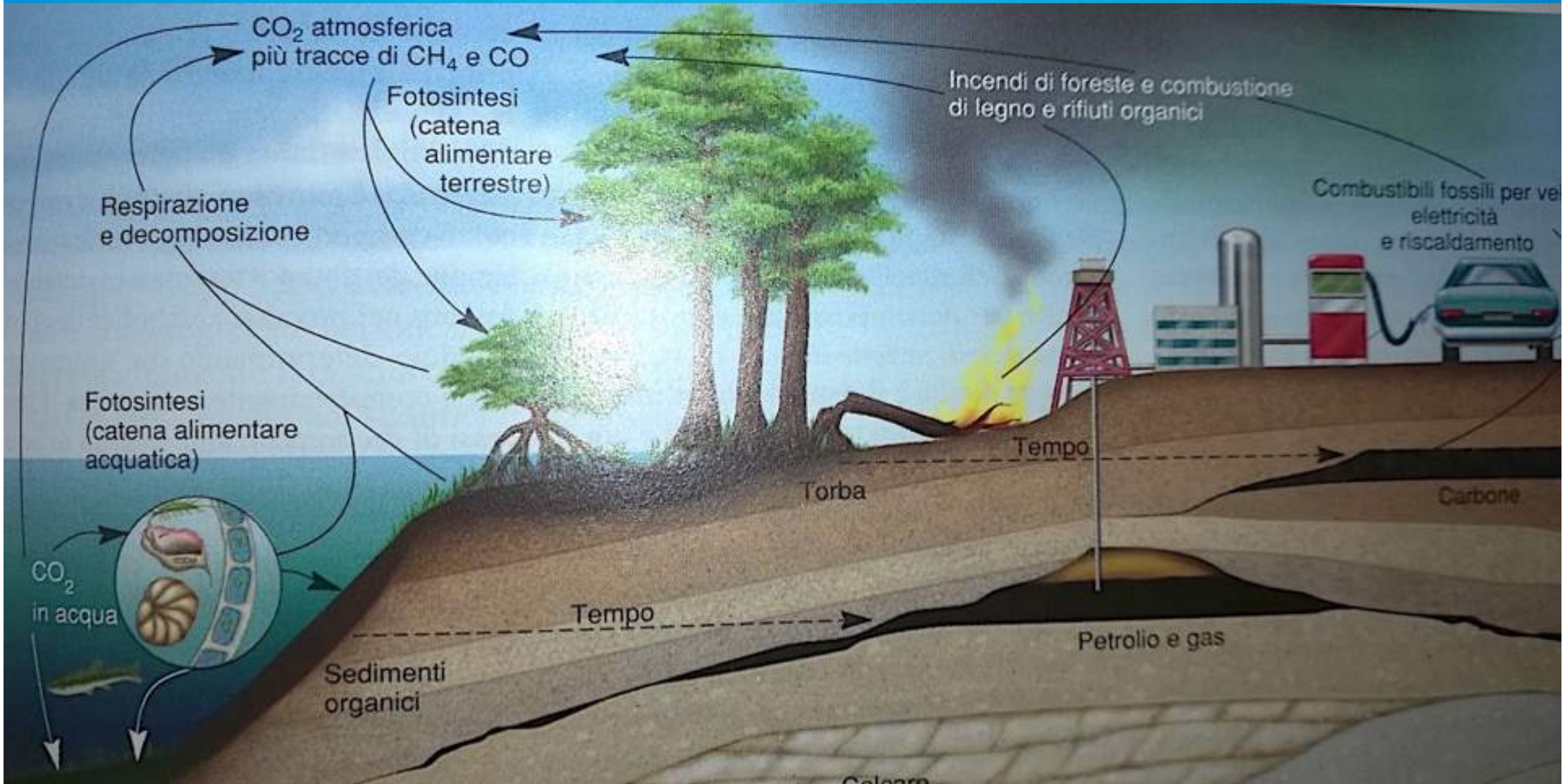
Tides a caused by the attraction of the moon and the sun. The strength of moon attraction is two times stronger than the sun. When the two are aligned, tides are higher. Neap-tides occurs when the moon and the sun form an angle of 90° (we have the lower high tide and the higher low tide). On average, tides have a cycle of 12 hours, so that there are two high tides within 24 h.

The width of tides depends on several factors: morphology of coast, type of tide, winds, closed seas.

They range between few decades of cm (e.g. Mediterranean Sea) until several m (e.g., Bay of Fundy, Canada)

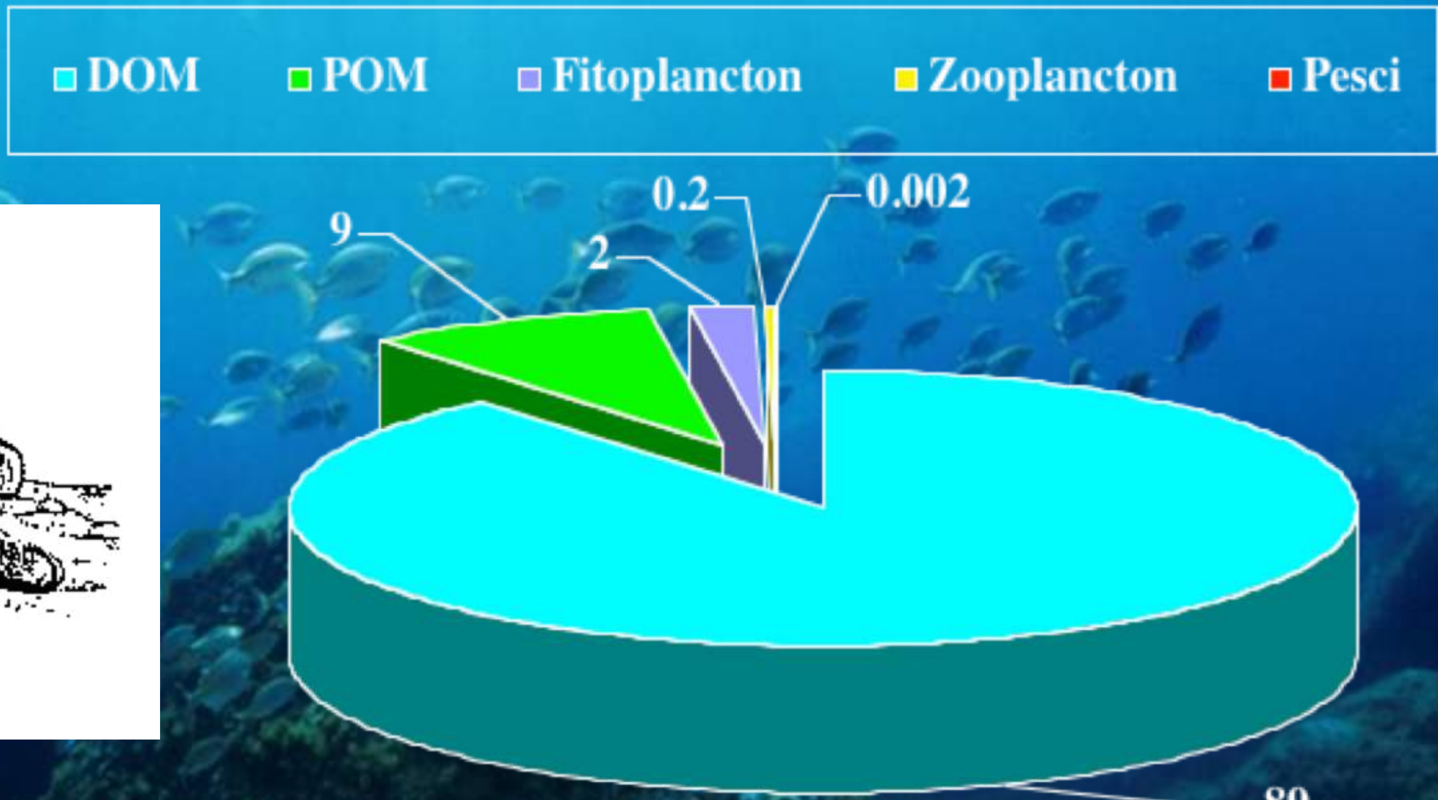
Carbon

1,85 billions Gt on Earth. Only 44.000 Gt are on the surface of the planet, while the remaining is in the nucleus and the mantle. 94% of carbon on the surface is stocked into the ocean (water and sediments, mostly as bicarbonate and carbonate ions), 4.5% in the biosphere and 1.5% in the atmosphere.



Organic matter

Most of organic carbon in the ocean is detritus, *"non-predatory loss of organic carbon from each trophic level or inputs from external sources"* (Wetzel et al.,1972). So, everything non-living and organic, irrespective of its size, composition and origin.



DOM (dissolved organic matter)
POM (particulated organic matter)

Origin

Terrestrial supply
Small plankton remains
Moults
Fecal pellets

Large animal remains
(fish and mammal carcasses)

Algal and plant debris
(kelp, seagrass, etc.)

Classification of organic matter

1. **Type**:	Living	(Organisms)	10%
	Detritus	(fecal pellets, excretions, etc.)	90%

2. **Size**: DOM (<0.45 μm = detritus+virus+bacteria)
POM (>0.45 μm = detritus+bacteria+ phytoplankton+microzooplankton)

3. **Sources**:	*in situ* production	10-90%
	exogenous	0-90%

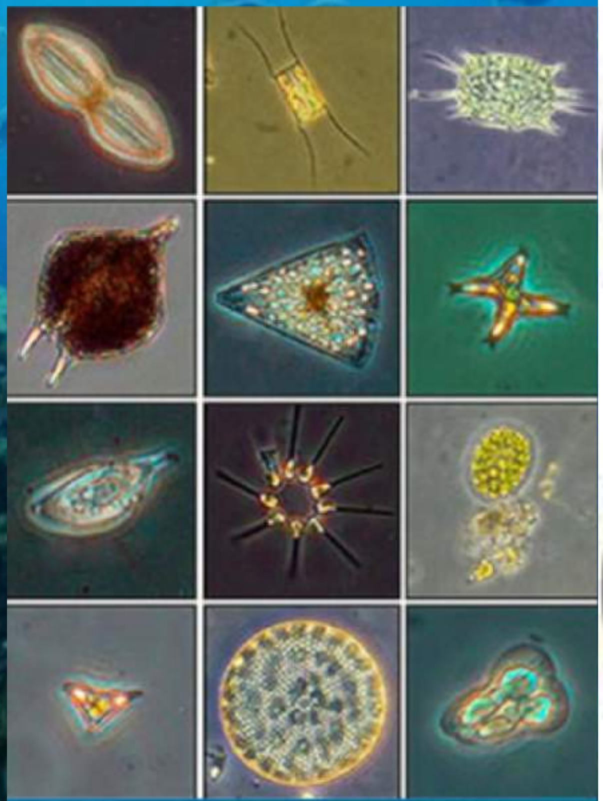
4. **Trophism**:	Bioavailable	1-10%
	Recalcitrant	90-99%

Type

Most of living organic matter in oceans comes from planktonic and benthonic bacteria, protists, phytoplankton, micro-zooplankton and meiofauna

Larger components are negligible in terms of amount and numbers

Microzooplankton are a group of heterotrophic and mixotrophic planktonic organisms between 20 and 200 µm in size. Important contributors to the group are phagotrophic protists such as flagellates, dinoflagellates, ciliates, radiolarians, foraminiferans, etc., and metazoans such as copepod nauplii, rotiferans and meroplanktonic larvae, among others.



Trophism

POM is composed by proteins, carbohydrates and fat acids

DOM is composed by a huge range of substances of molecular weight from very few until >100.000 d, and includes, for instance,

a. virus
b. carbohydrates (glucose, 50-60%)
e. aromatic compound (e.g., phenol, lignin, lipids)
f. amino acids
g. DNA and RNA

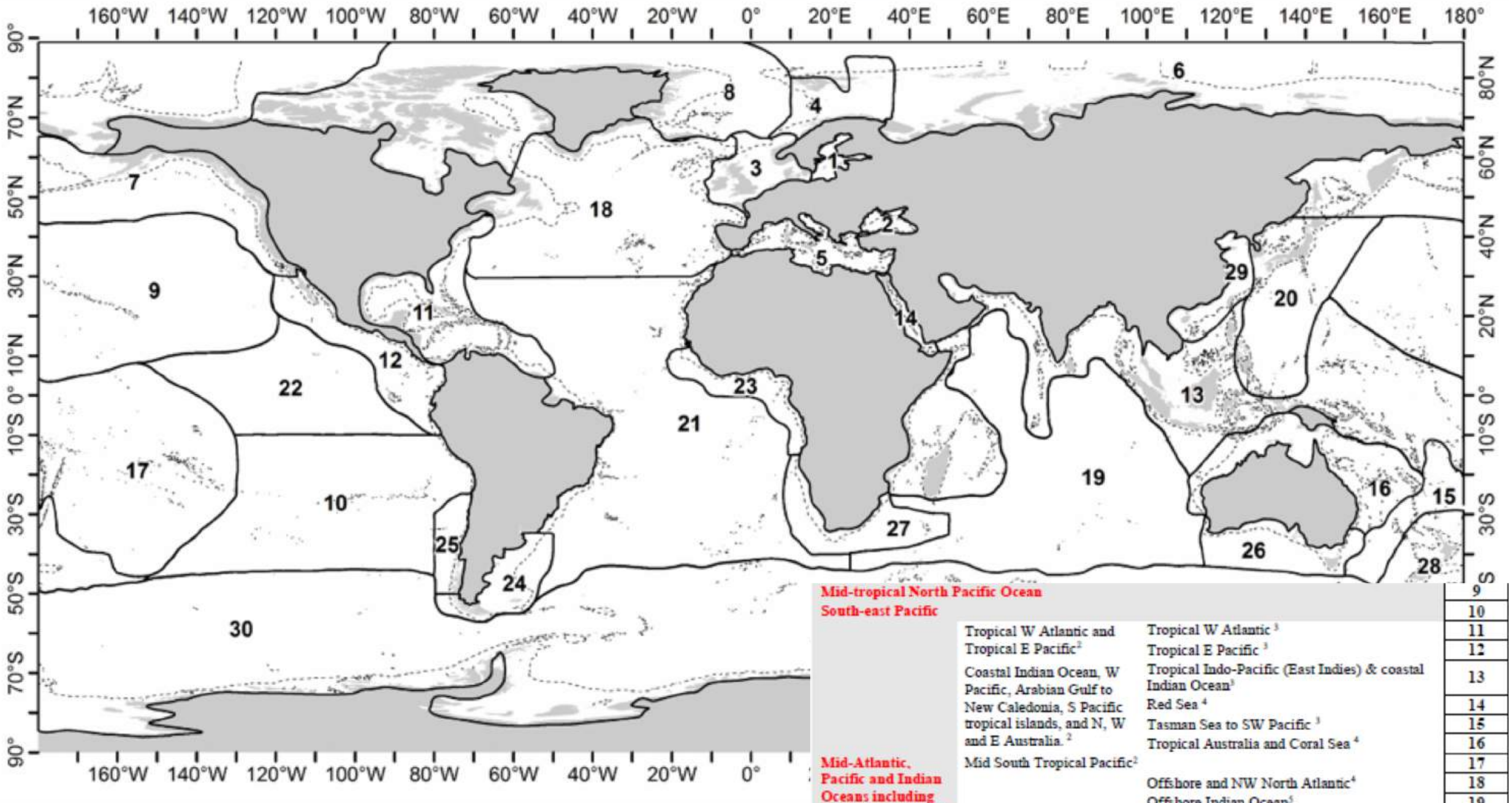
DOM pool is largely produced by phytoplankton and decomposition or bacterial and virus action

DOC/POC ratio 10-20:1 in the water column
DOC < 5% del TOC in sediments

Labile organic matter is easily and rapidily available to be remineralized by organisms, whereas recalcitrant organic matter is formed during decomposition and other processes (agglomeration), and is difficult to be degraded by bacteria unless during long periods. Example: CRAM (carboxyl-rich alicyclic molecules) amino-sugars, amino acids, terpenoids, lignin)

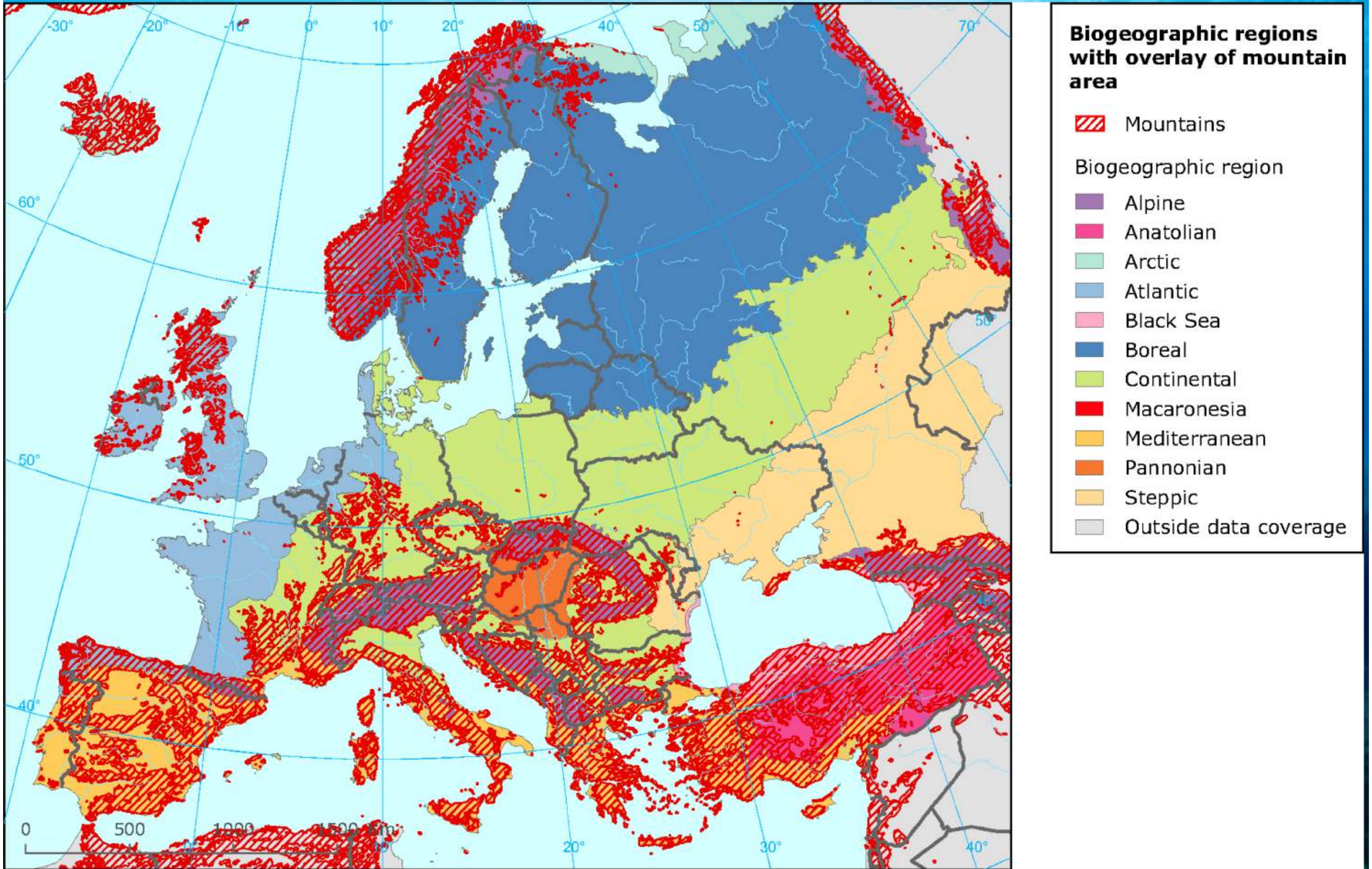
Zonation on land

In oceans and seas

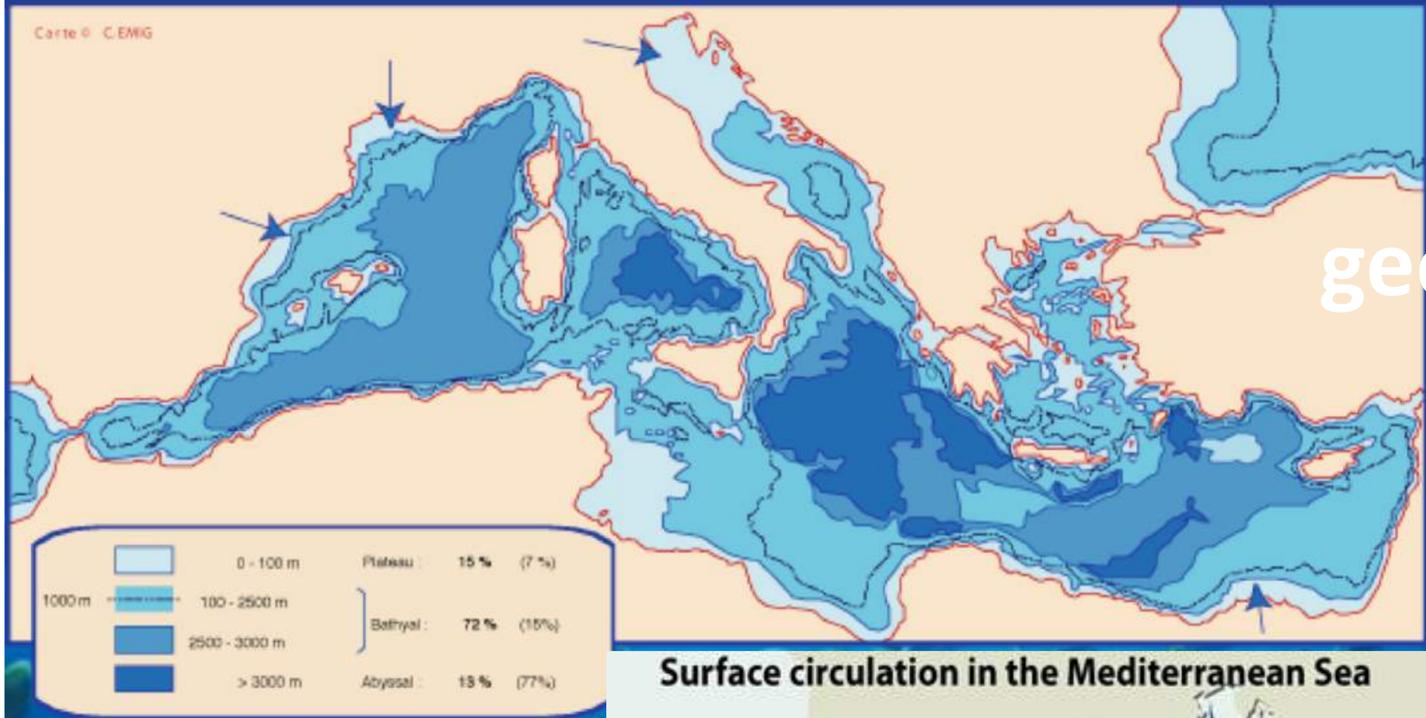


			Realm
Inner Baltic Sea			1
Black Sea			2
NE and NW Atlantic and Mediterranean, Arctic and North Pacific	NE Atlantic and Mediterranean[2]	NE Atlantic[3]	3
		Arctic Europe[5]	4
		Mediterranean[3]	5
	Arctic and N Pacific[2]	Arctic [3]	6
		North Pacific[3]	7
	N Atlantic boreal and sub-Arctic from Canada to Greenland Sea[2]		8
Mid-tropical North Pacific Ocean			9
South-east Pacific			10
Mid-Atlantic, Pacific and Indian Oceans including coastal tropics and warm-temperate areas	Tropical W Atlantic and Tropical E Pacific[2]	Tropical W Atlantic [3]	11
		Tropical E Pacific [3]	12
	Coastal Indian Ocean, W Pacific, Arabian Gulf to New Caledonia, S Pacific tropical islands, and N, W and E Australia. [2]	Tropical Indo-Pacific (East Indies) & coastal Indian Ocean[3]	13
		Red Sea [4]	14
		Tasman Sea to SW Pacific [3]	15
		Tropical Australia and Coral Sea [4]	16
	Mid South Tropical Pacific[2]		17
	Open Atlantic, Indian, and Pacific oceans[2]	Offshore and NW North Atlantic[4]	18
		Offshore Indian Ocean[5]	19
		Offshore W Pacific[6]	20
		Offshore S Atlantic[6]	21
		Offshore mid-E Pacific [7]	22
		Tropical E Atlantic[6]	23
	S South America[2]	Argentina [3]	24
		Chile[3]	25
	S Africa, S Australia, and New Zealand[2]	S Australia[6]	26
		S Africa[5]	27
		New Zealand[6]	28
North West Pacific			29
Southern Ocean			30

Zonation on land



The Mediterranean Sea

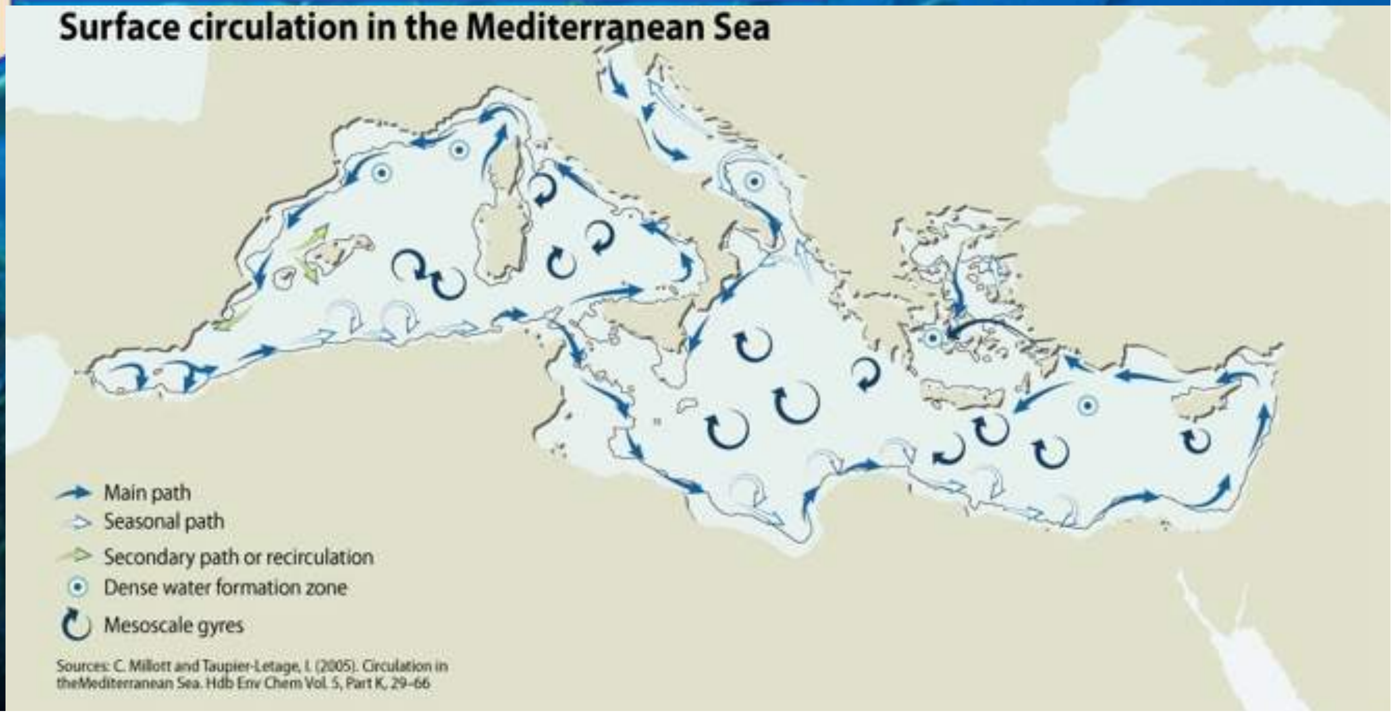


depth

geomorphology

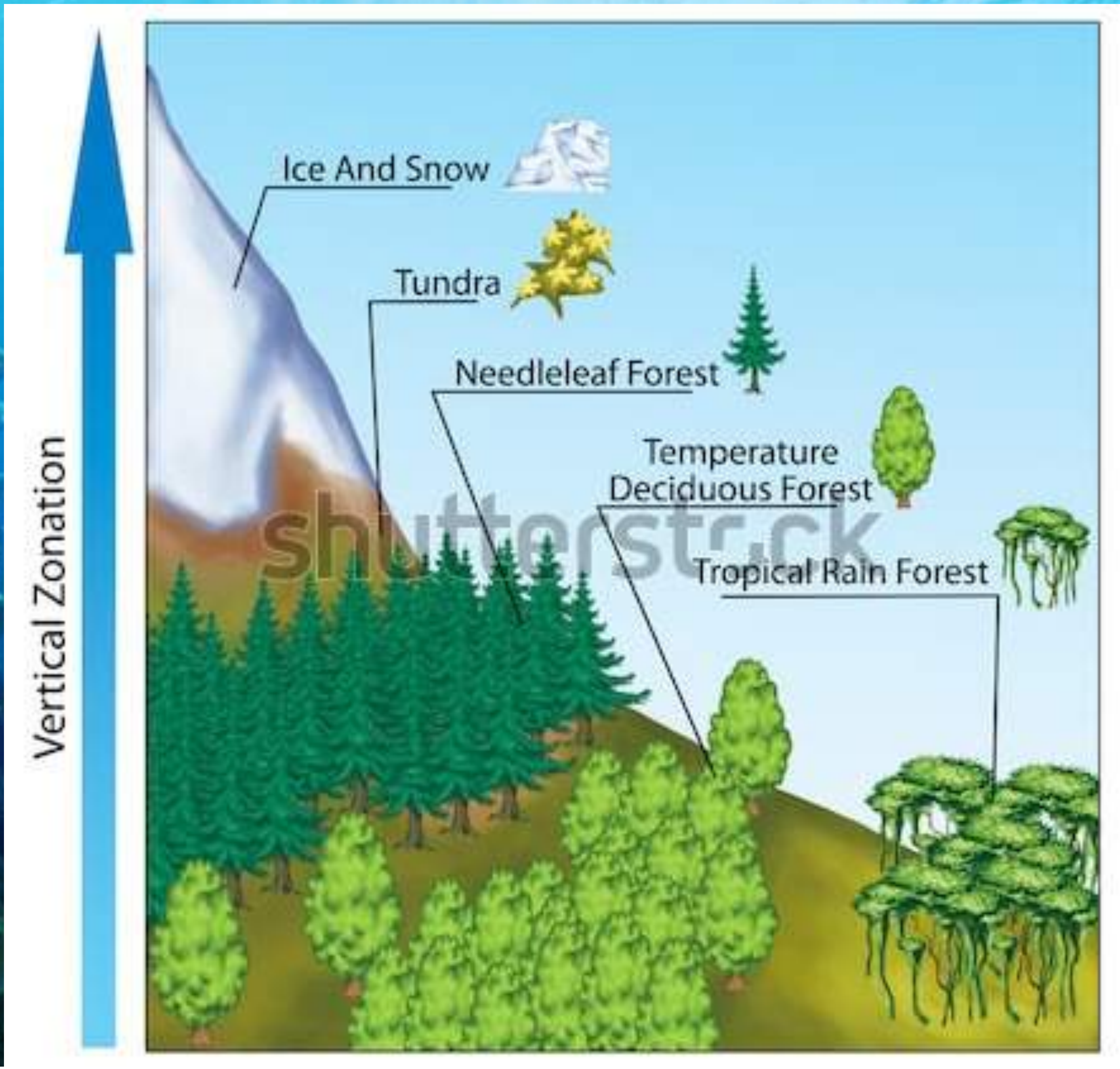
historical factors

Currents and circulation



Biogeography of the basin

Zonation on land



Zonation on sea