GLOBAL CHANGE ECOLOGY AND SUSTAINABILITY
a.a. 2023-2024

Conservation and Management of Marine Ecosystems
Prof. Stanislao Bevilacqua (sbevilacqua@units.it)

The marine environment

The importance of oceans

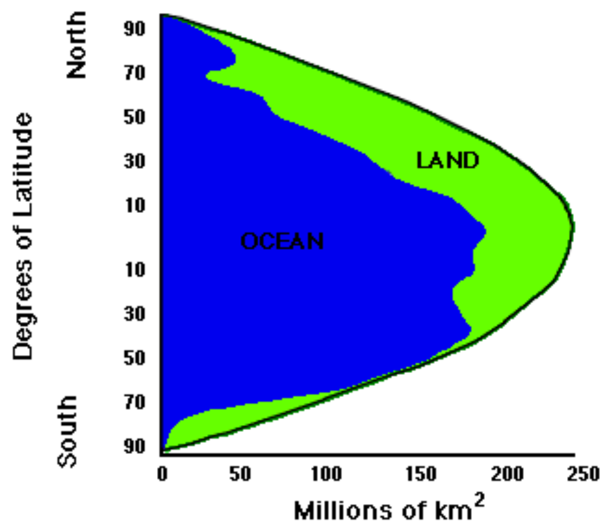
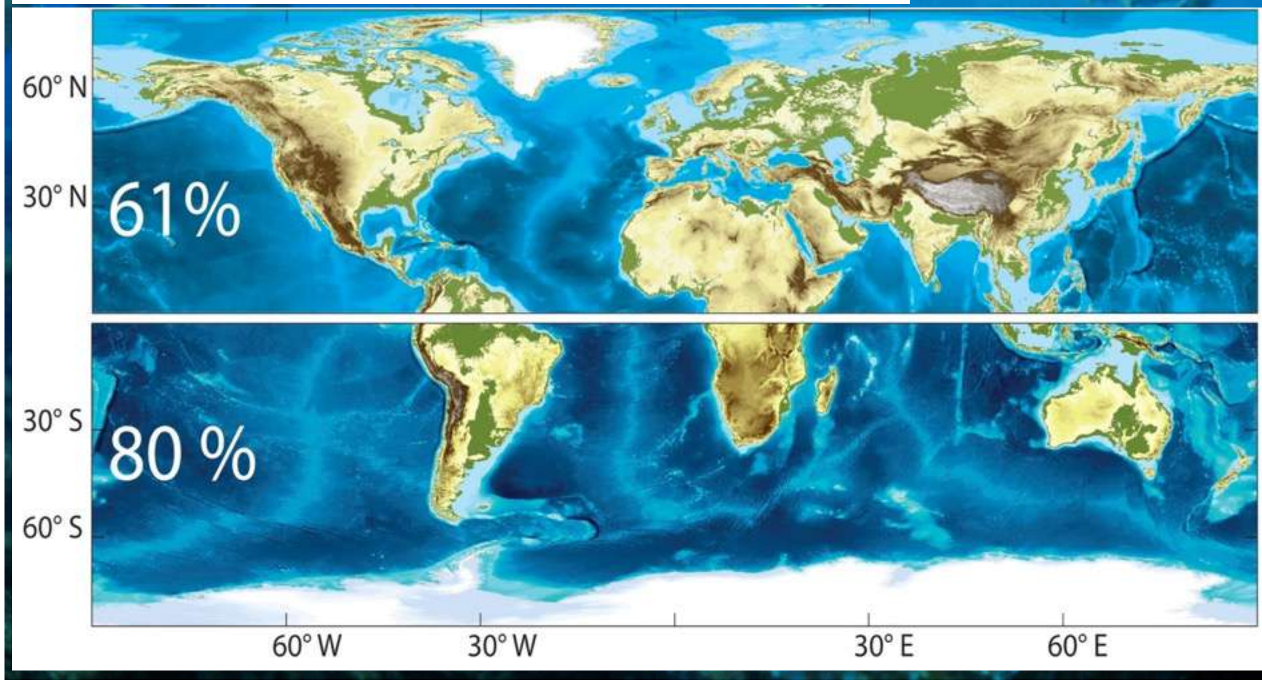


Diagram showing the distribution of land and water with latitude. The shaded portion is land and the area to the left of that is ocean. Note the large percentage of land in the Northern hemisphere as compared with the southern hemisphere.



More than 70% of Earth's surface is covered by sea water, 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 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

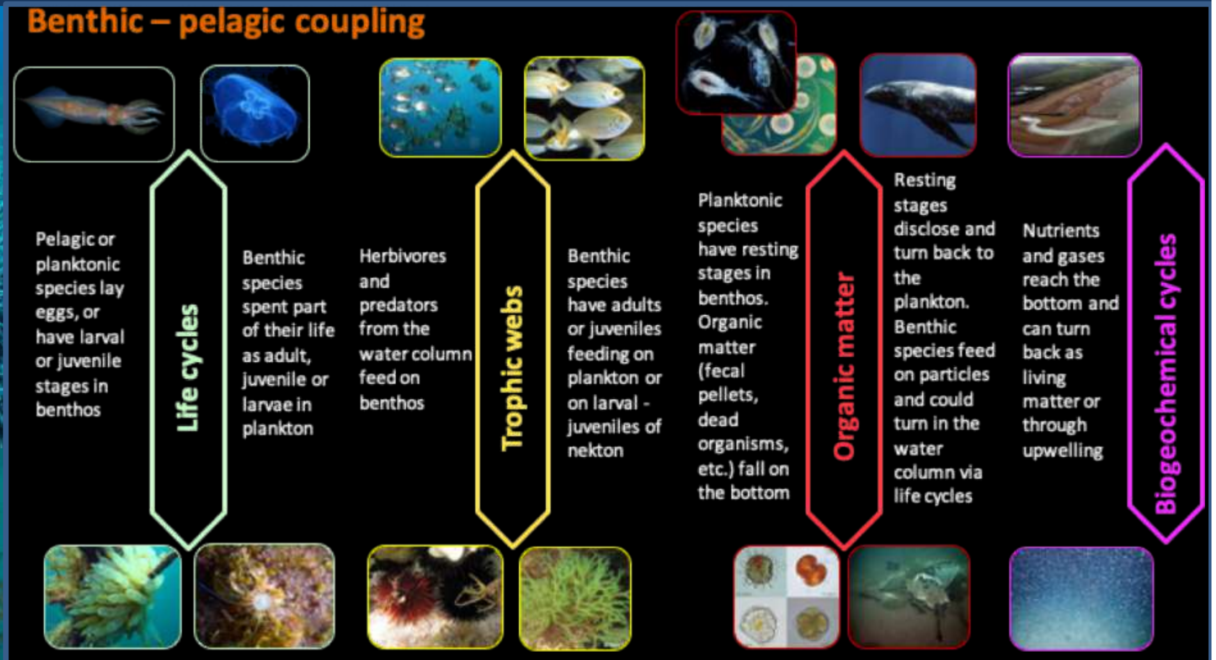
1. We do not know the impact of most activities on our seas
   - Increasing impact from old (e.g., oil) and new chemicals
   - Overexploitation of marine resources
   - New pollution sources

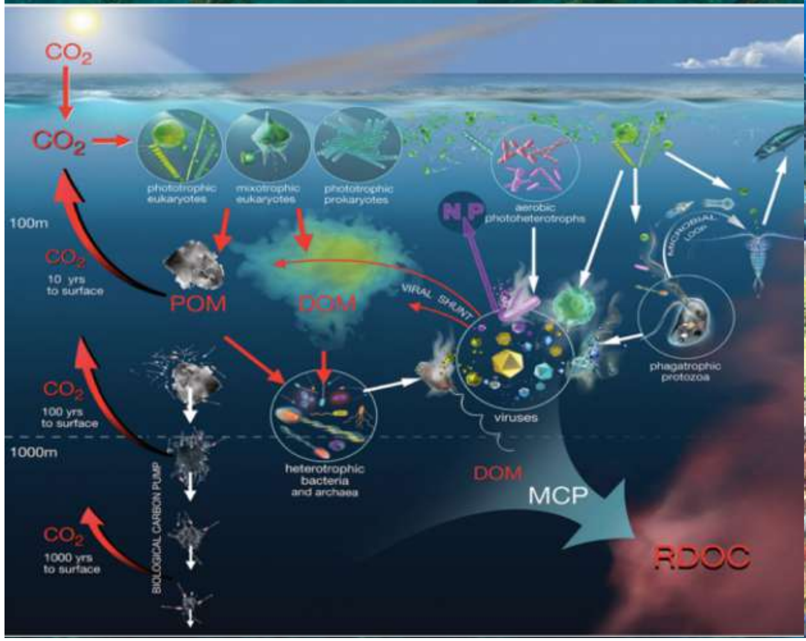
2. Systematic underestimation of marine ecosystems and their economical functions
   - Europe has 89,000 km of coastline with a very high coast to surface ratio
   - European and Italian economy are increasingly dependent upon resources from the sea

3. Increasing tourism impact:
   - 75,000,000 international tourists (EU)
   - 60,000,000 domestic tourists every year (EU)

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

Ecosystems goods and services





The importance of oceans

Managing the oceans means:

1. Scientific and socio-economic basis for sustainable development based on seas and their resources

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

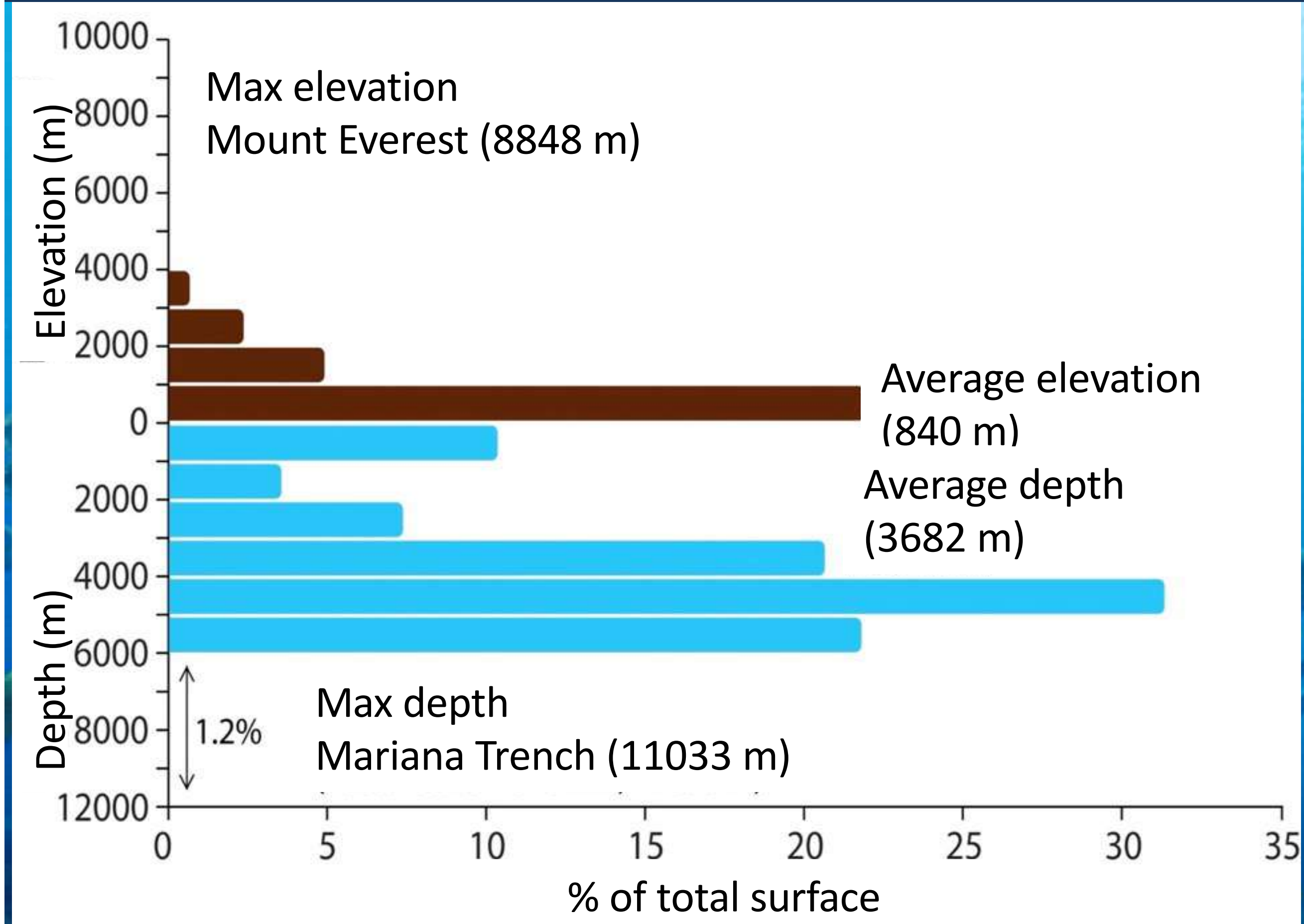
3. New frontiers in research and technologies

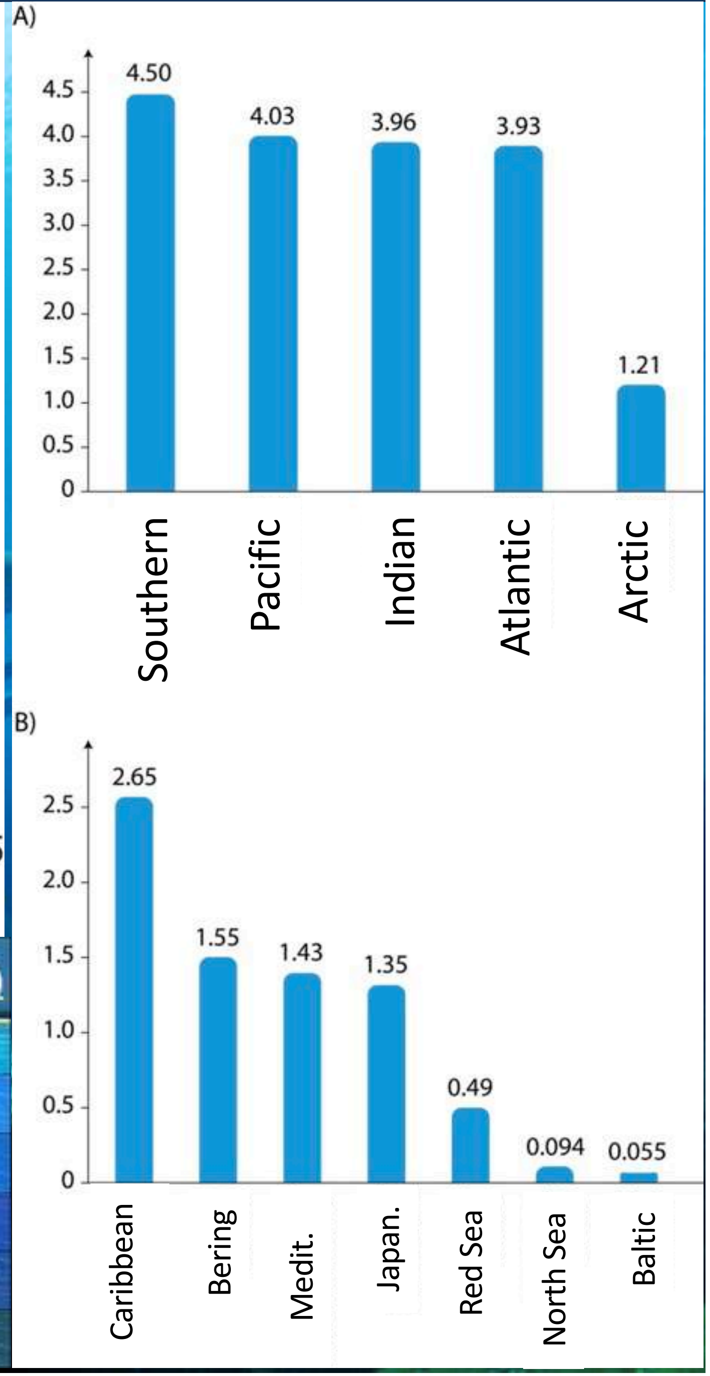
The importance of oceans

Main threats

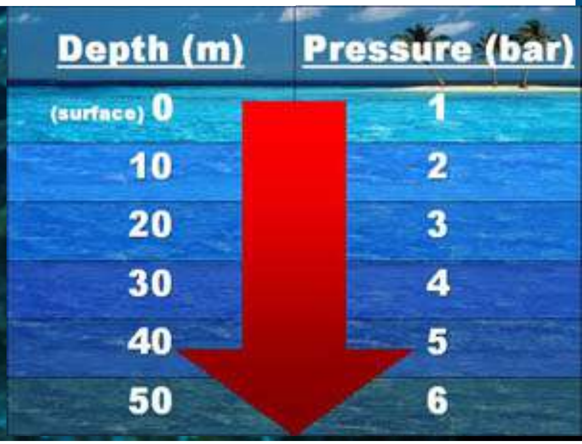
1. Hydrocarbons and other contaminants
   - New forms of chemical pollution (micropollutants and secondary metabolites)
2. Habitat destruction
3. Eutrophication
4. Pathogenic forms and sanitary problems
5. Overfishing
6. Introduction of alien species
7. Climate changes and potential consequences on marine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

Depth



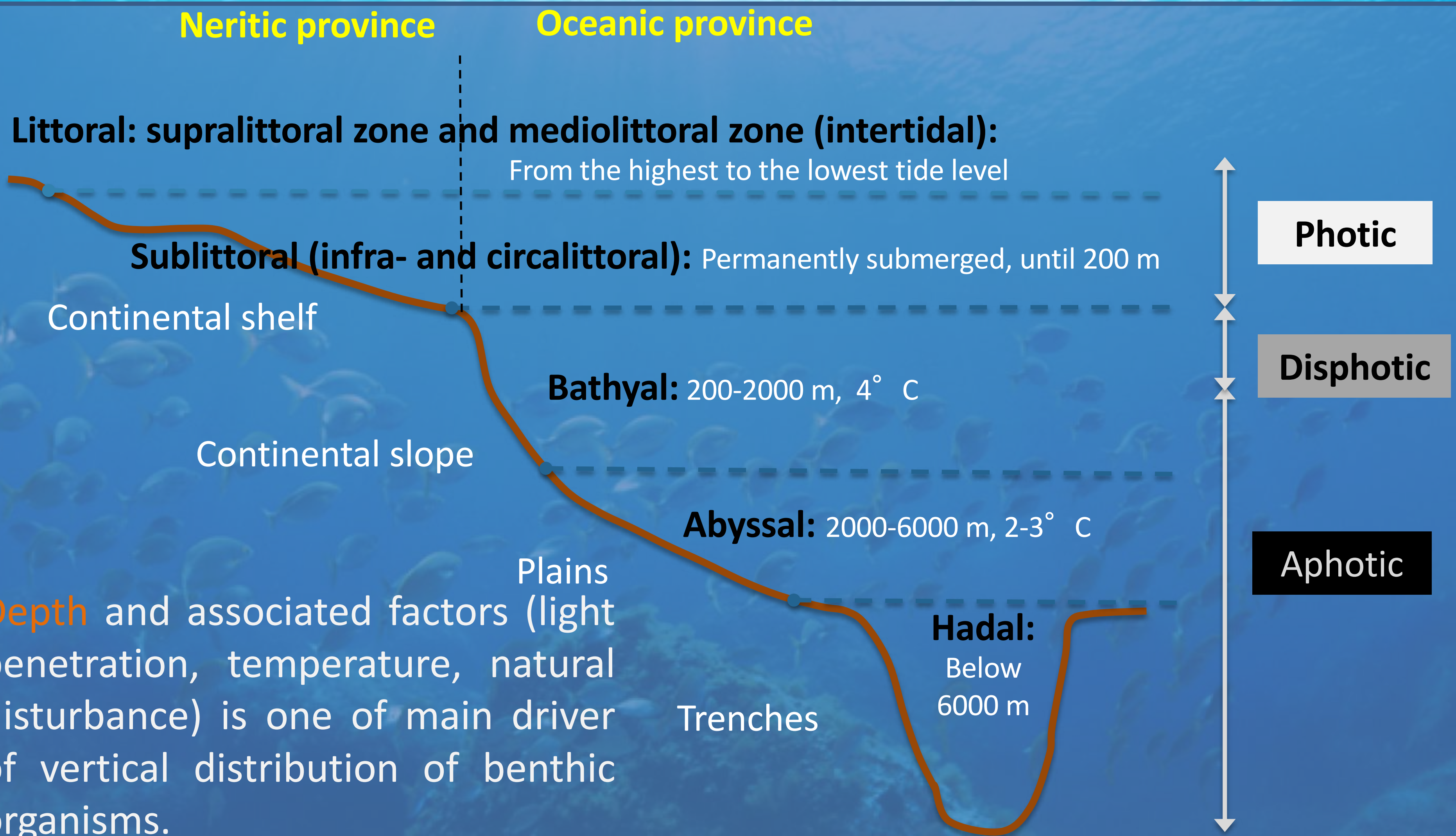


>80% of the seafloor (and therefore of the Earth's surface) and 98% of volume are 2 km under the surface



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

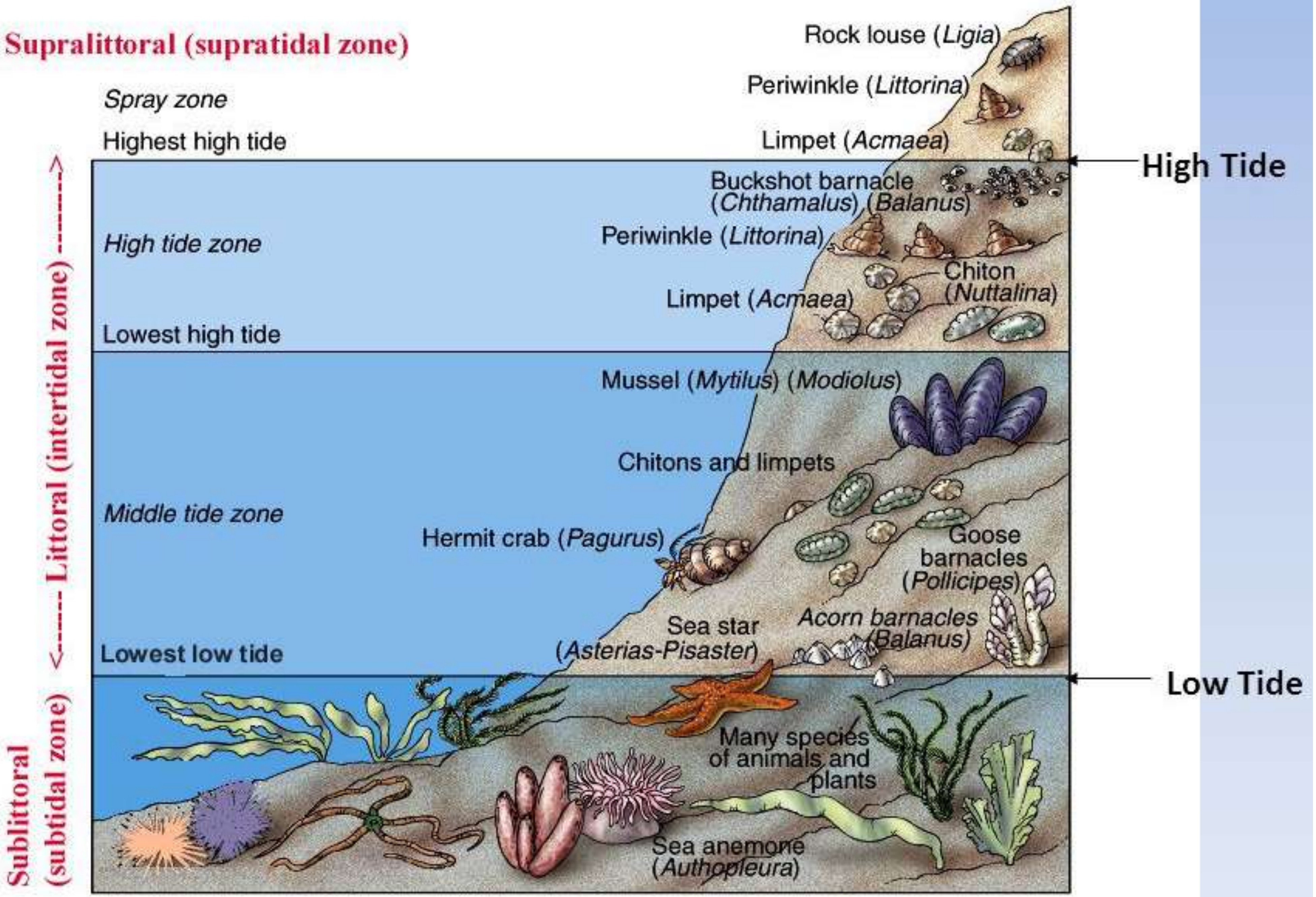
The benthic domain



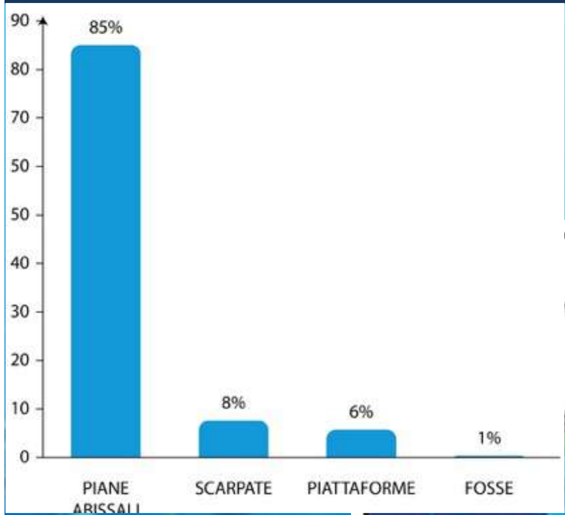
Depth and associated factors (light penetration, temperature, natural disturbance) is one of main driver of vertical distribution of benthic organisms.

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

Zonation on sea

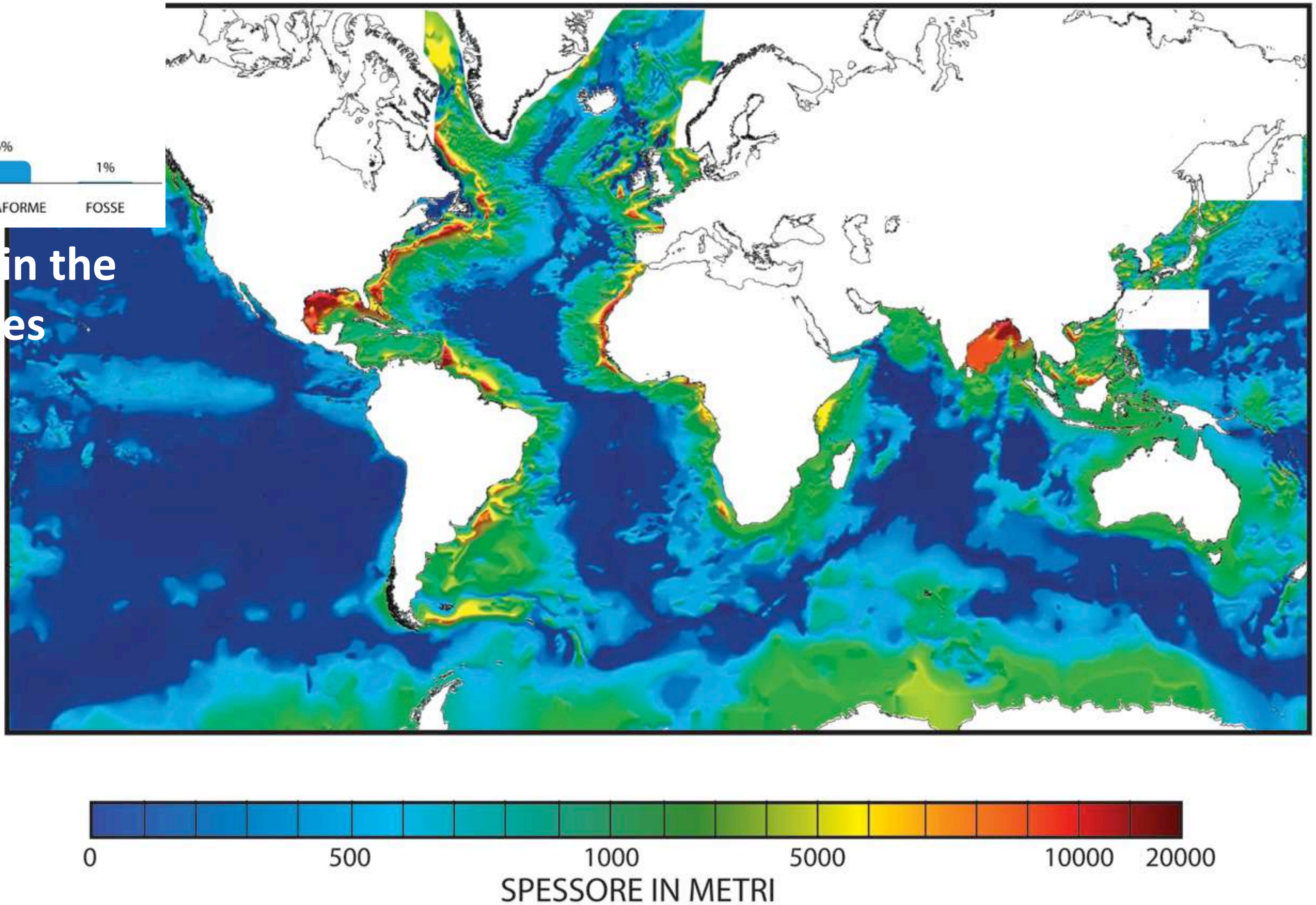


Sediments

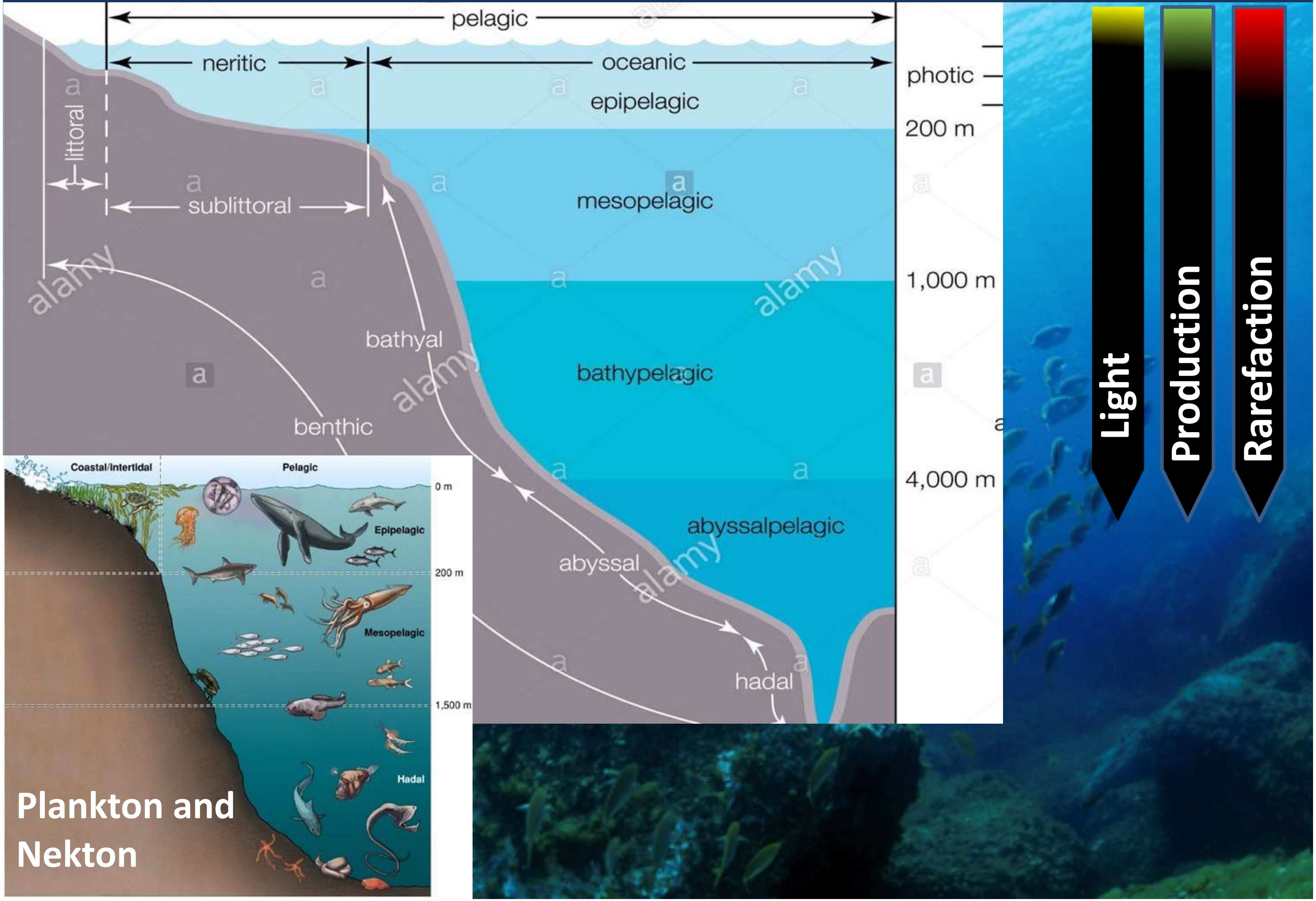


Thickness of sediments in the ocean

% of surface in the different zones

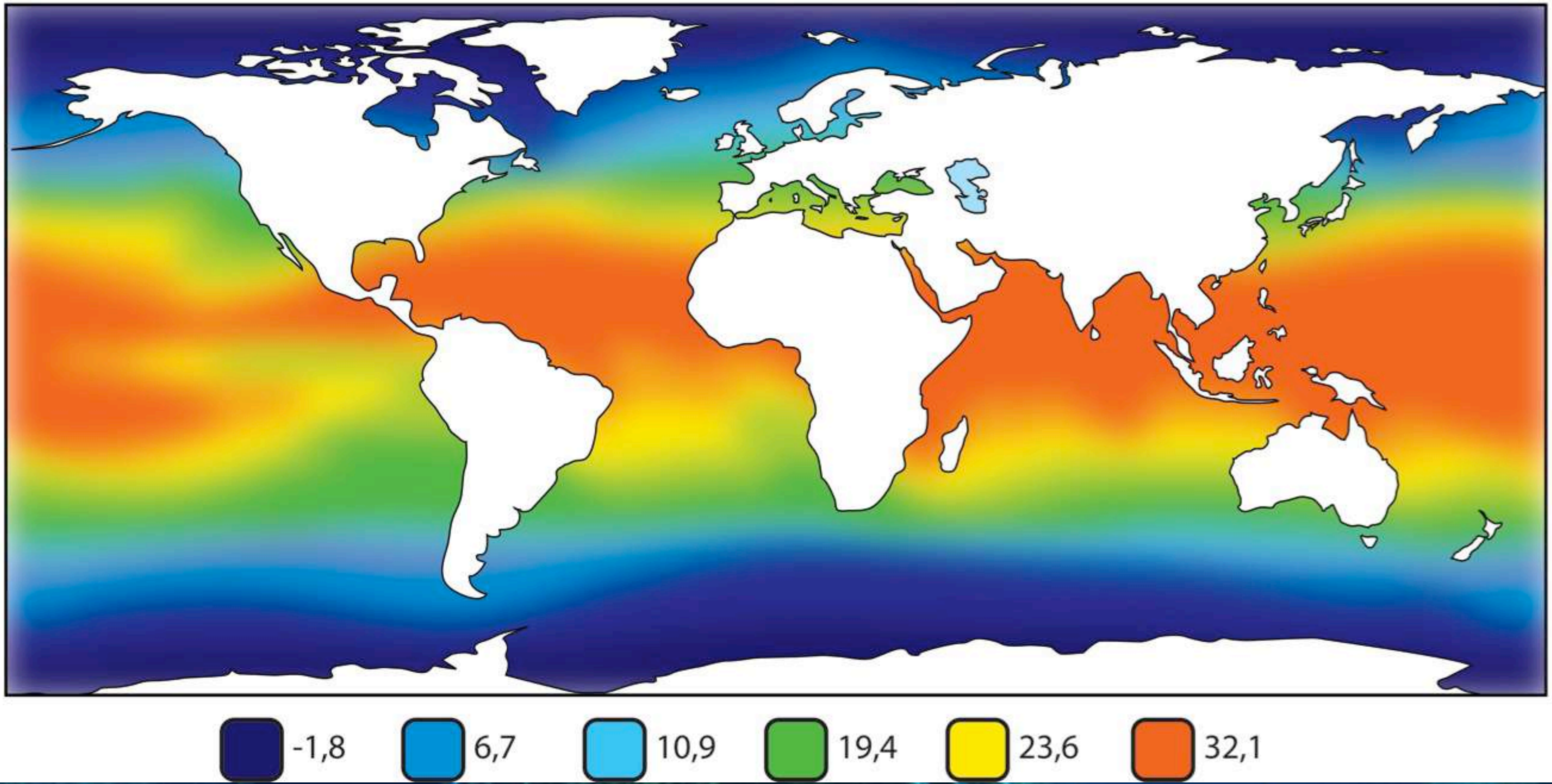


The pelagic domain



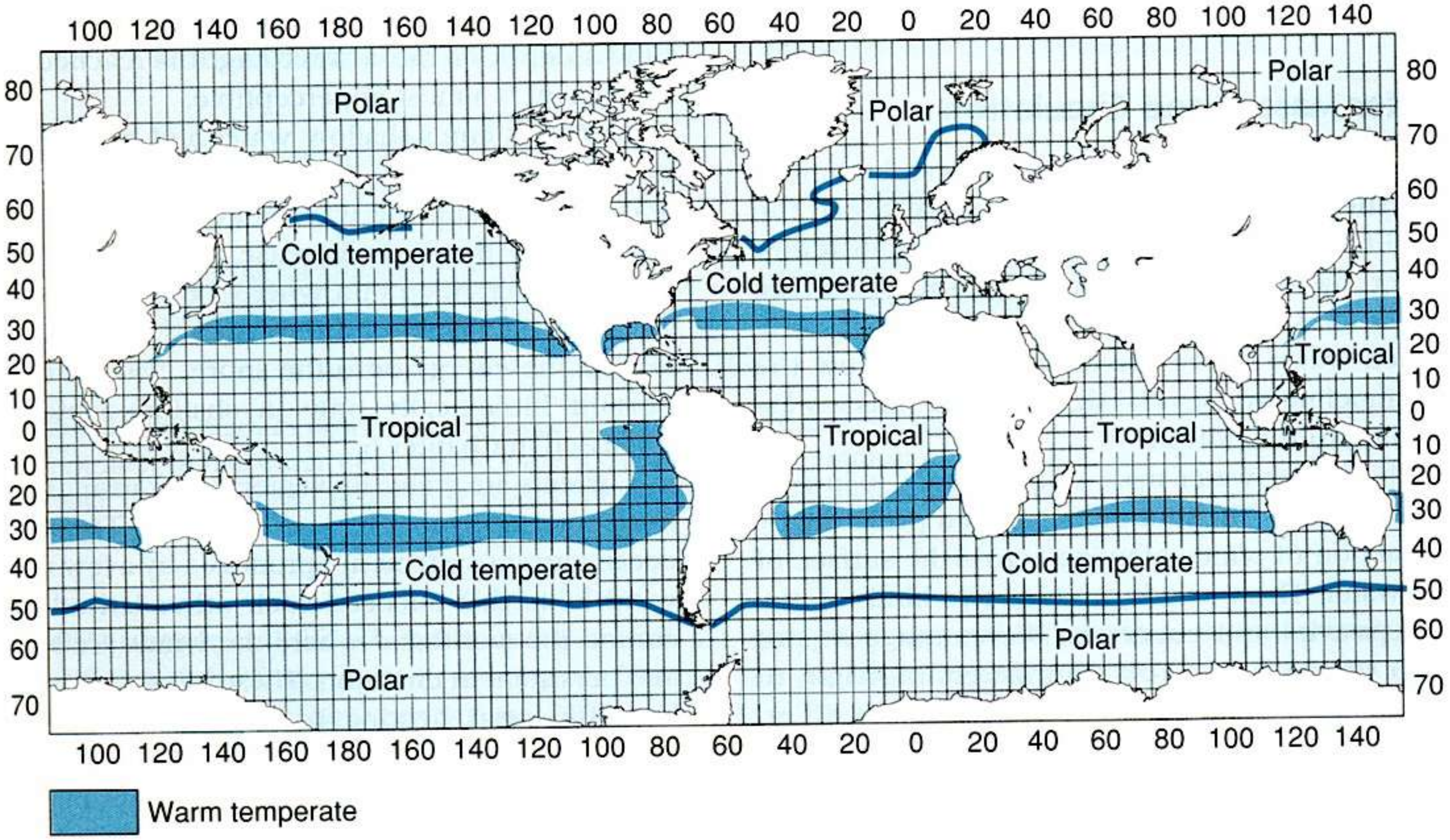
Plankton and Nekton

Temperature

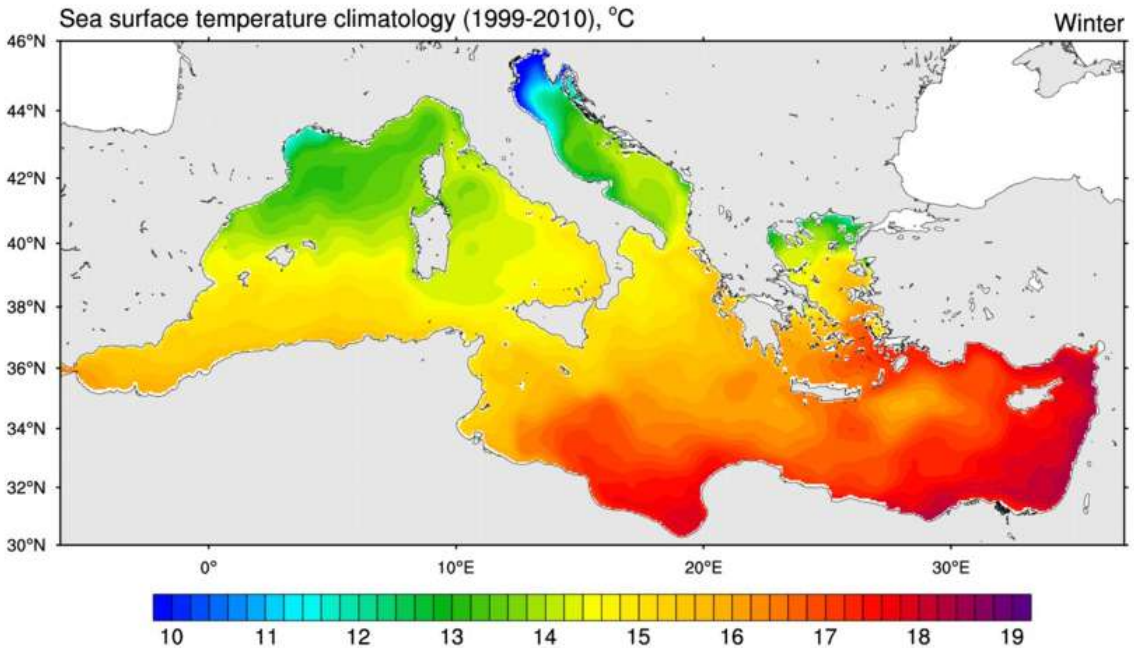


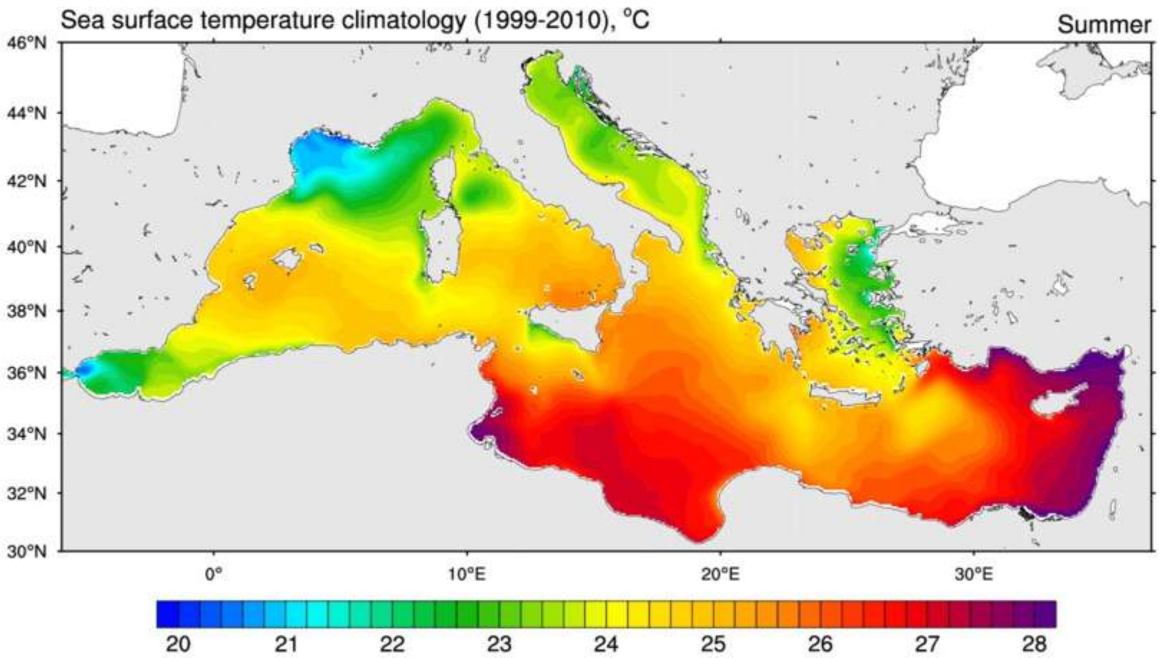
Average SST range from about – 2 ° C a the poles to 35 ° C in tropical areas. Seasonal variations in superficial water are typical of temperate areas and depend also on geomorphology and other characteristics of the basin

Temperature



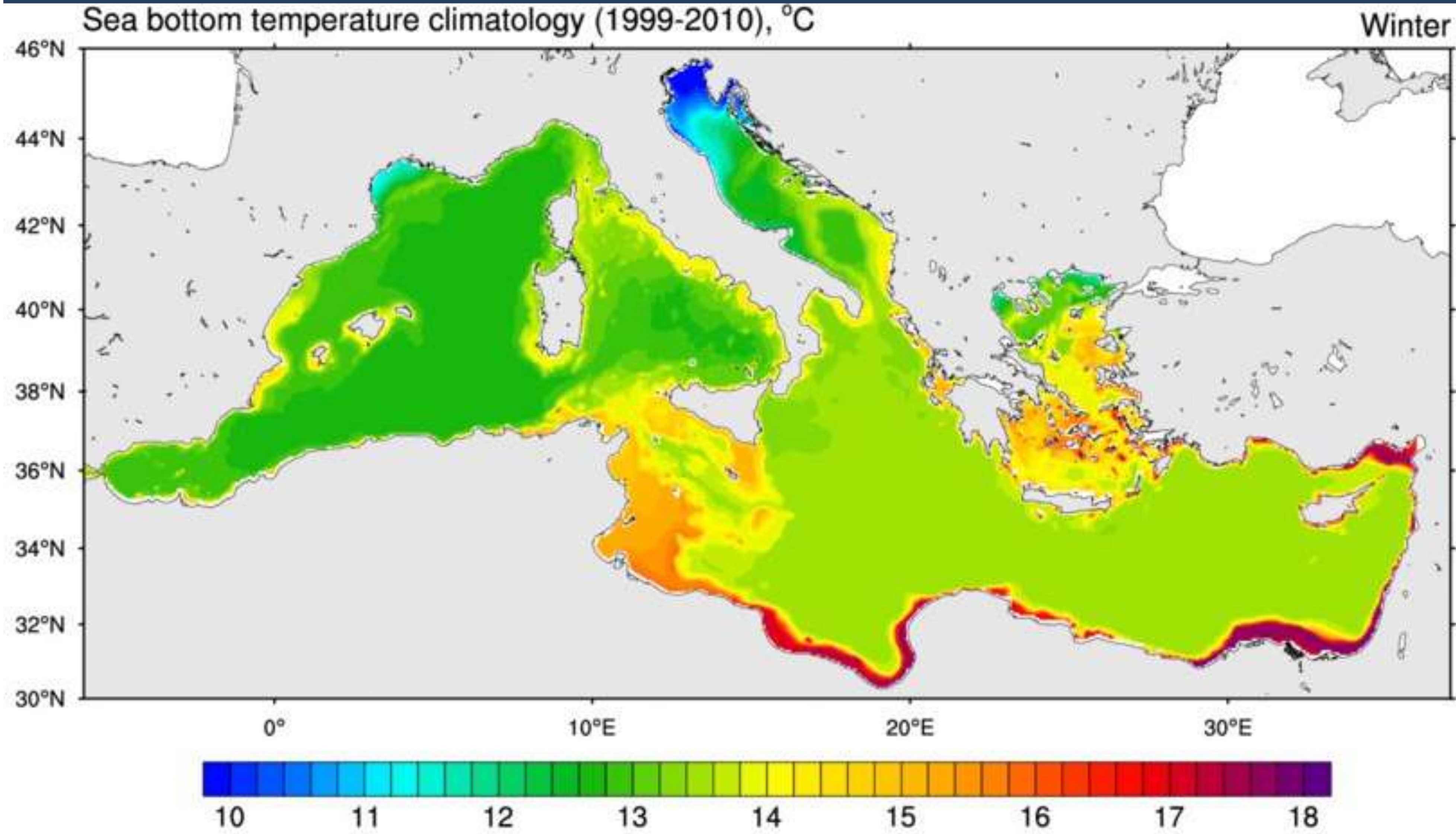
Temperature





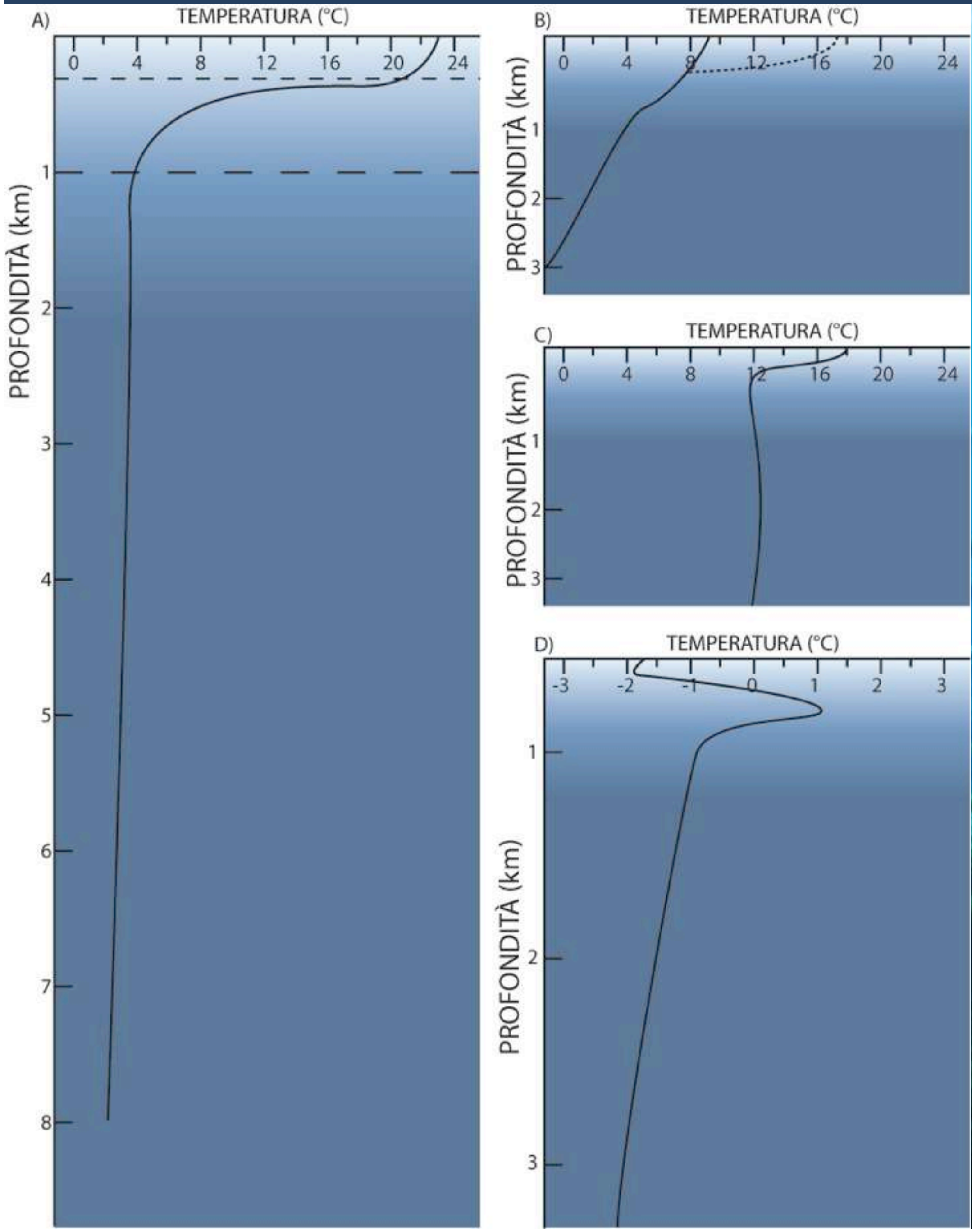
The Mediterranean Sea has a dual nature as far as temperature. It is close to a subtropical sea, in the southeast basin, and a temperate sea in the western basin. The seasonal variability in temperature, light availability and dissolved nutrient concentrations are similar to temperate seas, but the average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

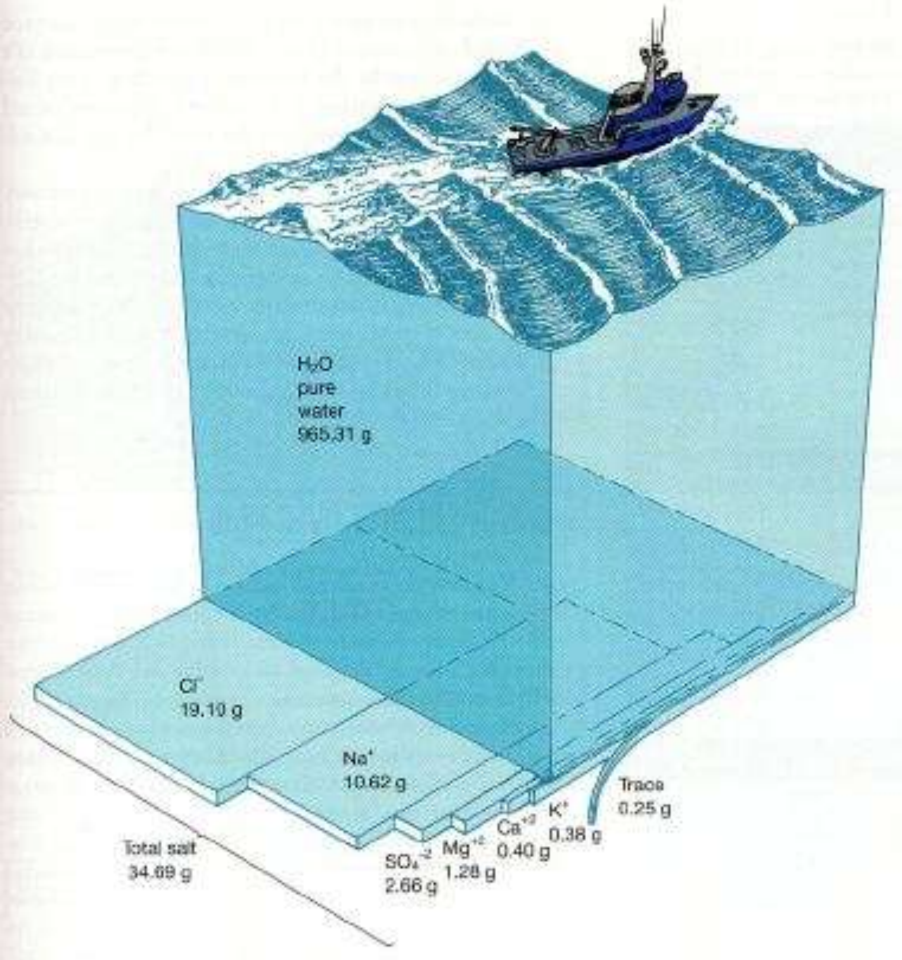
At high latitudes, the thermocline could be inverted or there could be two thermoclines, due to different layers (d).

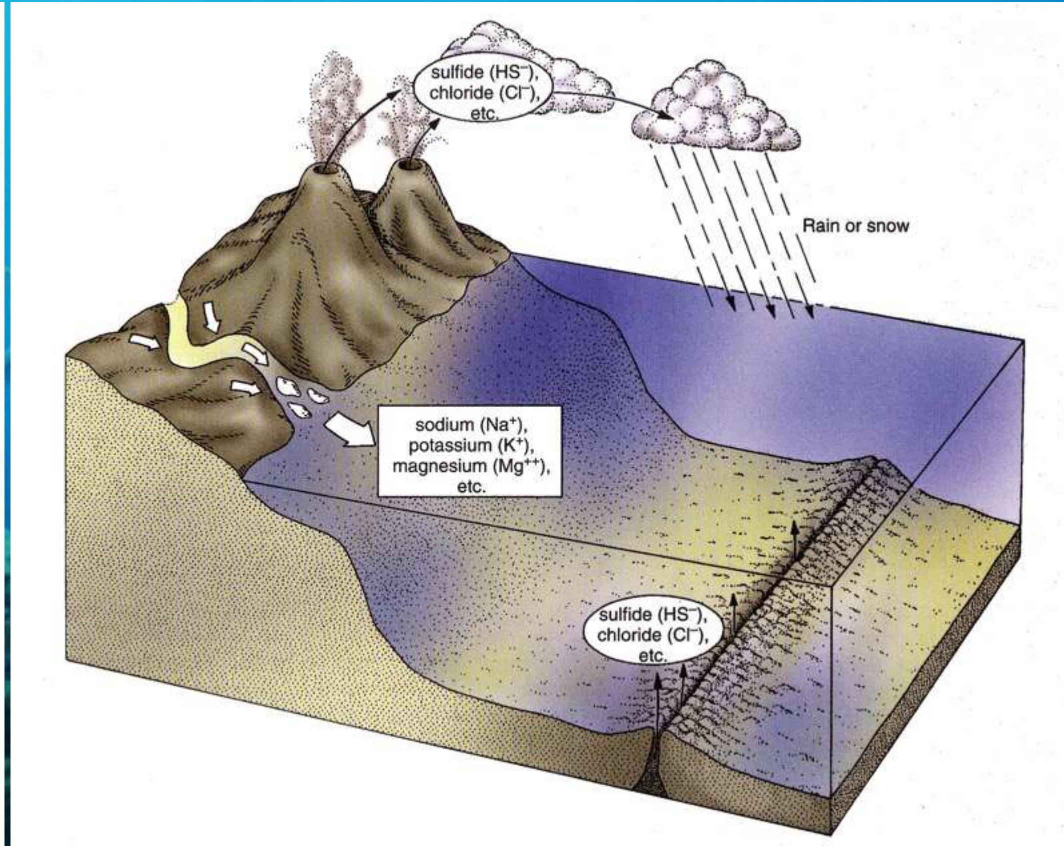
Salinity

Average salinity: 35‰ (0.5-40 ‰)

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

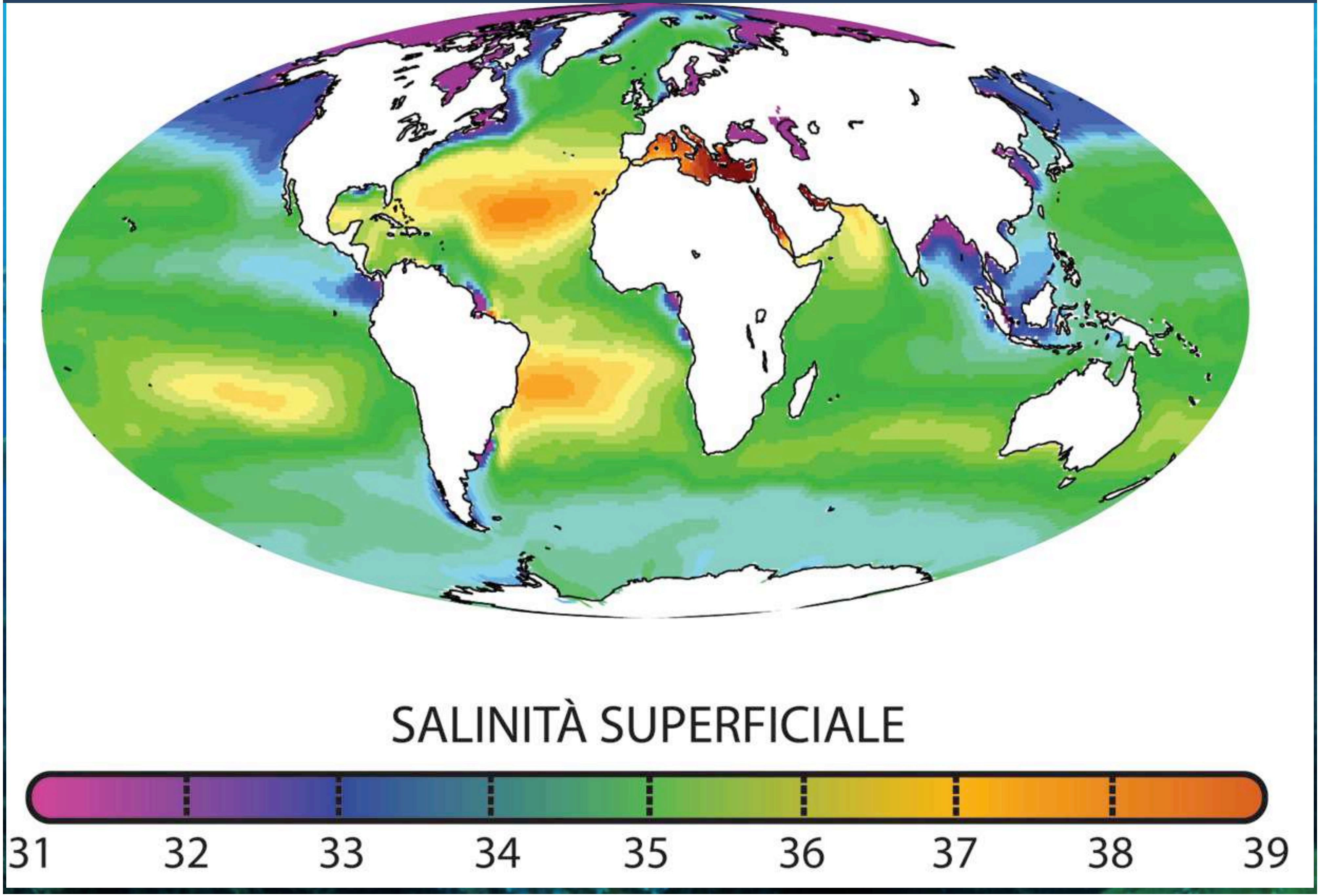
Elements derive from erosion on mainland, river transport and volcanic activity





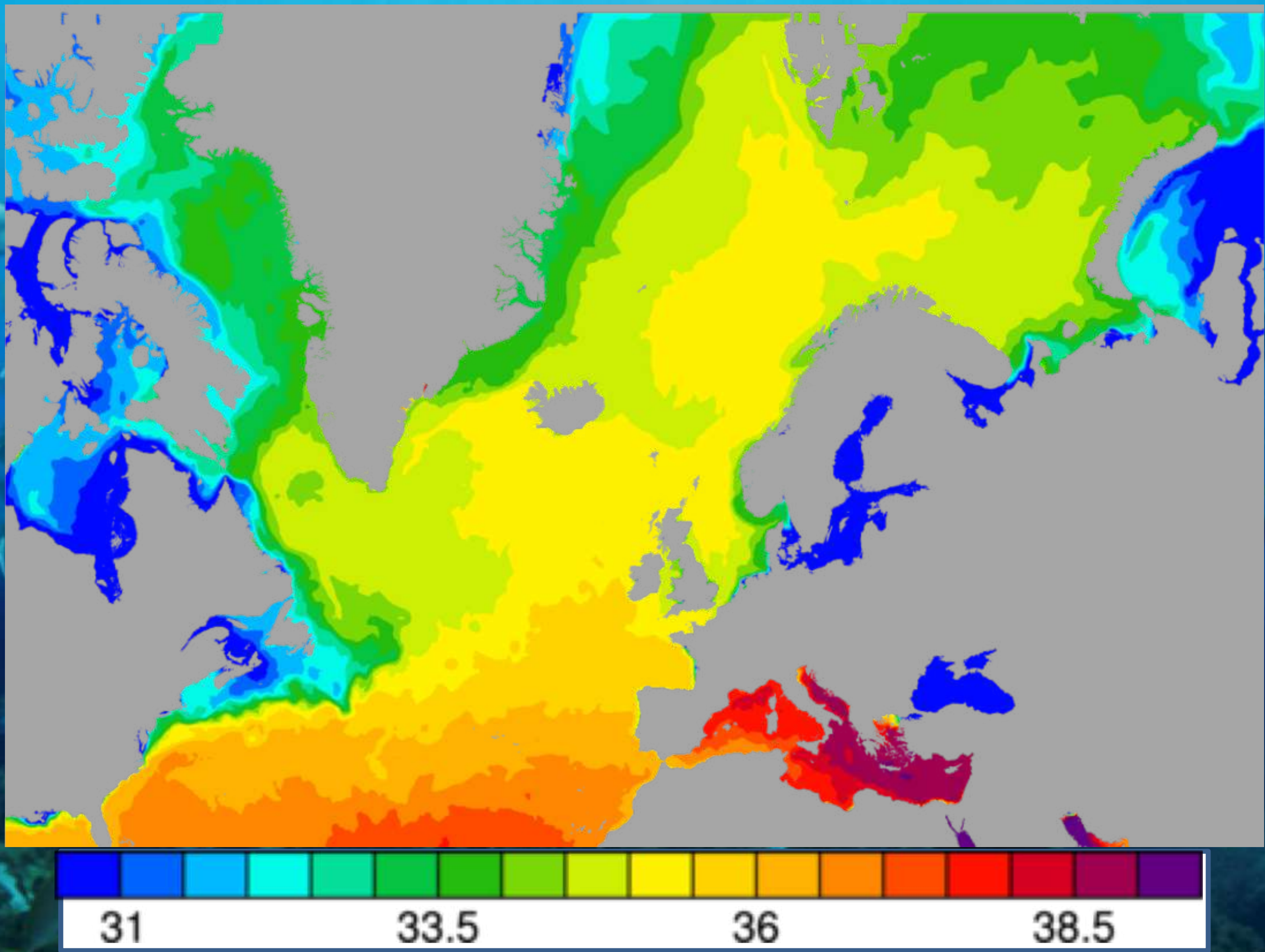
Sodium chloride, magnesium chloride, magnesium, calcium and potassium sulfate, calcium carbonate

Salinity: global average



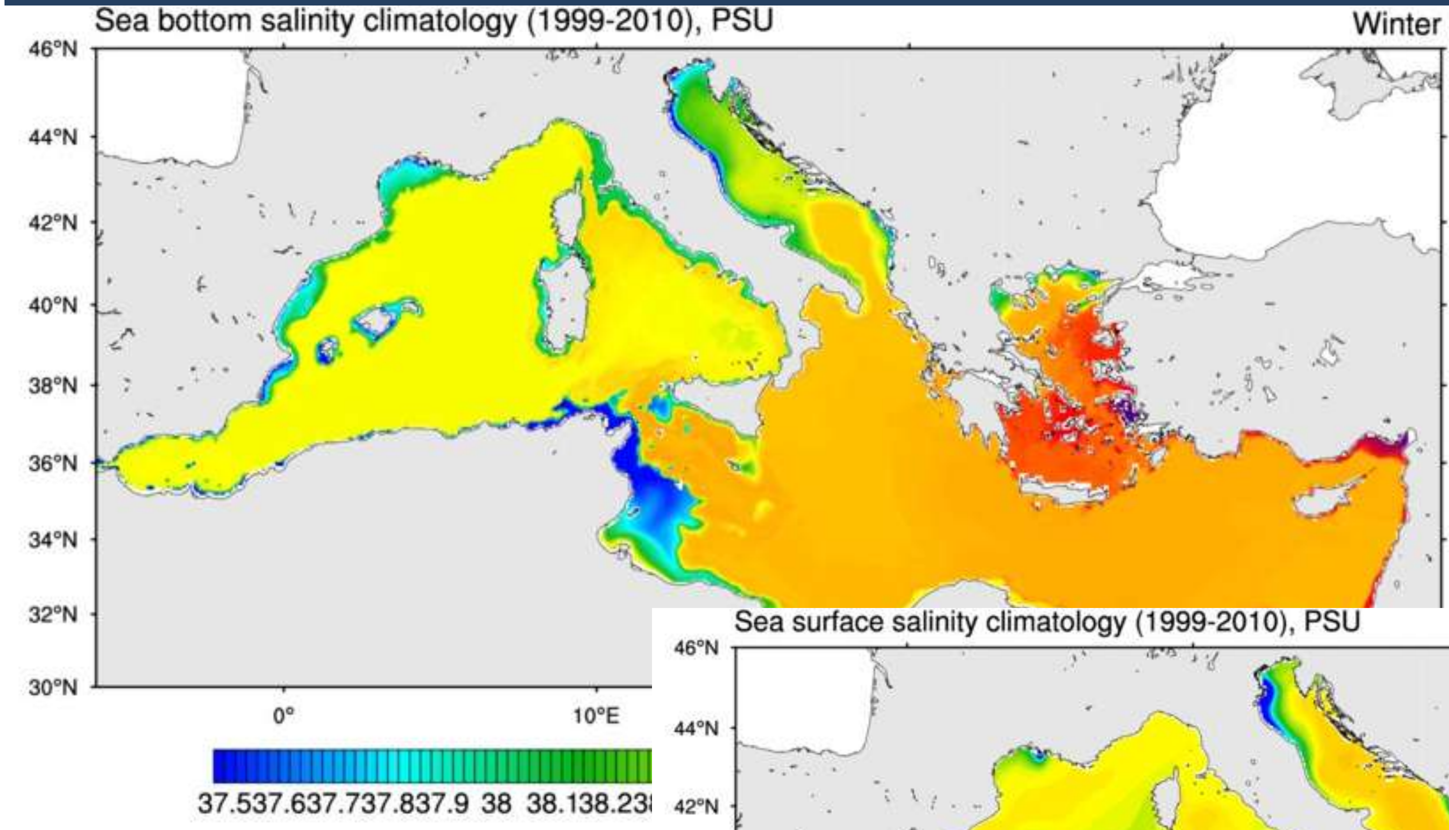
Salinity: N Atlantic

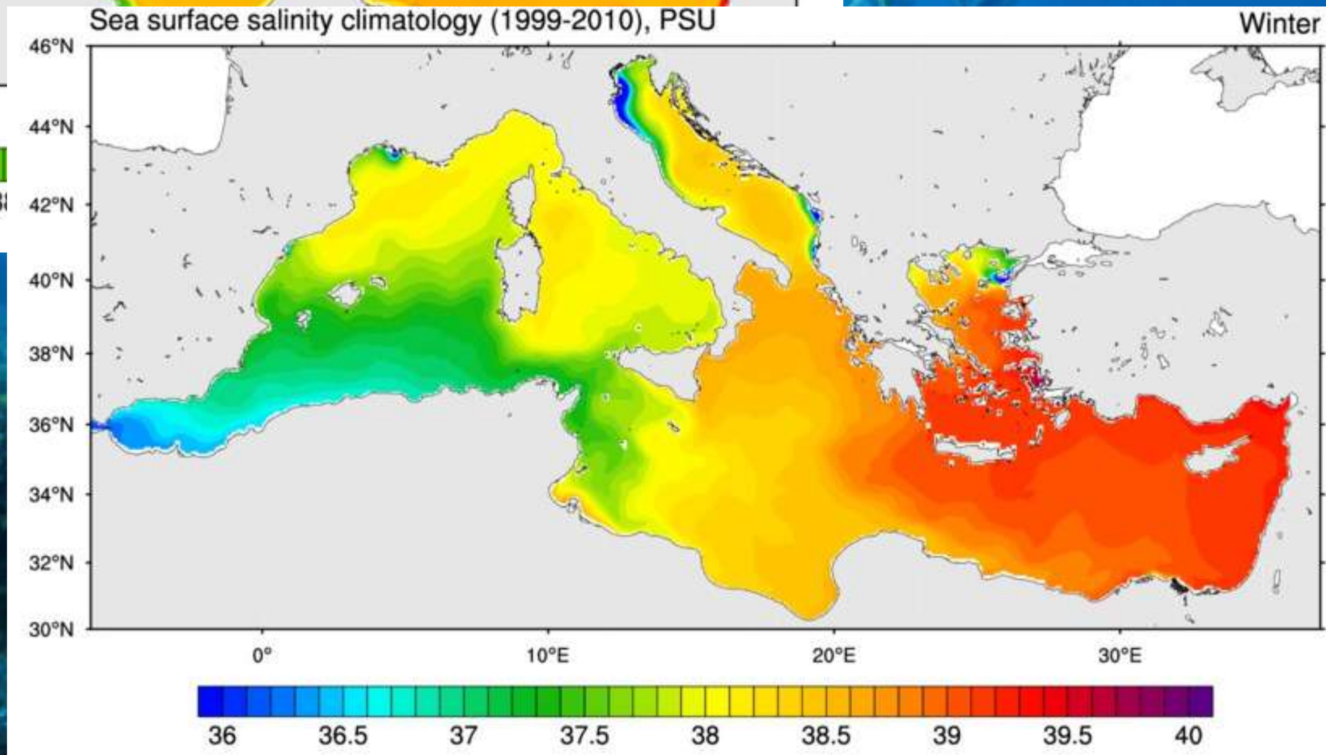
North Atlantic: sea-surface salinity - Autumn 2012 (PSU)



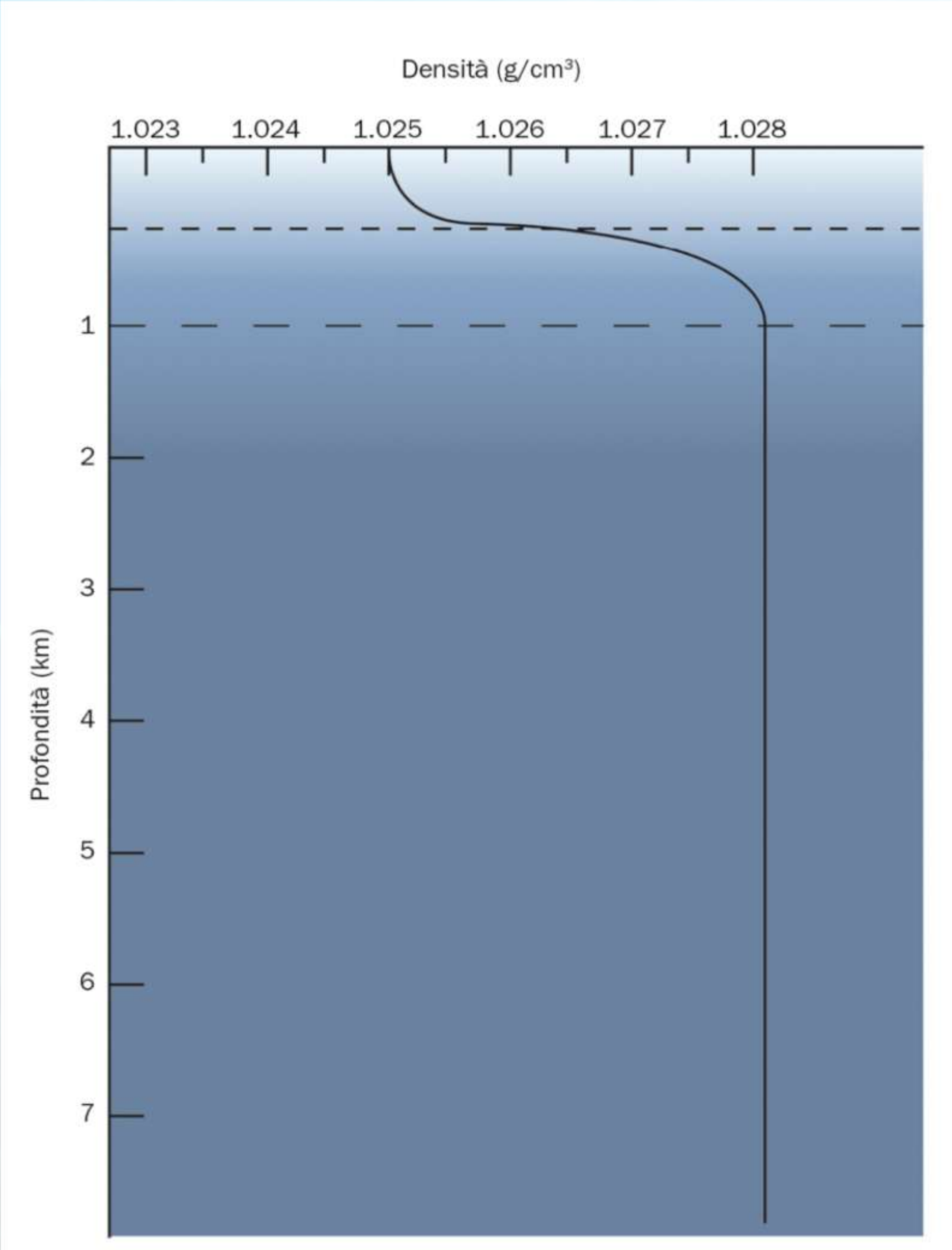
Note in dark blue areas (below 31) salinity values can equate to anything between 0-31psu

The Mediterranean Sea





Density



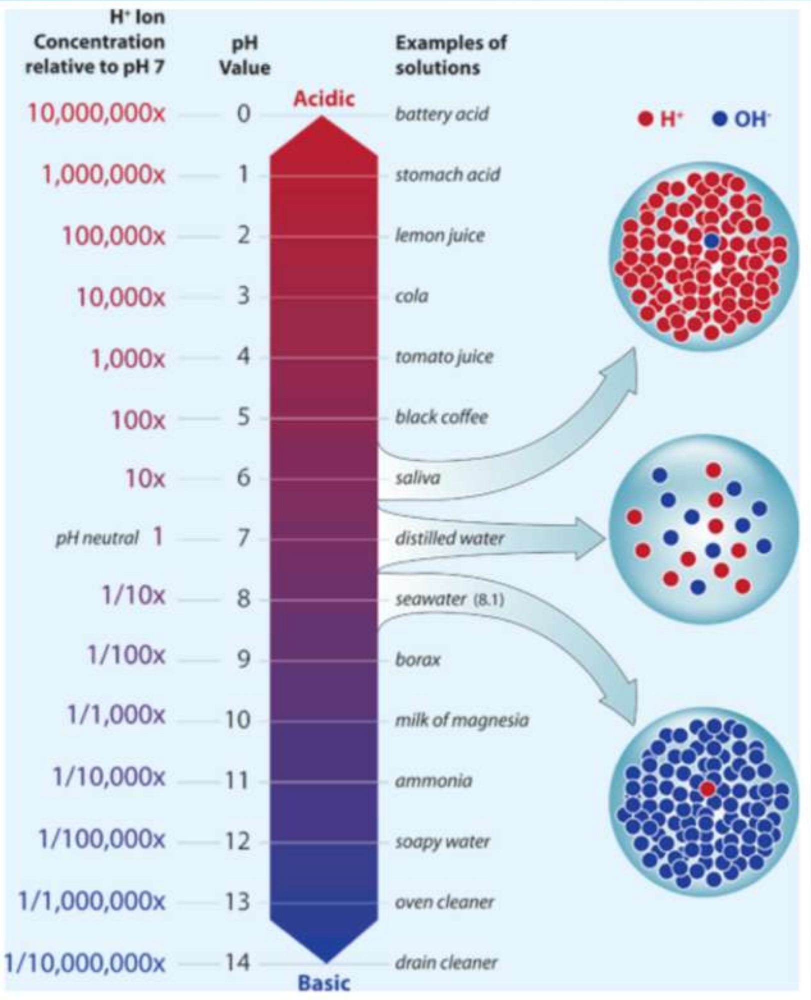
Density changes depending on temperature, pressure, and salinity.

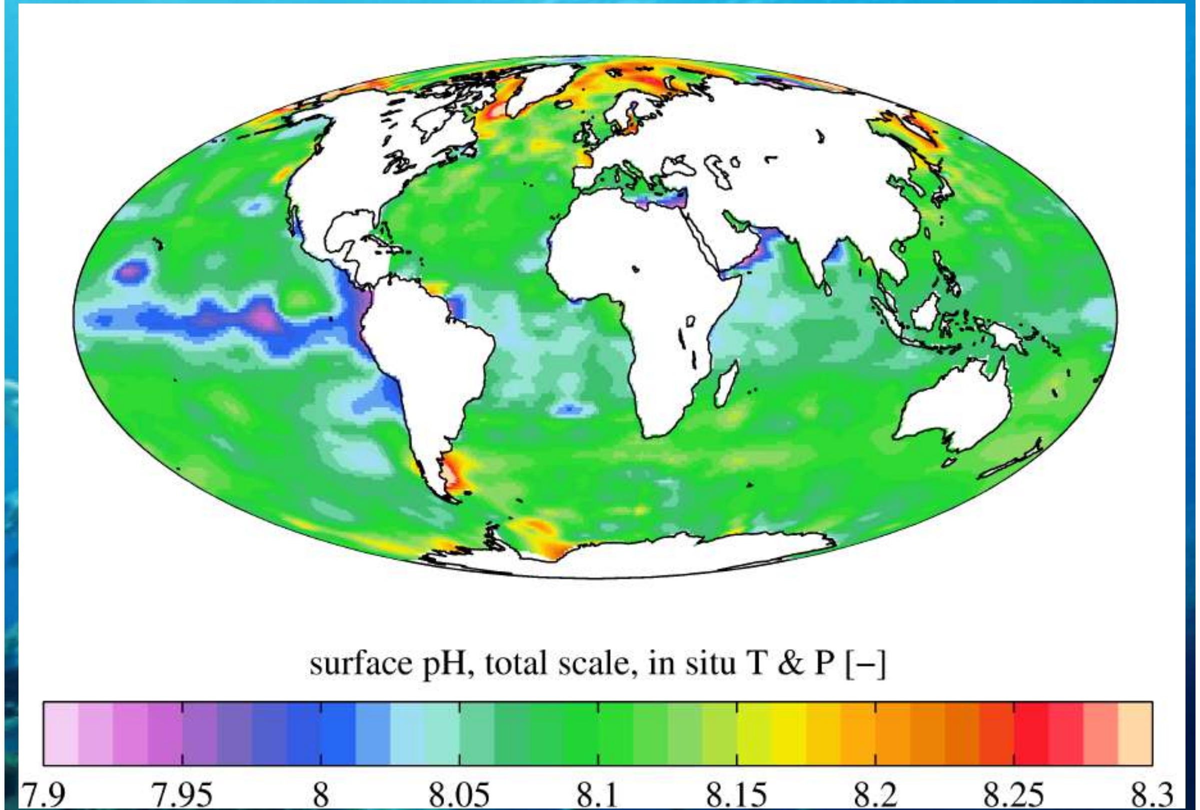
Warm waters are less dense than cold waters.
Increased salinity increases sea water density

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

Generally, 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



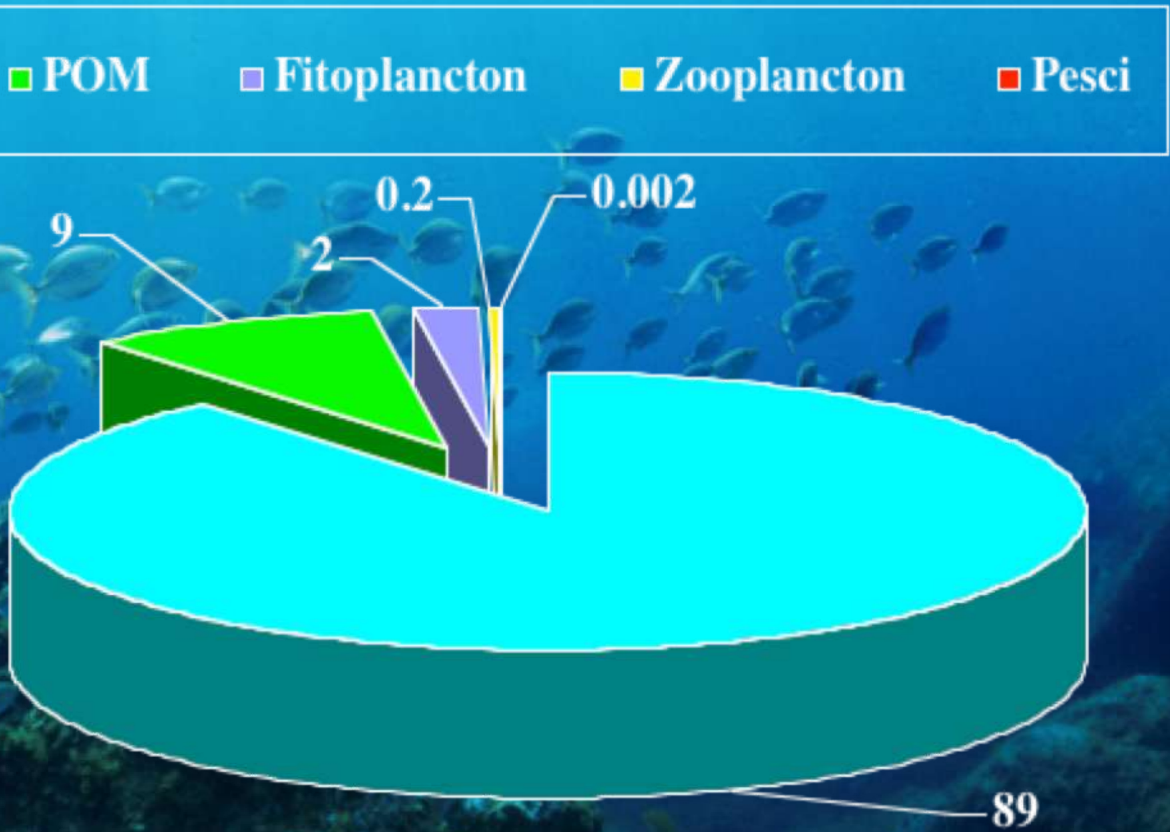


Average pH = 8.1

Mostly depend on CO_2 diffusion in seawater. Changes in pH could strongly affect marine organisms

Organic matter

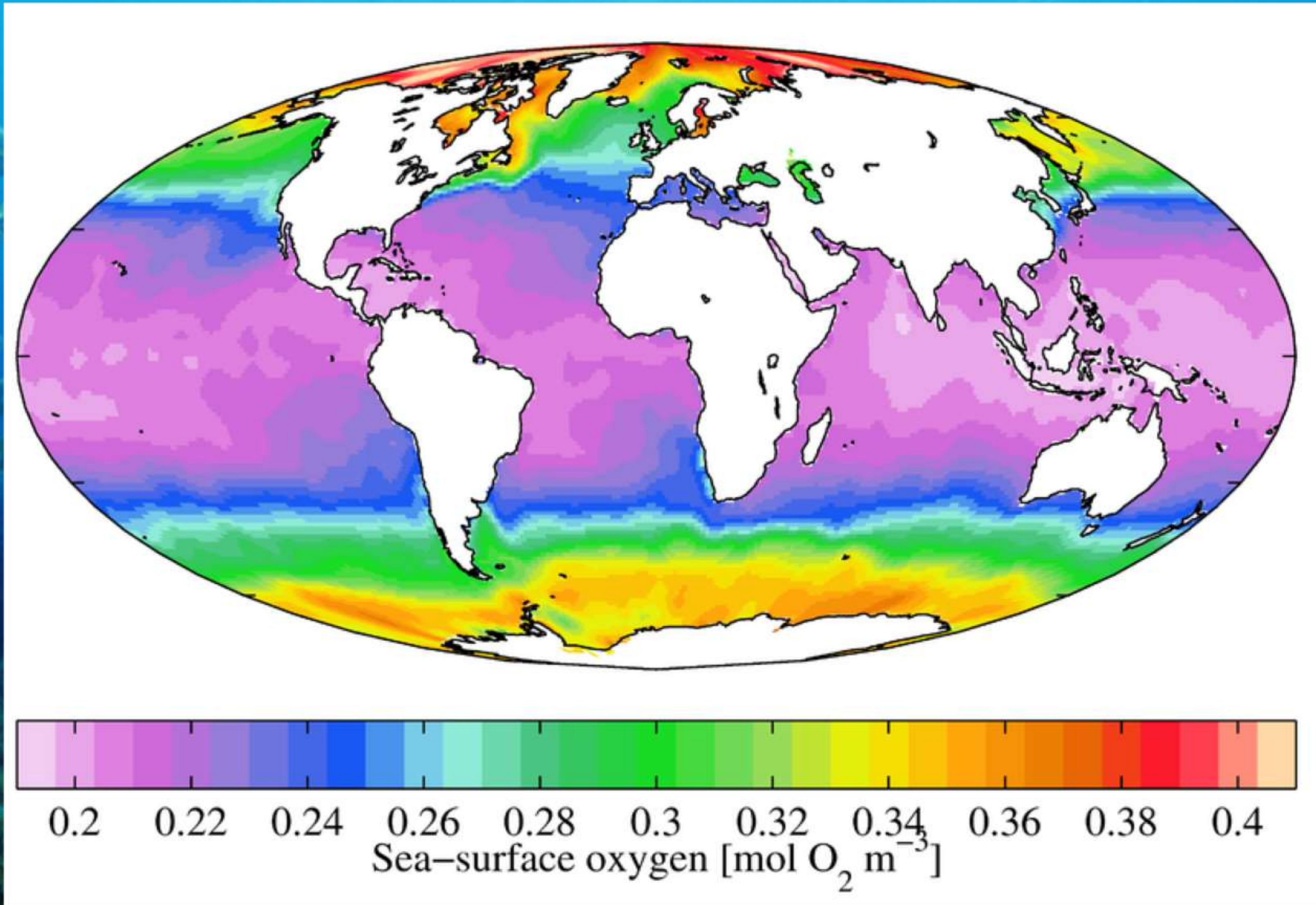
Most of organic carbon in the ocean is detritus, *"non-predatory loss of organic carbon from each trophic level or inputs from external sources"* (Wetzel et al.,1972). So, everything non-living and organic, irrespective of its size, composition and origin.



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

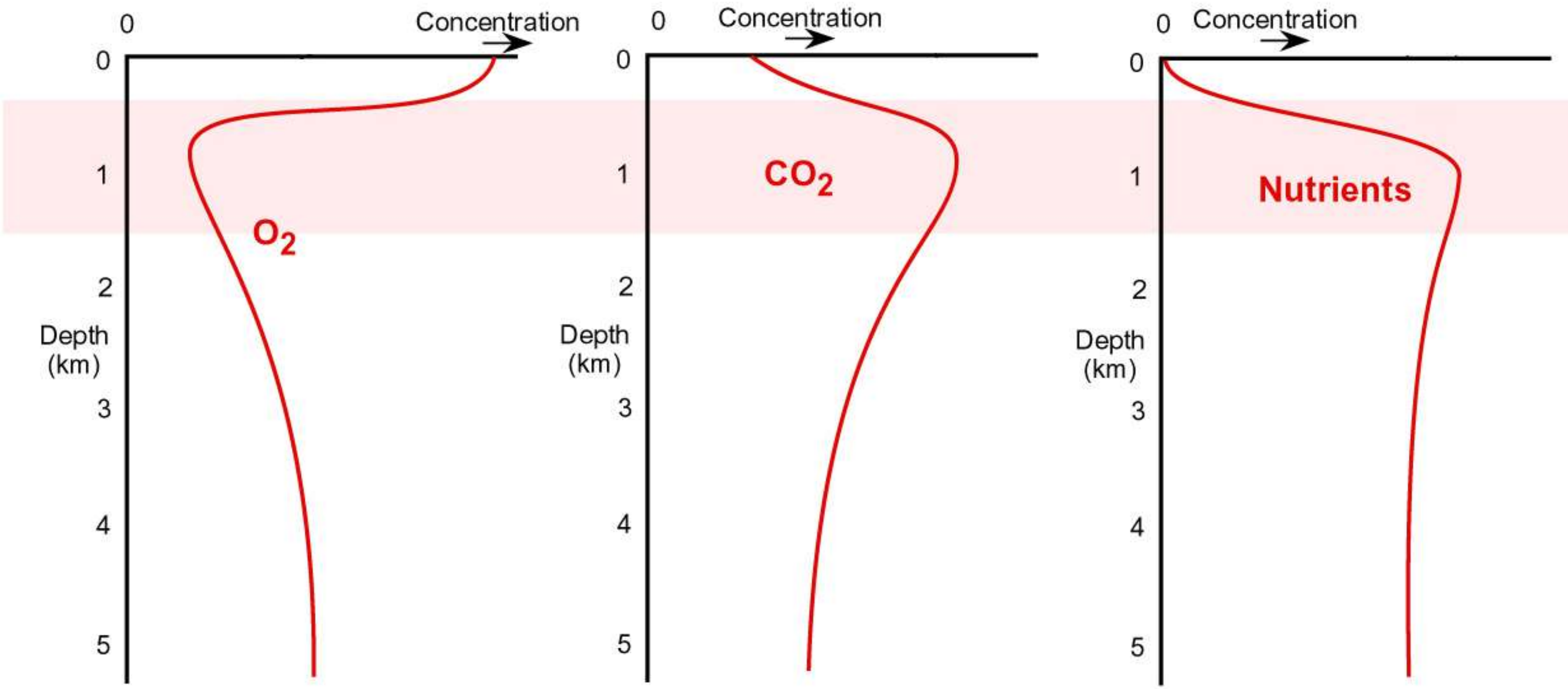
Oxygen

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

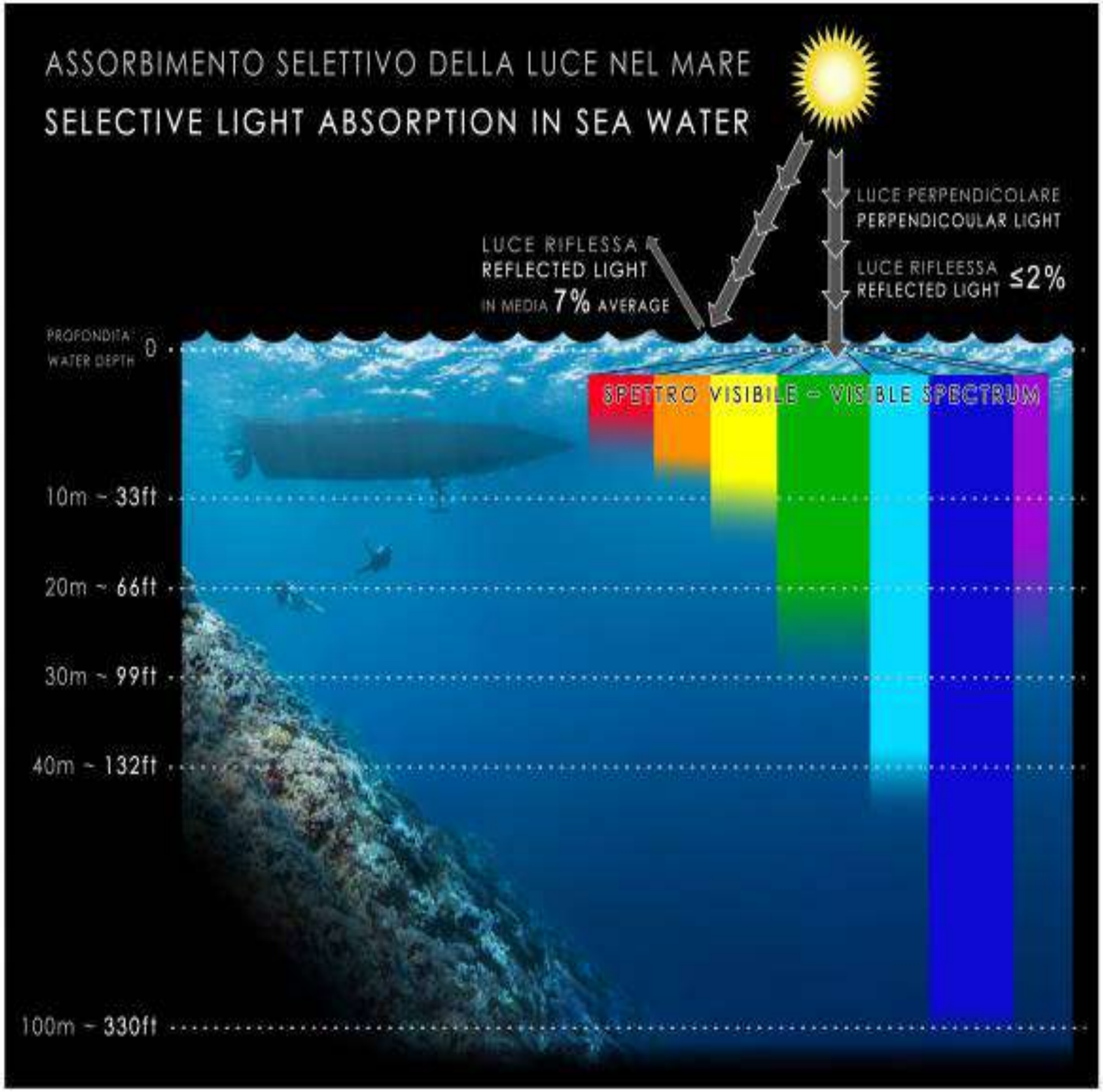


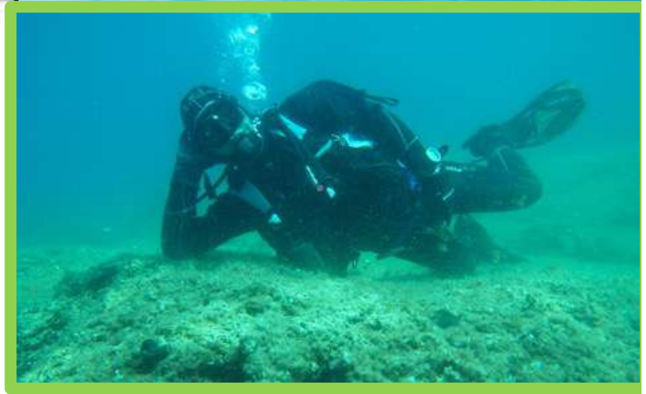
Main environmental features

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)

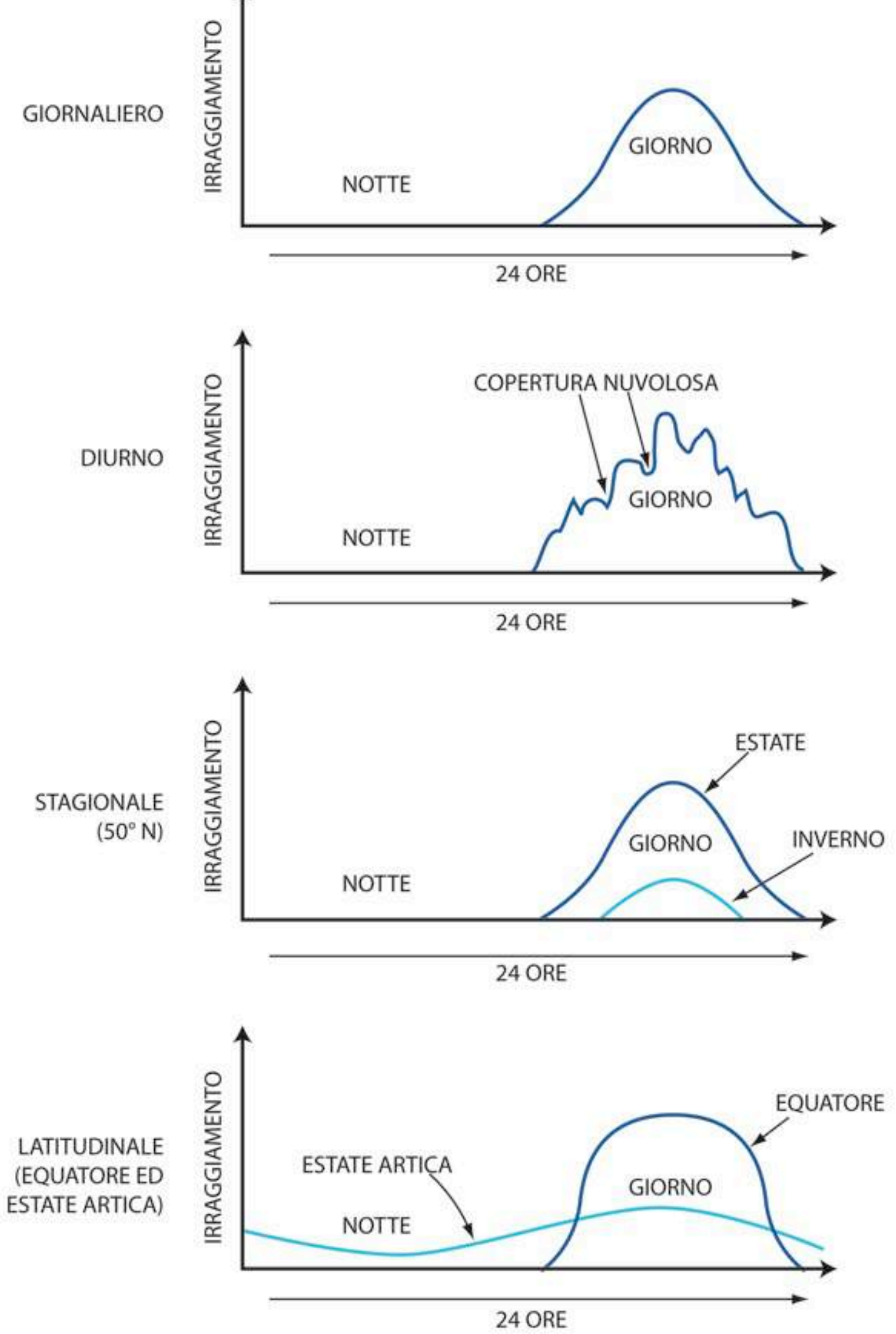


Light

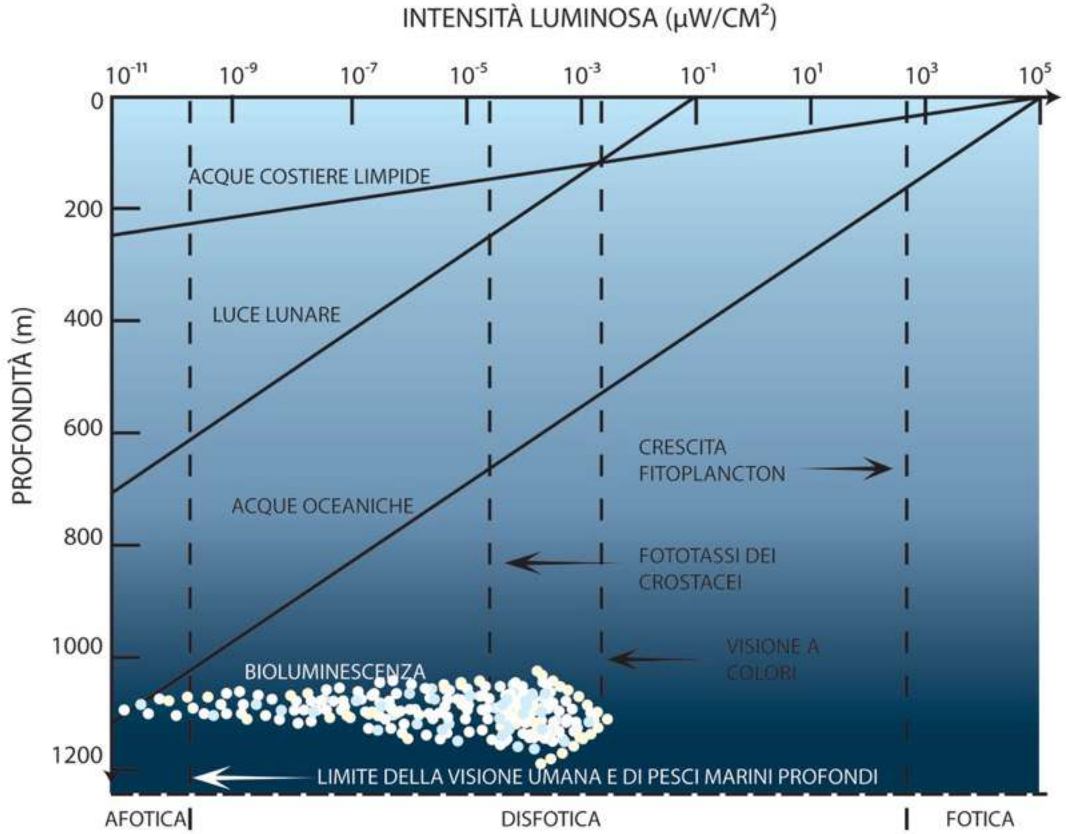

ASSORBIMENTO SELETTIVO DELLA LUCE NEL MARE
SELECTIVE LIGHT ABSORPTION IN SEA WATER
LUCE RIFLESSA
REFLECTED LIGHT
IN MEDIA 7% AVERAGE
LUCE PERPENDICOLARE
PERPENDICOULAR LIGHT
LUCE RIFLEESSA
REFLECTED LIGHT ≤2%
PROFONDITA'
WATER DEPTH
0
SPETTRO VISIBILE – VISIBLE SPECTRUM
10m ~ 33ft
20m ~ 66ft
30m ~ 99ft
40m ~ 132ft
100m ~ 330ft



Light

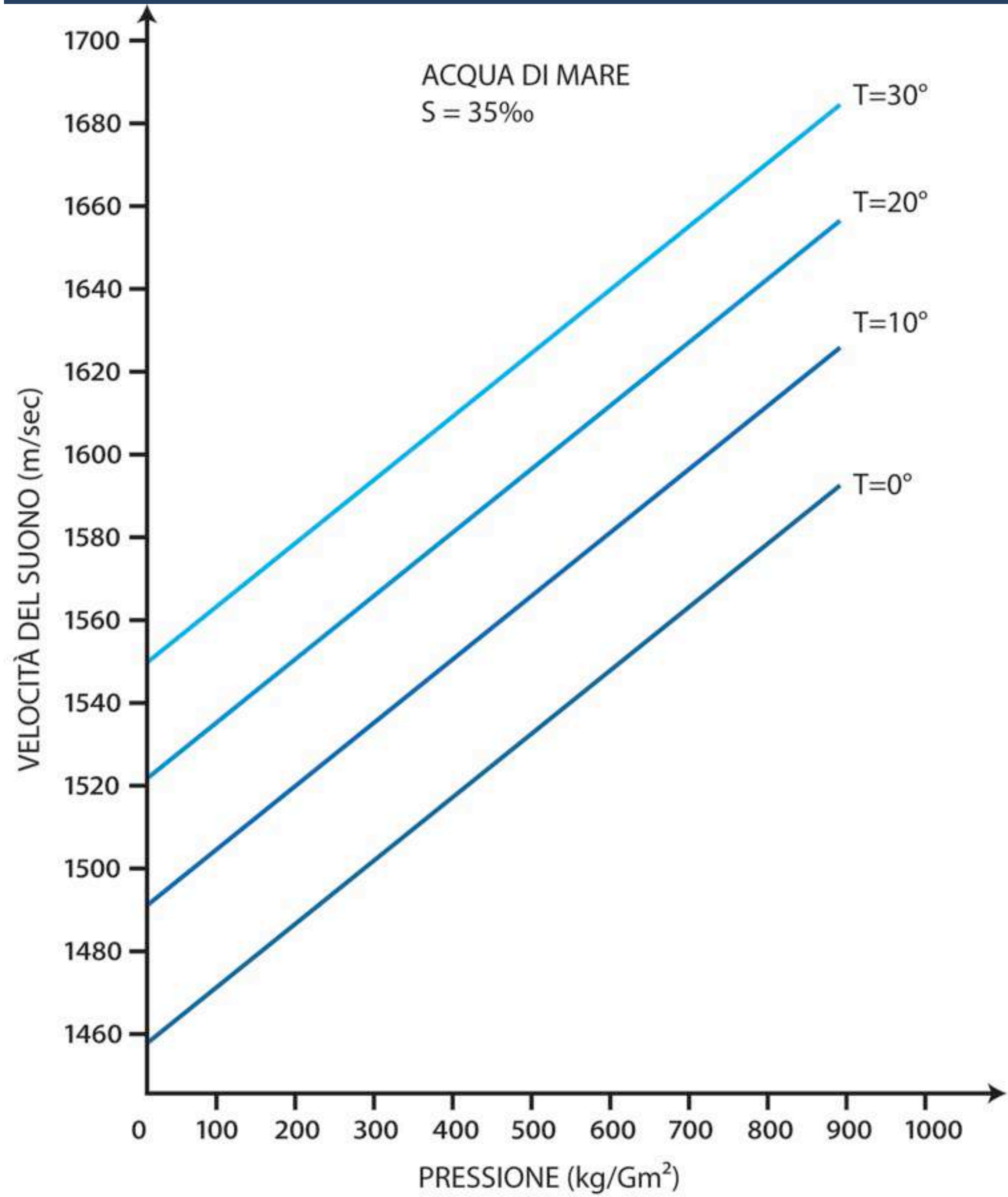


Light varies during the day and with seasons in temperate areas.



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



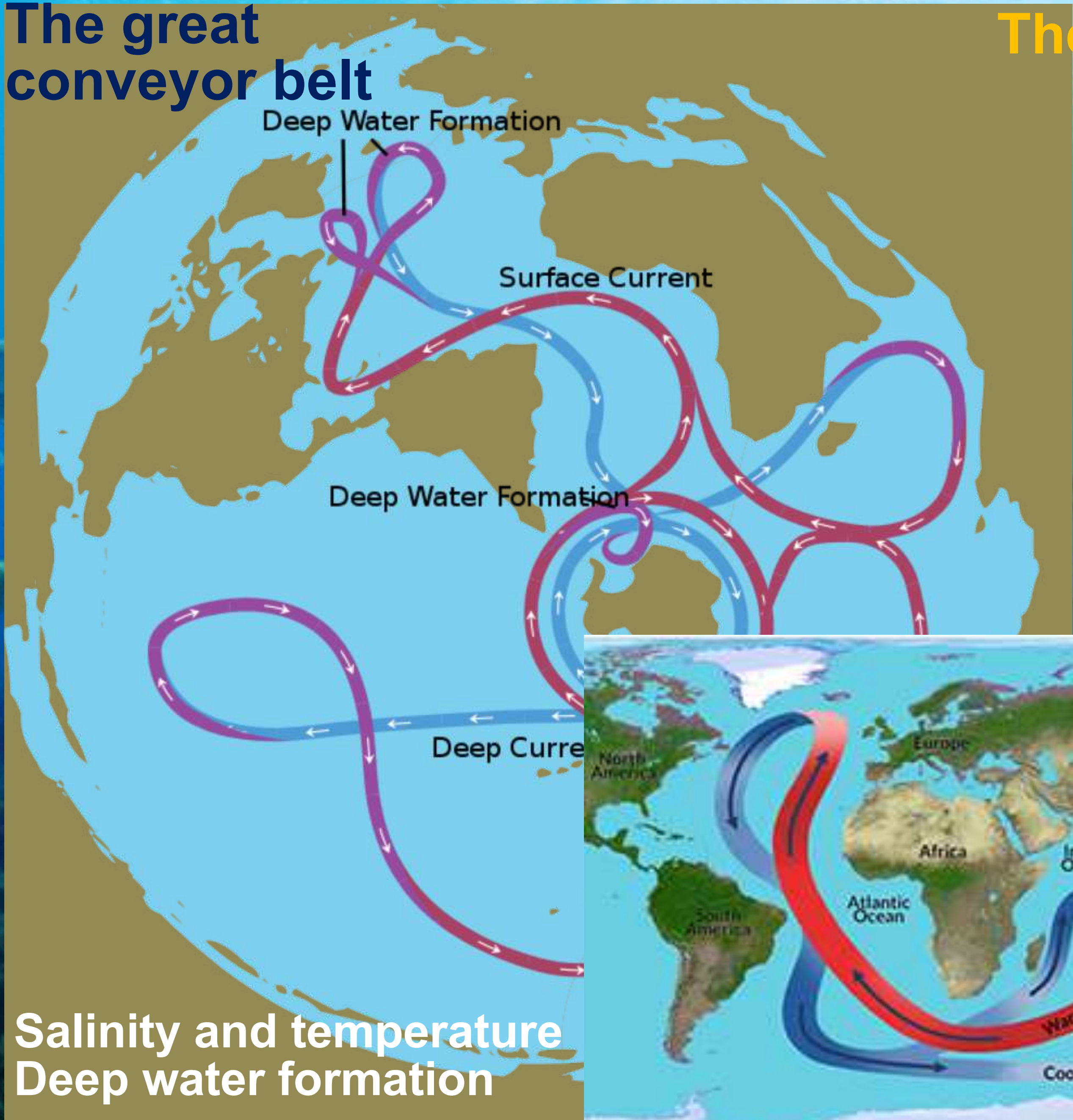
Sound propagate more quickly in water than in the air (340 ms^{-1}). Typically, sound speed in the sea water is around 1500 ms^{-1}

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

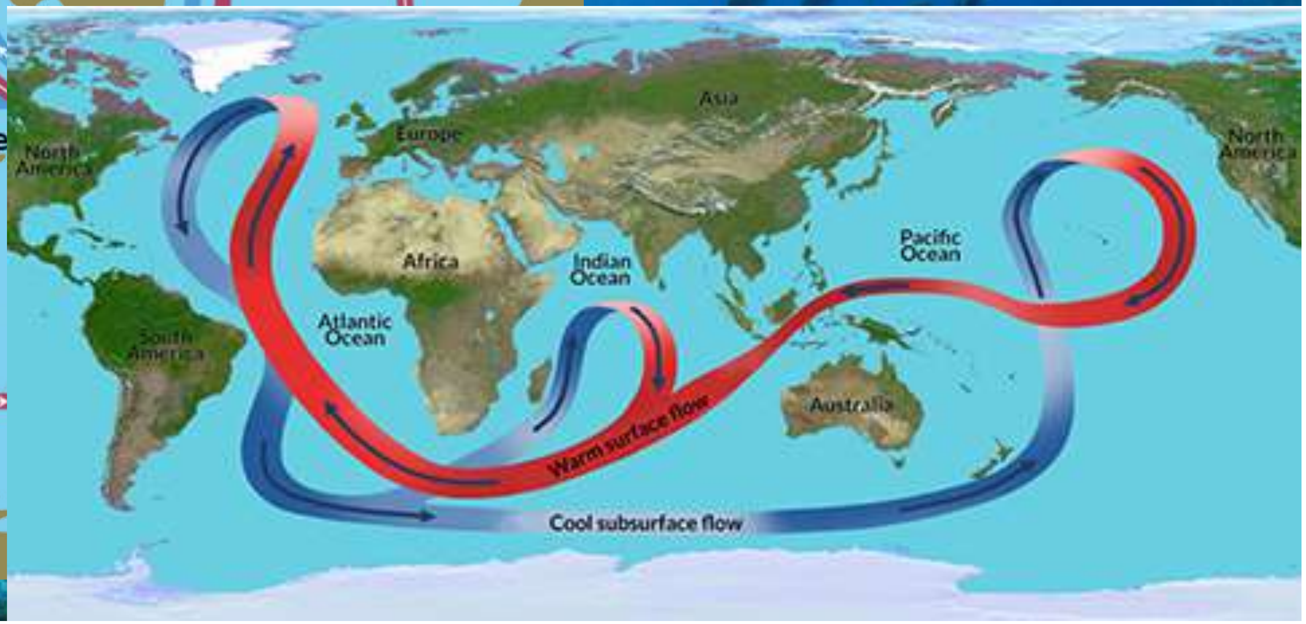


Salinity and temperature
Deep water formation

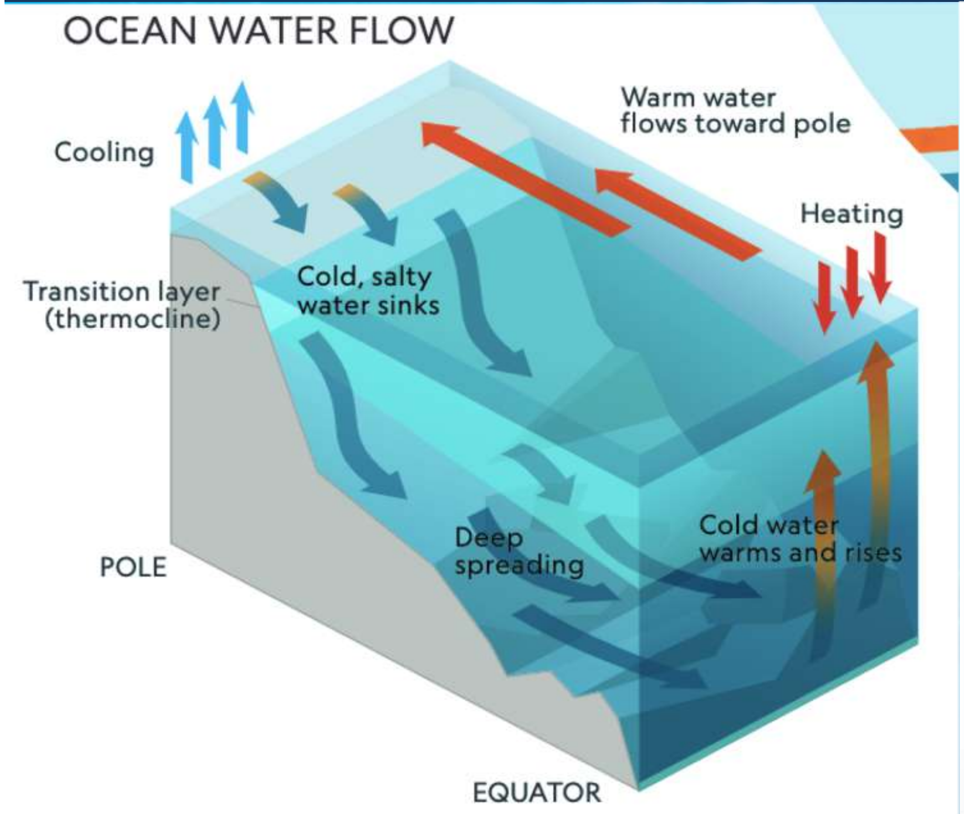
Thermohaline circulation

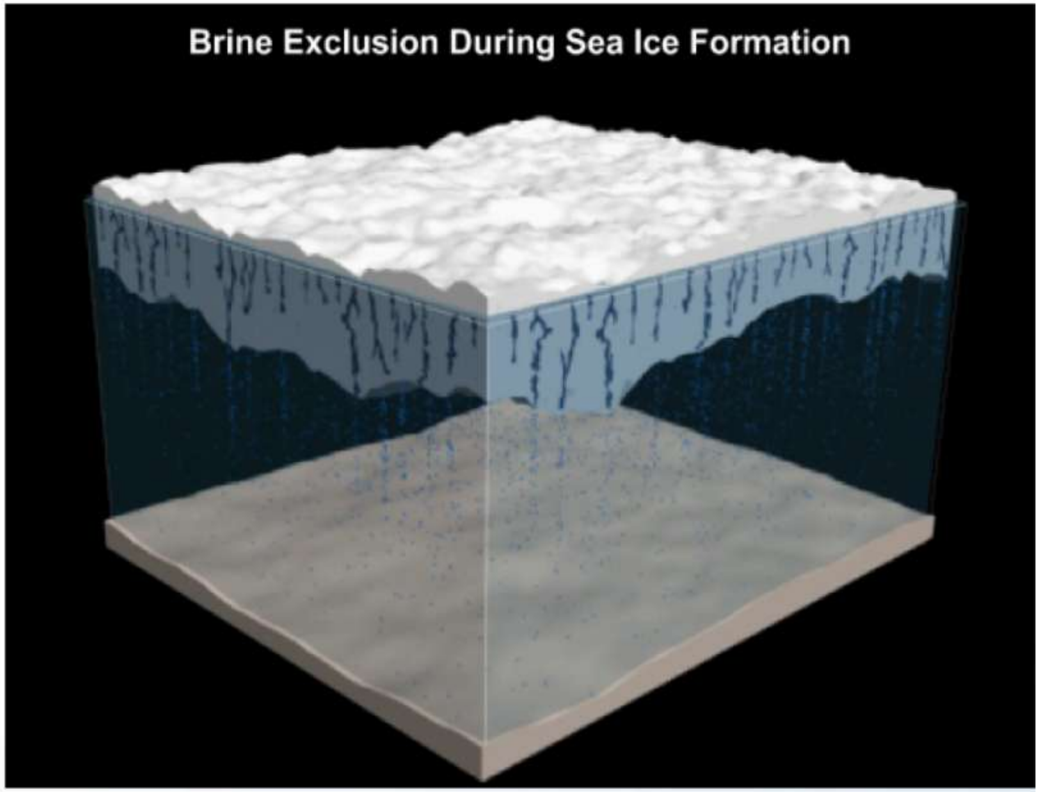
(few cm s^{-1})

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



Deep water formation



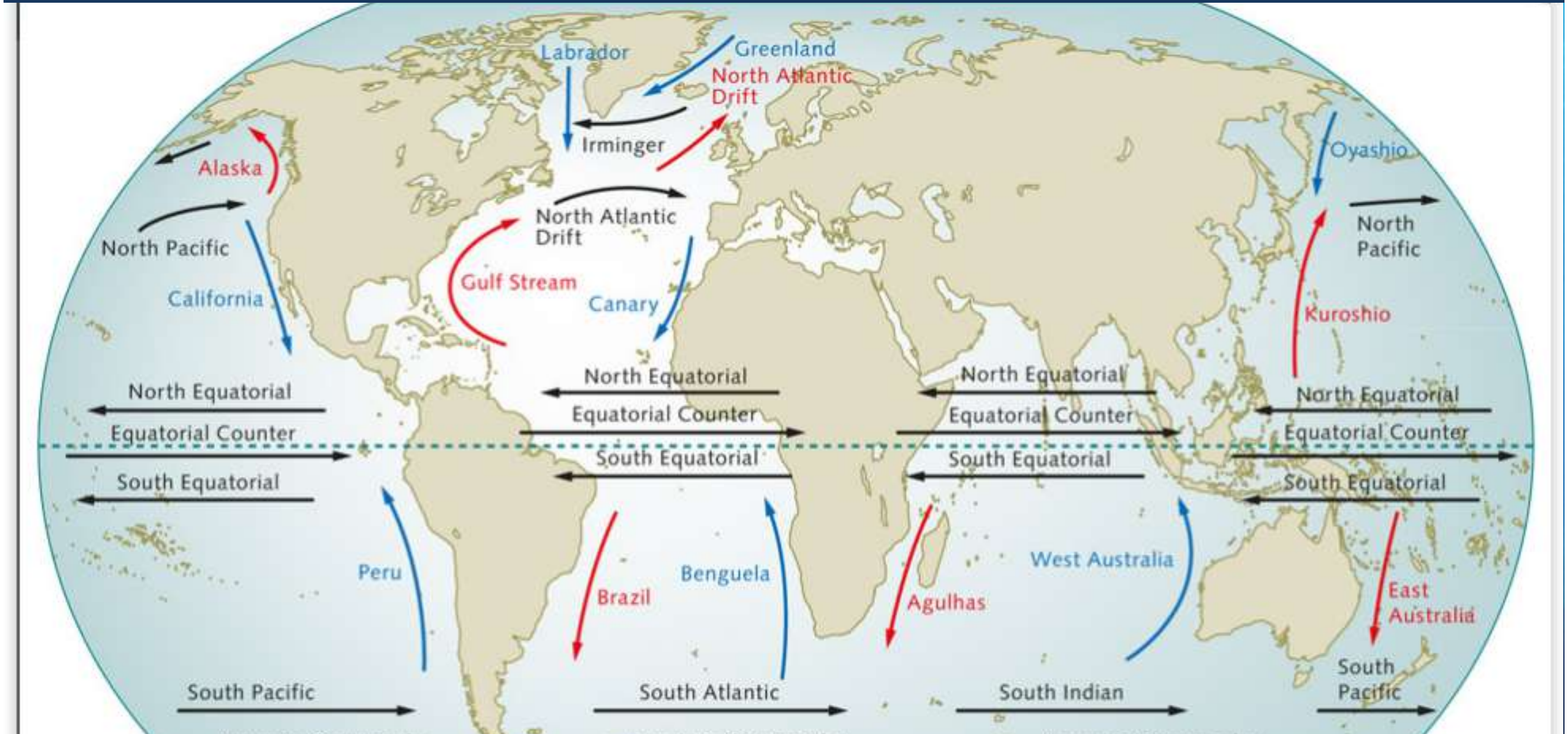


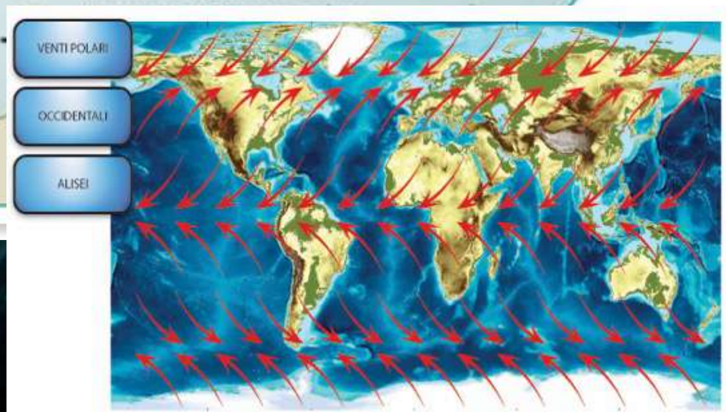
Cold polar winds cause evaporative cooling of seawater, and increase of salinity

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

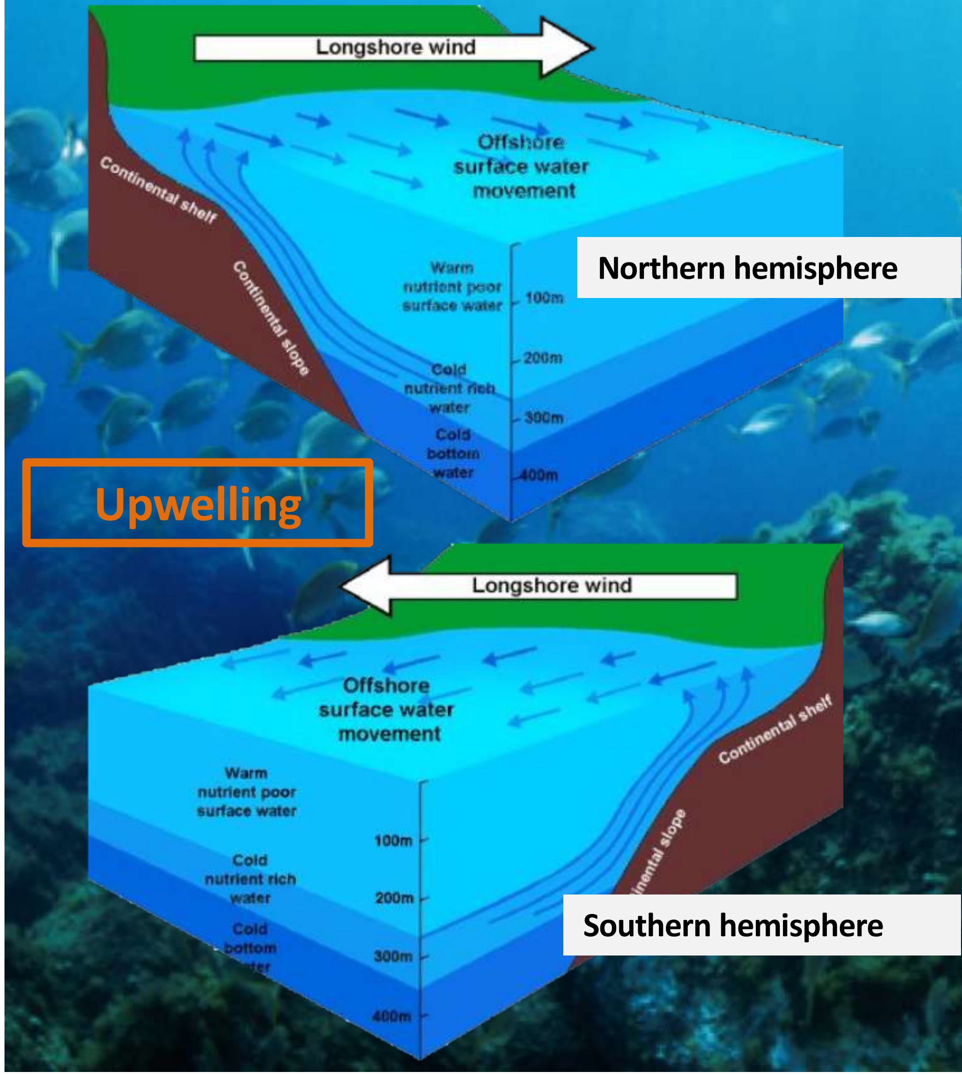


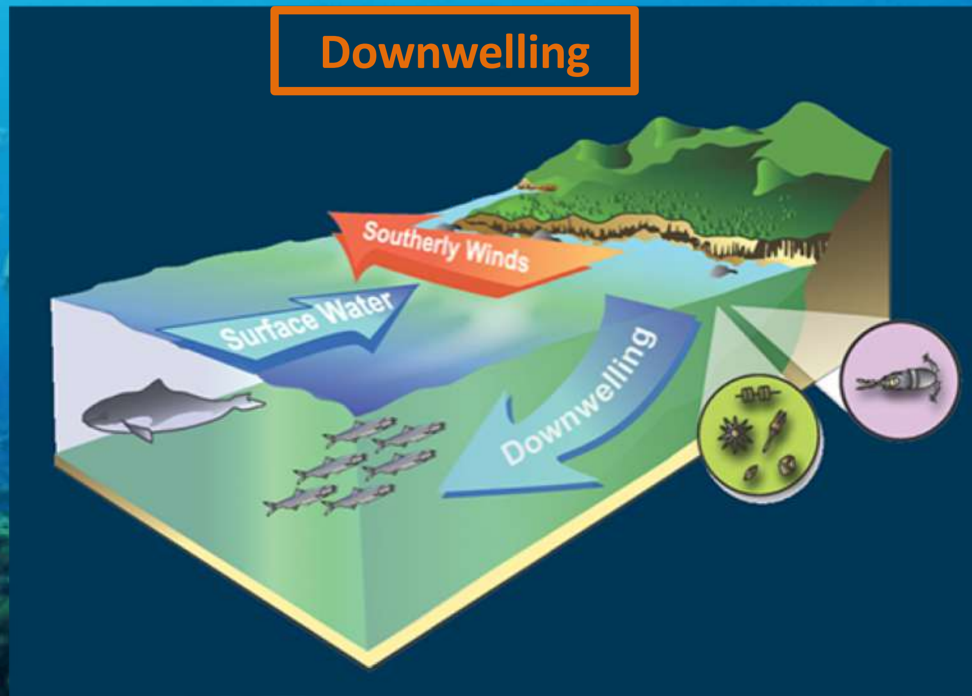


Surface currents are driven by winds, continental shapes, Earth rotation

Vertical circulation

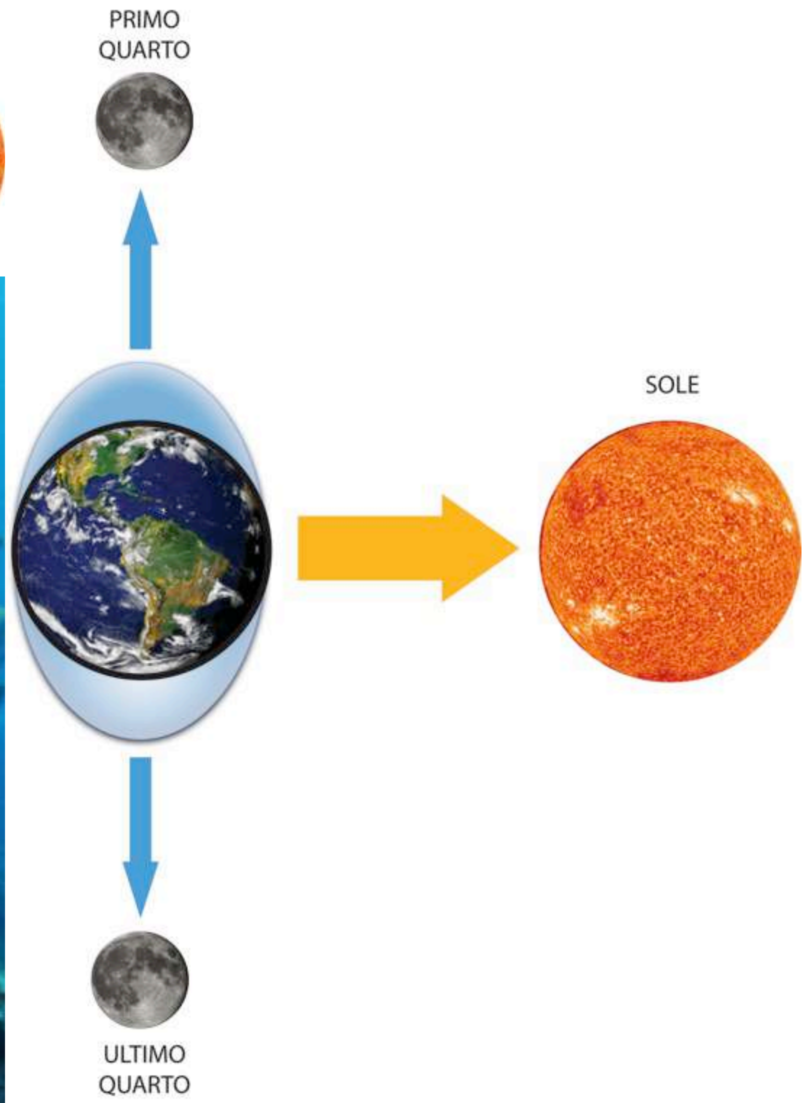
Vertical circulation is also important for the functioning of marine ecosystems. It allows replacing warm and nutrient-poor surface waters with cold and nutrient-rich waters from the bottom, and to transport oxygen towards the bottom





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

Tides

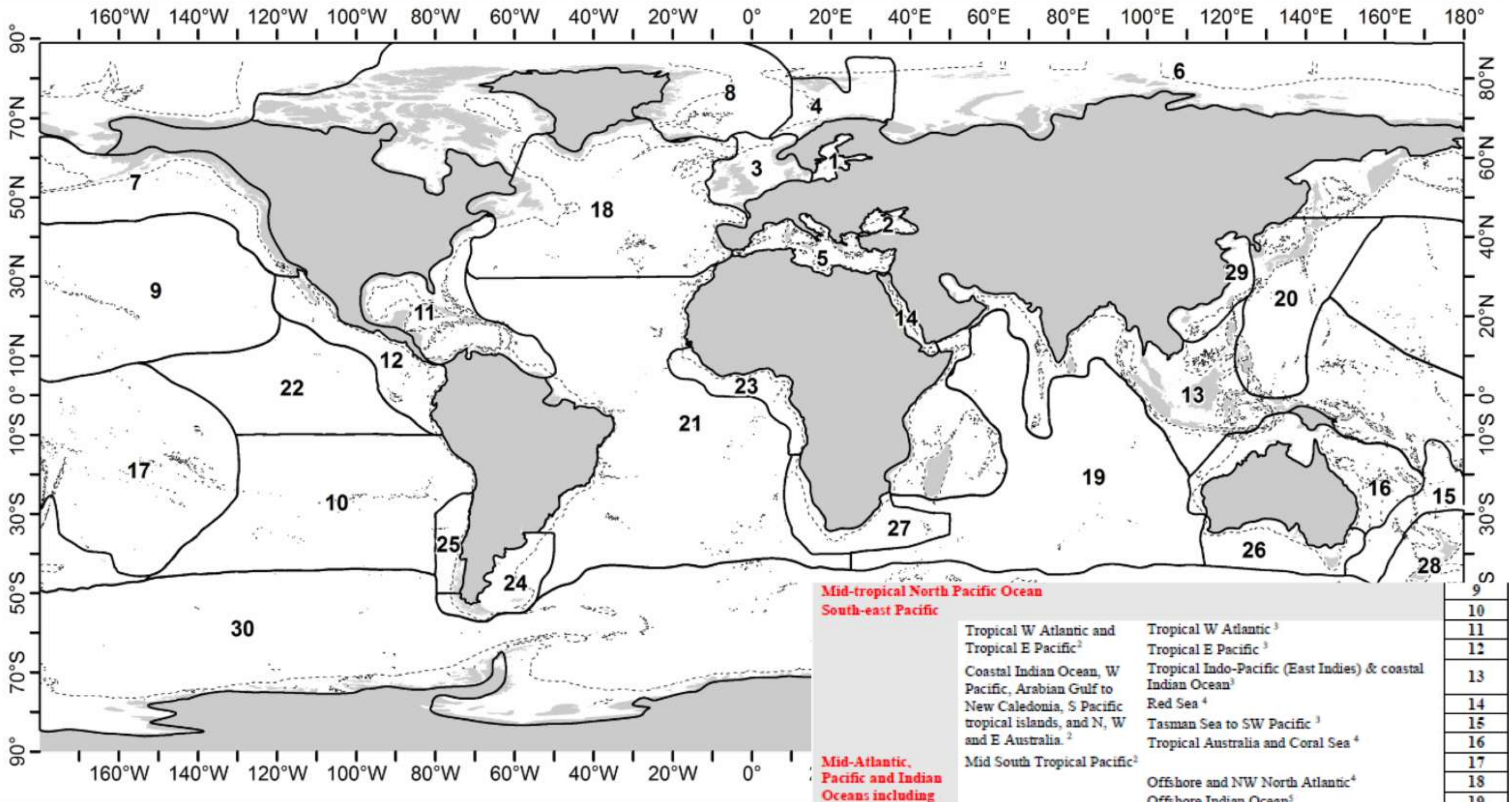


Tides a caused by the attraction of the moon and the sun. The strength of moon attraction is two times stronger than the sun. When the two are aligned, tides are higher. Neap-tides occurs when the moon and the sun form an angle of 90° (we have the lower high tide and the higher low tide). On average,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

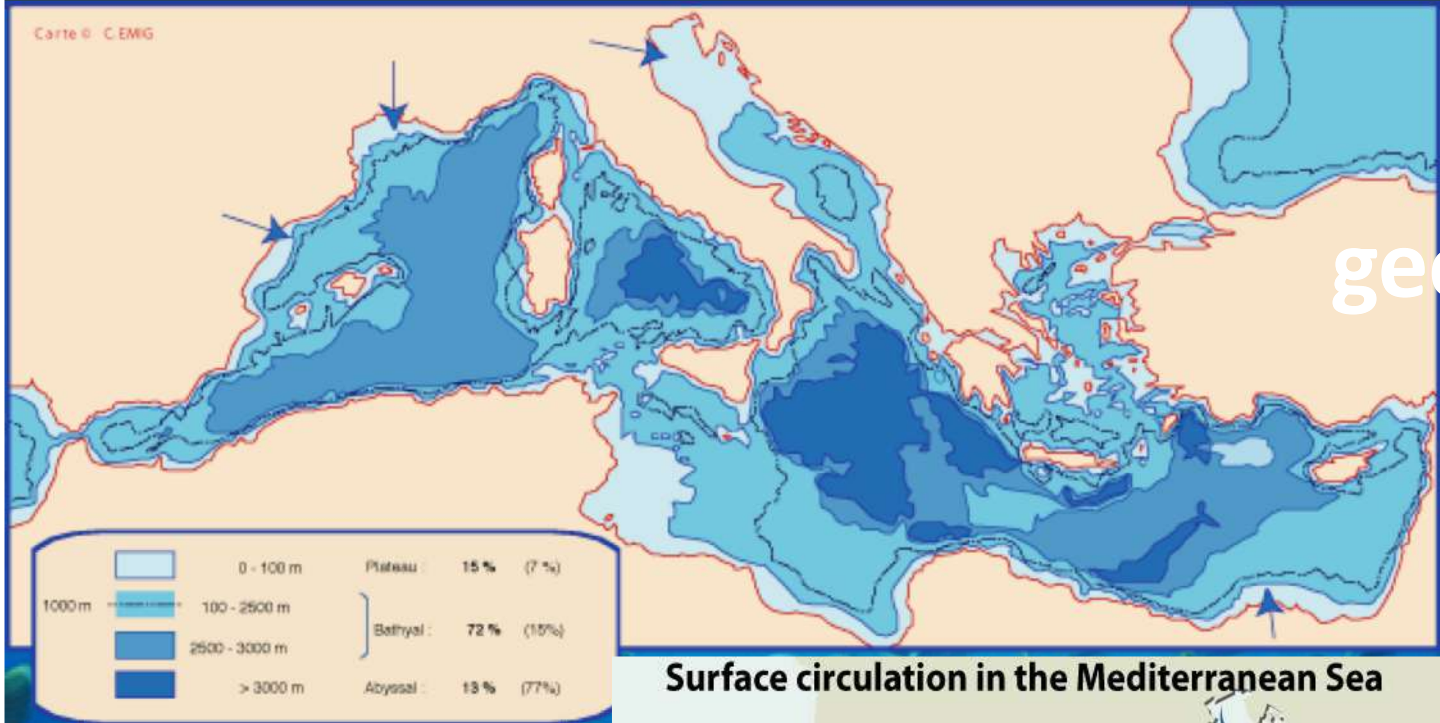
They range between few decades of cm (e.g. Mediterranean Sea) until several m (e.g., Bay of Fundy, Canada)

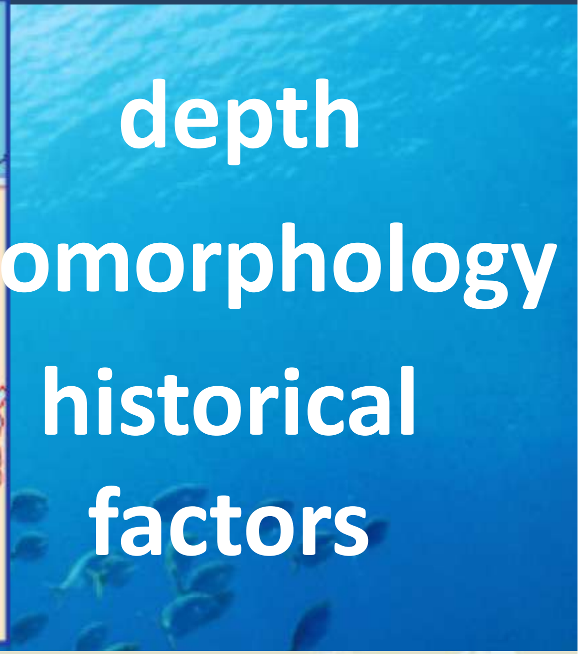
Biogeographic areas in oceans and seas



			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

The Mediterranean Sea

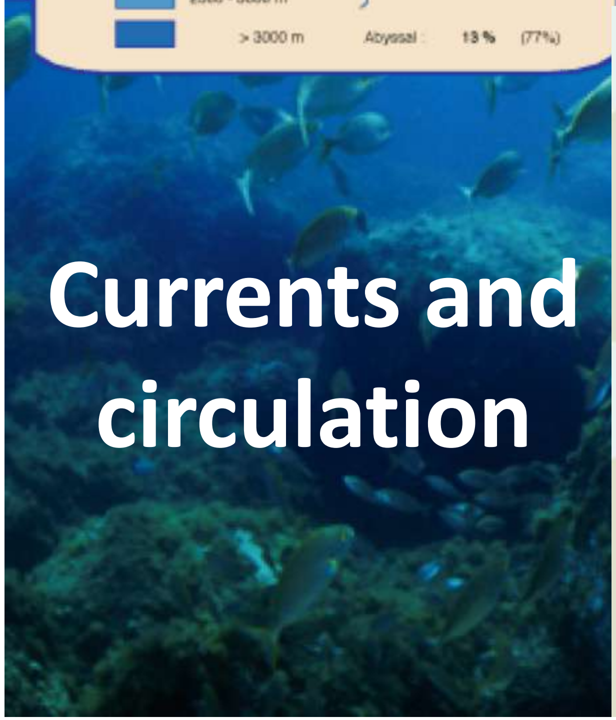




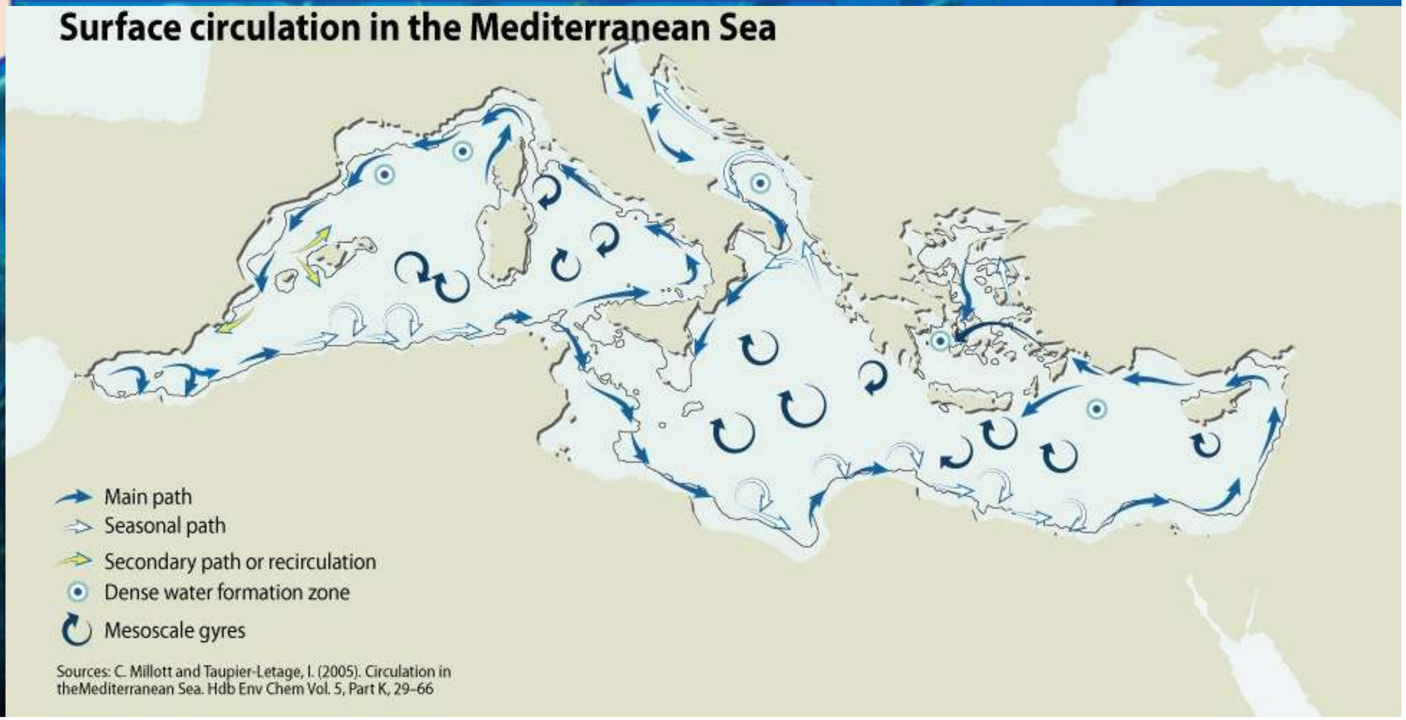
depth

geomorphology

historical factors



Currents and circulation



Biogeography of the basin