# *Hydrosphere*

Module course: Ecological geology

Lecture 3

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* 1. Definition of the hydrosphere
* 2. Chemical composition of water
* 3. Hydrologic cycle
* 4. Ocean characteristics
* 5. Marine mineral deposits
* 6. Anthropogenic water pollution

# Definition

* **Hydrosphere is a discontinuous water shell of the Earth between atmosphere and solid Earth crust (lithosphere), including oceans, seas and water surface on the land.**
* **In broader sense the hydrosphere composition includes subsurface waters, ice, and snow of Arctic and Antarctic as well as atmospheric water and water contained in living organisms.**
* **The major part of the Earth water concentrates in seas and oceans, the second in volume is ground water, the third is ice and snow of Arctic and Antarctic. Surface water, atmospheric and bio-related water amounts some percent of the whole volume of the hydrosphere water.**

# *Three quarters of the planet are covered with seas and oceans, the rest is the islands*

# Types of water

| Types of water | Name | Volume, billion km³ | Amount with respect to entire volume of the hydrosphere, % |
|---|---|---|---|
| Sea water | Sea | 1370 | 94 |
| Ground (except soil water) water | Ground | 61,4 | 4 |
| Ice and snow (Arctic, Greenland, mountain regions, ice regions) | Ice | 24,0 | 2 |
| Surface water: lakes, reservoirs, rivers, swamps, soil water | Fresh | 0,5 | 0,4 |
| Atmospheric water | Atmospheric | 0,015 | 0,01 |
| Water in living organisms | Bio-related | 0,00005 | 0,0003 |

# Ice distribution on the Earth (according to Reymes, 1990)

| Ice type | Volume | | Square of distribution | |
|---|---|---|---|---|
| | t | % | billiob km$^2$ | % |
| Ice caps | 2,4*10$^{16}$ | 98,95 | 16,1 | 10,9 of land |
| Subsurface ice | 2*10$^{15}$ | 0,83 | 21 | 14,1 of land |
| Sea ice | 3,5*10$^{13}$ | 0,14 | 26 | 7,2 of ocean |
| Snow cover | 1*10$^{13}$ | 0,04 | 7264 | 14,2 of Earth |
| Glaciers | 7,6*10$^{12}$ | 0,03 | 63,5 | 18,7 of ocean, (sporadically) |
| Atmospheric ice | 1,7*10$^{12}$ | 0,01 | 510,1 | 100 over the Earth |

# Snow-ice cap of African mountain top of Kilimanjaro melted during 11000 years

# Arctic and Antarctic glaciers are gradually melting

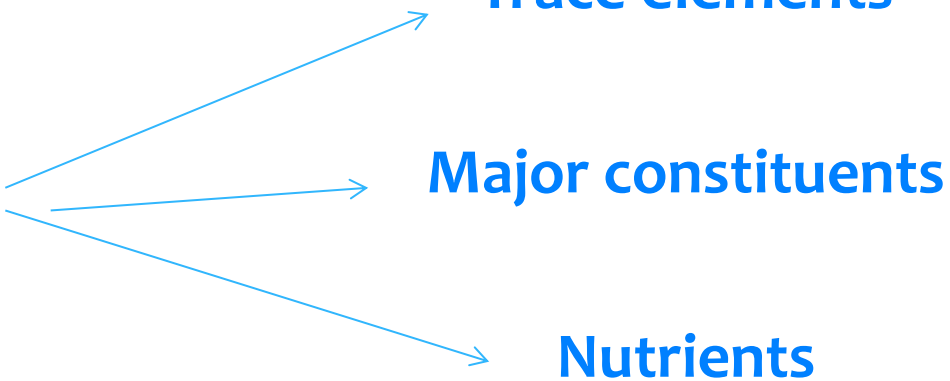

Nearly 94% of the whole water volume is concentrated in oceans and seas; 4 % are in ground waters; about 2 % - in ice and snow (mainly in Arctic, Antarctic, and Greenland); 0,4 % - in surface waters (rivers, lakes, swamps).

Insignificant amount of water is contained in atmosphere and organisms. All types of water are transformed from one form to another in circulation process (global cycle).

# 2. Chemical composition of water

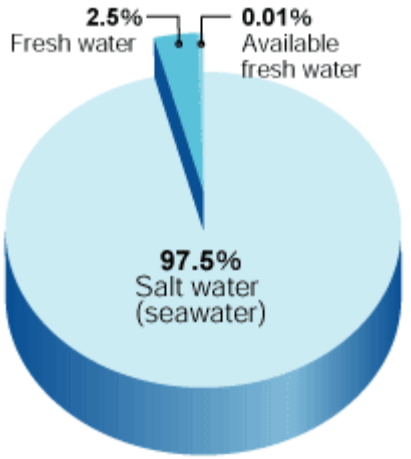
**Classification of matter in sea water**
**(according to Horn, 1972):**

* Gases
* Organic compounds
* Particulate matter



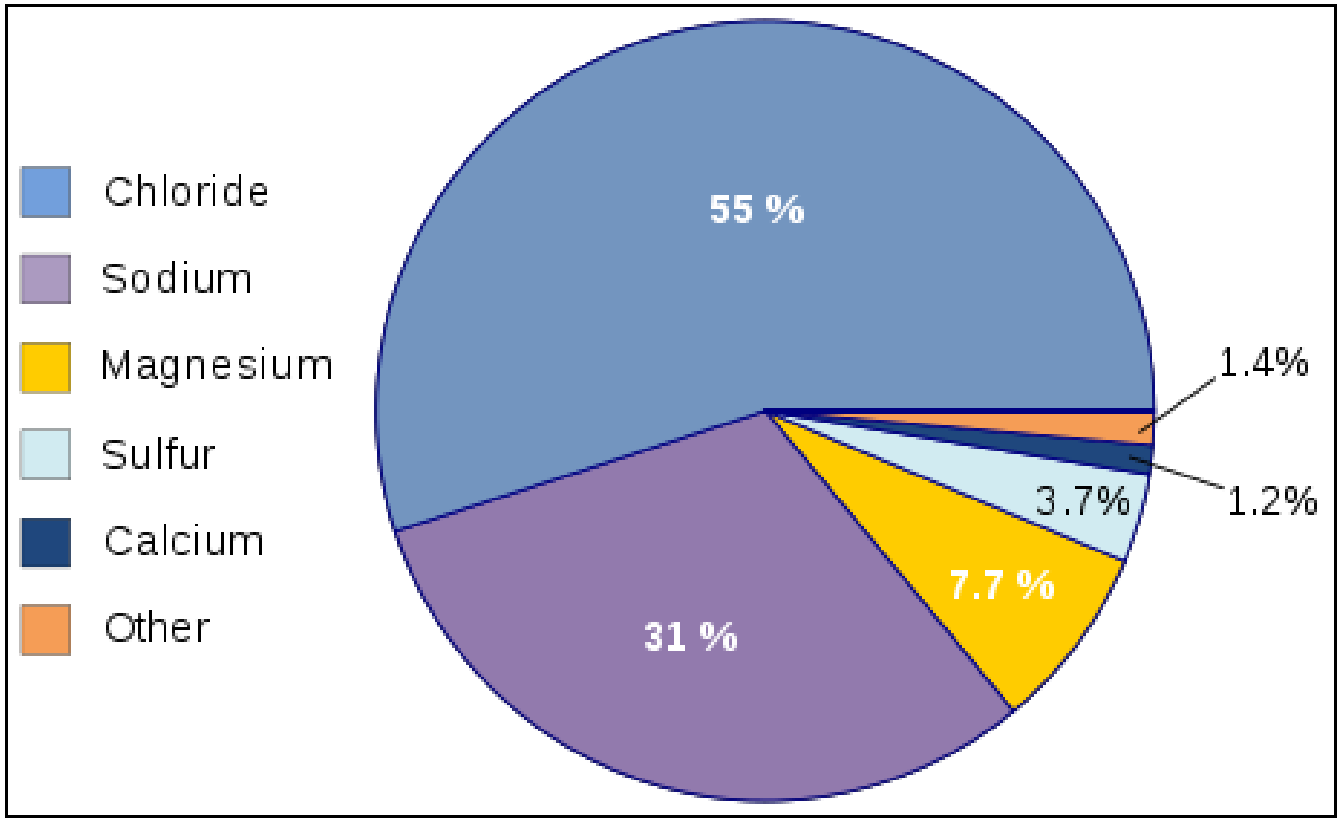
# Chemical composition of the hydrosphere

* Chemical composition of the hydrosphere approximates to the average composition of sea water, where hydrogen, oxygen, chlorine, and sodium prevail.
* In land water carbonates prevail. Content of mineral substances in land water (salinity) fluctuates greatly depending on local conditions and, first of all, climate. Usually land water is weakly mineralized – fresh ***(river and fresh lake salinity ranges from 50 to 1000 mg/kg).***
* Average salinity of Oceanic water is around 35 g/kg (35 %), sea water salinity ranges from ***1-2 % (Gulf of Finland, Baltic Sea) to 41,5 % (Red Sea).*** The maximum salt concentration is in salty lakes ***(Dead Sea up to 260 %)***



Composition of the earth's water supply

# Chemical composition of oceans



# ELEMENT COMPOSITION OF THE SEA WATER (Horn, 1972)

| Element | Concentration, mg/l | Modes of occurrence | Residence time in environment, years |
|---|---|---|---|
| H | 108 000 | $H_2O$ | - |
| He | 0,000005 | He(r) | - |
| Li | 0,17 | U+ | $2{,}0*10^7$ |
| Be | 0,0000006 | - | $1{,}5*10^2$ |
| B | 4,6 | $B(OH)_2$; $B(OH)_4$ | - |
| C | 28 | $HCO_3^-$;$H_2CO_3$; organic compounds | - |
| N | 0,5 | $NO^-_3$; $NO^-_2$; $NH^-_4$; $N_2$(r); organic compounds | - |
| O | 857 000 | $H_2O$ж; $O_2$(r); $SO^{2-}$ and other ions | - |
| F | 1,3 | $F^-$ | - |
| Ne | 0,0001 | Ne(r) | - |
| Na | 10 500 | $Na^+$ | $2{,}6*10^8$ |
| Mg | 1 350 | $Mg^{2+}$; $VgSo_4$ | $4{,}5*10^7$ |
| Al | 0,01 | - | $1{,}0*10^2$ |
| Si | 3 | $Si(OH)_4$; $Si(OH)_3O^-$ | $8{,}0*10^3$ |
| P | 0,07 | $HPO^{2-}_4$; $H_2PO_4$; $PO^{3-}_4$; $H_3PO_4$ | - |
| S | 885 | $SO^{2-}_4$ | - |
| Cl | 19 000 | $Cl^-$ | - |
| Ar | 0,6 | Ar (r) | - |
| K | 380 | $K^+$ | $1{,}1*10^7$ |
| Ca | 400 | $Ca^{2+}$; $CaSO_4$ | $8{,}0*10^6$ |
| Sc | 0,00004 | - | $5{,}6*10^3$ |
| Ti | 0,001 | - | $1{,}6*10^2$ |
| V | 0,002 | $VO_2(OH)^{2-}_3$ | $1{,}0*10^4$ |
| Cr | 0,00005 | - | $3{,}5*10^2$ |
| Mn | 0,002 | $Mn^{2+}$; $MnSO_4$ | $1{,}4*10^3$ |
| Fe | 0,01 | $Fe(OH)_3$ | $1{,}4*10^2$ |
| Co | 0,0005 | $Co^{2+}$; $CoSO_4$ | $1{,}8*10^4$ |
| Ni | 0,002 | $Ni^{2+}$; $NiSO_4$ | $1{,}8*10^4$ |
| Cu | 0,003 | $Cu^{2+}$; $CuSO_4$ | $5{,}0*10^4$ |
| Zn | 0,01 | $Zn^{2+}$; $ZnSO_4$ | $1{,}8*10^5$ |
| Ga | 0,00003 | - | $1{,}4*10^3$ |
| Ge | 0,00007 | $Ge(OH)_4$; $Ge(OH)_3O$ | $7{,}0*10^3$ |
| As | 0,003 | $HAsO^{2-}_4$; $H_2AsO^-_4$; $H_3AsO_3$ | - |
| Se | 0,004 | $SeO^{2+}_4$ | - |
| Br | 65 | Br | - |
| Kr | 0,0003 | Kr (r) | - |
| Rb | 0,12 | $Rb^+$ | $2{,}7*10^5$ |
| Sr | 8 | $Sr^{2+}$; $SrSO_4$ | $1{,}9*10^7$ |
| Y | 0,0003 | - | $7{,}5*10^3$ |
| Zr | - | - | - |
| Nb | 0,00001 | - | $3{,}0*10^2$ |
| Mo | 0,01 | $MoO^{2-}_4$ | $5{,}0*10$ |

# ELEMENT COMPOSITION OF THE SEA WATER (Horn, 1972)

| Element | Concentration, mg/l | Mode of occurrence | Residence time in environment, years |
|---|---|---|---|
| Tc | - | - | - |
| Ru | - | - | - |
| Rh | - | - | - |
| Pd | - | - | - |
| Ag | 0,00004 | $AgCl^{-}_{2}$; $AgCl^{2-}_{3}$ | $2,1*10^{6}$ |
| Cd | 0,00011 | $Cd^{2+}$; $CdCl^{2-n}_{n}$; $Cd(OH)^{2-n}_{n}$ | $5,0*10^{5}$ |
| In | <0,02 | - | - |
| Sn | 0,0008 | - | $1,0*10^{5}$ |
| Sb | 0,0005 | - | $3,5*10^{5}$ |
| Te | - | - | - |
| I | 0,06 | $IO^{-}_{3}$; $I^{-}$ | - |
| Xe | 0,0001 | Xe(r) | - |
| Cs | 0,0005 | $Cs^{+}$ | $4,0*10^{4}$ |
| Ba | 0,03 | $Ba^{2+}$; $BaSO_4$ | $8,4*10^{4}$ |
| La | $1,2*10^{-5}$ | - | $4,4*10^{2}$ |
| Ce | $5,2*10^{-6}$ | - | $8,0*10^{1}$ |
| Pr | $2,6*10^{-6}$ | - | $3,2*10^{2}$ |
| Nd | $9,2*10^{-6}$ | - | $2,7*10^{2}$ |
| Pm | - | - | - |
| Sm | $1,7*10^{-6}$ | - | $1,8*10^{2}$ |
| Eu | $4,6*10^{-7}$ | - | $3,0*10^{2}$ |
| Gd | $2,4*10^{-6}$ | - | $2,6*10^{2}$ |
| Tb | - | - | - |
| Dy | $2,9*10^{-6}$ | - | $4,6*10^{2}$ |
| Ho | $8,8*10^{-7}$ | - | $5,3*10^{2}$ |
| Er | $2,4*10^{-6}$ | - | $6,9*10^{2}$ |
| Tm | $5,2*10^{-7}$ | - | $1,8*10^{3}$ |
| Yb | $2,0*10^{-6}$ | - | $5,3*10^{2}$ |
| Lu | $4,8*10^{-7}$ | - | $4,5*10^{2}$ |
| Hf | - | - | - |
| Ta | - | - | - |
| W | 0,0001 | $WO^{2-}_{4}$ | $1,0*10^{3}$ |
| Re | - | - | - |
| Os | - | - | - |
| Ir | - | - | - |
| Pt | - | - | - |
| Au | 0,0000004 | $AuCl^{-}_{2}$ | $5,6*10^{5}$ |
| Hg | 0,00003 | $HgCl^{-}_{3}$; $HgCl^{2-}_{4}$ | $4,2*10^{4}$ |
| Tl | <0,00001 | $Tl^{+}$ | - |
| Pb | 0,00003 | $Pb^{2+}$; $PbSO_4$; $PbCl^{2-n}_{n}$; $Pb(OH)^{2-n}_{n}$ | $2,0*10^{3}$ |
| Bi | 0,00002 | - | $4,5*10^{5}$ |
| Po | - | - | - |

# ELEMENT COMPOSITION OF THE SEA WATER (Horn, 1972)

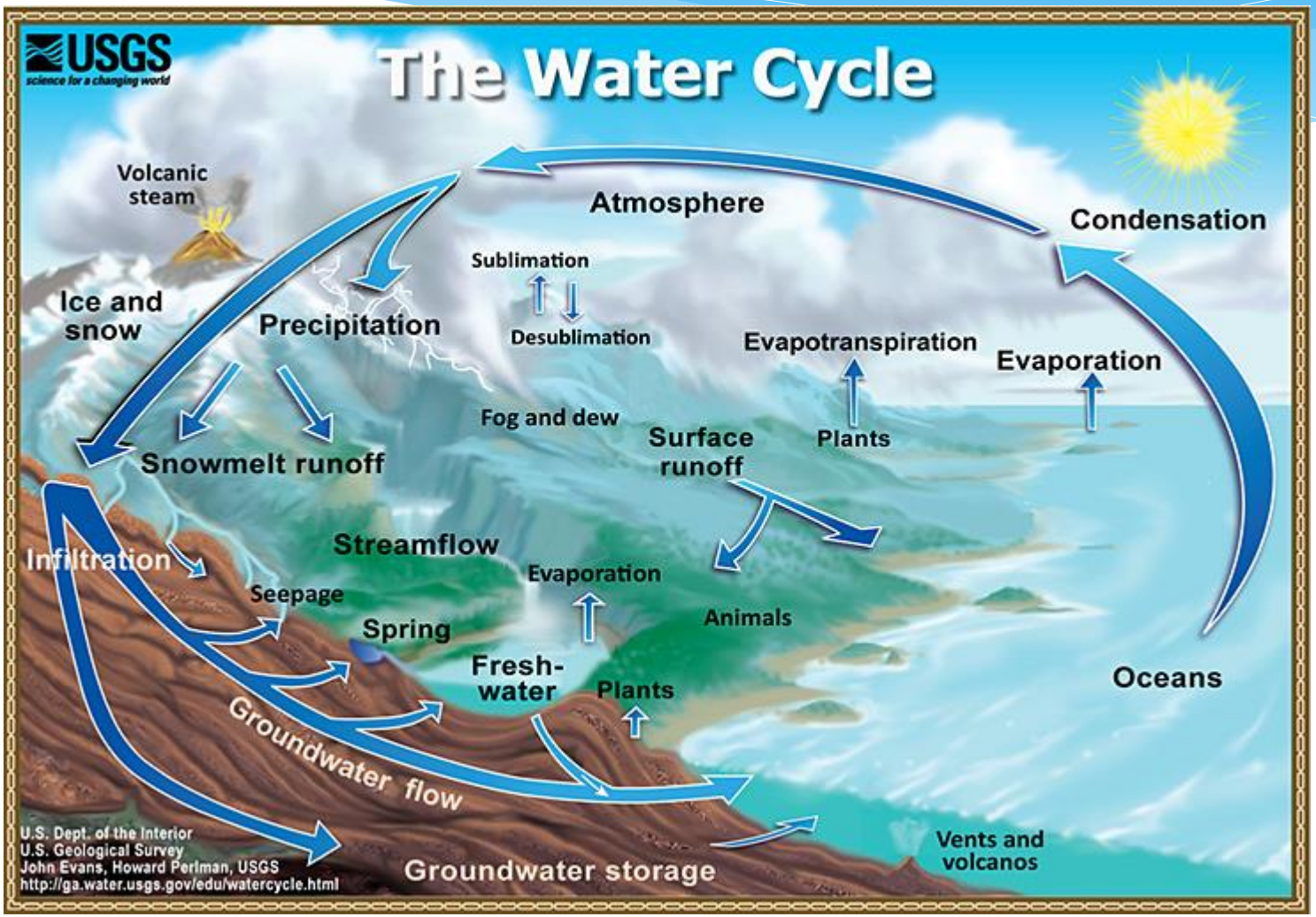
| Element | Concentration, mg/l | Modes of occurrence | Residence time in environment, years |
|---|---|---|---|
| At | - | - | - |
| Rn | $0,6*10^{-15}$ | Rn(r) | - |
| Fr | - | - | - |
| Ra | $1,0*10^{-10}$ | $Ra^{2+}$; $RaSO_4$ | - |
| Ac | - | - | - |
| Th | 0,00005 | - | $3,5*10^{2}$ |
| Pa | $2,0*10^{-9}$ | - | - |
| U | 0,003 | $UO_2(CO_3)^{4-}_3$ | $5,0*10^{5}$ |

# Hydrologic cycle

* The components of the hydrosphere, including the **cryosphere** and atmosphere, as well as the **biosphere**, participate in the global **hydrologic cycle.**

* Annually the amount of precipitations falling on the ground is equal to that of water evaporated in total from the surface of land and oceans. In general cycle of water the atmospheric water is most movable.

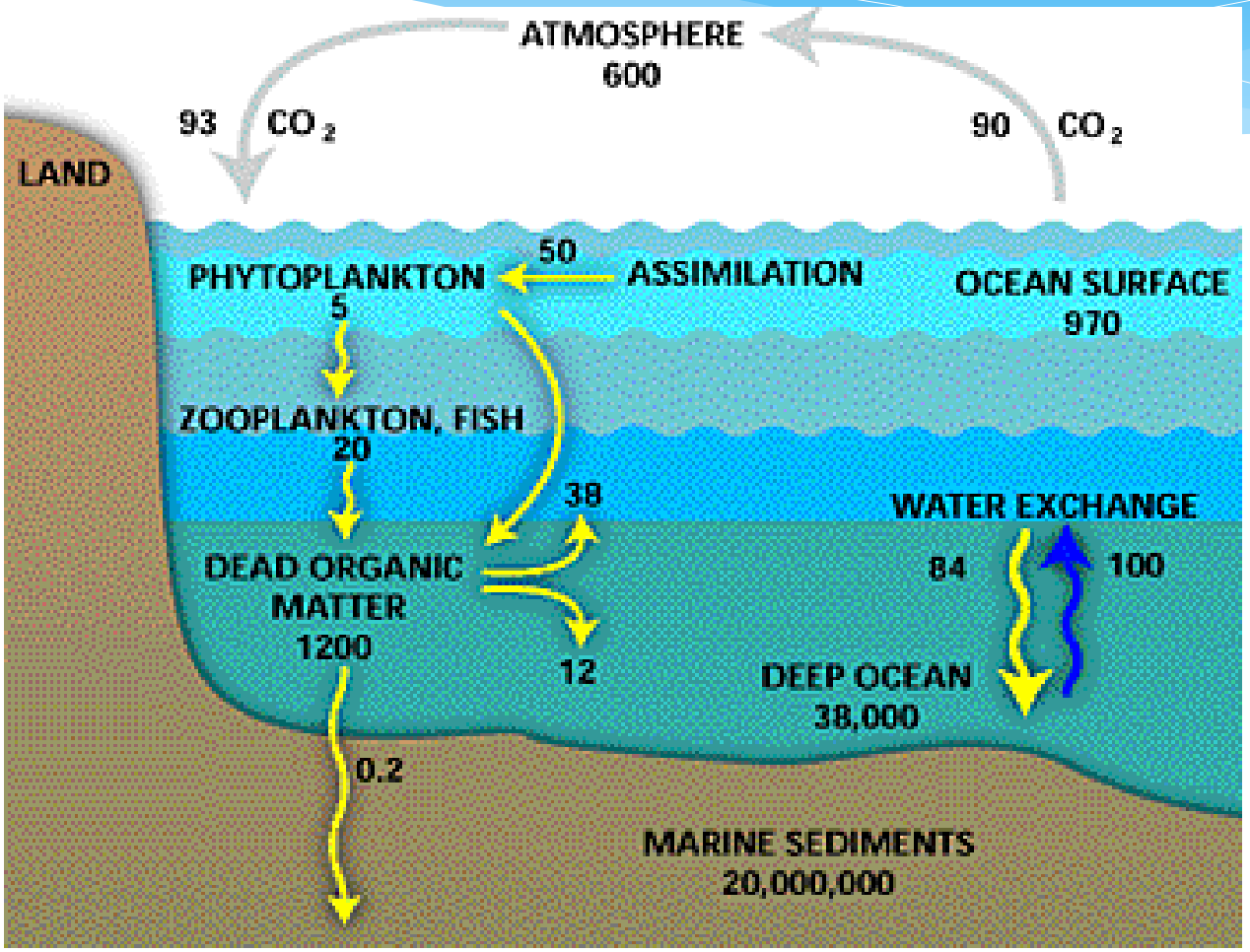
# Global water cycle



# Matter movement in water

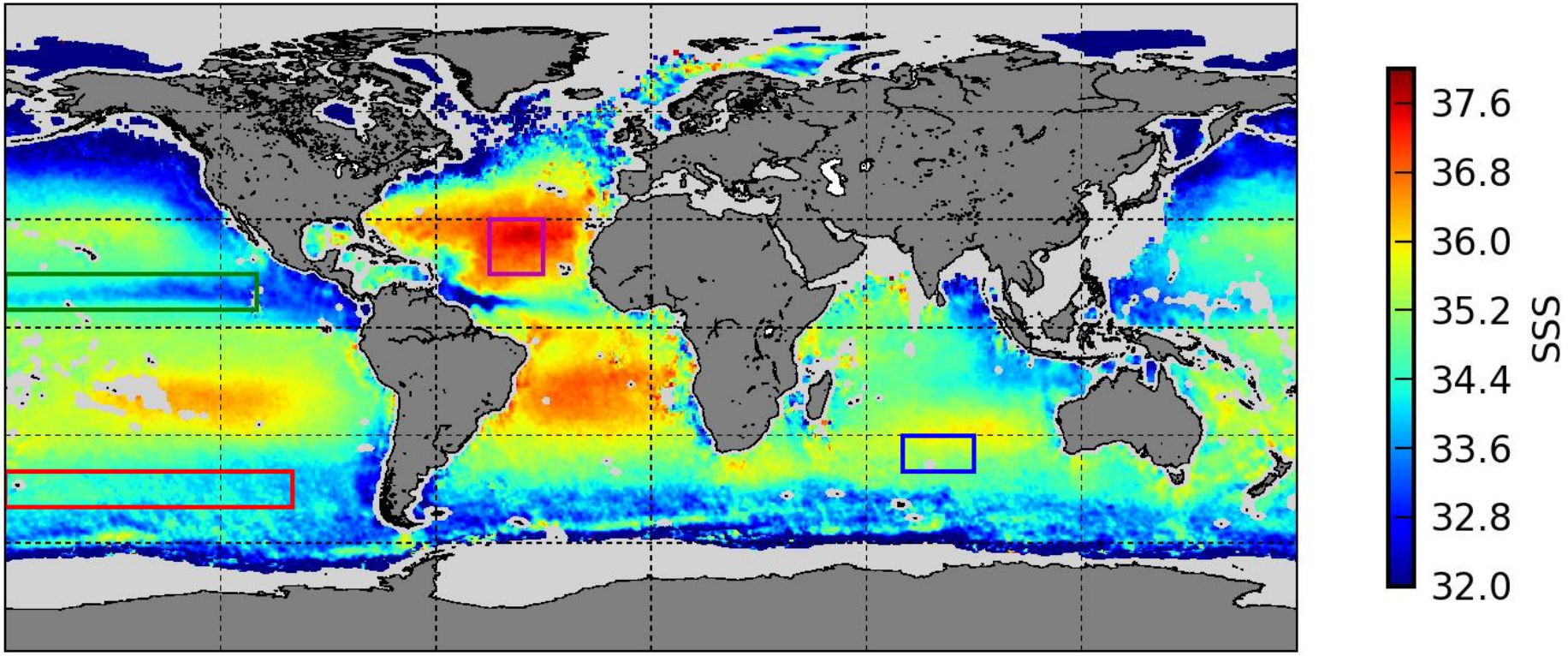
| A. Matter is transported from land and air to the sea | | B. Matter is transported from sea to land or air |
|---|---|---|
| Precipitations – rain and snow, wind | Carry of dust; precipitations | Water evaporation transporting not only water, but also NaCl etc. |
| Land organisms, matter in solution | | Wind and splashes<br>Undissolved sea deposits on the bottom |
| Solution by the Ocean | | Gas circulation, Gas escape at temperature and pressure changes |
| Cosmic dust and gas | | Transition of sea organisms onto land.<br>Eating sea organisms by land organisms.<br>Human activity. |
| Rivers carrying large amount of matter into the Ocean in solutions and suspended state | | |
| Gas absorption by sea water from atmosphere | | |
| Human activity | | |
| Volcanic eruptions (submarine, subaerial) | | |

# Carbon exchange between the ocean and the atmosphere (in billions of metric tons)



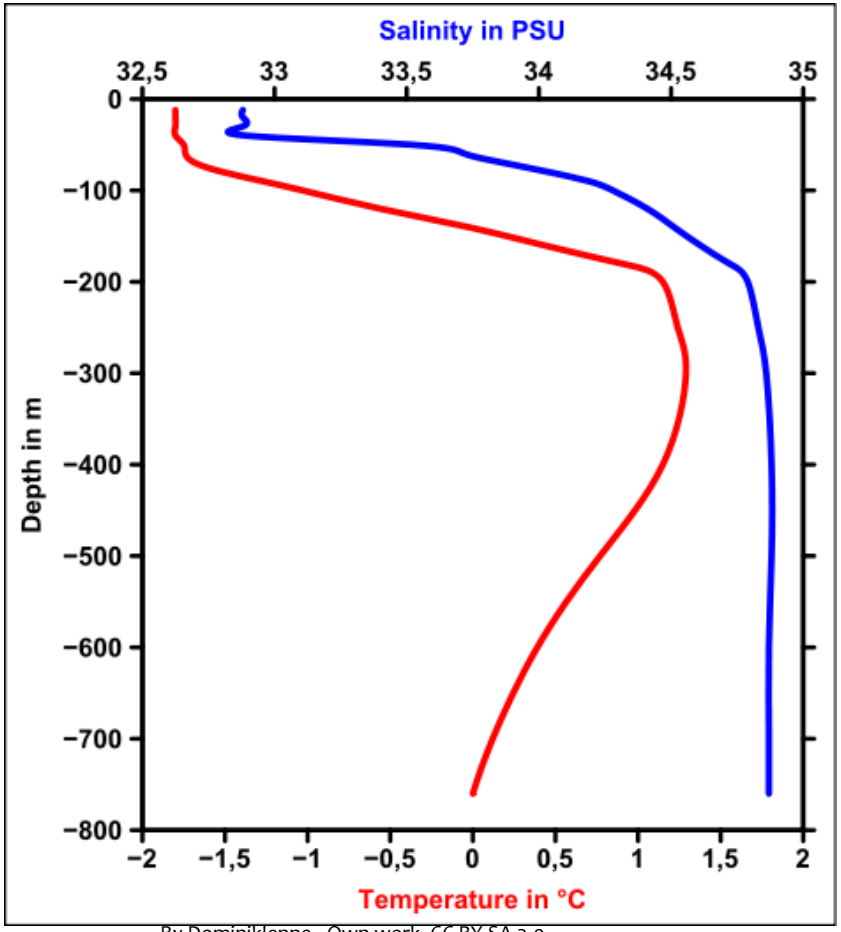
# Salinity in the Ocean surface layer as a function of geographic latitude

Global map of oceanic surface salinity,
by the European Space Agency (2011).



# 4. Ocean characteristics

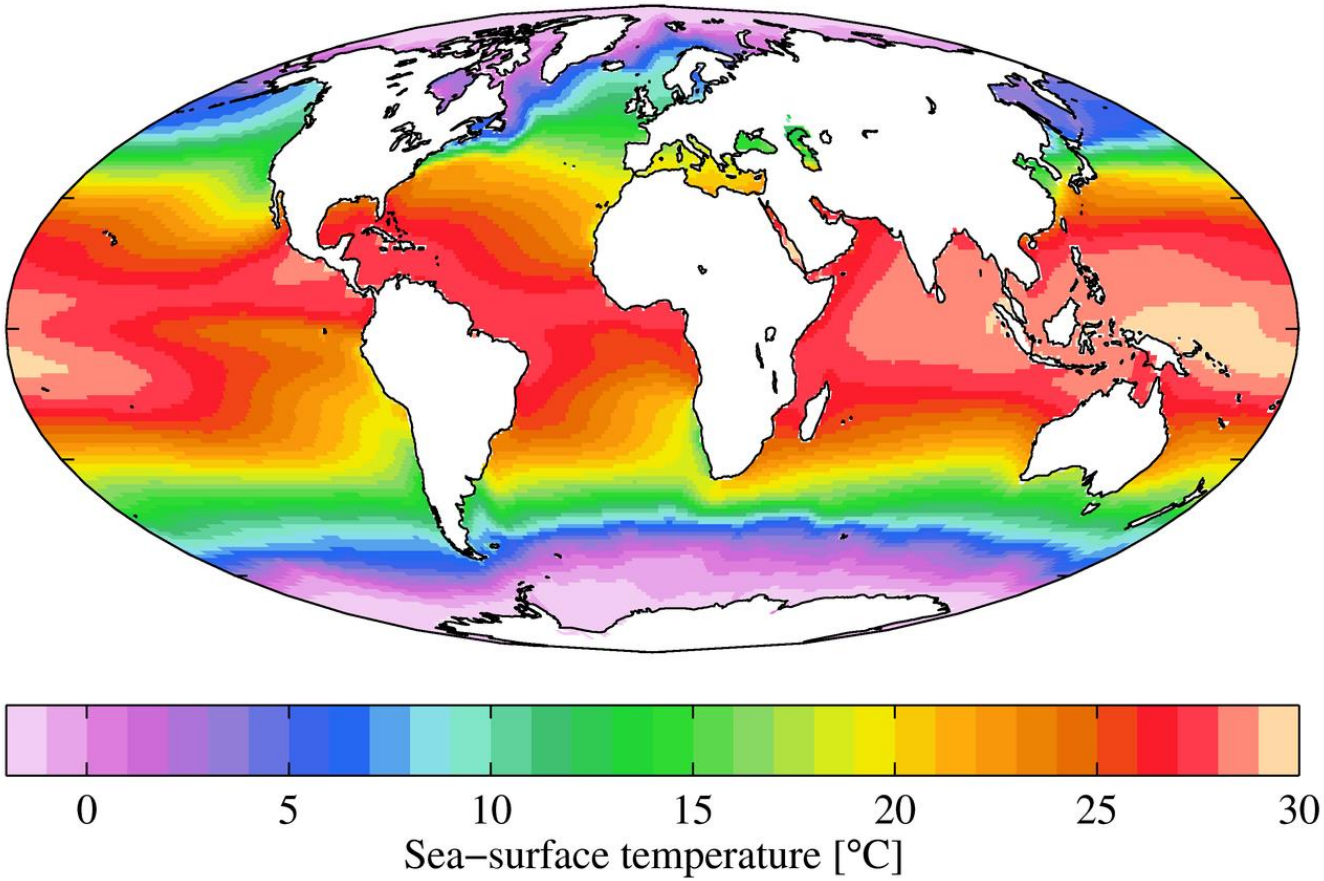
**Typical profiles of sea water temperature and salinity**



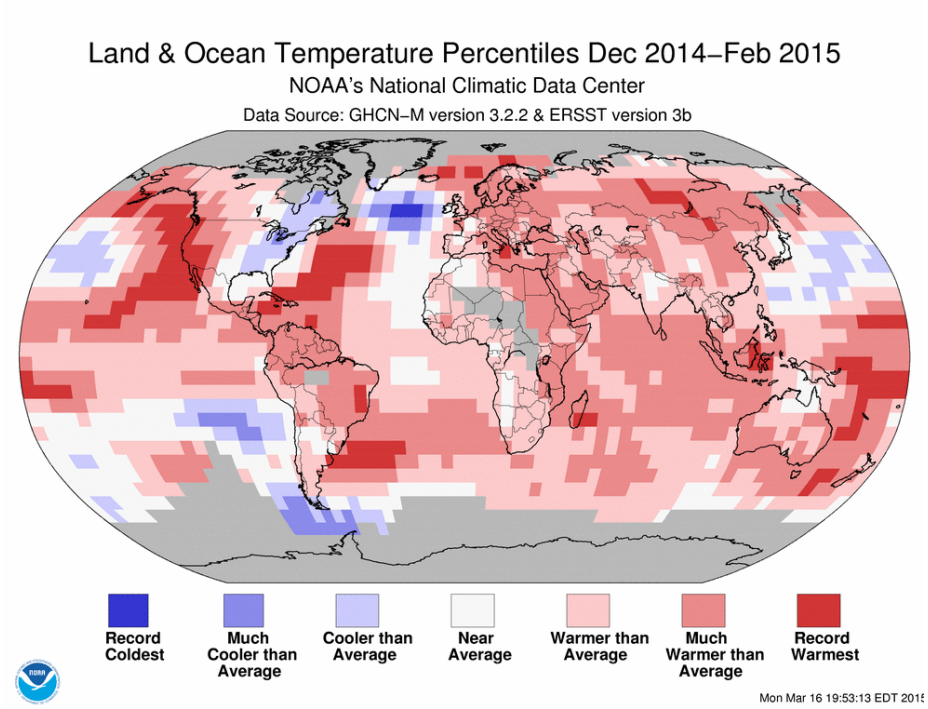


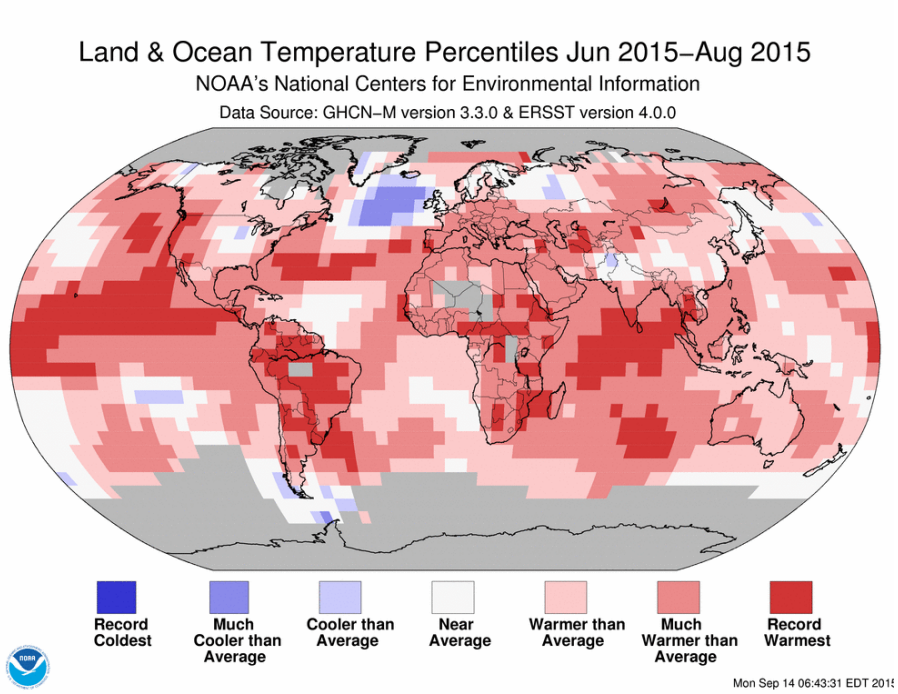

* *PSU - practical salinity unit (measured by electroconductivity)*

# Mean sea surface temperature (2009)



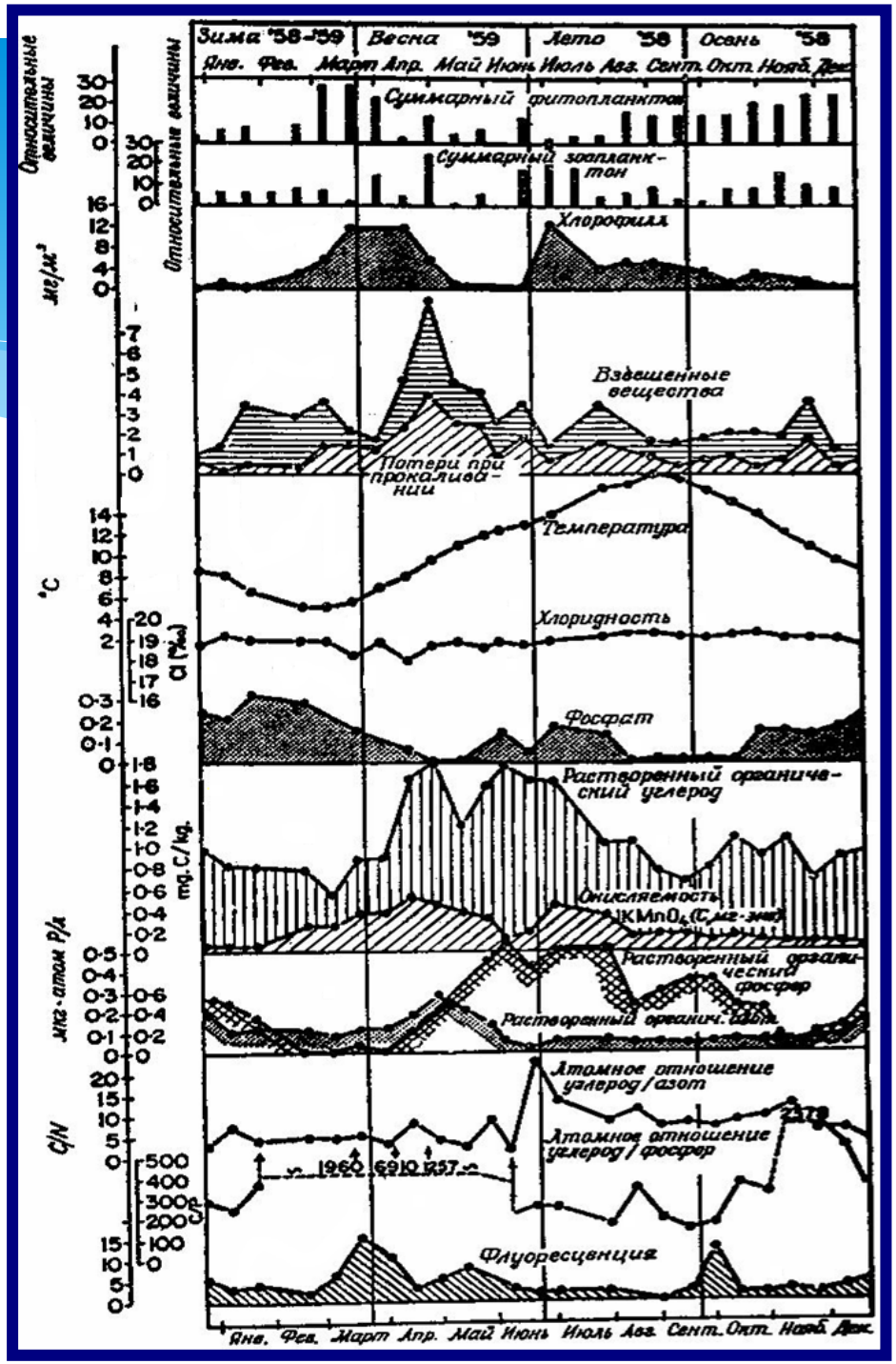
# Earth surface temperatures (winter and summer)



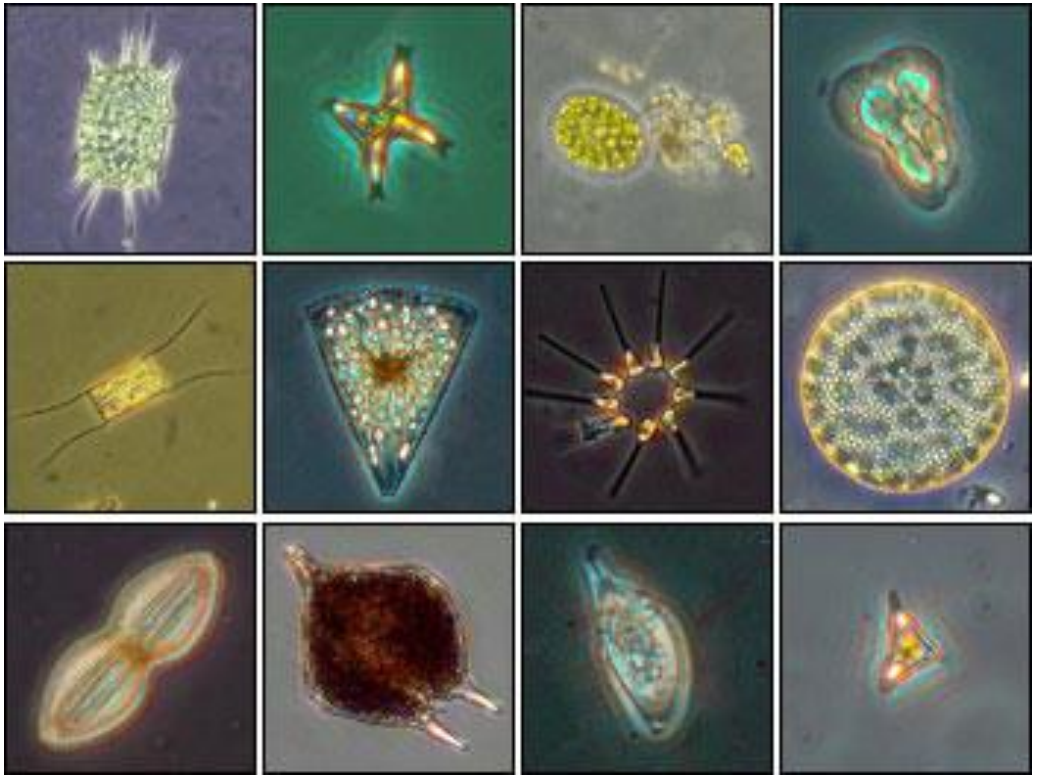




www.ncdc.noaa.gov

# Seasonal changes in oceanic water composition (*according to Horn R.,1972*)

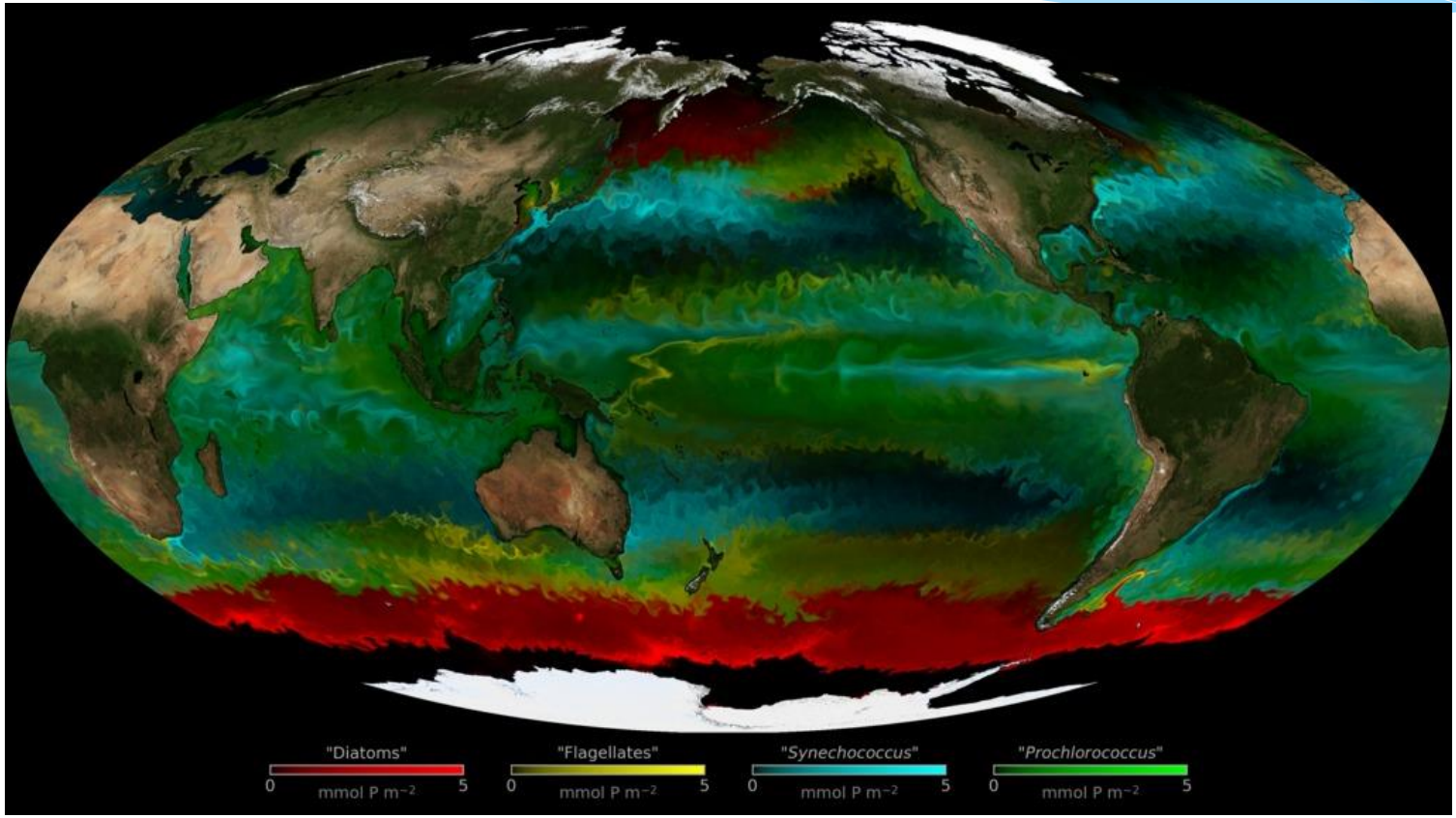


# Phytoplankton layer in ocean



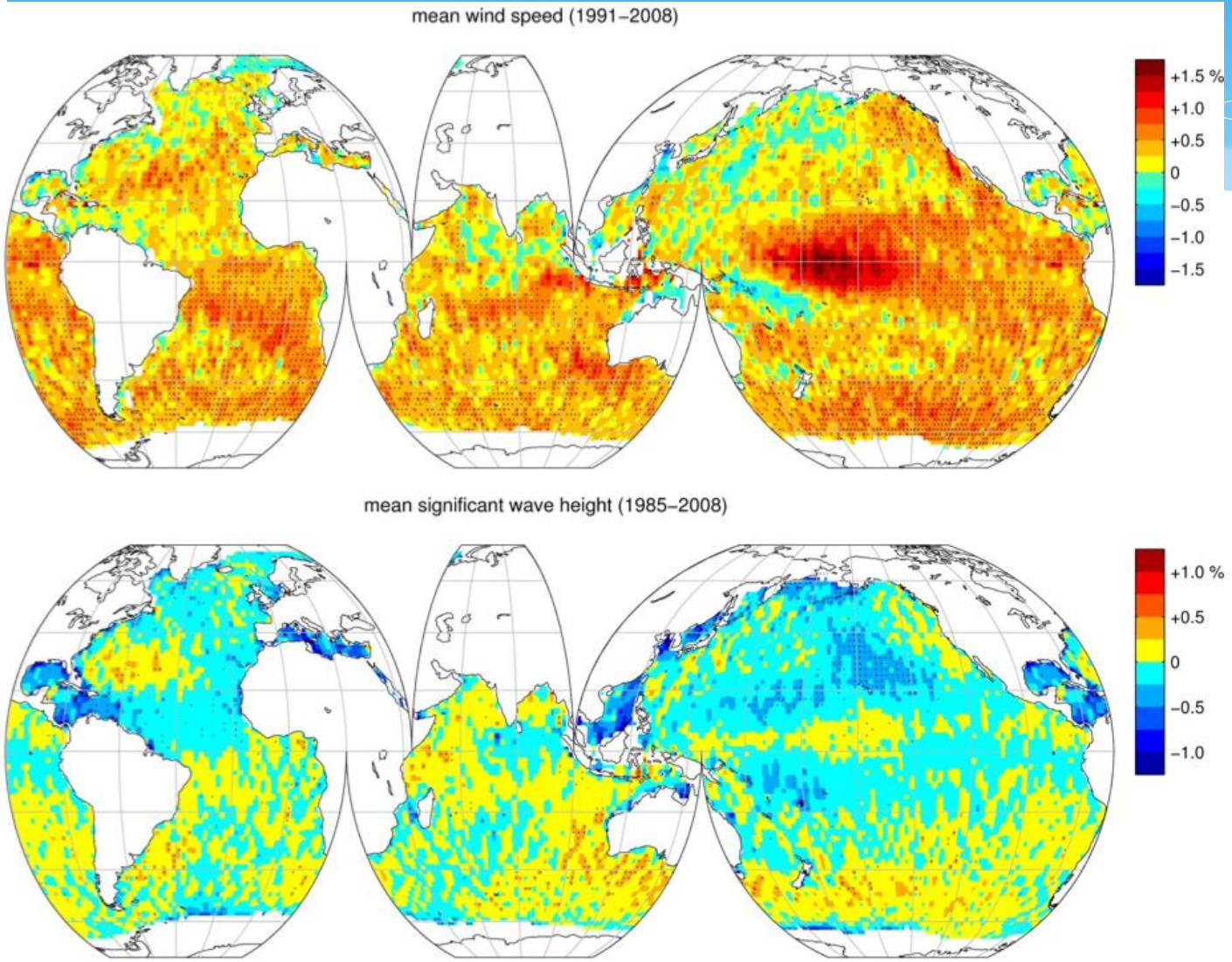
Microscopic green plants, called phytoplankton, form the lowest level of the marine food web and play important roles in many geochemical processes.

# Global distribution of phytoplankton




svs.gsfc.nasa.gov

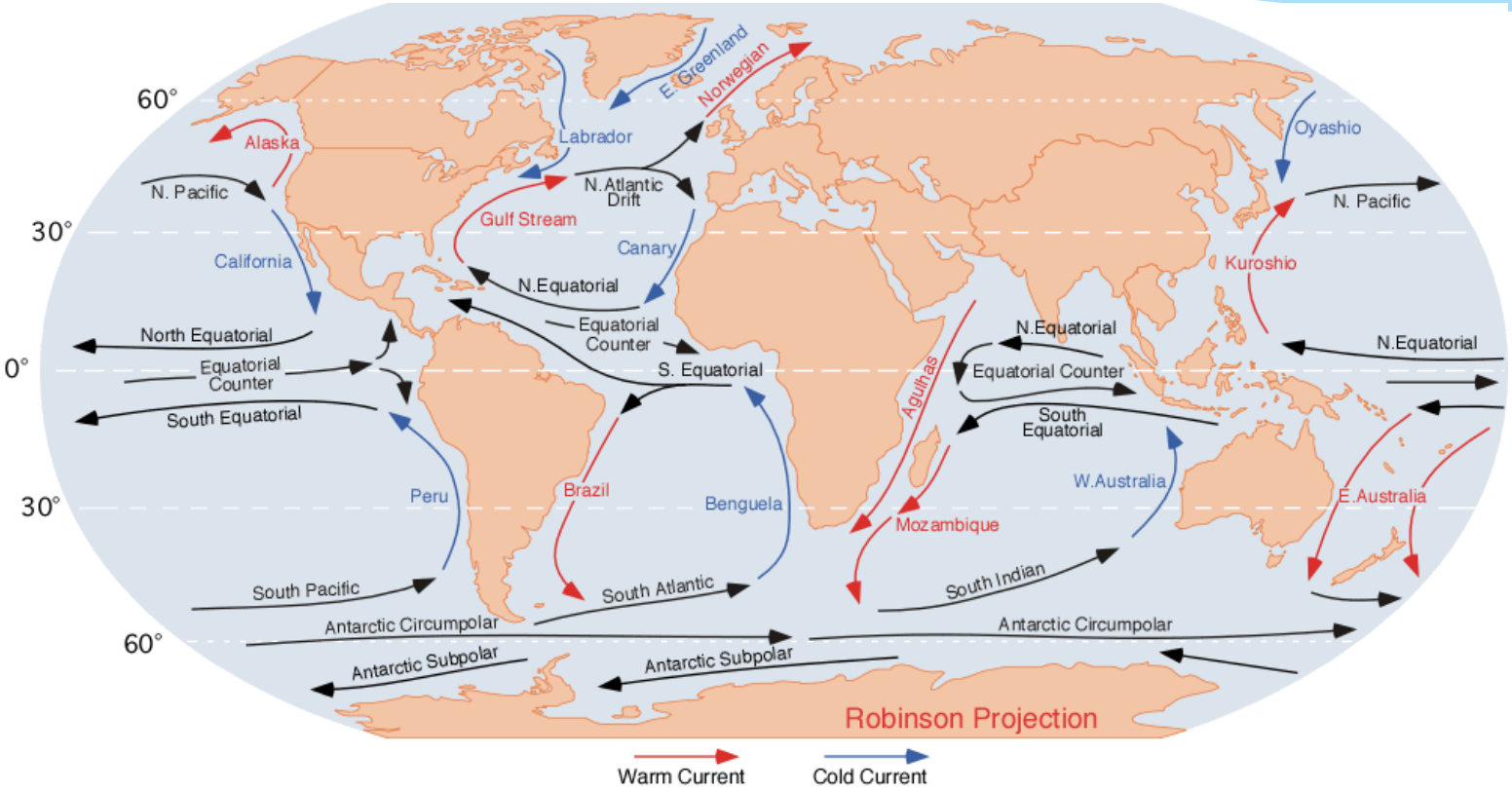
# Ocean wind and waves (Young et al 2011)




Ocean wind and waves increased substantially over the last two and a half decades.

I. R. Young, S. Zieger, and A. V. Babanin. Global Trends in Wind Speed and Wave Height // Science 24 Mar 2011

# Surface currents




red–warm
blue–cold

# 5. Marine mineral deposits

Approximate data on mineral production from natural mineral water
(according to Bandarenko S.S. et al., 1986)

| Raw material | ∑ Production | Production from water,% |
|---|---|---|
| Sodium chloride (NaCl) | $2,2*10^8$ | 30-35 |
| Potassium salts | $2,6*10^7$ | 5-10 |
| Sodium carbonate | $3,5*10^7$ | 5-10 |
| Sodium sulfate | $4,6*10^6$ | 20-30 |
| Calcium chloride | $2,7*10^6$ | 20-25 |
| Boron(B) | $1*10^6$ | 20-30 |
| Bromine(Br) | $3,9*10^5$ | 30-95 |
| Magnesium (Mg) | $1,1*10^5$ | 25 |
| Lithium (Li) | $5,5*10^4$ | 15-20 |
| Iodine (I) | $1,3*10^4$ | 80-85 |
| Iron (Fe) | $4,1*10^6$ | + |
| Copper (Cu) | $6*10^6$ | ++ |
| Zink (Zn) | $5*10^6$ | ++ |
| Lead (Pb) | $2,3*10^6$ | + |
| Uranium (U) | $3,8*10^4$ | ++ |
| Silver (Ag) | $1*10^4$ | ++ |

**+ - technologies available;**

**++ - project designed**

**Sea water can be estimated as a technological solution**

# Sea submarine placers

**Their role has increased in recent years.**
**They are, as a rule, delta placers** or **embedded marginal-marine placers.**
**They are at different depths and distances from coast.**
**Their length is sometimes up to 1600 km.**

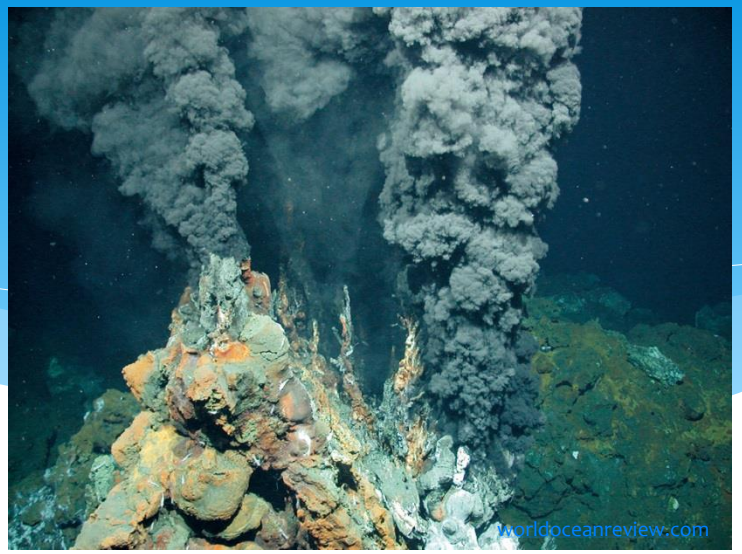
**Cassiterite – Indonesia**
**h = 35 m, l from coast – 10-50 km.**
**Volume – kg/m³.**

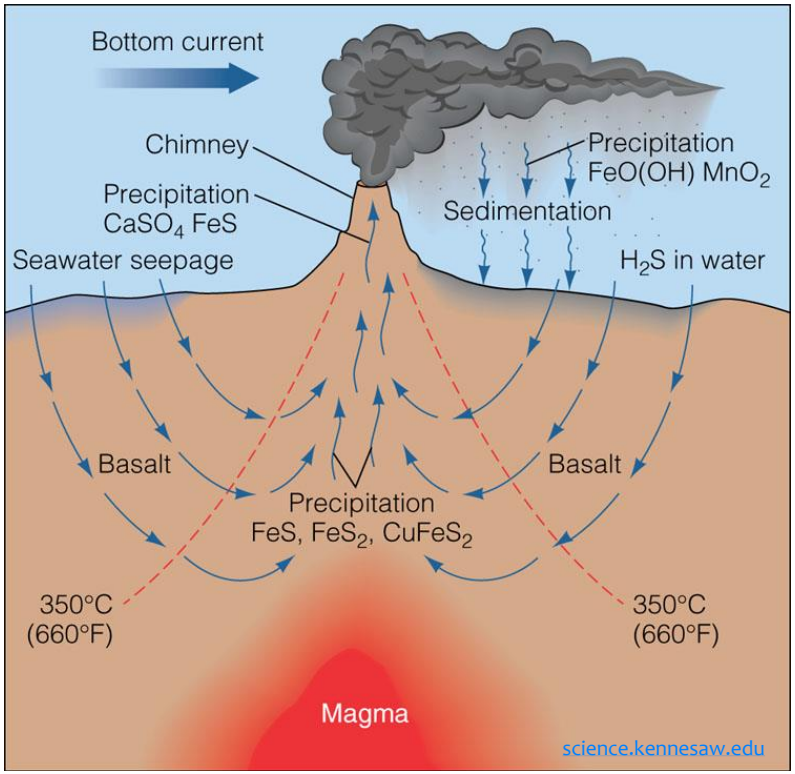
**Gold – Alaska**
**h = 5-60 m, l from coast – 5 km.**
**Sand layer thickness – 6 m.**

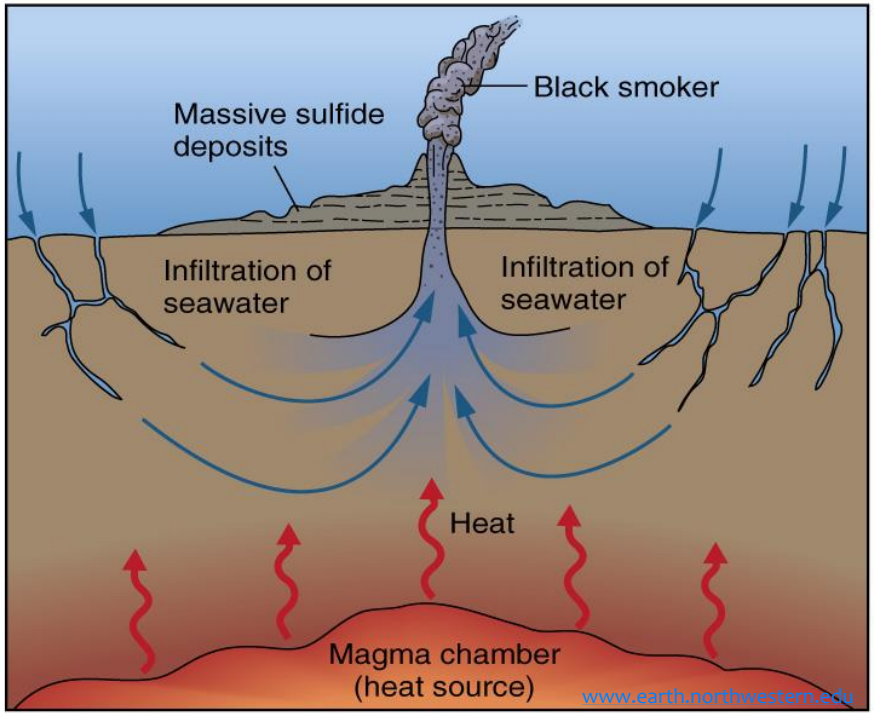
**Diamonds – Western coast of Africa**
**h to 120 m, l from coast – 5 km.**
**Length 1200 km**
**5 carats/1 g. (in original – 0,5 carat m³)**
**Production ~ 300 th. carats**

***There is a problem of international regulation.***

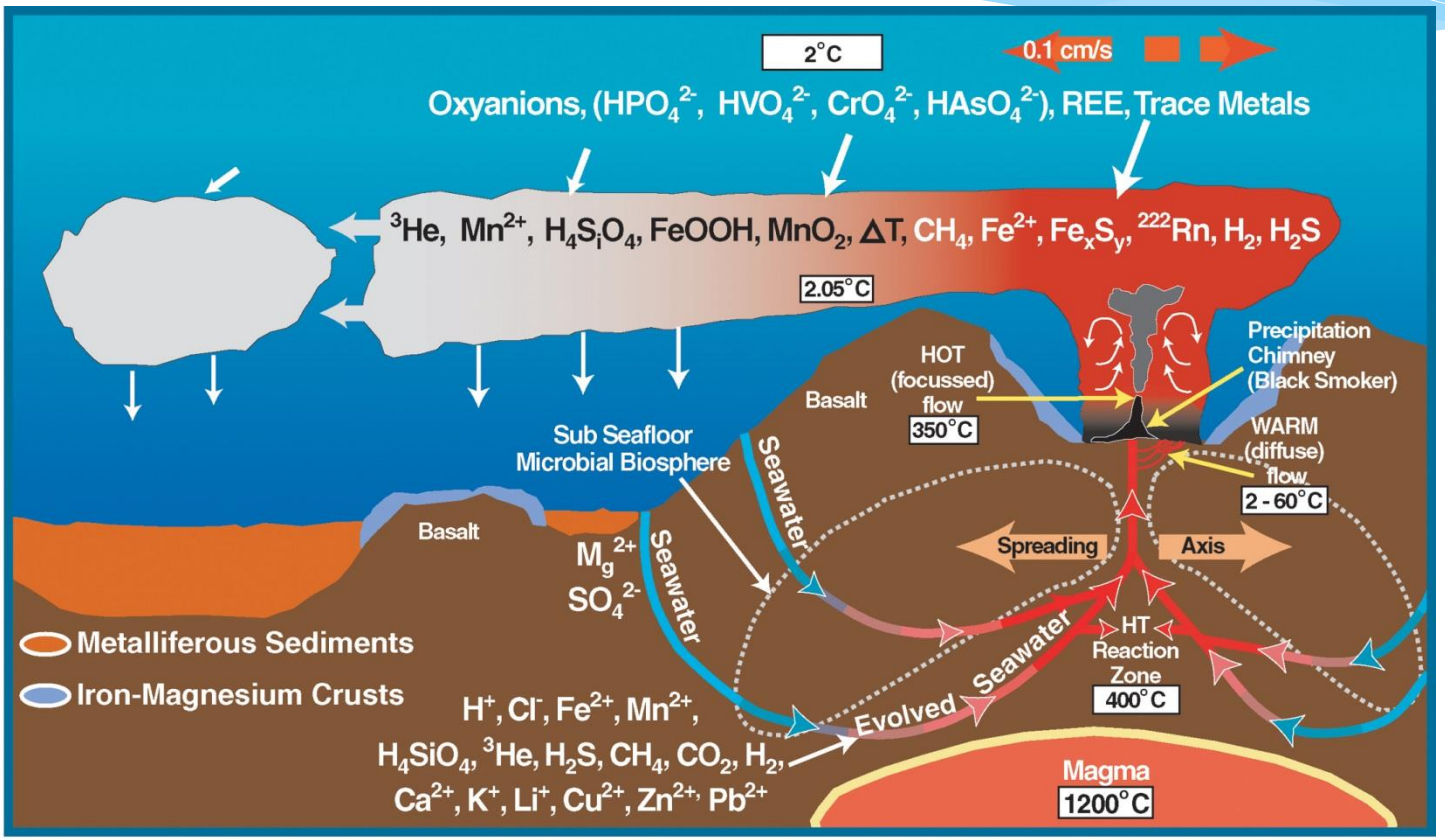
# Black smokers



* Under-sea volcanic activity gives rise to high-temperature plumes of water, containing particles of igneous rock that give rise to the appearance of black smoke.
* The boiling point of water under the high pressures on the ocean floor can be considerably higher than at the surface; hence the temperatures of the volcanic plumes can be much higher as well.
* Some species of animal life thrive on the environment of these “black smokers”, including their very high temperatures.




volcanocafe.wordpress.com

# Current hydrothermal ore formation at the ocean bottom

**In the SPREADING zones of the Ocean bottom the numerous sites with sources of THERMAL brines, forming thick sulfide deposits, were revealed:**

**GALAPAGOS region, RED SEA (Atlantis depression, Juan de Fuca range).**

**Atlantis: Salt thermal deposits reserves - >100 billion tons.**
**Content:**

| | | |
|---|---|---|
| Fe>29%<br>Zn-2-5%<br>Cu-3-9% | Ag-60 g/t<br>Au-5 g/t | $Sr^{87}/Sr^{86}$= 0,7034 |

**It is a modern analogue for a number of ancient stratiform depositions (Zhezqazghan, Mount Isa (Australia), Sullivan (Canada) and other deposits of Pb, Zn, Cu)**

**Deposits are formed by thermal benthic-oceanic processes.**

# Composition of Sulfide ore in the World Ocean

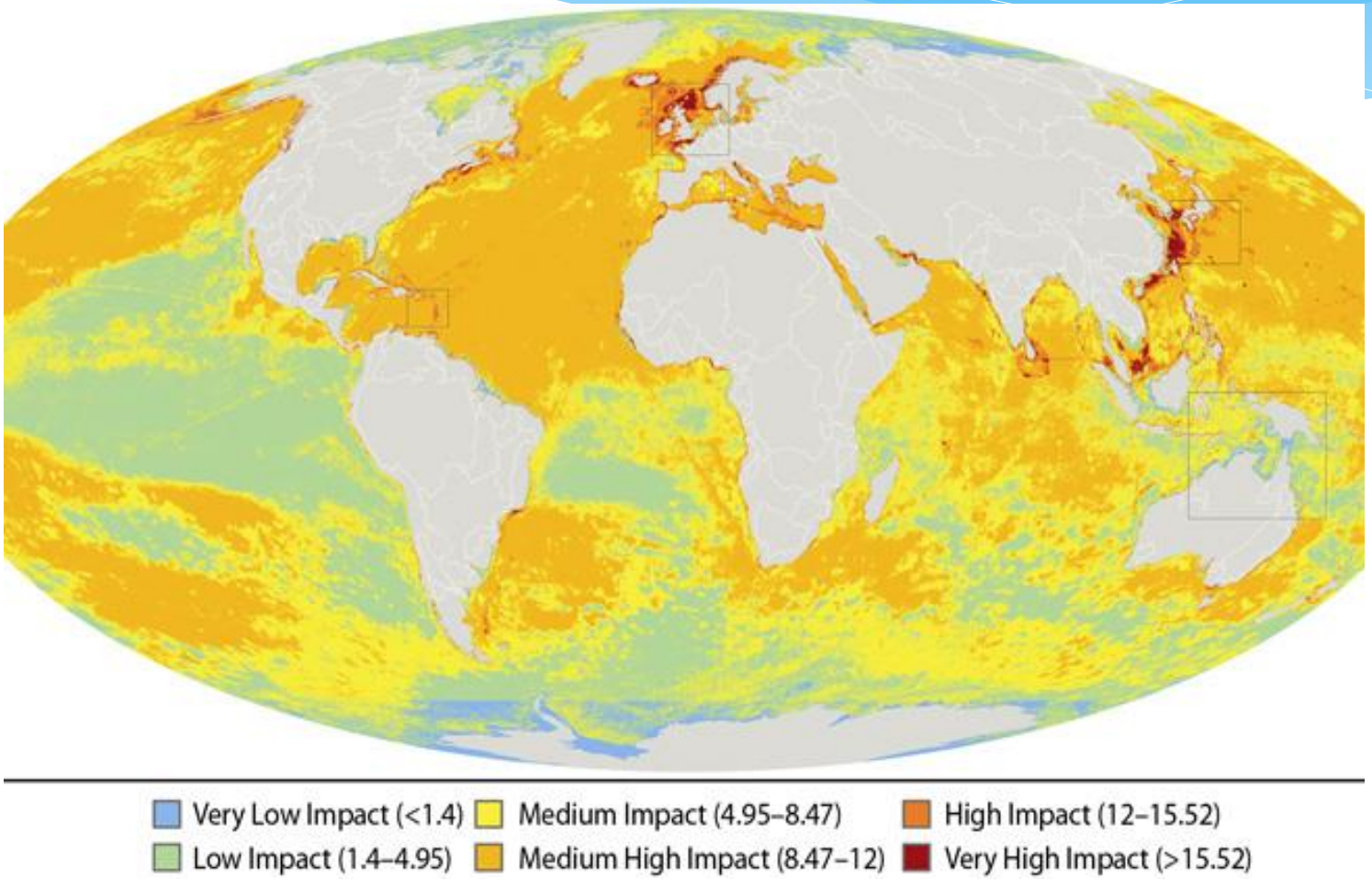
| Elements | Mid-Atlantic ridge | East-Pacific Rise | Juan-de-Fuca | Galapagos ridge |
|---|---|---|---|---|
| Fe, % | 17,6-30,2 | 23,1-28,7 | 5-24,7 | |
| Cu, % | 2,01-16,25 | 0,61-1,89 | 0,06-0,61 | |
| Zn, % | 1,39-4,06 | 2,80-5,93 | 11,48-28,84 | |
| Ba, % | 0,05-0,09 | 0,07 | 0,03-1,37 | |
| Pb г/т | 260-460 | 230-1160 | 1920-2150 | |
| Co | 15,9-103,8 | 44-62,1 | 5,4-10,5 | |
| Ni | 38-45 | 2,7-56,5 | 25,8 | |
| As | 62-67 | 431-480 | 421-711 | |
| Cd | 52 | 122-493 | 134-550 | |
| Ag | 42,7-48,6 | 121,3-172,6 | 63,1-165,2 | |
| Au | 1-12,85 (до 70 г/т) | 0,18 | 0,13-4,42 | |
| Mn | < 0,1 | < 0,1 | < 0,1 | < 0,1 |

# 6. Anthropogenic impact

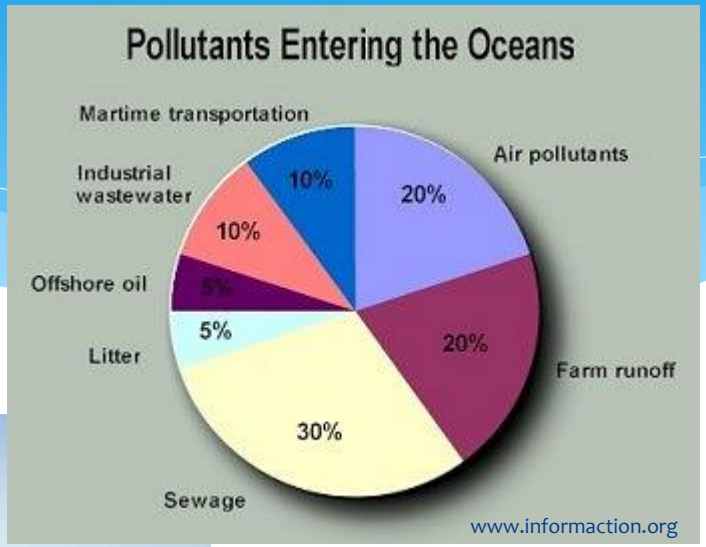
***Man-induced nature transformations (according to Reimers, 1990)***

| Type of impact | Production, changes, release or size of human use in absolute numbers | Production, changes, release or size, % (of natural quantity) | Additional information |
|---|---|---|---|
| Balance disturbance | - | 9 | Mainly due to irrigation and reservoirs |
| Irreversible water consumption | 430-570 $km^3$/year | - | Mostly due to water pumping from wells. |
| Irreversible outflow into the ocean | $2135x10^6$ t/year | 3560 times | Data of different authors differ. |
| Oil pollution | - | since the 19-th century 10-15 times on average | Oil film covers up to ¼ of the World Ocean surface. |
| Heavy metal pollution | | | Sometimes geochemical abnormalities differ from catastrophic level by one of values |

40% of the world's seas are heavily degraded.
Less than 4% are relatively pristine.

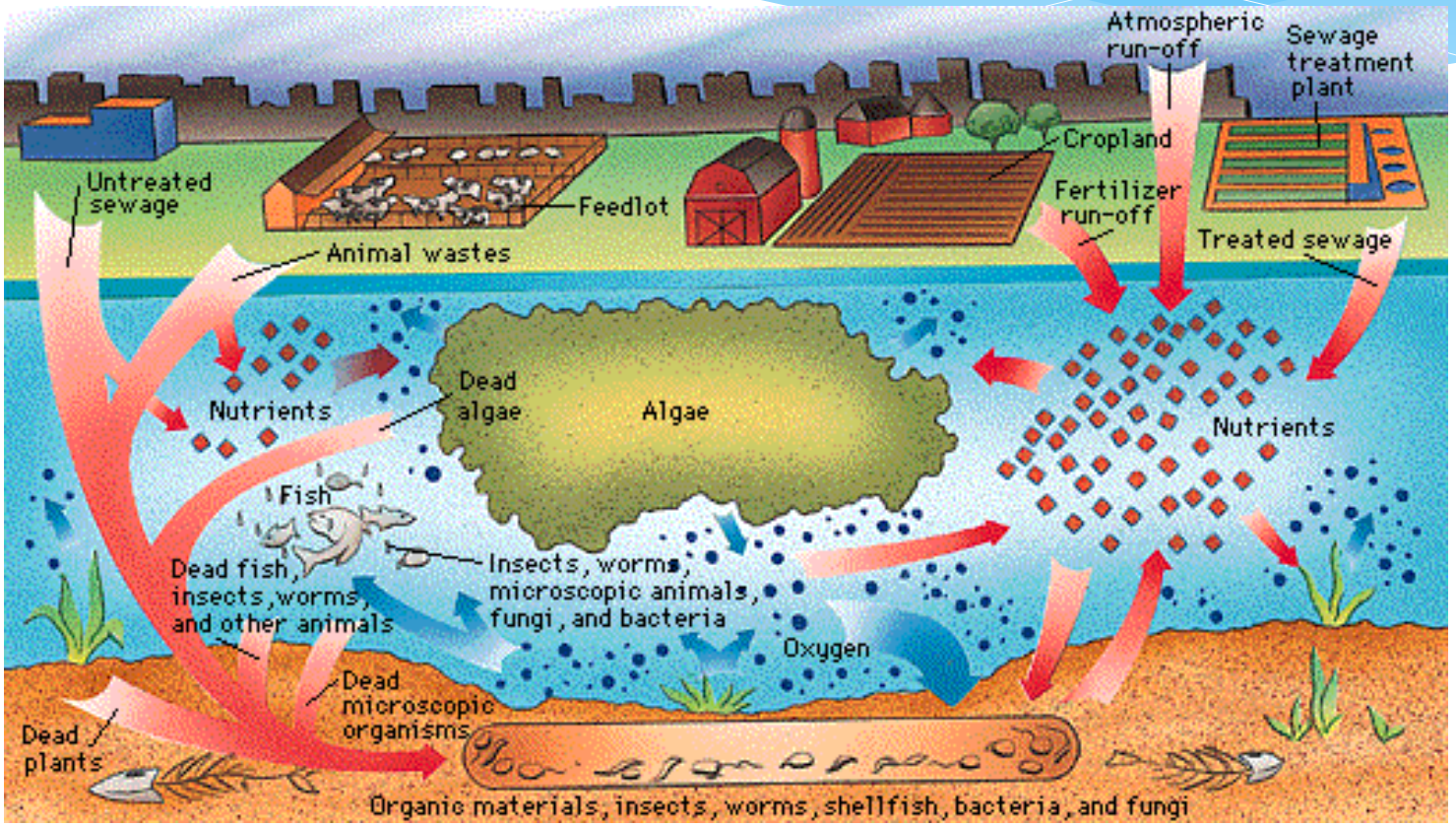



(Source: Ben Halpern and colleagues, National Center for Ecological Analysis and Synthesis (NCEAS) at UC, Santa Barbara)
https://www.allianz.com/en/about_us/open-knowledge/topics/environment/articles/091112-how-humans-are-killing-the-oceans.html/



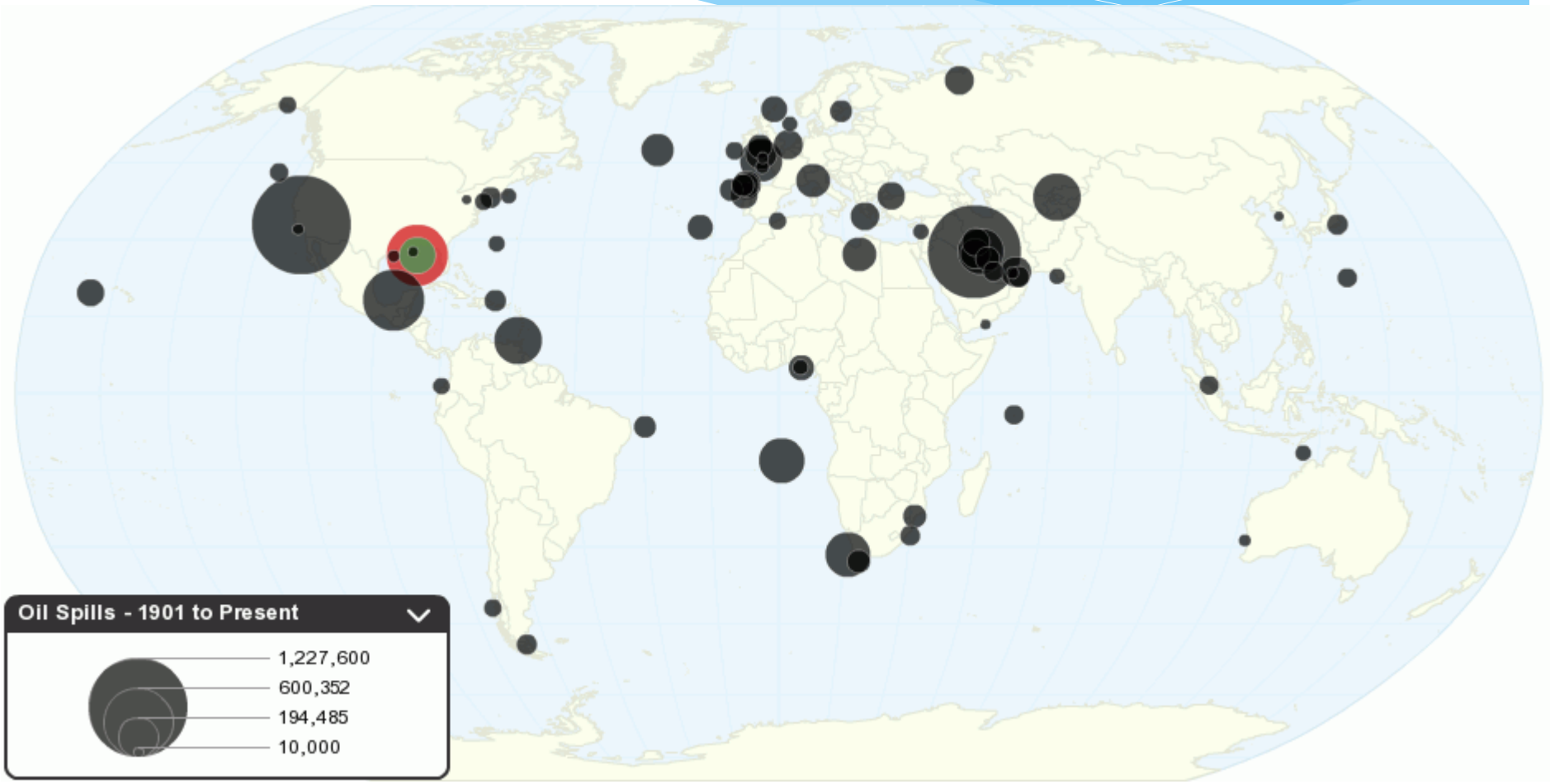

http://www.henry4school.fr/Environment/Pollution/water-pollution.htm

# Waste water pollution

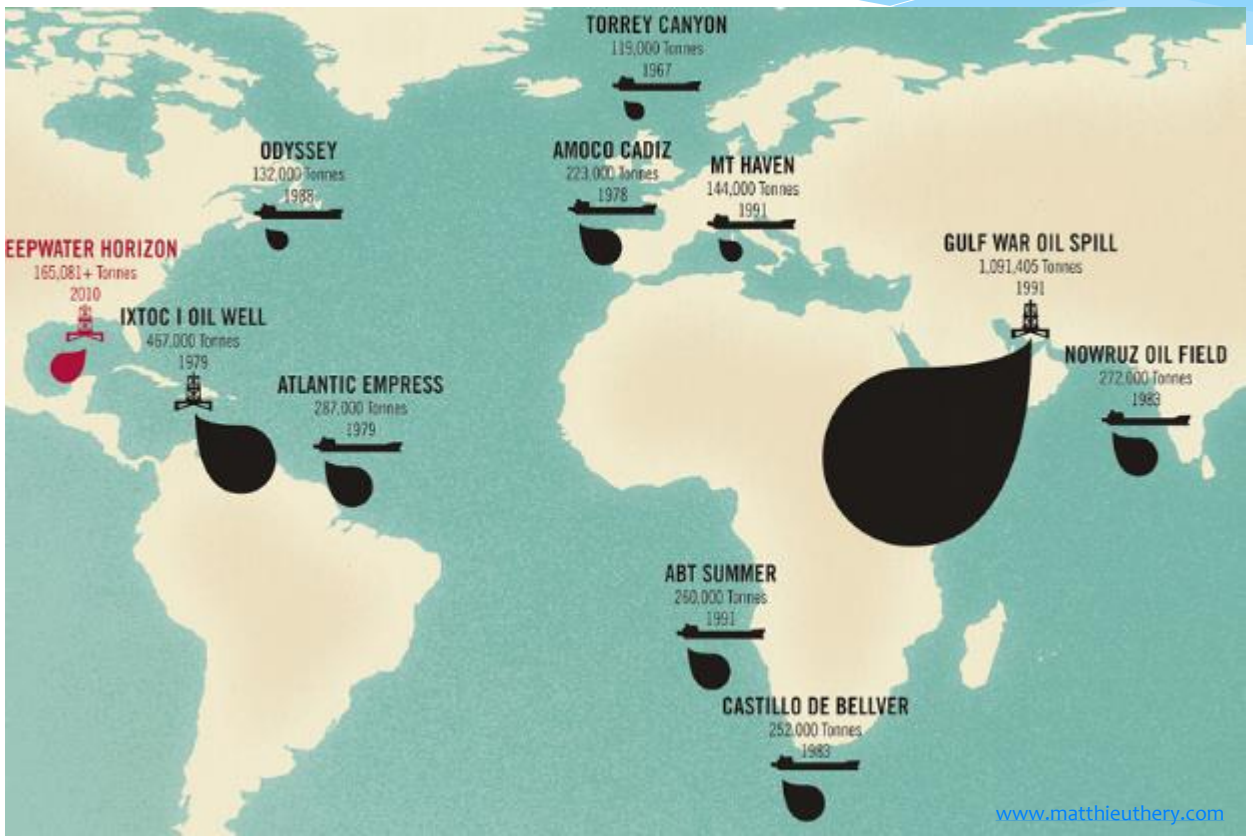



http://www.cpcbenvis.nic.in/water_pollution_control.html

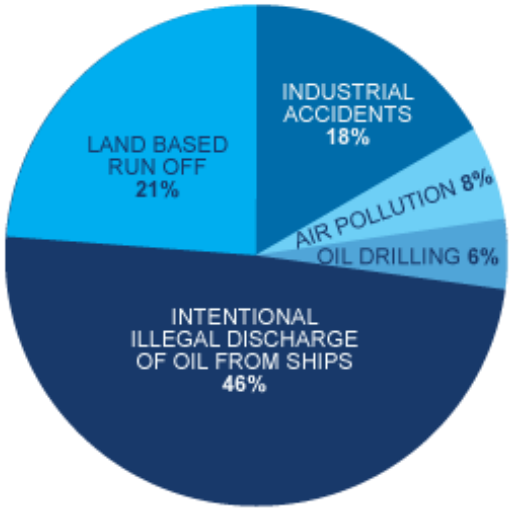
# Oil spills



# History of marine oil spills

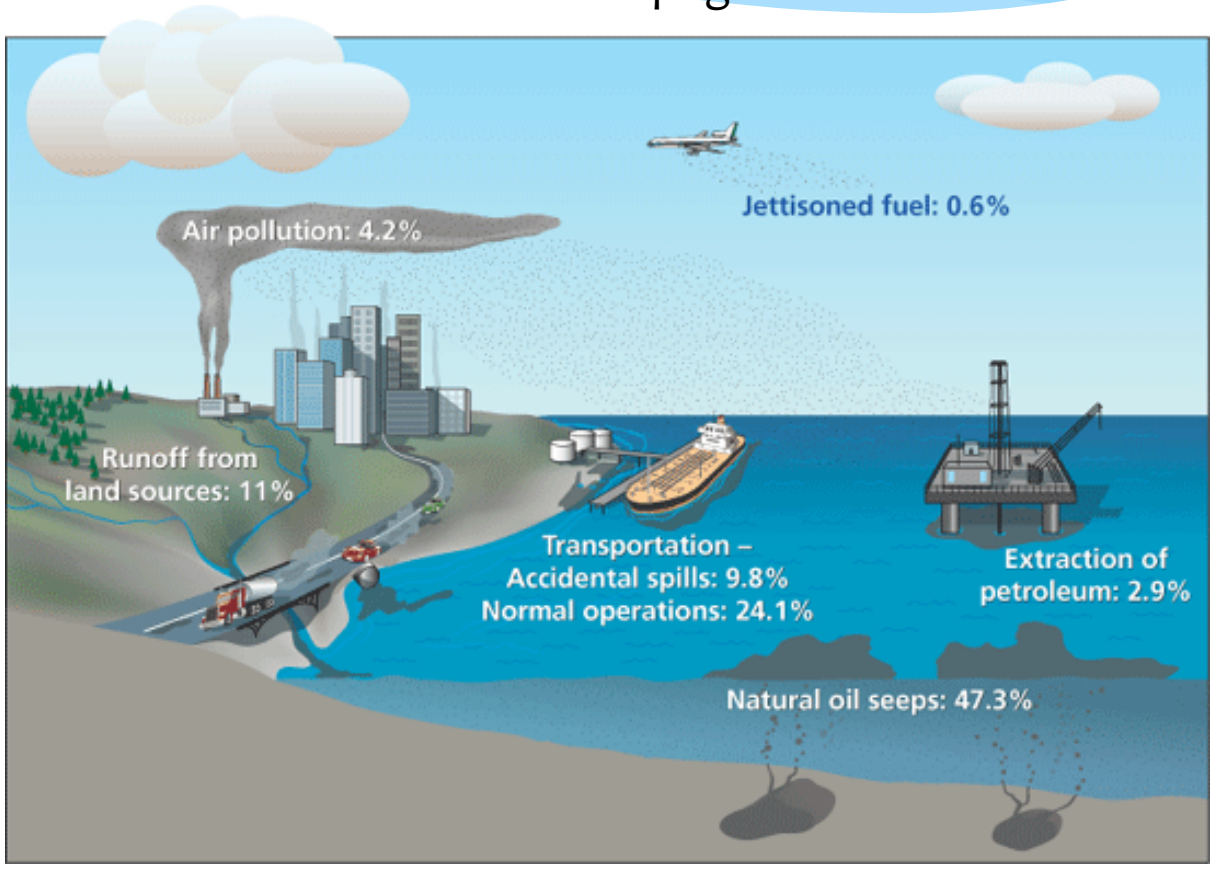


# Sources of oil pollution in water



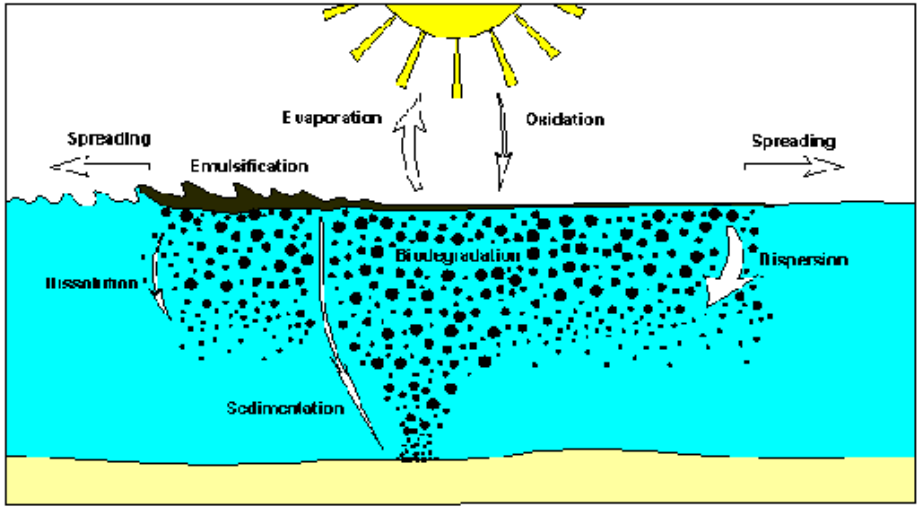

Anthropogenic sources

Natural and anthropogenic sources



# Processes of oil degradation

* **Spreading** of oil over the surface of the water is a relatively rapid process. Within days, a single ton of oil could cover up to 12 square kilometers.
* **Evaporation** removes light petroleum products, such as kerosene and diesel, from the marine environment, but is much less relevant for heavy fuel oils and most crude oil.
* **Dispersion** describes the breakup of oil on the surface of the water into drops or fragments that spread and sink into the water column.
* **Emulsification** refers to the process whereby two incompatible liquids become mixed.
* **Dissolution** occurs when the soluble compounds of the oil are dissolved into the water. This is a relatively unimportant process since most of the soluble compounds in oil evaporate before they can dissolve.




* **Oxidation** depends on the type of oil and the availability of sunlight. However oxidation reactions which are catalyzed by sunlight can lead to polymerization of oil molecules and lead to the formation of persistent "tar balls" which can last for a very long time without breaking down.
* **Sedimentation and Sinking** of oil takes place slowly. The sedimentation can occur when the oil adheres to suspended particles or microbes in the water and then sinks.
* **Biodegradation** of oil by microorganisms present in the sea is the often the slowest, but ultimately the most important, process in the natural degradation of oil. These organisms consume the oil, converting it to simpler and less harmful compounds in the process of metabolizing it to generate energy. The final byproducts of biodegradation are simply water and carbon dioxide.

http://www.groundtruthtrekking.org/Issues/AlaskaOilandGas/OilDegradation.html#ixzz45gibGgoo

# Video on the water pollution

* Water Pollution
  from EPA Ireland

https://www.youtube.com/watch?v=fxZ4IMpM45Y

* Explore More: Water Quality

https://www.youtube.com/watch?v=RMyCcWECbNE