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Proxecto de Educación Ambiental CAMBIO CLIMÁTICO

DOES CLIMATE REALLY CHANGE?

Does climate really change?
The key is the CO_2 present in the atmosphere
How has climate evolved since the earth's origins?
Usual climate change
Climate change due to human activity
Consequences and impacts of climate change on terrestrais ecosystems
Impacts on marine ecosystems

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ISBN: 978-84-453-4376-0

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INVESTING IN OUR COMMON FUTURE

1. Does climate really change?

1.1. What does climate change mean?

Climate change is not always dealt with accurately. This can lead us to confuse extreme weather events with climate change. Climate change is not only anything you can read about in scientific or specialised literature, since now you can hear about it in the street. In addition, apart from talking about what the weather is like, you can hear people speaking about the new data confirming the climate change while having a drink.

But do we really know what we are talking about or do we only repeat what we have heard? Obviously, we accept the information we obtain from different sources without wondering whether it is true or not. This leads us to making many mistakes.

You only have to listen to the news on the radio or on TV in order to realize that many terms are not used accurately. An example is the use of the terms 'weather' and 'climate'. We are used to listening to expressions like "Such event could not take place due to adverse climate conditions". Whereas the term "weather" refers to the state of the atmosphere at any given time, the term "climate" refers to all the weather states which have taken place in a region over a long or short period of time.

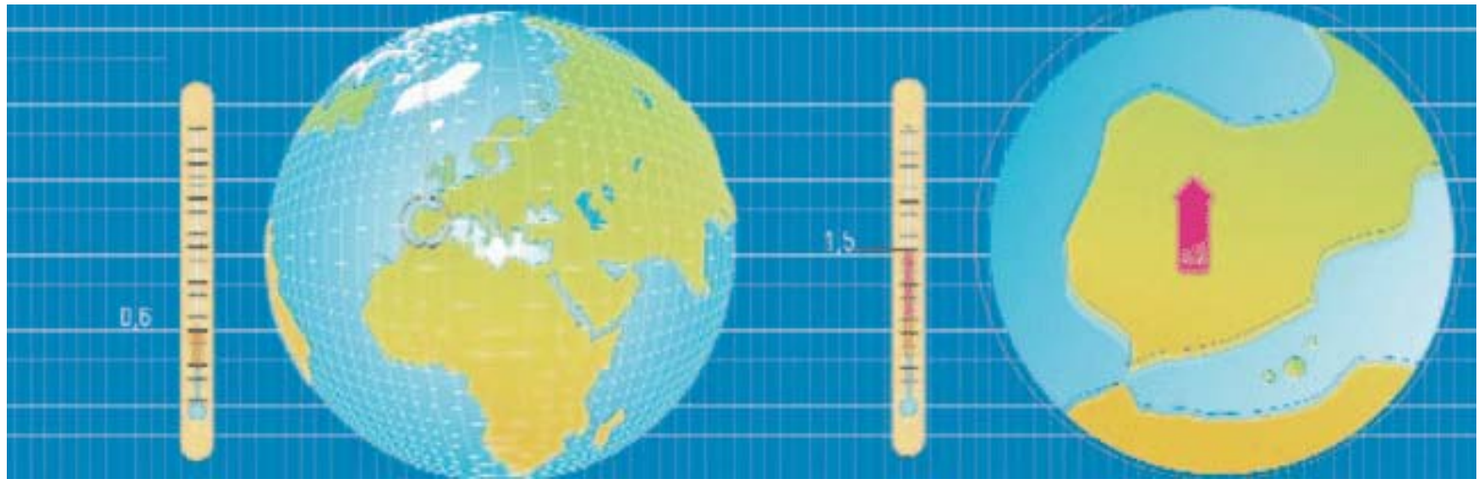
Concerning the media, you can notice that the news regarding weather is usually dealt with in a catastrophic or alarmist tone. Any meteorological event, such as intense snowfalls, strong rainfalls or extreme heat waves, is immediately attributable to a man-made weather change. But you cannot forget that some natural causes can influence on climate variations. Most scientists agree that in the last few years the global temperature in our planet is increasing. Although we can agree or not on the human beings' degree of involvement in this process, the scientific community is sure about it. In this way, we will have to change our actions that have been damaging the environment for a long time, and find out new ways of sustainable development for the life on our planet.

1.2. Evidence of climate change based on the increasing global temperature

The data on the 20th century' climate provided by scientists and experts confirm that the global temperature on our planet has increased. At the same time, some extreme and strange weather events such as droughts in winter, windstorms, the retreat of glaciers and the rise in sea level have been confirmed.

The data confirming climate change are obtained from meteorological stations.

The average Earth's surface temperature has increased over the 20th century by about 0.6 degrees Celsius. In Spain, temperature has increased by about 1.5 degrees Celsius -over three times the average global increase-.This confirms the predictions that the Iberian Peninsula would be the country most affected by climate change in the European Union.



These data on average temperature confirm a trend to the increase of the average temperature on the Earth. These variations linked to climate changes have taken place since the Earth became a planet. This shift in climate has different causes, but nowadays it is believed to result from human activities.

Apart from these data about the increase of average temperatures, there is more evidence of climate change.

1.3. Evidence based on sea level rise

The evidence of the Earth's surface warming and other changes in the climate system is now stronger and clearer since it has been observed that the last two decades were the warmest in a millennium. Over the 20th century, in addition to this warming, the Arctic ice caps are proved to have gone up by 15 per cent in 50 years. Moreover the sea level rose 15 cm over the last century and the rainfall patterns have changed in some regions. On the other hand, some events such as those triggering extreme and frequent storms have become more and more intense.

Finally, further evidence of climate change regarding the increasing temperatures is given by the fact that the sea level has risen on average by 10-30 cm over the 20th century. The Cantabrian coast in Spain has recorded measurements of up to 3.5 mm/year. In Galicia, there are data form A Coruña and Vigo, confirming a slightly lower increase, registering values of about 2-3 mm/year during the second half of the 20th century.

1.4. Biological evidence

The biological spring takes place sooner ant the winter has been delayed, so that many plant species have flowered about 5 days before per decade for the last 50 years. In the mountains some Mediterranean plant species seem to have been migrating upwards.

Moreover, the past plant traces give evidence to climate change. Plants and particularly the oldest trees' trunks and leaves found in herbariums showed that climatic and atmospheric changes took place. For example, the tree rings show their growth. The thickness of the rings

More frequent and severe droughts can lead to an increasing risk of forest fires. In order to find out the link between the increasing temperatures and more frequent droughts, some species are proved to be more affected by drought and warming than others. In addition, it has been observed that the more affected species are the same as those retreating from current ecosystems. These warmer and more arid conditions, together with other events related to the Global Change such as the increase of shrub due to the change of land uses associated to a strong summer drought, lead to the fact that Galician ecosystems are more sensible to forest fires

and water conditions are linked, since a ring formed in a dry period is thinner than another one formed in a wet period.

On the other hand, the number of stomata per unit area (stomata density), is reduced by adapting themselves to warm and dry conditions, in order to avoid a surplus of evapotranspiration. Since there are less stomas per surface units, the plant loses less water by means of transpiration and faces drought more efficiently. Studying the variations in stoma's density of the same species taken from herbariums for the last two millenniums, the number of stomas per surface unit in those species was found to be reduced by 21 per cent. Climate change increases the plants' water stress, causing the retreat of those plants on the limit.

1.5. Geological evidence

There have also been extreme climate changes related to above mentioned data, such as those obtained from the Quaternary period –the last 2 million years of the Earth's history-. During this time, extremely cold periods called ice ages were followed by warmer periods called interglacial. During the cold periods ice covered most of the Earth's surface and they can be traced through the landscape. Although nowadays there are no glaciers in Galicia, evidences of their past existence can be found in the relief. For example, in the mountain chains of Os Ancares, O Courel, Manzaneda, located in Galicia, forms due to glacial erosion can be recognised –circles, valleys, weathered rocks- or to their deposits.

Bertrán Glacier (Patagonia Ice Field, South Argentina). Icebergs as those below are ice blocks released from the glacier front floating on water. The apparition of iceberg on oceans is favoured by global warming, resulting in a danger for navigation. Since the iceberg is almost exclusively made of water, the blue colour of the ice can be appreciated by our eyes.

Weathered rocks result from the eroding action of the glacial ice when advancing. These rocks have a polished part due to the ice's abrasion caused by its movement over it. On the front the forms are more irregular because some fragments have come off. In areas where glaciers have disappeared, the direction of the movement can be deduced. In Galicia examples of these rocks can be found in the mountains of Lugo and Ourense.

Glacier front (Patagonia, Argentina). Global warming accelerates ice melting, giving place to the retreat of the glacier front and diminishing the ice-sheet. Lateral deposits exposed to erosion, give evidence of the low level achieved by ice formerly.

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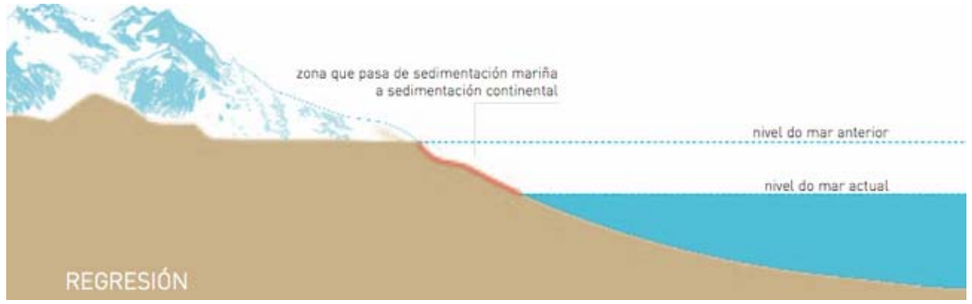
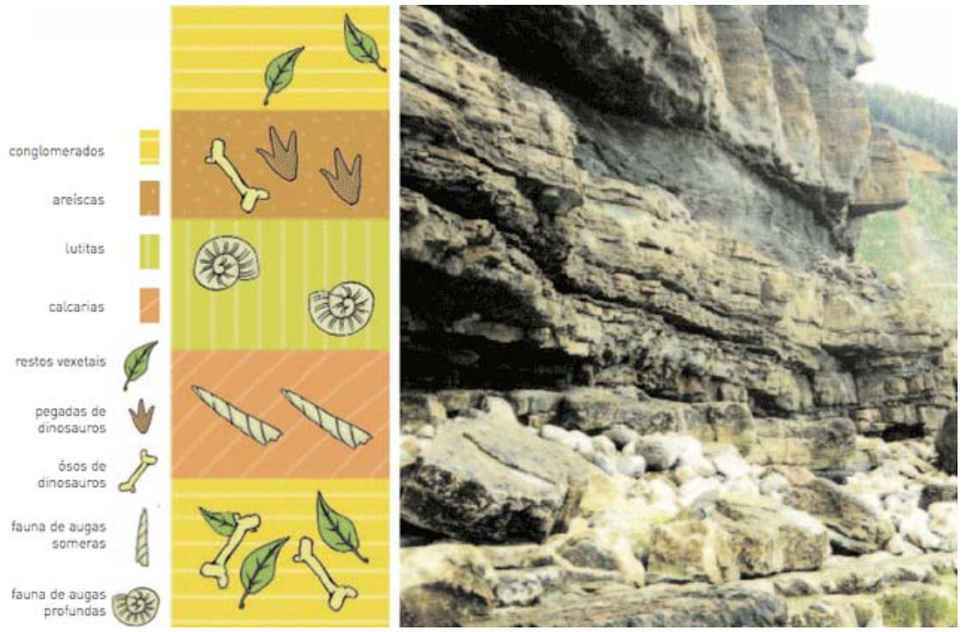
Does climate really change?
Geological evidence

Glacier formation triggers changes in the sea level giving place to sea transgressions and regressions. During cold periods, the sea level descends, causing a regression due to a higher water concentration in glaciers transformed into ice.



The apparition of fossil beaches, such as those of Area Longa and Cabo Silleiro, confirms a sea level higher than the present one. This sea level rise is called sea transgression and reveals a warm climate period.



The sediments of ancient Jurassic deltas, now transformed into strong sandstone strata, constitute the cliffs along a long stretch of coastline in Villaviciosa, Asturias. The Cantabrian coastline between Gijón and Ribadesella has the most important jurassic tracksite of footprints and bones of dinosaurs and other reptiles in Spain

As a consequence of sea level oscillations, the coastline can advance or retreat and rivers can follow periods of erosion/ sedimentation producing different levels of terraces. In a river outline the higher terraces are older than the lower ones.

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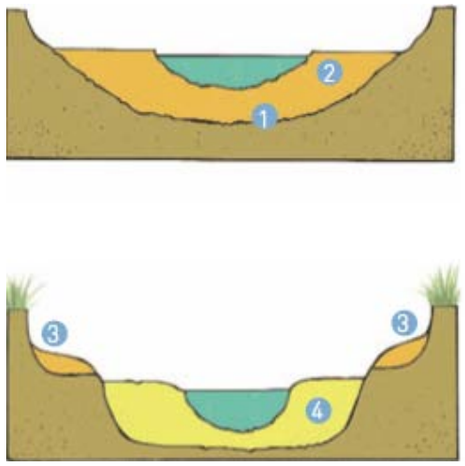
Does climate really change?
Geological evidence



1) An important sea level decline took place due to an ice age (regression). As a result, the river flowed at lower levels eroding the oldest ground (dark brown).

2) Later on, the sea level rose again, probably due to the thaw (transgression), making the river flow at higher levels. This stopped the stream and allowed the light brown materials settle, being eroded once the sea level starts again to decline.

3) An abrupt decline of the sea level (regression), probably due to a new ice age, caused serious erosion. This new period of erosion affected both material layers. In this way, both terraces were made of different material, being the oldest on the higher one and the youngest on the lower one.

4) The sea level rises again (transgression), probably due to the thaw. This raised the mouth level, making the clearer and newer material settle. This material starts to erode when the level declines again, forming a new terrace which is lower and newer that the higher ones.

These fossil beaches and river terraces can be dated by studying the fossil pollen. This allows us to discover the vegetation of that period.

Other paleoclimatic indicators can be found out in the fossilized traces of plants which grew in a climate very different from the present one. Examples can be the palm tree fossil logs that were found on the site of Gándaras de Budiño (Porriño, Pontevedra), which remarks the existence of a tropical climate in this area in the past.

The discovery of fossilized traces of palm trees (Nipadites burtinii) in the tertiary basin of Budiño, Pontevedra as well as the apparition of red soils are indicators of a tropical climate in this area in the past. Both animal and vegetal fossils and the study of sediments and rocks containing them provide a reconstruction of the landscape at that time.

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2. The key is the CO_2 present in the atmosphere

2.1. How does solar energy reach us?

The Sun releases energy by means of light passing through the atmosphere. Only one third of the light sent by the Sun to the Earth reaches the planet's surface, since the atmosphere acts as a very high illuminating radiation filter. Our eyes only perceive a very small part of the light that reaches the Earth, the so-called visible light.

Light travels in the form of waves. In order to understand what a wave is, imagine some particles moving as in the figures below:

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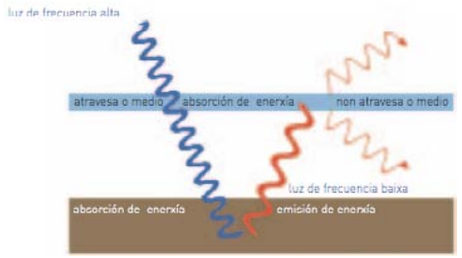
2.2. Why do we see objects in different colours?

You can see that waves travel by means of oscillations: the first one oscillates more than the second and therefore it is said to have more frequency. Each complete wave oscillation is called a cycle and therefore, the frequency measures the number of cycles completed by the wave per second. Wavelength means a cycle's length, as you can see in the figures above.

Light does not always produces the same quantity of energy, since the more frequency its wave has the more energy it produces, or the shorter its wave length is.



There are two reasons to explain why substances do not let in light: first, because they rebound it off and second, because they absorb it. In this case, the absorbed radiation is transformed into calorific radiation, which it is non-visible (infrared). White objects reflect all the illuminating radiation that reaches them, whereas black objects absorb it and make it into calorific radiation.

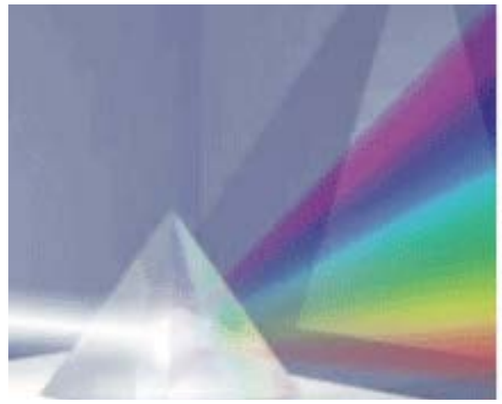
You can perceive the colour of things because they have absorbed the complementary colour. That is the reason why you perceive the colour that is not absorbed by them, therefore that reflected ("rebounded off"), allowing us to perceive it.

A transparent object such as glass lets in almost all the illuminating radiation but not all the solar radiation because glass is a filter suitable for infrared radiation (calorific radiation). This explanation allows us to understand the introduction and establishment of greenhouses in agriculture.

These agricultural facilities are built when it is necessary to maintain a higher temperature on a farming land's surface and therefore to avoid the worst consequences of frost on plants. The best greenhouses are made of glass, which is transparent for all colours of light, but they do not let in most infrared or calorific radiation.

If glass were painted red only a part of the visible illuminating radiation could pass through it. In this case the light added to the red light would be absorbed (greenish or bluish colour). From the outside of the greenhouse you could see the non-absorbed light, that is, the reflected ("rebounded off") red light, which would reach our sight when it is reflected. Part of this non-absorbed red light would pass through the glass and therefore, you could see reddish colours inside the greenhouse. This means that the red glass is not transparent for all the colours of light. In fact, not all the solar radiation passes through the standard glass, but it lets all colours of light in. Therefore, radiation that does not pass through it cannot be perceived by our eyes (infrared or calorific radiation).

While colourless glass lets in almost all the visible radiation, black glass does not; it absorbs all the visible radiation, changing it into calorific radiation (infrared radiation). Therefore, if the greenhouse was made of black glass it would not let in visible radiation and its inside could not be seen. In this case the surface of the black glass would be very hot when the sun shines because it is changing all the



illuminating radiation absorbed into infrared radiation. If it was white, it would neither let in most visible light, but in this case not because it absorbs it, but because it reflects it.

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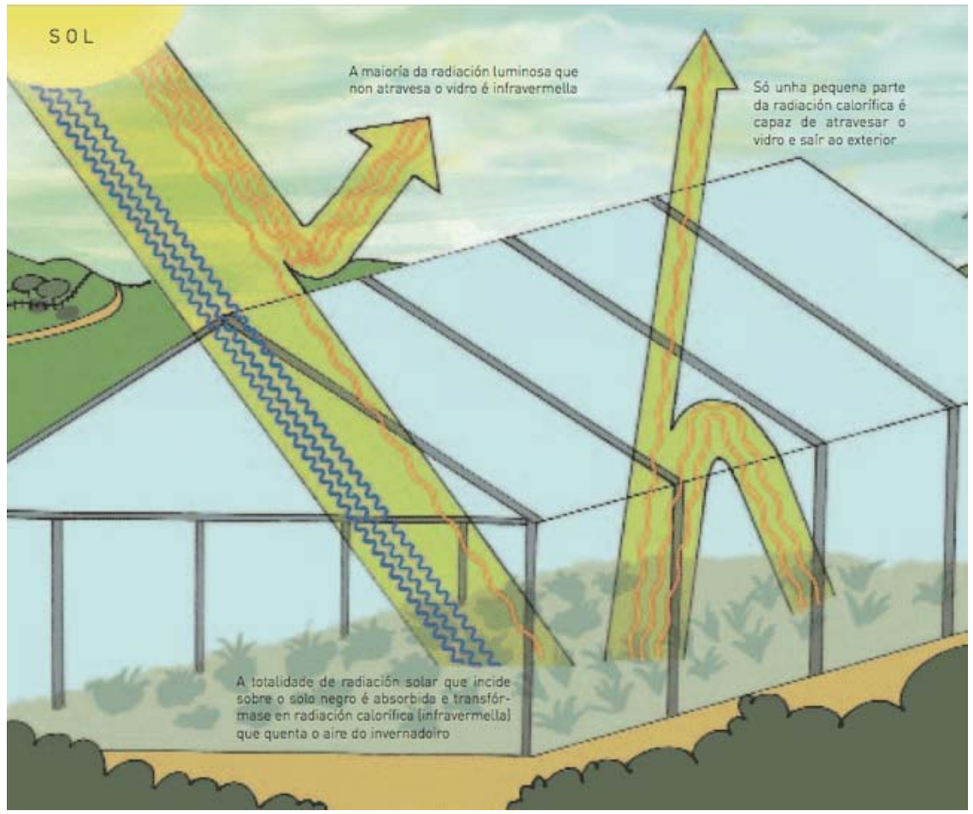
The key is the CO2 present in the atmosphere

Why is it warmer inside than outside a greenhouse?

2.3. Why is it warmer inside than outside a greenhouse?

When the illuminating radiation falls on the black ground of the greenhouse, it is completely absorbed, changing into infrared or calorific radiation, which is released by the Earth towards the atmosphere.

Although it is very easy for the objects that are in the open air to rebound off the infrared radiation (calorific) rebounding it off towards the atmosphere, almost a small part of that irradiated by the ground of a greenhouse can pass through the glass towards the outside atmosphere. Nevertheless, most of it bounces on the inside of the glass, resting inside the greenhouse, which causes the increase of temperature inside.



This effect is felt inside the cars or rooms full of windows, mainly in summer sunny days. In some Galician buildings this effect was also used to make winter temperatures warmer, building galleries in sunny spaces.

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2.4. The role of carbon dioxide (CO_2) in the warming of the atmosphere

2.4.1. Greenhouse gases

The Earth's atmosphere is composed of many gases including the nitrogen, the oxygen and the argon. These gases are quite transparent both for the visible light and the infrared or calorific radiation released by the Earth when it is warm.

Other gases, representing less than 1 percent, act in a similar way to the glass wall of a greenhouse. The most important are the carbon dioxide (CO_2), the methane (CH_4) and the nitrous oxide (N_2O). Among the greenhouse gases, the carbon dioxide plays an important role as a thermo-regulator, as well as water (H_2O) vapour, although in a different way from that of the glass walls of a greenhouse.

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The key is the CO2 present in the atmosphere

The role of carbon dioxide (CO2) in the warming of the atmosphere

The atmosphere's filters

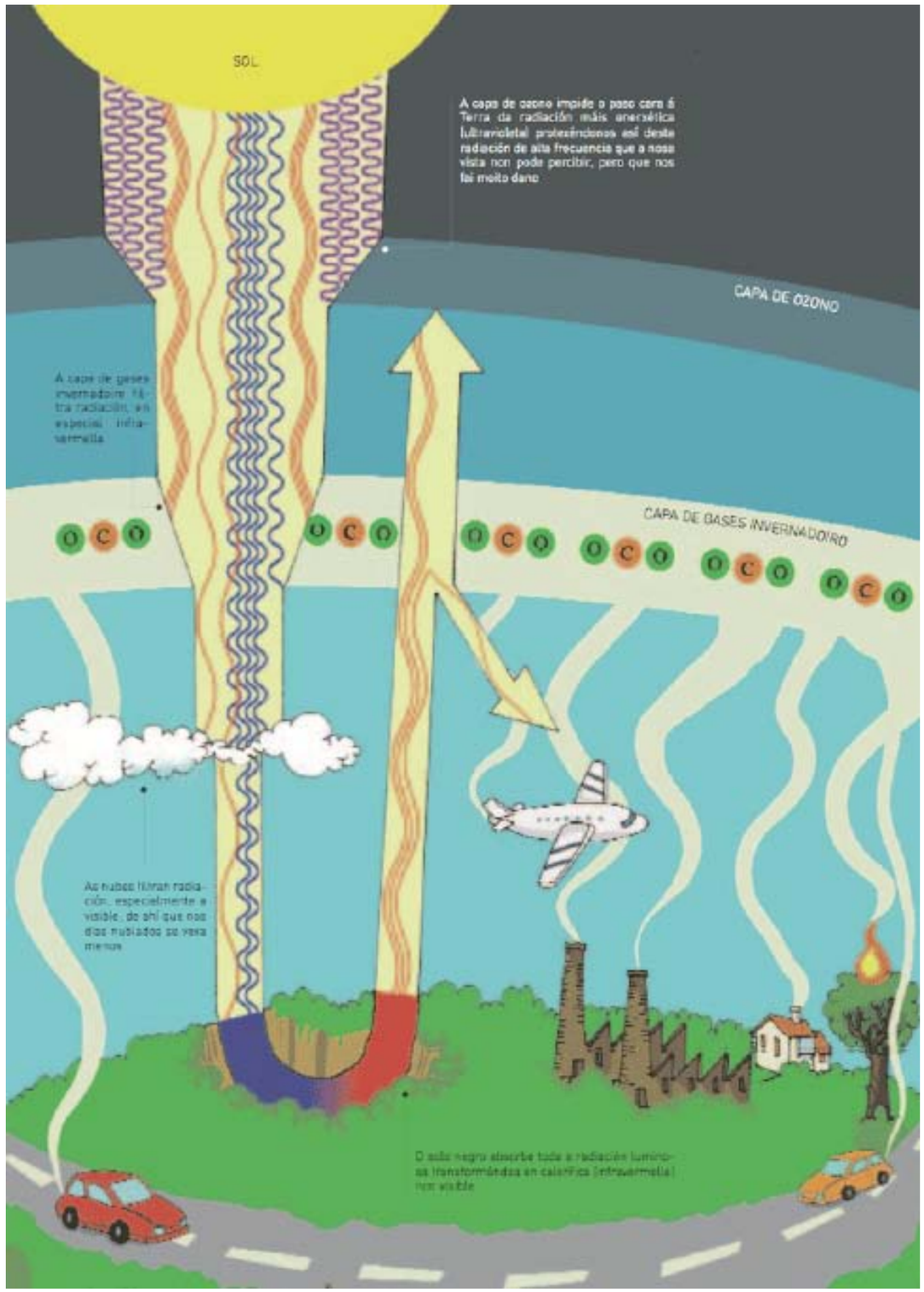
2.4.2. The atmosphere's filters

When sunlight reaches the atmosphere, some of this energy is filtered through different points by means of absorptions and reflections. The radiation that gives out more energy is not the non-visible one but the ultraviolet one, which is filtered through a very high layer that has a gas called ozone which absorbs it.

Another different filtering layer is that of greenhouse gases, particularly the carbon dioxide. This is different from the former due to its position, the type of gases and the type of radiation that is filtered by them, which is in this case the least energetic: infrared or calorific.

Since this layer does not let a part of the infrared radiation in, the heat released by the Earth, as a result of changing the illuminating radiation absorbed, is rebounded off again towards the Earth's surface, so that it becomes very similar to the glass walls of a greenhouse, although it acts as if it were a sponge.

Finally, clouds also reflect back and absorb radiation. That is the reason why in cloudy days there is less light. By means of the thermo-regulating action of water, the water vapour layer is also relevant to the thermal regulation that allows life on Earth, although in a different way from the carbon dioxide.



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The key is the CO2 present in the atmosphere

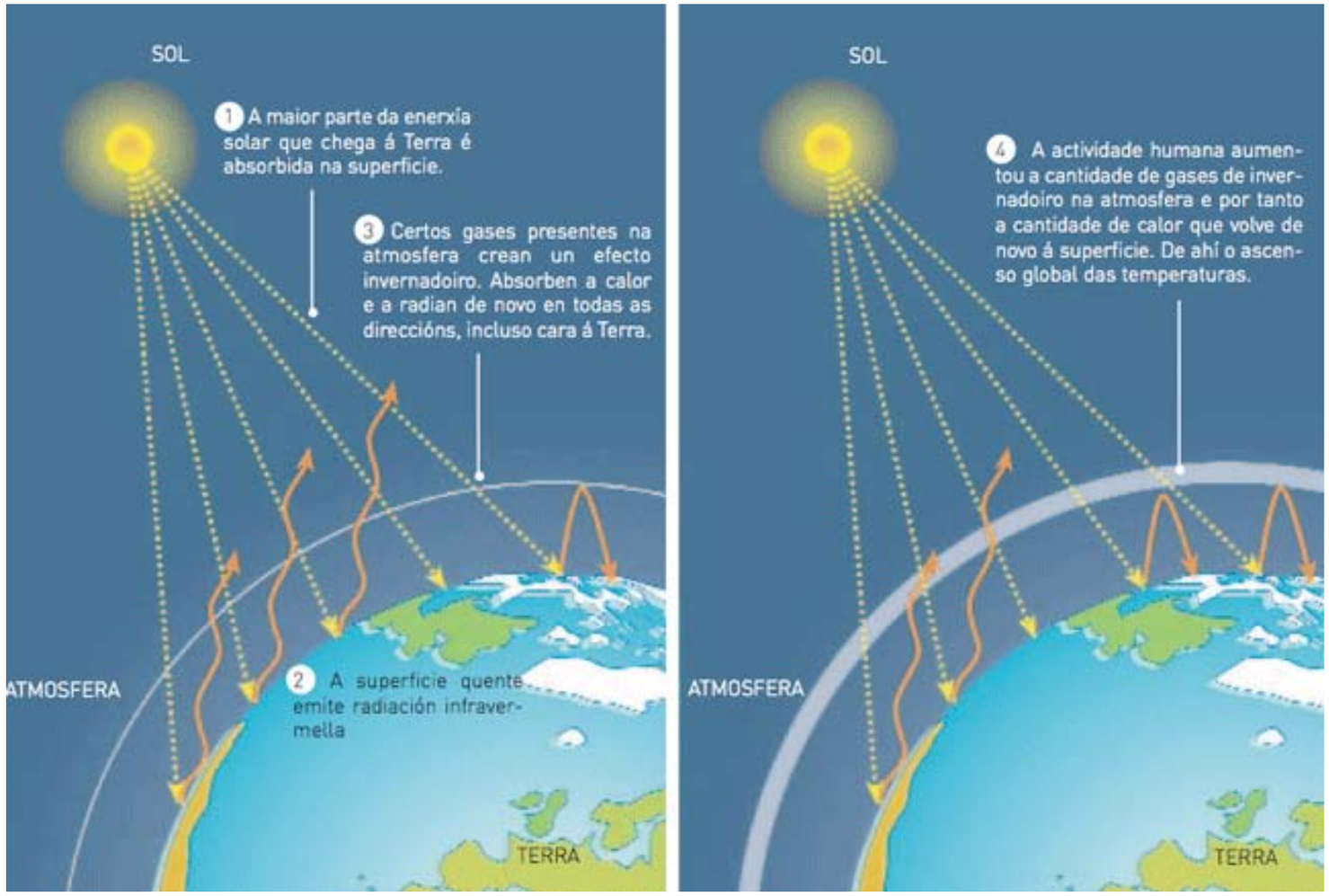
The role of carbon dioxide (CO2) in the warming of the atmosphere

The greenhouse effect

2.4.3. The greenhouse effect

That part of calorific energy retained by greenhouse gases is released again towards the Earth's surface. This effect, known as greenhouse effect due to its similarity to what happens inside these agricultural facilities, warms the air surrounding the Earth. If there were not greenhouse gases, the planet would be about 30 degrees Celsius colder than it is at present.

In such conditions life would never be possible on Earth. This is what happens in Mars, where the temperature is -50 degrees Celsius. Nevertheless, these circumstances seem not to have been always the same since there seem to be morphological traces of riverside relief on it.



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2.4.4. Relationship between the CO_2 and the Earth's temperature

After passing through all these atmospheric filters, about one-third of the solar radiation reaches the Earth. All the visible radiation that strikes the black soil is absorbed and the rest that strikes white objects is reflected ("rebounded off"). The radiation that strikes on objects of different colours is partly absorbed and partly reflected. This reflected illuminating radiation allows us to see the objects in the complementary colours of those absorbed.

Nevertheless, the part of illuminating energy absorbed is transformed into heat. This calorific energy is released into the atmosphere in the form of infrared radiation. Part of that heat released is trapped by the greenhouse gas layer.

As it can be inferred from above, the Earth is warmer due to the carbon dioxide contained -0.03 percent-, which acts as a calorific radiation filter, in a similar way to a glass wall of a greenhouse, since it is quite transparent for visible radiation but not so much for the infrared or calorific radiation.

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The key is the CO2 present in the atmosphere

The role of carbon dioxide (CO2) in the warming of the atmosphere

Effects of the increasing CO2

2.4.5. Effects of the increasing CO_2

If the content of carbon dioxide in the atmosphere was higher -0.06 percent-, the greenhouse effect would also be increased, warming the Earth several degrees, so that the polar caps could be gradually melting. The thicker the carbon dioxide layer is, the more similar to the glass wall of a greenhouse its behaviour is. If Arctic polar caps melted, the sea level would rise 72 metres.

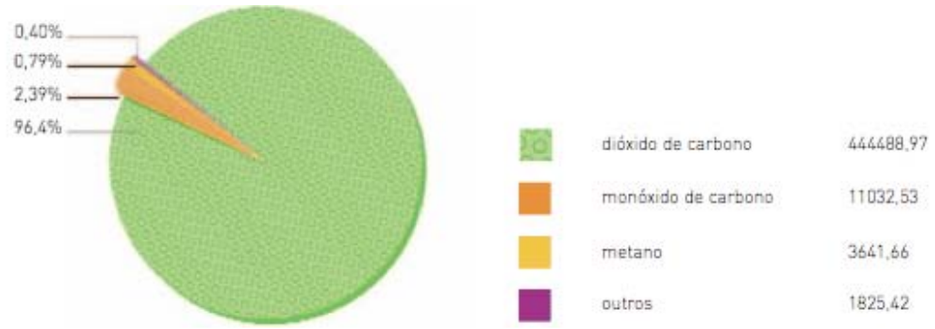
The opposite occurred as a consequence of the last ice age 18.000 years ago, when the sea level was 120 metres below the present level, so that the old coastline is covered by waters today. Eight thousand years ago there was a transgressive phase which raised the sea level by two meters above the actual coastline.

[+...]

2.5. Where does the carbon dioxide come from? Where does it go? The carbon cycle

2.5.1. The role of CO_2

Although the content of carbon dioxide (CO_2) in the atmosphere represents 0.03 percent, nevertheless it is the main gas containing atmospheric carbon (C). Therefore, considering the atmospheric volume unit divided into one million parts, the CO_2 would cover 358 parts –that is, the CO_2 represents 358 parts per million-. The other two atmospheric gases containing carbon (C) are the methane (CH_4) and carbon monoxide (CO), the first one standing for 0.1 parts/million and the second 1.6 parts/million.



herefore, the carbon dioxide contains almost all the carbon in the atmosphere. But this gas is also found in the oceans and in the soil. There is a constant exchange of carbon between these three elements.

The carbon dioxide is one the chemical ways through which the carbon moves cyclically, so that the C released into the atmosphere from a source, returns again to that point, acting as a sink.

The main carbon reservoirs in the form of CO_2 molecules that can be assimilated by living beings are found in the atmosphere and the hydrosphere.

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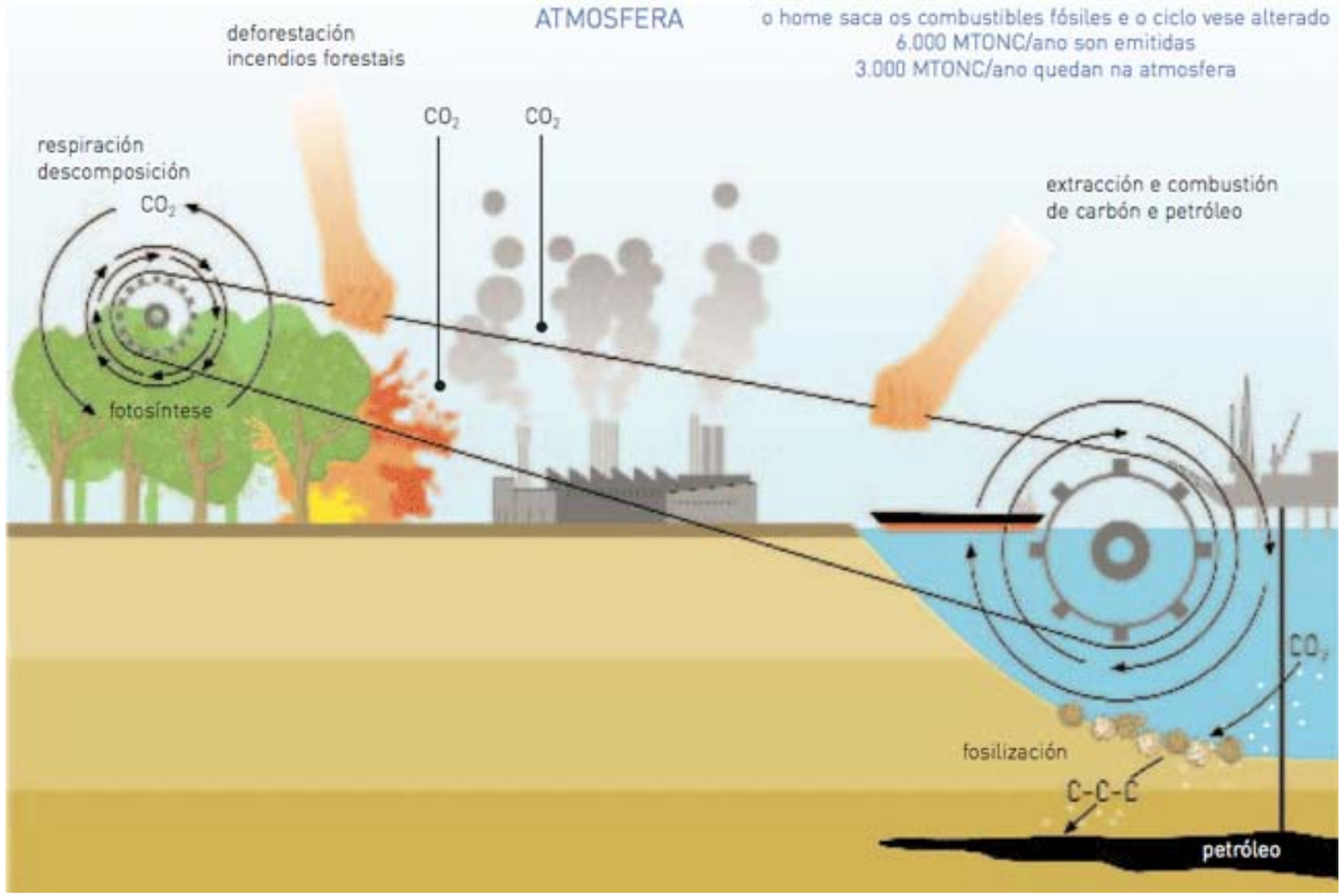
The key is the CO2 present in the atmosphere

Where does the carbon dioxide come from? Where does it go? The carbon cycle

The carbon cycle

2.5.2. The carbon cycle



The carbon trapped from the atmosphere by living beings in the process of photosynthesis passes from some living beings to the other by means of the nutrition processes and it is released again into the atmosphere by means of respiration, bodies' decomposition or burning, becoming a cycle. Some of these bodies does not decompose but become fossil inside the soil, getting rid of the carbon, since volcanoes, earthquakes, erosions and so on can release it again into the atmosphere in the form of CO_2.

Then it can be said that the Earth's carbon is on a constant move (carbon cycle). At the same time, this cycle can be divided into two adjusted sub-cycles produced at a different pace. This can be explained by means of the standard cycle path of the bicycle's chain, as a result of the combination of the movement of the chain wheel and the sprocket wheel.

The quickest cycle (sprocket wheel) is related to the living beings' and their bodies' photosynthesis, nutrition and decomposition. The slowest cycle is geochemical since it is responsible for regulating the exchange between the soil and the atmosphere and it is related to the formation of fossil fuels from organic matter fossilization (carbon, natural gas and oil) and its burning or release as a result of geological processes).

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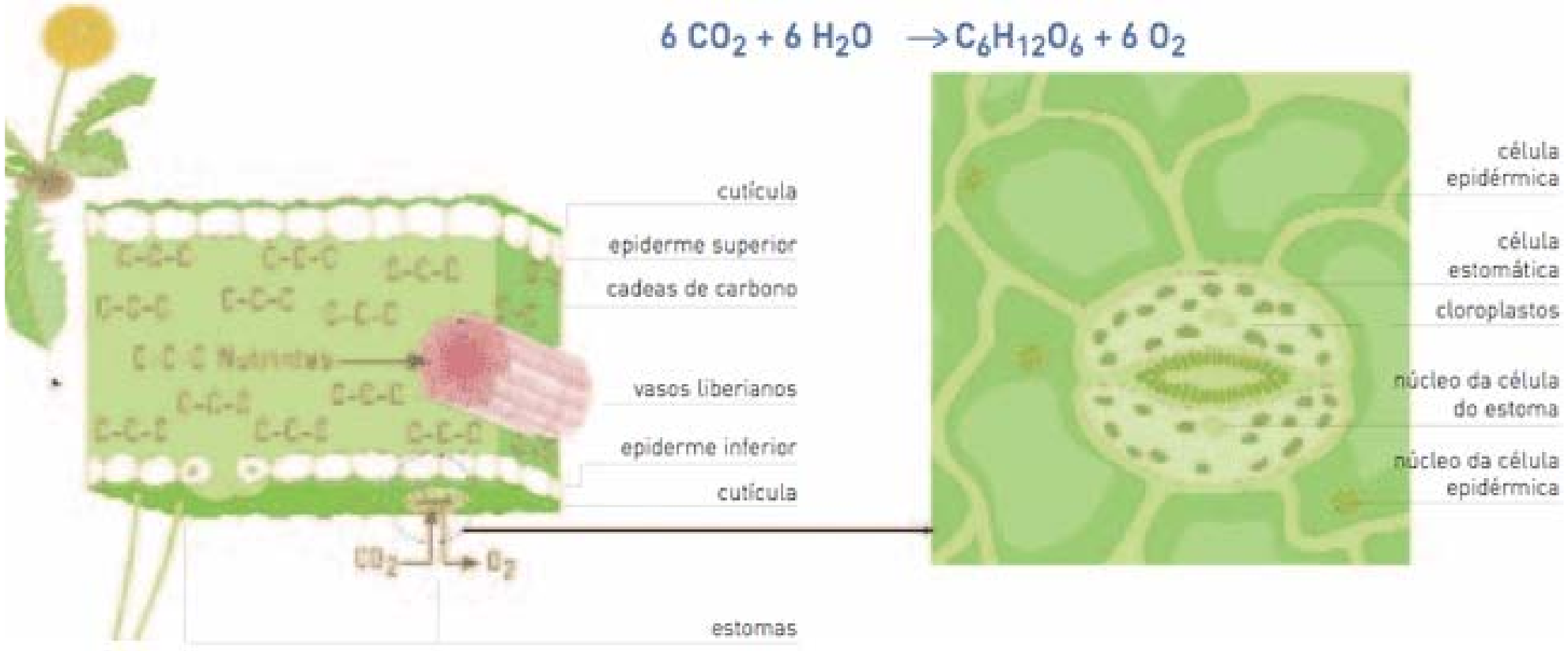
The key is the CO2 present in the atmosphere

Where does the carbon dioxide come from? Where does it go? The carbon cycle

The quick cycle and the role of photosynthesis as a sink

2.5.3. The quick cycle and the role of photosynthesis as a sink



Chloroplasts are inside the leaves. Photosynthesis is realized in them with the carbon dioxide coming from the air introduced through the stomata. This process takes place only if there is illuminating energy that is transformed into chemical energy stored in the linkages of G chains (nutrients) formed during the process, using the C from the CO_2. Oxygen going out into the atmosphere through the stomata is also released. Nutrients (C chains) dissolved into water become the juice that enters the Liberian vessels.

Regarding the quick cycle, by means of photosynthesis biological processes introduce carbon dioxide from the atmosphere into organic compounds (carbon chains), which is stored in unions, the chemical energy resulting from the transformation of illuminating energy during the photosynthesis process. The gas goes into the plant through the leaves' stomata (pores). The organic matter first produced is the carbon hydrates such as glucose, and from it the remaining substances are produced. The photosynthetic process can be summarized as follows:

Carbon dioxide occurs mainly in young forests. It is well-known that plants grow stronger in environments rich in carbon dioxide. As long as trees are growing, the relevance of respiration increases in order to maintain more biomass, keeping a balance between respiration and photosynthesis regarding carbon dioxide intake and release.

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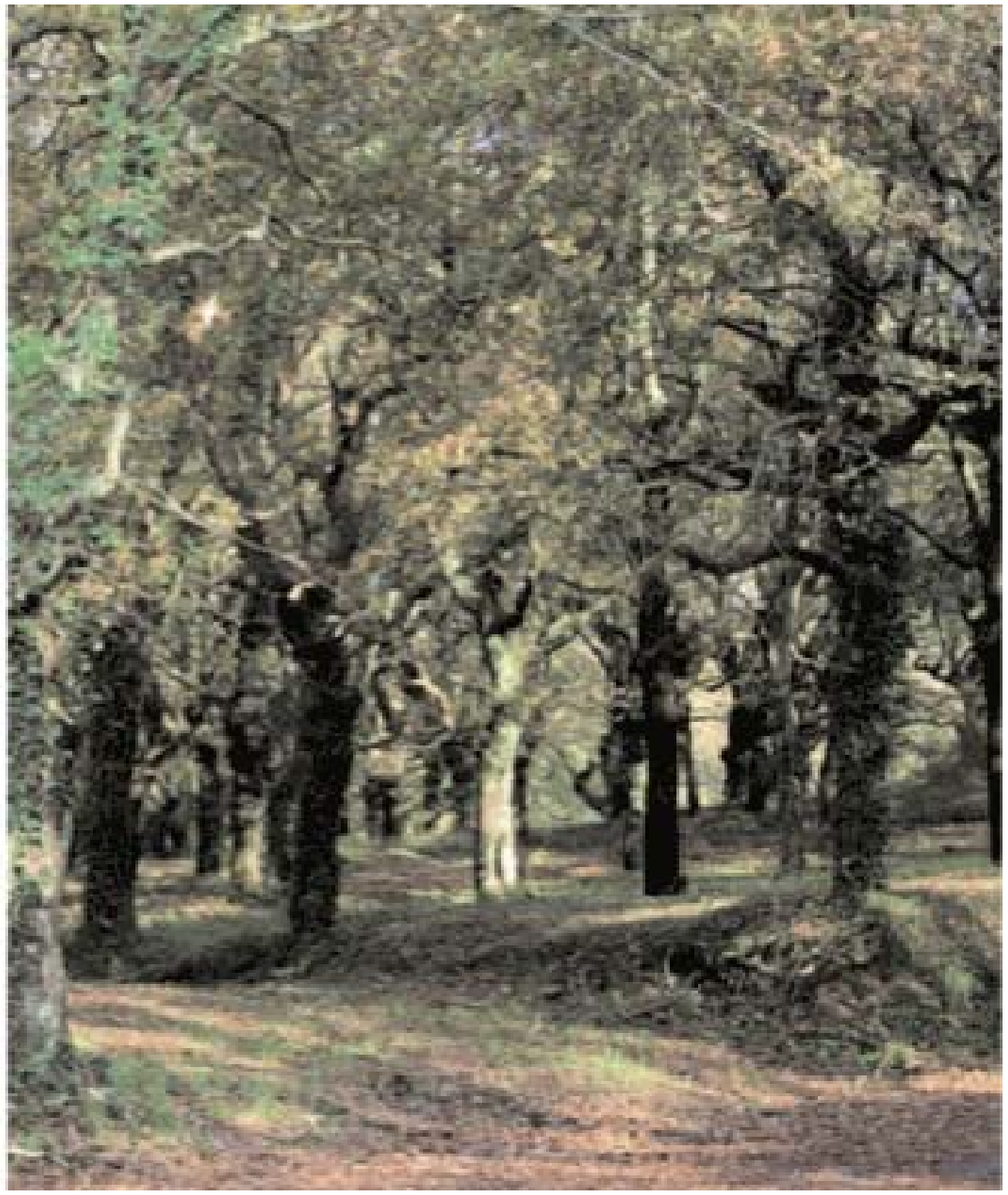
Where does the carbon dioxide come from? Where does it go? The carbon cycle

Forests in the quick cycle

2.5.4. Forests in the quick cycle



In this sense, a forest ecosystem acts as a sink (a net atmospheric CO_2 release), when there is an increasing sum of the total stocks retained by the same forest vegetation -trees and plants- in relation to the carbon dioxide released by that forest's respiration and decomposition (the opposite to photosynthesis), as it occurs in young forests.

As far as the forest becomes mature these quantities of carbon dioxide source and sink become similar, reaching the balance. In this progress there can be the case of old forests where the CO_2 release can overcome the CO_2 sequestration.

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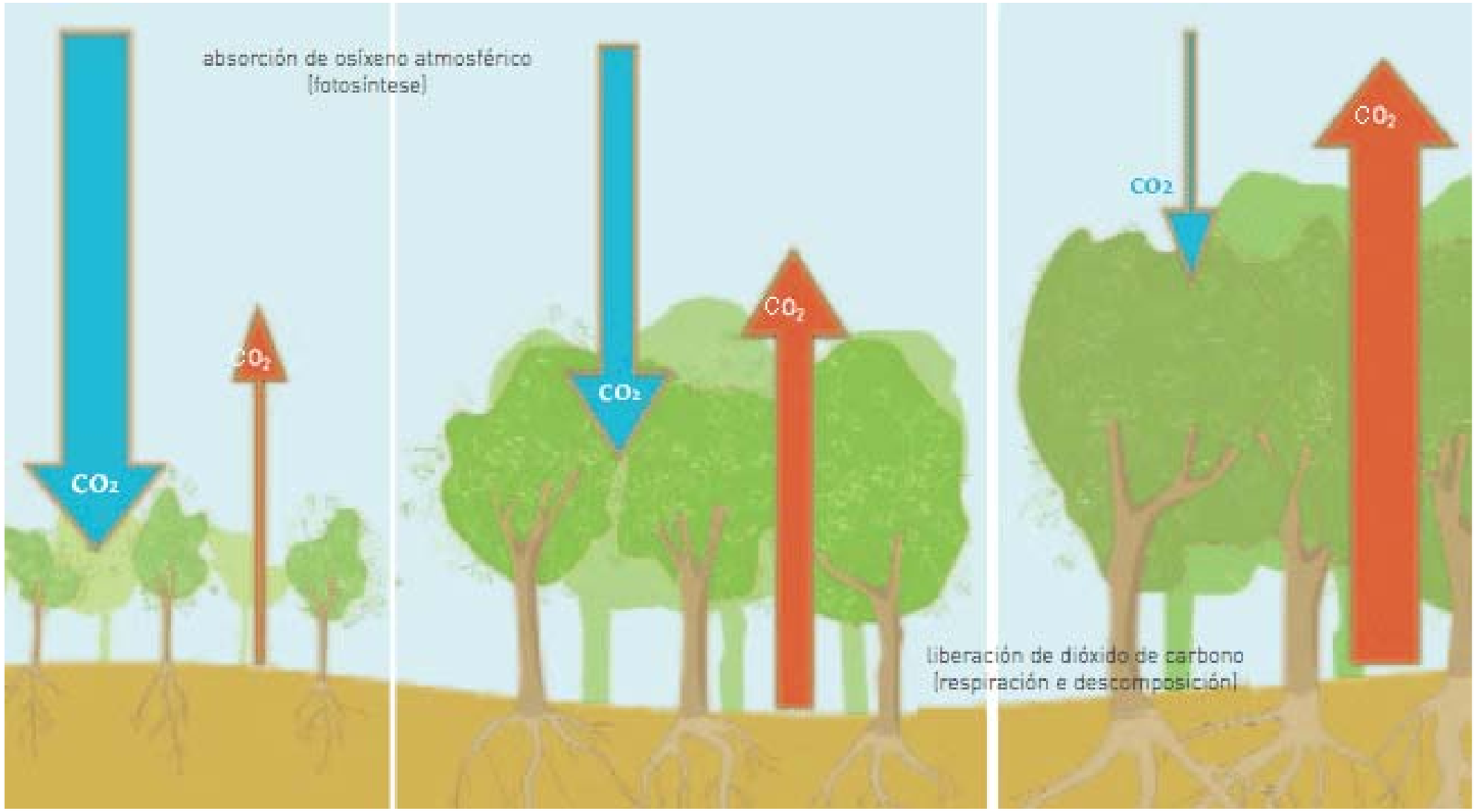
The key is the CO2 present in the atmosphere

Where does the carbon dioxide come from? Where does it go? The carbon cycle

Forests in the quick cycle



Considering that forests become older at the same time as the problems of deforestation and forest fires are increasing, the forests' capacity to act as carbon dioxide sinks is limited, trapping no more that 20 percent of our emissions into the atmosphere.

Although the role of forests as CO_2 sinks should not be dismissed, the key to achieve the removal of carbon dioxide surplus can be found in the sea, where the carbon dissolved is 50 times higher than that in the atmosphere. Therefore, the most important C sinks are found in the hydrosphere, mainly in the crustacean's and molluscs carbonated shells as well as in the coralline formations.

[+...]

The key is the CO2 present in the atmosphere

Where does the carbon dioxide come from? Where does it go? The carbon cycle

Forests in the quick cycle

"The figure represents a forest in three moments of its evolution.

(a) On the left the forest is on a young stage. In this case it is acting as a carbon dioxide sink because it absorbs in photosynthesis more than it releases in respiration and decomposition. Therefore it is contributing to diminish the greenhouse effect.

(b) In the middle it is on a mature stage. In this case the carbon dioxide intake and release are on a balance. Therefore, it is neither sink nor source and it does not affect the greenhouse effect.

(c) On the right, there is an old forest where carbon dioxide emissions (source) overcome the absorptions (sink). Therefore it is contributing to the increase of the greenhouse effect. [+...]

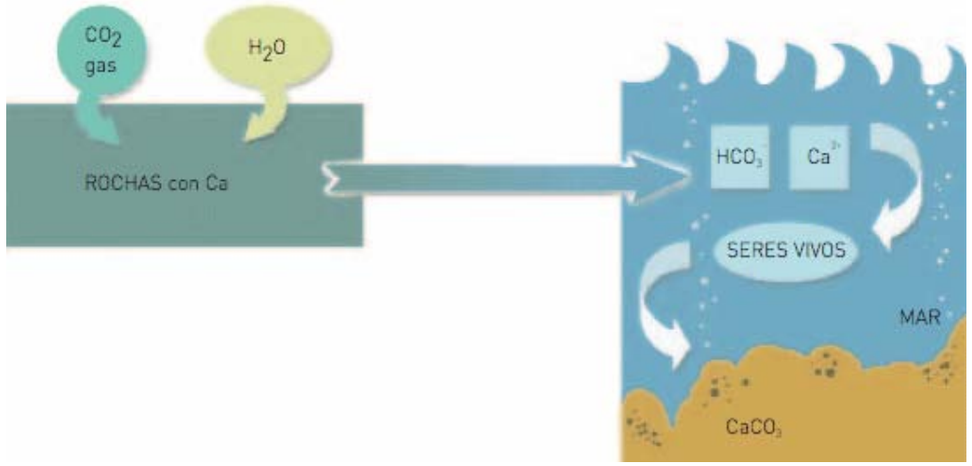
The key is the CO2 present in the atmosphere

Where does the carbon dioxide come from? Where does it go? The carbon cycle

The slow cycle related to this issue

2.5.5. The slow cycle related to this issue

O dissolves rocks with calcium silicates from the continent (for example basalts), producing bicarbonates dissolved in water, deposited in the ocean. Here bicarbonates enter living being introducing the C from the atmosphere. Some of the living beings' bodies are buried without being decomposed, becoming fossil as in the case of oil, or producing sedimentary rocks. These geological structures formed from living beings withdraw the C from the cycle.

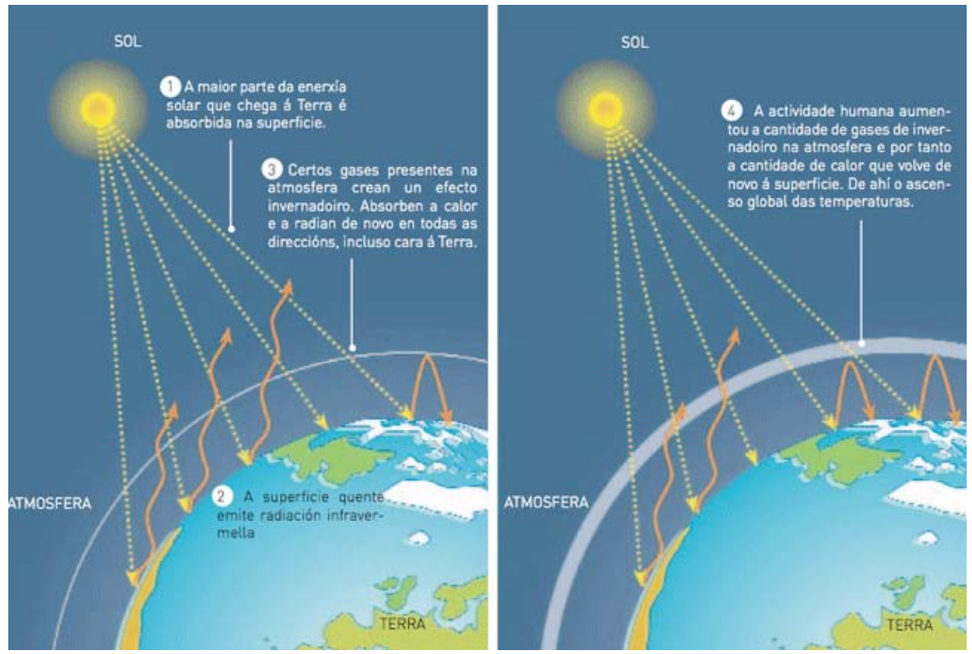


Without the greenhouse gases' layer, most of the Earth's heat would go back to the Earth. This layer results from a natural balance achieved for a long time. With this layer the Earth has reached the necessary temperature for the development of life on it and thus the living beings managed to play a key role in keeping the balance to maintain this layer and the natural greenhouse effect necessary for life (carbon cycle).

Nevertheless, although these gases are good by themselves, too much carbon dioxide released by cars and power stations is causing a constant increase of temperature. This is due to the fact that these combustions derived from the human activity result from the extraction and burning of fossil fuels, accelerating artificially the cycle –artificial acceleration of the sprocket wheel-.

Unbalances are taking place in the quick cycle (the chain wheel) due to human activities related to forest fires and deforestation.

This surplus of carbon dioxide released into the atmosphere by burning fossil fuels together with the effects of human activities on deforestation and forest fires mean that the carbon cycle is altered and that a surplus of $CO_2(g)$ is released into the atmosphere, increasing the thickness of the greenhouse gases layer.



While this layer is growing, it becomes similar to the glass since the greenhouse effect increases and this causes a constant rise of temperature. Most of the hottest twenty years recorded occurred after 1980. One of the main challenges faced by scientists in the 21st century is to stop the Earth's atmosphere from changing this state of greenhouse into a state of natural heating.

[+...]

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How has climate evolved since the earth's origins?

Paleoclimatic markers as remarkable instruments

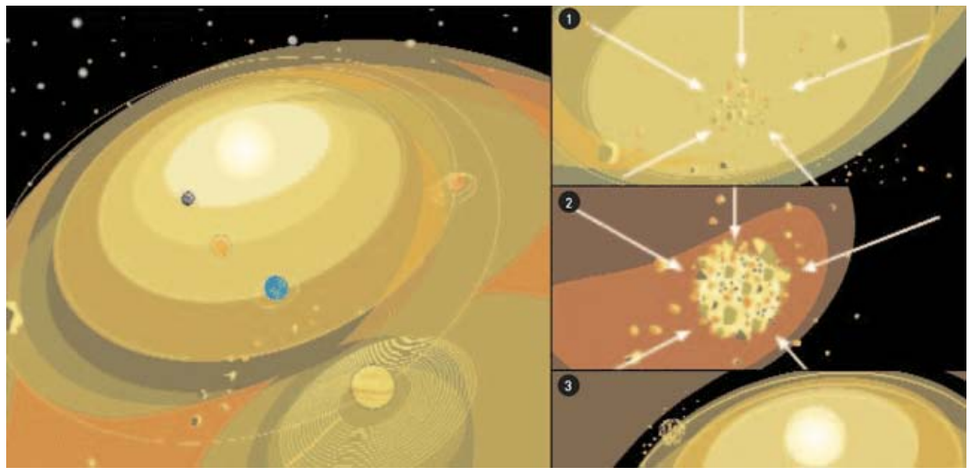
The planet's history

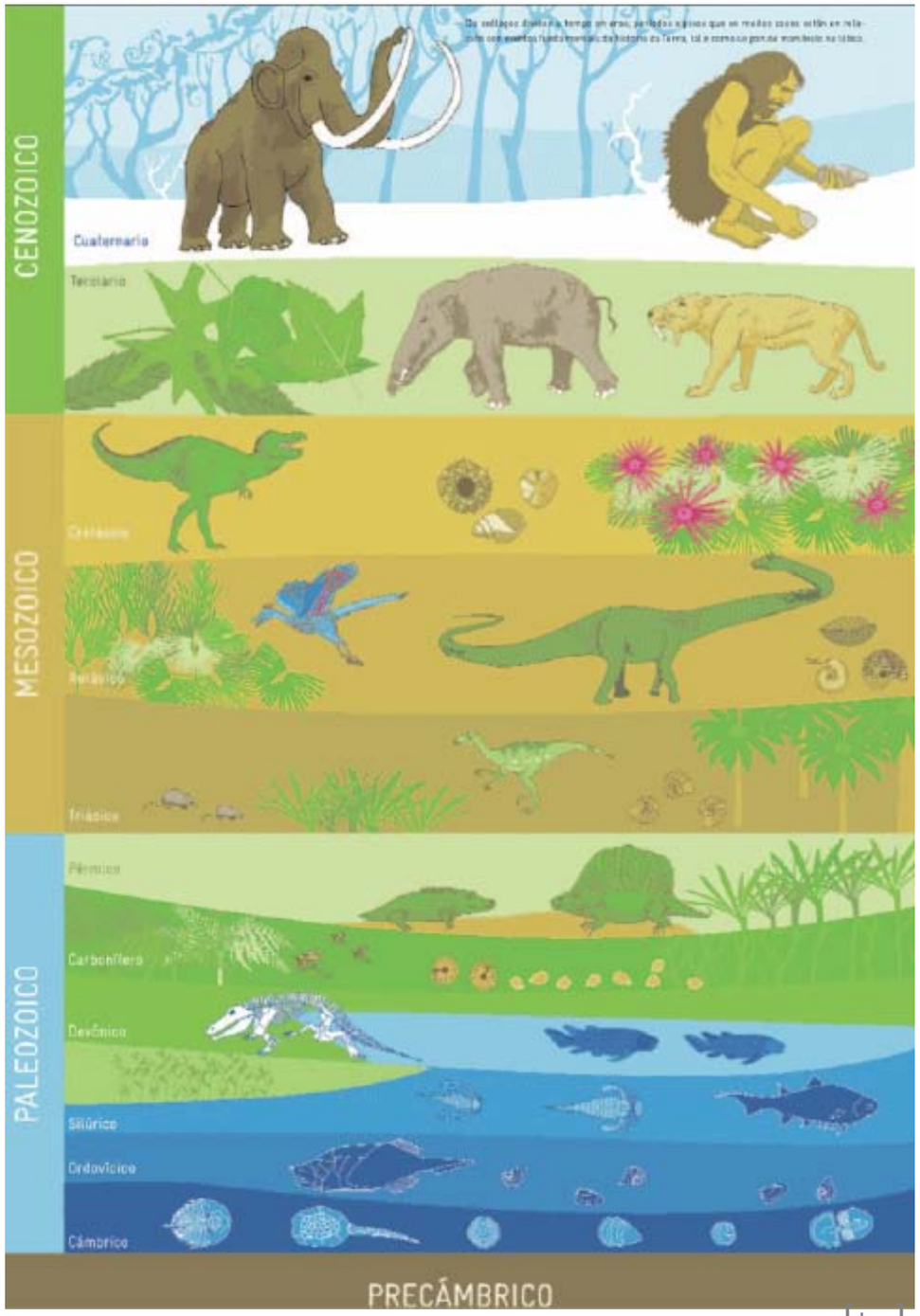
3. How has climate evolved since the earth's origins?

3.1. Paleoclimatic markers as remarkable instruments

3.1.1. The planet's history

Our planet's history started 4500 million years ago when several stellar bodies were joining themselves until the Earth achieved the present size. As a young planet, the Earth's surface and internal features were changing due to the meteorites' impacts and later on, to the movement of tectonic plates which caused the opening and closing of oceans, the rising of mountain ranges and so on.





[+...]

How has climate evolved since the earth's origins?

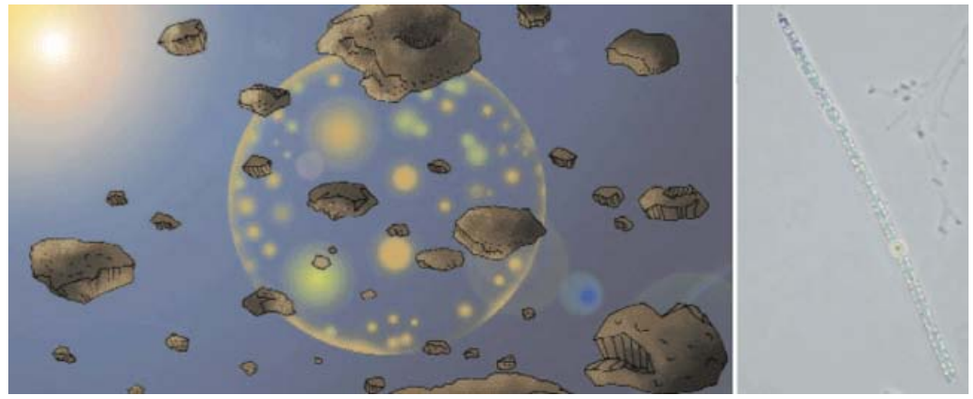
Paleoclimatic markers as remarkable instruments

The Earth's calendar

3.1.2. The Earth's calendar

We are used to measuring time in days, months, and years and to studying events which date back to several centuries in the humankind's history. But it still becomes very hard for us to change our perception of time and to locate events dated in million years.

A key moment on the planet's history is the appearance of the first forms of life we have proof of, thanks to the discovery of 3 500-years-old fossils.



Therefore, it seems reasonable to think that until the present the Earth underwent several shifts in climate that had to, as it actually happens, leave traces in natural elements, such as rocks, fossils, plants, etc. The science that studies the past climates is called Paleoclimatology.

[+...]

How has climate evolved since the earth's origins?

Paleoclimatic markers as remarkable instruments

The study of past climates

3.1.3. The study of past climates

Scientists have to work like detectives, looking for clues that help them understand the shifts in climate that took place in distant times. The instruments they use are different from those used to study today's climate: you should remember that we only have at our disposal those data gathered by meteorological instruments designed by man since 1860.

These situations were used to organise markets on the frozen river.

In their process of piling up on the polar caps and glaciers, snow and ice retain valuable information on the planet's climate conditions over the last million years. Then it is necessary to apply methods on the ice samples that kept in that information which will act as a sort of "clocks" in order to determine the age of the ice block and to know when those components were retaine

The study of past climates requires the use of different instruments adapted to the needs of the time scale to which they are going to date back: these instruments are called the paleoclimatic markers.

One of the first paleoclimatic indicators we have in mind are the historical records used for climatic reconstructions at thousand-year-scales. They are mainly based on ancient writings and inscriptions related to periods of droughts, floods, remarkable frosts. There are engravings from the 17th century that show the London's river Thames completely frozen.

[+...]

How has climate evolved since the earth's origins?

Paleoclimatic markers as remarkable instruments

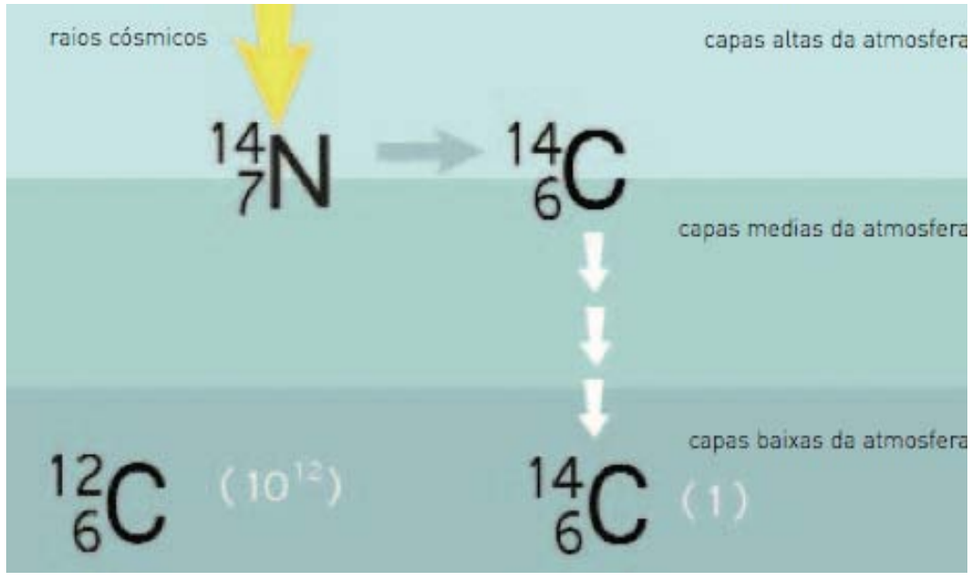
what do tree rings tell us?

3.1.4. what do tree rings tell us?

The first step consists of dating this ice traces by means radioactive isotopes such as 14C. This is the best-known radio chronological method and it is based on the idea that in living beings the proportion between standard carbon (12C) and radioactive carbon (14C) keeps constant in their composition because plants trap it from the atmosphere.

This proportion is due to the fact that the radioactive form is produced on the higher layers of the atmosphere by means of the cosmic rays' impact on the stable nitrogen (14N), which transforms it into radioactive carbon (12C) per each radioactive carbon (14C):

$$^{14}C/^{12}C = 1/10^{12} = 10^{-12}$$



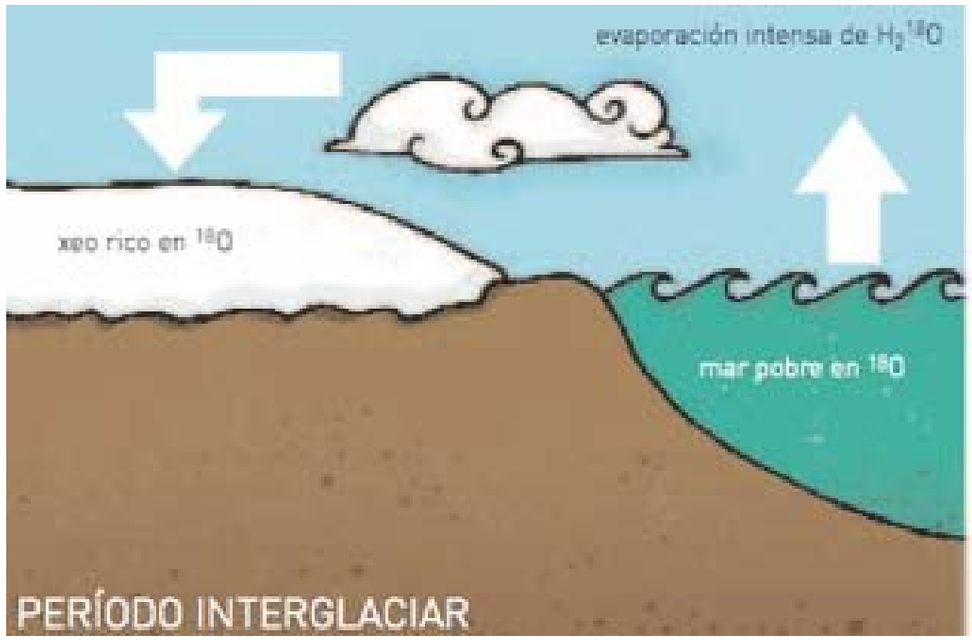
When animals or plants die they stop introducing the atmosphere's carbon by means of nutrition. Therefore, the radioactive carbon is decomposed into standard or stable carbon, reducing this proportion. In this way, the proportion is diminishing gradually over the time, since the numerator (14C) diminishes and the denominator (12C) increases. 5 730 years (average life) have to pass so that this proportion is reduced to a half. If the 14C/12C proportion of a fossil is known, its estimated age can be known by using the data of average life. In order to be able to date with this method, the "average life" or time in which half of certain quantity of radioactive isotope decomposes must be known. Therefore, this sort of methods consists of studying the proportion between the radioactive initial isotope and the resulting isotope.

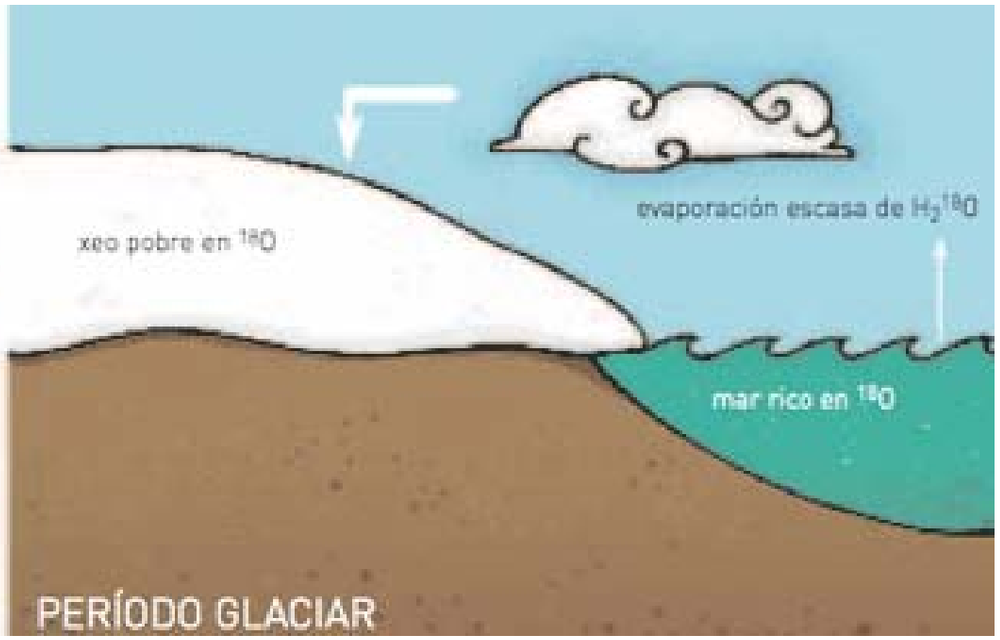
[+...]

3.1.5. Ice cores

With theses radioactive methods the age of different ice traces sampled at different levels can be determined. Once the age of the ice trace is determined, the scientists who want to know the relevant moments regarding the climate change study the relationship between the oxygen isotopes of the sample, since it is a gas that allows reconstructing the shifts in climate taking into account the relationship between its isotopes. The oxygen has two stable isotopes: the 160 and the 18º. The latter, which is the heaviest, will mount more resistance to evaporation on the ocean's surface.

Taking into account that during the warm (interglacial) periods the process of water evaporation makes oceans poor in 180, increasing after this condensation in the glaciers ice. In contrast, during the old periods (ice ages), water evaporation containing 180 was lower, producing an opposite effect: ice became poorer in that isotope. In addition, ice contains dust particles as a result of volcanic eruptions than influenced on the atmosphere's composition.





[+...]

3.1.6. what do tree rings tell us?s

Another paleoclimatic marker is the tree rings, where data from 10 000 years ago can be obtained. At the same time, comparing the fossil trunk rings of the same tree species (for example, the sequoia) dated by using radioactive methods at different times, a comparative idea between the characteristic times of the fossils can be obtained.

This science called "Dendrochronology" studies the relationship between climate and the tree's growth that can be affected by the degree of insolation, the rainfall or the temperatures to which is subject in the different growing stages.

According to the dating with radioactive methods like 14C , fossil trunks from the same species located in the same region and which lived in different times allow compare the climate of those regions at those trees' times. The reason is that tree rings register the growth for a year because the ring is made of the wood vessels produced during the spring and summer growth.

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How has climate evolved since the earth's origins?

Paleoclimatic markers as remarkable instruments

The sediments of ocean depths

3.1.7. The sediments of ocean depths

Other remarkable evidence of climate change is given by the sediments left on the ocean depths, made of organic remains and inorganic matter that can provide with data on temperature, water salinity, volume of nutrient in the first case, and the humidity or dryness conditions in the case of land material. A lot of organisms are used to living under specific climate conditions: for example, if the relative proportion of cold water species as compared to those of warm water is studied on a sample of sea depth sediment, an idea of that region's climate can be obtained..

evaporite deposits

glaciogenic deposits

If you want to go further in the research on past climates and date back to million years in the planet's history, it is necessary to study the sedimentary rocks. The type of rock is mainly conditioned by climate in the moment when sediments were settling, which later on, after litification, gave place to it. Some examples of these rocks are the following: evaporites, formed in warm and dry climates; carbon, linked to warm and hot climates; and calcarian reefs found in warm and shallow seas.

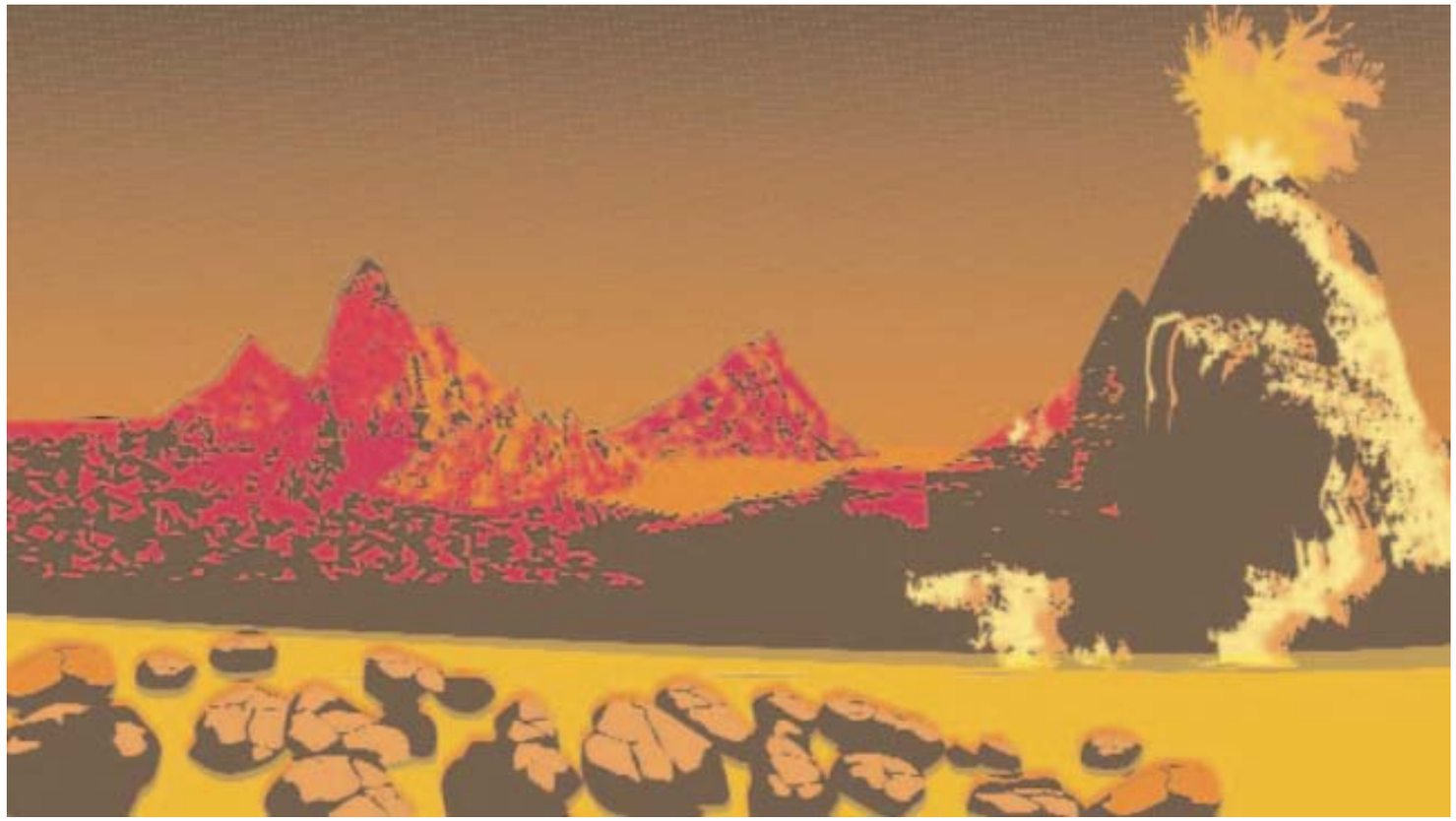
[+...]

3.2. What can we explain about the climate's evolution with all this information?

3.2.1. Very hot origins

Now we have the necessary instruments, we only have to implement them in order to get a global vision of the climate changes taken place on the planet. On the other hand, the geological knowledge explains that the Earth's climate evolution is complex and that is directly linked to several aspects regarding the atmosphere-ocean-Earth interactions and the position occupied in the Solar System.

Conclusions on climate's evolution can also be withdrawn regarding the atmosphere and the existence of life. Scientists accept that there was a primitive atmosphere that disappeared giving way to a secondary atmosphere composed mainly of water vapour and CO_2.



[+...]

How has climate evolved since the earth's origins?

What can we explain about the climate's evolution with all this information?

The appearance of living beings on Earth

3.2.2. The appearance of living beings on Earth

The planet managed to retain the atmosphere due to gravity, letting the lightest gases such as the hydrogen out, and keeping the heaviest compounds. At this stage, the land surface's temperature would be still high due to the greenhouse effect caused by CO_2 and water vapour.

GASES	THE EARTH TODAY	THE EARTH PRIMITIVE
CARBON DIOXIDE	0.036%	98%
NITROGEN	78.08%	3.5%
OXYGEN	20.95%	0.0%
ARGON	0.93%	0.1%
METHANE	1.7ppm	0.0%

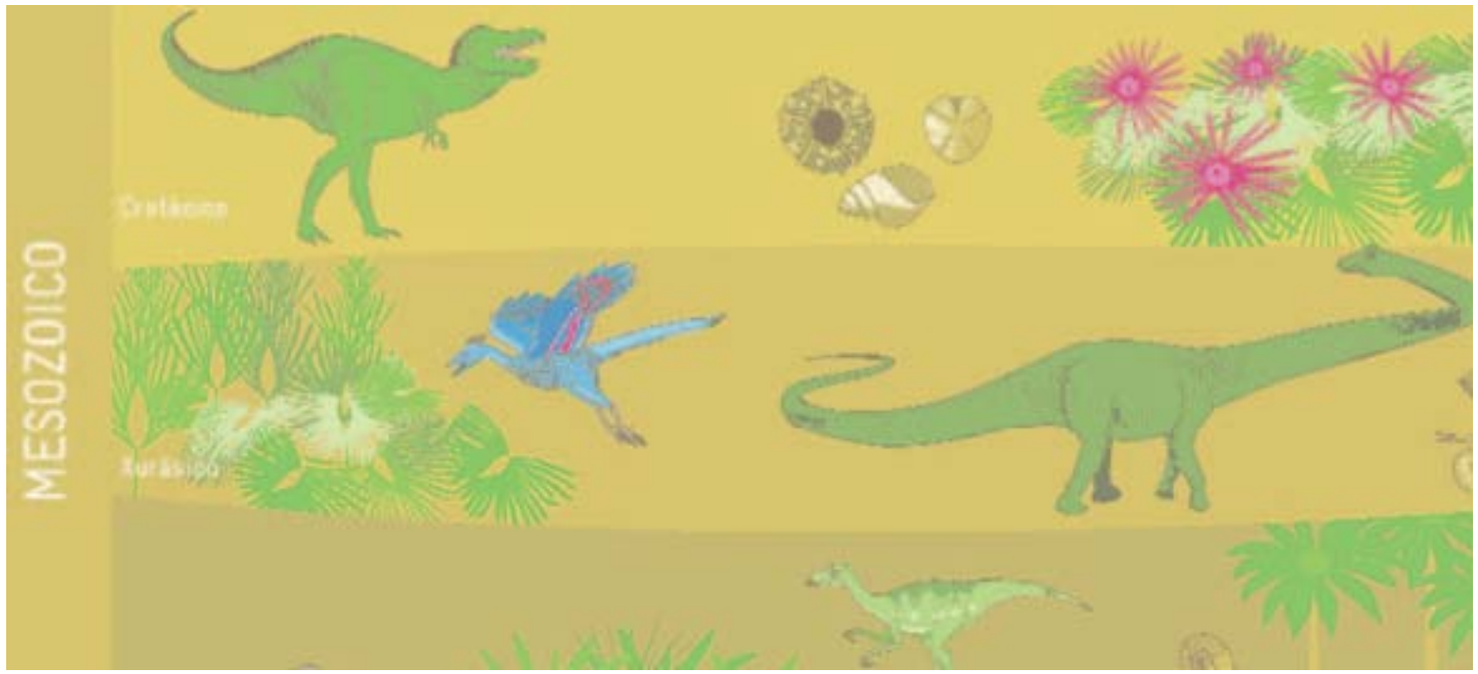
The atmosphere's conditions have remarkably changed when the first form of life appeared on the Earth. The first living beings, the cyanbacteria, are CO_2 consumers which trap it in sedimentary structures called stromatolites, releasing O_2 into the atmosphere.

In the course of the Earth's history the carbon dioxide variations can be correlated to the living beings' activity. The succeeding ice ages about 1 000-570 million years ago coincide with an enormous biological diversity that largely helped eliminating the CO_2 from the atmosphere with a subsequent decrease of temperatures.

Stromatolites are sedimentary formations produced by the action of micro organisms such as cyanbacteria. The oldest date back to the Precambrian period, that occurred 3.500 million years ago. These micro organisms were the first to recycle the CO_2, releasing oxygen into the atmosphere. Nowadays stromalites grow in warm waters coasts, such as the Australian Shark Bay.

[+...]

3.2.3. The Dinosaurs Age was warm



Along the Mesozoic –informally called "the Dinosaurs Age"- the Earth went through a period of warm climate used by animals and plants to spread themselves and get to high latitudes such as the "bread tree", typical of the Tropics, whose fossil remains were found in Greenland. The data provided by the Cretaceous sedimentary records show a concentration of CO_2 by about twice to twelve times higher than today's levels.

3.2.4. Mammals spread across the Earth as the climate cooled down

The Earth conquered by mammals, after the extinction of most dinosaur groups –remember that birds -survived to the last Cretaceous extinction- started to become colder then. It was 38-36 million years ago when the first glaciers appeared in the South Pole and then caused a reduction of global temperatures through a "domino effect", since the whiteness of snow reflects much more solar radiation. As a result ice reached the North Hemisphere covering half of North America and Europe over the last million years.

[+...]

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How has climate evolved since the earth's origins?

A natural database: The Antarctica

3.3. A natural database: The Antarctica

The answer to many questions and the contrast to some climatologic hypotheses is in a book made of frozen pages and the information is codified in isotopes. We are talking about the ice drillings dealt with in this chapter.

In the Antarctica's deepest drilling, about 3 km ice were drilled out, collecting the climate's history for the last 740 000 years. On one hand, the quantity of CO_2 is determined in the air bubbles trapped and, on the other, the proportion of O_2 isotopes provides us with the data on temperatures. The detailed study on these records backs up the scientific theories about the influence of CO_2 on the climate system.

The interglacial period we are in occured 18 000 years ago, when the climate oscillations were constant. During the last millennium there have been data on a warm age, known as the Medieval Warm Age (between 900-1850) and a colder period, called Little Ice Age (between 1550-1850), when the surface's temperatures were about 0.6–1 degrees Celsius lower than the present ones.

In the 20th century human activities trigger the global warming due to the burning of fossil fuels.

Perhaps we might think about what the past traces are telling us and become aware that harmful activities for the environment cannot be very friendly to the other part of the planet.

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4. Usual climate change

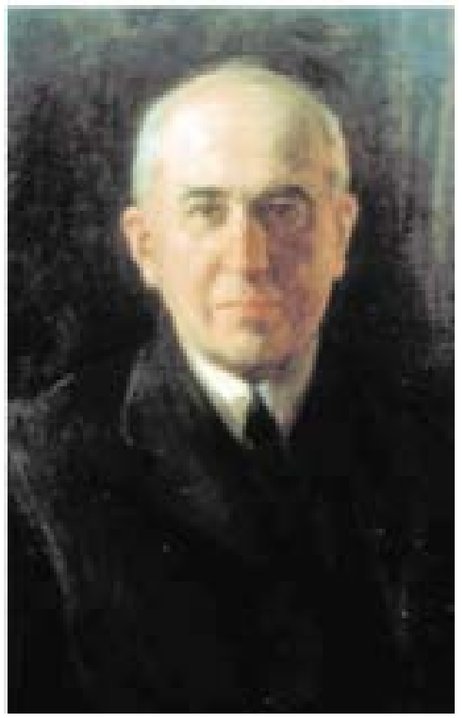
4.1. Climate changes in the Earth's history

4.1.1. Climate change always

The Earth has constantly gone through shifts in climate occurred naturally, changing from warm to cold climates and vice versa for long periods or suddenly. In these changes, temperature has overcome the present average temperature -15 degrees Celsius- by about 8-15 degrees Celsius, preventing ice from remaining on the Poles.

Scientists distinguish two main natural causes to explain the origins of climate changes: external and internal causes. Firstly, the external causes are related to the Earth's orbital movements and their relationship with the Sun as the planet's main source of energy, so that its variations will influence on climate changes.

At the beginning of the 20th century the mathematician Milutin Milankovitch pointed out the main external causes of the climate's variability.



Milutin Milankovitch (1879-1958) was a Serbian mathematician who started his research in Belgrade University. It had soon to go away to Budapest because of the First World War. Here he started to work in the library of the Hungarian Science Academy where he researched on the ice ages' origins. As a result of this research, Milankovitch established an astronomical theory on the relationship between the Earth's orbital movements, the sunshine degree and the Earth's climate.

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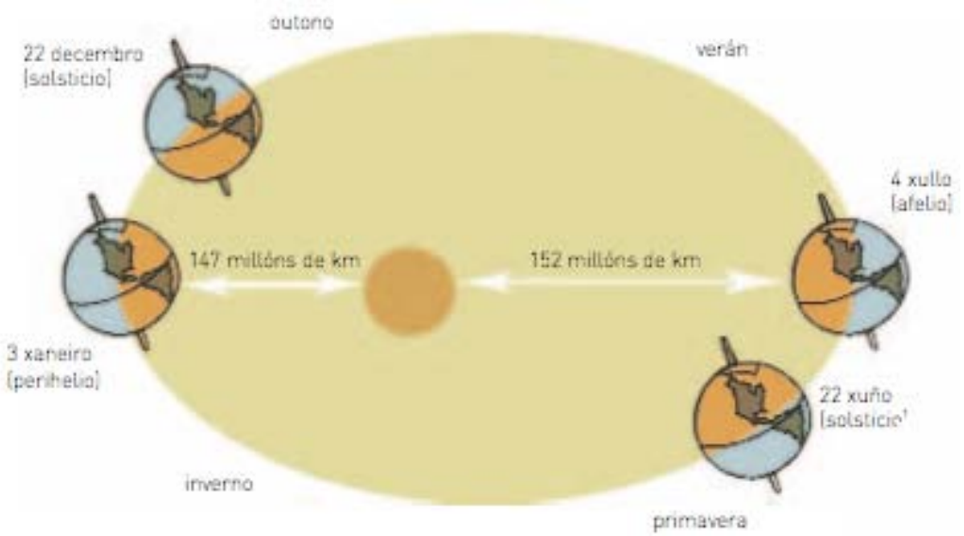
4.1.2. The Earth's orbit and the shifts in climate

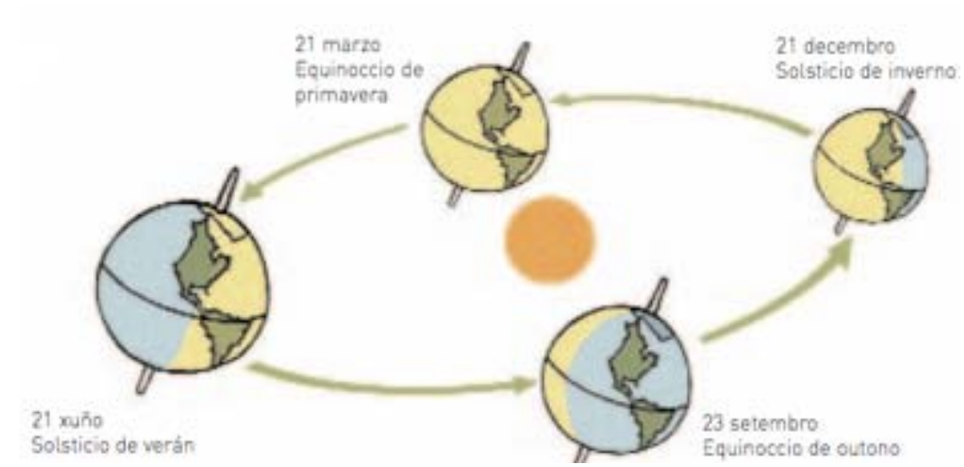
The orbit described by the Earth into the translation movement around the Sun is elliptic and therefore at any time during the year the planet will be nearer to it. The quantity of solar radiation falling on the Earth depends on its distance from the Sun. The Earth will receive more solar radiation on the nearest point (perihelion) to its surface than when it is more distant (aphelion).

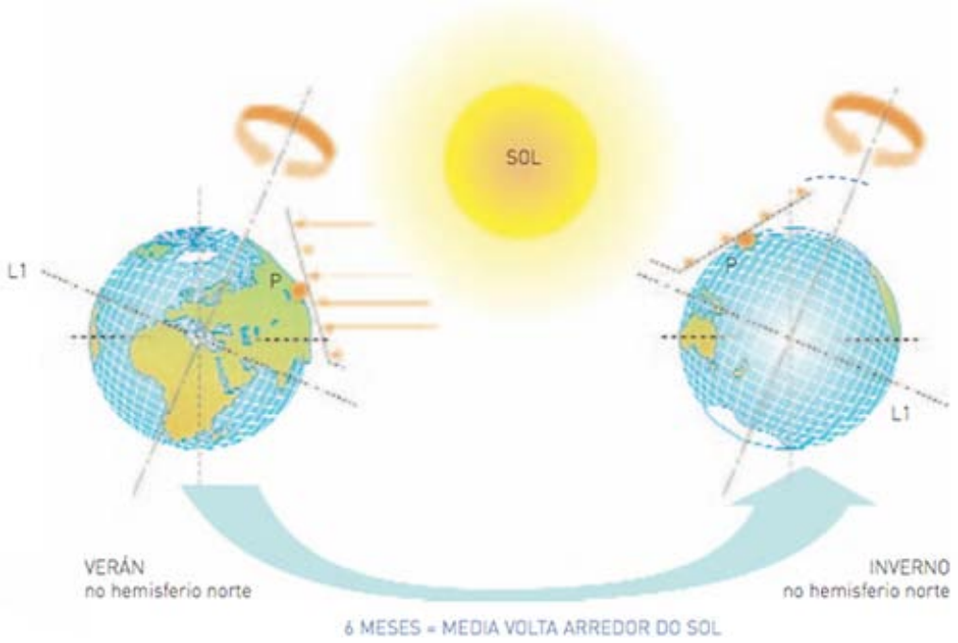
11.000 years ago, the location where seasons took place on Earth was reversed. Thus, in the North Hemisphere winter was reached during the aphelion and summer during the perihelion, so that winters were colder and summers were warmer.

Nowadays the Earth passes through the farthest point during the South Hemisphere's winter, making it colder and the summer warmer than those from the North Hemisphere.

But due to the attraction forces exerted by other planets on the Earth, the orbit varies changing its form from elliptic to round, and these variations –called eccentricity- occur in 100 000 and 400 000-year cycles. When the orbit is strongly elliptic, the planet will pass by nearer or more distant points from the Sun.







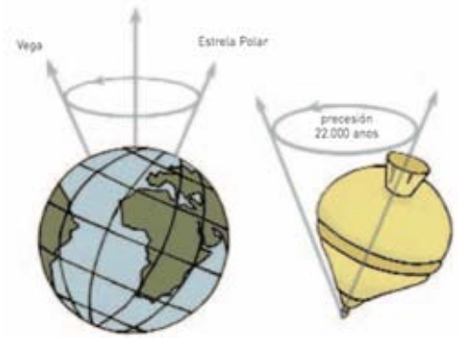
[+...]

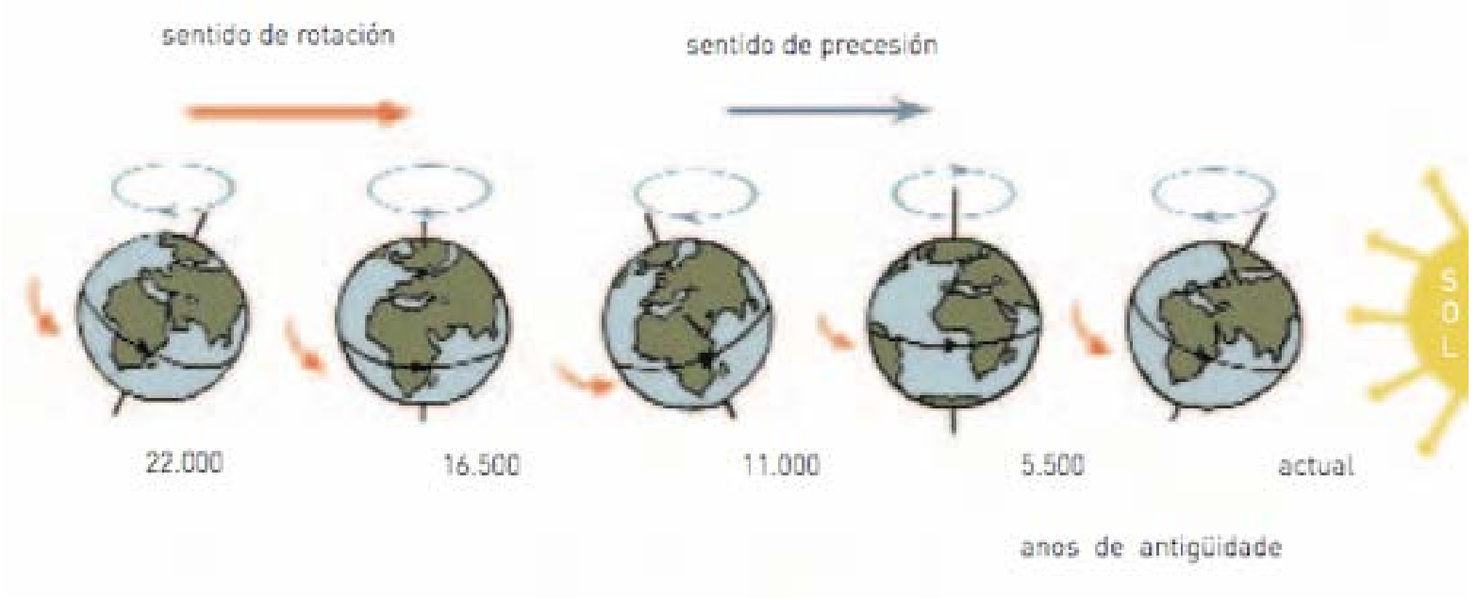
4.1.3. Shifts in climate due to changes in the inclination of the Earth's rotation axis

On the other hand, the Earth turns around a rotation axis that does not always keep the same inclination, called obliquity-, but it varies between 22-25 degrees Celsius -today it is 23.4 degrees Celsius-, in 41 000-year periods, making considerable changes in seasons. The greater the axis' inclination is, the greater the seasonal changes are.

Milankovitch's last cycle (precession) refers to the fact that the Earth moves like a spinning top around its axis because it is not a perfect sphere, so that the North Pole does not point to the Sun always at the same point of the terrestrial orbit. The precession triggers changes in climate since the position where the stations take place changes, that is, it determines if summer or winter in a Hemisphere corresponds to a point more distant or closer to the Sun. This cycle is completed every 23 000 years.

If the effects of Milankovitch's cycle are grouped, the minimum of sunshine and the maximum of cold permitting the advance of glacial caps correspond to the farthest distance from the sun. This event occurs in December with the maximum inclination of the Earth's axis.





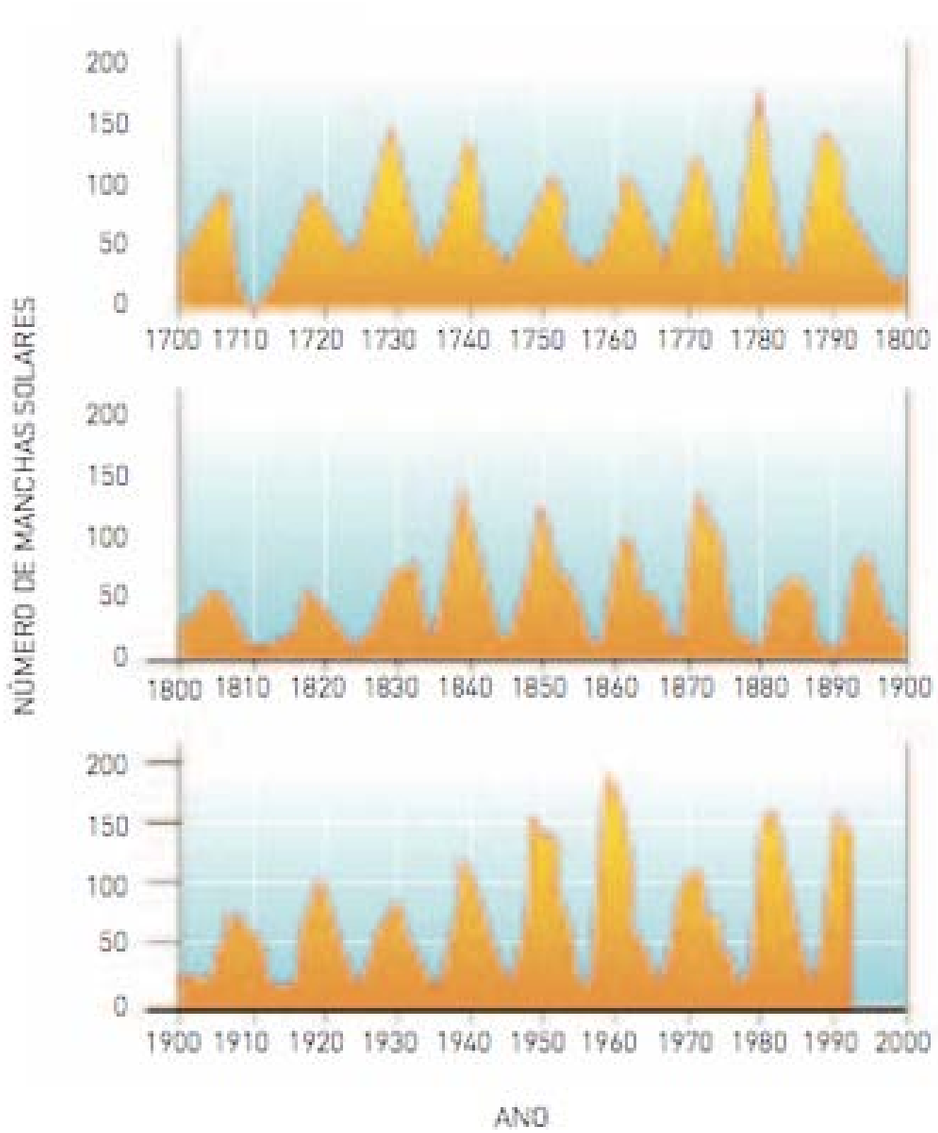
The Earth's precession movement that took place 11 000 years ago made its axis to point to the Vega star. Today it points to the Pole star.

[+...]

4.1.4. Shifts in climate due to changes in the solar activity

The solar activity and therefore the energy it releases, is not constant over the time, but it varies. The increasing energy received by the Earth will produce its warming and the same in the opposite sense. Scientists quantified the number of sunspots related to the solar activity and linked them to climate events. The more numerous these sunspots are the more radiation is released towards the Earth. Between 1645 and 1715 Europe registered very intense cold periods, during a time when the number of sunspots had diminished, called Maunder minimum, since it was the British astronomer Walter Maunder who made these observations.

By 1810, the wheat's price rocketed in Europe as a consequence of the permanent loss of harvest due to a very cold season. These extreme climate events take place at the same time than the so-called Dalton's Minimum, when the number of sunspots became considerably reduced.



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Usual climate change
Internal natural changes

4.2. Internal natural changes

The internal causes of climatic variability include the distribution of continents and seas, volcanic eruptions and oceanic currents:

1. The Earth's continental mass did not remain motionless over the time, since tectonic structures have been moving around so that for about 2.5 billion years lands have joined up and separated rising mountains, opening and closing oceans. Continents have influence on oceanic currents that transport heat from Ecuador to the Poles and this has an impact on climate.

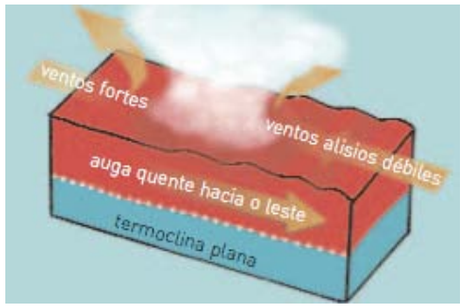
   During the Triassic period, the lands raised were joined in a big continent called Pangaea, symmetrically located as regards Ecuador. This favoured an increasing number of oceanic currents carrying heat towards the Poles, and this gave way to warm climates and lack of ice on high latitudes.

2. Oceans are the main source of water vapour production in the atmosphere. They absorb the solar radiation and distribute the heat all over the planet through the sea currents. The main features of these currents are the pressure, temperature and water salinity, which condition the water density, creating density gradients both in the horizontal gradient (between high and low altitudes) and in the vertical one (surface and deep waters). The difference in density causes the main water movement in oceanic basins. The influence of wind is reduced to the first 200 metres on the oceans' surface, generating surface currents such as the >Gulf Current, the North Atlantic Current, etc.

The figure indicates the areas represented in the sketch below

The Pacific and Atlantic oceans are featured by a sharp contrast in temperatures between eastern and western surface waters. Trade Winds usually control the balance on the movement of warm waters from the West and the cold waters from the South American eastern coast, replacing the higher layer blew by winds. These risings make the Ecuadorian and Peruvian coast the richest in fisheries around the world. But the phenomenon called "El Niño" changes this situation. In six-to-seven-years cycles, warm waters go towards South American coasts, causing climate changes that can last several years in that area. This can be explained by the fact that Trade Winds in these cycles stop or are reduced so that the warm surface water layer does not move from the Eastern Pacific area, stopping the rising cold waters and therefore increasing the ocean's and the air's temperature in these areas. Water evaporation is higher and it will produce more rainfall causing floods and river rising in areas where drought is usual. Another consequence of El Niño is related to the reduction of fisheries. That lack of nutrients in waters moves fisheries southwards looking for colder waters.

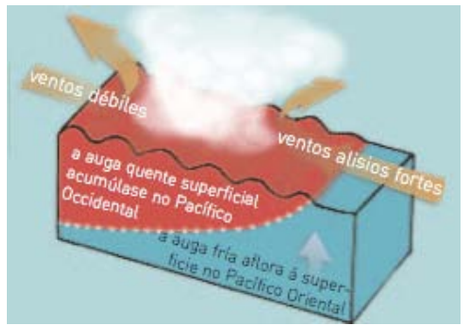
Air becomes warm and wet on the ocean's surface and raises forming storm clouds in the Central Pacific.



EL NIÑO / WARMING

When the eastern Trade Wind becomes weak, the western Pacific's warm water flows eastwards. This layer which is about 150-metre deep flows into colder waters rich in nutrients, and stops its increase along the American continent. Sea life can suffer from lack of food.

Storm clouds are formed over the Western Pacific's hot waters surface.



STANDARD

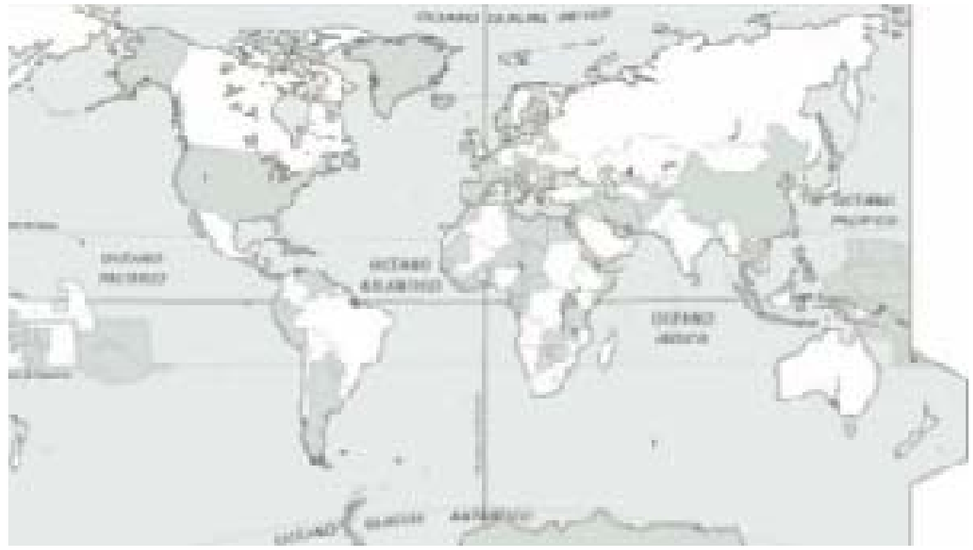
Generally speaking, Trade winds keep a balance between the Western Pacific's warm waters and the Eastern Pacific's cold waters, but the limit between warm and cold water rich in nutrient called Termoclina is 40 metres under the surface.

[+...]

Usual climate change
Internal natural changes

3. Volcanic eruptions released into the atmosphere lots of gases (CO_2, SO_2) producing the greenhouse effect at a regional level, and ashes and volcanic dust having an effect on the global temperature of the planet's distant areas. In recent eruptions occurred in the Philippines's Pinatubo, the temperatures of a broad region located near the volcano increased in almost half a degree in two years.

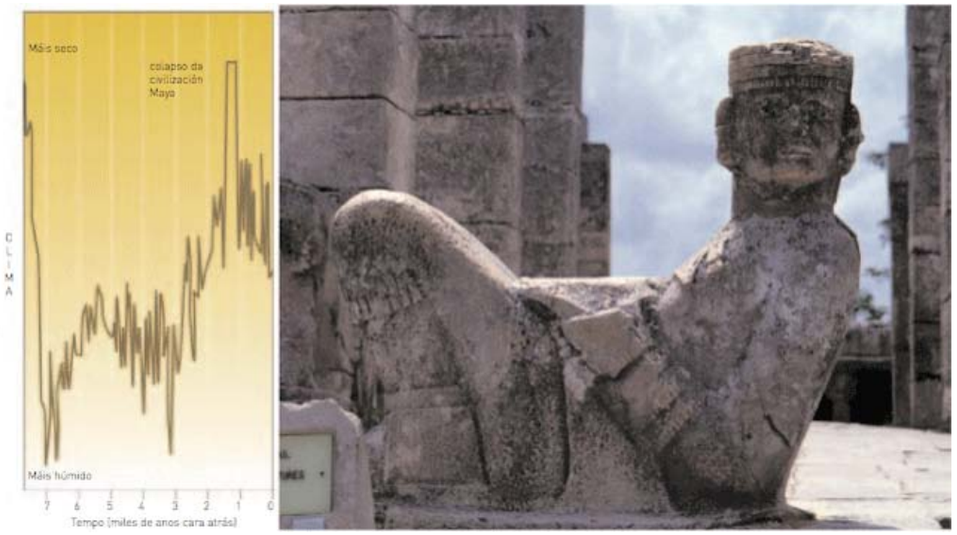
of ashes is high and reaches the highest levels, acting as a screen for solar radiation. This was observed in the Tambora eruption in Indonesia in 1815: the following year was called the "year without summer". Ashes reached 50 km forming a dust cloud dispersed by the wind all over the planet. This cloud hide the Sun's light reducing temperatures for two years and damaging considerably the harvests in many regions of the North Hemisphere.



But at a global level, volcanic eruptions can cause the cooling of the atmosphere if the quantity

4.3. Climate changes and natural disasters

Sudden shifts in climate have sometimes caused considerable changes in the peoples' and animals' way of life, playing a key role in the development of ancient civilizations such as the Mayas.



The data taken from the study of sediments in the Mexican Yucatan Peninsula's ancient lakes indicate that climate has changed suddenly into extremely dry conditions.
The Mayan people's offerings to their gods were not efficient to attract the desired rain, and the adverse climate conditions caused the disappearance of the Mayan civilization 1 100 years ago.

At the end of the 20th century the American geologists William Ryan and Walter Pitman proved that a catastrophic event took place in the Black Sea area about 7 500 years ago, that could be the origin of the Biblical story about the Noah's Flood. By analysing in detail the data provided by intense oceanographic campaigns in this area, the Black Sea was proved to be a big freshwater lake which was not linked to the neighbouring Marmara Sea.

One of the most remarkable discoveries consisted of finding in the river bed remains of freshwater organisms covered by sea sediments containing animals adapted to salt waters.

The next step was to search for an event adapted to such changes, which was located towards the end of the last ice age, when the ice piled up started to melt and the flowing of such quantity of water over thousands of years caused a sea level rise. This process caused the Marmara Sea fall as a waterfall on the Black Sea, digging out a broad and deep channel.

This event was quick enough to move all peoples living on the lake's shores. The flooding force is estimated to be about 200 times higher than the Niagara waterfall's and the lake level is presumed to have increased about 100 metres in a few months.

[+...]

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Usual climate change

Climate changes and natural disasters

Some years later, Robert Ballard, who discovered the remains of the well-known Titanic, delimited that old coastline about 170 metres below the present one, and found under the Black Sea slopes wooden buildings, pottery and several tools proved the existence of settlings on the lake's shores before the flooding.

Later on these peoples started to pass orally from one generation of the other the story of the Big Flood and this could possibly be its link to the origins of the Noah´s Flood myth.

The waterfall formed when preceding Mediterranean salt waters fell into the Black Sea basin caused the rising of its level at about 15 cm a day.

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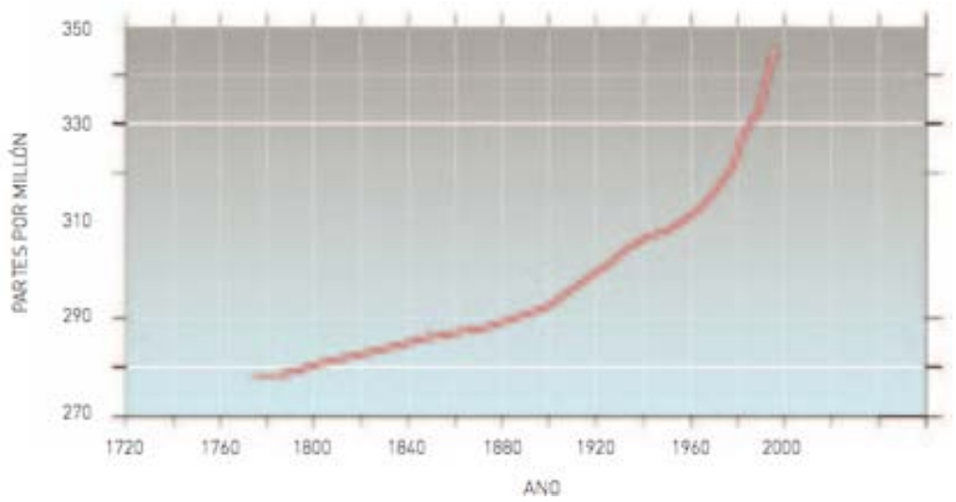
Climate change due to human activity
Impacts of human activity on climate

5. Climate change due to human activity
5.1. Impacts of human activity on climate

The impact of human activity has been changing the volume and proportion of greenhouse gases in the atmosphere. This process started at the beginning of the Industrial Revolution and since then, the CO_2 in the atmosphere has increased by about 20 per cent.

Since the beginning of industrialization, a large quantity of CO_2 has been released into the atmosphere through the carbon, oil and gas burning.At the beginning of the Industrial Revolution in the late 1700s, the quantity of CO_2 started to increase, getting up the highest levels during the last 50 years.



A very efficient technique to get these data consists of analysing the content of this gas from the ice cores, dug out at about two kilometres deep.

These bubbles can help scientists study the presence of carbon dioxide and therefore estimate the atmospheric levels of carbon dioxide dating back 160 000 years.

These bubbles can also help measure the oxygen isotope concentrations trapped and their deviation from the atmospheric values in order to know their changing rate. Since this depends on the temperature, estimates can be made on the surface temperature in the Antarctica when the ice was formed

At the same time as the use of fossil fuels in industrial processes increased, wide forest surfaces were cut down or burnt in order to get new areas for agriculture and livestock.

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Climate change due to human activity

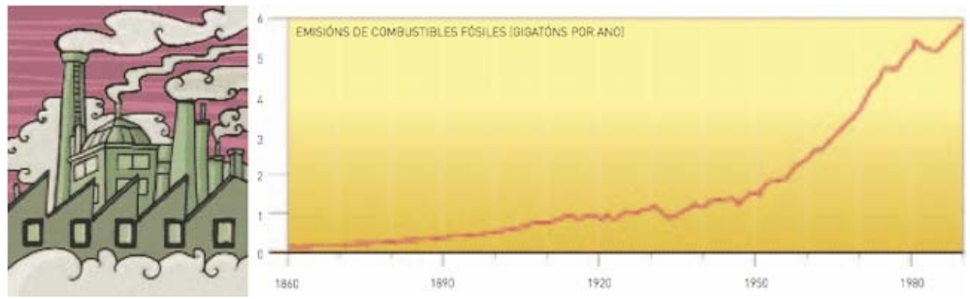
The relevance of fossil fuels

Carbon was at the origins

5.2. The relevance of fossil fuels

5.2.1. Carbon was at the origins

Fossil fuel burning is, at large, the main cause of the increasing carbon dioxide concentrations in the atmosphere. The graphic below shows fossil fuel emissions over the time. It shows that carbon dioxide emissions increased slowly from 1860 until mid-20th century. From the 40-50`s this curve increased sharply up to the present levels, overcoming more than six times those in 1860.



Before the Industrial Revolution, it was mainly wood what was burnt. But with the economic and demographic development forests have been disappearing in Europe. The Industrial Revolution produced a lot of inventions associated to carbon, formed by fossil vegetal remains that lived in marshes, particularly in the Carbonipherous period. Some of these inventions are remarkable due to their mobility, particularly the locomotives and the steamers that carried the material demanded by the heavy industry. All this transport activity and industry linked to carbon caused the towns to be full of smoke coming out from the industries.

The analysis of the type of fossil fuels contributing to such a development shows that the use of carbon has increased constantly over the last 100 years. At the beginning of the 20th century, industries started to adapt themselves to oil and natural gas since they were more comfortable and easier to use, and less pollutant. Nowadays their use has increased significantly. Nevertheless, due to the higher costs and the fear that oil becomes limited in the future, this trend seems to change, and now carbon is more and more used in order to produce electricity.

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Climate change due to human activity

The relevance of fossil fuels

Oil and natural gas

5.2.2. Oil and natural gas

The use of oil and natural gas instead of carbon started in the United States after being discovered in Pennsylvania in 1959. The interest in sea drillings were relaunched a decade after the Arab oil seizure in 1973. Nowadays, by about 20 percent of the world production is oil and about 5 percent is natural gas. The oil extraction in oil platforms and its transport by sea in oil tankers is linked to a high risk of accidents that give rise to serious oil spills. This produces even worse environmental consequences derived from the use of these fuels.

these resources are non-renewable due to their formation process. Oil comes from organic matter as well as carbon, which provides with the carbon chains formed in the photosynthesis process when those organisms lived.

Plataforma petrolífera

Chapapote vertido polo petroleiro Prestige

Although the use of this sort of fuels is increasing and this trend will probably be maintained in the future,

[+...]

Climate change due to human activity

The relevance of fossil fuels

How was oil formed?

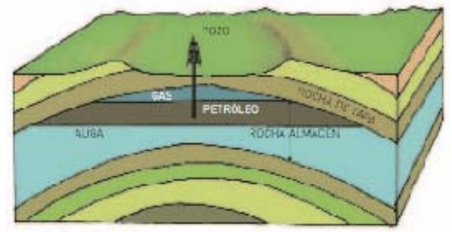
5.2.3. How was oil formed?

This organic matter that produced oil derives from the microscopic organisms that lived at the beginning on surface waters developing the plankton. Once these first organisms died, their remains settled and piled up among the sediments on the depths where there was hardly oxygen making, then, their decomposition very difficult.

Plankton comes to the surface giving a pale green colour to North Atlantic waters on the surroundings of the French coast (on the right) and England (on the left)

After being buried in a sedimentary basin, the organic matter gets very hot under a high pressure changing its chemical composition so that the organic matter becomes hydrocarbons.

In order to get oil out, it has to migrate through a porous sedimentary rock, such as granulated stones, which act as a sponge containing the oil. In the course of the migration process through this rock, the oil hits on geological structures such as folds, faults or salt domes that retain it. It is possible to dig it out by only drilling these wells, where it is retained by those traps, since its pressure and density makes it climb more easily. Natural gas comes out earlier since it is lighter and therefore it is placed on the top of the oil wells.



[+...]

Climate change due to human activity

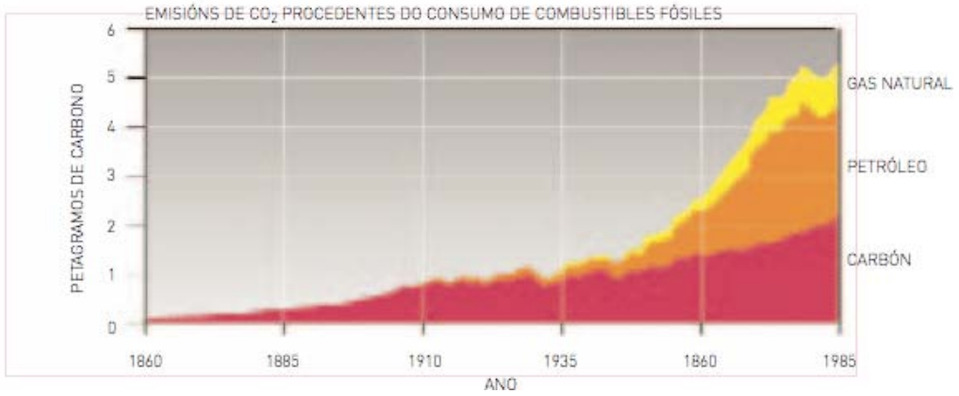
The relevance of fossil fuels

Relationship between the three fuels and this issue

5.2.4. Relationship between the three fuels and this issue

The use of these three types of fossil fuels made the carbon retained in sinks move around and this unbalanced the carbon cycle. This carbon dioxide rise in the atmosphere derived from the fossil carbon should be compensated in the photosynthesis of plants that act as immediate sinks and the carbonate precipitation in oceans and slow formation of new fossil fuels that will restore the balanced functioning of the cycle.

invention of internal-combustion engines. The use of public transport together with heating and electric power at home is a daily activity in which you can make your personal contribution to reduce the fossil fuel consumption. Among the means of transport, air transport is the most remarkable due to its constant increase and the fuel it consumes during its travelling.



Fossil fuels represent the surface carbon that remained permanently stored under the earth, where natural processes cannot release it again into the atmosphere. The human activity of drilling it out impacts on the drilling out transport and transformation, and it also lets the carbon stored and isolated from the cycle out into the atmosphere.

Oil opened amazing possibilities for us to move around with the

[+...]

Climate change due to human activity

The relevance of fossil fuels

Deforestation made this problem more serious

5.2.5. Deforestation made this problem more serious

The increasing carbon dioxide in the air as a consequence of deforestation is also extremely important, since the photosynthesis average of a tree absorbs a high quantity of this gas. If trees are eliminated and non-wood trees are sowed instead, the C absorption can be reduced due to a much slower development and a shorter life of sowing plants in contrast to trees.

In Galicia a lot of fields have been left uncultivated for the last 20 years. This process was followed by forestation, the piling up of fuel and the increase of shrub on soils, which not very long time ago were fertilized for agriculture.

Climate change due to human activity

The relevance of fossil fuels

Forest fires

5.3. The relevance of fossil fuels

5.3.1. Forest fires

The increase of shrub and forests in dry summers become ecosystems where forest fires can take place. Although the vegetation-fire relationship is complex, it becomes more and more evident that most forest fires are caused by human actions like negligence or accident, or are even provoked deliberately.

Fire extremely disturbs vegetation and landscape: it lets animal and vegetal species out, creates open spaces, and changes the habitat structure and the food availability for fauna. It also produces nutrient loss and erosion on slopes. Carbon dioxide emissions are high due to the burning of wood, vegetation and the organic matter from the soil that becomes a temporary CO_2 source instead of an important sink.

Forest fires jeopardize the soil's future because they remove the organic matter from it. This fact added to the loss of vegetal cover can reduce the water filtration into the soil and increase the surface runoff, giving rise to soil erosion.

From a socio-economic point of view, forest fires risk human lives and lands, reduce income derived from wood in the long term and change drastically beautiful landscapes.

[+...]

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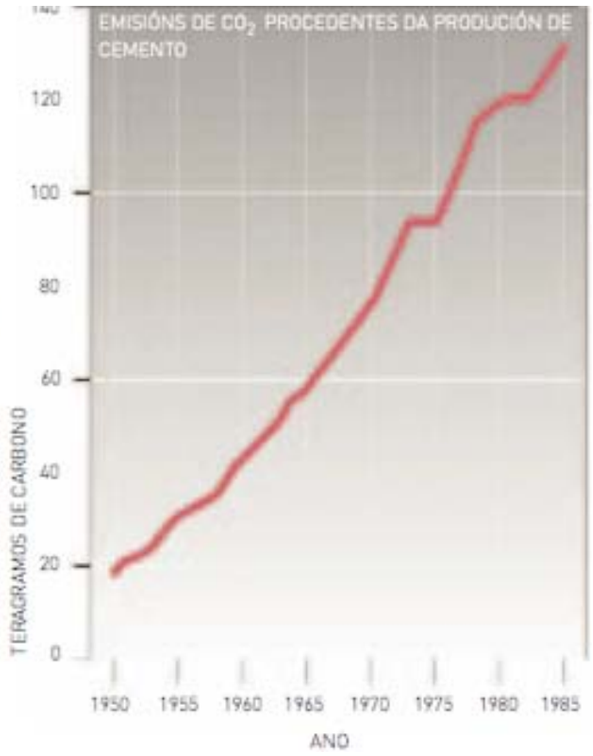
5.3.2. Industry

Concrete factories are another source of CO_2 emission into the atmosphere. The carbon material used to make concrete releases significant quantities of carbon dioxide during the transformation process until the final product is obtained. This product is becoming more relevant in sustainable development, since from mid-20th century its use has become more and more usual for building roads, bridges, buildings, electricity industries and factories. Nowadays it is extremely relevant in developing countries like China and India, with the subsequent risks for environment and therefore for climate change.


Fábrica de cemento



6. Consequences and impacts of climate change on terrestrais ecosystems

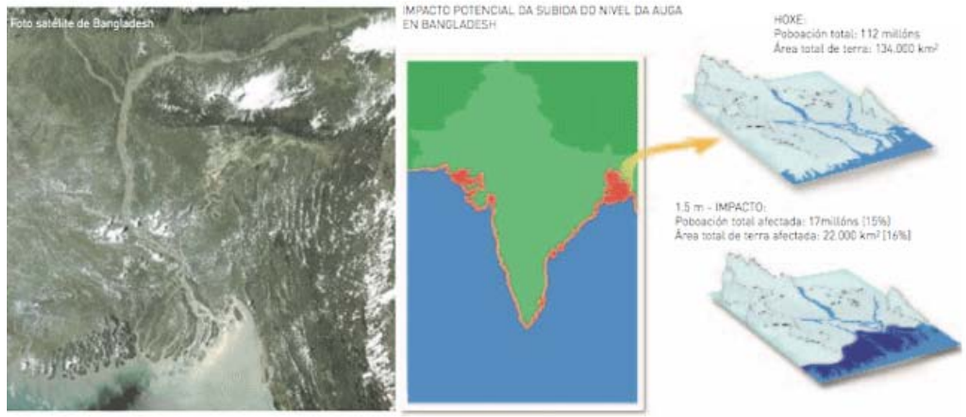
6.1. Consequences of global warming

6.1.1. Consequences of global warming.

The greenhouse effect was changed by human beings because it threatened their security. Poor and developing countries are those that suffer directly the impact of environmental degradation.

In this sense, increasingly severe hurricanes and cyclones are taking place in tropical areas and most of them involve poor countries so that their consequences enhance their degree of poverty.

In addition, these areas that suffer from social and economic injustice undergo increasing droughts in places where rainfall diminishes, and floods in those places where rainfall increases.



A warmer atmosphere could make the ice near the Poles melt. As it has already been said, the resulting water could raise the sea level.. If the sea level rises only 60 cm, Bangladesh's fertile lands on which thousands of people depend could be flooded.

Scientists have recently agreed on the fact that "El Niño" is possibly caused by man-induced global warming, unbalancing the planet's climatic state. As a consequence, in some countries it rains so much that there are floods whereas other countries undergo severe droughts. In addition, extreme temperature changes and atmospheric pressure bring about tornadoes and typhoons.

Human activity's impact on greenhouse effect and therefore on climate, become a serious concern from the seventies. In this way, the First World Conference on Climate took place in 1979, when climate change was identified as a serious challenge to face.

[+...]

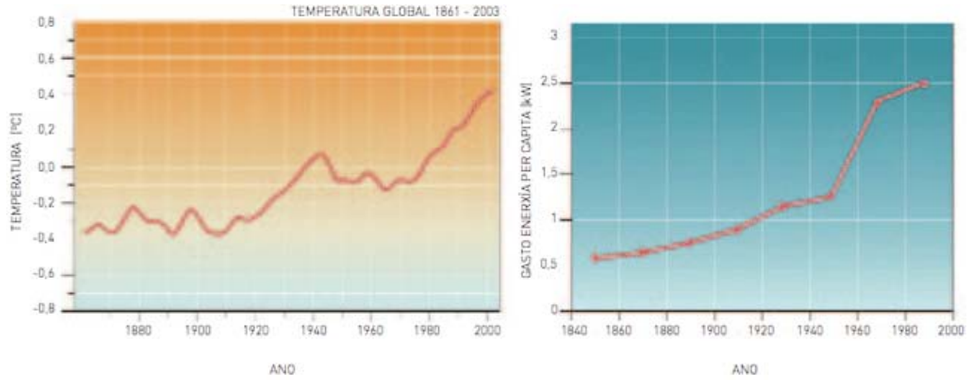
Consequences and impacts of climate change on terrestrais ecosystems

Consequences of global warming

The IPCC faces the consequences.

6.1.2. The IPCC faces the consequences.

In 1988 the United Nations established the Intergovernmental Panel on Climate Change (IPCC) in order to assess the state-of the-art on the global climate system, on climate change and its social, economic and environmental impacts and the possible international strategies to cope with these global issues.



The representation of running means in the last decades' average temperatures shows a remarkable trend to an increase in temperature. This global warming causes evident consequences for us and for life on the Earth.

Nevertheless, when climatic changes at a local level are studied, the degree of uncertainty increases, since trends to a reduction in some places can be observed within the framework of this evident trend to a global increasing temperature. But these global effects always influence on the balance of the nearest ecosystems and on social and economic life.

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Consequences and impacts of climate change on terrestrais ecosystems

Alterations in terrestrial ecosystems transitions

Alterations in terrestrial ecosystems transitions.

6.2. Alterations in terrestrial ecosystems transitions

6.2.1. Alterations in terrestrial ecosystems transitions.

There are many types of terrestrial ecosystems and most of them are conditioned by human action. Only in the Iberian Peninsula we can find a great variety of them, among which there are two main groups: those from the Atlantic region and those from the Mediterranean region. This variety is easier to describe in Portugal due to the predominance of the North-South axis in its geography. The following model can be established on an imaginary North-South line:

1. Wetland ecosystems: meadows with fences.

2. The Miño river's ecosystems, where there is a mixture of vineyards and corn fields.

3. The Sil and Douro's terraces, typical from Porto.

4. Pasture ecosystems.

5. Very dry and eroded landscapes and greenhouse crops.

Although the effects on Atlantic ecosystems -limited by temperature- are different from the Mediterranean ecosystems -limited by water-, intrusive species tend to move upwards.

Mediterranean vegetation tends to move upwards and the Mediterranean area tends to become desertified due to more and more frequent and severe droughts and to an increasing risk of forest fires. These desertification processes have a serious impact on one third of the Spanish surface, mainly Southern and Eastern regions, where the Mediterranean climate –rainfall over 400 mm and with a seasonal nature- is gradually becoming an arid climate –rainfall under 400 mm-.

and is becoming more and more arid, salinization processes due to the evaporation of the soil's water saturated in mineral salts increase during periods of extreme droughts. They form salt layers, usually gypsum, which damage the soil in many Mediterranean vegetation areas. In addition, sea water can be introduced into soils due to the lower phreatic level of deep waters, as in Almeria's greenhouse crops.

pIn South-Eastern Spain's climate, which is less and less Mediterranean

[+...]

Consequences and impacts of climate change on terrestrais ecosystems

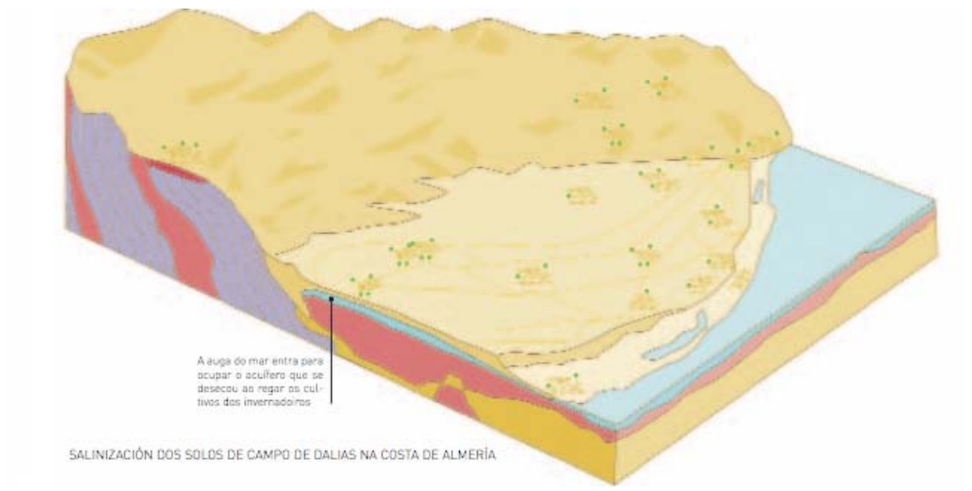
Alterations in terrestrial ecosystems transitions

Tendency to desertification.

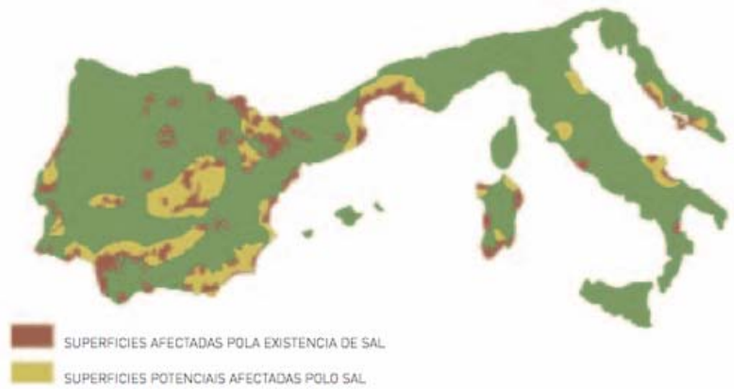
6.2.2. Tendency to desertification.

A vista dende o aire da zona suroeste de Almería, amosa unha paisaxe desértica invadida por infinidade de invernadoiros.

Soil salinization is possibly the most important deterioration process in arid and semi-arid countries. These processes are related to over-irrigation in dry climates, to thin soils and to the use of too salty water in irrigation and sea intrusions.



SALINIZACIÓN DOS SOLOS DE CAMPO DE DALIAS NA COSTA DE ALMERÍA



In Southern areas flora diversity diminishes and this is linked to a decrease in the associated fauna. This decrease has to do with the fact that species that are less resistant to water stress are extinct.

[+...]

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Consequences and impacts of climate change on terrestrais ecosystems

Alterations in terrestrial ecosystems transitions

Changes in the species' behaviour.

6.2.3. Changes in the species' behaviour.

Apart from increasing the water stress, climate change' effects on vegetation have an impact on the foliation, flowering and fructification periods and on the delay of the leaf fall. Plants are flowering as an average of 10 days before than they did 30 years ago. At the same time, the insects' life cycle is also affected by larvae acceleration and this becomes a risk for them in case of frost, and also for animals depending on them for their food.

The tendency towards a Mediterranean climate observed in Galicia is helping Mediterranean species find here the conditions to which they are adapted and are losing their present distribution areas. Therefore, if the present trend is maintained, the whole Galician region, except the Northern area of Lugo, will have Mediterranean ecosystems and most of Galician landscapes will be similar to those from the Douro region, in Portugal.

[+...]

Consequences and impacts of climate change on terrestrais ecosystems

Alterations in terrestrial ecosystems transitions

Pests and forest ecosystems.

6.2.4. Pests and forest ecosystems.

Among the most important types of ecosystems described along the North-South line, the most relevant are forestry ecosystems, mainly forests and shrub. These ecosystems, usually located on slopes and areas very difficult to cultivate, bring about economic advantages as well as important ecological benefits such as protecting against erosion, controlling and regulating the water cycle, preserving the biodiversity and finally, the development of leisure activities.

As seen above, in early stages forests play a key role in the carbon cycle, but these trees are more exposed to environmental stress, causing their regression. This makes the forests' recovery more difficult in eroded areas due to the lack of vegetal cover.

Pests favoured by climate change can be very relevant in this process of forest fragmentation and the subsequent development of ecosystems observed in the resulting landscapes. This is due to the fact that increasing temperatures and the subsequent better conditions for the development of pests and diseases result in a longer impact on the vegetation on which they feed. The best-known example is that of the pine's processionary moth (Thaumetopoea pityocampa) that increases the area subject to colonization, since it can go up in warmer winters, and colonize it in a natural way, so that pinewoods can be affected by this pest.


Larva de procesionaria saindo do "niño".


Larvas de procesionaria nun típico desprazamento en filas.

The processionary is a nocturnal moth that is so called because when it goes out from the nest where it deposits its eggs on the bottom of the pine's branches, it moves in a queue as if in a procession. The link between their biological cycle to pines is being a pest for these trees, mainly when they are located at the sea level. Nevertheless, climate change allows their invasion towards higher pinewoods, and it starts being a threat to high-mountain pines (Pynus silvestris).

[+...]

6.2.5. Disruptions in biological cycles.

Observations demonstrate that an earlier biological cycle has been verified within the butterflies' group, as well as an earlier caterpillar hatching of some species due to the increasing global temperature. In addition, leafs and flowers are blooming earlier leading to disruptions in the trophic relationships of species relying on these hatchings.

Studies on the nocturnal moth Operophtera brumataque are the most relevant since this species feeds on the oak's leaf buds that are also blooming earlier. At the same time this has also an impact on the feeding of the great tit's youngs.

Nowadays the oak's leaf buds bloom 10 days earlier than in 1985 but larvae come out from eggs 15 days earlier, reducing the number of individuals in this species due to the lack of food. As the great tit relies on these larvae for its food, it has had to change its feeding habitudes. This sort of disruptions can change the trophic relationships among the ecosystems, affecting their dynamics and development.

Climate change also favours the arrival of important winter moths from warmer climates because it is easier for them to adapt and spread themselves as a consequence of climate change. These insects can have an important impact on the stability break and the ecosystem's continuity.

6.3. The substrate unbalance. Disasters

The periodicity and virulence of some natural events can be strengthened by climate change. This is the case of forest fires, river floods and landslides.

1. FOREST FIRES

Forests are the most important CO 2 sinks and play a key role in the alleviation of climate change's effects since they contribute to reduce the planet's warming by storing this gas. Nevertheless, the exacerbated forest clearing and fires reduce the benefits derived from the forests.

Most forest fires are man-made but climate change can alter their frequency due to increasing temperatures and intense wind. These changes together with drought make forests more vulnerable to fire. The forests' benign effects become damaging when they are burnt, because in the combustion process the fixed carbon is released into the atmosphere causing the greenhouse effect and, therefore, the Earth's global warming.

Forest fires have an impact on the soil quality because they are responsible for the erosion. The loss of vegetation and burnt soils' degradation lead to erosion processes due to runoff waters. More intense rains foreseen by scientists lead to erosion and therefore to the soil loss.

Soils affected by a forest fire show a devastating image. Apart from the visual impact of this burnt landscape, they are exposed to erosion since the tree roots are not able to hold down to the soil. Runoff waters during intense rainfall periods cause the substrate mobilization and transport down the slope. [+...]

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Consequences and impacts of climate change on terrestrais ecosystems

The substrate unbalance. Disasters

Later on, ashes settled on burnt forests are swept along by water into the estuaries where they are deposited. The seafood fisheries in the Galician "Rías Baixas" (estuaries) are affected by these ashes and eroded sludge deposits because the sea species are buried by them and die from suffocation. This causes important economic losses in that sector.

Our region has always been affected by forest fires. Data show that in 1970-1990 the surface burnt in Galicia was about one fourth of the Spanish global burnt area. Those areas most exposed to forest fires are located on the South. In addition future estimates on climate change confirm that in these areas temperatures will rise up to 5 degrees Celsius in summer and this can increase the risk of forest fires in this area.

2. RIVER FLOODS

Floods are caused by intense rainfall; that is the reason why their origin is in the atmosphere. Climate change can strengthen extreme meteorological events that give rise to intense rainfall in areas where such a large quantity of water cannot be absorbed. Nevertheless it is true that floods produced in areas through which rivers flow are processes integrated into the river system dynamics. From a long time ago the Nile's annual overflowing has introduced a large quantity of sludge into the river, leaving fertile lands on its banks which are used for different crops when the water level descends.

Nevertheless, it can be said that there are many countries where floods produce an enormous damage. River basin banks as well as flooded plains are places where human settlements are usually located, but they run the risk of being flooded when it rains intensely. In many cases, the soil's capacity to infiltrate and store water has an impact on the development and virulence of floods. Those soils that are less affected by floods have a higher infiltration capacity and a good water movement under the earth.

Clearing or burning forests trigger surface runoff and as a consequence of that process, currents transport a large quantity of sediments that can settle on dangerous places. These sediments can act as natural dams blocking the river beds and therefore causing their overflowing, and multiplying the devastating effects of floods.

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Consequences and impacts of climate change on terrestrais ecosystems

The substrate unbalance. Disasters

Torrential rains that fall on a soil affected by a forest fire can trigger runoff down the slope, digging erosion channels as those shown below located in Quiroga, Lugo.

3. SLOPE INSTABILITY

Although the anthropogenic action is one of the main causes of slope instability due to the change in land uses, climate change has to be considered in order to value whether an area is exposed or not to erosion. These variations imply changes in rainfall (intensity and duration) and increasing temperatures. Human action can worsen the instability problems by clearing forests, altering river beds and levelling lands to build roads. These actions often cause land breaking and landslide.

Superficie debida a un deslizamento

The main cause of landslide is the rain because it causes soil instability when it is infiltrated and therefore it increases the pressure on it. When this pressure reaches the highest levels, the slope breaks and the landslide starts. In alpine areas where snow covers the land, the risk of avalanche is linked to increasing temperatures and the subsequent melting of the snow piled up on the land and the permafrost under it.

In Galicia the areas that are mostly exposed to landslide risks are located in the mountains of Lugo and Ourense where the substrate is formed by slate.

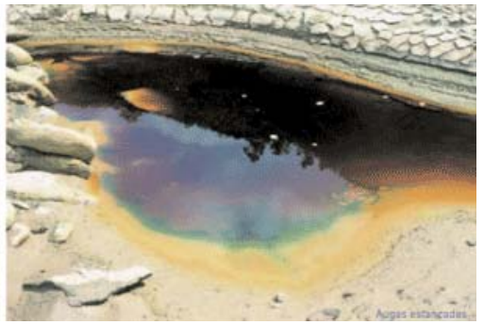
Surveys indicate that the areas most exposed to future landslides linked to climate change are on the Cantabrian Mountain range and on the Douro's North basin due to the increasing winter rains. As a contrast, in Mediterranean areas where rainfall will be more irregular, landslides are limited to wetter periods. On the coast, sea level rise and frequent storms will have an impact on the erosion of cliffs that can cause landslides, mainly of rock cliffs walls..

The gradual increase of temperatures in high mountains such as the Pyrenees, the Cantabrian or the Baltic mountain ranges will shift the risk of avalanches and landslides to higher levels due to the ice retreat and to the snow piled up on higher tops.

[+...]

4. EFFECTS ON FRESHWATER: WATER RESOURCES

Water is an essential resource for life on Earth. Climate change will have more impact on the Globe's arid and semi-arid areas where water availability is limited. As a contrast, wet areas will have to face important changes in the rainfall regime by adapting themselves to eventual droughts and to the devastating effects of more frequent floods. The water level in aquifers and dams can descend as a consequence of droughts and this situation will be even worse when the river water flow is lower because this causes water stagnation and the degradation of its quality. The stagnation process can lead to a potential source of infection and diseases in regions where water change is very limited.



When resources are analysed an increasing demand should be considered due to the world's growing population. In these terms, it is necessary to take initiatives to manage efficiently the use of water resources as well as improve agricultural and urban planning policies.

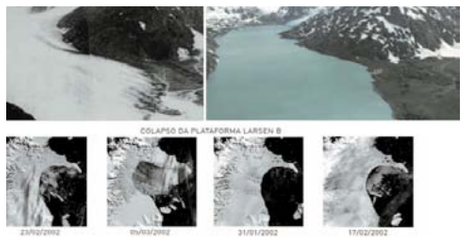
It is estimated that in Spain water resources can be reduced at about 17 percent if temperatures rises 2.5 degrees Celsius and rainfall is reduced at about 8 percent. These changes will be more remarkable in Levant –Jucar and Segura-'s, the Southern Guadiana and Guadalquivir's and the islands' river basins.

With all these climate change's impacts on the land, those areas covered by forests at present can change into areas covered by shrub, and therefore they will be exposed to the risks of erosion and desertification.

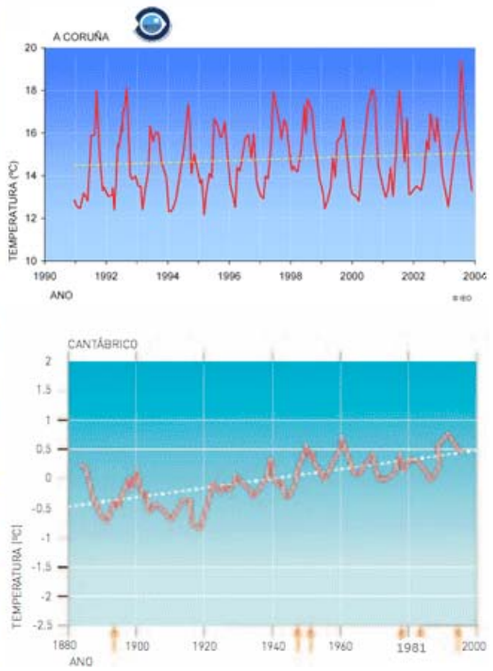
Impacts on marine ecosystems
Water temperature rise

7. Impacts on marine ecosystems
7.1. Water temperature rise

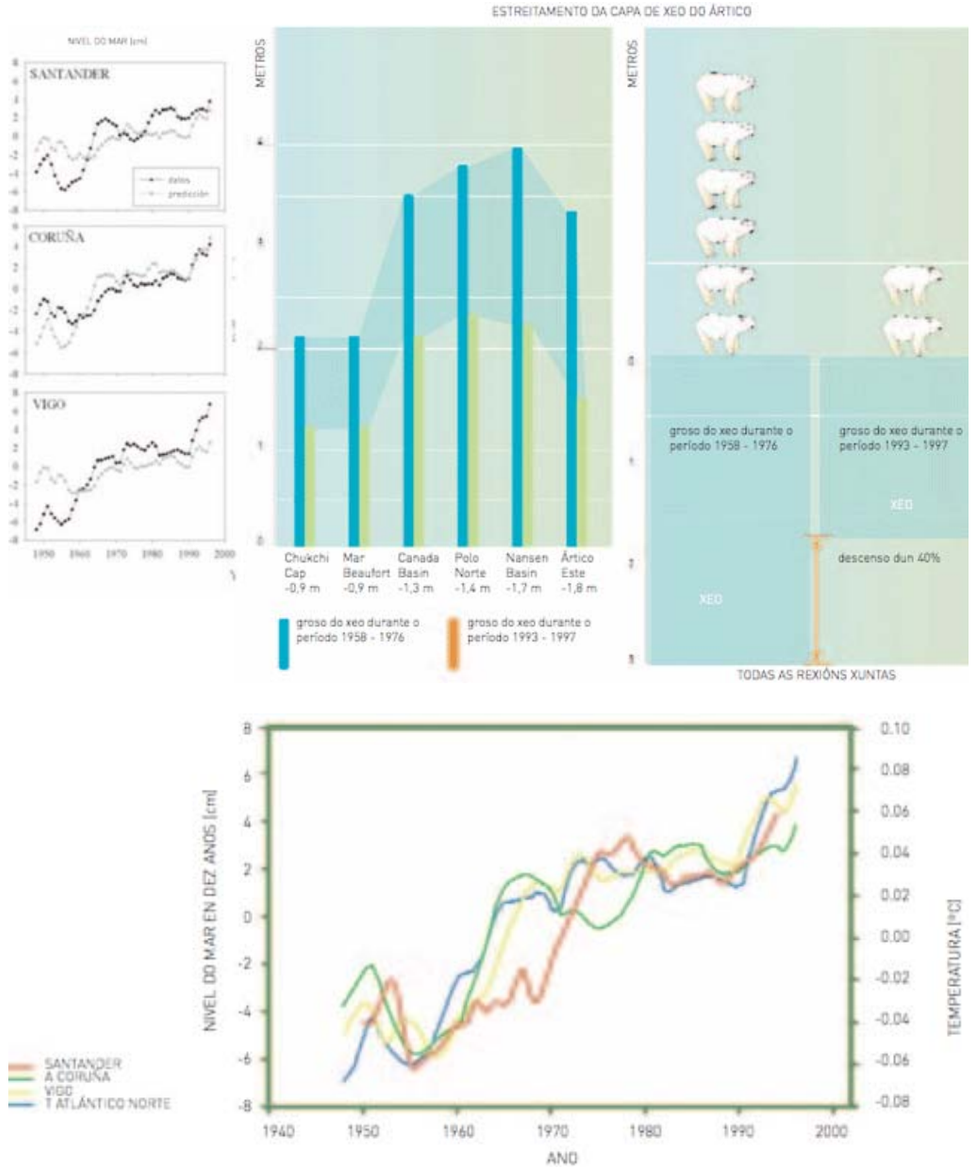
The ocean also gets warm, by about 0.04 degrees Celsius per decade. This is a general trend but at a local level these trends can change. Thus, in the province of A Coruña observations indicate that this trend is less clear than in the Cantabrian area.



As a consequence of this warming, ice on the Poles is gradually melting, leading to a sea level rise. Historical records show that the sea level has risen about 1-2 mm/year over the 20th century. At the same time this increase varies according to the different coastal areas. For example, Galician coasts have gone through a sea level rise of 2-3 mm/year over the second half of the 20th century.



This means that during the last century it has risen 10-20 cm, and by 2100 a rise of 9-88 cm is considered possible. But this sea level rise is not only attributable to ice melting but also to water expansion due to warming.

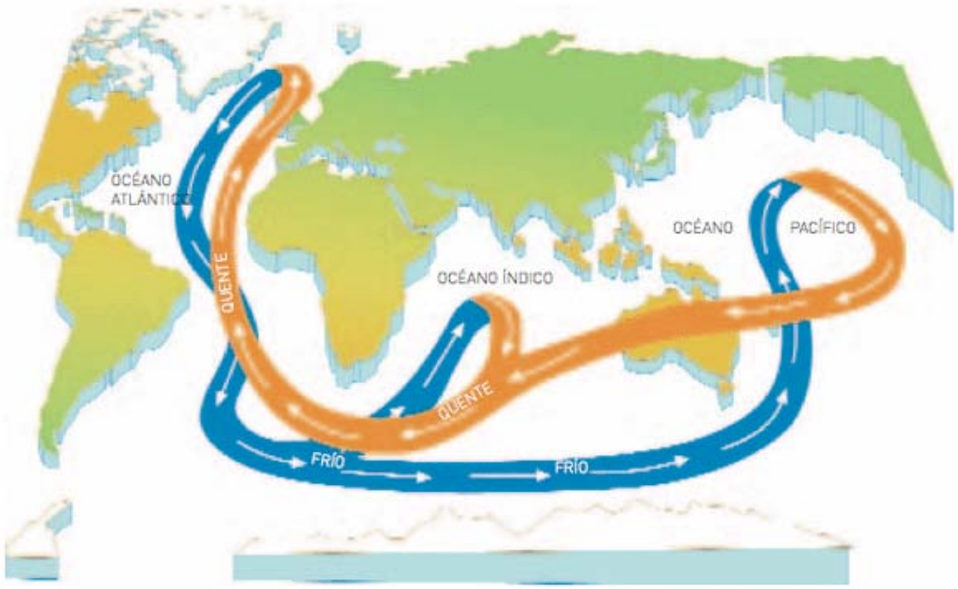


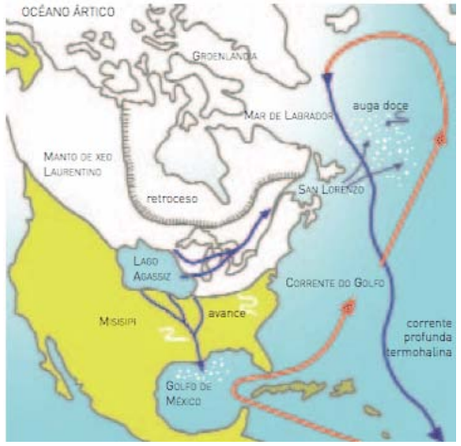
7.2. Effects of the freshwater influx into sea due to ice melting

Although observations confirm that the ocean's global temperature has increased in some areas there is evidence of temperature decrease. Thus, the North Atlantic has become significantly cooler and the degree of salinity has been reduced in 1885-1999 at the same time as the global temperature is rising.

cannot flow downwards into the depths in order to become colder.

The nearest drastic effects due to interferences into this current took place at the end of the last ice age, when the biggest ice sheets started retreating towards the Polar regions. As the Earth's global





Although these effects do not take place today, it is clear that more and more freshwater is being introduced into the North Atlantic, changing the Gulf Stream and the ocean's stream circulation.

This event can be understood as an effect of the influx of melt water from the Greenland ice sheet and therefore, making water less salty and less dense. As a consequence, surface warm water masses float over denser ones, but this depends on the salinity provided by dissolved salts. Therefore, climate conditions whose thermal regulation depends on these circulation currents can be affected, since warm surface water

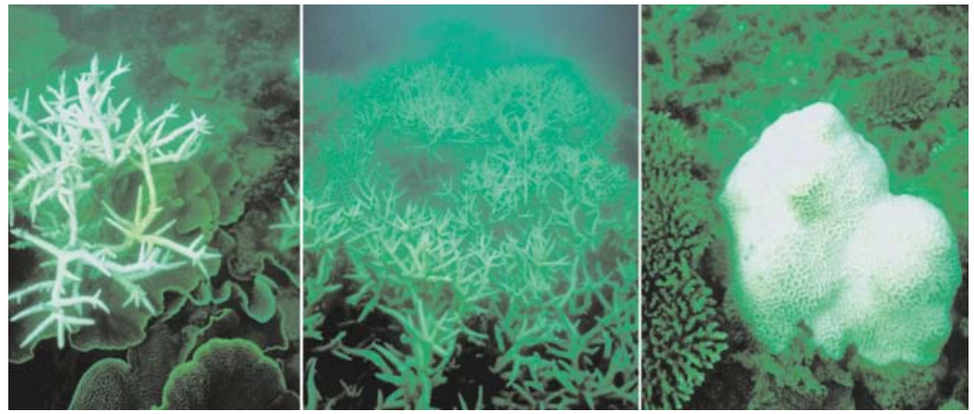
temperature increased at the end of the last ice age, 10 800 years ago, a sudden climatic change took place in Europe, giving rise to a strong decrease in temperature. It seems that it was caused by the influx of melting water from the North Atlantic, most of which came from the disappeared Agassiz Lake

7.3. Effects on marine species

Global warming has impacts on marine ecosystems derived from the rise in global temperature, such as coral bleaching and migration of species.

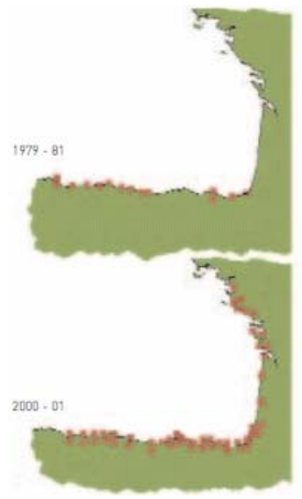
Coral bleaching can damage very seriously or even destroy coral reef colonies. The corals that form the structure of the great reef ecosystems depend on microscopic algae called zooxanthellae that feed and give coral its particular coloration. Under stress, corals may expel their zooxantheallae, which leads to a lighter or completely white appearance, hence the term "bleached". If the zooxanthellae clade is not restored, coral is killed.

If temperature rises only 1 degree Celsius over the summer temperature in shallow areas where coral lives, it can undergo bleaching. Tropical waters, where the world's biggest coral reefs are found, have gone through such temperature rise over the last 100 years. The Great Barrier Reef along the Australia's Northeastern coast suffered a mass coral bleaching event in 2002, with over 60% of corals killed.



Many organisms respond to climate change conditioned by water temperature rise traveling towards waters with temperatures where they are better adapted. Many thermal expansions are known in different species.

The species that are fixed to the substrate, such as the big brown algae Sacchorrhiza polyschides, are those that mainly suffer this migration process.



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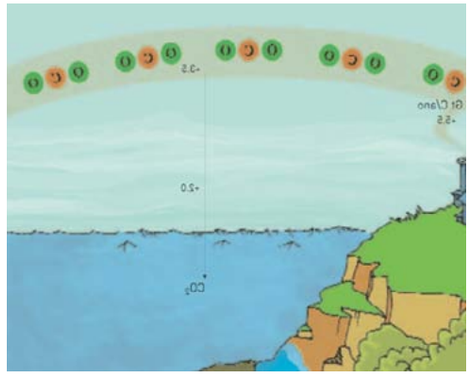
7.4. Effects of the increasing dissolved carbon dioxide

Climate change's impacts on marine environment include acidification caused by carbon dioxide dissolved in sea water.

As it was said in the chapter on the carbon cycle, the sea environment is very efficient in carbon sequestration since phytoplankton removes carbon dioxide via photosynthesis by means of the food chain, and it is finally deposited in the shell sediments introduced in the sedimentary rocks and the oil fossil carbon chains.



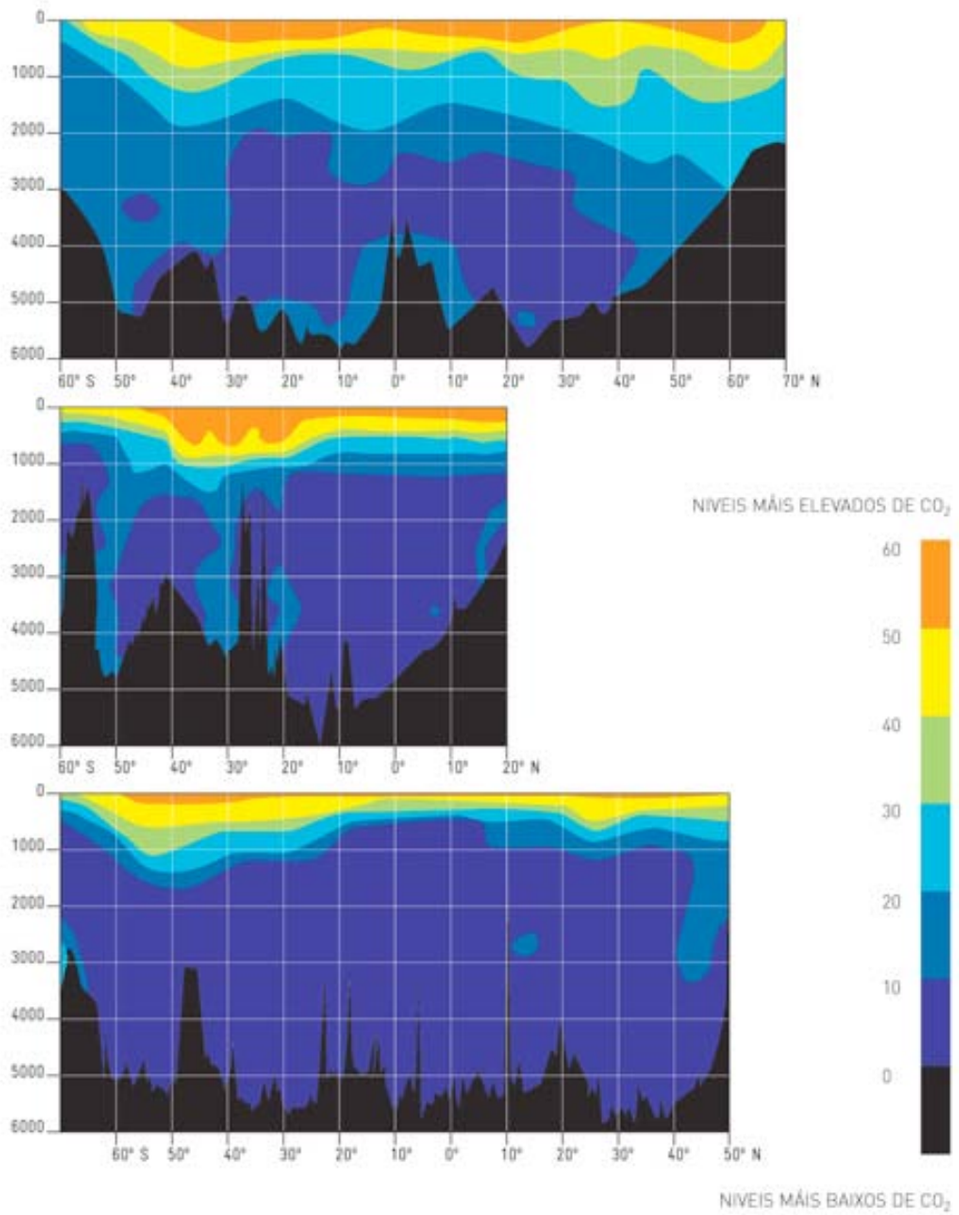
By means of the absorption process oceans helped to mitigate climate change. Nevertheless those

Nevertheless, oceans are nowadays an enormous carbon dioxide sink caused by human activity. Recent research reveals that over the last 200 years oceans have absorbed almost half of the CO_2 released into the atmosphere by human activity.

sequestration mechanisms cannot take the carbon dioxide released by human activity into the Earth and, therefore, it is quickly released into the atmosphere in fossil fuel combustion processes.

Carbon dioxide is found on the oceans' surface and it can be identified by the carbon isotope present in fossil fuels. In the Atlantic Ocean it can be introduced more easily due to the degree of waving.

Increasing CO_2 concentrations on the ocean surface are changing the sea's chemistry, causing water



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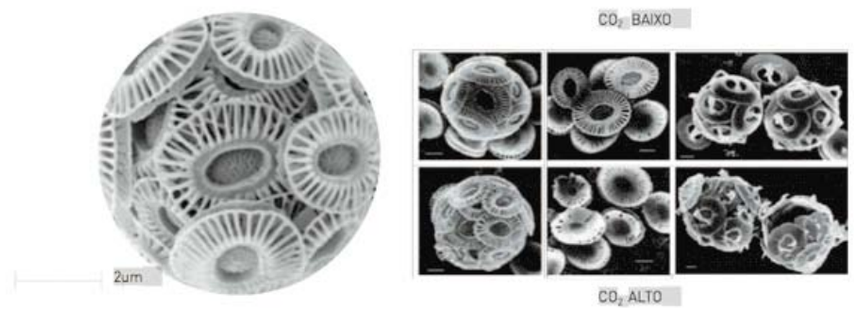
Impacts on marine ecosystems

Effects of the increasing dissolved carbon dioxide

acidification by means of carbon dioxide reaction with water. Scientific research indicates that this change in the ocean's chemistry could have a devastating impact on corals, shellfish, specific groups of phytoplankton and other organisms with covers exposed to acidification.



This problem could be solved if sequestration increased, but the cycle rate considered relevant to remove the carbon dioxide released by natural processes acts too slowly to remove the carbon dioxide caused by human activities. Therefore, technological tools should be found in order to increase the sequestration of this surplus carbon dioxide.

7.5. Effects on the coastline

Analysing the world population distribution, it can be observed that about two thirds of the population live on coastal areas. In Spain, 45% of the population lives on the coast, and in Galicia that percentage is even higher. These data show that many people could suffer serious problems in these areas caused by these alterations on the coastline. The most important impacts of climate change on these areas result from the average sea level rise, which will cause floods and erosion on the coastline. According to the IPCC (Intergovernmental panel on Climate Change) models predict a rise of 10-68 cm by the end of the 21st century, and the most pessimistic predictions indicate that this rise could be one metre high. The Panel advises that every year flood risks are increasing and they will have serious effects on towns, tourism, crops and natural habitats such as wetlands, which could be reduced to a half.

Venetia's Channel. In this town, New Orleans and other towns in the Low Countries, the sea level rise risk seriously life if this problem is not faced accurately.

The first coastal areas to be damaged will be marshes and deltas, most of them being flooded mainly in the Cantabrian coast where the effects of incident waves are foreseen to increase on the coast.

The most significant elements influencing on the sea level are the ocean's thermal expansion (increasing volume due to water temperature and salinity), glacier retreating and the continental surface and deep water volume. Perhaps one of the main effects is water dilatation. The ocean's level varies according to water density and, therefore, temperature and degree of salinity. This effect is due to melting ice since ice provides the system with freshwater that reduces its salinity. Recent information reveals that the ocean has been expanded 2-7cm over the last 100 years

Ice is the planet's biggest freshwater reservoir. As a consequence of global warming, Antarctica's and Greenland's glaciers and ice sheets are constantly retreating, either due to direct ice melting or to blocks loosening in the form of icebergs, which becomes a risk to navigation. At this moment if all the ice piled up on the continents melted, the sea level would rise about 50cm. It is believed that from 1890 glaciers' water has increased the sea level by about 0.5mm as average.

Finally, variations in the freshwater volume have also an impact on the sea level. In this case, the human action plays a key role, since the overexploitation of water reservoirs, such as dams, lakes, aquifers, either for consumption or for agricultural uses, has an effect on the water flowing into the sea.

Coral reefs are coastal ecosystems that play a key role in preserving the low coasts along the Pacific Ocean against sea erosion. Even though, they are so highly exposed to the sea level rise that these ecosystems are believed to disappear in the near future according to the most pessimistic predictions.

DOES CLIMATE REALLY CHANGE?

INDEX