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THE INTERACTIONS BETWEEN OCEAN AND CLIMATE

8 fact sheets

WITH THE HELP OF:

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HOW DOES THE OCEAN WORK?

The definition of words starred with an asterisk can be found in the OCP little dictionnary section, on the last page of this document.

OCEAN CIRCULATION (1/2)

Ocean circulation is a key regulator of climate by storing and transporting heat, carbon, nutrients and freshwater all around the world . Complex and diverse mechanisms interact with one another to produce this circulation and define its properties.

Ocean circulation can be conceptually divided into two main components: a fast and energetic wind-driven surface circulation, and a slow and large density-driven circulation which dominates the deep sea.

Wind-driven circulation is by far the most dynamic. Blowing wind produces currents at the surface of the ocean which are oriented at 90° to its direction (on its right in the Northern Hemisphere and on its left in the Southern Hemisphere) due to the Earth rotation. As a consequence, it creates zones of convergence or divergence of ocean currents at the point where they meet. Divergence of currents will create an upwelling phase (interior waters reach the surface) and convergence a downwelling phase (surface waters sink in the interior ocean), linking surface and interior waters.

The slow and deep circulation is largely driven by water density, and thus its temperature and salinity. It acts on the ocean as a whole and has a major influence on the abyssal properties where wind-driven circulation has no effect. However, this circulation is slow and generates weak currents, it is therefore more difficult to observe: a single drop of water travels 1,000 years to close the global overturning circulation.

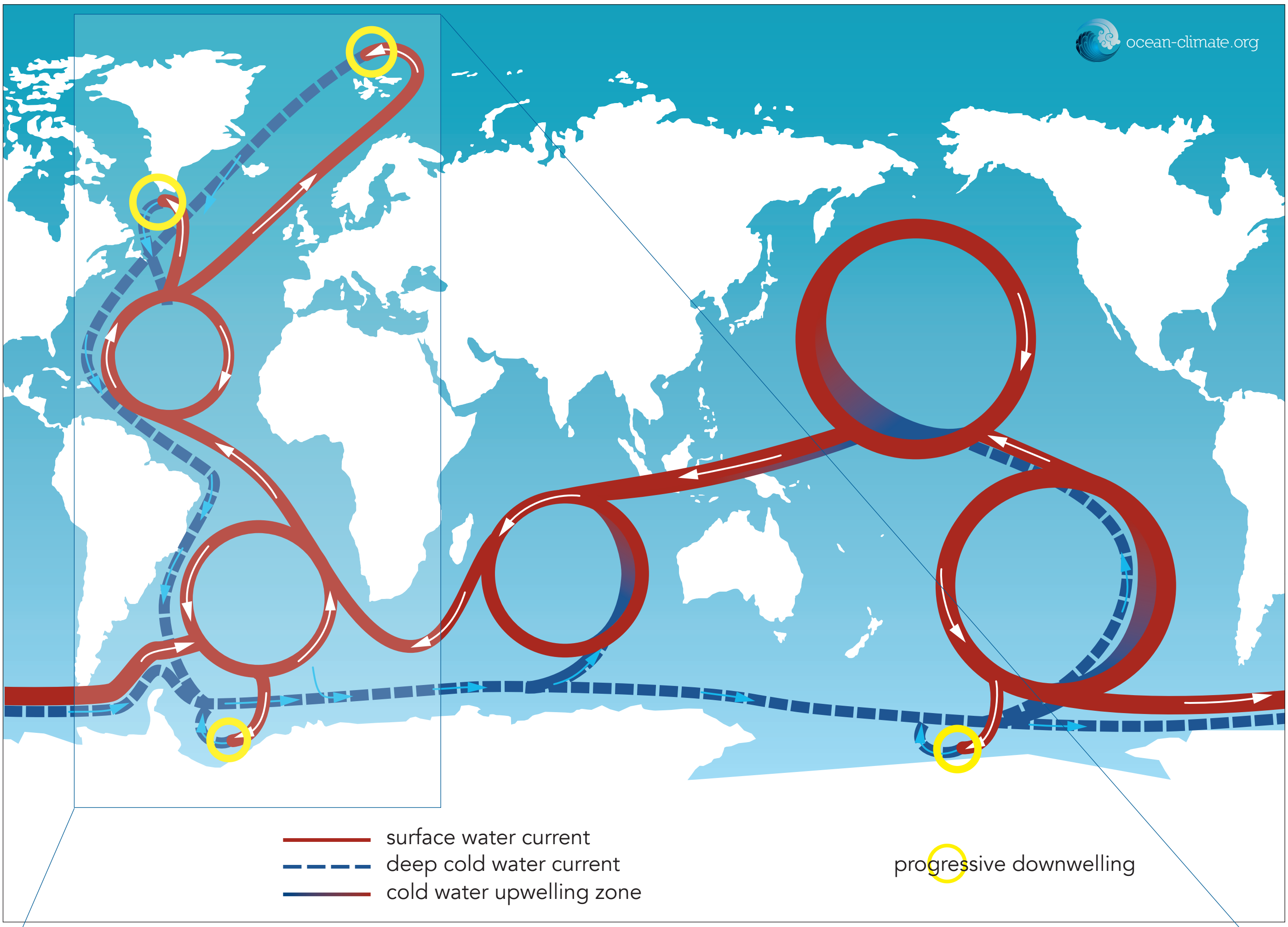
The large-scale circulation is relatively stable on long timescales. At some very specific locations – mainly in the Northern Atlantic and around Antarctica – surface waters become denser and sink to the depths. Densification occurs due to both cooling surface waters and increasing salinity, the latter as a result of the removal of freshwater and the formation of ice. Surface waters are then pulled up to replace the sinking ones. How waters upwell from depths to the surface is still unclear. As stated above, zones of divergence of waters are of critical importance for these phenomena but near-seafloor turbulence also plays a major role. These mechanisms are still poorly understood and their spatial variability remains largely unknown.

Oceanic circulation is very sensitive to the global freshwater flux. This flux can be described as the difference between [Evaporation + Sea Ice Formation], which enhances salinity, and [Precipitation + Runoff + Ice melt], which decreases salinity. Global warming will undoubtedly lead to more ice melting in the poles and thus larger additions of freshwaters in the ocean at high latitudes. This input of freshwater, by decreasing surface water density near the poles, could limit downwelling, prevent deep waters formation, slowing down global circulation.

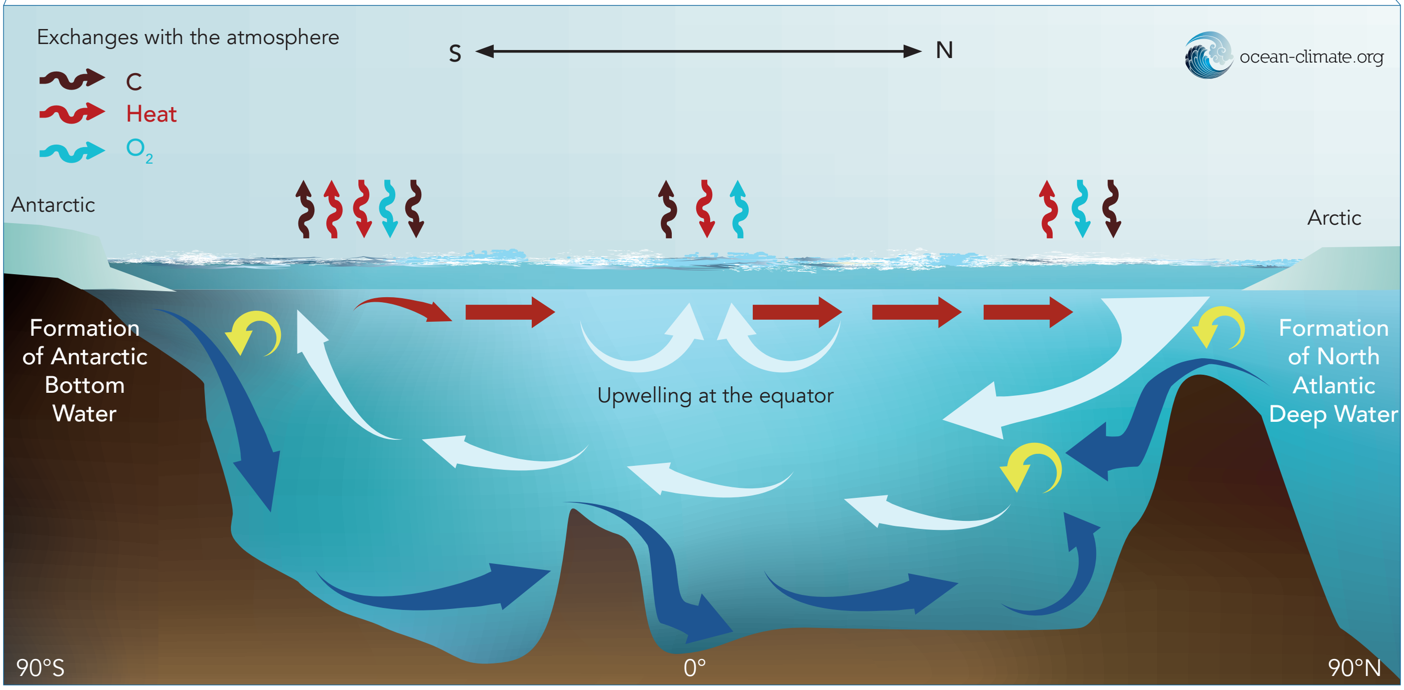
Such a process could have tremendous consequences for our societies. It would mean less carbon and heat uptake by the ocean and thus higher rates of both carbon and heat in the atmosphere. It could potentially accelerate global warming and enhance its negative effects.

More generally, it is important to note that interactions between oceanic circulation and climate are still poorly understood: more observations, an increased understanding and reliable numerical models of oceanic circulation are needed at different space and time scales. Such progress could dramatically improve IPCC global climate projections.

OCEAN CIRCULATION (2/2)



Simplified diagram of large scale ocean circulation



Zoom on the Atlantic (vertical cross-section)

THE OCEAN, AN INDICATOR OF CLIMATE CHANGE (1/2)

Through its permanent exchanges with the atmosphere, the ocean plays a major role for world climate. When the planet gets warmer, the ocean stores most of the energy received. It is possible to quantify and follow the extent of global warming by measuring the quantity heat stored by the ocean.

Our planet mainly receives energy from solar radiation. While the Earth captures part of this energy, the remainder is reflected beyond the atmosphere. The rapid increase in greenhouse gas emissions into the atmosphere causes an accumulation of heat within the climate system.

The ocean absorbs over 90% of excess heat accumulated in the climate system and gets warmer. It is a crucial regulation role but the quantity of heat accumulated now has consequences on sea level evolution, temperature increase or ice melts…

The quantity of energy stored in the ocean is estimated by analyzing the thermal content of oceans. The temperature of ocean surface water is measured with sensors attached to satellites. The data is inserted into models*, which quantifies the thermal content of oceans over the entire water column.

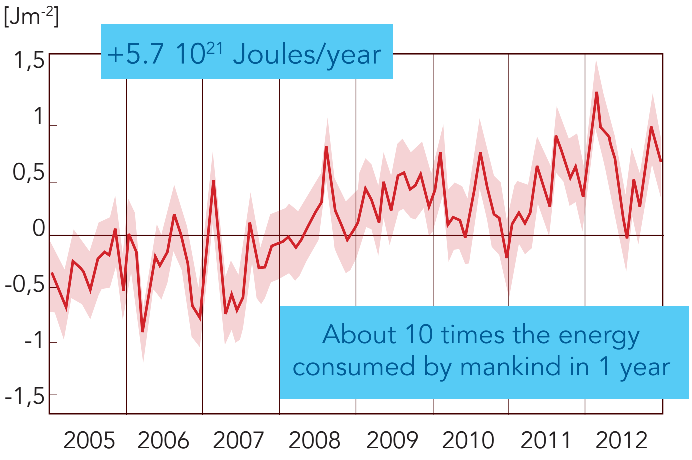
According to estimations, oceans store up to the equivalent of 10 times the quantity of energy consumed by mankind over the same period.

It is more reliable to monitor the evolution of this quantity of energy than to observe surface temperatures. The latter are particularly sensitive to local vertical redistribution mechanisms and are not necessarily representative of global warming.

In the future, it is crucial to have better knowledge and accurate monitoring of the quantity of heat captured by the ocean to improve scientific knowledge on changes in the climate system, climate predictions and to analyze the impact of climate change mitigation policies.

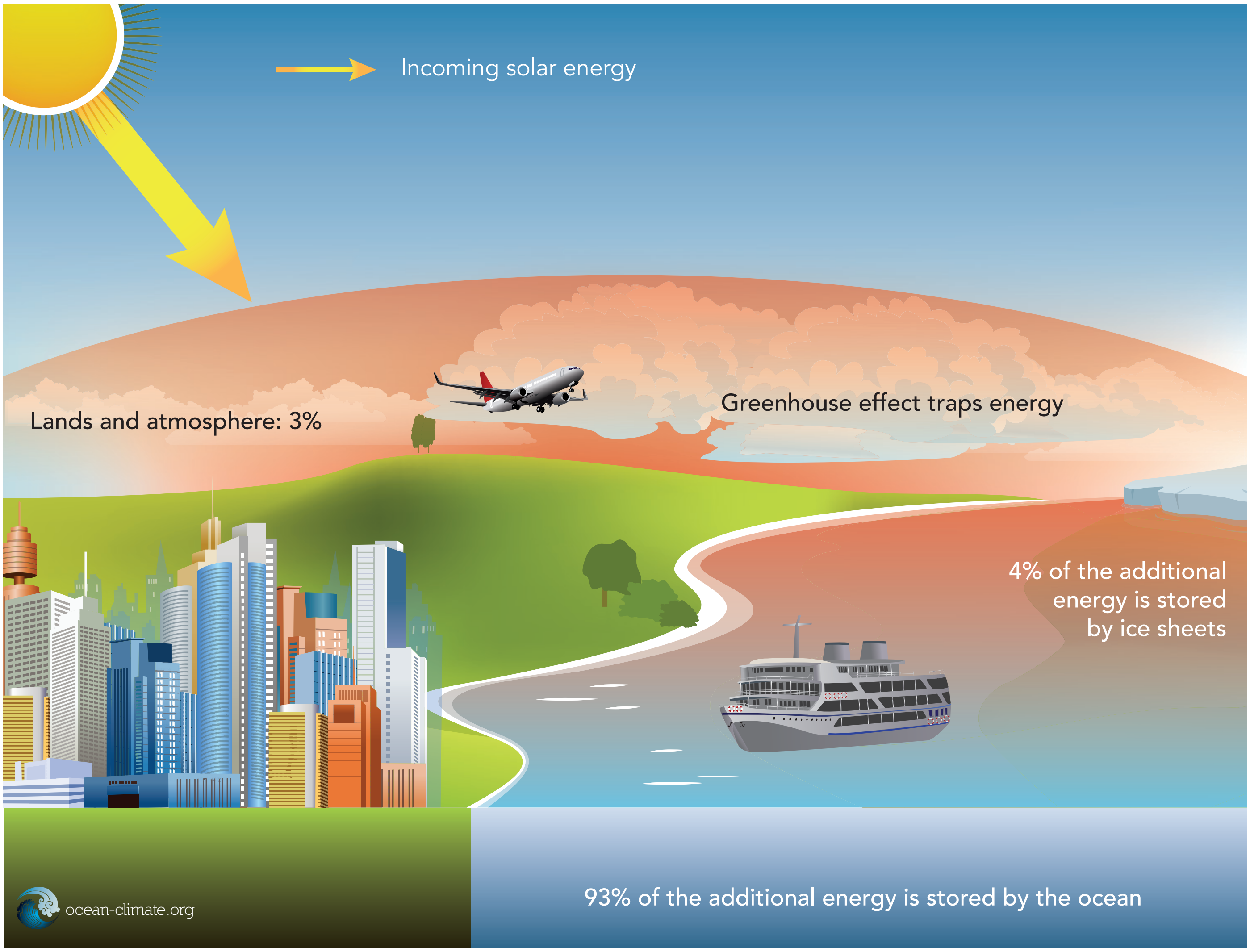
THERMAL ENERGY, *EL NIÑO*, AND CLIMATE CHANGE

On a seasonal level, thermal energy stored in the ocean greatly influences atmospheric conditions.
For instance, studying the evolution of the thermal content enables a monitoring of the evolution of hurricane intensity, or the return of the *El Niño* phenomenon. Oceanographers know this phenomenon very well: it is an episode of emphasized warming of surface waters in the Pacific (down to 300 metres deep) close to the South American coasts which frequently takes place around Christmas – hence, the Spanish name "*El Niño*" which refers to the baby Jesus. When this phenomenon occurs, it affects wind regimes, sea water temperature, precipitations and distribution of marine resources throughout the entire globe tropical belt. Through its extent and the size of the area affected, scientists know that *El Niño* affects global climate. However, the role of climate change in the frequency and the extent of the phenomenon has yet to be discovered.



Ocean heat content, updated by Von Schuckmann K. and P.-Y. Le Traon, 2011, Ocean Science, 7, 783–791, www.ocean-sci.net/7/783/20

THE OCEAN, AN INDICATOR OF CLIMATE CHANGE (2/2)



Heat storage by various elements of the planet

SEA LEVEL: 300 YEARS OF OBSERVATION

The need for sea level observation has increased with the attraction to coastal zones for the development of human activities. The indication of water levels along coasts has become crucial, because it allows, among other things, to better understand and quantify climate change effects, and to attempt preventing coastal extreme phenomena (wave submersions, tsunamis…).

In fact, as the astronomer, Pierre Simon de Laplace, described in his *Mémoire sur le flux et le reflux de la mer* (1789), Brest is an ideal location to observe the sea level, and systematic observations of the sea level have been conducted there since 1679. Brest, thanks to its harbor extending out into the sea that is yet protected, gives a better visibility of the sea level. By not facing interannual variations due to world or regional weather processes, the evolution of the sea level in Brest is constant and regular with time.

Observations were initially conducted with tide gauges. These measurement tools have developed and become extremely precise and accurate. Tide gauges operated by SHOM (French Navy National Hydrographic and oceanographic Services) since the middle of the 19th century in several urban harbors have evolved and their automatic and continual measurements are now, more than ever, irreplaceable.

The structure of these long series of sea level observations gives a global view to better understand the processes linked to climate change and its evolution. Over three centuries of measurements in Brest have shown a local sea level rise of 30cm, as observed on this graph, with a more significant rise during recent decades. The various measurements taken around the world show that sea level variations are not identical everywhere.

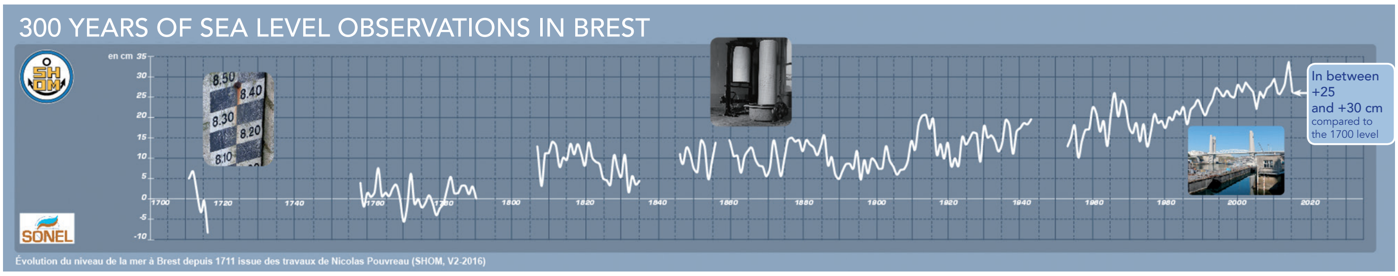
In France, as part of SONEL (long term sea level variations observation system), the evolution of the sea level is calculated for all of the French ports. SONEL provides high quality data collected from tide gauges, to calculate the relative sea levels based on modern geodetic technics to determine the vertical movements and absolute levels of the sea.

Throughout the world, sea level observation represents a quantifiable data of climate change effects because it is one of the physical-chemical indicators the most used by the Intergovernmental Panel on Climate Change (IPCC).

Regular observation of water levels, including during storm episodes, is irreplaceable information for the analysis of extreme levels and wave submersions, which are further proof of current changes. In reality, forecasting these phenomena is essential for tsunami alert centers as well as for submersion wave weather watch. It is also possible to calculate the recurrence of extreme events for prevention policies such as rapid submersions plans, which covers flood risks of submersion waves, sudden floods or confined streaming and dyke bursting.

Consequently, the measures implemented for observation and dissemination of information on water levels is crucial to understand, analyse and prevent climate change manifestations that are potentially amongst the most devastating for lower zones in direct connection with the sea, in the medium term with the slow process of elevation of the mean level, or with violent weather phenomena.

Observations of water level in real time, generated by tide gauges operated by SHOM and its partners (coordination by REFMAR) are available online at: data.shom.fr.


300 YEARS OF SEA LEVEL OBSERVATIONS IN BREST

Évolution du niveau de la mer à Brest depuis 1711 issue des travaux de Nicolas Pouvreau (SHOM, V2-2016)

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WHAT DOES THE OCEAN DO FOR US?

The definition of words starred with an asterisk can be found in the OCP little dictionnary section, on the last page of this document.

MARINE AND COASTAL ECOSYSTEM SERVICES

Over the past ten years, the environment has entered the public debate. Why protect nature? Why preserve biodiversity? Our environment is made of a series of ecosystems, each supplying numerous services daily. Ecosystems are defined as dynamic complexes of plant, animal and micro-organism communities and the nonliving environment, interacting as a functional unit.

When we analyze interactions within an ecosystem, we can identify which services each ecosystem produces. These services are diverse: fish make up the primary source of protein for a billion people worldwide, forests absorb a substantial amount of greenhouse gas emissions, etc. Therefore the concept of ecosystem services was created to recognize and quantify all beneficial interactions to human populations. A famous example concerns pollination: when bees visit flowers to gather nectar, they transport pollen grains from one flower to the other, thereby participating in plant reproduction.

But ecosystem services are not limited to the terrestrial space. On the contrary, the ocean plays a major role in climate regulation. Studies have shown that the seas absorb almost a third of the carbon dioxide emitted annually. Moreover, marine and coastal ecosystems are home to numerous plant and animal species, which all produce various useful services for humans. For instance, mangroves help retain friable, or crumbly, soil on the coast, and therefore help prevent coastal erosion. They are also natural barriers to water currents, and as such constitute a favoured habitat for the birth and development of many species of fish. Mangroves therefore help maintain the available fish stock. Whale feces, on the other hand, contain high quantities of iron, which is an essential nutrient for photosynthesis. The level of iron present in the ocean has a direct impact on the development of phytoplankton, a key component of carbon storage.

The Millennium Ecosystem Assessment (MEA) defined four types of ecosystem services. Marine and coastal ecosystems produce various services, including:

- provisioning services: fisheries, building materials;
- supporting services: life-cycle maintenance for both fauna and local, element and nutrient cycling;
- regulating services: carbon sequestration and storage, erosion prevention, waste-water treatment, moderation of extreme events;
- cultural services: tourism, recreational, aesthetic, and spiritual benefits.

The total value of the services produced by marine and coastal ecosystems is valued at USD$ 29.5 trillion per year, which is worth more than the USA's gross national product in 2015. However, the quality of these services depends on the ecosystems' resilience and its level of protection. When an ecosystem is degraded, it delivers fewer services. For instance, posidonia meadows are underwater flowering plants in the Mediterranean Sea. These plants are very vulnerable to human disturbance. Natural habitats are threatened by growing coastal urbanization, as well as by the increasing amount of boats, whose anchors wrench posidonia plants out. Yet these meadows are crucial to the fight against coastal erosion. Moreover, these plants constitute a safe haven for fish to reproduce and establish nurseries for their offspring as they protect juvenile fish from predators. The destruction of Posidonia plants reduces the overall fish stock, which in turn has a negative impact on fishermen and recreational divers.

Furthermore, ecosystems offer great, but underrated, opportunities. Cultural services are often overlooked when computing the total value of the ocean, because such services are difficult to value. The fishing industry is an important business sector in many countries, but we tend to forget that the sea is a major cultural arena. From tourism to navigation to the arts, the sea is a place to relax and be inspired. The ocean is also a source of economic growth, particularly for biotechnologies, which consist in developing goods out of biological principles seen in nature. For instance, the analysis of the poison contained in cone snails helped isolate ziconotide, an analgesic agent currently used in the medical sector. And yet, the ocean remains relatively understudied. Many more practical applications of great use to mankind could still be discovered.

For ecosystems to keep supplying many services, we need to preserve them, i.e. to protect biodiversity and reduce to a minimum the human impact on ecosystem functions. Protecting marine biodiversity means protecting the climate and thus protecting humans.

THE OCEAN, A CARBON SINK (1/2)

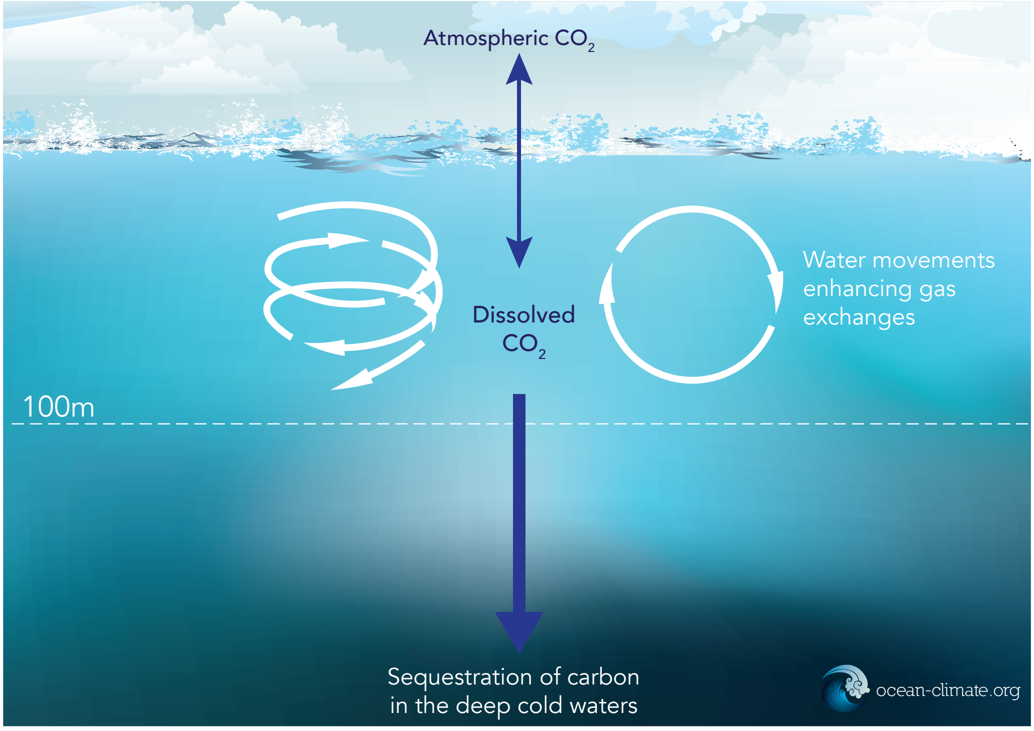
A carbon sink is a natural or artificial reservoir that absorbs and stores the atmosphere's carbon with physical and biological mechanisms. Coal, oil, natural gases, methane hydrate and limestone are all examples of carbon sinks. After long processes and under certain conditions, these sinks have stored carbon for millennia. On the contrary, the use of these resources, considered as fossil, re-injects the carbon they hold into the atmosphere. Nowadays, other carbon sinks come into play: humus storing soils (such as peatlands), some vegetalizing environments (such as forming forests) and of course some biological and physical processes which take place in a marine environment.

These processes form the well-known « ocean carbon pump ». It is composed of two compartments: a biological pump* which transfers surface carbon towards the seabed via the food web (it is stored there in the long term), and the physical pump* which results from ocean circulation. In the Polar Regions, more dense water flows towards the Deep Sea dragging down dissolved carbon. Actually, in high latitudes water stores CO_2 more easily because low temperatures facilitate atmospheric CO_2 dissolution (hence the importance of Polar Regions in the carbon cycle). It is difficult to determine the quantity of carbon stored by these mechanisms, but it is estimated that the ocean concentrates 50 times more carbon than the atmosphere. For some scientists, the Deep Sea and its water column may be the largest carbon sink on Earth but its large-scale future is still unknown. Also, with ocean acidification, this process could become less efficient because of a lack of available carbonates*.

When talking about carbon storage, the notion of time is crucial. The biological pump is sensitive to disturbances. Consequently, it can be destabilized and re-emit carbon into the atmosphere.

The physical pump acts on another time-scale. It is less sensitive to disturbances but it is affected on a long-term basis. Once the machine is activated, it will be difficult to stop it. The carbon, transferred to the Deep Sea due to ocean circulation, is temporarily removed from the surface cycle but this process is rather poorly quantified. Also, after a journey of several hundred years, what will this carbon become when these waters resurface?

The biological pump is actually easier to assess. It relies on ecosystems' good health. In the high seas for instance, the planktonic ecosystem is a major player. All organic materials that reach the bottom participate in the biological pump and when conditions permit it, they also participate in oil formation. Calcium-containing materials such as coccolithophore, a microscopic one-celled alga, participate in subtracting carbon from the natural cycle. When they die, they generate a vertical net flux of carbon. This carbon can then be stored in the Deep Sea for long geological periods. These processes can leave traces. For instance, chalk cliffs are an accumulation of coccolithophores (micro algae covered with plating made of limestone) on the ocean seabed, which have later resurfaced to the continent due to geological movement.

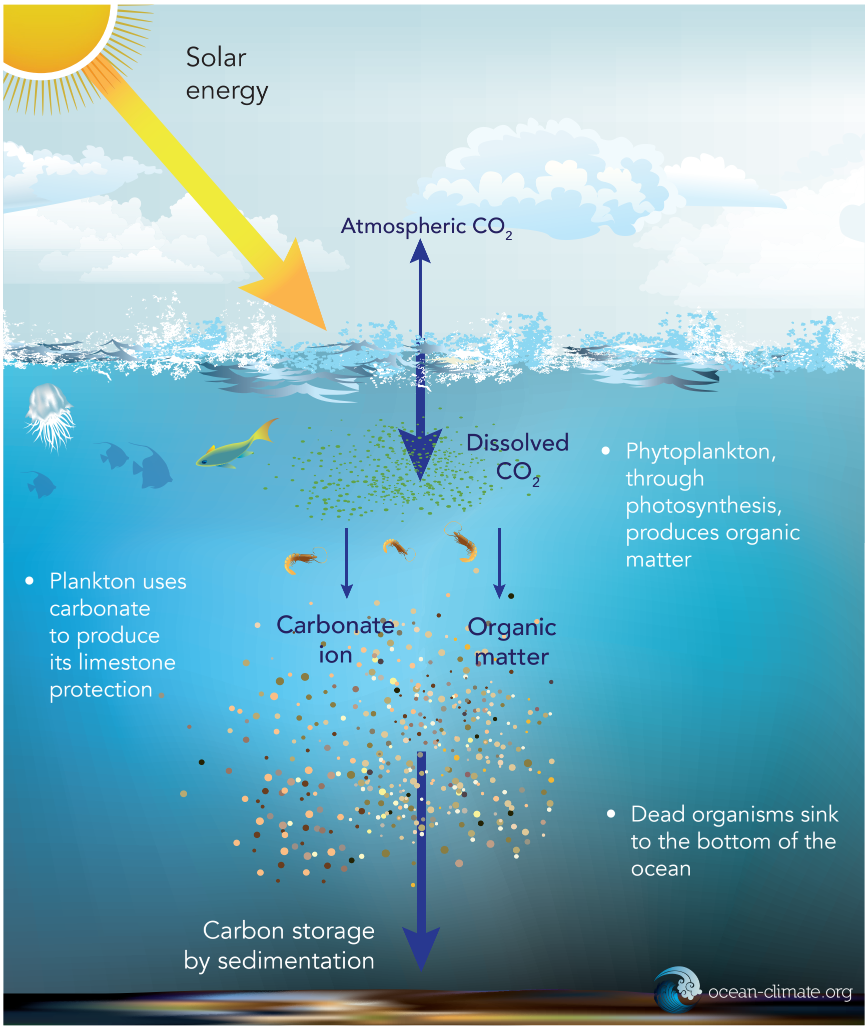


Physical carbon pump

THE OCEAN, A CARBON SINK (2/2)

Healthy coastal ecosystems play a mitigation* role against climate change, especially by capturing carbon for their development. For instance, mangroves, seagrass beds and salt marshes are significant carbon sinks. These last three examples, store at least ten times more carbon than continental forests when they develop by capturing carbon in their calcium skeleton. However, these coastal ecosystems cover little surface on a global planet scale. Also, these ecosystems are weakened by coastal urbanization and coastal economic activities. Ecosystem restoration remains a priority to improve storage of carbon excessively released into the atmosphere and requires ambitious policies.

In order to combat climate change, geoengineering* techniques to store CO_2 artificially in the ocean carbon sink are under consideration. The scientific community is rather concerned because negative consequences of potential disequilibrium have not been explored yet. However, the concept of carbon sink is very controversial. The carbon cycle is rather complex as it is associated with other cycles which favour global warming. Consequently, storing CO_2 also releases steam water, which plays an important part in the greenhouse effect. In addition, because of the increase in greenhouse gas concentration, the water temperature and its acidity are changing. This modifies physical, chemical and biological equilibriums and may affect the ocean pump. All of this data should encourage us to think about the future of marine ecosystems. This uncertainty should encourage us to be more careful and to preserve marine ecosystems.



Biological carbon pump

FISHERIES AND CLIMATE CHANGE

Scientific research shows that climate change impacts on the ocean have already affected fisheries. While abundance of several cold water species is reducing, some tropical species are appearing on our coasts. In future decades ocean warming and acidification can affect growth and reproduction processes of many marine organisms, which may reduce stocks available for many significant commercial species. For instance, shellfish (oysters, mussels…) are especially sensitive to acidification. Also, while they are crucial for the economy of small islands and human nutrition, almost all coral ecosystems in tropical areas are expected to disappear by 2050. Climate change is also going to impact bacterial and phytoplankton communities, which are key to the marine food web. Consequently, if we keep on producing greenhouse gases at the current pace, changes expected before the end of the century in terms of biodiversity could be similar to those that occurred during the prior 20 or 30 million years.

On a global scale, models available today expect very significant modifications of primary ocean production, which is the source of the majority of food webs. Global ocean productivity should increase in Polar Regions and drastically reduce in inter-tropical areas, which will affect fisheries. In the Pole regions, fishing operations have increased by 30 to 70%, which favours countries such as Norway, Iceland, Russia or the State of Alaska. On the contrary, in inter-tropical areas fishing operations have reduced by 10 to 40%, which has significant repercussions for near countries, highly dependent on fisheries, such as Peru, Angola, Bangladesh, India, Vietnam or Indonesia. Predictions for Africa are rather uncertain; however several scientific studies expect an actual fisheries crisis, which will increase political and economic North-South inequalities. The impacts in Europe should be relatively limited, slightly positive for the northern countries and negative for the southern countries.

In response to modifications of ocean life conditions, models predict a displacement of most of the exploited species towards the Polar Regions. By 2050, these displacements will be estimated in hundreds of kilometres. This change should favour short life span species, more abundant in tropical waters, with still barely identified impacts on ecosystems. Consequently, captured species partially will not be the same at a global level. It is the case in particular in temperate regions, where the presence of tropical species is going to increase, while other European fish species will move towards the North. For instance, this is the case for the cod, whose population in the North Sea is already declining while its population in the Barents Sea further North is increasing.

Fishers will have to adapt to climate change impacts on fish stocks and their geographical distribution, by changing their modes of exploitation, sometimes ships, calendars and fishing areas. Public policies in management, control and governance will also need some redesigning to avoid reconsidering all efforts undertaken to resupply fish stocks for over several decades. For example, the cod stock in the Gulf of Maine has recently dropped because fish quotas had been determined without taking global warming into consideration. Consequently, it is important to learn how to constantly evolve, and this adaptation has a cost and will not happen without difficulty.

Limiting CO_2 emissions is a major issue, not only to mitigate current changes but also to slow them down and give ecosystems a (slight?) chance to adapt. On the contrary, if changes occur too quickly, the implementation of all adaptation processes by humans might be more difficult or even inefficient for them and the ecosystem. Chaotic situations or extreme crisis situations are expected, in particular in the field of fisheries.

THE DEEP SEA: A KEY PLAYER TO BE PROTECTED FOR CLIMATE AND ECOSYSTEMS (1/2)

The depth of the ocean is on average 4000 metres. In this area also known as "deep sea" there is no light, extremely high pressure, and temperatures that are much more stable than at the surface. Life exists under these conditions and every day we discover a little more about its diversity, weaknesses and the crucial services it provides to the entire planet.

The Deep Sea plays a major role in climate change mitigation. By storing a large part of the CO_2 produced by human activities and by absorbing the heat accumulated by greenhouse effect, the Deep Sea slows down the warming of surface waters and land. Thanks to this immense mass of water, climate change is still "bearable" for most species on Earth.

In addition, Deep Sea ecosystems capture huge quantities of carbon. For instance, on the continental shelf, microorganisms play a major role in sustainable storage of carbon produced by phytoplankton, but are also filters for methane formed by this fossilized matter. By using methane as energy, these microorganisms transform this greenhouse gas, which is much more powerful than CO_2, into minerals. This process prevents greenhouse gases from resurfacing and accelerating climate change.

Life and services provided by Deep Sea organisms depend very much on atmosphere and surface activity. As they are deprived of light, Deep Sea ecosystems are highly connected to food produced at the surface of the ocean, on which they depend greatly. Marine snow, a rain of organic matters, which drops from the surface, is often the base of the food web. Surface waters also provide oxygen for the deep abysses when they move down to the Deep Sea in the Pole Regions.

Consequently, modifications taking place at the surface, such as oxygen exhaustion or a decrease in phytoplankton, have impacts on life in the Deep Sea and can affect ecosystem functioning. According to observations, there are significant changes of food type and quantity originating from the surface and shifting to the abysses, several thousand metres deep. Are those "natural" events or the first signs of disturbances of the global water column from surface waters to the abyssal plains? 15 to 25 years observation series are still too short to come to a conclusion, but they confirm that Deep Sea biodiversity changes very quickly as soon as available resources are modified.

These ecosystems are dependent on many on-going changes. Concurrently with climate change, resource exploitation (minerals, hydrocarbons, fisheries) is spreading to the Deep Sea and brings its share of disruptions in fragile environments.

One point needs particular attention. When surface waters are warmer, they don't mix as well with deep waters. By reducing Deep Sea "ventilation", warming reduces the already low oxygen content, which naturally affects "intermediate" waters (several hundred meters deep) over wide regions of the tropical ocean. In some very productive regions, north of the Indian Ocean, the West Coast of the United States or even Peru, Chile or Namibia, observations show that less oxygenated waters or waters deprived of oxygen spread and greatly reduce habitat spaces for certain species, like Tuna or Marlin, in favour of other species capable of tolerating these conditions, such as calamari which can affect the entire ecosystem by proliferating.

Other more subtle modifications can have drastic impacts on ecosystems. The increase in water temperature, even by a 10th of a degree every 10 years in certain Polar Regions, enables some predator crabs to expand their territory and decimate species until then protected by extremely cold waters (-1,5°C).

In other regions, there are concerns over the acidification effect of waters, which have absorbed great quantities of CO_2, and can cause the deterioration of deep coral reefs, while many fish and shellfish species depend on them. Lab studies show that a combination of this phenomenon with deoxygenation of waters, like in the Gulf of Mexico, where the warming of deep waters already unusually as warm, like in the Mediterranean, is particularly critical.

As deep biodiversity reacts rather rapidly to change, it is crucial to consider these risks in order to avoid jeopardizing the mitigation capacity of oceans toward climate disruption and other services provided by the Deep Sea's biodiversity.

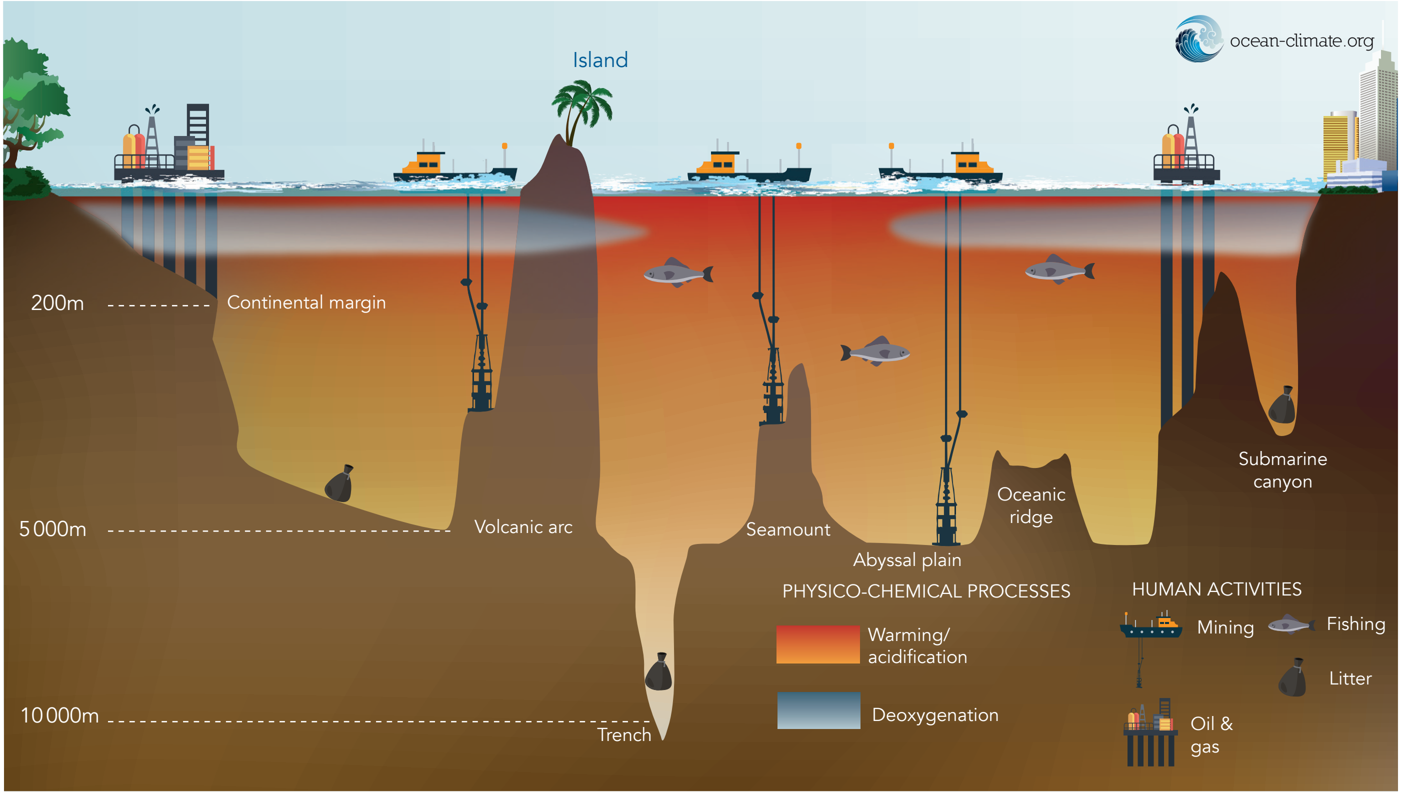
THE DEEP SEA: A KEY PLAYER TO BE PROTECTED FOR CLIMATE AND ECOSYSTEMS (2/2)

The first step is to explicitly acknowledge the role of the Deep Sea in climate change mitigation, the sensitivity specific to Deep Sea species, and their potential effects on the surface of the ocean or the atmosphere. The regulation of excess heat and CO_2 can have irreversible short term consequences on Deep Sea organisms.

Shared effort is crucial to develop the knowledge and necessary tools for an efficient protection of most vulnerable ecosystems. Deep Sea ecology remains a young science. Less than 150 years ago, scientists factored out the possibility of marine life below 500 meters under the sea level. Since then, each exploration brings new proof of extraordinary diversity of life in the ocean and the capacity of species to live in exceptional conditions (temperature, oxygenation, acidity, pressure, etc.). The question is whether or not this adaptation capacity will resist to climate change-induced disruptions. However, it is important to acknowledge that for now there is very limited visibility of the destabilization these ecosystems suffer due to disturbances predicted by the greenhouse gas emission scenarios.

In this context, Marine Protected Areas are valuable, especially when they spread to the open sea and include remarkable Deep Sea ecosystems, such as those of canyons or underwater mountains which play an important role in the interaction with surface ecosystems. By protecting and enabling a long term follow up of these biodiversity "hotspots", these Marine Protected Areas are also natural laboratories for a better understanding of climate change effects and impacts on these ecosystems.

Anticipating vulnerabilities and defining efficient protection measures is a crucial issue, while many climate emergencies tend to leave behind this remarkable heritage, invisible to most of us.



By Levin and Le Bris,Science 13 Nov. 2015 • Vol. 350 Issue 6262.

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PERSPECTIVES

The definition of words starred with an asterisk can be found in the OCP little dictionnary section, on the last page of this document.

CLIMATE CHANGE LONG-TERM CONSEQUENCES

Most of the debate regarding mitigation* and adaptation* measures to take against climate change is based on data collected in the last 150 years, for instance temperature measurement. It is also based on climate predictions for the next 85 years, until 2100. Concurrently with medium term climate change consequences on our planet, scientists are drawing scenarios to expand our field of vision beyond 2100 and consider future scenarios. These studies provide crucial information to clarify the long term destiny of Planet Earth's climate and the public consultation on measures to be taken.

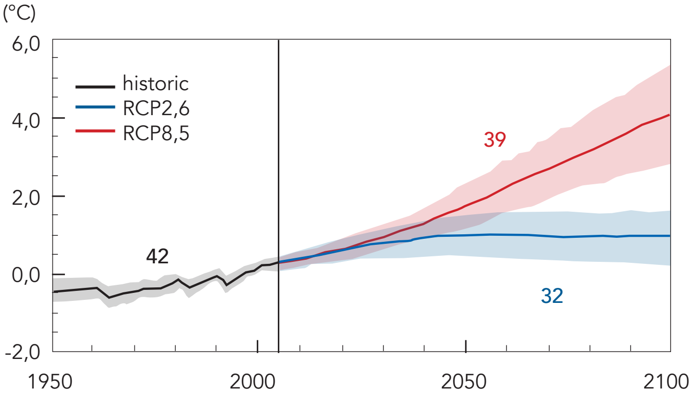
The study based on digital simulations considers 4 total carbon emissions produced in the atmosphere. It shows that even if we use approximately 15% of existing resources, very significant changes are anticipated: a high probability of going over the +2°C limit mentioned in the Paris Agreement and approximately a 10 metre global sea level rise. In this reduced emissions scenario, there is a population of 1.3 billion people living in 2010 on to-be flooded land due to future sea-level rise. This scenario lets us produce 1.5 times the total quantity of CO_2 emitted since the industrial revolution. At the current pace this should take 70 years, beyond which all emissions should stop.

For the most pessimistic scenario, the use of 70 to 90% of existing resources would most likely lead to over 5°C temperature increase for over 10,000 years. Concurrently, a 2 to 4 metre sea level rise per century is expected during the next millennium. The sea level could end up going beyond its current 25 to 50m level.

These results confirm the importance of efficient actions to leave as much available fossil fuel as possible underground. On the contrary, merely reducing CO_2 emissions even significantly, does not resolve anything in the long term.

In order to understand long term effects of our current emissions, two factors must be considered: *1)* a great part of anthropic CO_2 that we produce remains active in the atmosphere for a very long time; *2)* planet Earth's climate system has great inertia (mostly due to the ocean), which means that when disturbed it takes several millennia to adjust, in temperature for instance.

As a result, current and future generations will suffer a small part of consequences due to current CO_2 anthropic emissions. Our children's descendants will suffer the majority of these consequences for hundreds of generations. The authors therefore support a presentation of climate risks not only limited to the next 85 years in order for decisions and public consultations to include very long term consequences of current emissions.



Mean temperature evolution
according to emissions scenarios (IPCC)

THE OPC'S LITTLE DICTIONNARY

ADAPTATION. Individual or collective measures that aim to reduce vulnerability of natural and human systems by adopting practices that will help cope with climate changes.

MITIGATION. Any action that stabilizes the concentrations of greenhouse gases in the atmosphere at a level that prevents irremediable consequences for the survival of ecosystems and humans alike.

CARBONATES. Ion carbonate (CO_3^{2-}) that contains carbon can associate with other elements such as calcium. Calcium carbonate is the main component of numerous organisms' shells. The formation and stability of calcium carbonate depend on the availability of Ca ions and on the waters acidity. In an acidic environment, calcium carbonate transforms into calcium bicarbonate, which is very soluble in water.

GEOENGINEERING. All techniques aiming to manipulate and modify the Earth's climate and environment.

MODEL. Conceptualised representation of a natural phenomenon allowing their understanding or prediction. Climate models couple representations of the atmosphere, ocean, sea ices, biogeochemical processes… To be valid, models are tested with known data. Then, data is injected to obtain forecast results at different timescales.

BIOLOGICAL PUMP. Biological processes to extract carbon from the physical environment it is in. All organic matters that fall on the seabed participate in the biological pump.

PHYSICAL PUMP. CO_2 dissolution process that is dependant on water temperature. As the water gets cooler, more CO_2 dissolves, hence the importance of Polar Regions in the carbon cycle.

PRIMARY PRODUCTION. Production of living matter generally linked to the fixing of atmospheric carbon by plants thanks to photosynthesis. In the ocean, this production is mainly due to phytoplankton micro-algae.

FISHING QUOTAS. In most industrialised countries, and namely in Europe, fishing quotas are determined every year, for each of the major exploited stocks, in order to limit the catch, and thus the pressure exerted on the resource.

Definitions match concepts as defined by the International Panel on Climate Change (IPCC)