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Climate changes

Introduction

The weather has a permanent influence on our lives. The sky is often the first thing we look when we wake up in the morning. Pressure and humidity affect our body and mood; who has never said “today I am depressed: I should probably blame it on the rain?”. At least once a day most of us want to see or hear a weather forecast and ever since we were born we are used to season cycles that regulate the biologic cycles of all living beings. Popular sayings have been invented about the weather that often sound silly; but the sentence “seasons no longer are the way they used to be”, no matter how old a complaint, because Virgil said it 2000 years ago, has never seemed so a propos as in the past years. In the last years, in fact, we have had springs that seemed like summers, winters that seemed like autumns and meanwhile the media keep telling us about greenhouse gasses and global warming, environmentalists give catastrophic forecasts for the future, while scientists and politicians are obviously trying to calm the alarmism. In all this great confusion it is always us “normal people”, to be left without any clear ideas and so it is our duty to at least try to understand a little bit better the way how things actually stand.

Climate

What is climate?

The word climate derives from the Greek word κλιμα, or inclination. Climate, in fact, is partly determined by the inclination of the sun’s rays on the Earth’s surface, which varies with the latitude and seasons. The term “climate” is often used as a synonym of meteorological “weather” even though their meanings are quite different.
Meteorological weather is the set of meteorological elements that characterize the atmosphere at a precise moment. If we look out of the window we can immediately see what the weather is like. The climate, instead, is defined as the “set of meteorological phenomena (e.g. temperature, precipitation, winds, etc.) that characterize the average state of the atmosphere at a particular point of the Earth’s surface”, (according to the definition given by J. Hann an Austrian meteorologist). Due to the extreme variability of meteorological parameters, the World Meteorological Organization has established that, in order to identify climatic characteristics, and therefore the “average state of the atmosphere”, of a particular location, the minimum duration of the historical time-series of meteorological data must be at least 30 years. The discipline that studies the climate, its elements and its factors, and classifies the types of climate is called climatology.

Sun and climate

If the Earth rotated around the sun in a perfectly vertical way like a spinning top, the weather wouldn’t vary during the year, in other words there wouldn’t be any seasons, because the amount of solar radiation reaching the planet’ surface would always be the same. If the earth’s axis wasn’t at an angle with respect to the orbital plane, not only would there be no seasons, but neither could there be any differences between one hemisphere and the other and obviously the tropics would not exist. Instead, fortunately for us, during the year the inclination of earth’s axis with respect to the solar rays changes thus varying the angle at which they reach the planet. Therefore on the 21st of June, summer solstice, the solar rays are perpendicular to the imaginary line called Tropic of Cancer in our hemisphere; while the 22nd of December, which is winter solstice in our hemisphere whereas it is summer in the Austral one, solar rays are perpendicular with respect to the imaginary line called Tropic of Capricorn which is in the southern hemisphere. During each equinox, instead, solar rays are perpendicular to the Equator. Rays that reach the ground perpendicularly have the maximum atmosphere penetration power and the maximum thermal effect at both tropics, which is why the tropical belt is the area with the hottest and most constant climate all year round. Climate variation increases as one goes north towards the boreal hemisphere and south towards the Austral one. The temperature difference among the various latitudes trigger the complex climatic thermodynamics which actually are influenced by many other factors: local geology, the presence of large water masses or high altitudes and atmospheric conditions. A clear example of how the local geography influences climate is the Assuan dam that created the Nasser Lake, PIC21 a huge artificial basin that had deep implications not only on the region's weather, but also on the southern Mediterranean area. Before it was built it was impossible to imagine that it would affect the weather so heavily and from that we have learned that weather dynamics are really complex phenomena to foresee with mathematical precision.

Radiation Balance and Greenhouse effect

Apart from a small amount of energy that comes from inside the Earth, the energy that feeds the climate system of our planet comes mainly from the Sun. In fact the Earth receives the radiant energy of the Sun (i.e. transported by electromagnetic radiation), about half of which is visible light, a small part is ultraviolet light, and the remaining part is infrared light.
The solar radiation that hits the Earth's surface in one hour is equal to approximately 342 w/m^2; out of which only 235 w/m2 are actually absorbed by the Earth's surface, while the remaining 107 are immediately reflected into space. The percentage of total incident radiation reflected from the Earth's surface is known as albedo. The Earth's albedo, therefore, is equal to 30% (342/107=30%). Out of these 107 w/m^2, 77 are reflected by the clouds, by gases and by the micro-particles that are present in the atmosphere (aerosol), while the remaining 30 w/m2 return to the atmosphere as they are reflected by light-coloured surfaces present on the Earth, consisting prevalently of glaciers, snow and deserts. Snow has a very high albedo, equal to 0.9, which means that 90% of the radiation that hits the snow is reflected.
The energy that is not reflected into space, equal to 235 w/m^2, is absorbed by the Earth's surface and by the atmosphere, and is re-emitted in the form of infrared radiations (heat). The atmosphere, which consists prevalently of nitrogen and oxygen, that are transparent to infrared thermal radiation, let these radiations escape into space. However there are some gases (known as greenhouse gases) that absorb thermal radiation and prevent their dispersion, and this causes a warming of the atmosphere. This natural physical phenomenon, called greenhouse effect is very important for life on Earth because it allows the Earth's surface to have an average temperature of 14°C instead of -18°C which would be the case without greenhouse gases in the atmosphere.

Greenhouse effect

Anthropic or natural?

As already mentioned in the previous paragraphs, the greenhouse effect is a natural phenomenon, provoked by a mixture of gases that are present in the atmosphere (and defined greenhouse gases) without which there would not be any life on the Earth. In the last century, however, the intense human production activities led to an increase in the concentration of "greenhouse gases" in the atmosphere. There are two main causes: on one hand the increasing amount of emissions originated prevalently by the traditional processes for the production of energy (fossil fuels); on the other, the progressive destruction of the forests which, thanks to plant chlorophyll photosynthesis, can "absorb" the carbon dioxide in the air and transform it into organic material (leaves, branches and roots), acting as true "tanks" or "sinks" for carbon dioxide. If the concentration of greenhouse gases continues to increase at the rhythm of the last decades, there is the risk that a rapid warming in the Earth's climate may be triggered, because the capacity of the atmosphere to hold back the heat on the Earth is increasing progressively. An excessive increase in a short period of time, of the temperatures of the atmosphere and of the oceans, would have dramatic effects on the climate balance and a remarkable impact on human beings.
According to some climate experts, if human behaviour does not change, in the next 100 years the Earth's temperature may increase an average of 1.0 to 3.5°C. Other data give us an indication of the variations which occurred in the past century: from the industrial revolution to date, the concentration of carbon dioxide in the atmosphere has increased 30%, during the same period the concentration of methane, emitted principally by the rice fields and cattle farms, has increased 145%. Many experts, appointed by national and international organizations, among which IPCC (Intergovernmental Panel on Climate Change) have, since some years, been monitoring the climate of our planet and

studying the possible effects of the increase in temperature of the lower atmosphere and of the Earth's surface, which will be examined in detail in the following paragraph.

Consequences of climate changes

Based on the researches of the International Organism that studies climate changes, IPCC (Intergovernmental Panel on Climate Change), the increase in the concentrations of greenhouse gas in the atmosphere is the main cause of the intensification of the following phenomena:

- Increase in Planet temperature: from 1860 to date, the Earth's average temperature has increased 0.6°C and almost 1°C in Europe alone. Scientists have estimated a further increase in the temperature ranging between 1.4°C and 5.8°C by the end of the century.
- Increase in the precipitation: mainly in the Northern Hemisphere, and in particular in the middle and high latitudes. In the tropical and subtropical regions, instead, a decrease in the amount of rain.
- Increase in the frequency and intensity of extreme climatic events: there still are no scientific data to demonstrate this point, however one of the consequences of climate changes apparently seems to be the increase in catastrophic events. In fact there may be long periods of draught, sudden exceptional rainfall, floods, waves of excessive heat and cold. Tropical cyclones may be strengthened by violent rainfall, winds and the sea level.
- Increase in the risk of desertification in some areas.
- Decrease in the glaciers and permafrost: 9 glaciers out of 10 in the world are melting, and it is probable that by 2050, 75% of the Swiss glaciers will have disappeared.
- Rise in the sea level: during the last 100 years, the sea level increased 10-25 cm and it seems that it might increase 88 cm more by 2100. At least 70 million inhabitants in the coastal areas of Europe may be at risk.
- Loss of biodiversity: many animal species will not be able to adapt to these rapid climate changes. In fact experts have established that ecosystems can adapt to changes amounting to 1°C in a century. Among the animals that are most endangered, we find the polar bears, seals, walruses and penguins
- Problems in food production: with excessive rainfall and intense heat, cultures are at risk, and famine and malnutrition follow. FAO has estimated that there will be a loss of approximately 11% of the land that is fit for cultivation in the developing countries by 2080, with a decrease in the production of cereals and a consequent increase in world hunger.
- Diffusion of diseases: it seems that climate change can favour the diffusion of tropical diseases such as malaria and dengue. In fact the mosquitoes that carry these diseases are shifting north, where the temperature is rising. Furthermore an increase in temperature favours the biological pollution of water, which leads to a proliferation of infesting organisms.

Greenhouse gases

Natural greenhouse gases include water vapour, carbon dioxide, methane, nitrogen protoxide and nitrogen. Some human activities contribute to the increase in the concentration of these gases in the atmosphere and, furthermore, they free other greenhouse gases that are exclusively anthropogenic in the air.
Let us now examine the characteristics of the principal gases which have a greenhouse effect, in detail:

Water vapour

Water vapour is the principal greenhouse gas, it is responsible for 2/3 of the natural greenhouse effect, due to its abundance in the atmosphere and due to its efficacy. Atmospheric water vapour is part of the water cycle, a closed system of water circulation from the oceans and the continents to the atmosphere in a continuous cycle of evaporation, transpiration, condensation and precipitation. Its concentration is very variable in space, but relatively stable in time. Furthermore it is not directly influenced by human activities, but depends exclusively on the air temperature. For every degree Celsius more, the content of water vapour in the air increases 7%.

Carbon dioxide

Carbon dioxide (CO_2) is the principal greenhouse gas deriving from human activities, and it is the one that contributes most to the anthropic greenhouse effect.

CO_2 is one of the main compounds of carbon and is the principal vehicle for carbon exchange in nature between reservoirs (or pools) that are present in the atmosphere, hydrosphere, geosphere and biosphere, through processes that form the carbon cycle:

- in the biosphere, carbon is present in organic molecules (e.g. lipids, glucides, etc.) amounting to about 2,000 billion tons or gigatons;
- in the oceans, carbon is dissolved in the form of carbonates and bicarbonates, amounting to about 39,000 gigatons;
- in the geosphere, carbon can be found in the form of limestone, amounting to 90,000,000 gigatons and fossil fuel amounting to 6,000 gigatons;
- in the atmosphere, carbon is found in the form of carbon dioxide, amounting to 750 gigatons.

These reservoirs are tied to each other by exchanges, and their natural balance, in absence of human activities, is practically equal. Starting from the Industrial Revolution, with the intensification of human activities, the concentrations of carbon dioxide in the atmosphere increased, and today CO_2 is responsible for 65% of the anthropic greenhouse effect. The carbon dioxide deriving from human activities is tied principally to the fossil fuels combustion reaction, to deforestation and changes in land use. CO_2 can persist in the atmosphere for a period that varies between 50 and 250 years before returning to the ground.

Methane

Methane (CH_4) is derived from anaerobic fermentation (i.e. from decomposition) of organic substances. In nature, methane is emitted by mangrove swamps, while the anthropogenic emissions derive mainly from the use of fossil fuels, animal farming, agriculture (paddy fields) and city dumps. Even though it is more powerful than CO2, methane contributes to 17% of the anthropic greenhouse effect due to the minor concentration and the shorter period in which it remains in the atmosphere, compared to carbon dioxide.

Nitrogen protoxide

Nitrogen protoxide (N_2O) is a very powerful greenhouse gas, with a very long time of persistence in the atmosphere (120 years). Natural sources of N_2O are the oceans, the rainforests and the bacteria that are present in the ground. With regard to human activities, instead, it derives mainly from nitrogen fertilizers used in agriculture and some industrial productions.

Chlorofluorocarbons

Chlorofluorocarbons or CFC, unlike the gases described here above, which can all be found in nature, are produced artificially by humans and used as refrigerants, spray bottle propellants, and fire extinguishers.

Besides being responsible for destroying the ozone in the stratosphere (Ozone Hole) they are powerful greenhouse gases and they persist in the atmosphere for thousands of years. Their emissions have been remarkably reduced with the application of the Montreal Protocol (1987) which prohibited their use. However even the gases that they have been replaced with (hydrofluorocarbons and perfluorocarbons) are powerful greenhouse gases.

Comparing greenhouse gases

In order to calculate the contribution of the different gases to the greenhouse effect, three fundamental parameters must be taken into consideration:

- concentration in the atmosphere;
- radiative forcing of each gas, i.e. the capacity to trap the energy going from our Planet into Space;
- persistence in the atmosphere of each gas, i.e. the mean time the gas remains in the atmosphere; in fact if a gas remains in the atmosphere for a short period of time it will have a lesser effect than a gas that remains for a long period of time.

Since the greenhouse gases have various capacities of absorbing infrared radiations, the concept of Global Warming Potential (GWP) has been introduced. Therefore all the gases are compared to carbon dioxide, which has been assigned a potential = 1.

When the greenhouse effect "born"

In 1824 the French scientist Jean Baptiste Fourier, who made some famous discoveries in physics and mathematics, was the first one to talk about "greenhouse effect" and measure it with the helium thermometer. The theory is that the atmosphere acts as the glass enclosure of a greenhouse, which lets solar rays through while it tends to trap the thermal rays which are released by the planet's surface. Thanks to this, Earth's average temperature is stable around 15°C, instead of approximately the -19°C that it would be without "greenhouse gasses". The greenhouse effect is a natural phenomenon which happens on all planets that have an atmosphere . Thus the problem arises from the atmospheric composition which can increase or decrease its effects.
In 1895, about 150 years after the Industrial Revolution the Swedish scientist Svante Arrehenius was able to understand that the increase of carbon dioxide (CO_2) in the atmosphere, was going to eventually bring about a global warming of the Planet. In 1955 Charles Keeling confirmed that carbon dioxide levels were rising to the point that an actual observatory was set up in Hawaii to keep track of the concentration of this gas in the atmosphere.
At the end of the 80's the United Nations created a committee of experts called IPCC (Intergovernmental Panel on Climate Change) to classify and analyze the results coming from the different studies.

What is the IPCC?

Since the end of the Eighties, scientists have become aware that the great amount of human-induced greenhouse gas emissions was causing an increase in the greenhouse effect, and consequently, significant changes in climate which could trigger many problems. In order to have a clearer and more thorough knowledge of the situation, the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) created the **IPCC**, the *Intergovernmental Panel on Climate Change,* in 1988 with the intention of providing "a clear scientific view on the current state of knowledge in climate change and its potential environmental and socio-economic impacts". The IPCC is an intergovernmental body which the member countries of both the UNEP and the WMO have joined. It does not involve carrying out direct research but rather assessments. So what does it do exactly? The IPCC aims at collecting and summarising all relevant information available to better understand the phenomenon of climate change and its possible impacts; in particular, the risks to human health associated with climate change, as well as the possible response strategies to be implemented, such as adaptation and mitigation. These measures, put forward by the scientific community worldwide, are carefully checked by hundreds of experts that ensure the validity of the information collected. Each participating government has a designated Focal Point IPCC, whose task is to coordinate the activities in the country. The importance of this project was recognised in 2007 when IPCC and Albert (Al) Gore Jr. were awarded the Nobel Peace Prize for "their efforts to build up and disseminate greater knowledge about man-made climate change, and to lay the foundations for the measures that are needed to counteract such change"

The IPCC è divided into three working groups (**WG**) and a task force:

- WG I assesses the climate system from a physical point of view;
- WG II assesses the vulnerability of natural and socio-economic systems, the impacts of climate change and the possible adaptation options;
- WG III assesses options for mitigating climate change and proposes economic evaluations;
- the Task Force on National Greenhouse Gas Inventories oversees the IPCC National Greenhouse Gas Inventories Programme which aims to develop and refine an internationally agreed methodology and software for the calculation and reporting of national greenhouse gas emissions.

Once a year the Panel meets in plenary session to adopt all official decisions such as the approval of reports and the definition of future work projects.
Hence the main task of the IPCC is to periodically produce an Assessment Report (AR) which contains the state-of-the-art of the most significant literature put forward by scientists in the field of climate change. The Assessment Report is divided into three parts, one for each Working Group. The first report was published in 1990, the second in 1995, the third in 2001 and the fourth in 2007. The Fifth Assessment Report was published in 2014; it was completed in April 2014.
Besides the Assessment Reports, the IPCC also prepares Special Reports and Technical Papers, which even provide scientific support to the United Nations Framework Convention on Climate Change – UNFCCC.

Climate through the ages

Climate on Earth

Through the centuries Earth has always had climate variations. What must be analyzed is how great they are, the impact that they have on our lives, and how long they last. In a human being's life time, one can experience seasonal or annual changes, such as years that are warmer or rainier than others. Throughout the centuries, in fact there have been much greater climate variations than we have nowadays. An increase in temperatures is always associated with the melting of polar and continental ices, with the consequent rise in sea levels. In the past 500 million years sea levels have varied by as much as a few hundred meters (200-300 meters) from nowadays level but with a much longer duration, roughly 300 million years, which means that they would not have been noticeable in a man's lifetime.

Sea level oscillation causes

There are several different causes involved in sea level oscillation but they are usually geological, climatic, astronomic or anthropical events.
The main ones are:

- variations in ocean basin capacity, meaning the areas occupied by water;
- variations in the amount of ocean water;
- minor variations such as: sea water density, sea water desiccation, marine meteorological parameters (atmospheric pressure and winds).

In the first case, variations in ocean basin capacity are caused by geological processes within the planet. We know that on the ocean floor there are belts called "oceanic ridges" where magma moves upwards, towards the surface swelling the earth's crust so the mass of water is displaced with the consequent rise in sea level. This is very slow process which causes the level to vary by approximately one centimeter every thousand years so man cannot notice it in a lifetime.
Ocean water quantity variation, instead, is brought about by climatic causes: during colder weather periods, a large part of the water of the oceans is trapped in the Arctic and Antarctic glacial caps as well as in continental glaciers, while during warmer weather, the ices melt causing the sea level to rise quickly, as much as one centimeter per year. In the

past century large quantities of man made greenhouse gasses have been added to the natural causes which are bringing about climate changes at a much faster pace, and all this is having a big effect on us.

Quaternary or glacial era

Major climate variations have taken place during the Quaternary period (the past 2,5 million years), which is when man made his first appearance on Earth, caused by the massive expansion of the polar caps approximately every 100 thousand years, that made the sea level decrease by as much as 120 – 140 meters below what it is today.
We must bear in mind that the last glaciation allowed man to spread all over the world, thanks to the spits of dry land emerging from the lowered sea level. These periods were followed by other warmer ones with temperatures which were similar to the ones we have today which allowed the ice to melt and consequently increase the sea level. Shortly before the beginning of the Quaternary because of the tectonic plates which allows vast areas of dry land to shift, the distance between south America, Africa and the Antarctic continent induced an ocean current similar to a gigantic “river” moving a volume of water 100 times the size of the Amazon River. This river submerged from the north Atlantic, reaching the ocean floor and traveling the whole length of the Atlantic Ocean from north to south going around Africa to then spread into the Indian Ocean while part of it went as far as the Pacific Ocean. This enormous volume of water is still moving today and acts as a huge conveyor belt for heat, as though it were a gigantic air conditioning system that controls the weather on Earth. When the hot current reaches as far north as Iceland it encounters the cold winds from Canada so it cools off, releasing the heat into the air and mitigating the effect that these winds would have on northern Europe.
With the evaporation water becomes more dense and tends to sink, generating a cold deep current. The amount of heat carried by this enormous “conveyor belt” depends obviously on how much is stored during its formation. At present the “conveyor belt” is near Iceland, but its latitude can vary, oscillating to the point of interruption, thus causing a break down of the heat distribution system.
As time passes, the sun’s heat reaching the surface of Earth and the sea, changes according to the orbital parameters of our Planet.
There are three main causes for latitude variations:

- shift in the axis inclination of Earth’s rotation: the Earth’s axis inclination has a slow oscillation that goes from 21,8° to 24,4° in a stable period spanning approximately 40,000 years. Currently the angle is 23.45° and is decreasing, thus diminishing the contrast between summers and winters.
- changes in the eccentricity of Earth’s orbit: the planet’s orbit changes from an almost perfect circumference to a marked ellipse. When it is an ellipse, the planet is closer to the sun, otherwise, it is more distant. A complete orbital cycle going from an almost round orbit to an ellipse one and vice versa, takes 100,000 years.
- precession of the equinoxes: this is the celestial phenomenon whereby the axis of our planet goes a complete circle around an imaginary cone every 26,000 years. This is the reason why the seasons have a slow tendency to come sooner and be modified. The same thing happens when one spins a spinning top which in fact is very difficult to keep straight with its axis perfectly perpendicular to the ground. It is more likely to have an eccentric spinning motion and its point will gradually design a cone as it goes around. Something similar happens to our planet although the forces that cause this are obviously different.

Therefore, over thousands of years, Earth changes its position with respect to the sun to then start all over again every 26,000, 40,000 and 100,000 years. The combination of these three elements will modify the amount of energy(Watt per m2): when the point of no return is reached, the heat is so intense that the glaciers melt and reach a peak, whereby the climate is similar to what we have nowadays and lasts for a time span ranging from 6,000 to 13,000 years, until Earth’s geometry gradually changes causing glaciers to build back up quite quickly (within just a few hundred years).

Recent ages: the year without a summer

During the Roman era the climate was rather warm, and we have proof of this from the pools that Ancient Romans used

to breed eel. In fact these pools had two holes, one at high tide level and the other at low tide level. At high tide fresh sea water would come in through the first hole while stagnant water left the pool through the second one at low tide, so that the pools had a constant fresh water turnover which worked the same way as modern day aquarium filtering systems. Tides in the Mediterranean sea range approximately 20 cm. so we can know exactly where the sea level was at in those times and consequently we also know what the climate was like.
In history we are told that in 218 b.C. Hannibal crossed the Alps with elephants, which gives us a reason to believe that at that altitude there was no snow, or better yet, perennial snow was easily accessible as opposed to nowadays.
In the Middle Ages they had a long warm period that spanned more or less from the 9th to the 12th century. At the time grapes were grown in England, 500 km further north compared to today.
From about 1200 to about 1850, Earth went through a long cold phase which affected particularly Europe. The Vikings left Greenland where the ports were blocked by ice. The glaciers crept forward and many alpine valleys were abandoned. This is the coldest time in the past 8,000 years, and is in fact called the “Small Glacial Era” and 1816 will go down in history as the year without a summer: In paintings from the 1700s Venice is portrayed as being completely frozen and Bethlehem is covered with snow. Apparently, even during the famous Waterloo Battle, heavy rains had blocked Napoleon and left his cavalry troops stranded in the mud. After that the temperature rose until it reached its peak in 1950.
Between the Small Glacial Era and today average temperatures have risen by 0.5 – 1.0 degrees. World glaciers are shrinking while sea levels are rising by about 2 mm. per year. This is the global warming which apparently has been caused by man. According to some scientists such as those from ICRAM (Istituto Centrale per la Ricerca Scientifica e Tecnologica Applicata al Mare), the current phase might indicate a part of the hot/cold cycle with a normal rise in temperatures following a cold phase which peaked, as we mentioned, during the first half of the 19th century, one of the most obvious in the middle and recent Holocene age.

Studying the climate

Core boring

Core boring is a sampling technique used to research mineral resources in the subsoil by boring wells in order to analyze the ground, and for other digging activities for civil engineering purposes. In core boring a cylinder shaped sample of rock or ice is extracted, which is known as a core. From these cores it is possible to obtain a large amount of information on the climate variations of the past, thanks to what remains imprisoned in the ice, such as : gas bubbles, chemical elements that form the ice, sediments, fossils and many other elements. These traces are true witnesses of past periods, and are useful in order to reconstruct the climatic history of the Earth. Ice cores, in fact, maintain the chemical and isotopic characteristics obtained from the snow in the atmosphere at the time of condensation and precipitation, characteristics that remain mostly unaltered in the ice. Ice core boring is possible in the internal areas of Greenland and the Antarctic as the temperature always remains below zero and therefore the is no surface fusion, and the snow that accumulates each year forms a regular and continuous stratigraphic succession of layer upon layer of snowfall. With the passing of time the snow is compacted and the empty spaces are decreased and the snow is transformed first into firn or névé and then into ice, the pores become occluded and the air bubbles are trapped and therefore provide samples of the atmosphere in the past.

Fossil pollens

The study of pollens can reconstruct the history of vegetation in the past, and therefore of climate changes in time. For example we can imagine a fossil lake, preserved in different sediments, just like a filing cabinet with many drawers: each layer is a drawer containing the pollens of all the plants that grew at that particular time in the surrounding area. There are plants, in fact, that are considered climatic indicators – in other words they live in a particular region only if the climate is suited to their needs. For example oaks, hazel trees and linden trees which are all broadleaf trees, only live in temperate-warm climates and will never be found in regions with a rigid climate. Fir trees and beech trees instead, live in regions with a fresher, humid climate. In regions with a cold continental climate, only some types of grasses can be

found, which form ecosystems such as the tundra or the steppes. If the climate of a particular region changes in time, obviously also the vegetation shall change and shall follow the various climatic oscillations very closely. This is exactly what we can see when we study the evolution of vegetation in a fossil lake or in any other deposit of sediments. Once a suitable area is identified, samples are obtained by drilling and core boring. Once the samples are extracted they are taken to a laboratory and treated with chemical agents in order to eliminate any excess organic and inorganic fraction, and finally the pollens are obtained.
Subsequently, with the help of a microscope, a detailed analysis will help to recognize the various species of plants that were present in the area and therefore reconstruct the climatic oscillations of the past. The data that are collected, are then summarized in diagrams that visually represent the vicissitudes of the various historical periods. The next steps of the analysis consist in attributing a relative age to each climatic phase, and following the sequence of the events that have taken place over the centuries.

Isotopic stratigraphy

Isotopic stratigraphy is based on the study of isotopes, especially carbon and oxygen isotopes. This technique can be used to study variations in temperature, salinity and volume of masses of ice in time. Generally, planktonic and benthonic foraminifera living in the surface layers of the sea or in sea sediments, are studied. After treating the organisms with the help of a specific instrument, the isotopic ratio of “heavy” oxygen-18 and normal oxygen-16, contained in the calcite shells of the foraminifera, is measured. If the calcite shows an isotopic equilibrium with the sea water, the ratio of the two oxygen isotopes varies with the precipitation temperature of the calcite. Therefore an increase in the isotopic equilibrium of the oxygen in a carbonate indicates a drop in the temperature, while a decrease in the same indicates a rise in temperature. Simplifying, it is therefore possible to trace the periodic fluctuations of the climate in time.

Geological traces

In certainly is no easy task to retrace all the sea level variations that have happened in thousands of years. Several different geological techniques which focus on studying specific areas near the coastlines have been used to trace these variations.

- the sea digs a horizontal crevice at water level at the base of a cliff which becomes deeper as time goes by. When the sea level decreases, it makes a new etching. Sea level variations can be discovered by measuring the height difference between these two marks
- speleothem: if near the sea there is a cave with stalactites, one can discover sea level variations by studying these stalactites. When the sea level is below the cave the stalactite grows because the water that seeps into the cave causes calcium carbonate to deposit, whereas its formation stops when the sea invades the cave but some organisms carry on with the stalactite’s concretion. These animals which are called serpulides have a calcium carbonate outer shell which therefore can be given an age with the radiocarbon technique and thus enable us to discover when the sea came into contact with the stalactite
- when the sea level rises and encounters a specific land conformation it will form a very shallow inland lagoon called “paleolagoon”. This lagoon is where sediment and fossil shells will deposit. Then when the sea level diminishes, one will find organic deposits at different heights on the hills. The age of these deposits is analyzed in order to find out when the sea was at that specific level
- when the sea level rises and meets a shelf made of soft rock which is easily eroded, it creates a terrace shaped platform known as “marine terrace” and a sort of slope. At the flex point between the abrasion platform and the beginning of the slope, a place called the “inner edge”, one can measure the sea level of the past.

Climate variations

If we have many geological markers we can draw a eustatic graph which traces the different sea levels over the

millennia. For instance, 220,000 years ago the sea was 3 meters below its current level and about 140,000 years ago it was as much as 140 meters below its level nowadays. Right after that, during the Tirrenian period about 125,000 years ago it rose suddenly to 7 meters above today's level.
That was a very warm period, much warmer than it is today and with a much higher concentration of carbon dioxide. Obviously, if the sea level was 7 meters above what it is today, many of the current coast areas, such as Venice, did not exist.
At a much more recent time, about 22,000 years ago, there was the last glacial acme, which is the coldest moment of the last glacial era which had lowered the sea level by approximately 120 meters. At this time half of the Adriatic was dry land, Corsica and Sardinia were joined together, Elba was part of the peninsula, and Sicily was joined both to Italy and to Africa. Thanks to these dry lands, many African animals were able to migrate and settle in Italy (i.e. rhinoceros and elephants). Once the islands became separated from Italy, these species adjusted to the new environment, spawning new characteristics such as dwarfism. In fact, fossil remains were found in Sicily of a dwarf elephant that was no more than 1 meter tall. It was much smaller than its African relatives because on the island there were no predators that it would have needed to protect itself from but there was also little food available. With this great a decrease in sea levels, man found new fertile lands and hunting territories. After the glacial acme, the sea level started rising again until the present day.
Therefore, at the end of the Glacial Era, a new warm phase began and the ices have melted making the sea rise very quickly (about 10 meters in 100 years). In fact we find both historical and religious references to this period which became known as the Deluge.
The plains that were inhabited by man were flooded by the sea which forced man to move several times in a lifetime, specially in the areas surrounding the Black Sea which are rather flat. About 10,000 years ago the sea was 50 meters below today's level, then there was a global warming trend so the sea level rose suddenly about 5,000 years ago. This phase peaked approximately between 7,500 and 4,600 years ago, when Earth reached its highest temperatures in the past 10,000 years. About 6,000 years ago the Sahara had a very humid climate and was covered with grass lands that were inhabited by highly civilized populations.

Future scenarios

Future IPCC scenarios

In the past 20 years scientists have researched calculation models which try to foresee climate variations. These models are known as GCM (General Circulation Models). Some IPCC studies have been able to foresee four possible future scenarios (A1, A2, B1, B2), by taking into consideration population growth, economic development, available resources (meaning primary energy sources) and technology. These hypothetical evolutions are called "scenario families".

A1: this scenario family foresees a rapid economic growth, the population will continue to increase until 2050 to begin decreasing after that and there will be a rapid introduction of new more efficient technologies. This family develops three groups that describe alternative directions for technological development in the energetic system: A1FI a future with fossil fuels, A1T non fossil resources, A1B a balance between fossil fuels and other sources.

A2: This scenario foresees a very heterogeneous world. There will be a constant demographic increase with very slow and irregular pro capita economic growth and technological development.

B1: This scenario as well foresees that the demographic growth will continue until the middle of the century to then start decreasing, but there will be a fast change in the economic structure towards an economy based on information and services, with a reduction in material use and the introduction of clean and efficient resource technologies, in other words there will be a sustainable kind of development with limited use of resources.

B2: The population will continue to grow but at a slower rate compared to the A2 family, the economic development will be average and technological changes slow and differentiated but always aware of sustainable development.

Each scenario is supposed to have different levels of carbon dioxide emissions for the period ranging from 1990 to 2100. The main changes pointed out be the models besides the increase of greenhouse gas concentration in the atmosphere are the following three:

- Global warming of the lower atmosphere and the planet's surface.
- Acceleration of the water cycle in the atmosphere and the ground.
- Sea level increase.

Global warming

All mathematical models that have been studied so far foresee an overall warming of the lower layers of the atmosphere and of the planet's surface of 1.5 to 5.8 °C and a cooling of the upper layers of the atmosphere. There will be different changes at different latitudes.
High latitudes (polar and subpolar areas):
During the winter temperature increase will be greater than the global average increase and will affect the dry lands more than marine surfaces. At the poles there will be a decrease in marine ices and because ice plays a role in heat exchanges among the oceans, warming of the arctic areas and high latitudes will be greater. During the summer instead, the temperature increase will be lower than the average global one because of the strong thermal influence of the ocean.
Intermediate latitudes (mild areas):
During the summer temperature increase in the northern hemisphere will be greater than the global average, whereas during the winter it will be very similar to the global average.
Low latitudes (subtropical and equatorial areas):
Temperature increase in these areas will be minimal and lower than the average global heating. As opposed to other latitudes, it will be even throughout the seasons. This area is occupied mostly by the sea so surface temperature increases will only increase water evaporation rather than making the air temperature warmer.

The water cycle in the atmosphere and the ground

Precipitations will increase globally because of the rising temperature, and because there will be more evaporation which will mean more water vapor in the atmosphere, this will increase the amount and speed up the water cycle in the climate system.
Precipitations will increase particularly at high latitudes and the intra-tropical area both during the winter as well as during the summer. At intermediate latitudes instead, precipitation will increase only during the winter months. Locally some areas will have more dry spells and/or floods while others will have less. Rains will become more frequent and more intense so there will be an increased risk of floods.
At present we do not dispose of sufficient data to know if floods, hurricanes or tropical cyclones will increase or simply change the areas where they occur.

Sea levels

The average sea level will rise because of the ice melting and, according to the more pessimistic forecasts, it could rise as much as a meter higher than it is today; whereas according to the more optimistic forecasts it will rise by only 10 to 20 cm. Intermediate scenarios expect the sea level to rise 50 cm. by 2100.

And if an extraterrestrial creature should land on Earth…

In the 1700s James Hutton, geology's and modern scientific reasoning's forefather, invented the "Principle of knowledge", according to which it is necessary to study the past in order to have the key to understanding the present and attempt to foresee the future. Only through intensive scientific research it appears possible to separate the influence of human actions and activities from the long term trend which is determined by natural events. Hence the great importance of science both in terms of prevention which can cut the huge costs of intervention following natural disasters, and as a means to help plan future population developments, in other words, sustainable development. One must bear in mind that climate cycles have always occurred on planet Earth, therefore one must study and observe very carefully what happened in the past. In fact, as scientists working for ICRAM say, a hypothetical visitor from outer space, could consider Earth's climate evolution in a completely different way based on the observation's time span. Let's imagine that our extraterrestrial visitor's spaceship has broken down and he has landed on a beach in the early hours of the morning. This creature, who knows nothing at all about astronomy, will notice that the temperature will increase drastically between 8 o'clock in the morning and midday. What is going to happen in the next few hours? The extraterrestrial may think that he is destined to fry under the sun but in the following hours, as dusk and night arrive followed by a new day, will help him to understand that there is a daily cycle.

In the same way, by observing the climatic evolution of the past century, we can notice a global warming trend of the climate. This trend however is a natural part of secular variations that have been happening since the beginning of history. In the same way, if we could record climate variations for a period of time spanning hundreds of thousands of years, we would notice the alternation between glacial and interglacial cycles.
The catastrophic forecasts on sea level increases issued during the '80s by the United States Environmental Protection Agency, that foresaw an increase between 0.56 and 3.45 meters within the year 2100 have been disavowed and estimates have lowered considerably. In 1986 it was still a common belief that the seal level could rise by as much as 2 meters during the next century, while more recent forecasts expect a more likely half a meter increase in the sea level by the year 2100. Obviously even if "only" a half meter rise occurs, it would have some very negative consequences on the environment such as erosions, floods, saline intrusions, etc. As one can imagine, problems would be greater for coastal areas and flat lands.
The degree of uncertainty of the different forecast mathematical models studied so far is still too high, while local effects, which are normally not taken into consideration in global estimates, could very likely be predominant. On the other hand it is very difficult to foresee what will happen to the climate in 50 years time when we are not even certain of what the weather will be like tomorrow!
We still have many doubts even from a scientific point of view so we must do more research in order to understand better the complex climatic patterns, and take advantage of the so-called "precaution principle", that is to foresee the worst case scenario in order to "prevent" before the "cure" may become useless. Worst case scenario forecasts, even though uncertain, must always be taken into consideration when facing environmental planning and managing activities.
And what can each one of us citizens do in this climate of uncertainty? Obviously each and everyone one of us can help. One just needs to think that 25% of North American carbon dioxide emissions are produced by private citizens, which is the equivalent of 9 tons of CO_2 pro capita per year.

Some clarifications about the climate

The myth of luxuriant Greenland

The example of Greenland is often mentioned, to show the climate changes caused by man. About one thousand years ago the Viking Erik the Red called the largest island in the world "Grönland", or "green land". 84% of its surface today is covered with ice. In 982 A.D. the Viking escaped from the south-western part of Norway, his native land, due to some homicides, and he ventured towards unknown faraway lands. He first reached Iceland and then Greenland. This land is characterized by short summers and very long cold winters, which, however, seen by a Norman who was used to extreme climates, might have seemed more hospitable than his own country due to the large amount of edible fish and sea mammals and birds that were present. In order to settle in an area where survival is however not so easy, Erik needed to attract people who would follow him. When he returned to his country he enthusiastically described a fertile land that, in fact, he called "green land", and convinced twenty five ships to set sail with him towards this "green paradise". Therefore the name "green land" alone cannot be an irrefutable proof of a much warmer climate at the time of the Vikings, but could instead be a kind of publicity "slogan" to convince others to settle in a rather inhospitable area. There are really many geographical names that do not reflect the exact reality of a place, such as Conca d'Oro (Gold

valley) near Palermo where once there were citrus orchards, and certainly no signs of gold.
There is another fact which must not be overlooked, the remains of Viking settlements have been found in the south-western coast of Greenland in areas that are still green today due to the presence of inland fjords that mitigate the temperature.
However, in 2007, illustrious scientists analyzed the DNA of fossil materials that were extracted from the depths of the ice in Greenland and so it was possible to identify the organisms that were present in the area: European spruce, pine trees, birches, alders, poplars, beetles, flies, spiders and butterflies. The researchers estimated that the DNA that was found dated back to a period 450,000 to 800,000 years ago, which was much before the period in which Erik the Red lived.

Medieval Warm Period and the Little Ice Age

We have all read about the Medieval Warm Period and the Little Ice Age in the newspapers and books. These terms, which are now commonly used, were introduced by the climate-historian Hubert Lamb in 1965 and by the glaciologist Francois Matthes in 1939, respectively. Climate historians and paleoclimatologists, however, do not agree on the time and duration of these periods and also the estimates of the variations in the temperature that characterized them are different. Furthermore the climate change in these periods did not vary only from one year to the another but also from one area to another of the Planet. Lamb positioned the Medieval Warm Period between 950 and 1200 for European Russia and Greenland, while for Europe he indicated the period between 1150 and 1300, with temperatures that were 1-2°C higher than in the first years of the Twentieth Century. Some experts disagreed with these statements and concluded that "in some part of the Globe, at some time of the year, relatively warm conditions could have prevailed". The Little Ice Age, instead, is a period of relative cooling, that regarded the Northern Hemisphere from 1300 to 1850. Even this cold period was not constant and global, and according to Fagan "there never was a monolithic deep freeze", but a "climatic seesaw", in other words an alternation of warm and cold periods often accompanied by disastrous climatic phenomena. The different theories proposed by the scientists with regard to the Medieval Warm Period and the Little Ice Age have led to the diffusion of not very precise information which has often been used as proof that the current climate changes have not been caused by humans. For a clearer explanation , refer to the chapter on "Paleoclimate" in the Fourth IPCC-WG1 Report, an authoritative source that states that the Medieval Warm Period and the Little Ice Age were respectively warmer and colder than the periods that preceded and followed them. Furthermore they were local phenomena that did not influence global climate and did not affect the entire planet at the same time And, in particular, they cannot be compared with the current rise in temperature. In fact the climatic data indicate that up to 1900 the variations in temperature were limited to a few tenths of a degree.

"Frozen" Thames

Since there has been a continuous alternation of very cold periods and very hot periods in the past, some believe that the current variations in temperature are quite natural and negligible. In this way the importance of climate changes is minimized and it is "convenient" to believe that this is an invention of the media. As proof of a past that was much colder than today, the frozen Thames is often mentioned. The Thames, in fact, used to freeze often during the cold season, but this has not occurred since the winter of 1814. It is true that the temperatures have changed, but there have been other very cold winters as the one of 1963, the coldest of the 20^{th} Century, when even lake Constance froze. Actually there are other reasons for the Thames not freezing anymore. In 1831, the London Bridge was built again with wider arches and without a dam to control the tides which therefore flow further upstream, and this prevents the water freezing in winter. In fact the frozen Thames would block the entire port, and also all the commercial activities. Furthermore the increase in civil and industrial waste discharged in this river increases the water temperature, which also prevents the formation of ice.

Venice on ice

Another example which has been mentioned to prove the cold in the Little ice age is the frozen Venice lagoon. There is a large amount of written evidence about the difficulties caused by the intense cold during the winter of 1788-1789, even in paintings showing boats stuck in the ice, which prevented supplies of goods and navigability. Actually the lagoon of Venice has frozen many other times, even after the so-called Little Ice Age. In fact there is proof of these events at the end of 1920, in 1956 in 1985 and even recently in 1991. However, in the past decades the ice in the Venice lagoon has surely been a less frequent condition, and this is not only due to an increase in the temperature, but also because here too there have been large structural changes in the port and the construction of canals that have changed the hydro-geological order of the lagoon. This has favoured better water circulation, but also the *acqua alta* (high water) phenomenon.