SCIENTIFIC DIAGNOSIS: FROM WARNING TO OPTION PERSPECTIVES

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The great unanimity of the scientific world about the risks that could lead to climate modifications related to increase of greenhouse gases, remains an important part of public debate, which was covered by media, international associations such as GIEC (Intergovernmental Panel on Climate Change, setting up of the initiative of the United Nations Environment Programme and of the World Meteorological Organization, the role of which will be explained below), or by many national academies. Despite that, the scientific diagnosis presents certain difficult problems, all of them not yet being solved. How to discuss the warnings that are at the same time stimulating enough and maintaining the discussion rigorous, that would be a part, at the same time, of the certainties related to subject of climate but also of numerous questions that affect every attempt of quantitative prediction of future climatic change? To separate what is well known from what is less known is of crucial importance, owing to the fact that the role of the scientific diagnosis evolves rapidly: besides the necessity of warning, occurs progressively a demand for help much more precise in dimensions of the environmental politics. However, the science does not offer all the required quantitative data. The options that we have before us can’t thus consider only the scientists. They ask for a larger debate, ethnical, political, national, debate that has to not only respect but also go beyond the technical data of the problem.

The diagnosis

The atmosphere, the oceans, the large glaciers or ice floes, form complex and fragile environments that interact constantly through the mechanical, physical, chemical or biological processes and determine what we call the climate system. This system is in essence a dynamic system, disposed to natural variations. Throughout the quaternary, for example, that is during the last two millions of years, it fluctuated between the glacial and interglacial conditions. We know well some of the mechanisms responsible for this evolutions. The Moon or the large planets of the solar system, provoked, for example, a slow modification of the direction of the Earth rotation axis and of its elliptic trajectory around the sun. On a longer time scale, a scale of millions of years, the climate of the planet had to create, with progressive increase, a solar power, with a reduction of atmospheric content of CO_2, with the continental drift. If we consider the last thousands of years, the period of the development of our civilisations, however, the perspective is quite different. Since 10 000 the Earth finds itself in an interglacial age, in a situation which seems to continue for some thousands of years. It is at this interglacial age of long duration that our civilizations developed. Even if we, in the beginning, until about 5000 years ago, experienced somewhat different conditions, such as, for example, strong monsoons on Africa, the climate of the Earth is globally quite stable since 5000 years. Probably more local fluctuations that yet did occur, such as the little ice age of the 18th century or the Medieval climate optimum (and whatever considerable social or economic impact they could have had) didn't manifest more then the global temperature variations of some tenth's of degrees, inferior to some warming degrees that lets us anticipate the increase of the greenhouse effect gases, or to some 5 to 6 degrees of warming that comes with the ending of a glacial age.

Since more then a century (from the beginning of the industrial era in the middle of 19th century), the human activities are brutally breaking that balance. A hundred years ago, the level of the atmospheric CO_2, for example, was 280 ppm (parts par million), which was maintained practically unchanged during many thousands of years. Nowadays, it has reached the level of 370 ppm, that has never been reached throughout the last million years (when the CO_2 fluctuations related to glacial-interglacial variations took a place in a scale from 180 to 300 ppm). The recent increase, which started in the end of 19th century and the major part of which was gained throughout the last decades, presents a brutality without an equivalent on a scale of the observed climate. It is the result of the oil, coal and gas combustion, a phenomenon almost non-existent before 1850, which reached a little after 1950 the rate of 2 billions of tons of carbon per year and which exceeds now 6 billions of tons per year. The human activity brings in the atmosphere the other greenhouse gases. The atmospheric content of methane, which is a tributary of the rice fields' or the ruminant farms' extension, has more then doubled, even if the level of increase seems to detain. The content of the other gases have also undergone an exponential increase: the nitrous oxide (N_2O), the atmospheric ozone or the freons (before they were banished by the Montreal Protocol, which was related to their activity on the stratospheric ozone, although their substitutes are also a greenhouse gases). The human activity takes furthermore a multiple forms, whether in the matter of dust or aerosol emissions or concerning the modifications of the natural landscapes by deforestation, irrigation, soil erosion. Among all these disturbances, however, the increase of the atmospheric content of greenhouse gases presents a very specific phenomenon, which can be explained by the very long duration of the atmospheric life of these gases: the "duration of the atmospheric life" of the carbon dioxide is more than 100 years, the duration of the atmospheric life of the methane belongs to this decade. In this way the greenhouse gases are generally gases, which are chemically low active, low toxic and their radiative effect grows by their capability of permanent accumulation in the atmosphere. This cumulative, therefore increasing effect, is to dominate strongly all the other anthropic disturbances. It is largely irreversible, with the consequences that are to be extended to the coming centuries. It is also global, for the gases emitted from whatever point of the planet tend to mix very rapidly (in few weeks in a given hemisphere, in few months on a scale of the entire planet) and they affect therefore the entire humankind. The increase of the greenhouse gases calls for a double solidarity, both planetary and intergenerational.

From the greenhouse gases to the climate disturbance

The risk posed by the greenhouse gases lies in a physical mechanism which can be described in a simple way: the presence of these gases prevents the soil of the earth, which is warmed by the sun, from loosing freely its' energy by infrared radiation directly towards the space: this radiation is absorbed by the atmosphere and partly reemitted towards the soil. This effect, which is named greenhouse effect by analogy with the warming that produces a glassed surface (glazing of a greenhouse or a windscreen of a car left in the sun), leads unavoidably to a warming of the low layers of the atmosphere. It is favourable in its' natural form: the greenhouse effect caused by a steam, by clouds, by some gases such as the carbon dioxide, makes it possible for the planet to be habitable, with a surface temperature of about 15 ºC, instead of –18 ºC, if the Earth were without the atmosphere. This effect is also fragile: the main atmospheric gases, the nitrogen and the oxygen, do not play almost any role. Only gases that represent less then a hundredth of the atmospheric mass contribute to the effect. This fragility accounts for the importance of the impact that the effects of human activity might have.

This simplified description of the role of the greenhouse gases is, of course, a simplistic description; one of the major risks in the establishment of the climate model was to propose a more precise and complete description of the process, depending on more and more complex instruments, which will be explained below. One of the characteristics of the posed problem deserves to be emphasised at this stadium: it is related to the very particular conditions created by the unusually long duration of the interglacial stage in which we live. The human activities disturb a system, certainly a very complex system, but also a system that had previously reached a high level of regulation and balance. The consequences can be a bit contra-intuitive: between 6 and 7 billions of tons of carbon injected into the atmosphere each year, for example, disturb a system which brews, at he same time, in a perfectly natural way, 150 billions of tons of carbon, exchanged between the atmosphere, the ocean and the continental vegetation. The idea that this modest disturbance of some percents of the natural cycle of a relative value could provoke after a few decades a demonstrated and indisputable increase of the atmospheric CO_2 of 30% is related to two effects: (1) the emissions related to the CO_2 combustion affect a system where the exchanges were previously balanced more then just a few percents and (2) their effect is cumulative.

We can make a parallel with the radiative effect of the greenhouse gases: the already obtained increase of the carbon dioxide, the methane, the atmospheric ozone, the freons or of the nitrous oxide represent a radiative forcing of about 3 Wm^{-2}, while the natural greenhouse effect is of 150 Wm^{-2}. Also here the disturbance is only of a few percents. But it affects a planet which has a temperature of about 300 degrees Kelvin and which is capable of provoking fluctuations of the global temperature of the surface of many degrees: also here the absence of fluctuations of this level during the last millenniums shows that the level of balance of the climate system was much more refined then a disturbance (which is to grow) already inflicted by the human activities. But contrary to the atmospheric carbon dioxide, whose very fast increase is already in evidence, the global warming caused by the greenhouse gases occurs with a delay, which is due to the oceanic inertia, and has been noticeable since not so long ago.

Are the expected effects already present?

Two related questions, although in question of very different scientific approach, dominate the concerns connected to the problem of climate change. Can we already see the first effects of the global warming? Can we try to characterize the future climate change in terms of amplitude or regional impacts?

The first question is probably the most difficult one because we are at the beginning of a process, which is about to grow and whose effects are clearly detectable since only a few years ago. The increase of the anthropogenic greenhouse effect makes progressively a dominant process compared with the other types of fluctuations, natural or man-caused. The climate system is, in fact, characterized by the natural oscillations, of internal or external origin (variation of the insulation), whose amplitude in terms of the global temperature fluctuations, is of about some tenths of degree. In addition to the (cumulative) effects of the greenhouse gases there are often the (non cumulative) effects of the aerosols or dust emitted by the human activities, or all the forced transformations that we impose upon soils and landscapes. But despite this complexity, from some years ago on, the symptoms are multiplying and testifying to an obvious evolution of the climate system that we don’t know how to explain other then as the first effect of the human activities: the warming of about 0.8 ºC since the beginning of the industrial era, which has been accelerating during the last decades, the melting of the mountain glaciers, withdrawal of the ice floes and of the snow-covered surfaces, rise of the sea level of about 3 mm per year, in a strong increase compared to the closest values of 1mm per year which were noticed during the whole 20th century.

The Intergovernmental Panel on Climate Change, which was already named in the introduction, played an important role in the synthesis of the numerous works concerning the observed evolutions. The GIEC is a group of experts named under a protection of the WMO and of the United Nations Environment Programme, according to a process that combines the recommendations of the different governments with acknowledgement of the competence and scientific recognition. It is divided into 3 groups: the group 1 handles the fundamental scientific aspects – those that are also discussed in this article. The authors (a score of “Convening Lead Authors” who are in charge of the different chapters, about 150 “Lead Authors” who participate actively in writing and co-sign the reports, several hundreds of “Contributing Authors” who submit the results or the elements of writing) are assigned to make a summarization of the published researches in accordance with the norms of the scientific community, that is in the newspapers of each discipline, after the review of the experts. The GIEC therefore doesn't produce an evaluation that would be independent from those of the learned societies (that run most often the newspapers), or the academies. On the contrary, it proposes a larger summarization, which depends on the work of the whole body of the scientific community. The GIEC gives also a technical summary and a summary for decision-maker, texts voted word by word by the representatives of the governments reunited in a general assembly, and who have to refer to the content of the elaborated rapports in an exclusive and explicit way. The GIEC is not a perfect system: the science is a matter of confrontations of ideas, of searching for consensus through the argumentation and debate; it is not decided by voting. Insofar, the GIEC enables an organized confrontation of knowledge, which reinforces considerably the diagnostic of the community.

The successive conclusions of the reports of the GIEC, in 90, 95 and 2001, testify, by the evolution of adjectives, the more and more strong significance given to the recent climate evolutions. There is no doubt that this evolution marks the beginning of the warming signal related to the greenhouse gases. There are two mistakes that should be avoided though: the first would be to believe that the observation of the actual tendencies constitutes the base of the scientific case concerning the evolution of the climates. As a matter of fact, it is the contrary: the results of the numeric models enabled to establish scenarios of the future climate change from the 80ies. What we have been witnessing for several years now represents rather a confirmation *a posteriori* of the simulations, which were realised in an anterior way. The second would be to believe that the recent climate warming, together with the regional climate events, constitute a useful prefiguration of what could occur: in fact, what we can expect in the future is of a much larger extent.

An instrument of anticipation of the future climate: the models

How can we predict what could occur during the 21^{st} century? As we have just seen, the scientific approach that leads to this diagnosis is completely different from the one used to evaluate the already detected impact of the greenhouse gases and is supported by one instrument: the climate modelization, which sometimes evokes a certain mistrust. The dominant position that the models have in the prognostic of the future climate change calls in fact for a detailed explication.

One of the questions, often posed to the scientists, shows partly the widespread incomprehension of the nature of the modelisation itself: "Which information do you bring into your systems?" One absolutely false and largely widespread idea is that the functioning of the climate systems consists in gathering of inventory data from the past in the computer in order to draw from it a future extrapolation: this is what brings on passionate debates, often away from the point, aiming to find which is the possible part of the solar radiation variations in the recent climate change – debates that lead to false understanding that the quality of the projection of the models for the future climate depends upon the answer to this question.

In fact, even if the observation of the earth certainly played a role in their development, the models are not based on the data but on the physical principles. We are dealing here with a method that goes a bit backwards from the traditional scientific method, which most often consists of reducing the complexity of the real world in order to set apart laws the most universal as possible. The establishing of the models presents, on the contrary, an attempt to recreate the complexity of the existent world from the physical equations and to create a numerical planet, as similar as possible to our "real" planet but easier or faster to do different experiments on. Also the main "data" that is a part of a climate model, in addition to a description of the planet (relief, distribution of the soil types, the speed of rotation…) and of the forcing to which it is exposed (sun), are the physical constants: the gravity field acceleration, the perfect gas constant etc. Of course, this is not completely sufficient and we need also the other information, as we will see, because of the fact that the spatial resolution of the models is not sufficient and because their development is not finished: for example, the chemical composition of the atmosphere remains the most often specified and not calculated. But the approach consists in creating an instrument that depends on the fundamental laws or processes and that could be used without modification for description of the climates that differ very much one from another: actual period, glacial maximum, warm period from 6000 years ago. The models are therefore not easily "adjustable": their improvement asks for refining or completing the representation of the physical processes, often quite complex ones, which is at the root of their formulation.

Similarly, it would be wrong and dangerous to think that the numerical climatology consists of integrating laws and different kinds of equations in powerful computers blindly relying on the result. The atmospheric and ocean flows are characterized by the great number of processes, which are often large-scaled: the organisation of tropical circulations in giant "cells" of several thousands of kilometres, depression of medium latitudes, monsoons, big "belt of the ocean transmission" which transports warm and salty waters from the Southern Hemisphere to the Northern Atlantic, Gulf Stream Rings, tropical oscillations of El Nino type, joining the atmosphere and the ocean. It is the existence of organized circulations on a scale of thousands of kilometres that makes the numerical prediction possible. It is also the understanding of these processes in a more theoretical mode that enables the establishing of the quality and the relevance of the models.

The models consider, in an explicit way, two big categories of the process: the energy exchanges, particularly in form of electromagnetic radiation, between the earth, the ocean, the atmosphere and the space, and the dynamic of the atmospheric and ocean flows. The corresponding equations are digitized on the intersection nodes. The intersection covers the whole globe and they are determined on each of the thousands of points of the intersection. In addition, a range of smaller-scale processes (clouds, vegetation, the effect of orography) are represented under the influence of collective rules, of statistical core. For many years, the coupling of atmospheric and ocean models, which enables the description of the interactions between the evolution of these two fluids, has become a fact relatively well controlled in a large number of laboratories. The progressive integration of the other components of the climate system (ice, sea ice, continental soils, cycles of chemical components such as the carbon or nitrogen cycle) lead progressively to more and more complex models, models called “Earth System Models”.

The models are used in many contexts where they each time demonstrated their relevance. The weather prediction – and the recently started ocean prediction - in France started as part of the Mercator project, made the continuous progress since its’ beginnings in 70-ies, winning multiple expiration days. The climate modelling consists of surpassing this expiration limit letting the model evolve during a much longer period: so, the model does not have any more a predictive value, it constructs, little by little, a climatology, namely a statistics of the simulated meteorological or ocean events. The quality of the models is the reflection of the quality of this climatology, which was growing during years: the models of today represent with a high fidelity the great characteristics of the atmospheric and ocean flows, as well as their seasonal or interannual fluctuations (which constitutes the first important test of the models – as the seasons constitute the most quickly and best observed climate change). The numerical models are also successfully being used to simulate past climate conditions or the atmospheric flow on the other planets, such as Mars or Venus.

In addition, the models are constantly evolving and the way crossed during last decades is enormous. In 1990 the first GIEC report (IPCC, 1990) presented the simulations of three models in response to a prolonged doubling of the atmospheric CO_2. It was about atmospheric models with law spatial resolution, coupled with quite strongly idealized ocean models (layer of well-mixed water in a layer of around ten metres). Only one of these simulations, the one of the British Met Office, was compared to the simulation of a true ocean-atmospheric coupled model, integrating a numerical representation of the deep ocean. On the contrary, all the models that are being used at the present are coupled ocean/atmosphere models. The increase of the resources in the time of the calculation has enabled a gain of spatial resolution in a moderate, but constantly sustained rhythm: in the second GIEC report many atmospheric models still presented a horizontal resolution of about 500 km (T21 in the spectral domain); in the serial of recent simulations made for the fourth GIEC report, which is in process of writing, a resolution of 300 km corresponds to a low resolution and several “high” resolution simulations have been performed (a bit more then 100 km or T106 in the spectral domain). The arrival of computing machines with the speed of several tens of Teraflops, like the Earth Simulator in Japan, has strongly reinforced this tendency.

The modelling limits

After all that was said, we have at our disposal vigorously tested models that have a strong physical base and that concentrate a significant evaluation. However, it is necessary to keep in mind a certain number of limitations and uncertainties, which we are now going to analyze. We can distinguish three categories of problems.

The first one is essential for the climate system itself: the climate system is simply not a completely predictable system. This feature is associated with mathematical movement equations, which are not linear and which combine the scales of time and space. That is the reason why they can't be solved analytically and why the usage of the computer is necessary. There is a particularly short limit of prediction for the atmospheric component: in approximately 10 days' limit the meteorological evolution can't be predicted anymore because of the instable character of the flow which has sent back to the whole globe a little initial error. It is the well-known effect, which was discovered by Edward Lorenz in 1963 and made popular by the name "the butterfly effect": it states that every disturbance, no matter how small it is, modifies irreversibly the history of the atmosphere (2). Certain components of the climate system, such as the vegetation, present as well an essential complexity, which results rather from a diversity of processes which enter in competition: so it is impossible to predict with certainty the evolution of all the species of a forest massif and their climate impact in return.

A second source of uncertainties corresponds to unavoidable simplifications that are brought to the model construction, in particular because of the fact of the too big spacing of the intersection nodes. The difficulty of the representation of the clouds is one of the examples: the clouds are produced by the movements of the small-scale air, going from several hundreds of metres to several kilometres, movements for which it is out of the question to be explicitly represented in the models; they are the place of the intense latent heat emission which results from the water condensation and they disturb the solar radiation and the infrared radiation depending strongly on a size of the water drops or of the ice crystals. Before so much complexity, and we could give some other examples concerning the sea ice, the vegetation or the continental hydrology, the modelling is necessarily simplifying.

A third factor limits the practical range of the models: it is only since very recently that they permit a description of the whole climate system. The models are still most often physical models, which neglect the biological or chemical components of the system, the essential role of which appears though more and more clearly. The sulphur aerosols, for example, have been recognized as one of the important factors capable of concealing, at least in the northern hemisphere, the initial manifestations of the greenhouse effect. The atmospheric CO_2 content depends also on a complex cycle where are involved at the same time the phytoplankton formation or the formation of the zooplankton in the oceans and the photosynthesis or the continental vegetation's respiration. We know that only the half of the CO_2 emitted by the human activities remains in the atmosphere, the rest is taken back by the oceans or by the continental biosphere: the first tests of the IPSL model in France or those of the Hadley Centre in Great Britain have shown that this part could evolve with the climate. A recognition of this factor (potentially aggravating for the planet warming) requires the use of the much more complex models, coupling representation of the climate and of the carbon cycle. The methane chemistry, the ozone chemistry, constitutes also a set of complex processes, which integrates the models bit by bit in order to form what we have called “Earth System Models”.

The accumulation of this uncertainty factors makes the detailed prediction of a future climate evolution beyond doubt illusionary for the time being. We could even exaggerate and say that more the research progresses, more the enormous complexity of the processes, which participate in the evolution of our environment, is revealed and the possibility to predict the future climate evolution in detail is growing more distant. But, at the same time, and in apparently contradictory way, the evaluation capability considering this system has considerably increased and the certainty level concerning the reality of the future warming has become much higher. In all the ongoing debates the models have served as an instrument enabling the study of stabilizing mechanisms’ propositions within the climate system and to appreciate their possible importance.

Future scenarios

The use of these models for the realisation of the future climate scenarios was largely made in the GIEC context. Besides the idealised scenarios (1% of the annual increase of the atmospheric CO_2) the model makers turned to the scenarios defined within the framework of SRES (Second Assessment Report on Emission Scenarios) (IPCC, 2000) in order to introduce simulations of future climate. These scenarios correspond to evolutions of our coherent planet on the socio-economic level (with a development more or less globalized, more or less sensible to the energetic constraints), translated in terms of greenhouse gases’ emissions and aerosols. These already old scenarios are still used today for the climate simulations: four reference scenarios (A1, A2, A3 and A4) had been initially chosen and completed by versions of the A1 scenario. These scenarios correspond to very contrasting evolutions. The most optimistic one (B1) corresponds to a stabilisation of emissions of the majority of gases of level in 2100 to the level of approximately year 2000, whereas the others, on the contrary, lead to increase of CO_2 emissions in 2100 about three times higher.

The choice of these scenarios enabled making the experience corresponding to evolutions dating from the period of climate change, from about 1850 to 2100. It is from these simulations that the GIEC report from 2001 presented results, bringing thereby a warming of 1.8 ºC near to 6 ºC in 2100. It is important to understand that this range is dependant at the same time on the uncertainty about the models and on the uncertainty about the scenarios. The low oscillation value is reached only in a very optimistic case of the B1 scenario and for models that have a low sensibility to a radiative disturbance. The promotion of the IPCC 2001 results’ range through the media has led to misunderstandings, leading to think that the whole range showed the uncertainties of the climate modelling, while about a half showed the differences between the scenarios and in that case, on the contrary, the breathing space that subsists for our societies concerning the future.

The models enable the completion of the forecast of the global evolutions by the results on a regional level. Several qualitative tendencies appear hardily and it is remarkable that some of them were characteristic for simulations made in 1980-ies: the simulated warming was more significant on the Poles and on high latitudes and more on the oceans then on the continents. The difference ocean/continent was affected by the coupling to an active ocean, manifesting in this way the role of the thermal inertness of oceans in the global distribution of warming. Despite very differentiated regional consequences according to models, the precipitation modifications tended to organize themselves according a common global mode, consisting in reinforcing the actual situation: more rain towards the equatorial zone and towards the medium-latitude regions, which are already rainy, while the semiarid subtropical belt was exposed to strong risks of dryness. This continuation of model prediction despite the growth of their complexity is a strong indicator of their relevance: the most significant identifiable large-scaled physical processes lead to climate variations, which are in that case predictable.

The transformation of atmospheric models into coupled models ocean/atmosphere allowed however the access to new results. The Northern Atlantic is so characterized by a less warming, even a light cooling, which results in a slowing of the water transport towards the North in a large number of models. This situation, often called "halt of the Gulf Stream", corresponds rather to its displacement. This growth of lower temperature transmits moderately over to Europe, which continues the warming process. In addition, the sea level rise, predicted by the models (the rise from 20 to 80 cm in 2100 compared to the present level) will affect a large set of coastal zones. This simulated rise corresponds well to the present observations (3 mm per year). It hardly depends on the chosen scenario, namely, the ongoing evolutions depend on 20th century emissions and it will be difficult to slow them down in a near future.

These scenarios, made within the framework of the GIEC (and a great part of those made more recently to prepare the coming GIEC report) can, however, be considered as "optimistic" because they don't consider many possible amplifier effects, and particularly the feedback connected to the carbon cycle. The simulations made at the IPSL and at the Hadley Centre showed that the effect of the climate upon the vegetation and the oceans, by reducing the percentage of the CO_2 that take these environments, can increase the coming variations for some degrees. Other potential feedbacks are not considered in these simulations: for example, an anticipated melting of Greenland, which seems to have started, or the possibility of cast off of methane from the bottom of oceans or the frozen soil of Siberia in case of warming.

The place of the science in the political decision

The picture showing thirty years of research has given the possibility to widely draw some conclusions, which are sufficient for determination of a need for a strong action:

- the degree of a future climate change is significant in relation to the documented past evolutions
- the climate change, favouring the increase of extreme meteorological events (dryness, storm and cyclones), enabling the increase of the sea level to touch the far-reaching coastal zones, provoking a fast and non-controlled mutation of high latitude regions, will create a situation of extreme tension on a global scale
- the evolution of future climate change will meet, in a hardly predictable way, multiple problems: water availability, biodiversity, health problems, energy use. It will therefore constitute one of important factors of a profound reconsideration of our way of development
- the speed of climate change is an element of major danger, to which we should add the capability of the climate system to react in an accelerated way if certain danger lines are crossed (allowing, for example, the mortality of a part of the vegetation or the start of the melting of the Antarctic). These elements militate in favour of very rapidly carried out measures.
- a certain level of climate change is from now on inevitable and demands to take action in order to conform to them
- the degree of future climate change remains hard to predict with precision, but the warming which has started could allow to affine this diagnosis in coming years

However, these elements are not self-sufficient in order to specify the details of a struggle against the increase of the greenhouse effect policy. The expectation of a society face to face of a science and scientists has as a consequence considerably evolved: to the necessity of warning, a demand for help, much more precise in dimensions of environmental policies, was progressively added. It is in this way that the (uncertain) limit of 2 warming degrees as a danger threshold, which is not to be exceeded, was imposed. Or the need of a division of CO_2 emissions by 2, in order to stabilize its' atmospheric concentration. The scientists have also provided keys (uncertain) of conversion of different gases to "carbon-equivalent", enabling their rating on a unique market.

However, the truth is that it is impossible to entirely base an environmental policy on numbers determined with precision. As in many domains, we have to act against a risk whose general outlines we know how to encircle, without being capable of quantitative predicting of all of their manifestations. In particular, we have to determine a policy that would bring the responsibility of polluting countries face to face with those who will suffer the strongest climate impacts, that would consider the engagement, probably irreversible, that determine our choices facing future generations. These choices, where the climate problem has to be considered together with other problems of the planet, can not only be a matter of scientists: they ask for a wide-ranging debate, ethical, political and national.

This article is translated on English by Djurdjica Hruskar