
Climate Change Sceptics

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By predicting a global change of the Earth's climate, scientists are delivering an uncomfortable message. The release of the fourth IPCC report in 2007 has led to a surge of scepticism and criticism of both the science and the scientists. All this has received a lot of press coverage. Here I discuss the roots of climate change scepticism and how it has been triggered by the complex and novel aspects of climate science. I also call for more transparent and open practice in science, as more light is precisely what its opponents cannot afford.

Climate science and climate scientists have worrying news about anthropogenic climate change. The uncomfortable message is that it will affect our lives and our planet. Climatologists have nothing to say about how societies should consider this threat or how they should react. They only warn that climate is changing, that the cause is primarily human agency, that this change is already measurable, and finally that it will increase dramatically over the next decades if no action is taken.

Delivering this warning is not an easy task, however. Since the publication of the fourth IPCC (Intergovernmental Panel on Climate Change) report in 2007, science and scientists have been under the fire from attacks that culminated in the so-called 'climategate' controversy. Charges were spread on the Internet and in the media that climate scientists were routinely manipulating data and were involved in an international conspiracy to diffuse such falsities and to reduce their opponents to silence.

In the UK, these charges led to a public inquiry against some scientists who have eventually all been cleared of any misconduct and fully re-established in their position and reputation, but who have also been strongly affected by this episode. As a new wave of scepticism will almost certainly accompany the publication of the fifth IPCC report in 2013, it is time to consider what we can learn from previous experience.

The focus of this short paper is the perception of climate science by the public and other scientists, the role of the specific nature of climate science, and the reasons for why scepticism is so well received in a large range of the society.

What we do, and do not, Know about Climate and How to Convey it to the Public

It took more than 30 years for climate scientists to reach a point where the doubts about anthropogenic climate change have virtually vanished. It is perhaps useful to recall that this evidence is not empirical but based on a combination of observations, the understanding of the underlying processes and quantitative modelling.

The physical laws of the 'greenhouse effect' are described by molecular spectroscopy, a well-established discipline. The numerical models used in climate projections are based on physical laws which are, usually, well-known and can be expressed as equations. The difficulty is that the direct solution of these raw equations, at the required resolution – that is from planetary scale down to that of the molecules – is a challenging task which cannot be performed.

We can only solve simplified sets of equations that represent, to some accuracy, the climate system, in which the small-scale processes are parameterised in a statistical way. There are also some processes that are not yet well understood, for instance the detailed physico-chemistry of aerosols, but generally our knowledge at the micro-physical scale largely exceeds what can be accounted for explicitly in a climate model. Experience and modelling skills have been gained by solving analogous problems in industrial flows and in the practice of numerical weather forecasts.

What we know about climate change is that a global warming of the ocean and the atmosphere is underway and is caused by the anthropogenic increase of greenhouse gases. There is virtually no doubt about this. The effect is predicted to be strongest in the Arctic and the observations are supporting this prediction. Extreme precipitation and droughts will both increase in intensity as a result of the intensified hydrological cycle. It will take several centuries to get rid of the excess greenhouse gases by natural processes, even if we stop all anthropogenic production.

This is well known; what we do not know nearly well enough is the future rate of sea level increase, the evolution of the mean distribution of precipitation in many regions, including monsoon areas, and the future frequency of tropical cyclones. We may adopt a very conservative assessment, which excludes any catastrophes associated with tipping points, where some component of the climate system changes abruptly (the list is fairly long, from the massive release of trapped methane to the breaking of the Antarctic shelf). Although such events have occurred in the past, their prediction is usually considered as speculative.

Hence, climate scientists have to convey results which are almost certain as their current inability to answer questions of huge practical relevance. This is a difficult task, as both policy-makers and the public are largely uneducated in science and see the scientist either as a genius who is able to encompass the knowledge of the universe into a single formula or as an extravagant fool pursuing irrelevant goals.

This view of the non-scientist is perhaps as much a caricature as the view of scientists themselves, but it contains a large grain of truth and it points to a dichotomy in the perception of the scientific expertise between excessive confidence and expectation on one side and excessive prevention on the other side.

It is, then, very difficult to deliver a message about our partial understanding, and to let people appreciate certainties and uncertainties, especially if the methodology is complex and cannot be explained easily. It is also easier for those who receive the message to use the doubts as a pretext for inaction.

On the Nature of Climate Science

Climate is a complex system, involving many processes and many scales and requiring a hierarchy of representation and models. The simplest models are idealised conceptual tools that can be used to describe and understand the processes but are not able to produce quantitative prediction. For instance, the greenhouse effect can be explained analytically for an idealised ‘grey’ atmosphere that retains only two broad domains of the light spectrum, the visible and the infra-red, without distinguishing molecular rays. A quantitative calculation of the radiative transfer in the real atmosphere, however, requires detailed knowledge of absorption for all the relevant molecular rays and to account for light-scattering. To do this practically involves a huge amount of numerical calculations. Similarly, general theories about atmospheric and oceanic circulation can be derived from first principles and put in the form of well-defined hydrodynamical equations. Applying standard techniques, remarkable solutions, such as waves or compact eddies, are produced from such equations. These structures are indeed observed in the atmosphere and the oceans, but the full solution, which takes into account the distribution of orography and the non-linearity of the dynamics, can only be solved numerically.

Modern meteorology and oceanography, and, in their wake, climate science, have developed in parallel to the electronic computer – since the 1950s when the first machines became available for civilian applications. The association of climate science with computers and numerical simulations of systems of equations has often generated discomfort among other scientists who were not using computers.

Nowadays, computer simulations are extensively used in most areas of science, including social studies, and this cultural gap has almost vanished. Nevertheless, the idea that climate modellers are some sort of computer engineers building complicated but unreliable tools, far from the real world and unchecked against data, has persisted, perhaps most commonly among senior scientists.

Recently, a famous French physicist, a member of the Academy of Sciences, asked why we were not trying to check our calculated radiative transfers against data by performing measurements; he suggested installing radiometers at the Southern European Observatory. He ignored the fact that such measurements have been done routinely for more than 50 years, from ground stations, airborne instruments and satellites, and that numerical calculations have been intensively cross-matched against such data.

Climate science invokes new concepts and new applications. Its fortune is to be widely popularised and its misfortune is to be mainly understood through the simplifications that are inherent in popularisation. It has not yet found its way through the education system, leaving room for a number of misconceptions – e.g. about the greenhouse effect¹ – floating around, even among distinguished scientists.

What is the Role of Consensus in Climate Science?

One of the main attacks against climate science is that no major discovery has been made by consensus and that, on the contrary, scientists going against the consensus have often been the leaders of scientific revolutions. Those who promote this idea modestly compare themselves to Galileo or Wegener who indeed were geniuses in their time and had to fight against an established truth.

Arrhenius, who was the first to formulate a theory of the greenhouse effect, also met strong opposition from Ångström. Actually, both Arrhenius's and Wegener's theories were incomplete and partially wrong, as pointed out by some critics; nevertheless, their new ideas laid the foundations for new paradigms, which are widely accepted today.

The scientific consensus about climate has been criticised through the description of the Intergovernmental Panel on Climate Change as an assembly where scientific issues are resolved by vote and where critical statements are discarded. Some elements in the media and politics have presented this consensus as a plot, motivated by political or financial reasons, against progress and development, led by a group of scientists who are alternatively described as incompetent and prone to cheating. The same voices urged for public inquiries that could break the *omerta* and expose the corrupt nature of climate science.

As a matter of fact, what the public generally knows about IPCC is the 'executive summary', a 15-page digest, including figures, of the 3000-page report. This summary is validated by a meeting of official delegates during which each sentence is considered separately and approved by a vote in the presence of journalists. This ceremony has been used to caricature the way climate science is done and has had a devastating effect.

However, a careful reading of this short summary does not show any kind of consensus. On the contrary, the statements are placed on a scale of confidence ranging from 'very high' to 'very low', and outcomes from 'virtually certain' to 'extremely unlikely'. This standardised language is based on probability analysis when it is possible, and on a careful assessment of the state of knowledge in other cases.

This could be the topic for a long discussion, but the main point to retain here is that the real goal of the IPCC report is not to demonstrate a consensus but to account for the state of understanding of the climate and to distinguish between what is well established and what is poorly known, including current controversies. Whether it fills this role perfectly is debatable; nevertheless, the outcome is very interesting and useful.

It is impossible for a single scientist to have a detailed understanding of all the aspects of climate sciences and to be aware of all the issues and shortcomings of such a complex domain. The first volume of the IPCC report, devoted to the scientific basis of climate change, is entirely based on published and reviewed literature. By showing where scientists agree and where results and understanding are converging, the IPCC does not create, but only reveals the consensus.

The interest of the report is also in establishing where the consensus is broken and on which matters knowledge is poor and the results are dispersed, fostering the intensification of further efforts. An important contribution of the fourth IPCC report, completed in early 2007, has been to show that the largest single source of discrepancies between climate models and data arose from the representation of low-level clouds. Since then,

this issue has been the focus of dedicated efforts, combining new observations by active satellite instruments (radar and lidar – light detection and ranging) and improvements in modelling, thereby reducing the discrepancies by almost an order of magnitude.

Consensus is the normal way to validate and recognise progress in science. In mathematics, a mathematical proof is traditionally accepted once it has been redone by a number of competent mathematicians who declare it free of flaws. A proof can be improved, but is seldom invalidated once it has been accepted. This procedure has been modified by the advent of computer-assisted proofs, which have raised some concerns among some mathematicians.

In physics, a result is never accepted until it has been reproduced independently by one or more other teams. So far, this has proved very safe. Such principles are of course valid in other fields including climate science. A recent illustration is the Berkeley Earth Surface Temperature project (<http://berkeleyearth.org>) in which a team of physicists has embarked on a re-examination of the surface temperature curve since the nineteenth century.

They used an enlarged set of stations and a new methodology for homogenisation. To their own surprise – some were initially holding sceptical views about global warming – they discovered that their results were strikingly close to those from NASA, the Goddard Institute for Space Studies, the National Oceanic and Atmospheric Administration and the University of East Anglia.

It is a somewhat different matter to ‘check’ the climate simulations that are the basis of climate projections for the future. Developing a state-of-the-art climate model from scratch would require the efforts of dozens of scientists for several years. Hence, the production of climate simulations is actually reserved for a small number of groups who have been engaged in this research for many years. There is nothing wrong here; we need to rely on our confidence in the professional skills of the scientists involved. It is therefore important that, if the whole procedure cannot be easily reproduced, the models and the data produced by the simulations are documented and made accessible to those who wish to make partial checks and comparisons.

The Importance of Data and of Public Access

Climate science, like other geophysical sciences, is based on the observation of the Earth. Unlike laboratory data, observations of the Earth are unique and cannot be exactly reproduced, even if many phenomena are recurrent. Once performed, they need to be archived and preserved. Long series of data, over several decades, are necessary to assess climate change. Reliable instrumental records are only available since the middle of the nineteenth century.

However these data need to be corrected for a number of biases before being exploited. For earlier periods there are no direct temperature measurements but a number of proxies, which range from log books of canal icing, tree-ring data, the isotopic composition of ice cores and that of shells found in sediments. The calibration of such proxies and their use to estimate temperature is difficult, liable to errors and misinterpretation, and it is still a matter of debate among specialists.

These difficulties are exploited by sceptics who are prone to turn uncertainty and errors into misconduct and incompetence, and have created a pseudo-controversy surrounding the 'hockey stick' shape of the temperature records.

Controversy is not uncommon in science and is often beneficial as the results that survive are usually rendered more robust. In this case, however, the controversy was tainted by personal attacks on several prominent scientists. After a decade of debate, it remains that many independent studies, using different data and methods, concur to show that the last 30 years have been the warmest over the last millennium and, according to some studies, over an even longer time period.

A grievance against climatologists is that they made accessible only processed data while raw data were not released. It is a common feature that a scientist tends to hold the data he/she has produced or collected. However, there is also a long practice of sharing data, particularly in atmospheric and oceanic sciences. It is fairly uncommon in these fields that a single instrument operated by a single scientist or even a single team can be exploited without using other observations made by different instruments.

The common strategy is to combine a whole battery of instruments deployed during a campaign or for routine operations, and to share these observations. Historically, the development of modern weather services has been based on deploying an international network of meteorological stations and on making data available to the meteorological services of all nations.

This network was established in the second half of the nineteenth century and it has operated since then, except during the two world wars. The network is now placed under the responsibility of the World Meteorological Organisation, a United Nations body.

Sharing the data between meteorological services does not mean that they are accessible to the public or even to all scientists. Choices differ from one country to the other. In the US, the point of view is that data collected with the support of public money should be public and all meteorological data produced by US agencies, from ground stations or satellites, are freely accessible in almost real time, setting a standard for the rest of the world. In Europe, a different point of view prevails; such data may have some commercial value, it is reasoned, and, therefore, meteorological data are not openly accessible. Generally, they are available for academic research but not to the public. In a number of other countries, meteorological data are still treated as a military secret.

In order to access data, scientists need to sign protocols that restrain the usage and forbid the dissemination. This is true for many meteorological services and also for other sources, like shipping companies who hold the books where oceanic temperatures along boat tracks have been recorded, or for the military. Clearly, climate scientists were not always able to release original data to avoid losing their sources.

This situation has, however, changed in recent years and it is generally perceived that the public release of data is an important method to establish confidence in the results obtained by climate scientists. This is now recognised by most services and agencies and many datasets have been opened, including those that have been used to establish the temperature curves over the last century. This has been exploited in particular by the Berkeley project mentioned above.

Public release of data is now mandatory to get public funding in many countries and databases and data centres are being organised to facilitate this access. These efforts are mainly aimed at serving the scientific community but this is done openly for anyone.

Methods and models should also be easily accessible. Many modelling groups have established websites where the numerical codes of the models are available, can be downloaded, and tested by anyone. The distribution is usually done under a variety of licences that preserve the intellectual rights of the authors without limiting the usage.

Exploiting such resources requires some expertise, but better technology has lowered the barrier significantly. In addition, many journals accept supplements where data and methods can be published and made available to a wide audience. Scientists are often motivated by seeing their method or model adopted by a large community; they also get more citations and increase their reputation.

It appears particularly important that the data and methods of climate science are easily accessible and well-documented to help those who are willing to check the calculations. It is also a good way to bring new scientists and teams to the field, since they can start their own investigations inspired by existing projects. In summary, it is the case that any relevant published literature should be, as much as possible, in the open access domain.

The Danger of Conveying a Disturbing Message, and the Roots of Climate-scepticism

It is not the first time that scientific theories have been rejected and submitted to criticism by non-scientists. This has often happened when science has been perceived to have challenged religious or cultural beliefs. Climate science has not so far had any serious problems with religion but it is delivering a disturbing message that anthropogenic action is able to modify the Earth to a point where its habitability is significantly affected.

This message is obviously disturbing for those in the fossil fuel industries and for those in charge of economies based on the heavy usage of fossil fuel. It is disturbing for those who perceive natural resources as essentially unlimited. It is also disturbing for – and is challenged by – those who contemplate the history of the Earth, the tectonic movements over billions of years, and how climate has varied between extremes before any anthropogenic action could have arisen.

It is not perhaps surprising that the ranks of the sceptics include many geologists (mostly retired) who can hardly accept the idea that a ridiculous living creature might disturb planetary-scale processes in the course of a few decades.

Concerns about the finiteness of the Earth and its resources, and its fragility, are not limited to climate science. Biodiversity, food and water resources are endangered in many regions. Awareness of such problems has become deeply political, leading to measures such as the Kyoto Protocol.

During the discussions around these protocols or about carbon taxes, climate science has been engaged in the turmoil of politics. Climate scientists have been called to provide advice or interviewed by journalists to relay the information to the public. Some scientists have become politicised. As a result, climate science has been often confused with politics and climate scientists perceived as doing science with a political agenda.

A peak was reached when the 2007 Peace Nobel Prize was attributed jointly to the IPCC and Al Gore. Although the intention was certainly good, this decision has been more damaging than profitable for the image of the IPCC. The point is not that Al Gore is a good or a bad politician but that he is clearly not a scientist, and by associating him with the IPCC, the Nobel committee has confused two messages that should be kept separate.

The fight against climate science is not a spontaneous reaction but is organised and relayed at many levels. A number of think tanks are sowing the seeds of doubt by propagating messages that have the appearance of science but which are not science. The methods used are directly inherited from the fight by the tobacco industry against regulation, and the same actors are found.

Such methods have been well documented by Naomi Oreskes and Erik M. Conway,² and other authors. These methods include, but are not limited to: pure nonsense, neglected facts, disguised data and forged results, giving weight to outliers, promotion of speculations, minor problems presented as major flaws, misquoting of the literature, incorrect physics, misuse of statistics, and pseudo-science wrapped up as science.

This activity targets policy-makers and tries to influence their decisions. It also targets scientists and particularly scientific societies, which have been put under pressure to express doubts about the anthropogenic role in global warming. This has happened recently at the French Academy of Sciences and in a number of other countries as well. Most societies have rejected such statements and instead have corroborated the IPCC conclusions, albeit after fierce internal disputes.

A notable role is played by a few scientists who have decided to be public sceptics. They are usually recognisable first by the fact that they prefer to discuss climate issues in front of journalists, rather than in front of specialists, and second by the fact that their results, when they manage to get published in scientific journals, are almost invariably rebutted for serious flaws or are not found to be reproducible by independent teams.

Many of them do not publish at all in referred scientific journals but only books or pamphlets published by general editors. Such books sometimes sell very well, much better than books explaining climate science. These few voices are amplified by the think tanks and by the mass media, which provide a disproportionate coverage of such 'alternative views', probably because that allows them to dramatise the issue and make a better story.

Finally, the Internet, by hosting a large number of blogs, propagates and multiplies misinformation. The role of these blogs in shaping opinion has not been evaluated, but is certainly a factor. It is easy to check that they saturate the web and that any search on climate change picks up a number, if not a majority, of sites expressing sceptical views. Most of them use ready-made pseudo-scientific arguments kindly provided by the previously-mentioned think tanks. I made a test with new students asking them to report on some questions closely related to climate change based on a web search. They ended as totally confused even after being warned about the contamination by pseudo-science.

Several climate scientists have recognised the need to be active in this field, in order to counter the propagation of falsity and to educate the public. The sites <http://realclimate.org> and <http://www.skepticalscience.com/> are established as references for the educated public. This is a time-consuming but necessary task. Some scientific journalists are also maintaining blogs relaying the information to a broader audience.

It is heartening to see that the forums which are attached to these blogs reveal very interesting and sometimes very sharp discussions among the readers.

In order to draw clearly the distinction with pseudo-science, it is important that science becomes more open and transparent, something pseudo-science cannot afford, and that scientific discussion is made public as much as possible. New open-review journals, such as those of the European Geophysical Union, are heading in this direction.

My conclusion is that the battle over climate change shows how science addresses complex systems and shines a lot of light on science's connection to society. It has also revealed the need for increased openness and transparency. Where there is light, there will surely be more understanding.

References

1. A common error is to believe that adding more carbon dioxide to the atmosphere is not important due to the saturation of absorption bands. This is supported by a simplified one-layer model of the atmosphere often used as a first step for pedagogical purposes. In fact, the atmosphere is a continuous medium and the thermal photon can be absorbed and re-emitted several times before reaching outer space. The addition of more carbon dioxide induces the emission to outer space to be displaced upwards, and there is no limit to the increase of surface temperature by the greenhouse effect. On Venus, carbon dioxide conspires with sulphur dioxide to create a hellish surface temperature of 460°C, exceeding the temperature of Mercury while receiving $\frac{1}{4}$ of its solar irradiance.
2. N. Oreskes and E. M. Conway (2010) *Merchants of Doubt: How a Handful of Scientists Obscured the Truth on Issues from Tobacco Smoke to Global Warming* (New York: Bloomsbury Press).

About the Author

Bernard Legras' research encompasses a number of contributions in various areas of the atmospheric sciences. He was one of the first to study organised eddies and coherent low frequency modes in geophysical fluid dynamics, and to promote the notion of weather regimes in weather forecasts. He has also worked on the ozone hole problem and the dynamics of the polar vortex. His current interests are in the Brewer-Dobson mean circulation of the stratosphere, which is increasing according to climate projections but this is not yet confirmed by data, and in the cloud processes and transport within the tropical tropopause layer, a key region in the climate system. He has recently published papers on the dangers of misusing statistical methods in the search of solar climate relations. He has served as chair or co-chair of a number of scientific bodies and is currently the scientific chair of the ICARE thematic centre on aerosols, clouds, water and radiation.