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Guido Visconti

Problems, Philosophy and Politics of Climate Science

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This book is dedicated to Richard Goody
He ran measurements on a de Havilland Mosquito
Was a friend of Werner Heisenberg
For 50 years, I learned from his papers and books

Preface[1]

Freeman Dyson is a world-renowned physicist known also for being a skeptic about global warming. Reviewing a book on the political implications of the global warming, he reports the contempt of the majority for the opinions of another skeptic, Richard Lindzen. In the preface of a report by the Global Warming Policy Foundation, the same Dyson observes that "the public perception of carbon dioxide has been dominated by the computer climate-model experts who designed the plan." These considerations contain two important points, the first is the implicit assumption of the existence of a "climate science" and the second is the fact that, if it exists, the climate science is identified with the global warming. The existence of a climate science could be proved only if we find that it follows the "scientific method" that can be summarized as follows. We start by observing some aspect of the climate system and then we make a hypothesis to explain the observations that is used to make some prediction. These predictions are tested observationally and when we arrive to a consistent picture our hypothesis become a scientific theory. A simple example could be made having meteorology in mind. Here, the observations were the basis to develop a theory for the general circulation of the atmosphere using new concepts like potential vorticity. With the advent of the computer, the relevant equations could be numerically integrated and the forecast can now be verified each day. The frontiers of such theory today are the long-term predictions and their precision.

For the climate system, the situation is such that detailed observations are lacking (for example, for the ice age cycles) and the predictions of future climate based on the General Circulation Models cannot be verified because the data are nonexistent. A possibility (which has not been very much exploited) is to make some hindcast (that is a simulation of the past) on the reconstructed (assimilated) data of the past 40 or 50 years. Even in this case, we cannot be sure that the system in the future will behave as in the past (for example, the climate sensitivity may

[1]Dennis Bray and Hans von Storch, Climate Science: An Empirical Example of Postnormal Science BAMS march 1999 © American Meteorological Society. Used with permission.

change). We are then left with a basic difficulty that is the partial lack of observations on which to base the theory and the absence of data to verify the prediction of the same theory. In any case the climate system is not studied for its general properties rather all the efforts today are directed to the prediction for the next century. As noted by Edward Lorenz in his 1975 paper on climate predictability, a real test for the climate theory would be the simulation of the ice age cycle that was beyond the computer performance at that time as it is today. This is mostly how physics works: the recent discovery of gravitational waves is the most vivid example of the confirmation of Einstein's general theory of relativity. Similar examples can be drawn from many other fields of physics like condensed matter, etc., climate science has never advanced in the same way but rather is always in the interpretative mode except now for the prediction of global warming. The prediction can only be confirmed by the future data so that there must be other ways to confirm the theory, for example, by developing new measurement strategies for the behavior of the Earth's energy balance.

Despite the lack of a consistent scientific theory, there exist a correspondent philosophy of climate science. Some paper appeared on the subject as early as 1984 (Naomi Oreskes) and then during the late 90 those of David Randall and Bruce Wielicki or Dennis Bray and Hans Von Storch. Philosophical discussion again is very much limited to climate models and most of the earlier papers were dealing with model validation. All those first class climate scientists embarked in discussions using freely Popper or Kuhn and whatever. Bray and von Storch, following professional philosophers, even classified climate sciences among "postnormal science". According to them this should be a further state of evolution from the "normal" science introduced by Thomas Kuhn and "*addresses the issue at hand when there is a considerable amount of knowledge generated by normal science in different disciplines and there is a high degree of uncertainty and the potential for disagreement due to empirical problems and political pressure. This characterization is consistent with the present state of climate sciences.*" The early studies were discussing mostly if the models were still falsifiable when they were using parameterization and tuning. Again the confusion was total considering that, the falsification concept, was introduced by Popper in connection with scientific theories and models are not theories. Philosophy of science has something to say about climate science. After all one of the purposes of the philosophy is decide if the climate sciences are within the physical sciences or if they are like biology. In the latter case the approach could be quite different but standard about quality of data, theories and models should be established. As we say somewhere in the book, "researchers work (or should work) in such a way that the nature should constraints their conclusions. Beside scientists aim to find out the real state of the nature without never reaching it. Philosophy on the other hand deals with absolute concepts." Judging from the available material these issues are quite marginal to the debate. We have not resisted the temptation to write about these topics. We start with a very simple introduction to some of the problems climate science is supposed to study and many of them are still without a reasonable answer. Then we proceed to summarize the methodology used in the study of climate including satellite observations before going to one of the central points: the environmental modeling. This is our first stint to elementary philosophy where the concept of "pragmatic realism" is introduced and also constitutes a first example how much suspect is the terrain we enter. We discovered much later that pragmatic realism is one of the main theories invented by Hilary Putnam, the Harvard philosophical guru. However Keith Beven the inventor of the "our" pragmatic realism never mention mainstream philosophy although the two concepts can be reconciled. According to Beven "practitioners" are developing and using models that are as "realistic as possible" given the external constraints (as computing capabilities). The most liberal interpretation of Putnam's pragmatic realism is on the same direction. In other words, the theory of truth is not the real goal but rather can we model the world in such a way to make sense of it and withstand its impact? Within this framework the General Circulation Models (GCM) enters full fledged in the pragmatic realism being the only tools available to predict future climate. However, important as they are, being simply an engineering method to predict climate, they must be based on climate science . Also, to be accepted as an engineering method, models need to be tested against data and climate data are quite scarce and of dubious quality. Nevertheless there are even suggestion to regard GCM as possible means to perform crucial experimentss in the science of climate and to introduce computational techniques as its third leg besides theory and experiment. This could be equivalent to substitute the Large Hadron Collider (LHC) or the LIGO (Laser Interferometer Gravitational Observatory) detectors with a supercomputer center. As a matter of fact, immense computer resources are employed to digest the data of the above experiments but nobody think that the software in itself could be called physics.

The same chapter deals with the uncertainty issue in model predictions. Uncertainty is the main excuse the establishment uses to postpone decisions while scientists do not regard it so important because the observed changes in climate in the past decades leave very few doubts about the reality. However, uncertainty must be important for scientists because considering all the intervening conditions they should be able to indicate which are the uncertainties accompanying their prediction. Citing Popper an encouragement should be given to the simplification of theories and/or models that become in this way more testable. A problem arise with the application of the falsification criteria of Popperian tradition because models are not a theory, but rather are based on it and as someone already said they arrive at the crucial test already largely falsified.

At this point, we need to ask the question on the existence of climate science and this necessarily implies to report largely Richard Lewontin ideas in particular when the traditional vision of science progress attributed to Popper, Kuhn and so on is compared with the Marxist point of view that "scientific growth does not proceeds in a vacuum." In our case, we have plenty of indicators of the political influence like the existence of the IPCC on one side (expressions of the world government) and the oil companies on the other. The proposed creation of a few supercomputer centers could implies an obvious dependence from the governments, who own them.

Finally, a short discussion is made about the deductive nature of the models meaning that from a model we can expect some kind of data to compare with reality. This contradicts the popularity the inductive method has in science and the support it got from one of the major geophysicist of all time, Harold Jeffreys. The warning from both lines of thought is not to drift too far away from data.

There are other pretenders to the field of climate science and these are the statisticians. There are many ideas from this field that could be useful with the Bayes statistics as the main force. Bayes statistics has a very peculiar feature that makes it particularly suitable to study climate and that is the possible prediction improvement as new data arrive. That approach has been shown could be decisive for a correct prediction of future climate. There was a NASA project that employed this concept but was postponed and stripped of its main qualities and now it is just too late. We all know that global warming is for real and that there are no chances to maintain the warming below the 2° and apparently it does not make sense to maintain a park of more than 40 GCM to predict a future which is already here. A possible proposal would be to use simpler models and return to consider climate science as composed of many other problems and to continue to study the functioning of the climate system with large, complex and long-term experiments as it is done in other fields of science. Climate scientists should not lose this occasion to enter the field of "big science".

This book was written in almost solitary confinement that coincided with my retirement. A great and essential support came from Richard Goody, who read chapter after chapter and provided comments that have been included here. At the end of each chapter, a box reports a discussion between a "humanist" and the "climate scientist" on the content of that chapter. The idea, probably based on something similar contained in a book by Harold Jeffreys, is from Richard. This book is dedicated to him.

L'Aquila, Italy Guido Visconti

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The idea of this book was born from a paper (never published) I wrote with Richard Goody. I carried out from that expanding the content and scope under the constant assistance from Richard. To write a book takes a considerable amount of time from the technical details to obtaining the permissions for the quotations. I have a debt to my student, Paolo Ruggieri, who took time out of his Ph.D. thesis to assist with Latex. Bruno Carli read the final version of the manuscript and made several suggestions to improve the text. My wife, Annamaria, and daughter, Sara, were patient enough to endure the many absences from the daily routine.

Contents

1 A Summary of the Problem 1
1.1 The Greenhouse Effect 2
1.2 The Climate Sensitivity 3
1.3 The Global Warming potential (GWP) 4
1.4 The Carbon Cycle: How the Concentrations of CO_2 and CH_4 are Determined 5
References 10

2 How Climate Is Studied 11
2.1 Meteorology and Climate 12
2.2 A Very Short History of Numerical Modeling 14
2.3 Earth's Climatic History: A Source of Data 15
2.4 The Oceanic Circulation 17
2.5 Climatic Changes in Recent Times 20
2.6 How the Observations Are Made 21
2.7 Satellite Observations 22
2.8 The Climate Through its Fluctuations 24
2.9 How Climate Predictions Are Made 24
References 28

3 Modeling the Environment 31
3.1 Introduction 31
3.2 Models Like Experimental Tools 32
3.3 The Validation of Models 38
3.4 The Responsibility of Scientists 39
3.5 The Falsification of Models 42
References 46

4 What Is Climate Science 49
4.1 Introduction 49
4.2 Another Bit of Philosophy 51

4.3 Physics and Philosophy of Climate Predictions 53
4.4 Are Climate Sciences Part of the Physical Sciences? 56
References. 63

5 Experimental Data and Climate 65
5.1 Introduction 65
5.2 Uncertainties in the Climate Prediction. 66
5.3 The Quality of the Climate Data. 69
5.4 Selection and Use of New Data 72
References. 77

6 The Bayes Statistics and the Climate 79
6.1 Introduction 79
6.2 The Bayes Inference Applied to the Climate 82
6.3 How Start to Distinguish with Bayes 86
6.4 Fingerprinting the Climate Variations. 87
6.5 Prioritizing the Data 93
6.6 Are There Alternatives to Bayes?. 95
References. 100

7 Statistics and Climate 103
7.1 Introduction 103
7.2 Definition of Weather and Climate. 104
7.3 How Statisticians Evaluate Models Results. 106
7.4 The Fortune Teller Approach and Related Stories 110
References. 115

8 Recent Developments 117
8.1 Introduction 117
8.2 The Warming Hiatus 118
8.3 Geoengineering. 120
8.4 Solar Radiation Management 123
8.5 SRM and Ozone. 125
8.6 A Note on Negative Emission Technologies NET 127
References. 131

9 Some Conclusion 133
9.1 Introduction 133
9.2 Again What Is Climate and Are GCM's Reproducing It?. 135
9.3 Long and Wasted Years ?. 138
9.4 Think About It 141
References. 147

Appendix A 149

Index 157

Chapter 1
A Summary of the Problem

Any discussion needs a base of knowledge and this chapter is necessary to summarize a few things that are essential in the debate on the climate change. There is a minimum of simple formulas involved in the introduction of concepts like the greenhouse effect or the climate sensitivity. The global warming is attributed to an intensification of the greenhouse effect which is due basically to gases that were present in the Earth's atmosphere before the industrial revolution.The concentration of some of these gases has been perturbed by the human activity and this is one of the few facts that can be proved experimentally. Different questions arise related to the sensitivity of the climate system (i.e., how many degrees will the temperature rises for a given increase of greenhouse gases, see par. 1.2) and to the mechanisms by which a production of greenhouse gases by natural or anthropogenic processes will impact on their atmospheric concentration. Naturally, we need a definition of climate as distinct from everyday weather. The most simple and efficient distinction between weather and climate is a popular saying "Climate is what you expect, weather is what you get". For some strange reason, the saying is attributed to Mark Twain but for the first time appears in a novel "Time enough for love" by the science fiction writer Heinlein (1973). However, it was explicitly reported by Edward Lorenz in a paper never published (Lorenz 1997). This distinction gives immediately the idea that climate is something of an average of the weather day after day. Each one of us (even without a degree in meteorology) can describe what is the climate in his city making unconsciously an average based on his experience that describes the characteristics of the winter or summer. This qualitative attitude toward the climate is one of the problems to be discussed several times in this book because it is apparently conserved at the highest scientific levels.

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More recently, especially thanks to some statistician suggestion (Chandler et al. 2010), climate has been defined as "the distribution of weather" and climatic change must be intended as changes in this distribution. They observe that most of the dangerous climate originates from weather extremes. These not only include heat waves but also precipitation extremes (drought and floods). We will discuss several times the different definitions of weather and climate and their implications.

1.1 The Greenhouse Effect

Planet Earth, like all of the other planets of the solar system, receives its energy (radiation) from the sun, contained mainly in the visible part of the spectrum. The surface of the Earth receives on the average about 350 W/m^2 but only part of this power (about 70%) is absorbed by the surface–atmosphere system. The absorbed energy heats the surface and the atmosphere, and these two components reemit energy in the infrared.

Reflection and absorption of solar radiation take place both at the surface and in the atmosphere. In the latter, reflection takes place mainly in the clouds while the main absorber is water vapor. The same thing happens for the emitted infrared radiation absorbed other than from water vapor (chemical formula H_2O) also by other gases present in the atmosphere like carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). These are known as greenhouse gases (GHG) and there are a few others. The absorption heats the atmosphere and then the surface and at the equilibrium the total absorbed solar power must be exactly equal to the net power emitted in the infrared. In the absence of such an equilibrium, for example, with the absorbed power less than the emitted power, the Earth would warm forever and vice versa. In the absence of an atmosphere (as the Moon), the emitted radiation would not be captured by the atmosphere and the surface temperature would be about 19 C below zero instead of the comfortable 15 C above zero that we experience on the average today. A difference of 34 C gives a numerical value for what is known as **Greenhouse effect**.

This term is somewhat misleading because it refers to an effect that does not exist. Usually, you are told that a greenhouse works on the same principle, that is, the solar radiation penetrates the greenhouse but the infrared radiation (heat) cannot escape, blocked by the walls made of glass or plastics. Actually, even if you build a greenhouse with transparent walls in the infrared the greenhouse would heat anyway as long as you keep windows and doors closed. As a matter of fact, what is causing the heating is the blocking of the air circulation inside the greenhouse. You can easily demonstrate that by parking your car in the Sun with closed windows.

The equilibrium temperature is a function of the amount of greenhouse gases present in the atmosphere. It is quite surprising that their concentrations are very small. The highest corresponds to water vapor with amount of the order of 10 g/kg of air. The carbon dioxide on the other hand has concentration around 400 molecules for each million of molecules of air (what is called 400 part per million (ppm)) and that is about 0.6 g for each kilogram of air. In conclusion, the atmosphere contains 99.9% gases with no effect whatsoever on climate except for the 0.1%.

If the concentration of a greenhouse gas increases, the absorption of infrared radiation in the atmosphere increases so that at its top there is a deficit in the energy balance (net infrared radiation (IR) is less than net solar radiation). In order to reestablish the equilibrium, the temperature of the surface must increase up to the point that the emitted radiation equals the absorbed one. The power deficit just mentioned is called **radiative forcing** and for a doubling the carbon dioxide concentration is about $4\,W/m^2$.

From 1750 until now, it has been evaluated (only computationally) that the total radiative forcing is due to 64% of carbon dioxide, 18% of methane, and 6% of nitrous oxide. The remaining 12% could be attributed to other greenhouse gases "Computationally" which means that nobody has obtained so far an experimental confirmation of these data. Someone has compared the change in temperature to the water level in a bathtub that receives a constant flow of water from the faucet (solar power). The water level stabilizes when the flow from the faucet equals the flow from the sink (outgoing infrared radiation) which is a function of the water level. If the sink is partly blocked (adding of greenhouse gases), the water level rises until the outgoing flux equals the flux from the faucet.

1.2 The Climate Sensitivity

One of the main problems in climate science is to evaluate how much changes the average temperature of the Earth has for an assigned radiative forcing. The answer to this apparent simple question is called **climate sensitivity** which is defined as the change in temperature (in degrees Kelvin, K) for a forcing of 1 watt per square meter. Again today this parameter is mainly evaluated using models and its "bare" value is around $0.3\ K/wm^{-2}$. Bare means that this would be the sensitivity without any feedback mechanism, that is, for a doubling of the carbon dioxide concentration, the average temperature of the Earth could increase by $0.3 \times 4 = 1.2\,K$ (remember here the $4\,wm^{-2}$ of the previous paragraph). Actually, the IPCC document gives a much larger uncertainty, that is, the change in temperature could be between 1.5 and 4.5 K and this could be attributed to the different feedback mechanisms present in the climate system. The value 0.3 corresponds to an atmosphere containing only carbon dioxide. However, just the presence of water vapor introduces an amplification effect. When the concentration of carbon dioxide (or any other greenhouse gas) increases, the temperature of the atmosphere increases with the effect of increasing the saturation pressure for water vapor. More water can then evaporate and increase the mass of this gas in the atmosphere. The net result is that the initial increase in temperature corresponds an increase in concentration of a very efficient greenhouse gas like water vapor that causes a further increase in temperature. This mechanism is known as **water vapor feedback**. There are several other feedbacks based on clouds or the Earth's albedo and they can be positive (in the same direction of the initial cause) or negative (in the opposite direction). There is a very simple expression which relates the climate sensitivity to the **feedback factor**, f. If a perturbation ΔF in the radiative flux is introduced, this will produce a temperature change ΔT given by $\Delta T_0 + f\Delta T$. The first term is simply the definition of climate sensitivity $\Delta T_0 = \lambda_0 \Delta F$, while the second term is the effect of the feedback that we assume to be proportional to the temperature through the feedback factor f. We have then $\Delta T = \Delta T_0 + f\Delta T$ from which

$$\Delta T = \frac{\Delta T_0}{(1-f)}.$$

From this simple expression, we see that with a feedback factor equal to 0.5 the temperature change doubles and tends to infinity for a feedback factor reaching 1. This explains why for a carbon dioxide doubling we may reach 4.5 C starting from a $\Delta T_0 = 1.2$°C.

The introduction of the feedback factor complicates the attribution of the causes for a generic increase in temperature. Besides, it can be easily shown that an uncertainty in the feedback factor introduces a much larger uncertainty in the sensitivity. It is worth to notice that the water vapor feedback has been measured many years ago in a very simple situation above the ocean. It seems to go in the direction we just described. This is one of the few experimental results that can be counted in the climate science. As an example, the climate sensitivity has never been measured experimentally. Although we will see later, many suggestions have been made.

1.3 The Global Warming potential (GWP)

Not all the greenhouse gases we mentioned have the same effects on the climate and then may be useful to invent a classification that may help in deciding about strategies to limit their production: the most dangerous first and those relatively unharmful last. This classification may depend on a number of parameters that range from the efficiency it absorbs infrared radiation, to its concentration, and to the modalities of its atmospheric release. All these data must be condensed in just one, that is, the **global warming potential (GWP)**. We consider one kilogram of gas