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.

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Springer

http://www.springer.com/978-3-319-65668-7

Problems, Philosophy and Politics of Climate Science
Visconti, G.
2018, XIV, 159 p. 21 illus., Hardcover
ISBN: 978-3-319-65668-7