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Holism, entrenchment, and the future of climate model pluralism

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Abstract

In this paper, we explore the extent to which issues of simulation model validation take on novel characteristics when the models in question become particularly complex. Our central claim is that complex simulation models in general, and global models of climate in particular, face a form of confirmation holism. This holism, moreover, makes analytic understanding of complex models of climate either extremely difficult or even impossible. We argue that this supports a position we call convergence skepticism: the belief that the existence of a plurality of different models making a plurality of different forecasts of future climate is likely to be a persistent feature of global climate science.

Introduction

How do we know when a complex computer model is good enough, or reliable enough, for a task for which we hope to depend on it? This is the issue of model validation, and it is the central issue in the epistemology of simulation. In this paper, we argue that issues of simulation model validation take on novel characteristics when the models in question become particularly complex. Our central claim is this: Computer simulation models that are highly complex, in the sense that they blend together a diverse mixture of models of different systems and effects, face novel epistemological challenges associated with a kind of epistemological holism. This holism, moreover, makes analytic understanding of complex models either extremely difficult or even impossible. Roughly, the concept of having an analytic understanding of a complex model refers to the ability to tease apart the various sources of success and failure of a simulation and to attribute them to particular model assumptions of different models. And while we think that the epistemological characteristics of highly complex models have their own general interest, we also believe that this topic has special importance given the role that these kinds of models play in climate science, and global climate forecasting. The claims that we argue for in this paper, therefore, should be of general interest to all those interested in the epistemology of simulation, but we also have a special interest in understanding the epistemological characteristics of the models that inform most of what we believe about the future of the earth's climate.

We begin with some background on the problem of holism in philosophy of science and also by introducing the notion of model plurality in current climate science. After this, our paper proceeds on two fronts. First, we identify two sources of holism: modularity and kludging. We argue that both of these are typical (because they are essential for practical reasons) of complex simulation models. Climate models will serve as illustrations here. Second, we move on to climate models as central examples. We investigate the actual process of evaluation as it is pursued in model comparison projects. This case will provide confirmation of our general claim about holism: in this special case we find persistent model plurality and problems of understanding what features of our models are responsible for their best and worst qualities—which is what would be expected on the grounds of holism.

We argue, finally, that the likelihood of us failing to gain analytic understanding of our models supports a position we call convergence skepticism:[1] the belief that the existence of a plurality of different models making a plurality of different forecasts of future climate is likely to be a persistent feature of global climate science. The implication for climate policy is obvious: it should not wait for convergence, rather take the pluralistic picture as a given.

Section snippets

Holism

Let us begin with a brief discussion of a concept that will play a central role in this paper: confirmation holism. Confirmation holism, as it is traditionally understood, is the thesis that a single hypothesis cannot be tested in isolation, but that such tests inevitably depend on other (the so-called "auxiliary") theories or hypotheses. It is always this collection of theories and hypotheses as a whole, says the thesis, that confront the tribunal of experience.

The problem of confirmational...

Validating climate models

To begin to see how and why this kind of holism arises, let us look at some of the key features of model validation. One key endeavor of climate science is to provide a range of possible, likely, or certain futures of the earth's climate. Because it is a pivotal for climate science and simulation is pivotal for forecasting. So, simulation model validation is a central issue in climate science if we want to address questions like: How certain and trustworthy are simulation-based forecasts? Is a...

Fuzzy modularity

The historical origins of climate analysis are rooted in models of the circulation of the atmosphere—general circulation models (GCMs) that have been developed since the mid-1950s. The theoretical core of these models is built out of the so-called fundamental equations, a system of partial differential equations motivated by fluid mechanics and thermodynamics. This is often referred to as the "physical core".[3] With the growing interest in climate change in the 1980s, these models began a process ...

Kludging

Modularity is one of the key features of modern climate models that we focus on. The other is the role of what we call "kludging". The term "kludge" or "kluge" initially stems from programmers' colloquial language and is an extremely useful one here. Andy Clark stresses the important role played by kludges in complex modular computer modeling in general. A kludge is "an inelegant, 'botched together' piece of program; something functional but somehow messy and unsatisfying", it is—Clark here...

Confirmational holism

We are now in a position to discuss the sources of holism and the failure of analytic understanding. It is possible, of course, to test the performance of climate models under a variety of conditions. And different models perform better under certain conditions than others. But if model A performs better at making predictions on condition A*, and model B performs better under condition B*, then optimistically, one might hope that a hybrid model—one that contained some features of model A and...

A case in point: model comparison

In the last three sections, we have argued, on more or less a priori grounds, that because of fuzzy modularity, kludging and generative entrenchment, one might expect confirmation holism, and a failure of analytic understanding, to arise in climate models. In this section, we will cite evidence from the field that there have indeed been concerted efforts to achieve analytic understanding, and that they have failed. Together, these two strands will comprise our argument that modularity...

Corollary on plurality

There is a corollary to our thesis about the difficulty or impossibility of achieving analytic understanding of complex models. The difficulty of attributing the sources of success and failure of complex models blocks model unification and hence makes model convergence unlikely. That is, it makes it difficult or even impossible, given the present plurality of climate models, to arrive at an unequivocal diagnosis of the sources of model divergence. Such a diagnosis, alas, is exactly what is...

Conclusions

We have argued that complex simulation models in general, and climate models in particular, are—due to fuzzy modularity, kludging, and generative entrenchment—the products of their contingent respective histories. We have also argued that, because of these features, the internal modules of a climate model do not (easily) exhibit their own intrinsic goodness of fit. As such, climate models are analytically impenetrable in the sense that we have been unable, and are likely to continue to be...

Acknowledgement

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