From Toy Models to MIPS: Science and Technoscience in Computer Climate Modeling 1957-2004

Mott T. Greene, University of Puget Sound
greene@ups.edu

Abstract

The use of computers in the 1950s to generate weather forecasts by numerical methods generated statistics that could be used for the study of climate, and computer climate modeling quickly became a separate field of endeavor.

From that time to the present, computer climate models have grown steadily larger and more complex, and now contain 100 and even 1000s of parameters, and perform integrations for three-dimensional coupled ocean-atmosphere-sea-ice models with short time steps and fine grid resolution. This has been made possible (and actually motivated) by an exponential increase in computing power over a half century, still proceeding.

The physics driving these models, however, is derived almost exclusively from the behavior of simple toy models with 0, 1, or 2 dimensions, and only a few parameters. While the large models produce interesting results, they do not serve as tools of discovery in the physical realm.

Within the last decade the large models, while becoming qualitatively more like the earth, have become quantitatively less accurate. Model Intercomparisons show that large models seek significantly different eqilibria, far from each other and from that of the actual earth, for a variety of reasons but not, significantly, because they employ different physical assumptions. Tunings, faulty parameterizations, and hidden internal errors are the likely culprits, though the models are so large and complex that the source of the errors cannot currently be determined in most cases.

While it would seem that a promising strategy would be to make the models simpler and smaller (at least temporarily) to root out the sources of error, there are substantial obstacles to this obvious line of attack.

The most formidable obstacle is the way the climate community is constituted, and the way climate scientists are trained and employed, especially in the United States. While climate modeling in the UK and Japan (for instance) is highly centralized, the US has pursued a climate science-policy funding course of competition, selection, and subsequent collaboration. Many models and modeling centers are funded, the models are compared, some are eliminated, and others merged. The emergence of

the Community Climate Models (CCMs) coordinated by the National Center for Atmospheric Research is the result of this process. The funding process produced a climate community in which the "authors" of the model number in the hundreds, directed by a coordinating committee of about 40 senior scientists. It is a collaborative effort not unlike the "open-source code" movement in computer operating systems.

The strength of the CCM is its openness to novelty and refinement, and its inclusiveness. Its weakness is that it is nearly impossible to make it anything but bigger, even with a strong intellectual rationale (occult errors) that make it advisable to make the model smaller. This weakness is the result of the way climate scientists are recruited and trained.

Most PhD students in the climate community begin their careers learning a technique that allows them to refine an existing parameter in a model, or to introduce a new parameter. Professional success is tied, to a certain extent, to the ability to get one's parameterization into the model. PhD advisers must support this, if their students are to have successful careers. So the way students are trained, in the main, automatically increases the size of the models.

Since the field techniques and modeling techniques for different parameters are complex and take a long time to master, careers tend to be wedded for some time and perhaps throughout the working lifetime to specific instruments and procedures. Many climate scientists are in fact highly skilled technicians whose mastery of technique deserves a PhD. but who simply do not have the breadth of training to do something else. They therefore become deeply vested in the preservation, not necessarily of any given version of a parameter, but to the retention of a family of parameters (a family to which they belong) in the models. So a parameter, once included, has a vested constituency that depends on its survival for its own survival..

This is not *as it might at first seem* an argument that the model expansion is driven simply by careerism. There are powerful sociological dynamics at work. The models are huge, they don't predict well. If they ever do, it will be decades from now. How is morale to be maintained in such a scientific community, where most workers will not see ultimate success in their lifetimes? The answer seems to lie, on inspection, in the community at large redefining career success in terms of collaborative work in some *modular component* of the model. In this sense there is almost no one who works on a model "as a whole": senior climate scientists admit these models are too big for any individual to understand. One works not on climate but arctic climate, and not just arctic climate but sea ice, and not just sea ice, but sea-ice snow-cover studies. This latter, perfectly respectable and important group becomes the career arena. It is about the same size as the entire arctic climate community 40 years ago. It is, from a sociological and psychological standpoint, *the right size*. This dynamic is at work in scores of modular communities participating in the model as a whole, conspiring to keep the model large and growing.

The ultimate point here is that things in the large-scale coupled ocean-atmosphere computer climate modeling world (in the area of quantitative accuracy and prediction) are not going well, not because people are behaving badly, but because they are behaving well, and doing what they were trained to do, following community norms and characteristic career trajectories.

I have tried to build a qualitative model of this interesting impasse, using the idea of a "fitness landscape" to show the constraints which keep these models large. I hope to present at least an outline of this model during my presentation.