Third, far from playing down the importance of plutonium in his speech in February 1942 to Hitler's officials, Heisenberg mentions the subject prominently (*Collected Works of Werner Heisenberg*, eds W. Blum *et al.*, Springer, 1989). He later reminds his audience that a reactor by-product will be explosive and that uranium-235 is also an explosive "of unimaginable strength". If he fell silent to Speer, it was only for fear of being ordered to produce the new weapon on demand.

Fourth, if Heisenberg really did know that the critical mass for a uranium bomb was as small as it is, then why was he so shocked when he learned of Hiroshima? Why was his calculation of the critical mass so flawed in his lecture to his fellow internees at Farm Hall on 14 August 1945 (see J. Bernstein, *New York Review of Books* **39**, 47–53; 13 August 1992 and J. L. Logan & R. Serber, *Nature* **362**, 117; 11 March 1993)? And why did he tell Otto Hahn on 6 August that "quite honestly I have never worked it out as I never believed one could get pure '235'"?

Finally, there is no credible evidence for the assassination plot, nor is it plausible. The Allies knew Heisenberg was working on fission: why not assassinate him outright, instead of waiting for him to reveal his research to a foreign audience? Why do the deed in a public forum? Why select an agent as unlikely as a multilingual baseball player? And why not target other travelling German scientists?

In rejecting Powers's portrayal of Heisenberg as hero, I do not mean to imply that Heisenberg was a fiendish villain, bent on producing nuclear weapons for Hitler or for Germany. Rather, he was what we might expect: a highly talented, cultured individual of normal decency who was unfortunately caught up in the dreadful circumstances of his time for which he, like most people, was totally unprepared. At times he did use his position to worthy ends. But to argue beyond that — to claim that he alone acted so very differently from the rest — is to stretch credulity, and the historical record, beyond the breaking point. □

David Cassidy is in the Natural Science Program, Hofstra University, Hempstead, New York 11550, USA.

A man's reach must exceed his grasp . . .

David Rind

Climate System Modeling. Edited by K. E. Trenberth. *Cambridge University Press: 1993. Pp. 788. £35, $49.95.*

To model the climate system, we apparently have to understand (with apologies to Douglas Adams), "life, the universe and everything". For example, in addition to knowledge about the atmosphere and climate, we must know how vegetation responds to soil moisture deficits (which affects the severity of droughts) and how marine biota take up nutrients in a food web (which affects the ocean's ability to absorb carbon dioxide). To understand the climate system's natural variability we must be able to quantify past and present climate forcing, which includes learning more about solar variability and stellar evolution. The concluding paragraph of this hefty tome rightly notes that "numerical modeling of the climate system is . . . one of the grand scientific challenges of our time"; and before the reader is finished with this survey of topics to be understood and modelled, he or she will be convinced that we need to know just about everything.

The book was conceived as a way for graduate students specializing in one area of the climate system to learn about the issues and techniques in modelling other, often adjoining areas. It should serve equally well for their professors. Chapters first present the science underlying the various subsystems, including the atmosphere, ocean, land surface, terrestrial biology, atmospheric chemistry and marine biogeochemistry. Then models of these components are introduced, in greater or lesser detail. The writing is of uniformly high quality by specialists in each field; the figures are attractive and of uniform style; and considerable effort has been made to cross-reference concepts among the different chapters.

Can climate system modelling really be learned this way? Readers will undoubtedly pick up some information about each speciality, although the presentations differ markedly in their approach. The chapter on atmospheric science tries to cover the whole field in 60 pages, and in some depth too. It is hard to imagine that a student unfamiliar with most of the concepts will be able to digest all of this concentrated material. In contrast, other authors discuss only the portion of their discipline that relates to the climate system. The marine biogeochemistry chapter, for example, devotes nearly 40 pages to the marine carbon cycle; it takes a dedicated reader to wade through all the details. In between are chapters such as that on atmospheric chemistry that fully realize the goal of the volume.

Similar disparities are found in the modelling chapters, partly influenced by the authors' desire not to duplicate too much of what appears in the background science sections. The chapter on sea ice modelling presents many of the detailed equations; the chapter on land ice modelling has almost no equations; and the discussion of atmospheric chemistry modelling spends almost all of its time on numerical solutions to the transport equations. There is also a varying tone in the authors' assessments of how well the individual models can simulate reality, ranging from brutal honesty to Pollyanna myopia. Again, occasional chapters stand out, such as the accessible and comprehensive one on ocean modelling.

How is the field represented by this book? There is some parochialism in the choice of contributors; more than half of the chapters are written by scientists at the National Center for Atmospheric Research in Boulder, Colorado, or at nearby organizations, and so some points of view are neglected. A more serious problem, however, arises because most of the modelling is done by physicists and numerical analysts. Rarely, for example, are biologists fully involved in modelling the biospheric components, chemists in modelling atmospheric or ocean chemistry, or oceanographers in producing global ocean models. (Oceanographers usually emphasize the importance of mesoscale eddies; the ocean modelling chapter, however, focuses on models that omit these eddies.) Specialists in these fields often rebel vociferously against the approaches of climate system modellers, and consider the models to be simplistic and misleading. I once had occasion to show a well-known land surface model to a prominent soil scientist. After reading the equations, he commented: "This is how I would have thought it worked if I didn't know better."

Is climate system modelling the ultimate example of hubris, or, by chopping away at areas of ignorance, will we truly improve our predictive capability? A thorough reading of *Climate System Modeling* provides support for both points of view. Unfortunately, our newly found capacity to alter the climate system through increases in carbon dioxide and so on makes this more than simply an academic question. □

David Rind is in the NASA Goddard Space Flight Center, Goddard Institute for Space Studies, 2880 Broadway, New York, New York 10025, USA.