

Making Global Models Accessible:  
The Earth Systems Project

Kenneth L. Simons<sup>1</sup>

Global models such as World3, IFs, and Globus are used in many nations' planning and policy making. They discuss, for example, transition to a sustainable demographic and economic future, energy and materials supply, national strategy, and the stability of international political relations. By explicitly incorporating interrelationships known and under investigation by scientists, they provide a quantitative backing for qualitative work by demographers, economists, environmentalists, political scientists, and others. They allow scientists to investigate possible complex interrelationships that would not be evident to those working within a single discipline, since systems of global development and change concern many academic disciplines.<sup>2</sup>

Despite their importance, such global simulation models have not been easily accessible to the public, government officials, or scientists. Books or reports are usually available, but these rarely detail the workings of models. Using or modifying models has required access to an appropriate computer, expertise with a field of modeling, and extensive familiarity with the workings of the model. The builders of the models have often put forth great efforts to create PC versions in which users can test the models and change key parameters, but even this software has been difficult to use and has lacked on-line documentation and learning tools.<sup>3</sup>

To help remedy this situation, in 1989 an Earth Systems software development project was begun at MIT. This was a collaboration between myself, Peter J. Poole, and teams of students hired to assist with the software development. The goal was to create an easy-to-use interface to some important global simulation models. The interface would let users run simulations and change assumptions. It would include an introduction to each model, a discussion of criticisms of the model, diagrams and equations that show how the model works, an annotated bibliography, and sample classroom exercises for teachers. Ideally, it would even explain why the model behaved as it did, though for now such expert assistance exists only in the most rudimentary

forms. Thus, the goal was to create software that made the models accessible to a broad audience, even to people unexperienced with any global models or simulation models of any kind.

This goal carries with it a danger. It is easy to abuse global simulation models. Some users interpret model outcomes as "predictions." For example, depending on how parameters are set when someone runs the World3 simulation model, she might declare either that the model predicts a collapse of the world's population or a high-technology utopia in which people learn to live as a global community. In fact, as with many global models, World3 makes no such predictions. Rather, World3 allows users to consider possible ways in which humankind may approach the world's (changing) carrying capacity, and what effects different "policies"—in this case, activities that humankind might pursue—could have on this pattern of change. Another common abuse of global models happens when users misunderstand the types of uses and conclusions that a model is capable of addressing. For example, World3 contains a variable named "jobs," intended only so that in the event of a population collapse the model can notice a shortage of workers compared to the number of machines. Use of the variable to analyze employment trends would be inappropriate; such analysis would require a more detailed specification of how and why employment patterns change. In this project, we tried to safeguard against abuses by making clear the purpose and construction of models, and by pointing out that simulation results should be treated not as predictions but as possible futures.<sup>4</sup> For the World3 model, we indicated that an important use of the model was to investigate the effects of possible policies, and the robustness of these effects to uncertainties in parameters.

With these goals and concerns in mind, we set out to create interfaces to four global models. The models span the biological, sociological, and physical systems of the Earth. The first model is the Daisyworld model, which illustrates the Gaia hypothesis that life on Earth influences and perhaps regulates the global environment.<sup>5</sup> Since this is a very simple model, it was first to be completed, in 1990. The second is the World3 model of *The Limits to*

*Growth and Beyond the Limits*.<sup>6</sup> This model was completed in 1992. The third and fourth models are an energy-CO<sub>2</sub> model<sup>7</sup> and an energy balance model of climate change. There are no plans to complete the software for these models—though the climate model was begun—because of a lack of funds.

The Daisyworld and Beyond the Limits programs incorporate the features that we intended originally to build into the global models software. To illustrate, I will describe the Beyond the Limits program.

The program is divided into three sections: a reader with an introduction and supplementary information, a section that allows users to examine and change the model, and the simulation itself. All three sections are reached from the program's main screen (fig. 1). The first section looks like a book, with a table of contents and pages of text (fig. 2). An introduction describes the World3 model

and explains how and why to use the program. A "World Today" chapter summarizes real-world data and trends related to the model, such as global food production, water use, and population growth. Other chapters include detailed discussions of criticisms of the model, a teacher's guide, a list of key concepts to understand, and a bibliography.

The second section of the program describes how the model works. A table of contents lists key concepts that involve changes to the model. Each concept is described briefly, but more information is available at the click of a button. Users make changes by moving sliding controls (fig. 3). After changing the model, users run the simulation to see how the changes affect the results.

The second section includes diagrams of the model. Depending on the type of model and its audience, it may make sense to use pictorial diagrams, causal loop diagrams with words and arrows, maps, or other representations. The Beyond the Limits program uses stock-and-flow diagrams as used in a popular modeling program.<sup>8</sup> Clicking with a mouse on any part of a diagram brings up a description of that part (fig. 4). A description defines each variable, clarifies how it fits into the model, and documents its equation and units. Users can change any constant or graphical function. They can also perform comprehensive sensitivity analyses of model parameters.

The third section of the program is where users run the model and view the results (fig. 5). Buttons on the lower left allow users to start, stop, and pause the simulation. During the simulation, bar graphs move up and down as key variables change. The date appears in the lower right corner, along with messages that alert users about key happenings in the simulated world. The sliding controls at the bottom allow users to change world policies as the simulation runs.<sup>9</sup> A button on the left side allows users to plot any of the model's variables over time.

The Daisyworld and Beyond the Limits programs are available from this author. They can also be found on the Internet; as of fall 1997 at:

<http://www.rhbnc.ac.uk/~uhss021>

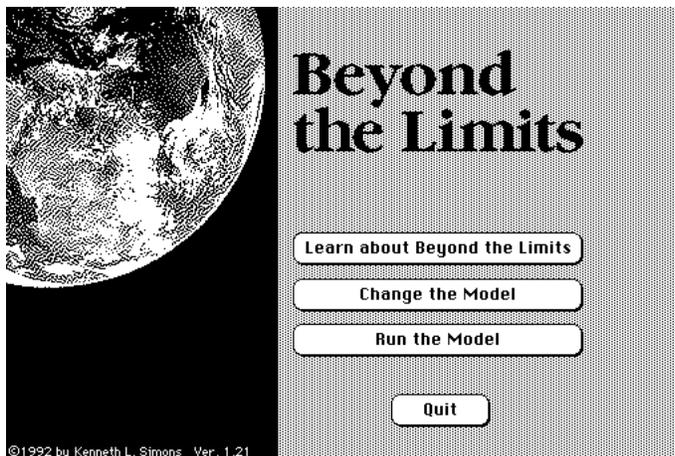


Figure 1. Main screen.

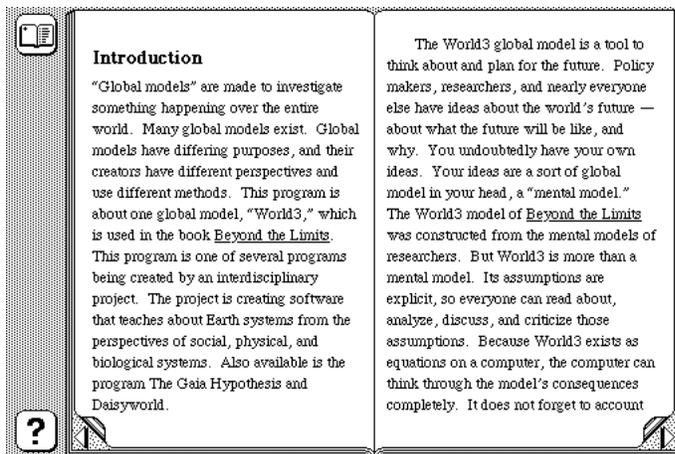


Figure 2. Introductory chapter in the reader.

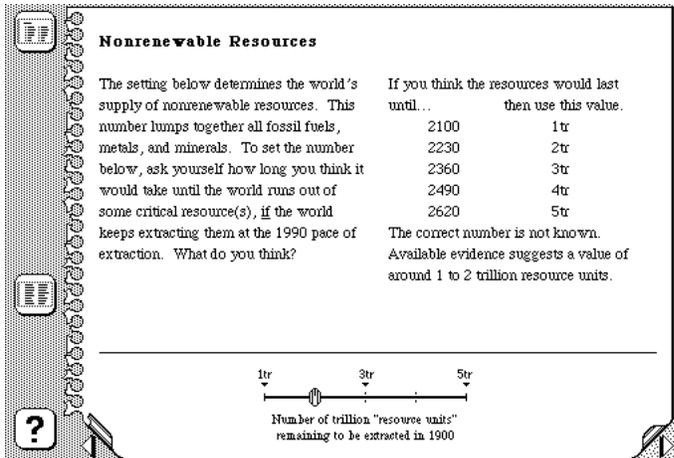


Figure 3. A model changes screen.

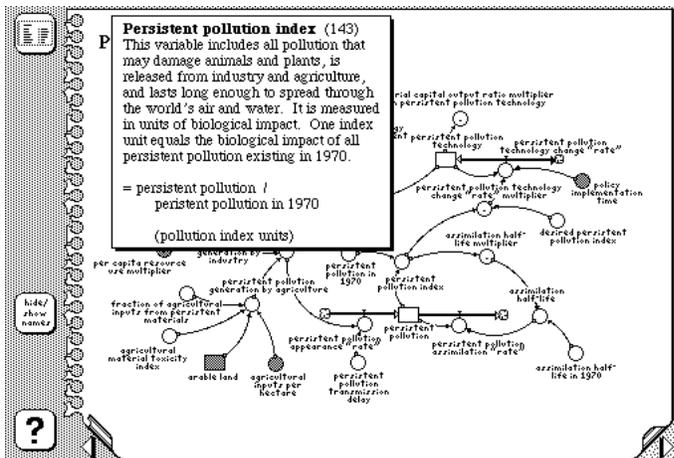


Figure 4. A model diagram screen with a description of one of the model's variables.

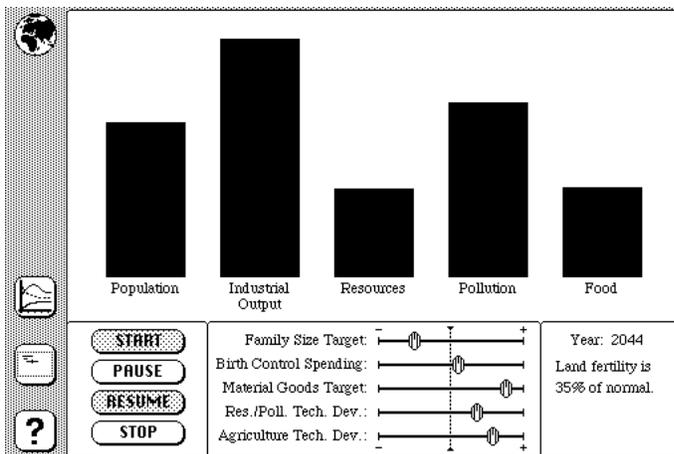


Figure 5. Run screen.

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## Notes

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<sup>1</sup> Address correspondence to Kenneth L. Simons. As of fall 1997, he is a member of: Economics, Royal Holloway, University of London, Egham, Surrey TW20 0EX, United Kingdom.

<sup>2</sup>Meadows *et al.* (1981) describes and compares seven principal global models and their modelers' viewpoints discussed in conferences of the International Institute for Applied Systems Analysis. Barney (1991) and an annotated bibliography in Meadows *et al.* (1992) describe readings related more generally to sustainable development and global future planning. Readers interested in global models which explicitly incorporate politics may wish to examine Bremer (1986).

<sup>3</sup>For an extensive catalogue of available software for simulation models, see Barney *et al.* (1991).

<sup>4</sup>Some models do intend to make predictions, but the models completed so far in this project are not intended for prediction *per se*.

<sup>5</sup>The Daisyworld model was introduced by Watson and Lovelock (1983). For a book that both describes the Gaia hypothesis and introduces the model, see Lovelock (1988).

<sup>6</sup>Meadows *et al.* (1972, 1992). For technical documentation, see Meadows *et al.* (1974).

<sup>7</sup>Edmonds and Reilly (1985).

<sup>8</sup>This is the STELLA modeling program, also called iThink (Richmond and Peterson 1990).

<sup>9</sup>Instead of using these controls, users normally change the model before rather than during each simulation. Changing the controls during the simulation gives the user a feeling of control and helps to generate excitement as with a video game, but it is likely to detract from learning. Users are more likely to learn from the simulation if they make a succession of small changes to the model and watch the results of the changes over multiple simulationd. Changing many variables continually during a simulation can make it hard to understand what changes caused what effects.