STELLA®
for Environmental Sciences

"The work we're doing today would not be possible without the ***STELLA*** *software."*
-- Professor Robert Costanza,
University of Maryland

Barriers and Opportunities

In the environmental sciences, everything *really* is connected to everything else. Indeed, many ecosystems are so full of interdependencies that it's often very difficult to understand who's doing what to whom, and when! As a result, modeling has been used quite extensively in environmental science in an effort to shed light on particular dynamics of interest.

The problem with much of the modeling is that it, too, often becomes too complex to understand. Even the most intrepid researchers frequently are challenged by the tangle of highly abstract differential equations. This leaves the average undergraduate virtually completely out to sea.

Enter the **STELLA**® software. **STELLA** is expressly designed for modeling the dynamics of highly interdependent systems. And, although the software can be used to capture very sophisticated relationships, no complex mathematics is required to do so. Rather than thinking in terms of abstract equations, the **STELLA** software provides a set of simple building blocks which faculty or students can use to piece together the relationships operating in an ecosystem. The software infers many of the equations needed to simulate the system from the structure you've laid out with the building blocks. It's easy to click or sketch the others in.

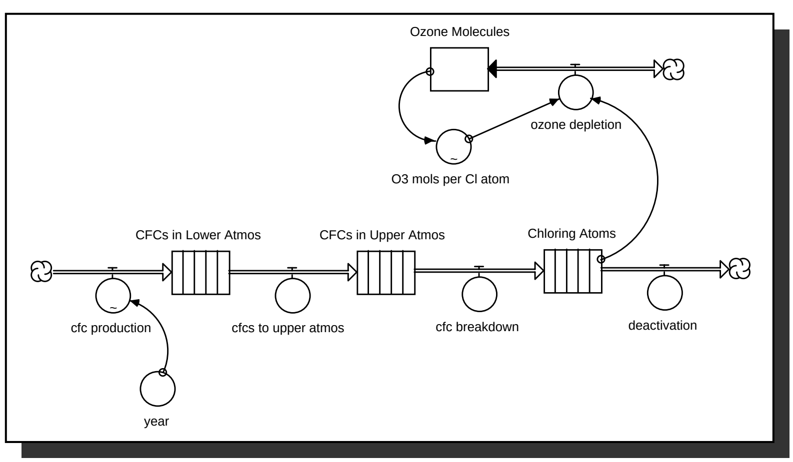
In short, if you can hypothesize it, the **STELLA** software will let you represent it. And, you won't have to be a mathematician to do it!

Case Study

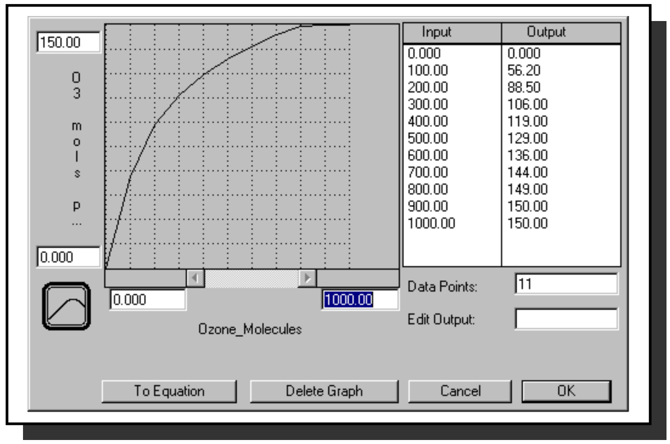
The Setting: A Northeastern college
The Topic: Depletion of the ozone layer
The Challenge: Compressing space and time

Background: Ozone depletion is potentially one of the most serious problems facing the world today. Despite the gravity of the problem, it has proven difficult to galvanize worldwide efforts to address the erosion of our ozone layer. This is, in part, due to the long distances and time delays that characterize the process, and also to the fact that none of the chemicals involved (including ozone) is visible. One way to compress the time delays and distances associated with the depletion of the ozone layer and to make the problem more visible, is to employ simulation. That's precisely what a particular environmental scientist at a Northeastern college did for his class.

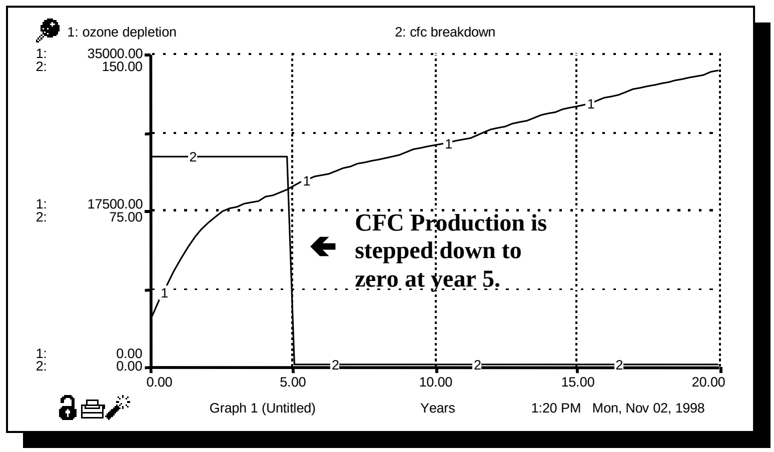
Step 1: Map. The first step the professor took was to lay out the flows and accumulations that are involved with the phenomenon of ozone depletion. This enabled students to see exactly what was flowing where, and what was building up where. The map shown below is a simplified representation of the basic "plumbing" of ozone depletion. As the diagram suggests, CFC's travel from the lower to the upper atmosphere. The journey takes up to 15 years to complete. Upon arrival, the CFC's are bombarded by ultra-violet radiation and slowly break down into their constituent parts. It's the chlorine part that does the damage, with each atom catalyzing the destruction of up to 100,000 ozone molecules.



Step 2: Model. Once the basic plumbing of a system was laid out, the next step was to outfit the diagram with assumptions. In this case, this meant including things like how long it takes CFC's to travel to the upper atmosphere, and once there, how long it takes for them to break down into their constituent atoms. One convenient way to incorporate assumptions is via the **STELLA** software's graphical function (illustrated at right). The relationship illustrated here indicates that when ozone molecules are abundant, each chlorine atom consumes a large number of them. However, as ozone molecules become less abundant, each chlorine atom consumes fewer of them. The relationship is assumed to be non-linear.



Step 3: Simulate. After the diagram was fully outfitted, the next step was to simulate. With the **STELLA** software, simulation output can be viewed as a plot (time series or scatter), a table of numbers, an animation of the diagram, or as a QuickTime™ movie. An illustrative time series plot appears at right. In this case, as the plot above indicates, one of the surprising results generated by simulation was that the rate of ozone depletion would continue to *increase* for at least a decade *after* CFC production was shut down to zero! Students did not anticipate this result. Working to understand why it occurred shed a lot of light on the dynamics of ozone depletion.



Step 4: Celebrate! After conducting numerous simulations, students began to develop a solid feel for the dynamics of ozone depletion. The long delays, huge distances, and non-visible chemicals became a much more palpable reality to the students.

Students also were able to explore a wide range of possible policy options for addressing the ozone problem. And, rather than simply reading about these possible initiatives, students were able to test them out for themselves. All in all, a tough environmental issue became much more understandable thanks to the use of the **STELLA** software.