Rice

Senior
Rice ES Dynamics

The senior-level course was "Earth System Dynamics" and it attracted 18 students from: physics, space physics, geology, ecology, and environmental science. These students were an even mixture of undergraduates and graduate students.

STELLA modeling assignments **required of all students** in the senior-level course:

- Global Hydrological Model
- Global Carbon Cycle with Seasonal Response
- Global Nitrogen Cycle
- Global Energy-Balance Climate Model with Doubled CO2 Response

In addition, each student in the senior-level course was required to build a independent STELLA Model of some process in the Earth system for a term paper. A list follows; some models were done by several students.

- Global Sulfur Cycle
- Global Phosphorous Cycle
- Population Dynamics for Developed and Underdeveloped World
- 3-Layer Atmosphere, Global, Energy-Balance, Climate Model with Clouds
- Zonal Energy-Balance Model with 1-Layer Atmosphere and Horizontal Diffusive Transport
- Exploring the Future with the World3 Model
- Multi-Layer Model for Venus
- Stratospheric Ozone Depletion
- Diurnal Solar Forcing of the Global Distribution of Thunderstorms
- Modeling the Nutrient Cycle of Phytoplankton using Isotope Tracers

The text that follows is my assignment of the term projects for the senior-level class. Many of the projects were completed by the students, as you note from the previous list. Some students suggested their own projects.

Spac/Envi 443, Spring 1994 Earth System Dynamics
Term Modeling Project Due Last Day of Finals
(degree candidates 4/28/94; others 5/4/94)

Individual Global Models
By: Arthur A. Few

1. Energy Balance Models.
   1.1 Expand your model to a 3-layer or 5-layer model; use a combined physical and empirical approach.
   1.2 Create a zonal EBM with tropical, mid-latitude, and polar zones in each hemisphere.
   1.3 Create a multi-layer model for Venus.. How many layers are needed to produce a surface temperature >400C? (The only clouds are at high altitudes.)

2. Nuclear Winters and Asteroid Impacts.
   Start with a 3-layer EBM with the capability of clouds in each layer. The clouds may be reflective (or white, which is the case for water and sulfate clouds) or absorptive (or dark, which is the case for smoke clouds containing carbon from fires) or some of both kinds. (Would dust clouds be gray?) In the infrared all clouds are blackbodies. Use your model to explore the climatic impacts of nuclear exchanges and asteroid impacts.

3. Diurnal and Seasonal Thermal Dynamics.
   Explore the dynamics of thermal changes at the earth's surface in response to diurnal and seasonal changes in solar radiative forcing. This is a boundary-layer problem and is important to the exchanges of energy, momentum, and water across the boundary layer. You will have several "thin" layers of air over several "thin" layers of soil and water; radiation, conduction, and convection will all be important in this problem.

4. Global Hydrological Cycle.
   4.1 (For 346 students only.) Our homework global hydrological model addressed the transition period during which global warming was occurring (i.e. land T > ocean T). If global warming stops at some point in the future (we will eventually run out of fossil fuels), a new warmer equilibrium may be reached in which the mean land temperature and the mean ocean temperature are equal. What happens to the hydrological cycle in the new warmer state? What happens if the global temperatures start to decrease?
   4.2 The land surface area is not distributed evenly with latitude, nor is the atmospheric dynamics the same at different latitudes. Create zonal hydrological cycles which reflect these differences and explore the impact of global warming on zonal hydrological cycles.

5. Global Carbon Cycle.
   5.1 Create a zonal carbon cycle model - tropical, mid-latitude, and polar in each hemisphere. Most fossil fuels are used in the north mid-latitudes; most deforestation is now in the tropics; the tropical plants do not have a strong seasonal response; the north and south mid-latitude plants have responses that are 6-months out of phase; land plants are not uniformly distributed; the polar regions have little interaction; etc. This is an interesting problem, and there are CO2 measurements at many latitudes to compare with your models output.

   5.2 Create a global carbon cycle model that separates the isotopes of carbon. (See the text page 25.) Fossil fuel is entirely 12C ; whereas, the atmosphere and modern plants contain some 14C produced by cosmic rays interacting with 14N in atmospheric nitrogen. This 14C decays with time and this process is used for dating organic materials (carbon 14 dates). Deforestation releases modern carbon (aka green carbon); whereas, fossil fuels release 12C. Modeling the isotopes in the global carbon cycle can help determine where the carbon is moving through the system.

   5.3 Over the history of the Earth the atmosphere has changed its chemistry from predominately CO2 to the present state in which CO2 is minuscule and O2 is substantial (20%). Create a model to track this changing global chemistry. The model will have atmospheric, oceanic, biospheric, and lithospheric components and must run for 4.5x109 years.

   5.4 The accompanying handout on the global carbon cycle describes several different carbon cycle models. Reproduce one of these in STELLA.

6. Global Phosphorus Cycle.
   We did not do the phosphorus cycle as a class homework assignment. See the nitrogen cycle handout. Try it.

7. Global Sulfur Cycle.
   We did not do the sulfur cycle as a class homework assignment. See the sulfur cycle handout from Schlesinger. This is an important chemical in long-term biogeochemistry. Try it.

8. Coupled Biogeochemical Cycles.
   As our readings have indicated most of the biogeochemical cycles are strongly coupled (eg. carbon, nitrogen, phosphorus, iron, etc.) Try coupling some of your models. Watch out for time constant changes in the coupled models.

9. Stratospheric Ozone.
   We had planned to do the stratospheric ozone model as a homework, but it got squeezed out. This should be approached as a chemical kinetics model rather than a purely empirical model.

10. Human Population Dynamics. (For 346 students only.)
    There are several modeling projects dealing with human population dynamics. See the handout provided.

****