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Using Stella in Earth System Science Colloquium (11:015:401)

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1. Objectives

- o To introduce students to the concept of modeling in sufficient depth to use it for projects in other courses.
- o To promote interdisciplinary communication between students.
- o To demonstrate two specific models related to Earth System Science. A population model and a zero-dimension radiative model of the earth-atmosphere system.
- o To have some groups use Stella in their team projects for the course.

2. Setting Up

First, the software had to be installed on a central server system for the students. The contact for the server was Scott Livesey (livesey@gandalf.rutgers.edu). He needed the software for about a month to test for reliability before he could fully install it on the network. The classroom reservations have to be done through Mey Lein Ho (mho@jigsaw.rutgers.edu). Reservations have to be done several weeks in advance to compete against other Rutgers computer seminars also held in the teaching lab.

3. Preparation

Several documents had to be prepared for the students to look at and use in the lab sessions. A Stella basics document was put together telling students how to get around the Stella program and use most of its features. Another document took the students through a very simple population model which was to be used in the first lab session. The homework assignment expanded on this lab session. A third document explained the second lab session. In class lectures on background material were given prior to each of the lab sessions.

4. Laboratory Sessions

Topics of the labs were population and the greenhouse effect. The population model was used as a springboard to help students become familiar with Stella. A full 80 minute period was used to teach students how to use certain parts of Stella.

A homework assignment was given to the students to expand on the population model. The model covered in the lab session used birth rates and death rates to control how a population grows or shrinks. The assignment incorporated a resource that was renewable. The birth rate and death rates were controlled by the amount of the resource available. This model showed students the effects on a population and its available resources by using different formulas to compute birth rate and death rate. The TA had office hours after the lab session to help students with the homework assignment.

The second 80 minute session was devoted to modeling the earth-atmosphere system. The first part of the assignment was to model an earth without an atmosphere using a zero-dimensional point model using only radiation and albedo. The second part added the atmosphere as a layer that absorbed long-wave radiation and reflected short-wave radiation (Few). The last part was the same as the second except that carbon dioxide levels in the atmosphere were allowed to change. Students examined the temperature responses as they varied parameters such as albedo, absorption, and rate of increasing carbon dioxide. All work was done in class and no assignment was given.

5. Team Projects

Stella was used by the Sea Level Rise group in their final project. Their model assumed a beach profile of the coast and calculated the inland intrusion due to sea level rise. They calculated how much sand would be needed to maintain the present shoreline and then ran a separate— model to determine whether beach replenishment projects would continue to be economically feasible into the future. —

6. Conclusions

Students responded well to the material presented to them. The laboratory sessions were improved when background material was given in the lecture prior to the lab. The students should be able to complete, independently, homework assignments on Stella after the first two, in class, laboratory sessions. The TA should make office hours available to help students with the homework assignment.

Non-science students have a difficult time writing formulas for their models. A worksheet to transform written words to formulas and vice versa would be helpful not only for the students in working with Stella and also for those students who are unfamiliar with the formulas appearing in articles, papers and journals.

Stella Basics

Stella is a software package for modeling dynamic systems. The following documentation gives an introduction to Stella. Words appearing in **BOLD** are objects on the Macintosh screen that can be selected or manipulated. Words UNDERLINED are actions, usually with the mouse or keyboard or items in pull down menus.

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I. Accessing Stella

You must be a registered student at Rutgers University and have an e-mail account under one of the student machines. Get help from the aid station at Loree Room 009 to obtain a student account.

Find a working Macintosh(Mac) not in use. DO NOT INSERT YOUR DISK. Login using your assigned student login and password that you chose. If the Mac is already on, Restart it by holding the mouse button down over the word Special and drag down the list until Restart is highlighted and then let go of the mouse button.

When you see the start-up menu, click on Student Login and fill in the appropriate login ID and password. If you do not have an account, use the **Guest** login.

NOTE: If you get an error at this point, try logging in as **Guest** as the student machine may be down and unable to confirm your login ID and password.

After it finishes, find the **CLASS-S/W** (class software) folder icon. An icon is a small picture, with a name, depicting the purpose. In this case, a folder containing our application for our class. Move the mouse over to the folder icon and double-click. Double-clicking means rapidly pressing the mouse button twice over the object to open or activate it. After opening the **CLASS-S/W** folder, open the **Stella II** folder. Find **Stella II LAB/LAN 2.2.2** and run it by double-clicking on the icon.

You are now in **Stella**. Proceed following these instructions given to you in class. You may also find other instructional manuals available at the aid station desk at Loree. For more detailed instructions consult your TA.

At this point, insert your disk. Inserting your disk after **Stella** is running will reduce the steps needed to save your work.

II. STELLA Menus and Definitions

This section describes what you see on your screen. If what is being described looks very different than what is being described, please seek some help by asking one of the computer aides, to help you find the **Stella** application. If there is a technical problem have them write down a description of the problem and bring it to our attention immediately.

File, Edit, Run

Across the top of the screen, you will see three words on the left hand side and maybe a word and very small icon on the right. The first three words are File, Edit, and Run. You need not concern yourself with the **Apple** icon in front of the word File.

These are pull down menus that you can look at by moving the mouse cursor over them and holding the mouse button down. You can select one of the choices by continuing to hold the mouse button down and dragging the mouse cursor down. You will see the choices light up as you move the cursor over them. Note that in the File pull down, you will be using New, Save, Save As, and Quit. Edit will not be used in these exercises. Several items under Run will be used and explained later using the sample simulation.

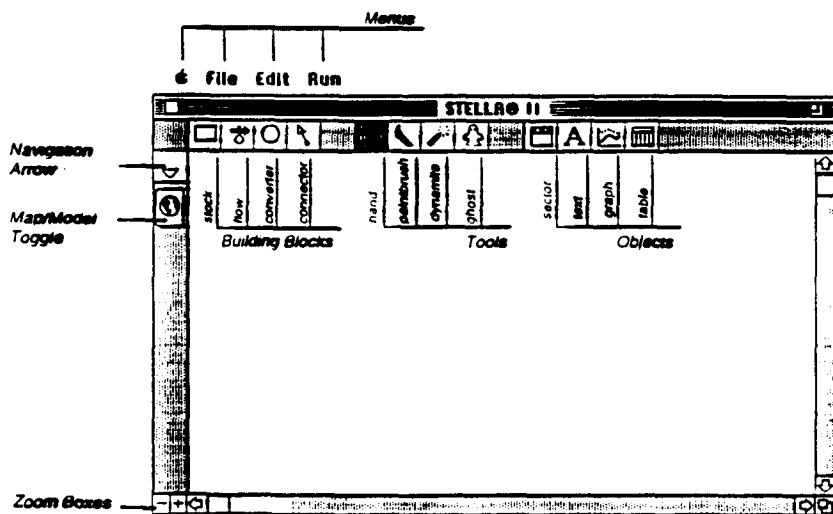


FIG #1

Always save your work!

Use the Save command frequently as there may be a power outage or system crash which may cause you to lose all your work. There is only one way you can save your work, to a diskette given to you in class.

Select Save as described above by using the pull down menu under File. Follow the steps below.

Selecting the correct Drive/Directory

After clicking save, insert your disk if you haven't already. Disks should always be inserted "label up." If you have not save your work before a menu should appear. "Untitled" should appear highlighted below the words "Save Model File as:". You can change the name by typing a new name. The first letter you type will erase the current highlighted name. To make a change, move the cursor to after the letter you wish to change and click once. The cursor will be positioned at that point, double-clicking will highlight the whole name again. You can now insert letters at this point or delete letters before the cursor. Once the filename is correct, make sure the program saves the model to your disk.

If the name you gave your disk does not appear at the top of this menu, click on the desktop button once. In the listing to the left of the button you just clicked, double-click the name of your disk. Another indication that you have selected your disk is to use the Eject button. Click it, if your disk comes out, push it back in.

Once those two steps are completed, you can click the Save button.

Formatting your disk

Put the new disk in the machine, label up. A small window should appear, asking if you wish to initialize the disk. If not, select Erase Disk, under the Special pull down menu. Click now on Double-Sided. Once formatting is completed, enter a name for your disk. Eject your disk by dragging the disk icon on the left side of your screen to the trash can. This does not damage your disk. You will insert your disk after **Stella** is started.

Using a model from your disk

First choose Close Model under the File pull down menu, and then choose Open Model under the same menu. If you have saved previous models, they will be listed in the box on the left. You can see one of them by double-clicking on the name.

III. Quitting Stella

Always Quit from **Stella** when finished. If you have not saved anything, **Stella** will prompt you to **Save** your changes. If you do not want to save your recent changes, click on **Don't Save**. If you quit accidentally, click on **Cancel** and you will return to **Stella**.

Once you are out of **Stella**, it is a good idea to select Restart from the Special pull down menu located on the top menu bar. This clears the computer memory of any work that you have done and ejects your disk. Take care to remove any files that you might have temporarily stored on the hard drive. You can do this by clicking on the file, in the window in which it appears, and dragging it to the trash can. The final step is to select Empty Trash from the Special pull down menu. Then Restart the Mac. You can use the same procedure to delete files on your disk.

IV. **The Stella Window** (Figure 1)

Across the very top you see three sets of four icons. The first set, going from left to right, consists of the building blocks and includes the stock, flow, converter and connector. The next set consists of tools which are the hand, paint brush, dynamite and ghost. The last set of icons represents objects called the sector, text, graph and table.

On the left margin of the frame, toward the top, are the navigation arrow and the map/model toggle. Clicking on the navigation arrow lets you see a list of equations associated with your **Stella** diagram. Clicking on the map/model toggle switch allows you to alternate between mapping mode (symbolized by the "globe" icon) and modeling mode (symbolized by the "X squared" icon). Finally, at the bottom left are zooming icons. These allow you to enlarge(+) or reduce(-) your diagram on the screen.

Building Blocks

Stock. The most common stock type we will use in these labs is called a reservoir. This type of stock will hold an initial value at time ($t=0$). The initial value can be the number of people, a starting temperature, a stress factor or any numerical quantity that will start as some initial value and change over time. This is called a stock because it keeps track of an amount after each time period in which flows into and out of the reservoir have occurred. For example, suppose say the stock is defined as the current population at time t and the number of births is fixed at 5 and deaths at 2 per year. Starting with a population of 10 at time $t=0$, the population in the stock would be 13 at time $t=1$ year.

Other types of stocks are available. Check with the TA, for more information.

Flow. These act only to change or modify the contents of a stock. Usually there is one flow into the stock and one flow out of the stock. Note: The flow into the stock starts from the "environment" and is controlled by a regulator in the center of the flow. The same regulator can be found controlling the flow out of the stock back into the environment. The number of births and deaths mentioned above are examples of flows in and out of the stock.

The regulators on the flows can be defined as constants or a set of equations (constraints) that describe how much should flow in and out of the stock based on conditions you set up in the model.

Converter. This acts as a constant or way to convert amounts into other types of information or an equation using several different types of information that represents a physical property that is used as input from another converter. For example, the births flow above can be adjusted by using output from a converter. The equation for the converter, say a birth rate of .15 (150 per 1000 people) of the existing population. As you can see, the converter would use input from the current population.

Connector. In order for converters to use values from stocks, flows or other converters, a connector is used to connect the source of the information to the converter that uses its values for input. From the previous example, the birth rate converter is needed as input from the stock. A connector would be needed from the stock to the converter. The result in the converter then needs to be sent to the births flow, thus using another connector.

Tools

Hand. This tool allows you to move things around on the diagram. The hand is always the default tool. Holding the option key allows you to keep using the same tool selected rather than switching back to the "hand" tool.

Dynamite. Once selected, you can move the **tip** over the object and click the mouse button, it will be deleted.

Ghost. After selecting this icon, move it over the object you wish to duplicate. This will make a copy of the item you have selected. Move the copy to the place you want to put it on your diagram and click the mouse. Once on the diagram, you can use it as if it were the original. This helps keep complex diagrams neat and readable.

Paint Brush. The paint brush will not be used in our labs, this only adds color to your system diagram. Rutgers only has black and white laser printers and it is a good idea to keep the default colors used by Stella.

Objects

Sector. The sector is used to break a large model up into smaller chunks. The examples developed in our labs are not extremely complicated and will not require use of this feature.

Text. The text icon allows you to put text on the system diagram. It's always a good idea to put your name and model title on your diagrams.

Objects (cont)

Graph. You can place any number of graphs on your system. When you place these on the system diagram they will appear just like the icon. To look at the settings for any of the graphs you have on your system diagram, position the cursor over the icon and double-click on it.

Table. This works much like the graph, but it will give you actual values listed on a table type format. You can select all or some of the variables in your system and the time interval in which you want the values reported.

V. A Stella Simulation

There are 6 major steps to a Stella simulation:

1. Focus (Purpose and variable identification)
Work on sharpening and narrowing the focus of the effort. List all the variables that you expect to use in the model, include units and a brief description.
2. Define (Variable relationships)
This is where you begin to define each of the variables. Focus on each variable in isolation. Keep things simple by including only those elements that are relevant to your purpose. Continually ask yourself: "What is accumulating? What is flowing? and to where? Which variables depend on others?" Record any assumptions.
3. Modeling (Designing the system diagram)
Using information you wrote down in steps 1 and 2, create your Stella model keeping your purpose in mind.
4. Simulation (Check for mistakes)
Learn as much as you can from each run. Then, after the simulation is complete, work to resolve any discrepancies. As required, fix your model, loop back to Steps 2 and 3 of the process to identify any potential problems.
5. Conclusions / Answers to questions
This is where you make your final conclusions about your model and use it help other people understand processes you are modeling.
6. Challenging
Take a another look at the finished model. Is it realistic? Are there simplifications that can be added to the model? Is this model more complex than it needs to be? Write some suggestions on what to do next.

A SAMPLE STELLA SIMULATION : POPULATION MODEL

STEP 1 (Focus)

Purpose

The purpose of this exercise is to understand how the **Stella** modeling package works by building a simple population model.

<u>Variable</u>	<u>Units</u>	<u>Description</u>
Population	persons	# of persons currently alive
Death Rate	persons/yr	# of persons that die each year
Birth Rate	persons/yr	# of persons born each year
Time	years	Simulation time interval

STEP 2 (Define)

Population is a stock that is accumulating. Population will depend on the Birth and Death rates.

The remaining elements, Death Rate and Birth Rate are assumed to be independent variables. Moreover, they are taken as constant in this simulation. Normally, the Death Rate and Birth Rates are given as rates per thousand people.

The Death Rate will decrease the contents (flow out) of the stock (population). The Birth Rate will increase the contents (flow into) of the stock.

STEP 3 (Modeling)

Note that your screen only shows a portion of the modeling page that you can use. If you use only the section showing, when you print it, you will use about 1/3 of a sheet of paper. Use the scroll bars to move to different parts of your model or the +/- buttons, to zoom in and out, at the lower left hand side of the screen. You will probably have to use these features on a more complex model.

Make sure you are in Mapping Mode. The globe icon will be displayed in the lower of the two left hand boxes on the left.

Start by creating a stock. Select the **Stock**, by clicking it once on the icon, and place it on the diagram frame and clicking once again. Once you click on the diagram frame a stock will be created and it is highlighted and named "noname1". This

highlighting means that it is selected and the name will be replaced when you type a letter. Now type "Population."

You can move the name to a different location around the stock and other building blocks by clicking on the diagram frame, unselecting the stock, and then by clicking and holding the mouse button down on top of the name. Drag the name around the building block to the new location and release the mouse button. To modify the name, click on the name and begin typing after releasing the mouse button.

IF MAKE A MISTAKE, you can erase anything on the diagram frame by clicking with the tip of the dynamite cursor on it.

Now to create your two flows. The inflow is named "Births." Select the flow icon and release your click. Click the mouse button, on the diagram frame left of the stock and then drag to the left end of the stock, the stock will highlight, and release the mouse button. Notice that on the left end of this flow is a cloud. This **cloud** represents an unlimited inflow from the environment. This flow is regulated by the equation you define in the flow itself. This is indicated by the small circle and valve structure in the center of the flow.

The outflow is the number of deaths. Again, select the flow icon. This time click and hold down the mouse button in the stock and then drag out to the right and release the mouse button. Name is "Deaths." Notice that there is a cloud to the right of this flow. This flows out into the environment.

You are going to need two additional converters. Place one converter below each flow and name them "Birth Rate" and "Death Rate." Link these converters, using **connectors**, to each of the flows such that the "Birth Rate" converter is pointing to the "Births" flow and the "Death Rate" converter is pointing to the "Deaths" flow. This is done by clicking the connector building block once. The cursor will change to a connector. Click and hold in the converter and then drag the mouse to the flow and release the click when the flow is highlighted. This same technique is used to link other building blocks together. If an object cannot accept a link, it will **not** highlight. The curvature of the arrow can be controlled by moving the small circle on the converter. Grab the small circle by clicking and holding the mouse button down and moving it around the converter.

Use **Ghosts** to reduce crossing of **connectors** and clutter in your diagram.

The last thing to be done is to define the converters using information from Step 2. Make sure you are in the Modeling Mode by clicking the **Map/Model Toggle** until it shows a "X squared" as the icon.

Begin with the stock named "Population." Double-Click on it

and a dialog box will appear. The text "{Place initial value here...}" is highlighted. Everything highlighted will be replaced, when you type in 100. You can include comments in the equation area by using the curly braces, thus by typing 100 {persons}. (This is particularly useful for entering physical constants for documentation purposes; for example, the solar constant = 1376 {W/m² in full sunshine}) Now that you have set the stock's initial value, click on OK and the diagram frame will return.

Now let's take a quick look at the equations. Click once on the **Navigation Arrow**. The equation for the stock is already defined and indicates that the population at time t is equal to the population one time step (or interval dt) before t plus the flows into the stock minus the flows out of the stock multiplied by the time step dt . Click on the Navigation Arrow again to return.

Double click on the "Births" flow. Replace "{Place the right hand side of the equation here...}" by clicking once on the Birth Rate variable in "Required Inputs". Click OK and double-click on the "Birth Rate" converter and fill in the value of 10 {persons}. Fill in "Deaths" flow the same way as "Births." Double-click on "Death Rate" and fill in a value of 5. If you make a mistake, click the CANCEL button instead of OK.

The modeling phase is complete, now test it!

STEP 4 (Simulation)

Before running your model, select "Time Specs..." from under the Run pull-down menu. Check to see that the run time is set to 50 and the time step (DT) is set to 1.0. The units need to be set to years. Click OK when you finish. If another message appears, click OK or Continue to get rid of it.

To make a graph, click once on the graph icon. Move the cursor over the diagram and click once. This will put a graph named "Graph 1" on your diagram. This will not show up when you print out your model, so you can place it anywhere. To set up the graph, double click the graph on your model diagram. This should show an empty graph. Double click in the graph area and the graph set up menu should appear.

The graph defaults to plotting selected parameters versus time. Select the variables you wish plotted versus time from the "Allowable" table by double clicking them. In this example, double click only on Population. It should appear in the "Selected" variable table on the right. You can plot up to five variables on one graph. Clicking OK, will return you to the graph. Population should be showing at the top of the graph as a parameter to be plotted.

Now select Run from the Run pull down menu at the top of the