Pan Water Cycle
Student Guide
Section I

Objective: To learn the basics of STELLA modeling and create a computer model of the open pan water cycle model.

Draw graphs and write answers as directed by your teacher.

Background Information:

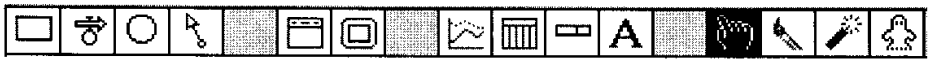
A **stock** is a component of a system that can store or accumulate something. The stock is indicated by a box ☐ and can store a system variable or act as a source of that variable. A battery is a stock that stores energy. A **flow,** indicated by a valve or faucet symbol represents how fast a variable enters or leaves a stock. Electrical energy in a circuit flows into or out of a battery.

Q1: Which components of the pan water cycle would be represented by a stock?

Q2: Which processes of the pan water cycle would be represented by a flow?

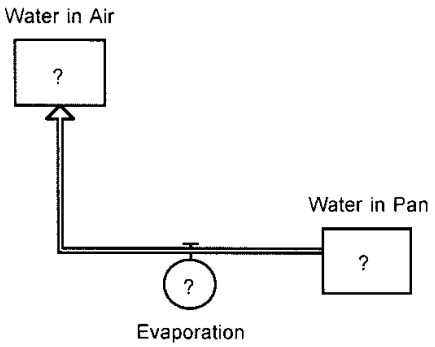
Part A: Setting Up the Diagram

1. **Double-click** on the **STELLA** icon.
2. When the screen appears, **click** on the icon of the world and it will change to an .
3. The tool bar looks like this:



This is the source of the icons we will use to build our model.

4. **Click once** on the stock icon: ☐. Slide your pointer to the upper left-hand corner of the screen and click again. A large stock should appear with the word **Noname 1** highlighted.
5. **Type** the words **Water in Air.** This can represent the invisible water gas in the atmosphere in the real ocean-atmosphere system or in the pan model used in class.
6. Place another stock on the screen about two inches diagonally down to the right of Water in Air. Name this stock **Water in Pan.** This can represent the ocean in the real ocean-atmosphere system or the pan in the pan model used in class.
7. **Click once** on the flow icon: . Slide your pointer inside the Water in Pan stock, **click and drag** to the left. When the pointer is directly under the Water in Air stock press the shift key. This will allow you to "bend" the pipe. Now slide the pointer upward toward Water in Air until the stock becomes shaded. Let go of the mouse button. Type the word **Evaporation.** Your diagram should look like the one on the next page:



Part B: Putting in Stock Values

8. **Double-click** on each stock. Enter each value given below in the appropriate window. **STELLA** requires that any units be enclosed in braces: **{}**. Click **OK** to close each window.

   Initial(Water in Pan) =
   100 {ml}

   Initial(Water in Air) =
   0 {ml}

Part C: Adding Temperature

Q3: What effect did turning up the temperature of the hot plate have on how much evaporation occurred in our pan model? How does this relate to the real ocean-atmosphere system?

Q4: What effect would moving the earth closer to the sun have on the real ocean-atmosphere system?

To model the effect of the water temperature on evaporation, you will use two converters: ○ Converters are used to hold parameters (variables or constants) of the problem being modeled.

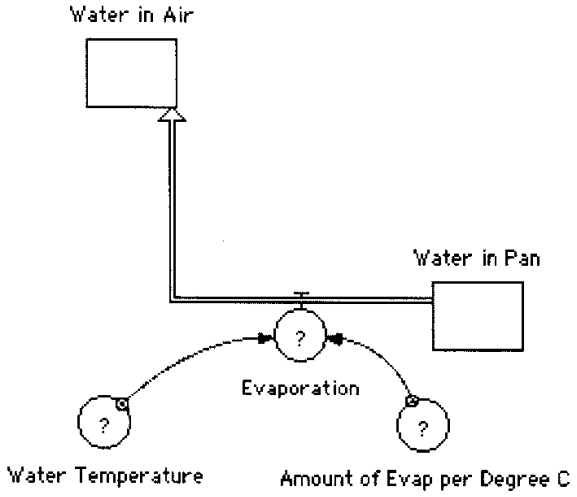
9. Place a converter on the screen below the Water in Air stock and to the left of the Evaporation flow. Name this converter **Water Temperature**.

10. Place another converter on the screen to the lower right of Evaporation and name it **Amount of Evap per degree C.**

You will show the relationship between Water Temperature, Amount of Evap per Degree C, and Evaporation by using the connector icon . Connectors are used to show that the value of one variable depends on the value of others. For example, if Evaporation depends on Water Temperature and the Amount of Evap per Degree C, two connectors will be drawn.

11. Now draw a connector from Water Temperature to Evaporation. Don't let go of the mouse button until Evaporation becomes shaded.

12. Draw another connector from Amount of Evap per Degree C to Evaporation. Your diagram should look like the one below.



Part D: Putting in the equation for Evaporation

By collecting data, scientists have found that the rate of evaporation in ml/min is proportional to the water temperature in degrees Celsius. That means that evaporation is equal to a constant times the water temperature. The constant represents the amount of evaporation per degree Celsius.

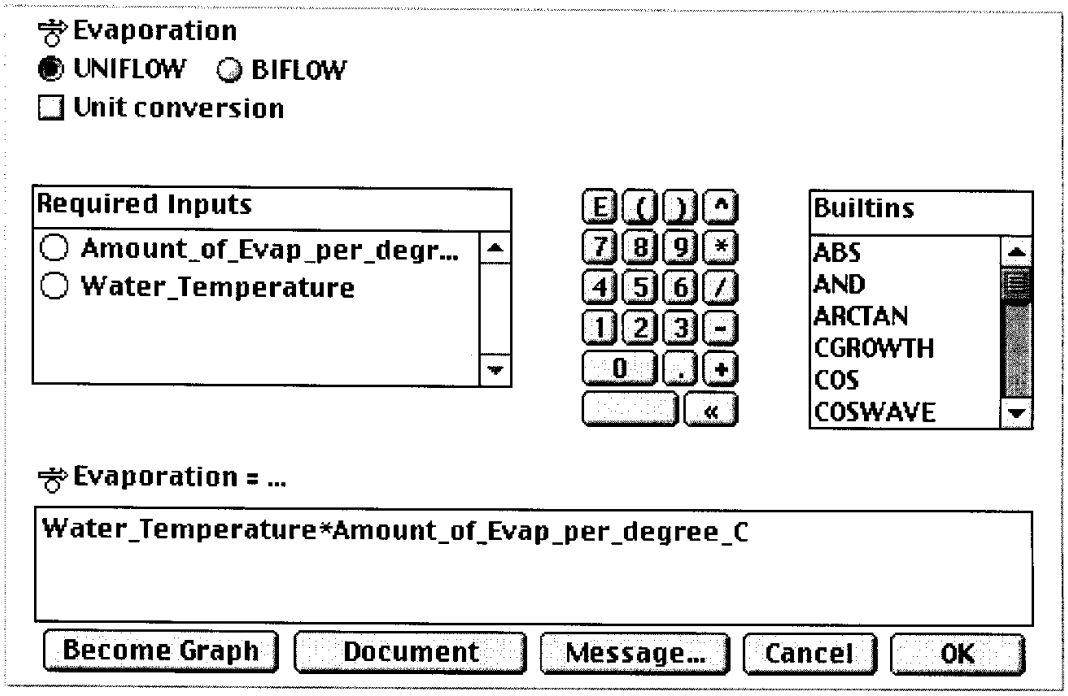
13. We will initially use the boiling temperature of water to set Water Temperature. Double click on the Water Temperature converter and enter
    100 {degrees Celsius}.

14. Double-click on the Amount of Evap per Degree C converter and enter
    1/20 {ml/min/degree Celsius}.

15. Double-click on the Evaporation flow. Notice that Amount_of_Evap_per_Degree_C and Water_Temperature are in the Required Inputs box. That's because we told the program they were required when we connected Water Temperature and Amount of Evap per Degree C to Evaporation. To add the right part of the equation to the box under "**Evaporation =**", use the mouse to click on

    Water_Temperature*Amount_of_Evap_per_Degree_C

If your window looks like the one below, click on **OK** to exit the dialog.



Q5: The model represents a situation in which 100 ml of water would evaporate into the air at the rate of 100{degrees Celsius}*1/20{ml/min/degree Celsius}. How many minutes should it take for the water in the pan to completely evaporate?

Q6: On the axes provided, sketch a graph that represents the number of ml of water in the pan during 20 minutes of evaporation. Label your graph according to the Level I Generic Graph Questions.

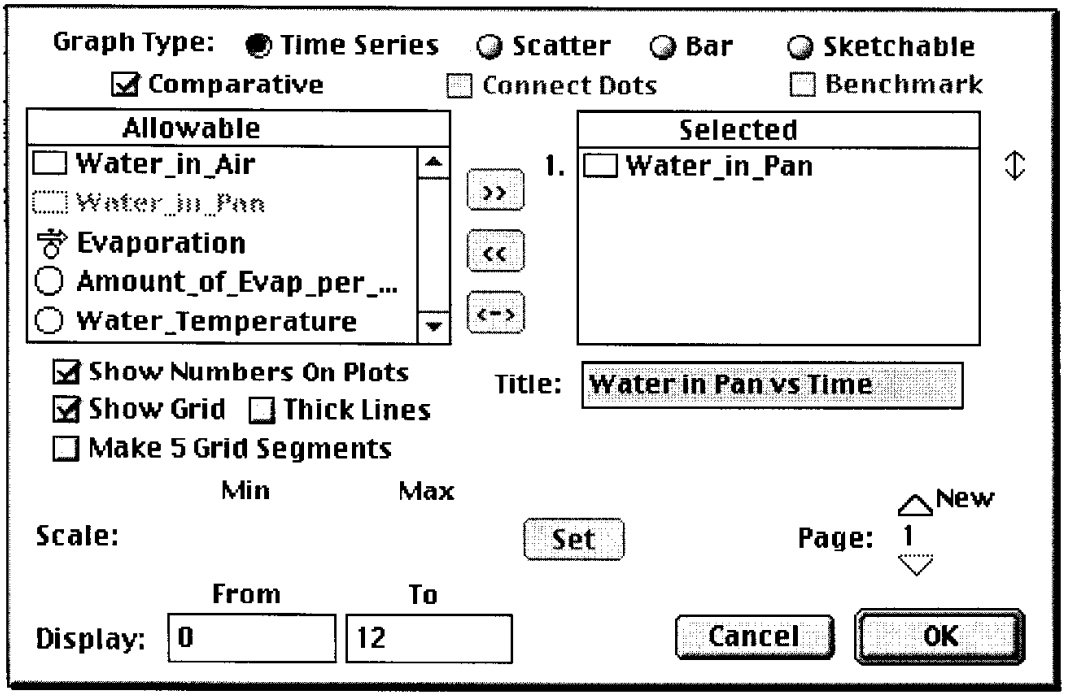
Part E: Setting up a Graph

16. Now go back to the tool bar and **click once** on the graph icon: . Slide your mouse pointer to a clear spot in the window and **click** again. **Double-click** anywhere in the large gray graph that appears and a window similar to the one on the next page will appear.

- Click on the box next to **Comparative** under Graph Type.
- **Double-click** on Water in Pan in the **Allowable** box to move it to the **Selected** box.
- Type Water in Pan vs. Time in the **Title** box.
- If your window looks like the one on the next page, click **OK**.

17. To prevent the graph box from disappearing every time you run the model, you should pin down the graph window.

- **Move your pointer to the horizontal bar at the top of the graph window.**
- **Drag the graph so it fits on the white space to the right of the model. If the graph doesn't fit on the screen, you can make it smaller by clicking on the lower right hand corner of the graph and moving it toward the upper left-hand corner to re-size it.**
- **Click once on the black circle (looks like a pushpin) in the upper left-hand corner of the graph.**



Part F: Setting the Time Specs

18. To tell your model to run for 20 minutes, go to the **Run** menu at the top of the screen and **click and hold.** Slide down to **Time Specs...** and release the mouse button.

19. In the box labeled **To:** change the 12 to **20.** In the box under **Other:** change Time to **Minutes.**

Part G: Running and Interpreting the Model

20. **Click and hold** at the word **Run** on the menu at the top of the screen. Then slide down to **Run** and release.

    Q7: Referring to the Level I Generic Graph Questions, sketch the Water in Pan graph on the axes provided.

    Q8: Referring back to your copy of the Graph Interpretation Guidelines, describe the graph in the context of the situation being modeled.

    Q9: If the water in the pan is decreasing from 100 ml to 0 ml over a 20 minute time period of evaporation at 100 degrees Celsius, describe what should be happening to the water in the air during the same time period.

Part H: Setting up a Second Graph

21. Go back to the tool bar, **click once** on the graph icon  and place it below the first graph.

- **Double-click** on the gray graph.
- Click on the box next to **Comparative** under Graph Type.
- **Double-click** on Water in Air in the **Allowable** box to move it to the **Selected** box.
- Type Water in Air vs. Time in the **Title** box and **click OK.**

22. Re-size the graph and pin it down just below the Water in Pan graph.

23. Go to the **Model** menu and select **Restore ... Graphs & Tables**. Then **Run** the model. You should see a line appear on each graph.

    Q10: Referring to the Level I Generic Graph Questions, sketch the Water in Air graph on the axes provided.

    Q11: Referring back to your copy of the Graph Interpretation Guidelines, describe the graph in the context of the situation being modeled.

    Q12: If the water temperature were lowered to 0 degrees Celsius, how would the evaporation change?

    Q13: If the water temperature were lowered to 0 degrees Celsius, how would the lines for the Water in Pan and Water in Air graphs be different from the lines drawn for a water temperature of 100 degrees C?

Part I: The Effect of Water Temperature on Evaporation

We want to see how different water temperatures affect evaporation. In the lab, we can see this effect by measuring the amount of water in the pan under different temperature conditions. In this computer model, we can see the effect by running the model with different water temperature values.

24. Double-click on the water temperature converter and set the value to 0 {degrees Celsius}. Run the model.

    Q14: Sketch the new lines on the axes already used in Q7 and Q10. Label each line with the water temperature setting used when the line was drawn.

    Q15: Pick two temperatures between 0 degrees Celsius and 100 degrees Celsius. Write a description of where the lines for Water in Pan and Water in Air should be for those temperatures in relation to the two existing lines on each of those graphs.

25. Change the water temperature converter to the values you chose in **Q15** and run the model each time. You should now have four lines on each graph.

    Q16: Sketch the new lines on the axes already used in Q7 and Q10. Label each line with the water temperature setting used when the line was drawn.

    Q17: On the Water in Air graph, what does the slope of each line tell you about evaporation?

Save your model as directed by your teacher.

Pan Water Cycle
Student Guide
Section II

Objective: To create a computer model of the closed pan water cycle model.

Draw graphs and write answers as directed by your teacher.

Open your Open Pan Water Cycle Model.

Q1: How should the model be changed to represent a closed container system?

Background: When we cover the pan, our physical model more closely resembles the real ocean-atmosphere system. We now see that water does not simply evaporate from the pan into the air never to be seen again. Instead, some of the evaporated water condenses on the cover of the pan just as liquid water is suspended in clouds. Some of this condensed water falls back into the pan just as precipitation from the clouds falls back into the ocean.

Part A: Adding to the Model

1. Add a stock to the upper right of Water in Air and name it **Water on Cover.** Enter 0 {ml} as the initial value.

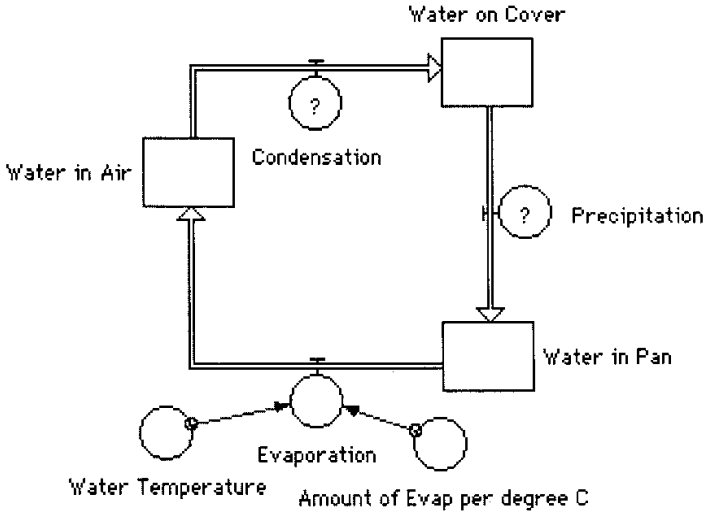
2. Add a flow from **Water in Air** to **Water on Cover**.

   Q2: What should you name the flow that transforms evaporated water in the air to liquid water on the cover?

3. Add another flow from **Water on Cover** to **Water in Pan**.

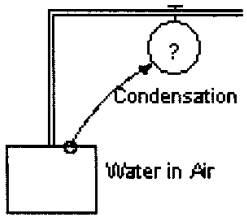
   Q3: What should you name the flow that moves liquid water on the cover to water in the pan?

4. Your model should look something like this:



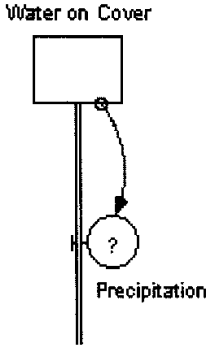
Part B: Setting up flow relationships

5. Suppose that during each minute, half of the water in the air condenses on the plastic cover. To show that the flow Condensation depends on the stock Water in Air, select and drag the connector from the stock to the flow.



6. Double click on Condensation. Complete the equation by typing 0.5* and then clicking on Water_in_Air in the Required Inputs column.

7. We will set up the relationship for precipitation in the same way. Suppose that during each minute, half of the water on the cover precipitates back into the pan. To show that the flow Precipitation depends on the stock Water on Cover, select and drag the connector from the stock to the flow.



8. Double click on Precipitation. Complete the equation by typing 0.5* and then clicking on Water_on_Cover in the Required Inputs column.

Part C: Running the model

9. Double-click on the Water in Air Graph. Click on the Comparative box to un-check it.

10. Double-click on Water_in_Air and Water_on_Cover to move them both to the Selected window.

11. Change the title of the graph to meaningfully represent the data to be plotted. Click OK.

12. Go to the **Model** menu and select **Restore ... Graphs & Tables**.

13. Set the water temperature to 100 {degrees Celsius}.

14. Run the model.

Q4: From the graphs, estimate the value of each stock after 20 minutes.
a) Water in Pan
b) Water in Air
c) Water on Cover

Q5: What is your prediction for the value of each stock after 20 more minutes?
a) Water in Pan
b) Water in Air
c) Water on Cover

Q6: Referring to the Level I Generic Graph Questions, sketch each curve on the axes provided.

Q7: Referring back to your copy of the Graph Interpretation Guidelines, describe the curves in the context of the situation being modeled.

Q8: What does it mean to say that our model of the closed pan water cycle is in equilibrium?

Q9: How is our computer model of the pan water cycle unlike the actual covered pan system?

Q10: How is the pan water cycle like the water cycle in the real world?

Q11: How is the pan water cycle different from the water cycle in the real world?