EXPLORATIONS

Activity 13

Do You Have the Temperature?

Objectives

- To graphically represent and analyze climate data
- To use linear regressions to understand the relationship between temperatures as measured in the Fahrenheit and Celsius scale
- To use linear regressions to understand conversion factors
- To use technology to find a linear regression

Materials

- TI-73 graphing device
- CBL 2™ data collection device (optional)
- Climate data for different ecosystems
- Cold cup with ice water
- Hot cup with boiling water
- Rubber band
- Watch with a second hand
- Celsius thermometer and Fahrenheit thermometer
- Two temperature probes (per CBL 2) (optional)

Introduction

A man was recently listening to the radio in his New York apartment. The radio announcer was giving the temperatures of cities in other countries. The announcer said, "The temperature in London is 68 degrees." At that same moment, another man was sitting in his London apartment listening to the weather report. The radio announcer said, "The temperature in London is 20 degrees." Both announcers were right! How could this happen?

Problem

There are different units of temperature: Celsius and Fahrenheit. How can you mathematically show the relationship between these two units of temperature?

Collecting the data — Part I

You will need twelve temperature readings using both Celsius and Fahrenheit thermometers. These readings will be obtained in one of three ways.

1. Collect the readings during class.

a. Take a Celsius and a Fahrenheit thermometer and rubber band them together so that the bulbs are next to each other.

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b. Place the thermometers in a cup with boiling water and allow the temperature to stabilize. You and your student partner will each read one of the two thermometers. Record the temperature on the **Data Collection and Analysis** page.

c. Place the thermometers in a cup with ice water and start timing. Take a reading every ten seconds, recording the values on the **Data Collection and Analysis** page. You and your student partner will each read one of the two thermometers.

2. Use two temperature sensors connected to a CBL 2™ (Calculator Based Laboratory-2). Set the temperature sensor in **CH1** to take readings in Celsius and set the temperature sensor in **CH2** to take readings in Farenheit. Set the CBL 2 to take a reading every 5 seconds for 12 samples. Follow step **1b**, as directed. For step **1c**, move the sensors into the cold water. Press **2: START** and stir the water with the sensors during data collection.

Record the values in **L2** in the Temperature (°C) section and the values in **L3** in the Temperature (°F) section on the **Data Collection and Analysis** page.

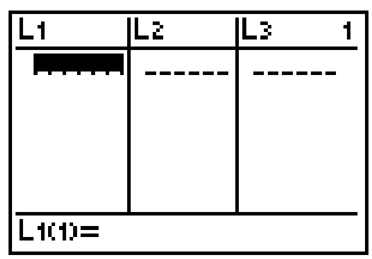
3. Use the 12 average monthly Celsius and Fahrenheit temperatures provided by the teacher.

Setting up the TI-73

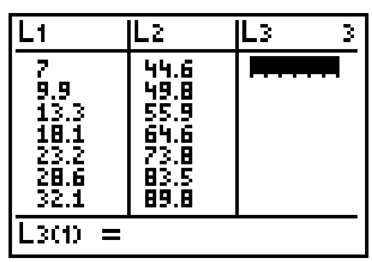
Before starting your data collection, make sure that the TI-73 has the STAT PLOTS turned OFF, Y= functions turned OFF or cleared, the MODE and FORMAT set to their defaults, and the lists cleared. See the Appendix for a detailed description of the general setup steps.

Entering the data in the TI-73

1. Press [LIST].



2. Enter the Celsius temperatures in **L1**.
3. Enter the Fahrenheit temperatures in **L2**. (Make sure that the pairs of Celsius and Fahrenheit temperatures match in each column.)



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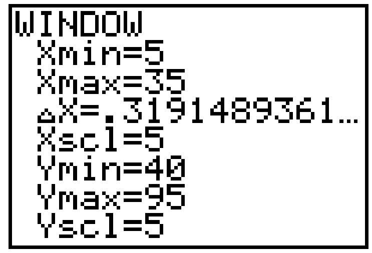
Setting up the window

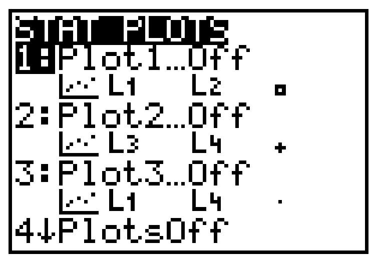


1. Press [WINDOW] to set up the proper scale for the axes.
2. Set the **Xmin** value by identifying the minimum value in **L1**. Choose a number that is less than the minimum.
3. Set the **Xmax** value by identifying the maximum value in each list. Choose a number which is greater than the maximum. **Do Not Change the ΔX value.** Set the **Xscl** to **5**.
4. Set the **Ymin** value by identifying the minimum value in **L2**. Choose a number that is less than the minimum.
5. Set the **Ymax** value by identifying the maximum value in **L2**. Choose a number which is greater than the maximum. Set the **Yscl** to **10**.

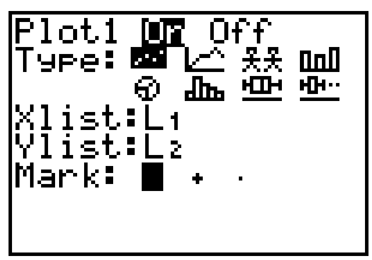
Graphing the data: Setting up a scatter plot

In order to analyze the data, you will need to set up a scatter plot and model the data by graphing a line of best fit.

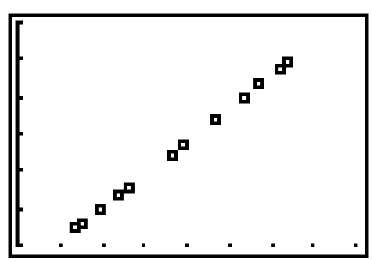
1. Press [2nd] [PLOT]. Select **1:Plot1** by pressing **1** or [ENTER].



2. Set up the plot as shown by pressing [ENTER] [▼] [ENTER] [▼] [2nd] [STAT] **1:L1** [▼] [2nd] [STAT] **2:L2** [▼] [ENTER].



3. Press [GRAPH] to see the plot.



What is the appropriate regression for the plot? Does the slope change or appear constant?

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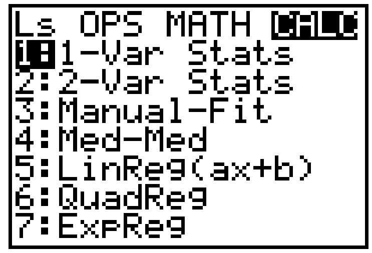
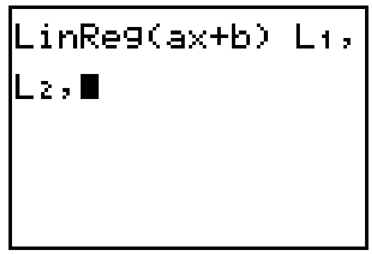
Analyzing the data: Finding a linear regression

1. Press [2nd] [STAT] [◄] to move the cursor to the **CALC** menu.

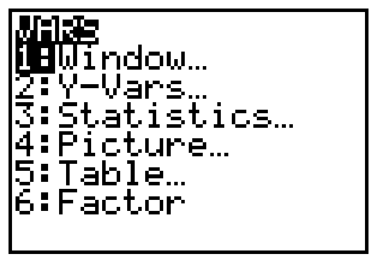


2. Select **5:LinReg(ax+b)** by pressing **5**.

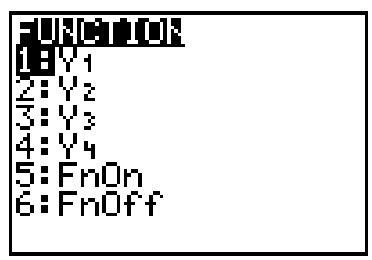
3. Press [2nd] [STAT] **1:L1** [,] [2nd] [STAT] **2:L2** [,].



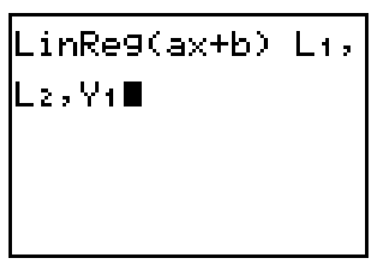
4. Press [2nd] [VARS].



5. Select **2:Y-Vars** by pressing **2**.



6. Select **1:Y1** by pressing **1** or [ENTER].



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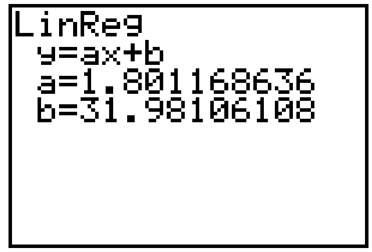
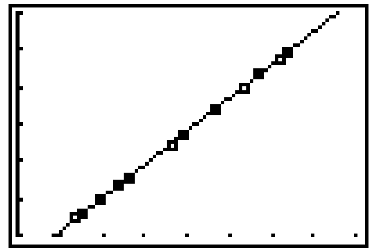
7. Press [ENTER] to calculate the linear regression. The function is pasted in **Y_1**.



8. Press [GRAPH] to see the linear regression.



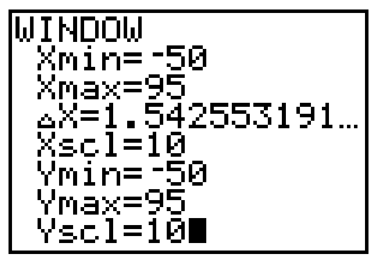
Answer Part I questions 1 through 6 on the **Data Collection and Analysis** page.

Collecting the data — Part II

Thus far, you have used the data to verify an equation for converting degrees Celsius to degrees Fahrenheit. What if you needed an equation for the opposite conversion, degrees Fahrenheit to degrees Celsius? Simply reversing the data in a **STAT PLOT** and then determining the linear regression for the data could produce this equation.

Setting up the window

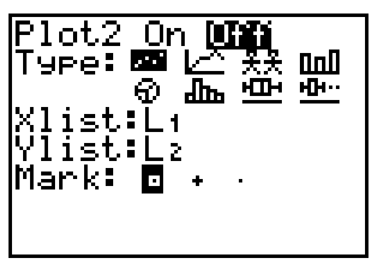
1. Press [WINDOW] to set up the proper scale for the axes.
2. Set both the **Xmin** and **Ymin** values to *–50*.
3. Set the **Xmax** and **Ymax** values by identifying the maximum value in both lists. Choose a number greater than the maximum.



4. Set both the **Xscl** and **Yscl** values to **10**. **Do Not Change the ΔX Value**.

Graphing the data: Setting up a scatter plot

1. Press [2nd] [PLOT]. Select **2:Plot2** by pressing **2**.



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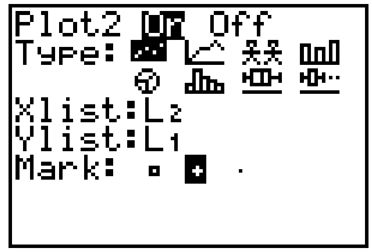
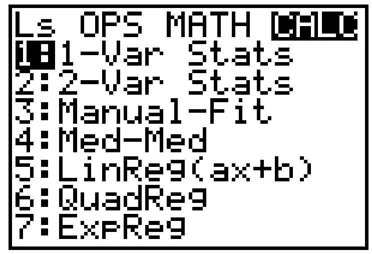
2. Set up the plot as shown by pressing [ENTER] [▼] [ENTER] [▼] [2nd] [STAT] **2:L2** [▼] [2nd] [STAT] **1:L1** [▼] [▶] [ENTER].

Note: *This is similar to* **Plot1**, *except that* **L2** *is now the* **Xlist** *and* **L1** *is now the* **Ylist.**

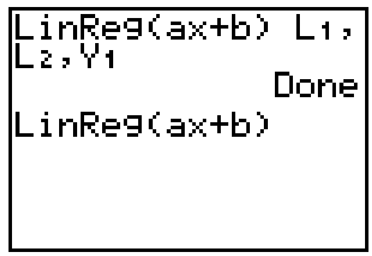


Analyzing the data: Finding a linear regression

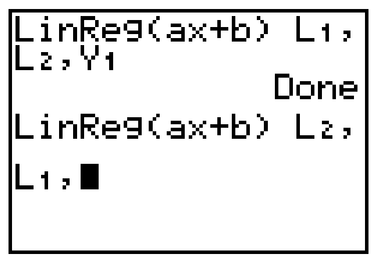
1. Press [2nd] [STAT] [◀] to move the cursor to the **CALC** menu.



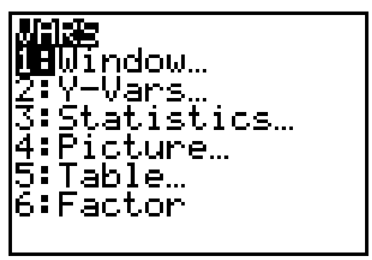
2. Select **5:LinReg(ax+b)** by pressing **5**.



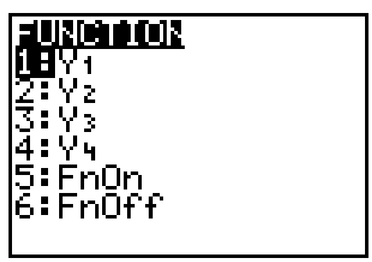
3. Press [2nd] [STAT] **2:L2** [,] [2nd] [STAT] **1:L1** [,].



4. Press [2nd] [VARS].



5. Select **2:Y-Vars** by pressing **2**.



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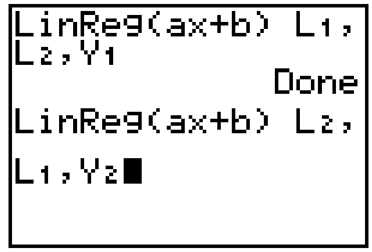
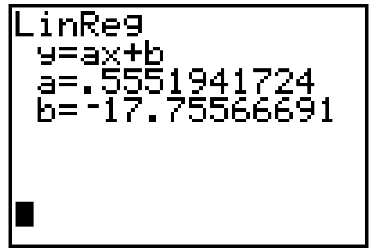
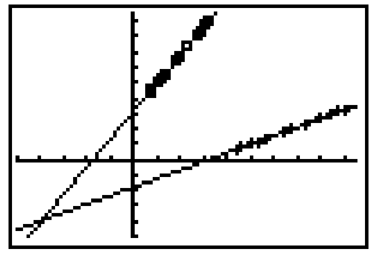
6. Select **2:Y2** by pressing **2**.



7. Press [ENTER] to calculate the linear regression and paste the function in **Y2**.



8. Press [GRAPH] to see the linear regressions.



Answer Part II question 1 on the **Data Collection and Analysis** page.

Observe the following statements about the point of intersection of equations **Y1** and **Y2**:

- The *x* and *y* value of the point of intersection must satisfy *both* equations.
- Since one function (**Y2**) was obtained by switching the *x* and *y* values of the other function (**Y1**), *x* must equal *y* at the point of intersection.

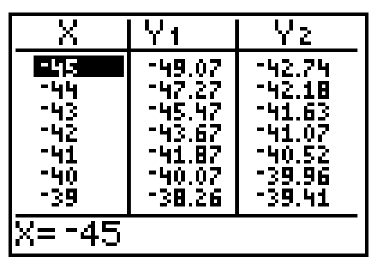
Identify the point of intersection.

9. Press [2nd] [TBLSET]. Type [(-)] **45**. Press [▼] **1** to set the **ΔTbl** value**.**

The table will allow you to examine increasing *x* values, starting at -45 degrees and the corresponding *y* values for both linear models that you plotted.

10. Press [2nd] [TABLE]. If necessary, use [▲] and [▼] to scroll the table.

Examine the table carefully. Note that when rounding off to the nearest whole number, there is one value that is the same for **X, Y1** and **Y2**. For this example, the coordinates of that point are (-40,-40).



To verify the coordinates graphically, you will plot a vertical line (*x*=-40) and a horizontal line (*y*=-40).

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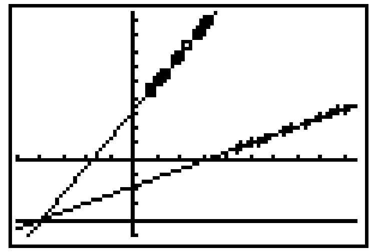
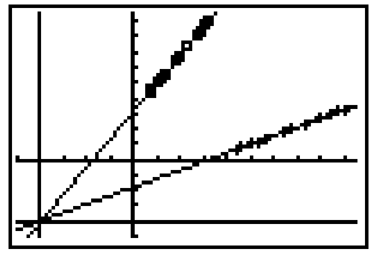
11. Press [DRAW]. Select **3:Horizontal** by pressing **3**. Type the *x* value from Step 10, then press [ENTER]. (For this example, the value is -40.)



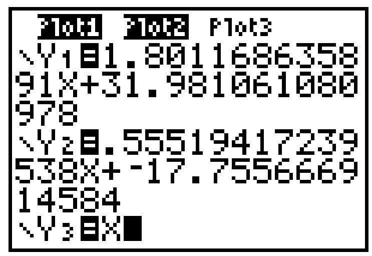
12. Press [2nd] [QUIT] [DRAW]. Select **4:Vertical** by pressing **4**. Type the **Y1** or **Y2** value from Step 10, then press [ENTER]. (For this example, the value is -40.)

Note: *In both linear models, the horizontal line (y=-40), and the vertical line (x=-40) all meet at the same point (-40, -40).*

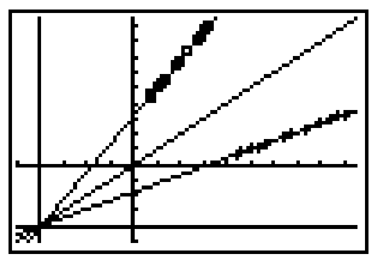


Add a graph of the function, y=x, to the graph.

13. Press [Y=]. Press [▼] to move the cursor to **Y3**. Press [x] so that the equation is **Y3 = X**.



14. Press [GRAPH] to see the plot.



Answer Part II questions 2 - 5 on the **Data Collection and Analysis** page.

Collecting the data — Part III

You have learned about the relationship between the two units of temperature measurement. You will now explore how graphical analysis of climate data can be used to compare different ecosystems. You will compare rainfall and temperature in three locations, the tundra (Fairbanks, Alaska), the desert (Las Vegas, Nevada), and the tropical rain forest (San Jose, Costa Rica). Climate data for the three ecosystems is provided.

Setting up the TI-73

Before starting your data collection, make sure that the TI-73 has the STAT PLOTS turned OFF, Y= functions turned OFF or cleared, the MODE and FORMAT set to their defaults, and the lists cleared. See the Appendix for a detailed description of the general setup steps.

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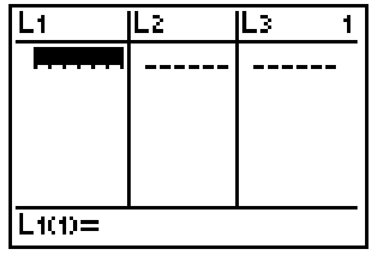
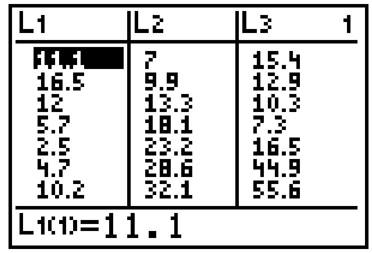
Entering the data in the TI-73

1. Press [LIST].



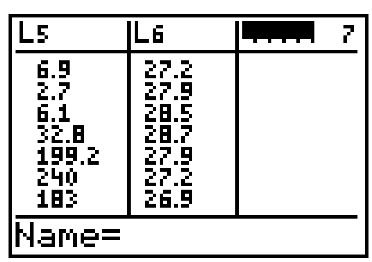
2. Enter the climate data in lists **L1** through **L6** according to the chart that follows.



	Desert		Tundra		Tropical Rain Forest	
Month	**Rainfall (mm)**	**Temperature (°C)**	**Rainfall (mm)**	**Temperature (°C)**	**Rainfall (mm)**	**Temperature (°C)**
	L1	**L2**	**L3**	**L4**	**L5**	**L6**
Jan	11.1	7.0	15.4	-21.1	6.9	27.2
Feb	16.5	9.9	12.9	-18.1	2.7	27.9
Mar	12.0	13.3	10.3	-10.4	6.1	28.5
Apr	5.7	18.1	7.3	-1.0	32.8	28.7
May	2.5	23.2	16.5	8.5	199.2	27.9
Jun	4.7	28.6	44.9	14.6	240.0	27.2
Jul	10.2	32.1	55.6	16.1	183.0	26.9
Aug	13.3	30.9	52.9	13.2	243.1	26.9
Sep	10.6	26.6	32.3	7.0	308.7	26.5
Oct	6.3	19.6	21.8	-4.0	253.0	26.6
Nov	6.2	11.9	18.7	-15.3	118.7	26.6
Dec	14.2	7.5	21.1	-19.7	32.7	26.8

Source: Reprinted with permission from WorldClimate (www.worldclimate.com).

3. Move the cursor to the top of **L6** to highlight it. Press [▸] to move to the top of the seventh, unnamed, data list.



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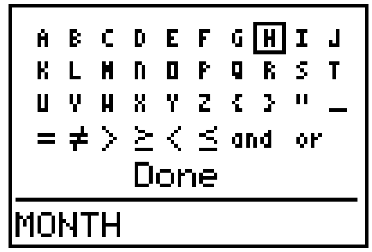
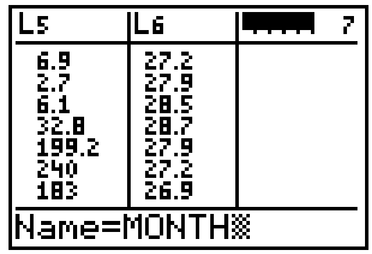
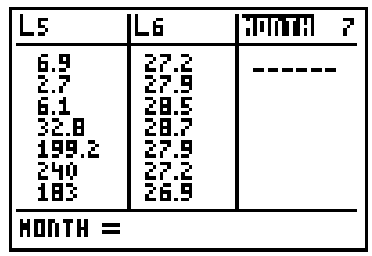
4. Name the list **MONTH** by pressing [2nd] [TEXT], moving the cursor to each letter of the name **MONTH**, and pressing [ENTER].



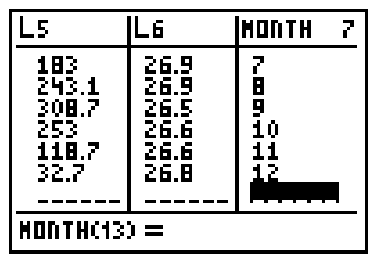
5. Use the cursor keys to move the cursor to **Done.** Press [ENTER] to exit the Text menu.



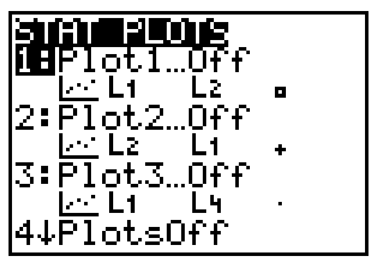
6. Press [ENTER] to save the list name.



7. Press [▼] to move the cursor down in the data cell and enter the numbers **1** through **12** for each of the 12 months.

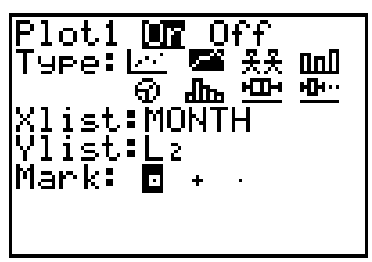


8. Press [2nd] [PLOT]. Select **1:Plot1** by pressing **1** or [ENTER].



9. Set up the plot as shown by pressing [ENTER] [▼] [▶] [ENTER] [▼] [2nd] [STAT] **7:MONTH** [▼] [2nd] [STAT] **2:L2** [▼] [ENTER].

__Note__: The list, __MONTH__, may not be in position 7 on the TI-73. Use [▲] and [▼] to move the cursor to the desired list, and press [ENTER] to select that list.



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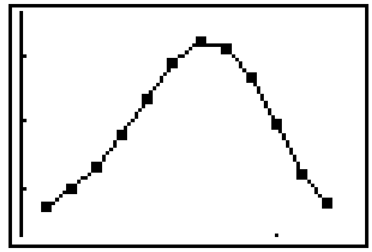
10. Press [ZOOM]. Select **7:ZoomStat** by pressing 7 to see a graph of monthly average temperatures for the desert.

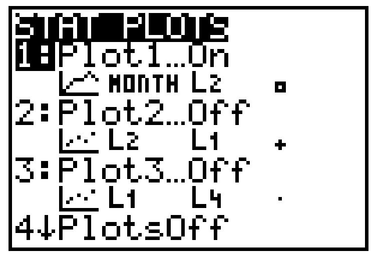


Answer Part III questions 1 and 2 on the **Data Collection and Analysis** page.

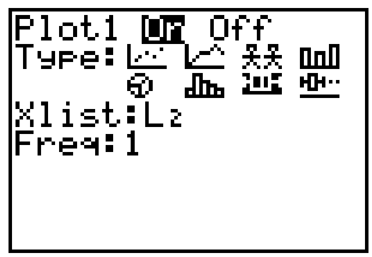
Graphing the data: Setting up a box-and-whisker plot

The type of analysis that you did with the desert temperature data could also be done with the other data from the table. Another way to analyze the data is by examining a box-and-whisker plot.

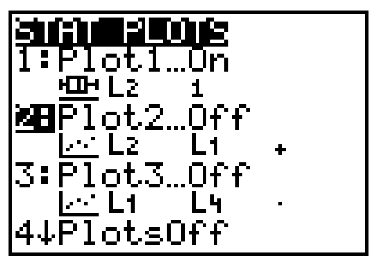
1. Press [2nd] [PLOT]. Select **1:Plot1** by pressing **1** or [ENTER].



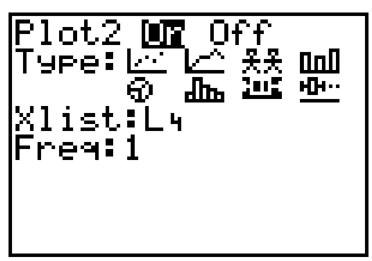
2. Set up the plot as shown by pressing [ENTER] [▼] [▶] [▶] [▶] [▶] [▶] [▶] [ENTER] [▼] [2nd] [STAT] **2:L2** [▼] **1**.



3. Press [2nd] [PLOT]. Select **2:Plot2** by pressing **2**.



4. Set up the plot as shown by pressing [ENTER] [▼] [▶] [▶] [▶] [▶] [▶] [▶] [ENTER] [▼] [2nd] [STAT] **4:L4** [▼] **1**.



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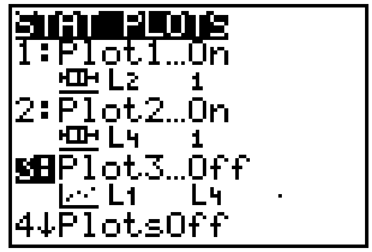
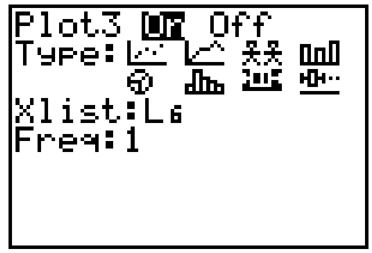
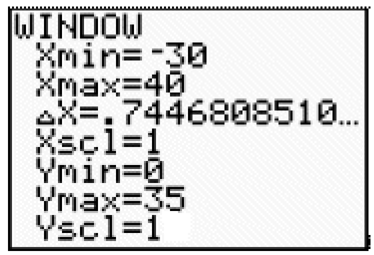
5. Press [2nd] [PLOT]. Select **3:Plot3** by pressing **3**.



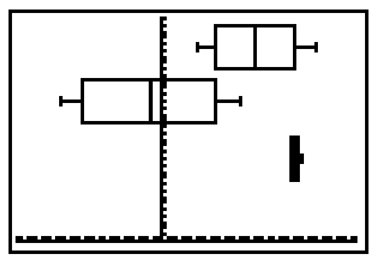
6. Set up the plot as shown by pressing [ENTER] [▼] [▶] [▶] [▶] [▶] [▶] [▶] [ENTER] [▼] [2nd] [STAT] **6:L6** [▼] **1**.



7. Press [WINDOW] and set the window values as shown. **Do Not Change the ΔX Value**.



8. Press [GRAPH] to compare the three box-and-whisker plots.



Answer Part III questions 3 through 5 on the **Data Collection and Analysis** page.

9. Repeat Steps 1-8 using the rainfall data for the desert (**L1**) for **Plot1**, the Tundra (**L3**) for **Plot2**, and the Tropical Rain Forest (**L5**) for **Plot3**.

Answer Part III questions 6 and 7 on the **Data Collection and Analysis** page.

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Extension

A useful tool to investigate ecosystems is a climagraph. A climagraph is a plot of Temperature (on the *y*-axis) versus Rainfall (on the *x*-axis). Each point on the plot represents the average rainfall and temperature for a given month.

Construct climagraphs for the desert (**L1**, **L2**), the tundra (**L3**, **L4**), and the rain forest (**L5**, **L6**). Since climagraphs are cyclical, repeat (re-enter) the first value of each list as the 13^{th} element of the same list. (The first and 13^{th} values of each list will be identical.)

What information does a climagraph give you that you cannot obtain from looking at the temperature or rainfall data in isolation?

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Data Collection and Analysis

Name___________________________

Date ___________________________

Activity 13: Do You Have a Temperature?

Collecting the data

Temperature (°C)												
Temperature (°F)												

Analyzing the data — Part I

1. What is the equation for the linear regression in **Y1**? (You can see the equation by pressing [Y=].)

 ____

2. What does *y* represent in this equation? What does *x* represent in this equation?

 ____

3. How might this equation be used to convert the temperature in one scale to the temperature in another scale?

 ____

 ____

4. How does this conversion equation compare to that in a math or science textbook?

 ____

 ____

5. What is the *slope* of this function?

 ____

6. What does the *slope* tell you? (Use the words degrees Fahrenheit and degrees Celsius to answer this question.)

 ____

 ____

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Analyzing the data — Part II

1. Examine the general appearance of the two functions (**Y1** and **Y2**) and answer the following questions:

   a. In which quadrant do the **Y1** and **Y2** functions intersect? ______________

   b. Describe the symmetry of the two functions.

   ____

   ____

   c. What function serves as a line of symmetry for the two functions? (Provide an equation with your answer.)

   ____

   ____

2. Rounding off to the nearest whole number, what is the point of intersection of functions **Y1** and **Y2**?______________________________

3. How do the *x* and *y* values compare at the point of intersection?

   ____

   ____

4. Press [Y=] to see the equations in **Y1** and **Y2**. Show that the point of intersection is correct for these two equations by substituting the *x* and *y* values. Show your work.

   ____

   ____

   ____

5. Based on the appearance of the three functions, confirm your answers to questions 1b and 1c. Explain.

   ____

   ____

   ____

   ____

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Analyzing the data — Part III

1. Describe the temperature pattern for the desert over a one-year period.

2. How would the graph of the average monthly temperature in the desert change from year-to-year? Explain.

3. Which ecosystem is most stable according to temperature? How does the box-and-whisker plot show this?

4. Which ecosystem has the lowest median temperature value during the course of the year?

5. Which ecosystem has the highest median temperature value during the course of the year?

6. Which ecosystem has the highest median rainfall amount during the course of the year?

7. Which ecosystem has the lowest median rainfall amount during the course of the year?

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Teacher Notes

Activity 13

Do You Have a Temperature?

Objectives

- To graphically represent and analyze climate data
- To use linear regressions to understand the relationship between temperatures as measured in the Fahrenheit and Celsius scale
- To use linear regressions to understand conversion factors
- To use technology to find a linear regression

Materials

- TI-73 graphing device
- CBL 2™ data collection device (optional)
- Climate data for different ecosystems
- Cold cup with ice water
- Hot cup with boiling water
- Rubber band
- Watch with a second hand
- Celsius thermometer and Fahrenheit thermometer
- Two temperature probes (per CBL 2) (optional)

Preparation

- This activity shows that conversions between scientific units of measurement are linear. Similar conversions could be done with centimeters to inches and pounds to kilograms. Since the *y*-intercept for the above conversions is 0, the slope is the conversion factor. In the examples used in this activity, the conversion equations are:

  $F = 1.8\ C + 32$ *and* $C = 0.56\ F - 17.8$

  Graphs of these equations form mirror images on both sides of the $Y = X$ line. They intersect at the one temperature where degrees C = degrees F (-40 degrees).

- If you do not want to collect temperature data, use the monthly average temperature provided for Las Vegas, Nevada, or look up similar data for your location.

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Answers to Data Collection and Analysis

Collecting the data

Sample data — Las Vegas, Nevada:

Month	J	F	M	A	M	J	J	A	S	O	N	D
Temperature (°C)	7.0	9.9	13.3	18.1	23.2	28.6	32.1	30.9	26.6	19.6	11.9	7.5
Temperature (°F)	44.6	49.8	55.9	64.6	73.8	83.5	89.8	87.6	79.9	67.3	53.4	45.5

Source: Reprinted with permission from WorldClimate (www.worldclimate.com).

- If the students collect their own data using thermometers, do not expect the equation to fit as perfectly as using the Las Vegas, Nevada, data in the table. There are several reasons for this:
  - The thermometer bulbs are not in the same place.
  - Slight errors in reading the thermometers may occur.
  - Convection currents within the container result in slight temperature differences.
  - Students may not take the reading at the same time.

  There are benefits to discussing the discrepancies that occur when using real world data.
- The web page mentioned above is an excellent source of data for cities all over the world. You may want to make this a web-based activity.

Analyzing the data — Part I

1. What is the equation for the linear regression in **Y1**? (You can see the equation by pressing [Y=].)

For the Las Vegas data, Y = 1.801X + 31.981.

2. What does *y* represent in this equation? What does *x* represent in this equation?

The y represents the temperature in degrees Fahrenheit. X represents the temperature in degrees Celsius.

3. How might this equation be used to convert the temperature in one scale to the temperature in another scale?

If you know the temperature in degrees Celsius, substitute the value for x and simplify to get the temperature in degrees Fahrenheit.

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4. How does this conversion equation compare to that in a math or science textbook?

F = 1.8 C + 32 (Textbook Equation).

5. What is the *slope* of this function?

1.8

6. What does the *slope* tell you? (Use the words degrees Fahrenheit and degrees Celsius to answer this question.)

The slope tells you that for each increase in a Celsius degree, the Fahrenheit temperature rises 1.8 degrees.

Analyzing the data — Part II

1. Examine the general appearance of the two functions (**Y1** and **Y2**) and answer the following questions:

a. In which quadrant do the **Y1** and **Y2** functions intersect?

*The **Y1** and **Y2** functions intersect in the third quadrant.*

b. Describe the symmetry of the two functions.

The two functions are inverses of each other.

c. What function serves as a line of symmetry for the two functions? (Provide an equation with your answer.)

They are symmetrical with respect to the line, Y = X.

2. Rounding off to the nearest whole number, what is the point of intersection of functions **Y1** and **Y2**?

(-40, -40)

3. How do the *x* and *y* values compare at the point of intersection?

The x and y values are the same at the point of intersection.

4. Press [Y=] to see the equations in **Y1** and **Y2**. Show that the point of intersection is correct for these two equations by substituting the *x* and *y* values. Show your work.

By substituting - 40 for the x and y values of the two equations, and simplifying, the equality will be shown.

5. Based on the appearance of the three functions, confirm your answers to questions 1b and 1c. Explain.

The equations all intersect at (-40, -40).

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Analyzing the data — Part III

1. Describe the temperature pattern for the desert over a one-year period.

The temperature pattern starts low, rises, and then falls to the same level.

2. How would the graph of the average monthly temperature in the desert change from year-to-year? Explain.

The graphs would be approximately the same although slight variations may occur. This is because average temperatures do not vary a great deal.

3. Which ecosystem is most stable according to temperature? How does the box-and-whisker plot show this?

The Tropical Rain Forest is the most stable according to temperature. The plot is the most narrow.

4. Which ecosystem has the lowest median temperature value during the course of the year?

The Tundra has the lowest median temperature value during the course of the year.

7. Which ecosystem has the highest median temperature value during the course of the year?

The Tropical Rain Forest has the highest median temperature value during the course of the year.

8. Which ecosystem has the highest median rainfall amount during the course of the year?

The Tropical Rain Forest has the highest median rainfall amount during the course of the year.

9. Which ecosystem has the lowest median rainfall amount during the course of the year? (This is hard to see from the graph.)

The Desert has the lowest median rainfall amount during the course of the year, but the Tundra is a close second.

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