

Learning to Use Visualizations:

An Example with Elevation and Temperature



Purpose

To introduce students to visualizations as a tool for scientific problem-solving, using elevation and temperature as an example.

Overview

In this learning activity, students use visualizations to make sense of elevation and temperature data and to explore the relationships between the two variables. Students color in visualizations of elevation and temperature so that important patterns in the data become evident. The relationship between the two quantities is studied by using them to compute the *lapse rate*, the rate at which temperature falls with increasing elevation.

Student Outcomes

Students can identify and communicate important patterns in a dataset by drawing a visualization, and can begin to interpret those patterns.

Students can analyze the correlation between two variables using visualization as a tool.

Science Concepts

General

Visual models help us analyze and interpret data.

Geography

Geographic visualizations help organize information about places, environments, and people.

Scientific Inquiry Abilities

- Identify answerable questions.
- Use appropriate tools and techniques.
- Use appropriate mathematics to analyze data.
- Develop and construct models using evidence.
- Communicate procedures and explanations.

Time

One 45-minute class period, although extensions are suggested

Level

Middle, Secondary

Materials

- Overhead projector and visualization overheads, or color copies of Figure AT-V-1
- Copies of *Work Sheet* for all students
- Rulers, crayons or colored pencils

Preparation

If you plan to do the extensions with GLOBE data, you may want to find appropriate schools in advance. See *Further Investigations*.

Prerequisites

Students should be familiar with computations using ratios. It is also helpful if students have some experience using visualizations (e.g., [Draw Your Own Visualization Learning Activity](#) in this Investigation).

Welcome

Introduction

Protocols

Learning Activities

Appendix



Background

Scientific visualizations of Earth systems appear in many places. Many newspapers include bright color visualizations of surface temperature and visualizations of the formation of an ozone hole have been featured on magazine covers. These visualizations help us to make sense of complicated scientific information. This learning activity will use visualizations in a similar way: showing patterns in scientific data and using that information to help solve a problem.

The first step in using a visualization is getting oriented: understanding how the visualization is organized and what it means, and connecting it to something you are familiar with (similar to the “You Are Here” arrow on a map). When you are presented with a new visualization, look for the following elements:

- 1. Data characteristics including type, units, and time.** The *type* of the data is what real world value it represents. In the first visualization illustrated in Figure AT-V-1A, Earth Elevation and Ocean Depth, the data type is elevation in relation to sea level (for areas covered by land) and depth below sea level (for areas covered by water). The *units* are in meters, with positive values above sea level and negative values below sea level. The values refer to the average elevation in that area, so they are not the maximum values at each point. The *time* is when the data were collected. Time is an important element in the second visualization in Figure AT-V-1B (Surface Temperature: January 1987), since surface temperatures vary a great deal over the course of a year.
- 2. Use of color.** The color scheme contains the colors that represent particular data values in a visualization: for instance, orange might represent temperatures between 20-30° C. The *legend* shows the arrangement of color and the range of values that each represents. Choosing a particular color scheme can help the visualization to point out patterns

or emphasize a particular view of the data.

The visualizations in Figure AT-V-1 use color in a strategic way. The colors are chosen to correspond to various natural phenomena. In the *Earth Elevation and Ocean Depth Visualization*, the depths of the ocean are shown in shades of blue. Most land is shown in shades of brown, with mountains shown in white. This type of color legend is useful for seeing global patterns, because the continuous data are now grouped and color-coded.

Global patterns can be made easier to see by using *landmark values* that mark off the range at which certain phenomena occur. Landmark values are the points on a color scale where the representative value undergoes a distinctive change. For example, a landmark value might be 0°C, where water freezes. Using colors to point out landmark values can make the visualization easier to understand.

The *Surface Temperature Visualization* in Figure AT-V-1B makes use of the associations we have with particular colors. Warm colors (yellows, oranges and reds) are used to show temperatures above the freezing point of water, and cool colors (blues, purples) are used to show temperatures below the freezing point of water. The map's legend will always tell you what the colors represent.

- 3. Geographical features.** The third element of a visualization is *geographical features*, which help to place the data spatially: what places on Earth do these numbers describe? In Figure AT-V-1B, outlines of the continents let you see, for example, that Australia's temperatures near the coast are cooler than temperatures inland.
- 4. Resolution.** The map's resolution is a measure of the smallest area in which two different values can be shown. For example, in the *Earth Elevation and Ocean Depth Visualization* each data value covers a 1° square area, so the

resolution of the maps in Figure AT-V-1 is 1° by 1° . This means that you can see differences between elevations at 23° S and 24° S, but not between 23.1° S and 23.3° S.

In *Work Sheet 1*, which you will be using for this exercise, the data are represented in 3° by 3° squares, which means that each square covers a larger area and the image of the data is less precise. Because of this, calculations on data read from the map will only be approximate.

All of the above features give visualizations power, communicating information in ways that give us insight into the data and the world in order to solve problems. In this activity you will use visualizations to consider the relationship between elevation and temperature, and then estimate the lapse rate as we move from the coast of the Indian Ocean to the Himalaya Mountains.

The *lapse rate* is the rate at which the air temperature changes with an increase in elevation. If you have ever climbed a hill or mountain, you may have felt the decrease in temperature: it gets colder as you go up.

Scientists calculate the lapse rate as the rate at which temperature decreases as you go straight up into the air. The value comes from weather balloons carrying instruments that measure temperature, air pressure, and humidity, which are sent up into the atmosphere. The locations of these balloons are tracked and the information they collect (plus their position) is sent back to a ground station. Using measurements from such devices, and models of the weather, scientists have calculated a lapse rate as a theoretical constant of 9.8° C per km of elevation.

Actual lapse rate can differ from the theoretical constant for a number of complicated reasons. For example, the rate is different if air is humid rather than dry. If the soil is dry, no cooling near the surface occurs from evaporation. This can cause very warm temperatures near the surface, which rapidly cool as elevation is gained. Moist air changes temperature more slowly as the water condenses from it (and forms droplets or dew). The energy stored in the water vapor is released as it condenses, thus raising the temperature. As a result,

the average lapse rate for moist air is only about 5.4° C per km; very different from the theoretical constant of 9.8° C per km.

Preparation

Hand out crayons (or other color media) to each student pair. Hand out a copy of the *Work Sheet*. Make a color transparency of Figure AT-V-1, or locate it on the GLOBE website for projecting in class.

What To Do and How To Do It

Do the following three steps.

1. Class discussion to orient students to the visualizations in Figure AT-V-1
2. Group analysis and problem-solving
3. Class discussion to reflect on the use of visualizations

Step 1. Class Discussion: Getting Oriented with Elevation and Temperature

This discussion will orient students to the use of visualizations. By looking at several visualizations of elevation and temperature, your students will learn their way around a visualization and be ready to do the second step, the problem-solving task.

Introduce the utility of visualization as a tool for making sense of data.

- Have students look at their *Work Sheets*, which contain visualizations they will color in. Each is a series of numbers in cells that represent an area of $3^{\circ} \times 3^{\circ}$. The first table shows the average elevation for each cell; the second shows the average temperature in July 1987 for each cell. It is hard to find patterns just by looking at this many numbers.

This activity will use *color visualizations* to point out patterns in the data. Of course, visualizing the data with colors is only one alternative. For example, elevation can also be shown on topographic maps that use contour lines instead of colors.

Orient students to the visualizations by connecting the colors with phenomena in the world: what do these data really mean?



- On the Earth Elevation and Ocean Depth visualization (Figure AT-V-1A), ask your students to locate the regions that are colored in white, and discuss what those areas have in common. Students should realize that these areas have the highest elevation. Now, help them identify why those areas are so high: the obvious explanation will be that there are mountain ranges in those areas (e.g., the Andes in Peru, the Rockies in the US, and the Himalayas in Asia). However, in some cases elevation is due to thick ice sheets (e.g., Antarctica and Greenland).
- Students may initially be confused about exactly what the colors represent in this visualization. For example, students may be familiar with visualizations of temperature in the newspaper, so they may interpret blue as cold and red as hot. Some students may also interpret blue as water rather than ocean depth. Reinforce the importance of orienting to the visualization using the information found in legends and keys.
- Other confusing elements of many visualizations are resolution and projection. In Figure AT-V-1A, the resolution is 1° square. (In the *Work Sheet* visualizations that students will color and analyze, resolution is 3° x 3°; it will be important for students to understand the implications of that for the precision of the data.) *Projection* is how the spherical shape of the Earth is shown on a flat space, causing distortions of size, shape, and distance. In Figure AT-V-1, the 1° squares are determined by regular grid spacing rather than depicting actual geographical features. The actual area of each square is variable depending on the latitude; this can be confusing at the poles, for example, where Antarctica appears as a large horizontal area. It may be useful to compare the size of the continent as depicted here with its projection on a globe.

Discuss strategic use of color in the visualizations.

- The idea of *landmark values* was introduced in the Background section and should be illustrated through discussion here. For example, the surface temperature map shows values below freezing (i.e., below 0° C), as shades of blue and values above freezing as shades of orange and red, making it easy to see at a glance where the temperatures are below freezing and where they are not.
- In the activity that follows, students will be coloring in the visualizations on their *Work Sheets*, using colors in ways that will help patterns to emerge from the data.

Step 2. Group Problem-Solving

The recommended group size for this activity is student pairs.

The student *Work Sheet* walks students through the process of selecting colors for their visualizations and coloring them in. The rubric section provides an example of how the completed visualizations might look.

The *Work Sheet* first asks students to select color schemes and color in the visualizations. The *Work Sheet* suggests that they use 1500 m as a “landmark value” as the height at which mountains begin. There are other possible values that could represent the minimum elevation of mountains, but using 1500 m works well with the particular data values in this visualization. For temperature, students will need to figure out the full range of temperatures represented (from a low of 1° C to a high of 36° C) and divide into four relatively equal ranges for their color scheme.

When students have colored the visualizations they are ready to use them for problem-solving: they will explore the relationship between change in elevation and change in temperature. In general, the change in temperature due to change in altitude is called the *lapse rate*. The Himalayas are a particularly good place to investigate this phenomenon since the changes are so dramatic. Students empirically derive the lapse rate by calculating the change that occurs between two points on the visualizations. The

lapse rate calculation involves some use of ratios and negative numbers; students may need guidance with this calculation depending on their mathematical backgrounds. Make sure they understand that the elevation visualization uses a unit of *meters*, and the commonly accepted unit for lapse rate is °C per *kilometer*; students will therefore need to multiply their calculated ratio by 1000. The rate they compute will generally be a negative number, since temperature *decreases* as elevation *increases*. For many students, this is a confusing concept that may need to be illustrated for the class as a whole.

The answers that students get will vary depending on which cells they choose. Lapse rate values are likely to be lower than the commonly accepted average lapse rate of 9.8° C per km of elevation. The theoretical lapse rate is measured by sampling air temperature in vertical elevations above the Earth. By contrast, students are working with air temperatures at Earth's surface which are affected by a number of factors, including surface absorption of sunlight. For example, if you release a weather balloon at sea level, the temperature it will measure at an altitude of 1 km usually will be less than the ground level temperature on a nearby mountain at an elevation of 1 km.

Students are likely to need guidance in thinking through question 8, which asks them to speculate on why they may have calculated a different lapse rate than classmates who chose different cells. Many possible reasons are valid. The most important factor is the resolution of the cells: each cell contains the average elevation or temperature across a large area, and therefore the values are not nearly as precise as points going up a mountain. Lapse rate is also affected by environmental factors such as humidity, which is affected by proximity to the ocean. If students are confused, you may want to include these issues in class discussion.

Step 3. Class Discussion

Close the class period with a brief discussion of the utility of color visualizations for seeing patterns in data. This is a good opportunity to link the tool of visualization with the GLOBE data your students are collecting: what types of analysis might such a tool help you to

conduct on particular GLOBE data? Can it help students to answer any questions about their local environment and how it relates to larger systems on Earth?

Further Investigations

These investigations offer ways to connect this activity to GLOBE data, and possibly to your own school.

1. Use the GLOBE Visualizations tool on the GLOBE website to investigate elevation-temperature relationships for GLOBE schools that have reported data, ideally finding a school to compare to your own. This comparison is best conducted with schools that report temperature data frequently, and that are at a latitude similar to yours (or to each other) but at very different elevations. Search first for schools that have reported large amounts of air temperature data (using the Data Count map type), and narrow the search either by using latitude restrictions on the Filters tab or through visual approximations on the visualization map.

From the time series tool, you can display data for one month. Students can also view a table of temperature for one month for each school, find the monthly average, and calculate the lapse rate between the two schools. Once again, the resulting lapse rate is likely to differ from either the theoretical average or from the rates calculated by students on the *Work Sheet* from Himalayan data. Actual lapse rate is affected by many factors; this is an opportunity to discuss local and global influences on local temperatures.

4. Other GLOBE activities link well with this one. The [Draw Your Own Visualization Learning Activity](#) is useful before or after this one to give students the experience of designing their own visualizations. In addition, there are a number of other visualization activities in the *Earth as a System Investigation* that build on the approach developed here.



Resources

Atlases generally contain useful collections of visualizations.

The GLOBE Website contains a wealth of visualizations, including 3D ones. In addition, there are many excellent visualization sites from scientific organizations such as NASA and NOAA where students can examine visualizations and analyze the underlying data.

The *Remote Sensing* portion of the [GLOBE Land Cover video](#) (located at <https://www.globe.gov/do-globe/for-teachers/globe-videos>) provides a good explanation of resolution, presenting an example of an airport shown at increasing resolutions until it becomes recognizable.



Learning To Use Visualizations

Work Sheet

Name _____

In this activity, you will draw visualizations and use them to help understand the relationship between elevation and temperature.

Part A: Drawing Visualizations

The last page of this *Work Sheet* provides two charts of numbers: elevations (in meters) and temperatures (in °C). These numbers are *spatially distributed*: each represents the average value across a 3° x 3° block of land in South Asia (3° latitude by 3° longitude). Your first goal is to identify the approximate southern border of the Himalayas, the highest mountains on Earth, from these charts by turning each of them into a visualization that can help you answer the question.

1. Assign a color scheme for elevation. When you pick colors to help illustrate where the mountains begin, it is useful to use a *landmark value*. A landmark value is a point on a color scale where the value undergoes a distinctive change. In this example, use 1500 m as the landmark value that defines where mountains begin.

Choose four colors for this visualization, and identify elevation ranges that each of them will represent. Make sure the landmark value of 1500 m is the border between two of them. You will want to make it obvious which cells are in the mountains and which aren't, so you should select very different colors—with a high degree of contrast—for values above and below 1500 m.

Color in the scale below the elevation map.

2. Assign a color scheme for temperature. There isn't an obvious temperature value that indicates where mountains begin, so select your four ranges to be of equal size (i.e., the same number of degrees in each range). Again, create the color scale on the map to show what your chosen colors represent.
3. Color in the visualizations. Using the color schemes that you selected, color in the *Elevation* and *Temperature Visualizations*.

Part B: Orienting and Problem-Solving with Visualizations

4. On the *Elevation Visualization* draw the southern boundary of the Himalayas, following the outline of the squares.
5. The highest elevation on your map is 5300 meters, but the highest mountain in the world (Mt. Everest) is 8800 meters, and is located in the Himalayas on your map. Explain this by considering the map's resolution.

6. Can you draw the border of the Himalayas using just the *Temperature Visualization* on *Work Sheet 1*? Try it! How closely does this match the border you drew in question 4?

Explain why it is possible to approximate the border of the mountain range just by using temperature data.

7. The rate at which temperature falls as you climb a mountain or go up in the lower atmosphere is called the *lapse rate*. To compute the lapse rate, pick two cells that are next to each other but have very different elevations. Find the corresponding temperature cells. Calculate the lapse rate as the change in temperature divided by the change in elevation.

$$\frac{\Delta T}{\Delta E} = \frac{\text{change in temperature}}{\text{change in elevation}}$$

You will get a negative number for either ΔT (the temperature dropping) or ΔE (the elevation dropping). For example, if the temperature map shows that Cell A is 4°C and Cell B is 16°C , and the elevation map shows that Cell A is 5200 m and Cell B is 2300 m, then the lapse rate is:

$$\frac{\Delta T}{\Delta E} = \frac{4^{\circ}\text{C} - 16^{\circ}\text{C}}{5200\text{m} - 2300\text{m}} = \frac{-12^{\circ}\text{C}}{2900\text{ m}} = \frac{-0.004^{\circ}\text{C}}{1\text{ m}} \times 1000\text{ m/km} = -4^{\circ}\text{C/km}$$

This ratio means that for every kilometer you climb, the temperature decreases 4°C and therefore, every kilometer you climb down the temperature will increase by 4°C .

Calculate the lapse rate for the two cells you chose:

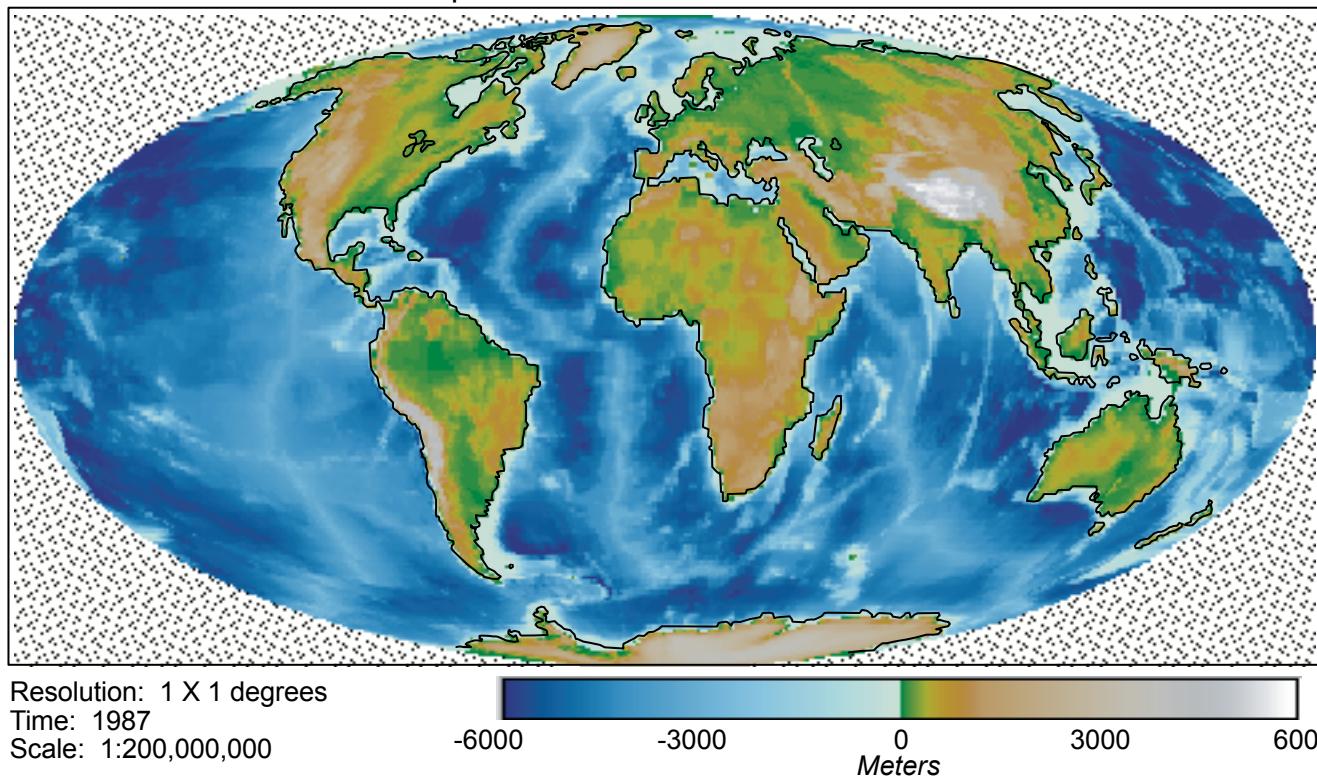
$$\frac{\Delta T}{\Delta E} =$$

8. Compare your answer with another team. Did you get the same lapse rate? If your answers differ, what might be some reasons why?

Figure AT-V-1

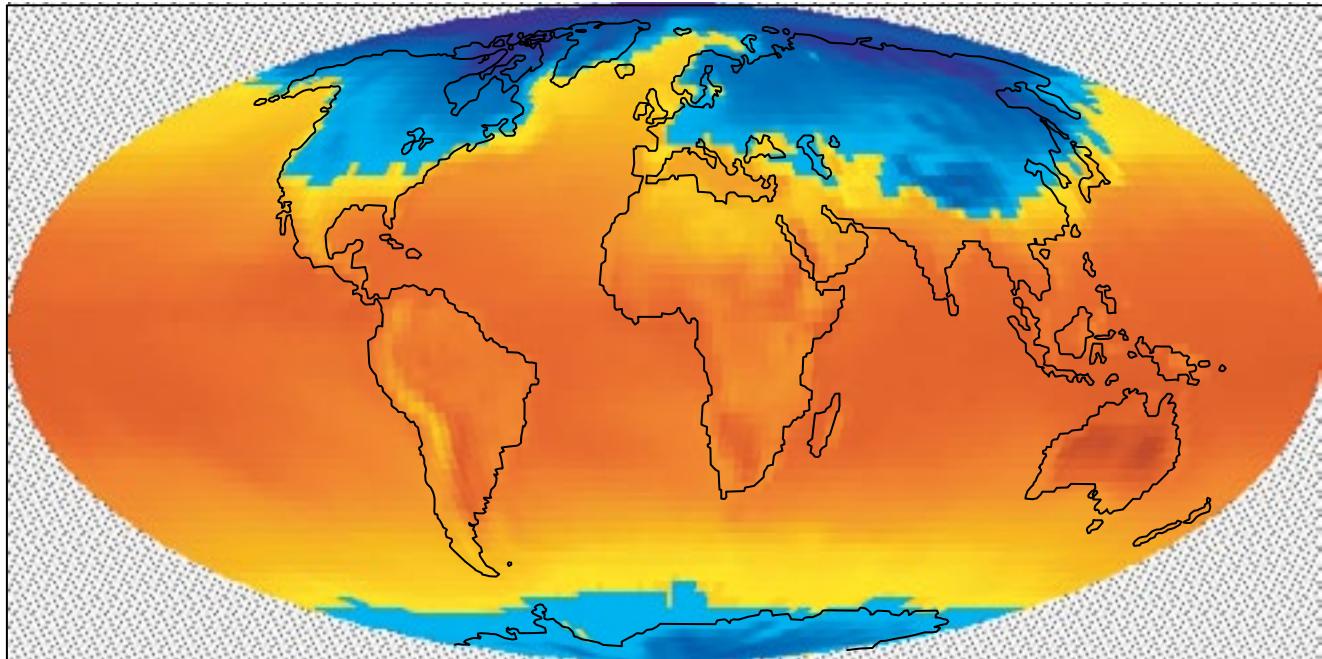
A. Earth Elevation and Ocean Depth: Visualization of Earth Elevation Above and Below Sea Level

Earth Elevation and Ocean Depth



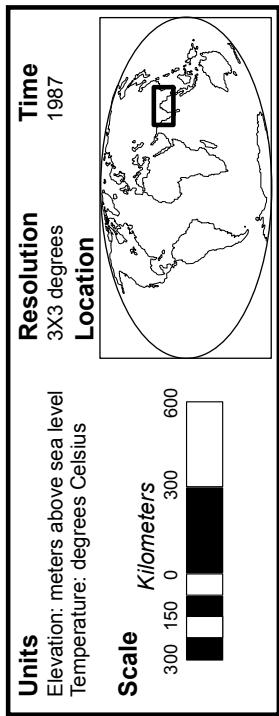
B. Surface Temperature: Visualization of the Temperature of the Surface of the Land and Oceans on Earth in July 1987

Surface Temperature, January, 1987

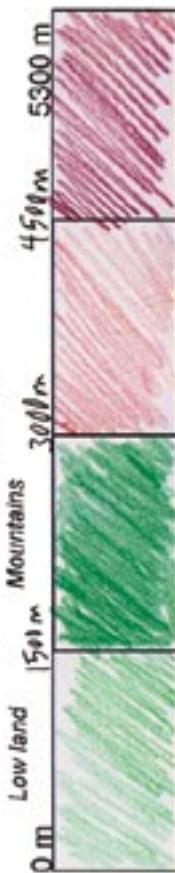


Learning To Use Visualizations Work Sheet

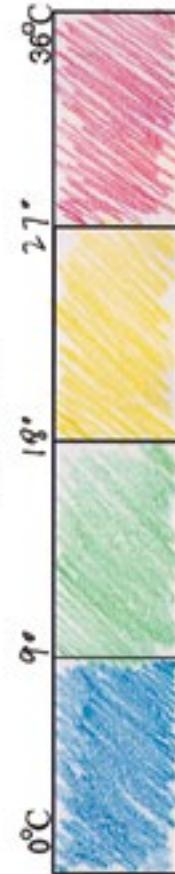
Name _____



Color Scale



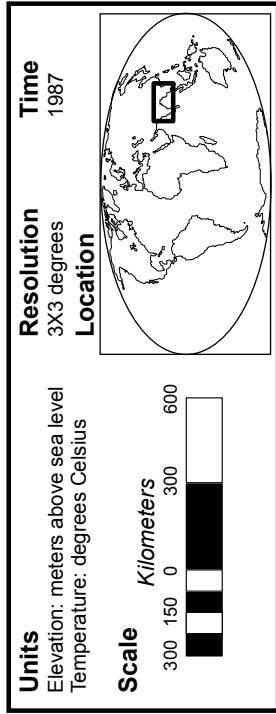
Color Scale



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Learning To Use Visualizations Work Sheet

Name



Average Elevation of Land Above Sea Level (m)

Average Surface Temperature: July, 1987 (°C)

Color Scale

Color Scale

The diagram illustrates temperature profiles across three horizontal levels: Lowland (0 m), Mountains (5300 m), and the surface (0 °C and 36 °C). The vertical axis represents temperature, with 0 m at the bottom, 5300 m in the middle, and the surface at the top. The temperature scale on the right indicates 0 °C and 36 °C.

| Level | Temperature (°C) |
|--------------------|------------------|
| Lowland (0 m) | 0 °C |
| Mountains (5300 m) | 0 °C |
| Surface | 36 °C |

Learning to Use Visualizations

Rubric

For each of the criteria on the following pages, student work is to be evaluated using the score levels and standards below:

- 3 = Shows clear evidence of achieving or exceeding desired performance
- 2 = Mainly achieves desired performance
- 1 = Achieves some parts of the performance, but needs improvement
- 0 = Answer is blank, entirely arbitrary or inappropriate

1. Drawing visualizations

A. Assigning landmark values and color scheme

| Score Level | Description |
|-------------|--|
| 3 | Visualizations have useful color schemes that illuminate important patterns in the underlying data and incorporate landmark values, as evidenced by color legend. Color scheme for elevation visualization uses landmark value of 1500 m for mountains; color transition is significant at that point (see example). Color scheme for temperature visualization divides the range into four roughly equal segments or another sensible division. |
| 2 | Visualizations have easy-to-read color schemes, but the elevation color scheme fails to indicate a major transition at 1500 m or the temperature color scheme does not assign ranges evenly. |
| 1 | No landmark values are used; colors appear chosen at random. |
| 0 | Color key is blank or confusing. |

B. Coloring the visualization

| Score Level | Description |
|-------------|---|
| 3 | Colors are assigned properly according to the color scheme in the key; visualization is neatly colored. |
| 2 | All cells with a numeric value are colored correctly, but work is messy, reducing the communicative power of the visualization. |
| 1 | Cells are colored incorrectly or so messily that accuracy cannot be determined. |
| 0 | Both visualizations are left blank, or they are not colored based on the assigned color schemes. |

2. Orienting and problem-solving with visualizations

A. Drawing the southern boundary of the Himalayas on the elevation visualization

| Score Level | Description |
|--------------------|---|
| 3 | Student work shows understanding of the problem and how to locate and use the appropriate information/data from the visualization to solve the problem. The student has clearly drawn in a southern boundary for the Himalayas, and this boundary appears to be selected by landmark or significant value color transition. See example. |
| 2 | Student work shows understanding of the problem, but may indicate some problems either in obtaining the appropriate data from the visualization OR in using the data to solve the problem. The student may have drawn a northern boundary, or drawn a boundary not based on landmark or significant color value transition. |
| 1 | Student work shows little understanding of the problem and/or how to solve it, but the work is attempted. May attempt to use the visualization to draw the boundary, but does not use a boundary based on landmark or significant color value transition, and has difficulty selecting a consistent boundary. Boundary appears to be drawn without use of color scale or numerical values in the squares. |
| 0 | The southern boundary is not drawn; evidence of student understanding of the problem and/or use of the visualization is missing. |

B. Explaining the concept of resolution

| Score Level | Description |
|--------------------|--|
| 3 | An answer is given which displays clear understanding of the concept of resolution. Student states that the number in each square is an average of all the elevations in the square, rather than a high or low value, and therefore a high point such as Everest would be masked |
| 2 | Answer displays understanding of differing ground heights and of resolution, but student does not state that the number in each square is an average of all the elevations in the square. |
| 1 | Response indicates some understanding of the concept of resolution, but is vague or does not connect the concept to the question asked. |
| 0 | Answer is blank, arbitrary or inappropriate. |

C. Drawing the southern boundary of the Himalayas from the temperature visualization and comparing results to the elevation visualization

| Score Level | Description |
|-------------|--|
| 3 | Student work shows understanding of the problem and how to locate and use the appropriate information/data from the visualization to solve the problem. The student has clearly drawn in a southern boundary for the Himalayas, and this boundary appears to be selected by landmark or significant value color transition. The student has written a short statement accurately describing how the boundaries on the temperature and elevation visualizations compare. See example of visualizations. Note that in this example, the boundaries are similar but not identical. This should be noted in the description, with explanation (for example, we would not expect a perfect correlation because many factors influence local temperatures besides elevation, and the resolution is too imprecise to expect exact transitions to be visible). |
| 2 | Student work shows understanding of the problem, but may indicate some problems either in obtaining the appropriate data from the visualization or in using the data to solve the problem. The student may have drawn a northern boundary, or drawn a boundary not based on landmark or significant color value transition. Some explanation is offered, but reasons for the differences are inaccurate or vague. |
| 1 | Student work shows little understanding of the problem and/or how to solve it, but the work is attempted. May attempt to use the visualization to draw the boundary, but does not use a boundary based on landmark or significant color value transition, and has difficulty selecting a consistent boundary. Explanation is inaccurate or missing. |
| 0 | The southern boundary is not drawn; evidence of student understanding of the problem and/or use of the visualization is missing. |

D. Calculating the lapse rate and explaining differences

| Score Level | Description |
|-------------|--|
| 3 | The lapse rate is correctly calculated and expressed in correct units (degrees C per kilometer). Students picked two cells that are next to each other and correctly computed the difference and the ratio. Explanation of differences draws on concepts of resolution or local factors that might influence lapse rate. |
| 2 | The lapse rate is correctly calculated but not expressed in correct units, or small errors in calculation have resulted in an incorrect answer. Explanation is attempted and indicates some understanding of lapse rate, but without noting specific factors that might explain the differences. |
| 1 | Lapse rate is calculated incorrectly; units are missing or incorrect; explanation is missing or incorrect. |
| 0 | Answer is blank, arbitrary or inappropriate. |