Data at Altitude:
A GLOBE Data Exploration

Purpose
Students learn how temperature varies with altitude while exploring GLOBE air temperature data collected at different elevations.

Overview
Students analyze temperature data from two GLOBE sites in Germany as a way of observing how temperature changes with altitude. They learn that temperatures cool as a function of elevation, the scientific concept called lapse rate.

Student Outcomes
Students will be able to:
- Compare temperature at different elevations to determine how temperature varies with altitude.
- Understand the atmospheric science concept of "lapse rate", an expression of the rate of cooling as a function of elevation.

Science Concepts
- *Physical science*
- *Earth systems Science*
- *Weather and Climate*
- *Weather can be described with quantitative measurements*

Science Practices
- *Analyzing and interpreting data*
- *Constructing explanations*
- *Obtaining, evaluating, and communicating information*

Time
One class period (50 minutes)

Level
Middle school (grades 6-8)

Materials and Tools
- Photo of the region (page 4)
- Projector and screen
- *Student Activity Sheets A-C*
- Rulers
- Calculators

Preparation
- Copy the *Student Activity Sheets* for each student.
- Prepare to project the photo of the region (page 4) or print it for students.
- Provide students with links to web articles listed below.

The Troposphere
scied.ucar.edu/shortcontent/troposphere-overview

Layers of Earth's Atmosphere
scied.ucar.edu/atmosphere-layers

Background
In the troposphere, the lowest layer of Earth's atmosphere, temperatures get cooler with increasing elevation. Atmospheric scientists refer to the rate at which this cooling happens (measured in degrees Celsius per kilometer) as the ***lapse rate***. The lapse rate is about 6.4°C/km. In other words, if the temperature at a location near sea level was 20°C, the expected temperature outside a balloon hovering 1,000 meters (3,281 feet) above that location would be 13.4°C (20° minus 6.4°).

The lapse rate of 6.4°C/km represents average conditions. The actual lapse rate varies somewhat from day to day and from one place to another. For example, the amount of water vapor in the air (humidity) can cause the lapse rate to vary from the standard value of 6.4°C/km.

Since the two sites in Germany where these GLOBE data are collected (see below) are close to each other, it is reasonable to expect that any weather systems that pass through the area should usually affect the two stations in roughly the same way. Therefore, on most days, the temperature difference between the stations should mostly be a result of the elevation difference between the stations.

About the data: The data used in this activity comes from two GLOBE sites in southern Germany near the border with Austria. The data were collected at solar noon, between the dates of 1 July and 31 August 2012.

The high elevation site is at the top of Zugspitze, the tallest mountain in Germany in the Alps Mountain Range, at an elevation of 2,962 meters above sea level (GLOBE site: Zugspitze: Hochster Berg Deutschlands:ATM-05)

The lower elevation site, Garmisch-Partenkirchen, is a resort town located in a valley just north of the mountain, 35.7 km away. The Garmisch-Partenkirchen site is at an elevation of 200 meters above sea level. (GLOBE site: Garmisch-Partenkirchen Wetterstation:ATM-04)

The Zugspitze station is 2,762 meters (9,062 feet) higher than the Garmisch-Partenkirchen station.

Data from both sites are associated with the school: Offene Schule Babenhausen, Babenhausen, Germany

What To Do and How To Do It

Step 1. Engage students with the question of how climate is affected by altitude.

- Show students a photo of the mountain, Zugspitze, and the lower elevation areas (Page 4). Point out the plants that are growing at the lower elevation and the rocky slopes of the mountain where trees cannot grow. Tell students that plants depend on the climate in order to survive. Ask students how they think climate is different between the bottom of the mountain and the top.
- Explain that in this activity, they will explore temperature data from an elevation in the valley and from the mountaintop. These two locations are approximately 26 km apart, and at very different altitudes. They will figure out how temperature changes with elevation.

Step 2. Students compare temperature data from two locations to make a hypothesis.

- Have students look at the graph on *Student Activity Sheet A*. Explain to students that the data in the graph is the noontime temperatures, in degrees Celsius, for the two locations in Germany. The data is from 1 July - 31 August 2012.
- Following the directions on *Student Activity Sheet A*, students will make observations and develop a hypothesis about how temperature changes with altitude. Having a ruler might be helpful to identify which data points on the two curves are the same day. If students are not familiar with forming hypotheses, you may wish to guide this part of the activity and do it together as a class.

Step 3. Class discussion

- Ask students what they noticed. Which location has warmer temperatures? For most of the dates, is the amount of difference in temperature between the two locations similar or does it vary?
- Write student hypotheses on the board. (Hypotheses should include that

temperature is lower at higher altitudes, although there might be other hypotheses in the class too.)

Step 4. Students learn the science of why these patterns occur in order to test hypotheses.

- Tell students that the temperature patterns they saw are due to the elevation of each location. In order to learn about Earth's atmosphere and how temperatures change throughout the troposphere, have them read the web articles: *The Troposphere* and *The Layers of the Earth's Atmosphere* (see URLs above). Have students refine their hypotheses based on the readings.

Step 5. Students calculate how much temperature decreases as altitude increases.

- Provide students with *Student Activity Sheet B* and a calculator. Have them follow the instructions to calculate the lapse rate based on one of the days.
- Have students compare with others who calculated lapse rate with data from other days in the table. Discuss what might cause differences in the lapse rate from day to day (such as weather events, humidity, cloud cover).
- Have students average the calculated lapse rate from all days to do the assessment (below).

Assessment

Student Activity Sheet C allows students to use the lapse rate that they calculated to predict what the temperature would be at the high altitude site.

Answers:

(1) 5.97°C

(2) -5.69°C, yes it could snow

(3) -17.24°C, it would be a cold ski trip

(4) So that the two sites are affected by similar weather events

(5) Answers will vary but should relate to phenomena such as storm fronts, latitude, or high and low pressure.

Extensions: Delve Deeper into GLOBE Data

Calculate lapse rate for other locations. Take the temperature of your location following the GLOBE Atmosphere Protocols, find the elevation of your location and another, nearby location that is at a different elevation, and make a prediction about the temperature at that location. Remember to make sure that the two sites are close enough that they are affected by the same weather patterns.

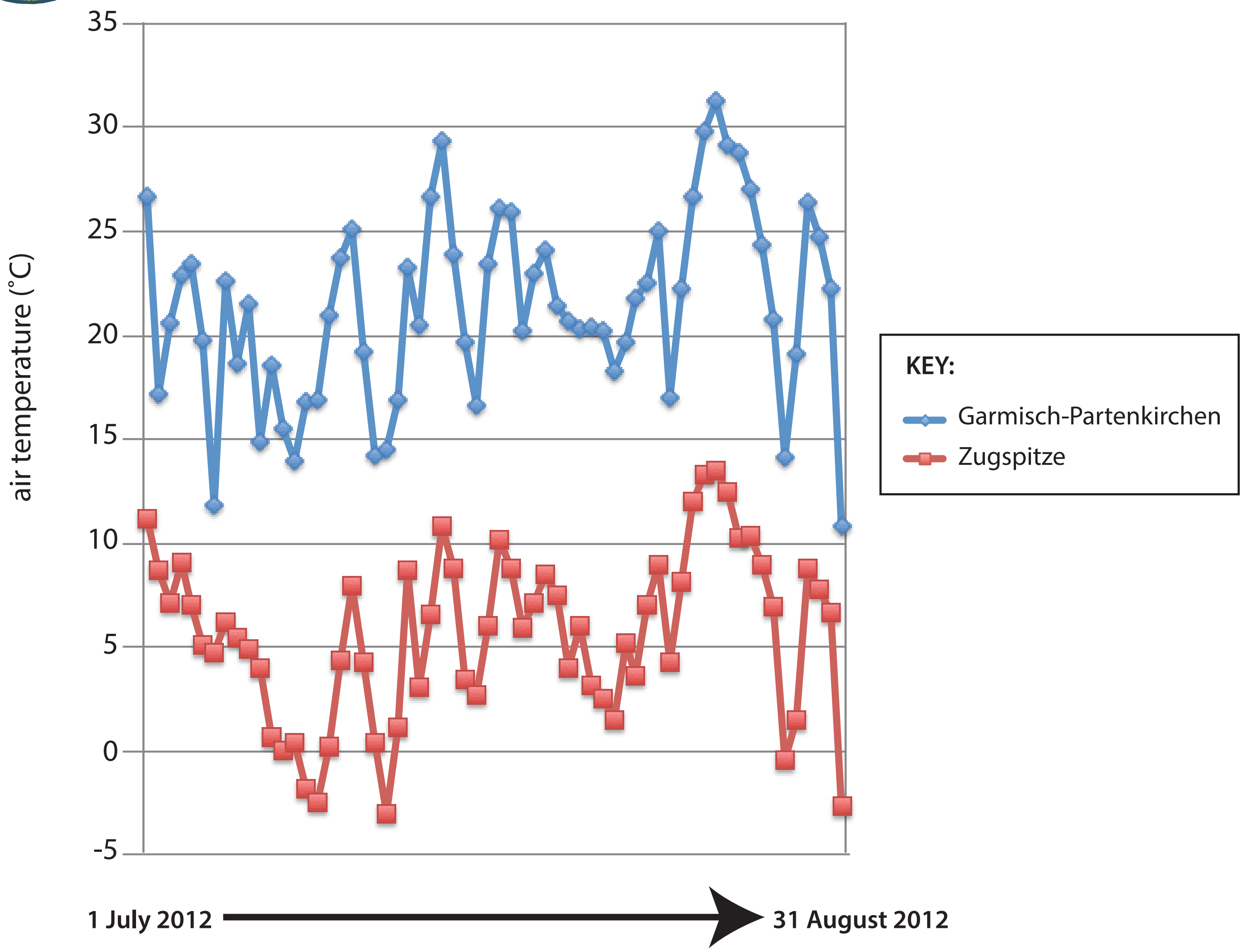
Credits

This activity is part of *GLOBE Data Explorations*, a collection of activities developed by the UCAR Center for Science Education (scied.ucar.edu), a GLOBE partner. Activities were reviewed by science educators and staff at GIO and field tested by teachers.

Zugspitze, the tallest mountain in Germany, with the town of Garmisch-Partenkirchen in a valley just north of the mountain
Image from Wikimedia Commons (Author: Octagon)

Name ______________________________

Date ______________________________



Examine the graph above. The dots are the temperature at solar noon each day. The red squares are the temperature each day on Zugspitze (the mountaintop). The blue diamonds are the temperature each day in Garmisch-Partenkirchen (the town in the valley).

- The Garmisch-Partenkirchen station is at an elevation of 200 meters above sea level.
- The Zugspitze station is 2,962 meters above sea level.

Compare the two lines. How are they similar? How are they different?

Based on what you observe in this graph, write a hypothesis to explain how temperature changes with altitude.

GLOBE Data at Altitude
Student Activity Sheet B

Name ______________________

Date ______________________

Air temperatures at solar noon:

Date	Garmisch-Partenkirchen temperature (°C)	Zugspitze temperature (°C)
19 August 2012	29.8	13.3
20 August 2012	31.3	13.5
21 August 2012	29.2	12.5
22 August 2012	28.8	10.3
23 August 2012	27.1	10.4
24 August 2012	24.4	9.0
26 August 2012	20.8	6.9

Choose a date to examine in detail.

____

What's the difference in temperature between the two locations on that date?

____

(Subtract the Zugspitze temperature from the Garmisch-Partenkirchen temperature.)

That difference in temperature occured with 2.762 kilometers of elevation difference. What would be the temperature difference for one kilometer of elevation difference? That's called the lapse rate.

LAPSE RATE: ______________
(Divide the difference in temperature you calculated above by 2.762.)

Share the lapse rate you calculated with others in your class. Get the calcuated lapse rate for the other days from other students and add those numbers to the table at the right.

Date	Lapse rate
19 August 2012	
20 August 2012	
21 August 2012	
22 August 2012	
23 August 2012	
24 August 2012	
26 August 2012	

Are all the lapse rates the same? If not, what do you think causes the difference?

Use a calculator to take the average of the lapse rate numbers.

GLOBE Data at Altitude
Activity Sheet C

Name

Date ______________________________

Now that you have calculated the lapse rate based on real temperature data, you can predict what the temperature would be at one site while you are measuring the temperature at the other site. You can also predict what the temperature would be at other sites nearby if you know their elevation. Predict what the temperature would be in the following situations.

1. LAPSE RATE (from *Student Activity Sheet B*): ________________

2. Let's say it's a cool September day in town at the lower elevation. At solar noon you measure that it is 10.8°C. Would it be cold enough to snow (below freezing, 0°C) on the mountaintop? What temperature would you expect at the high elevation based on the lapse rate you calculated?

**Hint: Multiply the elevation difference (2.762 km) by the lapse rate and subtract this from the lower elevation temperature.*

3. It's February and you are planning a ski trip to another nearby mountaintop that is 1.85 km higher than the low elevation. You would like to predict how cold it is at the top of that mountain. You measure that it is -6.2°C at the low elevation. What temperature would you expect at the top of the mountain based on the lapse rate you calculated?

4. Why do you think the high and low altitude sites need to be geographically close together for this to work?

5. What might impact the temperature at one site but not the other?