This document provides a lesson outline using a phenomenon from the Global Vegetation Project (gVeg). Our intent is to provide you with a phenomenon from gVeg that you can use to stimulate discussion and lessons within your classroom. Bookmarks are present throughout the document to ease your navigation. Your class may take the phenomenon in many directions; we aim to anticipate a few of those directions and provide resources and ways to utilize gVeg. We also recognize that each educator has specific styles, student needs, time restraints, and outcomes to hit. This is intended to be a resource that fits your needs as an educator while sparking student interest and joy. Use this resource in whatever way best suits you!

Overarching Phenomenon

Wyoming is experiencing many recent weather changes: reduced snowpack, record breaking temperatures, drought, and algae blooms. What is going on?

Introduction and Background

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Climate change is affecting nearly every environment in the United States. While it may be protected from visible changes like sea level rise, hurricanes, and other deadly weather phenomena, Wyoming is still becoming impacted. As temperatures continue to rise in the state, several impacts are occurring that affect humans, wildlife, vegetation, and all other life forms. Increased temperatures in Wyoming have brought on warmer summers with less precipitation, leading to widespread drought. This drying out of vegetation and soil also predisposes the state to more wildfires in late summer. If trends continue, drought and wildfires will continue to worsen.

The warming temperatures impact water availability through the snowpack as well. Warmer temperatures mean less snow; in fact, Wyoming snowpack has decreased over the last 70 years. The state also depends on the water stored as snow throughout the summer. In years past, the snowpack melted slowly, allowing aquifers and reservoirs to fill, recharging groundwater as well. However, with warming temperatures, the snowpack is melting more quickly. This causes more water to be lost downstream and leads to the extreme dryness of late summer. Glaciers that were once steady sources of water and ice year-round are becoming depleted. The state is losing water at a rapid rate.

Both wildlife, vegetation, and other forms of life are also impacted. Warming temperatures allow certain species to access environments they had not before. This is especially true at high elevations, where trees and other plants previously living below tree line can now live at higher elevations. Warming temperatures also shift climates into conditions that are no longer amenable for certain species, pushing them from their historic ranges. Some species are more at risk: the fragile species that have adapted to higher elevations have nowhere to go, threatening their extirpation.

Warmer temperatures also can lengthen the life cycles of organisms like bark beetles, who have now been seen to go through two life cycles in a year as opposed to one. If plant communities begin to change rapidly, this impacts the larger animals such as moose, deer, pronghorn, bears, and others that depend on them. Communities are also threatened by algal blooms, which can increase with climate change. Algae prefer warm water, high carbon dioxide levels, higher salinity (increased by drought), and increased runoff from intense storm events. These blooms threaten freshwater environments throughout Wyoming.

Climate change in Wyoming also poses significant impacts to humans. Wyoming does not see many days over 90- or 100-degrees Fahrenheit. This is changing. The infrastructure is not in place in Wyoming to tolerate many of these extremely hot days. This also puts vulnerable individuals, such as the elderly, children, and those with preexisting health conditions, more at risk. In terms of snow availability, less snow threatens a crucial industry in Wyoming: winter sports. Ski resorts and companies relying on snowmobile travel may have smaller windows in which to operate, losing revenue. Drought also impacts nearly everyone, from homeowners using water on a daily basis to farmers and ranchers who depend on water to keep their crops and livestock alive. Resort owners, ranchers, and farmers may need to make difficult decisions in the coming decades if these trends continue.

The climate data on gVeg shows some of these trends in both temperature and precipitation levels. Looking at the data from 1960-2009 compared to 2010-2018, evidence of drier summers, less overall precipitation, and higher levels of spring rains compared

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to late winter/early spring snows is evident. Students will interpret the data visible to them and use it to make projections on Wyoming's climate in the future. Students will investigate six sites from the state, from different locations and ecoregions. An ecoregion is "an area where ecosystems are generally similar" (EPA, 2021). Students will also take the opportunity to compare biomes using Whittaker diagrams. Biomes are environments characterized by similar amounts of precipitation and temperature. The Whittaker diagram visually represents this relationship and shows what biome exists at certain ranges of temperature and precipitation. For more information, see the attached guide on Whittaker diagrams or the link below. There will be an opportunity for students to compare how climate change is impacting ecoregions differently. You may also choose to tie this into the various impacts on Wyoming's environment, resources, and human population.

Information sourced from:

Burrows, J. (2020, August). *Field Notes*. Wyoming Outdoor Council. https://wyomingoutdoorcouncil.org/2020/08/13/climate-change-the-new-front-line-for-conservation-in-wyoming/

Fisher, M. R. (n.d.). *3.3: Terrestrial biomes.* Open Oregon. https://openoregon.pressbooks.pub/envirobiology/chapter/3-3-terrestrial-biomes/

States at Risk. (n.d.) *Wyoming*. States at Risk. https://statesatrisk.org/wyoming/all

United States Environmental Protection Agency. (2016, August). *What climate change means for Wyoming.* Environmental Protection Agency. https://19january2017snapshot.epa.gov/sites/production/files/2016-09/documents/climate-change-wy.pdf

United States Environmental Protection Agency. (2020, November 27). *Climate change and harmful algal blooms*. Environmental Protection Agency. https://www.epa.gov/nutrientpollution/climate-change-and-harmful-algal-blooms

United States Environmental Protection Agency (2021, June 10). *Ecoregions.* https://www.epa.gov/eco-research/ecoregions

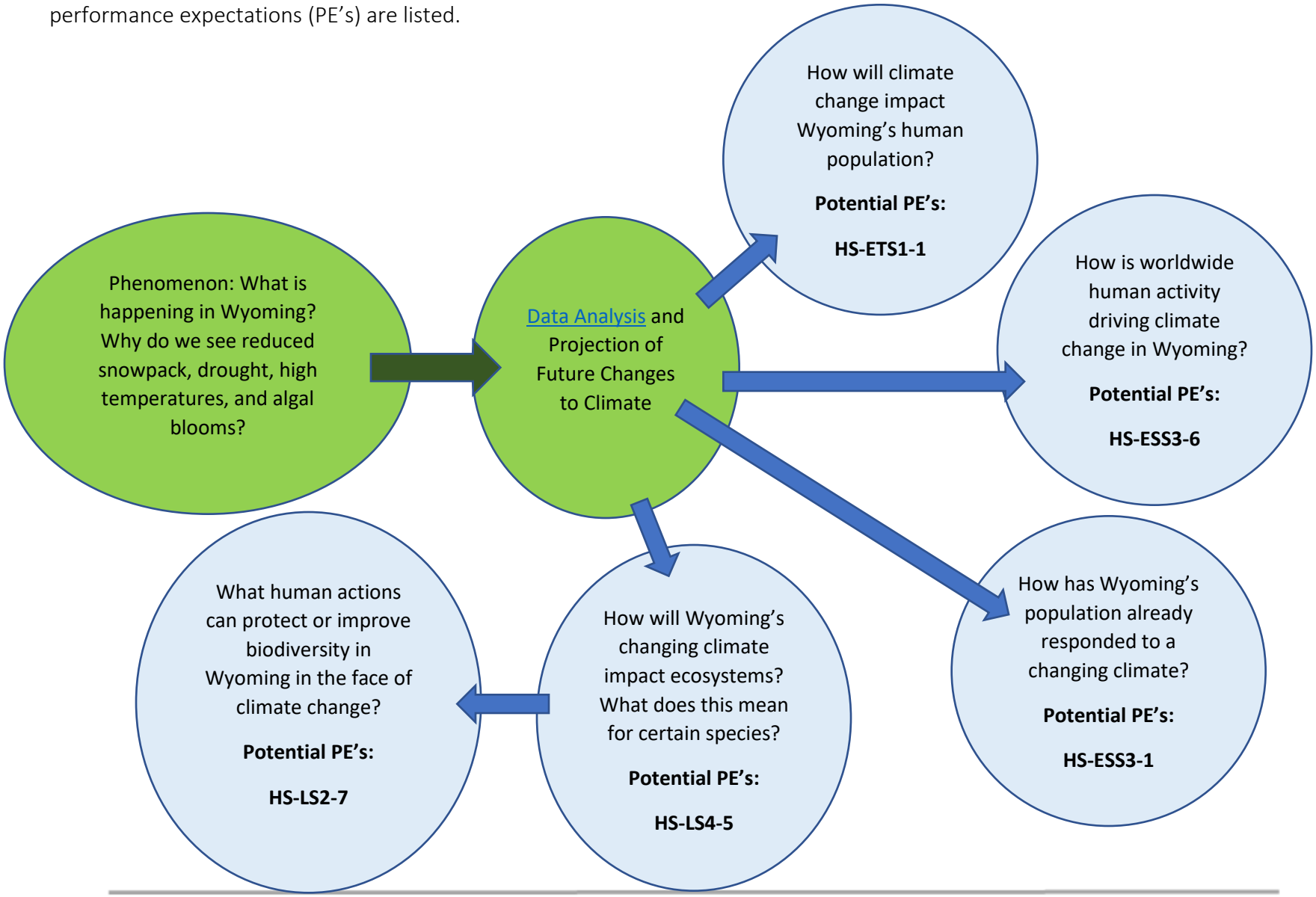
Lesson Ideas

Below is written a framework for presenting the phenomenon, a plan for analyzing data, and several potential lines of student-generated inquiry that may develop. A suggestion for the presentation of the phenomenon is at the beginning. Following that, the Phenomenon Map provides several lines of inquiry that your students may generate. You may choose to go in any of those directions. Allow the students to guide the path of your teaching!

Phenomenon Map

The figure below maps a potential course for engaging students with the phenomenon and given material. The green bubbles are the activities described in this document and support by gVeg. The blue bubbles are potential lines of inquiry that this activity can serve as

a starting point for; however, gVeg itself does not support these investigations directly. For these investigations, potential performance expectations (PE's) are listed.



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Presentation of Phenomenon

Students will read several articles discussing the impacts of climate change in Wyoming, including reduced snowpack, drought, high temperatures, and algal blooms. Students will have an opportunity to explore six different sites throughout the state of Wyoming, representing different ecoregions or parts of the state. For more information on the ecoregions of Wyoming, look here. For more information on ecoregions in general, look here. Students will first have the opportunity to explore the Global Vegetation Project (gVeg) platform. They will then observe the data and come up with initial explanations and questions to explain the phenomenon.

Activities	Rationale
Present students with the following short news articles related to Wyoming. You may choose to have students read one, two, or all four. You may frame it like this: "We are going to read about some interesting things that have been happening recently in Wyoming related to weather. After you read these articles, I want you to think about what is going on and how we may explain some of these impacts." Links to articles are found below: Reduced Snowpacks Record Breaking Temperatures Drought Algal Blooms	By presenting students with these articles, they can see specific observable phenomena that have been occurring in their state. Attempting to explain these phenomena will lead them to an analysis of the climate and how climate has been changing in Wyoming. This is where gVeg comes in: providing climate data that students can use and compare to make claims about the impacts of climate change on Wyoming. This sets the table for the lesson.
Have students share their reflections in groups. If you did not have students read all articles, group them with peers who read different articles so that each student has an opportunity to learn about each one. In their groups, have students generate initial explanatory ideas and questions.	Allowing students to process out loud serves as a starting point for the discussion. Students can learn about the other articles if they did not read one and also gather ideas from their peers. Often, students will put together snippets from things their peers say and add to their own growing ideas.
Bring the class back together. Have students share any thoughts, explanations, and questions that they have. Record all preexisting knowledge and questions somewhere that all students can see.	This part collects student prior knowledge and questions focused on the specific phenomenon. Collecting their answers here is important; returning to this document will allow you to direct your lessons in a student-driven way. While the next part of the lesson will be a dive deeper into the data, where you go from there will depend greatly on your students.

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If students bring up anything to do with climate change and shifting patterns of weather, you have your entry into gVeg! Tell students that they will be engaging in a web-based tool that will allow them to look at the impacts of climate change across the state of Wyoming. Transition students to devices where they can access gVeg.	It is crucial that the investigation comes from student-generated inquiry. If there are other more pressing lines of inquiry that arise, feel free to pursue them! We are hopeful that gVeg can provide an entry point into investigating climate data and using evidence to back up some of the climate changes students see through the phenomenon.

Lesson Ideas

Data Analysis and Projection of Future Climate

Below are the Performance Expectations, Science and Engineering Practices, Crosscutting Concepts, and Disciplinary Core Ideas present in this lesson. The color coding is in line with the Next Generation Science Standards (NGSS). The color coding is consistent throughout the document, reflecting where each of the three dimensions are present.

Performance Expectations	**HS-ESS3-5.** Analyze data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems.
Science and Engineering Practices	**Constructing Explanations and Designing Solutions** Construct an explanation based on valid and reliable evidence obtained from a variety of sources and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena **Analyzing and Interpreting Data** Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims. Consider limitations of data analysis (e.g., measurement error, sample selection) when analyzing and interpreting data.
Crosscutting Concepts	**Cause and Effect** Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. Cause and effect relationships can be suggested and predicted for complex

	natural and human designed systems by examining what is known about smaller scale mechanisms within the system. Changes in systems may have various causes that may not have equal effects. **Stability and Change** Much of science deals with constructing explanations of how things change and how they remain stable. Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.
Disciplinary Core Ideas	**Global Climate Change** Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts

Lesson Progression

This lesson sees students graph both historical and recent temperature and precipitation data for a single Wyoming location. Students will analyze the data in three-month seasonal periods, describing what the weather might have been like (on average) during these stretches. Students will compare the historic and recent data for each location, looking for how things have changed over time. Students will also explore how temperature and precipitation impact biome. For more information on biomes, look here. Students will compare locations, determining if things differ depending on location in the state or ecosystem. Students will then use the data to make projections on what Wyoming's climate and biomes may look like in the year 2048. From there, students can begin to think about how this might impact both the human and non-human populations of Wyoming.

Activities	Rationale
Have students go to the Global Vegetation Project site. At first, have them simply explore the platform. Perhaps guide them with questions like this: • What kind of information is found on this platform? • What can you change? What can't you change? • How might this information be useful in understanding global climates or plant life? • Why do you think someone would use a platform like this? What does the platform make you wonder?	This activity is intended to get students a little more familiar with the gVeg platform. It will get them thinking about both the benefits to the platform but also to its limitations. This can also be a great chance for you to source phenomena that may be related to other lessons. If students are curious and have questions, jot them down. It may be useful for future classes!

Now, send students to the six points found below. These link to six different sites throughout Wyoming. Students may go through them one at a time. Ask students to record things they notice about the six points, what it reminds them of, and what it makes them wonder. They may choose to look at the pictures, climate data, or other information about these points. Point 1: Northeastern Wyoming near Sheridan, Temperate Conifer Forest, Central Rockies Point 2: Western Wyoming, Montane Conifer Forest, Central Rockies Point 3: Central Wyoming, Sagebrush Steppe, Wyoming Basin Point 4: South-Central Wyoming, Montane Forest, Southern Rockies Point 5: Southeastern Wyoming, Mixed grass Prairie, Western High Plains Point 6: North-Central Wyoming, Sagebrush Steppe, Northwestern Great Plains	This focuses students in on the particular Wyoming sites. By giving them the opportunity to share observations and wonderings, it provides another opportunity to assess what questions students have and what background knowledge they already bring. This serves valuable information as you guide students through lessons. It may also spark ideas for future phenomena.
Assign students to one of the six Wyoming locations. Student should work independently or in pairs at this point. Eventually, they will come together in groups with students who worked on the same point.	Students will have the opportunity to engage by themselves or with a single partner so they can practice analyzing data trends and using evidence to build explanations. If students are in groups right away, some students may take charge and reduce the chance for all students to engage. By having various sites around the state, students can also see if the impacts of climate change are consistent across the system.
Even though students may have seen the Walter-Lieth diagrams on the website, provide them with the data tables and blank graphs (this can be found in the attached excel sheet). Each student will graph the data and then interpret what the data tells them about climate. Distribute this graphic organizer that will allow students to describe what is happening in 3-month periods that correspond to the seasons. Students will then compare the historic to the recent data and describe what has been stable and what has changed. This is a	By providing students with the graphic organizer, students can really begin to connect the data to explanations for phenomena. This will give students a better sense of what the data tells them is happening throughout the year. Students will hopefully notice the increases in temperature, the drier summer periods, and shifts in precipitation that may mean more rain and less snow. They can also start exploring the cause-and-effect relationship between temperature and

good opportunity to have students look at the Whittaker biome diagrams (see attached guide). It may be helpful to have students review the guide or this page. This can give students some perspectives on how temperature and precipitation work together to cause different climates. It gives perspective on what classifies as "dry" environments as well. Students will return to these diagrams later.	precipitation. The Whittaker diagrams also allow students to connect precipitation to temperature in causing climate. When students make climate predictions later, they will use this diagram to determine whether the area's biome may change.
Before moving students into groups, provide students with several reflection questions: • How does temperature affect precipitation? Do you think precipitation has an impact on temperature? • How do temperature and precipitation together affect the type of biome? • What patterns do you observe in the changes of climate? • What aspects of climate were stable? • What do you think caused some of the changes in climate? • What further evidence do you need to back up some of the claims you have made?	These questions are staged to get students thinking more about the crosscutting concepts of cause and effect and stability and change. They were adapted from this document. Research shows that students benefit from explicit framing of crosscutting concepts in addition to the implicit work they have already been doing. These questions provide further investigation to how these concepts are operating in this given system.
Now, have students move into groups with other students who analyzed the same data set. Allow students to compare their analysis and interpretations. Have them share what they find similar and different. If there is a discrepancy, allow students to defend their claims using evidence. Some sentence frames are provided.	By combining students who looked at the same data, students have the opportunity to justify their claims and reflect upon their thinking. If other students came to different conclusions, this is a rich opportunity to explore those differences and consider other ways of thinking.
When students have finished exploring the similarities and differences in their data, pose them this question: "Based on the data we have, what does this mean for the climate at your location in the future? Based on the changes you have seen from the historic data to the recent data, draw a predictive climate diagram for the year 2048 (30 years from the last point of data collection). Also, use the Whittaker diagram to determine if the biome may change or remain stable. You will work on this together as a group. Be ready to share	This challenge is purposefully open-ended for students. They can take a mathematical approach to the problem, calculating the changes in temperature and precipitation from the historic to recent data and extrapolating that over a 30-year period. They may take a less mathematic approach, observing broader trends over time to make their claim. They may also choose to bring in outside research on climate change, using expert predictions or projections to inform their work. Either

out your graph along with the process and evidence it took you to get there." You may give students the option to explore other resources on climate change (scientist predictions and projections) to guide their work. If not, they must use only the data from gVeg.	way, students should produce a new Walter-Lieth diagram and a statement on what biome their location will be in 2048. Students must be ready to back their explanation and prediction with evidence.
Allow each of the six groups to share out their findings. You may encourage students to critique or challenge their peers. You can use the same sentence frames as before.	By sharing out, students can see the different ways in which their peers analyzed and interpreted the data, built explanations, and used evidence. They also have the opportunity to critique and evaluate their peers claims as well. This hits on several aspects of science and engineering practices including engaging in argument from evidence and communicating information.
Before concluding, have students reflect upon benefits and limitations of this data and their analysis methods. You may ask questions like: • What was beneficial about using this set of temperature and precipitation data to predict future climate? • What are the limitations of using this data? What other data or evidence would you have liked to use? • Consider the differences in the historic and recent data sets. One was collected over a nearly 50-year period (1961-2009). The other was less than a 10-year period (2010-2018). How might this difference in sample size have impacted your analysis? How may the smaller sample size have affected your predictions? • What is the relationship between temperature and precipitation? How did this relationship benefit your analysis? How might this relationship come up short in telling the whole story? • What is the value of your predictions and projections? How do you think is this similar to what climate scientists do?	This stage is important in having students consider the limitations of the data here. It is also important to have students realize the limitations of cause-and-effect relationships. It is vital that there is a discussion around sample size. The small sample size of the recent temperature and precipitation data, as opposed to the historic data, is an important aspect for students to realize. Because it is a small sample size, outlier years may have a significant impact on data. This may prevent some aspects of the whole story from being told. While the data is valuable, it prevents us from getting a complete picture. It is also important that students recognize their projections and predictions as such. They are using data and existing patterns to make guesses, much like scientists do. There is also much more to the story that was not investigated.

At this time, you may return back to the original phenomenon questions: "We saw that Wyoming's climate is changing from the gVeg data. What does this indicate for the future of Wyoming's climate? How can we make predictions about what Wyoming's climate may look like in the future?" Ask if students feel like they improved or revised their answers, and what other questions they have in order to complete the story. As before, record new explanations and new wonderings for the whole class to see.	It is important that students can see how ideas or thoughts changed. They may see that initial ideas were supported by the activity, or they may revise some previous ideas. They may have answered some of their initial questions and may end up with more. Science is an ongoing process of generating questions and ideas, exploring them, and then returning to revise, eliminate, and ideate again. This is an opportunity to steer the class in a new direction based on their inquiries. You have a rich set of data that includes different ecosystems and different locations in Wyoming to compare. Refer back to the Phenomenon_Map for ideas on where to take the class next!

Resources

Climate Data Graphic Organizer

Data Set	For each season, describe the following: What would the weather be like? How much precipitation was there? Was the precipitation mainly rain or snow? Generally, it will snow when average temperatures are below 2°C. Averages from 2-4°C may have mixes of rain and snow. Averages 5°C and above indicate mostly rain. Remember, precipitation is measured in **mm**. For context, an area is classified as a desert if it gets 250 mm or less of precipitation in a year. Forests and grasslands can have precipitation ranges from 250 mm to 2000 mm per year. Use the Whittaker biome diagram to analyze what biome your area represents.			
	Winter (Jan. – Mar.)	Spring (April – June)	Summer (July – Sept.)	Fall (Oct. – Dec.)

Historic Data (1961- 2009)				
Recent Data (2010-2018)				
Comparison: How has the climate changed? What has remained similar?				

Using Evidence Sentence Frames

When Defending Your Own Claims

From the data I found that [insert claim]. This is supported by [insert evidence].

I noticed a pattern in the data. [Insert claim/pattern]. I can defend this because…[insert evidence].

When Agreeing With Classmates

I also found that [insert claim]. I got there by [insert evidence]. What was your evidence?

I really like that you said [insert classmate's claim]. I also found [insert similar claim]. What evidence did you use to get to your claim?

When Questioning Classmates

You made the claim [insert classmate's claim]. I am curious as to how you got there. What is your evidence?

You found [insert classmate's claim], but I found [insert contradicting claim]. Can you explain to me how you came to that conclusion? What evidence do you have?