S5: Seasonal Change on Land and Water

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Purpose

To further students' understanding of the causes of seasonal change using visualizations to compare effects of incoming solar energy in the two hemispheres

Overview

The class reviews global visualizations of incoming sunlight and surface temperature and discusses seasonal change. Students use the visualizations to support inquiry on the differences in seasonal change in the Northern and Southern Hemispheres, culminating in an evidence-based argument about why one hemisphere experiences warmer summers although it receives less total solar energy.

Student Outcomes

Students can use color visualizations to understand phenomena and solve problems.

Students understand the link between heat capacity of land/water and climate variations between the two hemispheres.

Science Concepts

Earth and Space Sciences

Weather changes from day to day and over the seasons.

Seasons result from variations in solar insolation resulting from the tilt of the Earth's rotation axis.

The sun is the major source of energy at Earth's surface.

Solar insolation drives atmospheric and ocean circulation.

Sun is a major source of energy for phenomena on Earth's surface.

Physical Sciences

Heat energy is transferred by conduction, convection and radiation.

Heat moves from warmer to colder objects.

Sun is a major source of energy for changes on the Earth's surface.

Energy is conserved.

Life Sciences

Sunlight is the major source of energy for ecosystems.

Energy for life derives mainly from the sun.

Living systems require a continuous input of energy to maintain their chemical and physical organizations.

Scientific Inquiry Abilities

Analyzing visualizations for important patterns

Comparing and contrasting visualizations

Evidence-based argumentation

Use appropriate tools and techniques.

Develop explanations and predictions using evidence.

Recognize and analyze alternative explanations.

Time

One 45-minute class period

Level

Middle, Secondary

Materials

Overhead transparencies of color visualizations and overhead projector

Copy of color visualizations for each student group. If high-quality color copies are not available, students can create them using *Work Sheet* copies and colored pencils or markers. Alternatively, if there are enough computers for each group (e.g., in a lab setup), students can access the visualizations on the GLOBE Web site.

Copy of *Work Sheet* for each student group

Wall map to support class discussions

Preparation

Create color copies of visualizations for each student group, or copy blank *Work Sheets* for students to color.

Divide students into groups of 2-3.

Prerequisites

Students should be familiar with the basic explanations for seasonal change: *Modeling the Reasons for Seasonal Change, Draw Your Own Visualization* and *Learning to Use Visualizations: An Example with Elevation and Temperature*.(suggested)

Background

Seasonal change can be partially explained by changes in insulation as the Earth orbits the sun and variations in the sun's intensity at different latitudes due to the Earth's tilt and its spherical shape. The GLOBE activity *Modeling the Reasons for Seasonal Change* explores these factors.

Taken alone, this explanation implies that seasonal change is the same throughout one latitude. Why, then, are Australia's coastal regions so much cooler than its interior, even at the same latitude? Incoming solar energy must not be the only factor in determining surface temperatures throughout the year. In this activity you will explore an additional factor: how land masses and bodies of water respond to the sun's energy.

Different materials respond to the energy from the sun in different ways. You have probably seen many examples of this. On a hot day, sand on the beach feels hot under your feet, but the water in the ocean feels much cooler. Similarly, it's usually cooler to walk barefoot in grass than on a nearby cement sidewalk. Scientists describe this phenomenon in terms of the amount of energy it takes to heat up different substances. *Heat capacity* is the ability of a material to absorb or lose energy before it changes temperature. Water has a relatively high heat capacity, requiring approximately 4.2 joules per gram of water to increase the temperature by 1˚ C. Conversely, one gram of water can lose 4.2 joules of energy before it cools by 1˚ C. In contrast, soil requires as little as 1.5 joules to heat up one gram by 1˚ C.

When land and water are exposed to the same amount of energy, land can heat up about three times faster than water. Conversely, land will cool down about three times as quickly as water. Actual heat capacity of soil varies depending on factors such as the water content of the soil: very moist soils have a higher heat capacity, closer to that of the water they contain, and therefore heat and cool more slowly than dry land. This is one reason that desert temperatures vary so greatly from daytime to nighttime.

Because of the difference in heat capacity between land and water, seasonal temperature patterns tend to be more extreme in large regions covered by land than in areas covered by water. Because water has a higher *thermal inertia*, than the ability to resist temperature change than land, large bodies of water tend to stay relatively constant in temperature throughout the year. This effect is relevant to global seasonal patterns because most of the land on Earth is in the Northern Hemisphere, thus making it easier to heat (or cool) than the Southern Hemisphere.

In this activity, you will use visualizations to explore the differences in received solar energy and resulting surface temperature between the Northern and Southern Hemispheres, and think about the implications for local climates.

What To Do and How To Do It

1. Conduct a class discussion to familiarize students with the visualizations.
2. Facilitate group work as students complete the *Work Sheets*.
3. Synthesize and discuss student findings as a whole class.

Step 1. Class Discussion

Seasonal Change: Review the spatial relationship between the sun and the Earth, and how Earth's tilt causes the amount of sunlight it receives in each hemisphere to vary, therefore causing the seasons. If students are unfamiliar with these issues, you can use the GLOBE activity *Modeling the Reasons for Seasonal Change* to teach them.

Ask: Are seasons exactly the opposite in the two hemispheres? For example, are January temperatures at latitude of 40˚ N the same as July temperatures at 40˚ S? If you wish, support this discussion by selecting a specific pair of locations at the same latitude in different hemispheres perhaps your town and a corresponding one in the other hemisphere and discussing their climates. Use GLOBE data or another Web site to make comparisons. This GLOBE learning activity will examine one of the reasons for the local variation of solar energy's effect on climate.

Orient Students to the Visualizations: Figures EA-S5-1 and EA-S5-2 present a set of visualizations showing incoming solar energy (Figure EA-S5-2) and surface temperature (Figure EA-S5-1) during two months (January and July). Each visualization shows a monthly mean, the average value for an entire month, at each location on the map. The months were chosen because they generally represent extremes of hot and cold in the annual surface temperature cycle. Consider beginning your explanation of these visualizations with surface temperature because it is a more familiar subject.

Surface Temperature

- In the surface temperature visualization (Figure EA-S5-1), colors have been selected so that there is a clear visual difference between the warm and cool temperatures. Colors that we refer to as "warm" (i.e., red, yellow, and orange) are used to represent warm temperatures. Colors that we refer to as "cool" (i.e., blue and purple) are used to represent cool temperatures. 3 C (32˚ F), the temperature at which water freezes, is where the transition from warm to cool or cool to warm occurs. This is an example of designing the colors for a visualization around a "landmark value." Landmark values are the points on a color scale where the representative value undergoes a distinctive change. Global patterns can be made easier to see by using landmark values that mark off the range at which certain phenomena occur. Designing a color scheme around a landmark value is useful in this case because it highlights which parts of the world are above or below freezing.
- Ask students to compare the two temperature visualizations, focusing on the areas that have below freezing temperatures. The visualizations show that in January both polar areas have sub-zero temperatures but that in July it is largely Antarctica that is below freezing. (Students will investigate this in the problem-solving activity.)
- Point out that the blues and greens on the map do not necessarily mean that the land at that location is frozen. The visualizations show average temperature over the whole month, including both daytime temperatures and nighttime temperatures, and in some areas pictured, temperatures are typically above freezing in the daytime and below freezing at night.
- Ask students to pick out different color patterns and connect them to their geographical causes: these patterns could be *minima*, *maxima*, or *contrast* with surroundings. For example, the Sahara Desert in Africa desert near the equator is the hottest place on Earth in July; the Rockies, Andes, and Himalayas are colder than their surroundings due to their high altitudes; and Greenland is shown as continuously frozen. This discussion may be aided by pointing out locations on a wall map of the Earth.

Solar Energy

- Solar energy comes to Earth in the form of sunlight and provides the Earth's primary source of heat. Solar energy is measured in units of watts per meter squared (watts/m^2). One way to make this more comprehensible is to relate it to light bulbs. For example, the average amount of energy coming to Earth in July is roughly 300 watts per meter squared. Students can imagine this as the energy from three 100-watt light bulbs for every square meter of the Earth. It is this energy that provides the basis for all life on Earth.

- The incoming solar energy visualizations in Figure EA-S5-2 show how energy is dispersed across the Earth. Why does the energy vary by latitude? The explanation for this has to do with how sunlight spreads over the spherical, tilted Earth. These spatial relationships are explored in another GLOBE visualization activity, *Modeling the Reasons for Seasonal Change*.
- The sun's energy is equal across lines of latitude (i.e., 40˚ N around the Earth on one day). Ask students to explain why this pattern occurs. They should refer to the Earth's daily rotation on its axis, which exposes each point on a line of latitude to the same amount of energy in a 24-hour period.
- Compare and contrast the two visualizations in Figure EA-S5-2. Ask students to describe the overall pattern of data in each visualization and to explain what the primary difference is between them.
- The pattern of incoming solar energy is very regular for each hemisphere. This leads to the following question: If solar energy is the primary cause of surface temperature, why do the surface temperature patterns vary from the solar energy patterns? One answer to this is that much of the energy from the sun is reflected away from the Earth-atmosphere system. For example, snow and ice can reflect up to 80% of sunlight. Clouds reflect strongly as well. This means that frozen surfaces can remain frozen despite substantial amounts of sunlight. In contrast, oceans and vegetation absorb most of the sunlight that falls on them and reflect little, thereby helping to warm the surface of the Earth. Other primary reasons are that surface temperature is strongly influenced by the type of material that is heated (such as land or water) and by air and water movements (i.e., air and ocean currents). This activity will investigate the impact of physical geography in some detail, focusing in particular on the effect of incoming solar energy on areas of land and water.

Step 2. Group Problem-Solving

The group problem-solving session asks students to further investigate the visualizations they discussed with the whole class, probing for why particular hemispheric patterns occur. The Work Sheet questions involve the students in considering fundamental climatic principles on Earth: the seasonal variation in the amount of sunlight (watts/m^2) received by different areas on Earth, the seasonal variation in temperature in the Northern and Southern Hemispheres, and the differences in how land and water respond to sunlight.

Students should work in groups of 2-3 for this exercise. The primary student materials are the color visualizations in Figures EA-S5-1, EA-S5-2, and EA-S5-3. It is easiest to conduct the analysis if each team has their own copy, either on paper or on computer (if this activity is done in a computer lab, each group could look at the visualizations posted on the GLOBE Web site). If neither of these is possible, copy and pass out *Work Sheets* 1-3 and color pencils or markers, so that students can create the color visualizations themselves by coloring in the template.

Guide students through the following steps.

A. *Students will use visualizations to compare incoming solar energy in January and July,* and see that the two hemispheres are almost opposite. They will also see that the Southern Hemisphere receives more energy during its summer than does the Northern Hemisphere. They are shown a depiction of the Earth's orbit around the sun as an aid to explain the difference: Earth is closer to the sun in January than in July. As students work, they may need help in interpreting the visualizations to support their inquiry.

B. *Students will compare temperature visualizations for January and July* to decide

Figure EA-S5-1

Average Earth Surface Temperatures for January and July

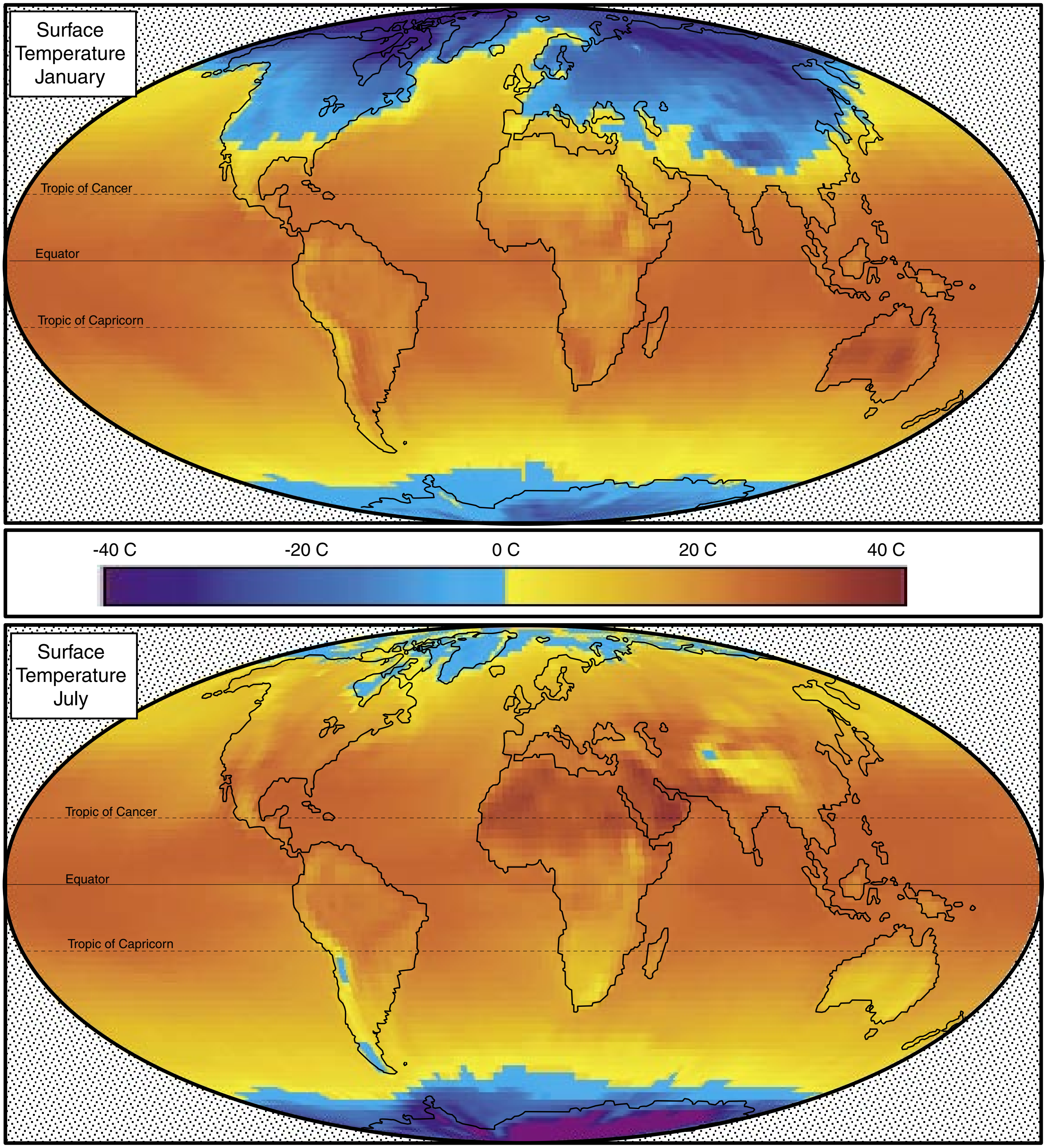
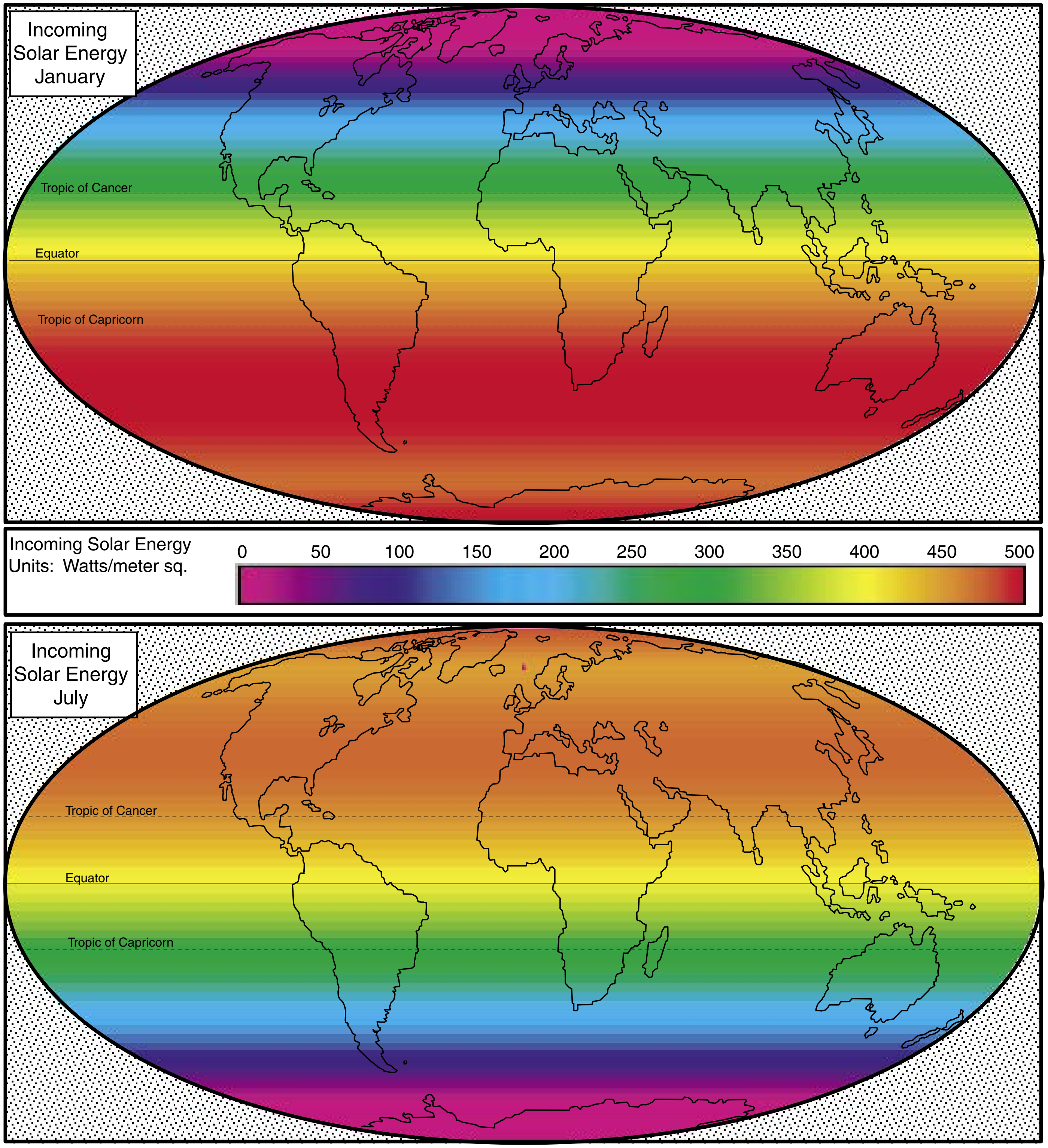


Figure EA-S5-2

Average Incoming Solar Energy for January and July



which hemisphere experiences a warmer summer. The temperature visualization shows that the Northern Hemisphere in July has more reds and dark reds than January in the Southern Hemisphere, and the graph of temperature averages shown in Figure EA-S5-3c shows this also. However, in July, the Northern Hemisphere received *less* insolation than the Southern Hemisphere did in January.

C. *Next, students will use Figure EA-S5-3a to compare temperature variation between two cities in opposite hemispheres: Beijing and Melbourne*. Figure EA-S5-3a shows a visualization of temperature range calculated as the absolute value of average temperatures for January minus average temperatures for July. Melbourne's temperature changes less even though the two cities are at similar latitudes. To explain this, students may look at GLOBE data for the two cities. Although altitude is an important factor in the difference, looking at fluctuations across the two hemispheres as a whole indicates that it is not a sufficient explanation. Australia is a relatively small landmass, while China is on a large landmass whose temperature will fluctuate significantly more than the nearby ocean.

D. *Students should generalize from this case to consider why surface temperature varies more in the Northern Hemisphere.* Figure EA-S5-3b shows a bar graph of the amounts of land and water in the two hemispheres to help students understand that the majority of land on Earth is located in the Northern Hemisphere, and as a result the Northern Hemisphere experiences more extreme temperature fluctuations than the Southern, which is covered mainly by water. Students should use specific evidence from the visualizations and graphics as support for their explanations.

Step 3. Class discussion

Have selected groups present their analysis. Guide them to support their explanations with evidence from the visualizations if they have not done so.

Many students believe that seasons are caused only by Earth's proximity to the sun and that summertime is warmer because the Earth is closer to the sun. This activity demonstrates that seasons vary despite proximity to the sun: summertime temperature change is in fact more pronounced when the Earth is farther from the sun and therefore receiving less intense incoming solar energy.

Further Investigations

An experiment that asks students to investigate the heat capacity of different substances would be useful to consolidate the underlying idea that some substances require more energy than others to raise their temperature. For example, a lab might ask students to expose a beaker of dirt and a beaker of water equally to a light source while they measure resulting changes in temperature. Similar issues can also be investigated through the GLOBE *Soil Moisture and Temperature Protocol.*

Another way to investigate heat capacity is to graph GLOBE data of air and water temperature. In general, the air temperature data will show more variation, consistent with the lower heat capacity of air relative to water. Comparing two schools at the same latitude where one school is near an ocean and another inland could continue this investigation.

Resources

The GLOBE Web Site offers a tool for creating a table (or spreadsheet) of visualizations, so that a variety of visualizations can be contrasted, for example, in order to look at incoming solar energy at different times of the year. Students can use this to conduct further inquiries, for example how solar energy varies over a year. The activity *Modeling the Reasons for Seasonal Change* uses visualizations as a means for analysis of contrasting solar energy during the solstices and equinoxes. The GLOBE Seasons Poster also provides a comprehensive table of this sort allowing solar energy visualizations to be compared and contrasted with visualizations of other variables including average temperature, cloud cover, precipitation, soil moisture, and vegetation vigor.

Figure EA-S5-3 a,b,c

Land Mass Distribution and Seasonal Temperature Change

Figure EA-S5-3a: Temperature Difference Between January and July

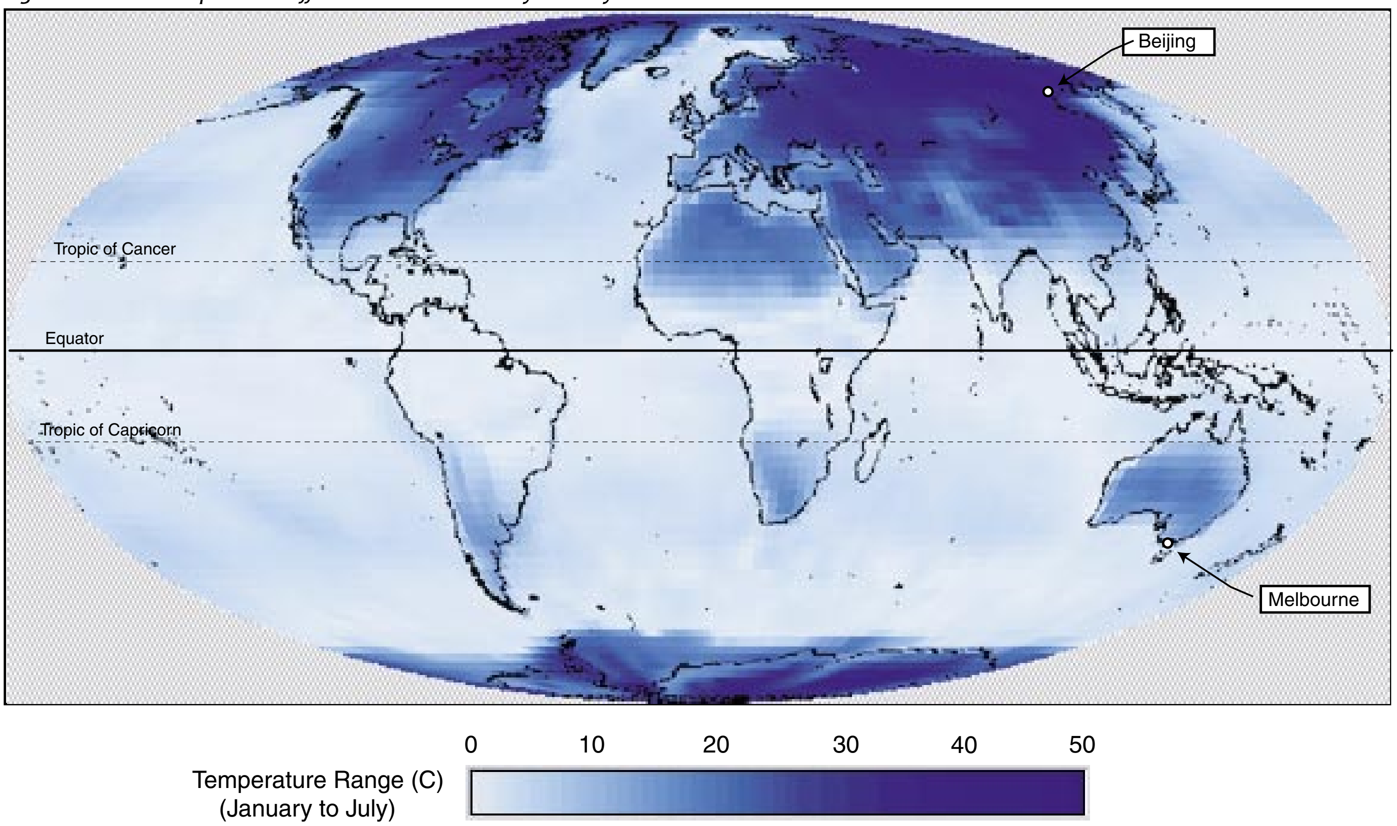


Figure EA-S5-3b: Area of Land and Water by Hemisphere

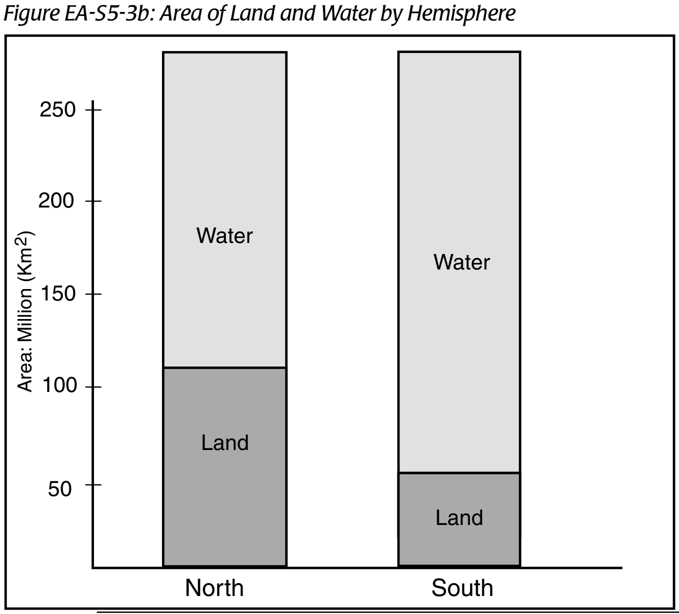
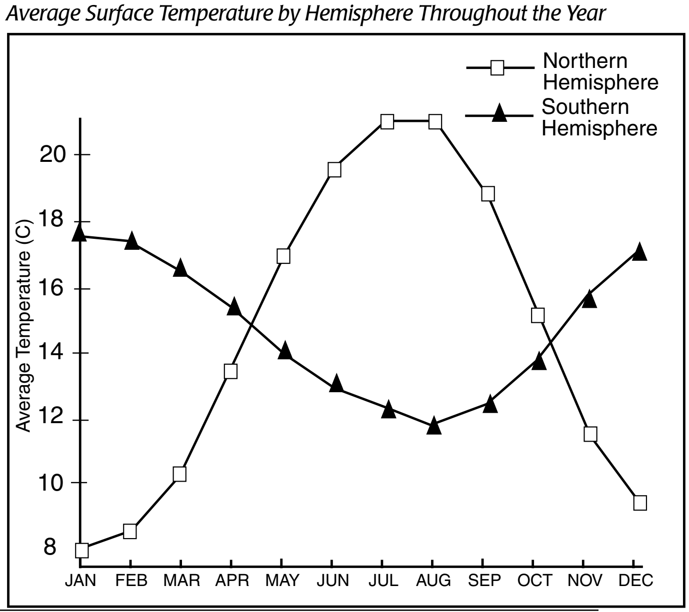


Figure EA-S5-3c:
Average Surface Temperature by Hemisphere Throughout the Year



Seasonal Change on Land and Water

Work Sheet

Names: ____

Seasons are more or less, but not exactly, opposite in the Northern and Southern Hemispheres . In this activity you will use color global visualizations and other data to analyze and explain important differences in the variation of seasonal change in the hemispheres.

Directions

1. Begin by looking at the visualizations of incoming solar energy for January and July (Figure EA-S5-1 or *Work Sheet 1*). Which hemisphere is experiencing its summer in January? (Northern/Southern) In July? (Northern/Southern) Explain how the visualizations support your answer.

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2. Does one hemisphere receive more incoming solar energy during its summer? Which one? In your answer, use both qualitative terms (e.g., more than, less than) and quantitative (e.g., a difference of 100 watts per square meter).

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3. Why might that hemisphere be getting more solar energy? The following picture of the Earth's location relative to the sun during the solstices and equinoxes can help you figure this out.

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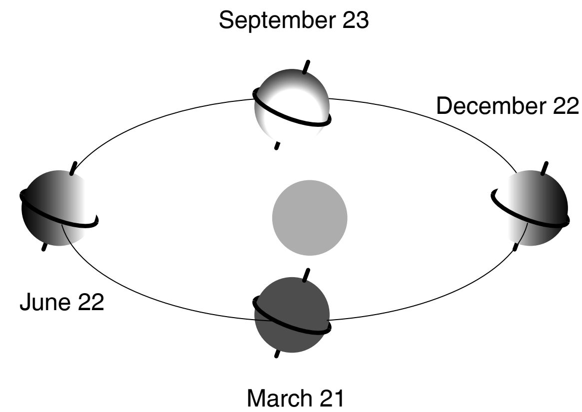
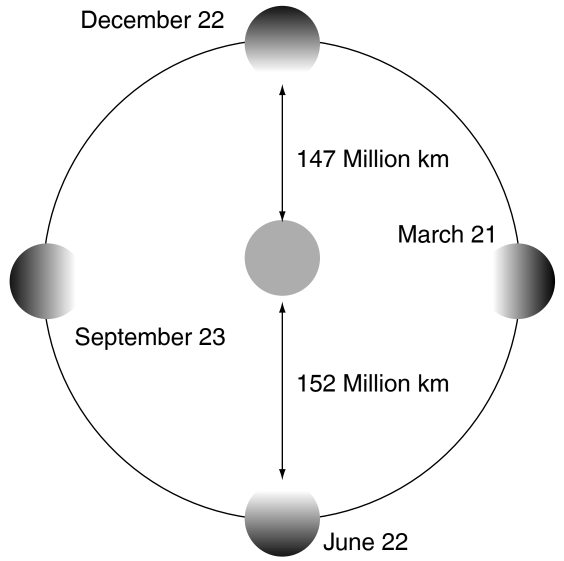
Earth's Location Relative to the Sun





4. Now look at the visualizations of Earth's surface temperature in January and July (Figure EA-S5-2 or *Work Sheet 2*). In particular, compare the areas of land and water around the poles. Which hemisphere seems to have a colder winter? (Northern/Southern) A warmer summer? (Northern/Southern) Describe the evidence you found in the visualizations that helped you decide.

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5. Compare your answer for question 2 to your answer for question 4. Is the hemisphere that gets more incoming solar energy in the summertime the one that has the warmer summer?

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Suggest a reason for this and then do the rest of the *Work Sheet* which will help you explore the reason.

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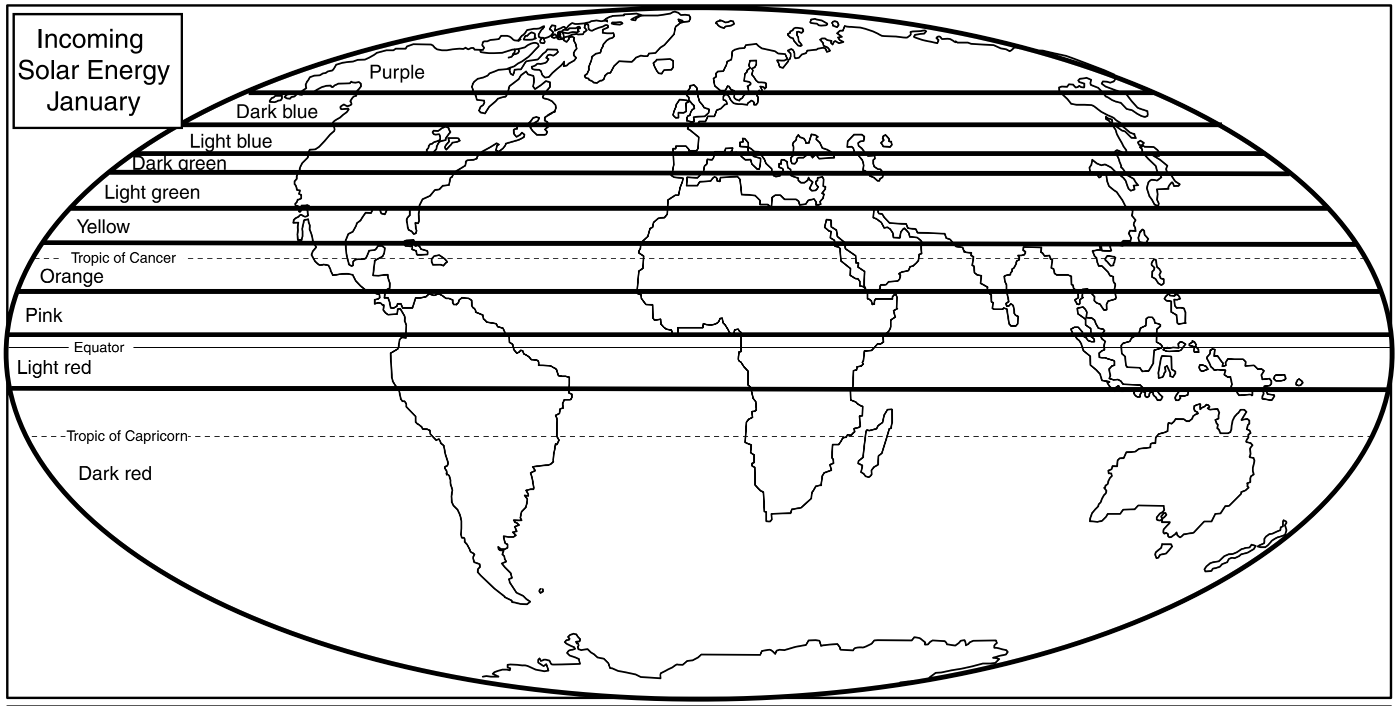
Name: ______________________________

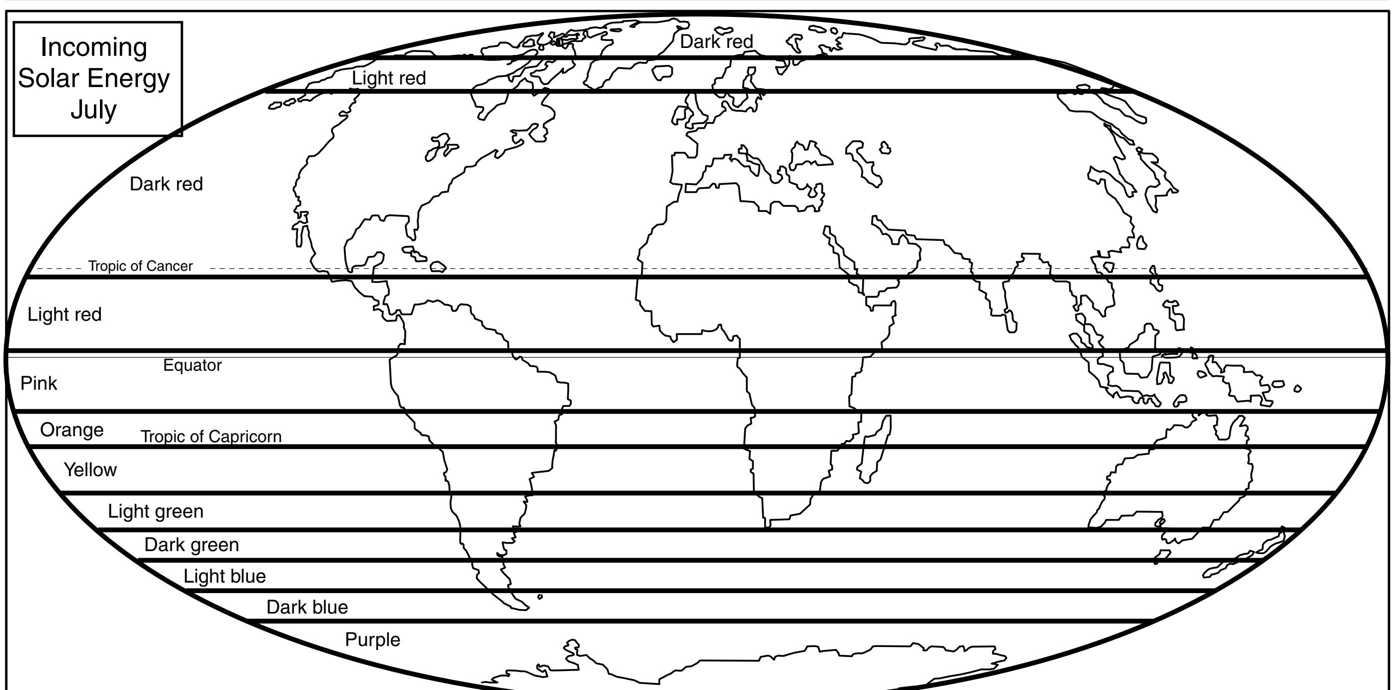
Work Sheet 1: Average Incoming Solar Energy for January and July

Directions: Color in the incoming solar energy bar and the visualizations for incoming solar energy for January and July. Use the color indicated and color in between the bold lines.



Incoming Solar Energy
Units: Watts/meter sq.

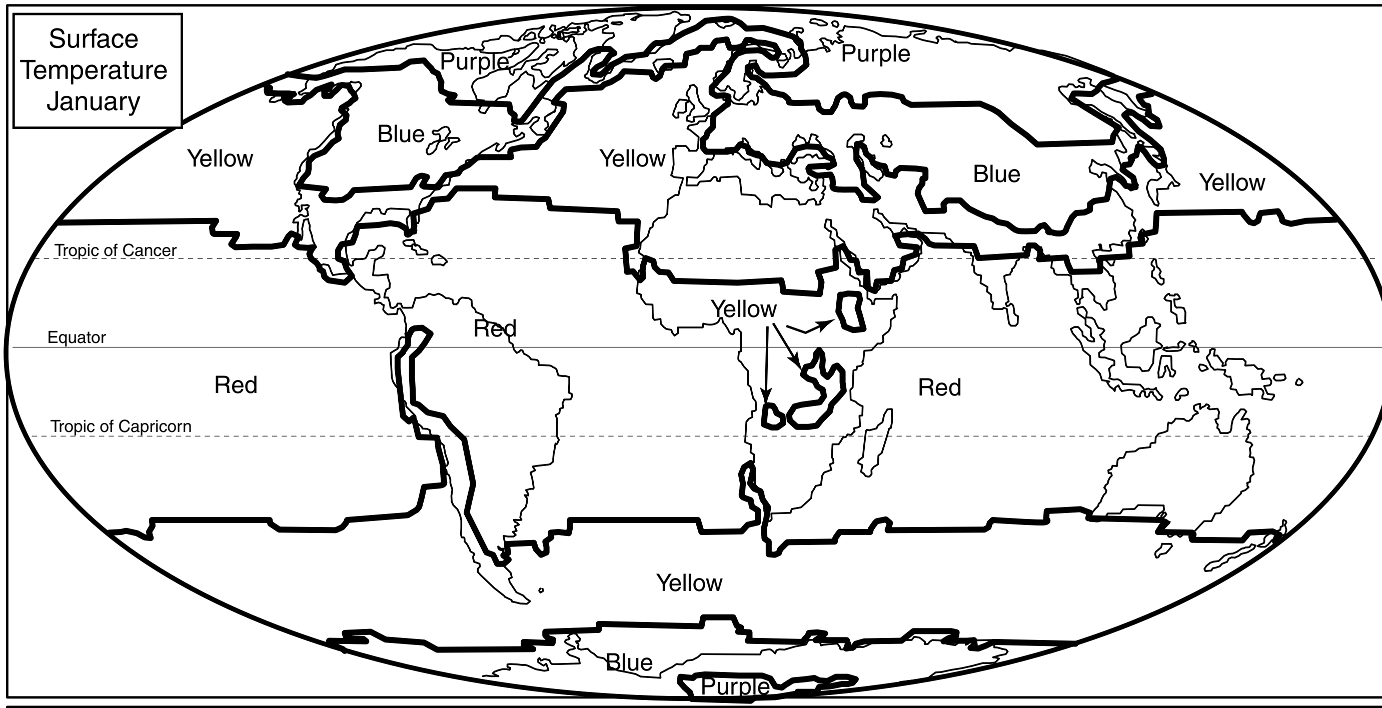
0–50	50–100	100–150	150–200	200–250	250–300	300–350	350–400	400–450	450–500
Purple	Dark blue	Light blue	Dark green	Light green	Yellow	Orange	Pink	Light red	Dark red



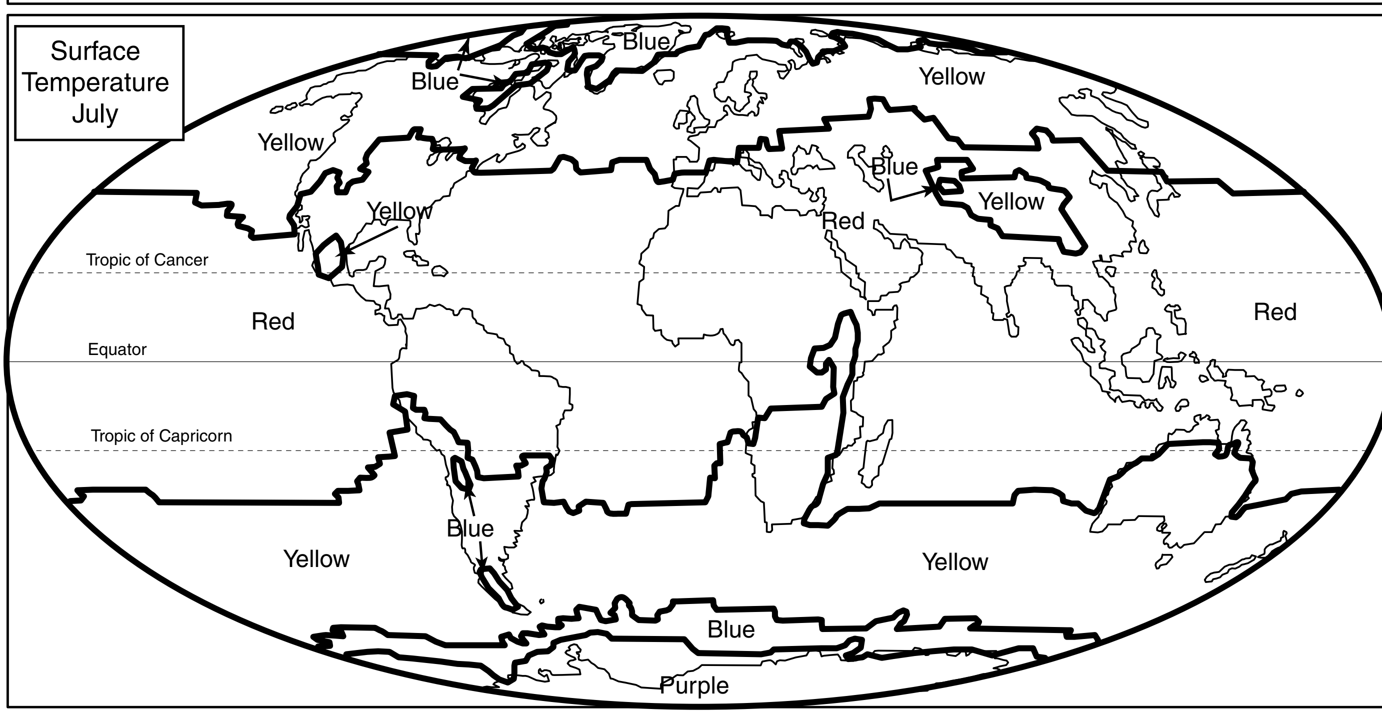
Name: ______________________________

Work Sheet 2: Average Earth Surface Temperatures for January and July

Directions: Color in the temperature bar and the visualizations for Earth surface temperature in January and July. Use the color indicated and color in between the bold lines. Each color represents a temperature range.



-40 C to -20 C	-20 C to 0 C	0 C to 20 C	20 C to 40 C
Purple	Blue	Yellow	Red



6. Consider the difference in temperatures between summer and winter in each hemisphere.

A. Figure EA-S5-3a (or *Work Sheet 3a*) shows a visualization of the January to July temperature ranges around the world: the shade of blue tells you how many degrees difference there is between the average monthly temperatures in January and July. If the temperature difference is large, the color is darker, and if the difference is smaller, the color is lighter. Beijing, China and Melbourne, Australia are at similar latitudes, but in opposite hemispheres, and they have very different temperatures ranges. Quantify the difference by analyzing the visualization and give reasons for the difference.

B. If you're having trouble deciding on a reason for the difference, think about the size of the continent the two cities are on. Which would you expect to heat or cool faster, Australia or Asia? Why?

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C. How does your answer to question B about which continent heats faster relate to question A, which asks about the difference in temperature?

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7. Finally, generalize your analysis to compare the Northern and Southern Hemispheres as a whole. Which hemisphere has the hotter summer and colder winter, Northern or Southern? Explain your answer and give reasons for the difference, using evidence to support your argument. Use the data shown in the visualizations in Figures EA-S5-1, 2, and 3 (or *Work Sheet 1, 2,* and *3*) as evidence. You may also refer to Figure EA-S5-3b (or *Work Sheet 3b*) which shows the amounts of land and water in the two hemispheres.

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Name: ____

Work Sheet 3: Land Mass Distribution and Seasonal Temperature Change

Directions: The top visualization is of seasonal surface temperature difference, or, the bottom drawing minus the top drawing in Work Sheet 2. Color in the color bar and the Seasonal Temperature Change visualization using the colors indicated.

Figure EA-S5-3a: Seasonal Temperature Range

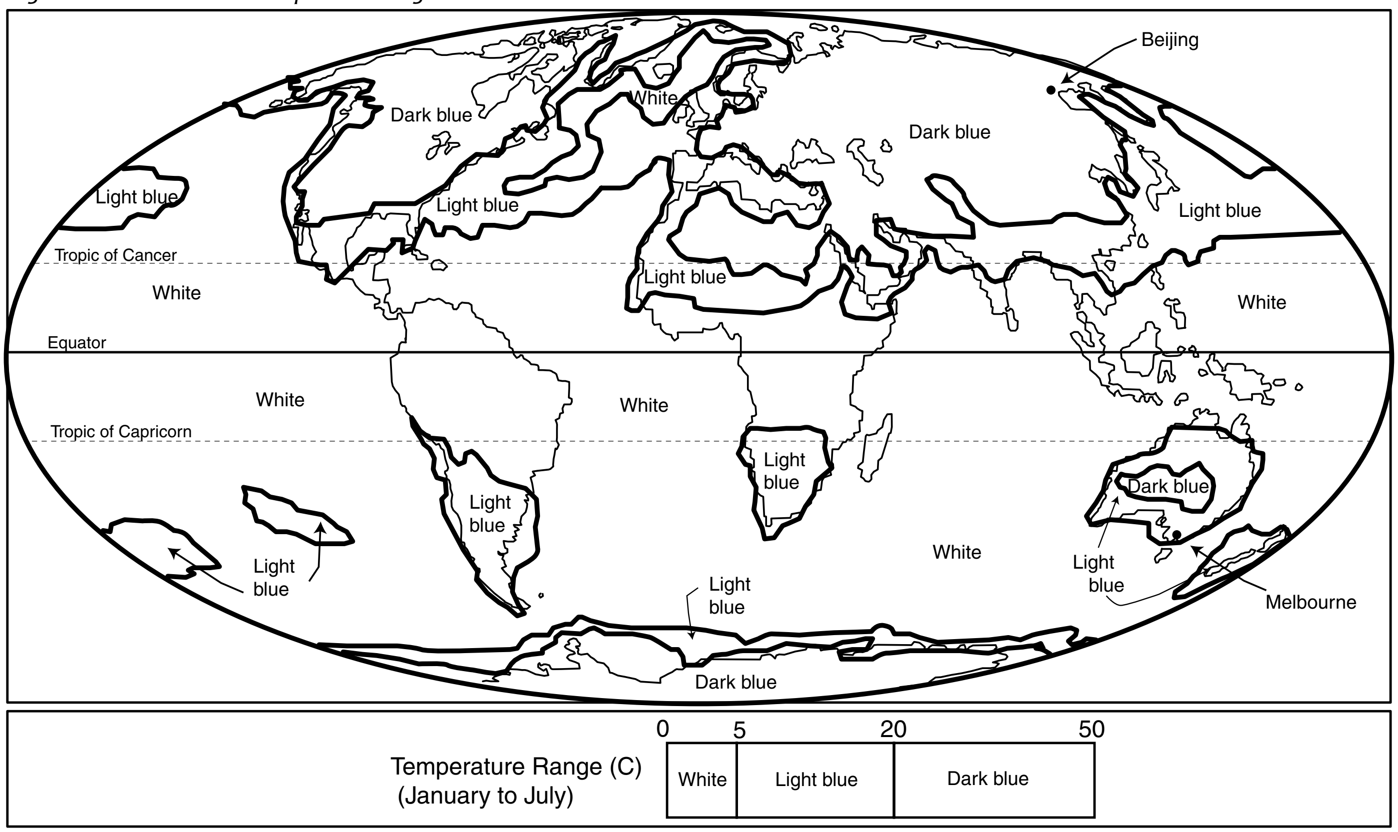


Figure EA-S5-3b: Area of Land and Water by Hemisphere

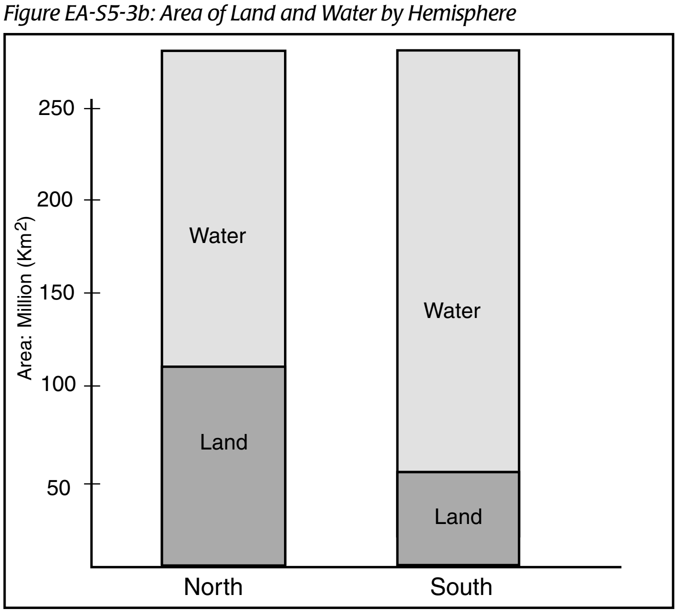
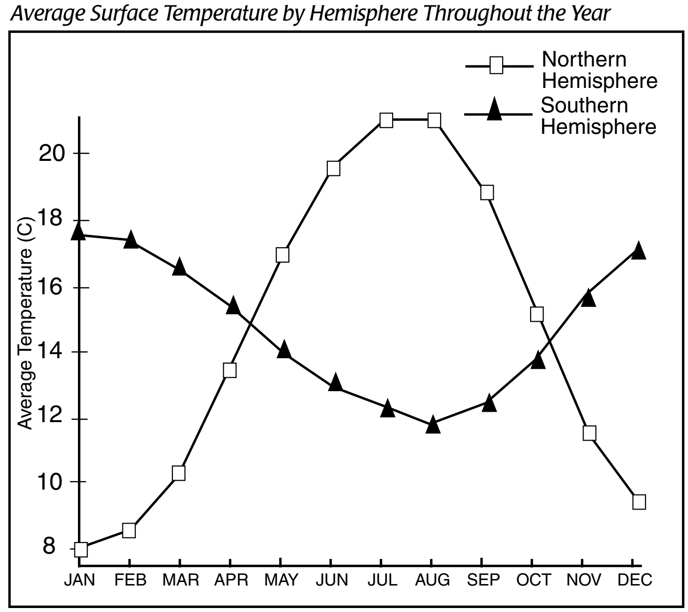


Figure EA-S5-3c:
Average Surface Temperature by Hemisphere Throughout the Year



Seasonal Change on Land and Water

Rubric

For each criterion, evaluate student work using the following score levels and standards.

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. Use evidence from the incoming solar energy visualizations to conclude which hemisphere has the summer in January and which in July.

Score Level	Description
3	Student states that the visualization for January shows more color in the orange to red range for the Southern Hemisphere, indicating it is summer there. The same is true for the Northern Hemisphere in the visualization for July.
2	Hemisphere answer is correct, and indicates that colors in visualization show this, but does not discuss colors or what they indicate.
1	Answer is correct but fails to refer to visualization for evidence.
0	Answer is blank or irrelevant.

2. Compare relative amounts of incoming solar energy during summers.

Score Level	Description
3	Student gives the correct answer that the Northern Hemisphere has more solar energy during its summer, and explains that the visualization shows more dark reds. Student quantifies their answer by suggesting that the overall values for summer in the Northern Hemisphere are around 500 watts/meter sq. and are around 450 for the Southern Hemisphere.
2	Gives correct answer, but one explanation (either quantitative or qualitative) is missing.
1	Answer is correct but fails to refer to visualization for evidence.
0	Answer is blank or irrelevant.

3. Understanding how Earth's orbit around the sun can explain solar energy data.

Score Level	Description
3	Student notes that the Earth is closer to the sun in December than in June.
1	Student refers only to the Earth's tilt and fails to suggest distance as a reason.
0	Answer is blank or irrelevant.

4. Use evidence from the temperature visualizations to conclude which hemisphere has a colder winter and which a warmer summer.

Score Level	Description
3	Student correctly answers Northern for both, and describes that the visualizations of temperature show that the Northern Hemisphere, in January, has more blues which indicate temperatures below freezing, and that in July the visualization shows more dark reds which indicate temperatures around 30˚-40˚C.
2	Hemisphere answer is correct, and indicates that colors in visualization shows this, but does not discuss colors or what they indicate.
1	Answer is correct but fails entirely to refer to visualization for evidence.
0	Answer is blank or irrelevant.

5. Preliminary conclusion that the hemisphere experiencing the warmer summer actually has less incoming solar energy during that time than the summer of the other hemisphere.

Score Level	Description
3	Student answers no and suggests something to do with landmass, or offers other reasonable suggestion.
1	Student answers yes or no but offers no suggestion why.
0	Answer is blank or irrelevant.

6. Analyze temperature range visualization to understand how land mass influences temperature.

Score Level	Description
3	Student is able to interpret the visualization to quantify the temperature ranges for 6A. For 6B, the student answers that Asia will heat and cool faster. For 6C, student connects the size of the continents with the difference in temperature.
2	Some combination of correct and incorrect answers for A-C.
1	Student answer fails to offer correct quantitative ranges or reasoning for 6A, states incorrectly that Australia is the answer for 6B, and does not connect continent size with temperature difference for 6C.
0	Answer is blank or irrelevant.

7. Student generalizes answer to 6 to whole hemisphere.

Score Level	Description
3	Explanation mentions that since the Northern Hemisphere has more land and land has a lower heat capacity (it heats up and cools down more quickly than water), it produces colder winters and warmer summers. Alternatively, the student could state that the Southern Hemisphere has more water than the Northern Hemisphere and since water has a higher heat capacity it leads to less cooling in the winter and less warming in the summer (i.e., less change overall).
2	Answer incorporates the idea of land distribution, but fails to note that land and water have a different heat capacity (seasonal temperature variation).
1	Answer focuses on differing amounts of incoming solar energy between hemispheres, closeness of Earth and sun, or other incorrect explanations.
0	Answer is blank or irrelevant.