LESSON 4: IS IT GETTING HOT IN HERE, OR IS IT JUST ME?
Exploring Land Surface Temperature and Longwave Radiation

PURPOSE/QUESTION
Students will use temperature and longwave radiation data to determine whether the climate has changed in their city over a 22-year time span.

GRADE LEVELS
9-12

TIME TO COMPLETE
1-2 – 50 minute time periods

STANDARDS
See appendix below-page 5

LEARNING OUTCOMES
- Students will find the longitude and latitude of a city on a world map.
- Students will learn the definition of longwave radiation and downward radiative flux.
- Students will discover how temperature and radiation trends vary across the globe.

STUDENT OBJECTIVES
- Access near-surface temperature and longwave radiation data
- Analyze and compare datasets
- Put conclusions in a global and long-term context using surface observations
- Draw conclusions from dataset evidence

TEACHER BACKGROUND
Climate is the long-term weather conditions for a region, generally determined by decades of records. To assess changes in climate, one has to look at average changes over long periods of time, typically 30 years or more. Satellites were first used to observe atmospheric and other environmental properties in the 1960s, so few satellite records have enough data to do such detailed trend analyses.

In this lesson, we look at two variables that allow us to do a limited analysis of surface temperature trends. The first is the near-surface temperature record, which is available for a 14-year period in the My NASA Data archive. The second is the clear-sky longwave downward radiation flux, which is available for a 22-year span. Clear-sky longwave downward radiation flux measures how much heat is trapped by the atmospheric greenhouse effect and returned to the Earth's surface. Thus, any trend in this flux can be attributed to changes in the greenhouse effect, primarily due to human activities adding greenhouse gases such as carbon dioxide to the atmosphere.

Finally, students will compare the trends they calculated for a single location and a short time period to those calculated based on 60 years of ground-based observations from weather stations around the globe. In some cases they may find that the shorter term trends are not representative of the longer term trends, likely because natural year-to-year variability is masking the longer-term global warming trends.

PREREQUISITES
- Greenhouse Effect
- Familiarity with latitude and longitude positions on a map
- Basic familiarity with Microsoft Excel
- Graphing skills

MATERIALS & TOOLS
- World and US map or atlas
- Computer with Internet access and Microsoft Excel
- Map of NASA GISS 10-year Temperature Anomaly
- Eco-Schools CCC Tech Tips

For more information on all-sky and clear-sky radiation please see the appendix on page 5.

VOCABULARY
- Climate
- Weather
- Radiation Budget
- Surface Temperature
- Longwave Radiation
- Anomaly

LESSON LINKS
- Live Access Server
- Radiation Budget Diagram
- Opening MY NASA DATA Microsets in Microsoft Excel

PART 1: Examine temperature trends for your city

ESSENTIAL QUESTIONS

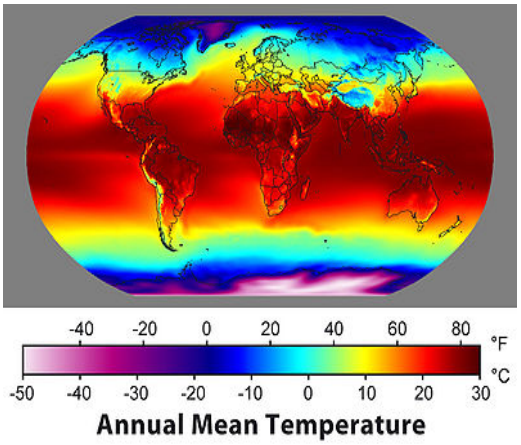
1. How does temperature vary through the course of a year? Over the full 14-year span?
2. How does temperature for the first 5 years of the record compare to temperature at the end of the record?
3. What factors might be affecting the trend in temperature?
4. What are the limitations associated with looking at just 14 years of data?
5. After working with different peer groups what conclusions can you draw regarding temperature at the national level?

PROCEDURE

1. Pick a city in the United States and determine the latitude and longitude for this location. Make a notation in your notebook.
2. Open the "Ls4_Temperature_STUDENT.xls" spreadsheet on your desktop.
3. In the Live Access Server (Advanced Edition), click on the ***Choose Dataset*** button. Then choose ***Atmosphere > Atmosphere Temperature > Monthly Near-Surface Air Temperature (ISCCP)***. A map will automatically appear.
4. Access temperature data for the entire time range at a single location.
   a. Under "LINE PLOTS", select: ***Time Series***
   b. Enter the latitude and longitude for your location into the appropriate boxes just below the small grey map on the left of the screen.
   c. Set the time settings in ***Data Range*** to be January 1994 to December 2007.
   d. Click ***Update Plot*** and a time series plot will appear.
   e. We want to access the data used to create this plot, so that we can do our own calculations. Click the ***Show Values*** button and then click ***OK*** to accept the defaults. The data will appear in the second window.
   f. Follow the instructions in the Eco-Schools CCC Tech Tips Sheet to import the data into the Microsoft Excel worksheet for this lesson. Put the raw data in the tab titled "Raw Data – Temperature"
5. Copy and paste the temperature data into the tab titled "Temperature Averages" in the column labeled "Temperature in K".
   a. Temperature will automatically be converted from Kelvin to Fahrenheit in the adjacent column.
   b. A time-series plot for temperature will automatically be created in the tab titled "Temperature Chart", with month/year on the x-axis and temperature in Fahrenheit on the y-axis. Adjust the y-axis minimum and maximum to reflect the range of temperature at your location.
   c. The monthly average temperatures for the first 5 years of the data set (1994-1998) and the last 5 years of the data set (2003-2007) will automatically be calculated. [Note: see box about 5-year averages.]
   d. Both sets of 5-year average temperature will automatically be plotted on the same line graph, with month on the x-axis and average temperature in Fahrenheit on the y-axis. Adjust the y-axis minimum and maximum as necessary.
6. Compare your results with what your peers have found for different locations. Then, answer the Essential Questions above.

WHY AVERAGE OVER 5 YEARS?

When examining climate trends, it is important to compare multi-year averages. This approach smoothes out natural year-to-year variability so that individual years don't bias the results.



PART 2: Examine how temperature may have changed over a longer time period using data for Monthly Surface Clear Sky LW Downward Flux (SRB)

ESSENTIAL QUESTIONS

1. Explain the relationship between near-surface air temperature and clear sky longwave radiation.
2. According to your graph, has temperature in your city changed significantly during the last 22 years? Explain your reasoning.
3. Hypothesize why your city might experience more or less impact on its climate due to global warming.
4. Do you think the effects of global warming might be more pronounced in some months or seasons than others? Explain why or why not.
5. Compare your data with your classmates who have studied different cities. What can you conclude overall about the temperature changes that occurred during this 22-year period?

PROCEDURE

1. Review the Radiation Budget and the Greenhouse Effect. Note the difference between longwave downward radiation and shortwave radiation, as well as the units both are measured in. Also discuss the difference between all-sky and clear-sky radiation. The Radiation Explanation link above may be helpful.
2. Access longwave downward radiation data.
    a. In the Live Access Server (Advanced Edition), click on ***Choose Dataset***. Then choose ***Atmosphere > Atmospheric Radiation > Surface > Monthly Surface Clear Sky LW Downward Flux (SRB)***.
    b. Under "LINE PLOTS", select: ***Time Series***.
    c. Enter the latitude and longitude for your location into the appropriate boxes.
    d. Set the time settings in ***Data Range*** to be January 1984 to December 2006.
    e. Click ***Update Plot*** and a new time series plot will appear.
    f. Click the ***Show Values*** button and then click ***OK*** to accept the defaults. The data will appear in the second window.
    g. Follow the instructions in the Eco-Schools CCC Tech Tips Sheet to import the data into the Microsoft Excel worksheet for this lesson. Put the raw data in the tab titled "Raw Data – Downward flux"
3. Copy and paste individual years of data into the tab titled "LW Down Averages" in the appropriately labeled locations for 1984 -1989 and 2002-2006. Both sets of 5-year averages will be plotted automatically.

PART 3: Put what you learned into a global context

ESSENTIAL QUESTIONS PART 3

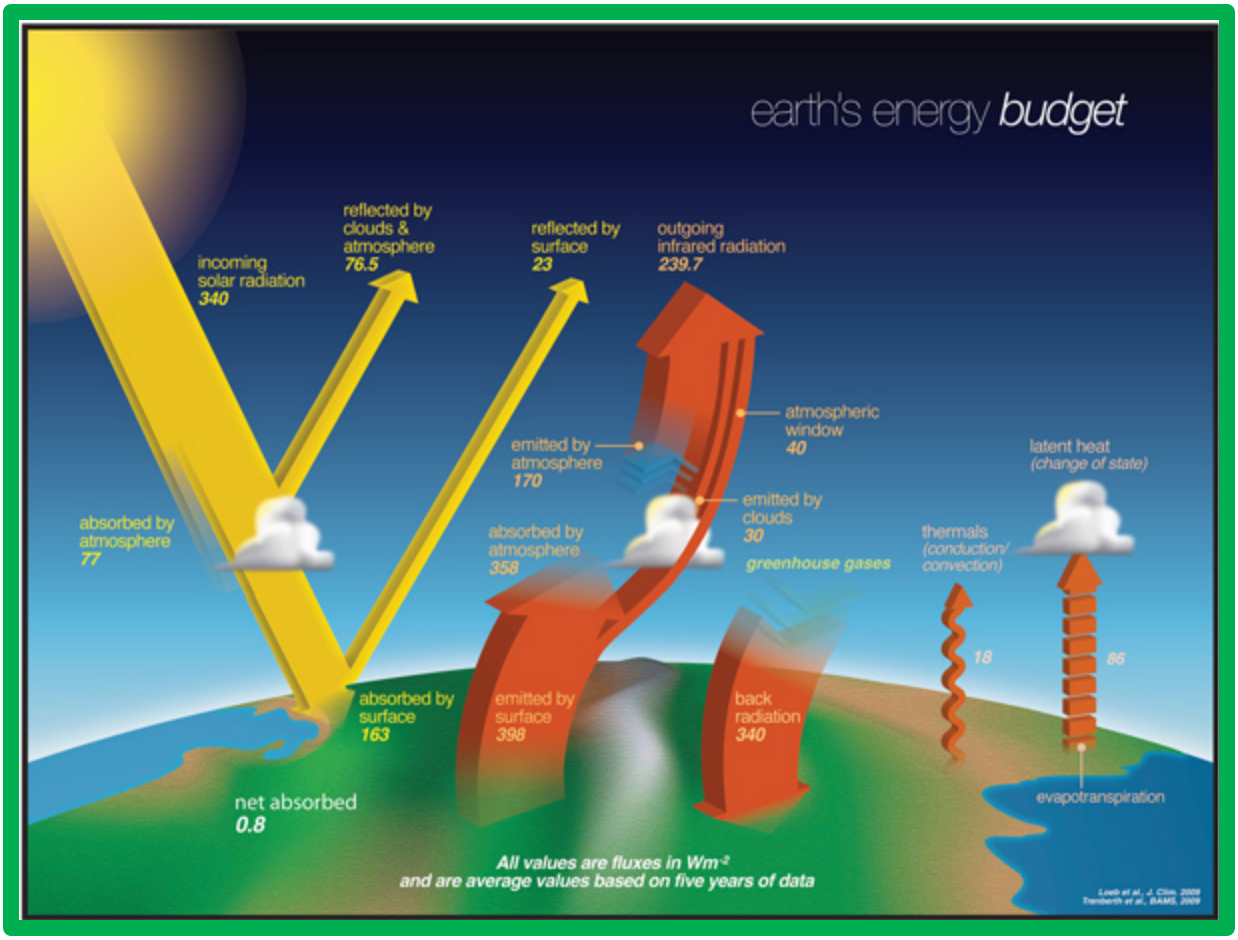
1. How do the temperature trends in your city compare to those being observed in other parts of the world?
2. How might the temperature trends you calculated in Parts 1 and 2 be affected by averaging over longer time periods or larger areas?
3. Where are temperatures increasing the most and least around the world? Why do you think this is the case?
4. What do you think may happen to global average temperature in the next 40 years if trends continue to follow the patterns shown in the map?

WHAT'S AN ANOMALY?

Climate scientists often study the difference between some variable today and the same variable during a reference period in the past. This value, called an anomaly, makes it easier to locate how and where the climate is changing.

PROCEDURE

1. Examine the map of NASA GISS 10-year Temperature Anomalies* provided in the Lesson Links. The map shows the difference between the temperature for the decade 2000-2009 and the average temperatures observed during 1951-1980. Note that the units are in degrees Celsius. This map was produced by scientists at the NASA Goddard Institute of Space Studies using observations from ground-based weather stations around the world.



WEBSITES FOR FURTHER LEARNING

- The Greenhouse Effect
- Weather v. Climate
- Climate Time Machine
- Global Maps: Land Surface Temperature

ASSESSMENT TOOLS

- **Concept Quiz – found on pg. 11**
- **Essay – found on pg. 15**
- **Foldables®**
- **Student Reading and Science Notebook Assessments – found in *Rubrics* folder**

STUDENT READING RESOURCES

- Global Temperatures 2008
- 2009 Ends Warmest Decade on Record
- NASA Climatologist Gavin Schmidt Discusses the Surface Temperature Record
- The Glory Mission's Judith Lean Discusses Solar Variability
- State of the Climate: Hottest Decade on Record

REFERENCES

Adapted from MND-Lesson 32 by Carol Ponganis

LESSON 3-APPENDIX

Understanding Radiation
The definitions are included in the overall explanations on this page https://mynasadata.larc.nasa.gov/radiation-energy-transfer/ . It's easiest to break it down and define the different parts of these variables.

Radiation
Energy that is emitted from a source in the form of rays or waves. Solar and terrestrial radiation are said to be electromagnetic, made up of oscillating electric and magnetic fields which propagate at the speed of light. Solar radiation is shortwave and terrestrial radiation is longwave.

All-Sky Radiation
The term for the actual observed conditions, including clear or cloudy skies wherever they occur.

Clear-Sky Radiation
Clear-sky parameters are obtained by taking all observations for a month, discarding any where clouds were present, and computing average conditions for cases of clear sky.

Longwave
Used to refer to radiation emission from the Earth, which is mostly at wavelengths longer than about 5 microns (because the Earth is a lot colder than the Sun)

Downward
Refers to radiation traveling from the sky toward the Earth's surface-downward radiation measured at the surface of the Earth will include a combination of radiation from the Sun, reflection of radiation by clouds, and heat emitted by atmospheric molecules. Downward radiation measured at the top of the atmosphere would include only radiation from the Sun (well, and a little from stars, etc.)

WEB ADDRESSES FOR HYPER LINKS

PREREQUISITE KNOWLEDGE AND SKILLS

- **Greenhouse Effect**
  http://earthguide.ucsd.edu/earthguide/diagrams/greenhouse/
- **Latitude and Longitude**
- http://www.compassdude.com/latitude-longitude.shtml

VOCABULARY

- **Climate**
  https://mynasadata.larc.nasa.gov/science-glossary/?page_id=672?&letter=C
- **Weather**
  https://mynasadata.larc.nasa.gov/science-glossary/?page_id=672?&letter=W
- **Radiation budget**
  https://mynasadata.larc.nasa.gov/science-glossary/?page_id=672?&letter=R
- **Surface temperature**
  https://mynasadata.larc.nasa.gov/science-glossary/?page_id=672?&letter=S

- **Longwave radiation**
  https://mynasadata.larc.nasa.gov/science-glossary/?page_id=672?&letter=L
- **Anomaly**
  https://mynasadata.larc.nasa.gov/science-glossary/?page_id=672?&letter=A

LESSON LINKS

- **Live Access Server**
  https://mynasadata.larc.nasa.gov/live-access-server/
- **Radiation Budget Diagram**
  http://mynasadata.larc.nasa.gov/radiation-energy-transfer/
- **Opening My NASA Data Microsets in Excel**
  http://mynasadata.larc.nasa.gov/opening-my-nasa-data-microsets-in-excel/

WEBSITES FOR FURTHER LEARNING

- **The Greenhouse Effect –** A website of the EPA designed for students to better understand global climate change
  http://www.epa.gov/climatechange/kids/basics/index.html
- **Weather v. Climate –** A section of the EPA website devoted to global climate change that helps students understand the differences between weather and climate
  http://www.epa.gov/climatechange/kids/basics/concepts.html
- **Climate Time Machine –** A website designed by NASA's Jet Propulsion Laboratory in California this website is designed to allow students to go backward in time and see how Earth changes.
  http://climate.nasa.gov/kids/ClimateTimeMachine/climateTimeMachine_kids.cfm
- **Global Maps: Land Surface Temperature –** A page in NASA's Earth Observatory website where students can better understand land surface temperature and see and animation of the data from February 2000 to August 2012.
  http://earthobservatory.nasa.gov/GlobalMaps/view.php?d1=MOD11C1_M_LSTDA

STUDENT READING RESOURCES

- **Global Temperatures 2008**
  http://earthobservatory.nasa.gov/IOTD/view.php?id=36699
- **2009 Ends Warmest Decade on Record**
  http://earthobservatory.nasa.gov/IOTD/view.php?id=42392
- **NASA Climatologist Gavin Schmidt Discusses Surface Temperature Record**
  http://earthobservatory.nasa.gov/Features/Interviews/schmidt_20100122.php
- **The Glory Mission's Judith Lean Discusses Solar Variability**
  http://earthobservatory.nasa.gov/Features/Interviews/lean_20100525.php
- **State of the Climate: Hottest Decade on Record**
  http://green.blogs.nytimes.com/2010/07/28/state-of-the-climate-hottest-decade-ever/?partner=rss&emc=rss

LESSON 3-STANDARDS

National Science Education Standards

Unifying Concepts and Processes

- Systems, Order, and Organization
- Evidence, Models, and Explanations
- Change, Constancy, and Measurement

Standard A – Science as Inquiry

- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

Standard B – Physical Science

- Conservation of energy
- Interactions of energy and matter

Standard D – Earth and Space Science

- Energy in the earth system

Standard E – Science and Technology

- Abilities of Technological Design
- Understandings about science and technology

Standard F – Science in Personal and Social Perspectives

- Science and Technology in Local, National, and Global Challenges

Standard G – History and Nature of Science

- Nature of scientific knowledge
- Historical perspectives

National Education Technology Standards

Standard 1: Creativity and Innovation

- Use models and simulations to explore complex systems and issues
- Identify trends and forecast possibilities

Standard 3: Research and Information Fluency

- Locate, organize, analyze, evaluate, synthesize, and ethically use information from a variety of sources and media.
- Process data and report results

Standard 4: Critical Thinking, Problem Solving, and Decision Making

- Collect and analyze data to identify solutions and/or make informed decisions.

Standard 5: Digital Citizenship

- Students understand human, cultural, and societal issues related to technology and practice legal and ethical behavior.

Standard 6: Technology Operations and Concepts

- Understand and use technology concepts
- Select and use applications effectively and productively
- Troubleshoot systems and applications
- Transfer current knowledge to learning of new technologies

National Council of Teachers of Mathematics Education Standards

Algebra

- Understand patterns, relations, and functions
- Use mathematical models to represent and understand quantitative relationships
- Analyze change in various contexts

Measurement

- Understand measurable attributes

Data Analysis and Probability

- Develop and evaluate inferences and predictions that are based on data

Process

- Connections
  - Recognize and apply mathematics in contexts outside of mathematics
- Representation
  - Use representations to model and interpret physical, social, and mathematical phenomena

Climate Literacy Principles

Principle 1: The sun is the primary source of energy for Earth's climate system.
Principle 2: Climate is regulated by interactions among components of the Earth system.
Principle 4: Climate varies over space and time through both natural and man-made processes.
Principle 5: Our understanding of the climate system is improved through observations, theoretical studies, and modeling.

Energy Literacy Principles

Principle 1: Energy is a measurable quantity that follows physical laws.
Principle 2: Physical Earth processes are the result of energy flow through the earth system.
Principle 3: Biological Earth processes depend on energy flow through the earth system.
Principle 7: The energy choices made by individuals and societies affect quality of life.

LESSON 3-ESSENTIAL QUESTIONS ANSWER KEY

Essential Questions-1

1. How does temperature vary through the course of a year? Over the full 14-year span?
   [Temperatures are hottest during the summer months and coldest during the winter months. Answers for the 14-year span will vary depending on location, but most should find that there are warmer and colder years, as apparent from the relative magnitude of the seasonal peaks and valleys.]

2. How does temperature for the first 5 years of the record compare to temperature at the end of the record?
   [Answers will vary depending on location, but generally the last five years of the record should be a few degrees warmer than the first five years of the record. Students might comment on whether winter or summer months have experienced more warming.]

3. What factors might be affecting the trend in temperature?
   [The increase in greenhouse gases leading to global warming is the primary factor. Students might also mention natural climate variability or changes in the energy Earth receives from the Sun.]

4. What are the limitations associated with looking at just 14 years of data?
   [A longer data record would provide more statistical confidence in whether there is a significant trend. A longer record would also help distinguish natural climate oscillation from long-term trends due to greenhouse gas emissions.]

5. After working with different peer groups what conclusions can you draw about temperature on a national level?
   [Answers will vary depending on locations chosen, but generally all locations should show an increase in temperature over this time period. Locations in the Southeastern US might show smaller or negligible increases. Locations in Alaska would likely show larger increases.]

Essential Questions-2

1. Explain the relationship between near-surface air temperature and clear sky longwave radiation.
   [The earth surface emits long-wave radiation at a rate that is proportional to the surface temperature. Some of the upward longwave radiation is then absorbed by greenhouse gases and remitted back to the surface. This downward long-wave radiation that we plotted is thus related to the temperature.]

2. According to your graph, has the temperature in your city changed significantly in the last 20 years? Explain your reasoning.
   [Answers will vary. Most all locations should have temperatures during the 2002-2006 period greater than that during the 1984-1988 period, for most if not all months. This would suggest that climate has changed. Whether or not this change is *significant* is another question. Could encourage students to compute the standard deviation for temperature observations for each month. If the difference between the two temperatures is greater than twice the standard deviation, then it would be reasonable to conclude that there is a statistically significant warming. Some students may want to include error bars on the graph to illustrate this visually.]

3. Hypothesize reasons why you might expect your city to experience more or less impact on its climate due to global warming.
   [Answers will vary. Temperatures have increased more at higher latitudes than at lower latitudes. Large cities might experience more local warming due to the urban heat island effect and the local concentration of greenhouse gases. Some natural climate patterns could affect local temperature changes.]

4. Do you think the effects of global warming might be more pronounced in some months or seasons than others? Explain why or why not.
   [Answers will vary depending on the locations chosen. In general,
   - Winter (Dec-Jan-Feb): Temperatures increase significantly in Alaska, little change or slight cooling for contiguous US.
   - Spring (Mar-Apr-May): Temperatures have increased across most of the contiguous US, except far Northwest. Cooling in Alaska.
   - Summer (June-July-Aug): Temperatures warmed in western half of continental US. Little change in Alaska and eastern US.
   - Fall (Sep-Oct-Nov): Temperatures increased in eastern US and Alaska, cooled in Pacific Northwest.

   Here are maps for seasonal temperature anomalies from the 1990s to the 2000s produced by NASA GISS: http://data.giss.nasa.gov/gistemp/graphs/2000s_vs1990s.pdf.]

5. Compare your data with your classmates who have studied different cities. What can you conclude overall about the climate changes that have occurred on our planet during this 22 year period?
   [Answers will vary. In general students should find a warming trend across the United States.]

Essential Questions-3

1. How do the temperature trends in your city compare to those being observed in other parts of the world? How might the calculated temperature trends be affected by averaging over longer time periods or larger areas?
   [Answers to the first question will vary. In general the warming in the continental US is slightly less than that in northern Eurasia, about the same as most of Africa and southern Asia, and more than that over most ocean regions, South America and Australia. Averaging over longer time periods would make it possible to detect larger and more statistically significant trends. Averaging over larger areas would eliminate any biases due to local influences, making it easier to identify the trend due to global warming.]

2. Where are temperatures increasing the most and least around the world? Why do you think that might be the case?
   [Temperatures are increasing most in the Arctic and the northern parts of continents in the Northern Hemisphere. There are several reasons why temperatures may be increasing faster in the Arctic: 1. the ice-albedo feedback would allow the region to absorb more solar energy; 2. less energy from the Sun goes into evaporation in the Arctic, where the cold air can hold little water, thus allowing more energy to go into directly warming the air; 3. the structure of the atmosphere over the Arctic restricts vertical mixing, trapping added heat near the surface; 4. changes in ocean and atmosphere circulation patterns could be bringing more heat to the Arctic.
   Land areas are warming more than ocean areas. This is because water has a high heat capacity, i.e., it takes more energy input to raise the ocean temperature. Thus, the oceans tend to warm more slowly than the land surface, and to radiate less energy back to the air just above them than land surfaces.]

Name: _____ Date: _____

Science Concept Quiz
Lesson 4: Is It Getting Hot In Here or Is It Just Me?
Exploring Land Surface Temperature and Longwave Radiation

Using the *Earth's Energy Budget* diagram answer the following question.
Which statement best describes earth's energy budget?

A. There is more incoming solar radiation absorbed than outgoing solar radiation.
B. There is more outgoing solar radiation than incoming solar radiation absorbed.
C. There is an approximate balance to earth's energy budget based on the diagram.
D. There are many forcings that influence the earth's energy budget.

_____ points out of 20

I. Answer

A. ○ B. ○ C. ○ D. ○

_____ points out of 15

II. What is the main science concept behind the question?

1. Making observations
2. Measuring
3. Earth's energy budget
4. Analyzing scientific diagrams

_____ points out of 25

III. Provide the reasoning behind your answer.

_____points out of 40

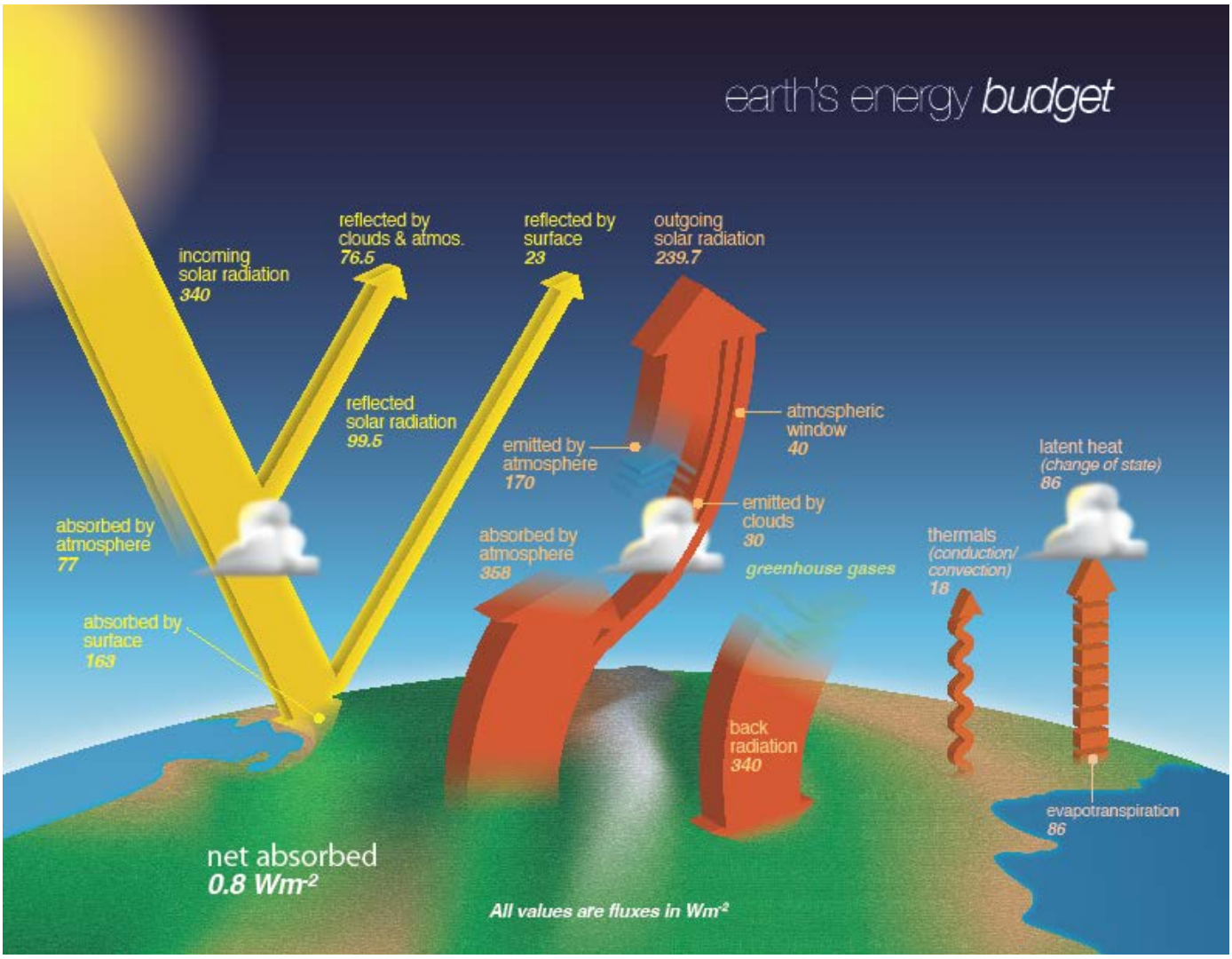
IV. Why are the other responses not the best answer chose?

A.

B.

C.

D.


earth's energy budget
incoming solar radiation 340
reflected by clouds & atmos. 76.5
reflected by surface 23
outgoing solar radiation 239.7
reflected solar radiation 99.5
emitted by atmosphere 170
atmospheric window 40
emitted by clouds 30
greenhouse gases
absorbed by atmosphere 77
absorbed by surface 163
absorbed by atmosphere 358
back radiation 340
thermals (conduction/ convection) 18
latent heat (change of state) 86
evapotranspiration 86
net absorbed 0.8 Wm-2
All values are fluxes in Wm-2

Teacher Answer Key

1. A

2. 4

3. Answers will vary. To successfully answer the question you must be able to observe and interpret the information in the diagram.

4. Answers will vary.

   A) This is the correct answer. By calculating the solar radiation input v. output one can see there is more solar radiation being trapped on earth than is let out of the earth system.

   B) This is the opposite of (A) and based on calculations is a false statement.

   C) When you calculate incoming v. outgoing solar radiation one should get equal amounts, but that is not the case the numbers are unequal.

   D) There are many forcings that influence earth's energy balance, but this is not the main idea of the diagram and so is not the best answer choice.

Student Name
Teacher/Class
Date

Lesson 4: Is It Getting Hot in Here, Or Is It Just Me?
Exploring Land Surface Temperature and Longwave Radiation

Based on your analyses, collaborations, and writings provide a position statement describing where you stand on land surface temperature as a predictor of warming climate both nationally and globally.

What Is the Expectation?

Accurate science relating to land surface temperature

Evidence supporting your claims

Visual representations

Key vocabulary

Evidence of on grade level spelling and grammar usage