

# LESSON 6: WHEREFORE ART THOU, ALBEDO?

## Ice-Albedo Feedback

### PURPOSE/QUESTION

Students will use satellite data to understand how the amount of sunlight reflected back to space relates to the amount of ice present in the Northern Hemisphere.

### GRADE LEVELS

9-12

### TIME TO COMPLETE

1-2 – 50 minute time periods

### STANDARDS

See appendix below-page 9

### LEARNING OUTCOMES

- Students will learn about Earth's radiation budget.
- Students will examine the seasonal and geographic distribution of Earth's albedo.
- Students will study long-term trends in albedo and hypothesize about their causes.
- Students will examine how changes in snow-ice cover relate to the trends in albedo.
- Students will use real satellite data to see the ice-albedo feedback in action.

### STUDENT OBJECTIVES

- Access and collect albedo, shortwave radiation, and snow-ice data.
- Analyze and compare the data sets to evaluate seasonal and geographic patterns, as well as long-term trends.
- Compute a linear regression of the data
- Draw conclusions from dataset evidence

### TEACHER BACKGROUND

Earth's albedo is the fraction of incoming radiation (sunlight) that is reflected into space. The Earth has an average albedo, which describes how much sunlight is reflected on average for the whole planet and the whole year. That value is about 0.3. The Earth also has a local albedo, which determines how much of the Sun's light is reflected from a particular place at a particular time. The local albedo depends on the particular local surface, which can change seasonally as vegetation changes. It also depends on more rapidly changing things such as snow and clouds.

For reference, the values of albedo range from 0.0 to 1.0, where a value of 0.0 is for a surface that absorbs all radiation (reflects 0 percent) that strikes its surface, and a value of 1.0 represents a surface that reflects 100 percent of the radiation that strikes it.

Fresh snow has an albedo ranging from 0.75 to 0.90.

Dry dark soil has an albedo of approximately 0.13.

Open ocean has an albedo of approximately 0.10.

How fast the planet warms in response to adding greenhouse gases to the atmosphere depends in part on climate feedbacks. These natural processes can amplify/hasten the warming (a positive climate feedback) or counteract some warming (a negative climate feedback). How snow and ice respond to warming and the resultant impact on surface albedo is an important positive climate feedback. As the climate warms, snow and ice melt, the earth's surface becomes less reflective (especially if sea ice melts, revealing open ocean, which is very dark), more solar energy is absorbed by the earth's surface rather than being reflected back to space, causing the temperature to increase and the cycle to continue.



**PREREQUISITE KNOWLEDGE & SKILLS**

1. Previous lesson on Earth's Energy Budget
2. What is a flux? The rate of flow of energy across a given surface
3. What is albedo? Earth's albedo is a measure of how strongly the earth's surface reflects the sun's energy.
4. What does [incoming and outgoing fluxes](#) have to do with Earth's energy budget?
5. For further information on Earth's albedo and the most current diagram of Earth's Energy Budget click [here](#). For the diagram click on "View Earth's Energy Budget (graphic, courtesy Loeb et al., 2009)".

**LESSON LINKS**

- CCC Tech Tips – found on pg. 7
- [NSIDC Snow Extent - Overview](#)
- [NSIDC Sea Ice - Overview](#)
- [Earth's Radiation Budget](#)
- [CERES website](#)
- [Live Access Server](#)
- [Importing data into Excel](#)
- [Earth's albedo animation](#)

**MATERIALS & TOOLS**

- Computer
- Internet access
- CCC Tech Tips – found on pg. 7

**VOCABULARY**

- [albedo](#)
- [reflectivity](#)
- [CERES](#)
- [shortwave radiation](#)
- [flux](#)
- [snow and ice](#)
- [radiation](#)

**ESSENTIAL QUESTIONS-PART 1**

1. Where is albedo higher in January? Where is it higher in July?
2. What do you think is the reason for these seasonal shifts?
3. Why do we look at "clear-sky" albedo to examine these seasonal variations?

**PROCEDURE PART 1 –****Examine spatial distribution and seasonal variations in albedo**

1. Create maps of clear-sky albedo for January 1985 and July 1985
  - a. In the Live Access Server (Advanced Edition), click on the **Choose Dataset** button. Then choose **Atmospheric Radiation > Top of Atmosphere (TOA) Clear-sky > Monthly TOA Clear-sky Albedo (ERBSSCAN)**. A map will automatically appear.
  - b. We want to compare albedo for two different times of year, so we need to make sure that the color scale is the same for both maps. To do this click on **Set plot options**. In the window that pops up, go to **Color fill levels** and enter "(-inf)(0.04,0.4,.01)(inf)". This will create a color bar that goes from a minimum of 0.04 to a maximum of 0.4, with intervals of 0.01. Adding the "(-inf)" and "(inf)" means that any values that are outside of this range will be filled in as the minimum and maximum color. Note that white areas are places where there is no data.
  - c. Click **Update Plot** to apply the new color bar. Save or print this map, which should be for the default year of **Jan 1985**.
  - d. Now, change the date to **Jul 1985**. Then click **Update Plot**. Save or print the resulting map.



**ESSENTIAL QUESTIONS PART 2**

1. Why are the values for shortwave radiation equal to 0 in Nov, Dec, and Jan?
2. How has surface albedo changed from the beginning of the satellite record to the end? Form a hypothesis for why you think these changes have happened.

**PROCEDURE PART 2 –****Examine long-term trends in surface albedo**

For this part we'll focus on a location in the Beaufort Sea, just north of Alaska (74.5°N, 156.5°W). We'll use observations of upward and downward shortwave radiation from the SRB instrument to calculate albedo for this location. The SRB instrument has a longer data range (1983 to 2007) and has observations at this northern latitude. To match the data range for the snow data, we will access data for 1994 to 2007.

1. Access shortwave radiation time series data sets.
  - a. In the Live Access Server (Advanced Edition), click on the **Choose Dataset** button. Then choose **Land Surface > Surface Radiation > Monthly Surface Clear-sky SW Upward Flux (SRB)**. A map will automatically appear.
  - b. Under "LINE PLOTS", select: **Time Series**.
  - c. Enter the latitude and longitude coordinates for the Beaufort Sea provided above. For the "Date Range", keep the default of **Jan 1994 to Jun 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 "CS SW Up - Raw"
  - g. Repeat steps a-f for **Monthly Surface Clear-sky SW Downward Flux (SRB)**, putting the resulting data into the tab titled "CS SW Down - Raw".
2. Calculate albedo, the ratio of upward shortwave radiation to downward shortwave radiation.
  - a. In the tab labeled "Albedo+Snow - Beaufort", copy the CS SW Up and CS SW Down data from the Raw tabs to the similarly labeled columns (Columns B and C). Albedo will be automatically calculated in Column D.
  - b. The average monthly albedo for 1994-1998 and for 2002-2006, and the percent change between these two different time periods, will also be automatically calculated for all months except November, December, and January.

**EXTENSION ACTIVITY**

Note that the units of shortwave radiation are Watts per square meter. This can be compared to light bulbs. A net radiation of 60 Watts per square meter means the amount of energy actually being received by the Earth is equivalent to having a 60 W light bulb over each square meter of the Earth. Have your students calculate the area of your classroom or their room at home, then figure out how many light bulbs would be equivalent to the net solar radiation for each season. You may want to use the LAS to get the value of the net radiation at your latitude and longitude location.



**ESSENTIAL QUESTIONS PART 3**

1. How has snow-ice amount changed in the Beaufort Sea over the 13 years analyzed? Based on you snow-ice data explain the reasoning behind your answer. How do these changes compare to the changes in albedo?
2. Based on the chart you created, does the data confirm the hypothesis you formed in Part 2cii? How confident are you in this conclusion and why?
3. What are some limitations of this analysis?

**PROCEDURE PART 3 - Relate surface albedo trends to changes in sea ice**

1. Access snow-ice data set and calculate trends over time.
  - a. In the Live Access Server (Advanced Edition), click on the **Choose Dataset** button. Then choose **Cryosphere > Monthly Snow/Ice amount (ISSCP)**. A new time series plot will appear.
  - b. Enter the latitude and longitude for the Beaufort Sea (same as in Part 2) in the boxes under the small map. Then click **Update Plot**. A new time series plot will appear.
  - c. 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.
  - d. 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 "Snow-ice - Raw".
  - e. Copy the Snow-ice data from the Raw tab to the similarly labeled column (Columns E) in the "Albedo+Snow – Beaufort" tab.
  - f. The average monthly snow-ice for 1994-1998 and for 2002-2006, and the percent change between these two different time periods, will also be automatically calculated for all months except November, December, and January.
2. Create a scatter plot relating albedo to snow-ice for the months of August and September.
  - a. The values for Snow-ice and Albedo for Augusts and Septembers from 1994 – 2006 will be automatically copied into the lower part of Columns G and H.
  - b. This data will be automatically plotted in the tab titled "Albedo-snow Aug-Sep CHART". A best fit line and the correlation coefficient will be included on the chart.

**ASSESSMENT TOOLS AND RESOURCES**

- Concept Quiz – found on pg. 13
- Essay – found on pg. 16
- Foldables®
- Science Notebooking and Student Reading Assessment Tools – found in **Rubrics** folder

**REFERENCES**

Adapted from My NASA Data Lesson D: Earth's Energy Budget – Seasonal Cycles in Net Radiative Flux

**STUDENT READING RESOURCES**

- [Incoming Sunlight](#)
- [Heating Imbalances](#)
- [Relationship between snow cover and net radiation](#)
- [Arctic Ice is Younger, Thinner, and Disappearing](#)
- [Solar Surprise for Climate Issue](#)
- [Arctic Sea Ice Minimum for 2012](#)



**LESSON 6-APPENDIX****WEB ADDRESSES FOR HYPERLINKS****PREREQUISITE KNOWLEDGE AND SKILLS**

- Incoming and outgoing fluxes  
[http://en.wikipedia.org/wiki/Earth's\\_energy\\_budget](http://en.wikipedia.org/wiki/Earth's_energy_budget)
- Earth's Energy Budget  
<http://mynasadata.larc.nasa.gov/radiation-energy-transfer/>

**VOCABULARY**

- Albedo  
[http://mynasadata.larc.nasa.gov/science-glossary/?page\\_id=672?&letter=A](http://mynasadata.larc.nasa.gov/science-glossary/?page_id=672?&letter=A)
- CERES  
[http://mynasadata.larc.nasa.gov/science-glossary/?page\\_id=672?&letter=C](http://mynasadata.larc.nasa.gov/science-glossary/?page_id=672?&letter=C)
- Flux  
[http://mynasadata.larc.nasa.gov/science-glossary/?page\\_id=672?&letter=F](http://mynasadata.larc.nasa.gov/science-glossary/?page_id=672?&letter=F)
- Radiation  
[http://mynasadata.larc.nasa.gov/science-glossary/?page\\_id=672?&letter=R](http://mynasadata.larc.nasa.gov/science-glossary/?page_id=672?&letter=R)
- Reflectivity  
[http://mynasadata.larc.nasa.gov/science-glossary/?page\\_id=672?&letter=R](http://mynasadata.larc.nasa.gov/science-glossary/?page_id=672?&letter=R)
- Shortwave radiation  
[http://mynasadata.larc.nasa.gov/science-glossary/?page\\_id=672?&letter=S](http://mynasadata.larc.nasa.gov/science-glossary/?page_id=672?&letter=S)
- Snow and ice  
[http://mynasadata.larc.nasa.gov/science-glossary/?page\\_id=672?&letter=S](http://mynasadata.larc.nasa.gov/science-glossary/?page_id=672?&letter=S)

**LESSON LINKS**

- NSIDC Snow Extent – Overview  
[http://nsidc.org/cryosphere/sotc/snow\\_extent.html](http://nsidc.org/cryosphere/sotc/snow_extent.html)
- NSIDC Sea Ice – Overview  
[http://nsidc.org/cryosphere/sotc/sea\\_ice.html](http://nsidc.org/cryosphere/sotc/sea_ice.html)
- Earth's Radiation Budget  
<http://mynasadata.larc.nasa.gov/radiation-energy-transfer/>
- CERES Website  
<http://ceres.larc.nasa.gov/>
- Live Access Server, LAS  
<http://mynasadata.larc.nasa.gov/live-access-server/>
- Importing Data from into Excel  
<http://mynasadata.larc.nasa.gov/opening-my-nasa-data-microsets-in-excel/>
- Earth's Albedo Animation  
<http://www.teachersdomain.org/resource/ipy07.sci.ess.watcyc.albedo/>



### STUDENT READING RESOURCES

- **Incoming Sun**  
<http://earthobservatory.nasa.gov/Features/EnergyBalance/page2.php>
- **Heating Imbalances**  
<http://earthobservatory.nasa.gov/Features/EnergyBalance/page3.php>
- **Relationship between Snow Cover and Net Radiation**  
[http://earthobservatory.nasa.gov/GlobalMaps/view.php?d1=MOD10C1\\_M\\_SNOW&d2=CERES\\_NET\\_FLUX\\_M](http://earthobservatory.nasa.gov/GlobalMaps/view.php?d1=MOD10C1_M_SNOW&d2=CERES_NET_FLUX_M)
- **Arctic Ice is Younger, Thinner, and Disappearing**  
<http://news.discovery.com/earth/arctic-ice-is-younger-thinner-and-disappearing.html#mkcpgn=rssnws1>
- **Solar Surprise for Climate Issue**  
<http://www.bbc.co.uk/news/science-environment-11480916>
- **Arctic Sea Ice Minimum for 2012**  
<http://earthobservatory.nasa.gov/IOTD/view.php?id=79256>



## Tech Tips for Eco-Schools USA Climate Change Connections Curriculum

### How do I import data into an Excel spreadsheet?

1. Access data from My NASA Data:
  - a. Once you have all the parameters set for your desired data set (and have clicked “Update Plot” to have your preferences processed), click the “Show Values” button. A new window will pop up with a Table of Values.
  - b. The first several lines of the Table will provide information that describes the data set, often called “metadata”, such as the name of the variable, what subset of the data is included in the file, and what time range. Make sure to keep this metadata with the rest of the data when you copy it into Excel. This way you’ll be able to easily keep track of which data you have!
2. Copy the data from the browser (note that these instructions are for Internet Explorer running on a PC, and may need to be modified for other platforms):
  - a. In this new window, select all. You can do this by clicking anywhere in the window and then typing “Ctrl-A”. Or you can right-click in the window, which will pop up a menu, and then choosing “Select All” from the options.
  - b. Next, copy this data. Again there are two options. You can use the keyboard shortcuts, and type “Ctrl-C”. Or you can right-click and choose “Copy” from the pop-up menu.
3. Paste the data into Excel:
  - a. Now open your Excel worksheet and go to the tab where you want to put the raw data. Click in the A1 cell.
  - b. Paste the data, either by typing “Ctrl-V”, by clicking “Paste” (located at the left under the “Home” tab), or by right-clicking in the A1 cell and choosing “Paste”.
4. Convert the data from text to columns:
  - a. Now, we have the data in Excel, but we can’t manipulate it very well because all the data for each row is lumped into one cell. We want to split out each data value into its own cell.
  - b. Starting at the row where the column headers are located (probably around row 7), highlight the A column down to the end of the data.
  - c. Click on the Data tab at the top of the window, and then choose the “Text to Columns” wizard (located a little to the right of center).
  - d. A dialogue box will pop up to help you through the process.
  - e. The first page of the wizard asks you to identify whether the data is “Delimited” or “Fixed width”. In most cases, the My NASA Data data will be “Fixed Width”, so select that option and click “Next”.
  - f. The next page of the wizard gives you a chance to check whether the column breaks make sense and to adjust them as necessary. Make any changes that are needed. Or, go back and switch to “Delimited” on page 1 if you notice that the columns are not lining up as you expected. Once you are satisfied with the columns, click “Next”.
  - g. The final page of the wizard allows you to designate what kind of data values are in each column and a destination for the data. For the purposes of the CCC curriculum, we’ll just accept the defaults and click “Finish”.
  - h. Now your data should be in beautiful columns and the values should make sense. It’s always a good idea to double check that nothing crazy happened!



### My NASA Data isn't working! What should I do?

1. Double check that you entered everything correctly. Especially check that you have the right data set and that you have entered dates and latitude/longitude values within the range of available data. Usually the user interface will prevent you from entering invalid data ranges, but sometimes there are glitches.
2. Refresh the browser and/or restart the browser. Occasionally, a fresh start is the easiest way to clear out any mistakes or glitches.
3. Update your browser and/or JAVA. If you have older versions of the software, then you might find that some functionality is lost.
4. If you're still struggling, consider whether problem might be at the My NASA Data website. It might be a temporary problem, in which case taking a break and returning to the site at a later time could be a good choice. Or it could be a more significant problem, in which case you'll want to explore the "help" resources provided by My NASA Data (link in upper right hand corner of page).
5. Ask your Eco-Schools contact for help or email [eco-schoolsusa@nwf.org](mailto:eco-schoolsusa@nwf.org)!

### How do I print or save a map or graph?

1. Use the "Print" button to generate a version of your map or graph that is suitable for saving or printing. Once you click on the "Print" button, a new window will pop up with your map or graph.
2. Print a map or graph by using the print option on your browser.
3. Save a map or graph in one of two ways:
  - a. By choosing "Save as" in the browser. Use the defaults to save as a "Web Archive, single file (\*.mht)".
  - b. By right clicking and choosing "Save picture as..." Use the defaults to save as a \*.png file.
4. When saving, make sure to give your new file a descriptive name and put it somewhere that you'll remember!

### How do I find my latitude and longitude?

A number of sites help you find your latitude and longitude. For example:

1. <http://itouchmap.com/latlong.html>
2. <http://www.findlatitudeandlongitude.com/>



**LESSON 6-STANDARDS****National Science Education Standards****Unifying Concepts and Processes**

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

**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
- Geochemical cycles

**Standard E – Science and Technology**

- Abilities of technological design
- Understandings about science and technology

**Standard F – Science in Personal and Social Perspectives**

- Natural resources
- Environmental quality
- Natural and human induced hazards
- Science and technology in local, national, and global challenges

**Standard G – History and Nature of Science**

- Science as a human endeavor
- 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 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

**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 5:** Individuals and communities make energy decisions every day.

**Principle 7:** The energy choices made by individuals and societies affect quality of life.



**LESSON 6-ESSENTIAL QUESTIONS ANSWER KEY****Essential Questions-1**

1. Where is albedo higher in January? Where is it higher in July?  
[In January, albedo is higher over the Arctic Ocean, northern landmasses, and Antarctica. The highest values are found in Greenland and Antarctica. In July, albedo is even higher over Antarctica and larger values extend as far as 60°S into the Southern Ocean. Albedo is still high over Greenland and the Arctic Ocean, but not as high as during January.]
2. What do you think is the reason for these seasonal shifts?  
[The seasonal variation in snow and ice cover would explain these changes. As sea-ice expands during the cold months, the albedo increases significantly. Likewise, more extensive snow cover on land has a major impact on wintertime albedo.]
3. Why do we look at “clear-sky” albedo to examine these seasonal variations?  
[“Clear-sky” albedo allows us to examine how changes in the land surface affect albedo. In contrast, “all-sky” albedo includes clouds, which reflect a significant amount of sunlight before it even reaches the ground. The all-sky albedo would mask some of the seasonal variations due to changes in snow and ice cover.]

**Essential Questions-2**

1. Why are the values for shortwave radiation equal to 0 in Nov, Dec, and Jan?  
[During the winter months, the Arctic gets no or very little sunlight. Thus, there is no downward shortwave radiation hitting the surface and can be no shortwave radiation reflected from the surface either.]
2. How has surface albedo changed from the beginning of the satellite record to the end? Form a hypothesis for why you think these changes have happened.  
[During the spring months, albedo has remained essentially unchanged or else increased slightly. This shift may reflect a trend toward more precipitation/snowfall. Bigger changes in albedo took place in the fall months of August and September, albedo declined by 46% and 70%, respectively. Declines in sea ice could explain these decreases.]

**Essential Questions-3**

1. How has snow-ice amount changed in the Beaufort Sea over the 13 years analyzed? Based on your snow-ice data explain the reasoning behind your answer. How do these changes compare to the changes in albedo?  
[The snow-ice amount has decreased during every month at this location. The largest decreases are during the summer and fall months, especially August and September. Snow-ice has likely declined because of increasing temperatures associated with human-caused climate change. The monthly declines in snow-ice amount are high in the same months when albedo declined significantly.]
2. Based on the chart you created, does the data confirm the hypothesis you formed in Part 2, Essential Question 2? How confident are you in this conclusion and why?  
[The data confirm the hypothesis that the declining albedo is due to declining snow-ice amount at this location during August and September. I have moderately high confidence in this conclusion because snow-ice and albedo for August and September are highly correlated, with an  $R^2$  of 0.7757. Also, because this location is over the ocean, it is unlikely that any other modifications to



the surface could explain the declining albedo. If this site were over land, on the other hand, there would be more variables to consider (e.g., changes in land use or land cover).

3. What are some limitations of this analysis?

[The analysis only considers a single location, making it hard to generalize for the full Beaufort Sea, much less the Arctic region more broadly. A more robust analysis would examine these relationships over a much larger region. Another limitation is that we have a relatively short data set for snow-ice amount (only 13 years). This means that we cannot rule out natural cycles or variations to explain the decline in snow-ice amount. Note that other analyses have attributed the declines in snow-ice to an increase in temperatures.



Name: \_\_\_\_\_

Date: \_\_\_\_\_

**Science Concept Quiz****Lesson 6: Wherefore Art Thou, Albedo? Ice-Albedo Feedback**

The National Snow and Ice Data Center reported that 2010 Arctic sea ice extent was the third-lowest on the satellite record at 4.6 million km<sup>2</sup> (1.78 million mi<sup>2</sup>). The record was set in 2007 at 4.13 million km<sup>2</sup>. The 2010 minimum was part of a larger pattern of overall Arctic sea ice decline dating back to at least the early 1970's. **Which explanation best depicts the problem associated with this natural climate feedback?**

- A. Exposing more open ocean allows a great deal of solar energy to be absorbed by the earth's surface causing temperatures to increase and the cycle to continue.
- B. Exposing more dark soil on land will allow for more solar energy to be absorbed by the earth's surface causing temperatures to increase and the cycle to continue.
- C. Exposing less open ocean allows more solar energy to be absorbed by the earth's surface causing temperatures to decrease and the cycle to continue.
- D. Sea ice extent is not a variable when considering earth's rise in global temperature.



\_\_\_\_\_ points out of 20

**I. Answer**

- A.  B.  C.  D.

\_\_\_\_\_ points out of 15

**II. Main Science Concept**

1. Change over Time
2. Earth's Albedo
3. Sea Ice extent
4. Climate change

\_\_\_\_\_ points out of 25

**III. Provide the science reasoning for choosing your answer in part II.**

\_\_\_\_\_ points out of 40

**IV. Why are the other responses in part I not the best answer choice?**

A.

B.

C.

D.

Use the rest of this page if more room is needed to fully communicate your thoughts.



**Teacher Answer Key**

1. A
2. 2
3. Answers will vary. Even though we are looking at patterns of change over time to be able to answer the question correctly one must understand what albedo is and how it affects the earth system.
4. Answers will vary.
  - A) This is the correct answer. Open ocean is dark in color as opposed to arctic sea ice and therefore absorbs instead of reflects earth's solar radiation.
  - B) This would be the correct answer if we were talking about land ice and snow cover.
  - C) Exposing less open ocean would be ideal as the light areas reflect the sun's radiation.
  - D) This is a false statement. Satellite data shows that sea ice extent is variable and has changed over time.



Student Name  
Teacher/Class  
Date

### Lesson 6: Wherefore Art Thou, Albedo? Ice-Albedo Feedback

Based on your analyses, collaborations, and writings provide evidence of understanding for what albedo is, how albedo can change based on local surface, and albedo's relationship to snow-ice cover.

#### *What Is the Expectation?*

*Accurate science relating to trends in Earth's albedo.*

*Evidence supporting your claims*

*Visual representations*

*Key vocabulary*

*Evidence of on grade level spelling and grammar usage*

