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THE UNIVERSITY OF TEXAS AT AUSTIN

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Austin, TX 78712
(512) 471-5847
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Reflections on a Sustainable Climate: The Earth's Changing Albedo

Lesson plan for grades 6-8
Length of lesson: 60 minutes
Adapted by: Jesús Aguilar-Landaverde, Environmental Science Institute, 09/25/12
Authored by: Jesús Aguilar-Landaverde (UTeach), Maliha Hasan (UTeach)

SOURCES AND RESOURCES:

- National Snow & Ice Data Center:
    - Albedo Definition
      http://nsidc.org/arcticmet/glossary/albedo.html
    - Feedback Loops
      http://nsidc.org/arcticmet/patterns/feedback_loops.html
- NASA Earth Observatory: Seasonal Changes in Earth's Surface Albedo (May 5, 2005)
  http://earthobservatory.nasa.gov/IOTD/view.php?id=5471
- Radiative Forcing Source:
    - Forster, P., V. Ramaswamy, P. Artaxo, T. Berntsen, R. Betts, D.W. Fahey, J. Haywood, J. Lean, D.C. Lowe, G. Myhre, J. Nganga, R. Prinn, G. Raga, M. Schulz, and R. Van Dorland, 2007: Changes in atmospheric constituents and in radiative forcing. In: *Climate Change 2007: The Physical Basis*. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor, and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, UK, and New York
        - http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-chapter2.pdf
- Vernier LabQuest™ Website quickstart guide
  http://www2.vernier.com/manuals/labquest_quickstart_guide.pdf
- Veriner LabQuest Interfaces and Sensor Guide
  http://www.vernier.com/products/interfaces/labq/
  http://www.vernier.com/products/sensors/ls-bta/

POTENTIAL CONCEPTS TEKS ADDRESSED THROUGH THIS LESSON:

§112.18.b, §112.19.b, §112.20.b Knowledge and Skills, Grade 6,7,8: 2A, 2B, 2E, 4A
§112.19.b, Earth and Space, Grade 7: 9A

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PERFORMANCE OBJECTIVES:

Students will be able to:

- Explain the definition of albedo as a ratio of reflectivity of visible light.
- Compare and contrast reflective materials using their calculated values of albedo.
- Implement scientific methodology in measurement by varying only one independent variable (the different reflective materials) and holding the others constant (angle of flashlight, distance of probe to materials).
- Compare and Contrast factors that affect the albedo of the Earth including the oceans, ice caps, and forests and how these change over the seasons.
- Report how deforestation and ice cap melting change albedo and its effect on local temperatures.

MATERIALS (per group of four):

- Ideally, 1 LabQuest™ or LabQuest 2™ instrument
- 1 Vernier light probe accessory
- 1 Standard classroom flashlight
- 2 Rubber bands
- 1 Rulers (with centimeters)
- Laminator access
- **6** total sheets of construction paper (five normal sheets and one **laminated** sheet that is the same color as one of the non-laminated)
- Evaluation Worksheet
- Data Sheet

CONCEPTS:

The focus of this lesson is the physical quantity known as **albedo**. That is, the measure of the reflectivity of different materials of visible light. Presented here is a lesson designed for the students to observe this property directly using appropriate classroom technology, namely the LabQuest™ instrument and its accompanying light probe.

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BACKGROUND:

The authors of this lesson wrote for an eight grade Earth Sciences core classroom. While a very interesting topic in its own right, we approached the subject from a climate sciences angle, culminating in an exploration of how the albedo of the Earth varies from season to season and with excessive heating of the earth. The questions to be addressed in this lesson include: how does the composition of a material affect its reflectivity? How do we experience these difference in every day life? How do these differences translate over into the whole surface of the Earth? What might uncontrolled heating of the earth do to existing albedo values? Why is this important?

PREPARATION:

The instructor should have sets for each pair of students ready, including flashlights, paper, rubber bands, and rulers. The teachers should also set up the clamp-ring stand combination such that each clamp is 40 cm above the ring stand base. The instructor should perform the experiment described below prior to the lesson to compare with the students' results (if desired). And, the instructor should have the included (links) plots or animations ready for presentation on a projector.

ENGAGE:

This lesson is about the physical quantity called albedo, a word perhaps not familiar to all junior high school students at this point. The author proposes this playful introduction to open a dialogue into the subject.

All song references aside (if it is appropriate for the classroom, the teacher might even play a sample of this famous song—"Sunglasses at Night," Corey Hart (1983)— as an intro, though the author suspects many students may not recognize it), why *don't* we normally wear sunglasses at night?

Why do we want to wear sunglasses to block the strong sunlight? It's not as if we stare directly at the sun (hopefully not!) in our daily activities.

What about on cloudy days; we can't even see the sun, so why can we still see in our homes without turning on the lights during the daytime?

Not to teacher: The aim of this opening is to prompt the students to think about their daily experiences with sunlight, namely how it is reflected from various surfaces. While ultraviolet radiation is certainly a concern with our everyday exposure to the sun, the instructor should redirect these ideas to focus more on the effects of the Earth on the incoming radiation as opposed to the radiation's intrinsic properties. Granted, it is certainly a valid point to remember ultraviolet radiation later in the lesson when discussing how the Earth absorbs and emits radiation to maintain its thermal equilibrium. For further questions, the author recommends asking why we (or their parents) often choose to wear sunglasses for driving or why it can be difficult to take a picture of a window or a lake. Some students may go as far as to bring up polarization, and at the teacher's discretion, this could certainly also lead to a discussion of Brewster's angle and the case for *zero* reflection; this lesson will focus on albedo.

Below are some sample probing questions and possible dialogues between the students and teacher:

- What purpose do sunglasses serve if one is never looking at the sun?
- Why do we need sunglasses to protect our eyes from sunrays if we seldom make direct observations of these?
    - Possible Answer 1: Because the sun is so bright.
        - Follow-Up: Can you tell me more about that? How does the sun's brightness come into play?
            - Possible Secondary Answer 1a: The sun is so bright that it can hurt our eyes.
                - Follow-Up: Okay. What about if I had in my hand a really strong and bright laser. Would it hurt your eyes if you didn't look at it?
                    - No.
                        - How does this compare with the sun?
                    - Yes.
                        - Okay. How would the "brightness" of the laser reach your eyes if you weren't looking directly at it? Is this different than the sun?
            - Possible Secondary Answer 2b: The sun emits harmful rays that can damage our eye tissue.
                - Follow-Up: Ah, very good. And if we don't look at the sun, are our eyes completely protected?
                    - Yes.

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- So why might doctors tell us it's a good thing to wear eye protection outdoors (other than to just look cool)?
  - No.
    - In that case, what else might still raise a health concern for our eyes under sunlight?
- Possible Secondary Answer 2c: The sun is so bright that it can light other things up. The light from these things can hurt our eyes.
  - Follow-Up: Can you expand on that? How does the sun “light up other things?”

- Possible Answer 2: Because light reflects off the floor into our eyes.
  - Follow-Up: The light reflects off the floor into our eyes. How do you know that?
    - Possible Secondary answer 2a: I read it somewhere.
      - Do you agree? How could you check that?
    - Possible Secondary answer 2b: Because that is how we can see.
      - Interesting. Can we do anything to measure the light that we see?

Again, this provides an introduction to reflection concepts to be explored in the subsequent sections.

EXPLORE:

Model Transition: “So, you’ve all told me (us) some interesting things about how that big ball of gas in the sky (literally) lights up or world. Let’s see now if we can discover more about this process by becoming real scientists (holding up LabQuest™).” [cue gleaming eyes].

In this section, the students will work in groups, ideally in pairs, using the LabQuest™ technology and its accompanying light sensor. The authors of this lesson have had the opportunity to work with the first version of this instrument, and we were able to notice a difference in illuminance readings using the photodiode in the light sensor (full specifications are contained in the user manual). Doing some preliminary analyses, it was also discovered that with proper calibration (see manual for instructions), the instrument is indeed sensitive enough to show albedo measurements when data is collected sampled over time.

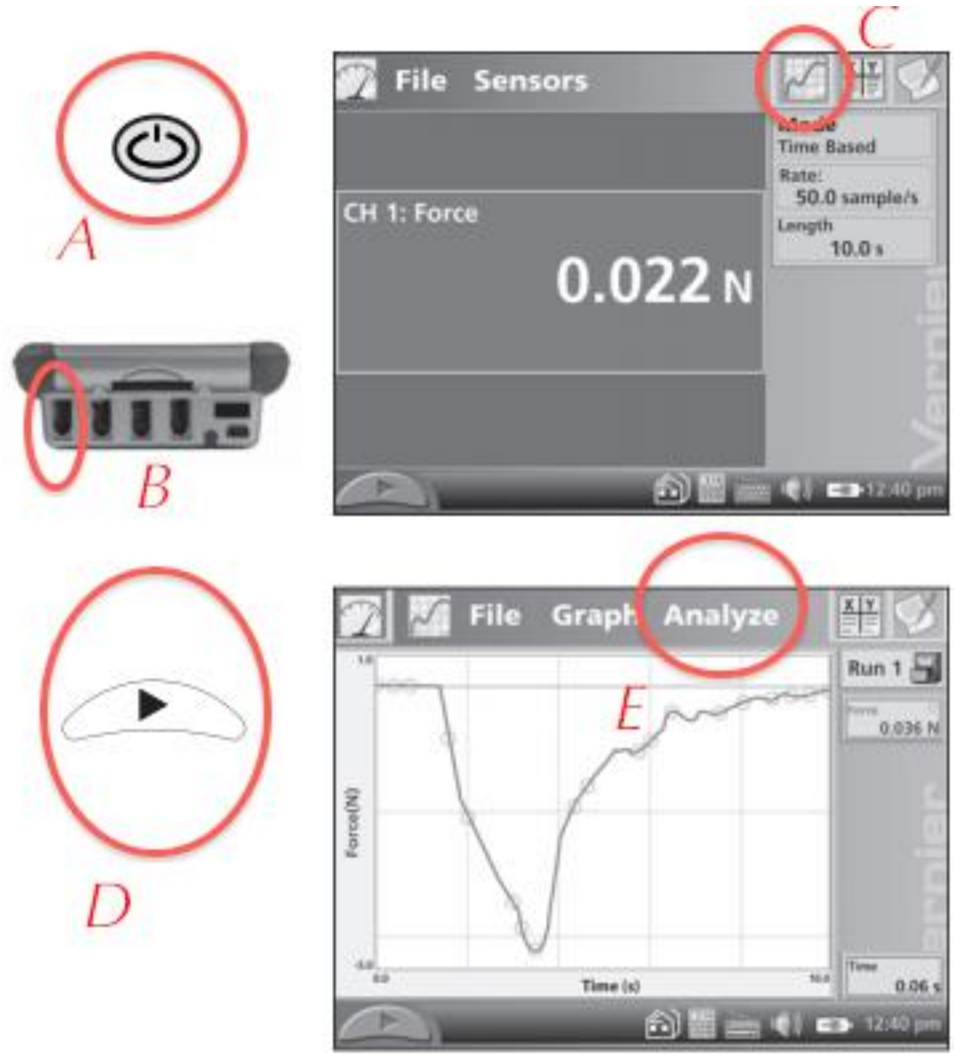

Figure 1: A sample LabQuest(TM) screen with procedure instructions.

To begin using the experiment for this step, one needs only to power on the LabQuest™ unit by pressing the button labeled **A** in Figure 1. If charged or connected to a power source, the screen will display its main menu. Connect the light sensor (distributed separately from the LabQuest™ unit) to one of the slots labeled **B.** A screen similar to the top image on the right-hand side of figure one

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should come up. Instead of force, however, “Ch 1: Light Level” will be the quantity displayed. To achieve the desired accuracy, students will need to tap on the icon labeled **C** to access the graph mode. A blank graph should be displayed. To record data, press the button labeled **D** on the face of the main LabQuest™ instrument. This will collect data from the light sensor (illuminance data) for ten seconds. The unit will display a graph of the light level over ten seconds in a graph afterward. The students should then click on Analyze, labeled **E**, and then tap on **Statistics/Ch 1: Light Level.** This will display basic statistical data including range, min, max, and **mean** on the right-hand side of the screen beside the graph. The students should record this value (**mean value)** as their collected data.

The student procedure for this activity is outlined in the attached instruction sheet; it may be adjusted for number of students at the teacher’s discretion. Students should record their data in the attached **data sheet.**

As the students are working, the following are some probing questions the instructor might ask independent groups as he or she walks among them:

- What do you notice about this instrument so far?
- Why might the number on the screen be changing?
- What do you think this number is measuring?
- Why do you think that the number on the screen doesn’t go any higher than one?
- Can you explain to me what you’ve found so far?
- What’s happening when you change the distance to the light source? Why?
    - It [the number on the instrument] gets bigger [when moved closer to the light].
        - Why do you think that is?
            - “The light is brighter if I hold it closer.”
                - The light is brighter. If you didn’t have this machine, would you say that the light gets brighter if you hold the probe closer? Why/not?
                    - Do things get brighter if we get close to them in normal life?
                    - How would you be able to tell if the light was actually getting closer?
                        - “There is more light.”
                        - Tell me more about that. Where is there more light?
- How do you think this instrument works?

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Notes to Instructor: In having done this lesson with an eighth grade class room, be sure to have a demonstration unit set up prior to the beginning of the lesson. This will give the students a model to follow in addition the written instructions. Before beginning of the lesson, I also made it known to the students that group collaboration would be required for the completion of the experiment.

Also, it is important to visit each group at the outset of the experiment to clarify any set up questions. We had students who had some difficulty maneuvering the touch screen or setting up the light probe-ruler combination. The light probe should be attached according to figure 2 below.

Finally, be sure to charge each LabQuest™ unit with the appropriate included chargers and set up the ring stands at the appropriate height (40 cm) for each group prior to the lesson.

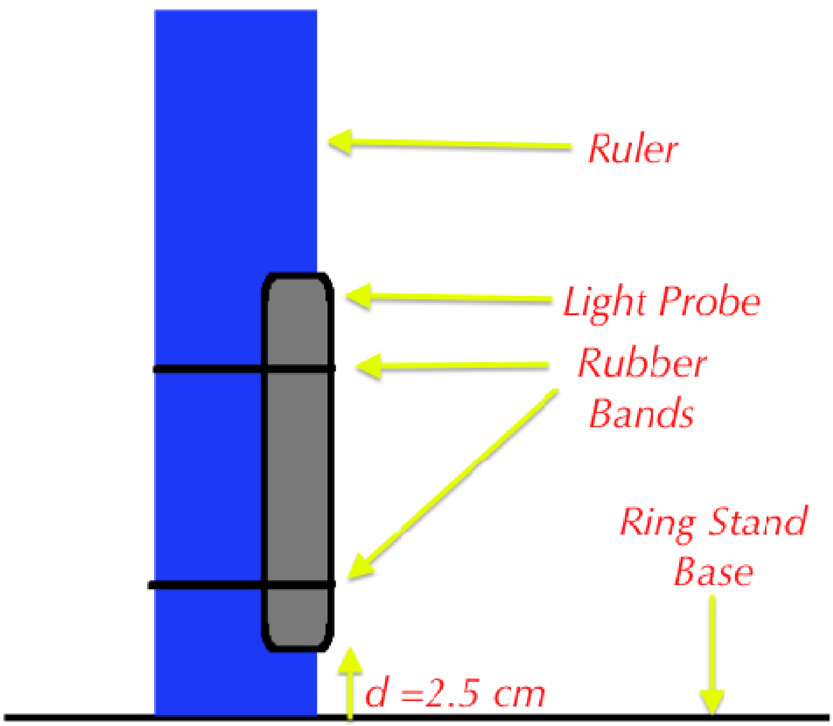

Figure 2: The light probe-ruler set-up

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EXPLAIN :

Model Transition: "Okay, everyone. At this time, I'd (we'd) like you to put down your instruments and hold down the power button to turn them off. If you were an A person in your group (where A here means role 1 or role 2), place your LabQuest™ in its box and come put it up here at the front. If you were a B person, come put your group's flashlight here. I'll (we'll) give you a few more seconds to collect your **thoughts on what your group found so we can talk about our work as scientists and/or researchers and/or** ***engineers."***

The instructor should now gather the students' attention. Each reporter from each group should briefly present their findings. Listen carefully for key vocabulary words the students might use such as light, dark, intensity, distance and record these on the board or overhead projector.

Ask the students to express their results in scientific terms, if needed. For example, "how did your values for laminated versus non-laminated? What about between the paper colors?" From this discussion, it is intended for the students to come to the formal definition of albedo in both conceptual and mathematical terms as a ratio of intensities. The instructor should define this term at this point. Specifically,

Albedo *or surface reflectivity [is] the* ***ratio*** *of the amount of electromagnetic radiation reflected by a body (surface) to the amount incident upon it, commonly expressed as a percentage. [NSIDC]*

Mathematically,

$$albedo = \frac{reflected\,(light)}{incident\,(light)} \times 100$$

Notice that albedo need not always be represented as a percentage. Often it is quoted as a **ratio**, and it is this ratio that should be emphasized in discussion. Also, the students may already be familiar with the word ***albino*** from biology. This word shares the root word.

Ask the students to calculate the ratio of incident light/reflected light (from their recorded values) for an idea of the quantitative value of albedo of each material. Collect data from each table and tabulate it on a chart where it is visible to the whole class such as on a projector. The instructor should also underline his or her own measured value for these quantities. It is very likely that the numbers may not all agree or be near the actual values of albedo for these materials. However, this is a perfect opportunity for the teacher to prompt the students on what kinds of uncertainties went into the measurement process. Model questions include,

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- Is this what you would expect from these materials?
- Do these numbers show any patterns?
- When you were taking measurements, did the meter always read zero when you weren't measuring light?
- Why might our numbers disagree with the definition of albedo and our expectations?
- Did anyone notice what happened to the reading if you moved the flashlight or the sensor? Could this have anything to do with our measurements?
- How might these materials compare with items around the room, say, compared to the wall or with the floor? Do you expect a higher or lower albedo? Why?
- **Extra:** What quantity are we measuring? What is our **standard** for this quantity (illuminance)?

ELABORATE:

Model Transition: "So, we've found in our experimentation as scientists that different materials have different albedo values, but let me ask you this now: can liquids and gases have albedo too? When we talk about these measurements, are we limited only to one state of matter (solids)?"

In having taught this lesson, it was discovered that the students were very interested in this new physical property, and we were able to identify some key questions that the students had. We continued our discussion of albedo as a ratio and opened up dialogue with the following plots from NASA's ERBE (1987).

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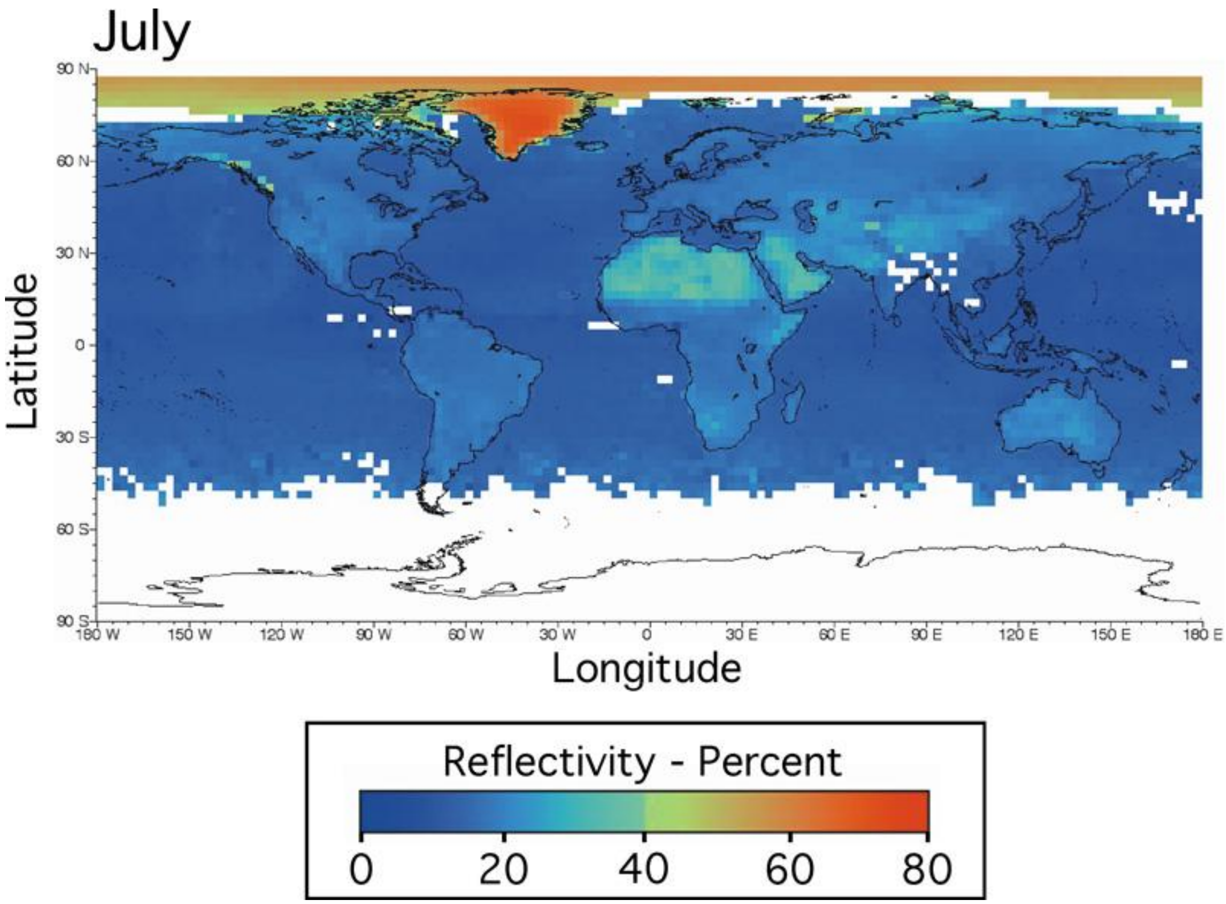

Figure 3: Surface reflectivity of the Earth for January and July 1987. Cells with missing data are colored white. Measured by sensors aboard a variety of satellites for NASA's Earth Radiation Budget Experiment (ERBE).

From: http://www.eoearth.org/article/Albedo?topic=54300

There are several plots on this website, and we used them on a projection screen to prompt the students over the following:

- What is this plot showing you?
- What do the colors mean? How does this tie in to what we've been talking about?
- Which areas have higher albedo? Which have lower? Why?
- Which do you think has a higher albedo: glaciers or forests?
- What about between deserts and forests?
- What about water?*

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*In this discussion, we found that the students were able to connect their measurements in the experiment with their hypotheses on the Earth's surfaces. However, it became a topic of special interest when water was brought up. There was disagreement over what sort of albedo water should have. On the one hand, the students claimed, water was clear. On the other hand, water is also blue—said other students—because it reflects the color of the sky. This lesson was **not** about the transmission of light, but this could serve as an interesting lead-in or exploration of a related physical property. Another student made the comment that at different angles, light reflect differently and can blind a person. In the lesson, I made comments about related physics of transmission and Brewster's angle, but did not probe further in order to focus on the objectives of the lesson.

EVALUATE:

For this section, the students should complete the attached **evaluation** worksheet (see Materials). There is a bonus question that touches on the extremes of albedo. There is no perfect reflector or perfect absorber in the natural world, but this question hints at **prefect mirrors** and **perfect** blackbodies—two constructs often used in science for their properties.

There are also questions on deforestation relate to how anthropogenic changes of land area impact net radiative forcing. More detail is found in Forster et al. 2007 above. It should be extremely well noted the uncertainties with which the IPCC quotes each of these factors with respect to total albedo radiative forcing. There is also a question on the ice-albedo positive feedback loop which may be supplemented by several of the provided NASA videos on the cryosphere. Especially powerful are the data animations for the change in arctic ice expansion over time.

http://www.nasa.gov/centers/goddard/earthandsun/climate_change.html

Of specific interest might be the following two facts reported for the Arctic and Antarctic Ice Seas in 2012:

Press Release: Arctic sea ice reaches lowest extent for the year and the satellite record (Sep 19 2012), http://nsidc.org/news/press/2012_seaiceminimum.html

Press Release: Antarctic Sea Ice Reaches New Maximum Extent (Oct 11, 2012), http://earthobservatory.nasa.gov/IOTD/view.php?id=79369