Greenhouse Effect Lab

We have seen that the bulk of the sun's electromagnetic radiation is concentrated in the visible part of the spectrum, but that blackbodies at the temperatures we live in (around 300K) emit in the infrared.

It is easy to create a miniature greenhouse because standard glass allows visible light to pass through but is opaque to infrared radiation. This also allows us to see the effects of changing the albedo (amount of light reflected) in an environment that has a greenhouse effect.

Materials

One glass jar with white foam thermometer stand attached to lid
One indoor/outdoor digital thermometer
Note: some of the thermometers display indoor and outdoor time simultaneously, while others display one at a time and require you to flip a switch on the back.
One black circular insert that fits over the white foam thermometer stand
Mesh shade cloth (if time allows for the third part of the experiment)

Directions

Experiment Goal: Simulate the greenhouse effect, clouds, and changes in surface albedo by comparing temperature changes between a thermometer inside and another that is outside the jar. Explore how changing the conditions in the jar impacts this difference.

Note: This experiment should be effective whether the sky is clear or cloudy. However, to take all the relevant conditions into account, the weather conditions during the entire experiment should be recorded. Note if the equipment is in direct sunlight, under cloud, or overcast when you begin the experiment, and whenever this condition changes, make a note of it along with your temperature measurements.

Record your hypothesis

In doing so, try to address the following issues:

- ⇒ Assuming you create a good seal so that little or no air flows into the jar once it is over the thermometer, how will the temperature change in the jar?
- ⇒ Will the temperature change slowly at first, then quickly? Or do you expect it to change quickly at first, then slowly?
- ⇒ What changes about the environment of the jar with the black insert placed on? How will this change the jar's rate of temperature change and its final temperature (once it stabilizes)?
- ⇒ What effect does the shade cloth have? How will it change the rate of change and final temperature in the jar?

Procedure

1. Find a flat place for the experiment, preferably one that is not too dark or hot to the touch.
2. Place the thermometer's external probe sticking up in the middle of the foam stand attached to the lid.
3. With the lid off, observe the temperature of the probe ("outdoor temperature") and at the display ("indoor"). (*Note, this is a bit confusing: the jar probe temperature is labeled as the "outside" temperature on the display*). Once each temperature is relatively steady (ie, varying by no more than 0.5 Celsius) proceed to the next step.
4. Record both the temperatures. Place the jar upside-down over the lid, trying to line the lip of the jar up exactly with the outline of the lid. The wire attached to the temperature probe will still be coming out of the jar, but since this is thin it will not greatly interfere with the closure of the jar.
5. With the jar upside-down monitor the temperature inside the jar and out (the "outdoor" temperature" and "indoor" temperatures). Record the temperature **every 15 seconds** because it might change rapidly. The temperature outside the jar might not change as rapidly but should be recorded as the control, or background conditions in this experiment.
6. Continue recording the temperatures until the jar temperature has stabilized (this might take about 10 minutes).
7. After the temperature stabilizes, remove the jar and place the black cutout circle over the foam thermometer holder, aligning the groove so it accommodates the temperature probe.
8. With the jar off, allow the temperature to stabilize.
9. Repeat steps 4_6, recording both inside and outside temperatures until the temperature of the jar stabilizes.
10. If time allows repeat steps 4_6 with mesh shade cloth casting a partial shadow over the jar, black cutout, and temperature probe. Be careful to hold the edges of the cloth in place.

Analysis

From looking at your data, you can clearly see the final temperature in the jar. However, the path it took to get to that temperature is also important - this is why you recorded the temperature every 15 seconds. It is often easier to analyze a large data set like this by plotting it graphically.

There is a simple template for Microsoft Excel to plot the temperatures over time available at http://meteora.ucsd.edu/~jnorris/cosmos/jargreenhouse.xls
Using this file it should be easy to plot the temperatures over time for each experiment: the jar with the white foam, the jar with the black plastic insert, and the jar with the insert and covered by shade cloth.

Once you have entered your data, print the graphs that are automatically generated and use them to answer the following questions:

1. How much did the jar temperature increase in each experiment? How long did this take? Mark the amount of increase and the length of time on your graph.
2. In which of the first two experiments (white foam holding probe, or black circular insert covering it) is the most visible radiation absorbed in the jar? Which one has the highest albedo? What are some ways that the Earth's albedo can change?
3. How does the total net amount of radiation (at all wavelengths) coming into the jar compare to the amount coming out at the start of the experiment? What about at the end of the experiment? (think about this carefully: how does the balance between energy coming in and going out affect temperature change?)
4. Since you measured the temperature repeatedly, the shape of the graph indicates how quickly the temperature was changing in the jar. Note the time in each graph where the temperature is changing most rapidly. Did this occur soon after you closed the jar, or was there a long delay before the jar started warming up quickly? Why do you think this is? Is the answer the same for each experiment?
5. What would happen if we did the experiments with thicker glass jars, or with a larger jar enclosing the small one?
6. What is the value of recording the control (outside the jar) temperature? Since we want to focus on the greenhouse effect, try removing background conditions by subtracting the air temperature from the jar temperature and plotting this as a function of time in Excel. Is the resulting graph line cleaner?
7. If you had time to try the shade cloth, discuss the amount of change in this experiment compared to the others. Also, note the period on the graph when it was changing fastest.
    a. How does the amount of visible radiation coming into the jar change when the shade cloth is used?
    b. Does the absorptivity (the percentage of radiation coming into the jar that is absorbed) change?