Reflecting on what is happening to Greenland's ice

Scientists use a variety of methods to investigate ice sheet changes. In this exercise, you will look at graph and map data to think about how, if at all, the Greenland ice sheet seems to be changing.

Data set #1: Reflectivity graphs

Albedo is the measure of a surface's reflectivity. An example of a material with a high albedo (high reflectivity) is fresh snow, whose albedo is approximately 0.84. In other words, fresh snow reflects approximately 84% of the incoming sunlight that strikes it. In contrast, glacial ice that is not covered with snow exhibits an albedo range of 0.2 to 0.6 (20%-60%).

In small groups, spend a few minutes answering the following questions:

(1) Brainstorm some reasons why glacial ice can exhibit such a wide albedo range.

(2) During which months of the year would you expect the Greenland ice sheet to exhibit the highest albedo? Why?

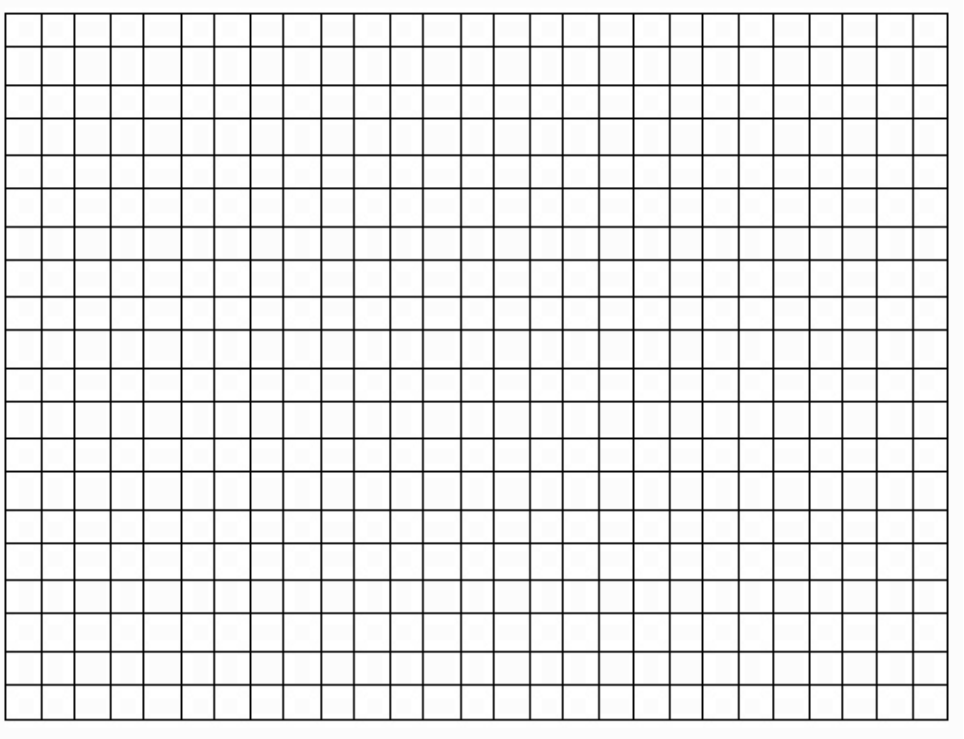
(3) During which months of the year would you expect the Greenland ice sheet to exhibit the lowest albedo? Why?

(4) During a given month, would you expect all of Greenland to exhibit the same albedo (for example, coastal vs. inland areas?)? Explain your answer.

What do the data show?
Satellite observations of Greenland's albedo are available from March 2000 to the present. Before you look at the data, let's make some predictions about how albedo varies annually.

(5) On the grid below, please complete the following:

- Label your axes with:
  - months of the year (starting with January) on the X-axis
  - albedo (no numbers necessary—just "low albedo" and "high albedo") on the Y-axis
- Think about what you just discussed with your group members. Based on what you talked about, sketch on your graph what you would expect a yearly albedo curve for Greenland to look like.



Above: Sketch illustrating the expected, annual albedo variation for Greenland.

Once you have completed your graph, compare your graph to the ones created by the other people in your group. Discuss any discrepancies that you see, and make sure that everyone in the group agrees on the general shape before you move on.

(6) You have been provided with some real albedo data from Greenland with time on the X-axis and albedo on the Y-axis. You may have a different graph than other people because albedo measurements were made at different elevations on the ice sheet. Study your graph and answer the following questions:

(a) Referring to the title of your graph, at which elevation range were your data obtained?

(b) What do the different colors on the graph represent?

(c) Why does the black curve abruptly end?

(d) Referring to the Y-axis of your graph, what albedo range is illustrated on your graph?

(e) How does the general shape of your data correspond to the predicted graph that you sketched in question 5?

(f) In general, which month(s) of the year has the highest albedo?

(g) In general, which month(s) of the year has the lowest albedo?

(h) Between April 1 and July 1, which year exhibited the lowest albedo compared to the other years? When during the year did it occur? What was the approximate albedo?

(i) Between April 1 and July 1, which year exhibited the next lowest albedo compared to the other years? When during the year did it occur? What was the approximate albedo?

(j) Describe how the 2012 albedo compares to the 2000-2011 albedo for the following time periods (you can describe it in terms of "higher", "similar", "lower", etc.)

April 1-May 1:

May 1-June 1:

June 1-July 1:

(7) Next, you will compare your albedo graph with 3 other group members' graphs. Complete the tables below, based on everyone's data. In table 2, be as descriptive as possible.

Table 1: Lowest albedo, April 1-July 1

Group member	Elevation (m)	Year with lowest albedo	Approximate date within that year	Approximate albedo (%)
	500-1000			
	1000-1500			
	2000-2500			
	2500-3200			

Table 2: How do the 2012 albedo data compare to the 2000-2011 albedo data?

Elevation (m)	April 1-May 1	May 1-June 1	June 1-July 1
500-1000			
1000-1500			
2000-2500			
2500-3200			

(8) Use the group data to answer the following questions:

(a) Based on the overall data, do the higher OR lower elevation areas in Greenland have the greatest albedo? Offer an explanation for WHY.

(b) In Greenland, do the higher OR lower elevations have 2012 data most similar to the 2000-2011 data?

(c) In Greenland, do the higher OR lower elevations have 2012 data most different from the 2000-2011 data?

(d) Of the four different elevation ranges depicted on your graphs, for which elevation range was the 2012 data most different from the 2000-2011 data? For this graph, explain how the albedo in 2012 differed from the albedo measured from 2000-2011.

Data set #2: Reflectivity anomaly maps

Next, you will work with a partner and look at a Greenland reflectivity anomaly map. Simply, an anomaly refers to a change from "normal". To obtain a reflectivity anomaly, the long-term average reflectivity is subtracted from the current reflectivity. In other words:

reflectivity anomaly = current reflectivity – long-term average reflectivity

The map illustrates the reflectivity anomaly in Greenland in 2012 vs. 2000-2011. In this map, the June 2012 reflectivity is being compared with the average June reflectivity from 2000-2011. The measurements on the map are unitless but can be converted to albedo percentages (like you looked at on the graphs in data set #1) by multiplying by 100.

(9) What does an anomaly of zero mean? (circle the best answer)

The reflectivity in June 2012 was the same as the average June 2000-2011 reflectivity.

The reflectivity in June 2012 was greater than the average June 2000-2011 reflectivity.

The reflectivity in June 2012 was less than the average June 2000-2011 reflectivity.

(10) Which colors are used to represent a positive anomaly? What does a positive anomaly mean?

(11) Which colors are used to represent a negative anomaly? What does a negative anomaly mean?

(12) Why are some areas of the map white?

(13) Did any areas of Greenland show positive anomalies in 2012? If so, where? If so, which areas of Greenland showed the most pronounced positive anomaly in 2012?

(14) Did any areas in Greenland show negative anomalies in 2012? If so, where? If so, which areas of Greenland showed the most pronounced negative anomaly in 2012?

(15) Why do you think that this map only includes data from June? Do you think that looking only at June changes how you interpret the information depicted on the map? Do you think that the data would be different if a different month of the year had been chosen?

Finally, think about all of the Greenland data that you've studied: yearly albedo plots from 2000-2012 and the reflectivity anomaly map for 2012 compared to 2000-2011. Based on these data, answer the following questions:

(16) Briefly summarize what the data suggest could be happening to the Greenland ice sheet.

(17) How certain would you be if you were asked to predict what the data for the rest of 2012 would look like? How certain would you be predicting what the data for 2013 would look like?

(18) Could the data be providing information about components of the system <u>other than</u> the Greenland ice sheet itself? (In other words, are the data providing information only about the ice?) Briefly explain your answer.

(19) What other information would you want to be more certain that you are interpreting the data correctly?