GEOL 553 Lab 1: Climate Forcing, Greenhouse Effect, Milankovitch

Name____

This lab is an attempt to link together several aspects of the course**.** It will incorporate consideration of: Earth – Sun relations, solar insolation, atmospheric processes, ocean – temperature conditions, dead bodies in seafloor sediments, ice cores, oxygen isotope data, CO_2, CH_4, and dust. There is extensive geological evidence that ice sheets have advanced and retreated several times over the past several hundred thousand years. Today, we will consider several aspects of the **Milankovitch theory** and then investigate **orbital signals in both ice-core and ocean-sediment records.**

1. Orbital cycles

In 1924, Yugoslavian mathematician Milankovitch presented a theory for the multiple ice ages of the past 2 million years. He postulated that variations in ***insolation***, which is the amount of solar energy received at the Earth's surface, were responsible for both the advance and the retreat of the continental ice sheets.

Essentially, for the purpose of this exercise, insolation variations are determined by **three parameters** related to the motion of the Earth around the Sun. Milankovitch solved for the values of these three orbital parameters, namely **precession, obliquity and eccentricity** in the (geologic) past, a task that occupied him for 30 years (he had no calculator). After adding up the variations of these three parameters over time, one can calculate insolation over time for all latitudes on Earth throughout the year.

We will examine each of these parameters, using the data source materials attached to this lab. Fill in the following table to explain each orbital parameter. (9)

Fill in the table	**A: Precession**	**B: Obliquity**	**C: Eccentricity**
Briefly describe it			
Draw it			
How long is one cycle?			

When we combine the effects from these three different ways in which the orbit of the Earth changes over time, we can solve for the insolation at any given latitude in any season. At the end of this handout, there are figures that show how insolation around the latitude of Victoria (data are for 47° N, Seattle) has changed over time; there are plots of both the summer (June 21) and winter (Dec 21) insolation.

1. What is the dominant orbital cycle in (a) summer insolation at 47° N? (1)

and in (b) Winter insolation 47° N? (1)

2. What is the difference between (a) summer insolation at 47^o N at the end of the last ice age (about 15,000 years ago) compared to today? (2)

and (b) Winter insolation at 47^o N at the end of the last ice age compared to today? (2)

3. Is summer insolation or winter insolation a stronger control on the growth and decay of ice sheets in the northern hemisphere? Why? (4)

2. Methane records from Greenland and Antarctic

Ice cores are repositories for many types of climatic information: **gases, stable isotopes, dust, etc.** In this section, we will study some of these records from the **Vostok ice core** and from the **GISP2 (Greenland Ice Sheet Project) ice core from Greenland**. Using what we have learned about insolation variations and some knowledge about ice-core records, we will try to shed some light on the connections **between insolation and the growth and decay of continental ice sheets.**

Methane

Bubbles in ice cores trap a tiny sample of what the atmosphere of the Earth was like at the time that the bubble closed. **Methane (CH_4) is a greenhouse gas** that is produced primarily in **wetlands** as a product of the decomposition of organic material. The extent of these wetlands changes over time as climate changes. The wetlands shrink as climate cools, leading to a reduction in methane production. Hence, methane records in ice cores can be used to assess the change in the size of the source regions and, by extension, the growth and decay of ice sheets.

1. **Compare the methane records from the GISP2 and Vostok ice cores**. Are methane concentrations generally higher or lower during glacial periods? (1)

2. How well do the two records match? Do they show the same increases and decreases? (2)

3. Based on this comparison, are the methane records indicative of local changes, or global changes? (1)

What does this imply about how well-mixed methane is in the atmosphere? (2)

In today's climate, wetlands are prevalent in lower latitudes. Consequently, if we calculate insolation changes through time at these latitudes, e.g., 47°N, we may expect to find a good correlation between insolation changes and the growth and decay of the wetlands.

4. (a) Compare the methane records with plots of insolation from 47°N. Do the methane records correlate better with the 47°N **summer or winter insolation** plots? (2)

(b) **Why**? (3)

3. Vostok temperature and insolation

δD, or $\delta^{18}O$, measurements from ice cores are used to see how **temperature has changed** at the ice-core site **over time**. The Vostok ice core has a long δD record. By making **some assumptions** about **how water was delivered** to Vostok and **how its elevation changed over time**, **its δD record has been converted into a temperature record**. **This record is plotted as changes from the present temperature at the site.**

This record will show temperature changes at Vostok over time, but **what drives the temperature changes there?** Earlier, we found that the insolation at a given latitude varies considerably over time. Therefore, one possibility is that the temperature changes are the result of local insolation changes. Use the graphs at the end of the lab to answer the questions below.

1. Compare the Vostok record of temperature changes with the plot of summer insolation at 78°S and 65°N. Which plot best matches the Vostok Record and why is the correlation stronger with this record than the other? (3)

2. Compare the Vostok record of temperature changes with the plot of annual average insolation at 78°S. What is the dominant periodicity of the local annual average insolation and how well does it compare with the Vostok record? (3)

3. What is the connection between the local annual average insolation and temperature? Why is the connection weak or strong? (4)

4. CO_2, dust, and temperature change

Glaciations and deglaciations are not instantaneous. Some time passes as glaciers and ice sheets gradually grow and decline. The climatic **indicators archived in ice cores** reflect these changes **from interglacial conditions**, like the conditions today (in the absence of anthropogenic climate influences), **to glacial conditions and back again**. Ice-core records reveal that these changes take some time to occur and **that not all indicators change at the same time or the same rate**. By comparing several records of different climatic indicators, including carbon dioxide, dust and methane, we can learn about the reorganization of the Earth's climate system over time.

Accurate depth-age scales are crucial for the interpretation of ice-core records. If the records are obtained from different cores, then it is possible that the time offset between records is due to small errors in the calculation of their respective depth-age scales. We will avoid this potential problem today by examining 3 records obtained from the same **Vostok ice core**. The observed offset in the records is therefore probably real and not an artifact of inaccuracies in the depth – age scale. The records we have are of **carbon dioxide and dust concentrations, and temperature (δD) changes**. By making some assumptions about how water was delivered to Vostok and how its elevation changed over time, its δD record has been converted into a temperature record. This record is plotted as changes from the present temperature at the site.

Examine the records of carbon dioxide, dust, and temperature changes from the Vostok core. Focus your attention on the most recent deglaciation.

1. Coming out of the last glaciation at 20 ka, which of these records led the others in its changes?
Order the 3 records according to which changes first, which changes second, etc., as they entered the most recent interglacial period. (3)

Order	**First**	**Second**	**Third**
Record			

2. Compare the sequence of events around 20 ka with the sequence of events accompanying the penultimate deglaciation around 140 ka. What was the sequence of events at 140 ka and how is it different from 20 ka? (3)

Order	**First**	**Second**	**Third**
Record			

3. Explain how the above sequence of events may have unfolded during the most recent deglaciation and **speculate** on how these records are connected. (4)

4. References

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Figure 1, for Question 1

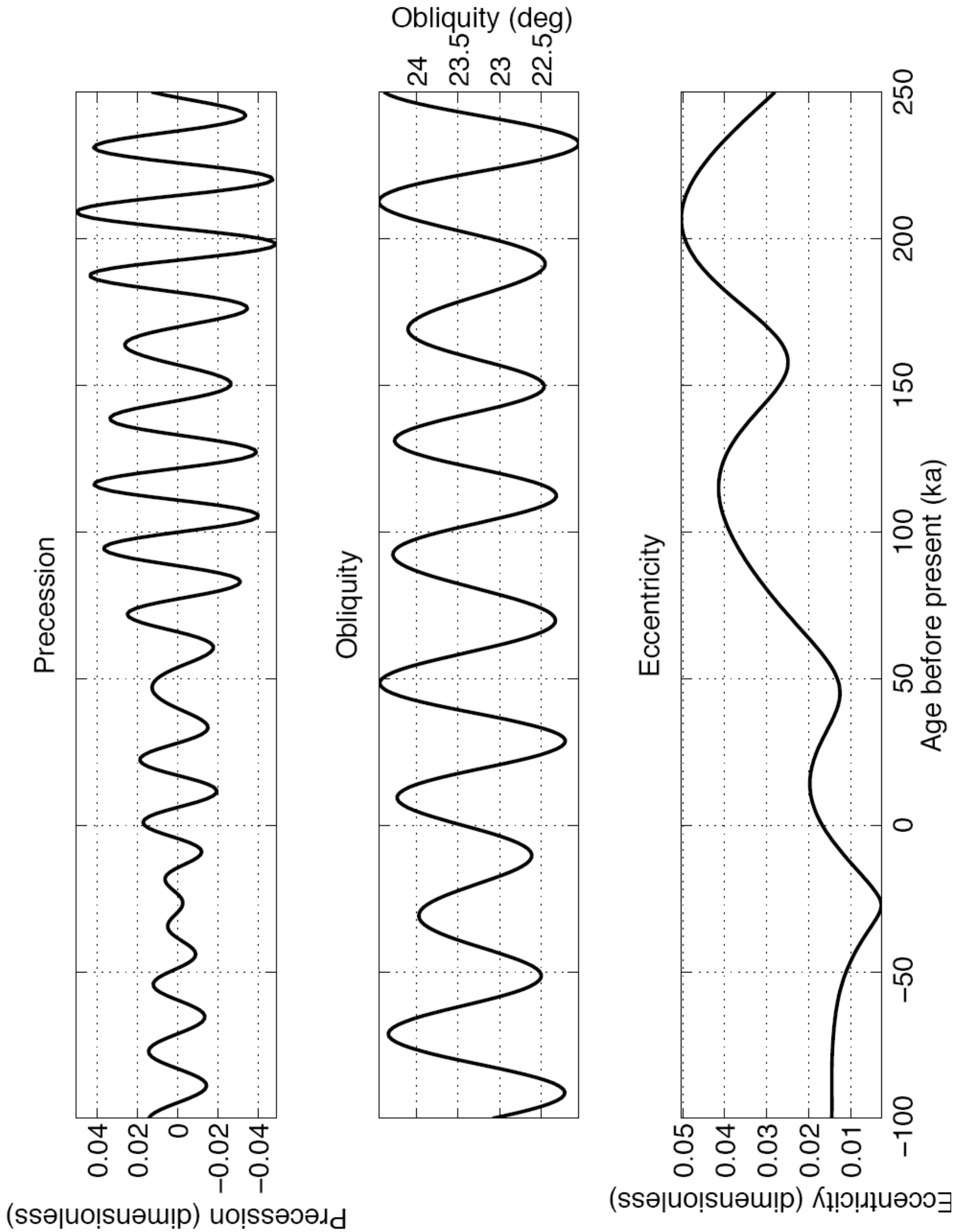


Figure 2, for Question 1

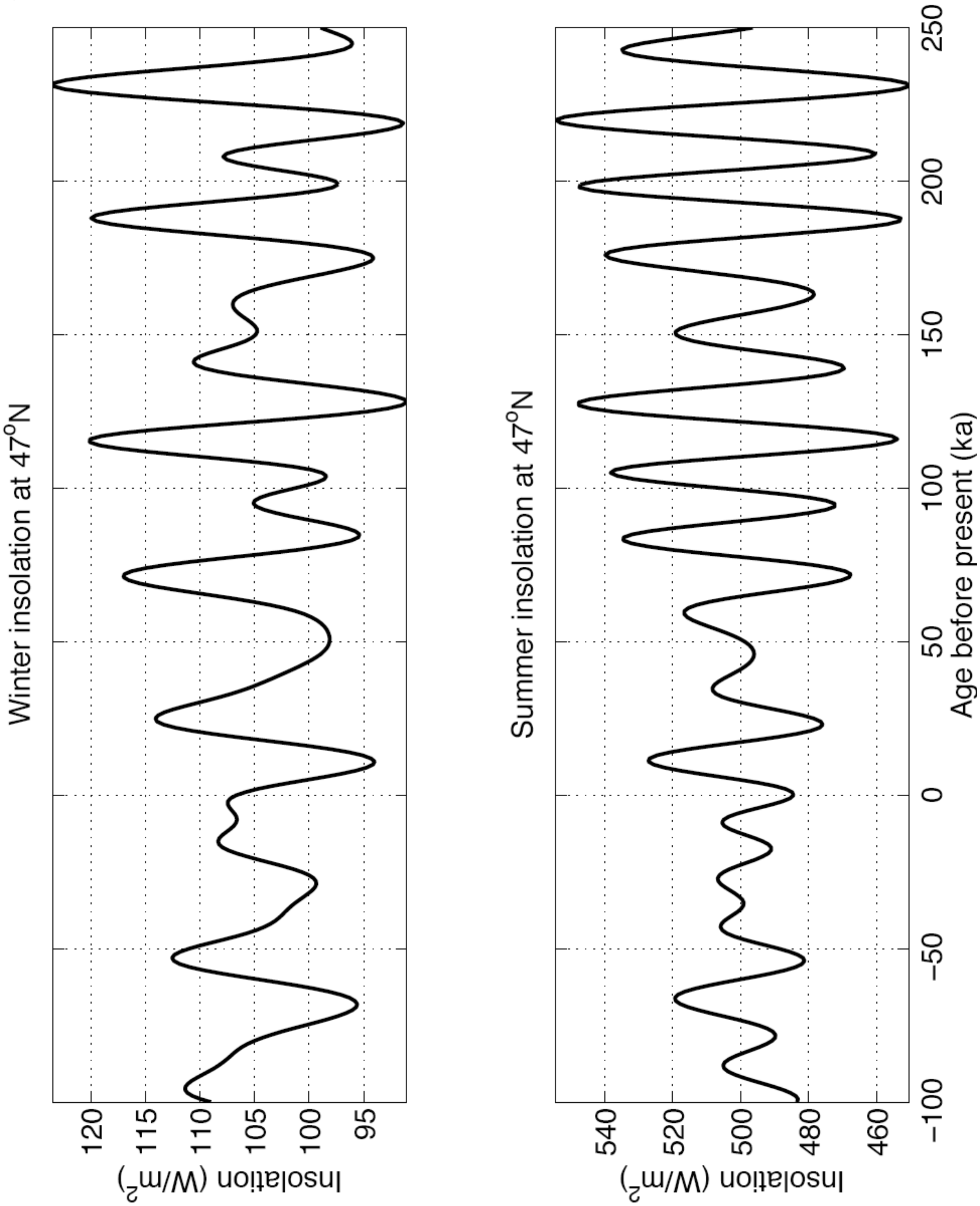


Figure 3, for Question 2

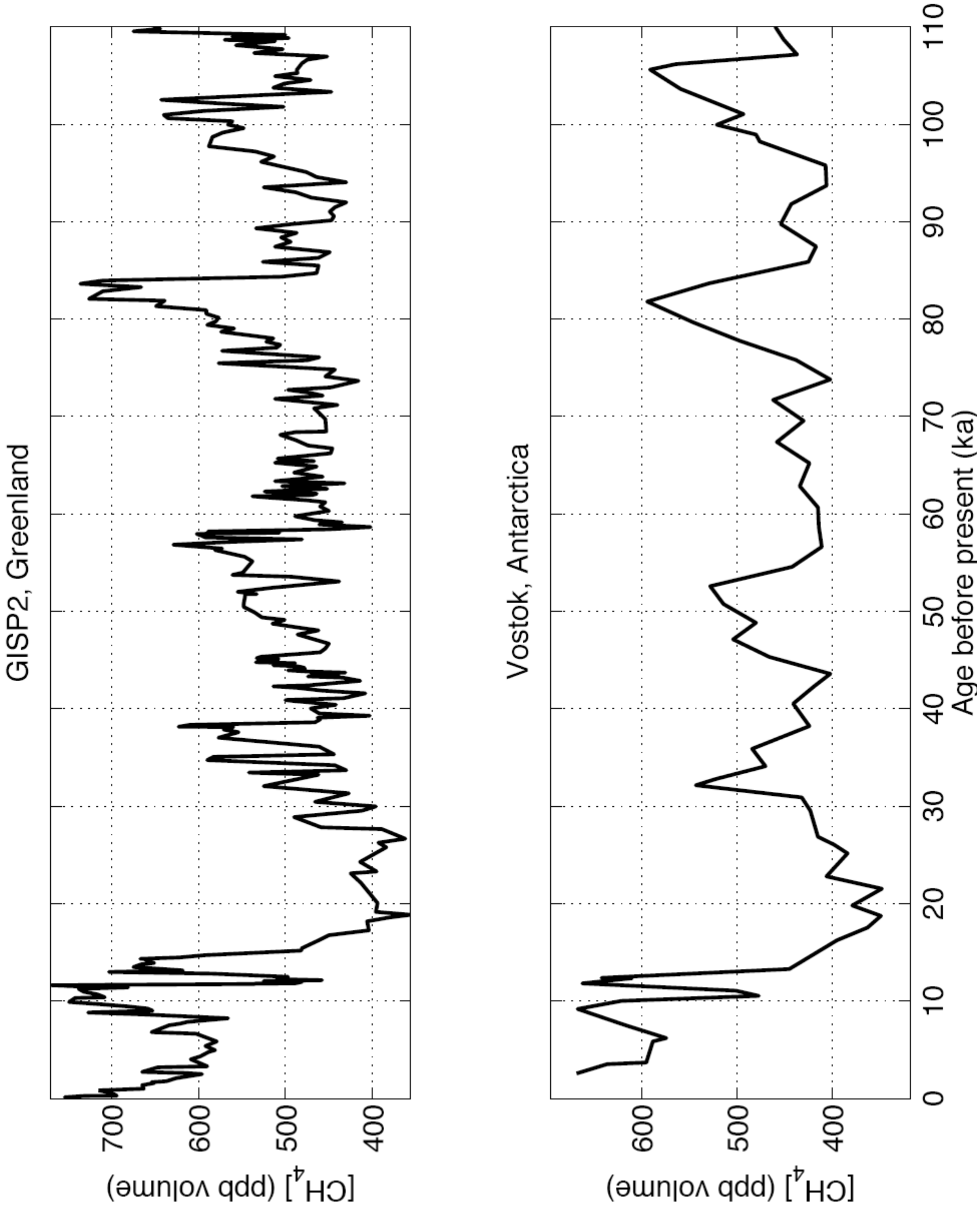


Figure 4, for Question 3

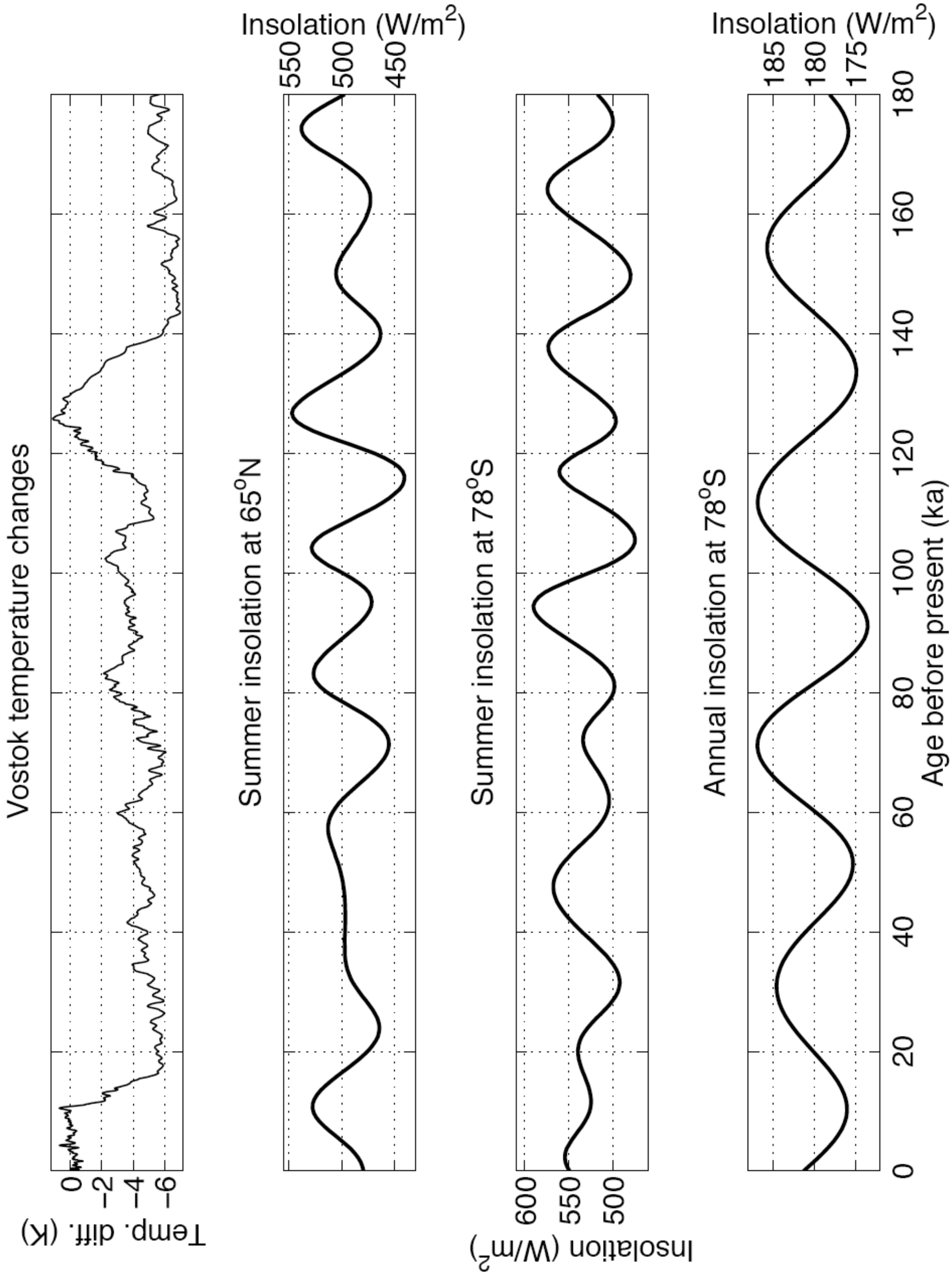
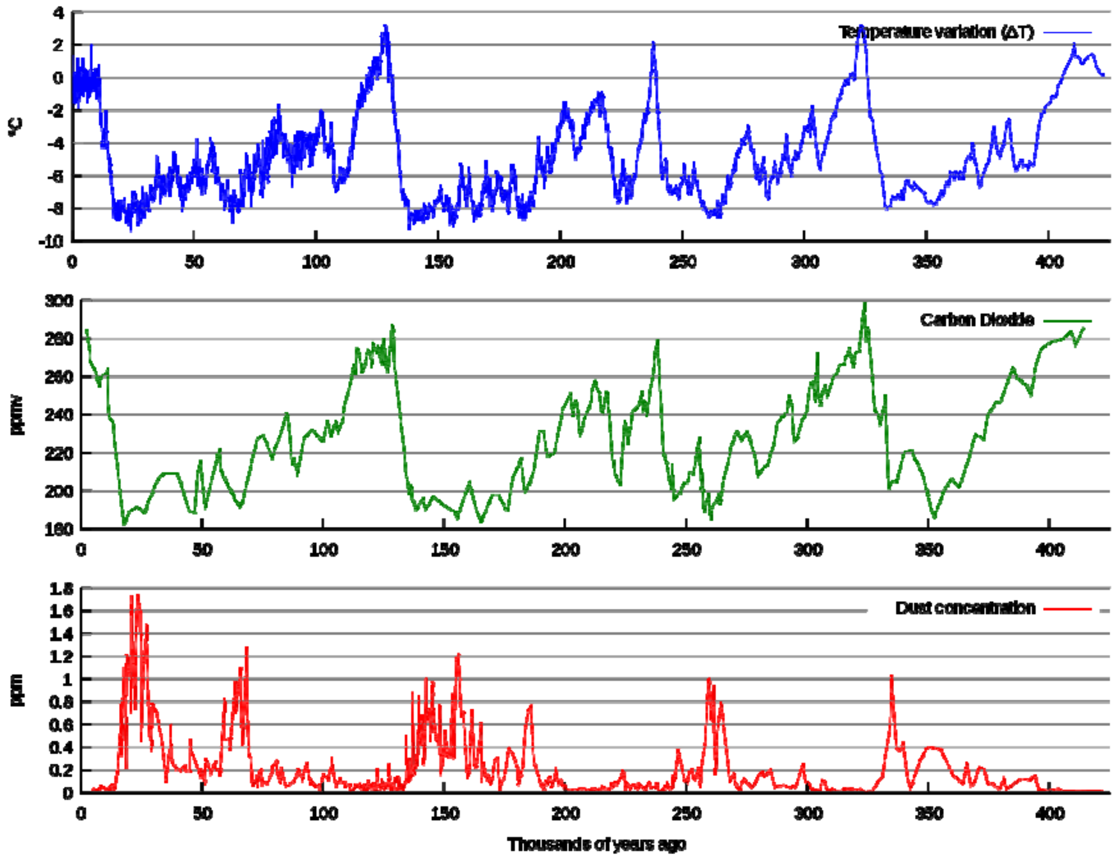


Figure 5, for Question 4



Source: [William M. Connolley produced figure using data from the National Oceanic and Atmospheric Administration, U.S. Department of Commerce, Paleoclimatology branch, Vostok Ice Core Data.]()