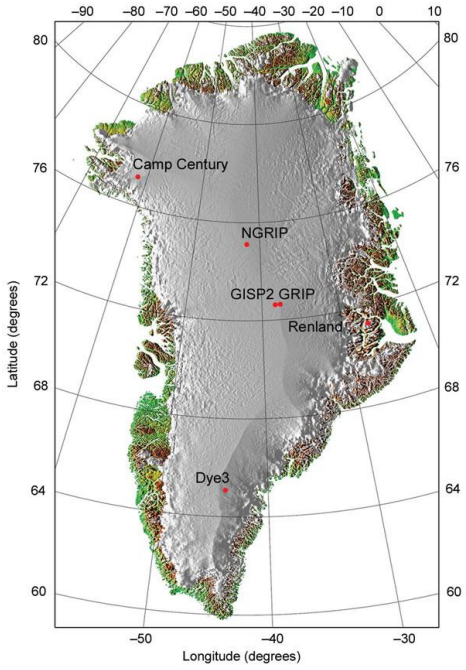
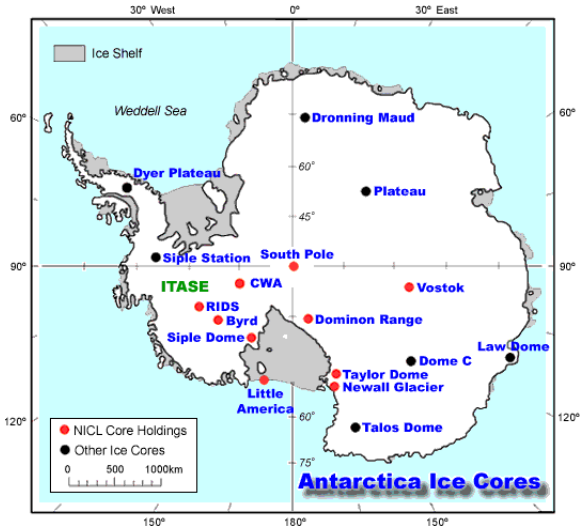
ESS 201: Paleoclimate
Spring 2010
Homework 2: Abrupt climate change, greenhouse gases, and the bipolar see-saw





In this problem set, you will compare Last Glacial/Deglacial (10 to 90 ka) $\delta^{18}O$ from the Greenland GISP2 ice core and the Antarctic Byrd Ice Core (see maps above) with the atmospheric CH_4 and CO_2 records (from the Byrd ice core.). All four records are given on a precise and accurate common timescale that was based on the correlation of atmospheric methane records from the GISP2 and Byrd ice cores. The data is contained in an Excel file called "Homework_2_data.xls". For more details on the age model, see Blunier and Brook, 2001.

Task 1:

As a first step, you should use Excel, Matlab, or the graphics program of your choice, to make a *publication quality* plot (see Barker et al., 2009, Fig. 2 or 3, for example) which shows all four climate records versus age (on a common x-axis, separate y-axes) for the period from 10 to 90 ka (the CO_2 data only covers ~20 – 90 ka). Each timescale is given in Years BP (where present is 1950) [20 pts].

a. On this figure, you should label the following periods: Last Glacial Maximum (LGM), Bolling-Allerod (B-A), Younger Dryas (YD), Heinrich Event 1, and the Antarctic Cold Reversal (ACR) [5 pts].

b. Next, starting with the B-A, and without looking it up, try to mark the millennial-scale Greenland Interstadials (D-O Events) on the GISP2 $\delta^{18}O$ record with an "*". A general rule for this is any rapid increase greater than ~2 ‰ [5 pts]

c. Now, on the Byrd $\delta^{18}O$ record, draw vertical dashed lines through the peak of the 8 most prominent millennial scale warm periods – extend these lines through the GISP2 d18O record [5 pts].

Task 2

Answer the following questions about the paleoclimate records (Write concisely: Your answers must fit on *three pages or less* (11 or 12 pt. font, single spaced, 1" margins).):

d. Compare and contrast the structure (amplitude, symmetry, timing) of the millennial scale temperature ($\delta^{18}O$) variations recorded in the GISP2 and Byrd ice cores. List any major assumptions/sources of uncertainty. [15 pts]

e. What is the Bipolar Seesaw? Is this mechanism supported by the GISP2 and Byrd $\delta^{18}O$ data? [15 pts]

f. Is the CH_4 record more similar to the Greenland or the Antarctic temperature record? What mechanism could be responsible for this? Can you give an example of another climate record we've discussed that supports this interpretation? [15 pts]

g. List at least three mechanisms that may contribute to the decreasing trend in pCO2 between 90 and 20 ka. Are the millennial-scale CO_2 variations more similar to the Greenland or the Antarctic temperature record? How could the bipolar seesaw mechanism explain these rapid CO2 variations? Again, use examples from previous lectures and readings to support your argument, if possible. [15 pts]

h. Calculate the rate of CO_2 increase ($\Delta CO_2/\Delta t$) for one of the large, abrupt events. How does this compare to the rate of CO_2 change from the pre-industrial to modern eras [Pre-industrial (1750 A.D.) CO_2 = 280 ppmv; Modern CO_2 = 390 ppmv]. How do these rates compare with the maximum rate of deglacial CO_2 rise of ~0.004 ppm/year? Any comments? [5 pts]

References:

Ahn, J. and E.J. Brook. 2008. Atmospheric CO2 and Climate on Millennial Time Scales During the Last Glacial Period. Science, 322, 83-85, doi: 10.1126/science.1160832.

Blunier, T., and Brook, E.J. 2001. Timing of millennial-scale climate change in Antarctica and Greenland during the last glacial period. Science, 291, 109-112.