Name: ______________________________

GEOL 1551 - Climate Change

Climate is different from weather. Weather is the day to day variation of temperature, precipitation and wind patterns. Climate is the long-term (multi-year) average of those conditions. It's actually defined as the 30-year average of those conditions by the World Meteorological Organization. So, when we have an unusually cold day in the summer or fall, you can complain about the weather, but it doesn't necessarily relate to what the climate is doing; you must consider decadal scale average conditions and their trends.

Earth Scientists rely on a myriad of different techniques to understand past, present and future climate conditions. By looking to the past and relying on "proxy" or indirect data such as geochemistry, fossils, rocks and sediments, etc., we can reconstruct ancient climate conditions during specific intervals of time, going back millions of years (this discipline is called paleoclimatology). This enables us to also understand mechanisms that drive climate change. We can use the understanding of climate conditions in the past (paleoclimate) as data to test climate models using different levels of CO_2, changes to ocean currents, etc. This helps us understand the sensitivity of climate to various types of perturbations (like rapidly pumping billions of tons of CO_2 into the atmosphere as we're doing today!).

Arrhenius, a Swedish scientist, calculated in 1896 that increasing atmospheric CO_2 would increasingly warm the atmosphere of the Earth (i.e., it's a greenhouse gas). In other words, the idea that anthropogenic emissions of CO_2 cause global warming is not something new, but has been known for well over a century. We know that CO_2 is increasing very rapidly in the atmosphere now due to anthropogenic (man-made) processes including burning of fossil fuels, deforestation, concrete manufacturing, and other things. So, how does that compare to natural variations in CO_2 and global temperatures? One interesting and rather astounding fact is that humans annually produce 130 times the amount of CO_2 produced by all the volcanoes on the planet, which is the most important natural source of CO_2. It's no wonder that atmospheric concentrations have increased from 280 ppm to 415 ppm in just one century, whereas it took at least 10,000 years to naturally increase concentrations from 180 ppm (during the last ice age or glacial maximum) to 280 ppm.

First, watch the video provided in Canvas.

Next, visit the link https://climate.nasa.gov/vital-signs/carbon-dioxide/

1. **What is the present atmospheric concentration of CO_2?**

Scroll down and look at the Proxy (Indirect) Measurements graph of CO_2. The CO_2 concentrations shown in this graph are measured on tiny air bubbles trapped in the ice of Antarctica or Greenland.

2. **What data (include units!) are shown on the x and y axes?**

   X:

   Y:

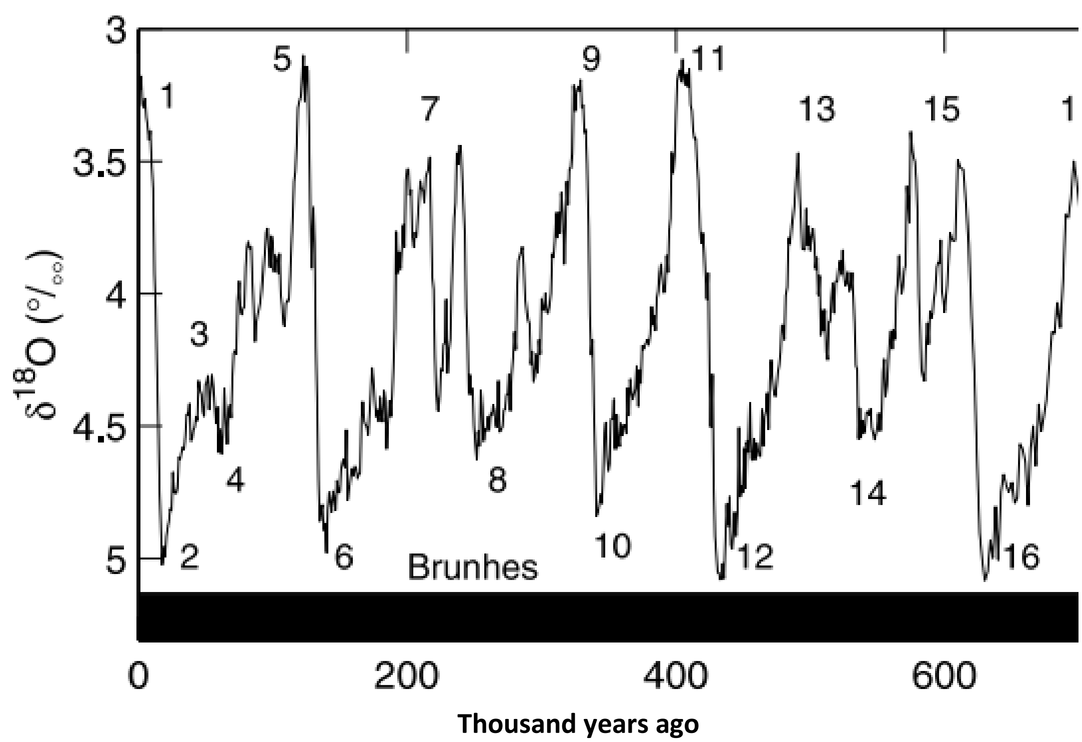
3. **What are the maximum and minimum concentrations of CO_2 prior to the most recent rapid increase?**
    a. **Maximum:**

    b. **Minimum:**

4. **Describe the variations you see, in terms of the period of the change and the magnitude of the change.**

As described in the video, these variations are driven by a combination of changes in the orbit of the earth affecting sunlight distribution on the globe through the year, and changes in CO_2.

Compare the record of CO_2 on the website to the graph below (from Lisiecki and Raymo - carefully note the different scales, including the time scale). The graph below shows the ratio of two isotopes of oxygen ($^{18}O/^{16}O$) measured on the $CaCO_3$ from calcareous zooplankton (foraminifera) in the oceans (see https://earthobservatory.nasa.gov/features/Paleoclimatology_OxygenBalance). When the ratio is high (downward on the graph – note the y-axis scale), it indicates the presence of ice sheets and low sea level (as water moves from the oceans to the ice sheets), when the ratio is low it indicates warm conditions and high sea level (as the ice sheets melt away).



5. **About <u>how often</u> do interglacial conditions (warm, minimal ice sheets, high sea level) like today occur?**

6. **Describe the relationship between CO_2 concentrations and the occurrence of interglacial versus glacial conditions. For example, when CO_2 is HIGH we have which condition? When CO2 is LOW we have which condition? Compare the graph above to the one on the website!**

Now scroll down and play the Time Series: 2002-2016 animation showing the global increase in CO_2

<u>Next go to the Global Temperature page</u> (see the link below the photo at the top of the webpage), scroll down and play the Time Series: 1884 to 2018 showing the global temperature anomaly (relative to the average from 1951-1980) during this time period.

7. **Describe the trend that is clear in <u>both</u> of these animations.**

Scroll up to the Global Land-Ocean Temperature Index

8. **What is the average temperature anomaly now (relative the 1951-1980 average)?**

<u>Now go to the Sea Level webpage. Read the information given there.</u>

9. **What two factors primarily cause sea-level rise?**

10. **What is the current rate of change based on the satellite data?**

11. **Look at the Ground Data: 1870-2013 plot. These data are from tide gauges and go further back in time than the satellite data. Is sea level rising or falling through time? Is the change linear (equal amount of change every year) or accelerating (increased amount of change each year)?**

Now go to the Ice Sheets page

12. **What data are shown on these two graphs?**

13. **What is a Gigaton in terms of kilograms?**

14. **What is the current rate of change (ice loss) in the Antarctica and in Greenland?**

15. **What impact does that melting have on sea level?**

Finally, visit the Sea Ice page

16. Watch the Time Series animation. What is the rate of change in Arctic sea ice per decade?

Watch the brief video at: **https://www.youtube.com/watch?v=3v9aRQpumPA**

17. **How does the computer model compare to the actual observations of sea ice?**

18. **What does the computer model suggest about the future of sea ice in the Arctic?**

19. **What happens to the temperature of the ocean as sea-ice melts, and what effect does that have on further sea-ice melting?**

Two brief but interesting and informative videos can be found in the Canvas module and two more through the links below:

https://vimeo.com/41807260

https://climate.nasa.gov/climate_resources/101/video-global-temperature-variation/