Name: _____ Laboratory Section: _____

Date: _____ Score/Grade: _____

Video
Exercise 18
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LAB EXERCISE 18 Climate Change

Lab Exercises and Activities

SECTION 1

Paleoclimate

1. How many years of data are displayed from the EPICA ice core?

   800,000 years (or 801,588 years)

2. What are the maximum and minimum temperature anomalies recorded? What is the range of temperature anomalies over this record?

   Max 5.4C°, min −10.5C°, range 15.9C°

3. How many interglacials (times where the temperature deviation reached 0 C° or greater) do you detect over the past 450,000 years? What is the average time between interglacials?

   5 interglacials over 0C°, roughly 100,000 years

4. How much has CO_2 varied in the EPICA record? What were the highest and lowest values? What was the range of CO_2 values?

   CO_2 has varied from 300 ppm down to 172 ppm, for a range of 128 ppm.

5. How many times has CO_2 exceeded 270 ppm in the past 450,000 years?

   CO_2 has exceeded 270 ppm five times in the past 450,000 years.

6. What is the period from peak to peak with regard to CO_2 and for temperature for the past 450,000 years?

   They have both fluctuated on a cycle of approximately 100,000 years.

7. Interglacial–glacial period climate cycles are often referred to as appearing saw-toothed, with an abrupt change followed by a more gradual change. When do we see an abrupt change: when going from interglacial to glacial times or when going from glacial to interglacial times? When do we see a gradual change?

   The abrupt change is seen going from glacial to interglacial conditions, while the return to glacial conditions is more gradual.

Examine **Figure 18.2**. The Vostok ice core is 3310 m (10,860 ft) long. The full record extends back to 422,000 years before the present. The figure shows CO_2 in parts per million (ppm) and temperature anomalies in Celsius degrees.

1. How many years of data are displayed from the Vostok ice core?

   Just over 420,000 years

2. What are the maximum and minimum temperature anomalies recorded? What is the range of temperature anomalies in the Vostok record?

   Max 3.2C°, min −9.3C°, range 12.5C°

3. How many interglacials (times where the temperature deviation reached 0 C° or greater) do you detect over the past 450,000 years? What is the average time between interglacials?

   Five times

4. How much has CO_2 varied in the Vostok record? What were the highest and lowest values? What was the range of CO_2 values?

   Max 300 ppm, min 182 ppm, range 118 ppm.

5. What is the period from peak to peak with regard to CO_2 and for temperature for the Vostok record? How does this compare with the period (time from peak to peak) of the EPICA record?

   100,000 to 110,000 years. Very close to the EPICA record.

6. Interglacial–glacial period climate cycles are often referred to as appearing saw-toothed, with an abrupt change followed by a more gradual change. When do we see an abrupt change: when going from interglacial to glacial times or when going from glacial to interglacial times? When do we see a gradual change?

   The abrupt change is seen going from glacial to interglacial conditions, while the return to glacial conditions is more gradual.

7. Why is it important to compare records from different locations? What other locations would you examine to study climate?

   It is important to determine if climatic changes are local, regional, or global. I would also want to examine other high latitude locations, along with mid-latitude and tropical locations.

SECTION 2

Modern Climate

1. What are the general characteristics of the CO_2 data set? What are the maximum and minimum CO_2 concentrations shown in Figure 18.4.? When did the minimum value occur? When did the maximum value occur? What is the general trend in CO_2 values?

   Max 408 ppm in 2016, min 310 in 1959. CO_2 has been steadily increasing since 1959.

2. Compare the CO_2 values from 2006 to 2016 in Figure 18.4 with the CO_2 values on the Vostok plot in Figure 18.2. Are the values for CO_2 levels on the Vostok plot as high as they are now? If so, during which time periods were CO_2 levels as high as they are now? If not, what are the highest values for CO_2 on the Vostok plot?

   The highest values for the Vostok plot are 300 ppm, recorded over 320,000 years ago.

3. Figure 18.5 shows monthly CO_2 values for 2010–2017. The CO_2 values show a short-term pattern of change. How long is the oscillation?

   The shorter pattern lasts 12 months.

4. Which months of the year have the highest and lowest values on Figure 18.5?

   The highest values are recorded in May, the lowest in October.

5. What causes the short-term oscillation of CO_2?

   CO_2 peaks after the northern hemisphere winter, due to low levels of photosynthesis. CO_2 is at its lowest after the northern hemisphere summer, due to high levels of photosynthesis.

6. What are the annual averages for each of the past 3 years?

   2014 398.5, 2015 400.5, 2016 404.5

7. What is the range from each of the past 3 years to the next year? Compare the range within years to the range between years. For example, compare the changes in CO_2 levels in 2010 to the change from 2010 to 2011.

   2014, 2015, and 2016 ranges were 7 ppm during the year, the increase from 2013-2014 was 4,2014-2015 was 4 ppm, 2015-2016 was 4.

8. Calculate the average annual increase as a percentage of total CO_2 and in ppm of CO_2 for 1970 to 1980 and for 2006 to 2016.

   Average increase from 1970-1980 was 5% and 17 ppm, 2006 to 2016 was 6% and 23 ppm.

9. What is the present level of CO_2? What would it be if it were 50% greater?

   Around 409 ppm, 613.5 ppm

10. Based on your calculation for the rate of increase from 2006 to 2016, how long do you estimate it will take for the CO_2 level to reach 450 ppm? How long to be 50% higher than the present level?

    Given a 23 ppm increase from 2006 to 2016, CO2 levels should reach 450 ppm in 25 years.

11. The Kyoto Protocol calls for an overall reduction of greenhouse gases of 5.3% below the 1990 levels. What was the average level of CO_2 in 1990? What would the level of CO_2 be if the Kyoto goal was met? How many ppm below current levels would that be? The "Group of 77" countries favor a 15% reduction below 1990 levels. What would that level be, and how far below present levels is it?

    The CO_2 level in 1990 was 354.16 ppm. To meet the 5.3% reduction goals, the CO_2 level would have to be lower than 335.38 ppm. A 15% reduction would result in CO_2 level of 301.03 ppm, which is almost 100 ppm lower than present level.

12. Dr. James Hansen of NASA has stated that we should set a goal of keeping CO_2 levels below 350 ppm. Which year did we first exceed that level? If we decreased CO_2 levels at the same rate that we have increased them over the past 10 years, how long would it take until CO_2 levels were again below 350 ppm?

    We exceeded 350 ppm in 1987. We could see 350 ppm in 21 years if we reduced levels by 6.4% every 10 years.

In order to examine the effects of volcanic eruptions on climate, we will look at the relationship between temperature and several major eruptions. The dashed line on Figure 18.3 at 1883 represents the eruption of Krakatau. Using colored pencils, draw vertical lines on Figure 18.3 at 1902, 1912, 1963, 1968, 1982, and 1991 to represent each of the above volcanic eruptions.

13. Complete **Table 18.1** for any *three* of the above eruptions. How much of an effect do these eruptions have on global temperatures? How much do they change global temperatures? How many years does it take for the climate to return to a normal temperature after a major eruption?

Answers will vary, depending upon which three years students choose. The eruptions decrease global temperatures by roughly 0.3C° for three years after the eruption.

TABLE 18.1 Major volcanic eruptions since 1867

Date of Eruption	Average Temp Year Before Eruption	Average Temp Year of Eruption	Average Temp 1 Year After Eruption	Average Temp 2 Years After Eruption	Average Temp 3 Years After Eruption
1883 Krakatau	***13.7°C***	***13.7°C***	***13.4°C***	***13.5°C***	***13.3°C***
1902 Soufriere/Pelee/ Santa Maria	***13.8°C***	***13.6°C***	***13.6°C***	***13.5°C***	***13.7°C***
1912 Katmai	***13.7°C***	***13.7°C***	***13.7°C***	***13.9°C***	***13.9°C***
1963 Agung	***14.0°C***	***14.0°C***	***13.7°C***	***13.9°C***	***14.0°C***
1968 Fernandina Island	***14.0°C***	***13.9°C***	***14.0°C***	***14.1°C***	***13.9°C***
1982 El Chichon	***14.4°C***	***14.1°C***	***14.3°C***	***14.2°C***	***14.2°C***
1991 Pinatubo	***14.5°C***	***14.5°C***	***14.2°C***	***14.3°C***	***14.5°C***

SECTION 3

Future Climate

1. **Chicago, Illinois**
   Latitude 41.81°N
   Longitude 87.68°W
   Elevation 182 m
   Population 2,714,856
   Current and projected total annual rainfall:

   902 cm, 106.6 cm

   Current and projected average annual temperature:

   Current and projected annual temperature range:

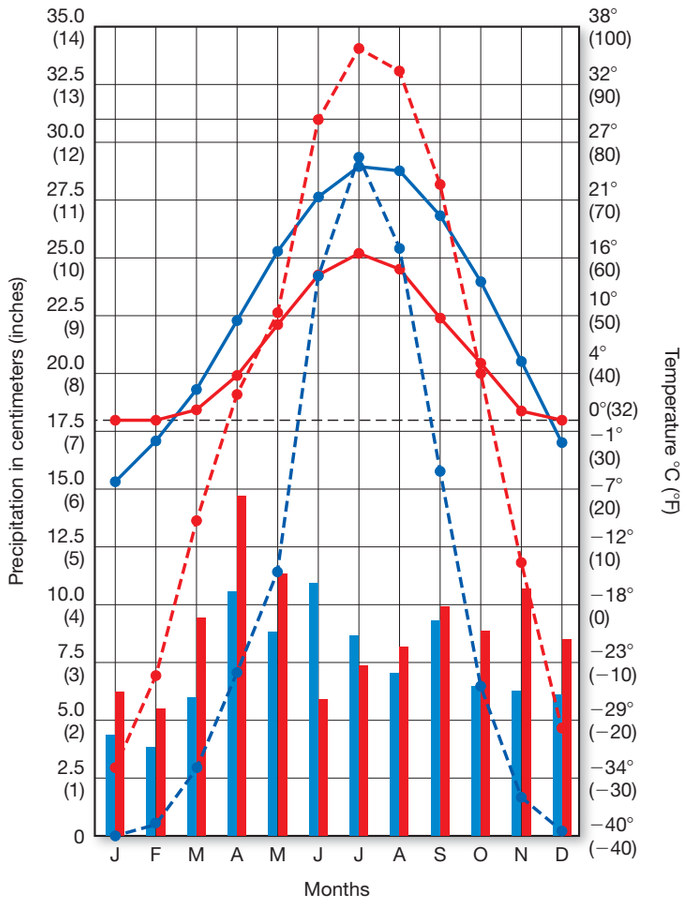
   Current and projected distribution of temperature during the year:

   Current and projected distribution of precipitation during the year:

   rainy all year

   Current and projected distribution of potential evapotranspiration during the year:

   rainy all year



▲ Figure 18.7

2. Current Köppen climate classification symbol: ***Dfa*** :

   Name: ***Humid continental***

   Explanation for this determination: ***Coldest month below 0°C, warmest month above 10°C, year-round precipitation.***

   Projected Köppen climate classification symbol: ***Cfa*** :

   Name: ***Humid subtropical***

   Explanation for this determination: ***Coldest month below 18°C, but above 0°C, year-round precipitation***

3. Compare the position of Chicago, Illinois, in Figure 18.6(a) to the world climate map inside the back cover of this lab manual. What climate classification border is closest to Chicago, Illinois, under current and projected conditions? Describe its future relations to conditions on this map.

Present location: ***At present, Chicago is towards the colder northern border of the Dfa climate zone.***

Projected location: ***It will be in the middle of the Cfa zone.***

4. Using the world biome map outside the back cover of this lab manual or the one in your textbook, determine:

Current representative biome (terrestrial ecosystem) characteristic of the region: ***MB/MF*** ;

Characteristic vegetation: ***Boadleaf and evergreen forest***

Projected representative biome (terrestrial ecosystem) characteristic of the region: ***MB/MF*** ;

Characteristic vegetation: ***Broadleaf and evergreen forest***

5. Evaluate Chicago's current annual March–May, June–August, and September–November water balances. What is the annual surplus or deficit? What are Chicago's projected annual March–May, June–August, and September–November water balances? What is the annual surplus or deficit? Which months have the greatest projected surplus? Which months have the greatest projected deficits?

Current March-May is a surplus of 11.3 cm, projected is a 14 cm surplus. Current June-August is a 14.7 deficit, projected is a 58.3 cm deficit. Current September-November is a 9.5 cm surplus, projected is a 6 cm surplus. The current annual budget is a 21.4 cm surplus, projected is a 19.1 cm deficit. The summer months have the greatest deficit of 58.3 cm.

6. Under moderate climate change scenarios, summer heat index temperatures in the twenty-first century are expected to rise in the American Midwest in a range between 2.7 C° and 13.8 C° (5 F° and 25 F°). A heat wave, similar to the 2003 heat wave that resulted in more than 70,000 deaths across Europe, could result in a tenfold increase in heat-related deaths in Chicago. How do you think this will affect air conditioning demand and related costs? What are your concerns, and what actions would you take if you were a Chicago public health official?

Personal answers

7. Go to www.globalchange.gov and find the National Climatic Assessment report for your region. Briefly summarize the impacts for your region on temperature, precipitation, heat waves, agricultural productivity, and any other significant changes. How are patterns of rainfall projected to shift? For example, will they stay the same, or will there be longer periods of no rain followed by heavy rain and flooding?

Personal answers