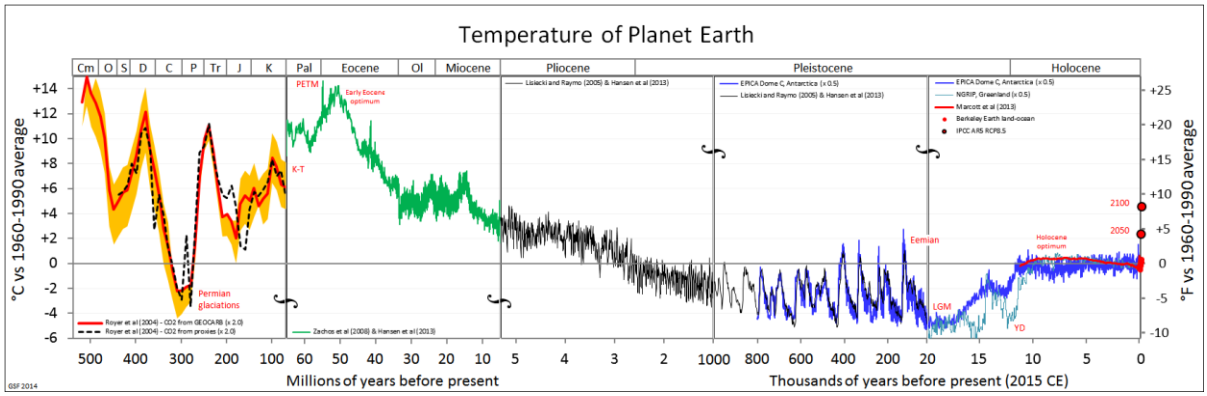
GEO 302C FINAL EXAM Spring 2016 Name_____

(White Version)

You may not refer to any other materials during the exam. For each question (except otherwise explicitly stated), select the ***best*** answer for that question. Read all choices carefully before selecting an answer and make sure your choice answers the question asked.

The following figure shows estimates of the Earth's temperature anomalies (differences) over the past 500 million years (My) relative to the modern climate (1960–1990 average) which is about 14°C / 57°F, in both Celsius (left) and Fahrenheit (right). Time is plotted backwards from the present, taken as 2015 CE. It is scaled *linear* in five separate segments, expanding by about an order of magnitude at each vertical break. The breaks are not evenly distributed; rather they are positioned at geologically relevant times: ~ 65 My ago, ~5.3 My ago, 1 million years ago, and 20,000 years ago.



1. Which of the following correctly describes the above figure?
   A. the climate over most of the past 500 million years is warmer than today.
   B. the past 60 million years show an overall cooling trend.
   C. the climate over most of the past 3 million years is colder than today.
   D. the climate over the past 20 thousand years has shown an overall warming trend.
   E. all of the above.

2. The above figure clearly shows tectonic-scale climate change
   A. in the left two segments.
   B. in the right two segments.
   C. in the rightmost segment.
   D. over the past 100 years.

3. The above figure clearly shows orbital-scale climate change
   A. over the past 500 million years
   B. over the past 1 million years.
   C. over the past 1000 years.
   D. over the past century.

4. The noteable "The Year Without a Summer" came after which volcanic eruption?
   A. Mt. St. Helen's
   B. Mt. Pinatubo
   C. Mt. Pompei
   D. Mt. Tambora

5. Which of the following is correct about global warming?
   a. Global warming is an increase in Earth's surface temperature brought about by a combination of human activities and natural forces.
   b. The most pervasive, and at the same time controversial, environmental change that is occurring today is global warming.
   c. The global warming issue is extremely complex, because it involves many different parts of the Earth system.
   d. The global warming issue is controversial because it is difficult to separate anthropogenic influences from natural ones and because its causes are deeply rooted in our global industrial infrastructure.
   e. All of the above.

6. Which of the following is correct about El Niño and/or La Niña?
   a. El Niño is a large-scale oceanic cooling of the eastern tropical Pacific Ocean.
   b. During El Niño, easterly trade winds strengthen.
   c. During La Niña, atmospheric pressure over the eastern tropic Pacific Ocean is weaker than its normal high.
   d. Both El Niño and La Niña are a phenomenon in the Pacific Ocean, so they do not influence weather and climate around the world.
   e. During La Niña, Texas tends to experience more droughts.

7. Consider the study of past climate change and determine which of the following is (are) correct.
   a. The resolution of proxy records is generally greater in the recent past than for the distant geologic past.
   b. The types of proxy records available are generally more diverse in the recent past than they are for the distant geologic past.
   c. Climate proxies allow scientists to directly read the temperature of the past.
   d. Both A and B are correct.
   e. Both A and C correct.

8. In a living tree ring there is one ^{14}C atom for every 600 billion atoms of stable carbon isotopes. We know that the half life $t_{1/2}$ = 5730 years. ^{14}C was analyzed in a tree ring from a glacial moraine in central Canada. In this sample there is one ^{14}C atom for every 1200 billion stable carbon atoms (i.e., only 1/2 as much ^{14}C). What is the ^{14}C age of the tree that grew on glacial moraine?
   a. zero years (i.e., modern)
   b. 5730 years
   c. 11,460 years
   d. 22,920 years
   e. 1,200 years

9. By analyzing records taken from proxy sources, scientists can extend our understanding of climate far beyond the 140 year instrumental record. The proxy sources include
   a. science fiction, dreams, and video tapes
   b. historical documents, tree rings, corals, ice cores, and ocean sediments
   c. speleothems
   d. b and c only
   e. a and c only

10. Ice cores are valuable climatic archives because
    a. The ice contains geochemical proxies of atmospheric ozone of the past.
    b. The ice contains geochemical proxies of temperature of the past
    c. The geographic distribution of coring sites ranges from both polar regions to the tropics (e.g. tropical high mountains).
    d. Both A and B
    e. Both B and C

11. Which of the following statements is true about glacial and interglacial periods?
    a. During the past half million years or so, ice sheets have peaked about every 100,000 years.
    b. Earth's climate tends to drift slowly into the peak of glacial periods which is rapidly terminated by sudden warming.
    c. During glacial periods, the level of the oceans dropped from their present levels by about 100 meters.
    d. During colder glacial periods, CO_2 levels were lower than during warmer interglacial periods.
    e. All of the above.

12. Which of the following is a greenhouse gas?
    A. Nitrous oxide (N_2O)
    B. Nitrogen dioxide (NO_2)
    C. Oxygen
    D. Nitrogen
    E. Sulfur dioxide

13. Which of the following is true about the Milankovitch Cycles?
    a. They explain glacial and interglacial intervals during the current Icehouse climate period.
    b. One part of the cycle is the change in the tilt of the Earth about every 1,000 years.
    c. One part of the cycle is the change in the shape of Earth's orbit over time scales of 10,000 years.
    d. One part of the cycle is the wobbling of the spin axis about every 100,000 years.
    e. The cycles have been supported by the trends of atmospheric O_2, O_3, and rainfall as recorded in the Antarctic ice core.

14. Erupting volcanoes can send tons of particles into the atmosphere, along with vast amounts of _____?
    a. Water vapor, carbon dioxide, and sulfur dioxide
    b. Oxygen, ozone, and CFCs
    c. Methane, CFCs, and sulfur dioxide
    d. Ozone, CFCs, and sulfur dioxide
    e. Carbon dioxide, CFCs, and sulfur dioxide

15. The water vapor-temperature rise feedback is a positive feedback because the initial _____ in temperature is _____ by *the addition of more water vapor*.
    a. decrease, unaltered
    b. increase, weakened
    c. decrease, reinforced
    d. increase, reinforced
    e. none of the above

16. Which of the following is true?
a. when ocean water evaporates, oxygen 16 tends to be left behind
b. oxygen 18 and oxygen 16 are found in roughly equal amounts in ocean water
c. the nucleus of oxygen 18 contains two more neutrons than the nucleus of oxygen 16
d. only oxygen 18 is found in the shells of marine organisms
e. a lower ratio of oxygen 18 to oxygen 16 in the marine sediment record suggests a colder climate

17. Which of the following is in the correct sequence from long to short term effects on climate?
A. ENSO – mountain building – eccentricity – obliquity – precession – thermohaline circulation
B. mountain building – eccentricity – precession – obliquity – thermohaline circulation – ENSO
C. mountain building – thermohaline circulation – eccentricity – obliquity – precession – ENSO
D. mountain building – eccentricity – obliquity – precession – thermohaline circulation – ENSO
E. mountain building – obliquity – eccentricity – precession – thermohaline circulation – ENSO

18. Solstices are
A. The degree of departure from a perfectly circular orbit
B. The position farthest from the Sun (the "distance pass" position)
C. The tilt of Earth's axis
D. The shift of the positions of the equinoxes with respect to Earth's eccentric orbit
E. The longest or shortest days of the year

19. Which of the following is correct to describe the surface air temperature trend over the past century?
a. Warming greatest in the tropics in the winter
b. Warming greatest in the tropics in the summer
c. Warming greatest in the mid-to-high latitudes in the winter
d. Warming greatest in the mid-to-high latitudes in the summer
e. None of the above because the temperature change will be globally uniform

20. The observed global mean surface air temperature has increased by about 1°C since the late 19th century. This warming trend is consistent with
A. a decreasing trend in the Northern Hemisphere snow cover
B. a decreasing trend of global sea level
C. a decreasing trend of atmospheric carbon dioxide
D. all of the above
E. none of the above

21. Water vapor is:
a. a gas
b. a cloud droplet
c. a rain drop
d. a snowflake
e. an ice crystal

22. The longest instrument records of regional temperature come from
a. Antarctica
b. America
c. Australia
d. Asia
e. England

23. What percent of the 1ºC global warming since the late 1800s can be attributed to long-term tectonic-scale climatic forcing?

a. 50%
b. 25%
c. 5%
d. 1%
e. Negligible

24. In January, at middle latitudes in the Northern Hemisphere, the day is ___ long and is ___ with each passing day.

a. less than 12 hours, getting longer
b. less than 12 hours, getting shorter
c. more than 12 hours, getting longer
d. more than 12 hours, getting shorter

25. Which of the following values best describes today's level of CO_2 in the atmosphere?

a. 1200 ppm
b. 2400 ppm
c. 600 ppm
d. 200 ppm
e. 400 ppm

26. Which of the following is a *negative* feedback that is taken into account in climate model temperature sensitivity tests of a doubling of CO_2?

a. Effect of water vapor
b. Effect of CO_2
c. Effect of snow and ice albedo
d. Effect of thick, low clouds
e. Both A and C

27. In climate science, the word insolation refers to:

a. a well-constructed, energy-efficient home
b. the solar constant
c. incoming solar radiation
d. an increase in solar output

28. If the average snowfall over an area of north central Canada is 1 meter per year, how long would it take for the snow to reach a depth of 1000 meters? (Assume that there is no melting in summer and no compaction)

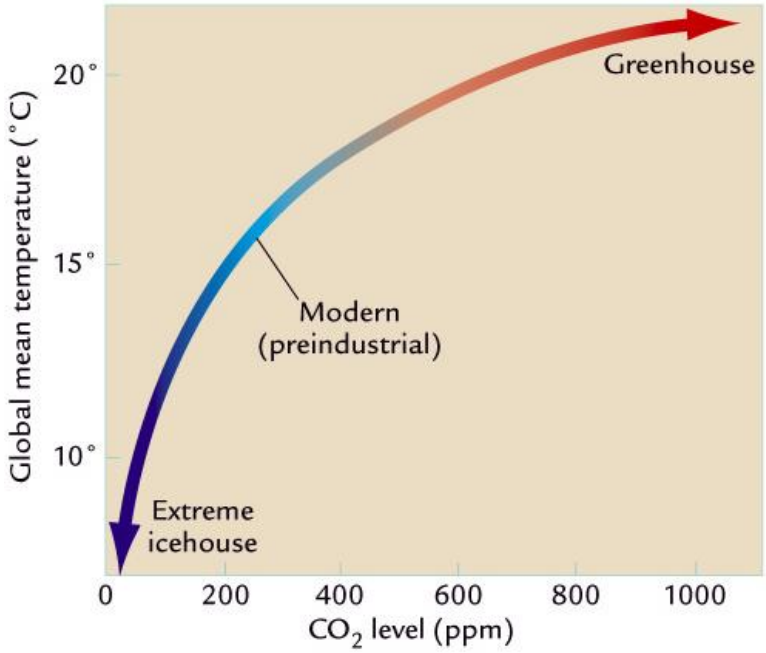
a. 10 years
b. 1,000 years
c. 10,000 years
d. 100,000 years
e. 10,000,000 years

29. Which of the following causes global sea level to rise?

a. Sea ice formation
b. Global cooling
c. Ice sheet formation
d. Thermal expansion of water molecules
e. Both B and C

30. During the Pleistocene epoch:
   a. continental glaciers continuously covered large parts of North America and Europe
   b. it was much warmer than now
   c. continental glaciers alternately advanced and retreated over large portions of North America and Europe.
   d. tropical vegetation was growing over vast regions of the Central Plains of North America.

31. What do the GCM sensitivity test results summarized in the following figure show?



   a. Greater warmth for higher CO_2 concentrations
   b. A linear (i.e. straight line) relationship between CO_2 and global mean temperature
   c. That a doubling of pre-industrial CO_2 levels would increase global mean temperature by about 1ºC
   d. All of the above
   e. Both A and B

32. If there were no anthropogenic aerosols in the atmosphere, the magnitude of current global warming caused by greenhouse gases would be
   a. greater than what is observed.
   b. less than what is observed.
   c. unchanged.

33. The most abundant greenhouse gas in the earth's atmosphere:
   a. carbon dioxide (CO_2)
   b. nitrous oxide (N_2O)
   c. water vapor (H_2O)
   d. methane (CH_4)
   e. chlorofluorocarbons (CFCs)

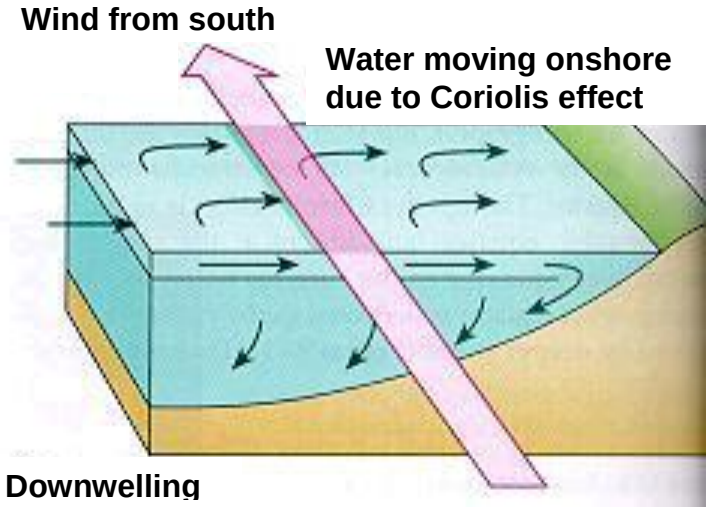
34. The Laurentide ice sheet was
    A. The boundary between the upper area of positive ice mass balance and the lower area of net loss of ice mass
    B. The ice sheet in northern Europe
    C. The deep frozen ground caused by the harsh winter cold and sparse snow cover
    D. The ice sheet centered on east-central Canada
    E. The ice sheet over the Rockies in the American West

35. Plate tectonics "explains" certain climatic changes by showing that these changes may be related to:
    a. mountain building
    b. the amount of CO_2 and H_2O released into the atmosphere
    c. the paths taken by ocean currents
    d. the position of the continents
    e. all of the above

36. What is the force that initially sets the air in motion?
    a. Coriolis force.
    b. Frictional force.
    c. Pressure gradient force.
    d. Earth's rotation.
    e. None of the above.

37. In the Earth's climate system, the term longwave radiation refers to
    a. The incoming solar radiation received by Earth
    b. The outgoing radiation emitted by Earth
    c. The albedo of Earth
    d. Solar radiation reflected by Earth's clouds
    e. Both A and D

38. The figure below refers to the relationship between wind and ocean currents occurring in
    A. Northern Hemisphere.
    B. Southern Hemisphere.



39. The PDO is
A. A computer model that can be used to study climate change
B. A low-pressure belt near the equator where air converges
C. A phenomenon in the tropical Pacific Ocean that can impact climate worldwide
D. Atmospheric pressure oscillations in the north Atlantic that influences climate in Europe and the United States
E. A phenomenon in the north Pacific Ocean where atmospheric pressure oscillates on decadal time scales

40. Ekman is the family name of a scientist who
A. first observed a north-south giant convection cell in the tropics
B. discovered an east-west giant convection cell in the tropics
C. first calculated that the moving subsurface seawater is turned with depth, progressively farther to the right in the northern hemisphere
D. found orbital-scale oscillations in ice sheets
E. discovered the ozone hole

41. Why has Earth remained habitable throughout its history?
a. Because chemical weathering of continental rocks both responds to and modifies the level of CO_2 greenhouse gases in the atmosphere over geologic time scales
b. Because it is exactly the right distance from the Sun
c. Because Earth is balanced between warming and cooling as it rotates on its axis
d. Because the incoming radiation from the Sun has been constant over time
e. Both B and D

42. Which of the following would be an appropriate archive for reconstructing what the climate was like 50 Myr ago?
a. Ice cores
b. Instrumental records
c. Tree rings
d. Ocean sediments cores
e. All but C

43. The climate of the last 1 million years can be characterized as:
a. mostly warm and without ice sheets on Earth
b. mostly cold but with a strong warming trend
c. mostly warm but with very strong glacial periods
d. mostly cold with relatively short warm periods
e. similar to the climate 100 million years ago

44. The science of reconstructing past climates advances best when
a. Mismatched data from geologic archives and model outputs are disregarded or thrown out
b. Climate modelers distance themselves from field geologists who collect proxy data
c. The strengths and limitations of both the data derived from geologic archives and the models are constantly tested against one another
d. All of the above
e. Both B and C

45. When it is January and winter in the Northern Hemisphere, it is ____ and ____ in the Southern Hemisphere.
    a. January and winter
    b. January and summer
    c. July and winter
    d. July and summer

46. Which of the following weather elements always decreases as we climb upward in the atmosphere?
    a. wind
    b. temperature
    c. pressure
    d. moisture
    e. all of the above

47. The ozone layer is located
    a. near the ground
    b. near the urban areas
    c. in the troposphere
    d. in the stratosphere
    e. none of the above

48. The word "weather" is defined as:
    a. the average of the weather elements
    b. the climate of a region
    c. the condition of the atmosphere at a particular time and place
    d. any type of falling precipitation
    e. the condition during chemical weathering

49. The wind direction is:
    a. the direction from which the wind is blowing
    b. the direction to which the wind is blowing
    c. always directly from high toward low pressure
    d. always directly from low toward high pressure
    e. the same as the pressure gradient force

50. Which of the following is **not** true in describing ocean sediments?
    a. Ocean sediments have the best resolution to describe how El Niño has evolved over tens of millions of years.
    b. Ocean sediments contain key indicators of past glaciations: ice-rafted debris, $\delta^{18}O$ records, and $\delta^{13}C$ records.
    c. Ocean sediments are available in the northern Atlantic Ocean only.
    d. All of the above.
    e. a and c only.

51. Which TA gave two guest lectures for this course during the semester?
    a. Maryia Halubok
    b. Seungwon Chung
    c. Sagar Parajuli
    d. All of the above
    e. None of the above.

52. Tree rings
a. can reveal how methane varied over the last few tens, hundreds, or (in exceptional cases) thousands of years.
b. are best developed in the tropics where it is pleasantly warm and wet.
c. can tell us about a wide range of past climate conditions including rainbow, salinity, wind direction, and atmospheric pressure.
d. are a good indicator of how fast the ocean-floor is spreading.
e. are a useful proxy for rainfall and temperature in the past.

53. Thick sheets of ice advanced over North America as far south as New York as recently as:
a. 1816 ("the year without a summer")
b. 1550
c. 18,000 to 22,000 years ago
d. 2 million years ago, at the beginning of the Pleistocene epoch

54. The thermohaline circulation
a. is also referred to the meridional overturning circulation.
b. can potentially be weakened by global warming, thereby leading to cooling or lesser warming in western Europe.
c. has never experienced shutdowns or slowdowns before, even during the Younger Dryas.
d. both A and B are correct.
e. both B and C are correct.

55. How do CO_2 oscillations from ice cores compare with changes in ice volume, as recorded by $\delta^{18}O$ records in marine sediments?
a. CO_2 is high when ice volume is high.
b. CO_2 is low when ice volume is high.
c. CO_2 lags ice volume by 41,000 years.
d. CO_2 shows small changes at glacial to interglacial transitions.
e. Both B and D are correct.

56. During a period when the earth's orbital tilt is at a minimum, which would probably **not** be true?
a. there should be less seasonal variation between summer and winter
b. more snow would probably fall during the winter in polar regions
c. there would be a lesser likelihood of glaciers at high latitudes
d. there would be less seasonal variations at middle latitudes

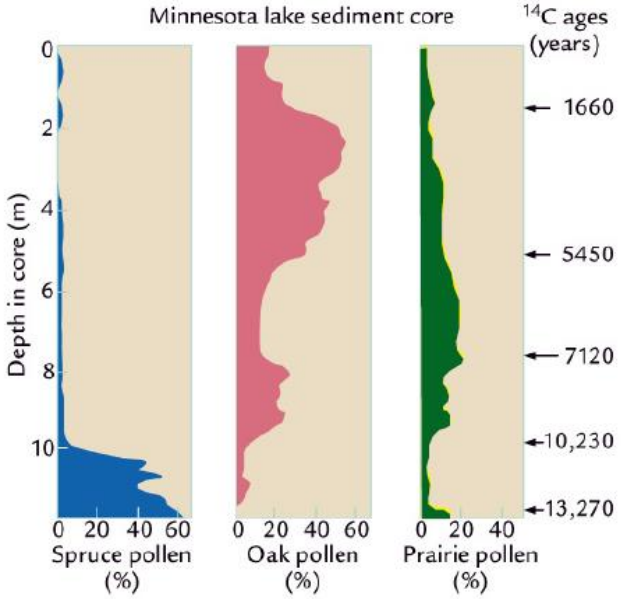
57. Which of the following factors helps explain the colder and drier glacial maximum climate compared to today?
a. Lower greenhouse gas levels
b. Large ice sheet feedbacks
c. Both of the above

58. Which of the conditions below would most likely produce warming at the earth's surface?
a. increase the amount of low-level global cloudiness (e.g. stratus)
b. increase the number of La Niña events
c. decrease the energy output of the sun
d. increase the amount of global snow cover
e. decrease the amount of global cryosphere coverage

59. The sunspot numbers
   a. are a useful indicator of my test score today.
   b. can be used to predict if next week's weather is good enough for me to play golf.
   c. are the most important source for pinpointing the past variations of atmospheric carbon dioxide.
   d. correlate with frequency of large volcanic explosions.
   e. show an 11-year cycle whose longer-term average resembles observed temperature changes during the 20th century.

60. Clouds often form in the:
   a. rising air in the center of a low pressure area
   b. rising air in the center of a high pressure area
   c. sinking air in the center of a low pressure area
   d. sinking air in the center of a high pressure area
   e. none of the above

61. Examine the following figure and determine which of the following statements is a logical interpretation of the southeast Minnesota lake pollen record.



   a. Climate was driest between ~12,000 and 10,000 years ago.
   b. Climate became wettest at ~6000 years ago.
   c. Climate was the warmest between ~5000 and ~1000 years ago.
   d. There is more spruce than oak in southeast Minnesota today
   e. Both A and C are correct.

62. The Vostok ice core was extracted from
   a. Alaska
   b. Tibet
   c. Greenland
   d. Russia
   e. Antarctica

63. Suppose last night was clear and calm. Tonight low clouds will be present. Assuming everything else is the same, from this you would conclude that tonight's temperature will be:
    a. higher than last night's temperature
    b. lower than last night's temperature
    c. the same as last night's temperature
    d. above freezing
    e. near boiling

64. If the present concentration of CO_2 doubles in 100 years, and climate models predict that for the earth's average temperature to rise 5°C, what gas must also increase in concentration?
    a. nitrogen
    b. oxygen
    c. ozone
    d. water vapor
    e. noble gas

65. The albedo of the earth's surface is only about 4%, yet the combined albedo of the earth and the atmosphere is about 30%. Which set of conditions below best explains why this is so?
    a. high albedo of clouds, low albedo of water
    b. high albedo of clouds, high albedo of water
    c. low albedo of clouds, low albedo of water
    d. low albedo of clouds, high albedo of water

66. During the last glacial maximum, where was the highest rate of deposition of ice-rafted debris in the North Atlantic Ocean?
    a. Near the Arctic Circle
    b. Near their sources areas in Greenland and Canada
    c. Near their source areas in Scandinavia and Iceland
    d. Where the icebergs first encountered warm water, at 45–50°N
    e. Where the icebergs first encountered warm water, at 5–15°N

67. The Viking colony in Greenland perished during:
    a. the Younger Dryas
    b. the Little Ice Age
    c. the explosion of Mt. Pinatubo
    d, the Last Glacial Maximum
    e. the Industrial Revolution

68. The earth is tilted at an angle of 23.5° with respect to the plane of its orbit around the sun. If the amount of tilt were increased to 40°, we would expect in middle latitudes:
    a. hotter summers and colder winters than at present
    b. cooler summers and milder winters than at present
    c. hotter summers and milder winters than at present
    d. cooler summers and colder winters than at present
    e. no appreciable change from present conditions

69. In Honolulu, Hawaii (latitude 21°N), you would most likely experience winds blowing from the:
    a. northeast
    b. south
    c. southwest
    d. northwest

70. A high concentration of oxygen 16 found in the ice caves of Antarctica and Greenland would indicate ___ at the time the ice was formed.
    a. cold air temperatures
    b. mild winters
    c. intense ultraviolet radiation
    d. the caves were under the ocean

71. Which of the conditions below would <u>most likely</u> produce warming at the earth's surface?
    a. increase the area covered by deserts
    b. increase the amount of sulfur-rich particles in the stratosphere
    c. decrease the energy output of the sun
    d. increase the amount of global snow cover
    e. increase the frequency and intensity of El Nino events

72. The Milankovitch Theory proposes that climatic changes are due to:
    a. variations in the earth's orbit as it travels through space
    b. volcanic eruptions
    c. changing levels of CO_2 in the earth's atmosphere
    d. particles suspended in the earth's atmosphere
    e. all of the above

73. Which statement below is <u>not</u> correct concerning the Coriolis force?
    a. It causes the winds to deflect to the right in the Northern Hemisphere
    b. It is zero at the equator
    c. It can cause winds to change direction, but not to increase or decrease in speed
    d. It deflects winds in opposite directions in the Northern and Southern Hemispheres
    e. It modulates the concentrations of atmospheric carbon dioxide

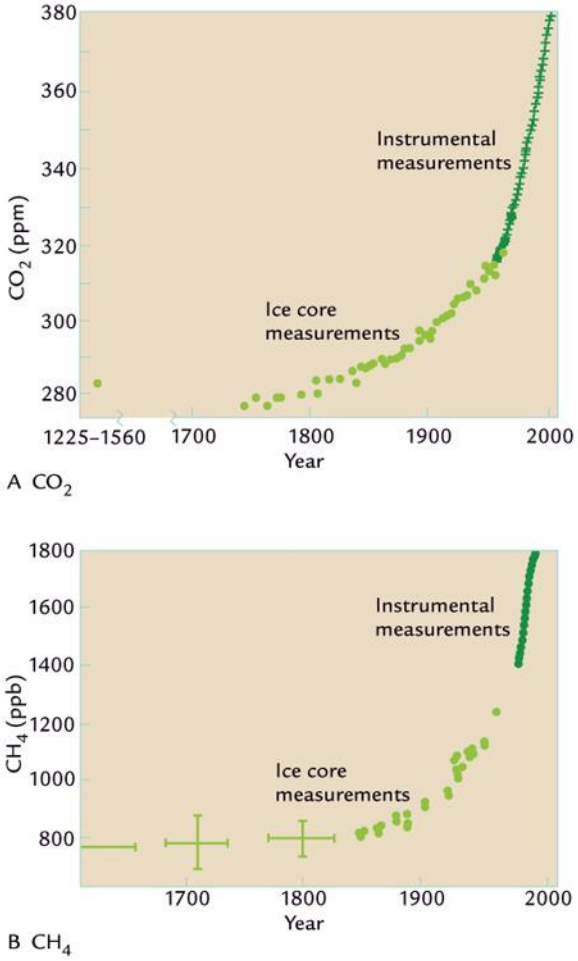
74. A Heinrich event is
    A. a period of sudden big drop in temperature during the middle of the last deglaciation in the North Atlantic region
    B. a period of very few sunspots during 1645–1715 A.D.
    C. a period between 1400–1900 A.D. when Europe was colder than today
    D. an interval of rapid flow of icebergs into the North Atlantic, causing deposition of debris eroded from land
    E. 2000–7000-year oscillations recorded in Greenland ice during glacial intervals

75. The most recent IPCC assessment report is also known as _____.
    a. First Assessment Report (FAR)
    b. Second Assessment Report (SAR)
    c. Third Assessment Report (TAR)
    d. Fourth Assessment Report (AR4)
    e. Fifth Assessment Report (AR5)

76. Earth's seasons are caused by
    a. The rate of Earth's spin around its axis
    b. The distance between Earth and the Sun
    c. The rate of Earth's movement around the Sun
    d. The changing position of the tilted Earth with respect to the Sun
    e. The interaction of the Moon and Sun on Earth's orbit

77. When is Earth closest to the Sun in its present orbit?
   a. During the northern hemisphere's winter
   b. During the southern hemisphere's winter
   c. During the northern hemisphere's fall equinox
   d. During the southern hemisphere's spring equinox
   e. A and C only

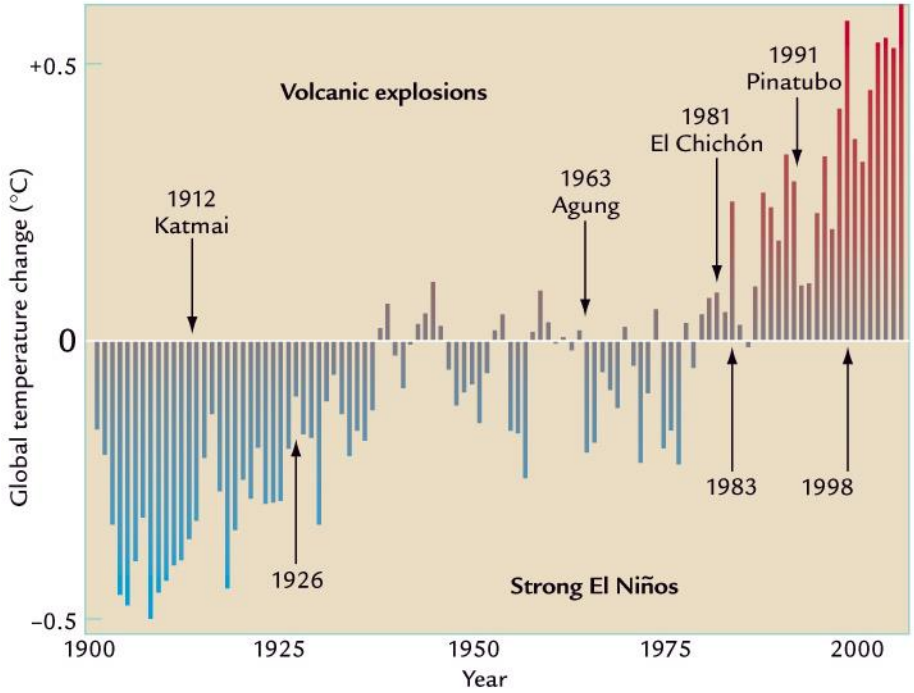
78. Examine the following figure and determine which statement correctly describes the information shown.



   a. Atmospheric CO_2 levels since 1700 have risen linearly (i.e. like a straight line).
   b. Instrumental measurements of CO_2 and CH_4 disagree with ice core measurements prior to 1950.
   c. Concentrations of CH_4 are much greater than those of CO_2 in the atmosphere.
   d. Levels of CO_2 and CH_4 are higher today than at any time in the past several hundred years.
   e. None of the above is correct.

79. Where does most of CO_2 produced by *humans* go?
   a. The atmosphere
   b. The biosphere
   c. Glaciers and ice sheets
   d. Oceans

80. Examine the following figure and determine which of the following statements is correct.



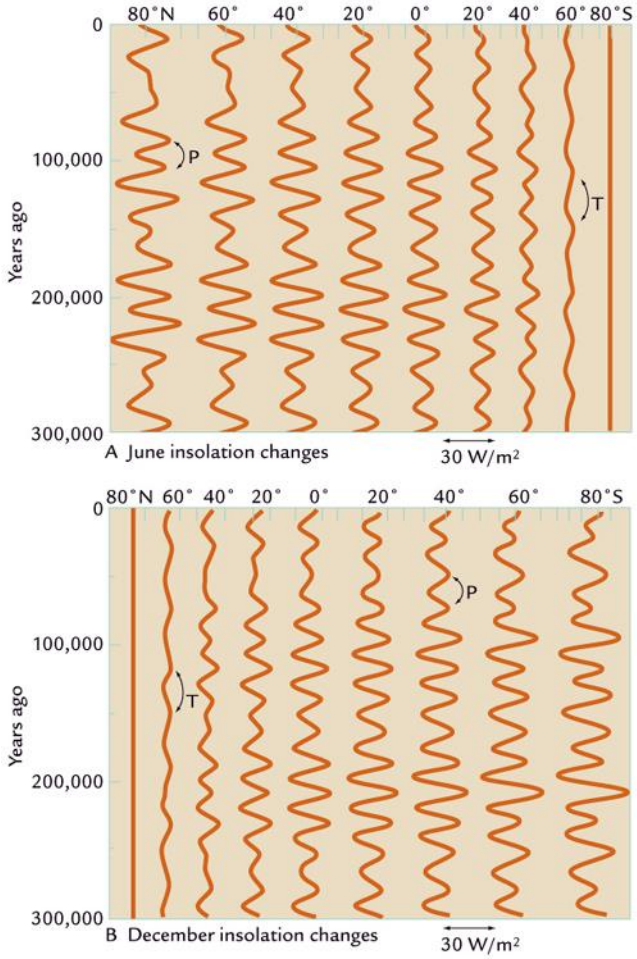
a. The effect of large volcanic explosions is not detected by instrumental temperature records.
b. The effect of large volcanic explosions contributed to the long-term baseline warming trend.
c. Large volcanic explosions caused short-term coolings, but had no effect on the long-term warming trend.
d. Strong El Niños contribute to the long-term baseline warming trend.
e. Both B and D are correct.

81. The melting of mountain glaciers will result in GLOFs. Where will this likely occur?
a. The Andes
b. South Asia
c. Iceland
d. The Alps
e. All of the above

82. Which of the following statements is true about climate change and global warming?
a. "True, climate changes year to year, but over a long period of time, climate does not change."
b. "Today's global average temperature is greater than 100 Myr ago."
c. "The *rate* of current global warming is greater than at any time in the past millions of years."
d. None of the above
e. All of the above

83. Oxygen isotopic ratios ($\delta^{18}O$) from ocean water recorded in foraminifera shells can tell us
a. the volume of continental ice sheets
b. the temperature of ocean water in which the shells form
c. wind directions
d. the ozone layer
e. both a and b

84. Examine the following figure to determine which of the following statements best describes your observations.



a. Low-latitude insolation is dominated by an orbital obliquity cycle in both June and December.
b. Eccentricity cycles of insolation change are dominant variation overall.
c. At any particular time, the northern hemisphere's insolation in June essentially matches that of the southern hemisphere's insolation in December.
d. The greatest changes in insolation in the high latitudes occur in the winter.
e. Both C and D only

85. At the northern hemisphere summer solstice
a. The sun is lowest in the sky in the northern hemisphere
b. The sun is highest in the sky in the northern hemisphere
c. The Earth's rotational axis is neither tilted toward or away from the Sun, but is parallel to the direction of Earth's orbit
d. The Antarctic Circle receives 24 hours of sunlight
e. None of the above

86. If measurements of $\delta^{18}O$ from ocean sediments show a long-term trend toward more <u>negative</u> values (or ^{16}O-depleted), this tells us a long-term _____ trend.
a. cooling
b. warming

87. What accounts for the sea level rise of the twentieth century?

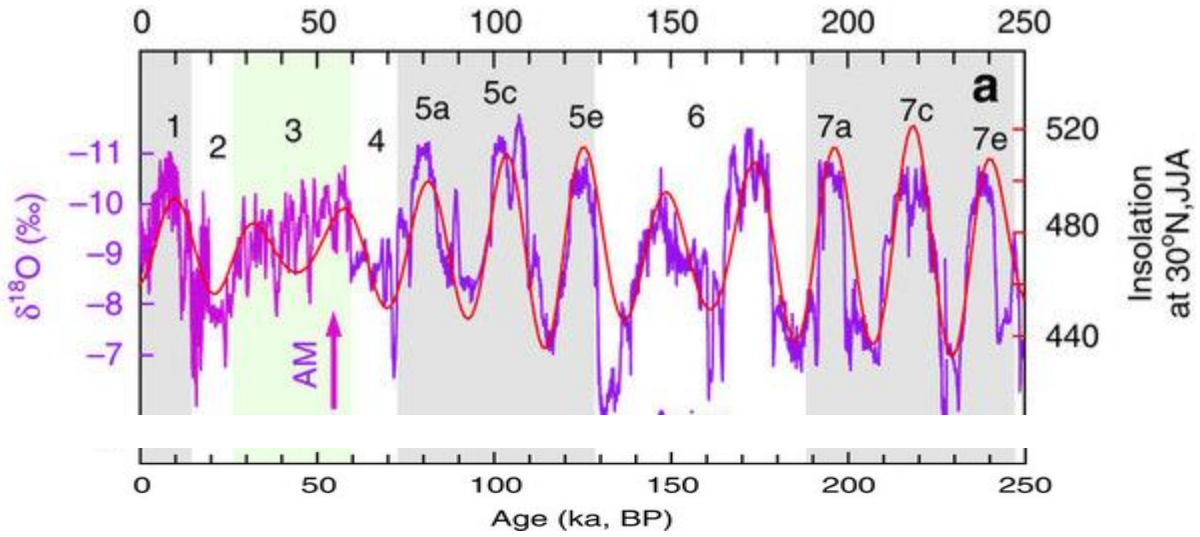
a. Melting of sea ice
b. Melting of land-based ice (e.g. glaciers and ice sheets)
c. Thermal expansion of sea water
d. Both A and B
e. Both B and C

88. Which of the following climate processes do **not** exist across tectonic, orbital, deglacial/millennial, historical, and recent global warming timescales?

a. Greenhouse effects
b. Hydrological cycles
c. Anthropogenic influences
d. Hadley Cells
e. Ice and albedo feedbacks

89. The figure below compares variations of summer insolation against $\delta^{18}O$ of $CaCO_3$ in a cave in China. Does increased insolation cause a stronger or weaker monsoon?

a. weaker
b. stronger



90. Why do you think the $\delta^{18}O$ variations in a cave (in the above figure) reflect monsoon variability?

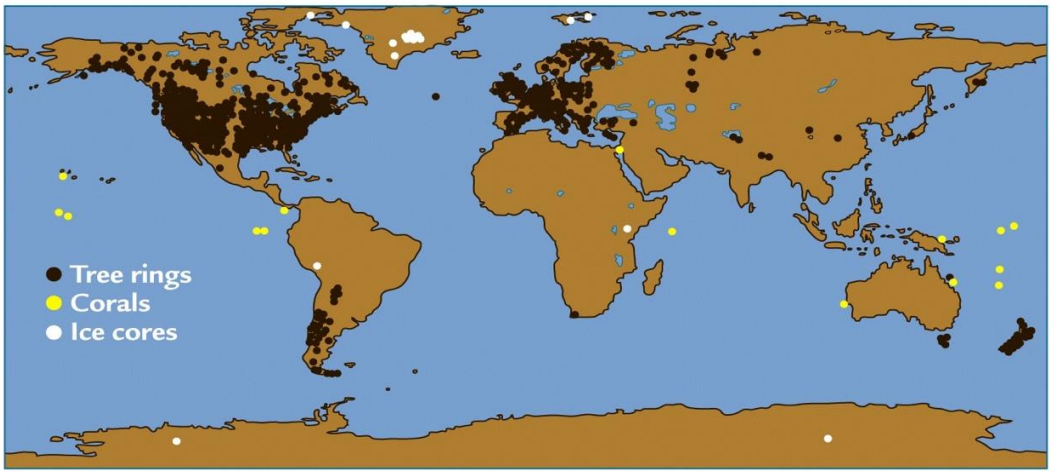
a. This is because the insolation changes in the past 250 ka affect the luminosity inside the cave.
b. This is because the monsoonal changes affect the circulation patterns inside the cave.
c. This is because the $\delta^{18}O$ of $CaCO_3$ reflects the $\delta^{18}O$ of drip water, which is directly driven by the monsoonal rainfall changes.
d. All of the above.
e. None of the above.

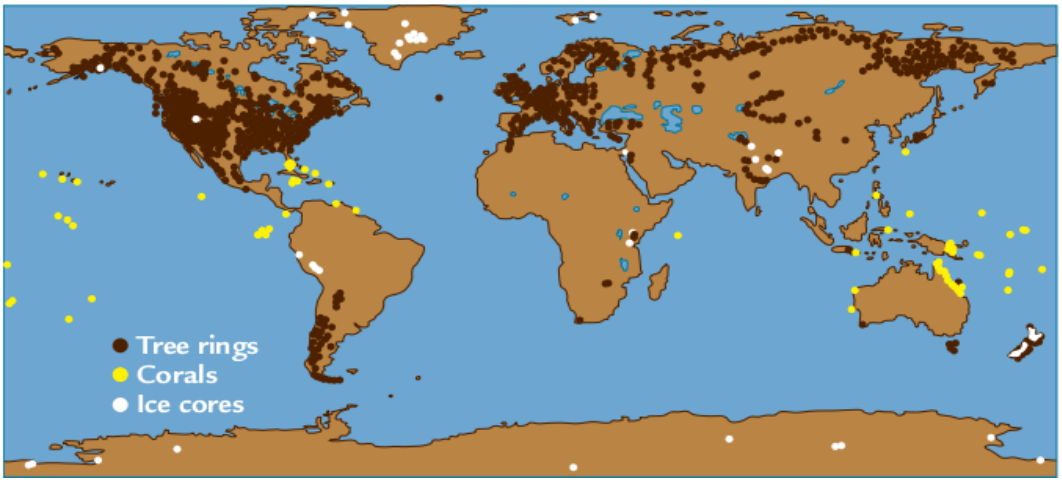
91. During the Last Glacial Maximum, summer insolation is not significantly different from that today.

a. True
b. False

92. Which of the following is evidence for warming of the middle and high northern latitudes?
    a. Decrease in northern mid- to high-latitude snow cover or glaciers
    b. Increase in the length of the growing season in Alaska
    c. Melting of the Greenland ice sheet
    d. All of the above
    e. A and C only

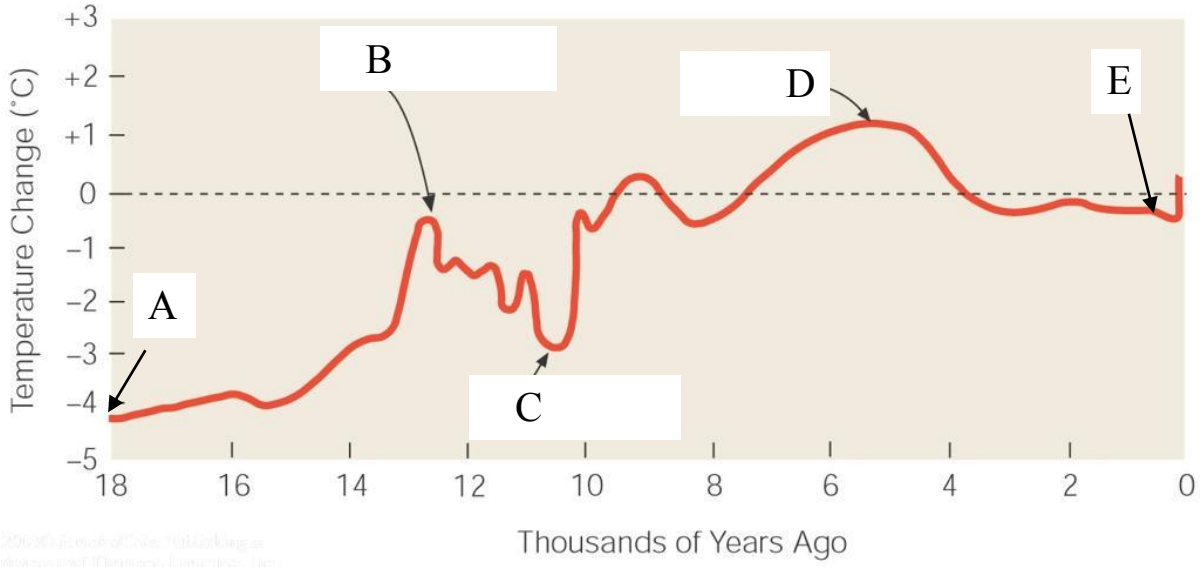
93. The following two figures show the locations of tree tings, corals and ice cores. They were talked about in class and used as one of in-class home works. Which of the following statements is true about the differences in the two figures?
    a. The bottom figure has more tree rings because global warming promotes more tree growth at mid- to high latitudes and in the high-elevation mountainous regions.
    b. The top figure has less corals because the increased oceanic acidity associated with higher atmospheric CO_2 kills corals.
    c. The decrease in ice cores in the top figure compared to the bottom figure is due to climate change induced ice melt.
    d. Because the climate-related phenomena are recorded in Earth's history, the bottom figure, which was made a few years later than the top one, likely had a more climate friendly environment for producing more data points.
    e. none of the above.





94. Critics of global warming have strong supporting evidence in
    a. Weather balloon atmospheric temperature measurements
    b. Satellite estimates of sea surface temperature
    c. Satellite estimates of tropospheric temperature
    d. All of the above
    e. None of the above because the full range of instrumental and satellite data now indicate major warming occurred over the last century

The figure below describes the average air temperature changes for the past 18,000 carbon-14 years. Refer to this figure to answer the remaining questions.



95. Data used in the figure were mainly from
    a. a 2004 American climate science fiction disaster film "*The Day After Tomorrow*"
    b. the winter landscape painting by Pieter Bruegel the Elder, *The Hunters in the Snow*, 1565, oil on wood, Kunsthistorisches Museum
    c. tree rings in the United States and Europe
    d. well-dated magnetic fields for seafloor in the Atlantic Ocean
    e. none of the above

96. The Little Ice Age is marked by ____ in the figure.
    A
    B
    C
    D
    E

97. The Younger-Dryas is marked by ____ in the figure.
    A
    B
    C
    D
    E

98. The Last Glacial Maximum is marked by ____ in the figure.
A
B
C
D
E

99. The Holocene Maximum is marked by ____ in the figure.
A
B
C
D
E

100. The Bolling-Allerod is marked by ____ in the figure.
A
B
C
D
E