

1. What is meant by the term “climate forcing?” How is it related to climate “response?”
2. Name two processes that can change the total amount of absorbed solar radiation.
3. Name two processes that can change the amount of outgoing longwave radiation from the Earth.
4. Name two processes that cause positive climate forcing.
5. Name two processes that can cause negative climate forcing.
6. What is meant by “climate sensitivity” to radiative forcing?
7. How much radiative forcing (in  $\text{W m}^{-2}$ ) do we expect for each doubling of atmospheric  $\text{CO}_2$ ?
8. What is climate feedback? Give an example of a positive and a negative climate feedback
9. *Without* climate feedback, how much global warming would be expected for each doubling of atmospheric  $\text{CO}_2$ ?
10. *Including* climate feedback processes, how much global warming is expected for each doubling of  $\text{CO}_2$ ?
11. What are two different ways to estimate the sensitivity of the Earth’s climate to  $\text{CO}_2$ ? Do estimates of climate sensitivity derived by different methods agree or disagree with one another?
12. Have there always been polar ice caps on Earth?
13. Name three things that caused the Earth’s climate to change a lot over geologic time.
14. How does plate tectonics and continental drift cause climate change over very long periods of time?
15. Briefly explain how the following influence the climate, and over what time spans:
  - a.  $\text{CO}_2$  released as volcanic gases
  - b. Chemical weathering of rocks on land
  - c. Stratospheric particles released from volcanoes
  - d. Continents at the Earth’s poles vs in the tropics
16. When and why did the dinosaurs go extinct, and what does that have to do with climate?

17. Over the 65 million years since the extinction of the dinosaurs, has the Earth's climate slowly warmed or slowly cooled? Why?
18. What is an Ice Age, and when was the Last Glacial Maximum?
19. How many Ice Ages has the world experienced in the past 10 million years?
20. How often do ice ages occur? What influences the timing of the ice ages?
21. Name three kinds of periodic change in the Earth's orbit around the Sun which are thought to influence the timing of Ice Ages.
22. The total amount of solar radiation received by the Earth hardly changes at all during Milankovitch cycles. What single characteristic of Earth's energy distribution (determined by orbital changes) is thought to be the most important in setting the timing of Ice Ages?
23. When was the last major interglacial period?
24. When the ice was melting after the last ice age, there was an event that caused the climate to rapidly cool again (about 13,000 years ago). What happened at that time to cool the climate?
25. What is meant by the "Holocene climatic optimum," and when did that occur?
26. When was the Medieval Warm Period? Was it warmer than today?
27. When was the Little Ice Age? Why did it occur? How do we know?
28. How has climate changed in the past 150 years?
29. Name three kinds of changes to the radiative forcing of the Earth's climate that have been documented over the past 1000 years
30. Compare the strength (in Watts per square meter) of three kinds of radiative forcing of the Earth's climate over the past 1000 years
31. Comparing the current climate to that of the Last Glacial Maximum 18,000 years ago, what is the radiative forcing due to differences in albedo and atmospheric CO<sub>2</sub>? What is the difference in global temperature? How can these numbers be used to estimate climate sensitivity to radiative forcing?
32. How do we know the amount of CO<sub>2</sub> in Earth's atmosphere during past ice ages?
33. How do we know the change in albedo associated with glacial to interglacial transitions?
34. How do we estimate the global mean temperature during the last ice age?
35. How are the fossil fuel "emission scenarios" used in climate models generated? Are they actual predictions? How are they used?

36. Under a high emission scenario, how much CO<sub>2</sub> will be emitted by fossil fuel burning in 2100? How much will be emitted under a low growth scenario?
37. What are three separate variables that show substantial climate change over the past 30 years.
38. What is the difference between an *empirical model* and a *deterministic model*?
39. Name three major components of a modern global climate model. What do modern climate models predict well? What don't they include?
40. Name a climate phenomenon that global climate models predicted long before it was observed.
41. How are climate projections made for the 21<sup>st</sup> Century (what steps are taken to produce the maps of projected changes)?
42. Given scenarios of future fossil fuel emissions, how much CO<sub>2</sub> is expected to be in the atmosphere in 2100? How many Watts per square meter of radiative forcing would these ranges of CO<sub>2</sub> produce?
43. What are "*representative concentration pathways*" used by the IPCC? What do their numbers (2.6, 4.5, etc) mean? Where do they come from?
44. Depending on emission scenarios, what is our current best estimate of the average amount of global warming by 2100?
45. Where in the world is warming likely to be strongest? Where is it likely to be weakest?
46. Is Colorado expected to warm by about the same amount as the global average? If not, why not?
47. Explain why a small change in the average summer temperature is likely to cause a large change in the frequency of extremely hot days.
48. How do natural plants and animals adapt to a changing climate? Why does the rate of climate change matter so much for natural ecosystems?
49. As the Earth's climate warms, what must happen to global average precipitation?
50. Over what regions is precipitation likely to increase in a warmer world? Over what regions is the precipitation likely to decrease?
51. Describe likely changes in temperature and water availability over the central USA in the late 20<sup>th</sup> Century, as projected by climate models. What are the main sources of uncertainty in these projections?

52. Explain how drought might become more of a problem in our region under a warmer climate even if there is no change in precipitation.
53. How much is the sea level expected to rise in the 21<sup>st</sup> Century? Why is this difficult to estimate?
54. In the geologic past, sea level rose and fell by tens of meters each time global average temperatures changed by a few degrees, but IPCC projections of sea level rise are much smaller for the 21<sup>st</sup> Century. Why?
55. Name three reasons why we expect more wildfires under a warmer climate in the Rocky Mountain region.
56. In what regions of the world is climate change likely to increase crop yields? In what regions are crop yields likely to decrease?
57. What is meant by the term “storm surge?” Why is this likely to get worse in a warmer climate?
58. If fossil fuel emissions were to completely stop, what would happen to the extra CO<sub>2</sub> in the atmosphere? Where would it go?
59. How long would it take for the CO<sub>2</sub> to come halfway back down to preindustrial levels? How long would it take to come all the way down to preindustrial levels?
60. Under a high emission scenario in which China and India industrialize their economies using coal as a major source of energy, for how long will the temperature remain more than 3 Celsius above current temperature?
61. If global temperatures reach 3 Celsius above preindustrial levels for thousands of years, how much is sea level likely to rise? How do you know?