1. Why is there a lag between changes in CO\textsubscript{2} levels and temperature?

There is a lag between changes in carbon dioxide levels and the temperature because it takes time for the carbon dioxide to move between reservoirs. It takes a while for the oceans to heat up enough to release enough carbon dioxide to warm the temperature very quickly.

2. Are models necessary to understand climate change?

No

3. Explain your answer.

Answers will vary. Climate change can be understood by knowing that greenhouse gases trap heat in the atmosphere, but this is not a full representation of all of the factors that are related to global temperature changes.

4. How can you (and scientists) tell that a model is good? What kinds of tests can you run to assess the validity of a model?

You can tell that a model is good when it does a good job of replicating past scenarios. When a model can predict the past future based on some inputs, then you can have more confidence in its ability to predict future futures.

5. How can scientists be sure that Earth is getting warmer when they are not completely certain about what is going to happen to Earth’s temperature in the future?

Scientists can be sure that Earth is getting warmer because of temperature data that they’ve measured and understanding that greenhouse gases trap heat in the atmosphere. They can be uncertain about the future because there are many things that are unknown: future levels of greenhouse gas emissions are prime unknowns.

6. Based on all of what you’ve learned from this module, how can scientists look at 542 million years of temperature data (in the graph) and still be fairly confident that humans are contributing to the current warming trend?

Scientists can look at long histories of data and see trends. They can match those trends with what they knew was happening at the same time: volcanic eruptions, solar flares, asteroid impacts, etc. Scientists can look at those trends over long periods—periods with and without much human impact. Then they can compare those trends to the more recent trends in which humans have put more greenhouse gases into the atmosphere. This doesn’t allow them to say that humans are the only cause of global warming, but it does allow them to say that humans have some effect on global warming because they’ve studied time periods in which there was little human activity.
7. How much did you need to change the human emissions to reduce the average global temperature in the model?
   50%-75%

8. Explain how reduction in human emissions can cause a temperature decline. In your explanation, include as many factors as possible.
   Explanations should include information about the relationship between greenhouse gases and temperature. Reductions in human emissions can cause a temperature decline as fewer greenhouse gases are emitted into the atmosphere. With fewer greenhouse gases, less heat is trapped in the atmosphere. Less water vapor is evaporated into the atmosphere as the water temperature doesn’t rise. More carbon dioxide can be dissolved into the ocean, leading to still lower greenhouse gas concentrations. As the temperature drops, more ice forms, which reflects solar radiation, leading to less heating of the atmosphere.

9. How certain are you about your claim based on your explanation?
   Answers will vary.

10. Explain what influenced your certainty rating.
    Answers will vary. Scientific evidence includes: specific reference to experiments with the model, as well as any reference to topics in this activity/unit: Greenhouse gases absorbing and reemitting infrared radiation, trapping heat in the atmosphere; carbon dioxide and water vapor are greenhouse gases; increased temperatures leading to increased water vapor and decreased carbon dioxide in ocean, leading to more carbon dioxide in the atmosphere; light colored surfaces reflecting solar radiation, leading to less heating; dark colored surfaces leading to absorption of solar radiation, leading to more heating.

11. What additional factors would you like to add to the model to be able to make a better prediction of the impact of a reduction of human emissions on the global temperature?
    Answers will vary. Students may suggest that they want to see the warming effects of clouds in the atmosphere or see the cloud cover linked to the level of water vapor in the atmosphere. Students may mention additional factors such as the amount of radiation coming from the sun, ocean currents, volcanic eruptions, or particulate pollutants and aerosols that can change the amount of solar radiation hitting Earth’s surface.