Investigation 1B

Earth's Climate System

Objectives

Fundamentally, climate represents the result of the Sun's energy as it is received on Earth and is reflected, absorbed, transformed, and eventually emitted back to space. The atmosphere, hydrosphere (including the cryosphere), lithosphere, and biosphere further define the interactions and changes occurring in the climate system. *Earth's climate system* results from its internal subsystems and external solar energy, their interactions and feedbacks.

After completing this investigation, you should be able to:

- Describe Earth's climate system and its interacting components.
- Identify characteristics of subsystems within Earth's climate system.
- Understand the carbon cycle and estimate your carbon footprint.

Earth's Climate System

Earth's climate system is inherently variable. No one single, simple explanation accounts for the variability and changes inherent in the climate system across geologic ages. The complex spectrum of climate variability and climate change is a response to the interactions of many forces and mechanisms operating both within and external to Earth's climate system.

Systems can be described as both closed and open, which interact with each other in a logical manner according to the laws of physics and chemistry. While an **open system** exchanges both energy and mass with its environment, a **closed system** only exchanges energy with the environment. Earth's climate system is considered a closed system because there is practically no exchange of mass between Earth and space.

However, the subsystems of Earth's climate system are open systems, with both mass and energy exchanged between them. As a mass, liquid water moves from the ocean into the atmosphere via evaporation, becoming water vapor. Transfer of matter or energy across a system boundary will cause fluctuations inside the system, leading to a change in the physical state of the system.

Earth's climate system is comprised of major subsystems:

- **Atmosphere**: Free-flowing, well-mixed (below 80 km) envelope of gases at the interface of Earth and space.
- **Hydrosphere**: Includes all water, in all its forms, on, under, and over Earth's surface, from Earth's liquid water to gaseous water (water vapor). The hydrosphere includes the cryosphere, all frozen water (ice).
- **Lithosphere**: The atmosphere, hydrosphere, and cryosphere are all underlain by the lithosphere, which includes the crust of our planet and the uppermost solid mantle region.

- **Biosphere**: The entire collection of Earth's ecosystems worldwide. An ecosystem is a communal system of plants, animals, and microbes within their physical environment.

Figure 1B-1 depicts components of Earth's climate system (atmosphere, ocean, cryosphere, land surface, and terrestrial and marine biospheres) that must be considered when understanding the interaction of Earth's climate as a whole. These components interact with each other through flows of energy in various forms, such as exchanges of water, the transfer of greenhouse gases (e.g., carbon dioxide, methane), and the cycling of nutrients.

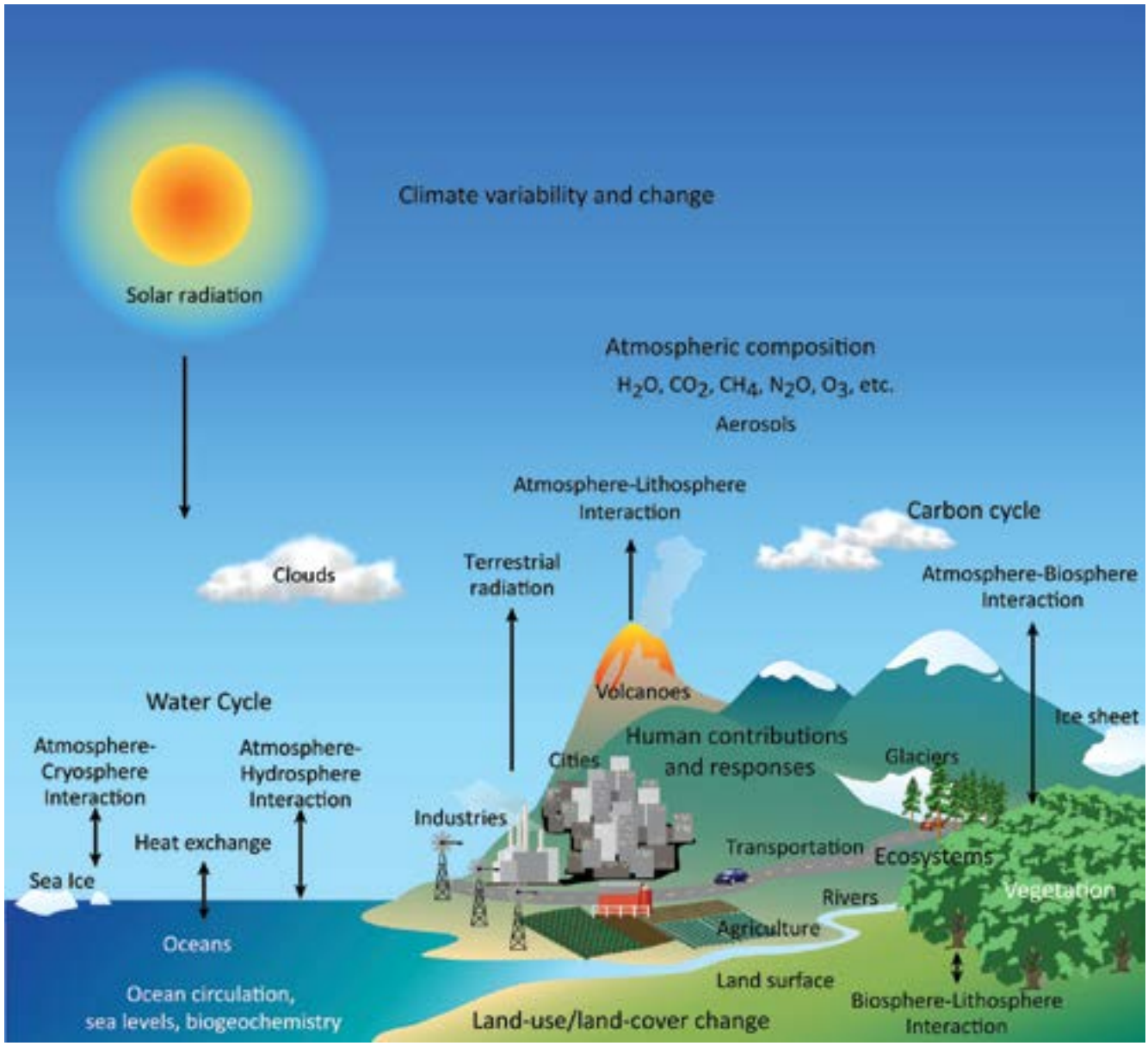

Figure 1B-1. Components of Earth's climate system, their processes, and their interactions. [Modified from NOAA Geophysical Fluid Dynamics Laboratory (GFDL), Link 1B-1]

1. Figure 1B-1 shows _____ is(are) the origin of energy and the driving force for the motion of the atmosphere and ocean, as well as heat transport, cycling of water, and biological activity.

   a. the sun

b. the wind
c. volcanoes

2. The various components in Figure 1B-1 can be thought of as scenarios of emissions and drivers that impact climate change. It can be inferred from the diagram that climate change is impacted by _____ changes.

   a. naturally caused
   b. human caused
   c. both of these

3. The arrows in the figure identify the processes and interactions with and between the major components of Earth's climate system. The *double-headed* arrows show that _____ of the interactions between climate system components (such as between atmosphere-hydrosphere or atmosphere-biosphere) involve bidirectional (upward and downward) flows.

   a. few
   b. almost all

4. While the human impact that most affects global climate is changes to the atmospheric *composition*, the human impact that most likely directly alters local and regional climate is changes in the _____.

   a. cryosphere
   b. water cycle
   c. land surface
   d. ocean

5. The atmosphere is composed of many gases, such as nitrogen, oxygen, and water vapor. A gas that contributes to global warming is known as a **greenhouse gas**. When these gases interact with outside influences, aerosols or heat-trapping greenhouse gases can form or be enhanced in concentration. Since these gases are part of the atmosphere, they will interact with _____.

   a. the biosphere
   b. the hydrosphere
   c. the cryosphere
   d. the lithosphere
   e. all of the above

Moreover, there are various cycles that contribute to the processes of Earth's climate system. In the carbon cycle, carbon is physically and chemically transformed within and between the biosphere, lithosphere, hydrosphere, and atmosphere, existing in many different forms in this process. A building block of life on Earth and present in all life forms, carbon is the backbone of many subsystems. By mass, it is the second most abundant element in the human body and is found in large quantities as coal, peat, and oil. As an inorganic compound, it can be found dissolved in the ocean, in limestone rocks, and as CO_2 gas in the atmosphere.

Estimating your Carbon Footprint

The effects that humans have on climate change are referred to as *anthropogenic* climate change. The amount of anthropogenic carbon dioxide produced by a person, activity, industry, or nation has been referred to as a **carbon footprint**. Carbon dioxide is the most significant greenhouse gas due to its atmospheric concentration and long lifetime. Its concentration has been on the rise since the 1850s, and accelerating since the 1950s. These emissions are bringing about increases in the average global surface temperature while perturbing other components of Earth's climate system.

Not surprisingly, carbon footprints vary around the world, especially when based on a national or per capita (per person) basis, and their effects linger. In fact, the impacts of today's carbon footprints will persist into the next century.

Many of our day-to-day activities cause greenhouse gas emissions. For example, we produce greenhouse gas emissions when we drive, heat or cool our homes, and use electricity generated by coal, natural gas, and oil. However, not all sources of emission are the same. The quantity of greenhouse gas emissions from your home electricity depends on the types of power, the efficiency, and the amount you use. There are other factors that can influence this carbon footprint, so let's explore alternative ways to reduce emissions.

To help you approximate your personal carbon footprint, the U.S. Environmental Protection Agency (EPA) has developed calculators. Visit Link 1B-2 to estimate your household's greenhouse gas emissions and to answer the next set of questions.

The calculator provides a quick, rough estimate of your carbon footprint from U.S. averages. We encourage you to gather your own information and enter it. From the EPA website, enter the number of people in your household and your zip code then click "Get Started."

6. The calculator estimates your footprint in several areas. The first section of the calculator covers your _____ emissions. Everyone's carbon footprint is different depending on their location, habits, and personal choices.

    a. home energy
    b. transportation
    c. waste

There are many sources of energy that you can use to heat and cool your home, including natural gas, electricity, fuel oil, propane, or a combination of them. Choose your primary source of energy for your home. In the calculator boxes for each home energy source, calculate the amount of "dollars" spent for each energy source. Click on the "i" next to each title to read what the current U.S. average dollar spent is and then calculate that based on the number of people in your household.

7. For the average household _____ emits the most pounds per year of CO_2 for a household of one person.

    a. natural gas
    b. electricity
    c. fuel oil
    d. propane

8. _____ is the most expensive energy source.

a. Natural gas
b. Electricity
c. Fuel oil
d. Propane

9. Scroll down to fill out the sheet on ways to reduce your emissions. One way is to program your thermostat. Read about thermostat savings at Link 1B-3. According to the information presented, you can save as much as _____ a year on heating and cooling by setting your thermostat back 7–10°F for 8 hrs a day.

a. 10%
b. 20%
c. 30%

Other home energy savings include replacing incandescent light bulbs with energy saving ones, enabling power management buttons on your devices, and washing your clothes in cold water. Fill out the form to the best of your ability. See how much CO_2 savings occur when you choose to change out a few light bulbs, or wash a load of wash in cold water. Which tips could you incorporate into your daily life?

10. The second section of the calculator covers your _____ emissions.

a. home energy
b. transportation
c. waste

11. According to the transportation section of the calculator, some ways to save on transportation emissions are to _____.

a. cut the number of miles you drive per year
b. perform regular maintenance on your car
c. drive a more gas efficient car
d. all of the above

12. The final section of the carbon emission footprint calculator focuses on waste and recycling to curb emissions. What is *not* listed as a common household product that you can recycle?

a. Plastic utensils
b. Glass jelly jar
c. Old magazines and newspapers
d. Styrofoam

Read more about common recyclable objects at Link 1B-4.

Click on “Continue to Report” when you are done with the calculator. You can read about all the ways you are helping to reduce the carbon footprint, as well as ways to reduce your footprint.

There is no denying that over the years, humans have emitted trillions of metric tons of carbon into the

atmosphere and there is no current, cost-effective way to return this carbon to the land or ocean, leaving only natural processes that will take millions of years. However, we are left with fewer choices of what to do about the predicament. It is up to us to act now.

Summary

While Earth's climate system is a closed system, exchanging only energy with the surrounding space, the subsystems are open systems within, both energy and mass cycling and interacting between their components. Though climate can be impacted by many factors, anthropogenic activities are the dominant force responsible for most of the warming observed in the last 60 years. Humans have impacted the amount of greenhouse gases in the atmosphere, and in particular carbon dioxide. A carbon footprint measures the amount of carbon dioxide emission produced by an individual, an activity, an industry, or a nation, however, the footprint can be reduced with effort.