Investigation 1A

Systems and Climate Change

Helpful Tips

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Objectives

Though long defined as the average weather and extremes at a particular location over a period of time, climate now includes a far greater understanding of the state of Earth's climate system. A **system** is a collection of interconnected components and processes that interact with each other and their environment. Systems are separated from their environment by **system boundaries**. For Earth's climate system, the outer extent of the atmosphere is the system boundary separating it from outer space.

In this investigation, we will:

- Differentiate between the mass and energy movement in closed and open systems
- Explore the Climate Literacy Essential Principles

Earth's Climate System

Systems may be described as either closed or open. Both closed and open systems exchange energy with their environments. An **open system** exchanges both energy and mass across its boundary, while a **closed system** exchanges only energy, not mass.

The sealed terrarium in **Figure 1A-1** is an example of a system. The glass jar is the boundary that separates the system from its external environment. The airtight terrarium can be described as a closed system because, while it does not exchange mass with the system outside the jar boundary, it does exchange energy, like solar energy from the Sun. Earth exhibits similar system characteristics on a much larger scale.

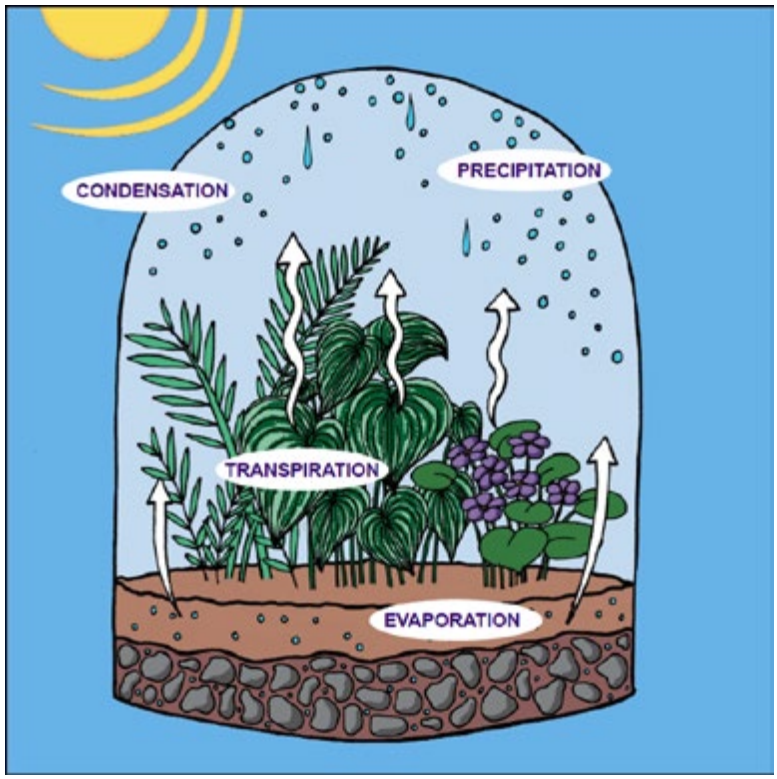

Figure 1A-1. Sealed terrarium example of a closed system. [Mississippi State University]

1. Earth's climate system contains _____.

    a. mass
    b. energy
    c. both mass and energy

Earth's climate system is a closed system because there is almost no exchange of matter between Earth and space, while Earth exchanges energy in the form of radiation. Earth intercepts solar radiation from the Sun and radiates infrared radiation (heat) into space. The subsystems of Earth's climate system (atmosphere, hydrosphere, lithosphere, and biosphere) are open systems because both mass and energy are exchanged between them.

Since the state of a system is determined by the mass and energy within the system, specifying conditions at the system boundary is essential to understanding that system. **Boundary conditions** refer to the magnitude and direction of energy and mass that cross a system boundary. For Earth's climate system and its subsystems, determining the current state of the system and the boundary conditions makes it possible to create climate models.

2. At the boundary between the hydrosphere (with the ocean as its largest component) and the atmosphere, known as the atmosphere-ocean interface, observational data such as humidity and water temperature are used to determine the magnitude and direction of _____ transferred across this boundary.

    a. mass
    b. energy
    c. mass and energy

Earth's climate system is a story of how energy from the Sun is intercepted by Earth then absorbed, refracted, stored, transformed, put to work, and eventually emitted back into space. Describing climate includes the continual changes within and between Earth's climate system and its subsystems. It encompasses a broad array of conditions and impacts that result from the interplay of these subsystems in response to energy flows.

As a closed system, Earth's climate is sustained by continuous energy gains and losses. The relative amounts of global incoming and outgoing energy determine whether Earth is in a steady-state condition, cooling, or warming. Earth maintains a balanced steady-state condition whenever its average global properties (e.g., temperature) remain constant over time.

3. A brighter, more intensely radiating Sun would change the state of Earth's climate system. The increase of incoming solar radiation crossing the system boundary between space and Earth would lead to _____ global average temperature.

    a. a decreasing
    b. an increasing
    c. an unchanged

4. Similarly, an increase of carbon dioxide in the atmosphere, which allows less infrared radiation (heat) to escape the system, would change the state of Earth's climate system. The increase of infrared radiation trapped within, not crossing the boundary between Earth into space, would lead to _____ global average temperature.

    a. a decreasing
    b. an increasing
    c. an unchanged

Climate is dynamic. Earth's climate system has changed in the past and is currently changing at an unprecedented rate, posing significant challenges for the biosphere. To lessen the negative consequences of these changes, we must transform our human-energy systems. The consequences if we do nothing are expected to expand rapidly. Addressing climate change requires intensifying social and political motivation. A crucial first step is to enhance climate literacy and foster informed, meaningful conversations and actions on this critical issue.

Climate Literacy

Teaching and understanding climate science are essential for addressing the challenges we face. As such, we closely align this course with the essential principles of climate science identified in *Climate Literacy: The Essential Principles for Understanding and Addressing Climate Change*, a climate literacy initiative by the U.S. Global Change Research Program (USGCRP).

Climate literacy includes understanding Earth's climate system, how natural and human-caused factors change the climate, and climate's effect on people and its subsystems. Climate literacy involves understanding the fundamental concepts of Earth's climate and the ability to locate credible information, as well as effective communication without expertise in all of climate's complexities.

5. While understanding every aspect of Earth's climate is unrealistic for most of us, we can grasp these interconnected concepts with a(n) _____.

    a. deep understanding of thermodynamics
    b. systems-thinking approach

c. awareness of public health issues
d. knowledge of farming practices

View the Climate Literacy Essential Principles, which summarize the USGCRP Climate Literacy Guide.

6. Scroll down to “1. How We Know” and review the points below. The first essential principle summarizes how scientists understand Earth’s climate system. Its components and processes operate based on _____, making it possible to model the climate.

   a. random variations
   b. scientific laws
   c. historic observations
   d. unpredictable patterns

7. Scroll down to “2. Climate Change” and read through all the points. Point C makes it clear that _____ are responsible for increasing greenhouse gases that are leading to global warming.

   a. natural climate cycles
   b. changes in Earth’s orbit
   c. human activities
   d. volcanic eruptions

8. Scroll down to “3. Causes” and read the points listed. Burning fossil fuels for energy is our main activity that is warming the planet. As is seen in points G and H, from 1850 to 2021, _____ emitted the most carbon dioxide, and _____ is currently the largest emitter.

   a. the United States ... China
   b. China ... the United States
   c. the European Union ... China
   d. the United States ... the European Union

9. Scroll down to “4. Impacts” and read the points listed. According to point C, the current social systems are vulnerable to climate change because they _____.

   a. rely on renewable energy sources
   b. developed during a stable period in Earth’s climate history
   c. are designed to operate best during rapid climate fluctuations
   d. are heavily reliant on outdated technologies

10. Also in principle 4, point D states that consequences of climate change include sea level rise and increased frequency of extreme events, including heatwaves, _____, strong storms, droughts, and wildfires.

    a. earthquakes
    b. volcanic eruptions
    c. floods
    d. tsunamis

As nations industrialize, their energy demands grow significantly. Since fossil fuels are often less ex-

pensive than renewable energy sources, restricting their use in developing countries can limit economic growth. However, rising temperatures disproportionately affect these nations. To mitigate global warming, it is essential to balance societal and economic needs with a transition to an energy system that relies less on fossil fuels.

11. Scroll down to “5. Equity” and read through the points. In point A, climate justice involves reducing greenhouse gas emissions and adaptation to a changing climate in a way that _____.

    a. prioritizes economic growth over environmental concerns
    b. share benefits equitably to all communities
    c. focuses exclusively on the marginalized and underserved
    d. avoids addressing social inequalities

12. In principle “6. Adaptation,” point B states that _____ will be necessary to reduce the risks of climate change.

    a. adaptation
    b. mitigation
    c. both adaptation and mitigation

13. Further down in principle 6, point F states that there is no one-size-fits-all model for climate adaptation because _____.

    a. climate risks are entirely the same everywhere
    b. communities differ in risks, resources, and potential solutions
    c. all adaptation measures must rely on a single global strategy
    d. adaptation only applies to certain regions.

14. The Paris Agreement, ratified in 2015, highlights the urgent need for international cooperation to combat climate change and reduce greenhouse gas emissions. To achieve its goal of limiting warming to below 2°C (3.6°F), principle 7 specifies that global carbon dioxide emissions must reach net zero, where emissions into the atmosphere are balanced by carbon dioxide removal by _____.

    a. 2030
    b. 2050
    c. 2075
    d. 2100

Current efforts and investments are insufficient to keep pace with climate change. Sweeping transformations in systems, behaviors, and values will be required to reduce vulnerability to risks and hazards from warming.

15. In “8. Hope and Urgency,” point A states that reaching net zero emissions _____ impacts and risks from climate change.

    a. will entirely stop
    b. will reduce
    c. will not change the

Climate literacy means understanding Earth’s climate system and providing informed discussions

and decisions regarding our actions on climate change. Governments, companies, communities, and individuals across the world are actively engaging in climate action to create a safer, healthier, more prosperous, equitable, and stable future for everyone. The acceleration of climate action is necessary to minimize risks and improve outcomes.

Summary

The goal of our course is to increase understanding of Earth's climate system by studying the broad array of conditions and impacts that result from the interplay of the subsystems in response to energy flows.

What you learn allows you to become climate literate, on a path leading to local and global-scale contributions, devising and implementing strategies for sustainable development, and long-term stewardship of Earth.

References

Figure 1A-1 – DelPrince, J. M. and G. Bachman, 2018: How to design a closed-system terrarium. Extension Service of Mississippi State University, accessed 16 December 2024, https://extension.msstate.edu/publications/how-design-closed-system-terrarium.

USGCRP, 2024: Climate literacy: Essential principles for understanding and addressing climate change. *U.S. Global Change Research Program,* 52 pp, https://doi.org/10.7930/clg2024.