Investigation A:
TODAY’S CLIMATE SCIENCE

Driving Question: What is Earth’s climate system and what are the empirical and dynamic definitions of climate?

Educational Outcomes: To identify some of the many reasons for studying Earth’s climate system. To learn more about the workings of Earth’s climate system and become more aware of the significance of climate, climate variability, and climate change for our well being wherever we live.

After completing this investigation, you should be able to:

- Describe Earth’s climate system and its interacting components.
- Describe and compare the complementary empirical and dynamic definitions of climate.
- Explain the AMS Climate Paradigm.

An Earth System Approach

*Earth’s Climate System (ECS)* employs an Earth system perspective. A view of the Earth system as seen from space is presented in Figure 1 of the Narrative. Examine the figure for evidence of the major components of the Earth system — atmosphere, ocean, biosphere, cryosphere (including ice sheets, sea ice, glaciers, and seasonal snow cover), and land surface. These components, or sub-systems, interact and determine Earth’s climate.

1. With our feet almost always firmly on the solid Earth, we live primarily in the atmosphere. It delivers our essential oxygen and provides other nutrients (e.g., carbon, nitrogen) to support living plants and organisms. The thinness of the atmospheric subsystem is evident primarily in Figure 1 ([over the continents](in the middle of the figure)along Earth’s visible circumference).

2. The ocean water surfaces are displayed in the image in hues of blue and green because water selectively scatters those colors of the visible solar spectrum back toward space. Even in this Figure 1 perspective where portions of four or perhaps five of the seven continents are seen, Earth's surface area is clearly ([more land than ocean](about the same land as ocean)(more ocean than land)).

3. In this Figure 1 perspective, the North Pole is approximately in the center of the broad expanse of uniform light gray Arctic Ocean sea ice which is seen in the image above the bright-white ice sheet covered ([Canada’s Baffin Island](Greenland)(Iceland)). This, the world’s largest island, is covered by ice up to 3 km (1.8 miles) thick which if melted would increase the global sea level by 7.2 m (23.6 ft). Significant melting of this ice sheet is just one likely outcome of global warming, demonstrating why it is essential that we better understand the scientific workings of Earth’s climate system and the possible consequences of climate change.
4. In Figure 1 the biosphere is evident primarily by way of the [(whitish)(greenish)(brownish)] hues of chlorophyll as seen in the Amazon Basin as compared to surrounding land and in near-shore ocean waters as along the southeastern U.S. coasts.

**Weather, Climate and Climate Change**

In *Earth's Climate System*, we will examine the unique combinations of conditions of the physical and biological environment that arise from the interplay of Earth’s subsystems in response to external influences (called forcings).

Fundamental to understanding weather, climate and climate change is the recognition that the Earth system is a complex energy flow system. The observable impacts of the energy flows (and associated mass flows) are embodied in the descriptions of weather and climate.

*Climate* is commonly thought of as a synthesis of actual weather conditions at the same locality over some specified period of time, as well as descriptions of weather variability and extremes over the entire period of record at that location. Climate so defined can be called empirical as it is based on the descriptions of weather observations in terms of the average and variability of quantities such as temperature, precipitation and wind over periods of several decades (typically the three most recent decades). Climate thusly defined can be thought of as the quantified description of the weather involving averages of appropriate components (e.g., temperature, precipitation), together with the statistical variations of those components.

Climate can also be delineated from a dynamic perspective of the Earth environment as a system. The definition of Earth’s climate system must encompass the hydrosphere including the ocean, the land and its features, and the cryosphere including land ice and snow cover, which increasingly interact with the atmosphere as the time period considered increases. While the transitory character of weather results from being primarily an atmospheric phenomenon, climate exhibits persistence arising from it being essentially an Earth system creation.

From the dynamic perspective, **climate is ultimately the story of solar energy intercepted by Earth being absorbed, scattered, reflected, stored, transformed, put to work, and eventually emitted back to space as infrared radiation**. As energy flows through the Earth system, it determines and bounds the broad array of conditions that blend into a slowly varying persistent state over time at any particular location within the system.

Whereas the empirical approach allows us to construct descriptions of climate, the dynamic approach enables us to seek explanations for climate. Each has its powerful applications. In combination, the two approaches enable us to explain, model and predict climate and climate change. In this course we will treat climate from the two complementary perspectives.

5. Local climatic data, including records of observed temperature, precipitation, humidity, and wind, are examples of [(dynamically)(empirically)] derived information.
6. Scientific predictions of such an altered state of the climate (i.e., climate change) must be based on treating Earth’s climate system from a(n) [(dynamic)(empirical)] perspective.

A scientific model is an approximate representation or simulation of a real system. Computer-based mathematical climate models can be either empirical or dynamic. Empirical climate models, based as they are on data sets of actual meteorological observations, are most appropriately used to predict climate variability. Dynamic climate models, based as they are on interacting forcing mechanisms, are best used to predict climate change.

7. Computer-based climate models that attempt to determine the impact of increasing concentrations of atmospheric carbon dioxide on future global temperatures produce [(dynamically)(empirically)] derived information.

8. Computer climate models relying on large databases describing past weather that attempt to forecast the probability of record low winter temperatures or the frequency of drought produce [(dynamically)(empirically)] derived information.

Figure A1 schematically depicts the components, or sub-systems, of Earth’s climate system (atmosphere, ocean, terrestrial and marine biospheres, cryosphere, and land surface). These major components interact with each other through flows of energy in various forms, through

![Figure A1. Schematic view of the components of the climate system, their processes and interactions. [IPCC AR4 WG1 faq-1-2-fig-1]](image-url)
exchanges of water, through flows of greenhouse gases (e.g., carbon dioxide, methane), and through the cycling of nutrients. Solar energy is the ultimate source of the driving force for the motion of the atmosphere and ocean, the flows of heat and water, and of biological activity.

9. The arrows in the figure identify the processes and interactions with and between the major Earth climate system components. The double-headed arrows show that [(few)(about half)(almost all)] of the processes and interactions between climate system components (e.g., precipitation-evaporation, land-atmosphere) involve bi-directional (upward/downward) flows.

10. Of all the processes shown in Figure 2, most are interactions within the Earth system. A process that would be an external forcing of the climate system is [(changes in the cryosphere)(changes in solar inputs)(clouds)].

11. Six of the displayed interactions depicted in Figure 2 are specifically labeled “Changes in ...”. While changes in the atmosphere (composition) is the one that most impacts global climate due to human activity, the one that most directly states human activity which alters the environment is the one concerning the [(ocean)(land surface)(hydrological cycle)(cryosphere)].

The Earth's Climate System Paradigm:

Utilizing a planetary-scale Earth system perspective, ECS explores Earth’s climate system. In pursuing this approach, ECS is guided and unified by a special climate paradigm that is given in the Preface, page ii. Refer to that Paradigm for these questions.

12. It is implied in the AMS Climate Paradigm that components of the Earth system (e.g., atmosphere, hydrosphere, cryosphere, geosphere, and biosphere) interact in a(n) [(random)(orderly)] way as described by natural laws.

13. This interaction of the Earth system components through natural laws would imply a(n) [(dynamic)(empirical)] perspective for climate studies.

14. The ocean as an Earth system component and player in atmosphere/ocean energy and mass distributions suggest it is a [(major)(minor)] part of biogeochemical cycles (e.g., water cycle, carbon cycle) operating in the Earth system.

15. According to the AMS Climate Paradigm, our understanding of the climate system is incomplete. However, it states that the risks associated with climate change call for the development and implementation of [(sustainable development strategies)(long-term stewardship of our Earthly environment)(both of these)].

In summary, Earth’s Climate System investigates climate science through complementary empirical and dynamic approaches as guided by the AMS Climate Paradigm.