Investigation 1A

Defining Climate

All Manual figures can be enlarged or printed by clicking on the figure to open it in a new browser tab or window.

Objectives

Climate has been traditionally thought of as a synthesis of weather conditions at the same locality over a specified period of time, as well as descriptions of weather variability and extremes over the entire period of record at that location. Long defined as the average of weather plus information on extremes at a particular location over a period of time, **climate** now encompasses the state of the climate system as a whole. **Weather** investigates the state of the atmosphere and on Earth's surface at particular places and times. Weather, fair or stormy, is not arbitrary or capricious. Both its occurrence and variability are determined by energy and mass flows through the Earth system.

The observable impacts of the energy flows are embodied in the descriptions of weather and climate. In pursuing these complementary approaches, understanding is guided and unified by a special overarching paradigm, the *AMS Climate Paradigm*.

After completing this investigation, you should be able to:

- Explain the AMS Climate Paradigm.
- Describe, compare, and contrast the empirical and dynamic definitions of climate.
- Define climate and the components that encompass Earth's climate system.

The *AMS Climate Paradigm*

The *AMS Climate Paradigm* employs an Earth system science approach, which we use throughout our study of Earth's climate system to uncover new understandings and insights into the role of climate in both our individual lives and society.

AMS Climate Paradigm

A Changing Climate in a Changing World

Climate, traditionally defined as the average of weather plus information on extremes at a particular location over a period of time, has expanded in meaning to describe the state of the climate system as a whole. The state of Earth's climate system, composed of atmosphere, hydrosphere (including the cryosphere), lithosphere, and biosphere, results from internal and external influences, mutual interactions, and feedbacks. Climate is fundamentally the journey of the Sun's energy received on Earth as it is deflected, stored, transformed, put to work, and eventually emitted back to space.

Earth's climate system establishes the environmental conditions and sets the boundaries of weather that determine where life, including people, can exist.

Climate is inherently variable, but is currently changing at rates unprecedented in recent Earth history. The warming of Earth's climate system is unequivocal and is most certainly caused in large part by our relentless burning of fossil fuels for energy and in the altering of the characteristics of Earth's surface. These human activities have become significant drivers of global environmental change, linking human systems to our planet's biophysical systems. This linkage positions climate change as part of a complex, coupled human/natural system. Unlike all other life on this planet, humans' ability to think informs us through science studies of our impact on climate. With this understanding comes the capability of making choices and taking actions to mitigate this impact and to adapt.

Rapid climate changes heighten the vulnerabilities of societies and ecosystems, impacting biological systems, water resources, food production, energy demand, human health, and national security. These vulnerabilities are global to local in scale, calling for increased understanding and surveillance of the climate system and its sensitivity to imposed changes. Scientific research on key climate processes, expanded monitoring, and improved modeling capabilities increase our ability to project the future state of the climate. Climate change is not an isolated problem, but occurs with concurrent environmental change and societal developments which affect our vulnerability and strategies for responding. Although incomplete, our current understanding of the climate system and the far-reaching risks associated with the negative impacts of climate change require dialog between scientists and the broader community for the immediate preparation and implementation of adaptation and mitigation strategies aimed at sustainable development and long-term stewardship of Earth.

1. It is implied in the *AMS Climate Paradigm* that subsystems of Earth's climate system (atmosphere, hydrosphere, lithosphere, and biosphere) interact in a(n) ______ way as described by natural laws.

   a. orderly
   b. random
   c. chaotic

2. The ocean is one of Earth's climate system components and contributes to the distribution of atmo-

sphere-ocean energy and mass distribution. This suggests that the ocean is a ______ part of biogeochemical cycles (e.g., water cycle, carbon cycle) operating in the Earth system.

a. minor
b. major

3. According to the *AMS Climate Paradigm*, modern climate and climate change are the results of a ______ system.

   a. biophysical
   b. human
   c. coupled human-natural

4. According to the *AMS Climate Paradigm*, our understanding of Earth's climate system is incomplete. Nonetheless, it states that the risks associated with climate change call for the development and implementation of ______.

   a. long-term stewardship of our Earthly environment
   b. sustainable development strategies
   c. both of these

Climate and Climate Change

The traditional definition of climate, as a collection of averages and extremes, is **empirical**, dependent on evidence or consequences that are observable. It is empirical as it is based on the descriptions of weather observations in terms of the statistical averages and variability of quantities such as temperature, precipitation, and wind over the three most recent decades.

The definition of climate has expanded to Earth's climate system as a whole, a **dynamic** perspective of the Earth environment, encompassing subsystems and their interactions, as well as external interactions, such as the Sun's energy. In this modern definition of climate, weather results from climate.

From a dynamic perspective, climate is ultimately the story of the solar energy intercepted by Earth that is absorbed, scattered, reflected, stored, transformed, put to work, and eventually emitted back to space. As energy flows through Earth's climate system, it creates a broad array of conditions across Earth's surface that blend into persistent states, and thus determines local climates.

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

5. As described in the *AMS Climate Paradigm*, the interaction of Earth's climate system subsystems through natural laws would imply a(n) ______ perspective for climate studies.

   a. empirical
   b. dynamic

6. In its definition of climate, the AMS *Glossary of Meteorology, 2nd. Ed.*, (Link 1A-1) states that cli-

mate "*...is typically characterized in terms of suitable averages of the climate system over periods of a month or more, taking into consideration the variability in time of these average quantities.*" This definition is derived from a(n) ______ perspective.

a. empirical
b. dynamic

7. The AMS Glossary's definition of climate continues with "*... the concept of climate has broadened and evolved in recent decades in response to the increased understanding of the underlying processes that determine climate and its variability.*" This expanded definition of climate is based on a(n) ______ perspective.

    a. empirical
    b. dynamic

8. Local climate data, including records of observed temperature, precipitation, humidity, and wind, are examples of ______ derived information.

    a. empirically
    b. dynamically

9. Scientific predictions of a changing climate treat Earth's climate system from a(n) ______ perspective.

    a. empirical
    b. dynamic

Determining actual **climate change** ("*any systematic change in the long-term statistics of climate elements sustained over several decades or longer*," from the AMS Glossary) is based primarily on evidence provided from an empirical perspective. In contrast, also from the AMS Glossary, "*Climate change may be due to natural external forcings, such as changes in solar emission or slow changes in Earth's orbital elements; natural internal processes of the climate system; or anthropogenic (human-caused) forcing*" is an example of a dynamic perspective.

An Earth System Approach

Climate is variable and changing, yet is currently shifting at rates unparalleled in recent Earth history. Rapid climate change heightens the vulnerabilities of societies and ecosystems, calling for increased understanding and surveillance of the climate system. Fundamental to understanding climate, climate change, and weather is recognizing that **Earth's climate system** is a complex system of energy. Earth's climate system is subjected to energy arriving as sunlight, flowing through the Earth system, and returning to space as infrared radiation. By utilizing a planetary-scale Earth system perspective, this course will explore Earth's climate system.

A satellite image view of the Earth system as seen from space is presented in **Figure 1A-1**. The view is a GeoColor "full-disk" view from the GOES-16 geostationary weather satellite positioned about 36,000 km (22,300 mi.) above the equator in South America at 75°W longitude. The satellite remains at that location relative to Earth's surface because it makes a full revolution around the planet as Earth makes one rotation in the same direction. Being *geostationary*, the satellite provides a continuous view of the same underlying surface from about 60° north and south and 60° east and west of the point directly below the satellite. Because the geostationary satellite is astronomically close to Earth, approximately one-third of our planet's surface can be observed from the satellite's position. Successive images can provide animations that show what moves across Earth's surface.

Figure 1A-1. GeoColor image of Earth from NOAA GOES East satellite at 2010 UTC on 28 JAN 2021 (3:10 p.m. EST, 2:10 p.m. CST, 1:10 p.m. MST, 12:10 p.m. PST.). [NOAA STAR, Link 1A-2]

Examine Figure 1A-1, noting outlines between land masses, waters, and clouds. The image is produced in GeoColor, which is a multispectral product created with True Color, similar to visible imagery during the daylight, and infrared imagery at night. In the east, almost reaching western South America, is the *terminator*, which separates the bright sunlit and shadowed night.

10. Compare expanses of land and ocean in Figure 1A-1. Earth's surface shows ______.

a. less water than land
b. equal water and land
c. more water than land

11. In Figure 1A-1, the sunlit edge of the disk marks the atmosphere, the boundary between Earth and space. The atmosphere is a very ______ layer compared to Earth's diameter.

   a. thin
   b. thick

Figure 1A-1 is a static view of the Earth from the National Oceanic and Atmospheric Administration's (NOAA) GOES-East Image Viewer, which also creates animations. The animations are composed of the 24 most recent full-disk images from the GOES-East satellite taken at 10 min intervals. The latest image is normally within 30 min.

View an animation at Link 1A-2. To look at individual images or to slow down the animation, use the controls above the image. Click on Pause then click successively on the Previous/Next buttons while noting the progression of day and night on Earth's surface as the rotating planet intercepts the radiant energy from the Sun. Choose an animation period of up to 150 images (25 hrs) by changing the "Loop" duration to answer the next set of questions.

12. At any instant, half of Earth's total surface area is in sunlight and half in darkness. The sunlit portion in each image shows what part of Earth in the satellite's field of view is receiving energy from outside the Earth system. Can you find your home in the animation? Watch it, or pick another location, for the full 150 image loop. Any given location receives sunlight ______.

   a. continuously with constant illumination
   b. that alternates between periods of brightness and darkness

During the sunlit hours, the brighter a feature, the more solar energy it is reflecting back to space. Conversely, darker regions indicate they absorb a greater amount of the incoming solar energy. In the dark regions of the image, or areas not exposed to sunlight, the infrared spectral bands allow us to differentiate between lower and higher level clouds and their temperatures.

13. The time and date of each image is displayed above the image. From a maximum length loop if necessary, pause the animation at or near 2010 UTC on the same time of day as Figure 1A-1, and compare it to Figure 1A-1. Both Figure 1A-1 and the loop show that ______ are generally where the most incoming solar energy is reflected.

   a. cloud tops
   b. land surfaces
   c. ocean surfaces

We will explore how the energy that entered the Earth system as solar radiation is emitted as infrared radiation (heat) back to space, and learn more about Earth's climate system and its interactions as we proceed through the course.

Optional: For contrast from the True Color satellite image, view the visible and infrared images alone. Go to the NOAA Image Viewer (Link 1A-3) and in menu bar at the top of the page, scroll over "Full Disk" then "GOES-East" and click on "Band 2 - Visible: red." You are viewing what is visible to the human eye, and hence why some areas of the image are sunlit, whereas some are dark. This view is great for visualizing clouds and their movements. Next, explore "Band 14 - IR: longwave." Here you are viewing images of "heat" radiation emitted by the Earth system out to space. In these infrared radiation (heat) images, the darker areas represent places where outgoing heat to space is greater and lighter gray where less heat escapes. Essentially, these are images of temperature.

Summary

Climate, traditionally defined as the average of weather and the extremes at a particular location over a period of time, has expanded to describe the state of the climate system as a whole. In this course we will investigate climate, climate variability, and climate change through complementary empirical and dynamic approaches guided by the *AMS Climate Paradigm*.