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

Long defined as the average weather and extremes at a particular location over a period of time, **climate** now encompasses the state of the climate system as a whole. **Weather** itself is the state of the atmosphere and on Earth's surface at a particular place and time. Climate, comfortable or disastrous, is not arbitrary or capricious, rather it is determined by the energy and mass flowing through the Earth system.

After completing this investigation, you should be able to:

- Explain the *AMS Climate Paradigm*.
- Contrast the empirical and dynamic definitions of climate.
- Describe an Earth system approach to understanding climate and its changes.
- Define climate and the components that encompass Earth's climate system.

The *AMS Climate Paradigm*

The *AMS Climate Paradigm* employs an Earth system approach, which we will use throughout our study of Earth's climate system to uncover new understanding of 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. The *AMS Climate Paradigm* implies that the 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 atmosphere-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, the risks associated with climate change *does not* call for _____.

a. mitigation of unsustainable transportation practices
b. adaptation of current agricultural practices
c. maintaining the status quo of fossil fuel dependency
d. reforming industrial and manufacturing processes

Climate and Climate Change

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

As the definition of climate expanded to Earth's climate system as a whole changing and fluid system, a **dynamic** perspective of the Earth environment emerged. It now encompasses subsystems and their interactions, as well as external interactions, such as the Sun's energy. In terms of climate, understanding and knowledge are continually evolving. 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 then 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. In its definition of climate, the AMS *Glossary of Meteorology, 2nd. Ed.*, (Link 1A-1) states that climate "*...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

c. both

6. 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
   c. both

7 Scientific models that utilize past measurements of weather over long time periods to see changes and predict future change in Earth's systems treat Earth's climate system from a(n) _____ perspective.

   a. empirical
   b. dynamic
   c. both

Climate change is "*any systematic change in the long-term statistics of climate elements sustained over several decades or longer*," and "*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,*" (from the AMS Glossary, Link 1A-2), which utilizes both an empirical and dynamic approach.

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 and climate change is recognizing that *Earth's climate system* is a complex system of energy. Earth's climate system is created from energy arriving as sunlight (solar radiation), energy flowing and changing forms through the Earth system, and energy leaving the Earth system as infrared radiation (IR). By utilizing a planetary-scale Earth system approach, we will explore Earth's climate system.

A satellite image view of the Earth system 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 geostationary satellite remains at the same location relative to Earth's surface because it makes a full revolution around the planet at the same rate Earth makes one rotation in the same direction. Approximately one-third of our planet's surface can be observed from the satellite's position.

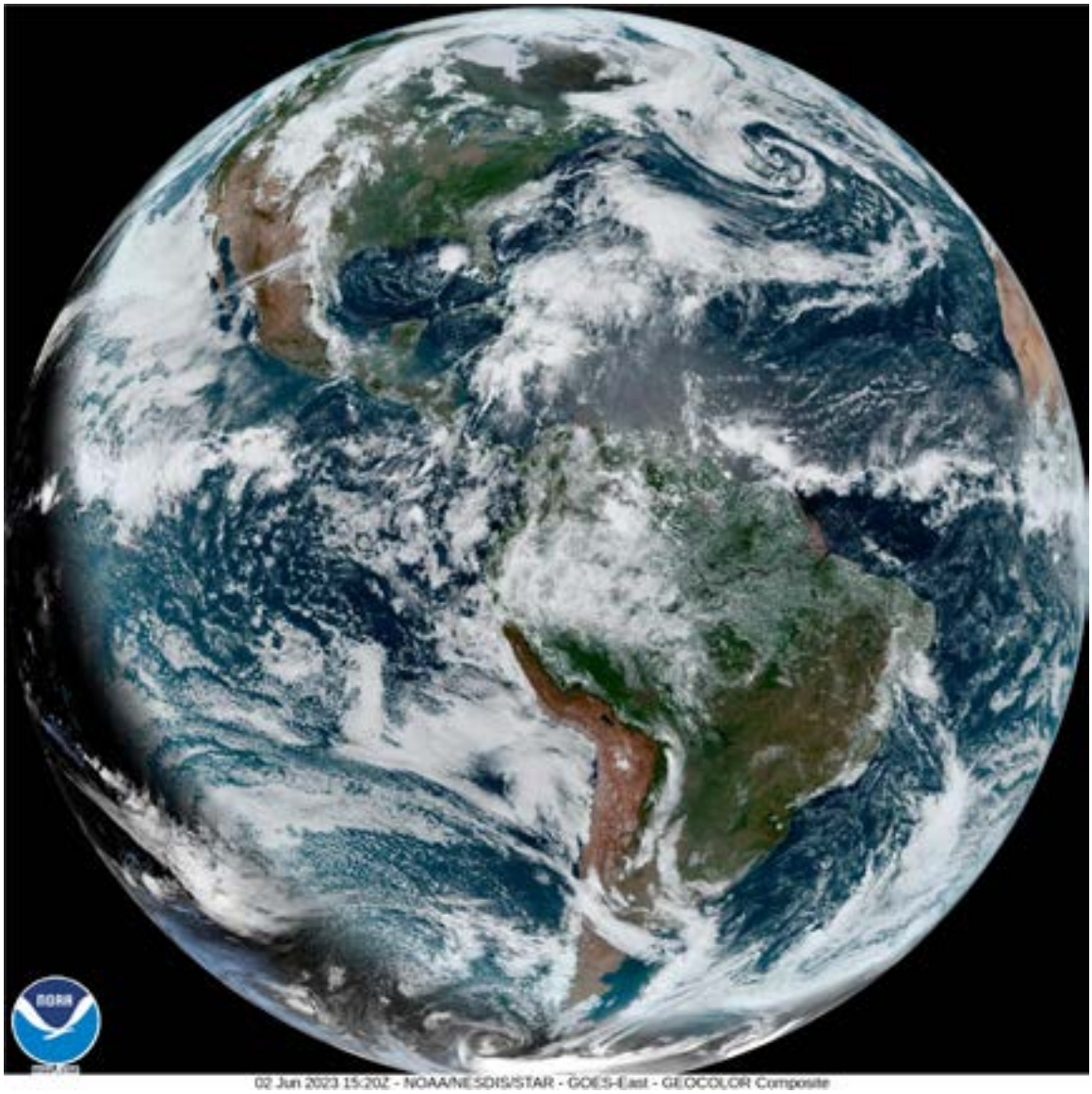

Figure 1A-1. GeoColor image of Earth from NOAA GOES East satellite at 1540 UTC on 02 JUN 2023 (10:40 a.m. EST, 9:40 a.m. CST, 8:40 a.m. MST, 7:40 a.m. PST.). [NOAA STAR, Link 1A-3]

In Figure 1A-1, examine the land masses, waters, and clouds that make up the Earth system.

8. 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

Energy enters the Earth system as sunlight (solar radiation). Figure 1A-1 is produced in GeoColor, with True Color during the daytime and infrared imagery at night. In the west, almost reaching western South America, is the *terminator*, which separates the sunlit day and shadowed night.

9. 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

The GOES-East Image Viewer also creates animations, which are composed of the 24 most recent full-disk images taken at 10 min intervals. The latest image is normally within the last 30 min.

View an animation from GOES-East GeoColor at Link 1A-3. 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 solar radiation from the Sun. Set Loop to 150 images (25 hrs) to answer the next set of questions.

10. 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. All locations receive _____.

    a. continuous sunlight
    b. alternating periods of darkness and sunlight

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

11. 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, the same time 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 radiation is reflected.

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

To contrast the GeoColor satellite image, we will view a band at 8.4 μm (micrometers) that shows the infrared radiation from clouds high in the atmosphere. Infrared radiation is energy that humans feel as heat. To view the most current image, go to the NOAA Image Viewer (Link 1A-4) and in the menu bar at the top, under the Full Disk heading, click "GOES-East" then scroll down and click on "Band 11." In **Figure 1A-2,** the bright colors from blue to red, show a range of less to more infrared radiation escaping Earth's atmosphere, while the gray indicates none to very small amounts of IR escaping at that specific wavelength.

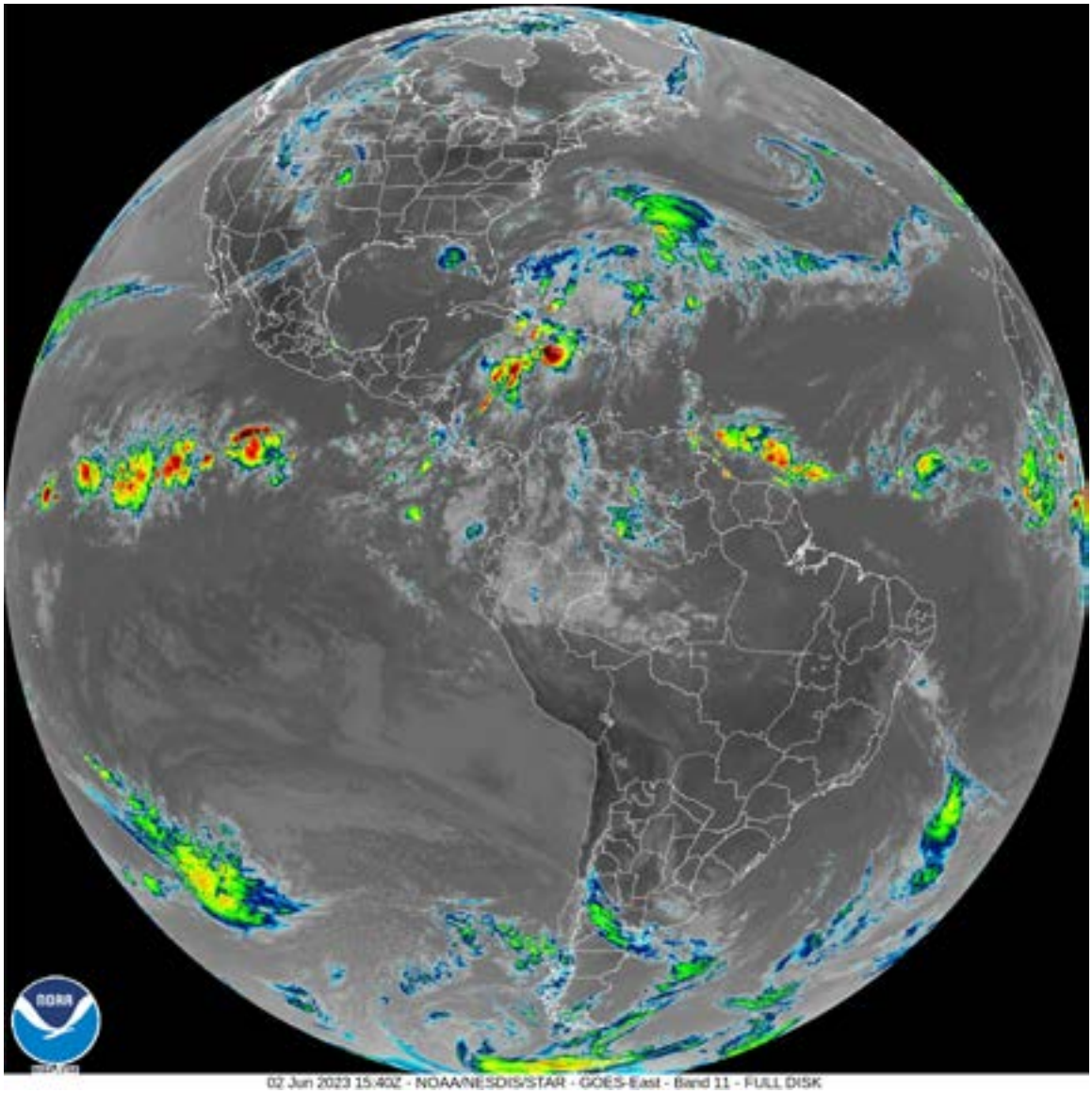

Figure 1A-2 Cloud Top Infrared image of Earth from NOAA GOES East satellite at 1540 UTC on 02 JUN 2023 (10:40 a.m. EST, 9:40 a.m. CST, 8:40 a.m. MST, 7:40 a.m. PST.). [GOES-East, Link 1A-4]

12. A line of clouds circles the equator in Figure 1A-2. This pattern suggests that clouds absorb solar radiation and release infrared energy into _____.

    a. space
    b. the atmosphere
    c. the lithosphere

Clouds can either reflect incoming solar radiation (sunlight) back to space or absorb and scatter it inside the atmosphere as other forms of radiation. The albedo of a cloud depends on various factors, including cloud type, altitude, thickness, and the size and concentration of cloud droplets or ice crystals.

As we proceed with the course, we will explore how energy that entered the Earth system as solar radiation is emitted as infrared radiation, and how that influences Earth's climate system.

Summary

Though traditionally constricted to the average of weather and its extremes at a particular location, climate now describes the state of Earth's climate system as a whole. In this course we will investigate climate, climate variability, and climate change through a complementary empirical and dynamic Earth system approach, guided by the *AMS Climate Paradigm*.