

Do Now:

1. Print this file.
2. Print the *Weekly Climate News* file and answer the two *Concept of the Week* questions in the *Weekly Climate News* File.
(**Note:** Check the *DataStreme RealTime Climate Portal* website during the week as breaking climate news stories may have been added.)

To Do Investigation:

1. Read Chapter 1 in the *DataStreme ECS* textbook and respond to the *Chapter Progress Questions* from the *DataStreme ECS Study Guide*. [Do **not** complete the *Questions for Review* and *Critical Thinking Questions* appearing in the text].
 2. Complete Investigations 1A and 1B in the *Climate Studies Investigations Manual*.
 3. Go to the *Current Climate Studies* link on the course website to complete this investigation.
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Introduction:

Welcome to the first of a series of *Current Climate Studies* which will be delivered in alignment with the other weekly components of this climate science course. Collectively, the course components are directed towards helping you build your own learning progression in which webs of interconnected ideas concerning Earth's climate system grow and deepen over time. This will enable you to become a more informed citizen on the science and societal issues of climate, climate variability, and climate change.

The Physical Bases of Earth's Climate System:

Climate is commonly described by properties (for example, temperature and precipitation) throughout the atmosphere in a set of long-term atmospheric statistics, **but it is much more**. Climate, climate variability, and climate change result from complex mass and energy flows, transformations, and feedbacks that are perpetually taking place on wide ranging space and time scales. This course focuses on building understandings of the physical bases of Earth's climate system. These encompass the forcing agents and mechanisms as well as the boundary conditions imposed by such factors and the internal dynamics of the system.

In a broad sense, Earth's climate can be regarded in terms of the mean (average) physical state of an energy-driven system. In physics, the term *system* refers to an arbitrarily enclosed portion of the physical universe (e.g., the Earth system) which may contain matter, energy, or both. A system is separated from its environment by a **boundary**

(e.g., for many purposes, the boundary separating the Earth system and surrounding space can be considered as being located at the outer extent of the atmosphere). The state of a system is determined by the observable properties of the matter and/or energy within the system.

The sealed terrarium in **Figure 1** is an example of a physical system. The glass jar represents the boundary separating the system from its external environment. The air-tight terrarium can be described as a **closed** system because it does not exchange matter with its surroundings. However, it does exchange radiant energy with the environment (i.e., sunlight comes in and heat energy goes out). Our Earth exhibits similar system characteristics.



Figure 1. Sealed terrarium
[Apartment Therapy Media]

1. The term **system** is a powerful concept in science as it focuses on a portion of the physical universe chosen for analysis. The system may contain _____.

- matter
- energy
- both matter and energy

Systems may be described as **closed** or **open**. A closed system does not exchange matter with its surroundings while an open system can. Both closed and open systems exchange energy with their environments. Earth's climate system is generally considered a closed system because there is almost no exchange of matter between Earth and space. At the same time, Earth exchanges energy with surrounding space in the form of radiation. It intercepts radiant energy from the Sun and it radiates infrared (heat) radiation to space. The subsystems of Earth's climate system (atmosphere, hydrosphere, geosphere, cryosphere, and biosphere) are open systems, as both matter and energy are exchanged between them. The transfer of matter or energy across a system boundary will cause changes inside the system, leading to a change in the physical state of the system.

2. A brighter, more intensely radiating sun would be expected to change the state of Earth's climate system because the increase in the rate of incoming solar radiation transferred across the boundary between surrounding space and Earth leads to a _____ global average temperature.

- lower
- higher

3. The global water cycle in which water circulates through the Earth system, including flow from ocean to atmosphere to land and back to the ocean, demonstrates that the several subsystems of Earth's climate system are _____ systems.

- closed
 open

Specifying conditions at a system's boundary is essential to scientific inquiry. **Boundary conditions**, a term drawn from mathematics, refer to information such as the magnitude and direction of flows of energy and mass at system boundaries. Applied to Earth's climate system and its subsystems, specifying the values at systems' boundaries make it possible to create mathematical models of climate.

4. Knowing the conditions at the boundary separating ocean and atmosphere subsystems is another example of how boundary conditions contribute to determining the state of Earth's climate system and its subsystems. At the boundary between the ocean and atmosphere, called the air/sea interface, acquisition of observational data (e.g., surface weather data, water temperature) can lead to determination of the magnitude and direction of _____ transfer across that boundary.

- matter
 energy
 both matter and energy

Our global climate is fundamentally the story of the energy from the Sun intercepted by Earth being absorbed, deflected, stored, transformed, put to work, and eventually emitted back to space. Climate describes the slowly varying aspects of Earth's climate system. Climate encompasses the broad array of weather conditions and impacts that arise from the interplay of the subsystems of Earth's climate system in response to these energy flows.

The relative amounts of incoming and outgoing energy on a global basis determine whether or not Earth is in a steady-state condition, cooling, or warming. As a closed system, Earth is sustained by the continuous gains and losses of energy. It can be assumed to have a balanced steady-state condition whenever its global properties (e.g., temperature) do not vary when averaged over time.

Figure 2 displays departures (anomalies) in Earth's global temperature from 1880 until 2015 measured from the 20th century average represented by the horizontal line labelled "0". The inclined straight black line shows the 1880-2015 trend (line of best fit) revealing a temperature change that averaged +0.07 °C per decade.

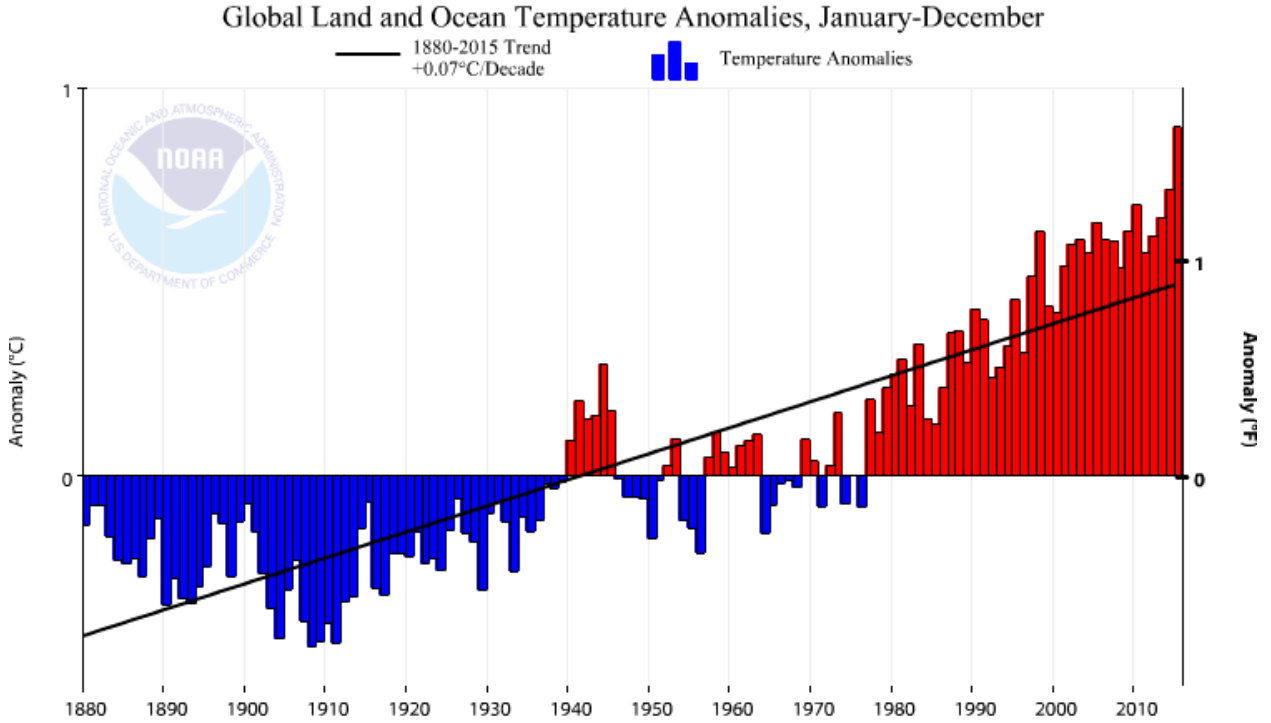


Figure 2. Annual Global Temperature Anomalies, 1880-2015
[\[http://www.ncdc.noaa.gov/cag/time-series/global\]](http://www.ncdc.noaa.gov/cag/time-series/global).

5. Figure 2 (and supporting data not shown here) shows that 1908 and 1911 had the coldest annual global temperature (-0.44 °C anomaly) during the time of record. Figure 2 also shows that every year since 1977 Earth’s global annual temperature has been above the 20th century average. The black trend line infers that from 1880 to 2015 Earth’s climate system _____ generally exhibited a steady state condition between incoming solar radiation and outgoing Earth radiation.

- has
- has not

The resulting changes in climate, due to variations in such factors as solar radiation and atmospheric composition, are described in terms of **radiative forcing**. As defined by the Intergovernmental Panel on Climate Change (IPCC), radiative forcing is a measure of the influence a climate factor has in *altering* the balance of incoming and outgoing energy at the boundary between the Earth system and space.

6. Radiative forcing arises from the change in the radiative energy budget of Earth’s climate system due to _____. This forcing is measured in Watts per square meter (W/m²).

- differences between the incoming radiant energy and the outgoing radiant energy
- changes only in the rate of incoming radiant energy
- changes only in the rate of total outgoing radiation

The magnitudes of the various radiative climate forcings and the directions they act are measured at the upper atmospheric boundary (the tropopause, where the troposphere and overlying stratosphere meet, is actually assumed to be the boundary), and are among the *boundary conditions* of Earth's climate system. **Specifying the values of the interactions at system boundaries make it possible to use numerical computer models to predict future states of the climate system.**

The solar radiation intercepted by Earth is a primary climatic boundary condition. It is the major external forcing that acts on Earth's climate system. If the flow of solar energy intercepted by Earth changes, then a change in a major Earth-system boundary condition occurs. Earth responds with a change in the emission of infrared (heat) radiation as its climate system adjusts to achieve global radiative equilibrium with space. That can be expected to produce changes in the amount of energy residing in the Earth system. This, in turn, brings about other changes such as an alteration in the prevailing atmospheric circulation pattern, and so on. The net result is climate change.

Beginning in *Investigation 1B*, the *AMS Conceptual Climate Energy Model (AMS CCEM)* is employed to investigate basic concepts underlying these global-scale flows of energy to and from Earth. The *AMS CCEM* allows you to track the paths that units of energy might take as they enter, move through, and exit an imaginary planetary system according to simple rules applied to different scenarios. We will refer back to the *AMS CCEM* as this course investigates the flow of energy in the real Earth climate system.

Summary:

The goal of this course is to assist you in the development of an in-depth Earth's climate system learning progression. It will be built on learning statistical characterizations of climate as well as fundamental scientific understandings of Earth's climate, climate variability, and climate change from a systems perspective. What you learn can start you, as an informed citizen, on a path leading to global-scale contributions towards devising and implementing strategies for sustainable development and long-term stewardship of Earth.

Record your responses to items in DataStreme ECS Investigations 1A and 1B on the **Investigations Answer Form** and responses for Current Climate Studies items on the **Current Climate Studies Answer Form** for transmission to your course mentor.

Instructions for Communications with Mentor:

After completing this week's applications, transmit the following work to your LIT mentor by Monday, 29 August 2016, or as coordinated with your mentor:

1. Chapter 1 **Progress Response Form** from the DataStreme ECS *Study Guide*, or the DataStreme *RealTime Climate Portal*.

2. Investigations 1A and 1B **Investigations Answer Form**, from the *Climate Studies Investigation Manual*, or the *DataStream RealTime Climate Portal*.
3. Current Climate Studies 1, **CCS Answer Form**.

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