UNIVERSITY OF DELAWARE
COOPERATIVE EXTENSION

Understanding Climate Change

Wylie Feaster

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Earth's Climate System

To understand climate change, one must first familiarize oneself with *Earth's climate system*, which is comprised of the five following components:

1. The **atmosphere** contains all the gases that cover Earth, including 78% nitrogen, 21% oxygen, 0.9% argon, and 0.1% trace gases.
2. The **cryosphere** is made up of all of Earth's surface areas that contain frozen water in the form of ice or snow, including ice sheets, ice caps, glaciers, permafrost, frozen waters, and snow-covered areas.
3. The **hydrosphere** includes all of Earth's fresh and saline waters, both on the surface and below ground, including oceans, seas, rivers, lakes and aquifers.
4. The **lithosphere** is the solid outer part of Earth that includes the crust and upper solid mantle.
5. The **biosphere** includes all the parts of Earth that contain life, whether on land, in water, or in the air.

Each component of the climate system interacts with the others through various physical, biological, and chemical processes. For example, plants (biosphere) utilize water (hydrosphere), sunlight, and carbon dioxide (atmosphere) for photosynthesis to create energy and oxygen.

Stability Begins With The Sun

When incoming radiation from the Sun equals the outgoing radiation emitted from all climate system components, the Earth's climate is considered stable.

Figure 1. Visual representation of climate system components: Atmosphere, hydrosphere, cryosphere, lithosphere, and biosphere. Photo credit: https://unsplash.com/license

However, several constant factors impact a region's climate, including its latitude, altitude, topography, and proximity to mountains and oceans. While locations at high latitudes receive less solar radiation, locations at lower latitudes receive more, like those near the Equator. This pattern stays true for altitude as well, since the higher up you go, the cooler it gets, which helps to explain why higher-altitude locations have climates that resemble higher-latitude locations.

In addition to latitude and altitude, physical topographic features, like the slope of the land, can impact the amount of sunlight that the Earth's surface absorbs. Likewise, by interfering with the movement of different air masses, mountains can influence the weather systems of surrounding areas by producing and preventing cloud formation and precipitation. Finally, oceans also play a key role in moderating the temperatures of coastal regions and the temperature differences between the land and the sea; these variations can produce winds that result in increased storm formation.

Earth's Atmosphere Is Like A Greenhouse

Since the end of the nineteenth century, scientists have come to understand that the Earth's natural warming occurs when gases in the atmosphere absorb and re-radiate heat from the Sun back towards Earth's surface. Known collectively as the "greenhouse effect," due to our atmosphere's ability to trap heat similar to the glass roof of a greenhouse, this natural phenomenon is facilitated by trace gases most commonly referred to as "greenhouse gases" (GHGs) (Figure 2). Of the many different GHGs, the most important include carbon dioxide, methane, nitrous oxides, and water vapor.

As the Sun's energy passes through the atmosphere, like light through a window, it is both absorbed and redirected in the following ways: 22.5% is reflected to space by clouds and aerosols (fine solid or liquid particles suspended in the atmosphere); 19.5% is absorbed by the atmosphere; 9% is reflected by the Earth's surface; and 49% is absorbed by the surface. However, as the Earth's surface begins to re-radiate the energy back out towards space, only 10% of it manages to escape to space. In comparison, the other 90% is absorbed by the GHGs in the atmosphere, thus contributing to further atmospheric warming.

Human Influences on Climate

Though the greenhouse effect is a natural climatic process, the concentration of GHGs in the atmosphere has significantly increased since the Industrial Revolution, a period of significant innovation and mechanization beginning in the eighteenth century. The industrial revolution transformed agrarian, rural societies into industrialized, urban ones. Since that time, global temperatures have increased. The Intergovernmental Panel on Climate Change (IPCC), a large global group of independent scientific experts within the United Nations, concluded that atmospheric carbon dioxide levels in recent centuries have increased from 280 to 400 parts per million due to human-produced GHGs. Though several factors can cause a rise in carbon dioxide in the atmosphere, it is primarily attributed to burning fossil fuels (like oil, natural gas, and coal) for transportation, electricity production, and other industrial processes. In addition to carbon dioxide, methane, and nitrous oxide concentrations in the atmosphere have increased due to various energy, agricultural, land use, and waste management practices.

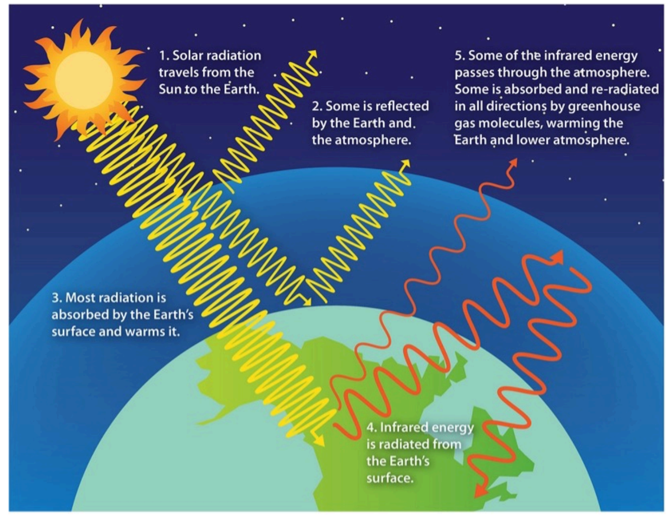

Figure 2. Description of the greenhouse effect

Delaware's Changing Climate

Though Delaware is the second smallest state in the U.S., it is still large enough to produce some stark climatic differences across its land area. Since Delaware is part of the Delmarva Peninsula, its climate is greatly influenced by the Atlantic Ocean and Delaware Bay to its east, and the Chesapeake Bay to its west. Additionally, with a mean elevation of only 60 feet and altitudes ranging from sea level (0 feet) at the coast to 450 feet above sea level at its highest point along the Pennsylvania border, Delaware's status as the lowest-lying state in the nation also significantly impacts its climate. Measurements from weather stations across Delaware dating back to 1895 show that the state's mean annual temperature has been rising at a rate of 0.2℉ per decade, or approximately 2℉ over the last century. As a result of this increasing temperature trend, Delaware experiences fewer nights with minimums below 32℉ and more nights with minimums above 75℉.

Regarding precipitation, rain patterns in Delaware remain highly variable, with no clear trends on an average annual basis. However, there does appear to be an increase in rainfall during the fall months, where statewide rainfall has been increasing at a rate of 0.27 inches per decade. Overall, trends over the historic record can be used to project how Delaware's climate might continue to change. These types of analyses indicate that, as a state, Delaware will continue to warm and experience more frequent and intense precipitation events.

Delaware Climate Change and Environmental Resources

Below are links to several other organizations working on better understanding, preparing for, and responding to climate change issues in Delaware.

Office of the Delaware State Climatologist – the principal scientific extension service for weather and climate information in Delaware, located within the Department of Geography in the College of Earth, Ocean and Environment at the University of Delaware. Several tools and resources include:

- Delaware Climate Data – climate data created and curated by the Office of the Delaware State Climatologist includes climate summary maps, climate normals (three-decade averages of temperature and precipitation), and precipitation frequency estimates for the state.
- Delaware Climate Projections Portal – provides data visualizations, downloads, and general climate modeling information from the Delaware Climate Change Impact Assessment report.
- Delaware Environmental Observing System (DEOS) – a real-time environmental service created by the Office of the Delaware State Climatologist- that provides the public with access to the latest conditions, summaries, data, and monitoring applications.

Delaware Environmental Monitoring & Analysis Center (DEMAC) promotes and coordinates environmental monitoring efforts and provides an effective, user-friendly interface for researchers to share their findings with the public.

Delaware Sea Grant – an education and outreach arm of the UD College of Earth, Ocean and Environment, Delaware Sea Grant helps communities use, manage, and conserve the state's coastal resources by prioritizing resilience and fostering environmental stewardship.

DNREC Division of Climate, Coastal, and Energy – a division of the Delaware Department of Natural Resources and Environmental Control that utilizes applied science, education, policy development and incentives to address Delaware's climate, energy and coastal challenges

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About the Authors

Wylie Feaster, 2022 Environmental Quality Extension Scholar, University of Delaware

Jennifer Volk (corresponding author), Associate Director, University of Delaware Cooperative Extension, Dover, DE (jennvolk@udel.edu)

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