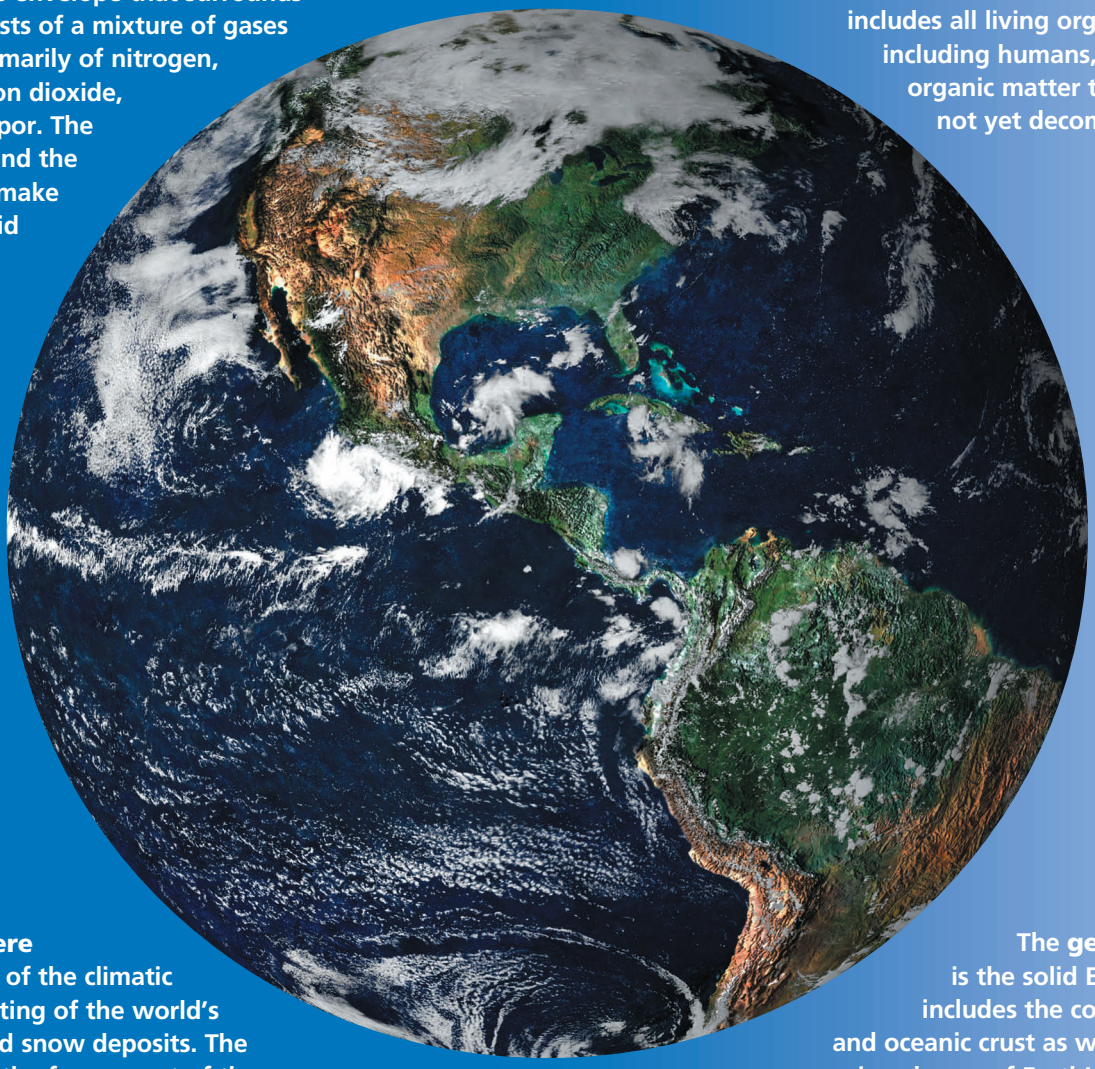
The Earth System

The **atmosphere** is the gaseous envelope that surrounds Earth. It consists of a mixture of gases composed primarily of nitrogen, oxygen, carbon dioxide, and water vapor. The atmosphere and the hydrosphere make up Earth's fluid spheres.

The **biosphere** is the life zone of Earth and includes all living organisms, including humans, and all organic matter that has not yet decomposed.



The **cryosphere** is the portion of the climatic system consisting of the world's ice masses and snow deposits. The cryosphere is the frozen part of the hydrosphere. This includes ice sheets, ice shelves, ice caps and glaciers, sea ice, seasonal snow cover, lake and river ice, and seasonally frozen ground and permafrost.

The **geosphere** is the solid Earth that includes the continental and oceanic crust as well as the various layers of Earth's interior.

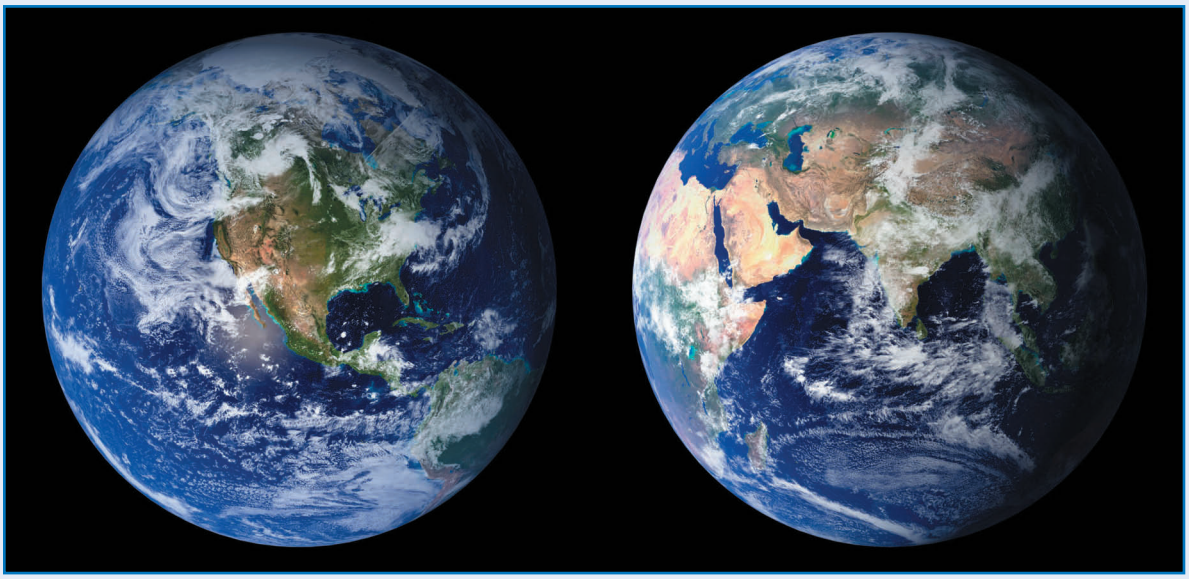
The **hydrosphere** includes the water of Earth, including surface lakes, streams, oceans, underground water, and water in the atmosphere. The hydrosphere and the atmosphere make up Earth's fluid spheres.

Earth/Space Science

Systems Thinking

Earth System Science

In 1946, cameras mounted on rockets were shot into space. They took the first pictures of Earth from space. The rockets then fell back to Earth. Scientists had to recover the cameras from the wreckage of the rockets. Today, scientists are still observing Earth from space. However, instead of using rocket-propelled cameras, they use Earth-imaging satellites that orbit the planet. Their observations and data are transmitted to Earth. These images and data have helped scientists to see that Earth is one big system—the Earth system. A system is a group of interacting or interconnected parts that work as a whole. Seeing Earth as a whole has helped scientists to study its major systems and provided insight into how the planet works.



The Earth system is not static. Earth is a dynamic planet. Technology makes it possible for scientists to observe many of the changes that are taking place. Through technology, scientists monitor many geologic processes as they happen. For instance, the movement of Earth's surface is measured using Global Positioning System (GPS) technology. Areas where one part of Earth's surface is moving under another part are explored using gravity measurements. Also, clouds of volcanic ash are tracked through the atmosphere using satellite imagery.

New technology also allows Earth system scientists to study the dynamics of climate and weather. For example, using satellites, scientists are able to measure temperatures across entire oceans and connect them to movements of the atmosphere. They can also peer into the atmosphere to measure water vapor otherwise invisible to the unaided eye. Also, from space, they can observe changes in glaciers and sea ice. They can also study the effects changes in climate have on living things, such as changes in the distribution of forests.

Earth is a gigantic system of interconnected parts and processes. Seeing Earth as an integrated system shows the importance of each of its parts. It demonstrates that humans are an integral part of the Earth system. What humans do affects Earth in many ways. As you journey through the chapters of *EarthComm*, you will explore how your community is part of the Earth system.

What is Systems Thinking?

Systems thinking is not only important in Earth and space science. Systems thinking can be applied to any kind of system. There are engineering systems, social systems, conceptual systems, natural systems, and so on. Even your school can be considered a system. Systems thinking is simply a method for understanding the relationships and connections between parts of a larger whole. It helps people analyze how things work, and simplify complex things by focusing on their most essential characteristics. It is a useful approach for looking at any problem you might need to solve.

In each *EarthComm* chapter, you will apply systems thinking. You will begin by considering the *parts* of systems and how they interact through *processes*. As you look at the interconnections within the Earth system, you will soon notice that systems are driven by sources of *energy*. Energy enables work to be done and *matter* to be transformed and moved. Sometimes you will make connections between parts of the Earth system that are separated by great distances in *space*. Systems can vary greatly in *spatial scale* from the size of an atom to entire solar systems and beyond. Making observations of patterns and cycles in the Earth system will help you to connect today's Earth system to events in geologic history. You will learn to look across *time* as you consider how the past can affect the future. Some aspects of the Earth system happen over very long *time scales*. For example, it takes *millions of years* for oceans to grow. On the other hand, there are events in the Earth system, such as earthquakes, that happen very quickly.

Connecting Earth's Systems

The Earth System diagram shows Earth as a group of interconnecting spheres. These include the geosphere, the hydrosphere, the atmosphere, the cryosphere, and the biosphere. Together, they make up the Earth system.

The **geosphere** is the rocky part of the planet. It is the part of Earth where oceans open and close, mountains rise and fall, volcanoes erupt, and earthquakes shatter the crust. The geosphere includes the continental and oceanic crust. It also includes Earth's mantle and inner and outer cores. The outer core generates Earth's magnetic field.

The rock cycle is an important process in this system. During this process, igneous, metamorphic, and sedimentary rocks are formed and destroyed. This is proof that Earth is a dynamic planet.

The **hydrosphere** includes the water of Earth. It includes surface lakes, streams, oceans, underground water, and water in the atmosphere.

The water cycle is part of the hydrosphere. It is an essential part of the planet. Evaporation of the oceans supplies water to the atmosphere. Precipitation flows across the continents in streams and rivers to the oceans. Liquid water can also be found below the surface in the pores of soil and sediments and in the fractures and spaces within bedrock. This water flows under the force of gravity through channels and spaces in rocks and eventually returns to the ocean.

Ocean water circulates deep in the ocean and at its surface. Circulation is strongly influenced by the conditions of the atmosphere. The movement of ocean water is closely linked to Earth's climate system. The properties of the oceans vary over time. One such example is the El Niño effect. This takes place in the equatorial eastern Pacific Ocean. However, it can affect the entire Earth system. El Niño demonstrates the strong connections between the atmosphere, the hydrosphere, and the *biosphere*.

The **atmosphere** is the gaseous envelope that surrounds Earth. It consists of a mixture of gases composed primarily of nitrogen, oxygen, carbon dioxide, and water vapor.

Earth's weather occurs in the atmosphere. The lower atmosphere contains the most water vapor and heat. It is also the most turbulent part of the atmosphere. Storm systems and severe weather occur there. Thunderstorms, lightning, tornadoes, and hurricanes, are all important processes in the lower atmosphere. The upper atmosphere absorbs ultraviolet light from the Sun. It creates a shield that prevents much of this radiation from reaching Earth's surface. Because of their dynamic nature, the hydrosphere and atmosphere are known as Earth's fluid spheres.

The **cryosphere** is the frozen portion of Earth's climate system. It consists of ice and snow. In Earth's polar regions and at high altitudes, parts of the hydrosphere often remain frozen. This sub-system includes ice sheets, ice shelves, ice caps, glaciers, and sea ice. It also includes seasonal snow cover, lake and river ice, and seasonally frozen ground and permafrost.

The cryosphere is particularly sensitive to climate. Scientists look for changes in the cryosphere as an indication of climate change. Since early in geologic history, the volume of Earth's oceans has been closely connected to the volume of ice on the continents.

The **biosphere** is the life zone of Earth. It includes all living organisms, including humans, and all organic matter that has not yet decomposed. The biosphere is widespread throughout the Earth system. Place where organisms can live are found in the each of Earth's spheres.

The biosphere is one of Earth's youngest systems. However, it is still billions of years old. As far as scientists *presently* know, it is entirely unique to the Earth system. No other planet has a biosphere. The development of the biosphere is closely connected to changes in Earth's other spheres. The biosphere has evolved over billions of years. Organisms have adapted to their environments. New species have developed. Some species have become extinct. Part of this long story is recorded in the rocks found in the geosphere. The species that you see today reflect part of an ongoing process of change.

The Earth system functions as a whole. In the classroom and the laboratory, you can study parts of the Earth system in isolation to understand them better. However, in nature, no part of the system exists in complete isolation. Keep this in mind during your studies. A chapter may focus more on one particular sphere than on the others. However, always think about how that part of the Earth system interacts with others. At the end of each chapter, you will be asked to reflect on how what you learned is connected to the other parts of the Earth system and how these parts work as a whole.