Earth’s atmosphere continuously interacts with the other components of the Earth System.

**FC 5.1** - Earth’s atmosphere exchanges energy and matter within the Earth System through processes such as photosynthesis, the water cycle, biogeochemical cycles, the rock cycle, and ocean currents.

**FC 5.2** - Interactions and feedbacks among the components of the Earth System can produce short-term oscillations (such as El Niño and La Niña conditions in the Pacific Ocean), long-term changes in the state of the system (such as global warming), and abrupt, unexpected events (such as sudden release of methane from permafrost).

**FC 5.3** - Earth’s atmosphere plays an important role in biogeochemical cycles in the Earth System. For example, the atmosphere is a reservoir of carbon in the Earth System, storing carbon released from natural processes and fossil fuel burning. Plants extract carbon from the atmosphere through photosynthesis.

**FC 5.4** - As a result of the long time-scales inherent in some Earth System processes, the impacts of some events may be felt only slowly throughout the Earth System and may continue to be influential long after the original event has changed. For example, because of the long time-scale of deep ocean circulation, an abrupt recent change in ocean salinity may take centuries to be reflected in the global circulation of the ocean.

**EP 6**

We seek to understand the past, present, and future behavior of Earth’s atmosphere through scientific observation and reasoning.

**FC 6.1** - Our understanding of Earth’s atmosphere comes from analysis, interpretation, and synthesis of accurate and purposeful observations of the atmosphere, ocean, biosphere, land surface, and Polar Regions.

**FC 6.2** - Data about Earth’s atmosphere are gathered by direct (in situ) measurement of temperature, precipitation, wind, pressure, and other variables, as well as by indirect (remote sensing) measurements taken at a distance using ground-based, satellite, and airborne instruments.

**FC 6.3** - Our understanding of Earth’s atmosphere allows scientists to develop numerical (computer) models that can be used to simulate Earth’s weather and climate. Such models are fundamental to modern weather analysis and forecasting and are essential to scientists’ efforts to understand Earth’s past climate and predict future climate.

**FC 6.4** - To generate predictions, numerical models must begin with observations of Earth’s atmosphere and the planet’s land and ocean surfaces. These data are used to provide starting conditions for models that are as complete as possible.

**FC 6.5** - Inaccuracies and the irreproducibility inherent in instruments, mathematical representations of physical processes, model resolution, and discrete numerical calculations limit the accuracy of the resulting simulations and predictions. Models improve with technological and theoretical advances, which improve data quality and quantity and our ability to represent physical processes. The chaotic nature of the inherent variability of some natural processes ultimately limits how far in advance atmospheric phenomena can be predicted, forcing the use of statistical projections.

**EP 7**

Earth’s atmosphere and humans are inextricably linked.

**FC 7.1** - Most living organisms on Earth are dependent on Earth’s atmosphere and its processes for survival. We require oxygen for breathing; rely on ozone in the stratosphere to protect us from harmful radiation from the Sun; depend on prevailing wind patterns for ocean upwelling and so supply food; rely on wind to power turbines, sails, and ventilators; and need rain for drinking water and agriculture.

**FC 7.2** - Living organisms can and do change the composition of Earth’s atmosphere and its processes. Many human activities, such as farming, forestry, building of cities, and burning of fossil fuels, alter atmosphere composition and thereby impact the functioning of ecosystems, human health, and climate on local, regional, and global scales.

**FC 7.3** - Humans around the world have adapted differently over hundreds of thousands of years to their unique local and regional weather and climate. Societies have different levels of vulnerability to rapidly changing weather and climate conditions. Severe weather can have major impact on individuals as well as society. Global and regional climate change may bring major changes to vulnerable cultures.

**FC 7.4** - Weather forecasts and predictions of future climate assist us in implementing mitigation strategies and adaptation to new climatic conditions.

**FC 7.5** - Citizens need to become educated about Earth’s atmosphere to make informed decisions on issues at local, regional, and global scales.

**Figure 7** - Often visible as a funnel-shaped cloud, tornadoes can develop with little or no warning. Deyop radar and other advanced technology now give advance warning of many formations which can damage property and lives. Copyright University Corporation for Atmospheric Research, Photo by Bob Hines.
All humans live in Earth’s atmosphere – we depend on it for air we breathe, the water we drink, and the food we eat. Humankind’s relationship with the atmosphere is aptly summarized by an unknown author:

“Man - despite his artistic pretensions, his sophistication, and his many accomplishments - owes his existence to a six inch layer of topsoil and the fact that it rains.”

Earth’s atmosphere, hydrosphere, geosphere, and biosphere comprise the Earth System. The atmosphere is a complex system in its own right that has co-evolved over time with these other components of the Earth System. The atmosphere is continuously changing – changes from hour to hour and day to day give us weather, while changes over periods of months to millennia give us climate. While Earth’s atmosphere provides many benefits, such as oxygen, rain, and power from the wind, it also brings hazards, such as tornadoes, hurricanes, floods, and drought.

We know, through our own experiences, scientific observations, and nearly daily news reports that Earth’s atmosphere is changing along with the rest of the global environment. Some of these changes are outside of human control – determined in some cases by solar and geologic processes. We are also increasingly aware that human activities are changing Earth’s atmosphere. Since there are no sharp boundaries in the atmosphere, pollutants resulting from industrial emissions in one place can travel across country and continental boundaries and negatively affect those that did not create the pollution.

We are challenged to live wisely with Earth’s atmosphere, utilizing it as a valuable resource while being good stewards. To understand what is happening in the atmosphere and make wise decisions about our vital interactions with it, it is important for us to have a basic understanding of the relevant scientific knowledge. That is, we must be literate with respect to the essential principles and fundamental concepts of atmospheric science.

**Atmospheric Science Literacy**

People who are literate in atmospheric science understand the "big ideas" of the relevant scientific knowledge. Armed with this understanding, they will have the basis to communicate about Earth’s atmosphere in a meaningful way, and be equipped to make informed and responsible decisions about activities that impact Earth's atmosphere. This framework for Atmospheric Science Literacy provides guidance to educators and the public on these big ideas. We have chosen to structure the framework with Essential Principles (EPs) at the highest level, on which more detailed information depends. Subordinate and more specific Fundamental Concepts (FCs) offer foundational knowledge which is needed to fully understand the Essential Principles.

**EP1** Earth has a thin atmosphere that sustains life.

FC 1.1 - Earth’s atmosphere is a mixture of gases with small, but important, quantities of liquid and solid particles.

FC 1.2 - The atmosphere has mass, is bound to Earth by gravity, and exerts pressure which is greater near Earth’s surface and decreases with altitude.

FC 1.3 - The atmosphere, which is very thin relative to Earth’s radius, varies vertically in layers which differ in composition, density, and temperature. The lowest 8-16 km of the atmosphere – the troposphere - contains most of Earth’s weather systems.

**EP2** Energy from the Sun drives atmospheric processes.

FC 2.1 - Energy from the Sun drives the atmospheric processes. Some of this solar energy is absorbed by the atmosphere, some is scattered back to space, and some is transmitted through the atmosphere to be absorbed or reflected by Earth's surface. The solar energy reflected by Earth's surface is absorbed, scattered, reflected, or transmitted by the atmosphere.

FC 2.2 - Energy from the Sun is transformed into other forms of energy in the Earth System. In the atmosphere these other forms include thermal energy of gas molecules, the kinetic energy of wind, and the latent heat of evaporation stored in water vapor.

FC 2.3 - On human time scales, the energy emitted by the Sun is nearly constant, varying only very slightly due to solar activity. The amount of solar energy received at a point on Earth’s surface varies due to Earth’s spherical shape, its daily rotation about its tilted axis, its annual revolution around the Sun, and the slight elliptical shape of Earth’s orbit, leading to important cycles such as day and night, and the seasons. In addition, cloud cover and aerosols can reduce the amount of solar energy that reaches Earth’s surface.

**EP3** Atmospheric circulations transport matter and energy.

FC 3.1 - Horizontal and vertical energy imbalances in the Earth System produced by unequal heating of Earth’s surface create movement in the atmosphere and the ocean.

FC 3.2 - Energy is exchanged within the atmosphere, as well as gained and lost across its interfaces with land and oceans through physical, geological, and biological processes organized in Earth System cycles (e.g., the water cycle). These exchanges help drive atmospheric circulations.

**EP4** Earth’s atmosphere changes over time and space, giving rise to weather and climate.

FC 4.1 - Weather is the state of Earth’s atmosphere at a particular place and time. The climate of a particular place encompasses the long-term range of weather conditions at that place. Earth’s global climate is determined by the energy received from the Sun and is regulated by atmospheric composition and by atmospheric and oceanic circulations.

**FC 4.2** - Climate changes over time periods ranging from seconds to weeks. Climate changes over intervals ranging from years to millennia. Earth’s history has been marked by gradual variations in global climate caused by long-term cyclical variations in Earth’s orbit and axial tilt, and modulated by changes over geologic time in the size and composition of the continental ice sheets. These gradual variations have been punctuated by relatively abrupt climatic shifts caused by volcanic eruptions and sudden redistributions of mass and energy in the oceans.

**FC 4.3** - Both weather and climate vary by region based on latitude, altitude, land use, proximity to physical features such as the ocean and mountains, and ocean currents.

**FC 4.4** - Weather phenomena are important to human society. As evidenced in art, literature, and human culture over time, some atmospheric phenomena are beautiful, inspiring the human spirit. Severe weather, such as thunderstorms, tornadoes, and hurricanes, can bring rapid, dramatic changes to ecosystems and to individuals, property, and infrastructure.