ESS2.D: Weather and Climate –1

Weather and Climate Factors

**ESS2.D - 1**

[Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns. (MS-ESS2-6)](http://www.nap.edu/openbook.php?record_id=13165&page=186)

**NGSS Evidence Statement:** [MS-ESS2-6](http://www.nextgenscience.org/sites/default/files/evidence_statement/black_white/MS-ESS2-6%20Evidence%20Statements%20June%202015%20asterisks.pdf)

**Framework Text:**

Core Idea ESS2

**Earth’s Systems**

*How and why is Earth constantly changing?*

Earth’s surface is a complex and dynamic set of interconnected systems—principally the geosphere, hydrosphere, atmosphere, and biosphere—that interact over a wide range of temporal and spatial scales. All of Earth’s processes are the result of energy flowing and matter cycling within and among these systems. For example, the motion of tectonic plates is part of the cycles of convection in Earth’s mantle, driven by outflowing heat and the downward pull of gravity, which result in the formation and changes of many features of Earth’s land and undersea surface. Weather and climate are shaped by complex interactions involving sunlight, the ocean, the atmosphere, clouds, ice, land, and life forms. Earth’s biosphere has changed the makeup of the geosphere, hydrosphere, and atmosphere over geological time; conversely, geological events and conditions have influenced the evolution of life on the planet. Water is essential to the dynamics of most earth systems, and it plays a significant role in shaping Earth’s landscape.

ESS2.D: WEATHER AND CLIMATE

*What regulates weather and climate?*

Weather, which varies from day to day and seasonally throughout the year, is the condition of the atmosphere at a given place and time. Climate is longer term and location sensitive; it is the range of a region’s weather over 1 year or many years, and, because it depends on latitude and geography, it varies from place to place. Weather and climate are shaped by complex interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions can drive changes that occur over multiple time scales—from days, weeks, and months for weather to years, decades, centuries, and beyond—for climate.

The ocean exerts a major influence on weather and climate. It absorbs and stores large amounts of energy from the sun and releases it very slowly; in that way, the ocean moderates and stabilizes global climates. Energy is redistributed globally through ocean currents (e.g., the Gulf Stream) and also through atmospheric circulation (winds). Sunlight heats Earth’s surface, which in turn heats the atmosphere. The resulting temperature patterns, together with Earth’s rotation and the configuration of continents and oceans, control the large-scale patterns of atmospheric circulation. Winds gain energy and water vapor content as they cross hot ocean regions, which can lead to tropical storms.

The “greenhouse effect” keeps Earth’s surface warmer than it would be otherwise. To maintain any average temperature over time, energy inputs from the sun and from radioactive decay in Earth’s interior must be balanced by energy loss due to radiation from the upper atmosphere. However, what determines the temperature at which this balance occurs is a complex set of absorption, reflection, transmission, and redistribution processes in the atmosphere and oceans that determine how long energy stays trapped in these systems before being radiated away. Certain gases in the atmosphere (water vapor, carbon dioxide, methane, and nitrous oxides), which absorb and retain energy that radiates from Earth’s surface, essentially insulate the planet. Without this phenomenon, Earth’s surface would be too cold to be habitable. However, changes in the atmosphere, such as increases in carbon dioxide, can make regions of Earth too hot to be habitable by many species.

Climate changes, which are defined as significant and persistent changes in an area’s average or extreme weather conditions, can occur if any of Earth’s systems change (e.g., composition of the atmosphere, reflectivity of Earth’s surface). Positive feedback loops can amplify the impacts of these effects and trigger relatively abrupt changes in the climate system; negative feedback loops tend to maintain stable climate conditions.

Some climate changes in Earth’s history were rapid shifts (caused by events, such as volcanic eruptions and meteoric impacts, that suddenly put a large amount of particulate matter into the atmosphere or by abrupt changes in ocean currents); other climate changes were gradual and longer term—due, for example, to solar output variations, shifts in the tilt of Earth’s axis, or atmospheric change due to the rise of plants and other life forms that modified the atmosphere via photosynthesis. Scientists can infer these changes from geological evidence.

Natural factors that cause climate changes over human time scales (tens or hundreds of years) include variations in the sun’s energy output, ocean circulation patterns, atmospheric composition, and volcanic activity. (See [ESS3.D](https://www.nap.edu/read/13165/chapter/196.xhtml#ess3.d) for a detailed discussion of human activities and global climate change.) When ocean currents change their flow patterns, such as during El Niño Southern Oscillation conditions, some global regions become warmer or wetter and others become colder or drier. Cumulative increases in the atmospheric concentration of carbon dioxide and other greenhouse gases, whether arising from natural sources or human industrial activity (see [ESS3.D](https://www.nap.edu/read/13165/chapter/196.xhtml#ess3.d)), increase the capacity of Earth to retain energy. Changes in surface or atmospheric reflectivity change the amount of energy from the sun that enters the planetary system. Icy surfaces, clouds, aerosols, and larger particles in the atmosphere, such as from volcanic ash, reflect sunlight and thereby decrease the amount of solar energy that can enter the weather/climate system. Conversely, dark surfaces (e.g., roads, most buildings) absorb sunlight and thus increase the energy entering the system.

**Main Concepts**

|  |  |
| --- | --- |
| **concept** | **weight** |
| Weather is defined as the conditions of the atmosphere at a particular place and time. | Core |
| Climate is defined as the average weather over decades in a particular region. | Core |
| The water cycle is dependent upon the flow of energy from the Sun. | Core |
| The Coriolis effect deflects atmospheric and oceanic currents, which affects regional climates. | Core |
| Because of differential heating from the Sun, climate is warmer at equatorial regions and cooler at higher latitudes. | Core |
| Ocean water heats and cools more slowly than land, causing temperate climates in regions near the ocean. | Core |
| The angle at which the sun strikes different latitudes on Earth causes unequal heating across the globe. | Core |
| Air pressure and temperature drop with elevation, causing changes in climate. | Core |
| The cycling of matter and energy between living things and the atmosphere affects climate. | Core |
| The flow of air as wind on Earth is related to heating from the Sun. | Core |
| When warm water evaporates from the ocean, it can condense to form storm clouds or intense tropical storm systems, such as hurricanes and tsunamis. | Core |
| Weather characteristics include: temperature, air pressure, humidity, precipitation, wind speed and direction. | Core |
| Atmospheric composition, including the amount of pollutants or greenhouse gases in the air, affects climate. | Core |
| The interactions affecting weather and climate vary with latitude, altitude, proximity to the ocean, topography, and surface characteristics. | Core |
| Ocean currents transfer thermal energy between the equator and polar regions of the globe. | Core |
| Gravity pulls denser air masses downwards, causing less dense air masses to rise. | Peripheral |
| Dense air masses are cool and dry, while less dense air masses are warm and humid. | Peripheral |
| Earth's hydrosphere includes all of the water existing in the atmosphere, bodies of water, and ground. | Peripheral |
| Albedo is the measure of how much light a surface reflects, which affects the climate in different regions. | Peripheral |

**Related Concepts and Applications**

* Tilt of Earth’s axis and seasons
* Climate change is a result of changes in position of continents and oceans, topography (mountain building and erosion) ocean currents, atmospheric composition, populations of living things, surface brightness, position and motion of Earth with respect to the Sun
* Weather is defined as the conditions of the atmosphere (temperature, air pressure, humidity, precipitation, wind speed and direction) at a particular place and time
* Climate is described by average weather (or typical weather patterns) over decades in a particular region
* Both weather and climate are influenced by:
  + **Latitude**: because Earth is a sphere and because its axis is tilted, lower latitudes received more consistent and more direct sunlight than high latitudes
  + **Oceans and ocean currents**: currents carry warm water to cool places and cool water to warm places
  + **Ocean vs. Land**: ocean water heats up and cools off more slowly than land;
  + **Topography**: air pressure and temperature drop with elevation; climate of one side of a mountain chain can be dryer than the other because of the rain shadow effect
  + **Atmospheric composition**: carbon dioxide absorbs thermal energy from the ground, keeping Earth warm
  + **Surface characteristics (albedo)**: bright surfaces reflect sunlight back to space; dark surfaces absorb sunlight and heat up
  + **Living things**: vegetation absorbs sunlight and carbon dioxide, and releases oxygen and water back to the atmosphere; animals
  + **Earth’s rotation**: Coriolis effect (NOTE: this effect occurs because masses of air and water maintain their original speed as they move from the equator to poles or poles to equator, not because Earth moves beneath the air and water)

**Related Crosscutting Concepts**

* **Patterns** patterns of atmospheric conditions (temperature, pressure, precipitation) are used to understand and predict weather; patterns of climate are used to understand the factors that influence climate
* **Cause and Effect** Many factors affect weather and climate; weather has many effects on Earth’s surface
* **Scales, Proportions, and Quantities** weather and weather systems can be local to regional; climates are generally regional, but variations in different factors can result in microclimates
* **Systems and System Models** weather and climate are studied system models of inputs, outputs, and processes
* **Energy and Matter** Weather involvesthe flow of matter (water and air), which is driven by the flow of energy from the sun (along with gravity)
* **Stability and Change**  Weather can be described as “stable” or “changing” on a very short-term timescale (hours to days). Although weather conditions on Earth change continuously, the forces, energy, and processes that drive weather and the factors that influence weather have not changed over Earth history. The same is true for climate.

**Practices of Science and Engineering**

Teachers will impressed if the game teaches students about or, better, involves students in one or more of the following:

* **Planning or Carrying Out Investigations** about the effects of various factors on weather and climate; choosing tools to collect and analyze data
* **Analyzing and Interpreting Data** interpreting weather and climate data
* **Developing and Using Models** creating or interpreting 2D static or animated models(or virtual 3D models) of weather and climate
* **Constructing Explanations** of how various factors influence weather and climate
* **Engaging in Argument from Evidence** predicting how weather or climate will change if different factors change

**Grade Bands:**

|  |  |  |  |
| --- | --- | --- | --- |
| **K-2**  You can assume that students already know that  . . . | **3-5**  Students should have learned this, but it is fine to review it . . . | **6-8**  **This is what students need to learn:** | **9-12**  You don’t need to go into this much depth  (but it is ok to go this far if it makes sense to do so . . .) |
| • Sunlight warms Earth’s surface. (K-PS3-1),(K-PS3-2)  • Weather is the combination of sunlight, wind, snow or rain, and temperature in a particular region at a particular time. People measure these conditions to describe and record the weather and to notice patterns over time. (K-ESS2-1) | • Scientists record patterns of the weather across different times and areas so that they can make predictions about what kind of weather might happen next. (3-ESS2-1)  • Climate describes a range of an area's typical weather conditions and the extent to which those conditions vary over years. (3-ESS2-2) | • Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns. (MS-ESS2-6) | • The foundation for Earth’s global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy’s re-radiation into space. (HS-ESS2-4)  • Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen. (HS-ESS2-6),(HS-ESS2-7)  • Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate. (HS-ESS2-6),(HS-ESS2-4) |

**Middle School Level Resources:**

These are examples of what middle schoolers are learning.

Textbook resources:

* Text for Middle School:  <http://www.ck12.org/earth-science/>; <http://www.ck12.org/book/CK-12-Earth-Science-For-Middle-School>
  + Weather: <http://www.ck12.org/book/CK-12-Earth-Science-For-Middle-School/section/16.0/>
  + Climate and Its Causes: <http://www.ck12.org/book/CK-12-Earth-Science-For-Middle-School/section/17.1/>
  + Air Movement: <http://www.ck12.org/book/CK-12-Earth-Science-For-Middle-School/section/15.4/>
  + Ocean Currents: <http://www.ck12.org/book/CK-12-Earth-Science-For-Middle-School/section/14.2/>
  + The Water Cycle: <http://www.ck12.org/book/CK-12-Earth-Science-For-Middle-School/section/13.1/>
  + Solar energy: <http://www.ck12.org/book/CK-12-Earth-Science-For-Middle-School/section/15.2/>

Other Resources: