

"Global Warming Guaranteed: What the ocean tells us about climate change"
related California Science Education Standards, Ocean Literacy, Climate Literacy

Here are the specific grade level standards that relate to climate and the ocean in the California Science Education framework.

(All of the California Education Content Standards can be found online here:

<http://www.cde.ca.gov/be/st/ss/>)

Grade 1

Earth Sciences

3. Weather can be observed, measured, and described. As a basis for understanding this concept:

- a. Students know how to use simple tools (e.g., thermometer, wind vane) to measure weather conditions and record changes from day to day and across the seasons.
- b. Students know that the weather changes from day to day but that trends in temperature or of rain (or snow) tend to be predictable during a season.
- c. Students know the sun warms the land, air, and water.

Grade 5

Earth Sciences

3. Water on Earth moves between the oceans and land through the processes of evaporation and condensation. As a basis for understanding this concept:

- a. Students know most of Earth's water is present as salt water in the oceans, which cover most of Earth's surface.
- b. Students know when liquid water evaporates, it turns into water vapor in the air and can reappear as a liquid when cooled or as a solid if cooled below the freezing point of water.
- c. Students know water vapor in the air moves from one place to another and can form fog or clouds, which are tiny droplets of water or ice, and can fall to Earth as rain, hail, sleet, or snow.

4. Energy from the Sun heats Earth unevenly, causing air movements that result in changing weather patterns. As a basis for understanding this concept:

- a. Students know uneven heating of Earth causes air movements (convection currents).
- b. Students know the influence that the ocean has on the weather and the role that the water cycle plays in weather patterns.
- c. Students know the causes and effects of different types of severe weather.
- d. Students know how to use weather maps and data to predict local weather and know that weather forecasts depend on many variables.
- e. Students know that the Earth's atmosphere exerts a pressure that decreases with distance above Earth's surface and that at any point it exerts this pressure equally in all directions.

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Grade 6

Heat (Thermal Energy) (Physical Sciences)

3. Heat moves in a predictable flow from warmer objects to cooler objects until all the objects are at the same temperature. As a basis for understanding this concept:
- Students know energy can be carried from one place to another by heat flow or by waves, including water, light and sound waves, or by moving objects.
 - Students know heat flows in solids by conduction (which involves no flow of matter) and in fluids by conduction and by convection (which involves flow of matter).
 - Students know heat energy is also transferred between objects by radiation (radiation can travel through space).

Energy in the Earth System

4. Many phenomena on Earth's surface are affected by the transfer of energy through radiation and convection currents. As a basis for understanding this concept:
- Students know the sun is the major source of energy for phenomena on Earth's surface; it powers winds, ocean currents, and the water cycle.
 - Students know solar energy reaches Earth through radiation, mostly in the form of visible light.
 - Students know heat from Earth's interior reaches the surface primarily through convection.
 - Students know convection currents distribute heat in the atmosphere and oceans.
 - Students know differences in pressure, heat, air movement, and humidity result in changes of weather.

High School

Earth Sciences

Energy in the Earth System

4. Energy enters the Earth system primarily as solar radiation and eventually escapes as heat. As a basis for understanding this concept:
- Students know the relative amount of incoming solar energy compared with Earth's internal energy and the energy used by society.
 - Students know the fate of incoming solar radiation in terms of reflection, absorption, and photosynthesis.
 - Students know the different atmospheric gases that absorb the Earth's thermal radiation and the mechanism and significance of the greenhouse effect.
 - * Students know the differing greenhouse conditions on Earth, Mars, and Venus; the origins of those conditions; and the climatic consequences of each.

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5. Heating of Earth's surface and atmosphere by the sun drives convection within the atmosphere and oceans, producing winds and ocean currents. As a basis for understanding this concept:
- Students know how differential heating of Earth results in circulation patterns in the atmosphere and oceans that globally distribute the heat.
 - Students know the relationship between the rotation of Earth and the circular motions of ocean currents and air in pressure centers.
 - Students know the origin and effects of temperature inversions.
 - Students know properties of ocean water, such as temperature and salinity, can be used to explain the layered structure of the oceans, the generation of horizontal and vertical ocean currents, and the geographic distribution of marine organisms.
 - Students know rain forests and deserts on Earth are distributed in bands at specific latitudes.
 - * Students know the interaction of wind patterns, ocean currents, and mountain ranges results in the global pattern of latitudinal bands of rain forests and deserts.
 - * Students know features of the ENSO (El Niño southern oscillation) cycle in terms of sea surface and air temperature variations across the Pacific and some climatic results of this cycle.
6. Climate is the long-term average of a region's weather and depends on many factors. As a basis for understanding this concept:
- Students know weather (in the short run) and climate (in the long run) involve the transfer of energy into and out of the atmosphere.
 - Students know the effects on climate of latitude, elevation, topography, and proximity to large bodies of water and cold or warm ocean currents.
 - Students know how Earth's climate has changed over time, corresponding to changes in Earth's geography, atmospheric composition, and other factors, such as solar radiation and plate movement.
 - * Students know how computer models are used to predict the effects of the increase in greenhouse gases on climate for the planet as a whole and for specific regions.

Structure and Composition of the Atmosphere

8. Life has changed Earth's atmosphere, and changes in the atmosphere affect conditions for life. As a basis for understanding this concept:
- Students know the thermal structure and chemical composition of the atmosphere.
 - Students know how the composition of Earth's atmosphere has evolved over geologic time and know the effect of out-gassing, the variations of carbon dioxide concentration, and the origin of atmospheric oxygen.

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- c. Students know the location of the ozone layer in the upper atmosphere, its role in absorbing ultraviolet radiation, and the way in which this layer varies both naturally and in response to human activities.
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(All of the Ocean Literacy Principles and Concepts can be found here:

http://oceanliteracy.wp.coexploration.org/?page_id=164)

Ocean Literacy Principle 3: The ocean is a major influence on weather and climate.

- 3a. The ocean controls weather and climate by dominating the Earth's energy, water and carbon systems.
- 3b. The ocean absorbs much of the solar radiation reaching Earth. The ocean loses heat by evaporation. This heat loss drives atmospheric circulation when, after it is released into the atmosphere as water vapor, it condenses and forms rain. Condensation of water evaporated from warm seas provides the energy for hurricanes and cyclones.
- 3c. The El Niño Southern Oscillation causes important changes in global weather patterns because it changes the way heat is released to the atmosphere in the Pacific.
- 3d. Most rain that falls on land originally evaporated from the tropical ocean.
- 3e. The ocean dominates the Earth's carbon cycle. Half the primary productivity on Earth takes place in the sunlit layers of the ocean and the ocean absorbs roughly half of all carbon dioxide added to the atmosphere.
- 3f. The ocean has had, and will continue to have, a significant influence on climate change by absorbing, storing, and moving heat, carbon and water.
- 3g. Changes in the ocean's circulation have produced large, abrupt changes in climate during the last 50,000 years.
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(All of the Climate Literacy Principles and Concepts can be found here:

<http://climateliteracynow.org/>)

Climate Literacy Principles:

1. THE SUN IS THE PRIMARY SOURCE OF ENERGY FOR EARTH'S CLIMATE SYSTEM.

- A. Sunlight reaching the Earth can heat the land, ocean, and atmosphere. Some of that sunlight is reflected back to space by the surface, clouds, or ice. Much of the sunlight that reaches Earth is absorbed and warms the planet.
- B. When Earth emits the same amount of energy as it absorbs, its energy budget is in balance, and its average temperature remains stable.

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- C. The tilt of Earth's axis relative to its orbit around the Sun results in predictable changes in the duration of daylight and the amount of sunlight received at any latitude throughout a year. These changes cause the annual cycle of seasons and associated temperature changes.
- D. Gradual changes in Earth's rotation and orbit around the Sun change the intensity of sunlight received in our planet's polar and equatorial regions. For at least the last 1 million years, these changes occurred in 100,000-year cycles that produced ice ages and the shorter warm periods between them.
- E. A significant increase or decrease in the Sun's energy output would cause Earth to warm or cool. Satellite measurements taken over the past 30 years show that the Sun's energy output has changed only slightly and in both directions. These changes in the Sun's energy are thought to be too small to be the cause of the recent warming observed on Earth.

2. CLIMATE IS REGULATED BY COMPLEX INTERACTIONS AMONG COMPONENTS OF THE EARTH SYSTEM.

- A. Earth's climate is influenced by interactions involving the Sun, ocean, atmosphere, clouds, ice, land, and life. Climate varies by region as a result of local differences in these interactions.
- B. Covering 70% of Earth's surface, the ocean exerts a major control on climate by dominating Earth's energy and water cycles. It has the capacity to absorb large amounts of solar energy. Heat and water vapor are redistributed globally through density-driven ocean currents and atmospheric circulation. Changes in ocean circulation caused by tectonic movements or large influxes of fresh water from melting polar ice can lead to significant and even abrupt changes in climate, both locally and on global scales.
- C. The amount of solar energy absorbed or radiated by Earth is modulated by the atmosphere and depends on its composition. Greenhouse gases – such as water vapor, carbon dioxide, and methane – occur naturally in small amounts and absorb and release heat energy more efficiently than abundant atmospheric gases like nitrogen and oxygen. Small increases in carbon dioxide concentration have a large effect on the climate system.
- D. The abundance of greenhouse gases in the atmosphere is controlled by biogeochemical cycles that continually move these components between their ocean, land, life, and atmosphere reservoirs. The abundance of carbon in the atmosphere is reduced through seafloor accumulation of marine sediments and accumulation of plant biomass and is increased through deforestation and the burning of fossil fuels as well as through other processes.
- E. Airborne particulates, called "aerosols," have a complex effect on Earth's energy balance: they can cause both cooling, by reflecting incoming sunlight back out to space, and warming, by absorbing and releasing heat energy in the atmosphere.

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Small solid and liquid particles can be lofted into the atmosphere through a variety of natural and man-made processes, including volcanic eruptions, sea spray, forest fires, and emissions generated through human activities.

F. The interconnectedness of Earth's systems means that a significant change in any one component of the climate system can influence the equilibrium of the entire Earth system. Positive feedback loops can amplify these effects and trigger abrupt changes in the climate system. These complex interactions may result in climate change that is more rapid and on a larger scale than projected by current climate models.

3. LIFE ON EARTH DEPENDS ON, IS SHAPED BY, AND AFFECTS CLIMATE.

- A. Individual organisms survive within specific ranges of temperature, precipitation, humidity, and sunlight. Organisms exposed to climate conditions outside their normal range must adapt or migrate, or they will perish.
- B. The presence of small amounts of heat-trapping greenhouse gases in the atmosphere warms Earth's surface, resulting in a planet that sustains liquid water and life.
- C. Changes in climate conditions can affect the health and function of ecosystems and the survival of entire species. The distribution patterns of fossils show evidence of gradual as well as abrupt extinctions related to climate change in the past.
- D. A range of natural records shows that the last 10,000 years have been an unusually stable period in Earth's climate history. Modern human societies developed during this time. The agricultural, economic, and transportation systems we rely upon are vulnerable if the climate changes significantly.
- E. Life—including microbes, plants, and animals and humans—is a major driver of the global carbon cycle and can influence global climate by modifying the chemical makeup of the atmosphere. The geologic record shows that life has significantly altered the atmosphere during Earth's history.

4. CLIMATE VARIES OVER SPACE AND TIME THROUGH BOTH NATURAL AND MAN-MADE PROCESSES.

- A. Climate is determined by the long-term pattern of temperature and precipitation averages and extremes at a location. Climate descriptions can refer to areas that are local, regional, or global in extent. Climate can be described for different time intervals, such as decades, years, seasons, months, or specific dates of the year.
- B. Climate is not the same thing as weather. Weather is the minute-by-minute variable condition of the atmosphere on a local scale. Climate is a conceptual description of an area's average weather conditions and the extent to which those conditions vary over long time intervals.

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- C. Climate change is a significant and persistent change in an area's average climate conditions or their extremes. Seasonal variations and multi-year cycles (for example, the El Niño Southern Oscillation) that produce warm, cool, wet, or dry periods across different regions are a natural part of climate variability. They do not represent climate change.
- D. Scientific observations indicate that global climate has changed in the past, is changing now, and will change in the future. The magnitude and direction of this change is not the same at all locations on Earth.
- E. Based on evidence from tree rings, other natural records, and scientific observations made around the world, Earth's average temperature is now warmer than it has been for at least the past 1,300 years. Average temperatures have increased markedly in the past 50 years, especially in the North Polar Region.
- F. Natural processes driving Earth's long-term climate variability do not explain the rapid climate change observed in recent decades. The only explanation that is consistent with all available evidence is that human impacts are playing an increasing role in climate change. Future changes in climate may be rapid compared to historical changes.
- G. Natural processes that remove carbon dioxide from the atmosphere operate slowly when compared to the processes that are now adding it to the atmosphere. Thus, carbon dioxide introduced into the atmosphere today may remain there for a century or more. Other greenhouse gases, including some created by humans, may remain in the atmosphere for thousands of years.

5. OUR UNDERSTANDING OF THE CLIMATE SYSTEM IS IMPROVED THROUGH OBSERVATIONS, THEORETICAL STUDIES, AND MODELING.

- A. The components and processes of Earth's climate system are subject to the same physical laws as the rest of the Universe. Therefore, the behavior of the climate system can be understood and predicted through careful, systematic study.
- B. Environmental observations are the foundation for understanding the climate system. From the bottom of the ocean to the surface of the Sun, instruments on weather stations, buoys, satellites, and other platforms collect climate data. To learn about past climates, scientists use natural records, such as tree rings, ice cores, and sedimentary layers. Historical observations, such as native knowledge and personal journals, also document past climate change.
- C. Observations, experiments, and theory are used to construct and refine computer models that represent the climate system and make predictions about its future behavior. Results from these models lead to better understanding of the linkages between the atmosphere-ocean system and climate conditions and inspire more observations and experiments. Over time, this iterative process will result in more reliable projections of future climate conditions.

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- D. Our understanding of climate differs in important ways from our understanding of weather. Climate scientists' ability to predict climate patterns months, years, or decades into the future is constrained by different limitations than those faced by meteorologists in forecasting weather days to weeks into the future.
- E. Scientists have conducted extensive research on the fundamental characteristics of the climate system and their understanding will continue to improve. Current climate change projections are reliable enough to help humans evaluate potential decisions and actions in response to climate change.

6. HUMAN ACTIVITIES ARE IMPACTING THE CLIMATE SYSTEM.

- A. The overwhelming consensus of scientific studies on climate indicates that most of the observed increase in global average temperatures since the latter part of the 20th century is very likely due to human activities, primarily from increases in greenhouse gas concentrations resulting from the burning of fossil fuels.
- B. Emissions from the widespread burning of fossil fuels since the start of the Industrial Revolution have increased the concentration of greenhouse gases in the atmosphere. Because these gases can remain in the atmosphere for hundreds of years before being removed by natural processes, their warming influence is projected to persist into the next century.
- C. Human activities have affected the land, oceans, and atmosphere, and these changes have altered global climate patterns. Burning fossil fuels, releasing chemicals into the atmosphere, reducing the amount of forest cover, and rapid expansion of farming, development, and industrial activities are releasing carbon dioxide into the atmosphere and changing the balance of the climate system.
- D. Growing evidence shows that changes in many physical and biological systems are linked to human-caused global warming.³ Some changes resulting from human activities have decreased the capacity of the environment to support various species and have substantially reduced ecosystem biodiversity and ecological resilience.
- E. Scientists and economists predict that there will be both positive and negative impacts from global climate change. If warming exceeds 2 to 3°C (3.6 to 5.4°F) over the next century, the consequences of the negative impacts are likely to be much greater than the consequences of the positive impacts.