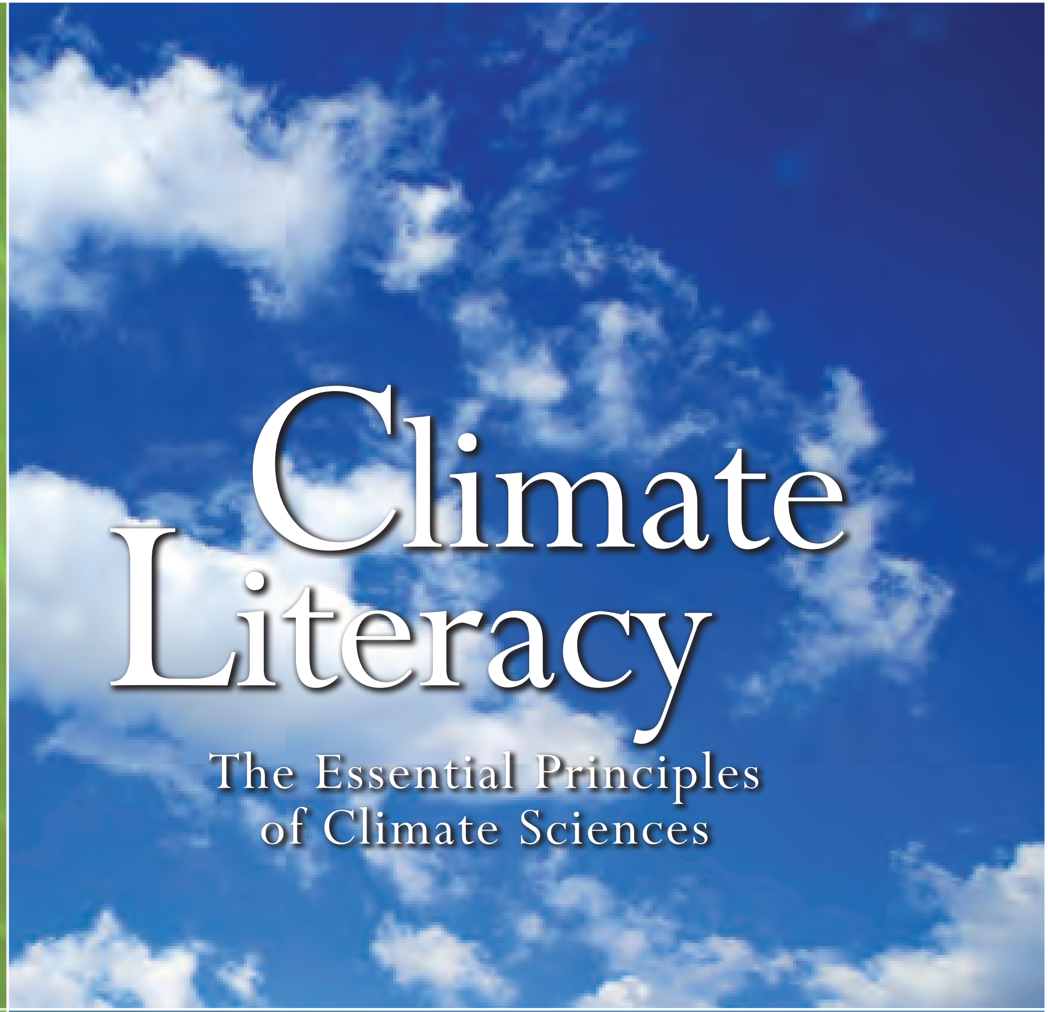
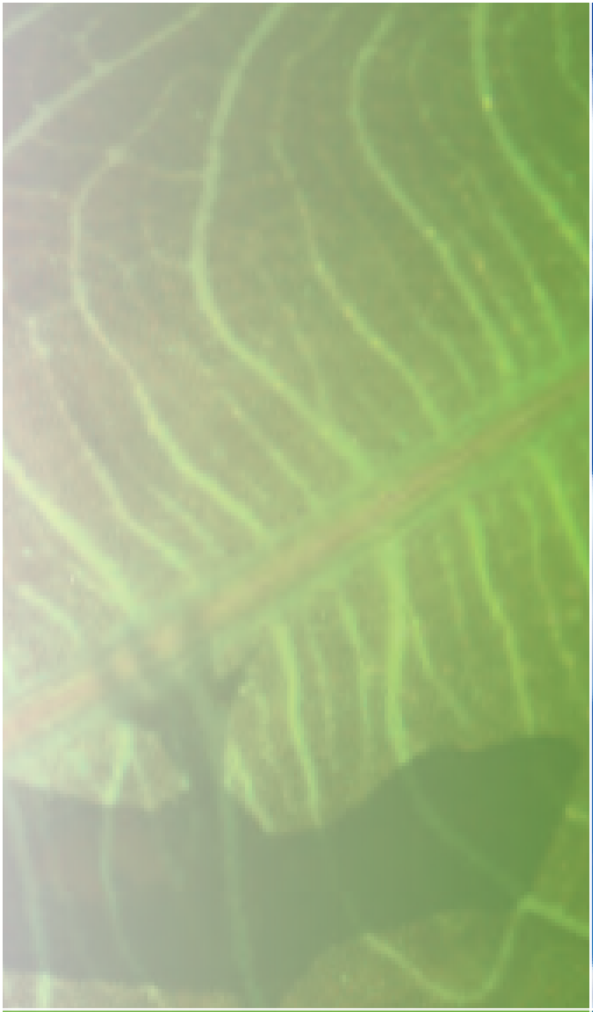


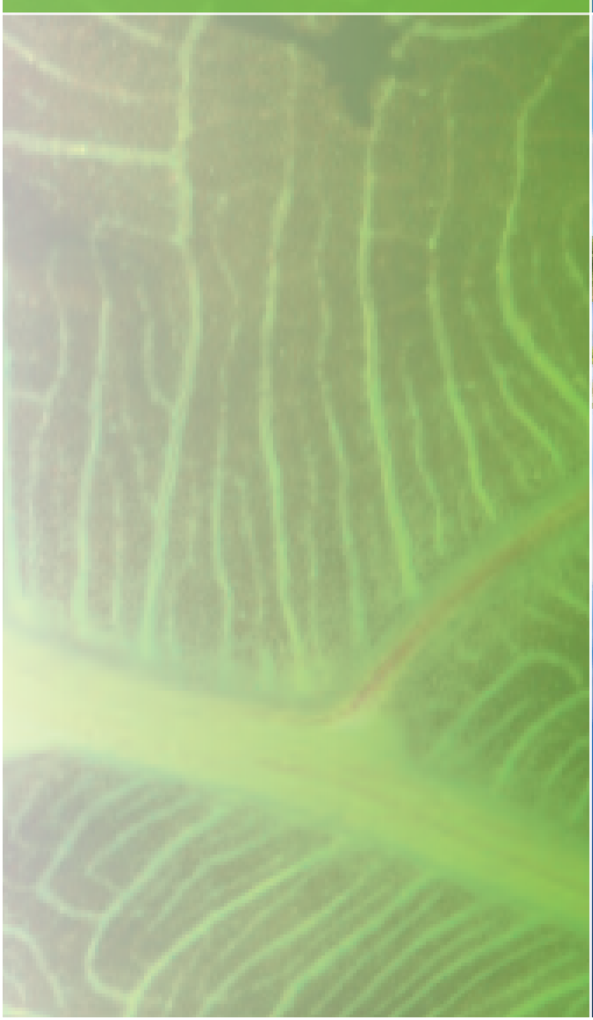
Climate Literacy

The Essential Principles of Climate Sciences



A CLIMATE-ORIENTED APPROACH FOR LEARNERS OF ALL AGES

A Guide for Individuals and Communities



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CLIMATE CHANGES

Throughout its history, Earth's climate has varied, reflecting the complex interactions and dependencies of the solar, oceanic, terrestrial, atmospheric, and living components that make up planet Earth's systems. For at least the last million years, our world has experienced cycles of warming and cooling that take approximately 100,000 years to complete. Over the course of each cycle, global average temperatures have fallen and then risen again by about 9°F (5°C), each time taking Earth into an ice age and then warming it again. This cycle is believed associated with regular changes in Earth's orbit that alter the intensity of solar energy the planet receives. Earth's climate has also been influenced on very long timescales by changes in ocean circulation that result from plate tectonic movements. Earth's climate has changed abruptly at times, sometimes as a result of slower natural processes such as shifts in ocean circulation, sometimes due to sudden events such as massive volcanic eruptions. Species and ecosystems have either adapted to these past climate variations or perished.

While global climate has been relatively stable over the last 10,000 years—the span of human civilization—regional variations in climate patterns have influenced human history in profound ways, playing an integral role in whether societies thrived or failed. We now know that the opposite is also true: human activities—burning fossil fuels and deforesting large areas of land, for instance—have had a profound influence on Earth's climate. In its 2007 Fourth Assessment, the Intergovernmental Panel on Climate Change (IPCC) stated that it had "very high confidence that the global average net effect of human activities since 1750 has been one of warming." The IPCC attributes humanity's global warming influence primarily to the increase in three key heat-trapping gases in the atmosphere: carbon dioxide, methane, and nitrous oxide. The U.S. Climate Change Science Program published findings in agreement with the IPCC report, stating that "studies to detect climate change and attribute its causes using patterns of observed temperature change in space and time show clear evidence of human influences on the climate system (due to changes in greenhouse gases, aerosols, and stratospheric ozone)."[1]

To protect fragile ecosystems and to build sustainable communities that are resilient to climate change—including extreme weather and climate events—a climate-literate citizenry is essential. This climate science literacy guide identifies the essential principles and fundamental concepts that individuals and communities should understand about Earth's climate system. Such understanding improves our ability to make decisions about activities that increase vulnerability to the impacts of climate change and to take precautionary steps in our lives and livelihoods that would reduce those vulnerabilities.

1. *Temperature Trends in the Lower Atmosphere: Steps for Understanding and Reconciling Differences*. Thomas R. Karl, Susan J. Hassol, Christopher D. Miller, and William L. Murray, editors, 2006. A Report by the Climate Change Science Program and the Subcommittee on Global Change Research, Washington, DC.

WHAT IS CLIMATE SCIENCE LITERACY?

Climate Science Literacy is an understanding of your influence on climate and climate's influence on you and society.

A climate-literate person:

- understands the essential principles of Earth's climate system,
- knows how to assess scientifically credible information about climate,
- communicates about climate and climate change in a meaningful way, and
- is able to make informed and responsible decisions with regard to actions that may affect climate.

WHY DOES CLIMATE SCIENCE LITERACY MATTER?

- During the 20th century, Earth's globally averaged surface temperature rose by approximately 1.08°F (0.6°C). Additional warming of more than 0.25°F (0.14°C) has been measured since 2000. Though the total increase may seem small, it likely represents an extraordinarily rapid rate of change compared to changes in the previous 10,000 years.
- Over the 21st century, climate scientists expect Earth's temperature to continue increasing, very likely more than it did during the 20th century. Two anticipated results are rising global sea level and increasing frequency and intensity of heat waves, droughts, and floods. These changes will affect almost every aspect of human society, including economic prosperity, human and environmental health, and national security.
- Scientific observations and climate model results indicate that human activities are now the primary cause of most of the ongoing increase in Earth's globally averaged surface temperature.
- Climate change will bring economic and environmental challenges as well as opportunities, and citizens who have an understanding of climate science will be better prepared to respond to both.
- Society needs citizens who understand the climate system and know how to apply that knowledge in their careers and in their engagement as active members of their communities.
- Climate change will continue to be a significant element of public discourse. Understanding the essential principles of climate science will enable all people to assess news stories and contribute to their everyday conversations as informed citizens.

CLIMATE SCIENCE LITERACY IS A PART OF SCIENCE LITERACY.

"Science, mathematics, and technology have a profound impact on our individual lives and our culture. They play a role in almost all human endeavors, and they affect how we relate to one another and the world around us. . . . Science Literacy enables us to make sense of real-world phenomena, informs our personal and social decisions, and serves as a foundation for a lifetime of learning."

From the American Association for the Advancement of Science, Atlas of Science Literacy, Volume 2, Project 2061.

People who are climate science literate know that climate science can inform our decisions that improve quality of life. They have a basic understanding of the climate system, including the natural and human-caused factors that affect it. Climate science literate individuals understand how climate observations and records as well as computer modeling contribute to scientific knowledge about climate. They are aware of the fundamental relationship between climate and human life and the many ways in which climate has always played a role in human health. They have the ability to assess the validity of scientific arguments about climate and to use that information to support their decisions.

CLIMATE SCIENCE LITERACY IS AN ONGOING PROCESS.

No single person is expected to understand every detail about all of the fundamental climate science literacy concepts. Full comprehension of these interconnected concepts will require a systems-thinking approach, meaning the ability to understand complex interconnections among all of the components of the climate system. Moreover, as climate science progresses and as efforts to educate the people about climate's influence on them and their influence on the climate system mature, public understanding will continue to grow.

Climate is an ideal interdisciplinary theme for lifelong learning about the scientific process and the ways in which humans affect and are affected by the Earth's systems. This rich topic can be approached at many levels, from comparing the daily weather with long-term records to exploring abstract representations of climate in computer models to examining how climate change impacts human and ecosystem health. Learners of all ages can use data from their own experiments, data collected by satellites and other observation systems, or records from a range of physical, chemical, biological, geographical, social, economic, and historical sources to explore the impacts of climate and potential adaptation and mitigation strategies.

HOW DO WE KNOW WHAT IS SCIENTIFICALLY CORRECT?

The Peer Review Process

Science is an on-going process of making observations and using evidence to test hypotheses. As new ideas are developed and new data are obtained, oftentimes enabled by new technologies, our understanding evolves. The scientific community uses a highly formalized version of peer review to validate research results and our understanding of their significance. Researchers describe their experiments, results, and interpretations in scientific manuscripts and submit them to a scientific journal that specializes in their field of science. Scientists who are experts in that field serve as "referees" for the journal: they read the manuscript carefully to judge the reliability of the research design and check that the interpretations are supported by the data. Based on the reviews, journal editors may accept or reject manuscripts or ask the authors to make revisions if the study has insufficient data or unsound interpretations. Through this process, only those concepts that have been described through well-documented research and subjected to the scrutiny of other experts in the field become published papers in science journals and accepted as current science knowledge. Although peer review does not guarantee that any particular published result is valid, it does provide a high assurance that the work has been carefully vetted for accuracy by informed experts prior to publication. The overwhelming majority of peer-reviewed papers about global climate change acknowledge that human activities are substantially contributing factors.

Source: *Roger J. Braithwaite, The University of Manchester, UK*

A meltwater stream on the Greenland Ice Sheet flows into the ice through a tunnel called a moulin. About half of the loss of Greenland's ice mass flows into the North Atlantic Ocean as melt water. Liquid water, which is denser than ice, can penetrate through the ice sheet, lubricating the underside, and also accelerate ice loss. Warmer temperatures cause melting in the summer months, which leads to faster flow, drawing more of the ice sheet down to warmer, lower altitudes.

Agricultural engineers inspect a dry stream.

Source: *Scott Bauer, USDA*

INFORMED CLIMATE DECISIONS REQUIRE AN INTEGRATED APPROACH.

In the coming decades, scientists expect climate change to have an increasing impact on human and natural systems. In a warmer world, accessibility to food, water, raw materials, and energy are likely to change. Human health, biodiversity, economic stability, and national security are also expected to be affected by climate change. Climate model projections suggest that negative effects of climate change will significantly outweigh positive ones. The nation's ability to prepare for and adapt to new conditions may be exceeded as the rate of climate change increases.

Reducing our vulnerability to these impacts depends not only upon our ability to understand climate science and the implications of climate change, but also upon our ability to integrate and use that knowledge effectively. Changes in our economy and infrastructure as well as individual attitudes, societal values, and government policies will be required to alter the current trajectory of climate's impact on human lives. The resolve of individuals, communities, and countries to identify and implement effective management strategies for critical institutional and natural resources will be necessary to ensure the stability of both human and natural systems as temperatures rise.

This climate science literacy document focuses primarily on the physical and biological science aspects of climate and climate change. Yet as nations and the international community seek solutions to global climate change over the coming decades, a more comprehensive, interdisciplinary approach to climate literacy—one that includes economic and social considerations—will play a vital role in knowledgeable planning, decision making, and governance. A new effort is in development within the social sciences community to produce a companion document that will address these aspects of climate literacy. Together, these documents will promote informed decision-making and effective systems-level responses to climate change that reflect a fundamental understanding of climate science. It is imperative that these responses to climate change embrace the following guiding principle.

GUIDING PRINCIPLE FOR INFORMED CLIMATE DECISION:

Humans can take actions to reduce climate change and its impacts.

A. Climate information can be used to reduce vulnerabilities or enhance the resilience of communities and ecosystems affected by climate change. Continuing to improve scientific understanding of the climate system and the quality of reports to policy and decision-makers is crucial.

B. Reducing human vulnerability to the impacts of climate change depends not only upon our ability to understand climate science, but also upon our ability to integrate that knowledge into human society. Decisions that involve Earth's climate must be made with an understanding of the complex interconnections among the physical and biological components of the Earth system as well as the consequences of such decisions on social, economic, and cultural systems.

C. The impacts of climate change may affect the security of nations. Reduced availability of water, food, and land can lead to competition and conflict among humans, potentially resulting in large groups of climate refugees.

D. Humans may be able to mitigate climate change or lessen its severity by reducing greenhouse gas concentrations through processes that move carbon out of the atmosphere or reduce greenhouse gas emissions.

E. A combination of strategies is needed to reduce greenhouse gas emissions. The most immediate strategy is conservation of oil, gas, and coal, which we rely on as fuels for most of our transportation, heating, cooling, agriculture, and electricity. Short-term strategies involve switching from carbon-intensive to renewable energy sources, which also requires building new infrastructure for alternative energy sources. Long-term strategies involve innovative research and a fundamental change in the way humans use energy.

F. Humans can adapt to climate change by reducing their vulnerability to its impacts. Actions such as moving to higher ground to avoid rising sea levels, planting new crops that will thrive under new climate conditions, or using new building technologies represent adaptation strategies. Adaptation often requires financial investment in new or enhanced research, technology, and infrastructure.

G. Actions taken by individuals, communities, states, and countries all influence climate. Practices and policies followed in homes, schools, businesses, and governments can affect climate. Climate-related decisions made by one generation can provide opportunities as well as limit the range of possibilities open to the next generation. Steps toward reducing the impact of climate change may influence the present generation by providing other benefits such as improved public health infrastructure and sustainable built environments.

Source: *NASA Goddard Space Flight Center Image by Reto Stöckli (land surface, shallow water, clouds)*

This spectacular "blue marble" image is the most detailed true-color image of the entire Earth to date. Using a collection of satellite-based observations, scientists and visualizers stitched together months of observations of the land surface, oceans, sea ice, and clouds into a seamless, true-color mosaic of every square kilometer (.386 square mile) of our planet.

CLIMATE SCIENCE LITERACY IS AN UNDERSTANDING OF THE CLIMATE'S INFLUENCE ON YOU AND SOCIETY AND YOUR INFLUENCE ON CLIMATE

CLIMATE LITERACY:
The Essential Principles of Climate Science

Each essential principle is supported by fundamental concepts comparable to those underlying the National Science Education Standards (NSES) and the American Association for the Advancement of Science (AAAS) Benchmarks for Science Literacy.

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.

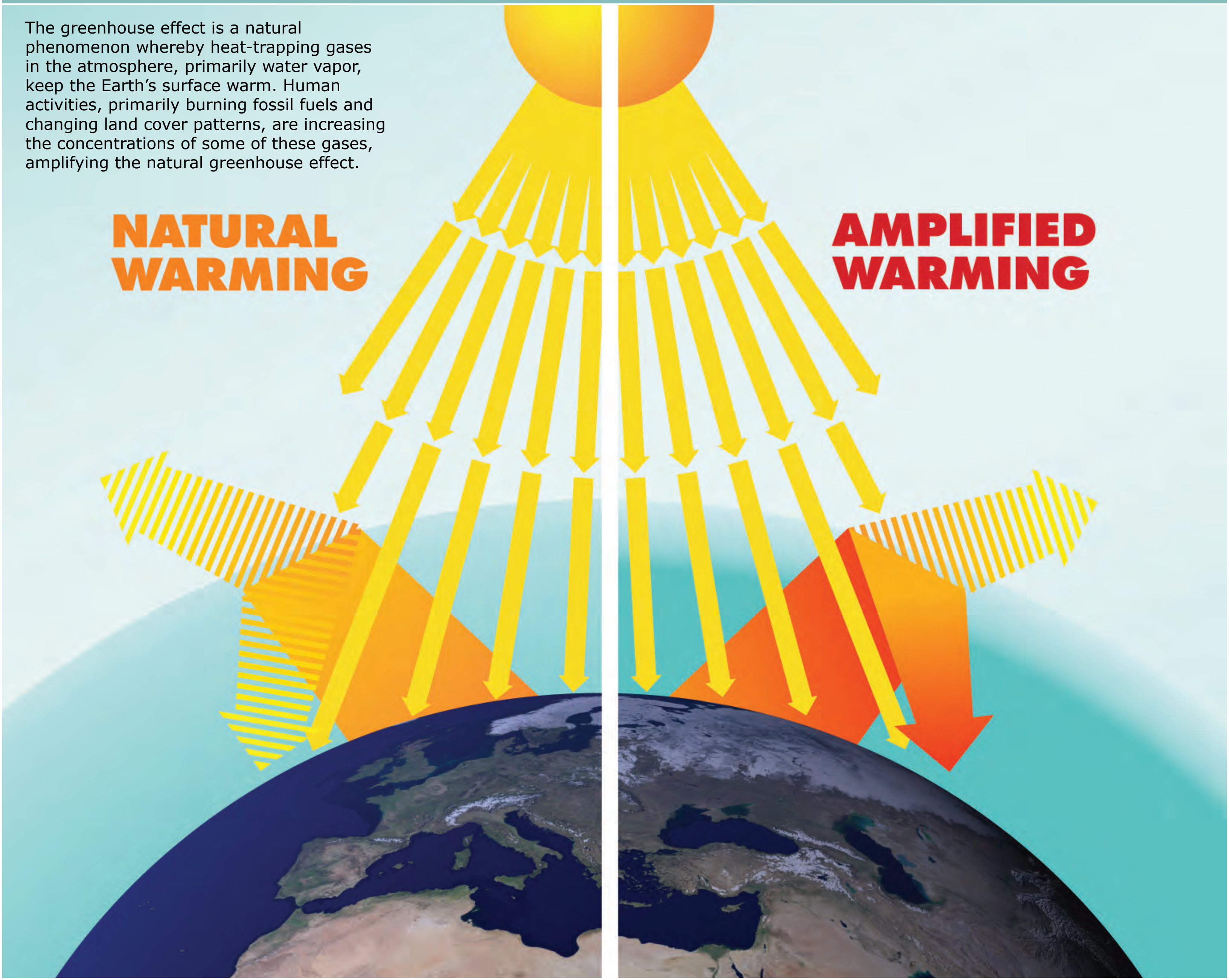
C. The tilt of Earth's axis relative to its orbit around the Sun results in predictable changes in the duration of daylight and the amount of sunlight received at any latitude throughout a year. These changes cause the annual cycle of seasons and associated temperature changes.

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.

Source: *Modified from the Marian Koshland Science Museum of the National Academy of Sciences' "Global Warming: Facts & Our Future" 2004*

The greenhouse effect is a natural phenomenon whereby heat-trapping gases in the atmosphere, primarily water vapor, keep the Earth's surface warm. Human activities, primarily burning fossil fuels and changing land cover patterns, are increasing the concentrations of some of these gases, amplifying the natural greenhouse effect.



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.

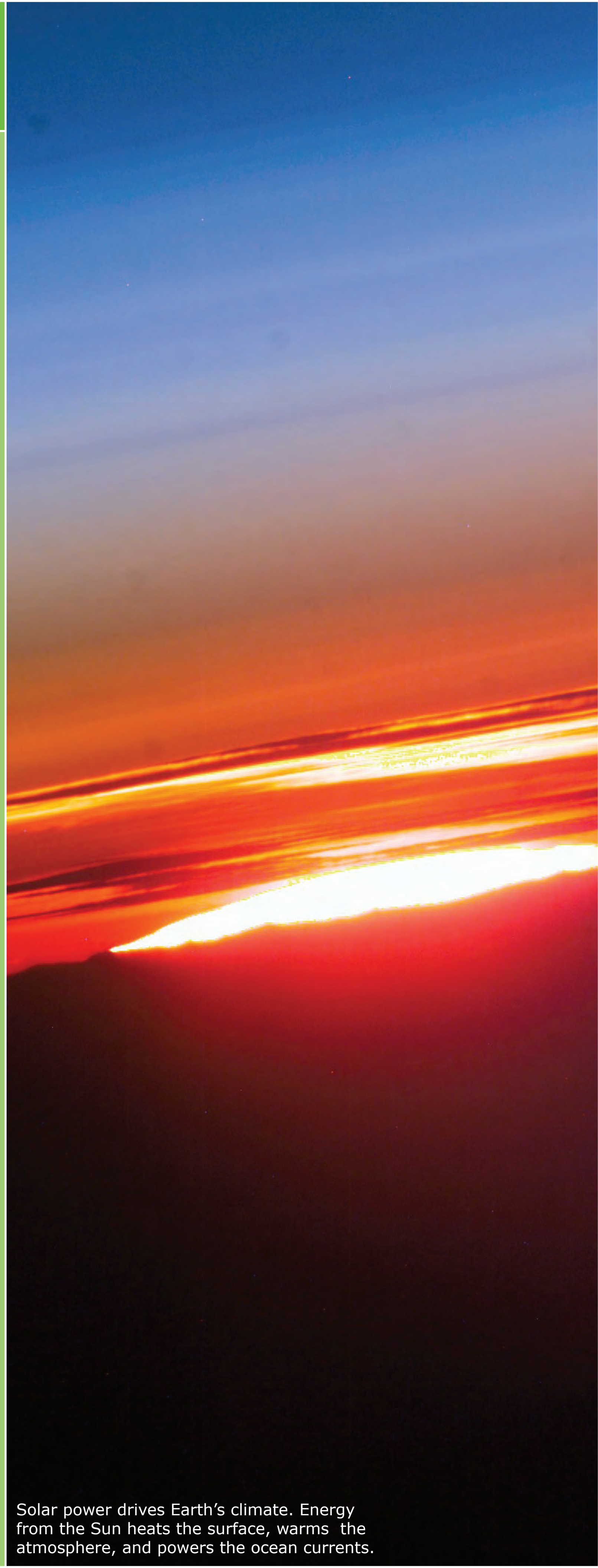
C. The amount of solar energy absorbed or radiated by Earth is modulated by the atmosphere and depends on its composition. Greenhouse gases—such as water vapor, carbon dioxide, and methane—occur naturally in small amounts and absorb and release heat energy more efficiently than abundant atmospheric gases 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. 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.

Source: *Astronaut photograph ISS015-E- 10469, courtesy NASA/JSC Gateway to Astronaut Photography of Earth.*



Solar power drives Earth's climate. Energy from the Sun heats the surface, warms the atmosphere, and powers the ocean currents.

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

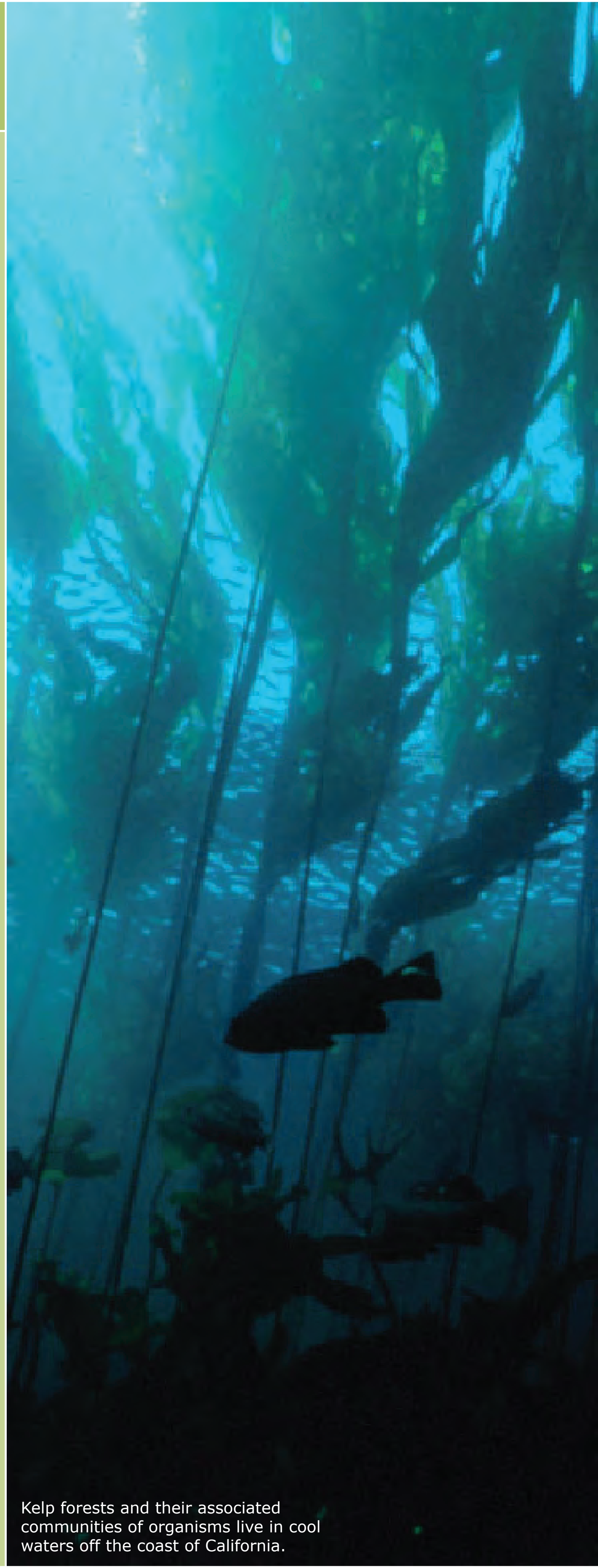
A. Individual organisms survive within specific ranges of temperature, precipitation, humidity, and sunlight. Organisms exposed to climate conditions outside their normal range must adapt or migrate, or they will perish.

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.



Kelp forests and their associated communities of organisms live in cool waters off the coast of California.

Source: *Steve Fisher*

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.

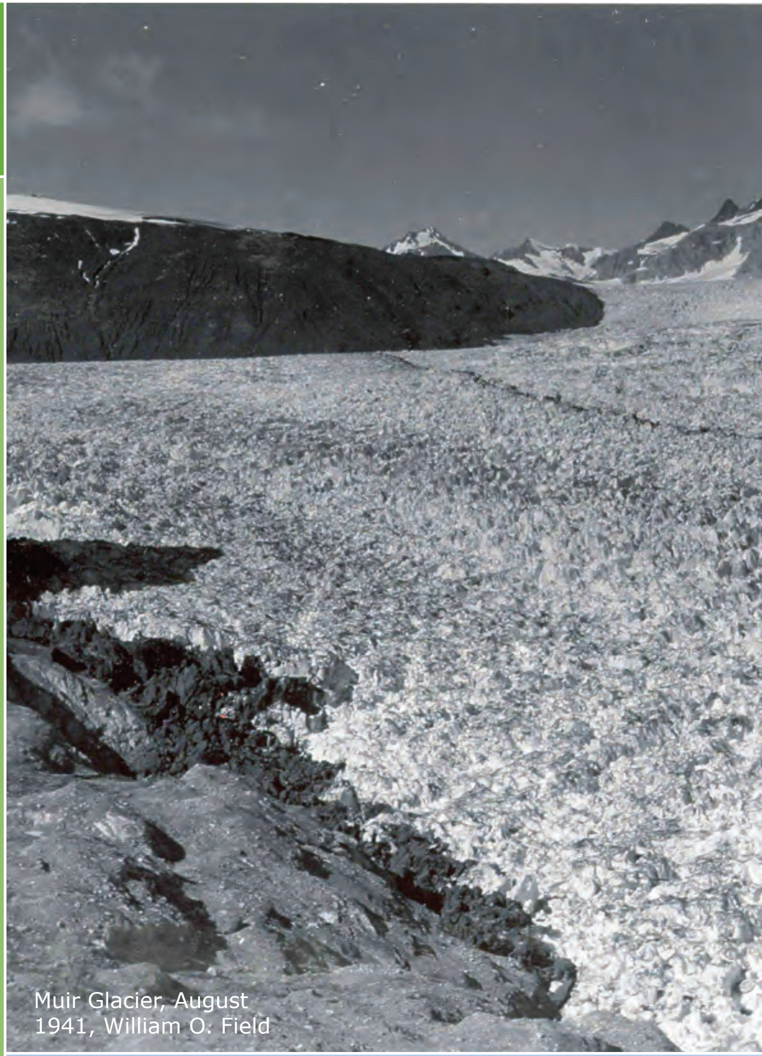
C. Climate change is a significant and persistent change in an area's average climate conditions or their extremes. Seasonal variations and multi-year cycles (for example, the El Niño Southern Oscillation) that produce warm, cool, wet, or dry periods across different regions are a natural part of climate 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.



Muir Glacier, August 1941, William O. Field

Muir Glacier, August 2004, Bruce F. Molnia

Source: *National Snow and Ice Data Center, W. O. Field, B. F. Molnia*

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.

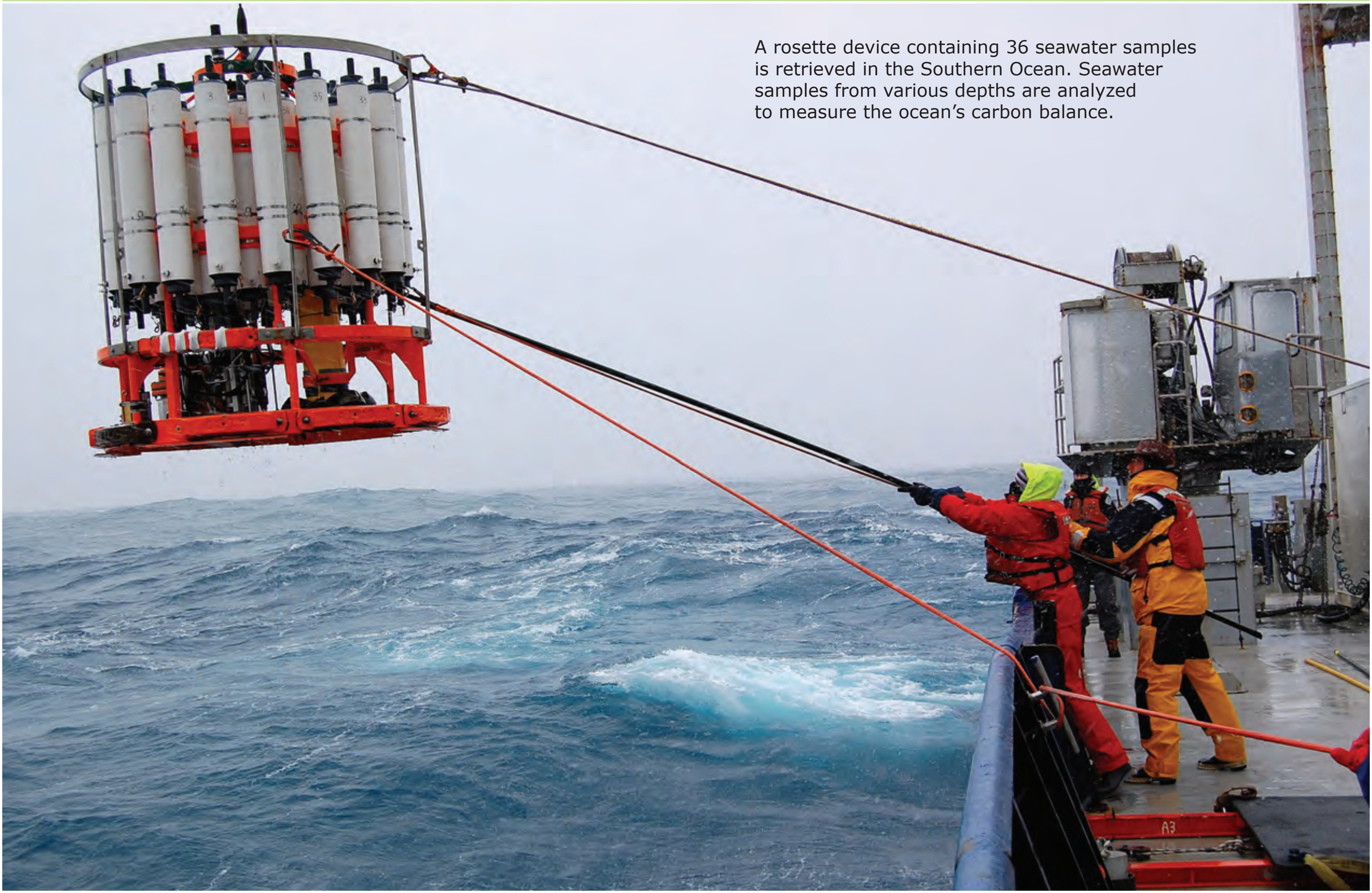
C. Observations, experiments, and theory are used to construct and refine computer models that represent the climate system and make predictions about its future behavior. Results from these models lead to better understanding of the linkages between the atmosphere-ocean system and climate conditions and inspire more observations and experiments. Over time, this iterative process will result in more reliable projections of future climate conditions.

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.[1]

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.

1. Based on "Climate Change: An Information Statement of the American Meteorological Society," 2007

Source: *B. Longworth © 2008*



A rosette device containing 36 seawater samples is retrieved in the Southern Ocean. Seawater samples from various depths are analyzed to measure the ocean's carbon balance.

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.[2]

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.

2. Based on IPCC, 2007: *The Physical Science Basis: Contribution of Working Group I*

3. Based on IPCC, 2007: *Impacts, Adaptation and Vulnerability. Contribution of Working Group II*

Source:: *A. Palmer, 2008*

Society relies heavily on energy that is generated by burning fossil fuels—coal, oil, and natural gas.

7

CLIMATE CHANGE WILL HAVE CONSEQUENCES FOR THE EARTH SYSTEM AND HUMAN LIVES.

A. Melting of ice sheets and glaciers, combined with the thermal expansion of seawater as the oceans warm, is causing sea level to rise. Seawater is beginning to move onto low-lying land and to contaminate coastal fresh water sources and beginning to submerge coastal facilities and barrier islands. Sea-level rise increases the risk of damage to homes and buildings from storm surges such as those that accompany hurricanes.

B. Climate plays an important role in the global distribution of freshwater resources. Changing precipitation patterns and temperature conditions will alter the distribution and availability of freshwater resources, reducing reliable access to water for many people and their crops. Winter snowpack and mountain glaciers that provide water for human use are declining as a result of global warming.

C. Incidents of extreme weather are projected to increase as a result of climate change. Many locations will see a substantial increase in the number of heat waves they experience per year and a likely decrease in episodes of severe cold. Precipitation events are expected to become less frequent but more intense in many areas, and droughts will be more frequent and severe in areas where average precipitation is projected to decrease.[2]

D. The chemistry of ocean water is changed by absorption of carbon dioxide from the atmosphere. Increasing carbon dioxide levels in the atmosphere is causing ocean water to become more acidic, threatening the survival of shell-building marine species and the entire food web of which they are a part.

E. Ecosystems on land and in the ocean have been and will continue to be disturbed by climate change. Animals, plants, bacteria, and viruses will migrate to new areas with favorable climate conditions. Infectious diseases and certain species will be able to invade areas that they did not previously inhabit.

F. Human health and mortality rates will be affected to different degrees in specific regions of the world as a result of climate change. Although cold-related deaths are predicted to decrease, other risks are predicted to rise. The incidence and geographical range of climate-sensitive infectious diseases—such as malaria, dengue fever, and tick-borne diseases—will increase. Drought-reduced crop yields, degraded air and water quality, and increased hazards in coastal and low-lying areas will contribute to unhealthy conditions, particularly for the most vulnerable populations.[3]

Source: *Iowa National Guard photo by Sgt. Chad D. Nelson*

Iowa National Guard preparing to put sandbags in place on a levee in Kingston, Iowa, to protect roughly 50,000 acres of farmland threatened by flood waters.

KEY DEFINITIONS

Weather The specific conditions of the atmosphere at a particular place and time, measured in terms of variables that include temperature, precipitation, cloudiness, humidity, air pressure, and wind.

Weather Forecast A prediction about the specific atmospheric conditions expected for a location in the short-term future (hours to days).

Climate The long-term average of conditions in the atmosphere, ocean, and ice sheets and sea ice described by statistics, such as means and extremes.

Climate Forecast A prediction about average or extreme climate conditions for a region in the long-term future (seasons to decades).

Climate Variability Natural changes in climate that fall within the normal range of extremes for a particular region, as measured by temperature, precipitation, and frequency of events. Drivers of climate variability include the El Niño Southern Oscillation and other phenomena.

Climate Change A significant and persistent change in the mean state of the climate or its variability. Climate change occurs in response to changes in some aspect of Earth's environment: these include regular changes in Earth's orbit about the sun, re-arrangement of continents through plate tectonic motions, or anthropogenic modification of the atmosphere.

Global Warming The observed increase in average temperature near the Earth's surface and in the lowest layer of the atmosphere. In common usage, "global warming" often refers to the warming that has occurred as a result of increased emissions of greenhouse gases from human activities. Global warming is a type of climate change; it can also lead to other changes in climate conditions, such as changes in precipitation patterns.

Climate System The matter, energy, and processes involved in interactions among Earth's atmosphere, hydrosphere, cryosphere, lithosphere, biosphere, and Earth-Sun interactions.

Likely, Very Likely, Extremely Likely, Virtually Certain These terms are used by the Intergovernmental Panel on Climate Change (IPCC) to indicate how probable it is that a predicted outcome will occur in the climate system, according to expert judgment. A result that is deemed "likely" to occur has a greater than 66% probability of occurring. A "very likely" result has a greater than 90% probability. "Extremely likely" means greater than 95% probability, and "virtually certain" means greater than 99% probability.

Mitigation Human interventions to reduce the sources of greenhouse gases or enhance the sinks that remove them from the atmosphere.

Vulnerability The degree to which physical, biological, and socio-economic systems are susceptible to and unable to cope with adverse impacts of climate change. [2]

Adaptation Initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects.[3]

Fossil fuels Energy sources such as petroleum, coal, or natural gas, which are derived from living matter that existed during a previous geologic time period.

Feedback The process through which a system is controlled, changed, or modulated in response to its own output. Positive feedback results in amplification of the system output; negative feedback reduces the output of a system.

Carbon Cycle Circulation of carbon atoms through the Earth systems as a result of photosynthetic conversion of carbon dioxide into complex organic compounds by plants, which are consumed by other organisms, and return of the carbon to the atmosphere as carbon dioxide as a result of respiration, decay of organisms, and combustion of fossil fuels.

1. *Temperature Trends in the Lower Atmosphere: Steps for Understanding and Reconciling Differences*. Thomas R. Karl, Susan J. Hassol, Christopher D. Miller, and William L. Murray, editors, 2006. A Report by the Climate Change Science Program and the Subcommittee on Global Change Research, Washington, DC.

2. Based on IPCC, 2007: *Impacts, Adaptation and Vulnerability. Contribution of Working Group II*

3. Based on IPCC, 2007: *Mitigation of Climate Change. Contribution of Working Group III*

ABOUT THIS GUIDE

Climate Literacy: The Essential Principles of Climate Science presents information that is deemed important for individuals and communities to know and understand about Earth's climate, impacts of climate change, and approaches to adaptation or mitigation. Principles in the guide can serve as discussion starters or launching points for scientific inquiry. The guide aims to promote greater *climate science literacy* by providing this educational framework of principles and concepts. The guide can also serve educators who teach climate science as a way to meet content standards in their science curricula.

Development of the guide began at a workshop sponsored by the National Oceanic and Atmospheric Administration (NOAA) and the American Association for the Advancement of Science (AAAS). Multiple science agencies, non-governmental organizations, and numerous individuals also contributed through extensive review and comment periods. Discussion at the National Science Foundation- and NOAA-sponsored Atmospheric Sciences and Climate Literacy workshop contributed substantially to the refinement of the document.

To download this guide and related documents, visit www.globalchange.gov.

FURTHER INFORMATION

For future revisions and changes to this document or to see documentation of the process used to develop this brochure, please visit www.climate.noaa.gov/education.

In addition, further information relating to climate literacy and climate resources can be found at:

- earthobservatory.nasa.gov
- www.epa.gov/climatechange
- http://nsdl.org
- www.education.noaa.gov

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Current Science and Educational Partners:

- American Association for the Advancement of Science Project 2061
- American Meteorological Society
- Association of Science-Technology Centers
- Bowman Global Change
- Centers for Disease Control & Prevention
- Challenger Center for Space Science Education
- Climate Literacy Network
- College of Exploration
- Cooperative Institute for Research in Environmental Sciences
- Federation of Earth Science Information Partners
- Lawrence Hall of Science, University of California, Berkeley
- National Environmental Education Foundation
- National Geographic Education Programs
- National Institute of Standards & Technology
- National Oceanic and Atmospheric Administration
- National Science Teachers Association
- North American Association For Environmental Education
- Sally Ride Science™
- TERC Inc.
- The GLOBE Program
- The National Center for Atmospheric Research
- University Corporation for Atmospheric Research
- U.S. Geological Survey
- U.S. Forest Service

For an up to date list of partners please refer to U.S Climate Change Science Program at http://www.globalchange.gov.

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