discover™ EARTH

HANDS-ON SCIENCE ACTIVITIES

Facilitator's Resources

For program facilitators

Background Information

The following information is specifically targeted to support the facilitator in conducting the activities and responding to questions from children or other patrons. There is a plethora of information specifically written for children and teens about these topics elsewhere; please refer young patrons to those books, websites, videos, and games listed in the resources section.

We Belong to Earth

We belong to a complex system of interacting water, ice, air, and life. Viewed from space, water is the most striking aspect of these four features of our planet — over 70% of Earth's surface is covered by that glistening blue. The polar ice caps, along with mountain glaciers, glint whitely on our "blue marble." Vegetation colors the land with green hues. Above the surface, the invisible atmosphere is studded with wisps of ever-changing clouds. These features interact and evolve over time — and rather quickly, compared to the drastic changes the solid Earth has experienced over the eons — to create the dynamic global environment we call home.

Water, ice, air, and life are among Earth's most distinctive features. Can you find your approximate location on this image of North America, as seen from space? Credit: NASA.

Water

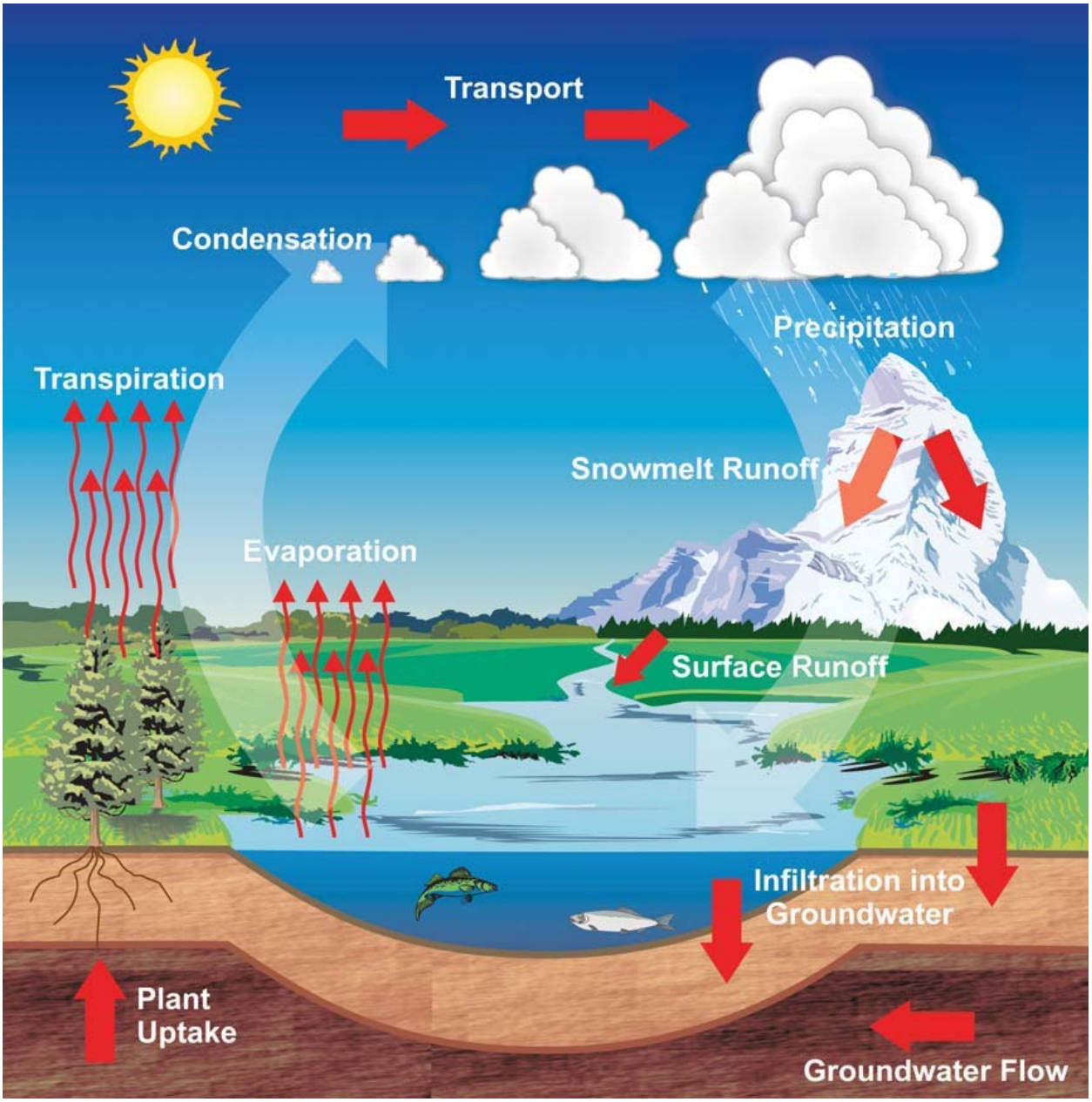
Water is arguably the most distinctive feature of our planet, since here it can be found in all of its states: liquid, gaseous, and solid. (Of all the places in our solar system, only two others may be able to make this claim: a moon of Saturn, called Enceladus, and Mars.)

Liquid - **Water** - A liquid is the state of matter that is a fluid that changes shape to fill a confining container. Liquids have distinct surfaces at their boundaries. The atoms or molecules making up a fluid move freely around the volume of the liquid.

Gas - **Water Vapor** - A gas is the state of matter that does not have a definite shape or volume. A gas is the least dense state of matter. The atoms or molecules making up a gas move around freely — and often energetically! in the space that the gas occupies.

Solid - **Ice** - A solid is the state of matter that is rigid; they resist changes to shape or volume. Solids have distinct boundaries. The atoms or molecules that make a solid are fixed in position relative to each other; they (essentially) are not moving.

Together, Earth's surface waters and water vapor in the air are called the **hydrosphere**. Water moves through its various states and across the globe via a dynamic "water cycle." Water moves from one location to another on the globe in its invisible, gaseous form — as vapor. Most of this evaporated water comes from the oceans, and the water molecules spend about 10 days in the air. On land, plants also add water vapor to the air as they process carbon dioxide and water to generate their own food. (Plants' contribution to the water cycle is called transpiration, and it contributes about 10 percent of the moisture in the air.) Under the right conditions, water vapor in the air condenses to form clouds, which may be made up of tiny water droplets (liquid), tiny ice crystals (solid), or a mixture of both. Rain and snow distribute water — most of it originating from the ocean — across both land and sea. Water flows from streams and lakes, through our cities and farms, to sink through soil and flow underground as groundwater or return to the ocean, with some areas receiving much more precipitation than others. The time a water molecule might spend in each of these locations, on average, varies greatly. A water molecule typically spends only a year or so in soil, but water molecules in Antarctica can spend hundreds of thousands of years frozen as ice, and those in the ocean may spend 34,000 years there. Water travels through the "water cycle," with the water molecules themselves persisting since the formation of Earth over four billion years ago.



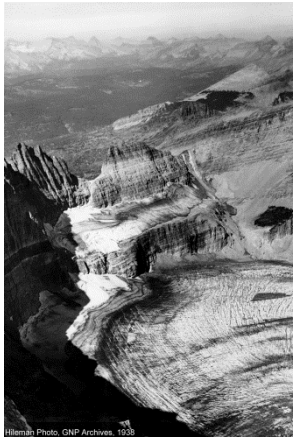
Water is continually cycled — interspersed with occasional long periods as part of deep groundwater or polar ice — through its liquid, gaseous (vapor), and solid forms and transported across the globe. Credit: Adapted from Introduction to Clouds *(http://science-edu.larc.nasa.gov/cloud_chart/PDFs/NOAA-NASA-CloudChart.pdf).*

Ice

Water is an essential need for our everyday lives — and indeed, liquid water is the one substance required by all life as we know it — but ice plays an important role on a global scale. We are familiar with ice in the form of ice cubes; hail, sleet, and snowflakes falling from the sky; icicles hanging from roofs and trees in winter; snow and ice on and in the ground (including permafrost, or ground that has remained frozen for two or more years); glaciers winding down mountain valleys; sea ice covering polar seas; and ice caps and very large ice caps, called ice sheets, covering large stretches of land at the north and south ends of our globe. These portions of Earth where water is frozen are collectively called the **cryosphere**.

Most of Earth's water is in our oceans as salt water (97%), but glaciers and ice caps hold the next largest portion of Earth's water — about 2% — in a frozen state. (Less than 1% of Earth's water is in groundwater, rivers, and lakes.) Glaciers are found at high altitudes on all continents, except in Australia. Ice caps are distinctive features of the Arctic and Antarctic. In addition to serving as storehouses of fresh water, the ice caps are "cold traps" that help regulate Earth's thermostat (see the section "Each Region Is Unique" below). Furthermore, the ice caps serve an essential role in regulating global ocean and air currents.

Earth's reservoirs of ice have undergone significant changes in recent years, and they continue to shrink. On a seasonal scale, glaciers and ice caps are dynamic — growing in the fall and winter and shrinking in the spring and summer. On a global scale, most ice is retreating rapidly as Earth's temperatures warm. Much of the fresh water stored in glaciers is melting and contributing to sea level rise. Ice on land in Greenland and Antarctica is also beginning to rapidly melt. Sea ice in the north polar region has decreased by 40% in the last 40 years. Because sea ice is already *in* the ocean, it will not increase sea level as it melts. However, the loss of sea ice is detrimental to the wildlife and humans living in the region.



1938 *1981* *1998* *2009*

Grinnell Glacier, on Mount Gould in Glacier National Park, demonstrates the sensitivity of glaciers to climate change. The glacier receded between 1938 and 2009, as documented above by the United States Geological Survey (USGS) Repeat Photography Project.

Credits (from left to right): T.J. Hileman, courtesy of Glacier National Park Archives; USGS / Carl Key; USGS / Dan Fagre; USGS / Lindsey Bengtson.

Air

Air is an invisible shroud around the Earth (the **atmosphere**), and places a crucial role in distributing the Sun's warmth and circulating water across the globe. Even though it is invisible, the bulk of air is substantial: At sea level, nearly 15 pounds per square inch (1 kilogram per square centimeter) continually press down upon us. However, this bulk is relatively thin-spread compared to the enormity of the planet: If Earth were the size of a basketball, the thickness of the main part of our atmosphere — 98% of the total air around Earth — could be represented by two sheets of paper wrapped around the ball. (The other 2% of Earth's atmosphere stretches very thinly out into the space around Earth.) Small amounts of gases in the

This oblique view of northwestern Africa from space captures Earth's curvature and atmosphere. Credit: NASA/JPL/UCSD/JSC.

atmosphere — namely water vapor, methane, and carbon dioxide — serve to trap the invisible infrared radiation emitted by the Earth as it is heated by sunlight and naturally warm the planet. The bulk of air is made up of nitrogen (78%) and — produced and maintained through biological processes — oxygen (21%).

As a point of comparison, consider the Moon, which has no atmosphere. Even though the Moon is Earth's closest neighbor in space, and is therefore the same distance from the Sun, the Sun creates an environment on the Moon that is far too dangerous for life to survive unprotected. Radiation from the Sun strikes the Moon's surface, unfiltered. Thanks to certain gases in Earth's atmosphere, types of radiation beneficial to life reach the surface, while most dangerous types of radiation are filtered out by the air that surrounds Earth.

Life

In this dynamic environment of water, ice, and air, life abounds in a multitude of manifestations, which are collectively referred to as the **biosphere**. To a large extent, the features of a particular region of the globe dictate what types of life can thrive there and in what abundance. For example, polar bears are suited to life on the Arctic ice cap with their thick fur and ability to hunt seals from the sea ice. Life, in turn, shapes the environment. Deep in Earth's history, bacteria fundamentally altered the chemical makeup of Earth's atmosphere when they began making their own food from carbon dioxide and water. We continue to breathe the molecules of oxygen they released through the process of photosynthesis long ago. Plants and photosynthetic bacteria continue to produce oxygen, even as other organisms use that oxygen and produce carbon dioxide.

Many life forms have the ability to alter their surroundings, but humans are adept at creating environments that suit our needs. Over the last 100 years, advancements in technology have reshaped Earth's features. Cars have reshaped the structure of communities as vast networks of urban, suburban, and rural areas. Entire biomes have been replaced: desert with reservoir, forest with agricultural fields, and wetlands with dry land for development. Our population has exploded as we thrive in our shaped environment. One of our greatest changes, however, has been invisible, as our use of technology has made another fundamental change to the makeup of Earth's atmosphere. Increases in the amount of carbon dioxide and other gases are warming our global climate, and the most major changes to the environment are only beginning to play out.

Lake Mead, upriver of Hoover Dam, shown at left, has brought water to the arid West, where it is mainly used for agricultural purposes.

An unintended consequence of water use in the West, including dams along the course of the Colorado River, has been the deterioration of the fragile coastal ecosystem at the Colorado River Delta, shown at right in a satellite image. The Colorado River historically emptied into the Gulf of California in Mexico. A satellite image from 100 years ago (if it were possible) would show the dark blue Colorado River in the upper left corner flowing all the way to the Gulf of California in the lower right.

Credit: NASA/GSFC/MITI/ERSDAC/ JAROS, and U.S./Japan ASTER Science Team

Rock

Water, ice, air, and life interact on long time scales with yet another important feature of our planet: the very rock beneath our feet. Earthquakes, volcanos, erosion and sedimentation all play a significant role in the story of our planet. Their story is beyond the scope of the relatively short term changes that children may observe through this *Discover Earth* module. For more information about the role of rocks and land on our planet and others in the solar system, see the *Shaping the Planets* background information.

Each Region Is Unique

Changes to distant oceans, air moving freely around our globe, and all living things have an influence on our regional environment, now and in the past and future. We experience Earth's global aspects of water, ice, air, and life on a regional level, as these systems interact to shape our varied climates. Climate, in turn, influences the weather, crops, plants, and animals that make each region a unique place to live.

Your Climate Connection

Your closet is probably full of clothes, shoes, coats, and hats that are appropriate for your local climate. What you choose to wear on any given day is determined by the weather. But, your community might be particularly proud of certain characteristics of your region that attract tourists, businesses, farmers, and families — all of which depend on climate! For instance, perhaps there is something about the amount of precipitation, air, and temperature that make the area a good place for growing scrumptious regional delicacies. Perhaps you brag to distant relatives about the warm winters or plethora of sunny days, or take visitors to local wild areas to observe the unique flora and fauna.

While weather can change in a matter of hours or with the seasons, climate is the long-term average weather of a region. Climate is the average of 30 years or more of weather in a region, i.e. the region's "typical" weather. A region's climate is determined mainly by its latitude and altitude (and influenced by the area's landscape, e.g. nearby mountains, oceans, and lakes). However, it is also shaped by global, rather than regional, influences: ocean currents, patterns of air flow, and cloud formation.

The United States consists of several regions that have defined characteristics that are influenced by climate. If you were to travel to a different region, you might expect to pack an entirely different set of clothing than what's in your closet. Be sure to check the weather report before embarking on your excursion, however; it is the nature of weather to not always fit in with what's expected for a region! Regions of the United States can be *generally* classified as one or more of the following designations:

- Tropical
- Dry
- Mild
- Continental
- Polar
- High elevations

Climate is the long-term average weather of a region. Different climates are found across the various regions of the United States, and these climates influence the weather, crops, plants, and animals that make each region a unique place to live. Image credit: HowStuffWorks.com.

Regions Are Home to Unique Biomes

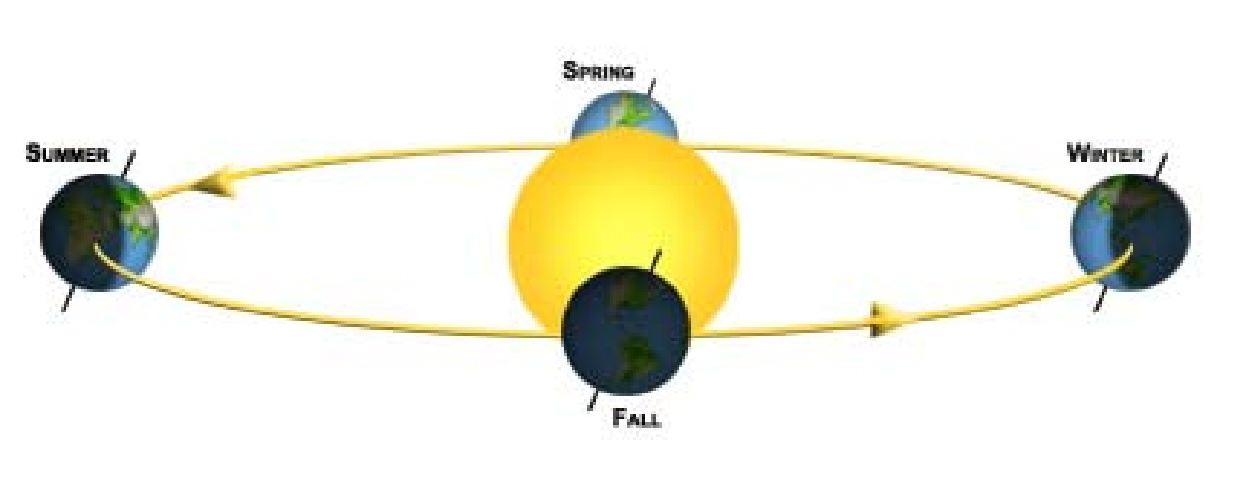
Life thrives in particular conditions, creating niches, called biomes, where the environmental conditions and types of flora and fauna living there go hand-in-hand.

All biomes have been facing changes in the last 100 years as our population has grown, cities have expanded, and agricultural technologies have advanced.

In the polar regions of northern Alaska, the changes of the past 100 years are particularly evident. Polar bears epitomize the Arctic struggle for survival, as they experience great change on a year-to-year basis. Floating sea ice dominates the land of the polar bears. The Arctic is an ocean surrounded by land. The land masses of Greenland, Iceland, and some islands in the Canadian Archipelago and large Russian Arctic islands have large glaciers and thick ice caps. Most of the ice in the Arctic is not ice on land, however: The ocean is covered by sea ice six to nine feet (nearly two to

three meters) thick on average. (Floating sea ice may be 12-15 feet thick, and it may become ridged into even thicker piles.) Polar bears live on this floating ice and have easy access to the sea to hunt for seals, fish, and beluga whales. Indigenous peoples likewise make their living from the sea ice and northern lands. They have hunted in the ocean since prehistoric times. Musk ox, reindeer, caribou, foxes, and wolves live on the land in the lower latitudes of the Arctic.

Natural changes brought about by the seasons are especially drastic in the polar regions. In the Arctic winter, the tilt of the Earth masks the Sun's warming rays for three months and plunges the Arctic into darkness from mid-fall through mid-winter. In summer, the tilt of the Earth bares the northern regions to the rays of Sun so that to a polar bear standing on the North Pole, the Sun appears to draw a daily circle around her low in the sky from late March to early September. Temperatures reach an average of 37-54° F (3-12° C). This perpetual morning offers enough warmth to melt some of the sea ice, although some remains throughout the year. The sea ice can expand as more ocean water is frozen, reaching to the encircling landmasses of Canada, Greenland, Russia, Alaska, Iceland, Norway, Sweden, and Finland. The coldest temperature recorded in the Arctic was about -90°F (-68°C), and the average wintertime temperature is -30°F (-34°C).



The Earth's tilt creates seasons. In summer, the North Pole points toward the Sun to create a 24-hour-long day. In winter, the night is equally long because the pole points away from the Sun. The seasons are reversed for the South Pole. Note that this drawing is not to scale. Credit: Lunar and Planetary Institute.

In recent years, scientists have observed an alarming trend: ice is melting across the world. Since 1979, scientists have documented an overall downward trend for sea ice in the Arctic Ocean (with more ice observed in some years than others): Each winter, less sea ice forms, it melts earlier in the spring, and less ice remains at the end of summer. For polar bears, climate change means the gradual loss of the sea ice that forms the necessary platforms from which they hunt.

Regions Are Home to Specialized Agriculture

In addition to the natural niches of life found in a region, farms and gardens are also particular to the quantity and quality of water, ice, air, and life of given location. Crops vary from region to region across the globe due to these parameters, and gardeners select plant types suited to the features of a given location to ensure growth. Even at the top of the food chain, humans are connected to the flora and fauna of our shaped and natural environment. Our diet — which may include fruits, vegetables, meat, poultry, and fish — ties us to the environmental conditions that produce our favorite foods.

Even as our communities grow and evolve, we remain intimately connected to the larger world.

Your Home Is Changing

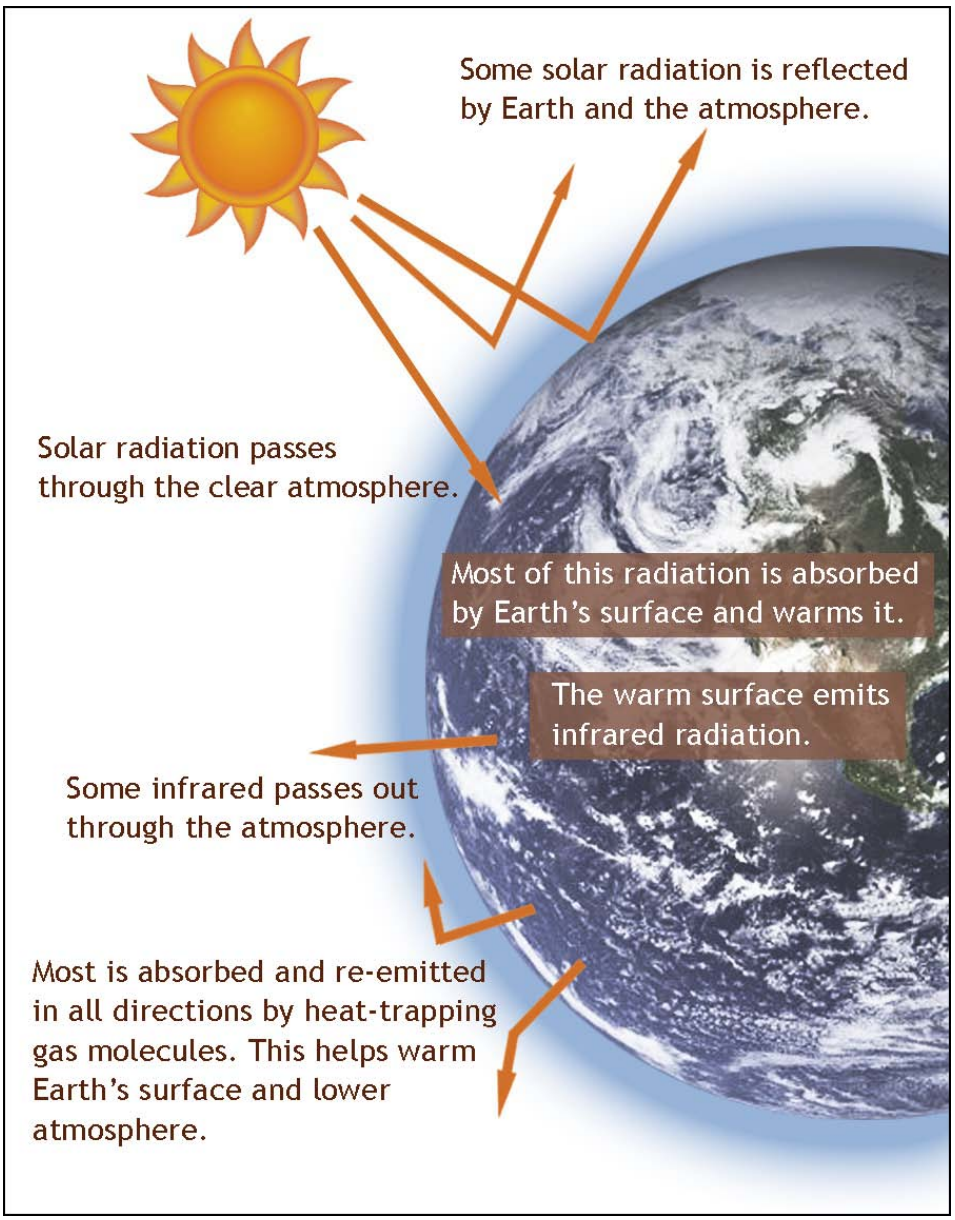
Earth's water, ice, air, and life will continue to interact over long-term scales, shaping the particular features of that place we each call home. In one important aspect, however, the global community of humans has proven influential enough to fundamentally alter the future of our planet. We continue to shape our environments at the local level by expanding our cities, changing forests to agricultural lands, and diverting water to suit our needs. Equally powerful are the changes we are making to the atmosphere as we burn fossil fuels, creating heat-trapping gases and tipping the Earth's balance toward a hot global climate.

Earth's Global Climate Is a Balancing Act

In the past, Earth's climate was shaped solely by natural factors. Astronomical factors determine how much of the Sun's energy reaches Earth, and the following changes occur over thousands of years: the shape of Earth's orbit around the Sun, Earth's "wobble," and the tilt of Earth's axis. Changes to the Earth itself, such as the configuration of the continents and changes in the way the atmosphere and ocean circulate, also influence global climate. Small components of Earth's atmosphere — introduced by life and volcanos — play a part. Earth's surface is highly reflective in

areas covered by ice, snow, and low clouds, but it absorbs sunlight — much like asphalt on a summer's day — in areas covered by forests and ocean. Together, these many details determine how much energy Earth receives from the Sun, as well as how effective it is at keeping that energy from escaping back into space.

Luckily, these factors interact in such a way as to create a comfortable planet. The Sun is the source of Earth's surface warmth; it provides over 99% of Earth's energy. Alone, energy from the Sun is enough for our planet to reach a rather chilly -2°F (-19°C) or so. (Geothermal energy from the Earth's interior contributes less than 1% of our energy at the surface. Radioactive decay of elements and gravitational energy inside Earth add such a small amount of surface warming compared to the Sun that they will be ignored here.) It is thanks to a small percentage of all the tiny gas molecules in our atmosphere that Earth is warm enough to inhabit. Naturally-occurring heat-trapping gases prevent some energy emitted by the Sun-warmed surface of Earth from escaping into space. Volcanos and bacteria in wetlands are examples of natural producers of heat-trapping gases. Earth is warmed to an average temperature of about 57°F (14°C) by a natural process called the greenhouse effect.



Earth's warm global climate is created by a natural greenhouse effect. The Sun's radiation is mainly in the visible range of the electromagnetic spectrum, and most of this high-energy light passes through the atmosphere to strike the Earth's surface and warm it. The warm surface gives off (re-emits) a lower-energy form of electromagnetic radiation that is invisible to our eyes: infrared radiation (IR). Unlike visible light, infrared radiation can be captured by heat-trapping gases in the Earth's atmosphere. Heat-trapping gas molecules re-emit the infrared radiation, and it is often absorbed by other heat-trapping gas molecules or the surface of the Earth. Through the greenhouse

effect, heat-trapping gases prevent energy emitted by the Sun-warmed surface of Earth from escaping into space, thus creating a much warmer climate than would occur without them. The addition of heat-trapping gases through human activities contributes to global warming beyond natural levels. (Note that the Earth, Earth's atmosphere, and Sun are not drawn to scale.) Credit: Lunar and Planetary Institute.

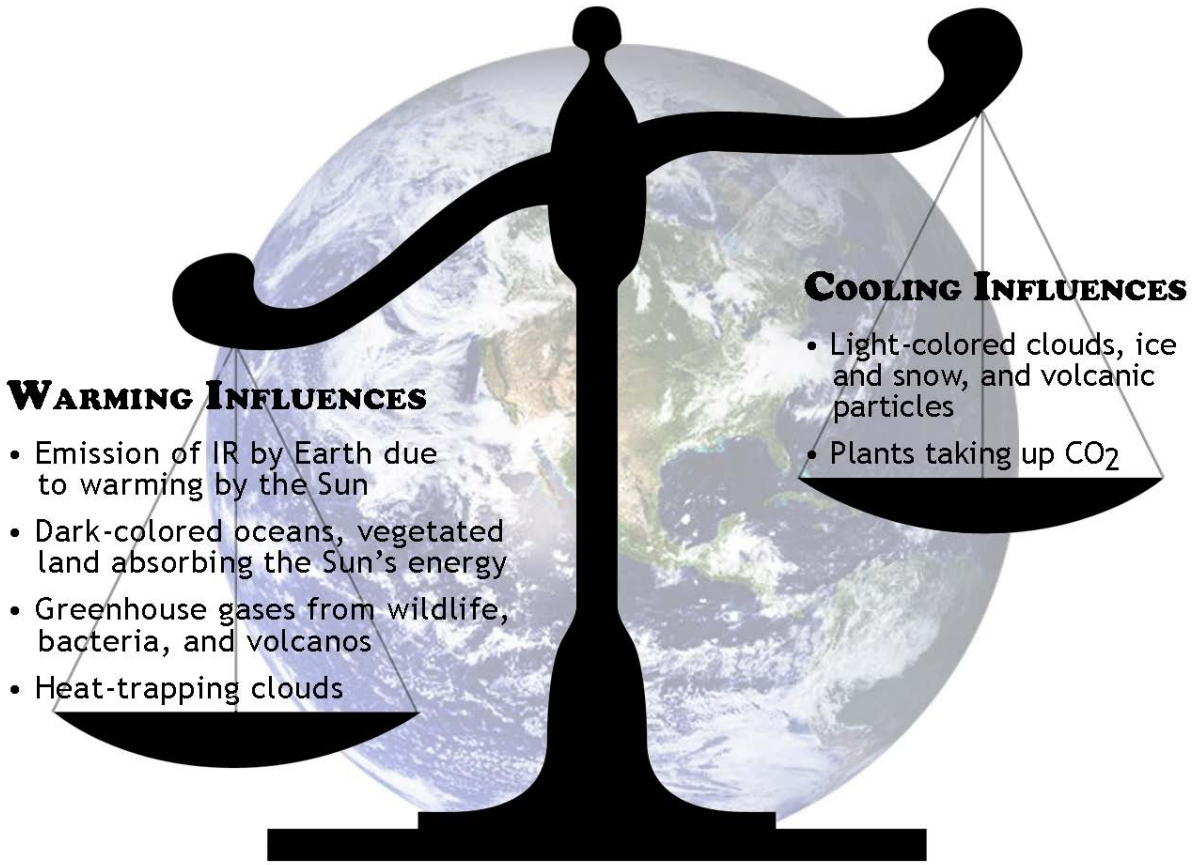
Much of the Sun's radiation is in the visible range of the electromagnetic spectrum, and for the most part, this type of light passes right through our atmosphere. Earth absorbs this radiation and warms up. Like all warm things, Earth gives off radiation of its own (think of the glowing coils in your toaster, which are hot enough to radiate in the visible portion of the electromagnetic spectrum). Earth emits infrared radiation, which is invisible to us. Unlike the higher-energy radiation from the Sun, the low-energy, long-wavelength infrared radiation can't pass back through the atmosphere with ease. Some of it does manage to escape back into space, but most of it is captured by heat-trapping gas molecules.

All molecules are able to absorb and emit light energy, but at the molecular scale, that light has to have *just* the right amount of energy for a particular type of molecule to absorb it. Heat-trapping gas molecules are all made up of at least three atoms bonded together. They are able to absorb infrared radiation because its energy is just right for causing the atoms of the molecules to move slightly in relation to each other, or vibrate. The visible light from the Sun was too energetic for the molecules to "catch." The molecules then emit the energy as infrared radiation, which is often caught by another heat-trapping gas molecule or the surface of the Earth.

Carbon dioxide, methane, nitrous oxide, and water vapor are heat-trapping gases. While the atmosphere is 78% nitrogen and 21% oxygen, heat-trapping gases make up only a tiny fraction of the air we breathe. For instance, carbon dioxide (CO_2) makes up almost 0.04% of the atmosphere; methane is more efficient at absorbing infrared radiation from the Earth but makes up only about 0.0002%. Water vapor comes and goes in the form of clouds, fog, and humidity. It is highly variable, and may represent between 1-4% of the atmosphere at the surface. Even in relatively small amounts, these heat-trapping gases have a very big impact on Earth's atmospheric temperature! Small increases in the amounts of these gases mean increased warming of our atmosphere.

In addition to the greenhouse effect, other factors help moderate Earth's temperatures by absorbing more of the Sun's energy or reflecting it. These factors have influenced each other and changed to create Earth's evolving climate over time. The warming effect of certain gases in the atmosphere and the heat-trapping global ocean, combined with the cooling effect of certain types of clouds and the ice caps and glaciers, work as nature's thermostat to maintain temperatures necessary for life. Life — mainly bacteria

— generated much of the heat-trapping gases in our atmosphere that act as crucial warming influences. Trees and further contributions from bacteria and other small organisms are cooling influences. They can help keep one kind of heat-trapping gas, CO_2, in check. Life is possible not only because Earth has a relative abundance of water, ice, and air, but because life continues to interact with these features to shape the dynamic place we call home.



Earth's global temperatures at any one time are a result of the balance between various natural warming and cooling influences. Thanks to these influences, Earth's temperatures are tipped enough to the "warm side" of the balance to have an average temperature near about 57°F (14°C). (In the past, the balance has also tipped toward the "cool side," perhaps even covering Earth entirely in ice!) Credit: Lunar and Planetary Institute.

Earth's climate is complex and dynamic, and the brief descriptions presented here cannot encompass all of the factors at play. The study of Earth's climate is in itself an entire field, and it is concerned with Earth's prehistory and a myriad of complex interactions not treated here. For more information on this topic, please see resources such as:

"Climate and Global Change," http://www.windows2universe.org/earth/climate/climate.html

"The Greenhouse Effect & Greenhouse Gases" includes an explanation of the important role played by water vapor: http://www.windows2universe.org/earth/climate/greenhouse_effect_gases.html

"Ocean and Climate Sciences for Teachers" includes materials, including videos, archived at http://cires.colorado.edu/education/outreach/ocean-climate/

Earth's global surface temperatures are rising at an unusually rapid rate. The past century has seen an increase of a little more than 1°F (0.74°C). A degree may not seem large to us, but we are accustomed to thinking locally. Local temperatures change with the weather, season, and time of day, often much more than a degree in a single day. G*lobal* changes in temperature are averages that take into account the large local variations and represent a change in the balance of factors that shape Earth's climate. Today's global temperatures are the highest of the past 500 years, perhaps even for the past millennium.

Temperature change is nothing new; the Earth has undergone many changes in global temperature in its past. Changes in Earth's orbit, in addition to less influential changes in the Sun's intensity, outgassing from volcanos and other sources, and changes in ocean currents, have resulted in cycles of cooling and warming. Certain eras in the Age of the Dinosaurs were warmer than today, and the ice ages were colder. However, modern human society has never encountered such profound and rapid change. Large changes in temperature occurred in the last million years during the glacial cycles, but the global warming at the end of an ice age is thought to have taken 5,000 years. In addition, these changes were all due to natural factors.

Scientists attribute most of the current climate change to increases in heat-trapping gas concentrations in the atmosphere. Scientists also agree that carbon dioxide released to the atmosphere by human activities is the main culprit of climate change. It is released from burning coal, oil, natural gas in power plants, cars, factories, and to some extent, from the clear cutting of forests. Human activities release other heat-trapping gases. Methane is released by farm animals, rice paddies, rotting garbage in landfills, mining, and extraction of natural gas. Chlorofluorocarbons (CFCs) are well-known for creating

the ozone hole — a separate environmental issue in itself — but are also implicated in their additional role as heat-trapping gases. The fertilizers used to grow our food add nitrous oxide.

Human activities contribute much more CO_2 to the atmosphere than volcanos. It is estimated that present-day volcanos release about 0.15 to 0.26 gigaton, globally, each year. Compare that to the amount released in 2010 due to human activities: 35 gigatons. Indeed, our use of cars, pickup trucks, and other light-duty vehicles releases at least about 12 times as much CO_2 as volcanos, at 3 gigatons per year.

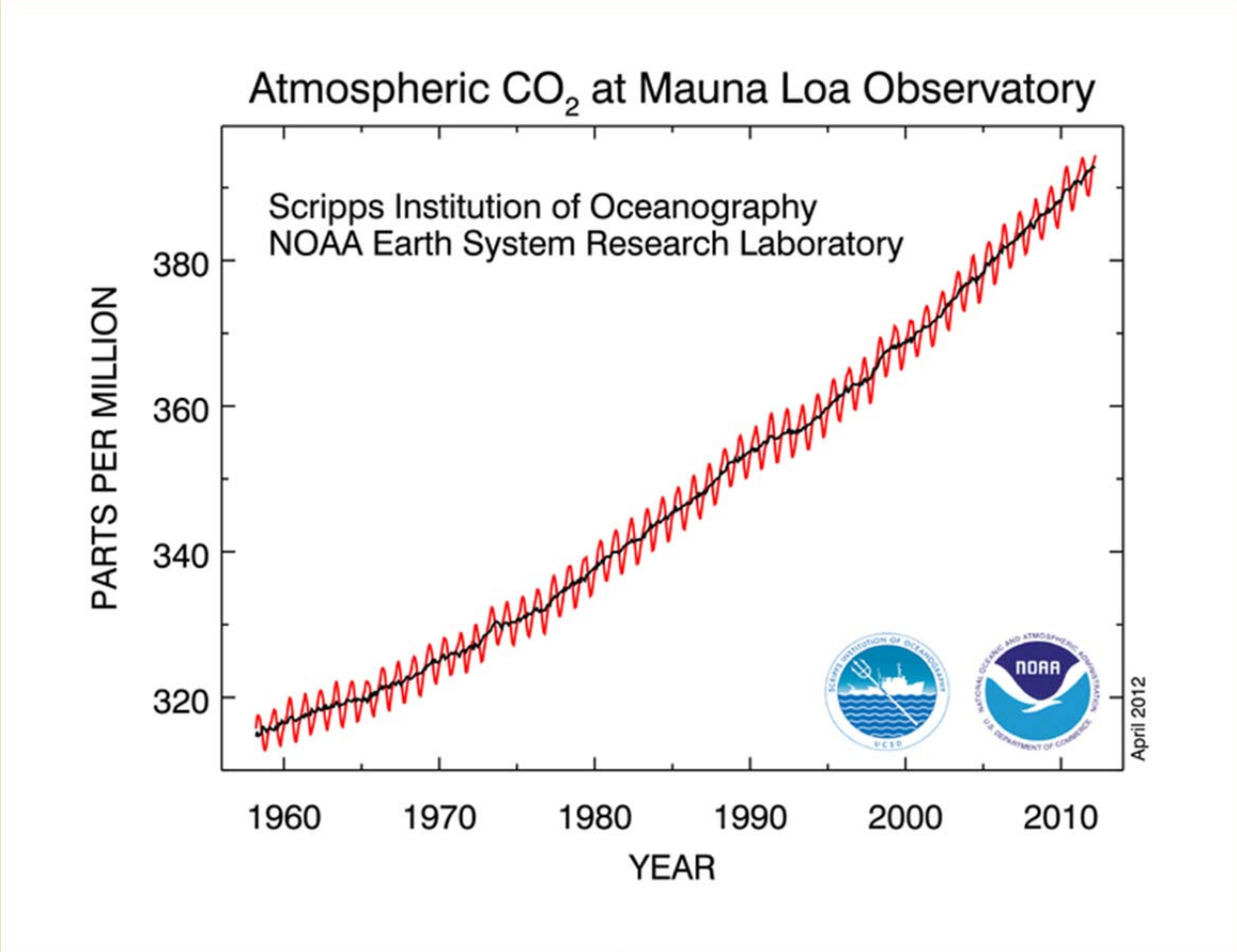
"Volcanic Versus Anthropogenic Carbon Dioxide," by T. Gerlach, EOS, Vol. 92, No. 24, 14 June 2011.

Scientists have records of the amount of carbon dioxide in Earth's atmosphere stretching thousands of years into the past.* A dramatic increase in the percentage of carbon dioxide in the atmosphere corresponds with the Industrial Revolution and has proceeded to climb sharply in the ensuing years. Today's levels far exceed even the highest levels of the past 750,000 years.

*Ice is a handy record-keeper. Air bubbles trapped in ancient ice have allowed scientists to measure the components of Earth's past atmospheres. Scientists drill cores in glaciers and ice sheets and analyze the preserved bubbles of prehistoric atmospheres. Also contained in the core is wind-blown volcanic ash, which is used to date its layers. Slight differences in the kinds of elemental oxygen within the ice tell the scientists how cold the air was when the snow fell.

Ice cores and other data provide evidence that the amount of carbon dioxide in Earth's atmosphere temperature have fluctuated in a cyclical pattern through time. These cycles of cooling and warming are natural, and caused, over the last 750,000 years, primarily by cyclic changes in Earth's orbit. During that time frame we have experienced alternating periods of warmth and periods of glaciations. However, at present, the levels of carbon dioxide in the atmosphere far exceed even the highest levels of the past half-million years. Our global temperature is increasing in response to this added heat-trapping gas.

The carbon dioxide (CO_2) concentration in the atmosphere has been measured directly since 1957. The instruments at Mauna Loa, Hawaii reflect the seasonal uptake and release of carbon dioxide by plants as "wiggles," but show an overall sharp increase.



The amount of carbon dioxide in Earth's atmosphere has been directly measured at Mauna Loa, Hawaii for half a century. The data reflects a sharp increase in carbon dioxide to levels higher than our Earth has experienced in the past half-million years – and certainly higher than humans have ever experienced. The seasonal uptake and release of carbon dioxide by plants in the northern hemisphere were captured here as "wiggles." Credit: Scripps Institution of Oceanography/ National Oceanic & Atmospheric Administration Earth System Research Laboratory, http://www.esrl.noaa.gov/gmd/ccgg/trends/*.*

The increases in atmospheric CO_2 are clearly due to human activities. The amount of CO_2 in Earth's atmosphere has risen in parallel with the increase in fossil fuel combustion. Furthermore, the carbon in fossil fuels has a unique signature: it lacks one particular type of carbon (i.e. isotope), called ^{14}C. (This isotope has decayed out of the fossil fuels, which are older than most other sources of carbon in the atmosphere.) From

1800 to 1950, the amount of naturally occurring ^{14}C in the atmosphere decreased as it was diluted by carbon originating from fossil fuels.

Scientists Work Together to Understand Our Changing World

Scientists work together to connect their understanding of local regions to a global vision...and they see great change happening now and into our future. Data from all realms of science are pulled together to understand our changing planet. For example, scientists note what species of flowers bloom earlier in the year and in what regions coral reefs die off because of warmer sea surface temperatures. They measure how increasing carbon dioxide is acidifying our oceans as it dissolves to form carbonic acid. Satellites take data on ice cover, precipitation, temperature, and other characteristics of our planet from above.

Our planet is so complex that climate scientists use complex computer algorithms, called climate models, to weigh the influences of the myriad of factors which shape our planet's climate. Computer models weigh the influences of heat-trapping gases from natural and human sources, changes in the Sun's intensity, ice and cloud cover, volcanos, ways in which different life forms shape their environments — and how these different factors interact in complicated ways over time.

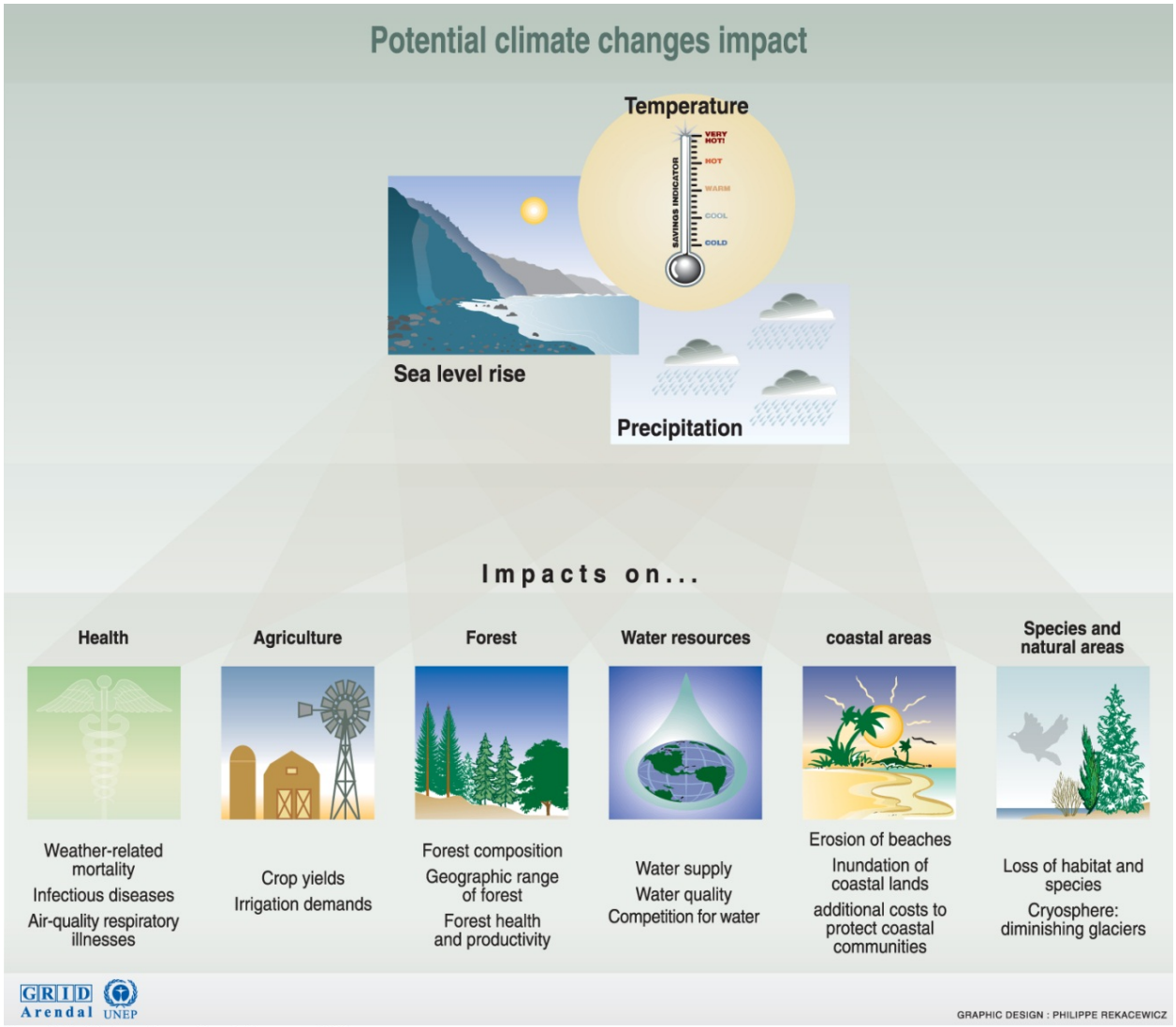
The scientific understanding of climate change is not as provisional as it is often portrayed in politics, in the media, and by the entertainment industry. Indeed, a study in the *Proceedings of the National Academy of Sciences* found that 97-98 percent of actively publishing climate researchers support the basic understanding of human-induced climate change. While the contributions of *natural* warming are still not fully understood, it is generally agreed that their effects are secondary. Changes in solar intensity and volcanoes produced most of the warming from pre-industrial times to 1950, but are not implicated in the current global change. For instance, when Mt. Pinatubo erupted in 1991, the global average temperature dropped by 0.9 °F (0.5 °C) as volcanic particles in the atmosphere reflected some of the Sun's energy. (The volcano also released carbon dioxide, a warming agent, but this addition is thought to be small compared to human contributions.) Studies by the National Center for Atmospheric Research (NCAR) attribute less than a third of the current warming to changes in the Sun's intensity. Earth's climate is changing mostly as a result of certain human activities.

Beyond the political debate that has shrouded our understanding of climate change, this field of science offers a glimpse into the process of science. Individual scientists and teams of scientists work on a particular aspect of Earth's climate and publish any replicable results. Their contributions are tested, weighed, and debated by the scientific

community. If the results are found to be valid by other scientists, they are integrated into the common knowledge base and our understanding moves forward. No one scientist or scientific team has all of the answers, and individual aspects of the scientific "puzzle" may be intensely debated — but the community moves together toward a broad understanding as the myriad details are tested and used to modify or advance existing theories.

Tomorrow's World Will Be a Different Place

The clothes in your closet, what you can plant in your garden — and when you can plant them — the varieties of local produce you buy at the grocery store, the types of plants and trees growing in your parks, and what wild animals live in or migrate through your area are all determined by your local climate. Imagine how your world might change as your local climate is reshaped by global climate change. While it might be tempting to blame a hot summer's day on global warming (or to say global warming is not happening because of high snow fall over one or two winters), short duration warmer- or cooler-than-average temperatures are a part of Earth's natural charm (just to keep us on our toes!). Scientists are trying to understand how changes in temperature, precipitation, wind, and sea level will impact Earth's diverse regions. Scientists use mathematical computer models to predict how the various warming and cooling factors will shape tomorrow's climate.



Source: United States environmental protection agency (EPA).

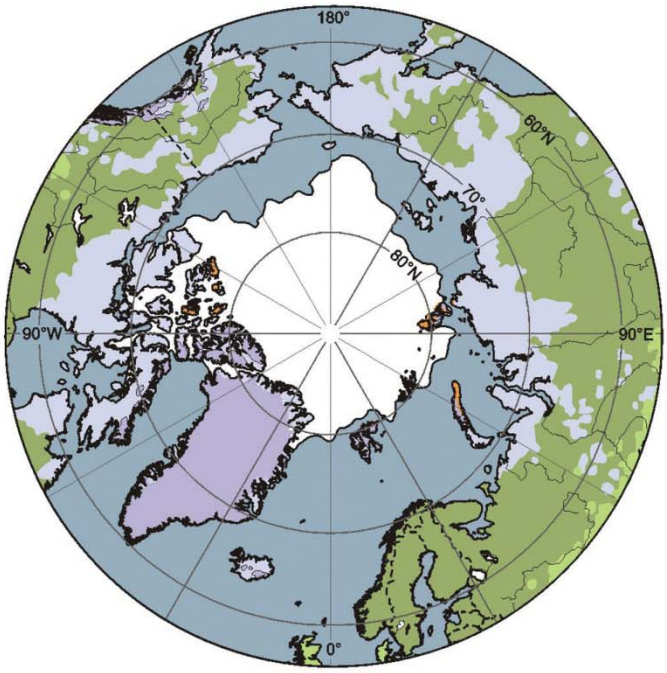
Climate change will potentially alter the temperature, precipitation, and sea levels, which will, in turn, impact human health, agriculture, forests, water resources, coastal areas, and species and natural areas. Image courtesy of United States Environmental Protection Agency (EPA) / Philippe Rekacewicz, UNEP/GRID-Arendal.

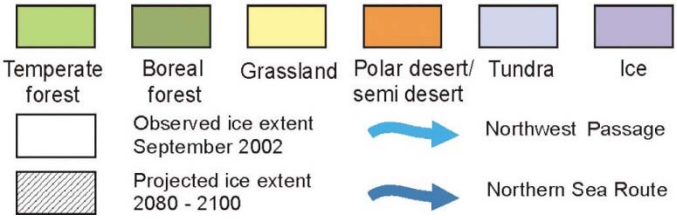
The thawing of Earth's freezers — the polar regions — will have far-reaching effects. The nature of the polar regions makes them more sensitive to the consequences of climate change than warmer latitudes. Reflective white ice and snow will melt into dark rivers and oceans that better absorb the Sun's energy. Like a freezer overdue for defrosting, increasing temperatures will expose organic matter long locked away in the frozen ground of the arctic tundra. This permafrost will thaw and plant matter decomposing in the resulting marshes will release the heat-trapping gas methane.

Antarctic sea ice is as necessary to penguins as forests are to songbirds. If the 3.6^{o}F (2°C) rise in global temperatures predicted over the next 40 years comes to fruition, essential nesting and feeding grounds will have melted away. The warming would translate to a 50% decline of emperor penguins. The Pt. Géologie colony that increased this species' fame through the movie *March of the Penguins* already is in decline as northern Antarctic temperatures increase. With less sea ice, Adélie penguins have a shorter journey from their nests of rock to fetch food from the ocean for their chicks. However, Adélie penguins are adapted to the cold and overall are harmed by increasing temperatures. They face a loss of 75% with the predicted temperature rise. Climate change adds to the problems of pollution and over-fishing of the Southern Ocean.

Arctic sea ice is predicted to continue disappearing. Commerce by sea will have entirely new opportunities for transport through the opened Arctic Ocean, but the changes for humans and animals dependent of the ice are grim. According to a study by the United States Geological Survey, the predicted loss of Arctic sea ice in future years may result in the loss of 2/3 of the polar bear population by the middle of this century. Of the 19 subpopulations of polar bears, 8 are currently declining. For 7 of the subpopulations, there was not enough data to determine whether they were growing or falling. One subpopulation is increasing…and Arctic researchers are hopeful that humans can work toward mitigating climate change and other threats to all of the subpopulations.

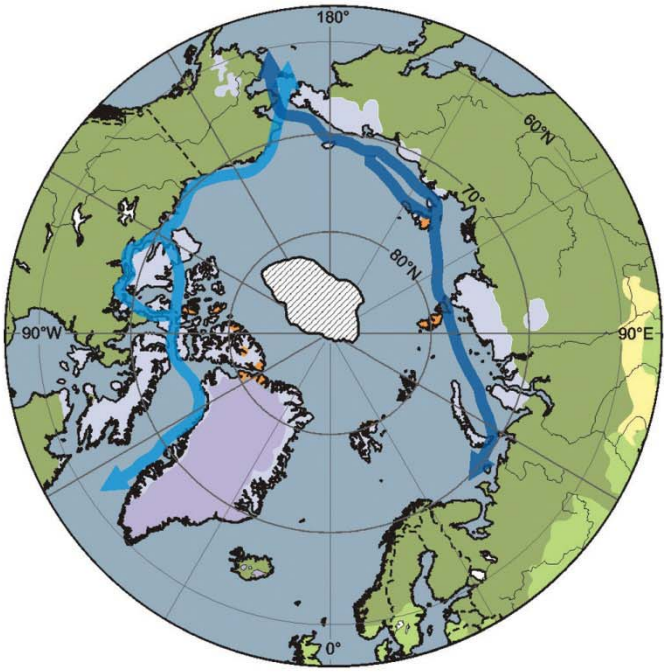
Current Arctic Conditions





Present and projected summer minimum sea-ice extent and vegetation types for the Arctic and neighboring regions. Credit: Figure 15.3, Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, 2007,* Cambridge University Press*, http://www.ipcc.ch/graphics/ar4-wg2/jpg/fig-15-3.jpg.*

Projected Arctic Conditions



Changes will vary across the globe. More warming is expected in the interiors of continents and in the northern latitudes of the Northern Hemisphere than at the coastal regions and tropics. Heat waves are expected to become more intense. Higher temperatures will lead to faster evaporation, and rain, when it occurs, may fall in the form of heavy downpours. More precipitation may provide additional water to some regions, but floods and droughts are also expected to become more frequent. Storms might increase in intensity; in addition, rising sea levels will impact coastal areas. Crops may experience longer growing seasons and fewer frosts. The warmer temperatures and increased carbon dioxide in the air may help some crop varieties, but they, too, have a point at which it is too warm to survive. The ranges of plants and animals, biodiversity, and migratory patterns are expected to continue to change in response to climate change. Pests, parasites, and diseases are likely to thrive in the warmer temperatures, much to the irritation of the plants, animals, and humans they prey upon. While heat waves may contribute to heat-related illness and death, milder winters may be a benefit for health issues. Beach erosion, reduced snowfall, and changes in flora and fauna may limit opportunities for outdoor excursions, but milder temperatures in some regions may provide more opportunities to venture outdoors.

Humans Have the Power to Stabilize Global Change

Humans clearly have an impact on the global environment and the ecosystems it supports. Our use of fossil fuels, such as coal and oil, has added carbon dioxide to the atmosphere and warmed our planet. Now, our influence can be used to stabilize or *reduce* climate change!

Use of fossil fuels pervades our everyday life and it is challenging to know where to begin reducing it. Not only do fossil fuels power our cars and school buses, coal often produces the electricity that runs our air conditioners and charges our cell phone batteries. In addition, fossil fuels are often used in the production and transportation of our goods before we even take them home from the store. For instance, fossil fuels are used for the energy and materials to create plastic bottles and transport heavy drinking water across the country to the local grocery store. Thus, not only does driving less and conserving electricity help combat climate change, so does being a savvy consumer of local produce and recycled goods.

In addition to carbon dioxide, the heat-trapping gases methane and nitrous oxide are by-products of everyday practices. Methane, a natural waste product of certain microbes living in the intestines of cattle, is released by these animals in large amounts. Stocking up on protein from fish, and especially beans and other vegetables, instead of beef is one way grocery shoppers can help slow climate change. Human-produced fertilizers break down in the soil and release nitrous oxide, so composting the vegetable

clippings from that high-protein bean salad to use as natural fertilizer can further help slow climate change.

It is amazing that something as tiny as heat-trapping gas molecules can create and change our global climate so drastically, even though they are vastly outnumbered by the nitrogen and oxygen molecules that make up the majority of our atmosphere. Though we may sometimes feel small and insignificant as individuals or communities in our complex societies, we likewise have the power to make a large impact — and make the changes necessary to manage Earth's resources wisely!

Be a Science Guide!

Modified from "Tips to Guide Your Child's Enjoyment of Learning: Be a guide on the side!," *Family Guide to Mars* - Field Test Version, © 2004 Space Science Institute.

This guide is intended to assist you in sharing the joy of exploration and discovery with your young patrons. It is a wonderful gift to enjoy our minds at play!

1. **Children are naturally curious and enthusiastic to learn about the world around them.** Listen to their ideas and opinions — they will fascinate you! Encourage your young patron's inclination to observe, wonder, and investigate.

2. **You can be a good teacher, even if learning about Earth science is new to you.** Your enthusiasm for the topic will go a long way!

3. **Good teachers introduce ways to find the answers, rather than presenting themselves as a source of all information.** Get in the habit of replying to children's questions with new questions that will help guide them to the answer. Remember that is the quest for discovery, rather than a mere listing of facts, that generally motivates individuals to become life-long learners.

4. **Even if you don't know the answer, you can explore with the child to find answers together.** The resources section of this *Discover Earth* module can assist your patrons in finding answers — as well as new questions!

5. **If you do know the answer, it is often valuable to ask leading questions that guide a child to discover something new for him- or herself.**

6. **The activities provided in this *Discover Earth* module can assist you in making enjoyable connections between Earth and your patrons' everyday experiences.**

7. **Encourage young patrons to use different dimensions of their intelligence to record their impressions and observations.** Telling stories, drawing pictures, creating poems or songs, making a photo album or collage, recording a video, and writing in a journal are all ways to remember and share information.

Resource Lists

Books

General

EARTH
Elaine Landau, Children's Press, 2008, ISBN: 0531147886
Children ages 9–12 may enjoy reading about Earth's place in the solar system, what Earth is made of, how water and air make life possible, and what a kid can do to fight global warming. Colorful images and fun facts accompany the easy-to-read text.

PLANET EARTH: WHAT PLANET ARE YOU ON?
Dan Gilpin and Simon Basher, Kingfisher Publications, 2010, ISBN: 0753464128
This fun book filled with cartoon creatures illustrate wonderful concepts of that are kid-friendly and easy to understand. Children ages 9-12 will encounter entertaining definitions of Earth's various components, including its interior and landforms, weather, climate, and biomes.

Weather

WEATHER
Mike Goldsmith, Kingfisher, 2014, ISBN: 978-0753471326
Readers lift flaps to discover the answers to weather-related questions. Appropriate for ages 3-6.

LOOKING AT WEATHER AND SEASONS: HOW DO THEY CHANGE?
Angela Royston, Enslow Publishers, Inc., 2008, ISBN: 0766030938
Royston answers questions such as "Where does rain come from?" in this well-illustrated book for children ages 4-8.

WEATHER
Catriona Clarke, Usborne, 2006, ISBN: 978-0794512538
Surprising facts and rich illustrations make this book an appealing introduction to weather. There are clear descriptions of the water cycle, clouds, and lightning, as well as sections about weather scientists and how weather affects animals. Appropriate for ages 6-8.

THE EVERYTHING KIDS' WEATHER BOOK: FROM TORNADOES TO SNOWSTORMS, PUZZLES, GAMES, AND FACTS THAT MAKE WEATHER FOR KIDS FUN!
Joe Snedeker, Adams Media, 2012, ISBN: 978-1440550362
Games, investigations, and engaging text bring aspects of weather and Earth's atmosphere — including air, water, clouds, the jet stream, weather stations, rainbows, and more — to life. Appropriate for ages 7-12.

NATIONAL GEOGRAPHIC KIDS EVERYTHING WEATHER: FACTS, PHOTOS, AND FUN THAT WILL BLOW YOU AWAY
Kathy Furgang, National Geographic Society, 2012, ISBN: 1426310587
This book about weather – including wild weather – is appropriate for ages 8-12.

WEATHER: WHIPPING UP A STORM!
Simon Basher and Dan Green, Kingfisher Publications, 2012, ISBN: 9780753468258
This fun book, filled with cartoon personifications of science concepts, is kid-friendly and easy to understand. Children ages 8-12 will encounter entertaining definitions of seasons, hail, sleet, snow, and other weather terms.

DO YOU KNOW THAT CLOUDS HAVE NAMES?
Becca Hatheway, Kerry Zarlengo, and Peggy LeMone, University Corporation for Atmospheric Research, 2006
http://nasawavelength.org/resource/nw-000-000-002-804
Readers explore the different types of clouds and their names through photographs, kid-friendly illustrations, and clear text. The book includes an explanation for how contrails can become human-made cirrus clouds. Appropriate for ages 8-12.

GASES, PRESSURE, AND WIND: THE SCIENCE OF THE ATMOSPHERE
Paul Fleisher, Lerner Publications Company, 2011, ISBN 9780822575375
This book offers a detailed look into the important role that air plays in shaping our planet. Appropriate for children ages 9–12.

Water

EXPLORE WATER!: 25 GREAT PROJECTS, ACTIVITIES, EXPERIMENTS
Anita Yasuda, Nomad Press, 2011, ISBN 1936313421
Children ages 7–9 can use this guide to undertake activities and projects about water. Fun facts and text discuss topics such as states of matter, glaciers, salt and fresh water, pollution, and more!

Ice

THE STORY OF SNOW: THE SCIENCE OF WINTER'S WONDER
Mark Cassino, Jon Nelson, and Nora Aoyagi, Chronicle Books, 2009, ISBN-13: 9780811868662
Children will enjoy this exploration of snowflakes and how they are formed…before heading outside to catch and photograph snowflakes for themselves! Appropriate for ages 3 and up.

THE GLACIERS ARE MELTING!
Donna Love, Sylvan Dell Publishing, 2011, ISBN: 1607181266
Love brings an environmental issue to young readers through this fresh take on the story of Chicken Little.

Life

GARDENING PROJECTS FOR KIDS
Jenny Hendy, Southwater, 2012, ISBN: 978-1780190198
Fun projects, like "grass head man" and painted pots, add a new twist to gardening for kids. Appropriate for ages 5 and up.

101 KID–FRIENDLY PLANTS
Cindy Krezel, Ball Publishing, 2007, ISBN: 978–1–883052–54–6
A comprehensive guide to using nontoxic flowers, vegetables, trees, and houseplants, includes seventeen gardening projects. For children ages 6 and up.

KIDS' CONTAINER GARDENING: YEAR-ROUND PROJECTS FOR INSIDE AND OUT
Cindy Krezel, Chicago Review Press, 2010, ISBN: 978-1883052751
Kids learn about their climate zones, the essential supplies for gardening, and other useful information for growing plants! Appropriate for age 6 and up.

Landscapes

ONE MILLION THINGS: PLANET EARTH
John Woodward, DK Children, 2009, ISBN-13: 978-0756652357
Visually stunning images and clearly written text cover multiple Earth science topics, including rivers and the landforms they create. Appropriate for ages 8 and up.

EARTH AS ART
Lawrence Friedl and Karen Yuen, National Aeronautics and Space Administration, 2012, ISBN 9780160913655, NP-2012-07-889-HQ
Children may enjoy the shapes, colors, and textures of Earth's land, oceans, ice, and atmosphere captured by satellites. Appropriate for ages 10 and up; younger children may need assistance interpreting these images, which are viewed from the unique vantage point of space.

Volcanos

VOLCANOLOGIST: THE COOLEST JOBS ON THE PLANET
Hugh Tuffen and Melanie Waldron. Capstone Press, 2015, ISBN: 978-1410966438
Color photographs and personal stories provide a glimpse into the amazing career of a volcanologist. Appropriate for ages 9 and up.

EVERYTHING VOLCANOES AND EARTHQUAKES
Kathy Furgang, National Geographic Children's Books, 2013, ISBN: 978-1426313646
Engaging images, informative text, and fun facts will draw children into the science and impacts of volcanos and earthquakes. Appropriate for ages 8 and up.

Rocks

EVERYTHING ROCKS AND MINERALS
Steve Tomecek, National Geographic Children's Books, 2011, ISBN: 1426307683
Children ages 9-12 may appreciate this visually stimulating introduction to geology.

Stewardship of the Earth: Regional Information and Celebrations

COOKING ROCKS! RACHAEL RAY 30-MINUTE MEALS FOR KIDS
Racheal Ray, Lake Isle Press, Inc. 2004, ISBN 1891105159

SALAD PEOPLE AND MORE REAL RECIPES
Mollie Katzen, Tricycle Press, 2005, ISBN: 1582461414

THE MITSITAM CAFÉ COOKBOOK
Richard Hetzler, Fulcrum Publishing, 2010, ISBN: 155591747X
While many of these recipes from Smithsonian National Museum of the American Indian are complex, they often feature unique regional ingredients. Tweens ages 10-13 may find the recipes "Fiddlehead Fern Salad," "Crabapple and Cranberry Relish," and Cranberry Crumble" applicable to this activity.

STATE SHAPES *series*
Black Dog & Leventhal Publishers, 2000-2010
Appropriate for ages 9-12.

STORIES FROM WHERE WE LIVE
Essays and poetry bring the regions of the United States to life. Each anthology features an appendix, which includes information about the region's habitats, animals and plants, and parks and preserves.

THE GREAT LAKES
Sara St. Antoine and Trudy Nicholson (Editor), 2003, Milkweed Editions, ISBN: 1571316396
Appropriate for ages 9-13.

THE GREAT NORTH AMERICAN PRAIRIE
Sara St. Antoine (Editor), 2001, Milkweed Editions, ISBN: 1571316302
Appropriate for ages 9-13.

THE SOUTH ATLANTIC COAST AND PIEDMONT
Sara St. Antoine and Trudy Nicholson, 2006, Milkweed Editions, ISBN: 1571316647
Appropriate for ages 9-13.

THE CALIFORNIA COAST
Sara St. Antoine, 2005, Milkweed Editions, ISBN: 1571316531
Appropriate for ages 9-13.

THE NORTH ATLANTIC COAST
Sara St. Antoine, 2004, Milkweed Editions, ISBN: 1571316434
Appropriate for ages 9-11

THE GULF COAST
Trudy Nicholson, Paul Mirocha, Katrinka Moore, and Sara St. Antoine (Editor), 2002, Milkweed Editions, ISBN: 1571316361
Appropriate for ages 12-18.

EARTH'S CLIMATE (WEATHER AND CLIMATE)
Robin Birch, Benchmark Books, 2009, ISBN: 0761444718
This book showcases each of the climate zones of the world, and concludes with a look at how global ocean currents and winds help create an area's climate. Children ages 9-12 may enjoy the maps, colorful diagrams, and photographs of featured animals and plants.

Stewardship of the Earth: Resources for Children

HUMAN FOOTPRINT: EVERYTHING YOU WILL EAT, USE, WEAR, BUY, AND THROW OUT IN YOUR LIFETIME
Ellen Kirk, 2011, National Geographic Kids, ISBN: 978-1426307676
Eye-popping facts about the average person's impact on the planet accompany kid-friendly tips for being Green. Appropriate for ages 8-12.

MISSION: SAVE THE PLANET: THINGS YOU CAN DO TO HELP FIGHT GLOBAL WARMING!
Sally Ride and Tom O'Shaughnessy, Roaring Book Press, 2009, ISBN: 1596433795
Children ages 9-12 will gain knowledge of how to reduce energy at home and school. Kid-friendly surveys, charts, and activities provide visuals for those who want to conserve energy and help fight global warming.

STEWARDSHIP OF THE EARTH: RESOURCES FOR TEENS AND ADULTS
We Are the Weather Makers: The History of Climate Change
Sally M. Walker and Tim Flannery, Candlewick, 2010, ISBN: 978-0763646561
This teen-friendly book reveals the facts to audiences, ages 14 and up, of his scientific research about what we know about global warming, what could happen in the future, and what we can do to make a difference.

THE GREEN TEEN: THE ECO-FRIENDLY TEEN'S GUIDE TO SAVING THE PLANET
Jenn Savedge, New Society Publishers, 2009, ISBN: 0865716498
This guide offers helpful tips and ideas for working toward environmental stewardship. Appropriate for ages 14 and up.

COOLER SMARTER: PRACTICAL STEPS FOR LOW-CARBON LIVING: EXPERT ADVICE FROM THE UNION OF CONCERNED SCIENTISTS
Seth Shulman, Union of Concerned Scientists, et al, Island Press, 2012, ISBN: 161091192X
The Union of Concerned Scientists provides recommendations for how individual actions really can make a positive difference toward combatting global warming. Appropriate for ages 17 and up.

GAIA'S GARDEN, SECOND EDITION: A GUIDE TO HOME-SCALE PERMACULTURE
Toby Hemenway, Chelsea Green Publishing, 2009.
This extensively revised and expanded second edition broadens the reach and depth of the permaculture approach for urban and suburban growers. The author demonstrates that it's fun and easy to create a "backyard ecosystem" by assembling communities of plants that can work cooperatively and perform a variety of functions. Appropriate for adults.

Related interactive and informational websites and online video clips

General

NATIONAL PARK SERVICE
http://www.nps.gov
Photos and multimedia of our nation's parks will engage all ages, and additional resources and opportunities are available for children and teachers.

NASA
http://science.nasa.gov/
NASA leads the nation on a great journey of discovery, seeking new knowledge and understanding of our planet Earth, our Sun and solar system, and the universe out to its farthest reaches and back to its earliest moments of existence. Click on "NASA Science for…" for links to educational activities to help investigate the world and universe using unique NASA resources.

U.S. FISH AND WILDLIFE SERVICE
http://www.fws.gov
The U.S. Fish and Wildlife Service offers photos and resources for kids, educators, and parents about public lands, endangered species, climate change, and more.

NATIONAL GEOGRAPHIC EDUCATION
http://education.nationalgeographic.com
Access encyclopedia entries, links to multimedia, text, and activities.

Weather

WEATHER WIZ KIDS
www.weatherwizkids.com/kids-questions.htm

Answers to questions submitted by children about weather are posted here. Children ages 8 and up, as well as younger children with the help of an adult, may enjoy looking for answers to their own questions on this list. Some examples include “Why does it rain?” and “Why do clouds float?”

Clouds in Art Interactive and Gallery

www.windows2universe.org/art_and_music/cloud_art/cloud_art_main.html
This interactive website identifies the types of clouds depicted in landscape paintings, and provides a side-by-side comparison with a photograph of that cloud type.

Gallery of Clouds

http://scijinks.nasa.gov/clouds-gallery
View pictures of different cloud types. Appropriate for all ages, although younger children will require adult assistance with navigation.

The National Weather Service

www.nws.noaa.gov
This site offers weather and climate data. Appropriate for adults.

The National Center for Atmospheric Research

http://www2.ucar.edu
Adult facilitators may benefit from the visuals (videos, animations, images, etc.) posted under “Libraries & Online Collections.”

Windows to the Universe

- Windows to the Universe Image Galleries (http://www.windows2universe.org/php/gallery/gallery.php?id=11)
- Clouds in Art Interactive and Gallery (www.windows2universe.org/art_and_music/cloud_art/cloud_art_main.html)

Adults and facilitators may benefit from the articles, activities, and images posted here.

National Oceanic & Atmospheric Administration

http://www.noaa.gov
Adults may benefit from the articles and links about weather, oceans, climate, and other topics on this website.

Ice

Make-a-Flake

http://snowflakes.barkleyus.com/

"Cut" your own snowflake with this interactive. Download images from the gallery as JPEG or EPS files. Appropriate for ages 5 and up.

SNOW CRYSTALS
http://www.its.caltech.edu/~atomic/snowcrystals/
Explore images of snowflakes taken under a microscope. Appropriate for all ages; adults may enjoy "No Two Alike?"

WHAT'S SO COOL ABOUT FROZEN WATER?
http://www.sciencefriday.com/video/01/27/2012/what-s-so-cool-about-frozen-water.html
NPR's *Science Friday* provides perspectives on ice from scientist Erland Schulson, head of the Ice Research Lab at Dartmouth College, and artist Shintaro Okamoto, founder of Okamoto Studio in Queens, New York. Appropriate for all ages (some of the science content is best suited for teens and adults).

Life

NATIONAL WILDLIFE FEDERATION KIDS
http://www.nwf.org/Kids.aspx
Animal- and habitat-related materials are available for ages 2-4, 5-7, and 7-14. Check out the crafts, recipes, outdoor activities, games, coloring pages, and even jokes listed under "Fun." Children 7 and older can navigate this site, and facilitators and parents may enjoy accessing the materials. Find even more activities, printable downloads, and games at http://www.climateclassroomkids.org.

Volcanos

Volcano World: For Kids
http://volcano.oregonstate.edu/kids
Kids can submit their drawings of volcanos to be featured on the site. There are games, puzzles, and simulations to explore! Other areas of the site provide current eruption reports, virtual volcano fieldtrips, interviews with volcanologists, and more. Appropriate for ages 8 and up.

USGS Hawaiian Volcano Observatory (HVO)
http://hvo.wr.usgs.gov
The Hawaiian Volcano Observatory (HVO) provides real-time images of Kilauea and Mauna Loa, the most active volcanoes on the Island of Hawai'i, as well as photo and text updates. Photos and videos appropriate for all ages.

Forces of Nature
http://education.nationalgeographic.com
The National Geographic interactive, "Forces of Nature," covers volcanos in addition to tornadoes, hurricanes, and earthquakes through maps, photos, and 3-D animations. Appropriate for ages 11 and up.

USGS VOLCANO HAZARDS PROGRAM
http://volcanoes.usgs.gov
Find a photoglossary and real-time images of several U.S. volcanos, as well as several image collections, maps, and a volcano FAQ. Site content is appropriate for all ages.

Volcanic Eruption and ***The Hot Zones***
www.pbs.org/wnet/savageearth/volcanoes
As part of its *Savage Earth*, "Out of the Inferno: Volcanoes" collection of resources, two animations feature cross-sections of the interiors of volcanos and the Earth to explore volcanism in detail. Appropriate for ages 11 and up, and for younger children with the assistance of an older child or adult.

Stewardship of the Earth: Resources for Teens and Adults

Environmental Protection Agency
http://www.epa.gov/
Provides information on science and technology, current issues, and laws and regulations. Air, climate change, ecosystems, health, land waste and cleanup, pesticides, substances and toxins, sustainable practices, and water are all discussed on the website. Information can be searched by topic, position in the community, or location. An interactive map on the homepage describes information on the air quality by state. This website also offers resources for getting your house and children tested for lead poisoning.

NATIONAL GEOGRAPHIC'S GLOBAL WARMING EFFECTS MAP
http://environment.nationalgeographic.com/environment/global-warming/gw-impacts-interactive
This interactive shows likely effects due to global warming.

U.S. Global Change Research Program **Impacts of Climate Change by Region**
www.globalchange.gov/explore
An interactive map of U.S. states and territories summaries how climate change affects your region. Appropriate for ages 12 and up.

TIMELAPSE
http://world.time.com/timelapse
View the changes to Columbia Glacier, Alaska, since 1984. Use the "Explore the World" search tool to watch changes in other locations across the globe.

GLACIER PHOTOGRAPH COLLECTION
http://nsidc.org/cryosphere/glaciers
The National Snow and Ice Data Center (NSIDC) archives a collection of historical photos of glaciers, primarily in Alaska, but also in the Pacific Northwest and Europe. Search for "repeat glacier photography" to find historical and contemporary images of the same glacier.

Climate Literacy & Energy Awareness Network
http://cleanet.org/resources/42813.html
The CLEAN project, a part of the National Science Digital Library, provides a reviewed collection of resources coupled with the tools to enable an online community to share and discuss teaching about climate and energy science. This website offers an online discussion forum, professional development materials, and webinars. Scientifically and pedagogically reviewed digital resources for teaching about climate science, climate change, and energy awareness are also available.

George Mason University Center for Climate Change Communication
http://www.climatechangecommunication.org/
This research center was created to conduct unbiased social science research that will facilitate public engagement in climate change issues. This site offers reports focused on climate change, links to informative websites, and a searchable database of research articles from academic literature.

Taking Action

COCORAHS: COMMUNITY COLLABORATIVE RAIN, HAIL, AND SNOW NETWORK
http://cocorahs.org
Collaborate with others to measure and map precipitation from your registered location. Appropriate for all ages, although children will require adult assistance in getting started.

SCIENCE FOR CITIZENS
http://scienceforcitizens.net
All ages can become involved in projects monitoring changing environments and living things on this website. Children will require adult assistance in getting started.

How prepared are you?

http://www.edu4hazards.org

This kid-friendly site provides step-by-step instructions for responding to emergencies. Details about how, when, and where earthquakes, volcanic eruptions, tsunamis, flash floods, tornadoes, and hurricanes occur are provided. Children may find a checklist of items to include in their own emergency kits, and they can submit images of their "Emergency Go-Bags" to the website for posting. A printable version of most of the website's content is available at http://www.edu4hazards.org/hazard_prepared_book.pdf.

Kids' Planet

http://www.kidsplanet.org/

Children, ages 8-13, can learn about endangered species and steps they can take to make a difference for those animals.

Young Voices for the Planet

http://youngvoicesonclimatechange.com

Ages 11 and up may benefit from the information, ideas, and inspiration from watching other young people make a difference in the "Young Voices for the Planet" series of films. The website offers suggestions for replicating their efforts.

BRAIN CAKE
http://www.braincake.org
Targeted toward girls ages 11-17 and their adult mentors, this site features an online community, links to games and career information, biographies of women who work in math-, science-, or technology-related fields, and help with homework and science fair projects. Girls can enter the "Green for Your Dreams" drawing contest to win money for programs and activities related to math and science.

KIDS VS. GLOBAL WARMING
http://www.imatteryouth.org/
Children ages 12 and up might benefit from this website's information about climate change and resources for taking positive action.

Guides to Science and Exhibits in the Library

EXPLORING SCIENCE IN THE LIBRARY: RESOURCES AND ACTIVITIES FOR YOUNG PEOPLE
Maria Sosa and Tracy Gath (editors), American Library Association, 2000, ISBN 838907687
This book covers many useful approaches for bringing science to your library. Chapters 6 and 8, "Inquiry-Based Learning in the Library" and "Partnerships to Promote Science Activities in the Library," respectively, are packed tips and even a few fun science activities. Selecting children's science books and fundraising ideas are also covered.

EXHIBITS IN LIBRARIES: A PRACTICAL GUIDE
Mary E. Brown and Rebecca Power, McFarland & Company, Inc., 2006, ISBN: 78642328
This guide covers the development, set-up, and programming of exhibits in libraries.

HOW TO STEM: SCIENCE, TECHNOLOGY, ENGINEERING, AND MATH EDUCATION IN LIBRARIES
Vera Gubnitskaia and Carol Smallwoodm Scarecross Press, Inc., 2014, ISBN 9780810892736.
Authors from public libraries and academy provide strategies for implementing STEM programs.

Library Programming Resources

Adult Programs in the Library
Brett W. Lear, American Library Association, 2012, ISBN 0838911404
Programming is an important means of not only drawing new people to the library but also better serving existing patrons. This edition includes updated chapters on basics such as funding, crafting guidelines, topic selection, publicity, post-program evaluations; a new section on technology, with ideas for online book discussions, offering programs via Skype, and turning programs into podcasts; methods for tailoring programs for specific groups, such as men, baby boomers, and seniors; and sample newsletters, press releases, scheduling forms, and program models, all available as downloads via weblinks.

Programming for Adults: A Guide for Small- and Medium-sized Libraries
Raymond Ranier, Scarecrow Press, 2005 ISBN 0810851555
This resource for library professionals at small- and medium-sized facilities provides practical suggestions for creating popular programming for adults. Coverage includes such topics as bringing speakers to the library, developing educational programs, and hosting book discussion groups. Ranier also suggests some ways of marketing library programming.

Cultural Programming for Libraries: Linking Libraries, Communities, and Culture
Deborah A. Robertson, American Library Association, 2005 ISBN 0838935516
This authoritative program resource outlines all the steps to: assess current community needs; set goals and establish measurable outcomes; develop winning partnerships that result in high quality, well-attended programs; highlight and drive the use of collections; gain community support and visibility through programming; enhance your library's role as cultural center based on successful models.

Click2Science PD
http://www.click2sciencepd.org
Click2Science is an interactive, professional development site for trainers, coaches, site directors and frontline staff/volunteers working in out-of-school time STEM programs, serving children and youth.

TECH BRIDGE ROLE MODELS MATTER PROJECT
http://techbridgegirls.org/rolemodels
The Role Models Matter Project is a collaborative effort among Techbridge, the Society of Women Engineers, the National Girls Collaborative Project and Girl Scout Councils to bring resources to role models and girl-serving organizations. An Online Training Toolkit

will help you develop skills to engage girls and underrepresented youth in STEM through readings, videos, questions, and more.

Further Activities and Lessons

"WHO DIRTIED THE WATER?," MUSEUM OF SCIENCE AND INDUSTRY
www.msichicago.org/fileadmin/Education/learninglabs/lab_downloads/TTW_dirtied_the_water_act.pdf
Children are read the story of an imaginary place, where the activities of wildlife and people influence the area's lake. At a key point in the story, each child adds a "pollutant" to the "lake" — usually eliciting an "ewwww!" from the audience! An aquarium or other large container is used to simulate the lake, and common materials like paper, vinegar, and molasses represent the pollutants. The story is used to start a conversation about pollution in our lakes, rivers, oceans, and groundwater. Appropriate for ages 8–13.

BEAUFORT WIND SCALE
www.spc.noaa.gov/faq/tornado/beaufort.html
www.mountwashington.org/education/center/arcade/wind/beaufort_scale_tbp.gif
Children ages 10 and up may relate what they see out the window to wind speeds using the Beaufort scale, listed on one of these easy-to-read charts. The National Weather Service chart lists the appearance of wind effects on both land and water, and the Mount Washington Observatory's chart provides illustrations, but lists the effects on land only.

THE PROJECT WET CURRICULUM AND ACTIVITY GUIDE
This guide to teaching about water resources provides fun, hands-on investigations and celebrations for children in grades K to 12. Find more information about this publication, and related training opportunities, at http://www.projectwet.org.

BOTTLE BIOLOGY, 2ND EDITION
Wisconsin Fast Plants Program, Kendall/Hunt Publishing Co., 2003, ISBN: 978-0-7575-0094-7
Children ages 8 to 13 can explore life — and make use of recycled materials — by creating over 20 different terrariums and other projects. The water cycle and biomes, among other science concepts, are explored.

IT'S YOUR PLANET — LOVE IT!
www.girlscouts.org/program/journeys/your_planet/
Girl Scouts explore water, energy, and air quality through this program. There is a guide for Girls Scouts adult volunteers, as well as the following activity books for children and teens.

> **GIRL SCOUTS' WOW**
> Children ages 7-8 investigate water through this activity book, which discusses the water cycle and features female professionals in water-related professions. Offers suggestions for taking action to conserve water and protect water environments.
>
> **GIRL SCOUTS' GET MOVING**
> Children ages 9-10 investigate our use of energy and develop a step-by-step plan for taking action.
>
> **GIRL SCOUTS' BREATHE**
> This book offers a path to leadership for children ages 11-13. The guide to asking questions of professionals in related careers, as well as information about wind,

global warming, ozone, weird weather, trees, and air pollution, are especially relevant to *Discover Earth.*

GIRL SCOUTS' SOW WHAT?
Teens ages 14-15 can use this book to start thinking about where their food comes from. They also may enjoy the challenge to create their own gardens.

ENDANGERED SPECIES FURNITURE PROJECT
www.dpc.ucar.edu/projects/bvsd03/activity1Feeney.html
This lesson, by Andrew Feeney, has teens refinishing furniture — with a "Green" theme!

Films and Videos

Following is a general list of films and videos that might be used with *Discover Earth* programs. This is not a comprehensive list, it is a starter list for libraries interested in showing films. Please preview films for their appropriateness for your audience.
Each library wishing to show films or videos to the public needs to evaluate if arranging for public performance rights is necessary.

Swank Motion Pictures, Inc. now offers a Movie Public Performance Site License to libraries on an annual basis. Information is at www.movlic.com.

NASA eClips
http://www.nasa.gov/audience/foreducators/nasaeclips/
Watch a scientist demonstrate the formation of a cloud from water vapor (with a little help from some chilly liquid nitrogen) in “Cool Clouds.” Discover how clouds come in different types â€” each with their own name — depending on their altitude, shape, and whether they are producing precipitation or not in “What Is a Cloud?”. Suitable for ages 8–10.

NASA’s Climate Reel
http://climate.nasa.gov/climate-reel
This collection of videos and visualizations of climate change cover the four main Earth parts or systems explored in *Discover Earth*: water, ice, air, and life. Different videos may appeal to various ages.

Climate Change, Wildlife & Wildlands
http://www.globalchange.gov/resources/educators/toolkit/video
This high-definition video offers explanations on climate change and how it impacts wildlife and their habitats in the U.S. High-school students and climate professionals are feature. Appropriate for ages 14 and up.

The Carbon Crisis in 90 Seconds
www.youtube.com/watch?v=85TQHzS88L4
NASA Earth Scientist Peter Griffith clearly and simply explains the difference between the “new” carbon that we eat every day and the “old” carbon that we burn as fossil fuels.

Geospatial Revolution, Episode Four, Chapter One: Monitoring a Changing Climate
http://geospatialrevolution.psu.edu/episode4/chapter1
Adults can learn how digital mapping is used to monitor climate change. Interviews with scientists and clear graphics provide insight into key climate change issues, such as drought, ice sheet mass change, solar radiation, carbon dioxide, and deforestation.

National Latino Coalition on Climate Change
http://latinocoalitiononclimatechange.org/
This website offers many resources, in English and in Spanish, for adults. Available downloads include “Latinos Going Green,” which offers quick tips for reducing, reusing, and recycling at home, on the road, and at work, and “Latinos & Global Warming: How Latinos Will Be Affected and How to Take Action.” News, events, and information relating to climate change, as well as links to “Green Jobs,” are listed.

Green Films

http://ecohearth.com/eco-zine/arts-and-culture/253-top-environmental-documentaries-.html
Check out this site for a list of environmental, ecology, and nature films.

Handouts and Visual Aids

Create Your Own Nature Journal

http://www.nwf.org/Kids/Ranger-Rick/Activities/Outdoors/Observing-Wildlife/Create-Your-Own-Nature-Journal.aspx

Weather Diary

www.naturedetectives.org.uk/download/weather_diary.htm
The large grid layout and images on this simple weather journal may appeal to ages five to eight. Show the children how to note the wind's direction in their journals.

Science Notebooks for Ongoing Weather Observations

The Michigan Reach Out! "Keeping a Daily Weather Log" activity at www.reachoutmichigan.org/funexperiments/agesubject/lessons/caps/log1.html includes a printable chart to record temperature, wind speed and direction, relative humidity, and other data. Alternatively, professional-grade journals, such as those manufactured by www.riteintherain.com, may serve as a valuable memento for the children.

Daily Forecast Flyer

www.wunderground.com/printer/cityforecast.asp
Customize a flyer of the weather forecast at your location and print it out. Children will appreciate the easy-to-understand graphics, and adults will find a wealth of local, regional, and global information on this single page.

Cloud Viewer

http://www.windows2universe.org/teacher_resources/cloud_viewer_web.pdf

Cloud Identification Guide: A Dichotomous Key

http://www.usc.edu/org/cosee-west/March06Resources/OtherResources/CloudID.pdf

Sky Watcher Chart

http://science-edu.larc.nasa.gov/cloud_chart

CloudSpotter Wheel

http://www.srh.noaa.gov/srh/jetstream/downloads/cloudwheel_10.pdf

Atmospheric Explorers Hand-outs

These one-page hand-outs were created by the University Corporation for Atmospheric Research. One side features colorful photographs, while the other describes four easy-to-do hands-on experiments. Appropriate for ages 8-13.

"Storms" (http://eo.ucar.edu/kids/images/AtmoExp1.pdf)
"Clouds" (http://eo.ucar.edu/kids/images/AtmoExp2.pdf)
"Biodiversity" (http://eo.ucar.edu/kids/images/AtmoExp3.pdf)

NASA Earth Observatory

http://earthobservatory.nasa.gov
Find images of the Earth and its features, which have been captured by satellites and astronauts in space. Search for key words such as "river" or "alluvial fan," or browse a topic such as "Surface Water." Appropriate for ages 10 and up; younger children may need assistance interpreting these images, which are viewed from the unique vantage point of space.

Earth as Art

As a slide show or image files to download from the U.S. Geological Survey Earth Resources Observation and Science (EROS) Center: http://eros.usgs.gov/imagegallery
For iPad devices, free from iTunes: https://itunes.apple.com/us/app/nasa-earth-as-art/id577527077?mt=8#
Children may enjoy the shapes, colors, and textures of Earth's land, oceans, ice, and atmosphere captured by satellites. Appropriate for ages 10 and up; younger children may need assistance interpreting these images, which are viewed from the unique vantage point of space.

National Geophysical Data Center Origami Balloon

http://www.ngdc.noaa.gov/mgg/image/origamiearth.pdf
Origami enthusiasts, ages 8 and up, will enjoy making a 3-D globe of the Earth — from paper! The template uses satellite data from the National Oceanic and Atmospheric Administration (NOAA). Kid-friendly folding instructions are available from http://oceanservice.noaa.gov/education/for_fun/EarthOrigami.pdf.

Contact Information

Your questions and comments about the *Discover Earth: Hands-on Science Activities* are welcome!

Explore Program Team
Department of Education and Public Outreach
The Lunar and Planetary Institute
3600 Bay Area Boulevard
Houston, Texas 77058
explore@lpi.usra.edu

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Development Team (Lunar and Planetary Institute, Houston, TX)
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Module Development and Workshop Implementation
Keliann LaConte
Dr. Stephanie Shipp
Yolanda Ballard–Zimmermann

Web Development and Graphics
John Blackwell
Ronna Hurd

Resources
Linda Chappell

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Content and Education Review

Dr. Gil Compo, Research Scientist, *Cooperative Institute for Research in Environmental Sciences, University of Colorado , Boulder, CO*
Dr. Sara Harris, *University of British Columbia, Vancouver, BC Canada*
Dr. Walt Meier, *National Snow and Ice Data Center, University of Colorado, Boulder, CO*

Beth Barrett, *Louisville Public Library, Louisville, CO*
Dr. Susan Buhr, *Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, CO*
Tiffany Clendenin, *Ruby M. Sisson Memorial Library, Pagosa Springs, CO*
Dr. Paul Dusenbery, *National Center for Interactive Learning at the Space Science Institute, Boulder, CO*
Deborah Morrison, *University of Colorado, Boulder, CO*
Karen Peterson, *National Girls Collaborative Project, Lynnwood, WA*

Field Tests

Appreciation is extended to the librarians who field tested the materials in their children's, youth, and teen programs.

Justin Barkley, *TLL Temple Memorial Library, Diboll, TX*
Sally Blevins, *Bitterroot Public Library, Hamilton, MT*
Laura Goss, *Adams County Library System, Gettysburg, PA*

Evaluation Team

John Baek, *National Oceanic and Atmospheric Administration*
Vicky Ragan Coulon, *Evaluation & Research Associates, Lynnwood, WA*
Ginger Fitzhugh, *Evaluation & Research Associates, Lynnwood, WA*
Kate Haley Goldman, *National Center for Interactive Learning at the Space Science Institute*