Curriculum Units by Fellows of the National Initiative
2021 Volume IV: The Sun and Us

Using Case Studies to Understand the Sun's Influence on Earth's Climate System in 3rd Grade

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Introduction/Rationale

This unit is written for teachers of third-grade students and aligns with the latest (as of 2021) Next Generation Science Standards (NGSS) for 3rd grade Earth Science topics about weather and climate.

In the summer of 2021, I worked with Dr. Sarbani Basu, Yale professor of Astronomy, in a seminar titled "The Sun, the Solar System, and Us." Although we covered various topics under that title, I chose to focus on 3rd grade-level content. There are three Earth Science standards under the NGSS framework for 3rd grade, and they all focus on weather and climate. In summary, they are:

1) Use tables and graphical displays to represent typical weather conditions expected during a particular season.

2) Obtain and combine information to describe climates in different regions of the world.

3) Evaluate the merit of a design solution that reduces the impact of weather-related hazards.[1]

There are additional science and engineering practices that span the K-12 framework that are also applicable. You will find an annotated list of these standards in more detail in the appendix of this unit.

This unit will guide you and your students to learn about why we have seasons and a diverse range of climate zones here on Earth. It will cover background information about the Sun, how the Earth's surface and atmosphere reacts to incoming solar radiation, the greenhouse effect, and the Koppen climate classification system, including tropical, dry, temperate, continental, and polar climate zones. Students will explore a mysterious, heavy hailstorm in Guadalajara, Mexico, that occurred in 2019. They will apply what they have learned about the Earth's climate zones and why climate zones exist as they unravel and explain the mystery.

Background Information

The Sun

Our Sun, the centerpiece and literal star of our solar system, is a massive sphere of hot plasma heated to incandescence by nuclear fusion reactions in its core. It emits electromagnetic radiation mainly as visible, infrared, and ultraviolet light. At birth, it was composed of about 71% hydrogen, 27% helium, and less than 2% oxygen, carbon, neon, iron, and all other elements combined. The Sun contains 99.8% of all the mass in our solar system, leading some astronomers to describe our solar system as "the Sun plus some debris." In comparison, the mass of the Sun is about 330,000 times the mass of the Earth. Thus, the volume of the Sun could fit approximately 1,000 planets the size of Jupiter, the giant planet in our solar system, or about 1 million planets the size of Earth.[2]

The mass of the Sun produces a gravitational force strong enough to lock into orbit the eight planets, along with their moons and all other objects in between and some beyond, such as comets and asteroids. The farthest known object in our solar system, discovered in 2018, is a planetoid aptly named Farfarout (2018 AG37) and is 132 astronomical units (AU) from the Sun. One astronomical unit is about 93 million miles, the distance from the Earth to the Sun. It takes about 1,000 Earth years for Farfarout to complete its orbit around the Sun![3]

Our Sun classifies as a medium-sized yellow dwarf star. Despite its dominance in our solar system, there are stars up to 300 times more massive in the Milky Way galaxy where our solar system resides. The most petite star in the Milky Way, EBLM J0555-57 discovered in 2017, is roughly the size of Saturn but also about 85 times the mass of Jupiter.[4] It is believed that it is the smallest a star can get and still contain enough mass for energy-generating hydrogen fusion.

Formation of the Sun

Our Sun formed in a nebula of dust and gas (mostly hydrogen and helium with small amounts of all other elements.) about 4.5 billion years ago. As the gas and dust began to collapse under its own gravity, it entered the protostar stage. In this stage, the center got denser and hotter as it developed an opaque, pressure-supported core. During the protostar phase, it continued to contract while gathering material from the formative molecular cloud around it. Protostars continue to do so until enough material accumulates to create a temperature exceeding 10 million K, the temperature needed for efficient hydrogen fusion to occur. This can take between 100,000 to 100 million years, depending on the size of the forming star. For a star like our Sun, it took about 50 million years. Once hydrogen fusion begins, any leftover material in the surrounding nebula can eventually form other solar bodies such as planets, asteroids, or comets. If a protostar does not accumulate enough mass for hydrogen fusion, it will become a brown dwarf star.[5]

Fortunately for us, our Sun did achieve hydrogen fusion and became a dwarf star. At that point, the Sun entered its main-sequence phase. It will spend most of its life in equilibrium between the inward pull of its gravity and outward expansion of pressure from gas heated by nuclear reactions when four hydrogen nuclei fuse to form helium. Our Sun will remain in this stage for about five billion more years until it has exhausted the hydrogen in its core. Eventually, the Sun will swell in size, possibly far enough to consume Earth, as it enters the red giant stage. By then, all evidence of life on Earth will have been obliterated (even though life as we know it will have ceased long before). The increased pressure in the core will cause it to become hot enough for helium fusion. Once helium is exhausted, the Sun will have shed its outer layers, and the Sun's core will become a white dwarf about the size of Earth. The white dwarf will cool over billions of years and eventually will become too dark to see.

Solar Energy

All matter with a temperature above absolute zero (where all atomic or molecular motion stops) radiates energy across a range of wavelengths in the electromagnetic spectrum. The peak wavelength of radiated energy becomes shorter as an object gets hotter. The hottest things in the universe radiate mostly gamma rays and X-rays, while cooler objects emit mostly longer-wavelength radiation, including visible light, thermal infrared, radio, and microwaves. For example, the surface of the Sun has a temperature of about 5,800 Kelvin (5,526ºC, or about 10,000ºF). At that temperature, most of the radiated energy is visible, infrared, and ultraviolet light. At Earth's average distance from the Sun (about 93 million miles), the average intensity of solar energy reaching the top of the atmosphere facing the Sun directly is about 1,360 watts per square meter. This amount of power is known as the total solar irradiance (also known as the solar constant).

The Sun does not always shine at a constant level of brightness. Instead, the Sun brightens and dims slightly, taking 11 years to complete one solar cycle. In addition, the Sun undergoes various changes in its activity and appearance, with levels of solar radiation going up or down, as well as the amount of material the Sun ejects into space and the size and number of sunspots and solar flares. These changes have various effects in space, Earth's atmosphere, and Earth's surface but are usually not severe enough to affect living things on Earth or Earth's climate. Human technology, however, is at risk. Satellites and electronic devices on the surface that we depend on today for our infrastructure and quality of life are susceptible to damage with increased solar activity.

Solar Energy & the Earth

Almost all (99.9%) of the energy on Earth originates from the Sun. It is our primary source of heat and prevents our atmosphere and water from completely freezing. It is necessary for plant growth (photosynthesis) and therefore the food, shelter, and oxygen needed by other living things. It powers Earth's hydrologic cycle and other Earth systems that play a role in weather and climate. We also depend on it to meet our energy needs, as even unearthed fossil fuels were formed millions of years ago from buried plants that absorbed and stored energy derived from the Sun.

What if the Sun suddenly disappeared? If this were to happen, the daylight side of the Earth would darken after 8½ minutes. The Moon and planets would no longer be visible. Solar system objects, including Earth, would continue in a straight path along their trajectory until they collide with something or encounter the gravitational force of a larger entity. Within days, global temperatures would fall below freezing. Most plant life would die due to no photosynthesis, and soon after, any animal life that depends on them. Eventually, the water on Earth would freeze, yet deeper bodies of water such as oceans might experience an insulating effect and not freeze completely. At least not for a few thousand to millions of years. Some microscopic life would persist, as well as some life sustained by geothermal activity such as ocean vents. The atmosphere would eventually freeze, therefore exposing the surface to any radiation from space. Over a few million years, the Earth would ultimately cool to a stable –400°F, the temperature at which the heat radiating from the planet's core would equal the heat that the Earth radiates into space. Of course, the sudden disappearance of our Sun is an impossibility, but without it, we simply would not be here, and our home planet would be inhospitable and nearly unrecognizable.[6]

I previously mentioned that our Sun radiates shortwave energy mainly in the form of visible, infrared, and ultraviolet light. Only a fraction of the Sun's energy output reaches Earth. And even then, not all the Sun's energy that reaches the top of the atmosphere reaches the surface of the Earth. About 30% of the solar energy that arrives at the top of the atmosphere is reflected to space by clouds, particles in the atmosphere, or reflective ground surfaces like sea ice and snow. This means approximately 70% of incoming solar energy is absorbed. Atmospheric dust, ozone, and greenhouse gases such as water vapor, carbon dioxide, and methane absorb about 23% of the incoming solar energy. Only 48% passes through the atmosphere and is absorbed by the surface.[7] The solar energy that reflects off Earth's surfaces emits back as longwave radiation. This flow of incoming and outgoing energy is Earth's energy budget. For Earth's temperature to be stable over long periods, incoming and outgoing energy must be in equilibrium.[8]

Although the Earth's atmosphere is thin in comparison to the size of the planet, much like an eggshell compared to the egg, it is enough to keep our world warm and protected as if wrapped in a blanket. Our Moon has an exosphere of trace elements instead of an atmosphere like Earth due to its low mass and weak gravitational and magnetic fields. Lunar surface temperatures can range from a high of up to 250ºF during a lunar day to a low as far as –387ºF during a lunar night because its atmosphere does not retain heat.[9] It is also quiet because sound cannot travel through the air as it does on Earth. The sky is black because the light does not scatter through the atmosphere. The surface shows the aftermath of many impact craters because objects collided with the surface rather than burning up in the atmosphere. There is also no protection from harmful radiation, which is part of the reason why lunar astronauts must wear suits that protect their entire bodies. We could expect similar conditions here on Earth if we did not have an atmosphere.[10]

Solar Energy Distribution on Earth

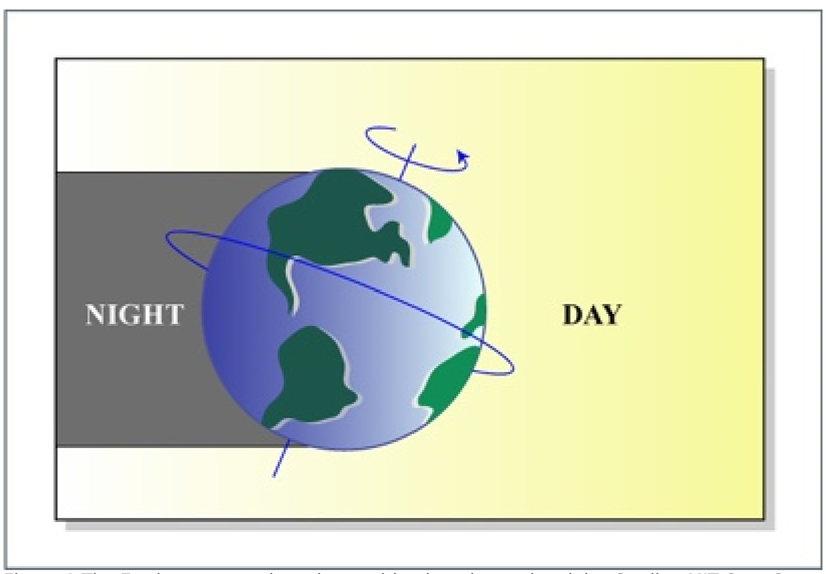


Figure 1 The Earth rotates on its axis, resulting in a day and a night. Credits: MIT OpenCourseWare

The reasons for the Earth experiencing seasons are rotation, revolution, sphericity, axial tilt, and axial parallelism. Earth is a sphere that rotates on its axis once every 24 hours.[11] Therefore, we have a day and night on Earth. If the Earth did not rotate, then a full day would span six months and a whole night another six months.

The Earth takes 365.24 days to orbit the Sun. Earth's orbit around the Sun is not a perfect circle. It is an elliptical, or oval-shaped, orbit. At aphelion, the Earth is farthest from the Sun at about 94.5 million miles. At perihelion, the Earth is closest to the Sun at about 91.4 million miles. One might assume that we have changing seasons and diverse climate zones on Earth because of our distance from the Sun. After all, the closer one gets to a source of heat, the warmer one becomes. And the opposite is true as well; the farther away, the colder it gets. While there is a difference of over 3 million miles, that is not much relative to the entire distance.

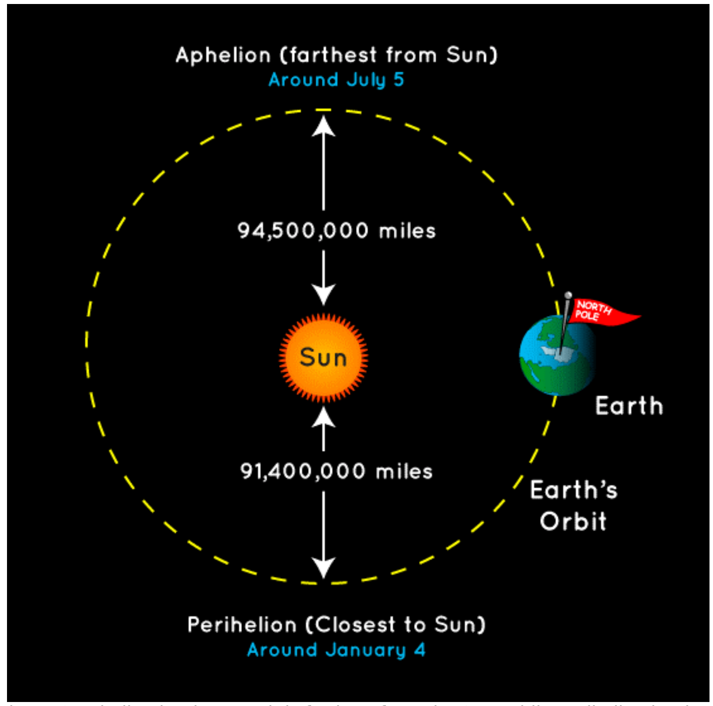
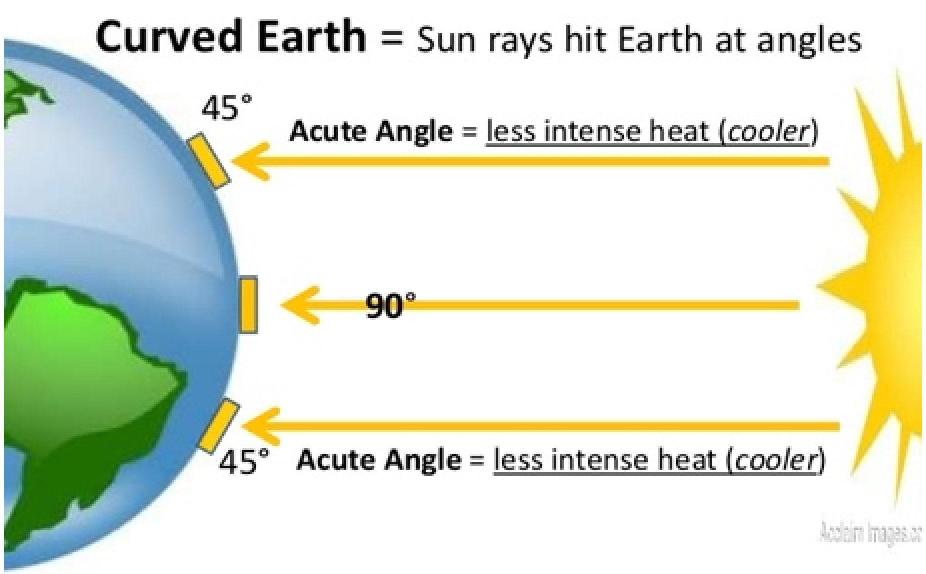


Figure 2 Aphelion is when Earth is farthest from the Sun, while perihelion is when Earth is closest. Credits: NASA

Aphelion (when Earth is farthest from the Sun) occurs in July, and perihelion (when we are closest) occurs in January.[12] For those of us who live in the Northern Hemisphere, where it is summer in July and winter in January, that may seem backward, but it does provide a clue that Earth's distance from the Sun is not the leading cause of the seasons.



The spherical shape of the Earth is another reason why we have uneven heating. A smooth, flat object would experience an equal amount of radiation from top to bottom. However, since the Earth is a sphere, the curvature of the Earth influences the angle and intensity of incoming solar radiation. As a result, the rays of solar energy are most direct and intense in the equatorial regions and less severe (and cooler) toward the poles.[13]

Figure 3 Incoming solar radiation hits Earth at different angles. Credits: NWClimate.org

The Earth is also tilted on its axis by about 23.5 degrees as it rotates. This tilt means that at one point in Earth's orbit around the Sun, the northern part of the planet is pointing toward the Sun, while the southern end points away from the Sun. This tilt also explains why different parts of the Earth have differing amounts of daylight at varying times of the year.
To tie this into the seasons, we also need to look at axial parallelism. While Earth is rotating on its axis at an angle of 23.5 degrees, it is always (at least in our lifetime) tilted in the same direction toward the North Star (Polaris). The tilt of the planet remains in a constant direction as Earth orbits the Sun. In December, the Southern Hemisphere points toward the Sun, and it is summer. Meanwhile, the Northern Hemisphere has pointed away from the Sun, and it is winter. Six months later, Earth has revolved halfway around the Sun, so now the Northern Hemisphere is pointed toward the Sun (summer), and the Southern Hemisphere has pointed away (winter).

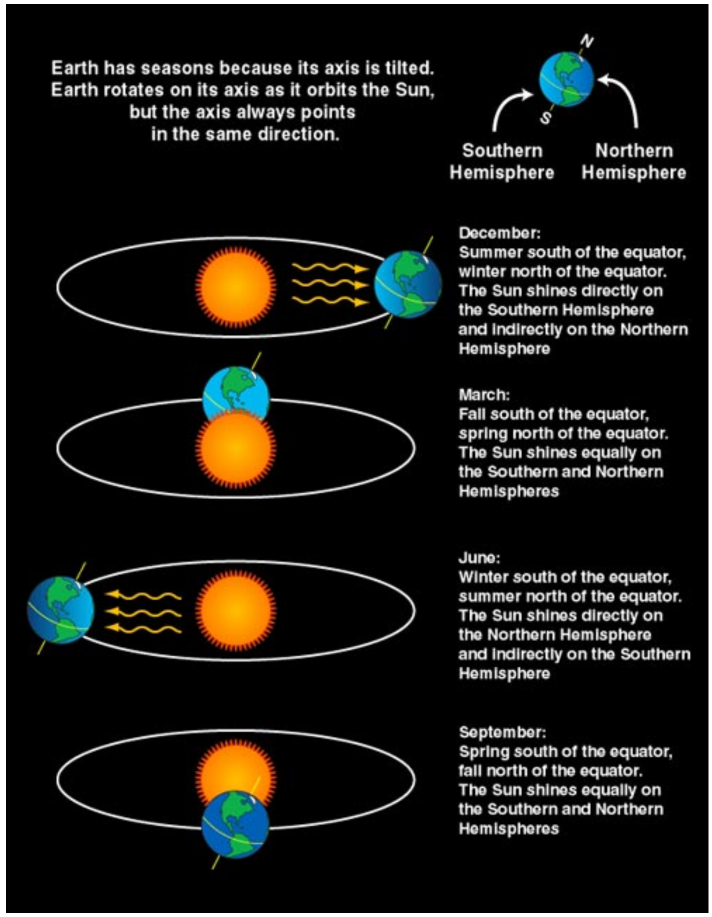


Figure 4 The tilt of Earth causes seasons. Credits: NASA

In addition, the land heats and cools faster than water. This uneven heating influences both ocean and atmospheric convection currents. Uneven heating of land and water produces wind systems. Differences in air pressure due to varying temperatures create wind as high-pressure areas move to low-pressure areas. The same happens in the ocean, where uneven heating and cooling produce the convection of ocean currents.

The Greenhouse Effect

The process that occurs when gases in the Earth's atmosphere trap heat, much like the Earth under a blanket, is known as the greenhouse effect. Students may relate more to a blanket analogy rather than a greenhouse, but either way – it is a process that keeps the Earth warm. Without greenhouse gases in our atmosphere, the Earth's average temperature would drop to as low as 0º Fahrenheit (14º Celsius). Earth would be an icy wasteland, hospitable only to organisms that could tolerate such conditions.[14] Key to this understanding is the natural balance that makes our planet unique in our solar system to support an abundance of life. However, too much greenhouse gas can have a detrimental effect. The planet Venus provides an example of a planet where greenhouse gases have significantly increased the atmospheric and surface temperature. Too much heat would be trapped, and to continue the blanket analogy, it would be like wearing a winter coat under a large pile of blankets on an already hot day.

Figure 5 The glass walls of a greenhouse trap the Sun's heat. Credits: NASA/JPL-Caltech

Greenhouse gases are water vapor, carbon dioxide, methane, nitrous oxide, ozone, and chlorofluorocarbons (CFCs). They absorb heat and radiate it out in all directions, very much like a stone heated by the Sun. Carbon dioxide has increased under the current balance as human activity releases more and more into the atmosphere each year. This increase in carbon dioxide correlates to a rise in temperature. Since warmer air can hold more water, this adds more water vapor to the atmosphere (and an increase in rainstorms in some regions).

A phenomenon known as albedo is a familiar concept that dark-colored objects left in the Sun get warmer than light-colored objects. Anyone who has walked barefoot on the white painted lines of a dark asphalt parking lot to reduce burning their feet is familiar with this concept. This difference in reflective surfaces has an impact on weather and climate on a planetary scale. In the Arctic regions, it can result in the melting (or build-up) of sea ice and glaciers. Sunlight is the primary driver of Earth's climate, with about 340 watts per square meter of energy from the Sun reaching the Earth. About one-third of that energy reflects to space, and the remaining energy is absorbed by land, ocean, and atmosphere. Exactly how much sunlight is absorbed depends on the reflectivity of the atmosphere and the surface. Albedo can range between 0 (nothing reflected) and 1 (completely reflected like a mirror). Ocean water albedo is about 0.06, or 6 percent. Sea ice can range from 0.25 to 0.8, or 25 to 80 percent. Sea ice melts as global temperatures rise. This change to the Earth's albedo as the result of melting ice further exacerbates climate change. The same can be said for man-made changes to the Earth's surface, such as removing vegetation and adding buildings while paving roads. Under current climate conditions, urban areas already experience a "heat island effect" where daytime temperatures are 1ºF to 7ºF warmer than outlying areas and nighttime temperatures about 2ºF to 5ºF higher.[15]

Weather Versus Climate

Weather is simply a description of the short-term atmospheric conditions, such as the temperature, humidity, level of cloudiness, and precipitation. Weather is what you get, but the climate is what you expect. Climate is the average, prevailing pattern of conditions of a region over a long period of time. The current standard considers an area's weather conditions during different parts of the year over thirty years. Can you expect snow in the winter? How hot does it get in the summer? Is it typically raining in the spring? These are some questions one would ask that are related to a region's climate. Knowing a region's climate can be helpful when choosing building materials or planning infrastructure or when considering what crops are likely (or unlikely) to thrive in a region. For visitors, knowing a location's climate can help them select appropriate clothing to pack.

Earth's Climate Zones

The Sun, Earth's orbit around the Sun, Earth's rotation and tilt on its axis, and the absorption or reflection of incoming solar energy are all factors of Earth's global climate system. Still, there are additional surface-level factors as well. Latitude, elevation, proximity to mountains or large bodies of water, ocean circulation, and long-term atmospheric circulation all influence a region's climate.

In 1884, German-Russian geographer, meteorologist, climatologist, and botanist Wladimir Koppen began to develop a climate classification system that is still widely used today and is known as the Koppen Climate Classification System.[16] It has been revised several times since then by Koppen and others. Even other climate classification systems, such as the Trewartha system, further divide the middle latitudes. The Koppen system divides climates into five main groups. They are Tropical, Dry, Temperate, Continental, and Polar.[17]

Each of these main groups divides into sub-groups based on temperature and seasonal precipitation. Understanding the main features of these climate zones is sufficient for third graders to understand.

Tropical

Tropical or megathermal regions are warm throughout the year, and the lowest monthly mean temperature exceeds 64ºF/18ºC. These areas can be found between 15ºN to 15ºS latitudes. These areas typically have significant precipitation because warm air can hold more water. Some of the subgroups are rainforest, monsoon, and tropical savannas.[18]

Dry

Dry or arid climates receive little precipitation, and what little precipitation there is usually evaporates quickly. This is the only Koppen climate classification based on precipitation rather than temperature. First, a precipitation threshold is established based on the total rainfall during the spring and summer months (April-September in the Northern Hemisphere, October-March in the Southern Hemisphere). If a region's annual precipitation exceeds 50% of the precipitation threshold, it classifies as a semi-arid steppe. If less than 50%, it ranks as an arid desert. Dry climates are typically between 50° N and 50° S, but they are mainly in the 15º–30° latitude belt in both hemispheres.[19]   Deserts can be hot or cold deserts.

Temperate

A temperate or moist sub-tropical mid-latitude climate is typical along the edge of continents. Temperate climates have only moderate temperature differences between summer and winter. Seasonal changes are not as extreme as in dry climates. If the average temperature of the warmest month is higher than 50ºF/10°C and the coldest month is between 65ºF/18°C and 32ºF/0°C, then it is considered a temperate climate.[20]

Continental

Moist continental mid-latitude climates are, as the name implies, usually found in the interior of continents. They have one month with an average temperature below 32ºF/0ºC and one month averaging above 50ºF/10ºC. The typical range is from 40º to 75º latitudes, but they are rare in the Southern Hemisphere.[21]

Polar

Polar climates are cold, and every month has an average temperature below 50ºF/10ºC. Polar climates include tundra regions generally north of 70ºN with average temperatures between 32ºF/0ºC and 50ºF/10ºC. Also included are ice cap climates, which dominate at the poles in Antarctica and inner Greenland, where average monthly temperatures remain below 32ºF/0ºC.[22]

Teaching Strategies

The NGSS were developed to improve science education in the United States by providing interconnected science standards, from kindergarten through 12th grade, rich in science content and practices. Curricula based on NGSS will promote deeper thinking about specific topics, possibly using a case-study method that emphasizes critical thinking and primary investigation. This shift in pedagogy fosters student engagement in the scientific practices of developing and testing ideas, gathering and evaluating evidence, and reasoning the validity of conclusions. I like this approach because students will figure things out as they learn rather than have content presented to them to pass a test or complete a science project.

Students will begin this unit by viewing a news report about an interesting, real-life phenomenon in Guadalajara, Mexico, in June of 2019. Residents were shocked to wake up to the aftermath of a massive nighttime hailstorm unlike anything they had ever seen. First, the city was blanketed in several feet of hail, with some areas accumulating piles up to six feet tall. Hundreds of homes and businesses were damaged, parked cars were buried, and city roads were impassable. Then the melting and flooding started, and roadways in some parts of town became surging rivers powerful enough to carry parked cars. As students watch the news report in wonder, they may observe some interesting details. The people in the news report are walking around on piles of ice, but they are not wearing winter clothing. Instead, they are wearing shorts, t-shirts, and sandals! The children are excitedly playing in the ice under a clear, summer sky as if they have never experienced a snow day. At the same time, the adults look on with exasperated faces as they assess the damage and begin the cleanup effort.

After viewing the news report, excitement grows in the classroom as some students share stories of their own experiences with hail or other forms of intense weather. They are already building personal connections. They discuss the details they noticed and begin to ask questions, but instead of providing answers, the teacher prompts them to develop their explanations. Giving them the answers is too easy. Unlike the instant gratification they may be accustomed to, they will have to work for this knowledge. And it is doubtful any of them will go home with a tidy answer that is quickly forgotten. By the way, the Guadalajara hailstorm was caused by a combination of factors. Guadalajara sits about 5,000 feet above sea level, and a higher elevation means it is closer to the freezing level. An updraft of warm, moist air encountered rapidly cooling air and sat at the hail core level for a significant amount of time, resulting in a deluge of hail and rain. Local topography, such as downhill slopes and obstacles like buildings, funneled tremendous runoff to some parts of the city, with more ice eventually accumulating on top. Guadalajara and other warm, continental mid-latitude areas, especially regions at higher elevations, are the most likely places to experience hailstorms. These include mountainous northern India, parts of China, central Europe, Australia, and North America east of the Rocky Mountains from Alberta, Canada, and south to eastern New Mexico.

Engaging students in a phenomenon like this can have advantages. It piques their interest. It gives them a sense of purpose and motivation for what they will be learning. It gets them thinking, questioning, reasoning, and sharing. I especially appreciate how it puts every student on a level playing field because now it does not matter how well someone can read, write, solve math problems, or speak the native language. Everybody witnessed the same phenomenon, and now anyone can experience the satisfaction of making valuable contributions to the discussion.

A case study or phenomenon exploration can be a practical approach to engage the class in applying NGSS scientific practices. The development and evolution of students' explanations will require making meaningful observations, formulating questions, conducting research, developing and testing ideas, gathering and evaluating evidence, and reasoning the validity of conclusions. Instead of just taking a test or completing a lab project, they will share and defend their methods and the rationale leading to their decisions. In turn, they will practice evaluating the techniques and reasoning of others. Knowing their claims will be questioned and scrutinized adds a layer of accountability and self-reflection to their work. This scrutiny is also a better model of how scientific research occurs in the real world, where scientists do not know all the answers and must put in the work to figure them out.

Learning something new can be a messy process that often produces more questions than answers. Over time, as students acclimate to this open-ended approach, they will build resiliency against feelings of frustration that may arise upon encountering a challenging obstacle, making mistakes, or arriving at an incorrect conclusion. Repeated exposure to struggles and practicing strategies to deal with them allows opportunities for personal growth. They may even learn to appreciate and apply other skills we try to teach them, such as organization, recording notes, learning to stay focused, and collaborating productively with others, especially those who disagree with them. They will learn science content by figuring it out. In doing so, they will be taking part in good scientific practices, developing science literacy skills, and discovering more about themselves in the process.

This brings me to share a blunt reality about effective teaching and what necessitated the development of the NGSS. Asking students to passively read, watch, or listen to a topic presentation, perhaps followed by a few teacher-selected activities to reinforce the same information, is not an effective way to teach. Especially if the class of students is primarily motivated by a grading system and the ensuing positive attention for being a "good student." It may get you and your students through the curriculum, and some students may genuinely retain some of the information you provided, but most will retain it only long enough to pass the test. Realistically, most of them will not retain much if the instructional methods are ineffective and they were not adequately motivated in the first place. Moreover, the disservice here can have damaging consequences if children develop a negative self-view of their intelligence and abilities. The ultimate role of a teacher is to provide the experiences and questioning that encourages students to grow academically and emotionally.

Lamentably, our education system has been failing the majority of our nation's students regarding science instruction. Reports from organizations that test students to measure science proficiency have all delivered a similar message. These include our government's National Center for Education Statistics (NCES) and the internationally renowned Programme for International Student Assessment (PISA). American students woefully lack in science proficiency. The NCES issued "The Nation's Report Card" in 2019, and the results for science reveal only 36% of 4th graders, 35% of 8th graders, and 22% of 12th graders scored at or above science proficiency levels. There was no significant improvement from the 2009 baseline score. The last PISA report in 2018 ranked the United States 19th out of 72 participating countries, which was an improvement from a ranking of 25th in 2015.[23] We can do better. Science literacy is essential, as the current debates over climate change and vaccinations reveal, because it provides a context for addressing societal problems and allows for making intelligent, well-informed decisions that have an impact on our quality of life.

I promise this is a unit to help 3rd graders learn more about the Sun and Earth's climate system! My above commentary intends to familiarize you with my mindset while researching and writing this unit. I also want to temper your expectations for what this unit is and what it is not. Commercial education units typically have some background information followed by lesson plans that you can jump into with prepared activities and attractive reproducible worksheets. Essentially, they just make it easier to present information as described above. The units written for the Yale National Initiative (YNI) are not like that. They were written by teachers who have worked closely in multiple small group seminar sessions led by a Yale professor who is an expert in their field. In turn, teacher participants enrich their content knowledge as they research and write these units. Most of the unit is an expository narrative that bridges the content learned in multiple seminar sessions with individual teacher research pertaining to the unit goals. The rest describes recommended teaching strategies and lesson ideas to inspire you to create learning materials as you see fit for your students. Links to helpful online resources are included, but you will not find worksheets to run off on a photocopier here.

Classroom Environment

Develop an environment that encourages students to learn science by figuring it out as well as explain it. Most of the teacher presentations should be providing exciting phenomena to observe, question, and investigate. Ideas for this unit are included in the lesson ideas section.

Promote the acceptance of mistakes or wrong ideas as part of the learning process.

Maintain a science literature section with books and other printed reference materials.

Maintain a digital hub (such as a bitmoji science webpage) with links to online content related to the topic. Interactive pieces can be added using applications such as Padlet or Flipgrid.

Classroom Engagement:

Utilize a KWL strategy (What I Know, What I Want to Know, What I Learned) to get students to share and reflect on the topic. For example, a KWL chart can help determine student preconceptions and misconceptions and be revisited throughout the unit.

Begin the unit and most lessons with exciting phenomena to observe and figure out. I like to introduce an overarching phenomenon or case study to inspire the entire unit and have other phenomena as the basis for each lesson.

Present several opposing viewpoints or explanations and have students argue for which they feel is most reasonable. The *Uncovering Student Ideas* series by Page Keeley is an excellent model to follow.

"How can we test this idea?" and "Does this make sense?" should be frequent questions.

Engage students in citizen science. Utilize organizations that promote data gathering or community projects.

Encourage data representation in various forms, using tables, charts, graphs, or annotated drawings whenever possible.

Lesson Ideas

Lesson 1: Introduce the unit by showing news clips of the 2019 Guadalajara hailstorm. The website *Mystery Science* has an excellent introduction to this hailstorm in their 3rd grade Stormy Skies unit (www.mysteryscience.com/weather/weather-climate). First, begin a KWL chart: "What we know about the hailstorm," "What we need to know to figure why it happened," and "What we learned" are suggested headings. Next, introduce highlighted selections from the classroom library and the digital resources for the unit.

Lesson 2: The Sun. Complete a KWL about the Sun. Introduce the Sun through a book (*Sun! One in a Billion* by Stacy McAnulty is a good choice) and view the projected NASA Kids site about the Sun. You can also find video clips from available streaming sources. This is the time to present about star formation, our Sun's history and projected life span, as well as composition and emission of energy.

Present an argument to the class to discuss. For example, six friends were wondering why the sky is dark at night. Which friend do you think has the best reason for why the sky is dark at night?

Jason: "The clouds come in at night and cover the Sun."

Sarbani: "The Earth spins completely around once a day."

Zach: "The Sun moves around the Earth once a day."

Joe: "The Earth moves around the Sun once a day."

Tina: "The Sun moves underneath the Earth at night."

Demonstrate a light source shining on a globe or a spherical object. Explain that we know the Sun does not revolve around the Earth in 24 hours to make a day and night. Instead, the Earth is rotating, and we are so used to it that we do not feel it, but we can observe it.

Update the unit opening KWL about the Guadalajara hailstorm.

Lesson 3: The Earth's Atmosphere. Begin by showing students a deflated ball. Place it on a balance and record its mass. You could also weigh it on a scale. Tell students that you will pump the ball full of air but ask them first to predict if the inflated ball will have the same, more, or less mass (or weight if using a scale instead of a balance). Next, inflate the ball and discuss its mass or weight due to the added air.

Another demo: Use a small fan or hair dryer (no heat) to levitate several small, light objects such as ping pong balls. I drilled several holes in the bottom of a clear, plastic pitcher and placed it over a small fan. Observe as one ping-pong ball bounces around. Then add several more, one at a time, and try to count the number of times two or more balls collide. Lead students to understand that this is what happens to air molecules. More balls in the same place increase the density and adjusting the fan's speed increases the energy that moves them.

Introduce graphics or videos of the Earth's atmosphere.

Update the unit opening KWL about the Guadalajara hailstorm.

Lesson 4: What Causes Wind? Begin with a demonstration of two balloons, blown up to equal size. Place one balloon in a freezer, a closed cooler with ice, or dip it into a bucket of ice water for a few minutes. Set the other balloon aside at room temperature until ready to compare. Observe what happened to the cold balloon compared to the room temperature balloon. Another idea would be to replicate a "use a bottle to blow up a balloon" demonstration using a balloon-covered bottle and two water containers, one hot and one cold, to inflate and deflate the balloon.

Complete a KWL about wind.

A discussion prompt for this could be that Tina filled a balloon with air and tied it tight. Then, she put it in the freezer for 30 minutes. No air escaped the balloon, but it had shrunk. Tina wondered if the mass of the balloon (including the air inside it) had changed.

A) the mass of the warm balloon was less than the mass of the cold balloon.

B) The mass of the warm balloon is greater than the mass of the cold balloon.
C) The mass of the warm balloon is the same as the mass of the cold balloon.

Which choice do you agree with the most?

Demonstrate how a toaster (or other heat sources) can spin a pinwheel. Discuss what causes it to move.

Explain or present how air moves around the Earth due to uneven heating.

Update the unit opening KWL about the Guadalajara hailstorm.

Lesson 5: The Greenhouse Effect. Demonstrate the temperature difference between the outside air and the air inside a glass or plastic box that sits under a heat source. Why is the air warmer in the box? Compare this to how a blanket keeps us warm. It traps heat! Does air trap heat? Explain and present how the greenhouse effect works. There are great, kid-friendly video clips on the NASA Climate Kids website (www.climatekids.nasa.gov/greenhouse-effect/).

Students will use the class maker space or collected materials to design a small solar oven. The goal is to build an oven that will melt an ice cube faster than it melts outside the oven under the same sunlight. You will need to provide ice cubes that are the same size and small trays to contain them. A standard freezer tray ice cube takes about 5 minutes to melt under direct sunlight on a warm day. I recommend recording a time-lapse video of the ice melting to present to the class. Then, students will design and construct a prototype solar oven to see if they can get their ice cube to melt faster. I recommend small groups of 2 to 3 students. Students can try to create another one as optional homework.

Another investigation to conduct at the same time is one that compares the albedo of different colored surfaces. For example, use exact size cutouts of different colored paper (or another material) placed under the same heat source and compare temperatures after a few minutes. The same investigation concept also applies to comparing the heating and cooling of land to water.

Update the unit opening KWL about the Guadalajara hailstorm.

Lesson 6: Earth's Seasons. Begin with this discussion prompt: Six friends were talking about why it is warmer in the summer than the winter in Connecticut.

Martine: "It's because winter clouds block the Sun."

Taryn: "The Sun gives off more heat in the summer than the winter."

Elizabeth: "It's because Earth's tilt changes the angle of sunlight hitting Earth."

Alexandra: "It is because the Earth orbits closer to the Sun in the summer."

Taryn: "It is because one side of Earth faces the Sun, and one side faces away."

Joanna: "It is because the Northern Hemisphere is closer to the Sun in summer than in the winter."

Which friend do you agree most with?

Complete a KWL for why we have seasons.

Have students watch, read, or engage in online activities about why we have seasons.

Update the unit opening KWL about the Guadalajara hailstorm.

Lesson 7: Climate vs. Weather

Directly present the difference between climate and weather. Explain climate zones and how we categorize them. Students will need to learn about the main parts of the Koppen climate classification system. They are tropical, dry, temperate, continental, and polar. Individual or group research presentations about characteristics of each climate type would work well here.

Update the unit opening KWL about the Guadalajara hailstorm.

Lesson 8: Mapping Climate Zones. Provide students with climate data for five different worldwide locations, one from each climate zone. Students will graph the data and determine the climate classification where they believe it belongs.

Update the unit opening KWL about the Guadalajara hailstorm.

Lesson 9: How Landforms Affect Climate. Introduce a phenomenon that demonstrates how a landform can affect a region's climate. One example could be the differences in climate and vegetation on different sides of a mountain range.

Have students create topographical maps of the United States or any other region. Salt dough maps are easy and fun to make.

Update the unit opening KWL about the Guadalajara hailstorm. If students have not already done so, have them research and report back what causes hailstorms and other types of extreme weather. What happened in Guadalajara to produce that storm?

Lesson 10: Citizen Science. Research organizations are collecting data from citizen scientists. The website www.scistarter.org, www.CoCoRaHS.org, or the mPing app are a few suggested places to start looking.

Lesson 11: Flood Prevention. One factor of the ice and water accumulation in Guadalajara was flooding. I built a large class stream table out of a plastic sandbox and a water pump. You can make smaller ones out of foil pans, some sand, and a little bit of water raining down from a cup with a few small holes drilled into the bottom. Students will design and create a prototype of a structure that prevents a house from flooding. They will test it on the stream table and keep trying different ideas until they succeed.

Annotated Next Generation Science Standards:

The art of crafting this unit is finding a balance between the relevant scientific understanding we will be discussing in seminar sessions with what students are expected to learn at the third-grade level without going overboard with too much information too soon. While preparing to create this unit, I realized that there is a great deal of information to absorb, and I have used the NGSS framework to guide my decisions about what to include and what to leave out (for future learning).

In first grade, students study patterns and cycles in space systems. This content includes observing the Sun, Moon, and stars to describe predictable patterns. Examples of patterns include that the Sun and the Moon appear to rise in one part of the sky, move across the sky, and set, and stars other than our Sun are visible at night but not during the day.

In third grade (where this unit fits in), students study weather and climate. This content includes representing data such as average temperature, precipitation, and wind direction in tables or graphical displays. In addition, students obtain and combine information to describe climates in different regions of the world. Students also make a claim about the merit of a design solution that reduces the impacts of a weather-related hazard (which can include Sun exposure).

In fourth grade, students learn about energy resources. They are introduced to the carbon cycle as they begin to understand the role of carbon dioxide in the atmosphere. The Sun's role as a driving force for our global climate is at the core of the content studied in this kindergarten to the 4th-grade level band. This age range is where students begin to wonder about the Sun, the Moon, the planets in our solar system, and many other facets of our universe. They are also fascinated by extreme weather. Many of those topics are studied in future grades, but the standards that connect to this topic and this grade level are:

3-ESS2-1 Represent data to describe typical weather conditions expected during a particular season.

3-ESS2-2 Obtain and combine information to describe climates in different regions of the world.

3-ESS3-1 Make a claim about the merit of a design solution that reduces the impact of a weather-related hazard.

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