Common Student Ideas about the Sun's Effect on Climate

Common Student Idea(s)	Scientific Explanation
1. Earth gets heat directly from the Sun.	The Sun is actually too far from Earth to heat it directly. Instead, objects on Earth, including clouds, land, the ocean, and gases in the atmosphere, absorb and reflect sunlight. Absorbed sunlight usually increases the energy in an object, causing it to heat up.
2. Only shiny surfaces (like a mirror) can reflect light. *[Students may also believe that an object can't absorb and reflect light. It must do one or the other.]*	All objects absorb and reflect light in varying degrees. Our ability to see objects depends on how well they reflect light. Being able to see the color of an object is an indication that it has absorbed certain wavelengths of light and reflected the specific color we observe.
3. Snow, ice, and clouds covering the Sun make it cold.	The temperature on a given day depends on many different factors, including the time of year, location, elevation, and prevailing winds. The presence of snow, ice, and clouds is an outcome of cold temperatures rather than the cause.
4. Earth's daily spin (rotation) is the same as its yearly orbit (revolution) around the Sun. *[Some students confuse Earth's rotation with its revolution. For example, they may believe that the side of Earth not facing the Sun experiences winter rather than darkness.]*	Day and night are the products of Earth's daily spin (rotation). We experience daytime if we're on the side of Earth that is facing the Sun, and nighttime when we're on the side of Earth that isn't facing the Sun.
5. The distance of Earth from the Sun causes seasons. Earth moves closer to the Sun in the summer and farther away from the Sun in the winter. *[Researchers attribute this misconception to textbook representations of Earth in which an elongated elliptical orbit makes it appear as if the Sun is closer to Earth during certain times of the year.]*	Distance from the Sun isn't the cause of Earth's seasons. Earth is only slightly closer to the Sun during winter in the Northern Hemisphere and slightly farther away from the Sun during the summer. The actual cause of seasons are the tilt of Earth's axis and varying amounts of energy from the Sun (solar radiation) that regions north or south of the equator receive during the year. Earth's tilt (which oscillates a little) is currently about 23.5 degrees. During the summer months, the Northern Hemisphere is tilted toward the Sun and receives light at a more direct angle, which means the Sun's rays are more concentrated. During the winter months, the Northern Hemisphere is tilted away from the Sun and receives light at a less direct angle, which means the Sun's rays are spread out over a larger area.

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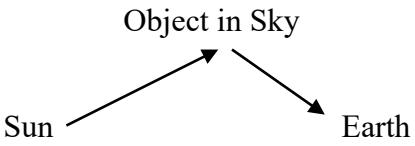
6. The temperature is warmer near the equator because it's closer to the Sun, and the poles are colder because they're farther away from the Sun.	Differences in the distance from the equator to the Sun or the poles to the Sun are too small and inconsequential to cause temperature variations at different latitudes. Rather, the cause of these variations is the angle at which sunlight hits Earth. At the equator, the angle is more direct (straight on), and light energy is more concentrated, while at the poles, sunlight hits Earth at a less direct angle, and the energy is more spread out (less concentrated). Because of Earth's tilt, the equator receives the most direct sunlight on the planet only twice a year, during the spring equinox (on March 20 or 21) and the autumn equinox (on September 22 or 23). The direct rays of the Sun travel north of the equator between the spring and autumn equinox (creating summer in the Northern Hemisphere and winter in the Southern Hemisphere) and south of the equator between the autumn and spring equinox (creating winter in the Northern Hemisphere and summer in the Southern Hemisphere).
7. The tilt of Earth on its axis causes seasons.	This is partly correct but demonstrates a shallow understanding of the reason some regions on Earth have seasons. The tilt of Earth on its axis leads to two factors that cause *differential* (uneven) heating of the two hemispheres at different times of the year (i.e., seasons). First, Earth's tilt causes more solar radiation to reach the hemisphere experiencing summer (the Sun's rays strike Earth at a more direct angle, resulting in more concentrated light energy), and less radiation reaches the hemisphere experiencing winter (the Sun's rays strike Earth at a less direct angle, spreading out the light energy). Second, Earth's tilt causes an increase in day length and, consequently, the amount of heating for the hemisphere experiencing summer.
8. When sunlight hits Earth at an angle, it means that it bounces off objects before it hits Earth. **Indirect Angle**  **Direct Angle**	When scientists talk about sunlight hitting Earth directly or indirectly, they more accurately mean that it hits Earth at different angles. Sunlight hits the equator directly at a 90° (perpendicular) angle only twice a year. North and south of the equator, sunlight hits Earth at increasingly less direct angles based on latitude. In the lessons on climate, the term *indirect angle* is avoided and references to *more direct* and *less direct* angles are used instead.

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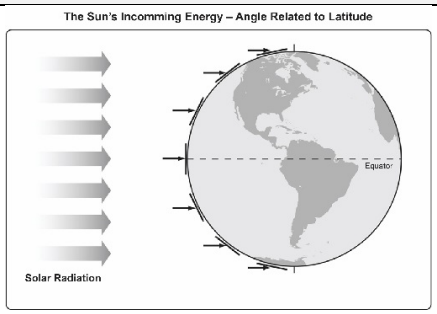
Sun ⟶ Earth	
9. Climate is simply long-term weather, so it can't really be predicted with accuracy.	Weather consists of the short-term (minutes to months) changes in atmospheric conditions. Most people think of weather in terms of temperature, humidity, precipitation, cloudiness, brightness, visibility, wind, and atmospheric pressure (as in high and low pressure). Climate, however, is an average of atmospheric weather conditions over longer time spans (seasons, years, and decades) and space (not a local city but broad geographic regions). An easy way to remember the difference is that climate is what you *expect* (like a very hot summer day) based on years of experience or data collection, and weather is what you *get* (like a hot day with pop-up thunderstorms).
10. Global warming, climate change, and the greenhouse effect are the same thing.	*Climate change* is a measure of differences in weather patterns across the world over long periods of time, ranging from decades to millions of years. Earth's climate has changed countless times throughout its 4.5-billion-year history, but these changes have often been very slow, with long periods of relative stability. Records indicate that Earth may have once, or even multiple times, been almost entirely covered in snow and ice. Some evidence also suggests that at other times in the past, Earth was exceptionally hot. Think of Earth's climate as a pendulum swinging back and forth from hot to cold roughly every 10,000 to 100,000 years. The *greenhouse effect* refers to the way gases in the atmosphere absorb light energy from the Sun and trap some of the heat energy (infrared light) that might otherwise be reflected or radiated from Earth back toward space. Without the greenhouse effect, Earth would be about 30 °C cooler, with wild temperature swings between day and night that would make the planet much less habitable for humans and other living organisms. *Global warming* refers to the impact of increasing greenhouse gases in the atmosphere (particularly increased levels of CO_2 from the burning of fossil fuels since the beginning of the Industrial Revolution) that trap more and more heat, causing a gradual rise in temperatures. The greenhouse effect (or the atmosphere's ability to absorb light

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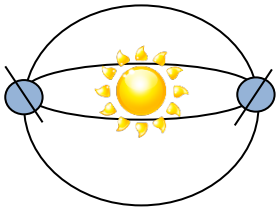
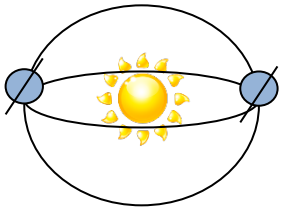
	and radiate heat) has been occurring as long as the planet has had an atmosphere, and long before humans contributed to it. But in recent decades, many scientists and citizens have become concerned about the impact of human activity on Earth's atmosphere, resulting in an increase in greenhouse gases and overall temperature and contributing to such global environmental effects as rising sea levels, shrinking habitats, and changes in ocean currents that influence climate and weather patterns.
11. Earth always tilts toward or away from the Sun or tilts back and forth once a year. 	Earth always tilts in the *same direction and angle* throughout its orbit around the Sun. We don't know for sure *why* Earth tilts, although the most common theory is that a tremendous impact from a Mars-sized object caused this to happen not long after the solar system formed. 
12. The temperature on a mountaintop is warmer than the temperature at sea level because mountains are closer to the Sun.	The distance between sea level and a mountain peak is insignificant compared to the distance between Earth and the Sun. Temperatures at higher elevations are actually much cooler because of lower air densities. As air rises into the atmosphere, it expands and cools, so higher elevations generally experience cooler temperatures than lower elevations.