Frozen Earth — The Cold's Far Reaching Influence

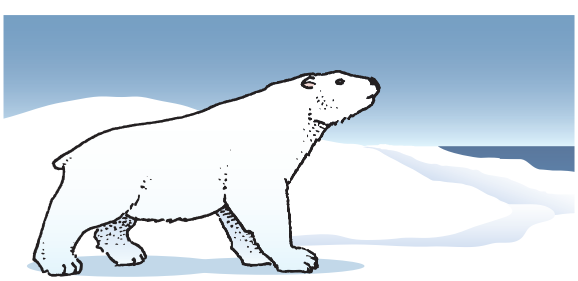
The surface of the Earth is subject to a wide range of temperatures, from the highs in the desert to the lows at the poles. The places where it is cold enough for water to remain frozen all year, year after year, are called the **cryosphere** and include the snow and ice in the North and South Poles, mountain glaciers, and areas of permafrost (frozen ground). The cryosphere is cold because it receives very little energy from the sun. The energy that does reach the poles or high mountains is reflected back to space by the white snow surface which makes these places even colder.

The **North and South Poles** are cold because sunlight falls at the poles at an extremely shallow angle and the tilt of the Earth results in long periods of perpetual night when temperatures rarely get above 0°F. At the North Pole is a sea surrounded by land. The most substantial ice sheet in the North Pole is Greenland which is covered in a layer of ice about one and a half miles thick in some places. Every winter a layer of sea ice forms over the Arctic Ocean. That ice persists through the year, reaching a maximum in March and a minimum in September. At the South Pole is land (Antarctica) surrounded by ocean making it quite different from the North Pole. It is covered in a thick ice sheet over two and half miles thick. Antarctica is also surrounded by sea ice every southern winter (when it's summer in the north).

Extremely high elevations are also cold enough to be part of the cryosphere. The air in the upper troposphere is much colder than the air at the surface where heat from the sun is absorbed. Glaciers are slowly moving bodies of ice and snow that form due to the accumulation and compaction of snow in high mountain areas and at the poles. The size of a glacier is the result of how much snow is added every winter and how much is melted every summer. Most glaciers around the world are shrinking – evidence that the climate is changing.

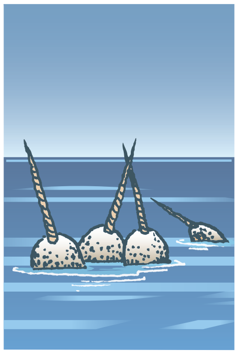
Although few people live in the cryosphere, we are all affected by it because it plays a critical role in regulating the climate of the entire Earth. Average temperatures on Earth are the result of a balance between energy coming from the sun (arriving at the surface as visible light), and energy leaving Earth to space (in the form of infrared light, invisible to the human eye). Throughout most of Earth's modern history the amount of energy coming in has been closely balanced by the amount leaving. But recently more energy comes in year after year than leaves, resulting in a warmer climate.

There are many factors that determine the rate of energy exchange between the Earth and space: clouds, the composition the atmosphere, and the color of the surface all have an impact. There are several gases in the atmosphere that change how well infrared light radiates to space, including water vapor, carbon dioxide, and methane, among others. When the levels of these gases increase in the atmosphere they trap more sunlight which leads to higher temperatures.



Dark surfaces absorb energy well, while light colors reflect it back to space. Water is the darkest, most absorbent surface on Earth when it is liquid, and the lightest, most reflective surface when it is frozen as snow and ice: 80% of the sunlight that strikes sea ice is reflected back into space, while 90% of sunlight that strikes the ocean surface is absorbed. The more sea ice that melts due to warm temperatures, the less reflective the surface becomes, as more of the dark ocean is exposed to the heat of the sun. This creates a positive feedback loop where warmer oceans lead to more melting of the sea ice and less sea ice leads to warmer oceans.

This project was funded through a Pennsylvania Department of Environmental Protection Environmental Education grant (EE#:16-186).



Sea ice isn't the only part of the cryosphere that is changing. After having remained frozen for thousands or millions of years, places on Earth with frozen soils, called permafrost, are thawing. Thawing permafrost does not change the color of the surface of the earth but it does release methane gas as it melts. Methane is a greenhouse gas and traps the heat that reaches the surface from the sun. So as permafrost melts, methane levels increase, resulting in warmer temperatures that melt more permafrost and release more gas – another positive feedback loop.

An important gas that affects how much heat stays in the atmosphere is CO_2 or carbon dioxide. It is released by the burning of fossil fuels, which heats and cools our buildings and fuels our cars. The more CO_2 added to the atmosphere, the more of the sun's energy gets trapped, resulting in higher temperatures that melt permafrost, snow and ice, and results in further warming as described in feedback loops.

If we continue to add CO_2 to the atmosphere at the rate we are today, the cryosphere will look very different in the near future and be substantially diminished in size. Many species will lose their habitat and may face extinction if they cannot adapt to the changing climate.

There are things we can do to reduce our contribution to climate change. We can reduce the amount of fossil fuels we use by driving less, using less electricity, and eating less meat, and we can switch to renewable energy sources that don't release CO_2 into the atmosphere, like solar or wind energy. We can also take actions to remove CO_2 from the atmosphere, such as planting trees which take up CO_2 during photosynthesis. But everyone needs to contribute, from individuals to cities and countries – we all play a significant part in affecting change.

Image courtesy of NOAA Environmental Visualization Laboratory

Frozen Earth — The Cold's Far Reaching Influence

Name:____

The cryosphere refers to the parts of the Earth that are cold enough to be below the freezing point of water for at least part of the year. This includes the North and South Poles, mountain glaciers, and areas of frozen soil (permafrost). The North and South Poles are cold because they receive little energy from the sun. High elevations are also cold because the thin air in the upper atmosphere is less able to retain heat than the dense air closer to the surface. Often you will find snow and ice in the cryosphere. White surfaces like snow and ice reflect what little energy the sun provides back into space making these places colder.

1. List the following locations from hottest to coldest based on their elevation and how far they are from the equator.

A low elevation near the South Pole ___________________________________

A low elevation near the equator ______________________________________

A high elevation near the North Pole __________________________________

The cryosphere helps control the climate, or average temperature, on Earth. The white surfaces at the poles reflect so much energy back into space that they help cool the entire planet. Dark surfaces like open ocean absorb energy. The composition of gases in our atmosphere also controls the climate. Some gases like CO_2 and methane trap heat from the sun in our atmosphere. The more of these gases in the atmosphere, the warmer the climate becomes. Water is especially important to our climate. Depending on its state as a liquid, solid, or gas it can be a reflector, absorber or trapper of energy from the sun.

2. Match the state of water to its effect on solar energy.

Liquid water	reflector
Ice	trapper
Water vapor	absorber

Glaciers are moving bodies of ice that are like rivers. If snow and ice accumulates on a slope, gravity pulls the snow and ice down to lower elevations. Some glaciers flow all the way to the ocean and some flow down to lower elevations. If snow and ice is added to the glacier as fast as it melts or loses icebergs into the ocean, then the glacier remains the same mass. Many glaciers on Earth are melting faster than new snow and ice are being added so they are shrinking.

3. Which of these glaciers would be shrinking, which would be growing, and which would be unchanged?

A glacier gains 20 feet of snow in a winter and melts 30 feet of snow in the summer________________

A glacier gains 10 feet of snow in a winter and melts 5 feet of snow in the summer ________________

A glacier gains 5 feet of snow in a winter and melts 5 feet of snow in the summer _________________

This project was funded through a Pennsylvania Department of Environmental Protection Environmental Education grant (EE#:16-186).

Permafrost is permanently frozen ground. In many parts of the cryosphere the top layers of soil may thaw out for a few weeks or months and refreeze for most of the year. This layer of soil that thaws is called the active layer. Deeper layers remain frozen all year, every year. These layers are inactive and may have remained continuously frozen for tens of thousands or even millions of years. When plants decay without oxygen they release methane gas, a greenhouse gas like CO_2. As the deep inactive permafrost layers thaw, methane gas is released.

4. Is the soil being described permafrost or not? If it is permafrost, is it active or inactive?

A deep layer of soil that is frozen year round. ____

A deep layer of soil that is never frozen.____

A surface layer of soil that is frozen for most of the year.______________________________

A surface layer of soil that is frozen only during the coldest three months of the year. _________

When **methane** is released into the atmosphere by the thawing of permafrost, temperatures increase, leading to more melting permafrost and more heating and so on. A change in the system like this that speeds up that change through cascading impacts is a positive feedback. Positive in this sense does not necessarily mean good, rather that the change is in the same direction. A change that slows further change is called a negative feedback. It works against the change that caused it. If we release CO_2 into the atmosphere, making areas like Alaska warmer and thawing the frozen soil, plants might grow better there and absorb some of that CO_2 – a negative feedback. Most climate change feedbacks we are aware of are positive feedbacks that lead to further heating.

5. Circle positive feedbacks and underline negative feedbacks.

A warming climate leads to melting sea ice and more heat absorbing open ocean.

A warming climate leads to melting permafrost and more methane in the atmosphere.

A warming climate leads to better growing conditions for plants which pull CO_2 from the atmosphere.

A warming climate leads to more heat absorbing water vapor in the atmosphere.