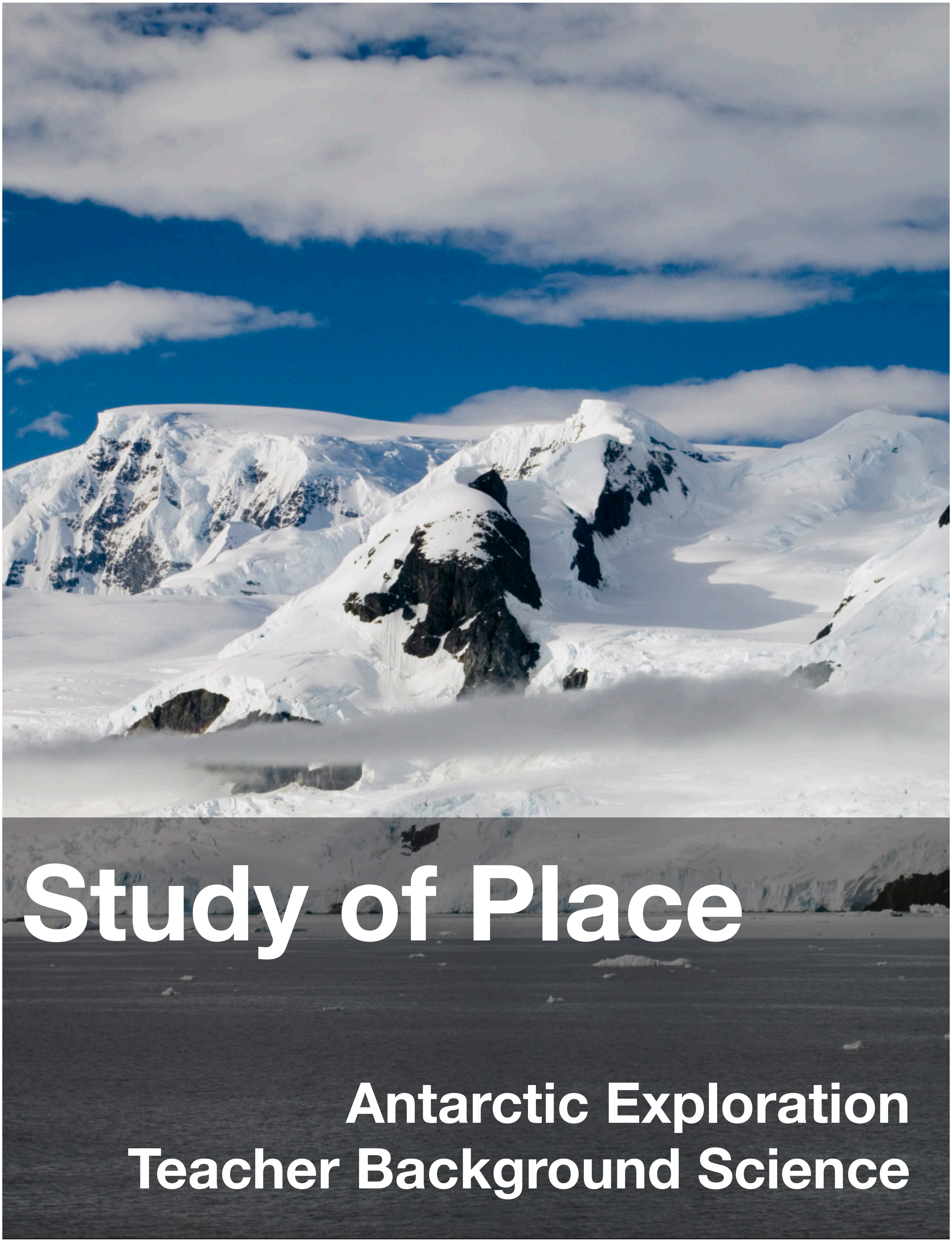

Study of Place

Antarctic Exploration
Teacher Background Science

Chapter 1

How Can We Explore Antarctica?

What the Teacher Might Want to Know

Historical context for module

Dr. Maurice Isserman has written an account especially for this curriculum called The Voyage of the Endurance. Alfred Lansing's book Endurance, Caroline Alexander's book The Endurance: Shackleton's Legendary Antarctic Expedition, or Frank Hurley's video South: Ernest Shackleton and the Endurance Expedition are other helpful and enjoyable resources.

About student understanding of spatial images

Students' familiarity with maps usually begins with symbols and names associated with the outline of a familiar physical space, e.g., a map of the classroom. Later, students work with maps of larger areas, learning that maps are created for different purposes and use different conventions according to those purposes. A political map, for example, will show lines that represent the boundaries of countries, while a topographical map will show contour lines to represent elevations.

Students have seen photographs in their social studies texts, but are not asked to compare them to other representations of the same location. By requiring these comparisons, we guide students toward understanding that different representations reveal different information. We also aim to introduce the idea of the complexity of the Earth system with this approach.

About satellite images

Many modern images of Earth are created from data collected by sensors carried aboard satellites. Some sensors can detect forms of light energy that are invisible to the human eye and to ordinary cameras. For example, certain electronic satellite sensors can measure and record the amount of infrared light being reflected or emitted by Earth at different wavelengths and bandwidths.

What kind of sensor a satellite carries depends on what kind of data it needs to collect. For example, weather satellites carry infrared sensors because clouds emit that infrared energy. Microwaves and radio waves can penetrate clouds, so microwave sensors and radar are used to monitor Earth at night or when the weather is bad. Each sensor is different, but they all have something in common: they can differentiate one type of surface from another (for example, clouds vs. ground) and represent the desired surface in an image. Whether recording visible light, infrared energy, microwaves, or radio waves, the sensor is mapping differences in reflectivity or emissivity between different types of Earth surfaces.

Radar: The term radar stands for radio detection and ranging. A radar system detects the position and movement of a remote object using radio waves reflected from its surface. The radar instrument beams radio waves to an object and measures the time it takes for them to return. Because Earth materials have different physical and chemical properties, some objects reflect and scatter radio waves more than others. The difference between the emitted signal and the return signal gives scientists information about the object being sensed. The information is converted to visible form and represented as an image on a screen. It can be used to create a map of an area.

Pixels Plus

Digital images are composed of rows and columns of picture elements called pixels. A pixel is the smallest component of a digital image. The amount of detail revealed in an image depends on the size of the area represented by each pixel. The ratio of pixel to area is called resolution.

When a pixel represents a large area (that is, when the resolution is low), variations in the data are averaged and contrasts recede or disappear. Colors are assigned to numerical values arbitrarily and are chosen for easy reading and emphasis. This convention is called false-color.

The term true-color means that the colors of objects in the image appear as they would if a person were looking at the object (e.g. - out the window of the spacecraft for Image 1.5).

Image 1.5
Spacecraft: Apollo 17
Sensor: camera using visible light
Image Date: December 7, 1972

Astronaut photograph AS17-148-22727 courtesy NASA Johnson Space Center Gateway to Astronaut Photography of Earth

Some images that students will see represent monthly averages of sea ice concentration data. Averaging takes care of the fact that in some years, no data were collected for some of the cells (pixels) on the grid. Averaging reduces the number of cells with no data and shows how sea ice typically fluctuates from month to month but not from year to year.

About the human eye as a sensor

The human eye is one example of a sensor. Light passes through the pupil, the lens, and the transparent jelly filling the cavity of the eye, until it falls on the retina. The retina is made up of millions of tiny sensory nerve endings that respond to a small band of wavelengths of the electromagnetic spectrum called “visible light.” Chemical changes in the retinal cells trigger nerve impulses that relay information about the intensity of light to the brain. Nerve cells in the brain then interpret the information and we “see” an image of the object.

About Topographic Maps

Middle school students may or may not have worked with topographic maps. In a topographic map, contour lines connect points of similar elevation. While the physical features exist, the lines do not. The closer the contour lines, the steeper the terrain.

What Is Microwave Radiation and How Does Earth Emit It?

E. Samuel Palmer Radio Astronomer Harvard-Smithsonian Center for Astrophysics

As Earth absorbs energy from the Sun, the surface of Earth heats up. If the average absorption increases (as by “greenhouse effect”), the average temperature of the planet will increase. If the average absorption decreases (as by increased snow or cloud cover reflecting more), the average temperature decreases.

The hotter a surface, the faster it radiates energy away. Thus, Earth, as it absorbs the Sun’s energy, continues to heat up until it is hot enough to radiate energy away to space at exactly the same rate it absorbs it from the Sun, on average. At all times the average surface temperature heads toward this equilibrium. Thus, at night, when there is no solar input, Earth’s temperature drops steadily until dawn. After sunrise, the temperature begins rising again due to solar heating and continues to rise until 3 or 4 in the afternoon. At this point, the surface reaches a high enough temperature to radiate energy out at just the rate its coming in from the Sun (whose input has been declining since noon).

The total rate of radiation from a square foot of Earth is about 22 watts, averaged over the whole planet and averaged over 24 hours. Microwaves make up only part of Earth’s thermal radiation. If “microwave” is taken to mean the whole microwave spectrum (from wavelengths of 1 mm to 1 meter) then the microwave portion of Earth’s natural radiation is about 1/100,000 of the total, or about 0.2 milliwatts for the square foot. (If “microwave” is taken to mean only the tiny slice of the spectrum at 2.45 GHz that is used by microwave ovens, then the output is minuscule, about a millionth of a millionth of a watt (1.4 x 10^-12 watt)! For this tiny slice of spectrum, the entire Earth radiates only about as much as just eight ovens.)

Like radio waves, microwaves penetrate clouds when they are radiated back into space and,though the amount of microwave radiation that Earth emits is quite small, certain satellite-mounted sensors can detect it from space. Images made from Earth’s microwave emissions are very useful to scientists because they can depict Earth conditions both at night and in bad weather. They are especially useful for Antarctica, which is under cloud cover much of the year.

Chapter 2

How Much Sea Ice?

What the Teacher Might Want to Know

About sea ice

Sea ice is formed when salt water freezes. Because the Antarctic region is so cold and the oceans so large and uninterrupted by land masses, sea ice forms and can spread out over an extremely large area. In fact, sea ice covers 3-4 million square kilometers at the end of the Antarctic summer, and 17-20 million square kilometers at the end of the Antarctic winter.

About Sea Ice and Climate Change

Sea ice responds to changes in the atmosphere and oceans; it varies from season to season and from year to year. Changes in sea ice may give us clues about changes in global climate. Because it is highly reflective and it provides insulation between the polar atmospheres and the southern oceans, sea ice is a key part of the climate machine. Scientists generally agree that changes in polar ice are at least partly the result of increased greenhouse gases. In Chapter 4 students will read an article about sea ice and global climate change.

About Sea Ice and Sea Levels

Sea ice is different from icebergs, land ice, ice shelves, and glaciers, all of which form from fresh water precipitated from the atmosphere. Land ice is formed from water that is evaporated from the ocean and snowed onto the land surface. When it is compressed under the weight of additional snow over a long period of time, it becomes glacial ice. Glacial ice forms the ice shelves that project from the continental coast over the ocean. Icebergs are pieces of glacial ice that have broken off into the sea.

When sea ice melts, sea level does not change. This is because sea ice forms from ocean water and floats on the ocean, where it displaces its own weight in water. Land ice and snow behave differently. When they melt, they add to the volume of the ocean and, in so doing, raise the sea level.

Try This: Fill a glass of water almost to the top. Add two or three ice cubes and, using a medicine dropper, add water until it reaches the brim of the glass. Observe the glass carefully as the ice melts. Does the volume change? Why or why not? Hint: evaporation does not occur quickly enough to be a factor in this experiment.
Because of hydrogen bonding between water molecules, the latent heats1 of fusion and of evaporation

PROPERTIES OF WATER

Water has most unusual thermal properties, in contrast to most other substances. When water is heated from 0°C (its melting point) to 4°C, it contracts and becomes more dense (most other substances expand and become less dense at this temperature range). And the converse is also true, of course. When water cools between 4 and 0†C, it expands.

Water expands as it freezes at 0†C, which means that ice is less dense than water. Here's why. As a liquid, water molecules bond to each other with hydrogen bonds, which are continually breaking and re-forming. The water molecules in ice bond to each other in a six-sided crystal structure, in which each molecule of water is connected to four others with hydrogen bonds. The crystal accommodates more empty space between the molecules than is accommodated in liquid water, so ice is less dense. Ice floats!

and the heat capacity of water are all unusually high. For these reasons, water serves both as a medium for transferring heat (e.g., ice for cooling and steam for heating) and as a temperature regulator (the water in lakes and oceans helps regulate the climate).

About Earth's Energy Budget

Whenever the Sun is below the horizon, such as at night and during the polar winter, that part of Earth gets no energy input from the Sun, yet energy continues to radiate from land, water, and the atmosphere. This net loss of energy causes temperatures to drop. When the Sun is above the horizon, that part of Earth again receives solar energy. The greater the Sun's angle, the more energy Earth absorbs per square meter of surface.

Seasons

The ecliptic describes the apparent path of the Sun across the sky; Earth's orbit around the Sun lies on an almost flat plane, called the plane of the ecliptic, or the ecliptic. If Earth's axis of rotation were perpendicular to this imaginary plane of the ecliptic, the Sun's position in the sky, seen from any point on Earth, would look exactly the same, day after day, year round. On the Equator, the Sun would always rise until it was overhead, then again descend to the horizon. At the poles, the Sun would always graze the horizon. Except at the poles, every point on Earth would be in shadow half the time, experiencing night, and in sunlight half the time, experiencing day.

However, the axis of rotation is tilted to an angle of about 23 degrees from the perpendicular to the ecliptic. Earth's constant tilt means that the North Pole is inclined toward the Sun at the summer solstice (around June 21), while the North Pole faces away from the Sun at the winter solstice (around December 21). Half way between the solstices, twice a year, Earth is neither tilted toward nor away from the Sun; at these times—the spring and fall equinox (around March 21 and September 23)—both hemispheres receive roughly equal amounts of sunlight.

The boundary between sunlight and shadow—between day and night—is always perpendicular to the ecliptic. However, because of the tilted axis, each point on Earth spends unequal lengths of time in daylight and in shadow. When it's summer in the Northern Hemisphere, day is longer than night north of the Equator, and close to the North Pole, there is no night at all because the Sun is always above the horizon.

At the same time south of the Equator, nights are longer than days. The further one gets from the Equator, the larger the imbalance—until one gets so close to the South Pole that the sun never rises. This is the famous antarctic night, with 24 hours of darkness each day. It is winter in the Southern Hemisphere.

As Earth continues to revolve around the Sun, the seasons change. Earth's axis has not moved, but Earth is at a different position in its orbit. Now the South Pole is bathed in constant sunshine and the North Pole is dark. Summer and winter have switched hemispheres.

Chapter 3

What Happens When Salt Freezes?

What the Teacher Might Want to Know

About the freezing and melting of fresh water and salt water

In the process of changing from a liquid to a solid, molecules of water form a matrix. Dissolved substances such as salt or food coloring are not incorporated into the molecular structure of ice and so are pushed aside (expelled) into tiny channels of salt water which drain into the ocean below.

The freezing point of salt water depends on its salinity. Seawater has roughly the same salinity around the world (35 parts per thousand) and freezes at just under -2 degrees C. The saltier the water, the lower the freezing point.

The temperature of an ice/water mixture remains constant until all the water has frozen or all the ice has melted.

Differences in ocean water density are one of the processes responsible for ocean circulation. Its temperature (thermo) and its salinity (haline) control the density of seawater. The circulation driven by density differences is called thermohaline circulation.

The temperature of ice is not constant; it rises and falls based on the temperature of the surrounding air or water, striving for equilibrium.

Thermohaline Circulation

Thermohaline circulation describes the global movement of currents that are created by differences in water temperature and salinity.

We can trace the path of thermohaline circulation beginning at high latitudes, where cold ocean water sinks because of its relatively high density. In the Northern Hemisphere, this sinking takes place in two locations: in the Labrador Sea and in the Norwegian-Greenland Sea. In the Southern Hemisphere, water from the Southern Ocean off the coast of Antarctica sinks to great depths because it is so cold.

Thus Earth's deep ocean basins are filled with waters from the northern North Atlantic and those that sink near Antarctica. This deep water cannot keep accumulating, and therefore, as new water moves in, the deep water is displaced and rises to the surface where it is warmed. Once at the surface, the waters flow back to the regions where sinking occurs, thus completing the cycle.

Sea Ice Formation

When sea water begins to freeze, very small millimeter-sized crystals, called frazil ice, begin to accumulate on or near the sea surface. As the water molecules form a crystal lattice, they exclude other molecules such as dissolved salts. These remain in the liquid water adjacent to forming ice crystals, increasing its salinity and thus lowering its freezing point. This saltier water is cold and dense. Because it is more dense, some sinks out of the ice as the ice forms, while some remains trapped between the crystals to form tiny brine channels (average diameter 100 micrometers).

As frazil ice accumulates it form slicks, which begins to give the sea surface a greasy appearance, giving rise to the name grease ice. As grease ice aggregates, it forms growing ice chunks. These eventually form circular floes of pancake ice, flotillas of flat ice floes with raised edges created by rubbing against each other in rough seas. As temperatures drop and the ice grows thicker, winds and currents force the pancakes over each other, which gives both ice surfaces a rough and rugged appearance.

The freezing temperature of sea water depends on how much salt it contains. Salinity is defined as the number of grams of salt per liter, expressed as parts per thousand. The ocean has a salinity of about 35 ‰. Ocean water freezes at about -1.91° C.

Freezing point of water at different salinities:

Salinity (%)	0	10	20	24.7	30	35
Freezing Temperature (degrees Celsius)	0	-0.5	-1.08	-1.33	-1.63	-1.91

About freezing salt water in a freezer

A container of water freezes from the outside in; this is because it loses heat to the colder air in the freezer, which surrounds the margins of the container. When the ice expels its salt, the salt moves toward the unfrozen center of the container. The unfrozen water thus becomes more salty, and the freezing point drops. If the freezer is not very cold, some of the salt water may not freeze at all.

As a container of salt water turns to ice, the ice takes up more volume and begins to push against the sides and bottom of the container as well as on the still watery salt solution at the center of the freezing core. The pressure forces the salty liquid center up. Thus, a salt water ice core may have a very slushy, salty center and top layer. The center and top zone may even remain liquid.

Why add food coloring?

Food coloring is used twice in this chapter. In one activity food coloring helps students distinguish between fresh water and salt water when they are both added to the same container. Red and yellow food coloring work well for this purpose.

As stated above, as salt water freezes, the molecular structure of the ice crystal forces salt out of the matrix. Something similar happens to molecules of food coloring. Hence, the distribution of color in an ice core suggests a similar distribution of salt: the more intense the color, the more concentrated the salt and vice versa. In the students' ice cores, the food coloring will show salinity in the expected pattern: higher at the center than on the sides, and higher near the top of the core.

States of Matter

Solids are made from arrays of molecules that are fixed in place, which is why solids have defined volume and shape. However, each molecule in a solid vibrates in place.

As heat energy is added to a solid, the molecules begin to vibrate more rapidly. Eventually the additional energy causes them to break out of their fixed positions, with the result that the solid becomes a liquid. Melting occurs at a temperature, the melting point,which is characteristic of each solid.

Although the molecules of a liquid can move throughout the liquid, intermolecular forces keep them from escaping altogether. This is why liquid have a defined volume but do not keep a defined shape. As heat energy is added to the liquid, it gives some molecules enough energy to break intermolecular forces and escape, or evaporate. Finally when molecules throughout the liquid become energetic enough to escape, they form bubbles of vapor which rise to the surface and escape.

The molecules of a gas are free to move anywhere, which means that the gas has neither a defined shape nor volume. It is free to expand to fill the container in which it is placed.

Density

Density is a measure of how much mass is contained in a unit of volume, expressed as grams per cubic centimeter or pounds per cubic foot. Put simply, if mass is a measure of how much stuff there is in an object, density is a measure of how tightly that stuff is packed together.

The density of a pure substance varies very little and can therefore be described as a characteristic property of the substance. However, most substances expand when heated, which means that they have lower densities at higher temperatures. Also, many substances (and gases in particular) can be compressed by increasing the pressure on them so that eventually they fit into a smaller volume. Because of these effects, scientists usually specify at which temperature and pressure they measure the density of a substance.

Water behaves differently. It expands as it cools below 3.98°C (which is the temperature at which it is most dense). As a result, its density decreases below this temperature. Density often is taken as an indication of how heavy a substance is. An anchor, which is very dense (lots of mass in a relatively small volume) sinks very quickly, while an inner tube (not much mass in a relatively large volume) floats and is very difficult to push underwater.

About hypothesizing and predicting

In Looking Closer students are asked to make a prediction. We do not ask students to hypothesize. Predicting and hypothesizing differ, although they go hand in hand. Wynne Harlen states, “The process of hypothesising is attempting to explain observations or relationships, in terms of an idea.” (Harlen, W. Teaching, Learning and Assessing Science 5-12, (c) 2000, p. 74-75.)

Here’s an example: Students on a field trip to a coastal tide pool notice that there appear to be two layers of water in the tide pool. They hypothesize that a heavy rain the night before has left a layer of fresh water on top of the ocean water. They predict that if they take water samples from the top and bottom of the tide pool, that the top will be fresh or only slightly salty and the bottom will be as salty as water from the ocean. They are now set to gather evidence to confirm their prediction and test their hypothesis. Note that neither hypothesizing nor predicting are guessing.

In this chapter, emphasis is placed on students making predictions, designing their own investigation, and holding up their predictions to the light of evidence they collect themselves. Asking them to articulate an hypothesis, and differentiating it from their prediction, would likely detract from the focus of exploration.

Chapter 4

How are Sea Ice and Climate Related?

What the Teacher Might Want to Know

About reflectivity

Reflectivity (technically called albedo) refers to the percentage of solar radiation reaching Earth's surface that is reflected back into space. Both the color and the texture of an Earth's surface affect reflectivity. For example, ice covered with fresh snow is as high as 90%. Sea ice varies with the condition of the ice, but on average, ranges from 60%–90%. The ocean, on the other hand, has a much lower reflectivity, from 1%–70% depending upon the angle of the sun and other factors such as waves, depth, and the incidence of plankton.

Scientists calculate the reflectivity of places all over Earth. These measurements have many uses, such as programming exposure settings for NASA satellite photography, tracking the movement of phytoplankton in the ocean, and monitoring erosion along riverbanks. Maps also provide a snapshot of a region's energy budget, showing how much of the incoming solar energy is being reflected and how much is being absorbed. A map of Antarctica in winter, for instance, will show that a great deal more solar energy is being reflected off of sea ice than is being absorbed by open water.

These maps can also help scientists track changes in Earth's surface over time. For instance, knowing that the leafy tops of trees are less reflective than the trunks of trees lying on their sides, scientists can use before-and-after images to trace the path of a tornado. Knowing that an uninterrupted expanse of sea ice has more reflectivity than sea ice that is patchy or slushy, scientists can use images to monitor the extent, concentration, and condition of sea ice at any given moment or over time.

The reflectivity of Earth's surfaces affects the local energy budget. In the Antarctic, sea ice reflects away much of the Sun's energy in winter, keeping the temperatures cold. In spring, when the sea ice begins to melt, the temperature begins to rise. This is because open water has a lower reflectivity. The more open water there is, the more solar energy is absorbed and transformed into heat that warms the ocean and atmosphere. Even skinny little passages of water between ice floes, called leads, can absorb solar energy that would otherwise be reflected by sea ice.

About the energy budget

The term energy budget refers to the balance between the solar energy that is absorbed by Earth's atmosphere, land, and water, and the heat energy that is continually lost in radiation from the Earth's surface and atmosphere into space. Temperatures on Earth depend on the energy budget. If more energy comes in than goes out, temperatures increase. Likewise, if Earth gives off more energy than it absorbs, temperatures fall. These temperature fluctuations occur daily, seasonally, and over long periods of time.

Whenever the Sun is below the horizon, as it is at night and during the polar winter, that part of Earth gets no energy input from the Sun, yet energy continues to radiate from land, water, and the atmosphere. This net loss of energy causes temperatures to drop. When the Sun rises above the horizon, that part of Earth again receives solar energy. The higher overhead the Sun gets, the more energy Earth absorbs per square meter of surface.

Earth's Energy Budget

Absorption and re-emission of radiation at the surface of Earth is one part of total heat transfer on Earth. Another important part takes place in the atmosphere, where molecules such as water and carbon dioxide selectively absorb and emit radiation. If Earth had no atmosphere, surface temperatures would be too low to sustain life. On the other hand, if too many gases were present in the atmosphere, absorbing and emitting infrared radiation, surface temperatures would be too high to sustain life.

The sun radiates energy in the visible band mostly, but also radiates energy in the shorter wavelength ultraviolet band. On average, 51% of the solar radiation striking Earth is absorbed, while the atmosphere absorbs 19%. The remaining 30% is reflected back into space. When averaged over a year, the incoming energy to the entire Earth-atmosphere system equals the amount leaving.

Reflection significantly affects the solar radiation that reaches the ground, since the Sun's rays can be reflected off air molecules, clouds or the ground itself. Light-colored or shiny objects reflect more radiation than dark objects.   Outgoing or reflected infrared radiation from Earth's surface is selectively absorbed by molecules such as carbon dioxide and other greenhouse gases. The radiation is emitted in all directions, including back to Earth's surface again. This re-emission to Earth's surface maintains a higher temperature than would be possible without the atmosphere. Condensed water also absorbs and emits infrared radiation efficiently; clouds act the same way greenhouse gases do.

The current atmosphere is warming Earth's surface, having a greenhouse effect. It acts as a greenhouse because of raised levels of gases that absorb and re-emit terrestrial radiation. These greenhouse gases include water vapor and carbon dioxide as we've already mentioned, and also ozone, oxygen, methane and nitrous oxide. Each absorbs specific wavelengths, for example, ozone absorbs ultraviolet radiation whereas water vapor absorbs infrared radiation more readily.

Heat Transfer and Thermal Equilibrium

According to The Benchmarks, middle school students have difficulty understanding heat transfer in terms of interactions, but rather think in terms of objects and functions (e.g., "metal is cold," or "metal holds heat."). Conduction and convection are typically understood either by attributing material properties to heat or by attributing heat-gathering properties to materials.

Moreover, students find the universal tendency toward temperature equalization mysterious. The distinction between heat and temperature is a new concept for most middle school students. Research has shown that major interventions are required before middle school students are able to differentiate heat from temperature. Therefore, we have chosen to not focus on this distinction.

About positive feedback

Students may not have heard of positive feedback. Positive feedback is a scientific term that refers to a process that reinforces itself. The more it happens, the more it makes it happen.

Here is an example of positive feedback that involves sea ice. When temperatures are low (-1.98° C or lower), sea ice forms, spreads, and thickens. Once the sea ice is in place, high reflectivity tends to keep temperature down. At the same time, sea ice acts as an insulator, inhibiting the transfer of heat from the warmer ocean to the colder air. This insulation property also preserves the cold. Once there is ice, positive feedback tends to keep things cold and preserve the sea ice.