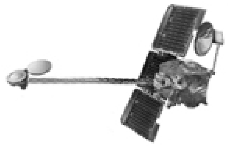


Remote Sensing Ices on Mars
Teacher Guide

GOAL

Students learn how scientists use remote sensing data to draw conclusions about the physical and chemical nature of planets.

OBJECTIVES

- Students compare maps of Mars showing different types of data (visible albedo, surface temperature, elemental composition) to characterize the types of ice at high latitudes on Mars during different seasons.
- In an extension activity, students can explore an online simulator to learn more about how gamma rays are produced at the surface of Mars and how these are used to determine the composition of the surface.

NATIONAL SCIENCE EDUCATION STANDARDS

9 - 12	Science as Inquiry	Abilities necessary to do scientific inquiry	Use technology and mathematics to improve investigations and communications.
9 - 12	Science as Inquiry	Understandings about scientific inquiry	Scientists rely on technology to enhance the gathering and manipulation of data. New techniques and tools provide new evidence to guide inquiry and new methods to gather data, thereby contributing to the advance of science.
9 - 12	Physical Science	Structure and properties of matter	Solids, liquids and gases differ in the distances and angles between molecules or atoms and therefore the energy that binds them together. In solids the structure is nearly rigid; in liquids molecules or atoms move around each other but do not move apart; and in gases molecules or atoms move almost independently of each other and are mostly far apart.
9 - 12	Physical Science	Interaction of energy and matter	Each kind of atom or molecule can gain or lose energy only in particular discrete amounts and thus can absorb and emit light only at wavelengths corresponding to these amounts. These wavelengths can be used to identify the substance.
9 - 12	Earth and Space Science	Geochemical cycles	The earth is a system containing essentially a fixed amount of each stable chemical atom or element. Each element can exist in several different chemical reservoirs. Each element on earth moves among reservoirs in the solid earth, oceans, atmosphere, and organisms as part of geochemical cycles.
9 - 12	Science and Technology	Understandings about science and technology	Science often advances with the introduction of new technologies. New technologies often extend the current levels of scientific understanding and introduce new areas of research.
9 - 12	History and Nature of Science	Nature of scientific knowledge	Because all scientific ideas depend on experimental and observational confirmation, all scientific knowledge is, in principle, subject to change as new evidence becomes available. In areas where data or understanding are incomplete, new data may well

			lead to changes in current ideas or resolve current conflicts.

TIME FRAME

- 2 class periods (100 minutes)

MATERIALS

- Copies of Student Guide (1 per student)
- Computer with projector, or overhead with photocopied transparency

Optional:

- 1 clear pitcher with liquid water and water ice
- 1 Thermometer

BACKGROUND

NASA has been collecting and using remote sensing data from satellite missions around Earth and other planets for years to help us understand planetary features and processes. Remote sensing involves using various energies of light to gather information about an object without direct contact. The more types of remote sensing data that can be obtained, the more we can learn about the surfaces of planets.

This lesson allows students to explore the high latitude regions of Mars using data from three different portions of the electromagnetic spectrum: visible, infrared, and gamma ray energies. Using visible data, students can recognize that the distribution of ice at the Martian poles changes with season, but they will not have enough information from this alone to be able to determine the composition of the ice. Using surface temperature based on infrared data, students will use the concept of frost point temperature to infer that the summertime permanent ice cap at the North Pole is made of water ice and that this cap is covered during the wintertime by a larger cap made of carbon dioxide ice. Finally, using gamma ray data, students will determine that significant amounts of water ice lay buried below the Martian surface poleward of about 60° latitude. In the lesson assessment, students are asked to interpret similar data from the region around South Pole that is presented textually.

A fundamental issue both for understanding the climate history of Mars and for understanding the possible existence of life on the planet is to characterize the distribution of water in any of its phases on the planet. This activity focuses attention on how we know what we know about the distribution of water ice and carbon dioxide ice at the Martian poles and high latitudes. Students will hopefully gain the sense that we can piece together and interpret multiple layers of remote sensing data to gain a better understanding of planetary surfaces and processes.

<u>Visible Observations</u>

Originally, scientists had to resort to observations of Mars from Earth-based telescopes. Although many surface features could be seen, it was difficult to determine with certainty the composition or nature of many of these features. Since the 1970’s, scientists have been able to use visual photographs and other remote sensing data taken from Martian orbit to better understand these physical features of the planet. As technology improved, so has the quality of these images. We are able to use images taken from Mars orbit to classify surface features we see by comparing them to similar structures on Earth. Many of these surface features have characteristics that suggest the prior existence of liquid water on Mars. For example, we see channel networks that appear to have been carved by moving water and certain areas that may have formed as parts of lakes or oceans. For more information on identifying these features that may have been formed by liquid water, see the "Mars Image Analysis Activity" developed by the Mars Student Imaging Program (http://msip.asu.edu/curriculum.html).

While evidence exists at the surface of Mars for past liquid water, the current atmospheric conditions are too cold and dry and the atmospheric pressure is too low to support liquid water. The atmosphere is too cold and dry and atmospheric pressure is too low. However, there is evidence for both water ice and carbon dioxide ice under current conditions. At visible wavelengths, a primary characteristic of several ices is albedo, or how bright or reflective the material is. Many ices often appear brighter and whiter than darker soils, dust, and rocky materials. Students should be able to easily identify the white color of polar ice caps in the visible images. However, albedo or brightness alone does not provide enough information to determine the composition of the ice. Students should not be able to determine the composition of these ices at this point in the lesson.

Infrared Imaging

Another means to gather information about Mars involves infrared light. Infrared light can be used to determine the surface temperature of the planet. Scientists can use these temperatures to infer the composition of surface ices. The Thermal Emission Spectrometer (TES) aboard the Mars Global Surveyor spacecraft has been used to collect infrared data from the planet. This instrument has measured surface temperatures at the Martian poles presented in this lesson.

The surface temperatures presented in this lesson are provided as both grayscale and false color maps. As with most remote sensing data, the shades of gray and colors on these maps are not "real," but are rather graphical means of representing the temperature data. During the activity, you should remind students that the scale bar provided with each map indicates the surface temperature range that each shade of gray or color represents.

Given the current atmospheric pressure and humidity on Mars, liquid water is not stable at the surface for extended periods of time. Liquid water at the surface will very quickly either evaporate into the atmosphere or freeze into solid ice. Even though liquid water freezes at ~0^{o}C on Mars, the current conditions on the planet allow solid water ice and water vapor to be in equilibrium at a much colder temperature -75^{o}C, the frost point. The frost point is the temperature at which a chemical changes from a solid to a gas if there is enough energy present. At and above this temperature, ice sublimates away to vapor because the humidity is too low. Similarly, the frost point of carbon dioxide on Mars is -123^{o}C.

Infrared data provide enough information to infer the composition of the ice caps during summer and winter months. Students should see that the polar ice cap during the winter is around –120^{o}C (dark gray or blue) while the polar ice cap during the summer is around –75^{o}C (medium gray or green). Using the carbon dioxide and water comparisons in the table provided below and in the background reading section of the lesson, they should be able to determine that there appears to be water ice on the North Pole during the summer that gets covered by carbon dioxide ice during the winter.

Substance	Chemical Formula	Visible Brightness	Martian Frost Point Temperature
Water	H_2O	Bright	-75°C
Carbon Dioxide	CO_2	Bright	-123°C
Ammonia	NH_3	Bright	Around –200°C
Methane	CH_4	Bright	Around –220°C

Gamma Ray Spectroscopy

The Mars Gamma Ray Spectrometer (GRS) aboard the 2001 Mars Odyssey spacecraft is able to detect elemental composition at or near the surface of Mars. Gamma rays emitted from the surface of Mars are collected and used to identify different chemical elements found on Mars. So far, GRS has been able to map the concentration of hydrogen, potassium, thorium, iron, silicon, and chlorine on the surface of the planet.

It is important to emphasize to students that GRS collects gamma rays from the upper few tens of centimeters of the surface of Mars because gamma rays are very penetrating. This is much deeper than techniques involving infrared and visible light. Infrared techniques can detect infrared light from less than a millimeter into the surface, and visible techniques involve light reflected off the very top of the surface. As a result, GRS can detect substances that other techniques cannot because the elements are covered by other materials like dust, soil, or carbon dioxide. For more information on GRS, see the activity titled "Remote Sensing with Gamma Rays."

One of the elements that GRS can detect is hydrogen. On Mars, hydrogen can be found in solid form as either water ice or hydrated minerals (such as clays). In high latitude regions, GRS detects very large amounts of hydrogen. Indeed, concentrations of hydrogen are larger than can be accounted for by hydration, and scientists are therefore fairly certain that water ice is required to explain the hydrogen signal found there. Using the maps provided in the activity, students should see large amounts of hydrogen at the north pole of Mars during the summer. In addition, the region of high hydrogen signal seems to cover a much larger area than the permanent polar ice cap shown in the summer visible image and surface temperature map. This indicates that there is water ice buried beneath the surface of Mars at these high latitude regions. The reason that this water ice is not detected during the winter is that carbon dioxide covers the water and this interferes with the collection of hydrogen gamma rays.

The South Pole

Once students have been led through this activity and have a basic understanding of the seasonal distribution of ices around the North Pole, students complete an assessment activity regarding the South Pole. Students are asked to interpret visible, infrared, and gamma ray information from the South Pole during winter and summer.

There is a key difference between the permanent ice caps at the two poles. Due to the orbit of Mars, winter months are longer and colder at the South Pole than at the North Pole. While carbon dioxide sublimates away during northern summer to expose a permanent water ice cap, there is a permanent carbon dioxide ice cap throughout the year at the South Pole. Water ice appears to be buried in the high latitude regions of the southern hemisphere and is probably also found below the permanent carbon dioxide cap at the South Pole.

TEACHER PREPARATION

- Make enough copies of the Student Guide for each student to have a copy.
- Make enough copies of the Ice on the South Pole assessment for each student to have a copy.
- Have a computer with projector ready for the preconception survey, or make an overhead of the preconception survey slide.
- Optional: Prepare a cup with ice cubes and a thermometer for a demonstration at the beginning of the activity.

SUGGESTED TEACHER PROCEDURES

1) To start the activity, talk with students about the three common states of matter: solid, liquid, and gas. Ask students what we call water in these three states: water ice, liquid water, and water vapor, respectively. Show students a clear pitcher full of ice water (liquid water with water ice). Discuss with students the fact that the ice will eventually melt as energy from the room is transferred into the pitcher and heats the ice. Have students predict the temperature of the ice water. Place a thermometer in the cup and ask a student to measure the temperature. The measured value should be close to 0°C. Record this temperature and have students predict the temperature the pitcher will be in five minutes.
2) Explain that today the class will be doing an activity about different types of ice found on the planet Mars using three different forms of remote sensing data from Mars to characterize the composition of ices found near the Martian poles. Using visible light, infrared light, and gamma rays collected by spacecraft orbiting Mars, students will be able to determine the types of ices found at the surface of the planet and buried beneath the surface.
3) Pass out photocopies of the Background Reading. Read or have the students read the information out loud. (Note that you may be able to save time in class by assigning the Background Reading as homework prior to the class.) Stop reading after finishing the section titled “Ice Properties.”
4) After reading the section titled “Ice Properties,” return to the pitcher of ice water. Have a student measure the temperature of the ice water. It should be noted that the temperature is roughly the same as before, around 0°C. Ask students to come up with reasons why the temperature has not changed even though the ice is clearly melting. If they do not come to it on their own, guide them to the idea that the temperature will not change until all of the ice has melted. When chemicals change from one phase to another, the temperature remains constant until all of the substance has changed (in this case until all the ice has melted). If you have already discussed molecular structure and would like to discuss the melting temperature in more depth, you can discuss the fact that energy is needed to break the bonds between the molecules in the ice and after all of the ice has melted, no more energy is needed to break the bonds and the temperature will rise to room temperature once again. In the case of solid water ice melting to liquid water on Earth, the melting/freezing temperature is 0°C. In the case of solid water ice melting into liquid water on Mars, the melting/freezing

temperature is also around 0°C. In the case of solid water sublimating directly to water vapor on Mars, the frost point temperature is -75°C. This will help them understand that if we detect a surface temperature on a region of Mars that corresponds with the frost point temperature of a particular substance, then this may indicate the presence of that particular substance.

5) Continue reading the Background Reading aloud. Have students complete the Reading Questions. Again, you can assign this as homework if you have limited class time. Discuss the reading questions with the class.
6) Explain to the students that they will be using data from all three remote sensing techniques. The data in the activity was collected from Polar Regions in the Northern Hemisphere during the winter and summer. With the help of these maps and some guiding questions, students should work in pairs to determine the compositional structure of the ices around the North Pole of Mars during winter and summer.
7) Divide students into pairs, answer any questions, and have students complete the activity.
8) Discuss the answers to the questions to check for understanding. In addition, ask follow-up questions, including the following:
9) Based on the information provided in this activity, how deep does the carbon dioxide ice have to be in the winter? How do you know? *(At least several tens of centimeters, because that is how deep the GRS can detect.)*
10) Once the discussion has been completed and you are confident that your students understand how to correctly interpret the data for the North Pole, inform them that they will next do a similar exercise for the South Pole. Students will use visible brightness, surface temperature, and the hydrogen gamma ray signal to characterize the type of ice at the South Pole during different winter and summer. The South Pole activity is intentionally less guided than the North Pole activity. You can use the South Pole activity as an assessment of how well students have learned to interpret the datasets provided. It is also interesting to note that while both the North Pole and South Pole are covered by carbon dioxide ice during the winter, the permanent summer ice caps present at the poles are made of different ices. The North Pole summer cap is made of H_2O, while the South Pole summer cap has CO_2 at the surface. Finally, significant amounts of water ice are buried beneath both poles, as evidenced by the high hydrogen signal strength detected using gamma rays. Much of this ice is buried beneath a few centimeters of dryer soil.

ASSESSMENTS

- Review answers to student packet
- Use class discussion to assess student understanding
- Review answers to South Pole assessment activity

EXTENSIONS

- To get a better idea about how the ice composition changes on Mars, have students do the extension activity about Martian seasons provided.
- Have students develop a hypothesis about what is happening to the carbon dioxide after it sublimates during the summer at each of the poles.

REMOTE SENSING ICES ON MARS
Student Guide

Background Reading

Life as we know it requires water. A key NASA science goal is to study past and current water on Mars. Liquid water is unstable under current Mars conditions. This is because temperatures are too cold and the air pressure is too low. However, solid water, known as water ice, and other types of ice can be stable. Studying these ices helps us understand what Mars is like today and may have been like in the past.

Ice Properties

In this activity, we will look at the types of ice found at high latitudes on Mars. We will also study how the ice caps on Mars change during different seasons. We will consider four different substances that could form ice: water, carbon dioxide, ammonia, and methane. The table below lists properties for each of these if they were solid ices near the surface of Mars.

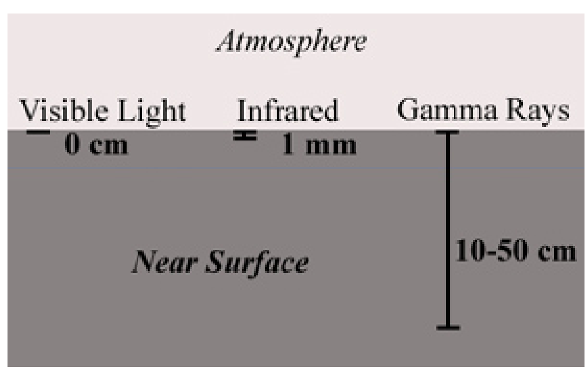
Substance	Chemical Formula	Visible Brightness	Martian Frost Point Temperature
Water	H_2O	Bright	-75°C
Carbon Dioxide	CO_2	Bright	-123°C
Ammonia	NH_3	Bright	Around –200°C
Methane	CH_4	Bright	Around –220°C

The table above gives the name and chemical formula of each type of ice. Notice that each ice would appear bright at the surface of Mars. However, each has a different frost point temperature. The frost point temperature is the temperature that the substance changes from solid to gas. This temperature is related to the energy needed to break chemical bonds and the amount of gas in the atmosphere. We will be able to tell the difference between water ice and other ices by its surface temperature.

Types of Data

The information in this activity was collected by spacecraft orbiting Mars. We will look at Mars using three different energies of light – visible light, infrared light, and gamma rays. Visible photographs will help us locate ice caps on Mars. At visible wavelengths, all of the ices listed in the table appear brighter than Martian rocks and soils. Next, we will use infrared light to figure out the surface temperature of an ice cap during different seasons. Because different ices have different frost point temperatures, the surface temperature of an ice cap tells us of what it is made. Finally, we will use gamma rays to figure out where hydrogen is present. This will help us find buried ice near the surface of Mars.

It is important to realize that we can see deeper into the Martian surface with different energies of light. Look at the figure below. Visible light reflects from the very top of the surface. Infrared light comes from within the top millimeter. However, gamma rays come from beneath the surface as far down as a few tens of centimeters. Gamma rays allow us to detect ice buried below the surface of Mars.



REMOTE SENSING ICES ON MARS
Reading Questions

1) What is another name for solid water? Why is solid water more likely to be found on the surface of Mars than liquid water?

   Another name for solid water is "water ice." Solid water ice is more likely to be found on the Martian surface because liquid water is unstable under current Martian conditions. Temperatures are too cold and the air pressure is too low on the planet for liquid water to be stable.

2) Can you tell the difference between various types of ice based upon visual appearance alone? Why or why not?

   You cannot tell the difference between different types of ices based only on their visual appearance alone because they all appear bright relative to the background of Mars.

3) What is the frost point temperature? How can we use the frost point temperature to figure out what an ice cap is made of?

   The frost point temperature is the temperature at which a chemical changes from solid to gas. Because different ices have different frost point temperatures, we can use the surface temperature of an ice cap to figure out what it is made of.

4) What are the three energies of light discussed in the reading? Which of these can measure the deepest into the surface of Mars and how deep can it measure?

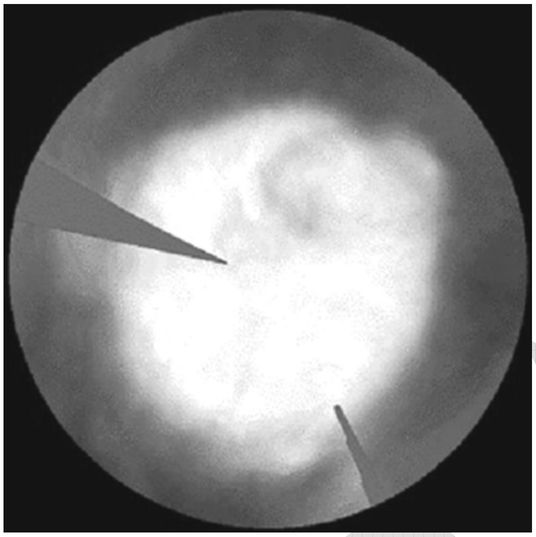
   The three energies of light discussed in the reading are visible light, infrared light, and gamma rays. Gamma rays can measure the deepest, down tens of centimeters.

REMOTE SENSING ICES ON MARS
North Pole Analysis

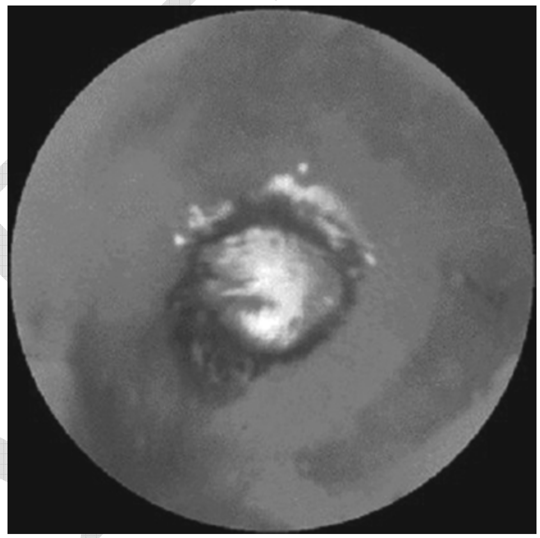
Part 1: Visible Data

The maps below show the visible surface of the North Pole of Mars (down to 45°N) during winter and summer. Each map is a mosaic of visible images taken with the Hubble Space Telescope (HST). The two dark pie-piece wedges in the winter map represent missing data where HST was not able to collect images to include in the mosaic.

North Pole Winter – HST Visible Mosaic



North Pole Summer – HST Visible Mosaic



1) Draw a circle around the location of the polar ice cap during each of the seasons above. How can you tell the difference between polar ice and surrounding rock and soil?

   Polar ice is brighter than surrounding rock

2) Is the ice cap larger during the winter or during the summer? Give a possible explanation for this observation.

   The ice cap is larger during the winter because it is colder during the winter and more ice can freeze onto the surface.

3) Can you determine whether the winter and summer ice caps are made of carbon dioxide ice, methane ice, ammonia ice, or water ice <u>based only upon the visual images</u> above? Justify your answer.

   No, you cannot tell based only upon the visual images because all of the ices listed would appear bright. All you can tell is where the ice is located at the surface, not what it is made of.

4) Do you agree or disagree with either or both of the students below? Explain your reasoning.

Student 1: I think the ice caps are made of water ice. There is more water ice in the winter when it is colder and less in the summer, just like on Earth.

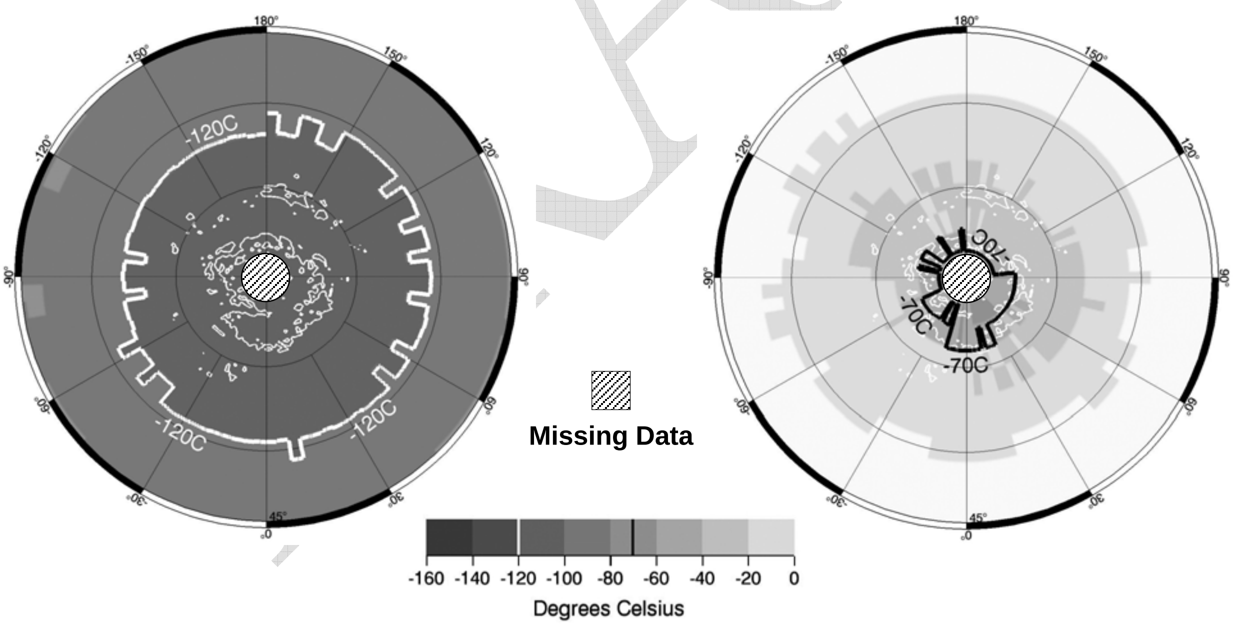
Student 2: I don't think we can figure out what kind of ice the caps are made of because other ices, like carbon dioxide and methane, are also bright just like water ice.

Students 1 is correct in noting that the ice cap shrinks during the summer months when temperatures are likely to be warmer, but there is not enough information in the visible images alone to determine what the ice is made of. Student 2 is correct in pointing out that all the ices in the background reading appear bright compared to surrounding rocks and soils and there is not enough information to determine the composition of the winter or summer ice cap.

Part 2: Infrared Surface Temperature Data

The maps below show the surface temperature of the North Pole of Mars (down to 45°N) during winter and summer. This information is based upon infrared light collected by the Thermal Emission Spectrometer (TES) orbiting aboard the Mars Global Surveyor spacecraft. Notice that the scale bar shows the surface temperatures that each shade of gray represents. Contour lines are drawn at temperatures of -120°C (white) and -70°C (black). Note also that TES did not collect data from the dashed regions on each map. The permanent ice cap you noticed in the <u>summer</u> visible image before has been outlined in white on both maps.

North Pole Winter – TES Surface Temperature   North Pole Summer – TES Surface Temperature



5) Do "darker" shades of gray represent warmer or colder surface temperatures? Explain why it makes sense that the winter temperature map is darker than the summer temperature map.

Darker shades of gray represent colder surface temperatures. It makes sense that the winter map is darker than the summer map because surface temperatures are colder during the winter and darker shades of gray represent colder temperatures.

6) What is the surface temperature of the ice cap during the winter?

Around -120°C

During the summer?

Around -70°C

7) Based upon the background reading on frost point temperature, what is the most likely chemical formula of the ice found at the surface of the ice cap during the winter? Explain your reasoning.

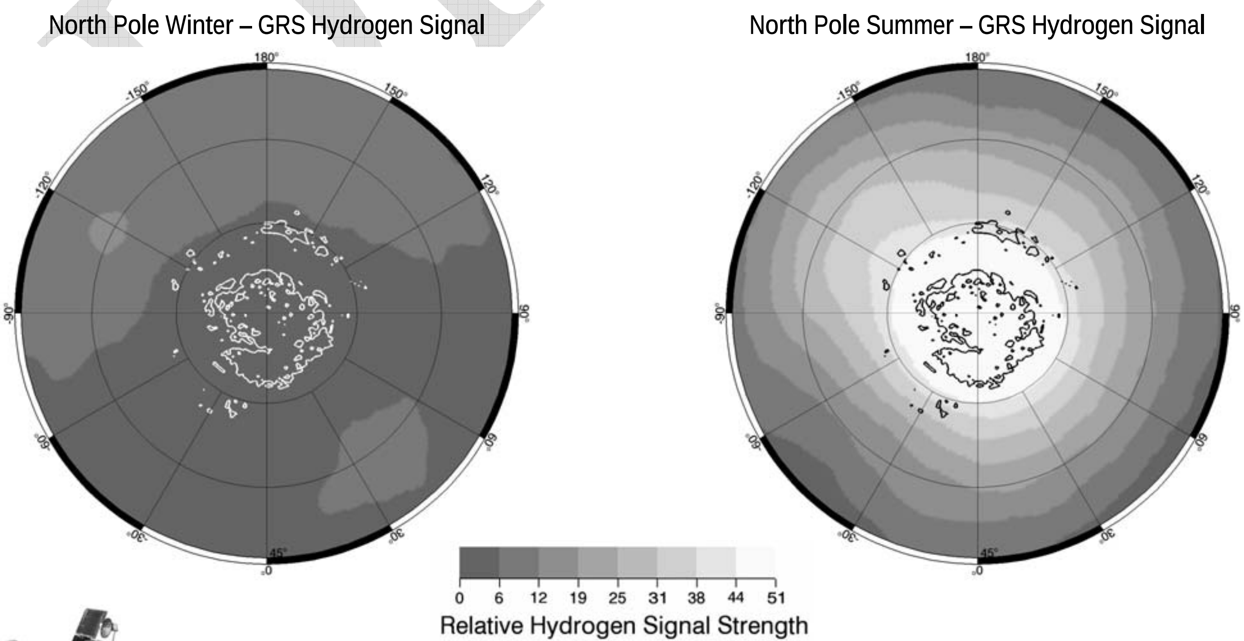
The winter ice cap appears to be made of CO_2 ice because its surface temperature matches the frost point of carbon dioxide which is -123°C. Water ice at the surface would be warmer and ammonia or methane ice would be much colder.

During the summer? Explain your reasoning.

The summer ice cap appears to be made of H_2O because its surface temperature matches the frost point of water ice which is -75°C. This surface temperature is too warm for the other possible ices to be stable.

Part 3: Gamma Ray Data

The maps below show the hydrogen signal strength at the North Pole of Mars (down to 45°N) during winter and summer. This information is based upon gamma rays collected by the Gamma Ray Spectrometer (GRS) orbiting aboard the 2001 Mars Odyssey spacecraft. The permanent ice cap you noticed in the summer visible image before has been outlined on both maps.



8) Is the hydrogen signal strong or weak during the winter? Why does this make sense given the chemical formula of the ice found at the surface during the winter (see Question 7)?

The hydrogen signal is weak during the winter. In Question 7, we determined that the ice cap during the winter is composed of carbon dioxide (CO_2) which does not contain any hydrogen. Because we can measure down several tens of centimeters with gamma rays, the carbon dioxide ice must be thicker than several tens of centimeters in order to block the hydrogen signal below.

Is the hydrogen signal stronger or weaker during the summer? Why does this make sense given the chemical formula of the ice found at the surface during the summer (see Question 7)?

The hydrogen signal is stronger during the summer. The ice cap during the summer is composed of water ice (H_2O) which contains lots of hydrogen. It therefore makes sense that the hydrogen signal is stronger during the summer after the winter CO_2 cap has sublimated away.

9) On the summer map, notice that we detect hydrogen even from regions surrounding the permanent ice cap (outlined in black). Give a possible explanation for why the surrounding region with darker rocks and soil at the surface (see Question 1) could still give a strong gamma ray signal from hydrogen. Keep in mind the different depths that visible light and gamma rays measure.

The surrounding region could still give a strong gamma ray signal for hydrogen if there is water ice buried a few centimeters below the darker rocks and soil. We could still detect this hydrogen using gamma rays even though it would not appear in the visible data (which only sees the top layer of the surface) or infrared data (which only detects a few centimeters into the surface).

Another explanation students might provide is that there could be hydrogen found in the rocks and soils as either hydrated minerals or as water ice mixed in with these darker materials. We have not provided enough information in the lesson to discount either of these possibilities. In actuality, the hydrogen signal is too strong to be explained by hydrated minerals alone. A more detailed analysis also indicates that the gamma ray data is most consistent with a dry layer of soil or dust covering a more water ice rich layer.

10) Do you agree or disagree with either or both of the students below? Explain your reasoning.

Student 1: I think that the water signal goes away in the winter because the water ice melts and evaporates into the atmosphere.

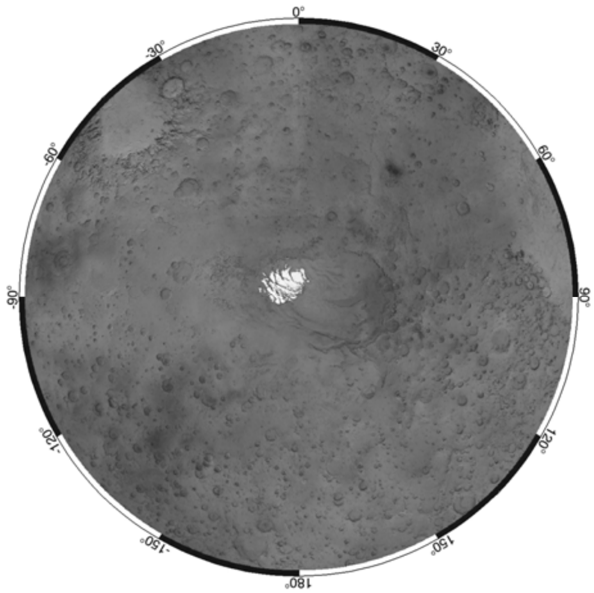
Student 2: That doesn't make any sense because it's colder in the winter. I think that both the water ice in the summer cap and the water ice buried below the surrounding rock and soil get covered up during the winter by a thick layer of carbon dioxide, which doesn't have any hydrogen in it.

Student 2 is correct; it is too cold in the winter time for water ice to melt. A more likely explanation for the data is that carbon dioxide condenses out of the atmosphere, covers both the permanent water ice cap at the pole and the buried water ice in the surrounding high latitude regions, and decreases the hydrogen signal.

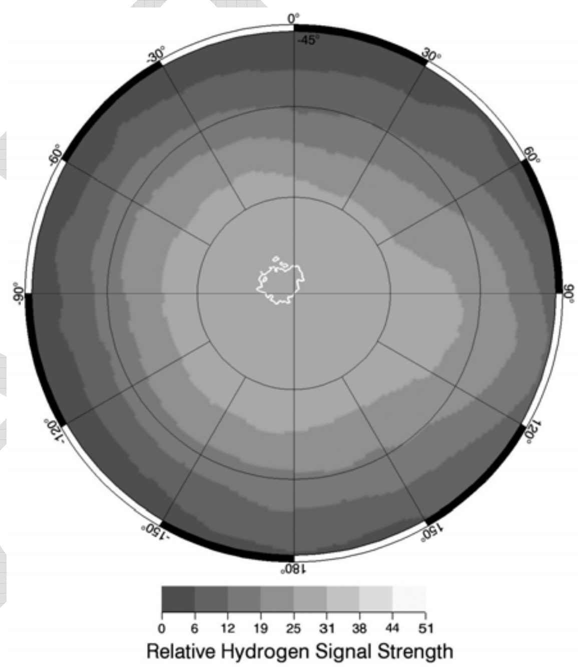
REMOTE SENSING ICES ON MARS
South Pole Analysis

Be sure to complete the North Pole Analysis activity first. The map below on the left shows the visible surface of the South Pole of Mars (down to 45°S) during summer. This information is based upon data taken by the Mars Orbiter Camera (MOC) orbiting aboard the Mars Global Surveyor spacecraft. The map below on the right shows the hydrogen signal strength for the same region and season. This information is based upon gamma rays collected by the Gamma Ray Spectrometer (GRS) orbiting aboard the 2001 Mars Odyssey spacecraft.

South Pole Summer – MOC Visible Mosaic



South Pole Summer – GRS Hydrogen Signal



1) Just like in the north, the South Pole ice cap grows significantly during the winter (not shown). The table below summarizes the approximate surface temperature of the ice cap during winter and summer. Complete the table by listing whether the ice cap is composed of water ice, carbon dioxide ice, methane ice, or ammonia ice.

Season	South Pole Ice Cap Temperature	South Pole Ice Cap Composition
Winter	Around -125°C	*Carbon dioxide (CO_2)*
Summer	Around -125°C	*Carbon dioxide (CO_2)*

2) Are the winter ice caps at the South Pole and North Pole similar or different in composition? Refer to your conclusions from the North Pole Analysis activity and explain your reasoning.

The winter ice caps at the poles are similar in composition. They are both composed of carbon dioxide ice that freezes out of the Martian atmosphere when temperatures drop due to lack of sunlight during the winter. We know they are made of carbon dioxide because the temperatures found at both the North Pole winter cap and South Pole winter cap is around -120°C, the frost point temperature of CO_2. Both caps grow and cover the permanent ice caps found at the poles.

Are the summer ice caps at the South Pole and North Pole similar or different in composition? Explain your reasoning.

The summer ice caps at both the poles are different in composition. The permanent cap at the North Pole is composed of water ice. The surface of the South Pole cap is carbon dioxide ice. We know this based upon their surface temperatures. The South Pole summer cap is colder (-120°C) than the North Pole summer cap (-75°C).

The summer caps are similar in that they are both brighter and colder than surrounding rocks and soil. They are also both permanent under current Martian climate conditions – that is the caps do not disappear completely during the summer.

3) Based upon the maps on the previous page, is water ice present in the regions around the South Pole during the summer? If present, is water ice found on the surface or is it buried? Explain your reasoning.

Yes, water ice is present in the regions around the South Pole. We know this because the hydrogen signal during the summer months is high in this region, even though the permanent cap is composed of carbon dioxide. This indicates that there must be some source of hydrogen in the region, and buried water ice is a likely candidate. We believe the water ice is buried because it is not measurable using visible and infrared remote sensing techniques. Gamma rays allows us to measure deeper into the surface of Mars to detect the buried water ice.

REMOTE SENSING ICES ON MARS
Student Guide

Background Reading

Life as we know it requires water. A key NASA science goal is to study past and current water on Mars. Liquid water is unstable under current Mars conditions. This is because temperatures are too cold and the air pressure is too low. However, solid water, known as water ice, and other types of ice can be stable. Studying these ices helps us understand what Mars is like today and may have been like in the past.

Ice Properties

In this activity, we will look at the types of ice found at high latitudes on Mars. We will also study how the ice caps on Mars change during different seasons. We will consider four different substances that could form ice: water, carbon dioxide, ammonia, and methane. The table below lists properties for each of these if they were solid ices near the surface of Mars.

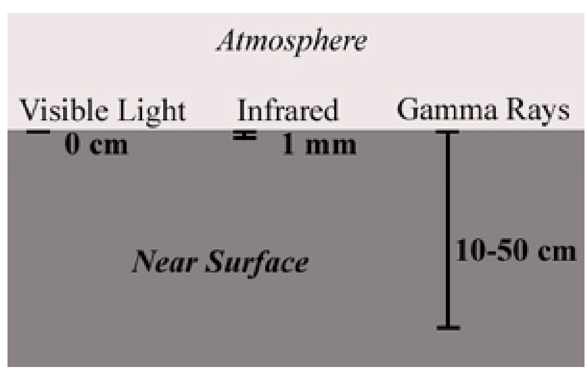
Substance	Chemical Formula	Visible Brightness	Martian Frost Point Temperature
Water	H_2O	Bright	-75°C
Carbon Dioxide	CO_2	Bright	-123°C
Ammonia	NH_3	Bright	Around –200°C
Methane	CH_4	Bright	Around –220°C

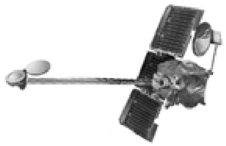
The table above gives the name and chemical formula of each type of ice. Notice that each ice would appear bright at the surface of Mars. However, each has a different frost point temperature. The frost point temperature is the temperature that the substance changes from solid to gas. This temperature is related to the energy needed to break chemical bonds and the amount of gas in the atmosphere. We will be able to tell the difference between water ice and other ices by its surface temperature.

Types of Data

The information in this activity was collected by spacecraft orbiting Mars. We will look at Mars using three different energies of light – visible light, infrared light, and gamma rays. Visible photographs will help us locate ice caps on Mars. At visible wavelengths, all of the ices listed in the table appear brighter than Martian rocks and soils. Next, we will use infrared light to figure out the surface temperature of an ice cap during different seasons. Because different ices have different frost point temperatures, the surface temperature of an ice cap tells us of what it is made. Finally, we will use gamma rays to figure out where hydrogen is present. This will help us find buried ice near the surface of Mars.

It is important to realize that we can see deeper into the Martian surface with different energies of light. Look at the figure below. Visible light reflects from the very top of the surface. Infrared light comes from within the top millimeter. However, gamma rays come from beneath the surface as far down as a few tens of centimeters. Gamma rays allow us to detect ice buried below the surface of Mars.





REMOTE SENSING ICES ON MARS
Reading Questions

1) What is another name for solid water? Why is solid water more likely to be found on the surface of Mars than liquid water?

2) Can you tell the difference between various types of ice based upon visual appearance alone? Why or why not?

3) What is the frost point temperature? How can we use the frost point temperature to figure out what an ice cap is made of?

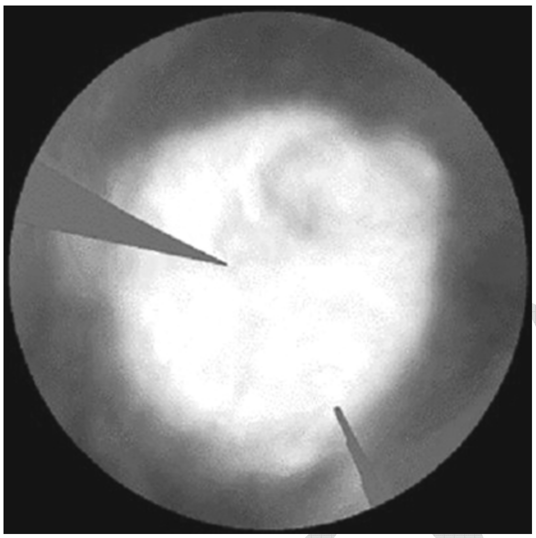
4) What are the three energies of light discussed in the reading? Which of these can measure the deepest into the surface of Mars and how deep can it measure?

North Pole Analysis

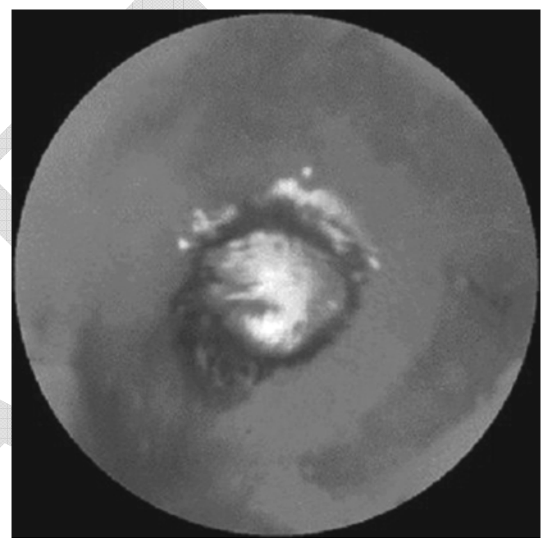
Part 1: Visible Data

The maps below show the visible surface of the North Pole of Mars (down to 45°N) during winter and summer. Each map is a mosaic of visible images taken with the Hubble Space Telescope (HST). The two dark pie-piece wedges in the winter map represent missing data where HST was not able to collect images to include in the mosaic.

North Pole Winter – HST Visible Mosaic



North Pole Summer – HST Visible Mosaic



1) Draw a circle around the location of the polar ice cap during each of the seasons above. How can you tell the difference between polar ice and surrounding rock and soil?

2) Is the ice cap larger during the winter or during the summer? Give a possible explanation for this observation.

3) Can you determine whether the winter and summer ice caps are made of carbon dioxide ice, methane ice, ammonia ice, or water ice based only upon the visual images above? Justify your answer.

4) Do you agree or disagree with either or both of the students below? Explain your reasoning.

Student 1: I think the ice caps are made of water ice. There is more water ice in the winter when it is colder and less in the summer, just like on Earth.

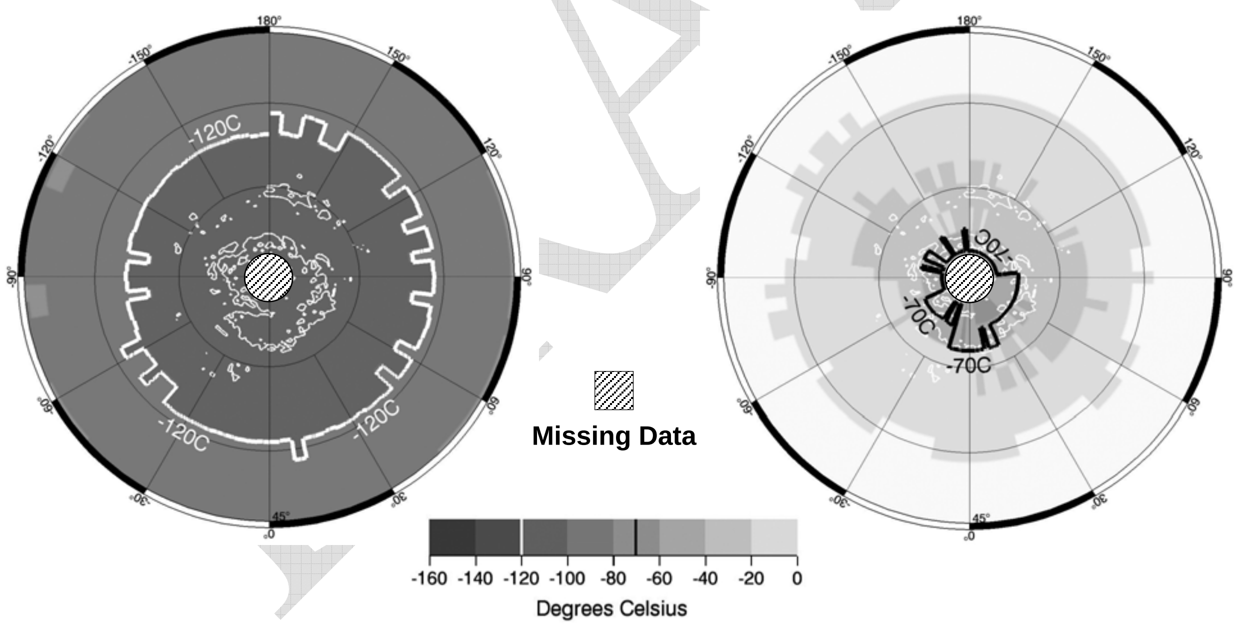
Student 2: I don't think we can figure out what kind of ice the caps are made of because other ices, like carbon dioxide and methane, are also bright just like water ice.

Part 2: Infrared Surface Temperature Data

The maps below show the surface temperature of the North Pole of Mars (down to 45°N) during winter and summer. This information is based upon infrared light collected by the Thermal Emission Spectrometer (TES) orbiting aboard the Mars Global Surveyor spacecraft. Notice that the scale bar shows the surface temperatures that each shade of gray represents. Contour lines are drawn at temperatures of -120°C (white) and -70°C (black). Note also that TES did not collect data from the dashed regions on each map. The permanent ice cap you noticed in the summer visible image before has been outlined in white on both maps.

North Pole Winter – TES Surface Temperature

North Pole Summer – TES Surface Temperature



5) Do "darker" shades of gray represent warmer or colder surface temperatures? Explain why it makes sense that the winter temperature map is darker than the summer temperature map.

6) What is the surface temperature of the ice cap during the winter?

   During the summer?

7) Based upon the background reading on frost point temperature, what is the most likely chemical formula of the ice found at the surface of the ice cap during the winter? Explain your reasoning.

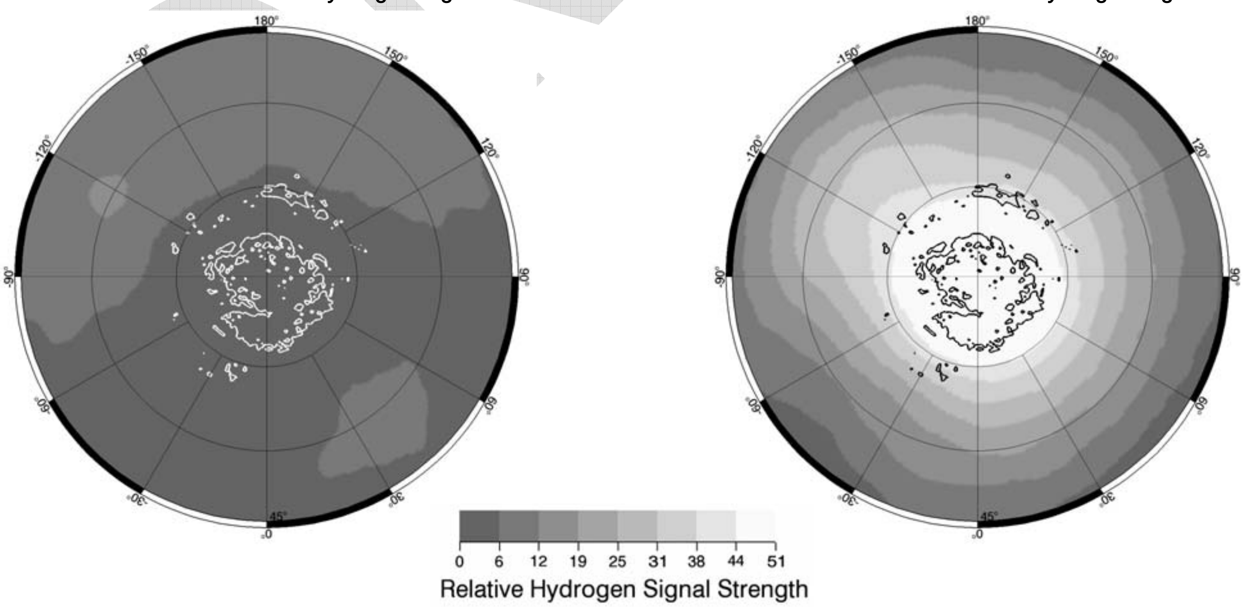
   During the summer? Explain your reasoning.

Part 3: Gamma Ray Data

The maps below show the hydrogen signal strength at the North Pole of Mars (down to 45°N) during winter and summer. This information is based upon gamma rays collected by the Gamma Ray Spectrometer (GRS) orbiting aboard the 2001 Mars Odyssey spacecraft. The permanent ice cap you noticed in the summer visible image before has been outlined on both maps.

North Pole Winter – GRS Hydrogen Signal

North Pole Summer – GRS Hydrogen Signal



8) Is the hydrogen signal strong or weak during the winter? Why does this make sense given the chemical formula of the ice found at the surface during the winter (see Question 7)?

Is the hydrogen signal stronger or weaker during the summer? Why does this make sense given the chemical formula of the ice found at the surface during the summer (see Question 7)?

9) On the summer map, notice that we detect hydrogen even from regions surrounding the permanent ice cap (outlined in black). Give a possible explanation for why the surrounding region with darker rocks and soil at the surface (see Question 1) could still give a strong gamma ray signal from hydrogen. Keep in mind the different depths that visible light and gamma rays measure.

10) Do you agree or disagree with either or both of the students below? Explain your reasoning.

Student 1: I think that the water signal goes away in the winter because the water ice melts and evaporates into the atmosphere.

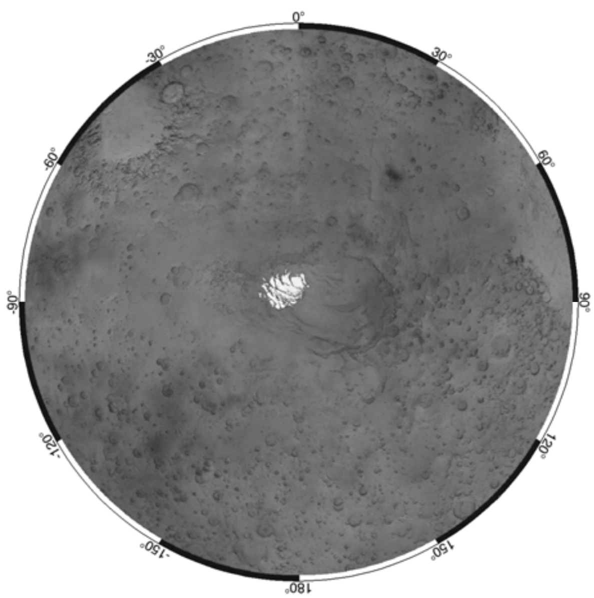
Student 2: That doesn't make any sense because it's colder in the winter. I think that both the water ice in the summer cap and the water ice buried below the surrounding rock and soil get covered up during the winter by a thick layer of carbon dioxide, which doesn't have any hydrogen in it.

Remote Sensing Ices on Mars
Student Guide

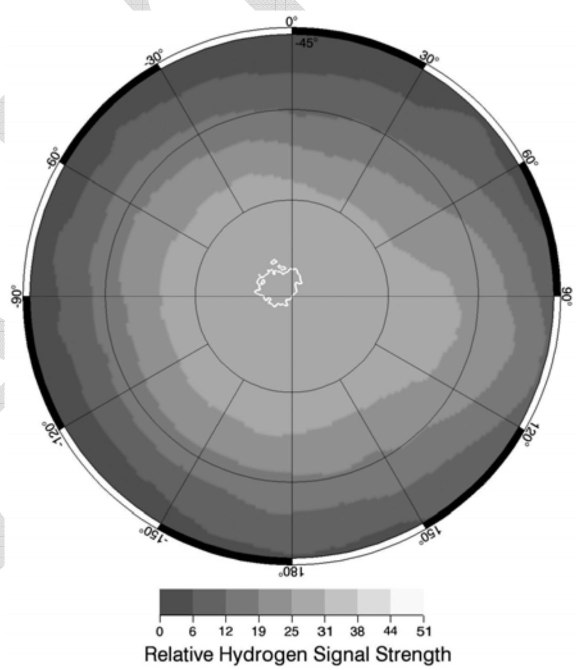
South Pole Analysis

Be sure to complete the North Pole Analysis activity first. The map below on the left shows the visible surface of the South Pole of Mars (down to 45°S) during summer. This information is based upon data taken by the Mars Orbiter Camera (MOC) orbiting aboard the Mars Global Surveyor spacecraft. The map below on the right shows the hydrogen signal strength for the same region and season. This information is based upon gamma rays collected by the Gamma Ray Spectrometer (GRS) orbiting aboard the 2001 Mars Odyssey spacecraft.

South Pole Summer – MOC Visible Mosaic



South Pole Summer – GRS Hydrogen Signal



1) Just like in the north, the South Pole ice cap grows significantly during the winter (not shown). The table below summarizes the approximate surface temperature of the ice cap during winter and summer. Complete the table by listing whether the ice cap is composed of water ice, carbon dioxide ice, methane ice, or ammonia ice.

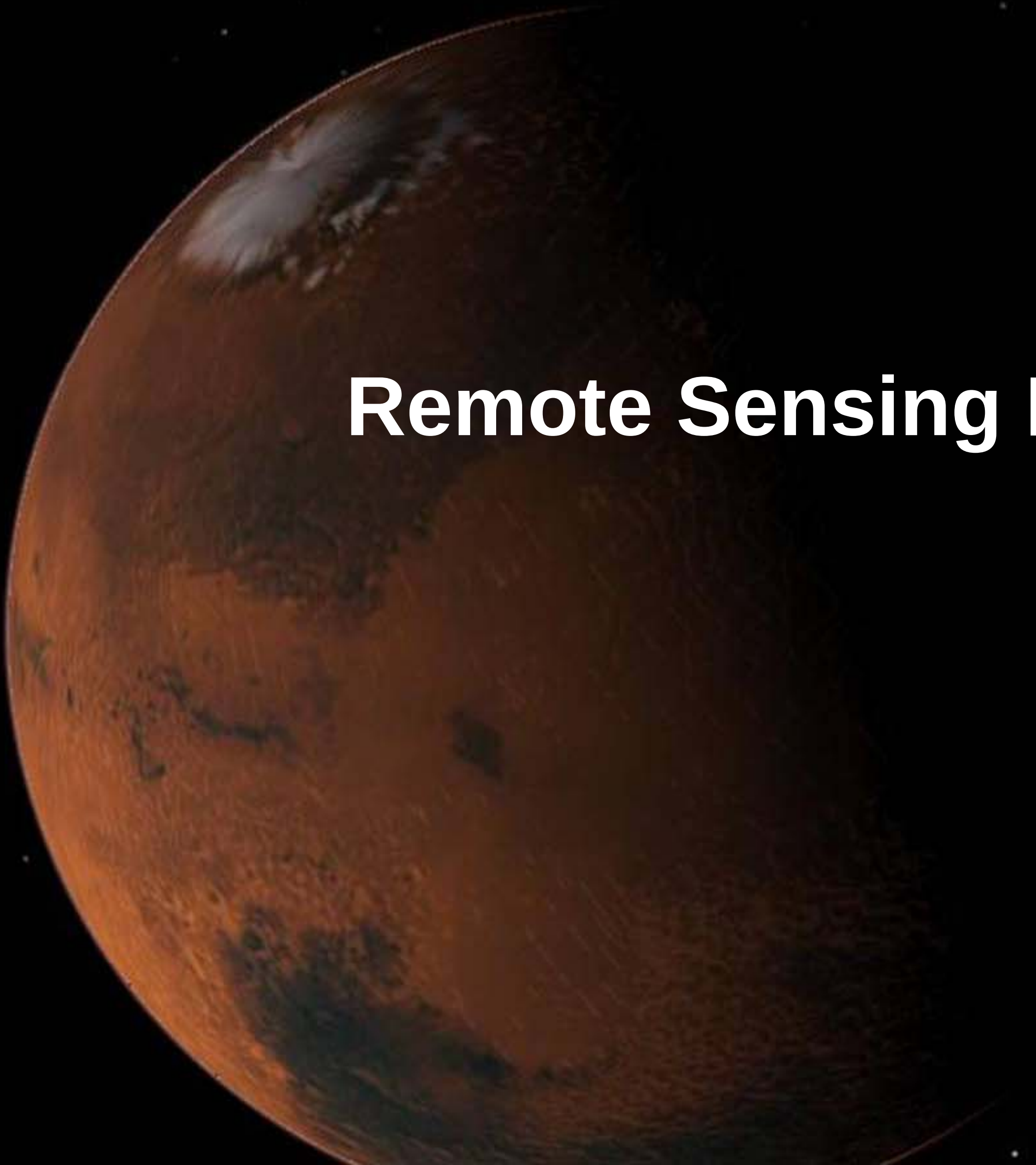
Season	South Pole Ice Cap Temperature	South Pole Ice Cap Composition
Winter	Around -125°C	
Summer	Around -125°C	

2) Are the winter ice caps at the South Pole and North Pole similar or different in composition? Refer to your conclusions from the North Pole Analysis activity and explain your reasoning.

Are the summer ice caps at the South Pole and North Pole similar or different in composition? Explain your reasoning.

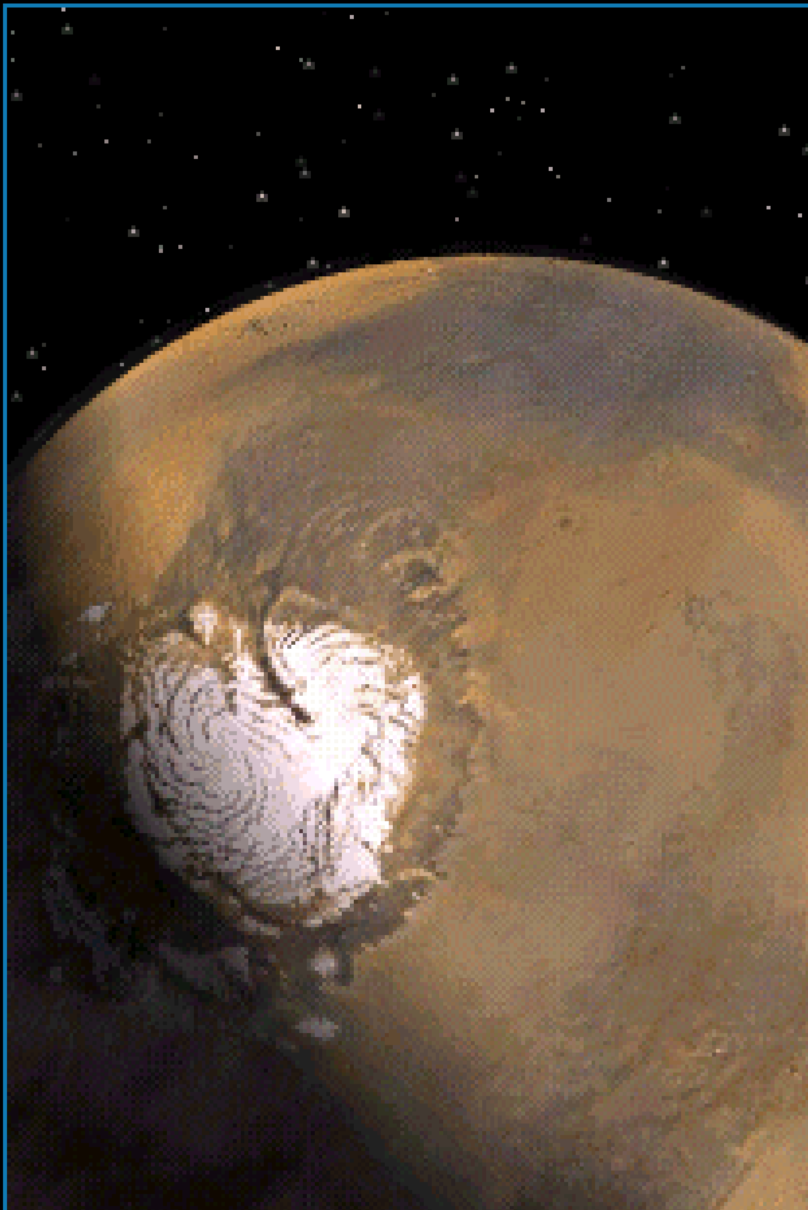
3) Based upon the maps on the previous page, is water ice present in the regions around the South Pole during the summer? If present, is water ice found on the surface or is it buried? Explain your reasoning.

Water on Mars



Remote Sensing Ices on Mars

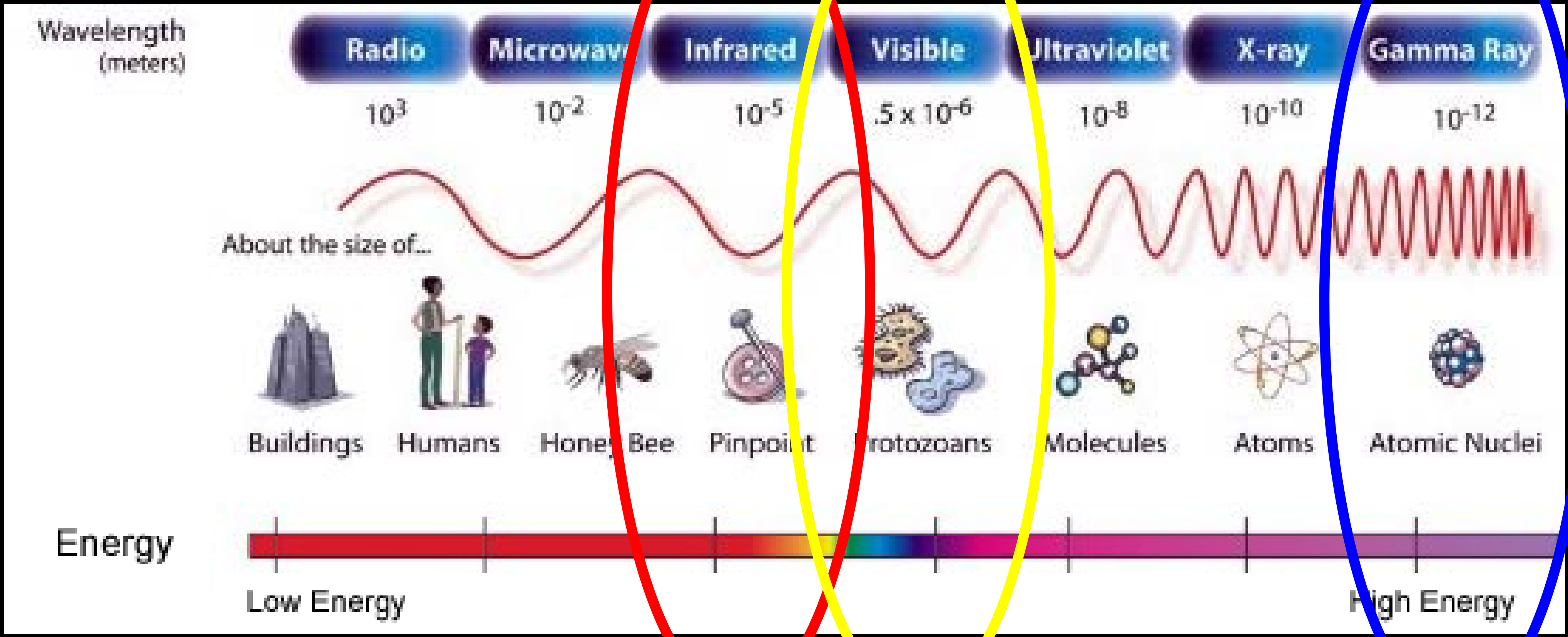
The North Arctic of Mars



- The white region does not move around from day to day.
- The white region increases in size during the winter and decreases in size during the summer.

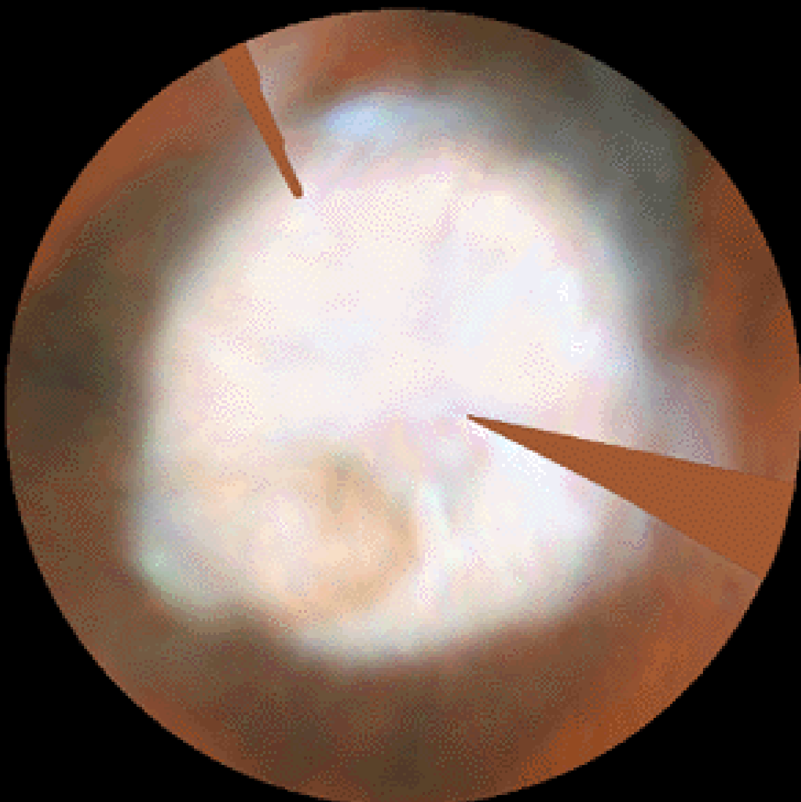
What do you think the white areas are? What might they be made of?

Types of Light

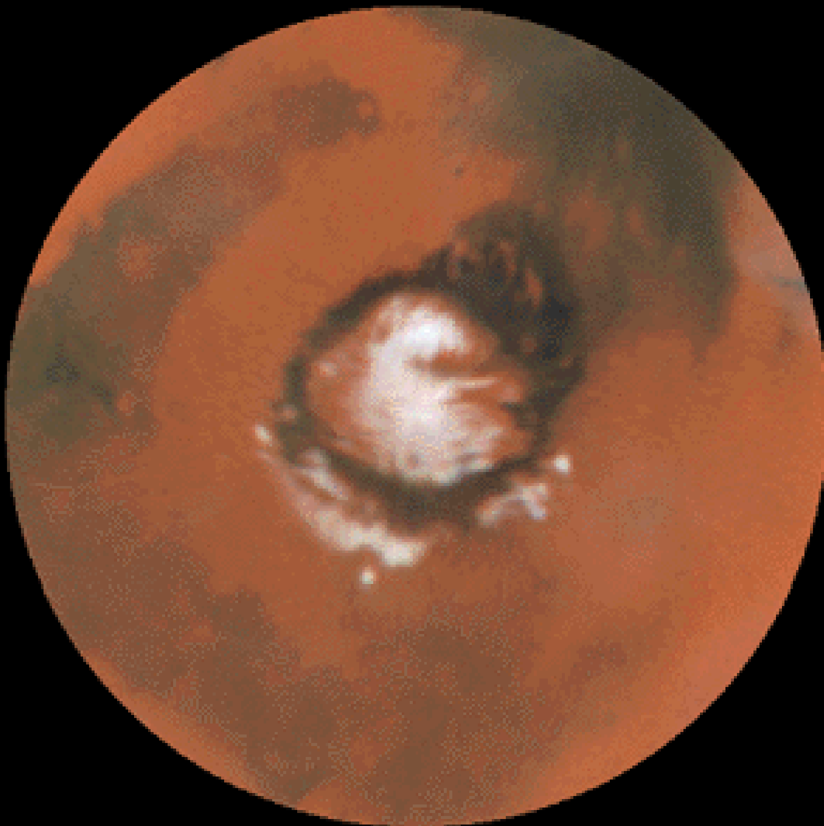


False color maps of the northern arctic

Seasonal Changes at the North Arctic

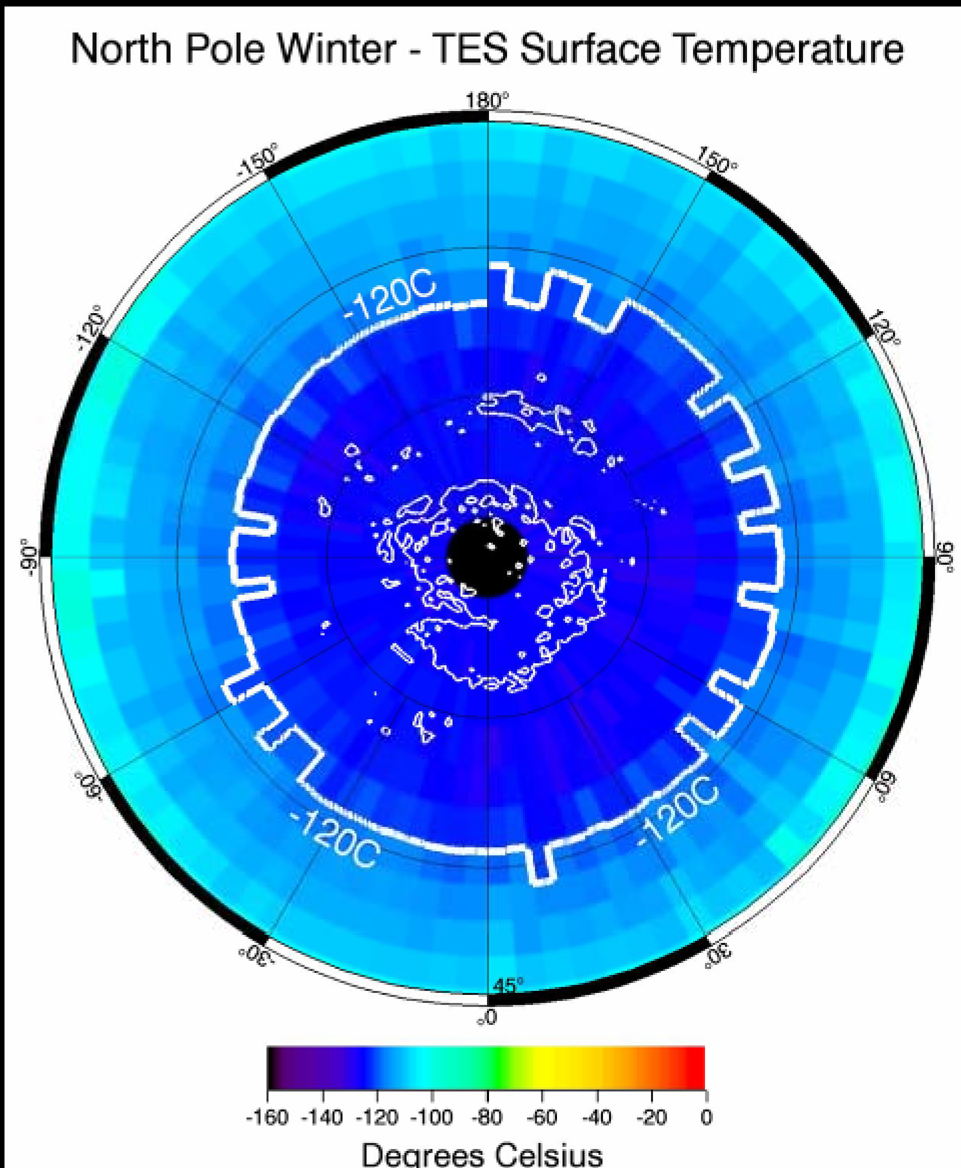


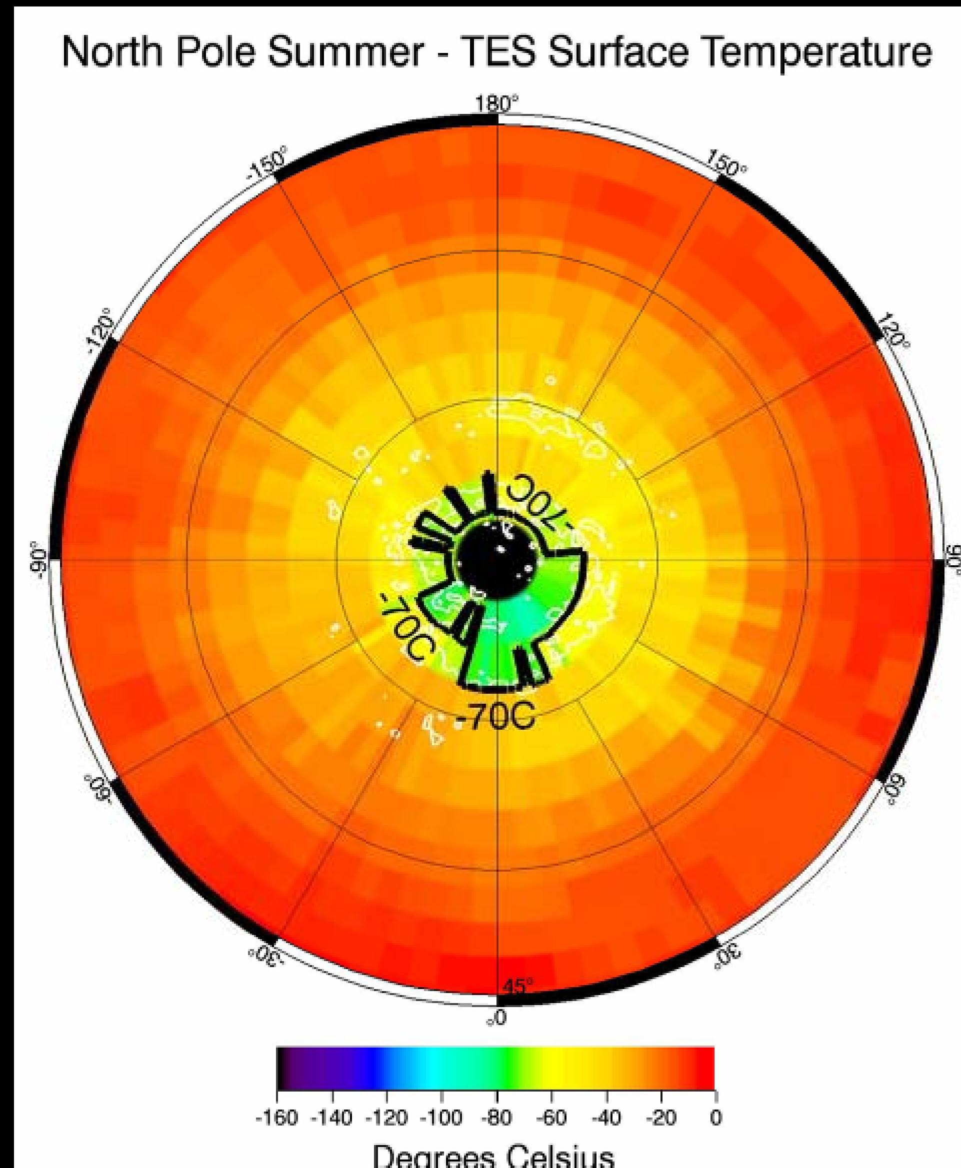
Northern Winter



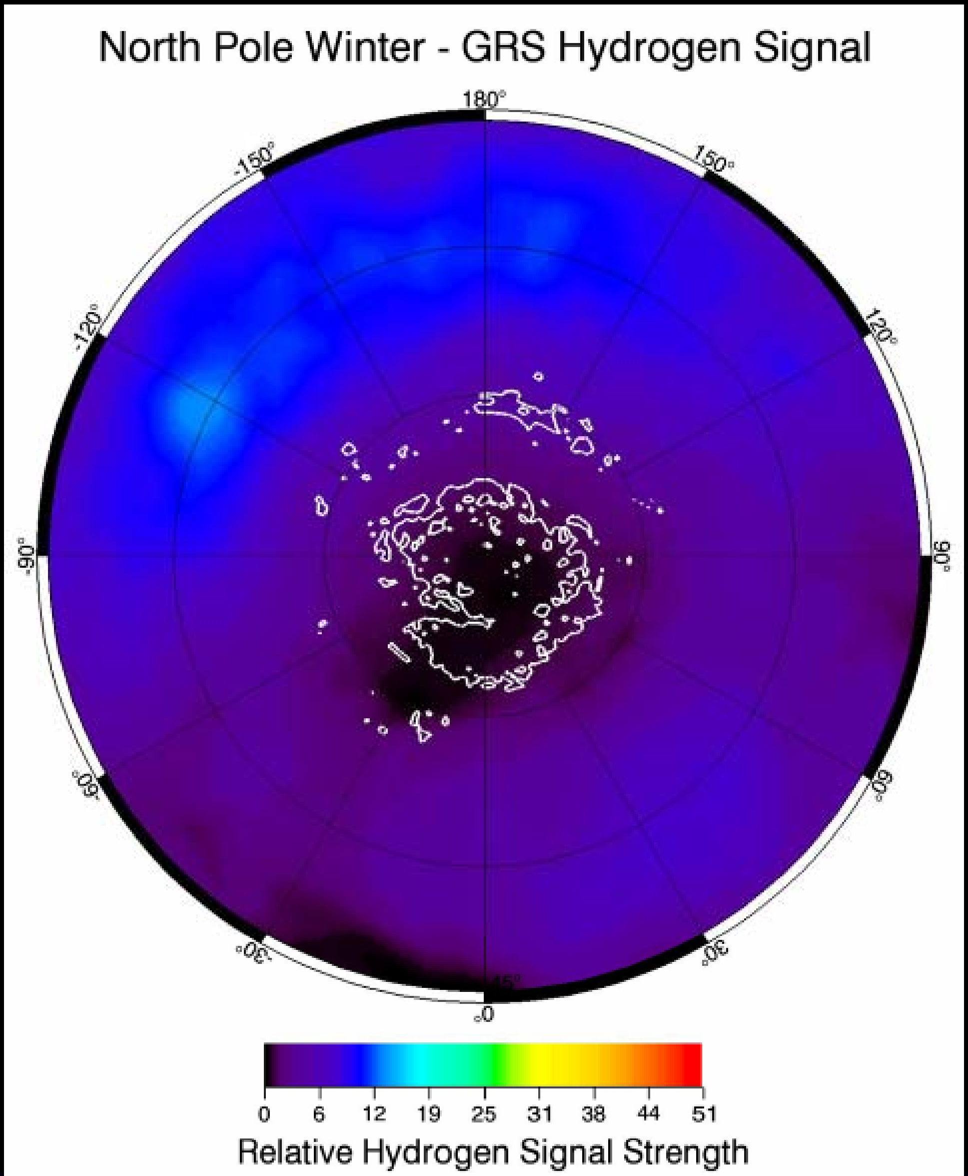
Northern Summer

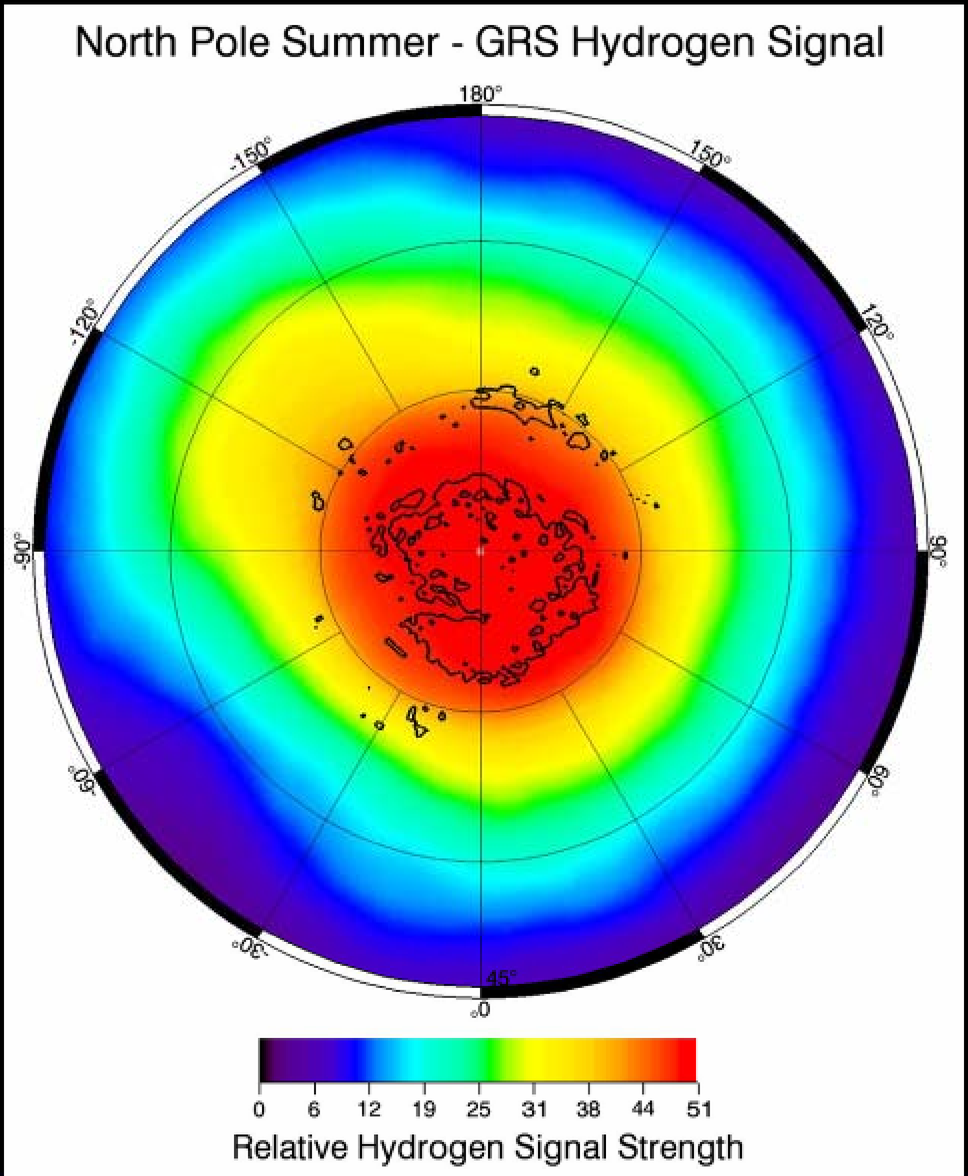
Infrared Data – North Arctic





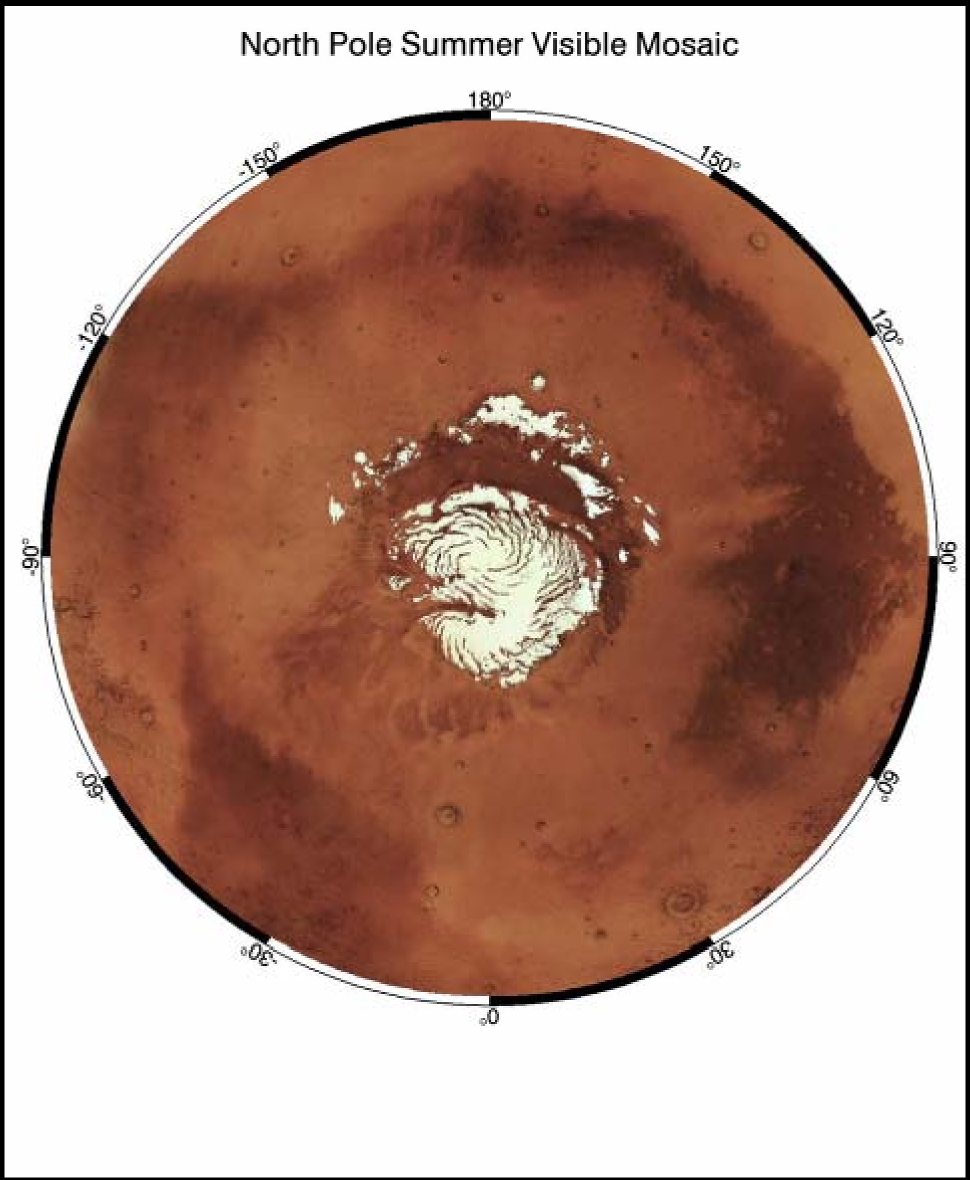
Gamma Ray Data – North Arctic

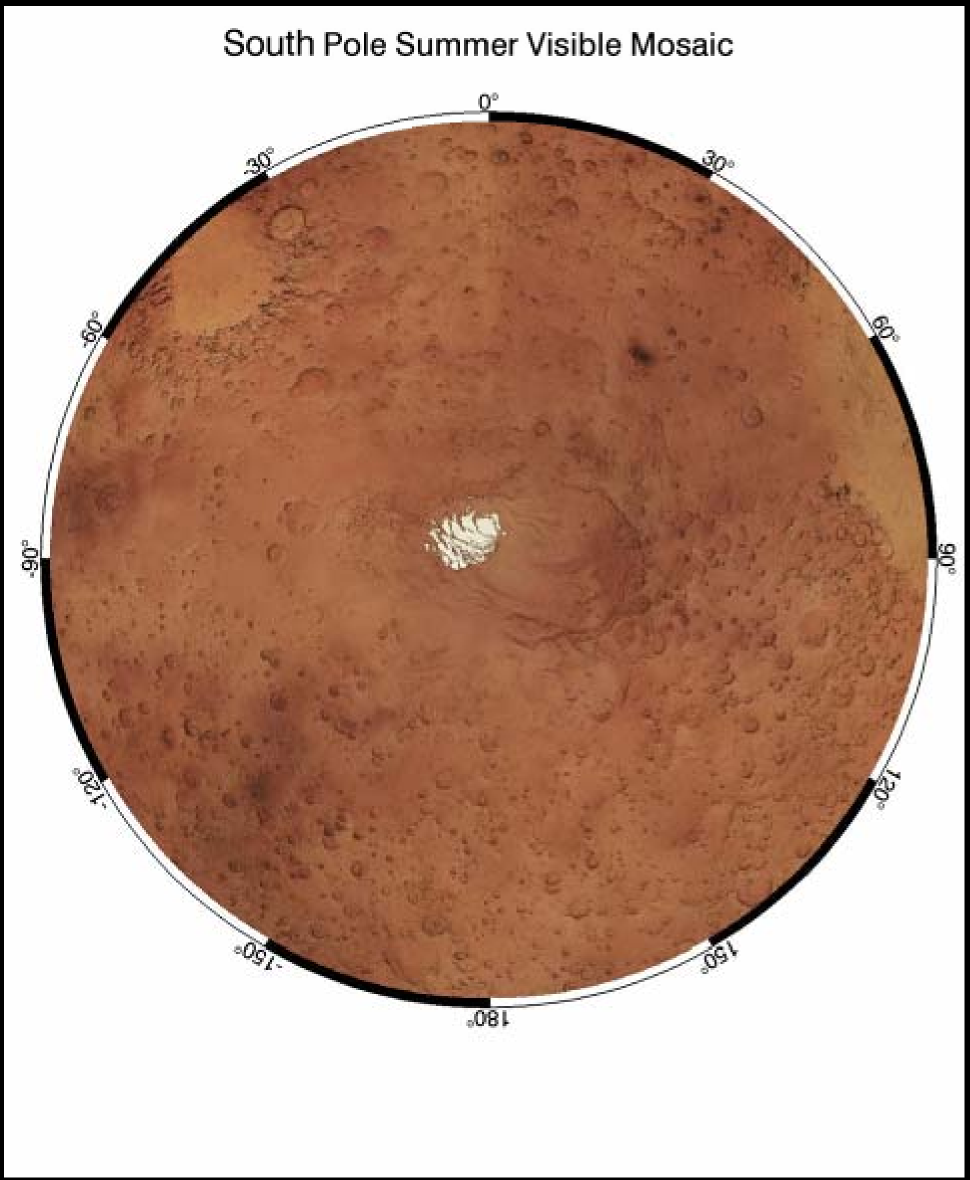




False color maps of southern arctic

Visible Data – North and South Arctic Summer





THE UNIVERSITY OF ARIZONA.
Lunar and Planetary Laboratory

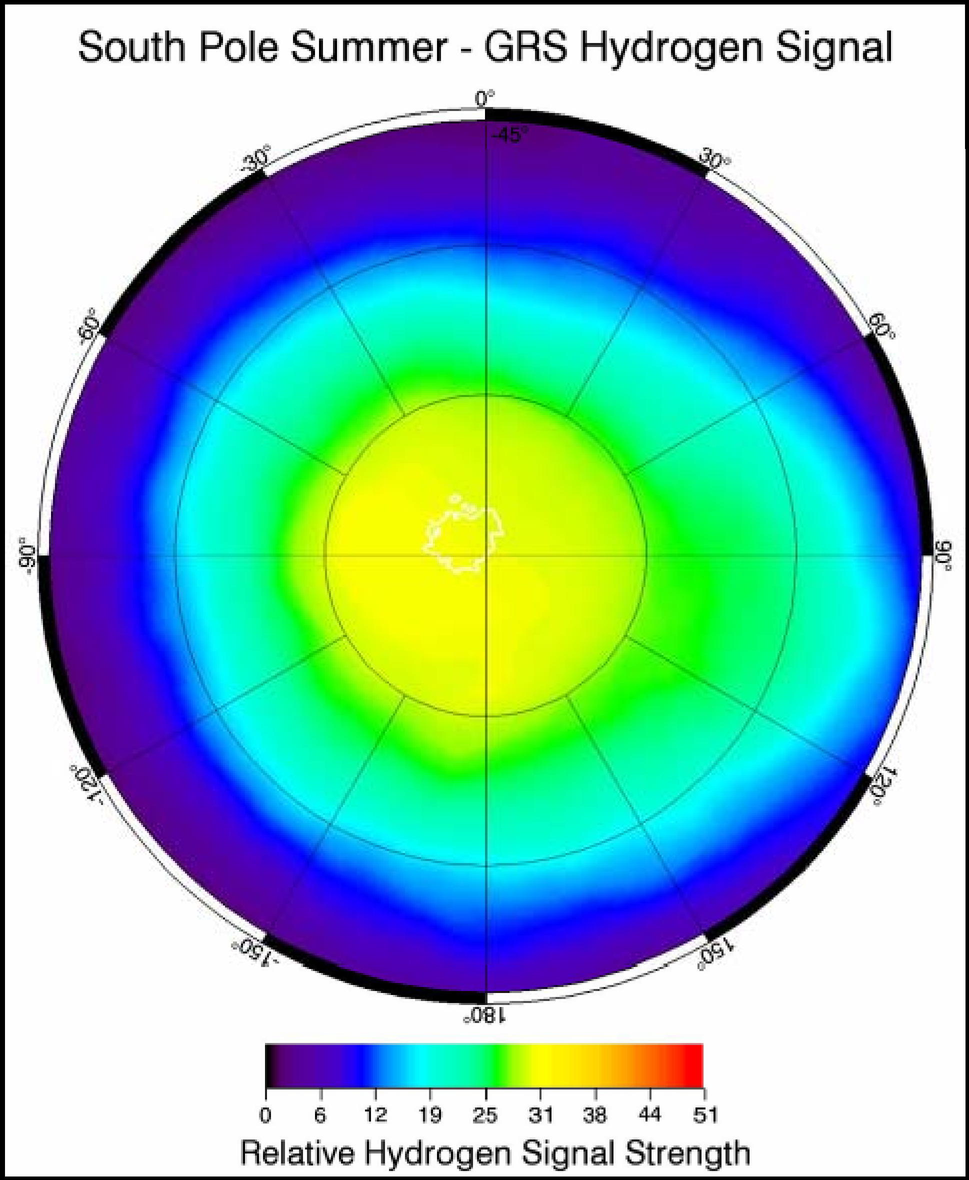
South Arctic Ice Cap Temperatures

Season	South Pole Arctic Cap Temperature	South Pole Arctic Cap Composition
Winter	Around -125˚C	
Summer	Around -125˚ C	

South Arctic Ice Cap Composition

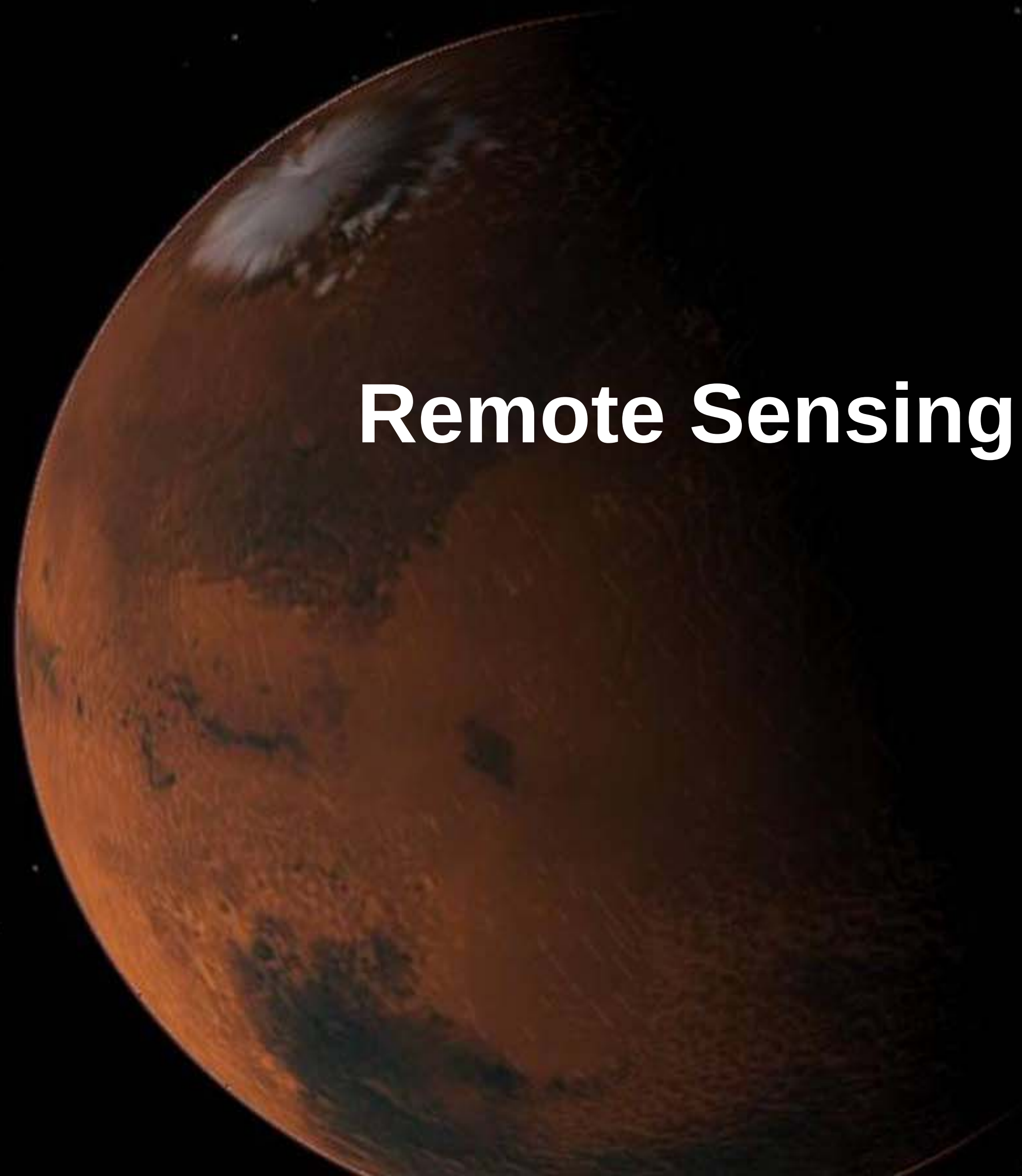
Season	South Arctic Ice Cap Temperature	South Arctic Ice Cap Composition
Winter	Around -125°C	CO_2
Summer	Around -125° C	CO_2

Gamma Ray Data – South Arctic Summer



Water on Mars

The University of Arizona
Lunar and Planetary Laboratory



Remote Sensing Ices on Mars

Objective: These slides provide false-color versions of the black and white images found in the activity titled “Remote Sensing Ices on Mars.”

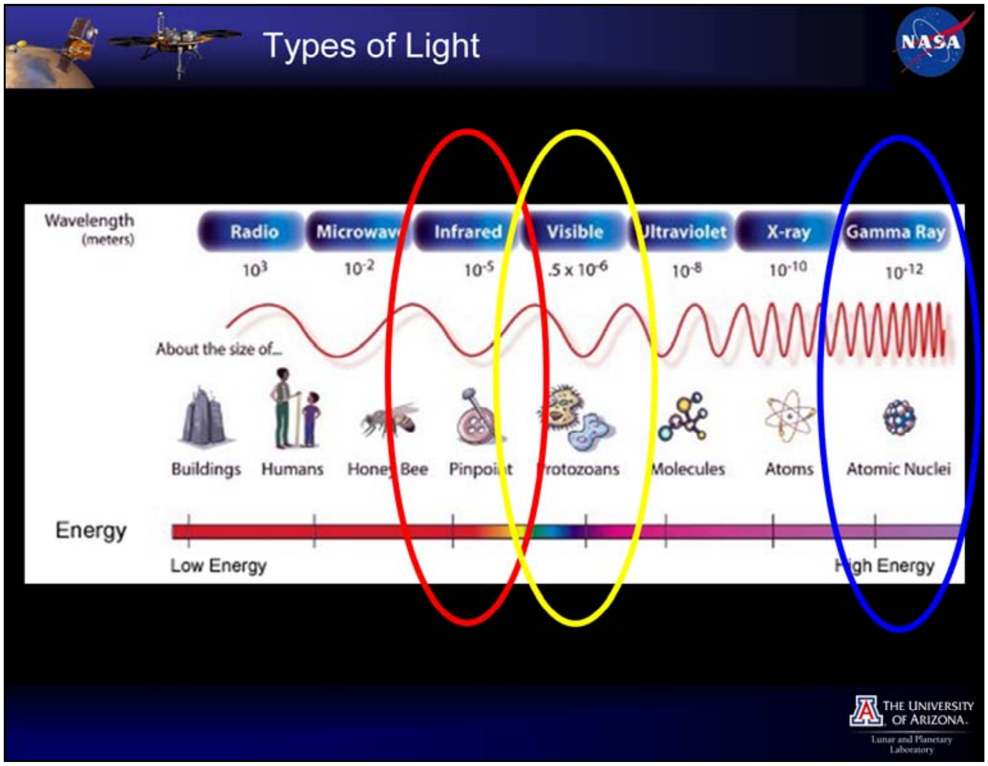
•Use this slide to provide context for students that there is ice at the poles of Mars.

•Some student may initially think that the white cap at the North Pole of Mars is caused by clouds. Ask students if clouds would stay in the same place from day to day.

•Emphasize that the white regions grows in size during the winter and shrinks during the summer. Guide students to the idea that there are ice caps at the poles of Mars.

•Ask students if they have any guesses about what the ice is made of. The most common answer will be water ice. Ask students if there are any other types of ice. Some students may mention dry ice (which is made of carbon dioxide), but it is okay if no other ices are suggested at this point in the lesson.

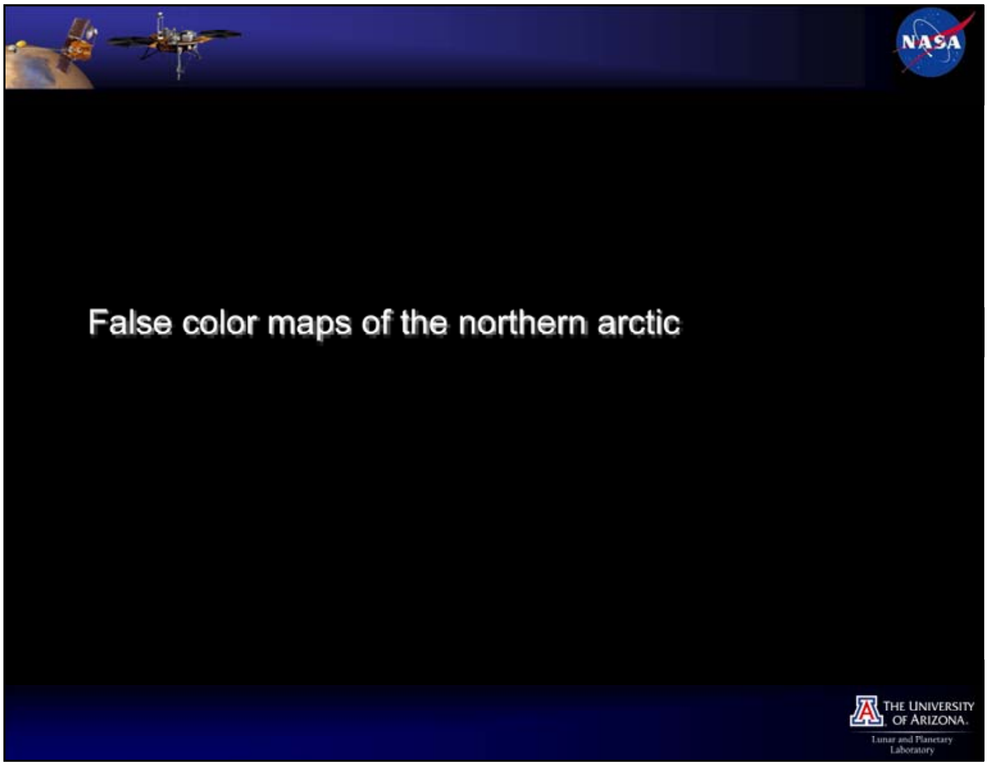
•Point out that in this activity you will be studying the arctic, or high latitude regions, of Mars, which includes both the white and brown portions of this image, and learn about the types of ices found there.



•Use this image to explain to students that there are different energies of light and that we can learn different things from each.

•In this activity, students will be using maps of Mars made using visible light, surface temperature maps made using infrared light, and hydrogen maps made using gamma rays.

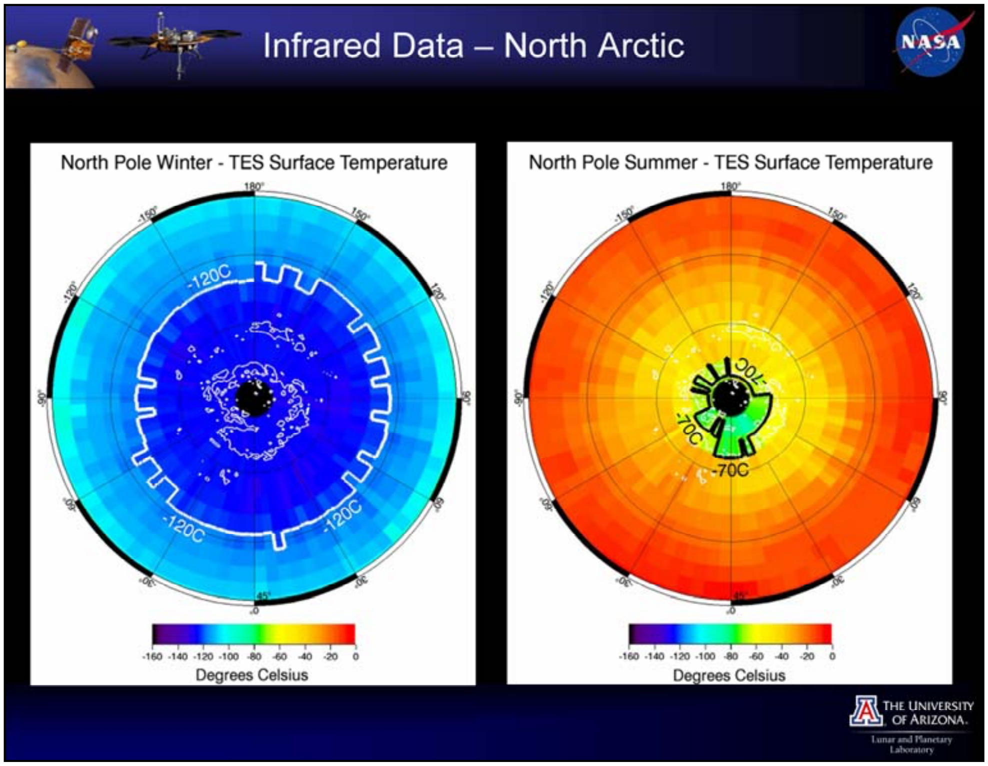
•Do not worry too much about discussing specifics about the electromagnetic spectrum. The main point of this slide is to emphasize that the data students were obtained using different energies of light.



•The next 3 slides provide false color images of the high latitudes of Mars. These maps correspond to the black and white maps found in the activity.

•You may find it useful to show these color images to help students interpret the black and white images in the activity.

- These color maps are identical to the visible maps in the student activity and are provided here if you would like to show your students the data in color rather than in black and white.
- The color maps were made by putting images from the Hubble Space Telescope together as polar mosaics.
- The image at the left shows the North Pole of Mars during the winter; the right image shows the North Pole during the summer.
- This is the evidence that the ice cap grows and shrinks with season. However, the image by itself does not confirm the composition of the ice.

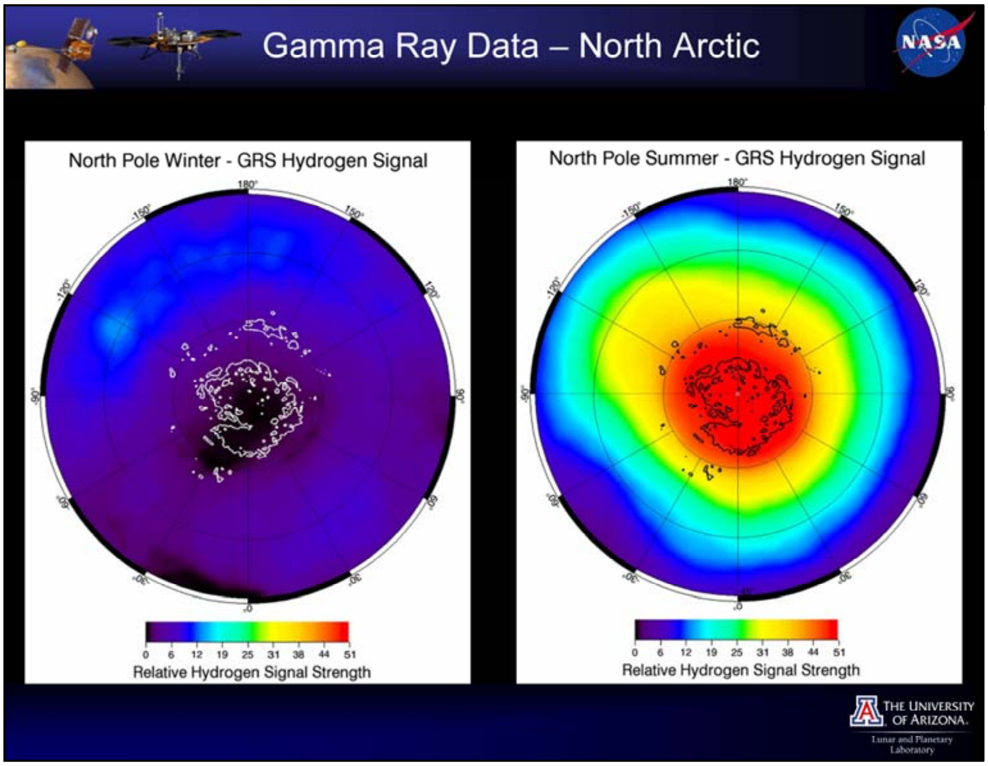


•These color maps are identical to surface temperature maps in the student activity and are provided here if you would like to show your students the data in color rather than in black and white.

•These maps were made using infrared data from the Mars Global Surveyor spacecraft.

•The colors shown on the scale bar indicate the average surface temperatures on the planet during the seasons shown.

•Through the activity, students should notice that surface temperatures correspond to carbon dioxide ice during the winter and water ice during the summer.

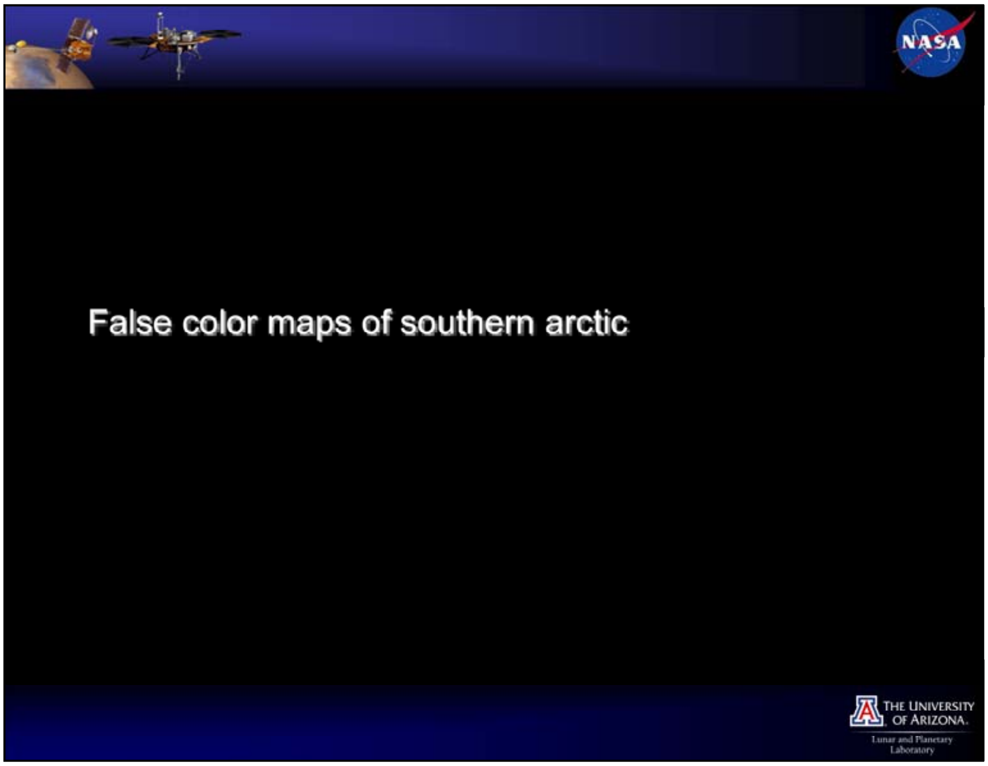


•These color maps are identical to hydrogen maps in the student activity and are provided here if you would like to show your students the data in color rather than in black and white.

•These maps were made using gamma ray data from the Mars Odyssey Spacecraft.

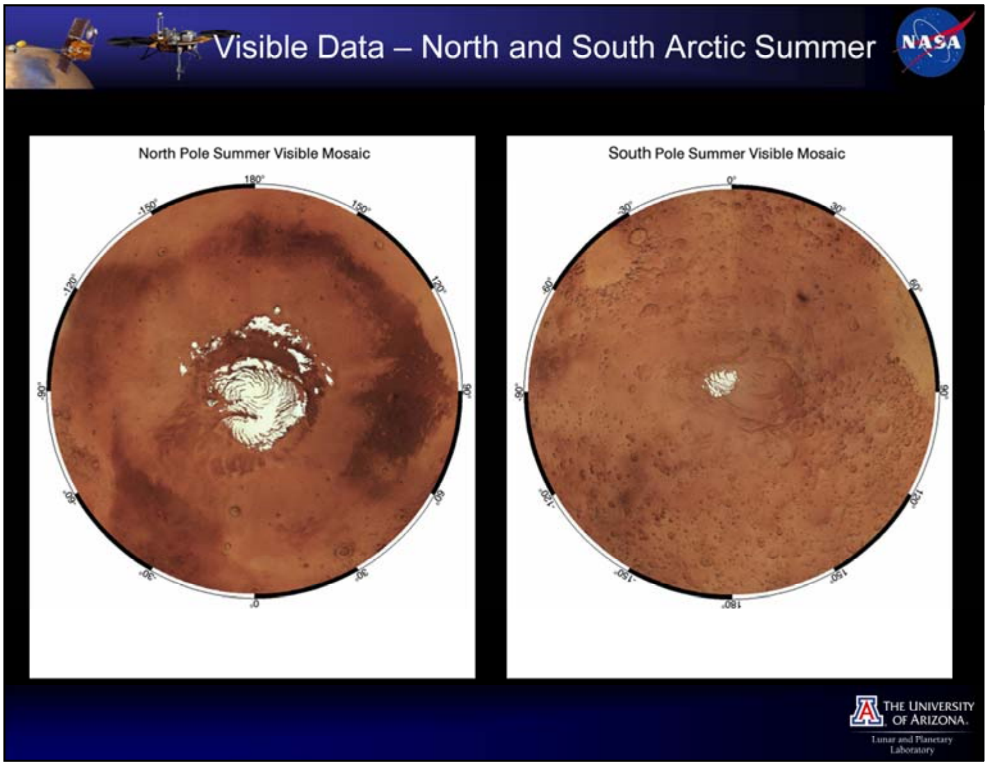
•The colors shown on the scale bar indicate the strength of the hydrogen gamma ray signal coming from the planet during the seasons shown.

•Through the activity, students should notice that the hydrogen signal is weak during the winter region is covered by carbon dioxide ice. The hydrogen signal is strong during the summer when both water ice from the ice cap and water ice buried by dirt in regions away from the ice cap.



•The next 3 slides provide color images of the northern arctic maps shown in black and white on the activity.

•You may find it useful to show these color images to help students interpret the black and white images in the activity.



•These color maps show visible data from the northern arctic and southern arctic and can be used to enhance student interpretation of the black and white images found in the activity.

•The color maps were made using visible data from the Mars Global Surveyor spacecraft.

•The image at the left shows the northern arctic of Mars during the summer; the right image shows the southern arctic during the summer.

•Students should note that the northern ice cap is larger during the summer than the southern ice cap.

South Arctic Ice Cap Temperatures

Season	South Pole Arctic Cap Temperature	South Pole Arctic Cap Composition
Winter	Around -125˚C	
Summer	Around -125˚ C	

•This slide provides surface temperature data for the southern arctic during winter and summer months. It is identical to the table found in the activity.

•These temperatures were obtained using infrared data from the Mars Global Surveyor spacecraft.

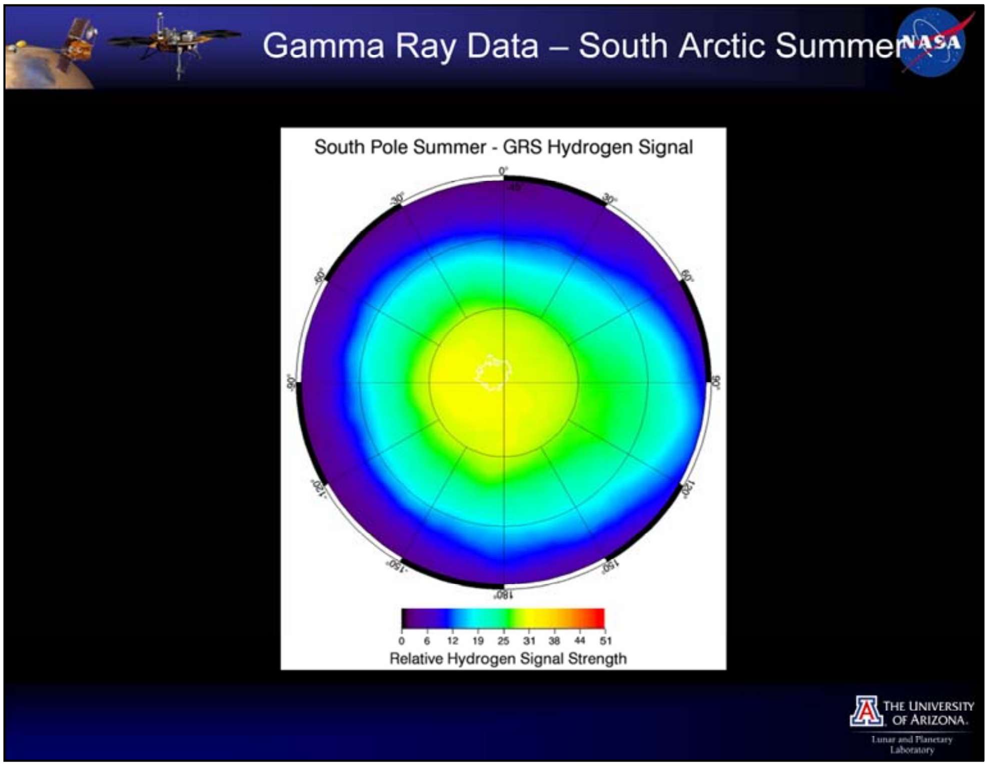
•Ask students what these temperatures imply about the composition of the southern ice cap.

South Arctic Ice Cap Composition

Season	South Arctic Ice Cap Temperature	South Arctic Ice Cap Composition
Winter	Around -125˚C	CO_2
Summer	Around -125˚ C	CO_2

THE UNIVERSITY OF ARIZONA.
Lunar and Planetary Laboratory

•This slide provides the correct answers that the southern ice cap is composed of carbon dioxide ice during both the winter and summer.



•This color map is identical to hydrogen map in the student activity for the southern arctic and is provided here if you would like to show your students the data in color rather than in black and white.

•This map was made using gamma ray data from the Mars Odyssey Spacecraft.

•The colors shown on the scale bar indicate the strength of the hydrogen gamma ray signal coming from the planet during the seasons shown.

•Through the activity, students should notice hydrogen signal from the southern arctic is strong even though the southern summer icecap is made of carbon dioxide ice. This is because there is water ice buried beneath the soil in the regions surrounding the ice cap.


Water on Mars
THE UNIVERSITY OF ARIZONA.
Lunar and Planetary Laboratory
NASA
Remote Sensing Ices on Mars

Remote Sensing Ices on Mars Extension
Teacher Guide
Remote Sensing With Gamma Rays

Background Reading:

The Mars Gamma Ray Spectrometer (GRS) aboard the 2001 Mars Odyssey spacecraft has started to map the composition of the near-surface of Mars using gamma rays. Even though the satellite is not in direct contact with the surface, we can gather information about the planet using light. In this case, the light is at gamma ray energies. This is just one example of "remote sensing."

In this activity, you will use a computer simulation to learn more about why Mars gives off gamma ray photons and how we can use these to learn about the surface of the planet. First, access the Mars Gamma Ray Simulator by going to the following website:

http://grs.lpl.arizona.edu/content/learning/simulator

Click on the Mars GRS Simulator button. This will take you to an **Introduction** page with a description of the simulation program. Read this brief introduction.

Next, click on the **Demo** button found towards the upper right of the screen. This will take you to a series of animations describing why gamma ray photons are released from Mars. Read the description found at the left side of each animation, and watch the animation by pressing the **Play** button at the bottom of the screen. You can watch each animation as many times as you like by clicking on the **Reset** button. After you feel comfortable with each animation, use the flashing **Arrow** buttons to navigate to the next animation. After you have viewed and read about each of the 8 animations, answer the following questions.

1) Describe each of the three ways that gamma rays are given off by atoms at the surface of Mars:

   Neutron scattering:

   Sometimes a neutron bounces off of an atom and energy is released in the form of a gamma ray photon.

   Neutron capture:

   Sometimes a neutron is captured by an atom, which makes this atom temporarily radioactive. When the atom decays to a more stable atom, it gives off a gamma ray photon.

   Radioactive decay:

   Radioactive elements such as potassium, thorium, and uranium are unstable. When one of these atoms decays into a more stable atom, it can give of a gamma ray photon.

Next, click on the **Simulator** button found towards the upper right of the screen. Read the description of the simulator found there. Select one of the **Soil Composition** buttons found towards the left side of the screen and click on the **Play** button found towards the bottom of the screen. This simulator shows cosmic ray particles (red spheres) bombarding the surface of Mars which causes the release of neutrons (yellow spheres). Some of these neutrons escape to space. Others cause the release of gamma ray photons (colored arrows) through either scattering or capture events. In addition, radioactive elements give off gamma ray photons through decay events.

2) For each soil composition, run the simulation for 10 GRS passes (see counter towards lower left of the screen) and complete the following table with the number of neutrons and gamma ray photons collected. Notice that you can click on the **Show Count** button to list the actual number of photons collected.

	Soil Composition 1	Soil Composition 2	Soil Composition 3
Neutrons (n)	*~30*	*~20*	*~40*
Hydrogen (H)	*~10*	*~20*	*~10*
Silicon (Si)	*~10*	*~10*	*~10*
Chlorine (Cl)	*~10*	*~10*	*~10*
Iron (Fe)	*~10*	*~10*	*~10*
Potassium (K)	*~10*	*~10*	*~20*

3) Hydrogen is an important part of the molecule water (H_2O). Which of the soil compositions is most likely to contain buried water ice? Explain your reasoning.

Soil Composition 2 is the most likely to contain buried water ice. The number of hydrogen photons collected is double the amount of hydrogen photons collected from either of the other two soil compositions.

4) Potassium (K) is a naturally radioactive element. Which of the soil compositions has the most radioactive potassium? Explain your reasoning.

Soil Composition 3 has the most radioactive potassium. The number of potassium photons collected is double the amount of potassium photons from either of the other two soil compositions.

5) Why is it more reliable to determine the concentration of elements in each soil composition using 10 GRS passes rather than 1 GRS pass?

The number of gamma ray photons coming from Mars is not very large. In order to build up enough signal to determine the concentration of elements, it is important to collect data from several GRS passes.

After answering the questions above, test your knowledge by clicking on the **Evaluation** button towards the top right of the screen and answering the nine questions found there.

Remote Sensing Ices on Mars Extension
Student Guide
Remote Sensing With Gamma Rays

Background Reading:

The Mars Gamma Ray Spectrometer (GRS) aboard the 2001 Mars Odyssey spacecraft has started to map the composition of the near-surface of Mars using gamma rays. Even though the satellite is not in direct contact with the surface, we can gather information about the planet using light. In this case, the light is at gamma ray energies. This is just one example of "remote sensing."

In this activity, you will use a computer simulation to learn more about why Mars gives off gamma ray photons and how we can use these to learn about the surface of the planet. First, access the Mars Gamma Ray Simulator by going to the following website:

http://grs.lpl.arizona.edu/content/learning/simulator

Click on the Mars GRS Simulator button. This will take you to an **Introduction** page with a description of the simulation program. Read this brief introduction.

Next, click on the **Demo** button found towards the upper right of the screen. This will take you to a series of animations describing why gamma ray photons are released from Mars. Read the description found at the left side of each animation, and watch the animation by pressing the **Play** button at the bottom of the screen. You can watch each animation as many times as you like by clicking on the **Reset** button. After you feel comfortable with each animation, use the flashing **Arrow** buttons to navigate to the next animation. After you have viewed and read about each of the 8 animations, answer the following questions.

1) Describe each of the three ways that gamma rays are given off by atoms at the surface of Mars:

   Neutron scattering:

   Neutron capture:

   Radioactive decay:

Next, click on the **Simulator** button found towards the upper right of the screen. Read the description of the simulator found there. Select one of the **Soil Composition** buttons found towards the left side of the screen and click on the **Play** button found towards the bottom of the screen. This simulator shows cosmic ray particles (red spheres) bombarding the surface of Mars which causes the release of neutrons (yellow spheres). Some of these neutrons escape to space. Others cause the release of gamma ray photons (colored arrows) through either scattering or capture events. In addition, radioactive elements give off gamma ray photons through decay events.

2) For each soil composition, run the simulation for 10 GRS passes (see counter towards lower left of the screen) and complete the following table with the number of neutrons and gamma ray photons collected. Notice that you can click on the **Show Count** button to list the actual number of photons collected.

	Soil Composition 1	Soil Composition 2	Soil Composition 3
Neutrons (n)			
Hydrogen (H)			
Silicon (Si)			
Chlorine (Cl)			
Iron (Fe)			
Potassium (K)			

3) Hydrogen is an important part of the molecule water (H_2O). Which of the soil compositions is most likely to contain buried water ice? Explain your reasoning.

4) Potassium (K) is a naturally radioactive element. Which of the soil compositions has the most radioactive potassium? Explain your reasoning.

5) Why is it more reliable to determine the concentration of elements in each soil composition using 10 GRS passes rather than 1 GRS pass?

After answering the questions above, test your knowledge by clicking on the **Evaluation** button towards the top right of the screen and answering the nine questions found there.

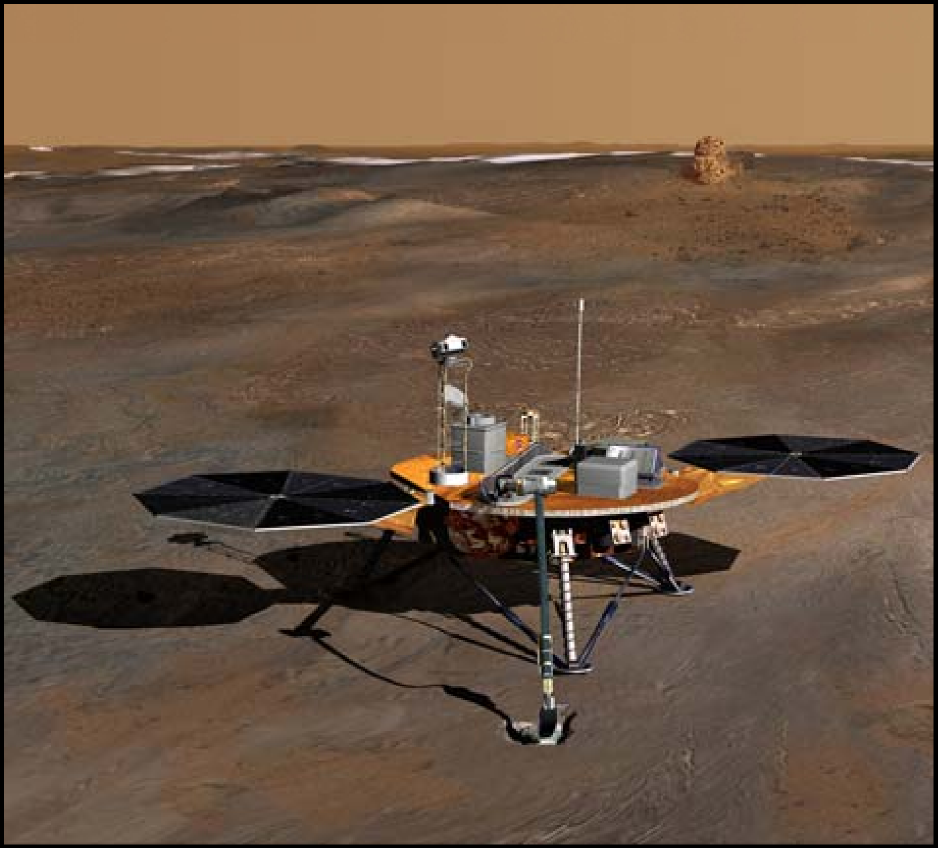
Water on Mars

Remote Sensing Ices on Mars Extension

Direct Lander Measurements

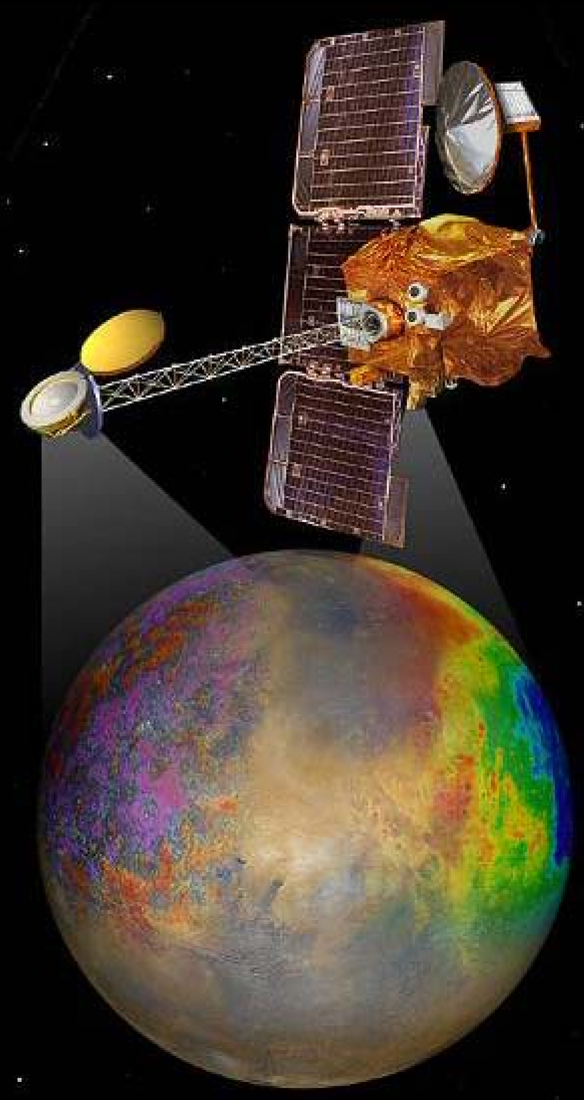
Mars Exploration Rover

Phoenix Mars Lander

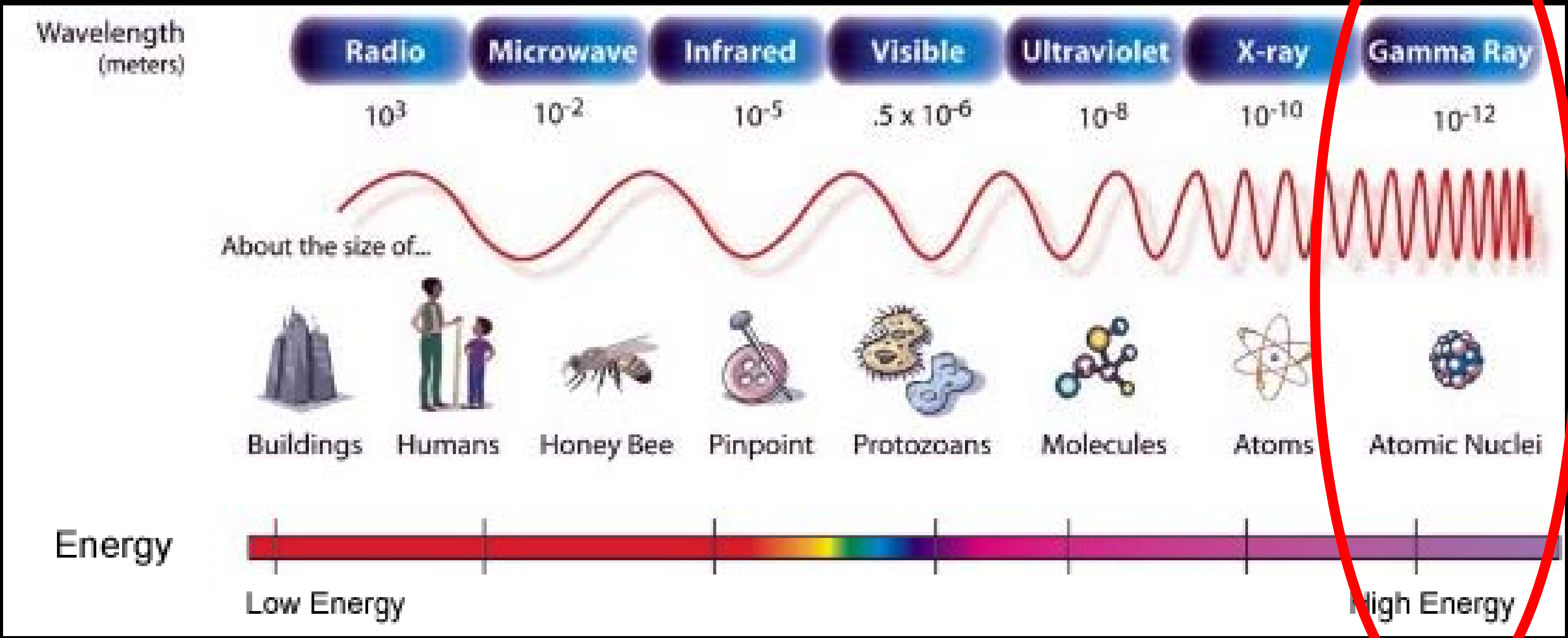


Definition of Remote Sensing

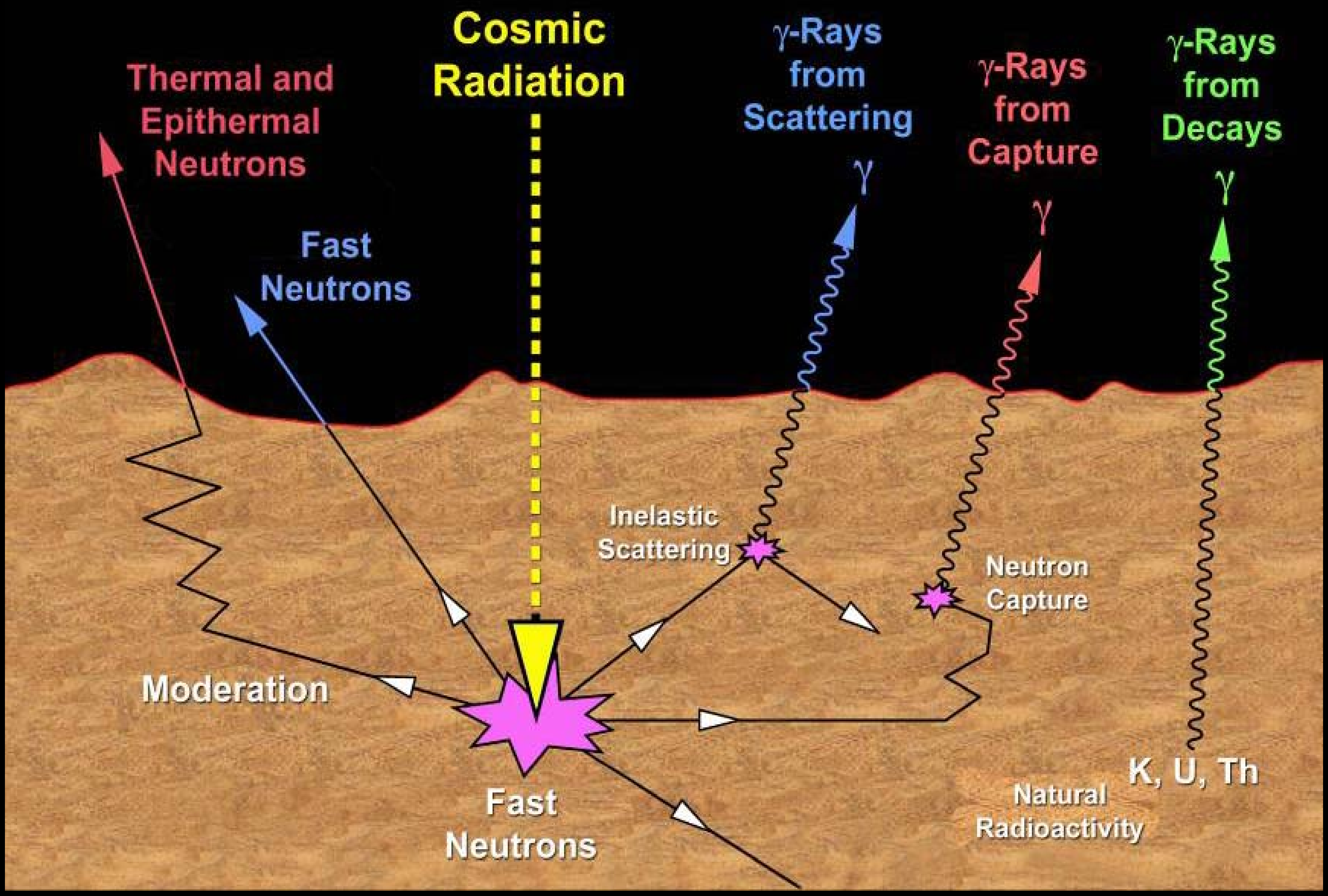
Remote Sensing: Gathering information about an object without coming into direct contact with the object.



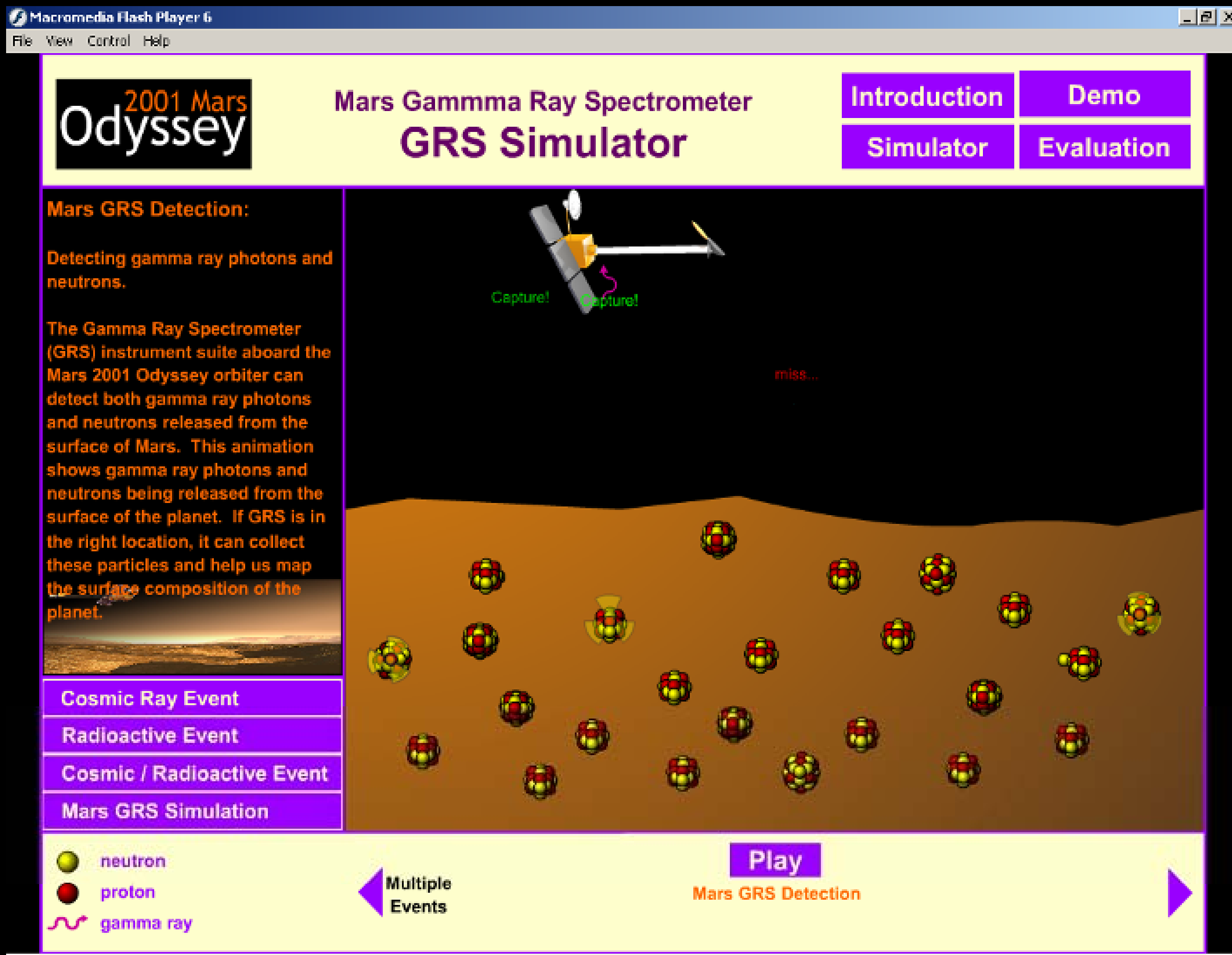
Types of Light



Neutron and Gamma Ray Production

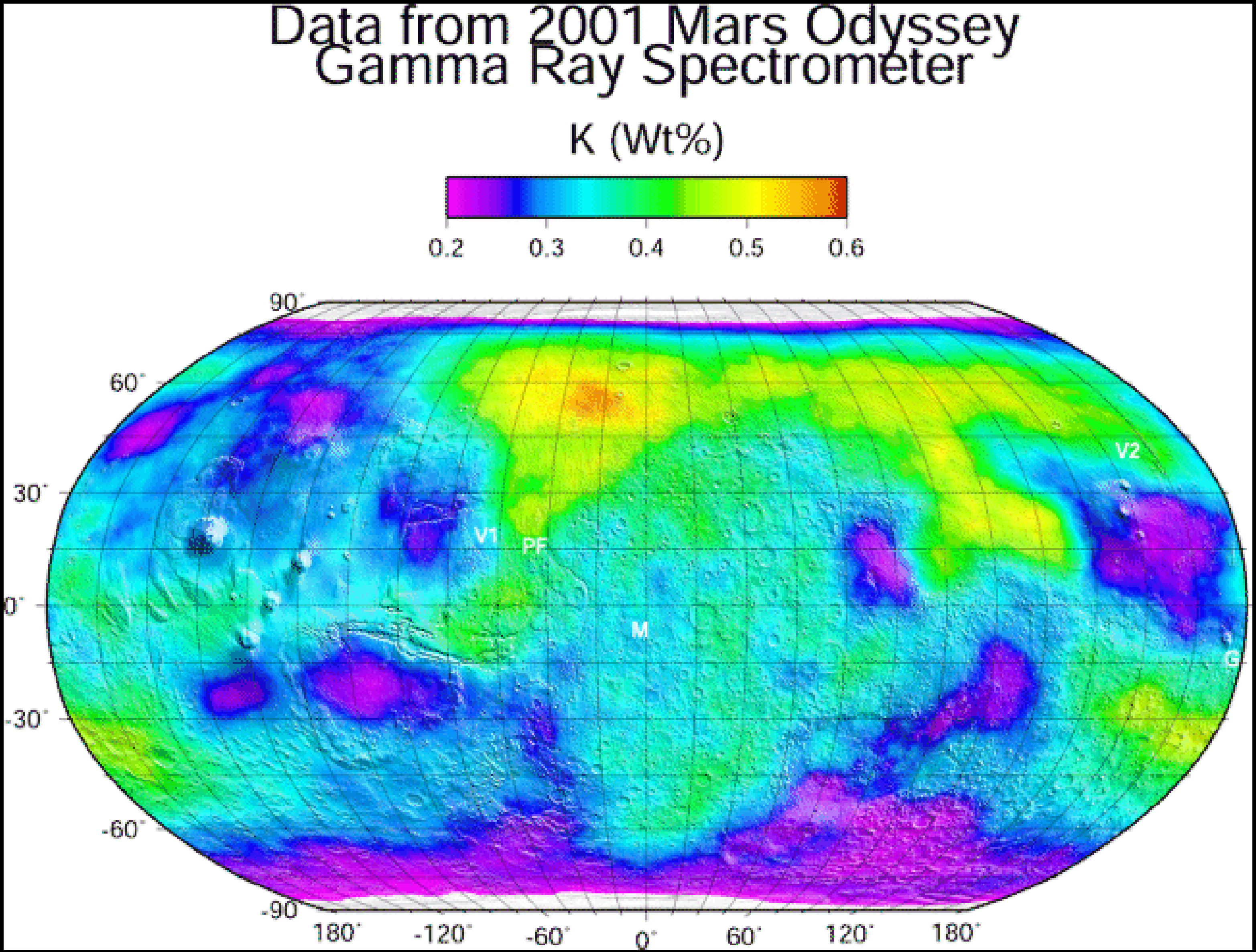


Neutron and Gamma Ray Production

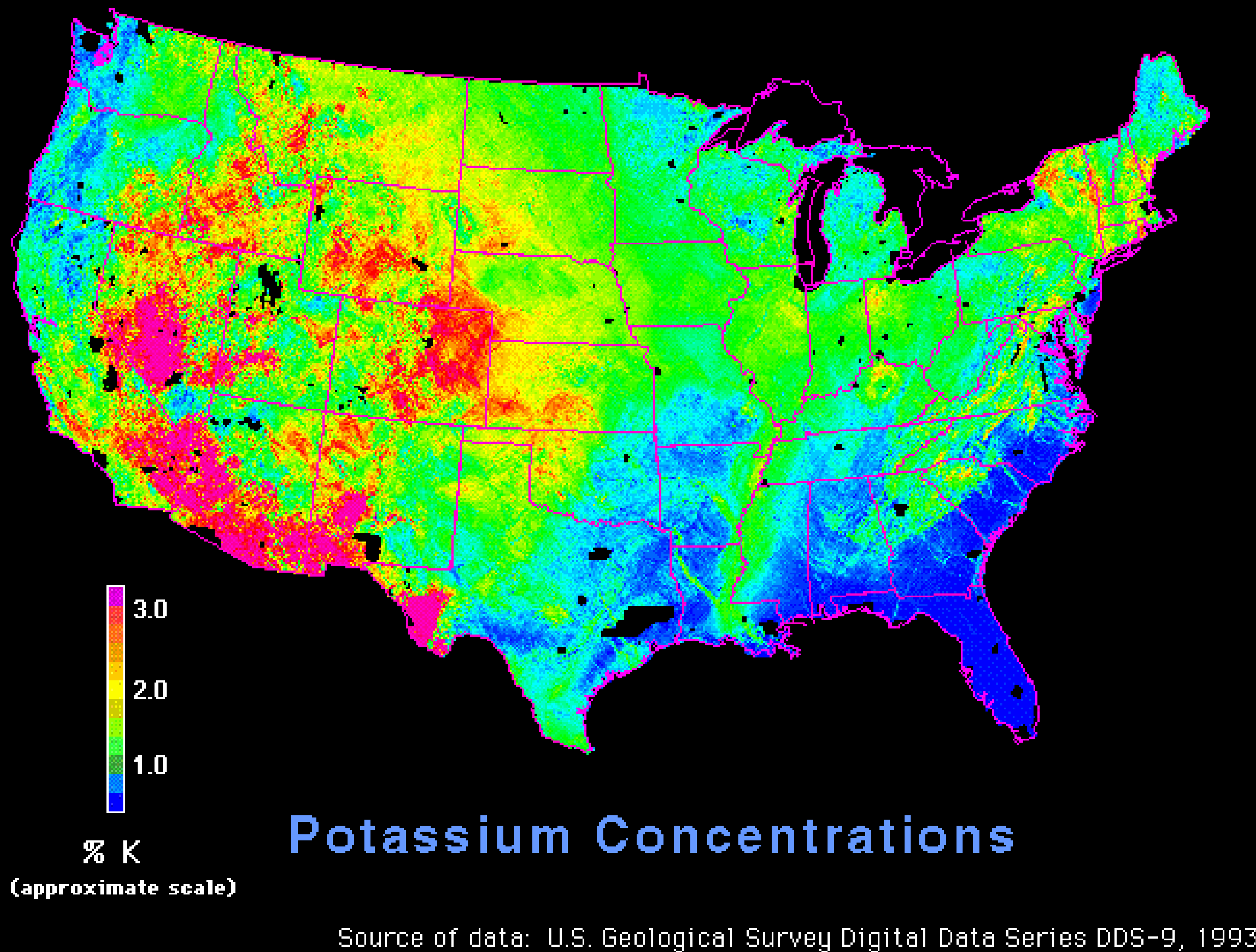


http://grs.lpl.arizona.edu/

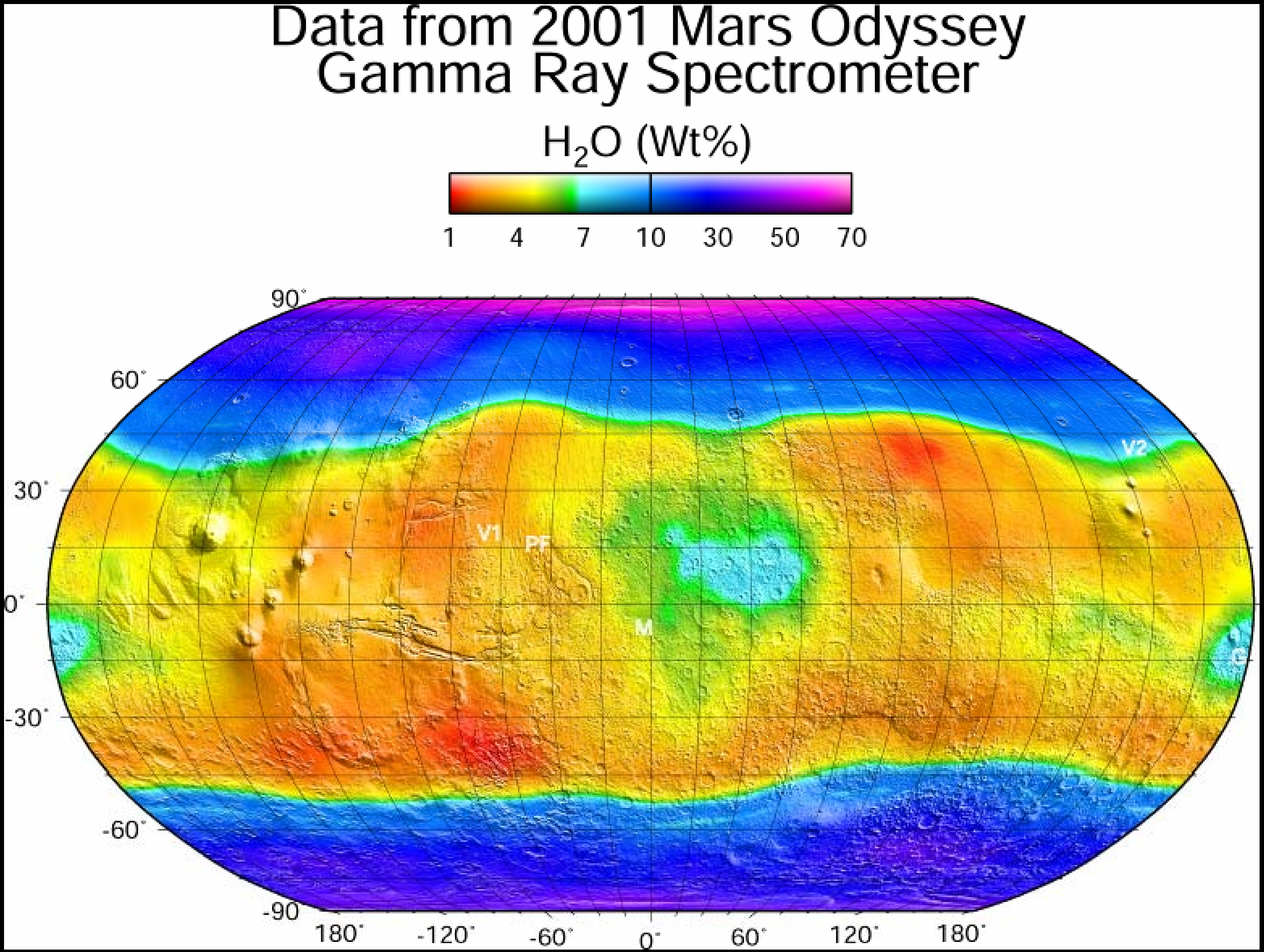
Potassium Map of Mars



Potassium Map of the US



Water Map of Mars

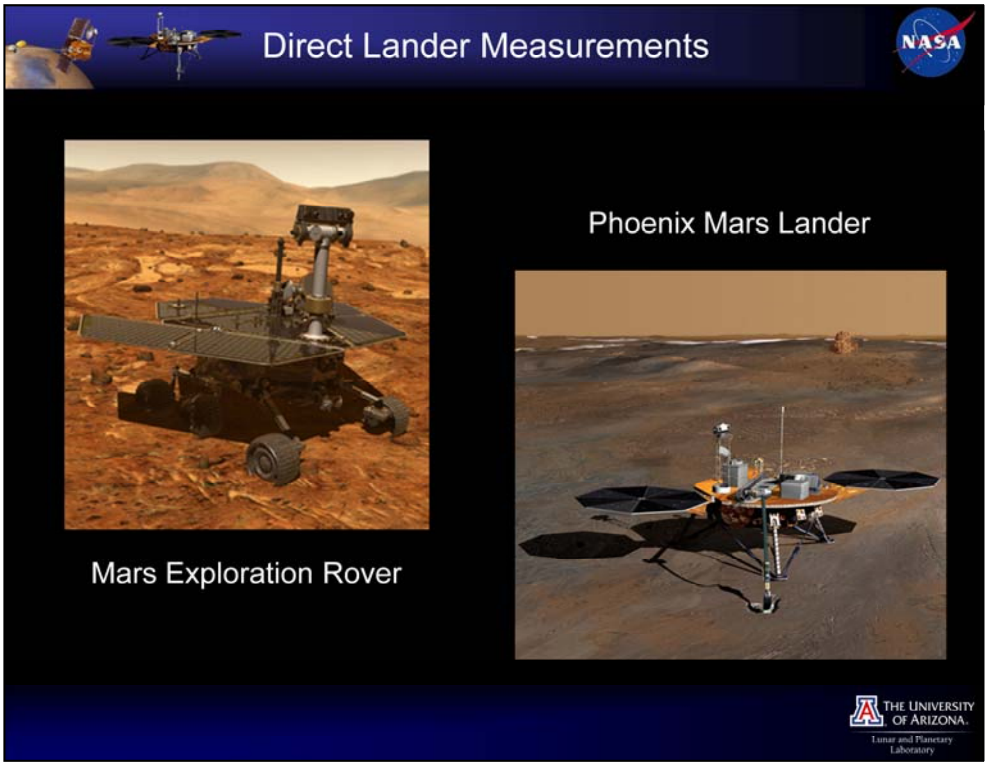


Water on Mars

THE UNIVERSITY OF ARIZONA
Lunar and Planetary Laboratory

Remote Sensing with Gamma Rays

Objective: To introduce the difference between direct lander measurements and remote sensing and discuss the concept of gamma ray production at the surface of a planet. These slides can be used to provide context for students using the computer simulation of gamma ray production.

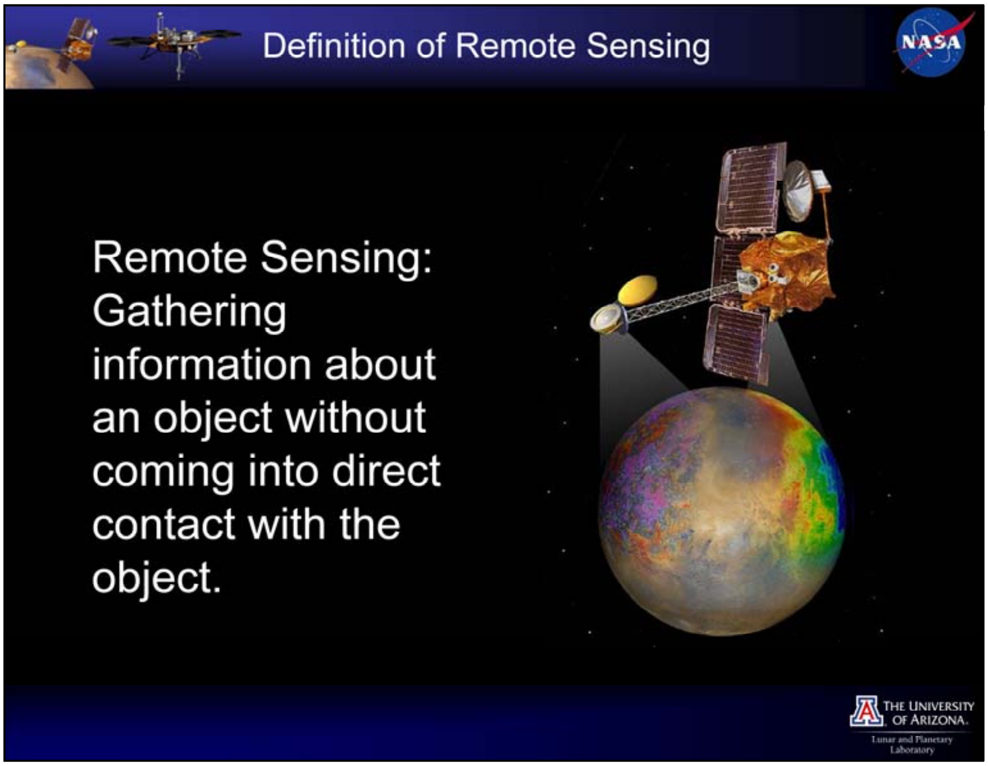


•One way to study other planets is to send landers to the surface to conduct experiments.

•This type of investigation is often called an “in situ” experiment.

•While you precise and detailed measurements can be made in situ, the area covered by a rover or a lander is very limited compared to the overall size of the planet.

•The slide shows artists conceptions of the Mars Exploration Rover and the Phoenix Mars Landers on the surface of Mars.

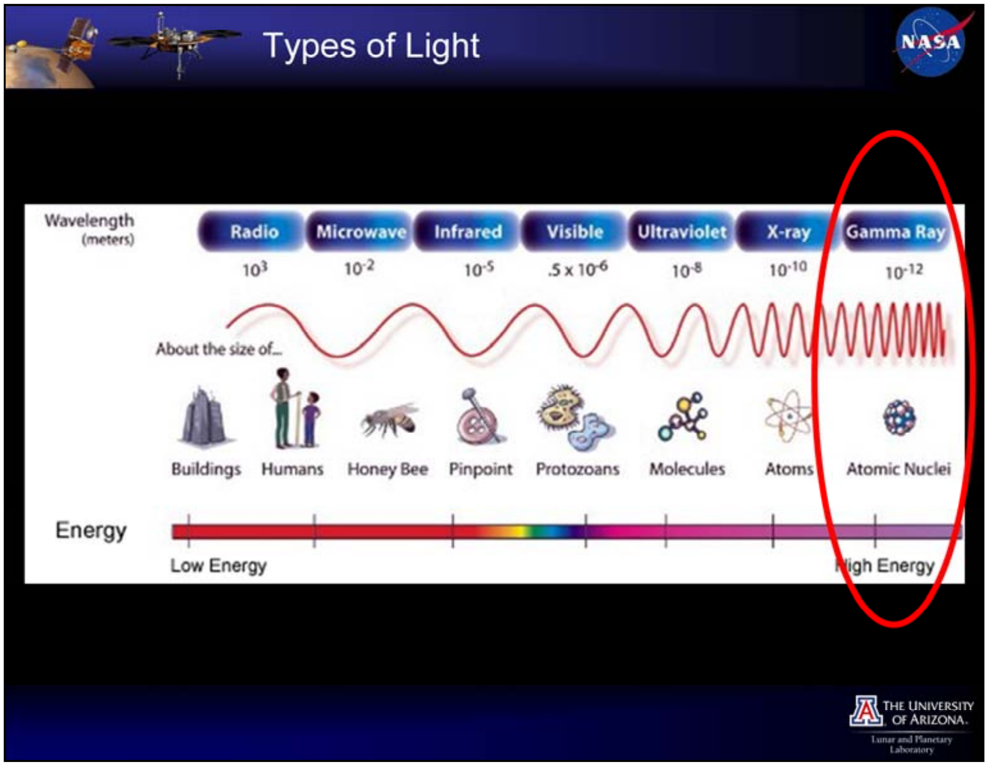


•A second technique for studying planets is called “remote sensing.”

•This involves the use of energy and particles coming from a planetary body to learn about that object, even though you are not in direct contact with it.

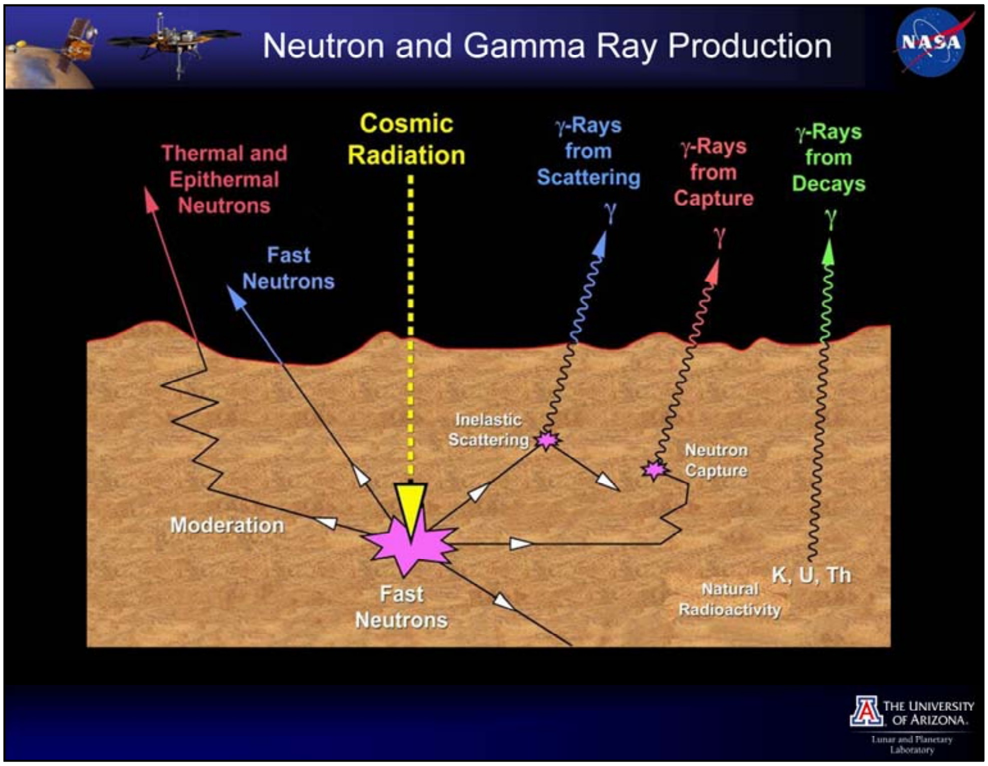
•One advantage of remote sensing is that you can gather data from a larger portion of the planetary object, even though resolution is not as good as with a lander mission.

•The image shows the 2001 Mars Odyssey spacecraft which collects infrared, visible, and gamma ray light coming from the surface of Mars to study the chemistry of the near-surface of Mars.



•Use this image to explain to students that there are different energies of light and that we can learn different things from each.

•This extension activity focuses on the use of the gamma ray light to do remote sensing of planetary surfaces.

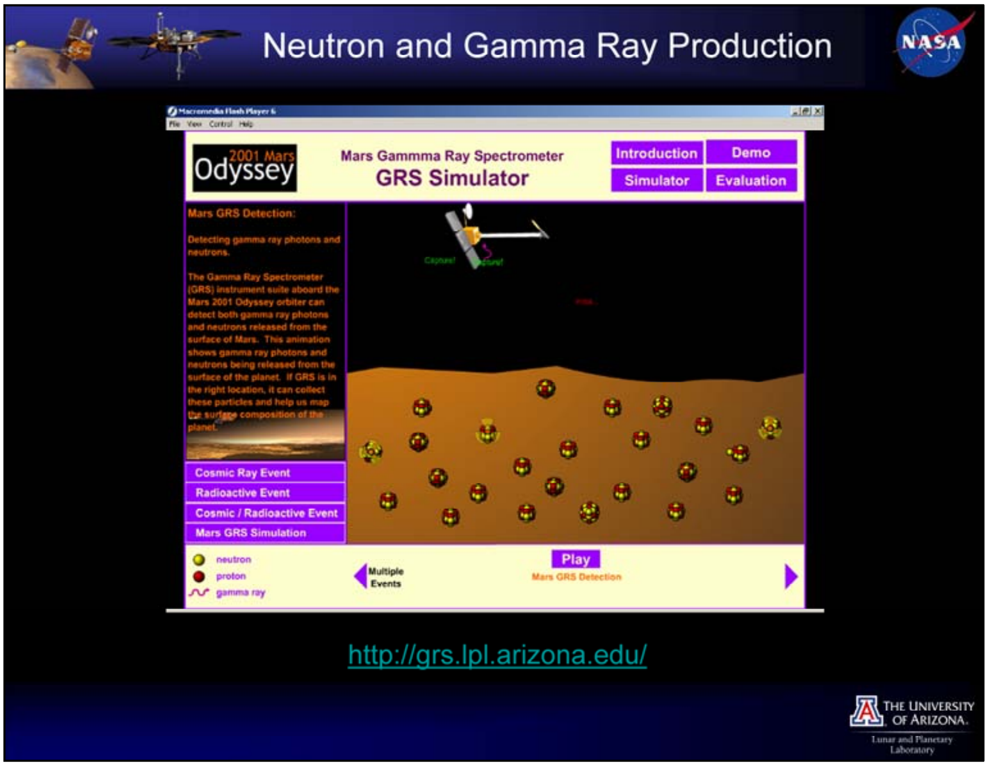


•This slide provides an overview of the processes that produce gamma rays at the surface of a planet.

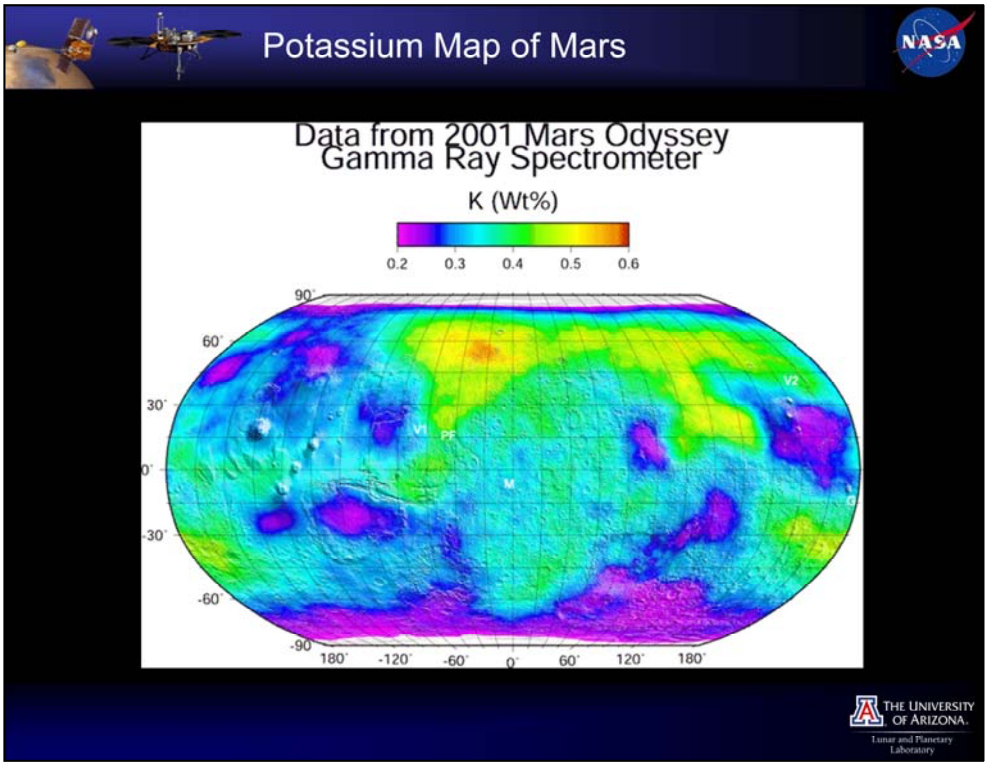
•In addition to decay of naturally radioactive elements like K (potassium), U (uranium), and Th (thorium), gamma rays are produced when neutrons collide with and are captured by atoms.

•These neutrons are generated when cosmic radiation in the form of fast moving hydrogen and helium atoms smash into the surface of Mars.

•The computer simulation used in this extension will explore each of these processes in more detail.

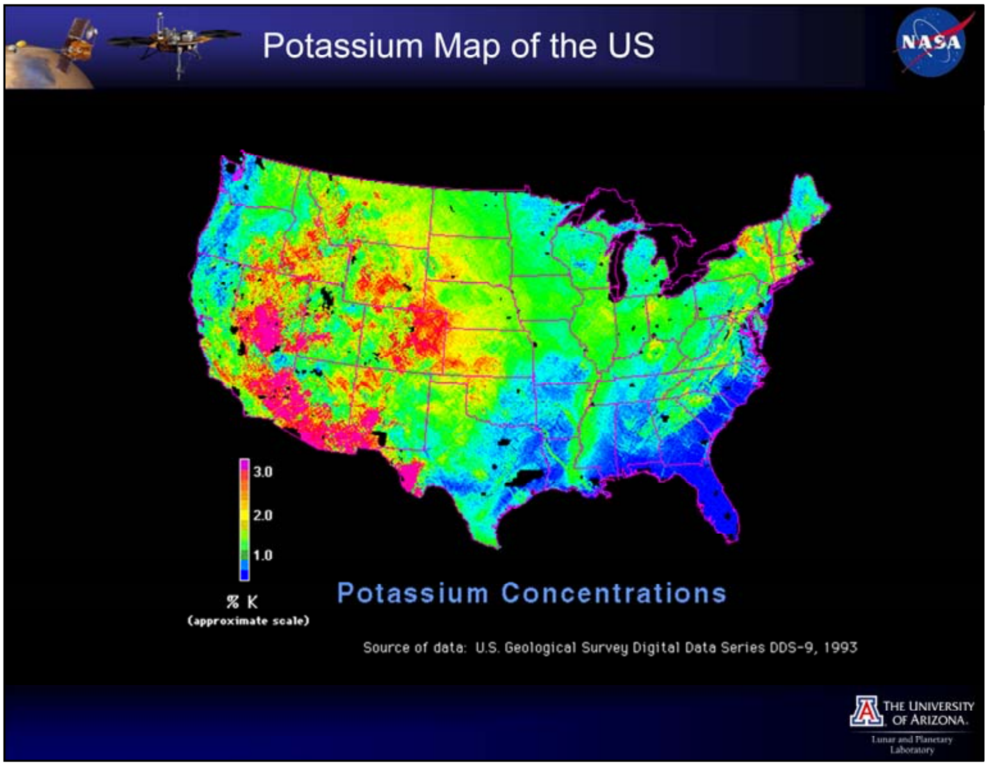


•Use this slide to transition to the computer simulation activity.



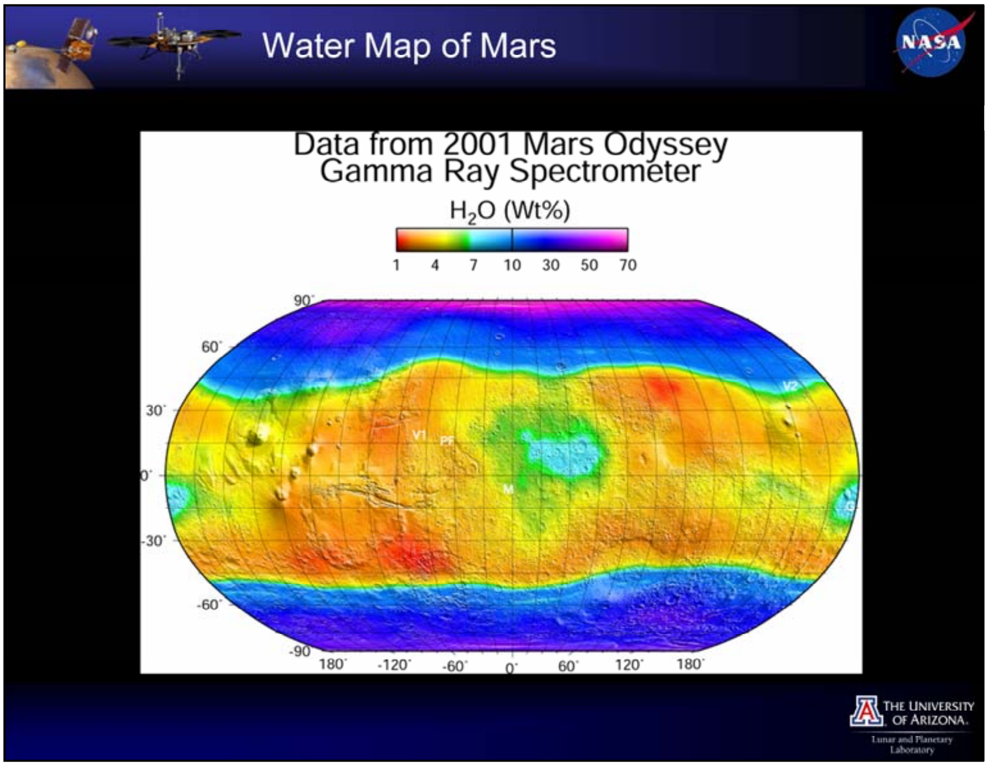
•Because different chemical elements give off different energies of gamma rays, we can map the composition of certain elements at the near-surface of Mars based upon the number and energy of gamma rays detected.

•This map shows the concentration of the radioactive element potassium (K) mapped by Mars GRS.

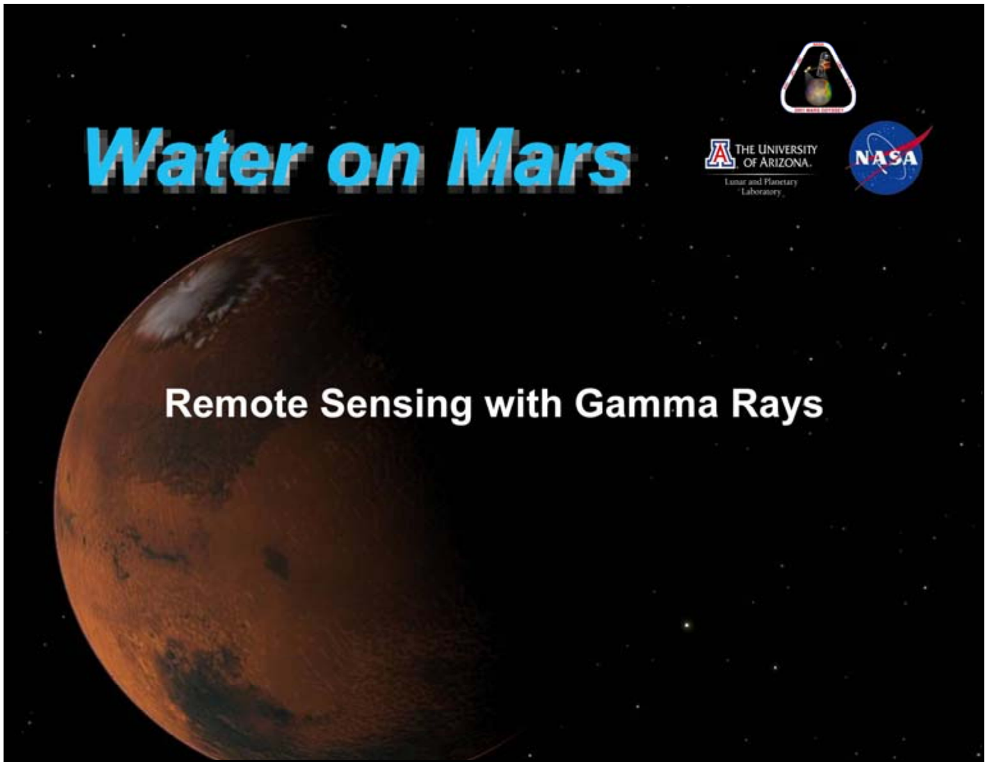


•This map shows a comparison between the previous GRS map of Mars and a gamma ray survey conducted over the United States using aircraft.

•Notice from the difference in the scale bar between this image and the previous concentration map for Mars that there is more potassium in continental rocks on Earth than in rocks on Mars.



- This map shows the concentration of water on the surface of Mars.
- This map was made using gamma rays given off by the atom hydrogen.
- Notice that there is a much higher hydrogen signal coming from the high latitude regions of the planet than from the equator.
- This is due to the presence of water ice buried near the surface in these colder regions.


Water on Mars
THE UNIVERSITY OF ARIZONA.
Lunar and Planetary Laboratory
NASA
Remote Sensing with Gamma Rays