



# Mars Image Analysis Extension Teacher Guide



## Water Ice Map of Mars

### Teacher Introduction:

In the Mars Image Analysis Activity (<http://msip.asu.edu/curriculum.html>), students use high-resolution visual images of Mars taken with the Thermal Emission Imaging System (THEMIS) aboard the *Mars Odyssey* spacecraft to make observations and study aspects of Martian geology. The extension activity described below incorporates additional Mars data collected by the Mars Gamma Ray Spectrometer (GRS), a second instrument aboard the same spacecraft. Using GRS data, we have been able to measure the abundances of various elements such as hydrogen, silicon, iron, and potassium near the surface of Mars. One of the most exciting discoveries is that large amounts of water ice appear to be buried in the regions surrounding the north and south poles of Mars. As the spacecraft flies over the exposed poles, it has detected a very

high hydrogen gamma ray signal interpreted to be due to this buried water ice.

In this extension activity, students are provided with a global map showing where the presumed water ice is located. Students use the global water ice map as context for analyzing and interpreting the THEMIS images used in the Mars Image Analysis Activity. While several of the THEMIS images show evidence for liquid water flowing on the surface of the planet in the past, the GRS water ice map shows where presumed frozen water ice deposits are present today on the cold surface of Mars. Students use the water ice maps as an additional tool for interpreting the geology of the regions on Mars and evaluating the prospects for exploring these regions in the future.

---

### Objective:

Students use an additional dataset from Mars to gain a better understanding of the nature of the shallow subsurface of the planet.

**Suggested Grade Level:** 5<sup>th</sup>-12<sup>th</sup> grade

**Time Frame:** 10-30 minutes for extension

### Materials Needed per Group (4 students per group):

- GRS map of water ice (For this map, go to the download link at <http://grs.lpl.arizona.edu> and access the GRS water ice map JPG.)
- Materials from Mars Image Analysis activity <http://msip.asu.edu/curriculum.html>

### National Science Education Standards:

**Content Standard A:** As a result of their activities, all students should develop the abilities necessary to do scientific inquiry:

- 1) Identify questions that can be answered through scientific investigations.
- 2) Conduct a scientific investigation.
- 3) Use appropriate tools to analyze and interpret data.
- 4) Develop descriptions and explanations using evidence.
- 5) Think critically and logically to make relationships between evidence and



- 
- explanations.
- 6) Communicate scientific procedures and explanations.

**Content Standard D:** As a result of their activities, all students should develop an understanding of:

- 1) Structure of the Earth system.
- 2) Earth in the solar system

**Content Standard G:** As a result of their activities, all students should develop an understanding of:

- 1) The nature of science

**Background Information on Global Water Ice Map:** (to be shared with students by teacher)

The global water ice map provided in this extension was created using data from the Mars Gamma Ray Spectrometer (GRS), an instrument aboard the *Mars Odyssey* spacecraft. This instrument collects gamma ray photons (which are extremely high energy particles of light) given off by the surface of Mars. These gamma ray photons result from two different processes: 1) the decay of naturally radioactive elements such as potassium, thorium, and uranium at the surface of Mars, and 2) interactions with high energy neutrons given off when cosmic ray particles (high speed hydrogen and helium nuclei from outer space) bombard the surface of the planet. Because different atoms at the surface of Mars give off gamma ray photons with different energies, scientists have been able to map the location of various elements on the planet based upon the energies of gamma ray photons detected by the GRS instrument in orbit around Mars. This is another example of remote sensing.

One of the elements detected by GRS is hydrogen. Whenever *Mars Odyssey* orbits over the exposed poles of Mars, GRS has detected an increase in the number of gamma ray photons with an energy specific to hydrogen (2.223 MeV or million electron-Volts). Scientists believe that this is because there are large amounts of water ice (H<sub>2</sub>O) buried near the surface at the poles. By

using the gamma ray photons detected by GRS and assuming the hydrogen signal is due to the presence of water ice, scientists have been able to map the global distribution of water ice buried within the upper few tens of centimeters of the surface of the planet. (NOTE: The Martian poles experience seasons just like on Earth. During the winter months, a given pole is covered in a layer of carbon dioxide ice that can be over a meter thick. GRS detects gamma ray photons unique to hydrogen during the remaining months when the exposed pole is not covered by CO<sub>2</sub>. The map provided here represents “frost-free” data collected during times when no winter carbon dioxide ice was present to obscure a given pole.)

The GRS map provided in this extension is a “false-color” map in which different colors represent different concentrations of water ice detected by GRS. Regions of high water ice content are shown using the colors of dark blue and violet. These regions are located poleward (i.e., in the direction of the poles) of 60 degrees latitude in both the northern and southern hemispheres. Drier regions with little to no water ice content are shown using the colors red, orange, and yellow. Because it is too warm for water ice to be stable near the Martian equator, the two light blue regions found near the equator of Mars likely indicate the presence



---

of hydrated, or water-bearing, minerals that have been altered by water at some time in the past. Hydrated minerals such as clays and sulfates are minerals containing bound water (H<sub>2</sub>O) molecules and/or hydroxide (OH<sup>-</sup>) ions. It is less likely that these blue regions are due to the presence of buried water ice because ice at the warmer equator would likely evaporate. By comparing the color shown on the map with the color scale bar found above the map, students can determine whether a region of Mars has a high or low hydrogen signal. Regions of high hydrogen towards the poles are likely due to buried water ice. Regions of high hydrogen around the equator are likely due

to water bearing minerals. For context, the map also shows shaded-relief elevation data from the Mars Orbiter Laser Altimeter (MOLA), highlighting topographic features on Mars such as impact craters, volcanoes, and canyons.

While the presence of buried water ice on Mars was predicted prior to 2001, the GRS instrument provides the first direct detection because it is sensitive to hydrogen within the upper few tens of centimeters of the surface. Prior Mars missions have been able to remotely sense only the very top surface of Mars and could not detect ice buried by a thin layer of dry soil in the high latitude regions.

---

### Procedure:

The GRS water ice map can be presented to students as an extension activity after they have completed the Mars Image Analysis activity (<http://msip.asu.edu/curriculum.html>). This provides an opportunity to highlight additional information that the GRS data provides.

- 1) After completing the Mars Image Analysis Activity (<http://msip.asu.edu/curriculum.html>), pass out the GRS water ice map and the student worksheet titled “Mars Image Analysis Extension: Part VI – Analyzing Water Ice Map.” Share the background information provided above with the students. Explain how to interpret the false color map. The GRS water ice map shows regions of low water ice near the surface in red colors and regions of high water ice near the surface in dark blue and violet colors. Because water ice is not stable at the surface near the Martian equator where temperatures are warmer, the two light blue regions found near the equator likely indicate the presence of hydrated minerals that have been altered by water at some time in the past. Discuss with students which regions of Mars currently have more and less water ice near the surface and possible explanations. Water ice is more stable towards the poles because of colder temperatures there.
- 2) Ask students to find the location of their THEMIS image on the GRS water map and determine if it is currently in a region that has high or low water ice content or hydrated minerals near the surface. Note that the GRS instrument is sensitive to water ice within the upper few tens of centimeters of the surface of the planet. Note also that large features such as river channels, mountains, impact craters, fractures, and lava flows appear in the THEMIS images. We can infer information about deeper materials from these images.
- 3) Ask students to re-evaluate their landing site in light of this new information. Does this change their interpretation of the surface or their evaluation of the landing site in any way? Would you expect to find water ice near the surface at the landing site? Would this be beneficial from a science perspective? From an engineering perspective?



---

**Assessment:**

- 1) Student work can be assessed using completed tasks from Student Worksheet.
- 2) Students can present their findings regarding the distribution of water within the top meter of the Martian surface and describe the water ice concentration corresponding to their THEMIS image. They can discuss whether they would expect to find dry soil, water ice, water-bearing minerals at their site.

DRAFT



---

## Student Worksheet – Mars Image Analysis Extension

### Part VI – Analyzing Water Ice Map

In addition to taking visible images of Mars, the *2001 Mars Odyssey* spacecraft has mapped chemicals found near the surface of the planet. Using a gamma ray detector on the spacecraft, scientists have mapped the estimated abundance of water ice. This water ice is buried close to the surface of the planet. It is too cold for liquid water to be stable at the surface today. However, buried water ice is stable and has been found at the Martian poles.

In the Landing Site Evaluation activity, you used visible images to evaluate a location on Mars. You will now use a global of the estimated abundance of water ice map to re-evaluate this location. On the map, regions of high hydrogen concentration are dark blue and violet. Dry regions of the planet are red. The light blue regions near the equator probably have minerals that have been altered by liquid water in the past but do not contain water ice currently. These minerals may include clays and sulfates.

#### What to do:

- 1) Where is most of the water ice currently located on the surface of Mars – near the equator, near the poles, or somewhere else? Explain your reasoning.

*Most of the water ice is located near the poles. The map is dark blue poleward of ~45-degree latitude. The buried water ice is stable in these areas where it is colder.*

- 2) Find the location of your THEMIS image on the water ice map. Is it in a dry region, a region with lots of water ice, or a region with minerals from past liquid water?

*Answers will vary depending upon the location of the THEMIS image. High latitude regions contain lots of water ice. Equatorial regions are typically dryer, although two blue sections on the map probably represent areas with minerals which were formed due to the presence of liquid water in the past.*

- 3) Does the water ice map match your observations regarding clues of liquid water at this location in the past? Why or why not?

*Answers will vary. Students may find THEMIS images showing evidence for liquid water (ancient river channels, gullies) in regions that are very dry based upon the water ice map. This is because the water ice map reflects water content within the upper tens of centimeters of the surface. Most of the equatorial surface is dry because water ice is not stable in these warmer regions, even though there was obviously liquid water there at some point in the past. Even if there were liquid water present at the surface for a short time before it evaporated, the water would not be detectable to GRS if it covered only a small area. Other regions may be rich in water ice but not show evidence of past liquid water. The water ice may have been deposited through snowfall in the past.*

- 4) Based upon the previous activity and the global water ice map, would this area of Mars be an interesting landing site for scientific reasons? Would you expect to find water ice reserves that you could use at the landing site? Why or why not?

*Answers will vary. The location may be rich in water ice, which could be used as a fuel source or melted into usable liquid water.*





# Mars Image Analysis Extension Student Guide



## Student Worksheet – Mars Image Analysis Extension Part VI – Analyzing Water Ice Map

In addition to taking visible images of Mars, the *2001 Mars Odyssey* spacecraft has mapped chemicals found near the surface of the planet. Using a gamma ray detector on the spacecraft, scientists have mapped the estimated abundance of water ice. This water ice is buried close to the surface of the planet. It is too cold for liquid water to be stable at the surface today. However, buried water ice is stable and has been found at the Martian poles.

In the Landing Site Evaluation activity, you used visible images to evaluate a location on Mars. You will now use a global of the estimated abundance of water ice map to re-evaluate this location. On the map, regions of high hydrogen concentration are dark blue and violet. Dry regions of the planet are red. The light blue regions near the equator probably have minerals that have been altered by liquid water in the past but do not contain water ice currently. These minerals may include clays and sulfates.

### What to do:

- 1) Where is most of the water ice currently located on the surface of Mars – near the equator, near the poles, or somewhere else? Explain your reasoning.
- 2) Find the location of your THEMIS image on the water ice map. Is it in a dry region, a region with lots of water ice, or a region with minerals from past liquid water?
- 3) Does the water ice map match your observations regarding clues of liquid water at this location in the past? Why or why not?
- 4) Based upon the previous activity and the global water ice map, would this area of Mars be an interesting landing site for scientific reasons? Would you expect to find water ice reserves that you could use at the landing site? Why or why not?

