Lunar Reconnaissance Orbiter: (LROC)

Audience
Grades 6-8

Time Recommended
5-60 Minutes (Two Class Periods)

AAAS STANDARDS
- 1B/1: Scientific investigations usually involve the collection of relevant evidence, the use of logical reasoning, and the application of imagination in devising hypotheses and explanations to make sense of the collected evidence.
- 11B/M3: Different models can be used to represent the same thing. What model to use depends on its purpose.

NSES STANDARDS
Content Standard A (5-8): Abilities necessary to do scientific inquiry:

c. Use appropriate tools to gather, analyze and interpret data.

d. Develop descriptions and explanations using evidence.

e. Think critically and logically to make relationships between evidence and explanations.

Content Standard E (5-8): Understandings about Science and Technology:

b. Technology is essential to science, because it provides instruments and techniques that enable observations of objects and phenomena that are otherwise unobservable due to factors such as quantity, distance, location, size, and speed. Technology also provides tools for investigations, inquiry, and analysis.

MATERIALS
- Image of the near side of the Moon
- Space shuttle image (transparency)
- Space shuttle model
- Visible light images of possible landing sites (camera angle 0 and with a known sun angle, preferably lower than 30 degrees)
  - » (Moscoviense #1, Humboldtianum #1, Goddard #1, and Reiner #1) (attached)
- Color relief (topographical) images of the same possible landing sites (Moscoviese #3, Humboldtianum #3, Goddard #3, and Reiner #3) (attached)
- Rulers
- Calculators
- Clay, Play-Doh or another material
- 1 shallow tray/paper plate per group
- Sealable bag to fit over tray/plate and model
- Rolling pin
- Object for making indentations in clay or Play-Doh
- Wax paper
- Digital cameras (if available)
- Flashlights
- Making a Model Day 1 and Day 2 reflection worksheets (attached)

Making a 3D Model of the Moon's Surface

Learning Objectives:

- Students will make estimates about the relative height/ depth of objects from images.
- Students will use the relationship between sun angle and shadow to determine the actual height of objects from images.
- Students will use the color representations on an image to determine the height and depth of objects.
- Students will create a 3D model using a 2D image and evaluate its accuracy

Students will explore the ways 2D images from the LRO mission can help us to understand the topography of the lunar surface. In groups, students will create models that will help them determine what makes a safe lunar landing site.

Preparation:

Fill trays with modeling material and level them off with the rolling pin so each group can start with a uniformly sized, flat surface. Reserve some modeling material for each group to use to add material to their model.

Procedure:

DAY 1

Show students an image of a space shuttle (transparency). What can we learn about the object in the image from looking at it? What information are we lacking? What additional information could we learn from a 3D model of the space shuttle? Show the students a 3D model of the space shuttle. What can we learn about the space shuttle from looking at the model? Discuss similarities/ differences.

When would you use each one? Is one better than the other? To understand more about the images we are getting from the Moon, it will help us to look at a model of the Moon. The images can help us create that model and making such a model will help us understand more about the image. The first day of this activity will prepare students to examine shadows as a tool for determining the altitude of features on the Moon on day two.

1. Explore the types of features that we would expect to see on the Moon. Ask students to share ideas. Teachers, browse this website http://lroc.sese.asu.edu/news/index.php?/categories/2-Featured-Image for detailed images of features on the surface of the Moon.

2. Explain that the Lunar Reconnaissance Orbiter Camera (LROC) is one tool on the Lunar Reconnaissance Orbiter (LRO). It is taking very high-resolution images of the Moon so we can learn more about the surface of the Moon. Teachers, for more background information about LRO and LROC visit: http://lroc.sese.asu.edu/EPO/LROC/lroc.php?pg=what

3. Distribute visible light images (#1 image of one of the regions) of the Moon and put up a transparency of a visible light image up to help with discussion. How can we tell what the surface of this area is like from this image? Students should mention placement of features, relative sizes, etc.

4. Ask them about the height and depth of features in the image. Is there any way we can determine the height or the depth of the features? Help students understand ways we can figure this out. In this image, we can make estimates by examining the shadows. Point out the shadows in the images and ask students to describe what is causing these shadows. Do all of the features make the same size shadow? How does the size of the shadow give us information about the size of a feature? As mentioned above, day two will examine this concept in more detail. At this point, students should just be thinking about this idea.

5. Explain that groups will work to create a 3D model of an image of the Moon. What will help us make these shapes? Introduce modeling materials.

6. Remind students to think about relative scale of height/depth and distances.

7. Remind students about what shadows can tell us about height. Groups will be given a flashlight to help them evaluate and revise their models.

8. Divide students into small groups (about four) and distribute the "Making a Model Day 1" worksheets. In each group of four, students can take on the following roles:

    a. **Materials Manager** (keep track of the different items used to manipulate the modeling material and use the camera to take an picture of the model),
    b. **Flashlight Monitor** (adjust and hold the flashlight based on feedback from the group)
    c. **Timekeeper** (watch the time and keep the group on task)
    d. **Reporter** (record and report group members' comments about the model using the student worksheet).

    All members of the group are responsible for manipulating the modeling material and comparing the model to the image in order to create an accurate model.

9. Students should work as a team for 15-20 minutes to create their model based on their respective image. As students are working on their models, dim the lights and allow students to explore the way the position of the light source affects the shadows. Can they find a position where the shadows on their model match the ones in their image? Are their features the correct height/ depth? Remind students that for the Moon, the light source is the Sun. As the Moon orbits Earth, and the Earth orbits the Sun, the shadows change. Students should continue to revise their model to best represent their image.

10. If digital cameras are available, challenge students to take a picture of their model that matches their image. Students should continue to revise their models to reflect what they have learned from the shadows and camera images. Ask them to think about how flashlight and camera position effect the way their model looks.

11. With 5-10 minutes left in class, ask students to stop working on their models and complete the "Making a Model Day 1" reflection questions. Collect student responses. Students should put their model in a sealable bag (keeps fresh) so they are able to continue revisions on day two.

DAY 2

1. Redistribute “Making a Model Day 1” sheets and visible light images (#1 image of one of the lunar regions) to students to guide review of the previous day’s work. Have students share their reflections from the previous day specifically focusing on additional information that would be helpful. If students do not bring it up on their own, ask them to think about how confident they are about the heights and depths of the features in their model. Did they make them the right height/ depth?

2. Ask the students to think back on their experiences with the flashlight. What did the flashlight represent? How did its position affect the shadows? Have the students think about the way that shadows change on Earth over the course of a day. You can demonstrate this by dimming the lights and asking a volunteer to stand. Move the flashlight to approximate the position of the Sun at different points in the day as seen from Earth. Students should see the shadow length changes depending on the angle of the Sun in the sky. This works the same way on the Moon.

3. Explain to students that if we know the Sun’s angle and the length of the shadow, we can use ratios to determine the height of the feature making the shadow. This process can be used to determine the heights and depths of each of the features on the Moon (see the Extension Activities section for suggestions on investigating this in more depth). Once we determine the heights and depths of features, we can create other kinds of images.

4. Distribute the color relief (topographical) #3 image of the same region as before to each group and put up a transparency of the Moscoviense Region #3 (topographical) color relief image to help with discussion. Ask students to share what they can learn from this lunar image. Make sure students understand on this image elevation is represented by the variant colors. These colors are added to the image to represent height and depth. The Moon is not really this colorful. To determine the colors, the image/ map-makers figured out the height of the features using the information they had about the Sun’s angle and the shadow lengths.

5. Explain to students these images are based on data from a different instrument on the Lunar Reconnaissance Orbiter (LRO) spacecraft called the Lunar Orbiter Laser Altimeter (LOLA). This instrument uses laser technology to determine the height and depths of features on the surface of the Moon. Teachers, if you would like more background information on LOLA, check out http://lunar.gsfc.nasa.gov/lola

6. Ask the students to find the colors on the image that represent a certain range of height and depth. What is the range that is represented? The range of elevations on the Moon is very similar to the range on Earth. The height of mountains on Earth is similar to the high points on the Moon. The depths of the ocean floors on Earth are similar to the depths of the deepest places on the Moon.

7. To model how high and deep these features are, use blocks, drawings or meter sticks. To help students understand a kilometer, use the Willis (Sears) Tower in Chicago as an example. The Willis Tower is 315 m (.315 km) tall. Three Willis Towers stacked on top of each other would be about 1 km (.945 km) tall.

8. Use the information on the next page to help students understand how high and deep the colors are compared to the average surface level of the Moon. This average surface level on the Moon is similar to sea level on Earth. Have students determine what color that object would relate to based on the color scale from their #3 image. **Note: The color scale for each region’s color relief (topographical), or #3 image, is different. Make sure students use the scale particular to their respective image when referencing it for the activity.**

Location	Height
Chicago	.179 km above sea level
Mt. St. Helens	2.6 km above sea level
Mt. Everest (highest elevation on Earth)	8.8 km above sea level
Grand Canyon	1.6 km above sea level
Puerto Rico Trench (deepest part of the Atlantic Ocean)	8.6 km above sea level
Mariana Trench (deepest point in the Pacific Ocean and the deepest point on Earth)	Approximately 11 km below sea level

9. Using information from the color relief (topographical), or #3 image, ask students to return to their model and make revisions. They can continue to check their work using the flashlight.

10. If digital cameras are available, challenge students to take a picture of their model with the camera that matches the image they were working from. Students can make changes to improve their model.

11. Ask students to think about why scientists would still value methods of determining topography through observing shadows at various sun angles when we have more sophisticated technology like laser altimeters. The laser altimeter instruments, like LOLA, can get specific, absolute measurements only to a certain scale. Determining relative topography utilizing observations of shadows is still useful for high-resolution data or small scale features like what can be observed in the NAC images coming from the LROC instrument.

12. With 5-10 minutes left in class, ask students to stop working on their models and complete the “Making a Model Day 2” reflection questions. Collect student responses.

worksheet

MAKING A MODEL
Day 1

Names: ____

Materials Manager: keep track of the different items used to manipulate the modeling material and use the camera to take a picture of the model

Flashlight Monitor: adjust and hold the flashlight based on feedback from the group

Timekeeper: watch the time and keep the group on task

Reporter: record and report group members' comments on the model using the student worksheet.

All members of the group are responsible for manipulating the modeling material and comparing the model to the image in order to create an accurate model. With your group, complete the following steps:

1. Study your image.
2. Work with your group to decide who will work on which parts of your model and how you will represent the sizes of the features in your image.
3. Use the available tools and materials to create a 3D model of your image.
4. Use a flashlight to check your model by adjusting the light source.
5. Keep working with your image and model to represent things as accurately as you can.
6. Use a digital camera to take a picture of your model. Does the picture look like the original image?
7. If time allows, continue to improve your model.
8. Reflect on the 3D model your group has created by answering the following questions.

Questions:

What parts of your model do you feel are most accurate? Be sure to give specific examples and support your examples with evidence from your image and model.

What parts of your model do you want to improve? Be sure to give specific examples and support your examples with evidence from your image and model.

How could you make those improvements?

What tools or information could help you make a better model?

worksheet

MAKING A MODEL
Day 2

Names: ____

Materials Manager: keep track of the different items used to manipulate the modeling material and use the camera to take a picture of your model

Flashlight Monitor: adjust and hold the flashlight based on feedback from the group

Timekeeper: watch the time and keep the group on task

Reporter: record and report group members' comments on your model using the student worksheet.

All members of the group are responsible for manipulating the modeling material and comparing your model to your lunar image in order to create an accurate model. With your group, complete the following steps:

1. Study both of your images.
2. Use the available tools and materials to refine a 3D model of your area on the Moon.
3. Use a flashlight to check your model by adjusting the light source.
4. Keep working with your images and model to represent things as accurately as you can.
5. Use a digital camera to take a picture of your model. Does the picture look like the original image?
6. If time allows, continue to improve your model.
7. Reflect on the 3D model your group has created by answering the following questions.

Questions:

What parts of your model do you feel are most accurate? Be sure to give specific examples and support your examples with evidence from your image and model.

What parts of your model are not accurate? Be sure to give specific examples and support your examples with evidence from your image and model.

How could you make your model more accurate?

What tools or information could help you make a better model?

SUPPLEMENTAL IMAGES/ MATERIALS/ RESOURCES:

Teacher Scoring Guide

Assignment: Making a Model Day 1 and Day 2

Student Name(s): ____ Date: ___________

Performance Indicator	0	1	2	3	4
Students completed all questions in the assignment.					
All responses were clear, accurate and thorough.					
Students incorporated new information and evidence from what they have learned in their responses.					
Student responses show evidence of thinking critically about their models.					
Student responses show evidence of the creation of a protocol for representing specific features in their work.					
Student responses show evidence of using information from all available sources.					
Point Total					

Point total from above: _____/ (24 possible)

Grading Scale:

A = 22 - 24 points

B = 19 - 21 points

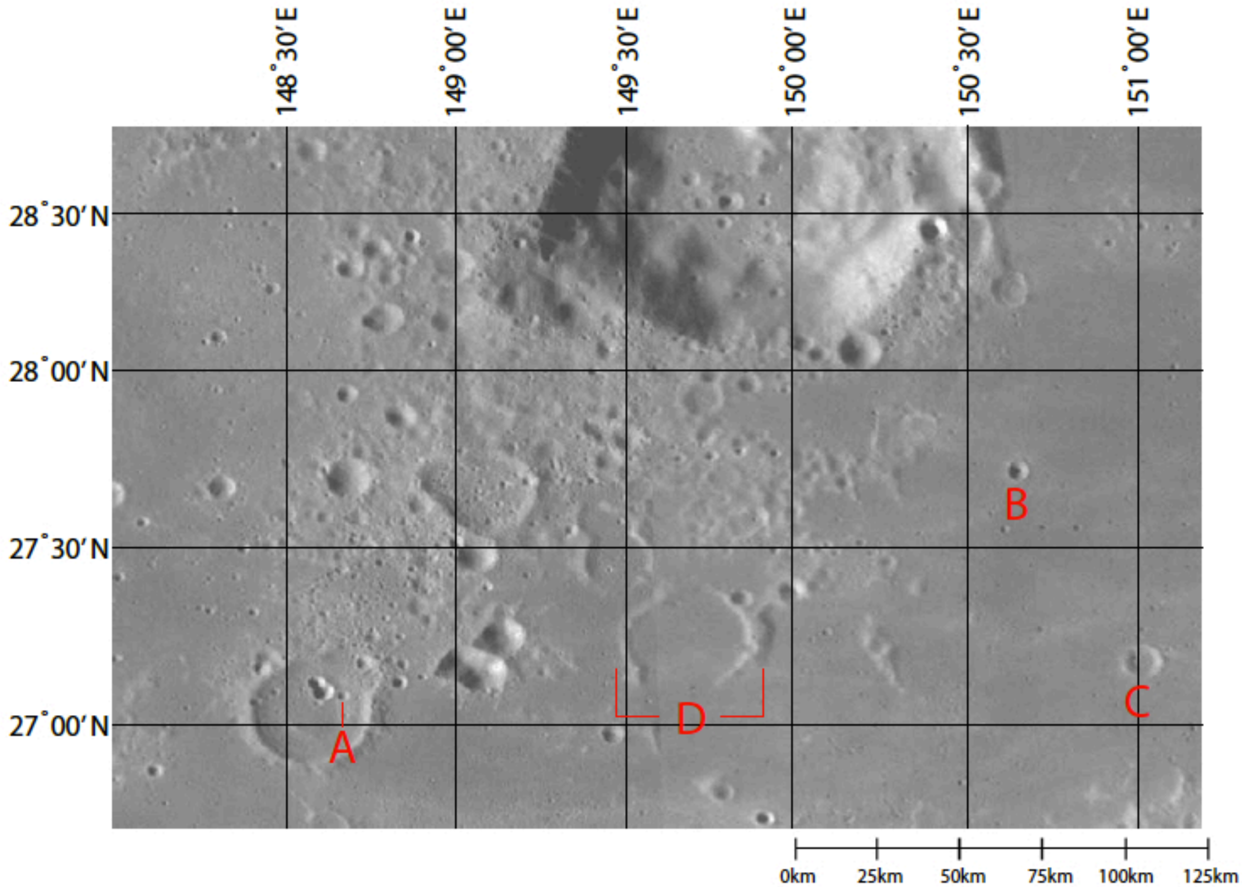
C = 16 - 18 points

D = 13 - 15 points

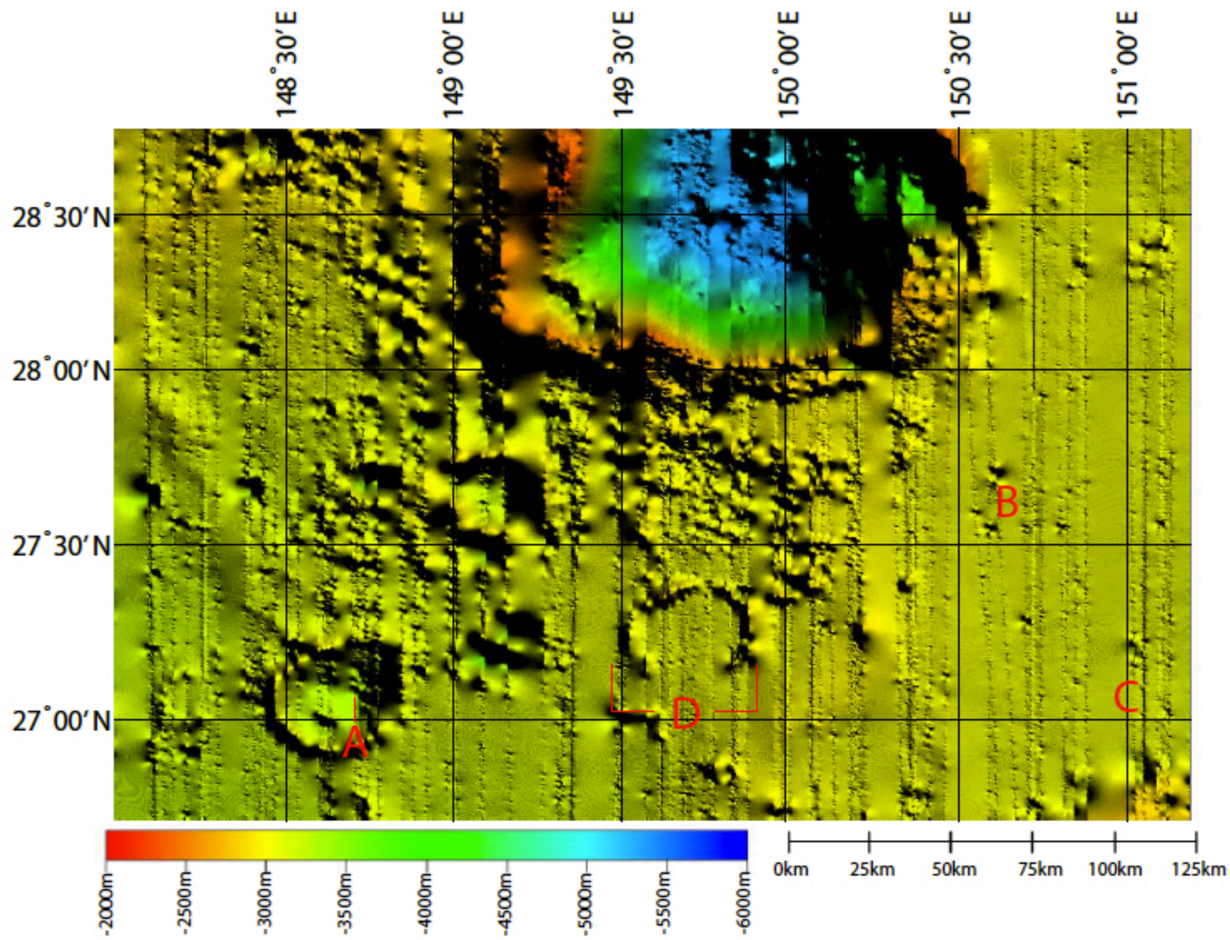
F = 0 - 12 points

Grade for this Assignment: _______________

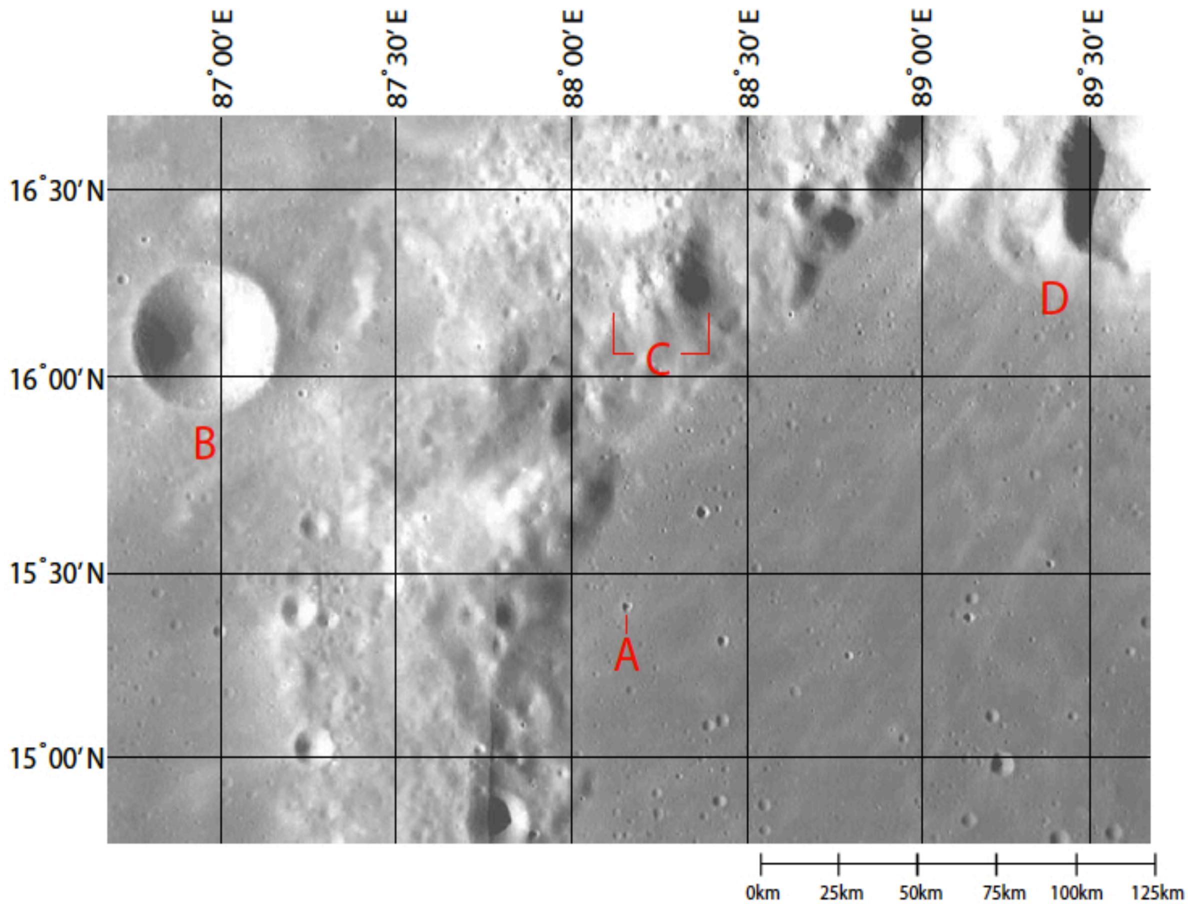
Moscoviense Region #1



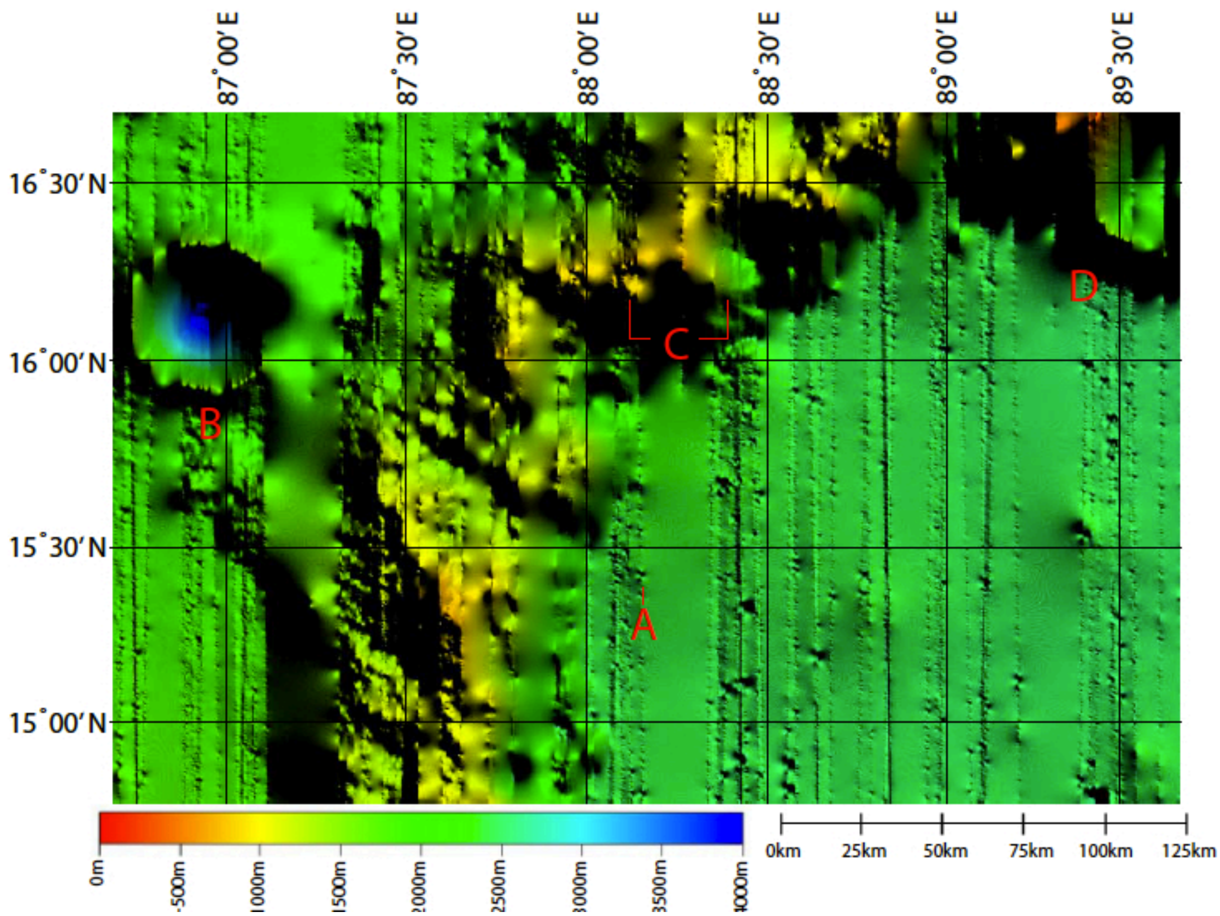
Moscoviense Region #3



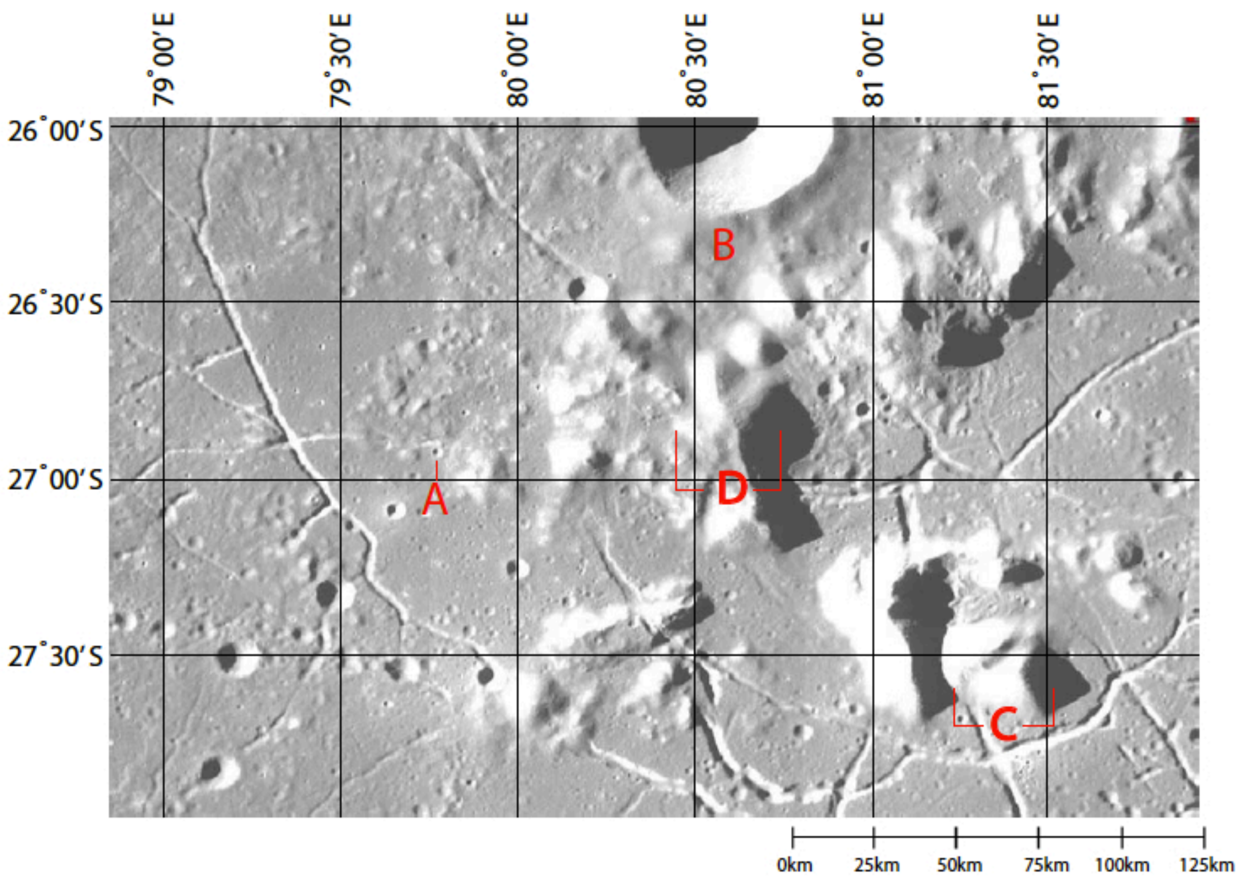
Goddard Region #1



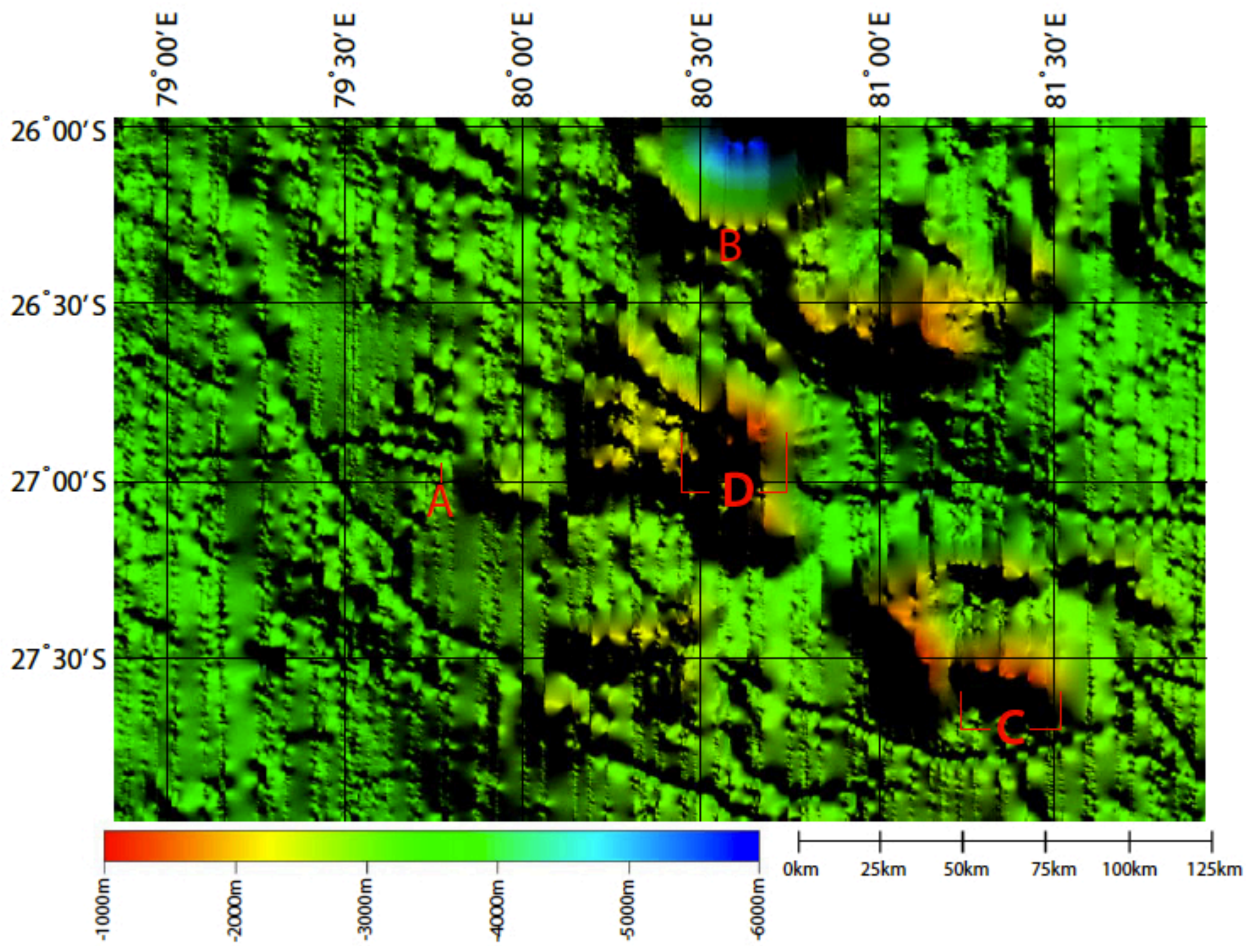
Goddard Region #3



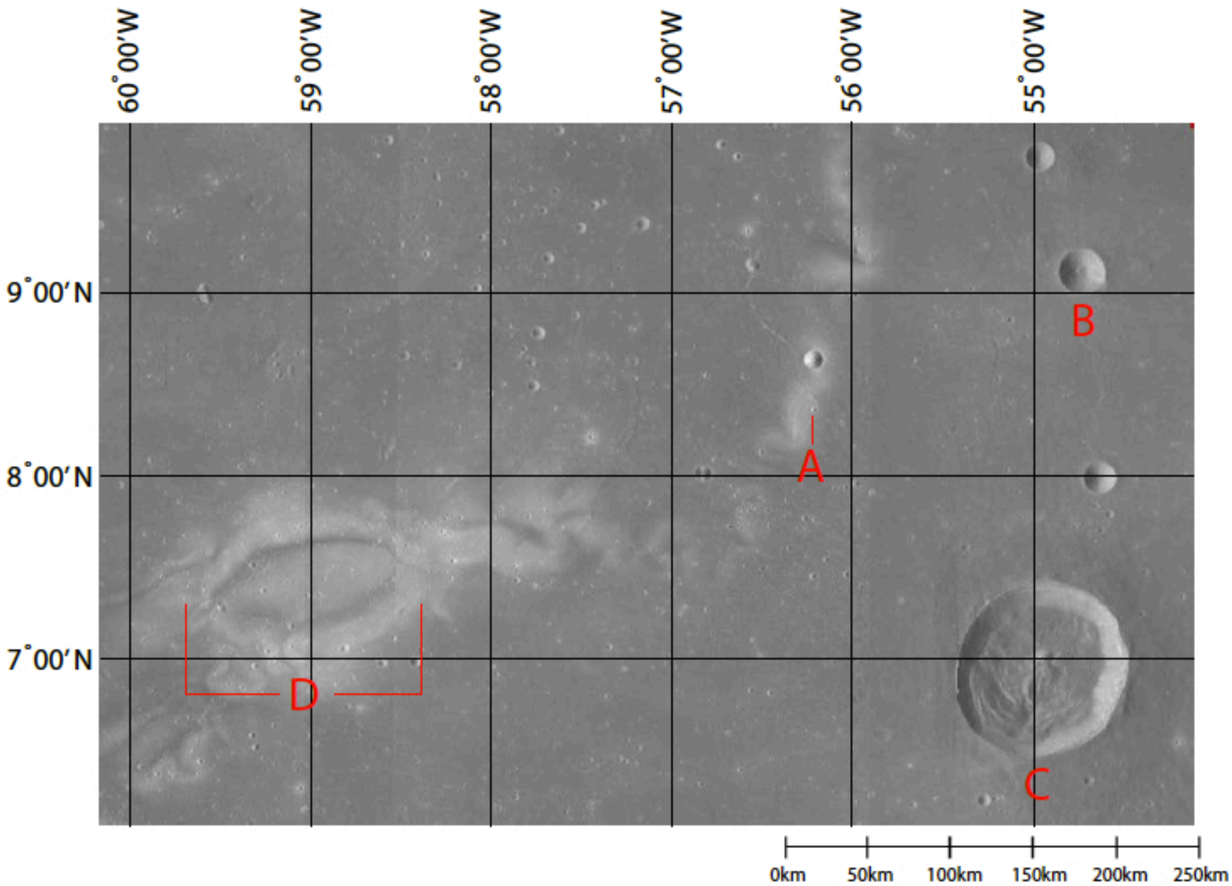
Humboltanium Region #1



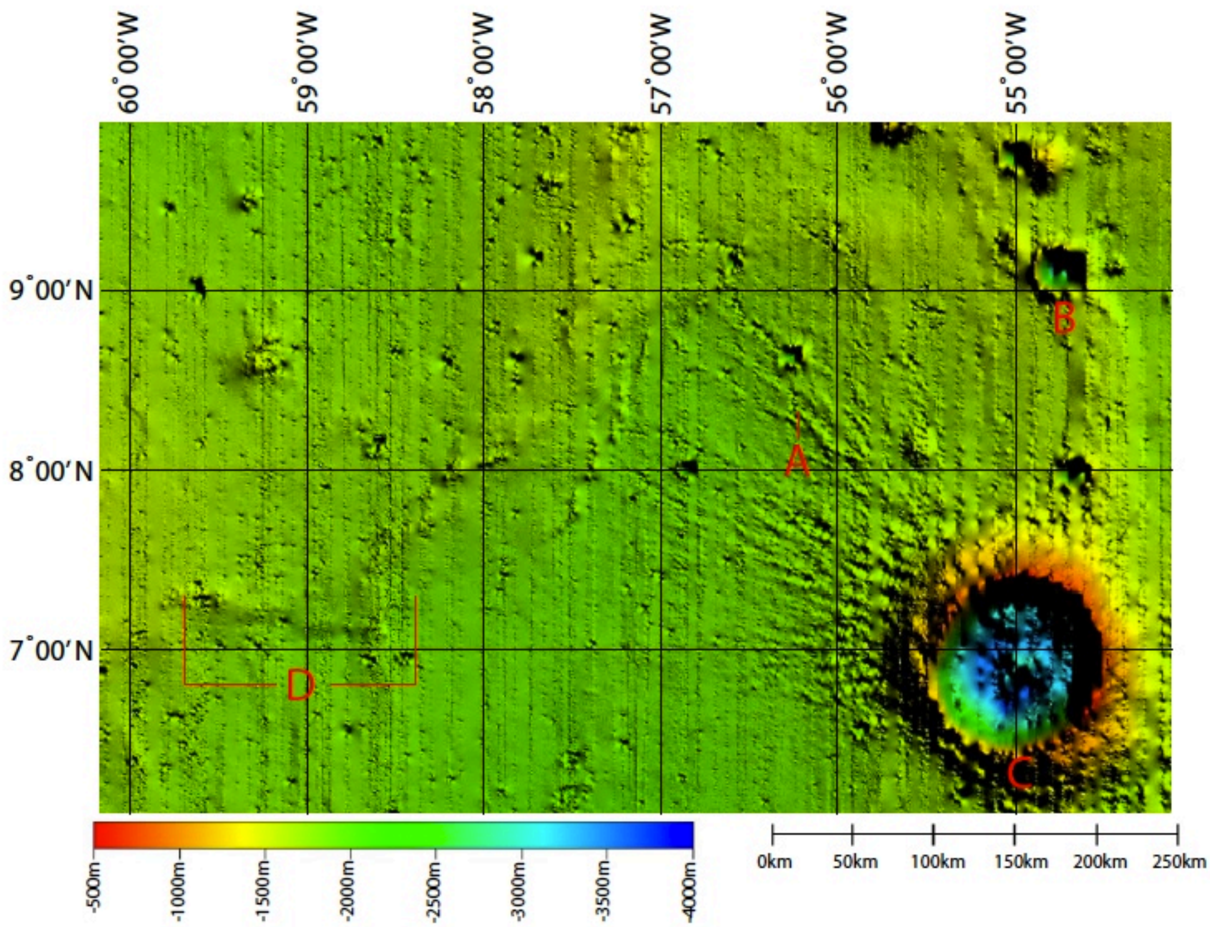
Humboltanium Region #3



Reiner Region #1



Reiner Region #3



Assessment:

Review the critiques of the model from Day 1 and 2 looking for the ways that new information was incorporated and evidence that students are thinking critically about their models. Review individual assignments for evidence that the group created some sort of protocol for representing features and used information from all the available sources. See the attached rubric in the supplemental materials section for a suggestion to grading your students' work.

Extension Activities:

This lesson can include a great deal of geometry. The following concepts can be explored as a part of this lesson or in a math class:

- Triangles with the same angle measures (90°, 70°, and 20°, for example) are called similar triangles. They have the same shape even though they may have different side lengths. The lengths of the sides of similar triangles have the same ratios. We can use this ratio to figure out the height of features/ objects based on the length of the shadow.

- For a challenge or for advanced math students, you may choose to introduce the use of sine, cosine, and tangent. In these triangles, we are using the tangent (opposite/ adjacent) of the sun angle to determine the height (opposite).