

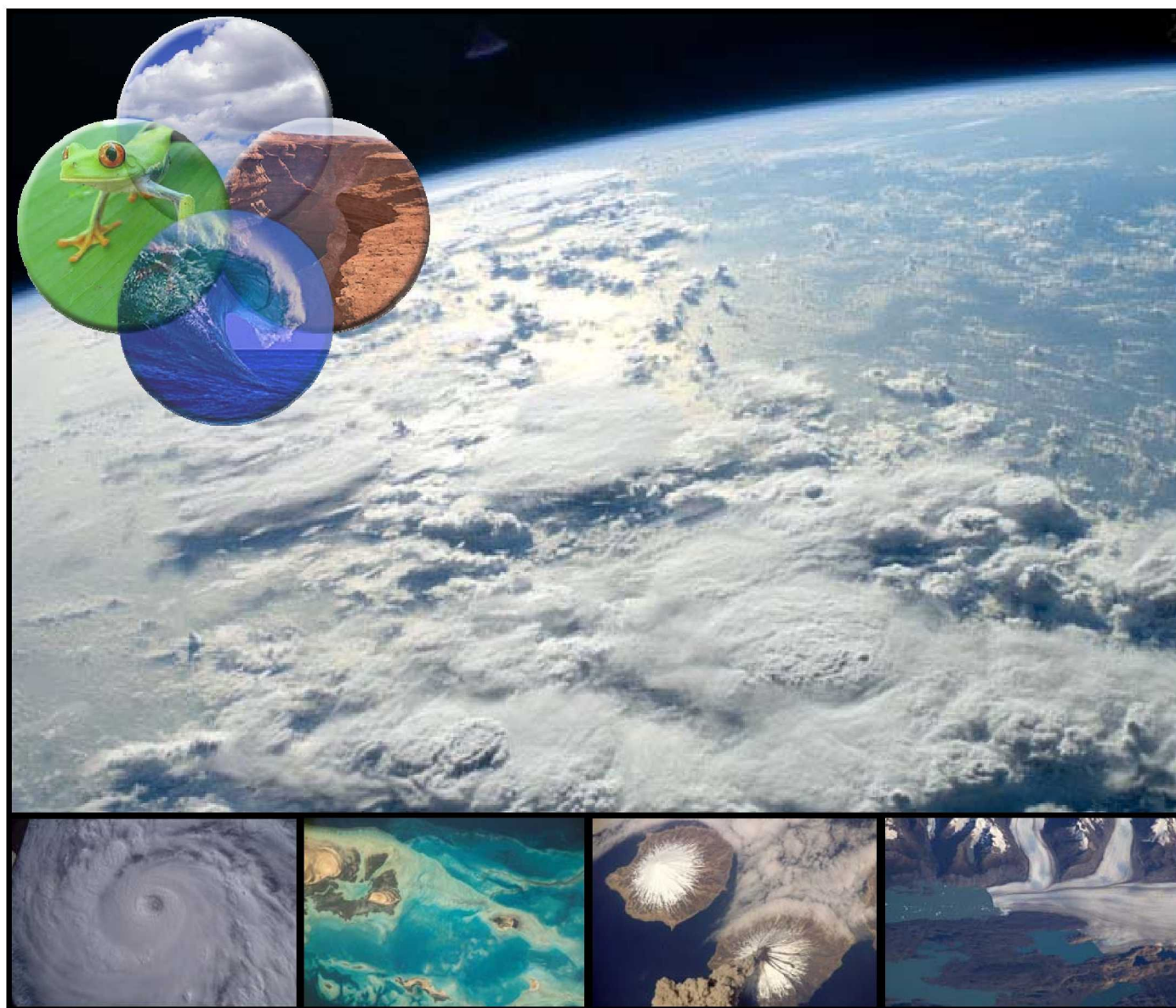


National Aeronautics and
Space Administration

SPHERES OF EARTH

An Introduction to Making Observations of Earth Using an
Earth System's Science Approach

STUDENT GUIDE



ARES

Astromaterials Research & Exploration Science



National Aeronautics and
Space Administration

SPHERES OF EARTH

An Introduction to Making Observations of Earth Using an Earth System's Science Approach

Written and Developed by:

Paige Valderrama Graff

Science Education Specialist, Expedition Earth and Beyond Director
Astromaterials Research and Exploration Science (ARES) Directorate
ARES Education Program, NASA Johnson Space Center
JACOBS - Engineering Science Contract Group (ESCG)

Edited by the following educators and scientists within the
Astromaterials Research and Exploration Science (ARES) Directorate
at the NASA Johnson Space Center:

Marshalyn Baker, *Classroom Teacher*

Trevor Graff, *Planetary Scientist*

Charlie Lindgren, *Classroom Teacher*

Michele Mailhot, *Classroom Teacher*

Tim McCollum, *Classroom Teacher*

Susan Runco, *Physical Scientist*

William Stefanov, *Senior Geoscientist*

Kim Willis, *Principal Geoscientist*



ENGINEERING & SCIENCE CONTRACT GROUP

JACOBS

ERC | Barrios | GeoControl | Hamilton Sundstrand | MEI



ARES

Astromaterials Research & Exploration Science

Front cover images courtesy of the ARES Image Science and Analysis Laboratory, NASA JSC.

<http://eol.jsc.nasa.gov>

© 2010 Astromaterials Research and Exploration Science (ARES) Education Program.
All rights reserved. This document may be freely distributed for non-commercial use only.



SPHERES OF EARTH

Part 1: KWL Prior Knowledge

In your small group, brainstorm ideas about what you think you know about Earth System Science and the “spheres” or systems of Earth. To help you get started, think about Earth Systems as you would the systems of the human body. For example, the circulatory system is one of many systems that make up the human body. “Features” or components associated with the circulatory system are the heart, blood, and blood vessels.

Name, list, or describe what you know about the different “spheres” or systems that make up Earth.	List any features on Earth that are associated with any of these “spheres” that can be studied using images from space?	What questions do you have about the different spheres of Earth?

SPHERES OF EARTH

Part 2: Background Information & Data Collection

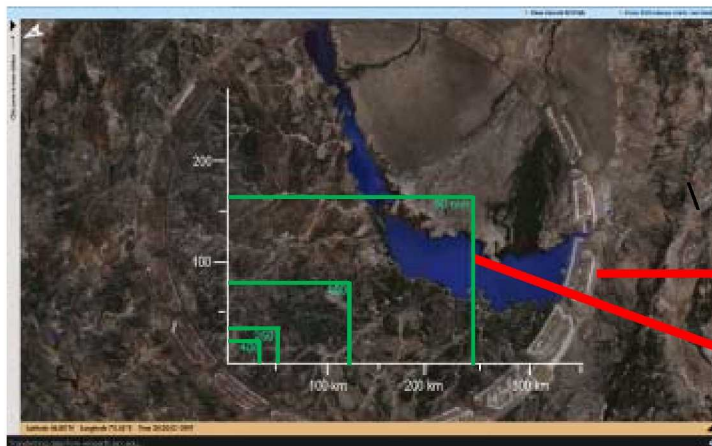
Background Information

Crew Earth Observations (CEO)

Scientists from the Image Science and Analysis Laboratory (ISAL) at NASA's Johnson Space Center (JSC) work with astronauts onboard the International Space Station (ISS) who take images of Earth. Astronaut photographs, sometimes referred to as Crew Earth Observations, are taken using hand-held digital cameras onboard the ISS. These digital images allow scientists to study our Earth from the unique perspective of space.

Astronauts have taken images of Earth since the 1960s. There is a database of over 900,000 astronaut photographs available at <http://eol.jsc.nasa.gov>. Images are requested by ISAL scientists at JSC and astronauts in space personally frame and acquire them from the Destiny Laboratory or other windows in the ISS. By having astronauts take images, they can specifically frame them according to a given request and need. For example, they can choose to use different lenses to vary the amount of area (field of view) an image will cover. Images can be taken at different times of the day which allows different lighting conditions to bring out or highlight certain features. The viewing angle at which an image is acquired can also be varied to show the same area from different perspectives. Pointing the camera straight down gives you a nadir shot. Pointing the camera at an angle to get a view across an area would be considered an oblique shot. Being able to change these variables makes astronaut photographs a unique and useful data set.

Astronaut photographs are taken from the ISS from altitudes of 300 – 400 km (~185 to 250 miles). One of the current cameras being used, the Nikon D3X digital camera, can take images using a 50, 100, 250, 400 or 800mm lens. These different lenses allow for a wider or narrower field of view. The higher the focal length (800mm for example) the narrower the field of view (less area will be covered). Higher focal lengths also show greater detail of the area on the surface being imaged.



The image shown here illustrates what an astronaut would see looking out the Destiny window from the ISS. You can see the circular outline of the window as well as the amount of surface area that would be imaged with different lenses.

Outline of Destiny window

Green boxes indicate the area included in images taken with different lenses.

Image source: Windows on Earth website: <http://winearth.terc.edu/applSSFlight>



Earth System Science



Our Earth is a diverse planet composed of a variety of features that can be studied from space. Many scientists study Earth using what is called an Earth System Science approach. This approach involves looking at individual features that are part of a specific system. Each individual system is connected to and influences other systems that make up the Earth as a whole. Each system plays a role in keeping our Earth in balance. A change in one system will cause a change in another. We can perhaps compare Earth's systems to the human body systems.

The human body has a nervous system, circulatory system, digestive system, etc. These systems are all connected to make our bodies function properly. Each system consists of individual body parts. You can study one part of one system, but must realize all systems are connected and play an important role for the body as a whole. All of Earth's systems are connected as well. Just like the human body system, all Earth systems interact and influence one another. Together, each Earth system plays an important role in the functioning of our Earth. Changes within one system will affect others and our Earth as a whole.

There are four major systems or spheres of Earth. They are:

1. **Atmosphere:** This system relates to meteorological features and phenomena such as weather, clouds, or aerosols (particles in the air). It includes an ever-changing **mixture of gas and small particles located above the Earth's surface**. Features associated with the atmosphere that can be studied using astronaut photography are:

-Clouds	-Hurricanes and Cyclones	-Aurora
-Air Pollution/Aerosols	-Dust and Sand Storms	

2. **Biosphere:** This system is associated with **living systems** such as **biomes** or **ecosystems**. This includes life on land, in the oceans and rivers, and even life we cannot see with the naked eye. Features associated with the biosphere that can be studied using astronaut photography are:

-Coastal Biomes	-Forests	-Deserts
-Grasslands	-Urban/Agricultural Ecosystems	

3. **Hydrosphere:** This system is associated with **water in solid (ice) and liquid states**. Water in a gas state (water vapor) is probably best considered as a feature of the atmosphere. Features associated with this system that can be studied using astronaut photography are:

-Oceans	-Lakes and Rivers
-Ice Bergs (Polar Ice Caps)	-Glaciers

4. **Litho/Geosphere:** This system is associated with solid portions of the Earth. It includes rocks, sediments and soils, **surface landforms** and the **processes** that shape the surface. Features associated with this system can be broken down into a variety of different processes. These are:

-Fluvial and Alluvial Processes: Deltas, river channels/canyons, alluvial fans

-Aeolian Processes: Sand dunes, yardangs, wind streaks

-Tectonic Processes: Folds, faults, mountains

-Volcanic Processes: Volcanoes, central vents, volcanic deposits

-Impact Processes: Impact craters

-Other Processes: Mass wasting processes, erosional processes



SPHERES OF EARTH

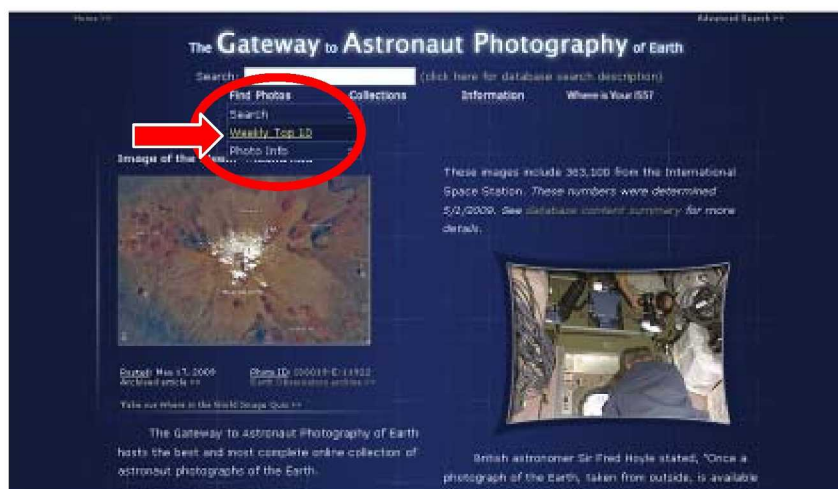
Part 2: Background Information & Data Collection

Discovering and Exploring Features on Earth Visible from Space

Now that you know a little bit about Earth systems and features, let's have you discover and explore features on Earth that are visible from space in astronaut photographs.

Directions:

1. Go to the Gateway to Astronaut Photography of Earth website: <http://eol.jsc.nasa.gov/>
2. You will see 4 search tabs at the top of the page: "Find Photos", "Collections", "Information", "Where is Your ISS"? Look under the "Find Photos" tab and select "Weekly Top 10."



3. For each of the Weekly Top 10 images there is a thumbnail of the image that shows you a small snapshot of the picture. To the right of each thumbnail, information is provided about the image. The important information to note is the image identification number and the brief description of features or the geographic location of the image. Click on the *Image Identification number* to view the image and its associated metadata (information about that image).





4. Once you click on the Image ID#, a new page will open showing the astronaut photograph along with all the metadata you could ever wonder about for any given image. It is important to be able to sort through the metadata to find important information that will be useful for you to log. Scroll down the webpage to locate these important metadata you would most commonly want to log for an image.
 - a. Image Identification number: This is a unique identifier for any given image. This number should appear at the top of the image you are viewing.
 - b. Country or Geographic Name: Learning about the geography of Earth is useful!
 - c. Features: Be aware that the “features list” provided on the website may not include all features visible in the image. You can revise and/or add information on your log sheet.
 - d. Center Point Latitude and Longitude: This will allow you to locate this image on a map of Earth. Be sure to log the center latitude and longitude of the image and not the nadir point (location point straight down) from the spacecraft.
 - e. Camera Used: Current images are often taken with the Nikon D2 and D3 camera series, but other cameras (Hasselblad, Kodak DSC760, etc.) have been previously used.
 - f. Camera Focal Length: The focal length gives you an indication of the field of view or if a wide or narrow area is covered in the image. The higher the number (or put another way, the longer the lens used), the more detail will be visible in the image. The area visible in the image will be correspondingly smaller however.
 - g. Date Acquired: It is useful to know when an image was taken so you can perhaps look at images taken of that same area on a different date and make comparisons.
 - h. Caption: If a caption is written, it can provide you with background information about the image or geographic area. You are highly encouraged to read it and pull out important information to help you understand what you are observing in an image.
5. You will also make your own observations of each image. Information to include is as follows:
 - a. Features Observed in the image along with their associated sphere or Earth system: This will help you start to differentiate between Earth’s systems and features associated with those systems. You can certainly use features already listed from the website, but you are encouraged to list features *you* can identify.
 - b. Miscellaneous Observations: This allows you to make general statements, observations, or sketches of the image you are observing.

Now you are ready to collect data! Use the *Data Collection* tables provided to log your data. Remember to follow the instructions listed above. 1) Go to <http://eol.jsc.nasa.gov>; 2) Go to the “*Find Photos*” tab and select “*Weekly Top 10*” etc....and log observations of at least 4-6 of the images.



SPHERES OF EARTH

Part 2: Background Information & Data Collection

Website: <http://eol.jsc.nasa.gov>

Astronaut Photography Image Metadata and Observations	
Image ID#:	Latitude (N): Longitude (E):
Camera Used:	Lens Focal Length:
Date Acquired:	Country/Geographic Region:
Background information about image:	
List 3 Visible Features, Associated Earth System, and Observations	Miscellaneous Observations and/or Sketch
Feature: _____ Earth System: _____ Observations of feature:	
Feature: _____ Earth System: _____ Observations of feature:	
Feature: _____ Earth System: _____ Observations of feature:	



SPHERES OF EARTH

Part 2: Background Information & Data Collection

Website: <http://eol.jsc.nasa.gov>

Astronaut Photography Image Metadata and Observations	
Image ID#:	Latitude (N): Longitude (E):
Camera Used:	Lens Focal Length:
Date Acquired:	Country/Geographic Region:
Background information about image:	
List 3 Visible Features, Associated Earth System, and Observations	Miscellaneous Observations and/or Sketch
Feature: _____ Earth System: _____ Observations of feature:	
Feature: _____ Earth System: _____ Observations of feature:	
Feature: _____ Earth System: _____ Observations of feature:	



SPHERES OF EARTH

Part 2: Background Information & Data Collection

Website: <http://eol.jsc.nasa.gov>

Astronaut Photography Image Metadata and Observations	
Image ID#:	Latitude (N): Longitude (E):
Camera Used:	Lens Focal Length:
Date Acquired:	Country/Geographic Region:
Background information about image:	
List 3 Visible Features, Associated Earth System, and Observations	Miscellaneous Observations and/or Sketch
Feature: _____ Earth System: _____ Observations of feature:	
Feature: _____ Earth System: _____ Observations of feature:	
Feature: _____ Earth System: _____ Observations of feature:	



SPHERES OF EARTH

Part 2: Background Information & Data Collection

Website: <http://eol.jsc.nasa.gov>

Astronaut Photography Image Metadata and Observations	
Image ID#:	Latitude (N): Longitude (E):
Camera Used:	Lens Focal Length:
Date Acquired:	Country/Geographic Region:
Background information about image:	
List 3 Visible Features, Associated Earth System, and Observations	Miscellaneous Observations and/or Sketch
Feature: _____ Earth System: _____ Observations of feature:	
Feature: _____ Earth System: _____ Observations of feature:	
Feature: _____ Earth System: _____ Observations of feature:	



SPHERES OF EARTH

Part 2: Background Information & Data Collection

Website: <http://eol.jsc.nasa.gov>

Astronaut Photography Image Metadata and Observations	
Image ID#:	Latitude (N): Longitude (E):
Camera Used:	Lens Focal Length:
Date Acquired:	Country/Geographic Region:
Background information about image:	
List 3 Visible Features, Associated Earth System, and Observations	Miscellaneous Observations and/or Sketch
Feature: _____ Earth System: _____ Observations of feature:	
Feature: _____ Earth System: _____ Observations of feature:	
Feature: _____ Earth System: _____ Observations of feature:	



SPHERES OF EARTH

Part 3: Presentation of Observations

You have now observed 4-6 images and seen a variety of visible features in images taken from space. You should also now be more familiar with the different Earth Systems. Choose one of the images you logged data for and explain to your classmates what you have discovered. **Use the table below as a guide for your presentation.**

Image ID#			
Background information about image and its location			
Observations of 3 features and associated Earth system	Feature: _____ System: _____ Observations of feature:	Feature: _____ System: _____ Observations of feature:	Feature: _____ System: _____ Observations of feature:
Two questions about a specific feature(s) that interest you	1. 2.		

As each group presents information about one of the images they observed, be sure to take notes. Be sure to log comments about the image or features that you found interesting. Use the table on the next page as a guide for your notes.



SPHERES OF EARTH

Part 3: Presentation of Observations

STUDENT PRESENTATION NOTES:

Student Presenters and Image ID#			
Observations of 3 features and associated Earth system	Feature: _____ System: _____ Observations:	Feature: _____ System: _____ Observations:	Feature: _____ System: _____ Observations:
Comments about image or features you found interesting			

Student Presenters and Image ID#			
Observations of 3 features and associated Earth system	Feature: _____ System: _____ Observations:	Feature: _____ System: _____ Observations:	Feature: _____ System: _____ Observations:
Comments about image or features you found interesting			



SPHERES OF EARTH

Part 4: Research Planning

Based on your observations of images and presentations given by your classmates, answer the following questions to initiate a research investigation you could potentially pursue.

1. List three visible features observed in images that interest you the most. Also list the most closely associated Earth system related to that feature. Indicate a specific aspect of each feature you find interesting that could become the focus of future research.

Feature	Earth System	Aspect of feature that is interesting
1.		
2.		
3.		

2. Think about each of the features you listed above. Using one of those features, create a question that could be researched about that feature using astronaut photography. Include an explanation of what methods you would use to go about answering that question. Be as detailed as possible including what specific data/metadata you would want to log from each image observed.

Feature	
Research Question	
Explanation of Research Methods	



SPHERES OF EARTH

Part 5: System and Feature Review

You are now familiar with different visible features in images taken from space and the four Earth systems. You will now be evaluated on your ability to recognize different features and their associated systems. The scoring rubric below indicates how you will be graded. For each image you will:

1. Identify 2 visible features
2. Identify which system those features are associated with
3. Justify or explain the association of the visible feature and system

As a quick review, list the names of the 4 Earth systems below. Include key word(s) to help you remember what each system is associated with.

List the 4 Earth Systems			

The following rubric will be used to evaluate the information you provide for each image:

SCORING RUBRIC

Exemplary (4 points)	All information is complete, accurate and detailed Two features were correctly identified Associated Earth systems for both features were correctly identified A suitable justification was provided
Meets Standards (3 points)	Most information is complete and accurate Two features were identified Earth system for at least one of the features was correctly identified A somewhat suitable justification was provided
Partially Meets Standards (2 points)	Information is somewhat incomplete and inaccurate Only one feature was correctly identified Earth system was not correctly identified A poor justification was provided
Needs Review (1 point)	Information is mostly inaccurate No features were correctly identified Earth system for one or both features was not correctly identified Justification was not provided



SPHERES OF EARTH

Part 5: System and Feature Review

Record the information for each image below:

IMAGE #1:

Visible Features	1.	2.
Associated Earth System		
Justification		

IMAGE #2:

Visible Features	1.	2.
Associated Earth System		
Justification		

IMAGE #3:

Visible Features	1.	2.
Associated Earth System		
Justification		

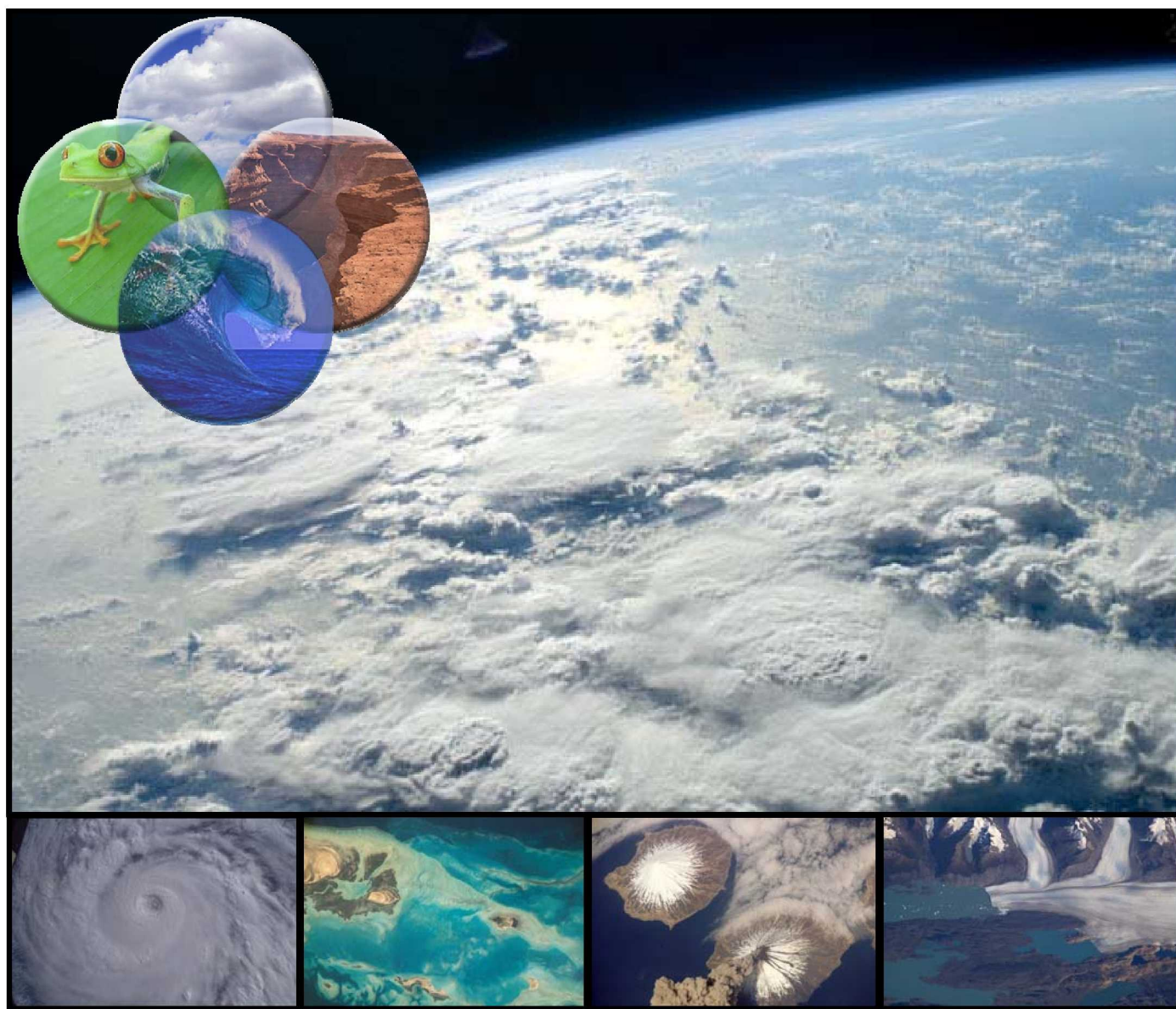


National Aeronautics and
Space Administration

SPHERES OF EARTH

An Introduction to Making Observations of Earth Using an
Earth System's Science Approach

TEACHER GUIDE



ARIES

Astromaterials Research & Exploration Science



National Aeronautics and
Space Administration

SPHERES OF EARTH

An Introduction to Making Observations of Earth Using an Earth System's Science Approach

Written and Developed by:

Paige Valderrama Graff

Science Education Specialist, Expedition Earth and Beyond Director
Astromaterials Research and Exploration Science (ARES) Directorate
ARES Education Program, NASA Johnson Space Center
JACOBS - Engineering Science Contract Group (ESCG)

Edited by the following educators and scientists within the
Astromaterials Research and Exploration Science (ARES) Directorate
at the NASA Johnson Space Center:

Marshalyn Baker, *Classroom Teacher*

Trevor Graff, *Planetary Scientist*

Charlie Lindgren, *Classroom Teacher*

Michele Mailhot, *Classroom Teacher*

Tim McCollum, *Classroom Teacher*

Susan Runco, *Physical Scientist*

William Stefanov, *Senior Geoscientist*

Kim Willis, *Principal Geoscientist*



ENGINEERING & SCIENCE CONTRACT GROUP

JACOBS

ERC | Barrios | GeoControl | Hamilton Sundstrand | MEI



ARES

Astromaterials Research & Exploration Science

Front cover images courtesy of the ARES Image Science and Analysis Laboratory, NASA JSC.

<http://eol.jsc.nasa.gov>

© 2010 Astromaterials Research and Exploration Science (ARES) Education Program.
All rights reserved. This document may be freely distributed for non-commercial use only.



SPHERES OF EARTH

An Introduction to Making Observations of Earth Using an Earth System Science Approach

5-E Activity - Teacher's Guide

Goal: This activity is designed to promote an interest in authentic investigations of Earth using an Earth System Science approach. The activity uses inquiry-based learning and the 5-E model of instruction. The use of images acquired by astronauts of Earth is used as a hook for potential future student investigations.

Objectives: Students will:

1. Be introduced and become familiar with the relationship among different Earth systems.
2. Identify and associate visible features on Earth with “spheres” or systems of Earth.
3. Understand remote sensing terminology associated with studying imagery from space.

Grade Level: 4 – 12+

Time Requirements: 2 – 4 class periods (if you do all parts of the activity)

Materials:

- Computer lab for students to explore Gateway to Astronaut Photography of Earth website (<http://eol.jsc.nasa.gov>) **OR** printed Spheres of Earth Image Set
- *Spheres of Earth Student Guide*
- *Spheres of Earth Teacher Guide (this document)*
- Projector (optional)

Other Useful Materials & Resources

- World map, or Google Earth/NASA World Wind, if available, to increase students knowledge of the geography of the Earth
- Individual Student Sheets are provided at the end of this Teacher Guide for printing as desired
- Spheres of Earth Image Set (with accompanying text) is available for download

National Science Standards:

CONTENT STANDARD A: Science as Inquiry

CONTENT STANDARD D: Earth and Space Science

CONTENT STANDARD E: Science and Technology

CONTENT STANDARD G: History and Nature of Science

Useful Websites for Additional Background Knowledge:

- Gateway to Astronaut Photography of Earth: <http://eol.jsc.nasa.gov>
- NASA Earth Observatory: <http://earthobservatory.nasa.gov>



Introduction and Background

This activity is designed to be used for multiple purposes. It can be used as a stand-alone activity introducing students to an Earth System Science approach to studying Earth. It can also be used as an introductory activity to students participating in the Expedition Earth and Beyond Program. The activity allows students to explore and discover visible features in astronaut photography acquired from space. There is a database of over 900,000 images available for students to view images from space, available at the Gateway to Astronaut Photography website, <http://eol.jsc.nasa.gov>. This activity provides a framework in which to have students observe our Earth from the unique perspective of space and teach objectives and standards you may be required to cover. Students will have an authentic experience of looking at current and past NASA data and they will be introduced to studying Earth using a System Science approach and gain insight into the process of science. The activity builds on students' prior knowledge about Earth and takes them through a process where they can recognize visible features of Earth and associate those features with an Earth system.

Our home planet, Earth, is the launch pad for learning and understanding other bodies in our Solar System. Our Earth System is made up of 4 major components. Those are the atmosphere, hydrosphere, biosphere and litho/geosphere. Most school textbooks likely use lithosphere as the term used for studying the "rocks" and geologic processes. Since the 1960's however, and the study of plate tectonics, the term "geosphere" is becoming more widely used in the scientific community to refer to what has traditionally been referred to as the lithosphere. For this activity, we will use the term litho/geosphere to enable you, as teachers, to parallel concepts traditionally taught without fear that the term geosphere is not a part of your standards. We also hope to have you and your students ahead of the curve with what current science has moved towards, that may or may not yet be reflected in your books or curriculum. Keep in mind there is no one correct way to divide up Earth's systems. For example, you may find that some scientists make reference to the cryosphere when they refer to water in the Earth's surface where water is in solid (ice) form. Others may include other spheres such as the magnetosphere, for example. For the purposes of this activity, we will divide up the components of Earth's systems as the atmosphere, hydrosphere, biosphere and litho/geosphere.

By using an Earth System's Science approach, scientists, and your students, are able to understand that our Earth is made up of a series of systems that all interrelate. It is similar to the human body system. We have the nervous system, the digestive system, etc. Each of those systems working together allows for healthy functioning of the body. In terms of Earth System Science, each of those systems allows Earth to function as a planet with life. A change in one system will affect other systems. Changes may be subtle, but with careful observation and critical thinking skills, students will be able to understand an introductory connection between the systems.

Features listed and associated with a system in this activity are not all-inclusive and there are certain features that can be considered a part of more than one system. For example, clouds are listed within the atmosphere system of Earth. They could very well, however, be listed under the hydrosphere system of Earth as it relates to water in a gaseous state. Likewise, let's think about glaciers. Thinking of glaciers as merely masses of ice and studying that ice might lead you to identify the hydrosphere as the main system related to glaciers. Looking at glaciers as a geologic feature or focusing on glacial



processes and how they shape the surface would be more related to the litho/geosphere. Students can scientifically debate (argue!) their justification of a feature being most closely associated with one system versus another. As long as they can justify the association based on the explanation of the Earth system and its association to that feature, there may or may not be a wrong classification. Justification is key.

The following information, also listed in the student guide, provides a breakdown of the four major systems or spheres of Earth and features associated with those systems that can be studied using astronaut photography. This is not an all-inclusive list of features, but does provide a good list to use to help students understand the different systems and features. Key words related to each system are in bold italics to help reinforce important information.

1. **Atmosphere:** This system relates to meteorological features and phenomena such as weather, clouds, or aerosols (particles in the air). It includes an ever-changing ***mixture of gas and small particles located above the Earth's surface***. Features associated with the atmosphere that can be studied using astronaut photography are:

-Clouds	-Hurricanes and Cyclones	-Aurora
-Air Pollution/Aerosols	-Dust and Sand Storms	

2. **Biosphere:** This system is associated with ***living systems*** such as ***biomes*** or ***ecosystems***. This includes life on land, in the oceans and rivers, and even life we cannot see with the naked eye. Features associated with the biosphere that can be studied using astronaut photography are:

-Coastal Biomes	-Forests	-Deserts
-Grasslands	-Urban/Agricultural Ecosystems	

3. **Hydrosphere:** This system is associated with ***water in solid (ice) and liquid states***. Water in a gas state (water vapor) is probably best considered as a feature of the atmosphere. Features associated with this system that can be studied using astronaut photography are:

-Oceans	-Lakes and Rivers
-Ice Bergs	-Glaciers

4. **Litho/Geosphere:** This system is associated with solid portions of the Earth. It includes rocks, sediments and soils, ***surface landforms*** and the ***processes*** that shape the surface. Features associated with this system can be broken down into a variety of different processes. These are:

- Fluvial and Alluvial Processes:*** Deltas, river channels/canyons, alluvial fans
- Aeolian Processes:*** Sand dunes, yardangs, wind streaks
- Tectonic Processes:*** Folds, faults, mountains
- Volcanic Processes:*** Volcanoes, central vents, volcanic deposits
- Impact Processes:*** Impact craters
- Other Processes:*** Mass wasting processes, erosional processes

Most images will include features that can be associated with more than one Earth system. This reinforces the idea that together these systems make up our Earth today and changes to any system or feature will also have an effect on what our Earth will be like in the future.



Crew Earth Observations – Astronaut Photography

Astronauts onboard the International Space Station (ISS) are asked to take images of our Earth as part of their science activities. Scientists at the Image Science and Analysis Laboratory (ISAL) at the NASA Johnson Space Center train the astronauts on identifying features from orbit and also help provide scientific context to the need for this data. While on the ISS, astronauts are sent task lists with imagery to acquire while on orbit. Images are acquired using hand-held digital cameras that are onboard the ISS. These off-the-shelf cameras and a variety of lenses allow astronauts to capture images of Earth from the unique perspective of space and at varying resolutions. Currently, the Nikon D2 and D3 series cameras are being used. Other cameras that have been used by astronauts (on both the shuttle and ISS) are the digital Kodak DCS760, as well as film cameras such as the Hasselblad 70mm camera, which was used early on. Images from space have been acquired by astronauts since the 1960's during the Mercury missions. The quality of the images has improved with camera technology and with the use of different focal length lenses. By changing the focal length of the lens, astronauts are able to acquire images that have a wider or narrower field of view. The higher the focal length (800mm for example) the narrower the field of view (less area will be covered). Higher focal lengths allow greater detail of the surface to be revealed but less surface area is covered. Lower focal lengths allow a larger area to be imaged, but the details of the surface will not be as crisp. The scientific need for the image drives the focal length that is requested. Sometimes astronauts also take images of Earth just to reveal its beauty from space. These images allow all of us here on Earth to enjoy the wonder and beauty of our planet.

The Gateway to Astronaut Photography website (<http://eol.jsc.nasa.gov>) houses the database of these 900,000+ images that have been acquired by astronauts. There are many ways to search for images. This activity has students make observations of images found in the Weekly Top 10 list. The images listed this week will change so it is important to make sure students use the provided observation logs to record their data. These log sheets are important for students to get accustomed to, as any science project or experiment requires logging data. The metadata students are asked to record will help them to sort through the variety of information that is provided for every image. As students become familiar with how to find this basic metadata, it will help them if they choose to conduct a research project using astronaut photography.

Oftentimes there are captions written for images on the website. These captions can be very useful to provide background information. It is important to have students read, or at least skim this information to help them as they decipher the image they are observing as well as help them as they look at other images. The more they observe and read, the more they will transfer that knowledge when examining other images. There is also a link listed that states, *"Download a Keyhole Markup Language (KML) file for use in Google Earth."* If you have Google Earth on your computer, clicking on this link will take you to the location in which this image was acquired on Earth. This provides a greater context for the image and its location. This will assist your students in learning geography of Earth, as well as the importance of context when trying to understand what is going on in an image.

Included below are examples of three astronaut photographs and information about some of the visible features and their associated Earth System. The images shown here include labeled features to help you identify the features being listed. Not all images on the Gateway to Astronaut Photography website include images with labeled features.

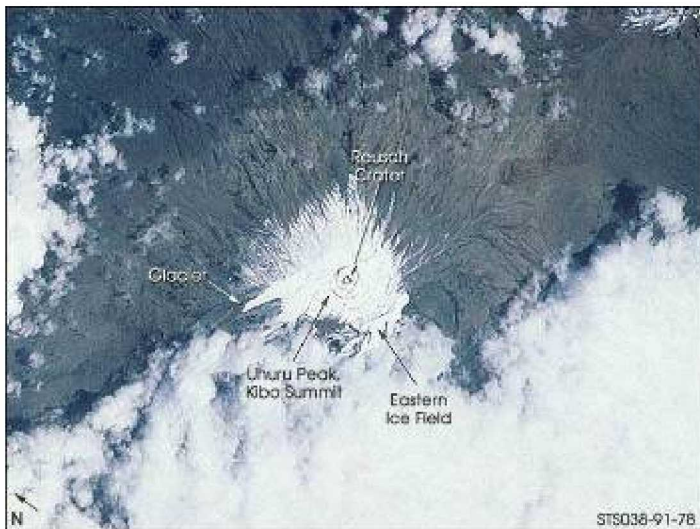


IMAGE EXAMPLES:



This image shows a variety of features. It includes glaciers (hydrosphere), a lake (hydrosphere), mountains (litho/geosphere) and snow or ice (hydrosphere).

Image ID#: ISS003-E-6061



This image contains features such as a volcano (litho/geosphere), volcanic caldera/crater (litho/geosphere), glaciers (hydrosphere), clouds (atmosphere), ice and snow (hydrosphere), and lava flows (litho/geosphere).

Image ID#: STS038-91-78



This image contains features such as an island/atoll (litho/geosphere), coral reefs (biosphere), sand deposits (litho/geosphere) the ocean (hydrosphere), clouds (atmosphere), and vegetation (biosphere).

Image ID#: ISS018-E-18129



5-E Model

The 5-E model is an inquiry based model of instruction that has 5 phases. They are: Engagement, Exploration, Explanation, Elaboration, and Evaluation. This model builds on prior knowledge students may have and helps them to expand on that knowledge while also correcting any inaccuracies. This model and activity is designed as guided discovery to maintain a structure for learning for your students.

5-E Phase	General Description	Spheres of Earth Activity
<i>Engagement</i>	Teachers engage students in questions and probe for prior knowledge and conceptions.	Prior knowledge activity: <i>What do we know about Earth System Science?</i>
<i>Exploration</i>	Students explore, make discoveries, and log observations of images helping to establish an understanding of content.	Use of the Gateway to Astronaut Photography website. Weekly Top 10 images with activity data collection sheets.
<i>Explanation</i>	Building on students' explorations and explanations, students communicate new understandings and listen to other students knowledge acquisition. Students use formal language and vocabulary associated with content.	Presentations by students of their data gathering activities. Students present preliminary identification of features seen in images and their associated Earth System.
<i>Elaboration</i>	Students apply new understandings to new problems.	Students elaborate on a scientific question that focuses on a visible feature and methods they could use to answer that question.
<i>Evaluation</i>	Teachers and students use formal and informal means to assess new knowledge and understandings.	Students view astronaut photography images independently and identify features and their associated Earth system.

Table 1. 5-E model of instruction with general description and application to *Spheres of Earth* activity.



ACTIVITY PROCEDURE

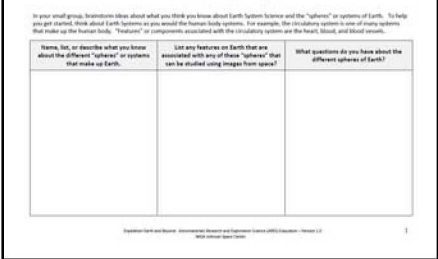
This activity procedure is provided as a suggested guide for the Spheres of Earth activity. Estimated times for each section are provided but can vary depending on your level of students and time you feel is necessary for engagement in discussion. Additionally, this procedure includes thumbnails of student pages for each section for your reference.

Part 1: KWL Prior Knowledge (Engage Activity):

Estimated time for Part 1: ~10 minutes

Materials needed:

- Page 1 of the *Student Guide*

1. Put students in groups of 2-4 and have them brainstorm and fill out the KWL table. This will enable them to build on knowledge they may have as a group and create a “safe” environment for any student that may not have much background knowledge. Have all students record the group information.
- 
2. Once students have brainstormed together, have each group report their information to the class. You can record their information on the board or overhead or simply listen and comment on the information they state. It is important not to correct inaccuracies stated by students. As they go through the activity they should be able to self-correct. Students will hopefully be able to answer the questions they list in column 3 as well at the end of the activity. These questions should not be answered by others during this initial discussion.

Part 2: Data Collection (Exploration Activity):

Estimated time for Part 2: ~20 minutes for review of information; ~40-60 minutes to log data. (It is recommended to review information as a group or have students read the Background information and instructions for homework so these can be discussed in class the following day.)

Materials needed:

- Pages 2-10 of the *Student Guide* (Note: pages 2 and 3 are Background Information, pages 4 and 5 are instructions on how to gather the suggested data, and pages 6-10 are data collection/observation sheets.
- Computer lab, or projector, or printed images

For this part of the activity, consider the following choices, depending on your access to computers or a computer lab.

- a. If you have access to a computer lab: If you have your students in groups of 4, it is recommended to separate them into 2 groups of 2 to complete this section of the activity.
- b. If you do not have access to a computer lab but you can project images from the front of the room: You can put an image on the screen in front of the room and have students in their groups of 4 discuss and log their observations. You can also show the metadata to the

class and have them note down that information as well. (Note: Seeing and reading the metadata may be challenging for the students to read on a projected screen.)

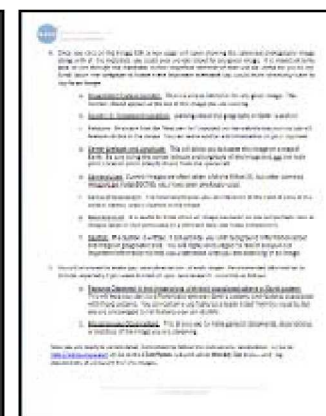
- c. **Hard Copy Images and Information:** You can print hard copies of images and information and distribute them to each group of students. A set of optional images to use is available as an addendum to this teacher guide.

1. Students should read the two pages of background information. You can have students read this for homework, or do a jigsaw to have students gain an understanding for the information provided. The background information introduces students to:


- a. Crew Earth Observations (an overview of astronaut photography)
- b. Earth System Science (definition of each Earth system and features associated with those systems that can be viewed in astronaut photography).



2. Review instructions on how to access the images and image information with students as you feel necessary. It may be important to go over the metadata students will be asked to log, depending on your students. This data is listed on the website but may be challenging for your students to sort through.



3. Once students are familiar with the instructions on how to access the information they are being asked to log, they are ready to begin logging observations of images. Have students log observations of 4-6 images. The information they are asked to log is mostly self-explanatory. The miscellaneous observations and/or sketch section is an area where students can log any information about the images that is beyond answering the formal questions. This can include a sketch of a feature or just some simple observations or thoughts they have about the image. It is not uncommon for students to leave this blank. Encourage them to at least log some thoughts about the image.



National Aeronautics and
Space Administration

Earth Science Data Center

SPHERES OF EARTH

Part 2: Background Information & Data Collection

Website: <http://eds.sci.gsfc.nasa.gov>

Astronaut Photography Image Metadata and Observations	
Image ID#	Latitude (N)
Camera Model	Longitude (E)
Exposure Start	Image Download Link(s)
Date Acquired	Country/Region/Earth Region
Background Information about Images	
<div style="border: 1px solid black; padding: 5px; margin-bottom: 5px;"> 144 S 100E Frames, Associated Earth Systems, and Observations </div> <div style="border: 1px solid black; padding: 5px; margin-bottom: 5px;"> Feature: _____ Earth System: _____ </div> <div style="border: 1px solid black; padding: 5px; margin-bottom: 5px;"> Observation of Interest: _____ </div> <div style="border: 1px solid black; padding: 5px; margin-bottom: 5px;"> Feature: _____ Earth System: _____ </div> <div style="border: 1px solid black; padding: 5px; margin-bottom: 5px;"> Observation of Interest: _____ </div> <div style="border: 1px solid black; padding: 5px; margin-bottom: 5px;"> Feature: _____ Earth System: _____ </div> <div style="border: 1px solid black; padding: 5px;"> Observation of Interest: _____ </div>	<div style="border: 1px solid black; padding: 5px;"> Additional Observations and/or Details </div>

ES&P Data and Books: Instructions for National Aeronautics Space (NASA) Earth Science Data Center

144 S 100E Earth System

1



Part 3: Presentation of Observations (Explain Activity):

Estimated time for Part 3: ~30-45 minutes

Materials needed:

- Pages 11-12 of the *Student Guide*
- Computer projector to display images or printed images

1. If students worked on the computers in groups of 2, they should regroup as their group of 4 to prepare for their class presentation. The table provided in the student guide allows students to put together their thoughts in an organized fashion to present to the class. Each student from each student group should present some of the information to the class.

SPHERES OF EARTH
Part 3: Presentation of Observations

You have now observed 14 images and seen a variety of visible features in images taken from space. You should also now be more familiar with the different Earth systems. Choose one of the images you liked best for and explain to your classmates what you have discovered. Use the table below as a guide for your presentation.

Image ID	Background information about image and its location	Feature 1	Feature 2	Feature 3
		Observations of 1 feature and associated Earth system	Observations of 1 feature and associated Earth system	Observations of 1 feature and associated Earth system
		Observations of 1 feature and associated Earth system	Observations of 1 feature and associated Earth system	Observations of 1 feature and associated Earth system
		Observations of 1 feature and associated Earth system	Observations of 1 feature and associated Earth system	Observations of 1 feature and associated Earth system

As each group presents information about one of the images they observed, be sure to take notes. Be sure to log comments about the image or features that you found interesting. Use the table on the next page as a guide for your notes.

SPHERES OF EARTH
Part 3: Presentation of Observations

STUDENT PRESENTATION NOTES:

Student Presenters and Image ID	Feature 1	Feature 2	Feature 3
Observations of 3 features and associated Earth system	Observations	Observations	Observations
Comments about image or features you found interesting			

As each group presents information about one of the images they observed, be sure to take notes. Be sure to log comments about the image or features that you found interesting. Use the table on the next page as a guide for your notes.

2. As students present their information to the class, students not presenting should take notes. There is a *Student Presentation Notes* table included in the Student Guide. A copy of this table is available at the end of this Teacher Guide so you can print extra copies for your students if desired. Alternatively you can have the students recreate the table on their own notebook paper and take notes during each group presentation. Students should include any remarks or comments on the image and information presented.

Part 4: Research Planning (Elaboration Activity):

Estimated time for Part 4: ~15-30 minutes

Materials needed:

- Page 13 of the *Student Guide*

1. Have students fill out the table provided. They should list 3 visible features, their associated Earth system and include an aspect of that feature that they think is interesting. For example, if they listed coral reefs, they should be able to identify what about coral reefs they find interesting that they can see in astronaut photography. The “aspect” of the feature becomes the basis for a research question they can formulate.
2. As students create a research question, it should focus on one of the features they have identified and should be formulated to address that aspect of the feature they find interesting. As part of their research methods, students should, at a minimum, include what metadata and other data they would need to log from each image in order to answer that question. Students should base this information on the metadata/data they logged during Part 2 of the activity.

SPHERES OF EARTH
Part 4: Research Planning

Based on your observations of images and presentations given by your classmates, answer the following questions to initiate a research investigation you could potentially pursue.

- List three visible features observed in images that interest you the most. Also list the most closely associated Earth system related to that feature. Indicate a specific aspect of each feature you find interesting that could become the focus of future research.

Feature	Earth System	Aspect of Feature that is Interesting
1.		
2.		
3.		

- Think about each of the features you listed above. Using one of those features, create a question that could be researched about that feature using current technology. Include an explanation of what methods you would use to go about answering that question. Be as detailed as possible including what specific data/metadata you would want to log from each image observed.

Feature
Research Question
Explanation of Research Methods



Part 5: Systems and Features Review (Evaluate Activity):

Estimated time for Part 5: ~15 minutes

Materials needed:

- Pages 14-15 of the *Student Guide*
- Computer projector or printed images

At the end of the activity, students should be able to identify visible features in an image and name and justify their associated Earth system. The justification should highlight an understanding of the definition of the Earth system. For step 2 listed below you can have students do this individually or as a group.

SPHERES OF EARTH
Part 5: System and Feature Review

You are now familiar with different visible features in images taken from space and the four Earth systems. You will now be evaluated on your ability to recognize different features and their associated systems. The scoring rubric below indicates how you will be graded. For each image you will:

1. Identify visible features.
2. Identify which system those features are associated with.
3. Justify or explain the association of the visible feature and system.

As a quick review, list the names of the 4 Earth systems below. Include key words to help you remember what each system is associated with.

List the 4 Earth Systems			

The following rubric will be used to evaluate the information you provide for each image:

SCORING RUBRIC

Exemplary (4 points) Information is complete, accurate and detailed
Two features were correctly identified
Associated Earth systems for both features were correctly identified
A suitable justification was provided

Meets Standards (3 points) Most information is complete and accurate
Two features were identified
Earth system for at least one of the features was correctly identified
A somewhat suitable justification was provided

Partially Meets Standards (2 points) Information is somewhat incomplete and inaccurate
Only one feature was correctly identified
Earth system was not correctly identified
A poor justification was provided

Needs Review (1 point) Information is mostly inaccurate
No features were correctly identified
Earth system for one or both features was not correctly identified
Justification was not provided

Expedition Earth and Beyond: Astromaterials Research and Exploration Science (ARES) Education – Version 1.0
NASA Johnson Space Center

SPHERES OF EARTH
Part 5: System and Feature Review

Record the information for each image below:

RANGE #1

Visible Features	1	2
Associated Earth System		
Justification		

RANGE #2

Visible Features	1	2
Associated Earth System		
Justification		

RANGE #3

Visible Features	1	2
Associated Earth System		
Justification		

Expedition Earth and Beyond: Astromaterials Research and Exploration Science (ARES) Education – Version 1.0
NASA Johnson Space Center

1. Students should be in their groups of 4 and should read through the information they will be asked to record about a given image and how they will be evaluated. Discuss as necessary. Have students fill in the list of the 4 Earth systems just to reinforce and review each system.
2. Show the class an image and give students 2-3 minutes to make observations and record the information on the System and Feature Review log sheet.

Note: This scoring rubric is provided in the *Student Guide*. It can be adjusted as you feel necessary.

SCORING RUBRIC

Exemplary (4 points)	All information is complete, accurate and detailed Two features were identified Associated Earth systems for both features were correctly identified A suitable justification was provided
Meets Standards (3 points)	Most information is complete and accurate Two features were identified Earth system for at least one of the features was correctly identified A somewhat suitable justification was provided
Partially Meets Standards (2 points)	Information is somewhat incomplete and inaccurate Only one feature was correctly identified Earth system was not correctly identified A poor justification was provided
Needs Review (1 point)	Information is mostly inaccurate No features were correctly identified Earth system for one or both features was not correctly identified Justification was not provided



Extensions:

1. Have students use this activity as a springboard to their participation in the Expedition Earth and Beyond Program. Students can discuss and debate features of interest that the class may be interested in studying as part of an authentic research project.
2. Have students investigate other planetary bodies in our solar system to discover if they have the same systems Earth does and how that may affect features we see (or may not see) on those planetary bodies.



SPHERES OF EARTH

Part 1: KWL Prior Knowledge

In your small group, brainstorm ideas about what you think you know about Earth System Science and the “spheres” or systems of Earth. To help you get started, think about Earth Systems as you would the systems of the human body. For example, the circulatory system is one of many systems that make up the human body. “Features” or components associated with the circulatory system are the heart, blood, and blood vessels.

Name, list, or describe what you know about the different “spheres” or systems that make up Earth.	List any features on Earth that are associated with any of these “spheres” that can be studied using images from space?	What questions do you have about the different spheres of Earth?



SPHERES OF EARTH

Part 2: Background Information & Data Collection

Website: <http://eol.jsc.nasa.gov>

Astronaut Photography Image Metadata and Observations	
Image ID#:	Latitude (N): Longitude (E):
Camera Used:	Lens Focal Length:
Date Acquired:	Country/Geographic Region:
Background information about image:	
List 3 Visible Features, Associated Earth System, and Observations	Miscellaneous Observations and/or Sketch
Feature: _____ Earth System: _____ Observations of feature:	
Feature: _____ Earth System: _____ Observations of feature:	
Feature: _____ Earth System: _____ Observations of feature:	



SPHERES OF EARTH

Part 3: Presentation of Observations

You have now observed 4-6 images and seen a variety of visible features in images taken from space. You should also now be more familiar with the different Earth Systems. Choose one of the images you logged data for and explain to your classmates what you have discovered. **Use the table below as a guide for your presentation.**

Image ID#			
Background information about image and its location			
Observations of 3 features and associated Earth system	Feature: _____ System: _____ Observations of feature:	Feature: _____ System: _____ Observations of feature:	Feature: _____ System: _____ Observations of feature:
Two questions about a specific feature(s) that interest you	1. 2.		

As each group presents information about one of the images they observed, be sure to take notes. Be sure to log comments about the image or features that you found interesting. Use the table on the next page as a guide for your notes.



SPHERES OF EARTH

Part 3: Presentation of Observations

STUDENT PRESENTATION NOTES:

Student Presenters and Image ID#			
Observations of 3 features and associated Earth system	Feature: _____ System: _____ Observations:	Feature: _____ System: _____ Observations:	Feature: _____ System: _____ Observations:
Comments about image or features you found interesting			

Student Presenters and Image ID#			
Observations of 3 features and associated Earth system	Feature: _____ System: _____ Observations:	Feature: _____ System: _____ Observations:	Feature: _____ System: _____ Observations:
Comments about image or features you found interesting			



SPHERES OF EARTH

Part 4: Research Planning

Based on your observations of images and presentations given by your classmates, answer the following questions to initiate a research investigation you could potentially pursue.

1. List three visible features observed in images that interest you the most. Also list the most closely associated Earth system related to that feature. Indicate a specific aspect of each feature you find interesting that could become the focus of future research.

Feature	Earth System	Aspect of feature that is interesting
1.		
2.		
3.		

2. Think about each of the features you listed above. Using one of those features, create a question that could be researched about that feature using astronaut photography. Include an explanation of what methods you would use to go about answering that question. Be as detailed as possible including what specific data/metadata you would want to log from each image observed.

Feature	
Research Question	
Explanation of Research Methods	



SPHERES OF EARTH

Part 5: System and Feature Review

You are now familiar with different visible features in images taken from space and the four Earth systems. You will now be evaluated on your ability to recognize different features and their associated systems. The scoring rubric below indicates how you will be graded. For each image you will:

1. Identify 2 visible features
2. Identify which system those features are associated with
3. Justify or explain the association of the visible feature and system

As a quick review, list the names of the 4 Earth systems below. Include key word(s) to help you remember what each system is associated with.

List the 4 Earth Systems			

The following rubric will be used to evaluate the information you provide for each image:

SCORING RUBRIC

Exemplary (4 points)	All information is complete, accurate and detailed Two features were correctly identified Associated Earth systems for both features were correctly identified A suitable justification was provided
Meets Standards (3 points)	Most information is complete and accurate Two features were identified Earth system for at least one of the features was correctly identified A somewhat suitable justification was provided
Partially Meets Standards (2 points)	Information is somewhat incomplete and inaccurate Only one feature was correctly identified Earth system was not correctly identified A poor justification was provided
Needs Review (1 point)	Information is mostly inaccurate No features were correctly identified Earth system for one or both features was not correctly identified Justification was not provided



SPHERES OF EARTH

Part 5: System and Feature Review

Record the information for each image below:

IMAGE #1:

Visible Features	1.	2.
Associated Earth System		
Justification		

IMAGE #2:

Visible Features	1.	2.
Associated Earth System		
Justification		

IMAGE #3:

Visible Features	1.	2.
Associated Earth System		
Justification		