



Instructional Guide for The ArcGIS Imagery Book



By Kathryn Keranen and Lyn Malone



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On the cover:

An aerial view of the Sydney cityscape, Sydney, New South Wales, Australia. Courtesy of Getty Images.

To Bob and Pat, for their constant support
and encouragement.

Kathryn and Lyn

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How to Use This Book

This Instructional Guide for The ArcGIS Imagery Book is designed for anyone who wants to learn—or learn more—about the countless uses of imagery, the many types of imagery, and the rapidly growing integration of imagery with GIS. It is also a valuable tool for those who want to help others learn. The instructional guide is a companion book to *The ArcGIS Imagery Book*. Each chapter in that volume includes learning opportunities such as Quickstarts, with information about relevant software, data, and web resources, and Learn ArcGIS lessons to provide hands-on practice in the skills discussed. This instructional guide starts where the first volume left off. In this guide you'll find videos and activities that support the development of basic skills and understanding about remotely sensed imagery. Each chapter also includes scenario-based lessons that put those concepts to use in answering questions and addressing real-world issues.

If a Swiss army knife is a multi-purpose, versatile, and adaptable tool, then consider this guide the Swiss army knife for learning and teaching about the integration of imagery with GIS. Use it as a personal tutorial, a refresher course, a lab manual, or a repository of training activities. Adapt it to meet your needs.

A personal tutorial

Use this guide on your own to learn about imagery. You'll learn how to make maps that combine imagery with other data layers and services in ArcGISSM Online and to share them in a variety of ways. You'll learn how to access different types of imagery online and to use that imagery to create and map your own new data. You'll use imagery to observe and analyze change over time by looking at sequential satellite images and using online apps such as Esri's ChangeMatters Viewer. Go through the book chapter by chapter or hone in on the topics and skills that are most relevant to your own situation. There is no wrong way to use this guide—make it work for you.

A refresher course

Use this guide to update your own remote sensing and imagery skills and knowledge. Instead of working with software and imagery stored on your computer, you'll learn to leverage the power of cloud computing and open data. Discover opportunities to collaborate and share your maps and data with an ArcGIS Online organizational account. Get hands-on practice in 3D imagery, live imagery feeds, and crowdsourcing with ArcGIS Online. Whatever your prior imagery or GIS experience, with this guide you can lift yourself to a new level.

A lab manual

Use this guide with a group of students to provide practice in basic skills and content. Focus on particular chapters and skills one at a time or encourage learners to go through the entire book at their own pace. By using the book in this way, you are offering people a foundation of imagery skills and knowledge they can build upon down the road.

A repository of training activities

Use this guide to design and deliver GIS/imagery training in a focused setting such as teacher professional development. Have you been asked to provide training in “the basics” of remote sensing, the use of imagery to analyze change over time, or the interpretation of Landsat data? The *Instructional Guide for The ArcGIS Imagery Book* will provide you with resources for all these requests. No matter what the focus of the training or learning, this guide provides the essential ingredients to combine and blend in any way you choose.

Introduction

This learning guide is a companion to *The ArcGIS Imagery Book* (Esri Press 2016), providing further resources and hands-on lessons to build upon the learning opportunities provided in that book. You can engage with this guide as a student or teacher, novice or expert, scientist or historian. Each chapter aligns with a parallel chapter in the companion book. The instructional guide includes activities and lessons designed to enhance your ability to expand the power of GIS by merging it with remote sensing and imagery. The lessons reflect the core of GIS—visualizing and analyzing spatial data—then adding the irresistible allure of imagery. Answers to questions are available at esri.com/esripress-resources.

This instructional guide focuses on the fluid interaction between ArcGIS Online and GIS applications on the web and on mobile devices. All the lessons in this guide can be completed with ArcGIS Online, a free resource for exploration of data and imagery. ArcGIS Online is a rich repository of maps and data resources contributed by scientists, GIS professionals, and other GIS users that anyone can use to ask questions and share answers.

Logging in to get an ArcGIS Online organizational account is free and will allow you to do some of the lessons in this guide. Other lessons do not require an organizational account. None of the exercises requires preloading data on user computers. You can do the scenario-based lessons in any order, which gives teachers and other users many instructional and learning options.

The new era of imagery technology has produced a definitive collection of big data. Cloud storage in ArcGIS Online helps make this big data accessible to everyone so there is a lot of new information waiting to be explored. Most of it is geospatial data requiring processing and analysis before it can be understood and shared. A GIS is the ideal environment for performing these tasks. The rapidly growing worlds of imagery and remote-sensing data clearly reflect the world of big data and all its implications.

So, at first glance, this is a guide about imagery. But once learners get their hands on the lessons within, it becomes much more. It is a road map to the power that results from the integration of GIS and imagery. Because GIS is a learning tool itself—used to ask and answer questions—in its broadest sense, this is nothing short of a guide on how to learn in a new era.



Imagery Is Visible Intelligence

A geographic Rosetta stone

Something amazing and unexpected happened when humans ventured into outer space—we saw Earth for the very first time. In 1968, Apollo 8 astronauts observing the moon’s surface from lunar orbit turned their camera toward Earth and captured the first image of earthrise on the lunar horizon. They were awestruck as were millions of Americans watching the historic moment from their homes. In 1987, writer Frank White published *The Overview Effect* about the transformational impact of seeing Earth from space. White called it the “overview effect”—a sense of awe at Earth’s profound beauty, its borderless unity, and its fragile systems, protected and nourished by only a paper-thin atmosphere.

The exponential growth in the number of Earth-orbiting satellites provides us with remotely sensed views of Earth from space every hour of every day. These richly varied images, too, capture Earth’s extraordinary beauty in the reflected colors of the electromagnetic spectrum. With sensors detecting surface and atmospheric conditions, these images reveal the interconnected vulnerability of its many systems such as vegetation and climate. Finally, the absence of visible boundaries and borders provides a sense of unity that supersedes the differences that often divide us. Imagery deepens our understanding of past, present, and future phenomena because it continually expands our perspective with new insights into our world.

Introductory activities

Video

Since videos motivate and inspire, as well as enhance discussion, go to the NASA: Best of "Earth As Art" video to see the top five Earth as Art images, as voted by the public. Landsat has been collecting data of the earth's surface since 1972. Some of the images are visually striking, and the favorites have been selected for this collection.

To access the following videos go to video.esri.com.

Search for each video by the title.



NASA | Best of "Earth As Art" -- Top Five

NASA Goddard

time=3.45 min

Counting down the Top Five Earth As Art images, as voted on by the public. Landsat has been collecting data of the Earth's

<http://www.youtube.com/watch?v=Tq88dRFokgg>

NASA | Best of "Earth As Art" --Top Five

Activity 1.1

Show me my home!

2005: The human era of GIS begins

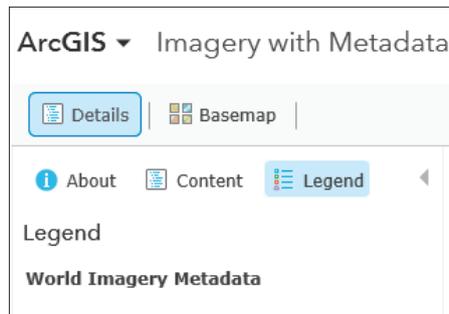
Location and place are two of the five themes of geography. Where is it located? What is it like there? These are the questions that organize space. With the availability of satellite and high-resolution aerial imagery, our perspective of location and place has never been greater. In this introductory activity, you will describe your location on Earth from three perspectives: your absolute location, your location within a regional boundary, and your location within a global boundary.



1. Click *Imagery with Metadata*.



2. Click Open in Map Viewer.
3. Click Content in the left panel.



4. Zoom all the way out to the world view of the map.



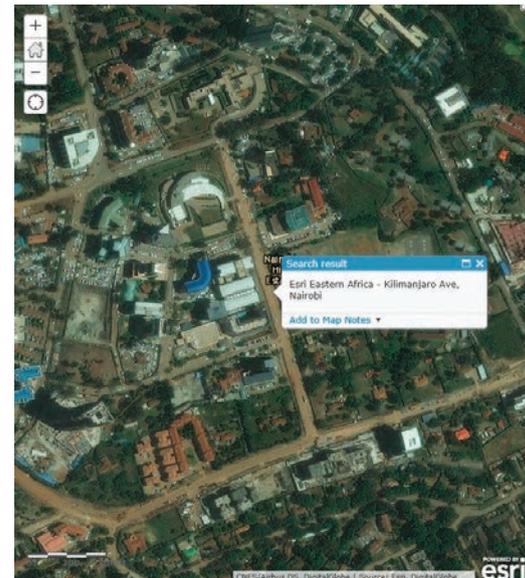
5. Examine the layers in the Contents pane.
List the layers.

Notice that some of the layers are dimmed. Multiscale maps allow you to view geographic data across a range of scales, also known as zoom levels, from buildings to the entire globe. Specifying at what zoom levels content is drawn is known as setting the visible range.

You will use the Esri Eastern Africa office for an example of the procedure to follow to describe a location.

6. In the Search box in the upper-right corner, type Eastern Africa, Kilimanjaro Ave, Nairobi.

Q1 Write a description of the local area.



7. Zoom out until you can see the administrative boundary of Nairobi..

Q2 Write a description of the landscape features within the Nairobi administrative boundary.



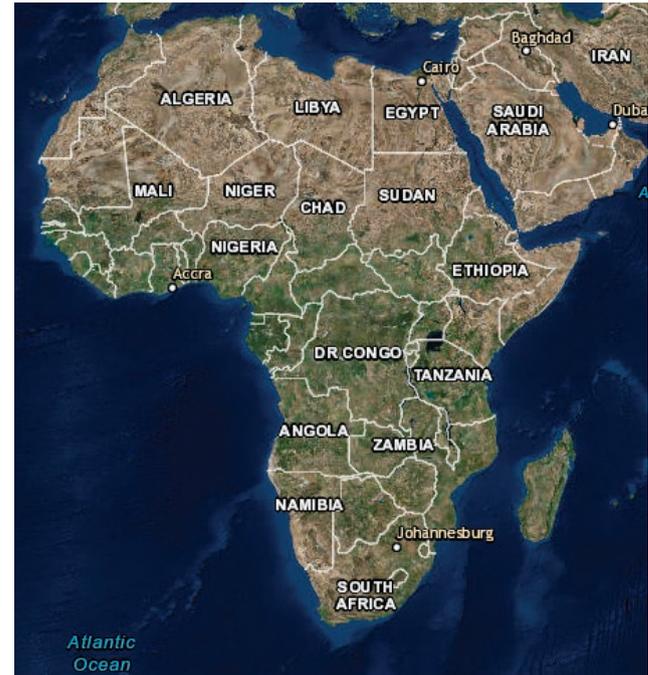
8. Zoom out until you can see the administrative boundary of Kenya.

Q3 Write a description of Kenya.



9. Zoom out until you can see the continent of Africa.

Q4 Write a description of Africa.



10. Repeat the preceding steps with your local location.

Activity 1.2

Three-dimensional scenes

Where and what?

ArcGIS OnlineSM 3D Scene Viewer allows users to explore the world in 3D. The scene viewer is an app built into the ArcGIS Online website for creating and interacting with 3D scenes. The scene viewer works with most modern browsers. Users can choose global or local views, switch basemaps, add layers, configure layers, capture slides, and save scenes. In this introductory activity, you will match a verbal description with a 3D scene.

1. Find the *Three-dimensional scenes map* in chapter 1 of *The ArcGIS Imagery Book*.
2. Click the Map.

Scroll down to the section titled “Working together at last.”



At the bottom, the app shows various locations on Earth. When you click on any of the locations, it opens within the scene viewer.

3. Navigate a scene. Use all the tools.

4. Practice opening different views by clicking scenes at the bottom.

Navigate your scene

In the upper left of your screen are the navigation controls.

- Click **Initial view**  to return to the initial camera position.
- Click **+** to zoom in.
- Click **-** to zoom out.
- You can also use your mouse and scroll wheel to zoom in and zoom out or press and hold the middle mouse button and move down or up to zoom in or out.
- Click **Pan**  to pan. Click and hold the left mouse button and drag the scene in the direction you want to move it. You may also pan by using the arrow keys on the keyboard.
- Click **Rotate**  to rotate. Click and hold the left mouse button and drag the scene in the direction you want to rotate and tilt it.

Tip: The black triangle in the upper right of the tool indicates which tool is selected.

- If you have a two-button mouse, you can use the left mouse button for the primary navigation and the right mouse button for the secondary navigation. For example, if you click **Rotate** , you can use the left mouse button to rotate and the right mouse button to pan.
- Compass**  gives you the orientation of the scene. Click **Compass**  to set your scene to North orientation.

5. Learn to use the scene tools, paying attention to changing the basemaps.

	Search and type a location into the search box
	View layers.
	Choose a basemap
	Adjust daylight
	Share the scene
	Change settings

6. Complete this chart by adding the region and selecting a description from the choices given.

Location	Region	Description
Mount St. Helens		
Mount Whitney		
Grand Canyon		
Bell Rock		
Horseshoe Bend		
Meteor Crater		
Bowknot Bend		
Devil's Tower		
Venice Lagoon		
Mount Blanc		
Mount Vesuvius		
Ayres Rock		
Diamond Head		
The Badlands		
Guitar Shaped		
World's Largest		
Star Fort		
Potash Ponds		

Descriptions:

- Farm shaped like a guitar as tribute to wife who died
- Only active volcano in mainland Europe
- Butte composed of sedimentary rock
- Evaporation ponds near Moab
- Meteorite
- Fort built in a style during the age of gunpowder cannon battlefields
- Enclosed bay of the Adriatic Sea
- Dramatic landscapes inhabited by bison, bighorn sheep, and prairie dogs
- Massive sandstone monolith that is sacred to indigenous inhabitants
- Sector of the Green River canyon that doubles back on itself
- Caused by 277-mile river eroding
- Highest mountain in the Alps
- A hairpin turn in the Colorado River
- Highest summit in contiguous USA
- One-of-a-kind flat-topped volcanic formation
- Butte composed of sedimentary rock
- Name of a volcanic cone on the Island of Oahu
- Highest mountain in the Alps

Activity 1.3

Imagery is beautiful

Earth as Art favorites

This chapter's introductory video, "NASA—Best of Earth as Art," shows the top five Earth as Art images according to the public in 2012. Since then, many stunning new images have been added to the collection.

When art experts critique a painting, they describe such things as *line* (delicate, bold), *tone* (muted, dramatic), *shape* (angular, elongated), *movement* (swirling, flowing), *contrast* (subtle, strong), and *color* (vibrant, pale). The same elements can describe Earth as Art's unique and beautiful views of our world.

1. Click the link to the [Earth as Art](#) link in the "Imagery Is beautiful" section of the first chapter of *The ArcGIS Imagery Book*.
2. Use the arrows to navigate through the site's 42 photos.
3. Select your five favorite images from the collection and explain why each is a favorite by using descriptive words about at least three of these image elements: line, tone, shape, movement, contrast, and color.



Image number	Why do you like it?

Lesson 1–1: Obtaining information from imagery

Measuring the Rondônia rain forest

Remember, you can access ArcGIS Online for all the lessons in this guide, either with no sign-in to an organizational account required (the first set of lessons in each chapter) or by signing in to your organizational account (for the last set of lessons in each chapter).

Satellite or aerial imagery can be described as a direct measurement or primary data source. Products derived from the primary source are considered secondary sources. Secondary sources can be derived by digitizing and obtaining vector information from imagery. With imagery serving as the basemap, you can use a mouse to perform manual digitizing, the process of converting geographic features on an analog map into digital format. As in any human procedure, errors can be introduced.

Build skills in these areas:

- ▶ Opening an existing online map
- ▶ Interpreting clear-cut forest regions
- ▶ Digitizing on screen
- ▶ Measuring on screen
- ▶ Calculating percentage
- ▶ Interpreting Landsat 8 (Moisture Index) imagery
- ▶ Visualizing derived moisture content imagery

What you need:

- ▶ Account not required
- ▶ Estimated time: 1 hour

Scenario

Deforestation is defined as the removal of a forest or stand of trees where the land is thereafter converted to a nonforest use. Clear-cutting is a type of deforestation logging practice in which most or all trees in an area are uniformly cut down. The practice of clear-cutting can be clearly seen from imagery in the state of Rondônia in Brazil. The deforestation in Rondônia is seen in a pattern that looks like a fish skeleton because the cutting fans out along the roads. You have been asked to provide a quick approximation of how much of Rondônia's land has been affected by clear-cutting. You have access to both high-resolution imagery and a Landsat 8 image that shows dry and wet areas.

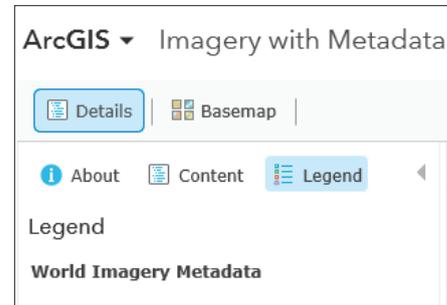


1. Click *Imagery with Metadata*.



2. Click Open in Map Viewer.

3. Click Content in the left panel.



4. Zoom all the way out to the world view of the map.



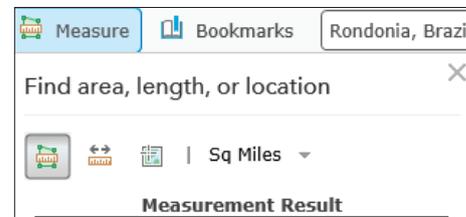
5. Search for Rondônia, Brazil.

Take a few minutes to zoom in and out and observe the fish-skeleton-like pattern of clear-cutting in Rondônia. As you zoom inward, you can see that the land is now agricultural.

6. Click Basemap on the left and change to Imagery with Labels.



8. On the upper right, click Measure and then the Area icon. The unit is Sq Miles.



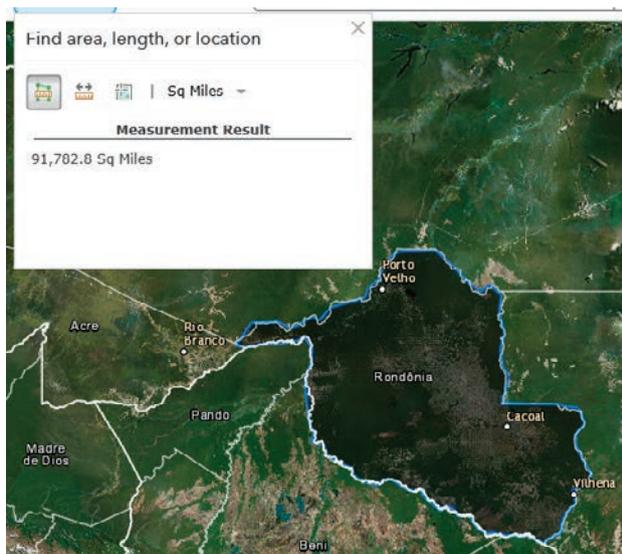
Q1 What are the major cities in Rondônia?

Q2 Zoom into the city areas. Describe the urban areas.

To calculate the percentage of Rondônia that has been deforested by clear-cutting, you need to know two numbers: the total number of square miles of Rondônia and the number of square miles already clear-cut. Remember, at the beginning of the exercise, it was determined that this secondary information can be obtained from the primary image source.

7. Zoom out so the entire state of Rondônia is visible.

9. After clicking the Area icon, digitize around the country by selecting points and creating a polygon. When the polygon is complete, record the area.



Total area of Rondônia: _____ sq miles.

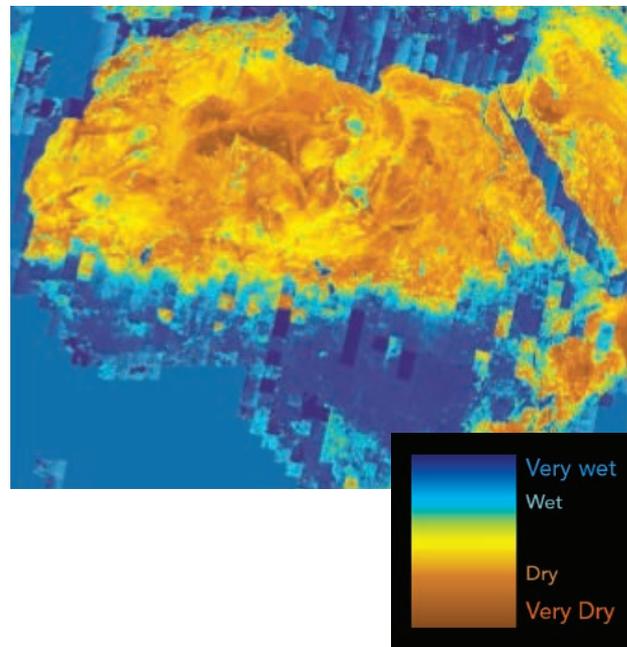
10. Zoom in and digitize around the areas of Rondônia that have been deforested by clear-cutting. You need to digitize several polygons and add the areas together for a total.

Total area of deforestation: _____sq miles.

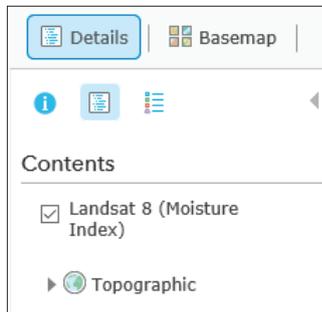
$$\text{Total area of Rondônia} / \text{Total area of deforestation} \times 100 = \text{_____ of deforested land.}$$

In the previous section, high-resolution aerial imagery was used to observe Rondônia. In the next section, a Landsat 8 Moisture Index image will be used. The moisture index has been derived from the most recent Landsat 8 imagery and is an estimated level of moisture in vegetation. Wetlands and other vegetated areas with high levels of moisture appear as blue, whereas deserts appear as tan to brown. The Normalized Difference Moisture Index (NDMI) is calculated by using the near infrared (band 5) and shortwave infrared (band 6). The map is updated daily, retaining the four most recent scenes for each path/row that has cloud coverage of less than 50 percent.

11. Open *The Moisture Index: How wet or dry?*



12. On the right panel at the bottom, click Data Source. This opens the Landsat 8 (Moisture Index).
13. Click Landsat 8 (Moisture Index) and then Open in Map Viewer.
14. In the upper-right search box, search for Rondônia, Brazil.
15. Below Details on the left, click Contents. That shows the two layers on the map. You can turn off the Landsat 8 (Moisture Index) to observe the outline of Rondônia.



Q3 Write a description of the deforested land using the Moisture Index legend.

16. Following the procedure explained in steps 8–10, digitize around the deforested region and perform the calculation for percentage of clear-cutting again. You may use the total area of Rondônia that you obtained previously.

Total area of Rondônia: _____ sq miles.

Total area of deforestation: _____ sq miles.

Total area of Rondônia/total area of deforestation × 100
= _____ of deforested land.

In this lesson, you have identified deforestation areas using both aerial and derived remote sensing imagery. You have used this imagery to obtain measurements to quantify the area of deforestation.

Lesson 1-2: Layering contemporary imagery with historical maps

Identifying coordinates for historic locations in New York's Central Park



Overlaying current satellite imagery with high-resolution historical map images (such as those in the David Rumsey Historical Map Collection) provides unique insights into the contemporary landscape.

In the past decade, the proliferation of mobile devices and apps has given birth to a revolutionary new genre in the world of tourism—mobile map tours. Using only your smartphone, you can take a campus tour of virtually any college or university, a walking tour of an urban historic district, or a guided tour of an art museum. The possibilities are endless.

Build skills in these areas:

- ▶ Opening and saving a new map
- ▶ Changing the basemap
- ▶ Creating and symbolizing an area map note
- ▶ Adding new map layers from ArcGIS Online
- ▶ Identifying latitude and longitude coordinates of specific locations
- ▶ Creating and symbolizing point map notes

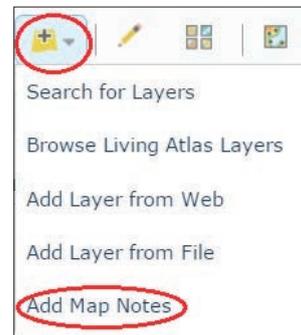
What you need:

- ▶ ArcGIS organizational account
- ▶ Note: If you do not have an ArcGIS organizational account, you can still create this map, but you cannot save it.
- ▶ Estimated time: 1 hour

Scenario

One of the largest arenas for mobile app development is tours of national, state, and local parks. You have been asked to work with an app tour developer to identify points of historic interest and importance in New York City's Central Park based on a map of New York City in 1836. Central Park did not exist at that time, but your company is creating a walking tour app that will highlight the park's history as well as its contemporary features. You will submit an ArcGIS Online map with selected 1836 historic locations noted so that a research team can develop appropriate text to go with them in the tour.

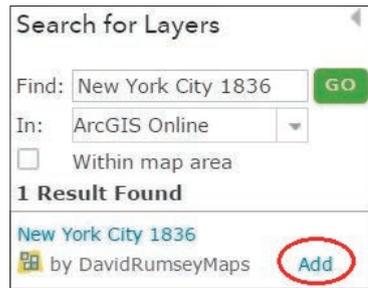
1. Sign in to your ArcGIS Online organization account and click Map to open a new map.
2. Change the basemap to imagery.
3. Save your map as **Central Park Tour**. Give the map appropriate tags and provide a summary.
4. Find Central Park by typing it in the Find box.
5. Create a map note (Add Content to Map>>Add Map Notes) called **Central Park** by digitizing Central Park's long rectangular shape from the Imagery basemap.



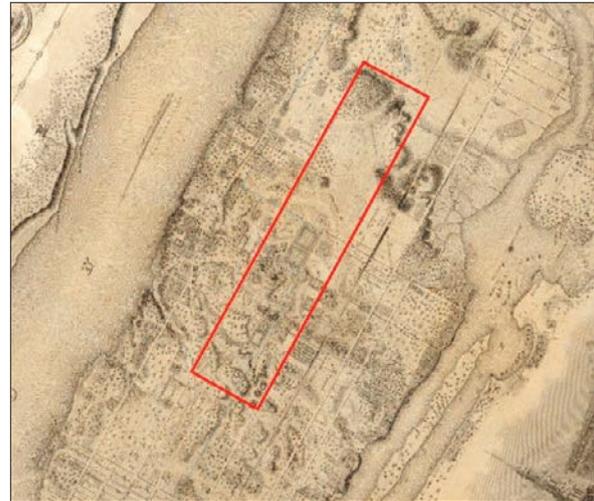
- Using the Area tool, click three of the park's corners. Double-click the fourth corner to finish.
- Symbolize the area with a red outline and no fill.
- Click Edit when you are done.



6. Add New York City 1836 from the David Rumsey Historical Map Collection (Add Content to Map>>Search for Layers). Search for **New York City 1836** in ArcGIS Online. When you find the David Rumsey map, click Add.



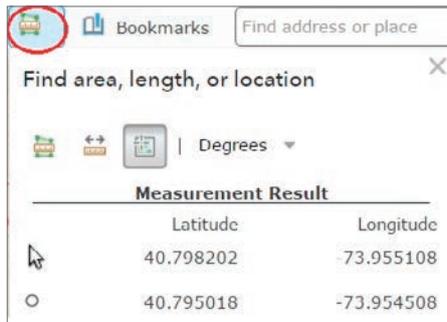
7. Turn on the 1836 map of New York City and move the Central Park map note above the historical map.



8. Zoom in to the map legend (Explanation) to learn what the map symbols represent



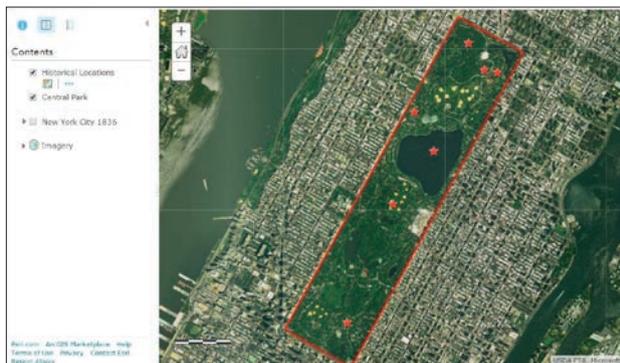
9. Zoom in to the area of Central Park as delineated by your Central Park map note. Using the legend symbology, make a list of area features from 1836 that later became Central Park.
10. Use the Measure tool to determine the coordinates of each of the following locations in the Central Park area in 1836. Simply click the Measure tool, the Location tool, and the appropriate location on the map to find its latitude and longitude.



- Powder House
- Fort Clinton
- Fort Fish
- The Receiving Reservoir
- Woods (one or more areas)
- An orchard (one or more areas)
- Marshland

11. Turn off the historical map layer, New York City 1836.
12. Create a map note for each of the locations in step 9. Use the following directions to create each map note:
 - In the Find box, enter the latitude and longitude coordinates for the Powder House. Note: enter the longitude (-73.97315), followed by a comma, and then the latitude (40.768908).
 - In the search results window, click Add to Map Notes
 - Click the new blue Map Note symbol. Title it Powder House.
 - To change the Map Note symbol, in the Shapes symbol, select the red star and change the size to 25 px.
 - Click OK and click Close.
 - Repeat these steps for each of the remaining locations on the list above. Give each an appropriate title (e.g., Powder House, Fort Clinton, and so on).
13. In the map contents, change the Map Notes layer name to **Historical Locations**.

14. Save your map.



Your task is complete. You used an historical map to identify and locate historical features from 1836 in the area that is now Central Park. You summarized your findings by creating a map showing each of the historical locations.

The ArcGIS Imagery Book, chapter 1

Questions for reading comprehension, reflection, and discussion

Teachers can use the items in this section as an assignment, introduction, or assessment, tailored to the sophistication of learners. Some learners can read all the sections at one time, while others are more comfortable with small segments. The questions and tasks are designed to stimulate thought and discussion.

1. What advances in the use of imagery for intelligence and reconnaissance were developed during World War II?
2. What can satellite imagery reveal that photography cannot?
3. Imagery has a wide range of uses and applications. What are some of the unique insights and capabilities that we derive from the use of imagery?
4. Imagery processing systems and GIS have common characteristics that allow them to work together today in ArcGIS. What are some of those shared characteristics?
5. Look at the various maps that are linked from this chapter in *01 Imagery Is Visible Intelligence*. Identify and briefly describe uses of modern imagery that these maps reflect.

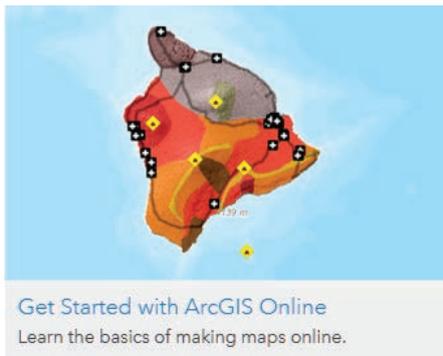
Additional resources

Learn ArcGIS: Guided lessons based on real-world problems



Get Started with ArcGIS Online

- Adding layers to a map
- Adding data stored as spreadsheet or file data to a map
- Changing map symbols
- Configuring pop-ups
- Sharing the map as a web app



Oso Mudslide - Before and After

- Creating an app with Web AppBuilder
- Adding metadata



Oso Mudslide - Before and After
Show disaster imagery by creating an app with Web AppBuilder.

Get Started with ArcMap

- Adding data to a map
- Analyzing relationships between data
- Digitizing features
- Symbolizing and organizing data



Get Started with ArcMap
Map the impact of roads on deforestation in the Amazon rainforest.



The Nature of Remote Sensing

Information gathered from a distance

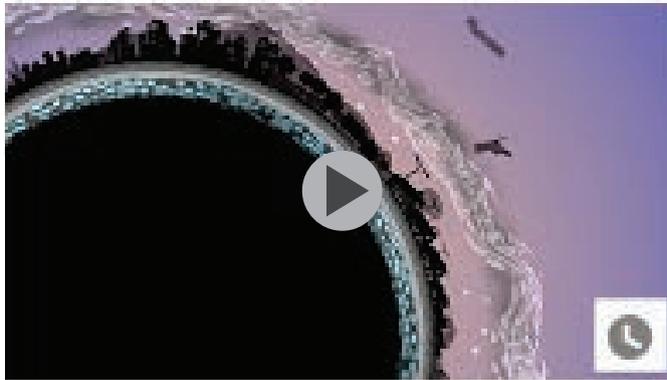
To the average person, the term *remote sensing* conjures images of satellites and oddly colored photographs taken from great heights. They would be surprised, then, to learn that they've been remotely sensing the world for their entire life. Remote sensing simply means gathering information about something from a distance. Human eyes, ears, and noses are sensors that detect electromagnetic light, sound waves, and atmospheric chemicals (gases) without being in actual contact with them. Focus on your own sensors for just a moment. What do you see, hear, smell? A squirrel in the tree outside your window? The sound of traffic on the street? The smell of coffee brewing? Your built-in remote sensors are informing you about the world around you.

Geographers use manufactured remote sensors to study Earth's surface. These sensors are mounted on all manner of high-flying vehicles such as satellites, airplanes, and drones, enabling them to observe Earth from above. Remote sensing has applications for almost every human industry, activity, and concern. Using remotely-sensed data, farmers are increasing crop yields, commuters are monitoring traffic flow, and environmentalists are investigating climate change. With the rapid proliferation of unmanned aerial vehicles (UAVs), the number of remote sensing applications is growing exponentially. Remote sensing is informing decision-making in every arena and will only grow in value and importance in years to come.

Introductory activities

Video

Videos elevate motivation and enthusiasm as well as enhance discussion.



NASA | Getting the Big Picture

NASA Goddard

time=2.40 min

A brief animated look at the different types of remote sensing techniques that NASA uses to study the Earth. This video is public...

https://youtu.be/rA_VCLzvbvM

A brief animated look at the different types of remote sensing techniques that NASA uses to study the Earth.

Activity 2.1

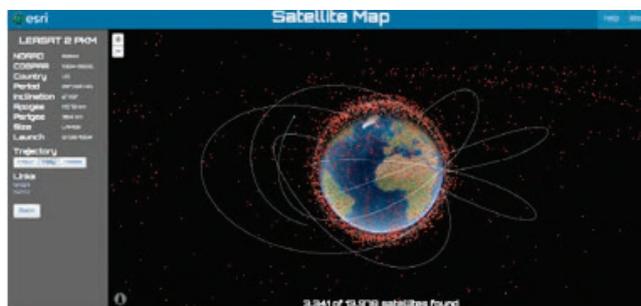
Satellite map: The constellation of Earth-orbiting satellites

When deciding how to organize their time around the lessons in this chapter, students and teachers might want to combine the next two lessons (the lesson on basemaps and the one on scale and resolution) as an activity.

In this activity, you will use an app that maps about 14,000 man-made objects orbiting the earth. You will use the app to research various types of satellites and their properties. The satellites and their positions are mapped by space-track.org, which is an organization designed to promote space flight safety by sharing space situational awareness services for both US and international satellites.

1. In chapter 2 of *The ArcGIS Imagery Book* under the section "Eyes in the sky," find the [Satellite Map](#).
3. Identify by number the country satellites

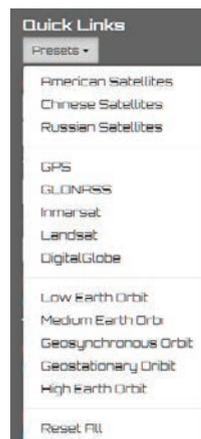
_____ American Satellites
_____ Chinese Satellites
_____ Russian Satellites



Whoa! 14,000 is a lot of man-made objects. Notice that you can not only zoom in and out, but you can rotate the Earth. The application comes with buttons and slides below preset dropdown menus, which allow you to build your own selections. There are 13,925 satellites loaded in the application. First deal with the preset quick links.

2. Click the Preset tab to investigate the Quick Links.

The first three quick links are self-explanatory **country links**.



The next set of Quick Links deal with the type of satellite.

4. Watch the video referenced at the beginning of the chapter again and complete the chart below:

Satellite	Type	Owner	Passive/ Active	# of satellites
GPS				
Landsat				

The next set of Quick Links illustrates different satellite orbits.

Before you complete the chart below you should define the following words:

Elliptical orbit

Perigee

Apogee

Geosynchronous orbit

Geostationary orbit

Orbit Name	Shape	Distance from Earth	Number of Satellites
Low Earth			
Medium Earth			
Geosynchronous			
Geostationary			
High Earth			

Remember the application also comes with buttons and slides that allow users to build their own selections. Below are some topics that you might want to explore.

5. How many man-made objects are junk? Junk consists of spent rocket boosters or debris from satellite collisions. Calculate the percentage of manmade objects that are junk.

6. List the countries in order of the number of satellites they have launched.

7. How many satellites have been launched by decade that are considered Not Junk?

1950–1960

1960–1970

1970–1980

1980–1990

1990–2000

2000–2010

2010–2020

8. Identify the following types of orbits:

- Geosynchronous
- High
- Geostationary
- Low
- Medium

9. Go to Quick Links and select Landsat.

10. Zoom in and find one of the two Landsat satellites.

11. Click the satellite to see its path projector.

By exploring the satellite map you have learned about the history of satellites, the types of satellites, and their orbits.

Activity 2.2

Natural color: Image resolution versus ground accuracy

Because of the way data is stored in a GIS, it is important to distinguish between image resolution and ground accuracy. Because image data is stored as pixels, the size of the pixel determines the resolution of the image. Image resolution is typically expressed as distance on the ground. The imagery community refers to this as the ground sample distance (GSD). An image with 1-meter spatial resolution means each pixel is 1 meter X 1 meter or covers an area of 1 square meter. Ground accuracy is the degree by which a measurement reflects the true value. Both measurements can be obtained by looking at the imagery metadata.

1. Click *Imagery with Metadata*.

Imagery with Metadata

Overview



Satellite imagery for the world and high-resolution aerial imagery for many areas, with available layers showing boundaries, places, and transportation including street names. Zoom in and click on imagery for metadata information.

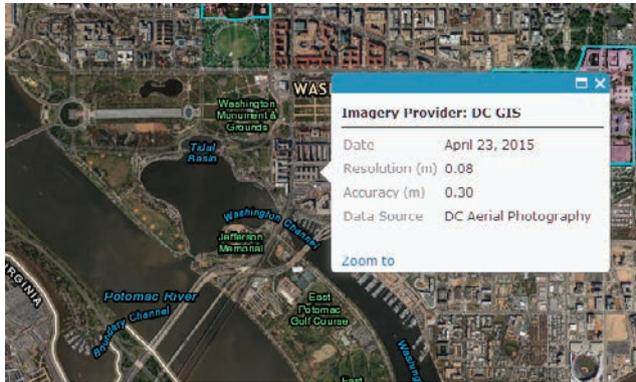
by [esri](#)

Last Modified: January 17, 2017

2. Zoom out to the world view.



3. Search for Washington, DC.
4. Zoom into Washington, DC until you see World Imagery Metadata appear in the contents pane.
5. Click the image. A pop-up shows you the Date, Resolution, Accuracy, and Data Source. Record this information the chart below.



6. Repeat steps 3 to 5 for the following locations and complete the chart below:

Name	Date	Resolution (m)	Accuracy (m)	Data Source
Washington, DC				
Ayres Rock, Australia				
Machu Picchu, Peru				
Moscow, Russia				
Rio de Janeiro, Brazil				
Cape Town, Africa				
Reykjavik, Iceland				

All the images have a resolution of 0.50 m which means each pixel is .5 m X .5 m. The accuracy changes depending on the location. Remember the basemap is compiled of a mosaic of many different images taken by many different satellites at different positions around the world. After doing this lesson you should be able to distinguish between accuracy and resolution.

Activity 2.3

Imagery application trends: Urban planning



The Urban Observatory is a web app that allows you to compare facts and live data about US and global cities. You can compare any three cities at one time on multiple variables or themes. The maps are synchronized so that zooming in or out in one map causes a corresponding change for the other two. In other words, you are always looking at the featured cities at the same scale.

One of the major systems connecting cities to their surrounding regions is their highway network. Urban geographers have identified several typical patterns of urban highway networks: radial highways leading from the surround to a central hub, linear patterns resulting from constraints caused by geographic barriers or obstacles (e.g. mountains, rivers), and irregular networks that have no obvious pattern (these may have historical roots that are not apparent). London, Istanbul, and New York provide examples of these patterns.

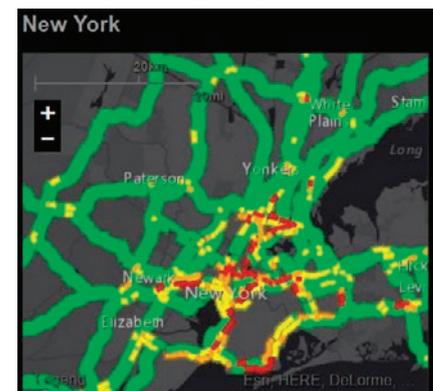
Radial highways network



Linear highways network



Irregular highways network

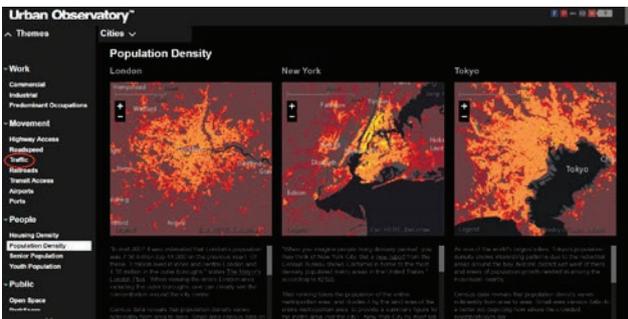


Follow the steps below to identify the highway network pattern of each of these cities.

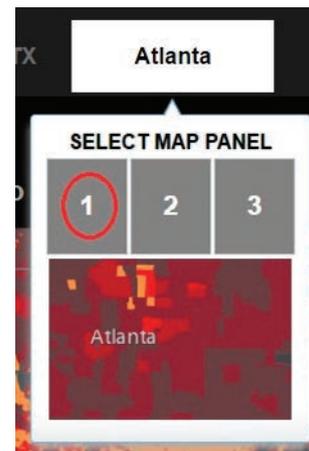
1. In the "Imagery application trends" section of chapter 2, click on the Urban planning thumbnail (the last of nine panels) to open the [Urban Observatory](#) app.



2. When the app opens, read the brief guidelines and click Start Comparing. (Note: The images below show a comparison of population density among three cities, but your app may open with a different comparison. You can ignore the difference and continue with the directions.)
3. To observe and compare patterns of urban highway networks, click Themes and select Traffic (under Movement) from the list of themes.



4. Now we want to select specific cities to observe. Above the maps, click Cities. The alphabetical list of cities is displayed. (Note: If a city name is grayed out, it is not available for the designated theme.) Click the right arrow > at the right of the list to advance the names.
5. Click Atlanta when you see it and select Map Panel 1 to display it in the left panel.



6. Add Auckland and Buenos Aires the same way, placing them in Map Panels 2 and 3 respectively. Your app should now look like this.



As you can read below the map, “this map shows the traffic conditions you can expect at this time of day in this city.” Use *the World Clock* to find out what time it is now in each city:

7. Decide which network (radial, linear, or irregular) best describes each city and put the appropriate letter in front of the city’s name in the list below.
8. When you have considered the first three cities, compare the next three: Cairo, Dublin, and Johannesburg. Add these cities to the app identifying a new city for Map Panels 1, 2, and 3.
9. Once again, decide which network (radial, linear, or irregular) best describes each city and put the appropriate letter in front of the city’s name.

Matching

Which network (A, B, or C) best describes the highway pattern in each city?

- | | |
|--------------------|-------------------------------|
| _____ Atlanta | A. radial highways network |
| _____ Auckland | B. linear highways network |
| _____ Buenos Aires | C. irregular highways network |
| _____ Cairo | |
| _____ Dublin | |
| _____ Johannesburg | |

Challenge

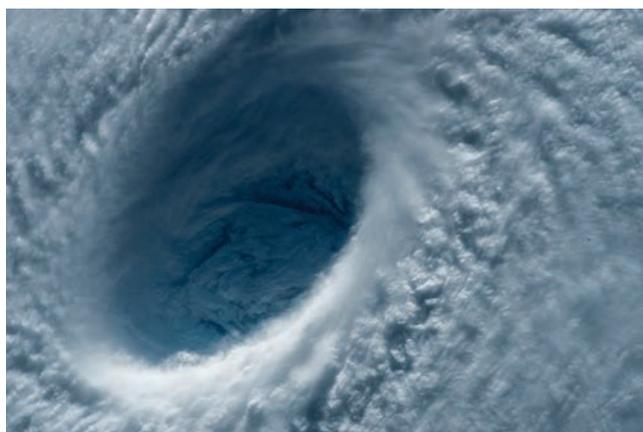
Find another example of each pattern

- | | |
|----------------------------|-------|
| radial highways network | _____ |
| linear highways network | _____ |
| irregular highways network | _____ |

Lesson 2-1: Using MODIS imagery in ArcGIS Online

Tracking Super Typhoon Yolanda

Remember, you can access ArcGIS Online for all the lessons in this chapter by signing in to your organizational account.



Meteorologists have been using satellite imagery to map the paths taken by tropical cyclonic storm systems (hurricanes, typhoons, cyclones) for many years. Today, you can do it yourself in ArcGIS Online by accessing satellite imagery provided in the Living Atlas of the World.

Build skills in these areas:

- ▶ Adding MODIS imagery to ArcGIS Online from The Living Atlas of the World
- ▶ Filtering imagery to select images from specific dates
- ▶ Creating a sequence of map notes from imagery to illustrate a storm track and provide basic storm facts
- ▶ Changing a Map Note symbol

What you need:

- ▶ ArcGIS Online account
- ▶ Estimated time: 45 minutes

Scenario

The Global Meteorological Institute is compiling case studies of the deadliest and most powerful Pacific typhoons since 1950. At the top of the list is Typhoon Haiyan, known as Super Typhoon Yolanda in the Philippines. This storm was one of the most intense tropical cyclones on record. Yolanda, a Category 5 Super Typhoon, caused over 6,000 fatalities. With sustained winds of 195 mph, it was the strongest typhoon to ever make landfall. That historic landfall in the Philippines took place on November 8, 2013.

You have been asked to prepare a map to be included in the Typhoon Yolanda case study.

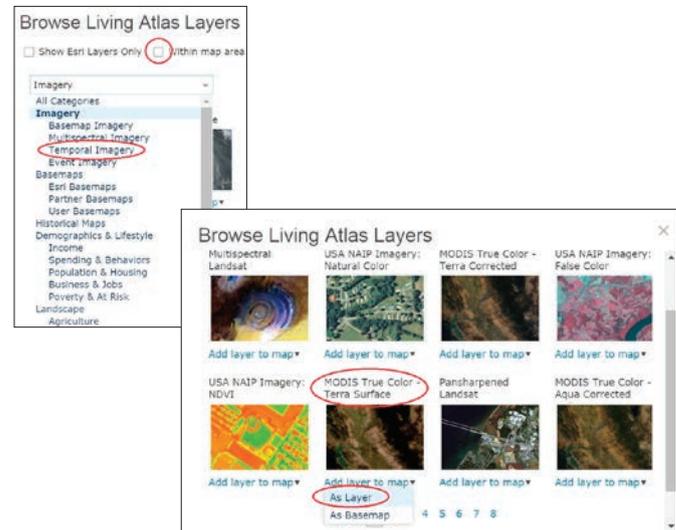
Your map should include the following:

- Satellite imagery of the location of Yolanda from November 5, when the storm became a typhoon, to November 11, when it broke apart after making landfall in Vietnam
- A storm path consisting of points locating the eye of the storm on each date
- Map notes that include basic facts about the typhoon associated with each date

1. Sign in to your ArcGIS Online organization account and open a new map.
2. Save your map as Yolanda 2013. Give the map appropriate tags and provide a summary.

3. Add MODIS Aqua imagery to your map.

- Click the Add Content to Map icon and select Browse Living Atlas Layers. Uncheck the box that says Within map area.
- From the All Categories list, select Imagery and Temporal Imagery.

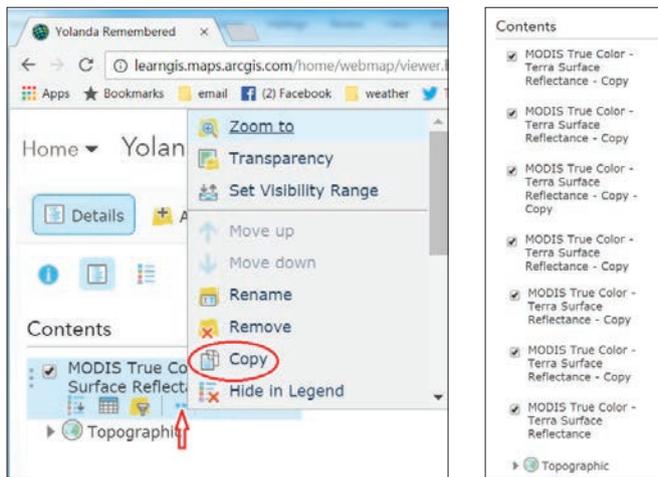


- On the first page of the temporal imagery list, select MODIS True Color – Terra Surface. Select Add layer to map As Layer.
- Click Close.

You now have a map with the Topographic basemap and one layer called Select MODIS True Color – Terra Surface Reflectance. You will need a separate layer for each of the days from November 5 through November 11 (a total of seven layers) so you can create a picture of Yolanda's path during that period.

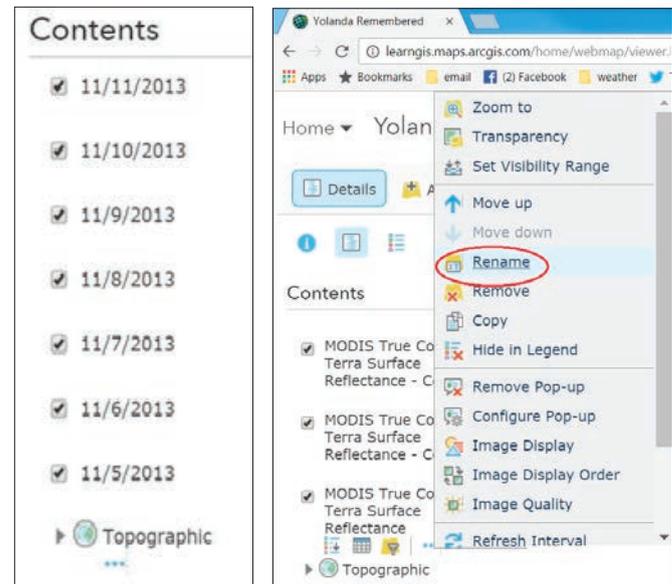
4. Copy MODIS layer:

- Click the More Options icon (3 dots) below the MODIS layer and select Copy. You should now see a layer called MODIS True Color – Terra Surface Reflectance – Copy.
- Repeat this process five more times until you have seven MODIS layers.
- Save your map.



5. Rename MODIS layers:

- Click the More Options icon below the original MODIS layer (it does not say "Copy") and select rename.
- Name this layer 11/5/2013.
- In the same way, rename all the MODIS layer copies moving up from the bottom of the list. Name each layer for a different date: 11/6/2013, 11/7/2013, etc.
- Save your map.



6. Re-center your map and zoom to an appropriate scale.

- Turn off all the MODIS layers in your map.
- Use the Find box to search for Philippines and center your map on the Republic of the Philippines.
- Close the Search results window.
- Zoom out slightly until the extent of your map is like the one below.
- Bookmark this extent and name it Yolanda.

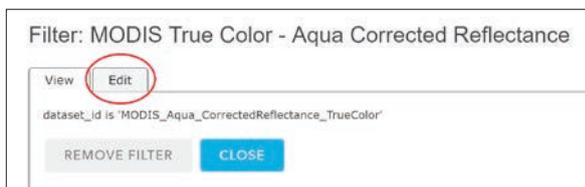


7. Set acquisition dates for MODIS imagery layers

- Click the filter icon beneath the 11/5/2013 layer.



- Click NO, CREATE A NEW FILTER..
- Click ADD ANOTHER EXPRESSION.
- Change the filter so that Acquisition Date is on 11/5/2013 then click the date in the dropdown calendar.
- Click Apply filter.
- Turn on the 11/5/2013 layer to see imagery of the storm on that date.
- Save your map.
- Repeat these steps to change each layer's acquisition date to the date in the layer name.



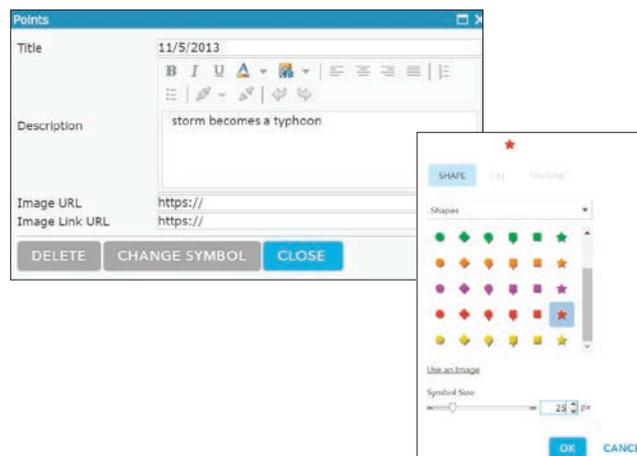
- Save your map.
- Turn off each of the MODIS layers.

8. Add a Map Notes layer:

- Turn on the layer named 11/5/2013.
- Click Add> Add Map Notes.
- Name the Map Note, Typhoon Yolanda.
- Click Create.

9. Add points for the typhoon's center on each date

- Place the pushpin at the center of the large circular cloud mass to the east of the Philippines (the eye of the storm).
- Enter the title: 11/5/2013.
- Enter the following in the description box: tropical storm becomes a typhoon.
- Click Change symbol and select the red star in the Shapes set.
- Click Close.



10. Click Edit to stop editing, and turn on the layer named 11/6/2013. Repeat the preceding steps to place a point on the center of Typhoon Yolanda for each of the remaining layers and dates

11. Save your map when you have completed the series.

12. Use the following table to write an appropriate description for each date.

Date	Description
11/6/2013	
11/7/2013	
11/8/2013	
11/9/2013	
11/10/2013	
11/11/2013	

13. Create map metadata:

- Go to your map's Details page (information > More Details).



- Enter appropriate text in the Description box. The description should include facts about the typhoon and the reason the map was created.

Your map is ready to be incorporated into the Typhoon Yolanda case study. It shows the location of the typhoon's eye on each day from November 5–11, 2013 and provides a note about its status on each of those days.

Lesson 2-2: Farming alfalfa and corn in Nebraska

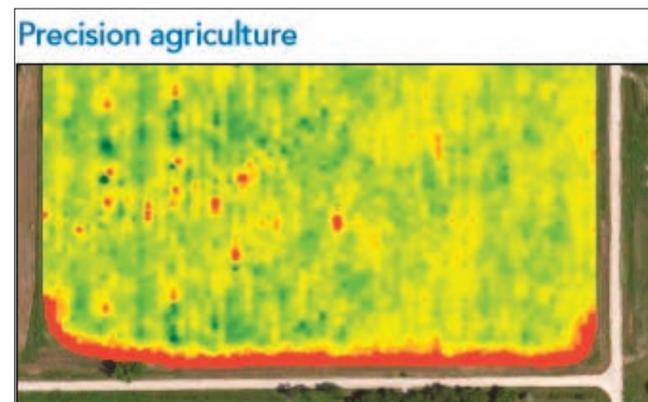
Geospatial technologies provide farmers with tools to help them decide which crops to plant and how to get the most from every acre. Agriculture data taken at specific points can be used to understand how different quantities change across a field.

Build skills in these areas:

- ▶ Opening an existing online map
- ▶ Symbolizing layers
- ▶ Performing multiple variable filters
- ▶ Adding a field to an attribute table
- ▶ Changing square meters to acres
- ▶ Understanding continuous surface maps from point data
- ▶ Interpolating point data
- ▶ Using continuous surface maps to answer questions
- ▶ Saving and documenting online map

What you need:

- ▶ Account required
- ▶ Estimated time: 1 hour



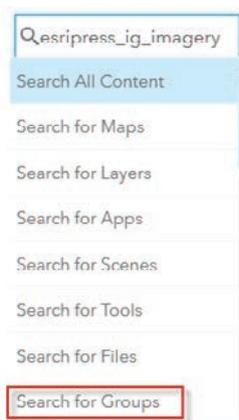
1. Go to [Precision Agriculture](#).
2. Read about precision agriculture.

Scenario

Precision agriculture is sometimes called “site-specific” farming. A farmer using precision farming will identify the variability of different quantities within a single field. This allows the farm to get the best results. Soil samples are used to determine fertilizer rates and production yields. In this exercise, you will use soil sample data to determine which fields are best to plant corn and which are the best for alfalfa. The table below lists the soil parameters that are best for corn and alfalfa.

	Com	Alfalfa
pH	6-7	7-8
P	25-80%	26-1%
K	1.8-2.9%	2.5-4.5%

1. Sign in to your ArcGIS organization account.
2. In the search box, type esripress_ig_imagery and Search for Groups



The default search returns results found only within your organization. To show all public results, you’ll remove that filter.

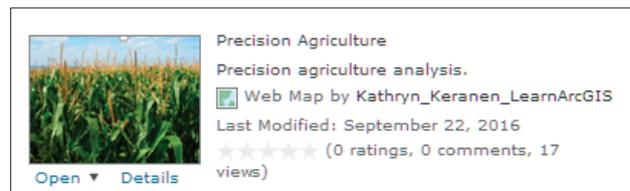
3. Uncheck the box that says to only search in your organization.



4. Click esripress_ig_imagery to view the group content.

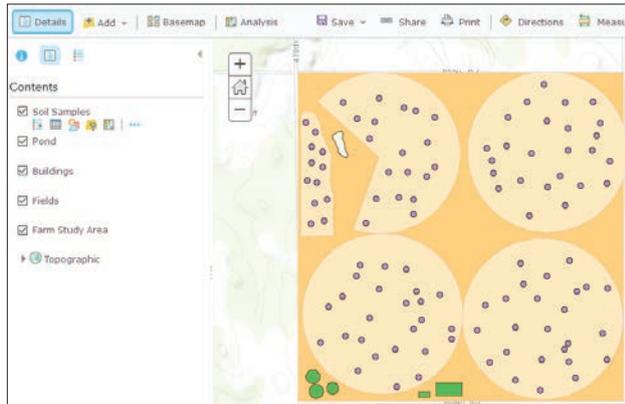


5. Click the thumbnail for Precision Agriculture to open the map.

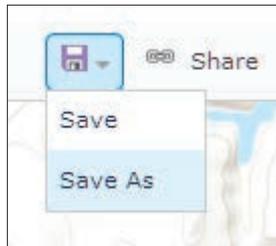


High-resolution aerial imagery has been used to construct field polygons. The field polygons provide the basic information needed to complete the precision farming exercise.

6. The map opens showing the Topographic basemap, Farm Study Area, Fields, Soil Samples, and Buildings.

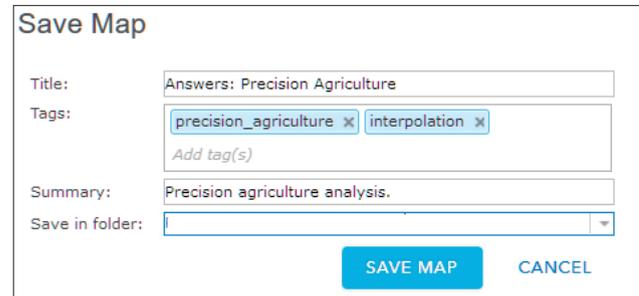


7. To save the map, on the top ribbon, click Save and choose Save As.



8. In the same Map window, type Answers: Precision Agriculture.

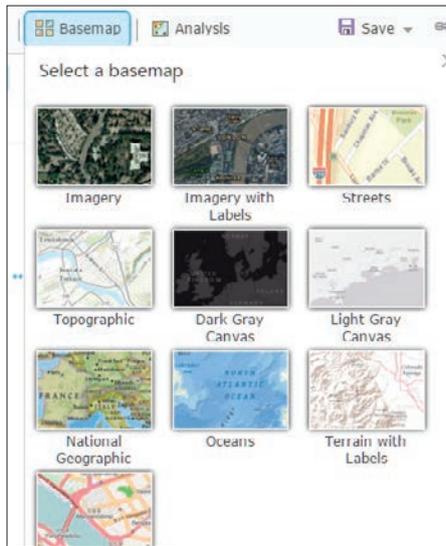
9. Type tags and a brief description of the map's content.



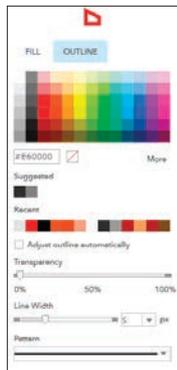
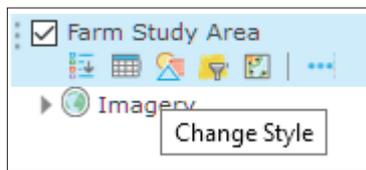
10. Click SAVE MAP.

Change the basemap and symbolize and label layers

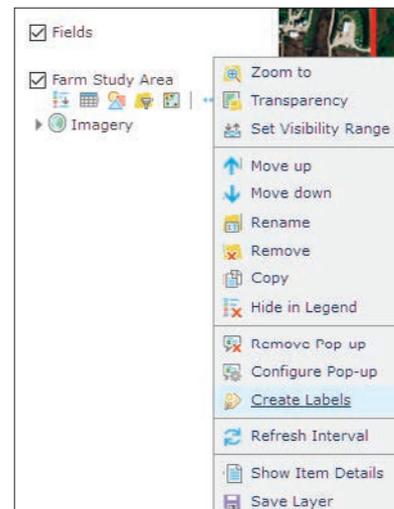
1. On the upper bar change the Basemap to imagery if it is set to Topographic.



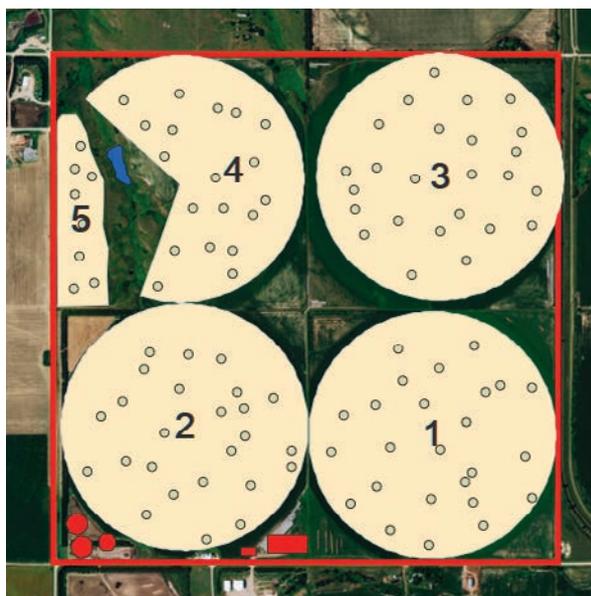
2. Under Details, click Show Contents of Map, and then click Farm Study Area and choose Change Style.



3. Click OPTIONS.
4. Click Symbols.
5. Click FILL and choose No Color.
6. Click OUTLINE and choose Red with a Line Width of 5 px.
7. Click OK.
8. Click OK.
9. Click DONE.
10. Click Fields>>Change Style>>OPTIONS>>Symbols.
11. Change the color to light tan.
12. Click OK.
13. Click OK.
14. Click DONE.
15. Click Fields>>More Options>>Create Labels.



16. Be sure the size is 32.
17. Click OK.
18. Click Buildings>>Change Style>>OPTIONS>>Symbols.
19. Select Red.
20. Click OK.
21. Click OK.
22. Click Done.
23. Click Pond>>Change Style>>OPTIONS>>Symbols.
24. Select Blue.
25. Click OK.
26. Click OK.
27. Click Done.
28. On the upper ribbon click Save



Filter double variables for crop growth

Remember your task in this exercise was to use the soil sample data to determine which fields are best to plant corn and which were best for alfalfa. You were given the table below to list the soil parameters best for the two crops.

	Corn	Alfalfa
pH	6-7	7-8
P	25-80%	26-1%
K	1.8-2.9%	2.5-4.5%

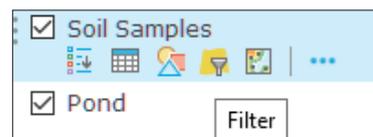
ArcGIS Online allows users to ask questions of data by using filters. A filter presents a focused view of a feature layer in a map. In this instance, you would like to see the soils samples that represent soil conditions good for corn and soil conditions good for alfalfa. You can create filters by using definition expressions. Definition expressions use three things:

- Field name
- Operator
- Value

Soil best for corn has:

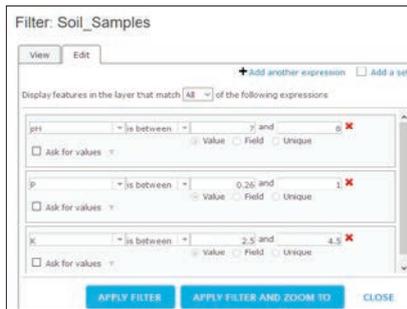
- A pH is between 6 and 7
- Phosphorous is between .25 and .80
- Potassium is between 2.5 and 4.5

1. Click Soil Samples>>Filter.

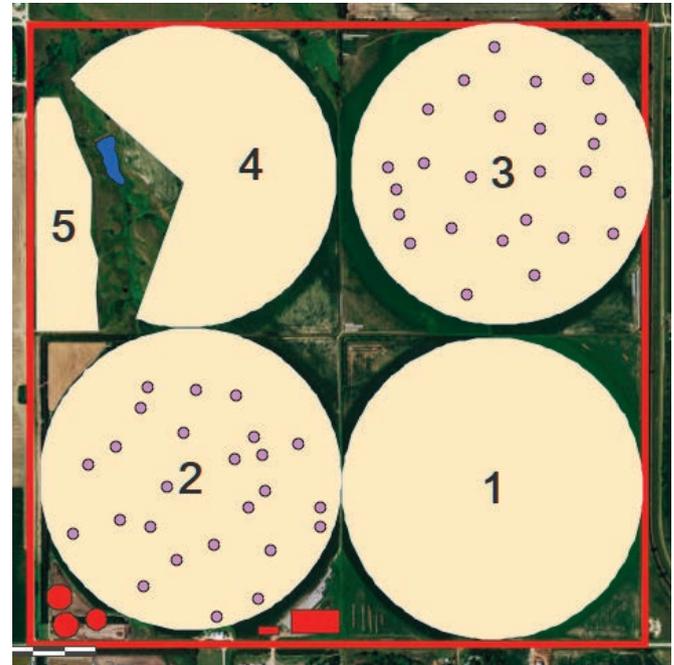
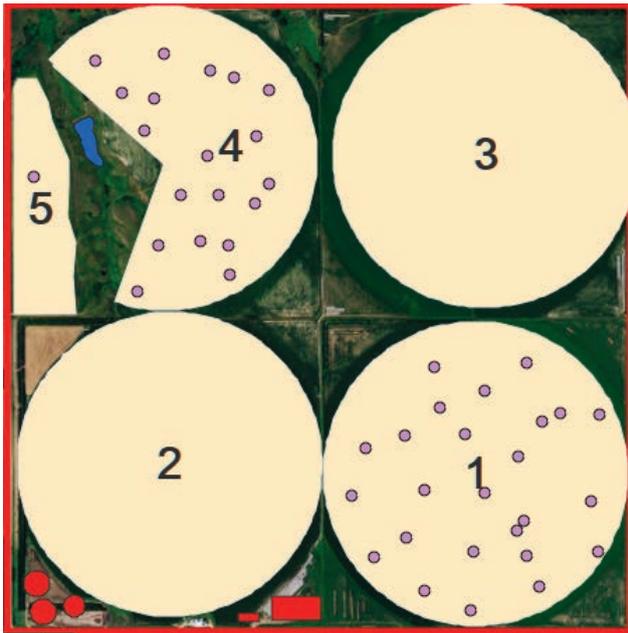


The filter menu opens ready to build the first expression.

2. The expression should be pH is between 6 and 7.
3. Click the + and Add another expression.
4. The expression should be P is between .25 and .80.
5. Click the + and Add another expression.
6. The expression should be K is between 1.8 and 2.9.
7. Click APPLY FILTER.
8. Click Soil Samples>>Filter.
9. Click REMOVE FILTER.
10. Build another complex filter expressions that identifies fields suited for alfalfa. Refer to the chart at the beginning of the lesson.



Q1 Which fields are most suited for corn?



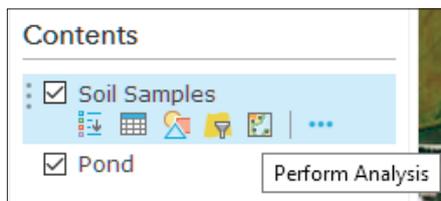
Q2 Which fields are most suited for alfalfa?

Create a continuous surface map by interpolation from point data

By using precision agriculture, farmers can use regular soil testing to understand where fertilizer needs to be applied. In this next section, you will establish a base line soil indicator for pH, phosphorous, and potassium. You will use interpolation to create a continuous surface map from point data. (A continuous surface represents phenomena in which each location on the surface is a measure of the concentration level or its relationship

from a fixed point in space or from an emitting source.) You will use the Interpolate Points tool to predict values at new locations based on measurement from the soil samples. The tool takes point data with values at each point and returns areas classified by predicted values. The tool uses the Inverse Distance Weighted or IDW algorithm. An algorithm is a set of mathematical rules followed in calculations by a computer. You will make a continuous surface map for pH, phosphorous, and potassium.

1. Click Soil Samples>>Filter>>REMOVE FILTER.
2. Click Soil Samples>>Perform Analysis.



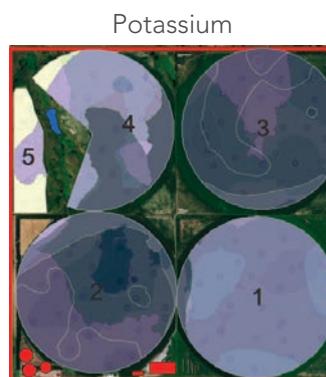
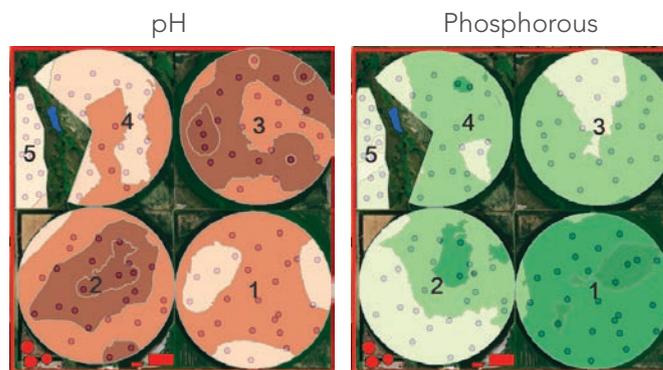
3. Click Soil Samples>>Perform Analysis>>Analyze Patterns>>Interpolate Points.

4. Click Interpolate Points, open the Interpolate Points interface and use the following parameters:

- Choose point layer containing locations with known values is Soil_Samples.
- Choose field to interpolate is pH.
- Click Options.
 - Clip output to Fields.
 - Classify by Geometric Intervals.
 - Number of classes is 5.
- Result layer name is pH.
- Uncheck Use current map extent.

5. RUN ANALYSIS.

6. Click pH>>Change Style>>Counts and Amounts (Color)>>SELECT>>OPTIONS>>Symbols.
7. If the selected ramp is dark red for high pH and light red for low pH, click OK.
8. Click Done.
9. Repeat steps 3–8 using P as the variable and selecting a green color. Name the file Phosphorous.
10. Repeat steps 3–8 using K as the variable and selecting a purple color. Name the file Potassium.



You have now established baseline data for the farm. As previously shown, fields 1–4 are suitable for the designated crops. Soil samples can be taken annually to determine where fertilizer is needed.

Analysis of field 5

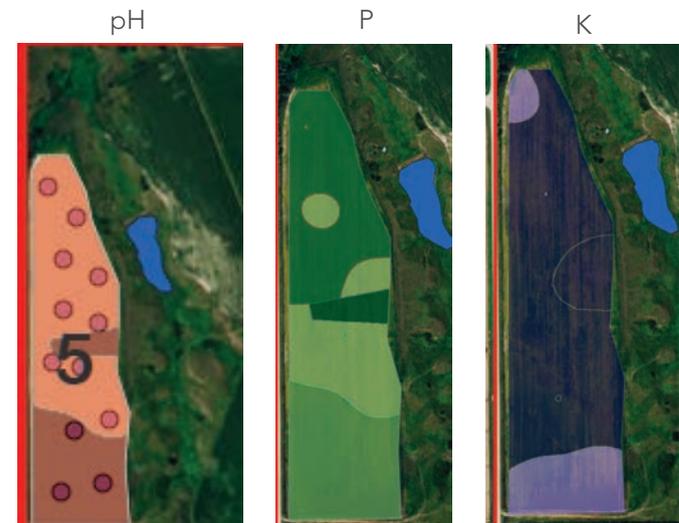
Field 5 has not been used in several years. Because of the poor quality of its soil, a more extensive individualized analysis should be done.



1. Click Fields>>Filter.
2. Expression should be: Name is 5.
3. APPLY FILTER.
4. Click Soil Samples>>Filter.
5. Expression should be: Name is 5>.
6. Apply FILTER.
7. Repeat steps 3–5 in the previous section.

8. Name the files:

- pH_field5
- P_field5
- K_field5



9. Click Fields>>Filter>>REMOVE FILTER.

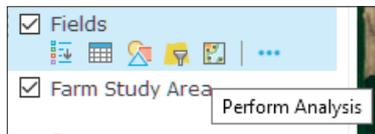
10. Click Soil Sample>>Filter>>REMOVE FILTER

From the above analysis, the farmer can decide how much fertilizer would be needed to make field 5 productive.

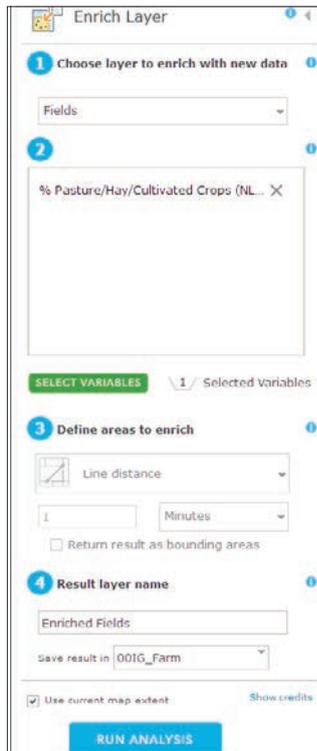
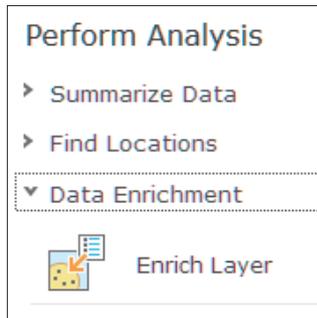
Data enrichment for fields

Data enrichment produces a layer that retrieves information about the people, places, and businesses in a specific area. It also creates a unique layer for each user, you will now enrich the fields by population. This is going to show the population of the farm, and it will create a layer that allows you to add fields.

1. Click Fields and Perform Analysis.



2. Click Data Enrichment and Enrich Layer.



3. Click Enrich Layer to activate the Enrich Layer pane.

Fields is the chosen layer to enrich with new data.

4. Click SELECT VARIABLE to open Data Browser and browse for variables.

- Be sure that the United States is chosen in the upper right hand corner.
- Click the arrow to go to the second page.
- Click Landscape.
- Click LAND COVER.
- Uncollapse Landscape Analyst Variables.
- Check Percent of Pasture/Hay/Cultivated Crops (NLCD).

5. Click APPLY.

6. The Result layer name is Enriched Fields.

7. Uncheck Use current map extent.

8. Click RUN ANALYSIS.

Add fields and calculate acres and hectares

Open the attribute table. Area is given in square meters. Square meters is not the unit that is used to describe farm fields. Farm fields are described in acres or hectares.

One acre = 4046.8 sq meters.

One hectare = 2.5 acres.

1. Click Enriched Fields and Open Attribute Table.

2. Click Table Options and Show/Hide Columns.

3. Uncheck all fields except Name and Area.

4. Click Options and Choose Add Field.



The screenshot shows a table with the title "Fields (5 features, 0 selected)" and a "Table Options" dropdown. The table has one column named "Area" with five rows of values: 846,553, 846,553, 846,553, 589,272, and 140,230. A context menu is open over the first row, listing options: Filter, Show Selected Records, Center on Selection, Clear Selection, Add Field (highlighted), and Show/Hide Columns.

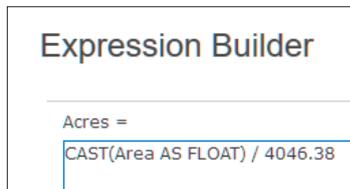
- Name is Acres.
- Type is Double.

5. Click ADD NEW FIELD.

6. Right click the gear on the new field Acres and choose Calculate.

7. Enter the following formula: Area/4046.38

8. Click CALCULATE.



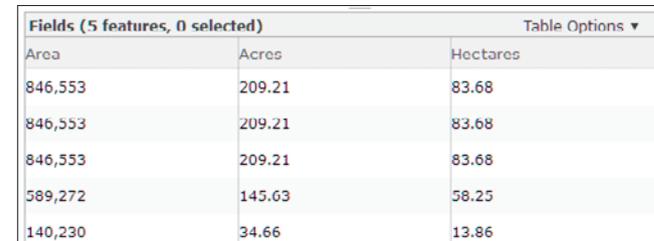
The screenshot shows the "Expression Builder" dialog box. It has a title bar "Expression Builder" and a text input field labeled "Acres =" containing the formula "CAST(Area AS FLOAT) / 4046.38".

The Acres field now contains acreage.

9. Repeat steps 3–8:

- Name the field Hectares.
- Type is Double.
- Use the formula: Acres/2.5.

You have now provided the farmer with some basic information about the health of his fields and he can make plans for future rotations and fertilizer applications plus decide about the value of Field 5.



The screenshot shows a table with the title "Fields (5 features, 0 selected)" and a "Table Options" dropdown. The table has three columns: "Area", "Acres", and "Hectares". The data rows are as follows:

Area	Acres	Hectares
846,553	209.21	83.68
846,553	209.21	83.68
846,553	209.21	83.68
589,272	145.63	58.25
140,230	34.66	13.86

10. Click Save.

The ArcGIS Imagery Book, chapter 2

Questions for reading comprehension, reflection, and discussion

Teachers can use the items in this section as an assignment, an introduction, or an assessment, tailored to the sophistication of learners. Some learners can read all the sections at one time, while others are more comfortable with small segments. The questions and tasks are designed to stimulate thought and discussion.

1. What technological innovations combined to create the modern field of remote sensing during World War I?
2. Match the imagery collection tool on the left with a common use listed on the right.
[Note: some listed uses may be addressed by more than one of these tools.]

___ Geosynchronous orbiting satellites

___ Sun synchronous orbiting satellites

___ Atmospheric satellites

___ Jet aircraft

___ General aviation aircraft

___ Drones

___ Ground-based/handheld imagers

A. Acquire high quality aerial and orthophotography

B. Monitoring changing phenomena such as weather conditions

C. Compare images from the same season over several years

D. Collect imagery over disaster areas in a very short time

E. Street level imagery

3. The section titled "Imagery application trends" demonstrates how remote sensing is being used in a range of industries. Pick three of the industries listed below and write a brief description of a) the type of remotely sensed imagery they are using and b) how that imagery is used in the specified industry.

Precision agriculture

Humanitarian aid, Syrian refugee camp

Forestry

Mining

Natural disaster assessment, Hurricane Sandy

Climate and weather study, El Nino Impacts on Florida

Engineering and construction, Pflugerville, TX

Oil and gas exploration, Kentucky geological survey

Urban Planning, Urban Observatory

4. Which of the imagery types listed on the right would you be most likely to use to answer the questions on the left?

___ How is logging in western Oregon affecting the health of old growth forests?

A. Natural color

___ Where, in the surrounding region, has the city of Las Vegas, NV expanded since 1950?

B. False color

___ How are cloud formations influenced by landforms on Earth's surface?

C. Color infrared

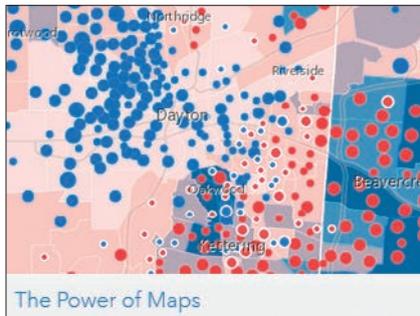
5. Natural color, false color, color infrared, and panchromatic imagery are products of a passive imaging sensor, while lidar, radar, and sonar images result from active sensors. What is the difference between an active and a passive sensor?

6. The section titled "Eyes in the sky" tells us that space is getting crowded. What does this mean?

7. How does an image with a small ground sample distance (GSD) differ from one with a larger GSD?

Additional resources

Learn ArcGIS: Guided lessons based on real-world problems



The Power of Maps

Exploring online maps and apps

Interpreting maps

Understanding spatial analysis



From London to Tokyo

Navigating and comparing maps

Asking and answering spatial questions



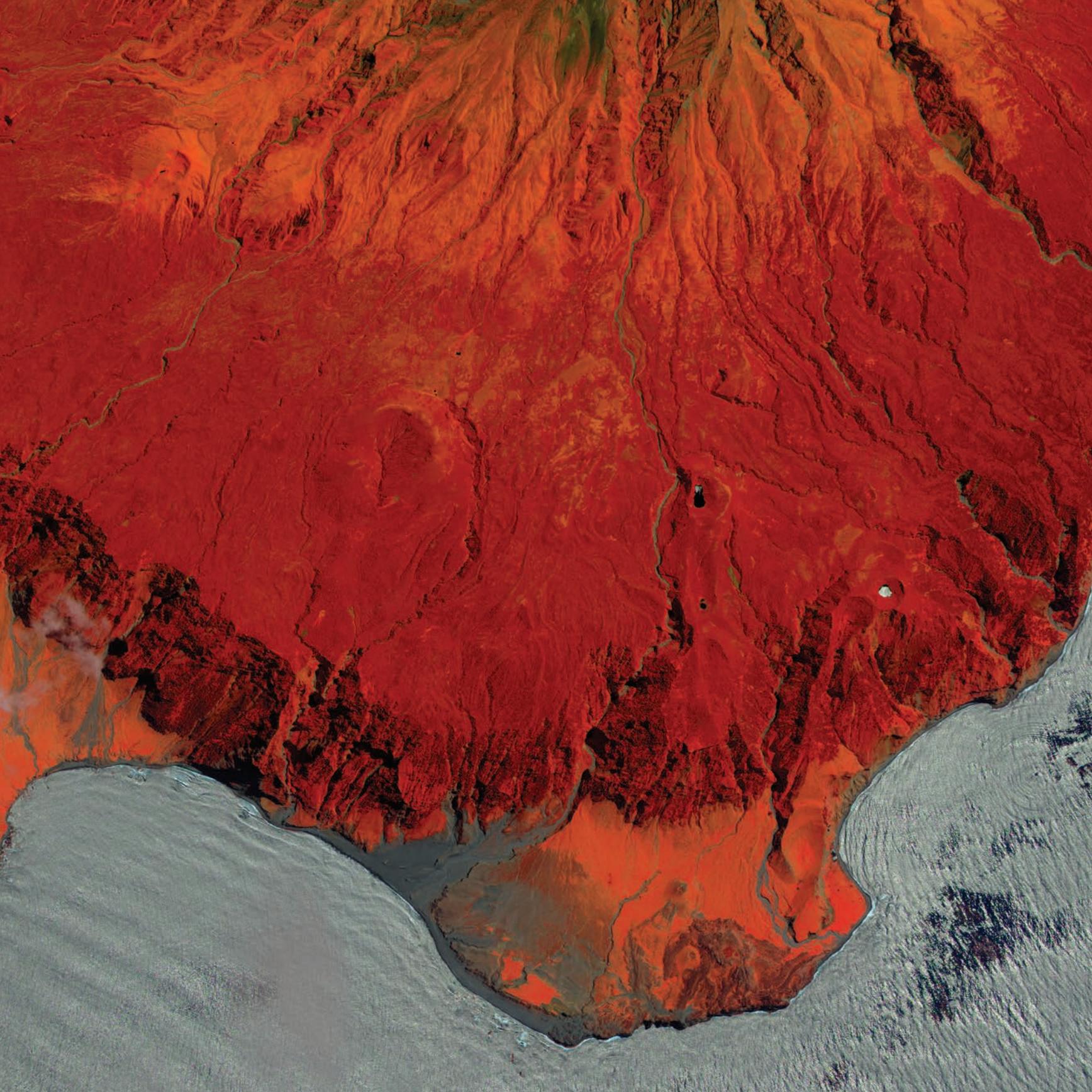
Analyze Volcano Shelter Access in Hawaii

Using drive-time analysis to evaluate accessibility to locations

Finding areas that meet specific conditions

Dissolving many features into a single feature

Finding how many features in one layer are inside another layer



Defining Imagery

GIS and imagery are synergistic

Close your eyes for a minute and, in your mind, listen to the powerful four-note beginning of Beethoven's *Symphony No. 5*. One of the most distinctive musical scores in the world, it consists of four separate notes, each delivered at a different pitch, intensity, and length. What you hear, though, is not four separate notes, but a dramatic and familiar musical opening. This experience reflects the concept that the whole is greater than the sum of its parts and the modern concept of synergy.

Synergy is the combined effect of two or more agents working together to accomplish more than any one of them could accomplish individually. The phenomenon exists in nature as when a bee moves from flower to flower gathering nectar and simultaneously fertilizing the flowers with pollen adhering to its body. This kind of synergy is called mutualism. Synergy is also used to describe the effect of drugs working together; one drug can often increase the effectiveness of the other.

GIS and imagery have a synergistic relationship. Individually, each is a powerful tool for visualizing and analyzing Earth. Working together, however, they create extraordinary new opportunities to explore, investigate, and even create new knowledge about our world. Their shared geographic anchor—georeferenced data—is the key to this relationship.

Introductory activities

Video

Videos elevate motivation and enthusiasm as well as enhance discussion.



NASA | A Landsat Flyby

NASA Goddard

time=1.43 min

The Landsat program is the longest continuous global record of the Earth's surface, and continues to deliver both visually stunning...

<https://youtu.be/ZZx1xmNGcXI>

NASA: A Landsat Flyby

The Landsat program is the longest continuous global record of the Earth's surface, and continues to deliver both visually stunning and scientifically valuable images of our planet. This short video highlights Landsat's many benefits to society.

Activity 3.1

Land cover

Land-cover data has many analytical applications. Temporal land-cover data is even more useful. The National Land Cover (NLCD) is derived from Landsat imagery along with various other components. The Landsat imagery is classified into categories and each pixel of the classified dataset represents a land-cover type. The NLCD has 30-meter resolution and is designed to provide data every five years. Currently datasets exist for 2001, 2006, 2011, and NLCD 2016 is under development.

1. In chapter 3 of *The ArcGIS Imagery Book* under the section "Imagery layers are universal and varied" on the second row, find Land Cover. A legend tells what type of land cover is displayed.



NLCD Land Cover Classification Legend	
11	Open Water
12	Perennial Ice/ Snow
21	Developed, Open Space
22	Developed, Low Intensity
23	Developed, Medium Intensity
24	Developed, High Intensity
31	Barren Land (Rock/Sand/Clay)
41	Deciduous Forest
42	Evergreen Forest
43	Mixed Forest
51	Dwarf Scrub*
52	Shrub/Scrub
71	Grassland/Herbaceous
72	Sedge/Herbaceous*
73	Lichens*
74	Moss*
81	Pasture/Hay
82	Cultivated Crops
90	Woody Wetlands
95	Emergent Herbaceous Wetlands

* Alaska only

2. Click [USA National Land Cover](#) database and zoom out until you see the entire United States..

Write a detailed description of the spatial distribution of land cover in the United States. For example, the East coast states, the Gulf of Mexico states, and the Great Lakes states have a significant number of wetlands.

3. Describe the West, central US, Northeast, and Southeast.

Activity 3.2

Rasters can represent time

Test your climate know-how with the Seasonal Changes web app.



Every image has an acquisition date making it possible to view change over time by displaying a sequence of images that were each collected on different dates. The Seasonal Changes web app is an example of just such a sequence; it is designed to show the monthly average global snowpack depth. Test your climate and geography IQ with the following activity.

Before you look at the Seasonal Changes app, take this simple quiz.

For each pair of cities or places, identify the one that is most likely to be snow-covered in the given month by putting a check (✓) next to its name.

Month	City/place 1	City/place 2
January	Sapporo, Japan	Vienna, Austria
February	Quebec City, Canada	Copenhagen, Denmark
March	Seoul, South Korea	Murmansk, Russia
April	Barrow, Alaska, USA	Bucharest, Romania
May	Cape Dyer, Canada	Reykjavik, Iceland
June	Helsinki, Finland	Valle Nevado, Chile
July	Auckland, New Zealand	Thredbo Village, Australia
August	Whakapapa Glacier, New Zealand	Valparaiso, Chile
September	Toronto, Canada	Yellowknife, NW Terr., Canada
October	Berne, Switzerland	Okha, Russia
November	Van, Turkey	Minneapolis, USA
December	Beijing, China	Riga, Latvia

Link to the Seasonal Changes app by going to chapter 3 of *The ArcGIS Imagery Book* under the “An adaptable format” section, click the thumbnail under “Rasters can represent time” to check your answers on the quiz. If you need help locating the named place, use the search function as shown in the figure.

Notes on using the app:

- Each map in the app has a time frame such as December–January. This simply means that the average snowpack shown on this map represents the period from the end of December to the end of January--i.e., the month of January..
- If you use the search function to locate a place, you’ll need to zoom out to see its location in relation to the snowpack.

If you scored 11 or 12, you are a climate aficionado and should go straight to NOAA!



Lesson 3-1: Zaatari refugee camp

Remember, you can access ArcGIS Online for all the lessons in this guide, either with no sign-in to an organizational account required (the first set of lessons in each chapter) or by signing in to your organizational account (for the last set of lessons in each chapter).

Although refugee camps are defined as temporary settlements built to accommodate displaced people, the United Nations has had a refugee agency called the United Nations High Commissioner for Refugees (UNHCR) for 66 years. The purpose of this organization is to protect the rights of refugees. It was created in 1950 to help millions of European refugees. Since then, the organization has tried to set standards for planned settlements or refugee camps. The UNHCR has set standards to determine the adequacy of refugee camps. One of the standards is indicated by the average camp area per person in square meters. A range of 45 to 35 square meters is acceptable, 34 to 30 square meters is unacceptable, and 29 square meters or less is critical. In the following activity, you will investigate the Zaatari refugee camp in Jordan, which was first opened in July, 2012. It is a holding place for Syrian refugees and has had an up-and-down population from 2012 to today. Below is a table recording the number of yearly inhabitants in the Zaatari camp since 2012.

Date	Refugees
2012	15,000
2013	76,000
2014	79,000
	84,000
2016	80,000

These figures were taken from the following site:

[Syria Regional Refugee Response Inter-agency Information Sharing Portal](#)

Build skills in these areas:

- ▶ Use various types of imagery
- ▶ Identify dates of images
- ▶ Calculate area from imagery ArcGIS.com.
- ▶ Use imagery to obtain vital information
- ▶ Determine the average camp size per person in square meters.

What you need:

- ▶ Account not required
- ▶ Estimated time: 1.5 hour

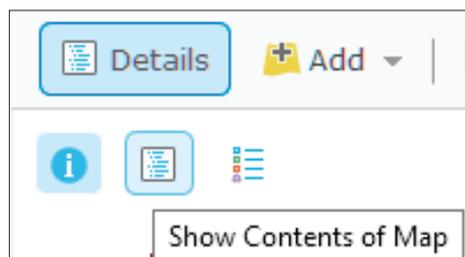
Scenario

The United Nations High Commissioner for Refugees is looking for information about the Zaatari camp. They would like to determine information about the area of habitation for the refugees starting from 2012 when it opened to the present.

In the following activity, you will find the Zaatari refugee camp on different basemaps and satellite images. After locating the camp you will identify features.

Locate Zaatari refugee camp

1. Go to ArcGIS.com.
2. On the upper ribbon, click Map.
3. In the upper-right corner, click Modify Map.
4. Under Details, click Show Contents of Map



5. On the top ribbon click Basemap and select Imagery with Labels.



6. In the upper-right search box, search for Jordan.



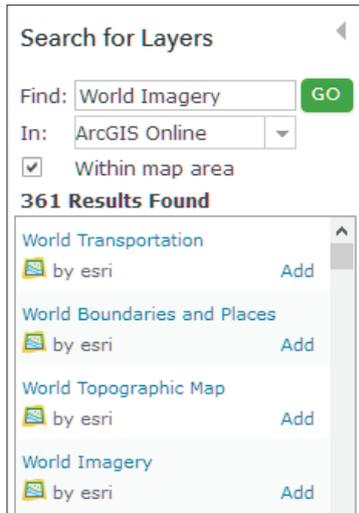
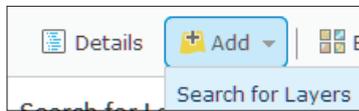
7. Once again in the search box, search for Mafraq. Mafraq is the capital city of the Mafraq Governorate in Jordan.



In this image, you can see an airstrip and the city of Mafraq. You cannot see a refugee camp in this image, and you cannot tell the acquisition date of the image.

8. On the top ribbon, click Add and Search for Layers.

9. Search for Find: World Imagery in ArcGIS Online.

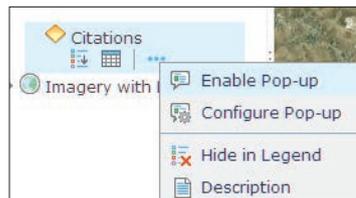
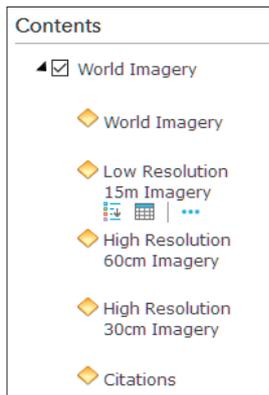


10. Add World Imagery.

11. Click DONE ADDING LAYERS.

12. Click on World Imagery to uncollapse the layer.

13. Click Citations > More Options > Enable Pop-up.
Descriptive information about features can be shown when a pop-up is enabled.



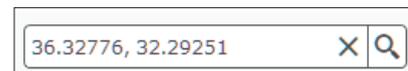
14. Click image to see Date. As you can see, the date of the image is February 23, 2011, or August 3, 2011, which was before the establishment of the camp.



The UNHCR has given you the exact longitude and latitude of the camp, which is given as:

36.32776, 32.29251.

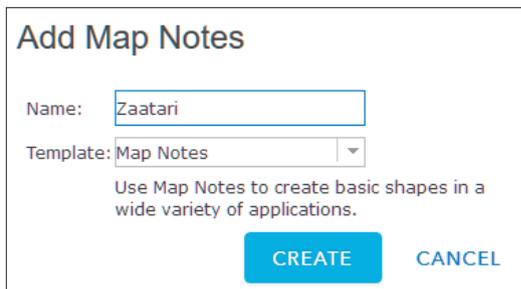
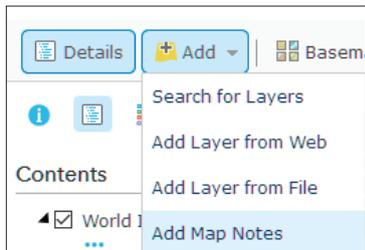
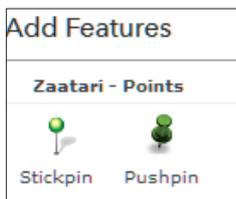
15. Enter the longitude and latitude in the search box to show the exact location of the refugee camp.



Mark Zaatari Refugee Camp

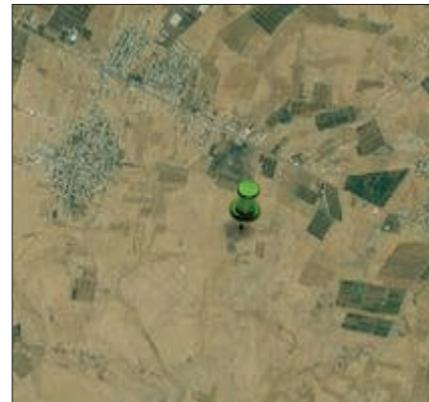
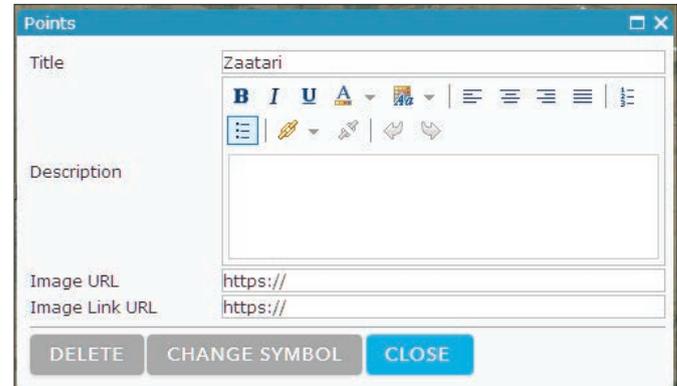
You can create features on your map by adding a map notes layer. You use features to symbolize something you want to show on your map—in this case, the exact location of the camp.

1. On the top ribbon, go to Add > Add Map Notes.
2. Name the map note **Zaatari**.
3. Click CREATE.
4. Choose the green pushpin and add to the located point.

A screenshot of the 'Add Map Notes' dialog box. It has a title bar 'Add Map Notes'. Below it, there is a 'Name:' label with a text input field containing 'Zaatari'. Below that is a 'Template:' label with a dropdown menu set to 'Map Notes'. A small text block says 'Use Map Notes to create basic shapes in a wide variety of applications.' At the bottom, there are two buttons: 'CREATE' (highlighted in blue) and 'CANCEL'.

5. Click CLOSE.

6. Zoom out on the map note until you can see the city of Mafraq and the airport.



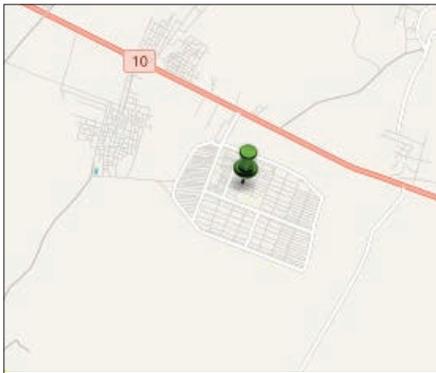
7. Click Details to close the Map Note template.

Use OpenStreetMap basemap:

There are other basemaps that can be used to help you visualize.

1. Click Basemap and choose the OpenStreetMap.

The OpenStreetMap is a free, editable map produced by an open collaborative project. Volunteers gather location data using GPS, local knowledge, and other free sources of information and upload it. For more information visit [OpenStreetMap](#).



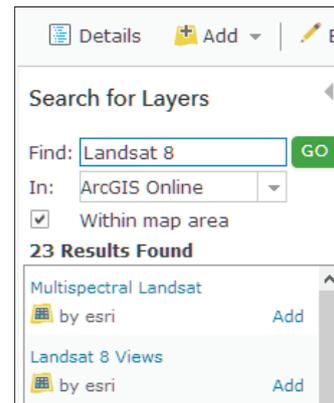
2. Turn on and off the World Imagery and OpenStreetMap layers. You can see that the OpenStreetMap layer has been updated more recently than the World Imagery layer.

Use Landsat 8 Imagery

Another source of imagery that can be used is the Landsat 8 satellite images. The Landsat 8 satellite images the entire Earth every 16 days. For more information on Landsat 8 visit the website below

[Landsat 8](#)

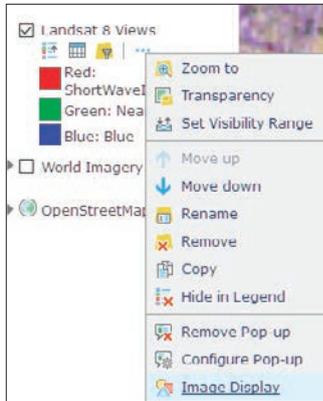
1. On the top ribbon click Add and Search for layers.



2. Search for Landsat 8.
3. Add Landsat 8 Views to the map.
4. Click DONE ADDING LAYERS.

You can change the image display by using a predefined template or setting the band combination and stretch parameters. The band combination allows you to specify which band are displayed using the red, green, and blue color composite scheme. The different color combinations display your imagery with various color effects. You can display your data in natural color which displays the layer as you would normally see it, or you can use color combinations that highlight vegetation, urban areas, water, and other features.

5. Click on Landsat 8 Views and go to Image Display.



6. Under the Renderer Tab select the various displays to view.

7. Click APPLY after each selection.



8. Click on the Landsat image to see the Date of Acquisition. You will see that the image was taken on February 21, 2017 (date will vary) which was well after the refugee camp was established.

Measure area of Zaatari refugee camp

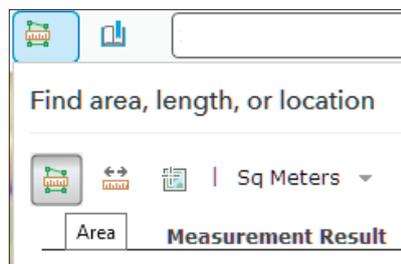
You are now ready to tackle the initial problem of deciding if the refugee camp meets the standards of occupation set by the UNHCR. As a reminder below are the standards set for occupation:

- 45 – 35 square meters is acceptable
- 34 – 30 square meters is unacceptable
- 29 or less square meters is critical

1. Zoom in so the refugee camp is visible.



2. Click Measure to display the Measure toolbar and select Sq Meters and the polygon tool.



3. To measure the camp, click Area and click the map once for every vertex of the area you want to measure. Double-click to complete the area.

4. Record the area in square meters.
_____square meters.

You are now ready to compile your information. To calculate the number of refugees per square meters use the following formula:

Square meters/Refugees = Square meters per Refugee

Remember the UNHCR has established the following habitat guidelines:

- 45–35 square meters/refugee is Acceptable
- 34–30 square meters/refugee is Unacceptable
- 29 or less square meters/refugee is Critical

There is a range of 45 square meters to 35 square meters as acceptable, 34-30 square meters as unacceptable, and 29 or less square meters as critical.

5. Complete the following chart:

Date	Refugees	Square Meters/ Refugee	Condition
2012	15,000		
2013	76,000		
2014	79,000		
2015	84,000		
2016	80,000		

In this exercise, you have used various types of temporal imagery to look at a location. You have also obtained information from the image to support decisions.

Lesson 3-2: Measuring fires

For 50 years, the Landsat Program has been monitoring the Earth. Landsat imagery can be used to monitor and assess the extent and severity of wild fires and as a baseline to monitor vegetation recovery.

Build skills in these areas:

- ▶ Filtering a temporal database of Landsat satellites
- ▶ Identifying before and after fire location
- ▶ Digitizing and calculating area from imagery
- ▶ Calculating and displaying the Normalized Burn Ratio (NBR) to define the severity of a burned area

Scenario

Your remote sensing company has been hired to create a series of lessons for a Massive Open Online Course (MOOC) being conducted for a global company. The group participating in the MOOC is global firefighters. The purpose of the lessons is to provide guidance about measuring burn areas from satellite imagery and displaying the burn scars most distinctly. You have chosen three fires for your exemplary study area:

- the Soberanes Fire in the Los Padres National Forest in Monterey County, California
- the Gibson Desert fire in Western Australia
- the fires on the Portuguese Island of Madeira

What you need:

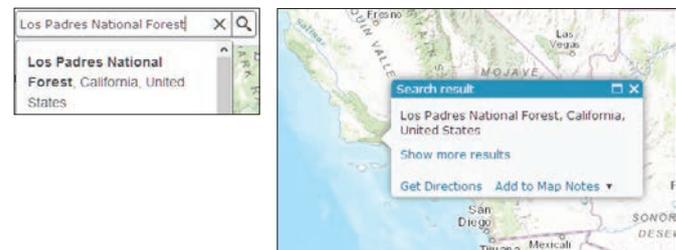
- ▶ Organizational account required
- ▶ Estimated time: 1.5 hour

The Soberanes Fire in Monterey County

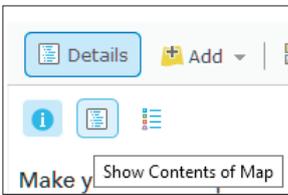
The Soberanes Fire started on July 22, 2016, from an illegal campfire and lasted until October 12, 2016 (82 days), burning approximately 132,127 acres. Normalized Burn Ratio (NBR) maps were used to map the spatial distribution of the fire's effects on the ground.

Locate the fire

1. Sign in to your organizational account at [ArcGIS.com](https://www.arcgis.com).
2. Click Map on the upper ribbon.
3. Search for Los Padres National Forest.



4. Click Details and Show Contents of Map.



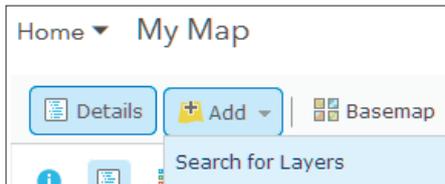
5. Click Add and Search for Layers.

6. Use the following parameters for the Search interface:

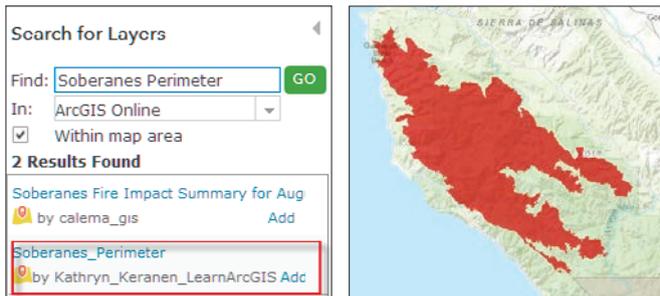
Find: Soberanes_Perimeter

In: ArcGIS Online

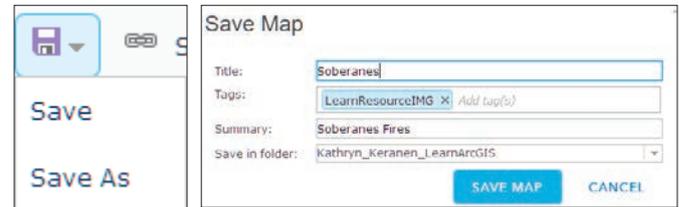
Uncheck Within map area.



7. Click DONE ADDING LAYERS.



8. Click the Save As icon on the top ribbon and complete the metadata.



9. Click SAVE MAP.

Landsat Imagery before and after the fire

The Landsat satellite takes a picture of the same place on earth every 16 days. The Soberanes Fire started on July 22, 2016, around 8 a.m. and lasted until October 12, 2016. You will look at a Landsat image taken on June 20, 2016 or before the fire and one taken on August 30, 2016, after the fire started.

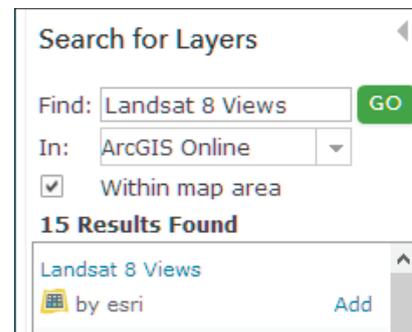
1. Click Add.

2. Click Search for Layers and enter the following:

Find: Landsat 8 Views

In: ArcGIS Online

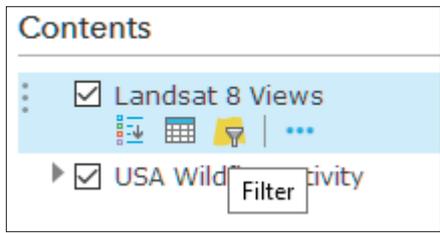
Uncheck: Within map area



3. Add the Landsat 8 Views and clear the checkmark..
4. Click DONE ADDING LAYERS.

You now need to filter to show a Landsat image before and after the fire.

5. Click Landsat 8 Views Filter.



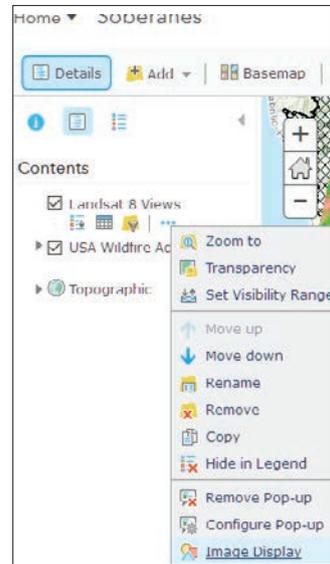
6. Click Edit and enter the following expression:
Acquisition Date is on 06/20/2016.
7. Click APPLY FILTER.



The default display for the Landsat is Agriculture with DRA that shows vigorous vegetation as bright green and stressed vegetation as dull green. Stressed vegetation is caused when factors reduce plant metabolism. As you can see, the vegetation is mostly bright green.

It is useful to look at the image using another display.

8. Right-click Landsat 8 View. Select More Options and go to Image Display.



9. Select Color Infrared with DRA.
10. Click APPLY.



In this display, healthy vegetation is bright red while stressed vegetation is dull red.

11. Click Image Display again and change back to Agriculture.
12. Click Landsat 8 Views and go to Rename.
13. Rename the Landsat 8 View as Pre-Soberanes Fire.
14. Click Add.

15. Select Search for Layers.
16. Add Landsat 8 Views again.
17. Rename the Landsat 8 Views Post-Soberanes Fire.
18. Click Post-Soberanes Fire and go to Filter.
19. Click Edit.
20. Change date to 10/17/2016.
21. Click APPLY FILTER.

You now have images showing pre- and post-Soberanes Fire.



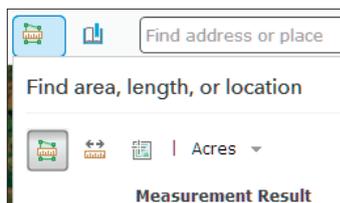
22. If you change the Image Display to Color Infrared, the fire is even more visible than displayed as Agriculture.



Determine the fire area

You can use the map to measure the area of the fire.

1. Click Measure to display the Measure toolbar and select acres and the polygon tool.



2. To measure the fire, click Area and click the map once for every vertex of the area you want to measure. Double-click to complete the area.
3. As mentioned, approximately 132.127 acres were burned. How does the area you obtained from digitizing the fire compare? Delta Answers + or – 2% are acceptable.

Calculate burn index to show severity

The Normalized Burn Ratio (NBR) calculates and shows the severity of a burn. The NBR equation is calculated from reflectance with high numbers indicating high severity of burn and lower numbers signifying low-severity of burn.

1. Click the Post-Soberanes Fire and select Image Display.
2. Under Rendered select NBR Raw.
3. Click APPLY.
4. Click CLOSE.

The legend shows burn severity from low to high.

The Gibson Desert Fire in Western Australia

The Gibson Desert covers a large part of the dry portion of Western Australia. It is characterized by thin desert grass and red sand dunes. Fires that occur in the area burn the desert grass and the burn scars are recognized from satellite imagery. Landsat 8 acquired an image of a burn scar on November 19, 2015. Using the workflow you followed to analyze the Soberanes Fire, analyze the Gibson Desert Fire.

Locate the fire

1. Sign in to your organizational account at [ArcGIS.com](https://www.arcgis.com).
2. Click Create New Map.
3. Change the Basemap to Imagery with Labels.
4. Locate the fire by typing the longitude and latitude of the fire in the search box.

Longitude: 127.859769

Latitude: -23.284888



5. Click Add to Map Notes.



Landsat Imagery before and after the fire

1. Add Landsat 8 Views.
2. Filter the Landsat for the pre-fire to Acquisition Date 10/17/2015.
3. Name the feature service Pre-Gibson Fire.
4. Add Landsat 8 Views service again.
5. Filter the Landsat for the post-fire to Acquisition Date 09/01/2016.
6. Change the Image Display to Natural.



Determine fire area

1. Use the measure tool to draw a polygon and determine the area of the fire in acres.



Calculate burn index to show severity

1. Change the Image Display to the Normalized Burn Index (NBR).
2. Add a Stretch Type to of Standard Deviation. The stretch function manipulates the digital values in an image to enhance the display.



The fires on the Island of Madere, Madeira, Portugal

In August, 2016, deadly wildfires raged on the Portuguese Island of Madeira. The blaze reached the island's largest city of Funchal, killing three people. Using the workflow you followed to analyze the Soberanes Fire and Gibson Desert Fire, analyze the fires in Portugal.

Locate the fire

1. Sign in to your organizational account at [ArcGIS.com](https://www.arcgis.com).
2. Click Create New Map.
3. Change the Basemap to Imagery with Labels.
4. Locate Madere, Madeira, Portugal using the search box.



Landsat Imagery before and after the fire

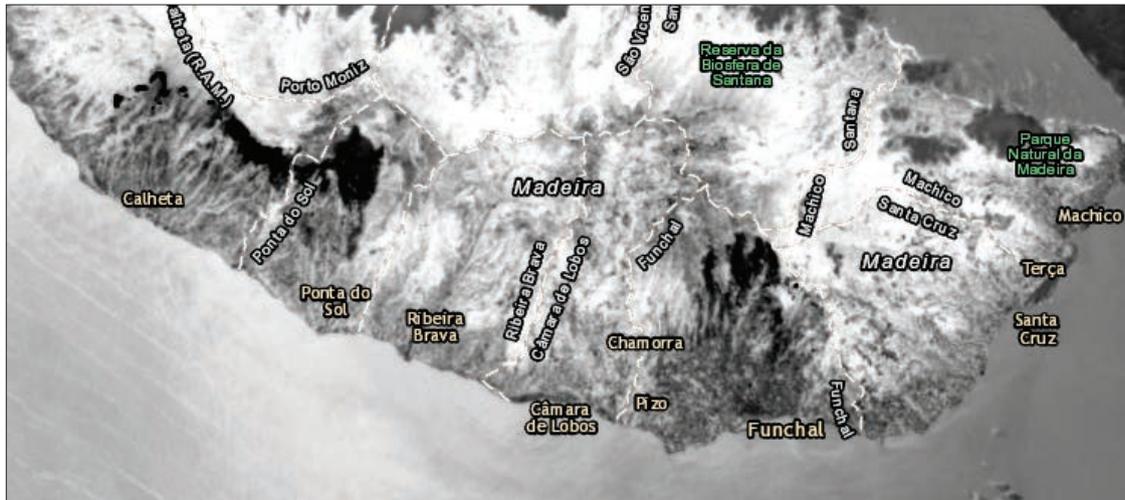
1. Add Landsat 8 Views.
2. Filter the Landsat for the pre-fire to Acquisition Date 06/08/2016.
3. Name the feature service Pre-Madere.

4. Add Landsat 8 Views service again.
5. Filter the Landsat for the post-fire to Acquisition Date 08/11/2016.
6. Change the Image Display to Natural Color with DRA.
7. Change the Image Display to Color Infrared with DRA.



Calculate burn index to show severity

1. Change the Image Display for 08/11/2016 to the Normalized Burn Index (NBR).
2. Add a Stretch Type of Standard Deviation.



In this lesson, you have identified and displayed Landsat 8 images before and after a fire. You have calculated the area of the fire and shown the image as a burn index to indicate burn severity.

Lesson 3–3: Disappearing lake

The Aral Sea is in Central Asia between Northern Uzbekistan and the southern part of Kazakhstan. It used to be the fourth largest lake in the world but water diversions for irrigation and recent droughts have caused the lake to shrink. In 2014, the eastern lobe of the Southern Aral Sea completely disappeared.

Build skills in these areas:

- ▶ Filtering a temporal database of Landsat satellites
- ▶ Digitizing and calculating area from imagery
- ▶ Creating layer files from graphics
- ▶ Calculating percentage change
- ▶ Building a story map series

What you need:

- ▶ Account required
- ▶ Estimated time: 1.5 hour

Scenario

Your geography teacher has given you an assignment of creating an online Story Map explaining with imagery and calculations the shrinkage of the Aral Sea.

Locate the Aral Sea

1. Sign in to your organizational account at [ArcGIS.com](https://www.arcgis.com).
2. Click Map.
3. Search for 60.00067, 44.95809.
4. Click Add to Map Notes.
5. Click Basemap and select Imagery with Labels.
6. Save the map with proper metadata.



Save Map

Title:

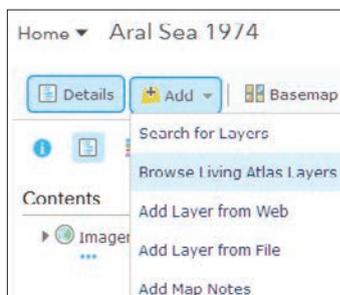
Tags:
Add tag(s)

Summary:

Save in folder:

Find temporal images of the Aral Sea

1. On the top ribbon click Save As and name the map Aral Sea 1974.
2. Click Add and select Browse Living Atlas Layers.

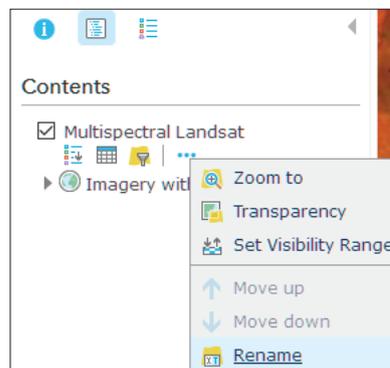


3. Choose Multispectral Landsat and Add layer to map.



4. Click CLOSE.

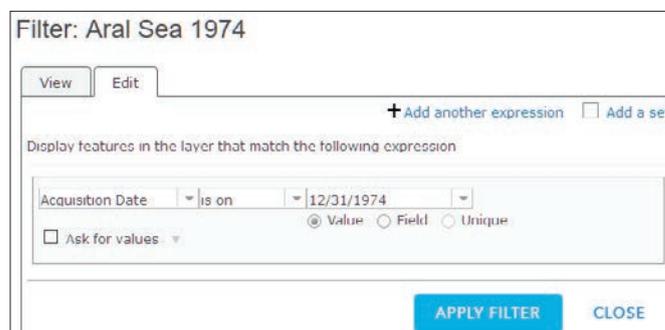
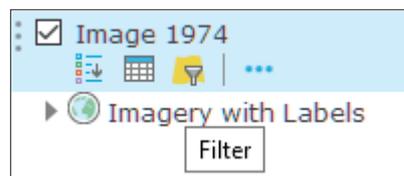
5. Click Multispectral Landsat and select Rename.



6. Rename Multispectral Landsat Image 1974.

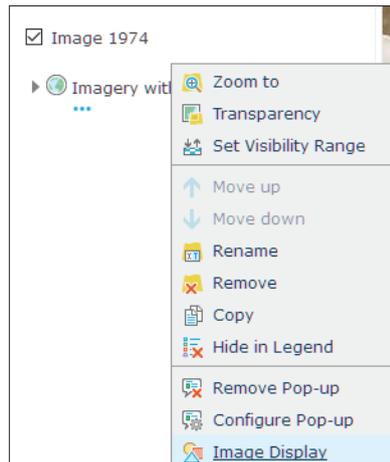
7. Under Image 1974 choose Filter.

8. Create the expression:
Acquisition Date is on 12/31/1974.

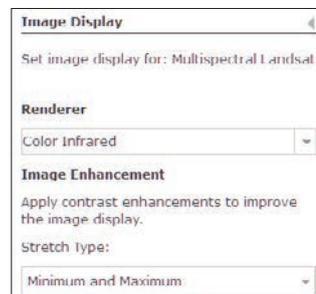
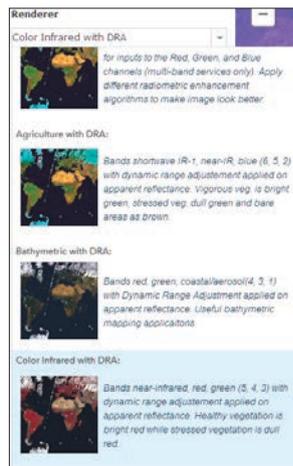


9. Click APPLY FILTER. This will isolate the Landsat image.

10. Click Image 1974 and select Image Display.



11. Select Color Infrared with DRA with a Stretch Type of Minimum and Maximum.



12. Click APPLY.

13. Click CLOSE.

Digitize and calculate the area of the Aral Sea for 1974

To find the area of the Aral Sea, you need to create a digitized polygon. Since two islands are within the sea, you need to create a water and a land polygon and then subtract the land from the water.

1. Click Add and select Add Map Notes.

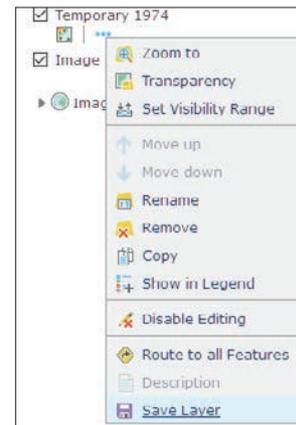
Name: Water 1974

Template: Map Notes

2. Click CREATE.

3. Select the Freehand Area  and draw around the water of the Aral Sea.

4. Double-click to end the polygon.



5. Click Close.

6. Click Details.

7. Click Water 1974 and Save Layer.

8. Complete information.

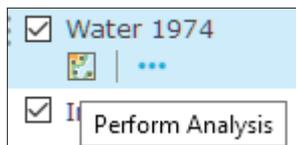
9. Click CREATE ITEM.

- Repeat steps 1–9 digitizing the two small islands shown within the Aral Sea and naming the Map Notes Land 1974.



Now you need to combine the water and land layers by erasing the land from the water layer. When you erase the land, area will be taken out of the total water layer.

- Click Water 1974 and click Perform Analysis.



- Click Manage Data.
- Click Overlay Layers.
- Use the following parameters:

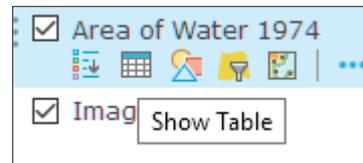
- Choose input layer is Water 1974 (Areas)
- Choose overlay layer is Land 1974 (Areas)
- Choose overlay method of Erase.
- Result layer name is Area 1974.

- Uncheck Use current map extent.

- Click RUN ANALYSIS.

- Remove Water 1974 and remove Land 1974.

- Click Area 1974 and Show Table. You can see that the area of the Aral Sea in 1974 has been recorded.



- Use the table below to start recording your findings.

- Click Save.



You need to follow the above steps 1-20 five more times. You will need to remove the Area of Water used in the previous map and rename the Image to match to year.

- Save the Map as Aral Sea 1989.

22. Change the Image name to Image 1989 and remove Area of Water 1974.
23. Use the Acquisition Date 12/31/1989.
24. Save the Map as Aral Sea 1999.
25. Change the Image name to Image 1999 and remove Area of Water 1989.
26. Use the Acquisition Date 12/31/1999.
27. Save the Map as Aral Sea 2004.
28. Change the Image name to Image 2004 and remove Area of Water 1999.
29. Use the Acquisition Date 12/31/2004.
30. Save the Map as Aral Sea 2009.
31. Change the Image name to Image 2009 and remove Area of Water 2004.
32. Use the Acquisition Date 12/31/2009.
33. Save the Map as Aral Sea 2015.
34. Change the Image name to Image 2015 and remove Area of Water 2009.
35. Use the Acquisition Date 07/06/2015.

- To calculate % change, use the following formula: (change in square miles/area of water in square miles) X 100.
- To calculate change /year, divide the % Change by number of years.
- Calculate the percent change per year for the 41-year period. {(total change in square miles)/original area of water) X 100}/ 41 years

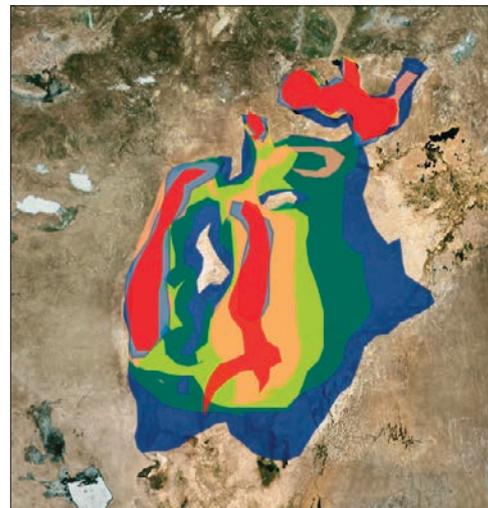
Combine area onto one map

1. Save Aral Sea 2015 as Final Area.
2. Remove Area 2015 and Image 2015.
3. Click the Add button on the top bar and Search for Layers.
4. Search for Area.
5. Add Area 1974, 1989, 1999, 2004, 2009, and 2015.
6. Click Change Style for each layer and make each a distinct color.
7. Click Save.

Calculate change

1. Record your findings and calculations:

Year	Area of Water square miles	Change in square miles	% Change	Number of Years	% Change/Year
1974					
1989					
1999					
2004					
2009					
2015					



Create story map series

ArcGIS Online offers a suite of configurable apps that you can use to tell a story. Here are some things to keep in mind as you consider which configurable app to use:

- Purpose—The most important consideration is the purpose of your app. Embedded within this goal is your intended audience: who is going to use your app and what are the key points that you want them to take away from the experience?
- Functionality—What is the critical functionality needed to support that goal?
- Aesthetic—How does the app's layout and color scheme support your brand or message?

In this story map, you should try to tell the story both qualitatively and quantitatively. Feel free to do research about the time areas shown and add pertinent data.

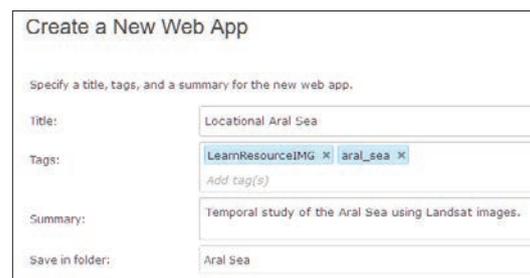
1. Open the Locational Aral Sea map.
2. On the upper ribbon click Share.
3. Click CREATE A WEB APP.
4. On the left panel choose Build a Story Map.
5. Click the Story Map Series.



Story Map Series

6. Click CREATE WEB APP.

7. In Summary type: Temporal study of the Aral Sea using Landsat images.

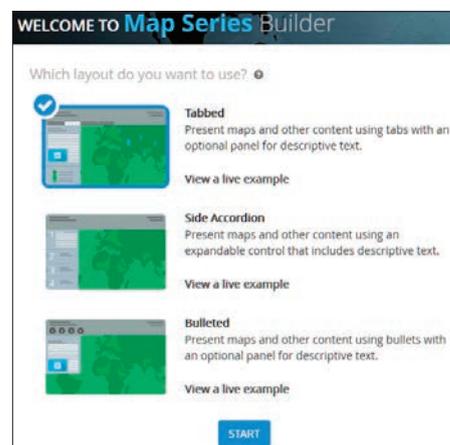


Create a New Web App	
Specify a title, tags, and a summary for the new web app.	
Title:	Locational Aral Sea
Tags:	LearnResourceIMG x aral_sea x <small>Add tag(s)</small>
Summary:	Temporal study of the Aral Sea using Landsat images.
Save in folder:	Aral Sea

8. Click DONE.

9. Choose the tab Map Series Builder.

10. Click START.



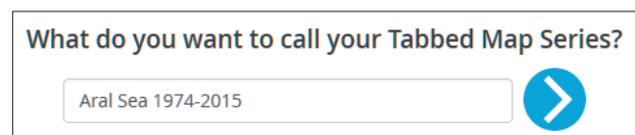
WELCOME TO **Map Series** Builder

Which layout do you want to use?

- Tabbed**
Present maps and other content using tabs with an optional panel for descriptive text.
[View a live example](#)
- Side Accordion**
Present maps and other content using an expandable control that includes descriptive text.
[View a live example](#)
- Bulleted**
Present maps and other content using bullets with an optional panel for descriptive text.
[View a live example](#)

START

11. Name the Tabbed Map Series: Temporal Study of the Aral Sea 1974-2015



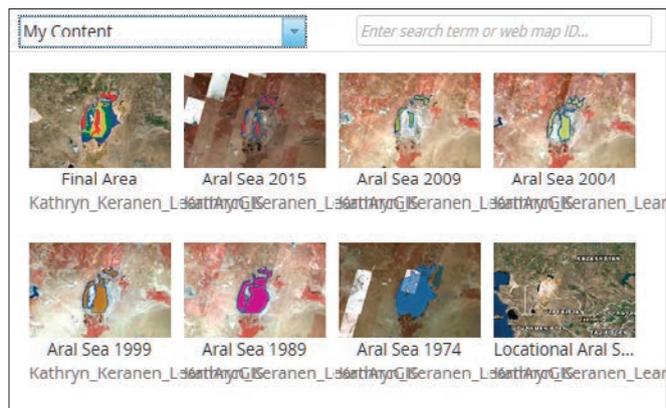
What do you want to call your Tabbed Map Series?

Aral Sea 1974-2015

12. Click the Arrow to go to the next page.
13. For Tab Title add Locational Aral Sea.
14. Select the Locational Aral Sea Map.
15. Click ADD.

You now have a box at the side that can contain text, images, or movies. Write a brief history of what is happening to the Aral Sea from 1974 to 2015.

16. Click Add.
17. Title the tab Aral Sea 1974.
18. Select the Aral Sea 1974 map.



19. Repeat steps 16–18 for 1989, 1999, 2004, 2009, 2015, and Final.

For each map, add your maps and enter text and calculations.



Lesson 3–4: Elevation

A raster is a grid of cells in a geographic space. The spaces with the grid are the cells. In the following lesson, you will take point data and turn it into a continuous surface raster. Surface interpolation tools create a continuous (or prediction) surface from sampled point values. The continuous surface representation of a raster dataset represents some measurement, such as elevation.

Build skills in these areas

- ▶ Opening an existing online map
- ▶ Interpolating point data based on the variable elevation
- ▶ Using a feature as a mask
- ▶ Changing basemaps
- ▶ Setting transparency
- ▶ Using continuous surface maps to answer questions
- ▶ Saving and documenting online map

What you need

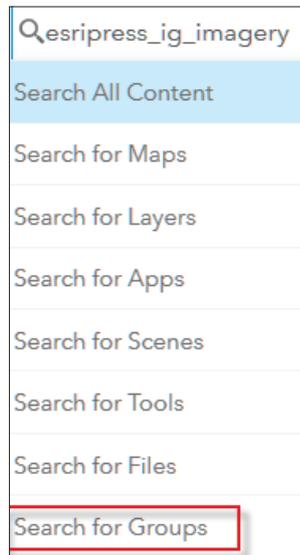
- ▶ Account required
- ▶ Estimated time: .5 hour

Scenario

You have been given the task of making a continuous surface map from point data that has been collected in Oaxaca, Mexico.

Open the map

1. Go to ArcGIS.com and sign in to your ArcGIS organization account.
2. In the search box type esripress_ig_imagery and select Search for Groups

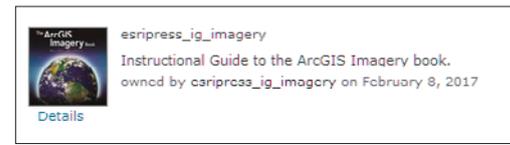


The default search returns results found only within your organization. To show all public results, you'll remove that filter.

3. Uncheck the box that says to only search in your organization.



4. Click the esripress_ig_imagery thumbnail to view the group content.



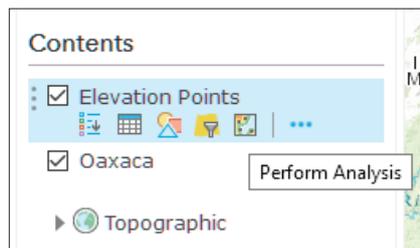
5. Click the thumbnail for Elevation in Oaxaca, Mexico to open the map.



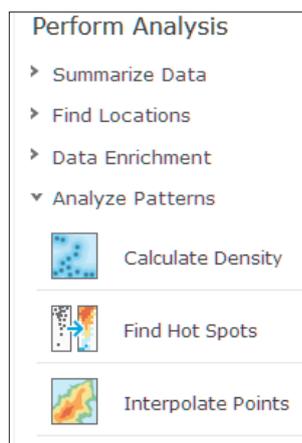
6. Save the map in your organization.

Create a continuous surface map

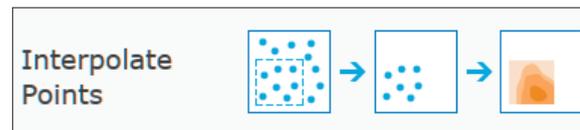
1. Click Content.
2. Click Elevation Points and select Perform Analysis.



3. Choose Analyze Patterns and select Interpolate Points.



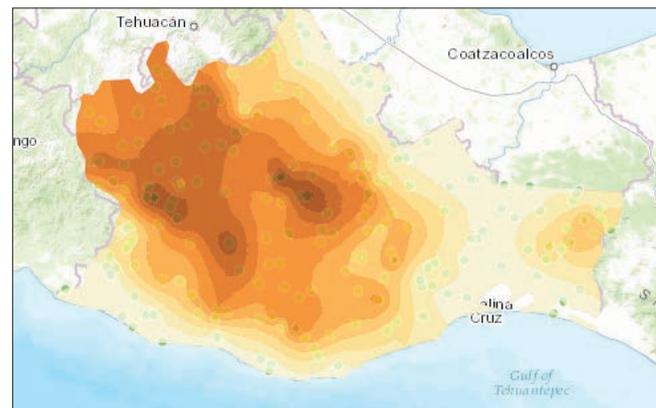
This tool allows you to predict values at new locations based on measurements found in a collection of points. The tool takes point data with values at each point and returns areas classified by predicted values.



4. After activating the tools, use the following parameters:

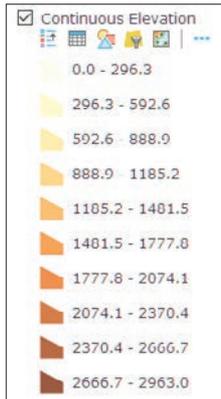
- Choose point layer containing locations with known values of Elevation_Points
- Choose field to interpolate of Elev_meter
- Click Options
 - Clip output to Oaxaca
 - Classify by Equal Interval
 - Number of classes 10
- Result layer name is Continuous Elevation
- Uncheck Use current map Extent
- Click RUN ANALYSIS.

You now see a continuous surface elevation map created from point elevation data.



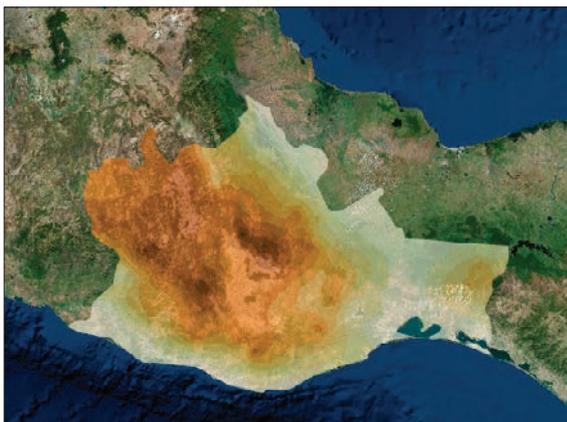
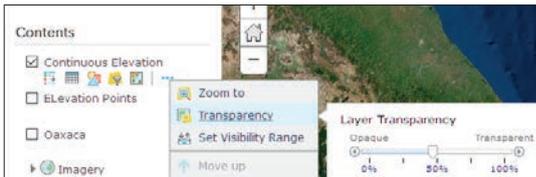
Symbolize the elevation map and set transparency

1. Uncheck Oaxaca and Elevations Points.
2. Click Continuous Elevation



The legend shows you a range of elevation by colors.

3. Click Basemap and select Imagery.
4. Click Continuous Elevation and choose Transparency and set the Transparency at 50%.



5. Write a description of the spatial distribution of Oaxaca. You might want to change the basemap to Imagery with Labels so you will know the names of some of the locational points such as the city of Oaxaca, Salina Cruz, Juchitan de Zaragoza, and Puerto Escondido.

In this exercise, you have created a continuous surface image by interpolating point data using the variable of elevation.

The ArcGIS Imagery Book, chapter 3

Questions for reading comprehension, reflection, and discussion

Teachers can use the items in this section as an assignment, an introduction, or an assessment, tailored to the sophistication of learners. Some learners can read all the sections at one time, while others are more comfortable with small segments. The questions and tasks are designed to stimulate thought and discussion.

1. Images are also called rasters. Briefly explain what a raster is and how it stores and displays data.
2. Give some examples from chapter 3 of different types of data that can be managed and stored in a raster.
3. How is the metadata for remote sensing images different from metadata for digital photographs from a cell phone or hand-held camera?
4. What characteristic of raster data makes it possible to combine imagery with layers of vector data (points, lines, and polygons) in a GIS?
5. What does it mean to orthorectify an image and why is this process necessary?
6. What are the “bands” that the Landsat 8 satellite collects?
7. Complete the table below.

Band combination	Band composition	Use/s
4,3,2		
4,5,3		
6,5,4		

8. What are mosaic datasets and what are the advantages of using them?
9. What data was used to determine habitat suitability for mountain lions in the example provided in the section “Combining rasters in models”? Briefly describe how each data raster contributed to the final habitat analysis
10. Dawn Wright tells us that the ocean is the “new frontier” of earth exploration. How are scientists using remote sensing to learn about the ocean?

Additional resources

Learn ArcGIS: Guided lessons based on real-world problems



Depict Land-Use Change with Time-Enabled Apps

Use historical imagery and time animation to show land-use change in Thailand.

Depict Land-Use Change with Time-

- Adding Landsat imagery to a map
- Enabling and configuring time animation
- Filtering historical satellite imagery
- Changing band combinations
- Creating and sharing time-enabled web apps

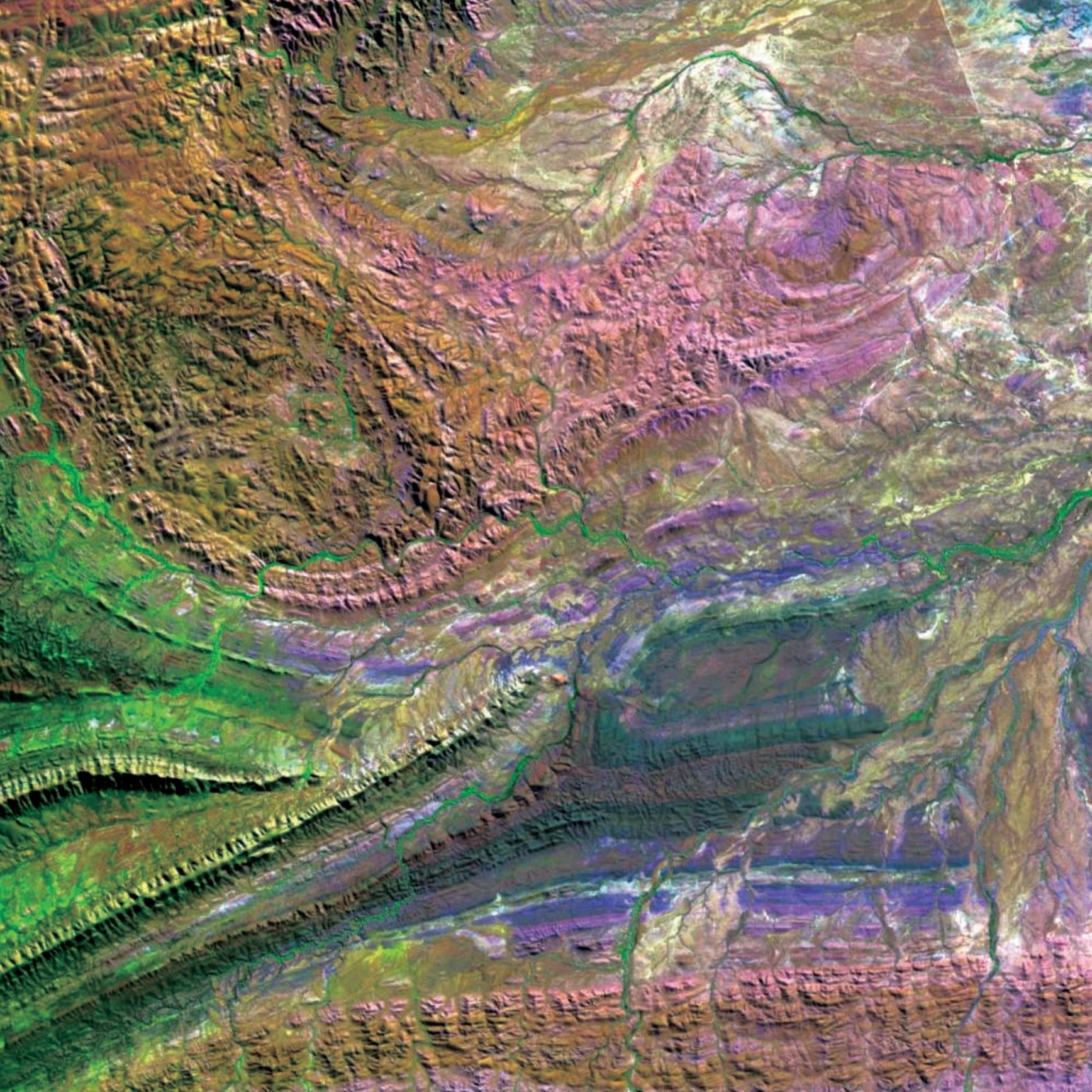


From London to Tokyo

Use the Urban Observatory to compare cities and ask spatial questions.

Assess Burn Scars with Satellite Imagery

- Displaying imagery with different band combinations
- Creating a custom band combination
- Calculating a Normalized Burn Index
- Creating a new feature class
- Publishing layers to ArcGIS Online



Perceiving the Imperceptible

Sensors give us superhuman eyes

Some superheroes have amazing abilities to see. Superman has x-ray vision that enables him to see the composition of rocks. Donna Dunlap's telescopic vision enables her to see an airplane passenger from the ground. The Falcon can see the world through his pet falcon's eyes.

Once limited to the realm of science fiction and comic book superheroes, superhuman vision is now a reality. Today, powerful sensors attached to satellites, airplanes, drones, and robots enable us to see the otherwise invisible, taking us far beyond the limitations of our native human senses. With our new sensor-based super vision we can closely monitor how our planet and its environment are changing. Our new-found super vision provides us with vital information that is guiding informed decision-making in fields as disparate as agriculture, wildlife management, mining, urban planning, and archaeology. Humans are problem solvers and tool users. Remote sensing is a powerful tool that is playing a vital role in solving problems ranging from global warming to food scarcity. The quantity and scope of remotely-sensed imagery grows exponentially, providing new and ground-breaking insights every day.

Introductory activities

Video

Videos elevate motivation and enthusiasm as well as enhance discussion.



Top 16 Earth Images of 2016

NASA Johnson

time=2.56 min

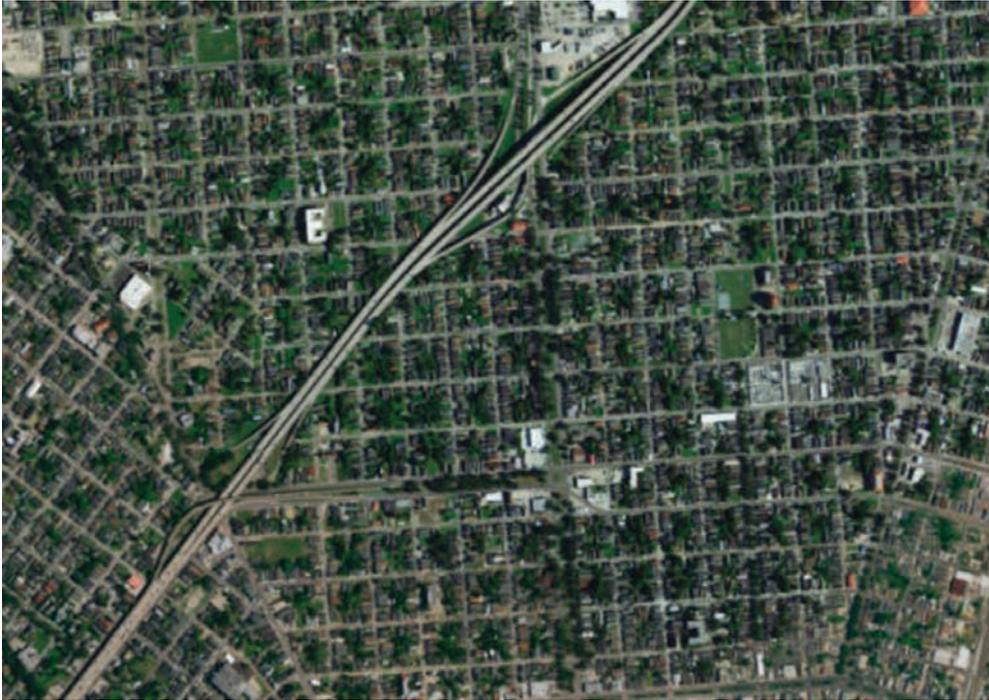
Astronauts on the International Space Station take pictures of Earth out their windows nearly every day over a year that adds up...

https://youtu.be/FZrqmg_bm7o

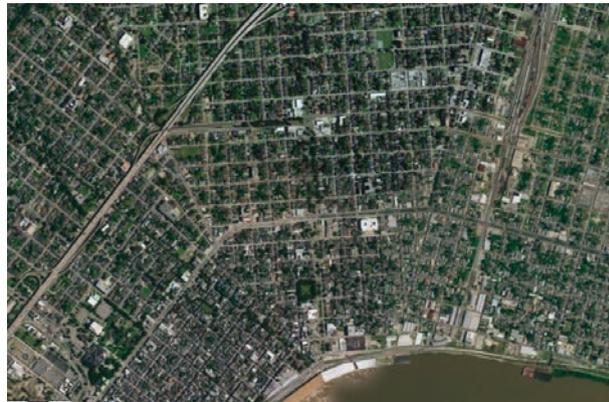
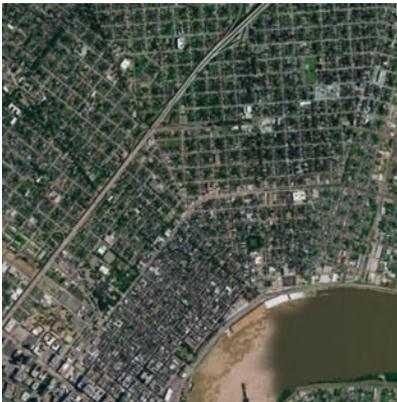
Top 16 Earth Images of 2016

Astronauts on the International Space Station take pictures of Earth from their windows nearly every day and, throughout a year, that adds up to thousands of photos. The people at the Earth Science and Remote Sensing Unit at NASA's Johnson Space Center in Houston pored through this year's crop to pick their top sixteen photos of Earth for 2016 shown in this video.

Activity 4.1
A world of squares



New Orleans was originally laid out as a square-block grid surrounding present-day Jackson Square. As the city grew, adjacent grids had to 'pivot' to accommodate the curved river bank as you can see in the two smaller images.



The *World of Circles* story map presents images of "a selection of natural and human-made circles of various sizes, locations and origins" around the world. Page through the story map to see the variety of images included.

How about squares? Can you find squares in world imagery too? Think about agricultural fields, street networks, or public plazas. What other types of squares could you find? Use the World Imagery basemap to find five examples of natural or human-made squares. Record your discoveries in the chart below. [Note: You may have difficulty finding examples of “natural” squares.]

Latitude, Longitude	City/State or Province/ Country	What kind of feature is it? (street grid, building, etc.)	Bonus: What is it?

Extension activity: In your ArcGIS Online organization account, build a Story Map Series (bulleted layout), like the one about circles, and title it A World of Squares.

Activity 4.2

The big three: Spatial, spectral, temporal

Remotely sensed images all have three things in common: a spatial, spectral, and temporal component. The spatial resolution of an image refers to the size of the smallest object that can be resolved on the ground and in digital imagery is limited by its pixel size. The spectral resolution of an image describes the frequency of the electromagnetic spectrum collected by the satellite. This spectral characteristic allows different features to be seen as separate entities. The temporal resolution of an image is defined as the amount of time needed to revisit and acquire data for the exact same location. In this activity, you will look at three different types of remotely sensed images, describe their spatial, spectral, and temporal components, and record your findings in the chart below.

Satellite	Spatial Resolution	Spectral Resolution	Temporal Resolution
Landsat 8			
MODIS True Color			
NAIP Preview			

1. Go to [ArcGIS.com](https://www.arcgis.com).

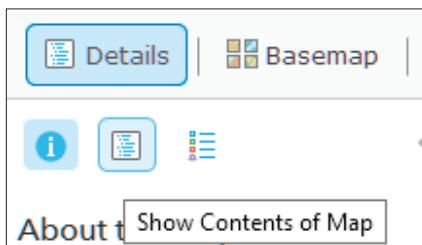
2. Click Map on the top ribbon.



3. Click Modify Map.



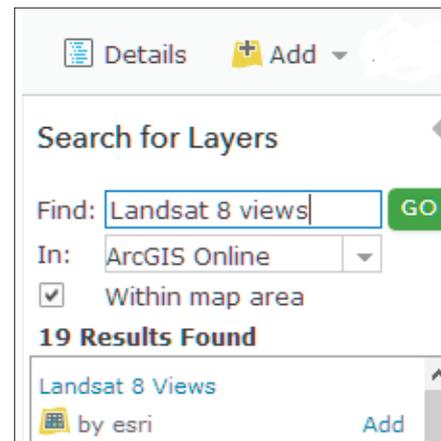
4. Click Details and select Contents.



5. Click Add then select Search for layers and ArcGIS Online.

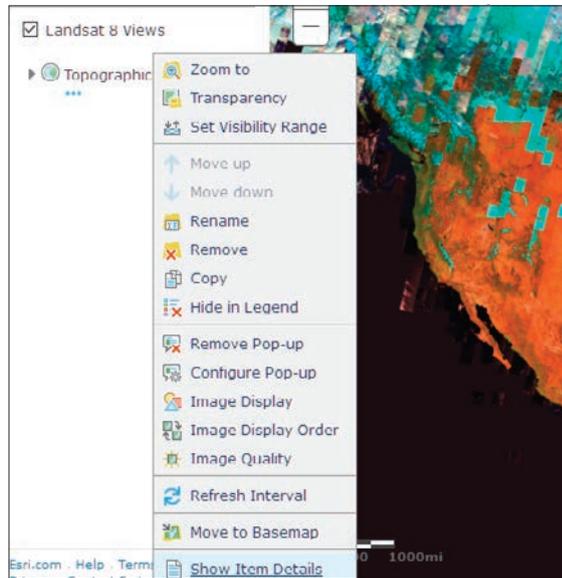
6. Search for Landsat 8 views.

7. Click Landsat 8 Views and Add.



8. Click DONE ADDING LAYERS.

9. Click Show Item Details.



10. Read the item details and record the spatial, spectral, and temporal resolution in the chart.

11. Repeat steps 6–10 searching for MODIS True Color.

12. Add MODIS True Color – Terra Surface by Esri and record information.

13. Repeat steps 6–12 searching for NAIP Preview by Esri.

14. Add NAIP_Preview by esri_atlas and record information.

Q1 Which of the three images shows the most detail?

Q2 Which of the three images has the most spectral reflectance information?

Q3 Which of the three images has the shortest and the longest temporal interval?

Build skills in these areas

- ▶ Opening the Landsat app
- ▶ Finding locations using addresses
- ▶ Using different spectral band combinations
- ▶ Analyzing various spectral profiles
- ▶ Accessing metadata about the imagery

Scenario

You have been asked to demonstrate the Landsat Explorer app to a group of learners without previous experience using Landsat. You need to analyze four different locations. You must qualitatively and quantitatively examine the location.

Washington, DC—urban area

1. Open the *Landsat Explorer app*.
2. Search for Washington, DC, District of Columbia, United States..



What you need

- ▶ Account not required
- ▶ Estimated time: 1 hour

The Landsat view opens in Natural Color. In this view, you can clearly see the bridges, highways, and concentrated developed land.

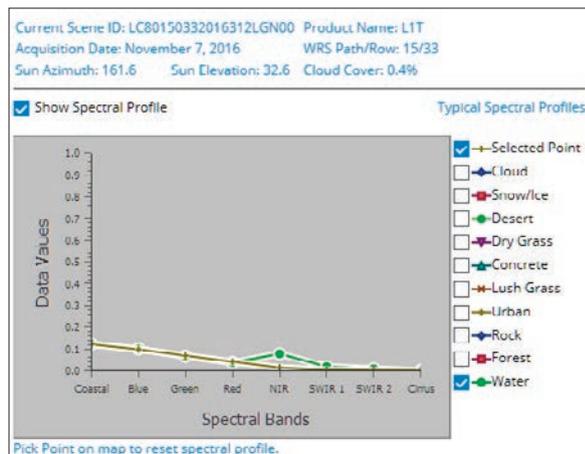
3. Change the Band combination to color infrared, which shows healthy vegetation as bright red. Click the third icon down on the left panel.



4. Locate Arlington Cemetery and the golf course to the West of Addison Heights. If Addison Heights is not immediately visible, zoom in another level. Spectral profiles indicate the value of each pixel for each band. They are essentially plots of the reflected radiation of different objects. Objects behave differently with different wavelengths and therefore they have different spectral profiles. In this next section, you will examine the spectral profile of water, developed land, and healthy vegetation.

5. Click I (for information) and click on water in the image.

You get information about the Landsat scene as well as a spectral profile. Typical spectral profiles are shown as well as the profile of the pixel you selected. Notice that the values are relatively low throughout all the bands. This is because water absorbs light and does not reflect as much as other objects.

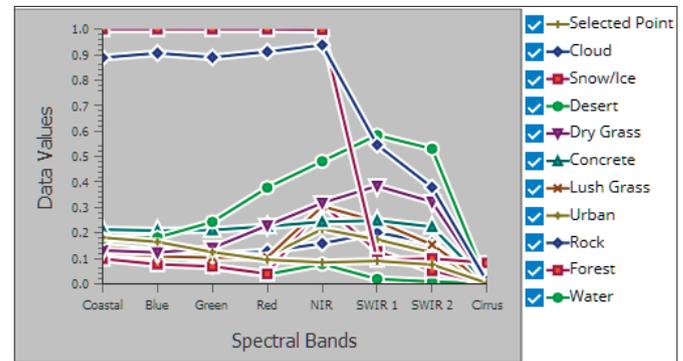


6. Click I and get a spectral profile of developed land.
7. Describe the spectral profile curve for development land, paying attention to where it spikes.
8. Click I and get a spectral profile of healthy vegetation.

9. Describe the spectral profile curve for healthy vegetation. Why does it spike in the NIR band?

10. Check all the Typical Spectral Profiles

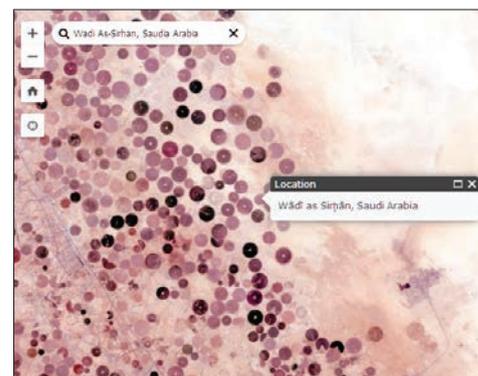
11. Looking at all the Spectral Profiles, write a summary of how spectral reflectance is reflected in the spectral profiles of different objects.



Wadi As-Suh, Saudi Arabia—agricultural area

Circular irrigation is a method of crop irrigation in which equipment rotates around and waters crops with sprinklers. In this section of the exercise, you will identify areas of circular irrigation and examine them using both the vegetation and moisture indexes.

1. Search for Wadi As-Sirhan, Saudi Arabia.

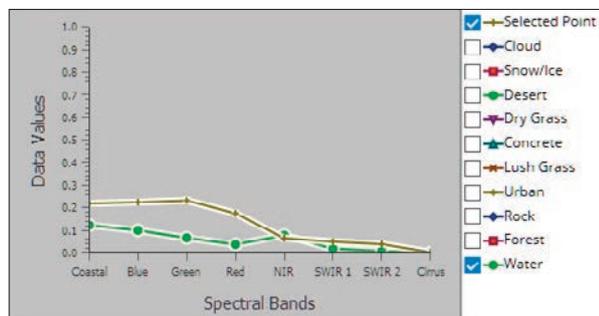


2. Show the image using the Vegetation Index that shows healthy vegetation in dark green.
3. Show the image using the Moisture Index where moisture-rich areas are bright blue.
4. Which band combination shows the circular fields the best?

Princess Charlotte Bay, Queensland, Australia—ocean area

Coral reefs, under threat from environmental conditions, can be monitored by remote satellite imagery. Using remote sensing data, coral reefs can be classified by structure and type and these classifications can be compared temporarily to show change. Find and identify the coral reefs in the area identified.

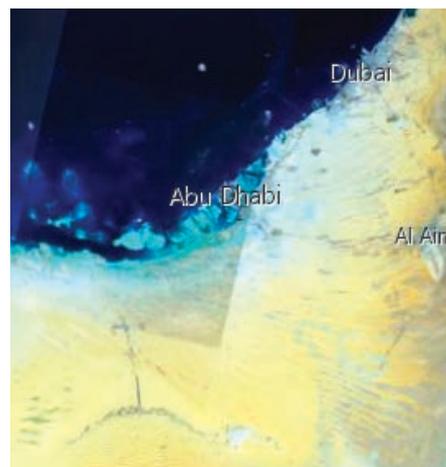
1. Search for Princess Charlotte Bay, Queensland, Australia.
2. Display the image using the Bathymetric band combination.
3. What color displays the coral reefs?
4. Calculate a spectral profile for the ocean.
5. Calculate a spectral profile for the coral reef.
6. How do the two spectral profiles compare?



Abu Dhabi—desert area

Eolian formations are found in places where wind is the cause of erosion and deposition.

Eolian sediments are usually materials that consist of sand and silt-sized particles. Remote sensing can provide valuable information about regional geomorphologic features caused by wind. The study of eolian formations helps us understand climate and the forces mold it.



1. Search for Abu Dhabi, United Arab Emirates and zoom until you see an image that matches the image shown here.
2. Display using the geology band combination.
3. Zoom out and look for the eolian formations.
4. Describe one pattern of an eolian formation.
5. To observe the dunes and orientation better, display as Panchromatic for a sharper image in black and white.

The next three lessons in this chapter use the Landsat Explorer. Esri's Landsat Explorer app is a powerful tool for visualizing our planet and understanding how Earth has changed over time. The app leverages the power of Landsat satellites, which gather data beyond what the eye can see. Users draw on Landsat's different bands to better explore the planet's geology, vegetation, agriculture, and cities. Additionally, the app offers instant access to the entire Landsat archive, allowing users to visualize how Earth's surface has changed over the last forty years.

Lesson 4-2: Visualizing the Shenandoah National Park Fire in the summer of 2016

The Rocky Mountain 2016 fire at Shenandoah National Park was the second largest in the park's 80-year history. The fire was believed to be started by humans in the remote South District of the park. At the fire's peak, 350 firefighters from thirty-three states assisted in the effort. Fire suppression costs are estimated at about \$4.2 million. The fire was at its worst around April 18, 2016.

Build skills in these areas:

- ▶ Adding data to the *Landsat Explorer app* from an ArcGIS online account
- ▶ Picking dates to compare and visualize
- ▶ Creating a visual story using imagery from the app

What you need:

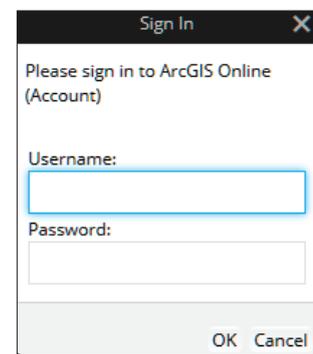
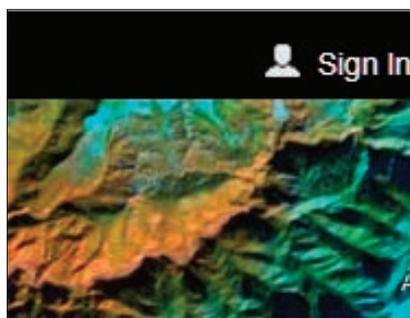
- ▶ Account required
- ▶ Estimated time: 1 hour

Scenario

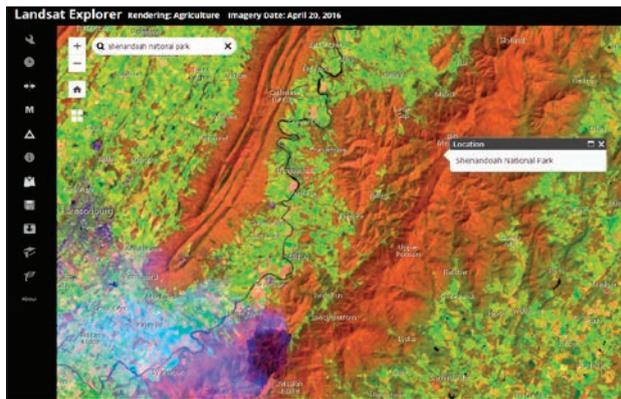
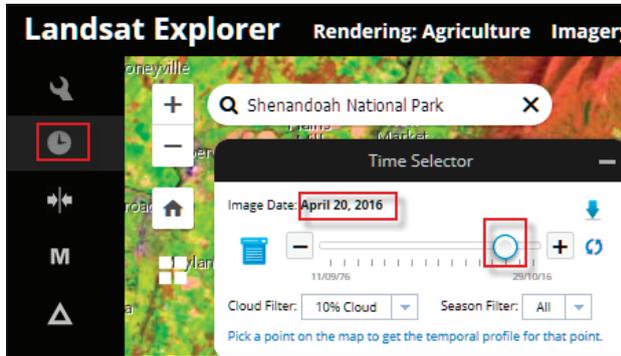
The National Park Service is asking all national parks to prepare story maps combining maps, text, images, and multimedia content to increase public awareness of major fires in their park for the year 2016. The story map will be used to inform the public and to advocate for public fire safety.

Identifying the park

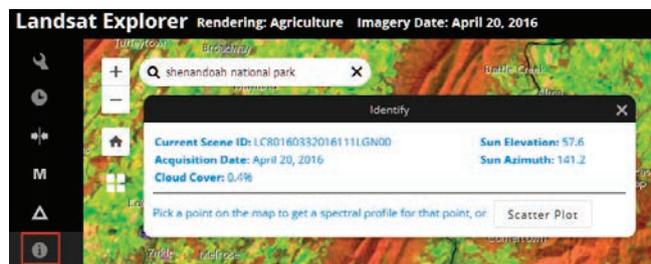
1. Go to *Landsat Explorer*.
2. Sign in to your organizational account.



3. Search for Shenandoah National Park.
4. Click the Time Selector on the side pane and, moving the slider, pick April 20, 2016. Observe the purple patch at the bottom of the screen. This is the location of the fire.

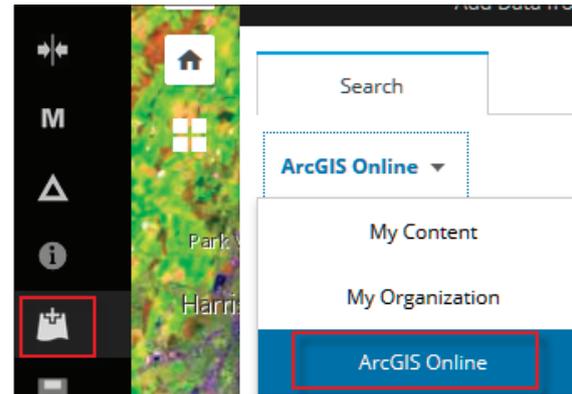


5. Click the I icon on the left pane and click the image. This opens more information about the scene.

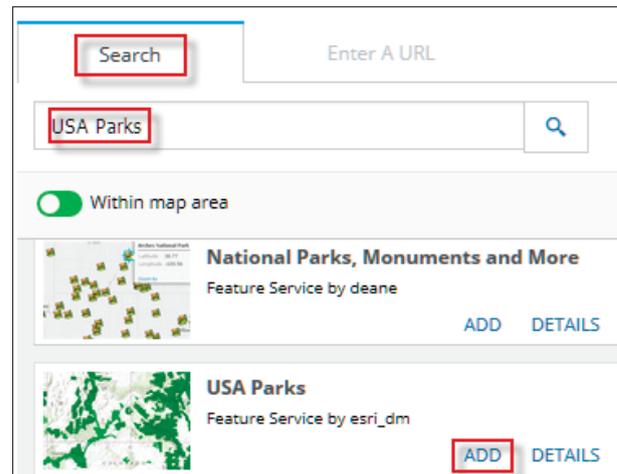


April 20, 2016 was the height of the fire.

6. On the left pane click Add Data from ArcGIS Online.
7. Select ArcGIS Online.



8. Search for USA Parks
9. Select USA Parks Feature Service by esri.dm
10. Click Add.



You now see a green Shenandoah National Park Boundary. After viewing the boundary, click Remove.

11. On the ArcGIS Online menu, close Add Data.

Compare fire image with image after the fire

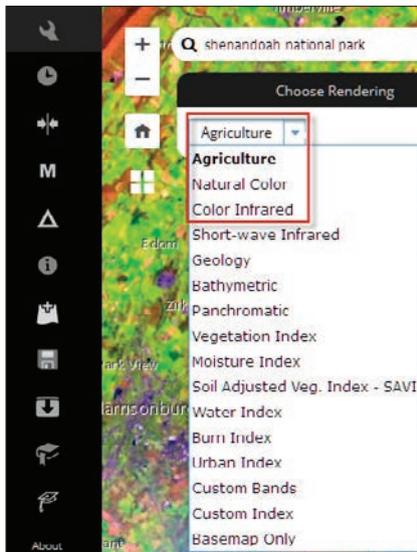
To compare the Landsat images during and after the fire, you first have to enable the time selector to pick dates to visualize and compare.

1. Click the Time Selector. The Image Date is April 20, 2016.

Q1 Describe where the fire is located within the park. Can you easily identify the fire?

2. Go to the left ribbon and select Renderer. Look at the fire in different band combinations such as natural color and infrared.

How do these different band combinations allow you to visualize the fire differently?

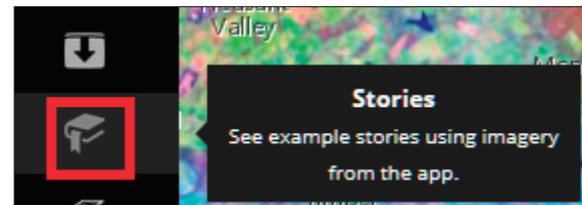


3. Open the time slider and move the date to October 29, 2016. It is easier to click the + sign and go forward one image at a time.

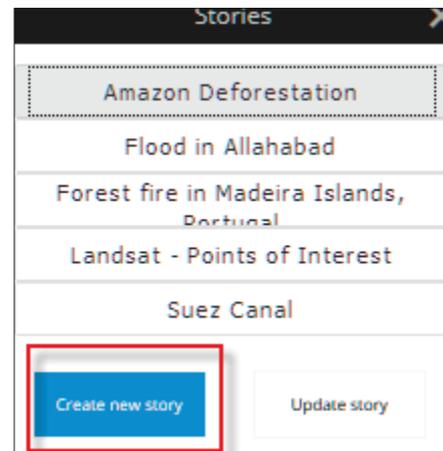
Q2 Is the fire as visible? Once again look at the image using different band combinations.

Create a story map

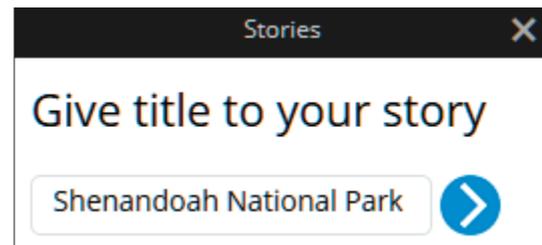
1. Go to the time slider and choose April 20, 2016.



2. Hold Ctrl and click the Stories icon on the side ribbon.



3. Title the story Shenandoah National Park Fire April 2016.



4. Click the blue arrow for next.

5. Add the following text:

The Rocky Mountain 2016 fire at Shenandoah National Park was the second largest in the park's 80-year history. The fire was believed to be started by humans in the remote South District of the park. At the fire's peak, 350 fire fighters from thirty-three states assisted in the effort. Fire suppression costs are estimated at about \$4.2 million. The fire was at its worst around April 18, 2016.

6. Add the following link. You can either copy the link or type it.

This image was taken April 20, 2016. You can see the fire in the southwest. It is darker than the other parts of the image. If you change band combinations, you can see the fire differently.

Shenandoah National Park Fire



7. Click ADD.

8. Select the time slider and pick the date October 29, 2016.

9. On the left panel click ADD SECTION.

10. Enter the following:
Section Title: After the Fire October 29, 2016

The burn scar is not near as obvious. The vegetation is returning.

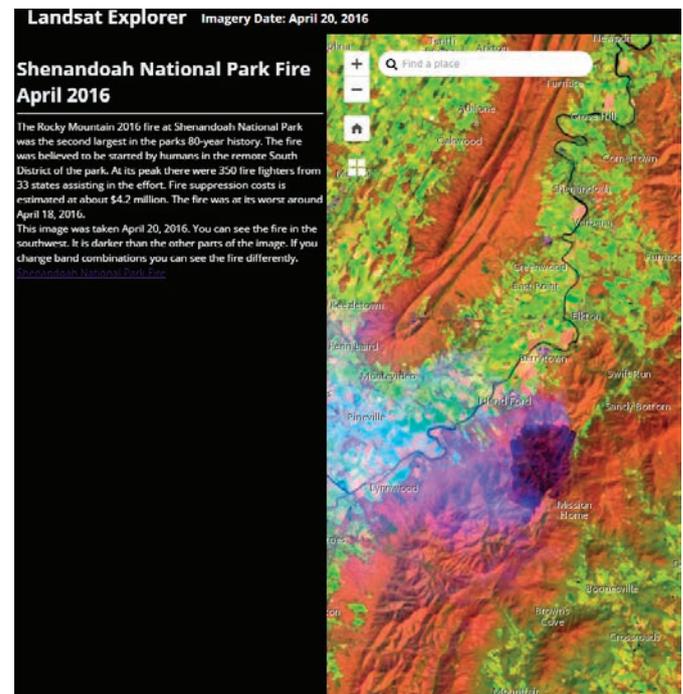
11. Insert this link:

[After the Fire](#)

12. Click ADD.

13. Click FINISH.

14. The web address is shown in the link. You have to sign in to your organizational account.



Lesson 4–3: Change detection after Hurricane Matthew in Les Cayes, Haiti

Remotely sensed data is useful in detecting and mapping changes caused by many types of natural hazards. Detecting and mapping the changes allows the recorded results to be integrated into the planning process for recovery. Remote sensing data provides a broad scale view of change detection.

Build skills in these areas:

- ▶ Using the time slider to pick dates to compare
- ▶ Computing change between two dates both qualitatively and quantitatively
- ▶ Using various band combinations to visualize change

What you need:

- ▶ Account required
- ▶ Estimated time: 1 hour

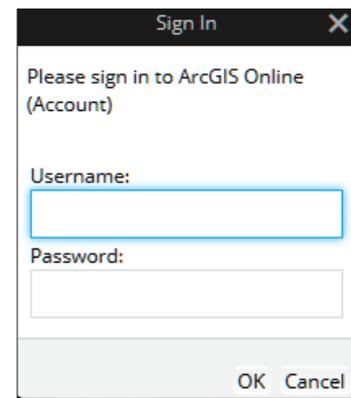
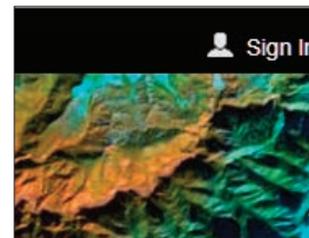
Scenario

Hurricane Matthew hit southwestern Haiti as a Category 4 storm on the morning of October 4, 2016, and left widespread damage to an already impoverished nation. Les Cayes is one of Haiti's major ports with a population of around 70,000. Les Cayes was hit hard by the hurricane with nearly 90 percent of the buildings either destroyed or damaged. You have been asked to map and calculate change both qualitatively and quantitatively to the port of Les Cayes. Since Hurricane Matthew hit on the morning of October 4, you will need a pre- and post-image to that data.

Identifying Les Cayes, Haiti

1. Go to [Landsat Explorer](#).

2. In the upper right corner, click Sign In and sign in to your organizational account.



3. Search for Les Cayes, Haiti.



4. Go to the Renderer icon on the left panel and change the band combination to Color Infrared to show healthy vegetation as bright as red.

Observe the high concentration of vegetation to the west of the river.



Now use the time selector to pick dates to visualize and compare.

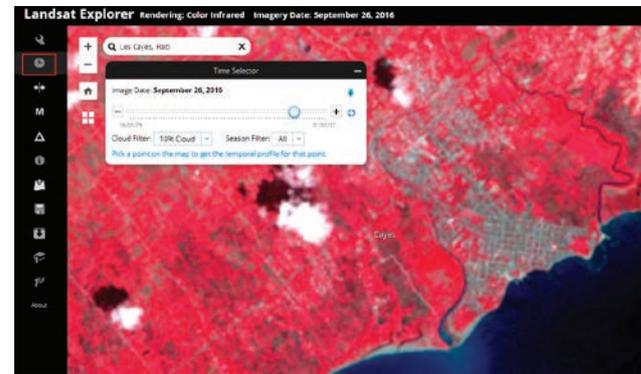
5. Zoom into the city of Les Cayes.

6. Pick the Time Selector on the left panel and use the minus sign to choose

September 26, 2016—a date before Hurricane Matthew.

Another way of selecting the dates is to select the Show Dates in a drop-down menu and individually select the dates.

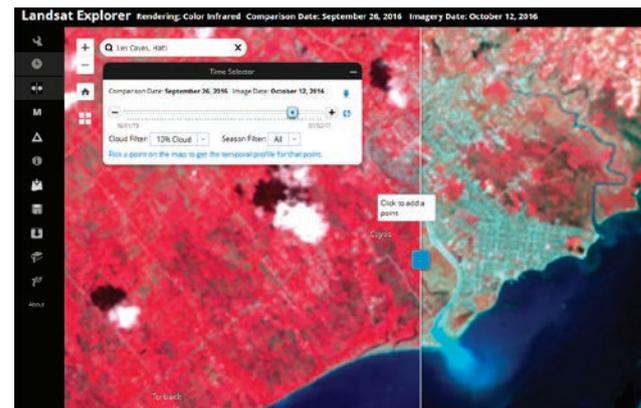
7. Click the blue arrow pointing down to Set Current as Secondary Layer.



Notice the bright red that shows healthy vegetation and the grayish color that shows developed area. Also, notice the Ravine du Sud River and the discharge going into the ocean.

8. Click the Swipe icon on the left panel.

9. Use the time slider to select October 12, 2016, which is after the hurricane.



Once again look at the bright red color and the gray and the Ravine du Sud River discharging into the ocean. Also, take note of the beach areas. Describe the differences that you see. Use the swipe tool to compare the two scenes.

To make quantitative measurements, you must compare the differences between the two scenes with a numerical value. The change detection tool will compute the change in spectral reflectance between the two dates. The change detection tool has three modes for change detection: difference image, difference mask, and threshold mask.

Difference Image mode illustrates all the changes in the select 2016 index between the two dates. Increases are shown in green and decreases are shown in magenta.

Difference Mask mode also calculates the difference in spectral reflectance between the two images. Here, you can use the different sliders to adjust how big the change between two images must be to show up in green or magenta. The transparency slider sets the opacity of the change layer.

Define Area of Interest allows the user to draw and calculate change for a custom area of interest

To make your calculations you will be using the Difference Mask.

10. On the left tab, click the Change Detection icon.

The Change Detection tool can calculate changes in vegetation health (NDVI). The tool is telling how the spectral reflectance has changed from the before to after date of the arrival of Hurricane Matthew.

11. Change the mode to Difference Mask.



Q1 Taking the default for positive and negative values, how many square kilometers between the scenes have decreased?

Q2 What type of land cover has changed the most? Where?

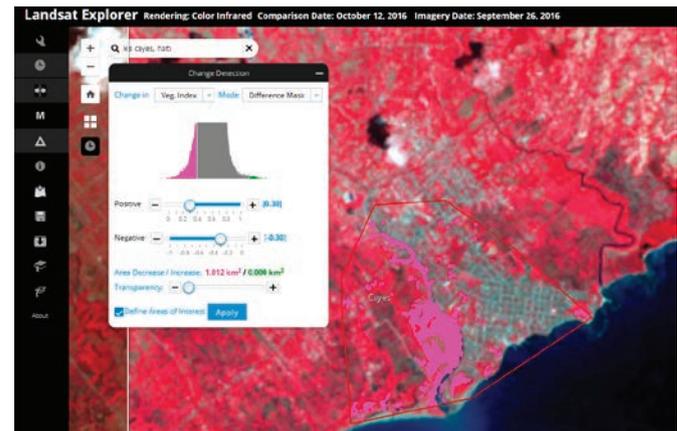
Note: The Area Decrease/Increase numbers will depend entirely on your view extent, how zoomed in you are, and how big your browser window is.

To more precisely study the change, define a more precise area at the heart of Les Cayes.

12. Click the box to Define Areas of Interest.

13. Draw a polygon around a specific area of Les Cayes. You are particularly interested in the section of the city that is nearest the ocean and you should include both sides of the river and some of the beach areas.

14. Click Apply.



Lesson 4–4: Using a mask to define flooded areas in Cedar Rapids, Iowa

Remote sensing data is used to monitor and assess flood damage. It has been used to increase the efficiency of flood monitoring as well as flood management. Flooded areas need to be isolated. Using the mask tool a flood layer can be created based on values.

Build skills in these areas:

- ▶ Isolate flood areas based on pixel values
- ▶ Present both a qualitative and a quantitative presentation of the flooded area
- ▶ Isolate specific areas to evaluate

What you need:

- ▶ Account required
- ▶ Estimated time: 1 hour

Scenario

Cedar River is the second largest city in Iowa. In September, 2016 Cedar River was hit by a flood caused by the remains of the Pacific Hurricane Paine. The river crested at 23 feet on Tuesday, September 27 causing the evacuation of over 5,000 people. The governor of Iowa is calling for a state of emergency and wants to know the number of acres of flooded land. He has asked the Cedar Rapids GIS department for a quick estimate.

Identifying Cedar Rapids, Iowa

1. Go to [Landsat Explorer](#).

2. Click Sign In and sign in to your organizational account

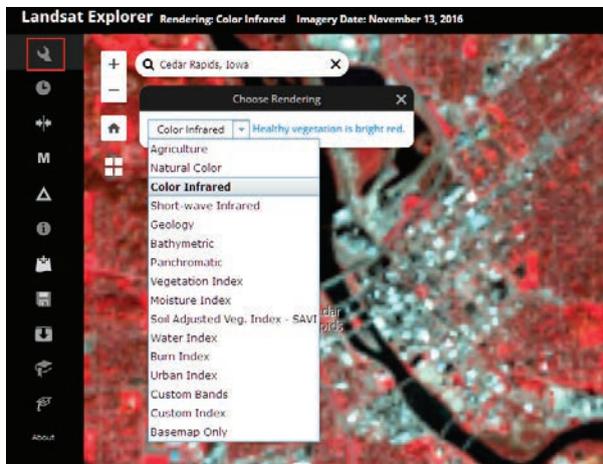


 A screenshot of the ArcGIS Online sign-in dialog box. The title bar says 'Sign In' with a close button. The text inside says 'Please sign in to ArcGIS Online (Account)'. There are two input fields: 'Username:' and 'Password:'. At the bottom, there are 'OK' and 'Cancel' buttons.

- Search for Cedar Rapids, Iowa in the search tab. This will take you to Cedar Rapids.



- Go to the Renderer icon on the left panel and change the band combination to Color Infrared to show healthy vegetation as bright as red.



Examine the image remembering that bright red is healthy vegetation.

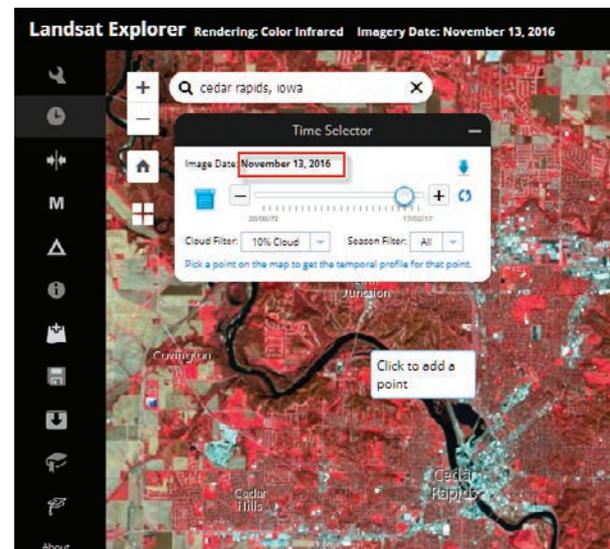
- Q1** *Does the city of Cedar Rapids lie on both sides of the Cedar River?*

Remember the gray to bluish gray section of the image is developed land. Notice the bridges going across the river.

- Q2** *What do you think the very bright sections of red are?*

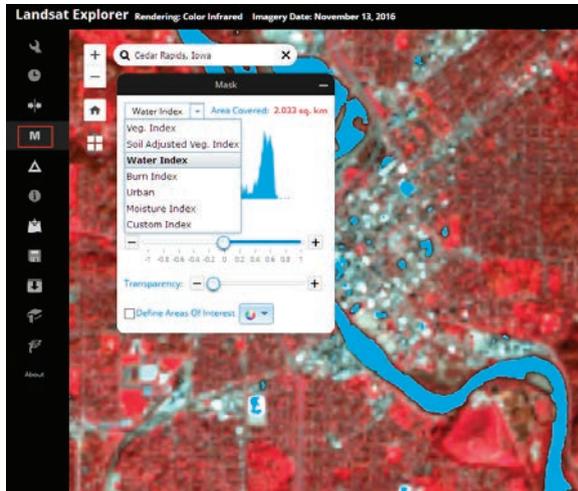
Using a mask to calculate flooded area of Cedar River

- Use the time slider to select the date November 13, 2016.

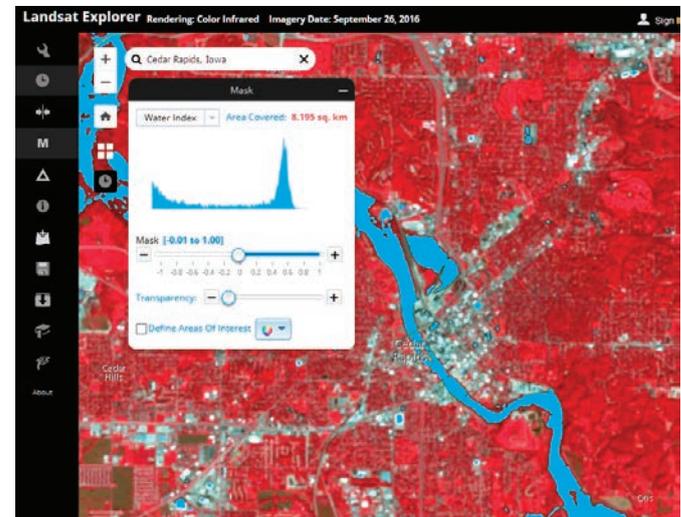


- Click the Mask icon on the left panel and select the water index.
- Move the mask slider to about 0 to 1 to isolate the water. The slider isolates pixels with similar spectral reflectance values.

4. Record the Area Covered.



8. Record the area covered by the mask.



5. Click Mask again to close mask.

6. Select the time slider on the side panel and select the date September 26, 2016, which was at the height of the flood.



9. Compare the amount of water at the height of the flood (September 26) and on a non-flood day (November 13, 2016).

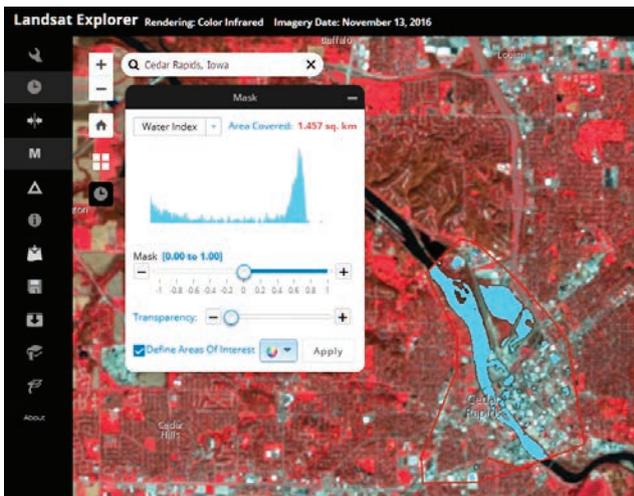
Note: The Area Decrease/Increase numbers will depend entirely on your view extent, how zoomed in you are, and how big your browser window is.

7. Select mask again with the water index and the same values.

Isolating the city of Cedar Rapids

In this next section, you will repeat the above process concentrating on just the city limits of Cedar Rapids.

1. Click Mask.
2. Click Define Areas of Interest.
3. Click to start drawing and digitize around the Cedar Rapids area.
4. Double click to end the polygon.
5. Click Apply.
6. Change the Mask to be 0.00 to 1.00.
7. Record the Area Covered.



Q3 How much land was flooded in the designated area?

The ArcGIS Imagery Book, chapter 4

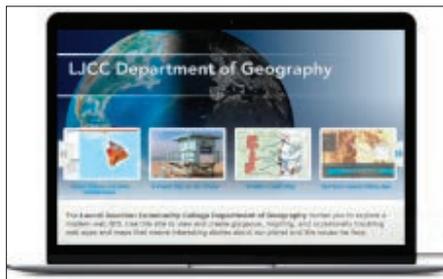
Questions for reading comprehension, reflection, and discussion

Teachers can use the items in this section as an assignment, an introduction, or an assessment, tailored to the sophistication of learners. Some learners can read all the sections at one time, while others are more comfortable with small segments. The questions and tasks are designed to stimulate thought and discussion.

1. Briefly explain the chapter's subtitle: "Sensors give us superhuman eyes."
2. By assigning data from three multispectral bands to the red, blue, and green (visible) display, it is possible to create visualizations that reveal patterns invisible to the naked eye. Give an example from chapter 4 of a phenomenon made visible through various band combinations.
3. In one sentence, briefly describe how multispectral imagery can play a role in the following areas:
 - Marine mammal detection
 - Locating particular minerals
4. How are drone-borne multispectral cameras helping agricultural growers?
5. How are lidar, radar, and sonar alike? How are they different?
6. How can lidar provide insight into catastrophic events?
7. What is unique about the elevation data collected by the Shuttle Radar Topography Mission?
8. How is "working in image space" different from "working in a map coordinate system?" How are they connected?

Additional resources

Learn ArcGIS: Guided lessons based on real-world problems



Set Up an ArcGIS Organization

Administer an ArcGIS organization

Designing the home page

Sharing content and creating groups

Creating custom roles and adding members

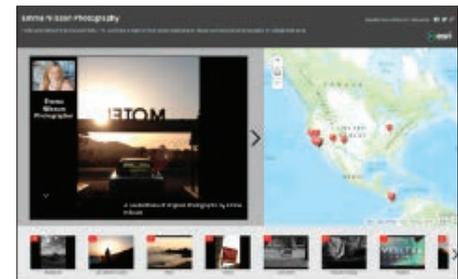
Calculating credits for analysis and storage



Get Started with Story Maps

Using the build-in GPS features of a smartphone or camera to geotag pictures

Using the Story Map Tour builder
Image handling, photography (optional)



Make a GeoPortfolio

Using the Story Map Tour builder

Handling images and photography



Turning Imagery into Information

Analyzing imagery to create understanding

The general hospital in your county is twenty-five years old and the county's population has been growing steadily over this period. Today, the hospital is struggling to meet the county's medical, surgical, and emergency care needs. As a result, the county has decided to build a new hospital and the only question yet to be resolved is where to build it. Among the many considerations in selecting a site for the new hospital (proximity and drive time to population centers, distance from major roadways, and more) is environmental impact. After years of decline, your county is home to a growing bald eagle population that the county wants to protect.

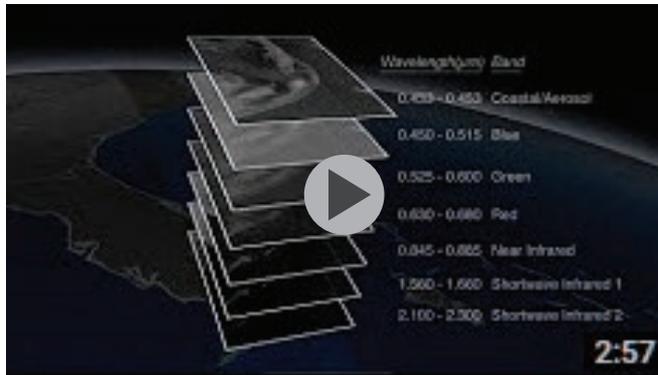
You have a problem to solve and what you need is the information that remotely sensed imagery can provide. Data derived from remote sensing will be vital to making an informed and data-driven site selection for your county's new hospital. Land-cover data, terrain models, and other landscape classifications will allow you to identify locations and extents of current and potential eagle habitats. Hydrological data will enable you to calculate potential locations' level of flood risk. Social, economic, and demographic data will enable you to identify the locations of key population and land-use patterns. Analysis of remotely sensed traffic movements will help identify the most accessible sites.

Image processing has evolved from creating remotely sensed visualizations of features for interpretation to creating near real-time data to solve problems, monitor change, and predict future changes. The derived data ranges from soil moisture to cellphone use, crocodile distribution, wildfire potential, highway access, and much, much more.

Introductory activities

Video

Videos elevate motivation and enthusiasm as well as enhance discussion.



NASA Peeling Back Landsat's Layers of Data

NASA Goddard

Landsat satellites circle the globe every 99 minutes, collecting data about the land surfaces passing underneath.

<https://>

Peeling Back Landsat's Layers of Data

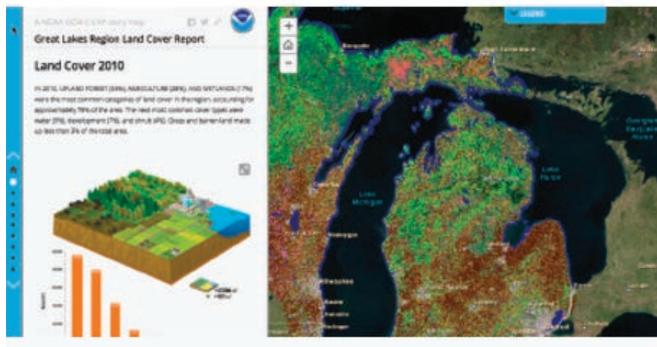
Landsat satellites circle the globe every 99 minutes, collecting data about the land surfaces passing underneath. After 16 days, the Landsat satellite has passed over every spot on the globe, and recorded data in 11 different wavelength regions. The individual wavelength bands can be combined into images, with different combinations of the 11 bands revealing different information about the condition of the land cover.

Activity 5.1

A closer look at land cover

USGS developed one of the first land-cover classification schemes to use remotely sensed data. It was a unique and extremely useful derivative from their Landsat satellite data collection. The land cover was classified using the Anderson Land Use/Land Cover Classification.

The land-cover classification shown in the app below was produced by the process described above. The individual wavelength bands have been combined and classified to produce a land-cover product. You will learn about the different classes of land cover and make spatial observations about their patterns. This app was designed to show changes in land cover, including rapid environmental changes occurring in places like the Great Lakes region of the United States.



1. Click to open the map [Great Lakes Region Land Cover Report](#).

Q1 *What states make up the Great Lakes Region?*

2. Click LEGEND and notice the different types of land cover.
3. Scroll down the story map and record in the following table the percentage of each type of land cover in 2010.
4. Go to [Regional Land Cover Change Reports, 1996 - 2010](#).

5. Record the numbers for all the other regions.

The screenshot displays five regional land cover change reports, each with a thumbnail image, a title, a subtitle 'Web Mapping Application', and a brief description of the report's content and key findings.

- Northeast Region Landcover Change**: This report provides an overview of land cover and change in the northeast coastal region of U.S. from 1996 to 2010. Key findings are presented using reader-friendly maps and graphics.
- Great Lakes Region Land Cover Report**: This report provides an overview of land cover and change in the Great Lakes coastal region of U.S. from 1996 to 2010. Key findings are presented using reader-friendly maps and graphics.
- Southeast Region Landcover Change**: This report provides an overview of land cover and change in the southeast coastal region of U.S. from 1996 to 2010. Key findings are presented using reader-friendly maps and graphics.
- West Coast Region Land Cover Report**: This report provides an overview of land cover and change in the west coast region of U.S. from 1996 to 2010. Key findings are presented using reader-friendly maps and graphics.
- Gulf Region Land Cover Report**: This report provides an overview of land cover and change in the Gulf of Mexico coastal region of U.S. from 1996 to 2010. Key findings are presented using reader-friendly maps and graphics.

Region	Forest	Agriculture	Wetlands	Water	Developed	Shrub	Grass	Barren
Great Lakes								
Northeast								
Southeast								
West Coast								
Gulf								

6. Write a summary of your findings. Include such things as which region has the highest percentage of change and which region has the least. In your summary write about the most significant land-cover change in each region.

Activity 5.2 Understanding the Global Ecosystems Map

Combining four global units together using GIS

1. Click *Explore a Tapestry of World Ecosystems*.



To understand the ecological land-unit map, you must first understand the four global units.

2. Click bioclimate, which represents climate regions.

Q1 Write a brief definition of bioclimate.

3. Click landforms, which has been derived from elevation.

Q2 Write a brief definition of landforms.

4. Click rock type based on lithology input.

Q3 Write a brief definition of lithology.

5. Click land cover to observe the classes.

Q4 How was the land cover derived?

By clicking each layer, you can identify the type of area. Individual places can be accessed by clicking the buttons on the right margin of the app. This story map represents the following places:

- Sweetwater Mountains, California, United States
- Husamlar, Turkey
- Barbreck River, Scotland, United Kingdom
- Praporiste, Czech Republic
- Bishop Creek, California, United States
- Susua and Guanica Forests, Puerto Rico, United States
- Sur, Switzerland
- Gardiner, Montana, United States
- Provo River, Utah, United States
- Waimea River, Hawaii, United States
- Sils, Switzerland
- Dolores Hidalgo, Mexico
- Ixtapan del Oro, Mexico
- Taku, British Columbia, Canada

6. Pick three places that represent different areas of the world. Compare the layers that make up the ecological units in the chart below:

Region	Bioclimate	Landform	Rock Type	Land Cover

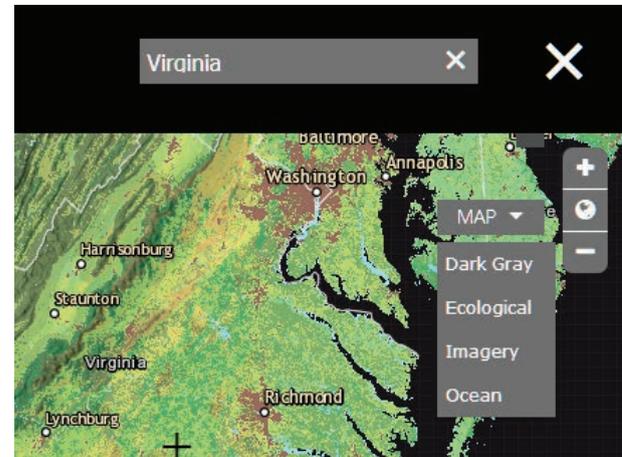
The app can be explored without the story map features by clicking [Explore the Ecological Tapestry of the World](#).



When you click on a point anywhere on the map, the contributing layers are displayed on the side indicating the values of the layers.

Use the source global ecological land units map of the world to do additional individualized study. The source map allows you to search for areas as well as change basemaps.

7. Search for the administrative boundary where you live and explore your ecological units.



Lesson 5-1: Identifying causes of deforestation and loss of biodiversity in Indonesia



Global Forest Watch (GFW) began in 1997 as an initiative to establish a global forest monitoring network and is now part of the World Resources Institute. Today, GFW is a free, online forest monitoring system using cutting-edge technologies to detect forest change in near real-time. Using satellite imagery, GFW delineates changes in land use and land cover, monitors changes in the tree canopy, and identifies fires set to clear forest land for agriculture. In Indonesia, GFW works to reverse deforestation by supporting informed and data-driven actions for effective and sustainable land use there.

Indonesia is home to some of the most biologically diverse forests in the world, and it ranks third in number of species behind Brazil and Democratic Republic of Congo. In the early twentieth century, deforestation began to significantly change the Indonesian landscape and the last 50 years witnessed unprecedented acceleration and intensification of this process. Deforestation in Indonesia represents one of Earth's most significant threats to biodiversity. In this lesson, you will use GFW's interactive map to explore and map the deforestation crisis in Indonesia.

Build skills in these areas:

- ▶ Navigating the Global Forest Watch interactive map viewer and performing the following tasks:
 - Adding and subtracting data layers: forest change, land use, land cover, conservation, and demographics
 - Changing the basemap
 - Applying forest change analysis tools
 - Visualizing animated forest change over time
 - Reading and making use of feature metadata
- ▶ Visually comparing extent and location of map features
- ▶ Sharing and saving maps created in the GFW map viewer

What you need:

- ▶ Internet access
- ▶ Estimated time: 1 hour

Scenario

The Museum of Natural History in your city is planning an exhibit on global biodiversity and the forces that threaten it. The museum has decided to include a brief article about a biodiversity hotspot in each of its quarterly newsletters prior to the exhibit launch. As a member of the museum's staff, you have been asked to write one of those articles, an overview of the deforestation crisis in Indonesia. You will use Global Forest Watch's interactive map to explore the issue, develop a list of factors contributing to deforestation and biodiversity loss in Indonesia, and create maps that support your conclusions.

1. Go to Global Forest Watch and click the Interactive Map link near the bottom of the home page.



Explore the default map

2. The Forest Change window on the left shows that tree cover loss and gain are currently displayed. Turn off the Tree cover gain layer by clicking the X next to it to see only global tree cover loss.



- Click the Hide Windows icon in the lower left so you can see the map without obstructions.



- Take a minute to pan and zoom the map to locate the areas of greatest forest loss.

Q1 *Where are the most significant areas of forest loss on each continent?*

View tree cover loss from 2001 to 2014 as a time series.

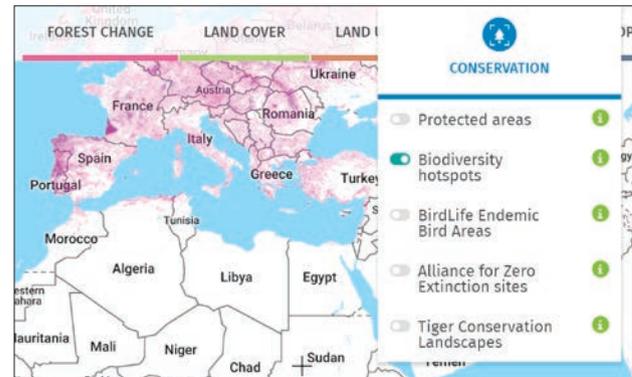
- On the bottom of the map, locate the time line.



- Press the play button on the left to view the entire time series, or drag ends of the time line to select a specific time.

Turn on new data layers. Available global data layers are organized by category across the top of the map.

- Click the Conservation tab and turn on Biodiversity hotspots to add the layer to your map.



- To read about the meaning of each biodiversity hotspot, click the *i* in the green circle next to the layer name.

- Pan and zoom the map to identify areas of greatest biodiversity risk.

Q2 *Where are the principal biodiversity hotspots on each continent?*

- Zoom to Indonesia.

- Click the Search icon in the lower left and type Indonesia in the search box.



12. When you click Enter, the map zooms to the country of Indonesia. Indonesia is an archipelago with over 13,000 islands.

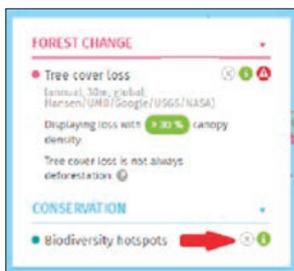


The large island, where the place marker is located, is Borneo. Borneo is politically divided among three countries: Malaysia and Brunei in the north and Indonesia to the south.

Q3 *Approximately how much of Indonesia is characterized as a biodiversity hotspot?*

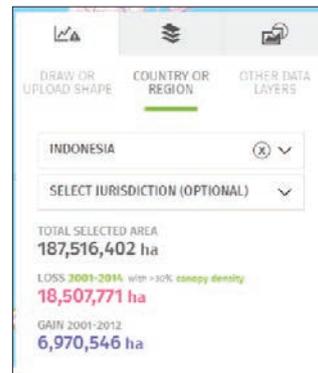
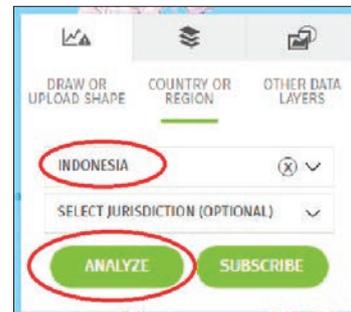
To analyze tree forest change in Indonesia, change the basemap to identify indicators of deforestation.

13. Turn off the biodiversity hotspots layer in the legend window on the left.



14. From the Forest Change tab, turn on Tree cover gain.

15. Select Indonesia in the dropdown list of countries, and click Analyze.



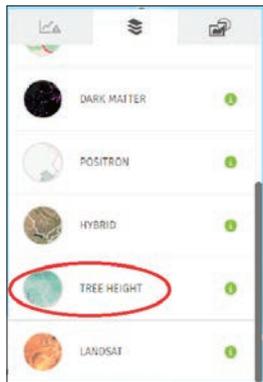
Although the gain and loss statistics are not directly comparable, they do give us a rough estimate of the percent of Indonesia's total area affected by the change.

Q4 *The total area of tree cover loss is approximately equivalent to what percent of Indonesia's total land area? Use this formula: (area of forest cover loss / total area of Indonesia) X 100 = Percent of total area lost.*

16. Turn off the Tree cover gain and Tree cover loss layers.

Explore indicators of forest change in Indonesia

1. Click the basemaps icon on the right side of the map and select the Tree Height basemap.



2. Zoom in so you can get a good look at the patterns of canopy height in Indonesia.

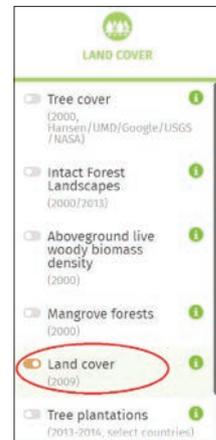


3. Under the Forest Change tab, turn on Tree cover loss again.
4. Turn the layer on and off several times to toggle between the basemap and the Tree cover loss layer. Observe what the tree height is in the areas with and without tree cover loss.

- Q5** What pattern do you see in comparing tree cover height to tree cover loss?

Observe patterns of land use in Indonesia

1. Turn on Global Land Cover under the Land Cover tab.



2. To better see the land cover data, go back to the default basemap.
3. Once again, toggle between layers (land cover and tree cover loss) to see patterns of land use in areas that have experienced tree cover loss. (Note: you will have to zoom into one area at a time to distinguish specific land use designations.)

- Q6** What is the most frequent land cover designation in areas that have experienced tree cover loss?

Observe patterns of plantation agriculture in Indonesia.

1. Turn off the Global Land Cover and Tree cover loss layers.
2. Under the Land cover tab, turn on the Tree plantations by species layer.

Q7 What type of plantation agriculture predominates in Indonesia?

Q8 What other types of plantation agriculture do you see?

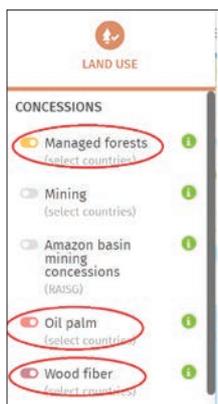
3. Turn on the Tree cover loss layer again

Q9 Where are the agricultural plantations in relation to areas of tree cover loss?

Investigate agricultural concessions in Indonesia

1. Turn off Tree plantations by species.

2. Under Land Use, turn on the following Concessions: Managed forests, oil palm, and wood fiber.



3. Click the green information button to read about each "concessions."

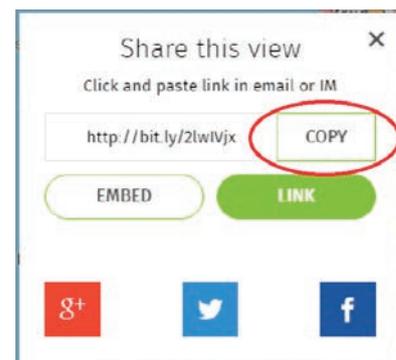
Q10 How are concessions different from plantations? Which cover more area? What are the implications of that difference?

Q11 Tell the story of deforestation and biodiversity loss in Indonesia. Make a bulleted list of three or more factors that contribute to deforestation and biodiversity loss in Indonesia.

Illustrate your conclusions with appropriate maps

1. Turning layers on or off and zooming to an appropriate scale, use the GFW interactive map to create two or more maps that illustrate your findings about deforestation and biodiversity loss in Indonesia.

2. When you have created the map to your satisfaction, click the share icon and copy the url for your map.



You are now ready to write your article for the museum newsletter. You investigated deforestation and biodiversity loss in Indonesia using authoritative data from Global Forest Watch. You can build a narrative discussion of deforestation and biodiversity loss in Indonesia from your bulleted list, and illustrate that narrative with maps you created with the GFW interactive map. Explore the GFW website for additional information about causes and implications of deforestation.

Lesson 5-2: Understanding elevation and derivative layers

ArcGIS makes it easy to work with elevation data by offering a dynamic world elevation service (TopoBathy) and a specific land elevation (Terrain). These services provide online access to elevation data.

Build skills in these areas:

- ▶ Displaying world elevation and bathymetry
- ▶ Identifying various elevations of the world
- ▶ Displaying terrain
- ▶ Displaying and understanding slope
- ▶ Comparing slope to contour lines
- ▶ Displaying and understanding aspect
- ▶ Displaying and understanding hillshade

What you need:

- ▶ Account required
- ▶ Estimated time: 1 hour

Scenario

You have been asked to provide an online experience introducing users to elevation services. You are to provide instruction in the use of the TopoBathy and USA elevation services. Derivatives produced from the elevation services are to be included in your explanations.

World Bathymetry: Display

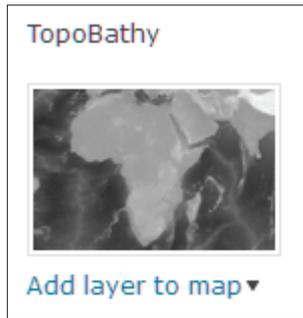
The TopoBathy image service combines topography (land elevation) and bathymetry (water depths) around the world. Heights are based on sea level = 0, and bathymetric values are negative downward from sea level. Once again, the unit of height of measurement is meters.

1. Sign into your organizational account at [ArcGIS Online](#)
2. Click *Map* on the top Ribbon.
3. Click *Add* and choose *Browse Living Atlas Layers*.

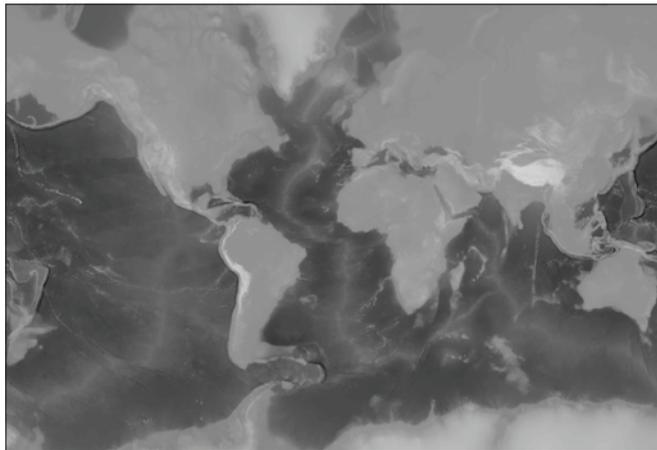


4. Collapse All Categories, Select Landscape then Elevation.

5. Select TopoBathy and Add to map as layer.



6. Zoom all the way out to see the land elevation and water depth.

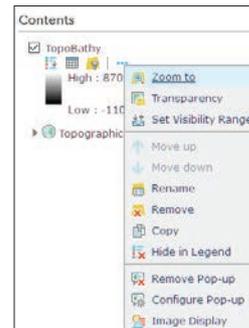


7. Uncollapse the legend in the contents pane.



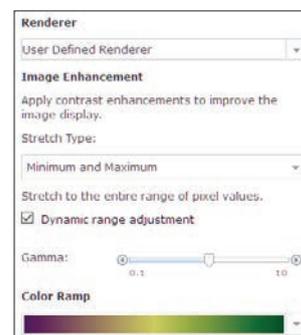
Q1 What is the lowest and highest elevation shown on the imagery server?

8. Right-click TopoBathy and go to Image Display.



9. Select the following parameters to the Image Display Menu:

- Renderer is User Defined Renderer.
- Stretch Type is Minimum and Maximum.
- Check Dynamic range adjustment.
- For Color Ramp choose Purple to Green, Diverging, Dark. This color ramp has been chosen so that the deepest place in the ocean is dark purple and the highest places on land is dark green.



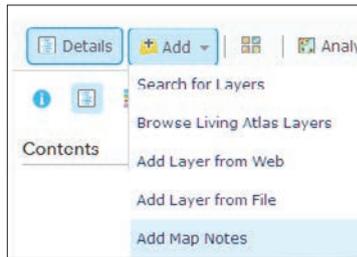
10. Click APPLY.

11. Click CLOSE.

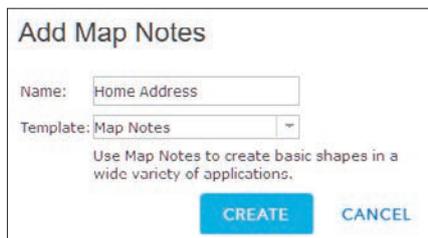
World Bathymetry: Structures

Using the TopoBathy image service you will now identify and mark various elevation structures on the map. All the following structures will be identified by searching and adding a map note marker. To learn how to add a map note, start by adding to the location where you live.

1. In the upper right corner, type your address and press Enter to go to a map of the designated location.
2. On the upper ribbon click Add and Add Map Note.



3. Click Add Map Notes:
Name is Home Address.
Template is Map Notes

A screenshot of a dialog box titled 'Add Map Notes'. It contains a 'Name:' field with the text 'Home Address' and a 'Template:' dropdown menu with 'Map Notes' selected. Below the fields is a small text box that says 'Use Map Notes to create basic shapes in a wide variety of applications.' At the bottom of the dialog are two buttons: 'CREATE' and 'CANCEL'.

4. Click CREATE.

5. Pick the Pushpin and click the location. Use the following parameters:

- Title is Home Location.
- Description is Where I live.

6. Click CLOSE.

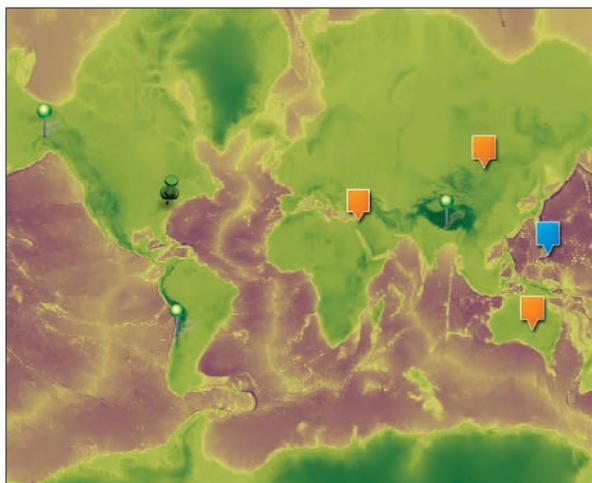
7. Repeat the process for the Highest Structures using a different type of map note.

8. Repeat the process for the Lowest Structure in the Ocean using a different type of map note.

9. Repeat the process for Structures Below Sea Level on Land using a different type of map note.

- Highest Structures
 - Mount Everest, Nepal
 - Aconcagua, Mendoza, Argentina
 - Denali, Alaska
- Lowest Structures in the Ocean
 - Mariana Trench, Northern Mariana Islands
- Structures Below sea level on land.
 - Dead Sea, Jordan
 - Lake Baikal, Russia
 - Lake Eyre, Australia

10. Click Save on the upper ribbon.



11. Complete the documentation for your map. Use the following parameters:

- Title - Elevations Around the World
- Tags: elevation, bathymetry, your initials
- Summary: Location of High and Low Elevations Around the World.

Save Map

Title:

Tags:
Add tag(s)

Summary:

Save in folder:

12. Click SAVE MAP.

Derivatives of elevation: Slope, aspect, and hillshade from terrain

Using the dynamic surface Terrain, you can access elevation values for use in analysis with slope, aspect, and hillshade.

1. Click Create New Map in the upper right corner.



2. Click Yes Open the Map.

3. Go to Browse Living Atlas Layers.

4. Choose Elevation and add the following layers:

- Terrain
- Terrain: Slope Map
- Terrain: Hillshade
- Terrain: Aspect
- USGS National Map



5. Turn off all layers but Terrain.

6. Right click Terrain and zoom to.

7. Go to Image Display and select the following:

- Renderer is User Defined Rendered
- Stretch Type is Minimum and Maximum
- Color Ramp is Elevation #2

8. Click APPLY.

This rendition of Terrain gives you land elevation.

9. Turn on Terrain: Slope Map

The slope map provides a colorized representation of degree of slope. Flat surfaces are represented as gray, shallow slopes as light yellow, moderate slopes as light orange, and steep slopes as red-brown.

Q2 *Where on the map is the greatest slope represented? Why?*

10. Zoom into Washington State in the United States.

Q3 *What are the cone-like features?*

11. On the top ribbon, change basemaps to National Geographic.

Q4 *What are the names of the cone-like features?*

12. Turn on the USGS National Map.

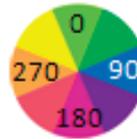
Q5 *How do the contour lines represent the slope?*

13. Turn off USGS National Map and Terrain: Slope.

14. Turn on Terrain: Aspect.

The terrain layer provides a colorized representation of aspect, generated dynamically using the server-side aspect function of the terrain layer. The orientation of the downward sloping terrain is indicated by different colors, rotating from green (North) to blue (East), to Magenta (South) to orange (West). The numeric aspect values are represented by values from 0 to 359 degrees and the values are shown in the image below. Aspect is used in northern climates to show areas that would not receive as much sun and would, therefore, stay

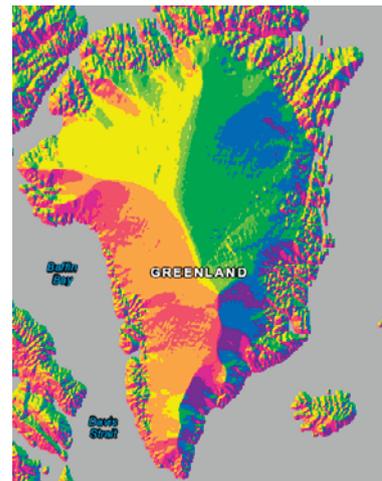
cold and icy longer. Aspect is also used in vineyard selection since a region's climate makes the aspect of the land important.



15. Zoom into any part of the land and identify by color which direction the land is facing.

Many places on the map will give you a numerical value for the aspect if you click on the map.

16. Zoom into Greenland since it is a good example of a landscape that shows distinct aspect.



17. Turn on Terrain: Hillshade. Hillshade is a grayscale 3D representation of a surface based on the sun's relative position.

This map provides a hillshaded surface based on a solar altitude angle of 45 degrees and solar aspect angle of 315 degrees. The map provides a quick indication of the shape of the terrain at a range of map scales.

18. Zoom to the West Coast of the United States.
19. Click and drag Terrain above Terrain: Hillshade.
20. Right-click Terrain and select Transparency.
21. Set the Transparency to 60 to give the Terrain layer a 3D look.



Q6 Write a paragraph description of Terrain, Slope, Aspect, and Hillshade.

Lesson 5–3: Elevation profiles

An elevation profile is a depiction of a two-dimensional cross sectional view of a landscape. It provides a side view of a terrain's elevation along a line drawn between locations on a map. ArcGIS Online displays an elevation profile for a selected feature or a measure line along a web map.

Build skills in these areas:

- ▶ Using the image service Terrain to show elevation profiles
- ▶ Showing change in elevation using an elevation profile
- ▶ Describing landscape of the United States using an elevation profile
- ▶ Identifying physical features using an elevation profile

What you need:

- ▶ Account required
- ▶ Estimated time: 1 hour

Scenario

Elevation profiles provide understanding of elevation and landforms. You have been asked as an instructor to provide your students with material that expands their knowledge of elevation and landform features through using elevation profiles.

USA profile

1. Sign in to your organizational account at ArcGIS Online.
2. In the top right corner, search for esripress_ig_imagery group.
3. Uncheck Only search in Participants and Resources.
4. Click the esripress_ig_imagery group.

5. Click Elevation Profile Map.



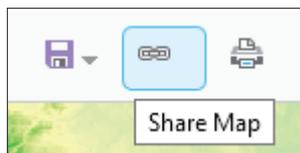
6. Click on the map.

- Save the map in your organization. When you save the map, be sure to remove the IGIMG tag and the LearnResourceIMG tag. Put in specific tags to your organization and membership.

Examine the layers. Notice that you have a Ground Surface Elevation model, with states and two map notes representing a United States Profile to be drawn, and Features representing various land forms.

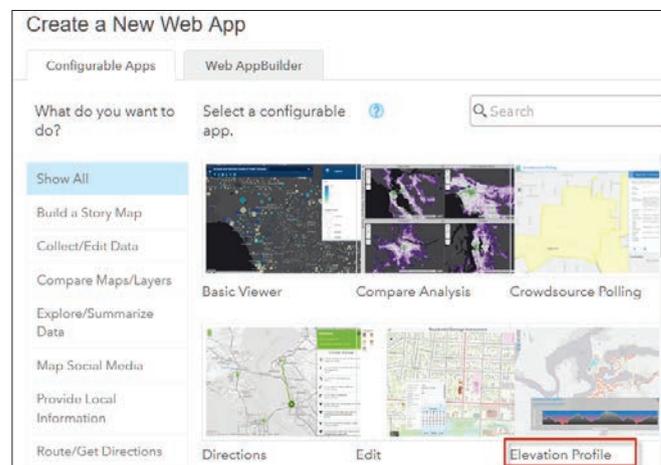
To use the Elevation Profile you need to share this map and Create the web app named Elevation profile. This web app generates an elevation profile for line feature drawn on the map using the measuring tool.

- Click Share Map on the top ribbon.



- Click CREATE A WEB APP.

- Select the Elevation Profile app.

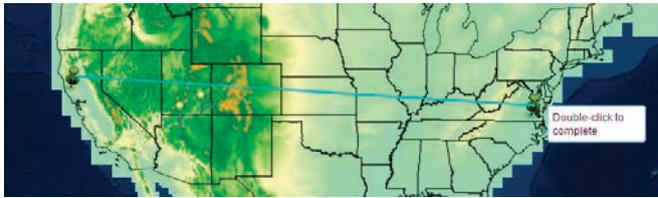


- Click CREATE WEB APP.
- Document your web app. Remember to delete the IGIMG and the LearnResourceIMG tags and specific tags for your organization.
- Click DONE.
- Click Launch.
- Click the pencil icon to draw a line on the map that generates a profile.

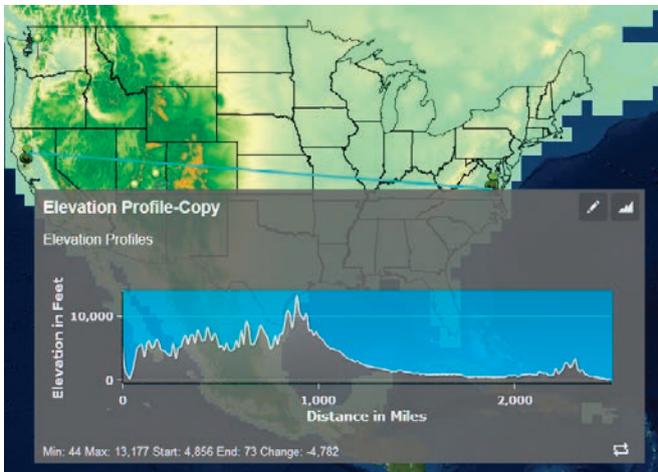
This first profile gives a view of the conterminous United States.

- Click the large green map note on the Pacific Coast and draw the profile line to the large green map note on the Atlantic Coast.

17. Double-click to stop drawing the line. It will take several seconds for the elevation profile to draw.



18. Move the pencil to hover over the line in the profile pane and move your mouse to view the numeric values of the elevations of the transect.



Q1 What are the units for the x-axis and y-axis?

Q2 On the profile and the map, try to identify the elevations of the following features:

- San Joaquin Valley
- Rocky Mountains
- Appalachian Mountains
- Great Plains

Landform profiles

Different land forms have different profiles. Draw a profile through each of the following landforms. The landforms are designated by stick pins. Sketch a picture of the profile and write a definition of the landform and how it relates to the profile. The landforms are each represented by a unique map note.

Point 1 Mount Rainier

Point 2 Grand Canyon

Point 3 Merrick Butte

Landform	Sketch	Elevation	Definition
Mount Rainier			
Grand Canyon			
Merrick Butte			

The ArcGIS Imagery Book, chapter 5

Questions for reading comprehension, reflection, and discussion

Teachers can use the items in this section as an assignment, an introduction, or an assessment, tailored to the sophistication of learners. Some learners can read all the sections at one time, while others are more comfortable with small segments. The questions and tasks are designed to stimulate thought and discussion

1. The introduction of chapter 5 tells us that "...imagery data—with its cell-based data structure—allows for the systematic and controlled analysis of a vast array of phenomena across multiple layers." How does the strategy used to identify potential mountain lion corridors (Cougar Corridors of Southern California) reflect that statement?
2. What four components are combined to create the ELU (ecological land units)?
3. Briefly explain the similarities and differences between image classification and image segmentation.
4. Define the task known as suitability analysis and provide an example of suitability analysis described in chapter 5.
6. Give an example of hydrological analysis of flood events (real or potential) that GIS can provide. What data is used in these analyses?
7. What does Gerry Kinn mean when he says that image analytics is not just about making a pretty picture?
8. How can lidar imagery contribute to analysis of coastal damage caused by hurricanes and inform decision-making for the recovery process?

Additional resources

Learn ArcGIS: Guided lessons based on real-world problems



No Dumping - Drains to Ocean

Finding watersheds and flow paths

Sharing your web map with others



A Place to Play

Using spatial analysis tools to find potential parks that meet specified criteria

Defining park access zones and enriching them with demographic information

Using visual map analysis to identify problems with potential parks

Creating maps and web applications to communicate your analysis results

Managing maps and layers in your ArcGIS Online account



Connect Streams for Salmon Migration

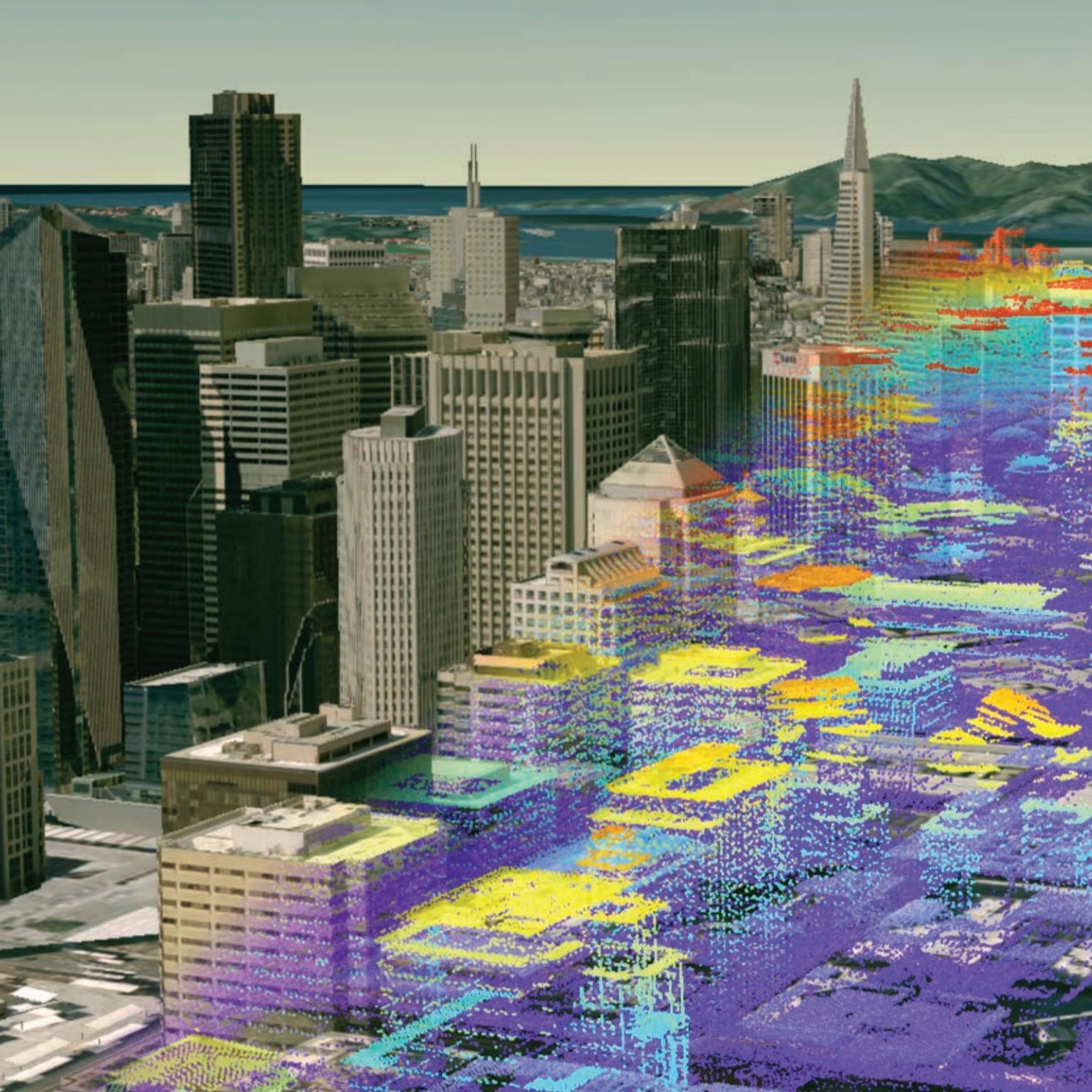
Visually analyzing imagery

Using the Create Watersheds tool

Using the Overlay Layers tool to derive new layers

Filtering layers with logical queries

Calculating tools with the Summarize Within tool



Creating Mirror Worlds

Enabling a new dimension with 3D imagery

The enhanced realism of 3D imagery has always captured our imagination. 3D films such as *House of Wax* and *It Came from Outer Space* thrilled viewers during the early 1950s—3D’s “golden era.” Three decades later, IMAX theaters electrified visitors with the 3D experience of climbing Mount Everest and soaring above the Grand Canyon. Today, you can watch everything from *Kung Fu Panda* to rock concerts in 3D.

In the 21st century, 3D imagery has moved well beyond the entertainment arena to become the workhorse of modeling, planning, and analysis in fields ranging from urban design to meteorology, archaeology, and disaster preparedness. This transformational shift is the result of technological advances that have enabled GIS to seamlessly integrate 3D visualizations and analysis across devices and platforms. Imagery of ancient and inaccessible Incan sites collected by remotely controlled drones provides an opportunity for in-depth exploration and analysis never before possible. Emergency responders can model the specific local impact of flooding on homes and infrastructure in the event of a dam failure. Urban planners have exceptional tools to compare the impacts of alternate design proposals for site development. Whether the issue at hand is global or local, 3D analysis in GIS drives informed and data-driven decisions.

Introductory activities

Video

Videos elevate motivation and enthusiasm as well as enhance discussion.



ArcGIS Online Scene Basics

Immerse yourself in the 3D world with the Scene Viewer. This video gives you the basics to get you started with 3D scenes.

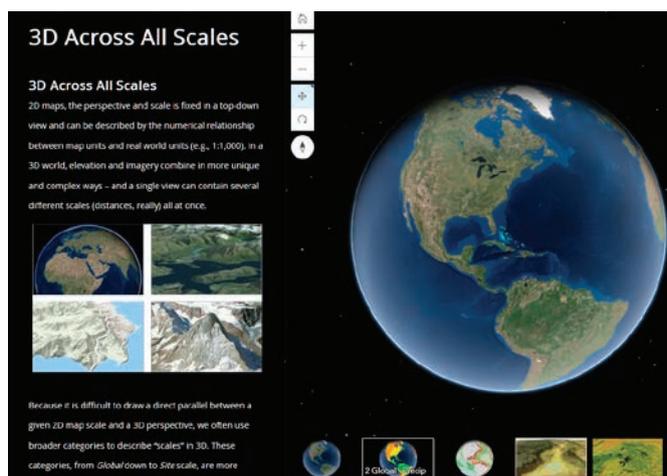
Activity 6.1

3D Across All Scales

The ArcGIS Online 3D scene viewer is an app built into the ArcGIS Online website for creating and interacting with 3D scenes. The scene app is spherical, which makes it ideal to view global data. The app gives users the option of looking at data in the global or local scene. A global scene is good to use when you want to understand or provide context for phenomena that wrap around the spherical surface of the earth. A local scene can display data that has a spatial reference in a local projected coordinate system. Local scenes are best used for displaying or analyzing data at the local or city scale that has a fixed extent in which you work. The following activity allows you to explore both global and local scenes.

Explore 3D

1. Open *3D Across All Scales*.

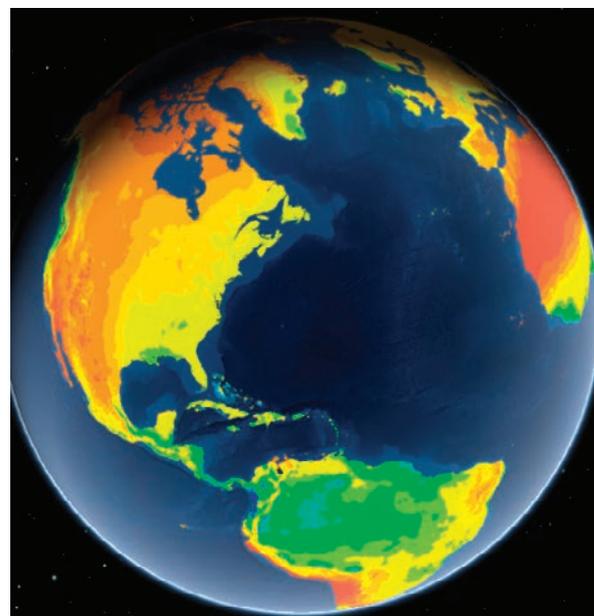


2. Hover your mouse below the scene, and then click the 2 Global – Precip slide.

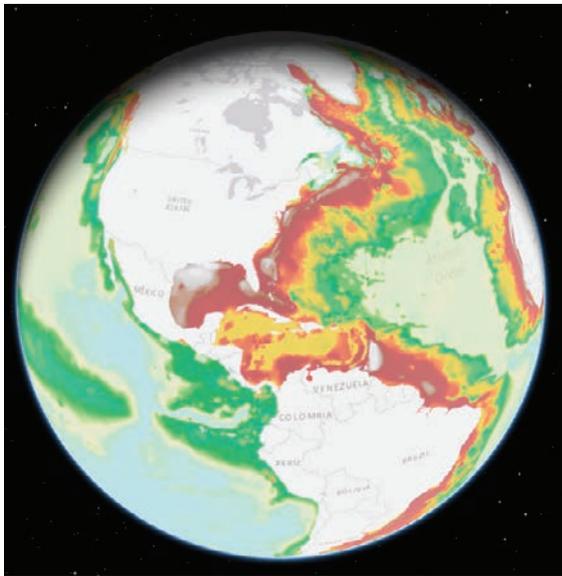
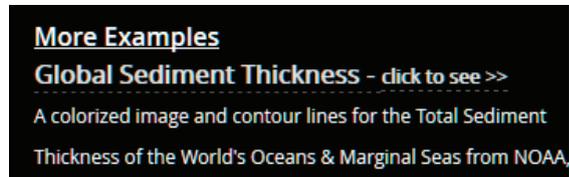
Q1 What do the colors mean? (Additional information can be obtained from the side panel.)

Q2 Describe the precipitation pattern of South America.

Q3 Describe the precipitation pattern of Africa.



3. Click the 3 Global Sediment Thickness slide.



Q4 Explain what the global thickness is measuring.

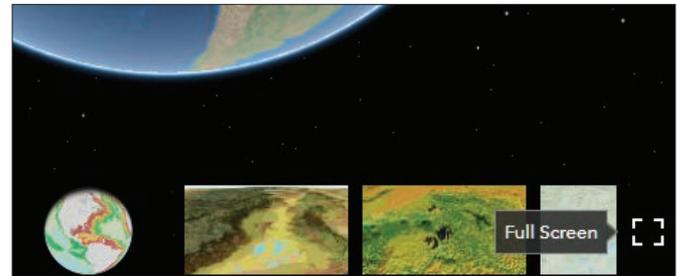
4. Click the 4 Regional Scale slide, which includes county- to country-sized areas.

Q5 Describe the regional view.

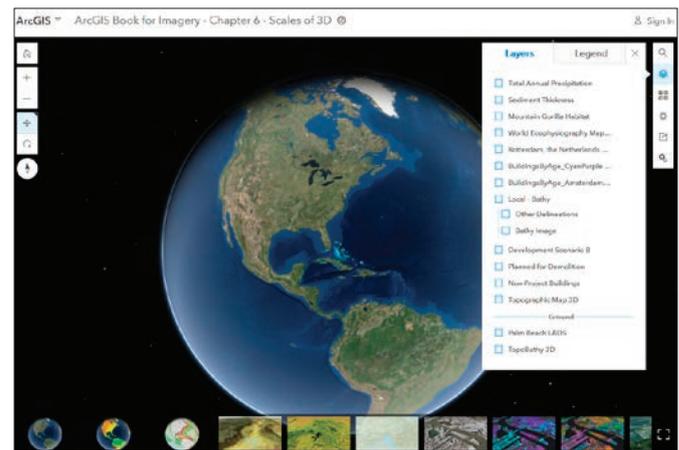
Q6 Explain what ecological land units are (Additional material can be obtained from the side panel).

For the next part of the exercise, activate the Full

Screen display at the lower right. The Full Screen icon is on the right side at the bottom of the screen.



When the app is viewed in full screen, more layers are displayed to investigate. Notice that the initial view tool is always available to allow you to zoom to the full extent.



Q7 Pick one world and one regional or local layer and write a description of the scene. Explain what layers are displayed.

Activity 6.2

Realistic and procedural texturing for photorealism

3D features include texture information for each displayed face of their geometry, which helps to create photorealism for a 3D view. Texturing can be either realistic or procedural. In this activity, you will explore and observe both realistic and procedural texturing.

Explore textures

1. Open *Realistic Texture*.
2. There are 15 examples of realistic texture. Pick three and complete the chart.

Realistic Textures		
Name	Location	Texture
Kilimanjaro	Tanzania, Africa	Topographic map draped on Elevation

3. Open *Procedural Textures*.

Q1 Write a short paragraph describing the procedural textures of Indianapolis and Philadelphia.

Lesson 6-1: Exploring hurricane variables in the 3D scene viewer

Remember, you can access ArcGIS Online for the lessons in this chapter by signing in to your organizational account.

ArcGIS Online Scene is an app that can symbolize 3D geospatial content that includes a multiscale basemap, a collection of 3D layers, styles, and configurations that allow you to visualize and analyze geographic information in an intuitive and interactive 3D environment. You can also create web apps with a scene by using a configurable app. Different configurable apps offer various bits of functionality.

Build skills in these areas:

- ▶ Adding layers to Scene in your organizational account
- ▶ Displaying hurricane track data in 3D by variables of speed and pressure
- ▶ Creating two web apps using configurable app template

What you need:

- ▶ Account required
- ▶ Estimated time: 1 hour

Scenario

You have been given the task of displaying hurricane track data by the two variables of wind speed and pressure. You are to show how atmospheric pressure and wind speed change along the path of the hurricane and show the relationship between the two. The hurricane data that you have been given is for Hurricane Katrina, which was one of the costliest natural disasters to ever hit the United States. It was active August 23–31 and was recorded as a Category 5 Hurricane. It impacted Florida, the Bahamas, and Cuba, but the most devastating damage was in New Orleans, Louisiana.

Open Scene

1. Click ArcGIS.com.
2. Sign in to your organizational account.
3. Click Scene on the upper ribbon.



4. In the upper-left corner of your screen are the navigation controls. Take a few minutes to familiarize yourself with the tools. Use all the tools.

Navigate your scene

In the upper left of your screen are the navigation controls.

- Click **Initial view**  to return to the initial camera position.
- Click **+** to zoom in.
- Click **-** to zoom out.
- You can also use your mouse and scroll wheel to zoom in and zoom out or press and hold the middle mouse button and move down or up to zoom in or out.
- Click **Pan**  to pan. Click and hold the left mouse button and drag the scene in the direction you want to move it. You may also pan by using the arrow keys on the keyboard.
- Click **Rotate**  to rotate. Click and hold the left mouse button and drag the scene in the direction you want to rotate and tilt it.

Tip: The black triangle in the upper right of the tool indicates which tool is selected.

- If you have a two-button mouse, you can use the left mouse button for the primary navigation and the right mouse button for the secondary navigation. For example, if you click **Rotate** , you can use the left mouse button to rotate and the right mouse button to pan.
- **Compass**  gives you the orientation of the scene. Click **Compass**  to set your scene to North orientation.

5. Pay particular attention to changing the basemaps.



Search and type a location into the search box

View layers

Choose a basemap

Adjust daylight (This setting can be used to change how sunlight and shadows affect your scene different times of the day and year)

Share the scene

Change settings

Create scene of wind speed

1. Add an additional layer to the scene by clicking **ADD LAYER**.
2. Search for **IGIMG_Katrina**.



3. Click the plus sign (+) and add the layer to the scene.

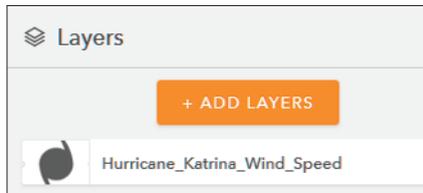
Notice that the point data for the hurricane track appears on the scene.

4. Click **DONE**.



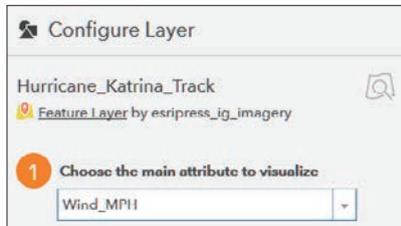
You will now configure the layer to show wind speed. The menus involved in configuring the layer can be accessed from the tab on the side of the feature.

5. Click Rename and rename the layer **Hurricane_Katrina_Wind_Speed**.



6. Click the tab again and select Configure Layer.

7. Choose the main attribute to visualize as Wind_MPH.



Notice that the wind speed is now represented on the map both as graduated symbols and using a color ramp. The symbols are spheres, and the larger the sphere, the stronger the wind. The wind speed is also shown as a graduated color ramp, with the darkest blue indicating the strongest wind.

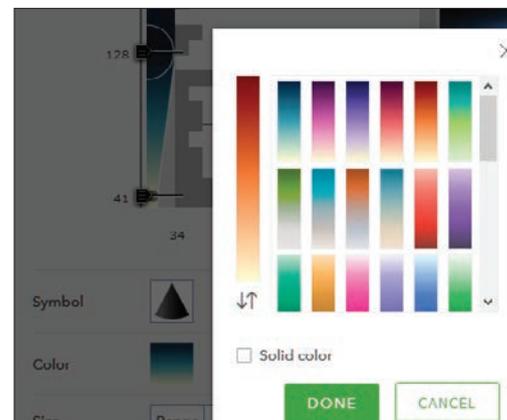
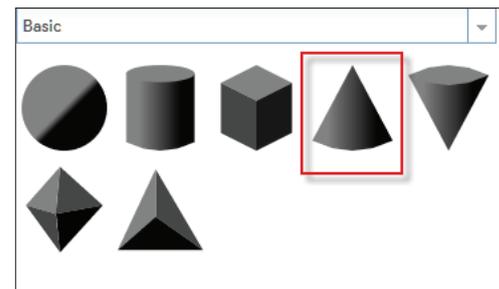
You will next choose a drawing style. You want to choose the Counts & Amounts 3D>>OPTIONS.

8. Click OPTIONS.

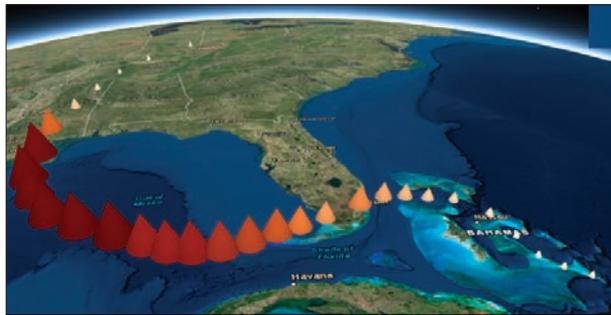
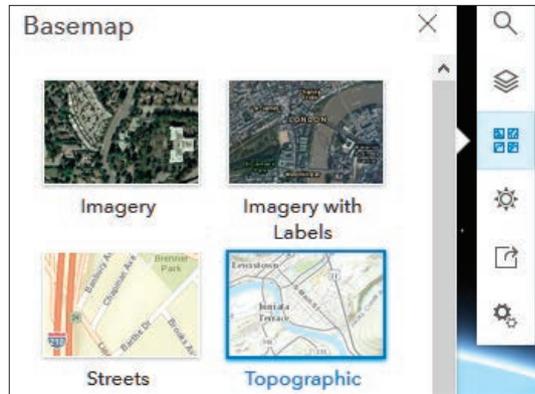


9. Click Symbol and change to cone.

10. Change the color to the graduated red ramp.



11. On the upper-right toolbar, change the basemap to Imagery with Labels to see the landscape better.



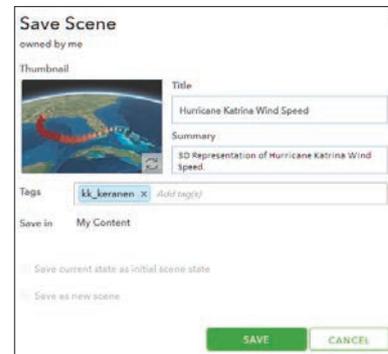
12. Before clicking DONE, use the Toggle to pan or rotate in 3D to see the cone shape.

13. Click DONE.

14. Click DONE again.

15. Click SAVE SCENE, and enter the following metadata:

- Title is Hurricane Katrina Wind Speed (and your initials).
- Summary: 3D Representation of Hurricane Katrina Wind Speed
- Tags: individual tags.



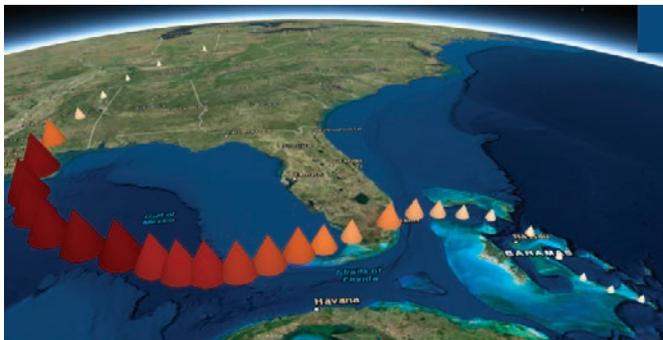
16. Click SAVE.

You have successfully made a 3D Scene showing Hurricane Katrina wind speed.

Create scene of barometric pressure

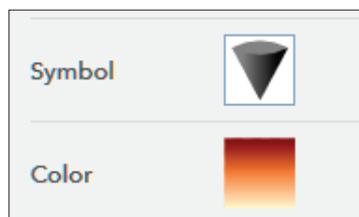
You will now make another map showing barometric pressure.

1. In the upper-right corner, click New Scene>>New Global Scene.



2. Repeat steps 1–16 from “Create scene of wind speed” to create the wind speed map with the following exceptions:

- Rename the layer **Hurricane_Katrina_Pressure**.
- For color, choose red.
- For symbol, choose an inverted cone.



3. Click SAVE SCENE, and enter the following metadata:

- Title: **Hurricane Katrina Pressure (and your initials)**
- Summary: **3D representation of Hurricane Katrina barometric pressure**
- Tags: individual tags

4. Click SAVE.

Configure a web app scene

Configuring a Web App Scene will let you view both 3D visualizations: wind speed and pressure.

1. Go Home and choose My Content.

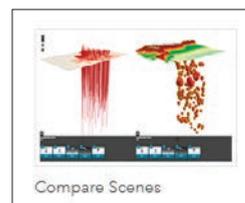


2. Click Hurricane Katrina Wind Speed and click Open.

3. Click Create Web App>>Using a Template.



4. Select Compare Scenes and click Open.



5. Click CREATE WEB APP, and enter the following metadata:

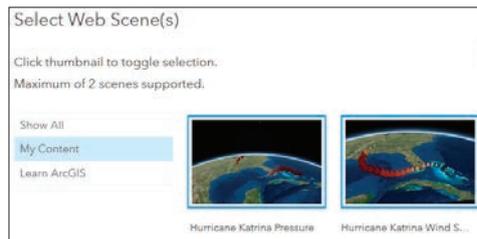
- Title: **Comparison of Wind Speed and Barometric Pressure**
- Summary: **Using Hurricane Katrina to compare wind speed and barometric pressure**
- Tags: individual tags

6. Click DONE.

You can now select the two web scenes to be visualized in your app.

7. Click Select Web Scene(s).

8. Select Hurricane Katrina Pressure and Hurricane Katrina Wind Speed.



9. Click OK.

10. Click Options on the top ribbon.

- Be sure that Link Views is checked.
- Do not select Open info panels at start.

11. Click SAVE.

12. Click Launch.

When you launch the Comparison of Wind Speed and Barometric Pressure app, you will be able to visualize the relationship between the two variables as well as compare the variables to their relationship of land and water.

Analysis

In this exercise, you have visualized how atmospheric pressure and wind speed change across the path of a hurricane.

Q1 Using the visualization, write an analysis listing all the variables and their relationships. Specifically include the relationship of wind speed to location on land versus water, wind speed to depth of water, and wind speed to atmospheric pressure.

Q2 Looking at the variables, where would the hurricane be the strongest?

Additional activity

Hurricane Matthew lasted from September 28 to October 20, 2016. It produced damage from Haiti to the southeastern United States and caused severe flood damage. Use this hurricane track to solidify your ability to display the pressure and wind speed of a hurricane in 3D to show their inverse relationship.

1. Open a new scene.
2. Search for **IGIMG_Matthew**.
3. Use the **Hurricane Matthew Track** to produce and analyze another set of hurricane data.

Lesson 6-2: How far can you see?

The viewshed tool identifies areas that can be seen from an observation location. It is useful when you want to know how visible objects might be, such as different landscape features.

Build skills in these areas:

- ▶ Filtering layers with logical queries
- ▶ Using the Create Viewshed tool
- ▶ Visually analyzing imagery

What you need:

- ▶ Account required
- ▶ Estimated time: 1 hour

Scenario

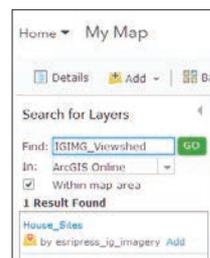
You are a retired couple that wants to relocate and build a home in Lake Junaluska, North Carolina. You have contacted a real estate agent in Waynesville, North Carolina, who has three pieces of land for sale in close proximity to the lake. You have asked a GIS analyst to determine which of the three proposed house sites has the best view of the lake.

Build the map

1. Click [ArcGIS.com](https://www.arcgis.com).
2. Sign into your organizational account.
3. Click Map on the upper ribbon.



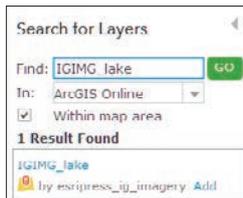
4. Click +Add.
5. Search for Layers with the following parameters:
 - Find: IGIMG_Viewshed.
 - In: ArcGIS Online.
 - Clear the Within map area check box.



6. Click Add.

This layer shows the three potential house sites.

7. Search for layers again and search for **IGIMG_lake**

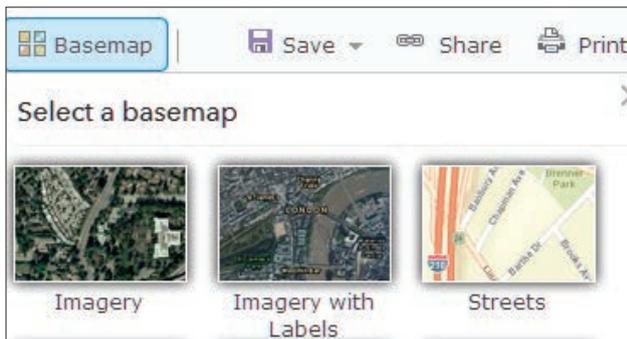


8. Click Add.

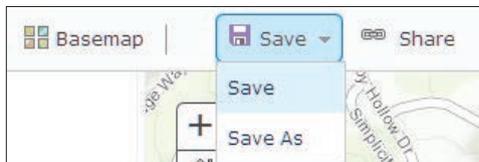
This layer shows Lake Junaluska, which is the view that the potential homeowners want to see from their house site.

9. Click DONE ADDING LAYERS.

10. On the top ribbon, change the basemap to Imagery.



11. Click Save As on the top menu.



12. Use the following parameters:

- Title: **Viewsheds for House Sites in Lake Junaluska, NC**
- Summary: **Viewsheds for House Sites in Lake Junaluska, NC**
- Tags: individual tags

13. Click SAVE MAP.

14. Click DONE ADDING LAYERS.



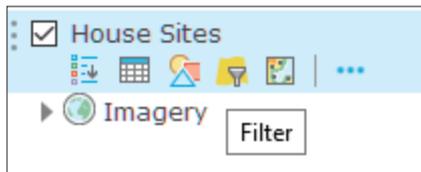
Now that the study area has been identified including the three house sites, the viewsheds must be calculated from each of the house sites.

Create viewsheds from each house site

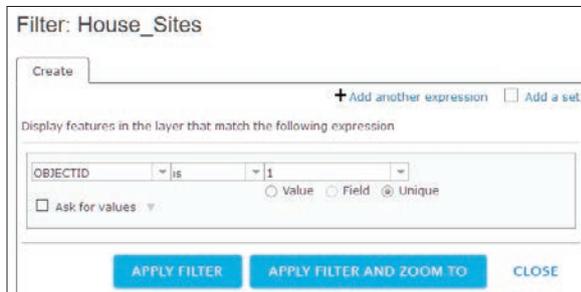
The Create Viewshed tool uses the Esri Elevation Analysis service to determine which areas are visible from specified observer points.

You must create a viewshed for each house site independently. Use the filter tool to select a feature layer in the map. You will select one house site at a time.

1. Click House Sites>>Filter.



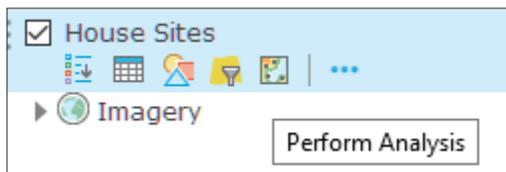
2. Construct the expression shown in the figure: (OBJECTID is 1). There are three OBJECTIDs. Each one represents a different house site.



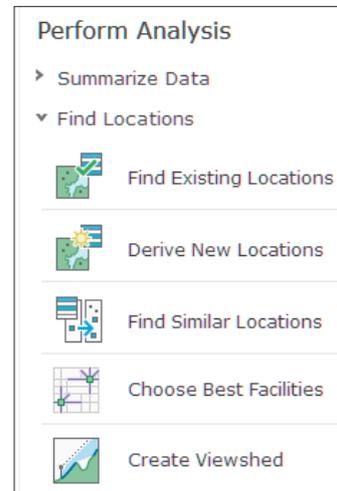
3. Click APPLY FILTER.

The filter isolates or selects one house site, and you are now ready to create the viewshed from house site #1.

4. Click House Sites>>Perform Analysis.



5. Click Find Locations>>Create Viewshed.



6. Use the following options in the Create Viewshed menu:

- Point features that represent observer is **House_Sites**.
- Height of observer location is 13 feet. (This is the height above ground of your observer location. In this case, set to 14 feet, which represents an eight-story building and a five-foot person.)
- Set the Maximum viewing distance at 1 mile. This is a cutoff distance where the computation of visible areas stops.
- Result layer name should be **Viewshed_1**.
- Clear Use Current Map Extent.

7. Click RUN ANALYSIS.

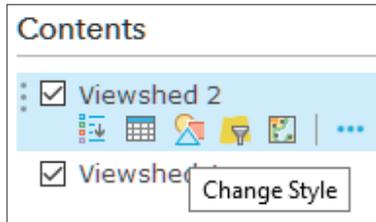
The resulting feature shows the viewshed from House Site #1.

8. Repeat steps 1–7 for House Site #2, with the following modifications:

- Click Filter>>Remove Filter.
- Create expression for OBJECTID is 2.
- Run viewshed using the same parameters as for house site #1.
- Name the viewshed **Viewshed_2**.
- Clear Use Current Map Extent.

You need to make Viewshed_2 a different color.

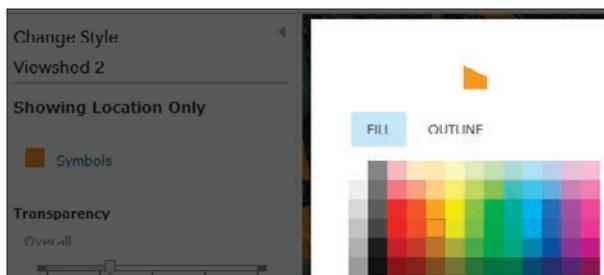
9. Click Change Style.



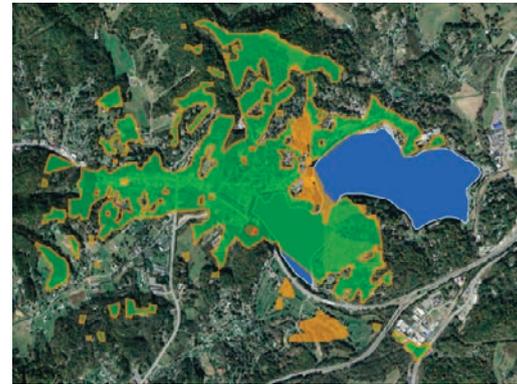
10. Click OPTIONS.

11. Click Symbols.

12. Select a different color.

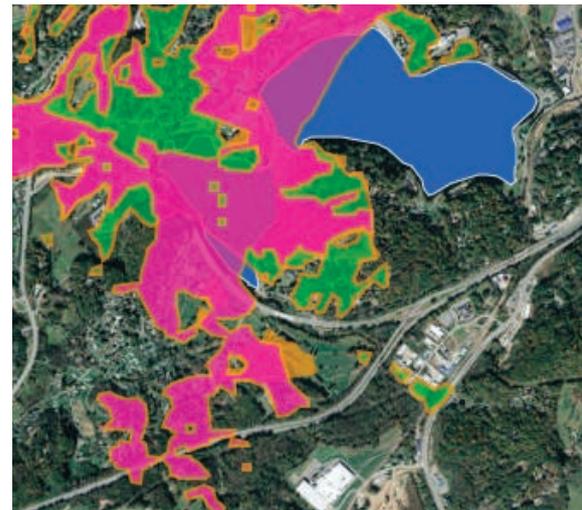


13. Click OK.



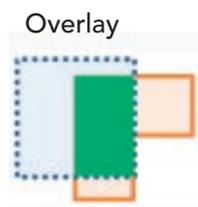
14. Repeat steps 1–13 for house site #3.

You have now created a viewshed from each of the three house sites.

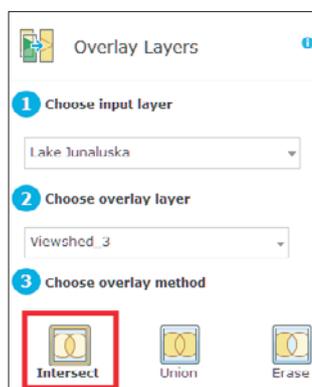
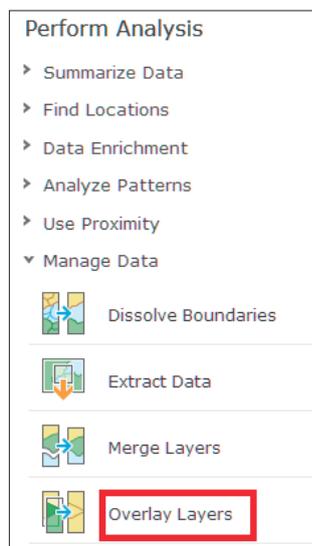


Intersect views with the lake

Now that the viewsheds have been created, you must isolate what section of the lake can be seen from each one. To isolate areas of the lake, you must combine two layers (viewshed and lake) into a single layer. To do this, you will use an overlay method called intersect. When you use intersect, it will result in only those features or portions of features in the overlay layer that overlay with features in the input layer.



1. Click Lake Junaluska.
2. Click Perform Analysis.
3. Click Manage Data.
4. Click Overlay Layers



5. Click Intersect and use the following parameters:

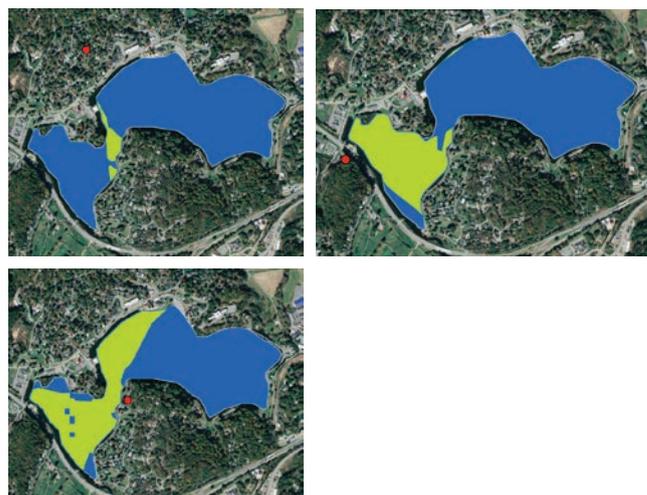
- Choose input layer: Lake Junaluska.
- Choose overlay layer: Viewshed_1.
- Output: Areas.
- Result layer name: **Lake_View_1**.
- Clear Use Current Map Extent.

6. Click RUN ANALYSIS.

7. Click DONE.

8. Repeat steps 1–7 for House Site 2 and Viewshed_2.

9. Repeat steps 1–7 for House Site 3 and Viewshed_3



In this exercise, you created three viewsheds and intersected them with Lake Junaluska to provide the retired couple with a visual representation of what part of the lake they will be able to see from each of the three house sites. From this information, the couple can make an informed decision.

Lesson 6–3: Local collection of tree features with height in a 3D display

This lesson consists of three separate sections. In the first section, you will create an editable feature service to collect height data. In the second section, you will collect the height data, and in the third section, you will display the data in 3D. An editable feature service allows you to collect data in any setting and upload the data to the cloud.

Build skills in these areas:

- ▶ Publishing an editable feature service from a preexisting URL
- ▶ Collecting height data
- ▶ Displaying height data in Scene
- ▶ Extruding data in Scene

What you need:

- ▶ Account required
- ▶ Estimated time: 1.5 hours

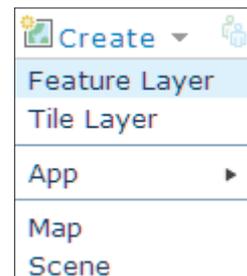
Scenario

Your class has expressed interest in creating a 3D scene of the school campus. You have decided to start with collecting height data of trees.

Download and publish a service definition

1. Click [ArcGIS.com](https://www.arcgis.com).
2. Sign into your organizational account.
3. Within your organization, click My Content on the top of the page.

4. In My Content, click Create>>Feature Layer.



5. Choose From URL.

6. Paste the following URL:

<https://services2.arcgis.com/3qTywX8SHZRf427P/arcgis/rest/services/structure/FeatureServer>

7. Click NEXT.

8. Select structure.

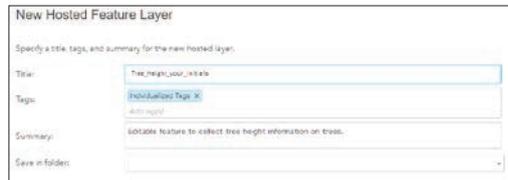
9. Click NEXT.

10. Zoom into an area of your choice that has trees.

11. Click NEXT.

12. Document the feature layers:

- Title: **Tree Height_your initials**
- Tags: individual tags
- Summary: **Editable feature to collect height information on trees**



13. Click DONE.

14. Open in Map Viewer.

15. Click DONE to close the Smart Mapping interface.

16. Zoom into your local area (school campus, park, or the like).

17. On the top ribbon, click Basemap and change the basemap to Imagery to provide information for locating **trees**.



18. Zoom into the area so you can visually see the trees.

Edit data

1. You will see the Edit icon on top of the page.



Data derived from aerial imagery is estimated or hypothesized by previous knowledge of the area or of the trees. Without knowing the area or physically collecting the data, the accuracy is questioned. This exercise is for educational purposes.

2. Click Edit.

3. Click structure, which is the Tree Height point.

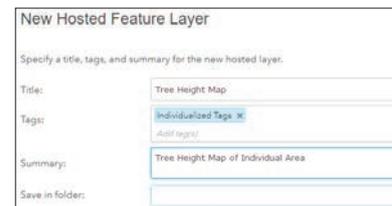
4. Click the location of an estimated 10 ft tree on the aerial image.

5. Enter 1 as identification and 10 for height_ft. (Do this for several trees.)

6. Click the location of a smaller tree, and enter 2 as the identification and 5 for height_ft. (Do this for several trees.)

7. On the top ribbon, click Save, and save the map with the following documentation:

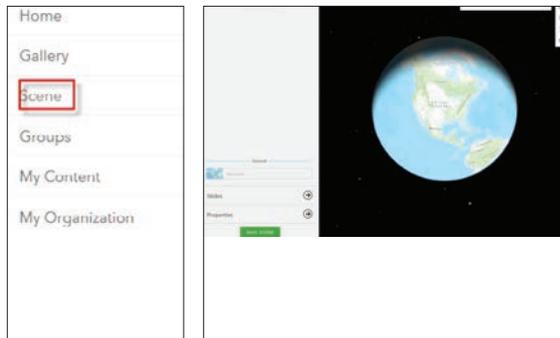
- Title: **Tree Height Map**
- Tags: individual tags
- Summary: **Tree Height Map of Individual Area**



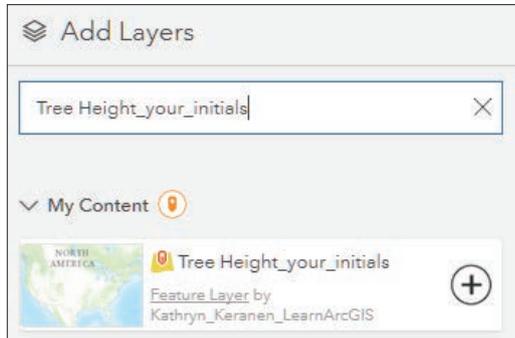
Add to scene and display in 3D

After you have collected the data in your map, you are ready to view the data in the 3D app Scene.

1. On the side panel, go to Home and open the 3D app Scene.



2. Click + ADD LAYERS and search for **Tree Height_ your_initials**



3. Click the plus sign to add the layer.
4. Click DONE.
5. Click the tab at the end of Tree Height_ your_initials – structure and select Configure Layer.

6. After selecting Configure Layer, use the following parameters:

- Choose the main attribute to visualize and select height_ft.
- Click Counts & Amounts 3D>>SELECT>>OPTIONS.
 - For Size, click Range.
 - Min: 5
 - Max: 10
 - Click Symbol
 - Select Realistic Trees Style
 - Select a tree that you think would be appropriate.



7. Select Elevation Mode: Relative to Ground
8. Click DONE.
9. Click DONE again.
10. Click SAVE SCENE with proper documentation.

In this exercise, you have created an editable features services to collect height data for trees. Using an aerial image, you have collected data about trees. The height values that you have entered have been hypothesized from the imagery.

The ArcGIS Imagery Book, chapter 6

Questions for reading comprehension, reflection, and discussion

Teachers can use the items in this section as an assignment, introduction, or assessment, tailored to the sophistication of learners. Some learners can read all the sections at one time, while others are more comfortable with small segments. The questions and tasks are designed to stimulate thought and discussion.

1. 3D imagery has evolved rapidly. What sorts of changes have facilitated this process?
2. Describe the four fundamental 3D scales and provide an example of how each might be used.
3. What two active remote-sensing technologies are used to create elevation models in raster format?
4. Identify the four key elevation models and provide an example of how each is used.
5. How is a web scene different from a web map? How are they alike?
6. What is a feature's z-value? Why is it essential for 3D modeling?
7. Identify the levels of detail (LoDs) that can be used to represent buildings. What sort of visualization and/or analysis is each suited for?
8. What are some of the ways that 3D imagery can be used in urban planning?
9. What are textures? Briefly explain the difference between realistic textures and procedural textures.
10. What new applications of 3D imagery are possible because of drone technology?

Additional resources

Learn ArcGIS: Guided lessons based on real-world problems



Get Started with Scene Viewer

- Navigating a scene
- Adding layers to a scene
- Making layer groups to organize data
- Capturing slides
- Creating a 3D web app



Fly Through South America in a 3D Animation

- Creating a scene with imagery layers
- Adding and labeling map notes
- Creating an animation
- Exporting an animation to video format



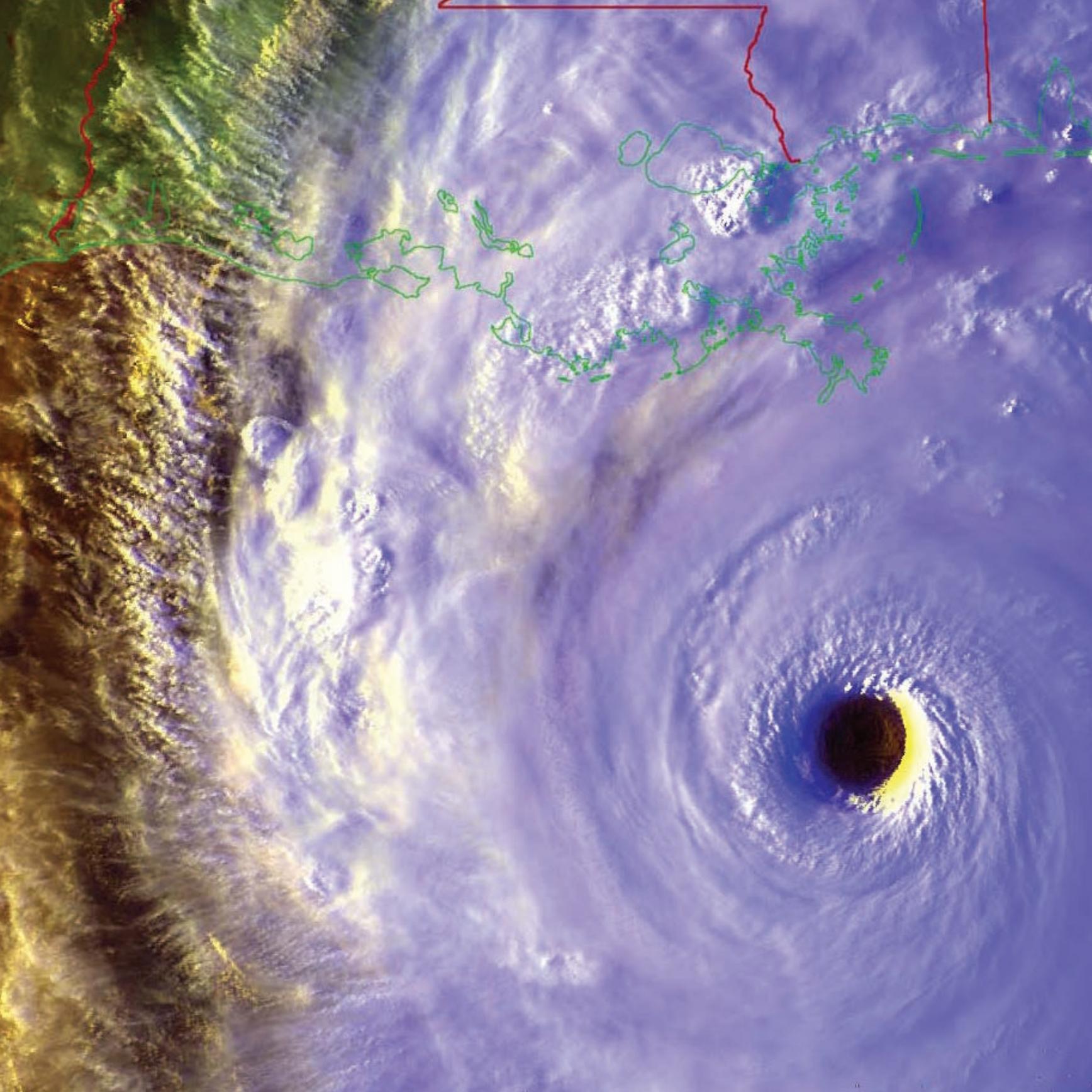
Get Started with Drone2Map for ArcGIS

- Adding drone images to a map
- Creating 3D data from 2D imagery
- Sharing 3D data to ArcGIS Online



I Can See for Miles and Miles

- Using spatial analysis to create viewsheds



Imagery in the 4th Dimension

The world's greatest time machine

Past, present, future. Questions about where we've been and where we're headed have been the source of scientific and philosophical investigation throughout human history. Ideas such as the big bang theory, continental drift, and evolution are well-known constructs to answer the first question, and global warming, species extinction, and the formation of a supercontinent reflect a selection of theories about the second. From Jean Auel's *Clan of the Cave Bear* to Frank Herbert's *Dune*, the genre of science fiction is built on alternative answers to questions about the past and future.

Until recently, research into such questions was based in the fields of geology, paleontology, archaeology, biology, climatology, and many more. Since the launch of Landsat 1, however, continual global observation and monitoring have offered an entirely new way to approach the questions of past and future. A virtual explosion of data provides ongoing insights into Earth's dynamic systems and feeds models predicting future events. Time series imagery has become a staple of Earth and population science investigation. The 4th dimension is an integral part of today's GIS.

Introductory activities

Video

Videos elevate motivation and enthusiasm as well as enhance discussion.

Both of the following videos are views of Earth's limb from the International Space Station (ISS)—an astronaut's-eye view, so to speak. The limb is the horizon or area where the curve of Earth meets the blackness of space. The first video is a time lapse series of images that re-creates the view from space when the images were captured. The second video is streamed live from the ISS and therefore appears to advance more slowly than the time lapse video. The live stream only records during daylight, so it shows previously recorded imagery when the ISS is in darkness.



[NASA ISS Time lapse—Timelapse of images from the International Space Station](#)

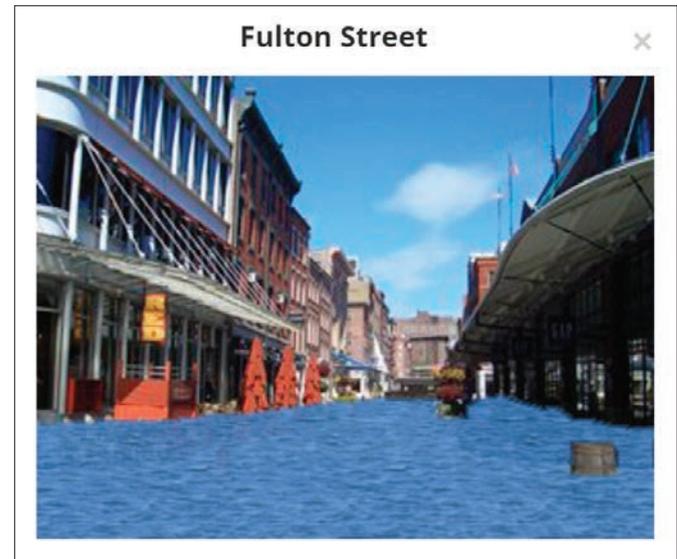
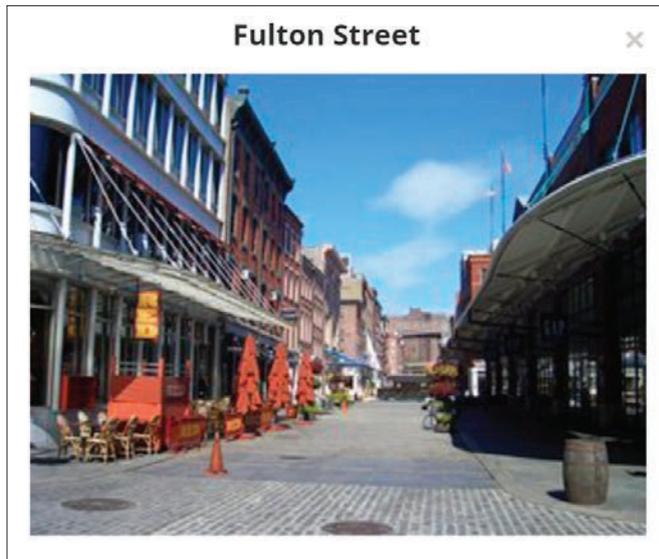
Bringing you the BEST Space and Astronomy videos online Showcasing videos and images from the likes of NASA, ESA, Hubble.



[NASA LIVE stream—Earth from Space LIVE Feed | Incredible ISS live stream of Earth from space](#)

Live video of Earth from space - as seen from the Nasa ISS live stream aboard the International Space Station

Activity 7.1
Forecasting the future



Coastal flooding and sea level rise are of particular importance in the United States where almost 40 percent of the population lives in relatively high-population-density coastal areas. Globally, eight of the world's ten largest cities are near a coast, according to the UN Atlas of the Oceans.

The NOAA Sea Level Rise and Coastal Flooding Impacts Viewer is a powerful tool that provides a vivid picture of any US community's potential exposure to inundation from coastal flooding and sea level rise as well as the potential impacts of that inundation. Maps show the areas that flood frequently today and project potential water extent and depth with various sea level rise scenarios ranging from one to six feet. For each of the sea level rise scenarios, land-cover data shows likely changes in coastal vegetation, while photo simulations show how flooding might impact local landmarks. In this activity, you'll explore the NOAA Sea Level and Coastal Flooding Impacts Viewer.

Open the [NOAA Sea Level Rise and Coastal Flooding Impacts Viewer](#). The map shows the areas of coastline on the Pacific Ocean, Gulf of Mexico, and Atlantic Ocean that can be explored with this viewer.

The following list reflects the twenty-five largest US cities by population as of 2014.

New York, NY	Indianapolis, IN
Los Angeles, CA	Columbus, OH
Chicago, IL	Fort Worth , TX
Houston, TX	Charlotte, NC
Philadelphia, PA	Detroit, MI
Phoenix, AZ	El Paso, TX
San Antonio, TX	Seattle , WA
San Diego, CA	Denver, CO
Dallas, TX	Washington, DC
San Jose, CA	Memphis, TN
Austin, TX	Boston, MA
Jacksonville, FL	Nashville-Davidson, TN
San Francisco , CA	

Q1 Find the cities on a map, and check the ones that are threatened by sea level rise and coastal flooding.

Q2 How many do you count?

Q3 How many of the top five largest cities are threatened?

We'll explore the capabilities and power of the Sea Level Rise and Coastal Flooding Impacts Viewer by looking at city No. 1 on the list, New York City.

1. Zoom to New York City in the Sea Level Rise and Coastal Flooding Impacts Viewer In the dialog box that says Enter an address or city, type. **New York City** and click Enter. Select the first search result, New York City, to zoom there.

New York City includes everything in the red circle on the map shown that is east of the New Jersey state line.



Examine sea level rise projections for New York City

The heading on the left side of the viewer show the topics you can explore. The default is Sea Level Rise. Note the Sea Level Rise slider bar on the right. As you slide it up incrementally, the map depicts 1, 2, 3, 4, 5, and 6 feet of sea level rise. The darker the color, the deeper the water.

1. Use the slider bar to see where inundation will occur with various sea level rise scenarios.
2. Use your scroll wheel to zoom in to get a better look at inundated areas. The transparency of the water layer allows you to see what has been covered by water.

3. One at a time, zoom to Lower Manhattan and Coney Island (circled in the figure).



4. Click the blue visualization icon in each location, and then use the slider bar to see how changing sea level will affect these places.

Observe changes in coastal wetlands

1. Move the sea level rise slider back to show current sea level (all the way down).
2. Click Marsh to see a map of coastal land cover and land use.
3. Use the slider bar to see how various sea level rise scenarios may impact the distribution of coastal marsh and wetlands types.

Note: for more information about the impact of sea level rise on coastal marshes, click the Information icon at the bottom of the list of headings (left side of the viewer).

Investigate frequency of flooding at current sea levels

1. Click Flood Frequency on the left side of the Viewer to show areas currently subject to shallow coastal flooding (shown in red).
2. Turn sea level rise on again and toggle between 6 ft sea level rise and the flood Frequency layer to compare projections about future inundation with current locations of frequent coastal flooding.
3. Click on a NOAA tide station in the map to see information on the current frequency of coastal flood events and durations as compared with hypothetical half-meter and one-meter sea level rise scenarios.

Observe impact of sea level rise on vulnerable populations

1. Click Vulnerability to show areas of high human vulnerability to hazards as defined by age, poverty, and the nature of the built environment.
2. Use the water level slider bar to see how rising sea level will affect the most vulnerable populations (dark red)..

Optional activity

If you live in a community at risk from sea level rise, investigate the projected impact of coastal flooding and sea level rise there.

Activity 7-2

Landsat is a time machine



Changes to Lake Urmia, Iran

The Landsat program started collecting global data on Earth's land surfaces in 1972 with Landsat 1 and continues with the current Landsat 8 mission. Change is a constant and ongoing process. Since every location on Earth is captured every couple of weeks, four decades of imagery provides a unique resource to see and analyze how places change over time. Use the Esri ChangeMatters Viewer to make your own observations.

Observe land changes

1. Open [ChangeMatters Viewer](#).

Image 1 is an infrared image of the summit of Oregon's Mount Saint Helens in 1975, two years before it erupted. Image 2 is an infrared image of the same location in 2000, 20 years following the eruption.

Q1 Identify three differences between the two images.

2. Image 3 shows the change in vegetation on Mount Saint Helens from 1975 to 2000.

Q2 Use the legend beneath the map to write a brief description of those changes.

3. Use the Change Matters Viewer to observe changes in the Great Salt Lake over 35 years.

- In the Search box above the images, type **Great Salt Lake** and click Enter.
- In the Select dates drop-down menu, select 1975–2010.

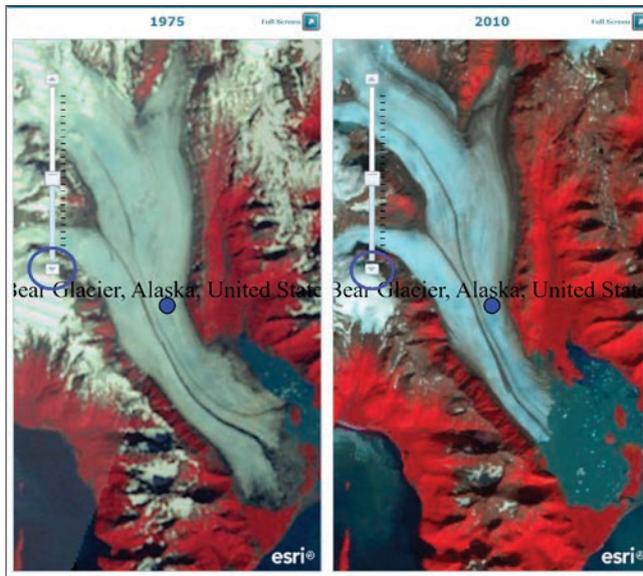
Q3 Describe the changes in size and vegetation around the lake in this 35-year period.

Q4 What are some possible reasons for the changes you can see?

Observe glacial changes

Use ChangeMatters Viewer to observe changes in Alaska's Bear Glacier between 1975 and 2010.

1. In the Search box above the images, type **Bear Glacier** and select Bear Glacier, Alaska, United States, when queried.
2. Check to see that the date selection is still 1975–2010.
3. Use the scale bar on the left side of the image as shown to zoom out. Zoom out about four clicks on the minus sign until your image looks like the figure shown.



Q5 Describe three changes that occurred in the glacier in the period from 1975 to 2010.

Q6 Why do you think these changes might have occurred?

Lesson 7-1: Visualizing change over time with historical topographic maps

Remember, you can access ArcGIS Online for all the lessons in this guide, either with no sign-in to an organizational account required (the first set of lessons in each chapter) or by signing in to your organizational account (for the last set of lessons in each chapter).

The USGS Historical Map Collection includes all scales and all editions of the more than 175,000 topographic maps published by the USGS since its inception in 1882. With the USGS Historical Topographic Map Explorer, not only can you see all 175,000-plus maps, but you can layer them over each other and download them to your own computer.



The USGS Historical Topographic Map Explorer

In January 1961, President John F. Kennedy set the goal to put a man on the moon by the end of the decade. This undertaking would require a large site with extensive test facilities and research laboratories for NASA's Space Task Group. Among other criteria, the site would need to have access to water transport by large barges, a moderate climate, availability of all-weather commercial jet service, and a well-established industrial complex. After consideration of over twenty-five locations, a 1,000-acre site twenty-five miles southeast of Houston, adjacent to Clear Lake near Galveston Bay, was selected in September 1961.

Build skills in these areas:

- ▶ Opening the USGS Historical Topographic Map Explorer (HTME) in a browser
- ▶ Searching for a specific location in the HTME
- ▶ Identifying available historic topographic maps for a given location

What you need:

- ▶ No account needed
- ▶ Estimated time: 30 minutes

Scenario

You have been asked to identify a set of historic topographic maps to show the transformation of a southeast Texas site from an undeveloped area used for cattle grazing to a world-class 21st-century scientific research and test facility. These maps will be used to create a display in the Johnson Space Center's Visitors Center depicting changes to the site and surrounding area from the 1930s to the present.

Locate the area

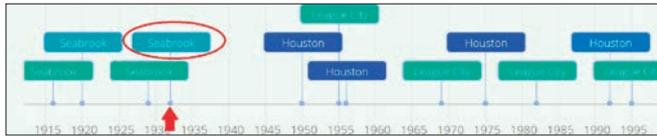
1. In a browser, go to [USGS Historical Topographic Map Explorer](#).
2. In the Find a Place search box, type johnson space center and click Enter
3. Use the zoom out (-) button to get a slightly wider view of the area and pan until your view is approximately the same as the one on the right.



4. On the map, click in the center of the tan Johnson Space Center area. A red + will appear where you click, and a time line of available maps will be displayed beneath the viewer.



5. Hover your cursor over a map name in the time line to see a thumbnail of the map as well as its scale.
6. In the time line, click the Seabrook 1932 map to add it to the map view.



The 1932 map is now shown in the map list on the left side of the view window. Clearly, the space center site was totally undeveloped at that time.

7. Use the transparency slider to hide or show the map. Use the X in the corner if you decide to delete it from the list.
8. Add the League City 1955 topographic map to see changes since 1932.

Q1 Describe changes to the space center site between 1932 and 1955.

Add the first historical topographic map following the selection of the Clear Lake site for the Johnson Space Center.

9. League City 1969 is the earliest topographical map after the 1961 site selection. Add it to see the changes to the area since the 1955 map. Use the transparency slider to compare the two maps. The changes since 1955 are shown in purple.

Q2 Besides construction on the site of the space center, what other changes can you see in the area? Add the League City 1982 and League City 1995 maps.

10. Turn all the maps off by changing their transparency to 100% (all the way right).
11. Turn them on, one by one, to observe change to this area over time.
12. Turn on the 1932 map and then the 1995 map to see the most dramatic comparison.

Experiment with other maps in the time line beneath the viewer.

Q3 Identify a set of maps to display at the space center to tell the story of the site in the 20th century. For each map, write a sentence summarizing what it shows about the evolution of the space center site during the time span covered.

Your assignment is complete. You used the USGS Historical Topographic Map Explorer to find historical topographic maps of the area surrounding the Johnson Space Center that could illustrate change over time – growth from undeveloped waterfront grazing land to a thickly settled residential, boating, research, and commercial area.

Lesson 7-2: Time enabling

Spatial phenomena collected with time information may allow map users to see what happened at a specific time, or what may happen in the future. By animating time-based data, you can visualize it at each step and see patterns or trends emerging over time. Feature layers that include temporal data can be enabled on the item page for the layer. Any CSV (comma-separated values) file that contains a time can be enabled.

Build skills in these areas:

- ▶ Identifying CSV files of crime, earthquakes, and terrorist attacks
- ▶ Adding CSV files to ArcGIS Online and converting to a feature layer
- ▶ Creating time-enabled feature layers

What you need:

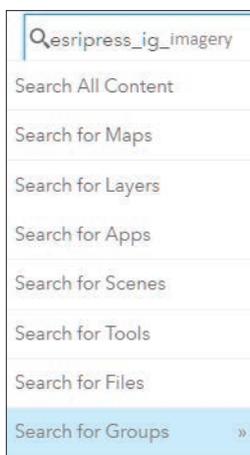
- ▶ Account required
- ▶ Estimated time: 1 hour

Scenario

You have been given three time-enabled files. You have been asked to time-enable them and analyze the data on the basis of the information being seen throughout a time period. The data you have been given is separate and contains unique datasets involving crime, earthquakes, and terrorist attacks. Visualizing temporal data can help you step through your data in a temporal sequence and see the patterns or trends that emerge in your data over time. For example, does a certain type of crime occur at different times of day, or what periods of time do terrorist attacks occur?

Build the map for time-enabled crime data

1. Click ArcGIS.com.
2. Sign into your organizational account.
3. In the upper-right corner search box, type **esripress_ig_imagery** and click Search for Groups.

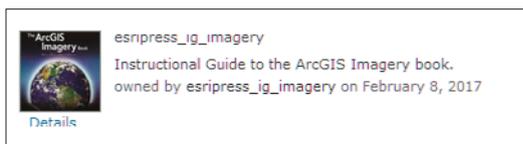


The default search returns results found only within your organization. To show all public results, you'll remove that filter.

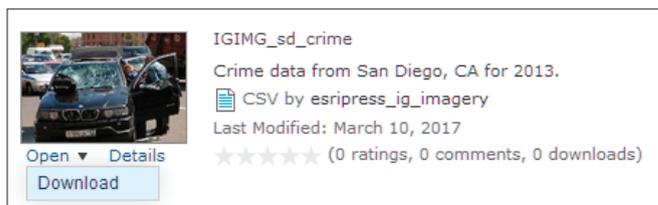
4. Clear the check box that says to only search in your organization.



5. Click **esripress_ig_imagery** to view the group content



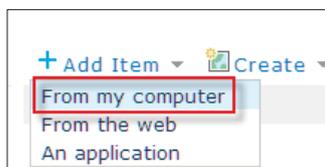
6. Click the Open arrow below the thumbnail for IGIMG_sd_crime.csv and click Download.



7. Save the file IGIMG_sd_crime.csv to a location of your choice.
8. On the upper ribbon of the software, click My Content.



9. Click Add Item>>From my computer and browse to where you stored IGIMG_sd_crime.csv.



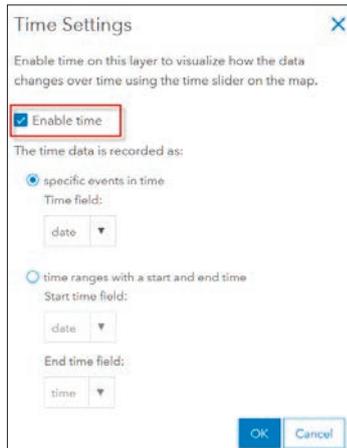
10. Add individualized tags of your choice.
11. Check Publish this file as a hosted layer.
12. Check Latitude/Longitude.
13. Click ADD ITEM. Latitude and longitude are correctly chosen as the defaults.



14. Go to the functions for Layers and click Time Settings.



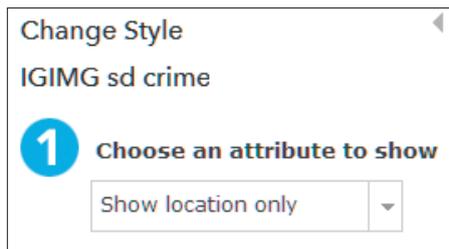
15. Click Enable Settings. Notice that the date field is located.



16. Click OK.

17. Click the feature layer box and open in Map Viewer.

18. Under Change Style, choose an attribute to show and select Show location only.



19. Click DONE.

Notice that the time slider now appears at the bottom of the screen.



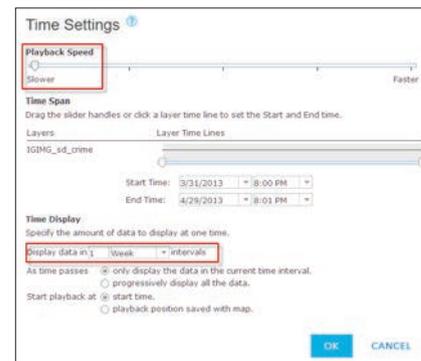
Q1 What is the time period segment, or the time interval selected?

You can configure the time settings by clicking Time Setting to the right of the slider and showing Advanced Options. You can control the following variables:

- **Playback Speed:** Slower or Faster.
- **Time Span:** shows the designated time period.
- **Time Display:**
 - Enter a numeric value for the time interval.
 - Choose units from a drop-down list.
 - As the time passes, choose:
 - Only display the data in the current time interval.
 - Progressively display all the data.

20. Set the Time slider to Slowest.

21. Set the display data to 1 Week. Looking at a time interval of a week allows the user to see if there is a variation in crime per day.



22. Click OK.

23. Click the Play/Pause icon to run the animation.



The animation covers a five-week period showing one week at a time.

Q2 *What are your general observations?*

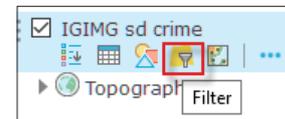
Filter expressions

The sd_crime data has many variables. Below are some of the variables:

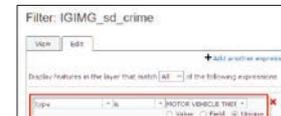
- Type
 - Arson
 - Assault
 - Burglary
 - Drugs/Alcohol Violations
 - DUI
 - Fraud
 - Homicide
 - Motor Vehicle Theft
 - Robbery
 - Sex Crimes
 - Theft/Larceny
 - Vandalism
 - Vehicle Break-In/Theft
 - Weapons
- Comm_pop: Community population total
- City
 - SndCHU _ Chula Vista
 - SndELC – El Cajon
 - SndLAM – La Mesa
 - SndLEM – Lemon Grove
 - SndNAT – National City
 - SndSAN – San Diego

You can use filters to look at these different variables. A filter presents a focused view of a feature layer in a map. By limiting the visibility of features in a layer, you can reveal what's important. For example, you might create a filter on a crime layer to show only assaults that occurred within a city boundary. By filtering the crime layer on the basis of crime type and city boundary, you can show patterns to help your police department allocate resources. In the next step, you will first filter crime by burglary and run the animation.

1. Click Filter under the IGIMG sd crime feature.

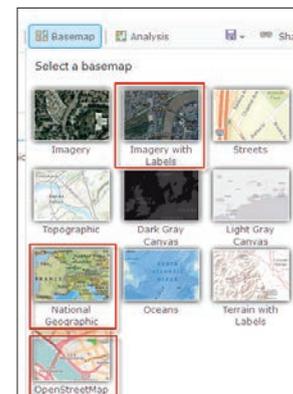


2. Construct the expression: type is MOTOR VEHICLE THEFT



3. Click APPLY FILTER.

4. Go to the top ribbon and select Basemap. Change the basemap to National Geographic, Imagery with Labels, or OpenStreetMap to give more information about the area.



Q3 What can you observe about the temporal distribution of MOTOR VEHICLE THEFT from March 31, 2013, to May 5, 2013?

Q4 Are there any features on the map that you can identify as having an impact on MOTOR VEHICLE THEFT?

Expand your filter by looking at MOTOR VEHICLE THEFT within an area with a population (comm_pop) of 77873. This requires a double expression that isolates MOTOR VEHICLE THEFT and also the area with a population of 77873.

5. Click Open Filter.

6. Click Edit.

7. Click the plus sign to add another expression:comm_pop is 77873



Filter: IGIMG_sd_crime

View Edit + Add another expression Add a set

Display features in the layer that match All of the following expressions

Type is MOTOR VEHICLE THEFT Value Field Unique

Ask for values

comm_pop is 77873 Value Field Unique

Ask for values

APPLY FILTER APPLY FILTER AND ZOOM TO CLOSE

8. Change Any to All so it reads, Display features in the layer that match All of the following expressions.

9. Click APPLY FILTER.

10. Play the animation.

Q5 Can you see any pattern or clusters to the MOTOR VEHICLE THEFT or any relationship to other features on the map?

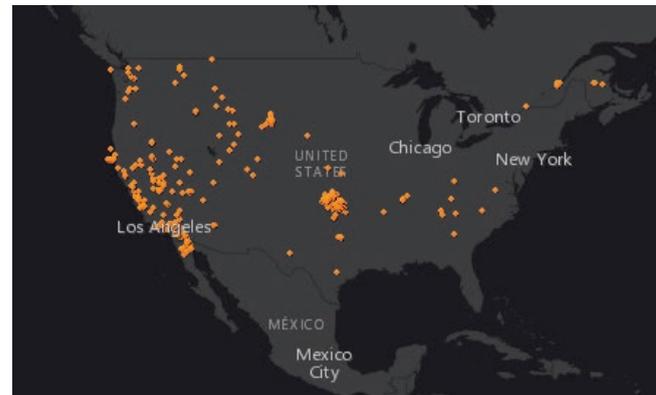
Make up questions of your own about types, cities, population, or other variables within the database. After defining the question, construct your filters, verify the animations, and analyze the results.

Build the map for time-enabled earthquakes

1. Repeat steps 3–23, under “Build the map for time-enabled crime data,” downloading IGIMG_earthquakes, and creating a feature layer.

2. Experiment with time span and filters. Try the variables of depth and mag (magnitude).

3. Try visualizing on a Dark Gray Canvas Basemap.



Build the map for time-enabled terrorist attacks

1. Repeat steps 3–23 under “Build the map for time-enabled crime data,” downloading IGIMG_terrorist, and creating a feature layer.

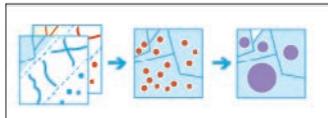
- Locate features using Address.
- Select geocoder: Esri World Geocoder.
- Select country: World.

2. Locate features using: Address. When it asks if you want to review addresses, say no.

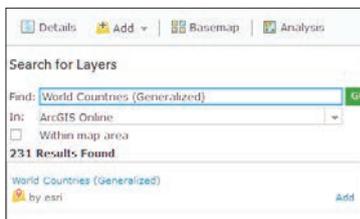
- Experiment with time span and filters. Try the variables of Target Type and Perpetrator.



Another way that you could look at this data is to join the terrorist attacks to world countries. The Join tool transfers the attributes of one layer or table to another on the basis of spatial and attribute relationships. Statistics can then be calculated on the joined features.



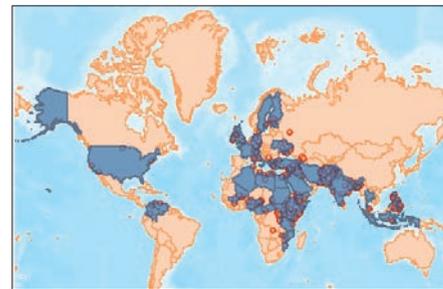
- Search for **World Countries (Generalized)** in ArcGIS Online.



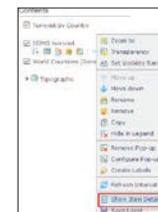
- Click Add.
- Click DONE ADDING LAYERS.
- Move IGIMG_terrorist above World Countries (Generalized).
- Under IGIMG_terrorist, click Perform Analysis.
- Perform Analysis>>Summarize Data>>Join Features.

- Click Join Features and use the following parameters:
 Target layer is World Countries (Generalized).
 Layer to join to target layer is IGIMG_terrorist.
 Choose a spatial relationship is Intersects.
 Choose the fields to match: Country = Country.
 Choose join operation: Join one to one.
 Result layer name is **Terrorist_by_Country**.
 Clear Use Current Map Extent.

- Run the analysis.



- Save your map with proper documentation.
- Go to Show Item Details > Time settings, and enable time.
- Click Terrorist by Country and go to Show Item Details.



- Click Time Settings and then Enable Time.



When you open your map again, the Time slider appears.

- Experiment with time span and filters. Try the variables of Target Type and Perpetrator.

The ArcGIS Imagery Book, chapter 7

Questions for reading comprehension, reflection, and discussion

Teachers can use the items in this section as an assignment, introduction, or assessment, tailored to the sophistication of learners. Some learners can read all the sections at one time, while others are more comfortable with small segments. The questions and tasks are designed to stimulate thought and discussion.

1. What are some examples of data about our planet that can be tracked and studied with time series observations?
2. "Time can be viewed as linear or cyclical," according to the discussion in the section "Types of Time."
Explain the difference between linear and cyclical time.
3. Both historical aerial photographs and historical terrestrial photographs can provide insight into processes of change over time. What kinds of change are reflected in the historical aerial photographs of Dubai and the historical terrestrial photographs of the Colorado River?
4. If you have an important historical paper map, what must you do to use it as a layer in a GIS?
5. Explain the concept of event-driven or near-real time analysis, and give examples of situations in which it is applied.
6. Meteorologists make extensive use of satellite imagery. What do they use it for?
7. How can GIS help us anticipate and plan for future changes in Earth's natural systems?

Additional resources

Learn ArcGIS: Guided lessons based on real-world problems



Tell the Story of Irish Public History

Adding layers from CSV files

Creating a web app

Creating a story map

Drawing conclusions from maps and data



Get Started with ArcGIS Earth

Navigating and exploring ArcGIS Earth

Changing the basemap

Finding data in the Living Atlas

Adding data from a file

Sharing your results



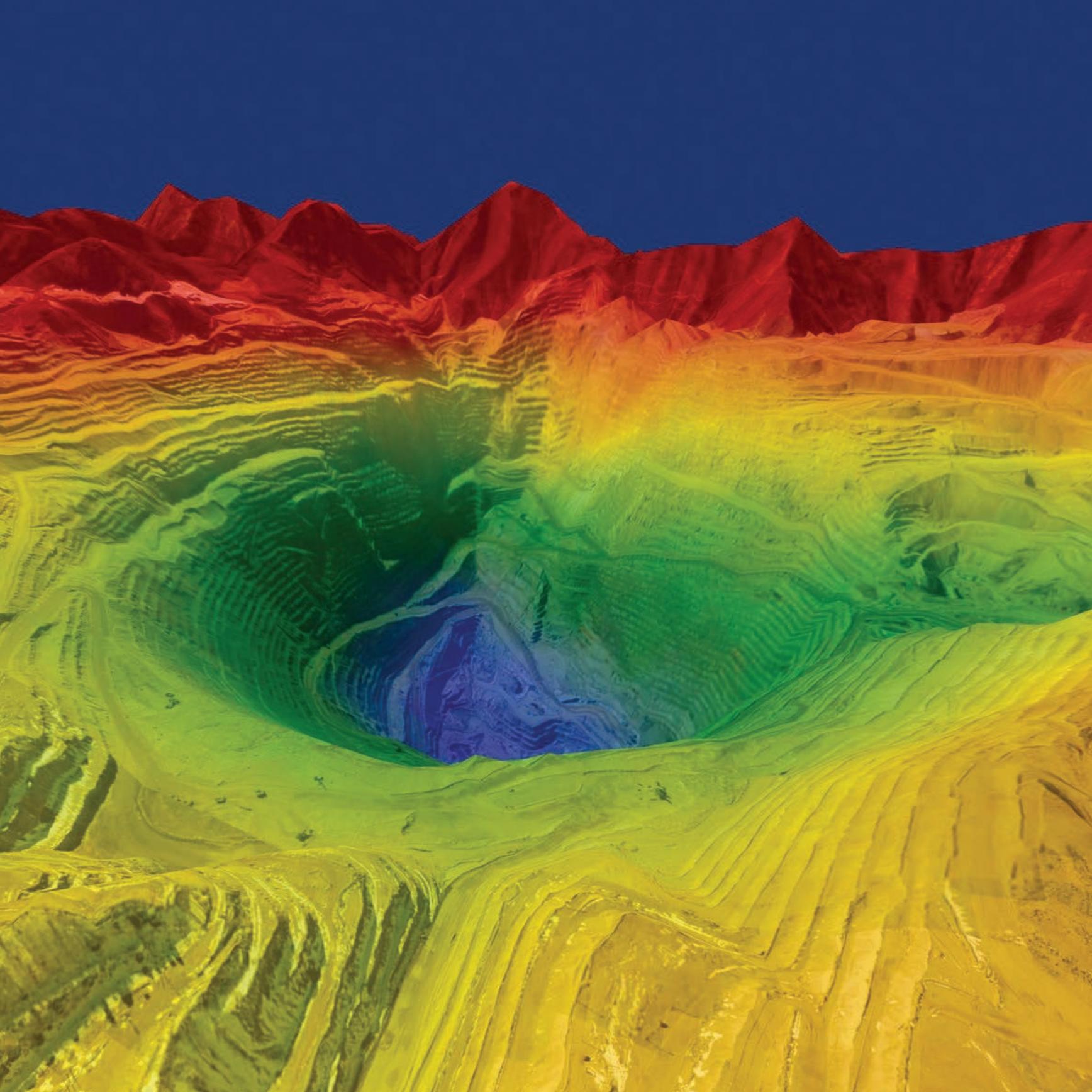
Map Voter Data to Plan Your Campaign

Geocoding addresses from a spreadsheet

Enriching layers using Tapestry data

Mapping US Census data

Creating a presentation



The Ultimate Big Data

Managing imagery information is a big data challenge

If you were asked to name the technology invention that has had the greatest impact on how we live today, what would you say? Some would say the automobile. The automobile has shaped not only our means of transportation, but the layout and location of our communities, the relation of our cities to the surrounding region, as well as more subtle constructs such as the concept of distance—what’s near and what’s far. Others might say the smartphone. What started out as a new version of the familiar telephone has become a handheld computer wielding as much computing power as the first astronauts had in their space capsule and shaping everything from the way we conduct banking transactions, to the way we find our way in unfamiliar settings, to the way we learn the news.

Another invention that certainly belongs in the discussion is “the cloud.” The cloud is an infinite repository for data storage, but it is a computing entity as well, making it possible for people with ordinary personal computers to undertake computing tasks that once—and not too long ago—required supercomputers. The cloud and cloud-based computing have profoundly changed many aspects of our lives. Thanks to cloud-enabled data storage and processing, computer models inform us of pending storm impacts, regional real estate trends, and when to expect our order from an online purchase. Big data has become a major driver of modern life, and the cloud is how we manage it.



Introductory activities

Video

These videos about the role of GIS in meeting global challenges opened the plenary sessions of the Esri User Conferences in 2015 and 2016.



GIS Enabling a Smarter World

2016 Esri User Conference plenary opening video



Esri User Conference 2015 – Video de Abertura

Versão legendada do incrível e inspirador vídeo de abertura da Plenária da Esri User Conference 2015 - o encontro de usuários da Plataforma de GIS/Map...

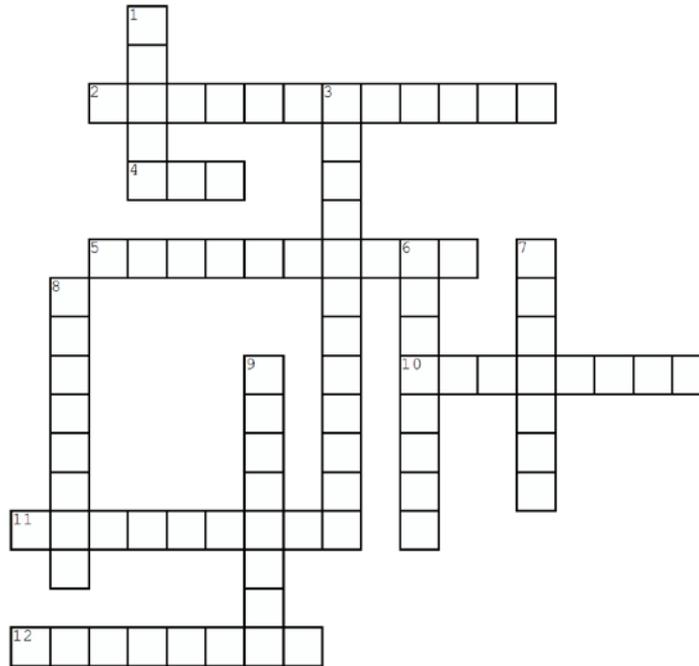
Activity 8.1: Getting to know the Living Atlas A crossword puzzle tour

The screenshot shows the ArcGIS Living Atlas of the World Gallery interface. At the top, there is a navigation bar with 'ArcGIS' and links for 'FEATURES', 'PLANS', 'GALLERY', 'MAP', 'SCENE', and 'HELP'. A 'Sign In' button and a search box are also present. The main heading is 'Gallery'. Below this, there is a section for 'Featured Maps from the Living Atlas' with a 'Sort By: Most Recent' dropdown menu. On the left side, there is a sidebar with 'Maps' and 'Apps' sections. The 'Maps' section includes categories like 'All', 'Imagery', 'Basemaps', 'Historical Maps', 'Demographics & Lifestyle', 'Landscape', 'Earth Observations', 'Urban Systems', 'Transportation', 'Boundaries & Places', 'Story Maps', and 'Scenes'. The 'Area' section includes 'All', 'United States', and 'World'. The 'Apps' section includes a search prompt and the ArcGIS Marketplace logo. The main content area displays a grid of 12 map thumbnails, each with a title and a small green checkmark icon. The thumbnails are: 'World Land Cover', 'World Population Estimate', 'World Regions', 'Virtual Pasadena - Pictometry 3D Buildings', '2014 Adults That Exercise Regularly in the', '2014 Tapestry Segmentation in the', '2014 Population Density for the United States', '2014 Alcoholic Beverage Spending in', 'Cooling Needs', 'Oceans', 'National Geographic', and 'Light Gray Canvas'.

The Living Atlas of the World is a collection of thousands of maps, intelligent map layers, imagery, tools, and apps on many topics. In this activity, you'll take a virtual tour of the Living Atlas as you search for answers to the crossword puzzle contained here. Go to the [Living Atlas of the World Story Map](#).

You'll find the puzzle answers hidden within!* Good luck.

*Hint: The title of each page in the map journal reflects one of the Living Atlas's categories for maps, layers, apps, and so on.



Created with TheTeachersCorner.net [Crossword Puzzle Generator](http://www.theteacherscorner.net/CrosswordPuzzleGenerator/)

Across

- 2.** _____ and lifestyle, is a Living Atlas category that has maps about consumer spending on many types of products
- 4.** a hydrologic model that simulates the observed and forecast streamflow in rivers and streams across the entire continental US
- 5.** _____ Maps is a Living Atlas category that includes maps that show the world as it existed decades and even centuries ago
- 10.** these frequently updated layers describe our planet's current conditions (weather, earthquakes, etc)
- 11.** this Living Atlas category includes maps that illustrate agriculture, wildlife, elevation, hydrology, and weather
- 12.** population _____ is a map that shows where population is projected to grow at a normal rate, grow at a very high rate, or shrink

Down

- 1.** in a Landsat image displaying band combination 652 healthy vegetation will be a bright version of this color
- 3.** you can add layers from the Living Atlas of the World to a map you create in this program
- 6.** land-use planning depends on landscape _____
- 7.** select one of these to provide background and context for the data on your map
- 8.** a collection of maps that includes narrative text along with engaging images and multimedia content
- 9.** the 1812 World Globe map is displayed in a projection developed by this cartographer

Activity 8.2: Map Projections

Data and map projection to look at the Arctic Circle

A map projection is a representation of the 3D earth on a 2D plane. Any way that the earth is represented on a 2D plane results in distortion both by size and shape. Map projections are selected for different studies that present the least amount of distortion of the study area.

The map used in ArcGIS Online is in the Web Mercator projection, which is the standard for sharing data on the web. Like any projection, Web Mercator has limitations. As with all Mercator projects, the North and South Poles are distorted.

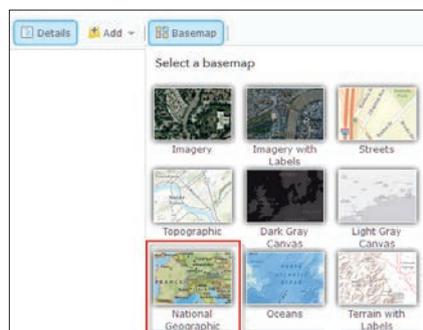
1. Go to [ArcGIS.com](https://www.arcgis.com).
2. On the upper ribbon, click Map.



3. In the right corner, click Modify Map.



4. Change the basemap to National Geographic.

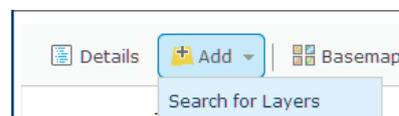


Q1 Identify the major lines of latitude.

Q2 What do you notice about the spacing of the lines?

Q3 As mentioned above, the map projection used for ArcGIS Online is Web Mercator. Can you identify areas of distortion?

5. Zoom out to a world view.
6. Click + Add>>Search for Layers.



7. Use the following parameters in Search for Layers:

- Find: World Latitude and Longitude Grids by Esri
- In: ArcGIS Online

8. Click Add.



9. Click DONE ADDING LAYERS.

The Esri basemaps are all multiscale maps that allow you to view geographic data across a range of scales—also known as *zoom levels*. Most data does not need to be shown across all zoom levels.

10. Examine the spacing between the latitude lines.

Q4 What countries are above the Arctic Circle?

Q5 What is below the Antarctic Circle?

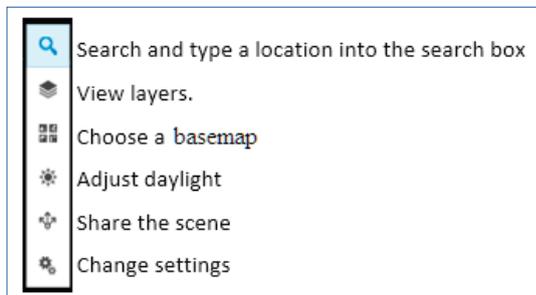
Q6 What continent is closest in size to Greenland?

Q7 Why or why not is this a good projection to study the Arctic?

In the next section of this activity, you will use a 3D representation of the earth. This is a realistic representation, and because of the unique ability to navigate, the Arctic is represented appropriately.

Explore the Arctic in 3D

1. Open [IGIMG_Scene_Latitude_Longitude](#).
2. Use the Navigation tools to examine the scene.



3. Examine the spacing between the latitude and longitude lines.

Q8 What countries are above the Arctic Circle?

Q9 What is below the Antarctic Circle?

Q10 What continent is closest in size to Greenland?

Q11 Is the Arctic represented correctly?

In this exercise, you have looked at map data in the Web Mercator projection and also displayed it on a 3D representation of the Earth.

Lesson 8-1: Using the Landsat Arctic app

Remember, you can access ArcGIS Online for all the lessons in this guide, either with no sign-in to an organizational account required (the first set of lessons in each chapter) or by signing in to your organizational account (for the last set of lessons in each chapter).

Landsat Arctic is a web app for accessing Landsat imagery covering the Arctic region. The layers are updated daily with new Landsat scenes. It uses a polar projection allowing visualization of the Arctic region without distortion. The app allows access to different band combinations, and it is time enabled.

Build skills in these areas:

- ▶ Opening the Landsat Arctic app
- ▶ Opening Arctic Scene View
- ▶ Recording latitude and longitude
- ▶ Comparing polar projection with ArcScene View
- ▶ Locating the Arctic Circle
- ▶ Identifying and exploring Arctic locations

What you need:

- ▶ No account needed
- ▶ Estimated time: 30 minutes

Scenario

You have been asked to develop a lesson that shows the Landsat Arctic app in comparison to Scene. You have been instructed to use latitude and longitude as your locational finders.

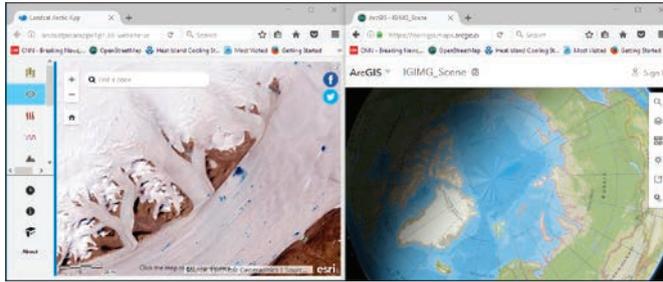
Where are you when you are looking at the Arctic App? To see where you are on the globe, you must first zoom out. However, when you zoom out, the Arctic App distorts. The Arctic App is built to be used with the polar projection.

It is beneficial to open both the Landsat Arctic app and an Arctic scene view at the same time. The Arctic scene view will be used for reference.

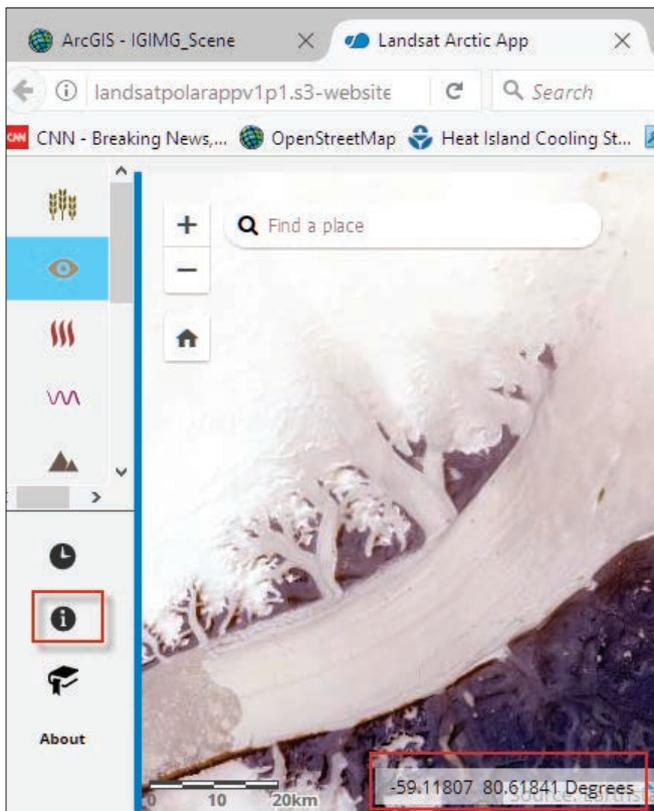
Compare views

1. Open [Landsat Arctic app](#).
2. Open [Arctic Scene View](#) and zoom into the Arctic Circle.

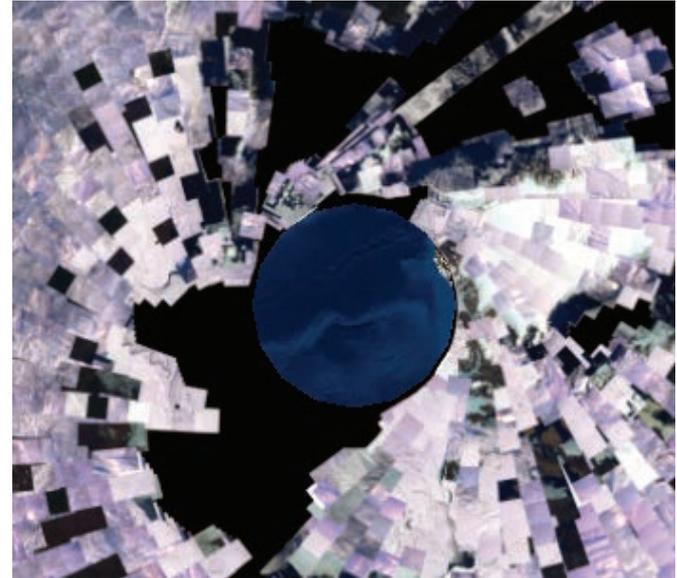
3. Arrange the two apps side-by-side on your computer screen.



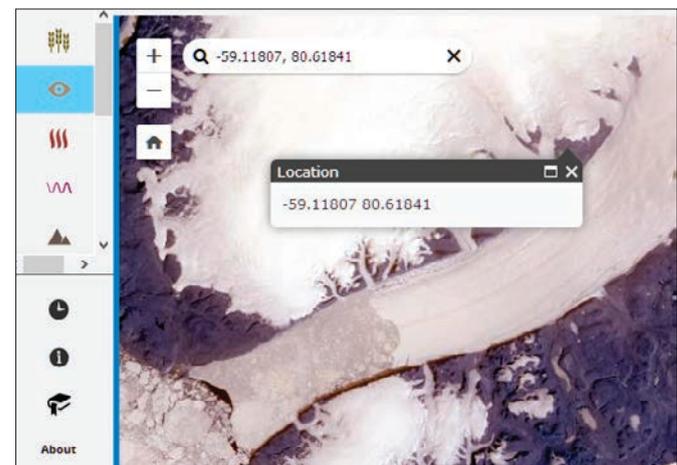
4. Using the *i* icon, click the middle of the scene in the Landsat Arctic app and record the longitude and latitude.



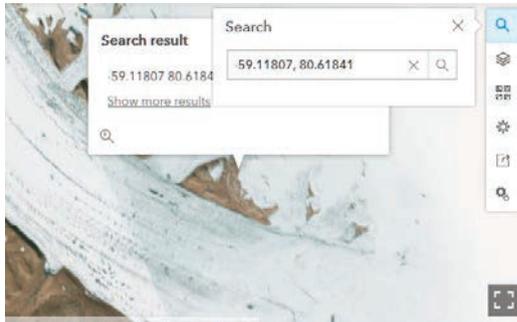
When you zoom out of the app, you will see the Arctic polar projection, but it is difficult to see where you are. The squares that you see are the Landsat scenes that are being fed into the app.



5. To return to the opening view of the Landsat Arctic app, type the longitude, latitude coordinates in the Search box, or click the Home button.



6. Now return to *Arctic Scene View* and type the same coordinates in the Search box.



7. On the side navigation bar, change the basemap to Imagery with Labels.



Q1 *Zooming in and out in the scene view identifies where the scene has been taken. What country is it?*

Q2 *Is it in the Arctic Circle?*

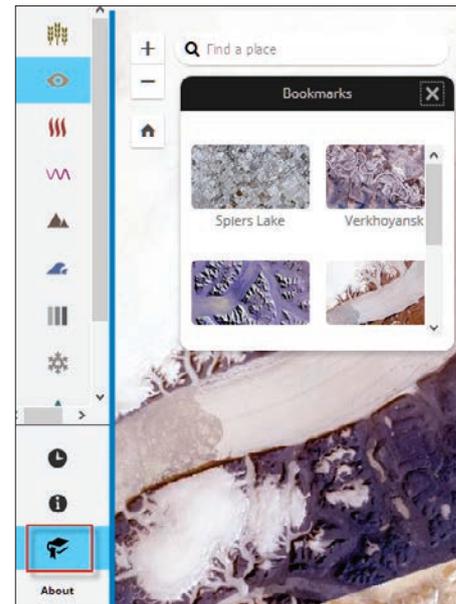
Q3 *What channel is it near?*

Additional activity

There are five more bookmarked scenes identified in the Landsat Arctic app. In this part of the activity, you will use the Landsat app, the Scene app, and your investigative abilities to visualize and write descriptions of the bookmarked scenes.

Identify locations

1. On the right tab, go to Bookmarks and identify the scenes.



2. Following the procedure in section 1 of this activity, identify the bookmark in the Landsat Arctic app and the Scene app.

3. Use your investigative skills to write a brief description of each of the bookmarked scenes.

The scenes are as follows:

Spiers Lake, Alberta, Canada

Verkhoyansk, Russia

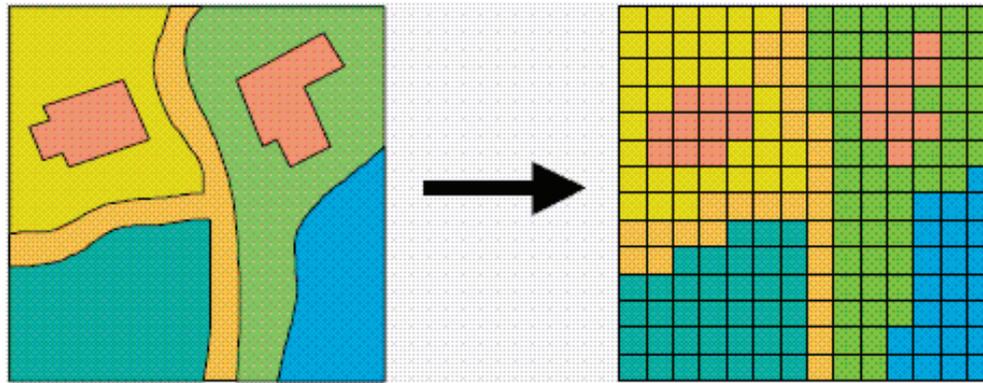
Geikie Plateau, Greenland

Petermann Gletsched, Greenland

Watkins Range, Greenland

Lesson 8-2: Raster is faster but vector is corrector

The old GIS adage “raster is faster but vector is corrector” comes from the two different fundamental GIS models: vector and raster. Each of these models has its own advantages and disadvantages. The vector model uses points and line segments to identify locations on the earth while the raster model uses a series of cells to represent locations on the earth. The figure represents vector (*left*) versus raster (*right*) data.



One of the most common types of raster data is land cover derived from satellite imagery. Land-cover data is produced by assigning each pixel in a Landsat thematic mapper image to one of 16 land-cover classes using a procedure known as *unsupervised classification*.

Build skills in these areas:

- ▶ Identifying vector and raster models
- ▶ Understanding the process of creating land cover from satellite imagery
- ▶ Calculating quantitative differences between the two models

What you need:

- ▶ No account needed
- ▶ Estimated time: 30 minutes

Scenario

You have been asked to prepare a lesson that explains to beginning GIS users the difference between vector and raster data. Also to be included in the lesson is a basic explanation of a land-cover dataset that has been derived from satellite imagery. You have chosen the Great Salt Lake in Utah to be your study area.

Build the map

1. Click [ArcGIS.com](https://www.arcgis.com).
2. Sign into your organizational account.
3. Click Map on the upper ribbon.
4. In the Bookmarks search box in the upper-right corner, search for **Utah Lake, Utah, United States**



5. On the upper ribbon, change the basemap to Imagery.



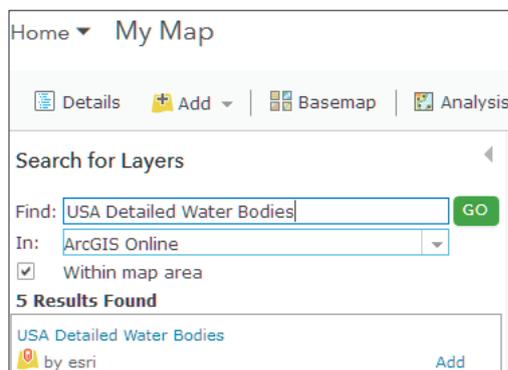
Zooming in and panning familiarizes you with the area, identifying different types of land cover and landscapes.

Add vectors

In this section, you are going to add and examine several vector layers to start the investigation. You will add both polygon and line vectors.

1. On the top ribbon, go to Add and search for USA Detailed Water Bodies. Use the following parameters:

- Find: **USA Detailed Water Bodies**
- In: ArcGIS Online



2. Click Add.



3. Expand the legend for USA Detailed Water Bodies.

Q1 What types of water are represented in the view?

Q2 Describe the border of the polygon.

Q3 Zoom into one of the sections of the polygon and describe the level of detail.

4. Following the same procedure as in steps 1 and 2, search for and add **USA Urban Areas**.

5. Click the three dots and set the visible range to be visible at all scales.



Once again, zoom in and examine the urban areas.

Q4 What urban areas are represented?

Q5 Describe the edge of the polygons.

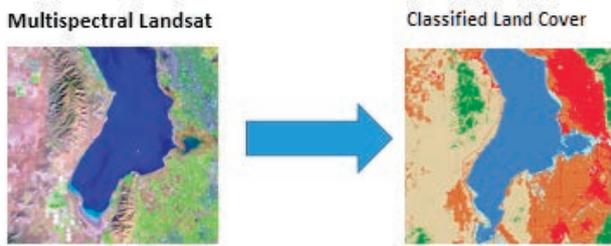
6. Following the same procedure as in steps 1 and 2, search for and add **Utah Major Roads Centerlines**.

Q6 What type of vector files are the roads?

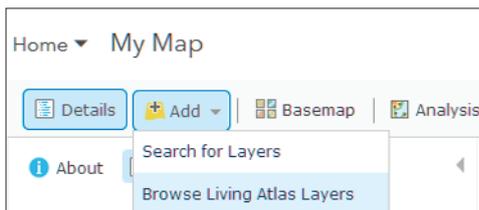
Q7 How well do they follow the imagery?

Add rasters

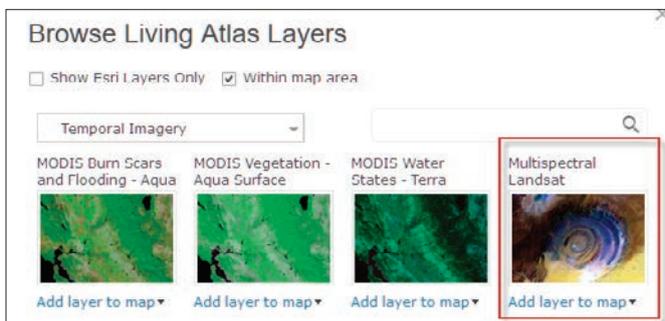
Now that you have added and examined some vector files, you will add two raster files. The first raster is land cover, which has been derived from satellite imagery. Starting with a Landsat satellite scene, an image is classified into one of the 16 defined classes of land. The procedure is represented in the figure.



1. On the top ribbon, go to Add>>Browse Living Atlas. The Living Atlas includes beautiful and authoritative maps on many topics. It combines reference and thematic maps relating to people, Earth, and life.



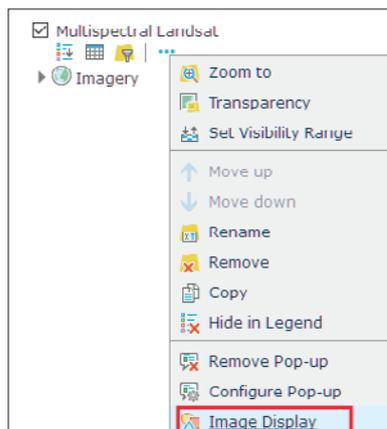
2. Search for Imagery >>Temporal Imagery and select Multispectral Landsat.



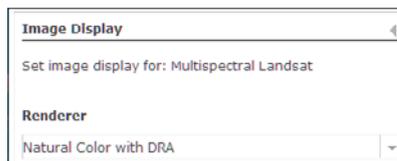
3. Click Add layer to map.

This multispectral Landsat image has a series of spectral bands that can be displayed in various combinations. For this exercise, you want to look at the image in natural color.

4. Right-click Multispectral Landsat and click Image Display.



5. Select Natural Color with DRA.



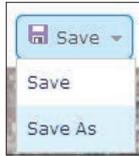
6. Click APPLY and click CLOSE.

Turn the Multispectral Landsat on and off and look at the basemap imagery below.

Q8 Which one is clearest?

Q9 What does this say about the resolution of the two images?

7. Now is a good time to save your map. Go to the top ribbon and click Save As.



8. Use the following parameters to save your map:

- Title: **Raster vs Vector**
- Tags: individual tags
- Summary: **Comparison of vector and raster data**

9. Click SAVE MAP.

10. Go back to Add>>Browse Living Atlas Layers>>Landscape>>Land Cover and click USA NLCD Landscape.



11. Click Add layer to map.

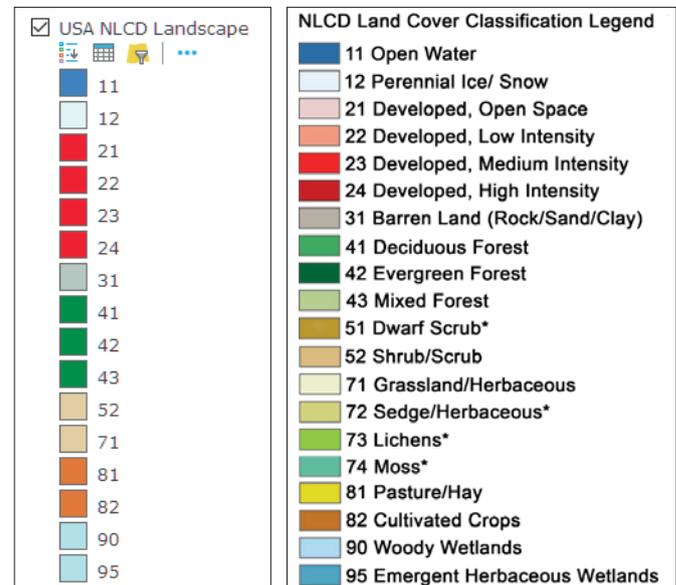
12. Click CLOSE.

The Multispectral Landsat image was a raster. The USA NLCD Landscape is another example of raster characteristics.

13. Zoom in close to any part of the Utah Lake.

Q10 Describe the appearance of the image. How is it different from the previous vector files?

14. Expand the legend of USA NLCD Landscape. Each one of the numbers is a designation of a land-cover type. These land-cover types are standards set by the US Geological Survey. A designation of each number is shown in the legend on the right.



Differences between raster and vector

You now have three vector and two raster images displayed on your map.

Q11 Write a comparison between the two feature types. Following are some focus questions for your analysis.

- Describe the difference between the two.
- Which is gridded?
- Which is the most appealing when you zoom in?
- Which is the most accurate compared with the basemap imagery?
- How are roads portrayed in vector and raster?
- Which feature type do you think is the most time consuming to produce?
- Which type shows the most detail?
- Give two examples when it would be best to use vector data.
- Give two examples when it would be best to use raster data.

Lesson 8-3: Classification accuracy of ground truthing

Ground truth is the accuracy of remotely sensed data on the basis of data actually measured in the field. It is the verification of a satellite image with what is already known about the location on the ground. Land-cover maps that have been derived from a classification of imagery can be validated by comparing features on the ground with the land-cover types.

Build skills in these areas:

- ▶ Gridding a study area
- ▶ Collecting a series of points
- ▶ Buffering points to represent resolution of Landsat imagery to be used (30 meters)
- ▶ Ground truthing points
- ▶ Comparing with land-cover image
- ▶ Calculating a simple percentage of ground truth

What you need:

- ▶ Account required
- ▶ Estimated time: 1.5 hours

Scenario

Your county GIS department wants to use some land-cover data for a series of zoning decisions. It wants to have some degree of confidence in the accuracy of the land cover and has hired you as a private consulting firm to ground truth the land cover.

Build the map and select the study area

1. Click [ArcGIS.com](https://www.arcgis.com).
2. Sign into your organizational account.
3. Click on Map on the upper ribbon.
4. In the upper-right corner, search for an area of your choice (in this exercise, the example area is Loudoun County, Virginia.)



5. On the upper ribbon, click Basemap and change to Imagery.



6. Click Save As and save your map.



7. Use the following for map documentation:

- Title: **Accuracy of Classification**
- Tags: individual tags
- Summary: **Accuracy of Classification**

8. Click SAVE MAP.

Add and isolate a study area boundary

Any study area boundary can be used; it can be a natural boundary such as a watershed or a political boundary such as a county. As previously stated, this study area will be Loudoun County, Virginia.

1. On the upper ribbon, go to ADD and search for Counties USA. Use the following parameters:

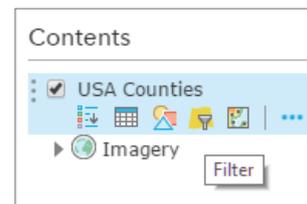
- Find: Counties USA.
- In: ArcGIS Online.
- Select USA Counties by esri_dm.



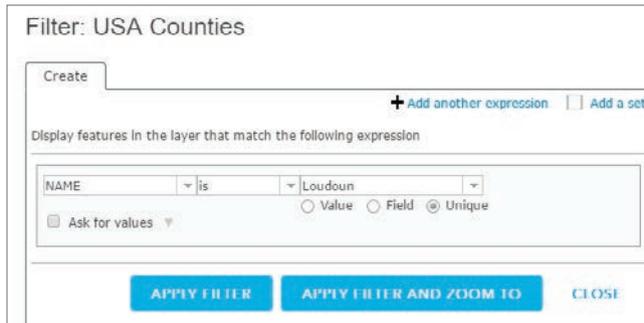
2. Click DONE ADDING LAYERS.

You want to isolate Loudoun County. You will do this by filtering the USA Counties feature layer.

3. Under USA Counties, click Filter.



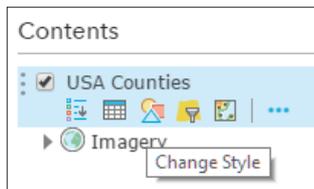
4. Create the following expression, as shown in the figure.



5. Click APPLY FILTER.

You now want to make the administrative boundary hollow with an outline so you can visualize the Imagery basemap.

6. Under USA Counties, click Change Style



7. Click OPTIONS.

8. Click Symbols.

9. Change Fill to No Color.

10. Change Outline to red with a line width of 3 px (pixels).



11. Click OK.

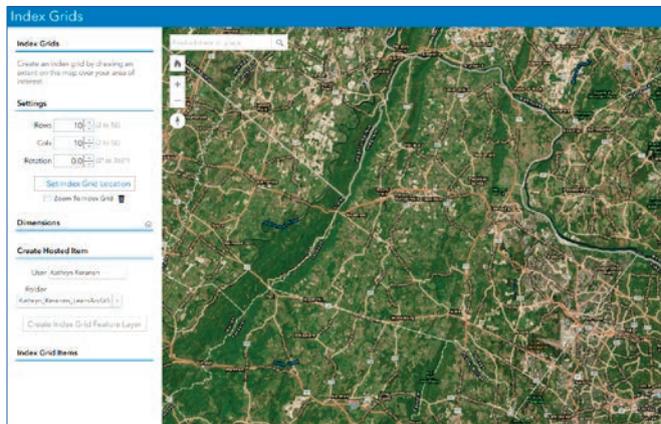
12. Click Save.

Grid the location

To insure a spatial distribution of points, the study area should be gridded. When a study area is gridded, points to sample can be assigned to each grid, thereby assuring an even spatial distribution to the study area.

The Esri Index Grid app allows you to divide the study area into columns and rows. The columns and rows define cells that can be used to assign sample points. The app creates a permanent grid that is stored in your organizational account and is always available to add to your map.

1. Click [Index Grid](#) to access the Index Grid App.
2. Sign in to your organizational account.
3. Zoom to your study area (in this case, Loudoun County, Virginia).



You must decide how many rows and columns you want to have in your index grid. For our purposes, we are choosing five rows and five columns.

4. Under Settings, choose Rows: 5 and Cols: 5.

5. Click Set Index Grid Location and draw a square around Loudoun County.

Index Grids

Create an index grid by drawing an extent on the map over your area of interest.

Settings

Rows (2 to 50)

Cols (2 to 50)

Rotation (0° to 360°)

Zoom To Index Grid

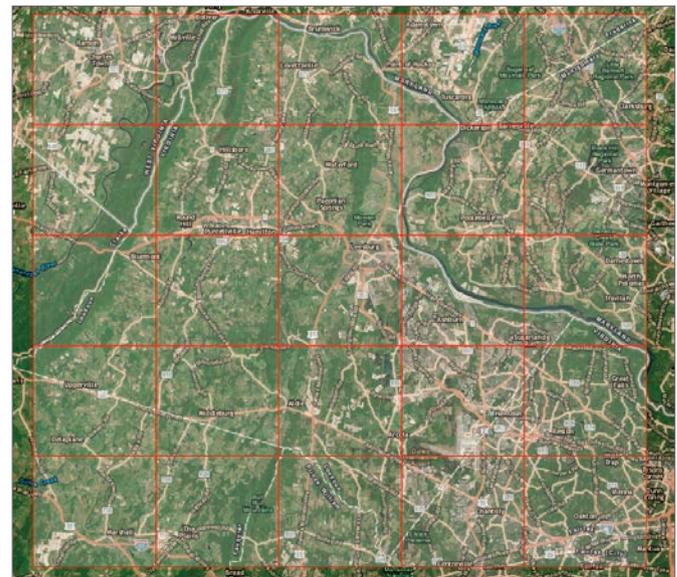
Dimensions

Create Hosted Item

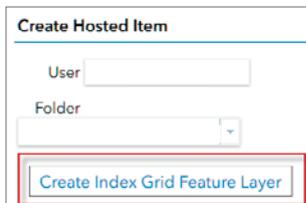
User

Folder

Index Grid Items

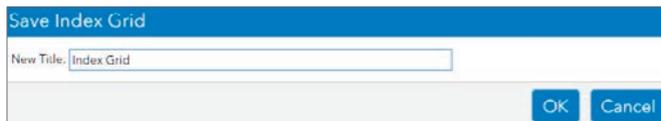


6. Click Create Index Grid Feature Layer.



The screenshot shows a dialog box titled "Create Hosted Item". It has two input fields: "User" and "Folder". Below these fields is a button labeled "Create Index Grid Feature Layer", which is highlighted with a red rectangular box.

7. Under Save Index Grid, enter a title of Index Grid.



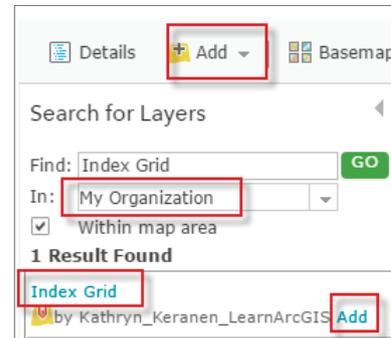
The screenshot shows a dialog box titled "Save Index Grid". It has a text input field labeled "New Title:" containing the text "Index Grid". At the bottom right of the dialog are two buttons: "OK" and "Cancel".

You have now created a new Hosted Index Grid Service that can be found under My Content in your organizational account.

8. Close the Index Grid app and go back to your Accuracy of Classification map.

9. Go to the + Add button and search for **Index Grid**.

10. Add Index Grid to your map.



The screenshot shows the "Search for Layers" interface. At the top, there are tabs for "Details" and "Basemap", and a red box highlights the "Add" button. Below, the search criteria are: "Find: Index Grid" (with a "GO" button), "In: My Organization" (with a dropdown arrow), and a checked box for "Within map area". Under the heading "1 Result Found", the item "Index Grid" is listed with a red box around its name and another red box around the "Add" button next to it.



11. Click DONE ADDING LAYERS.

12. Click Save.

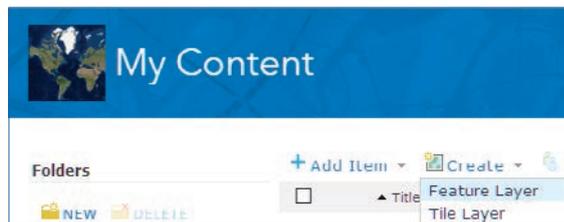
Create point collection feature layer

You will now create an individualized feature layer from another hosted feature layer. When created in this way, the hosted feature layer does not contain data but has the properties of the template or existing feature layer from which you create it. This allows you to duplicate properties such as the schema, while allowing others to populate the new layer with new features. In this instance, the feature layer you create will allow users to ground truth the accuracy of remotely sensed data.

1. Copy this shared URL of the hosted feature layer:

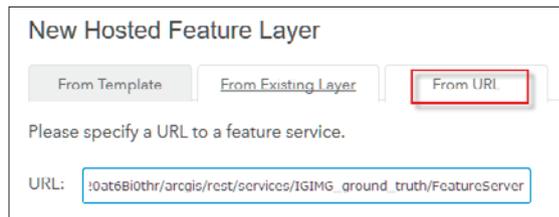
http://services2.arcgis.com/j80Jz20at6Bi0thr/arcgis/rest/services/IGIMG_ground_truth/FeatureServer

2. In My Content, click Create>>Feature Layer.



3. In the New Hosted Feature Layer window, click the From URL tab.

4. Paste the service URL you copied in step 1.



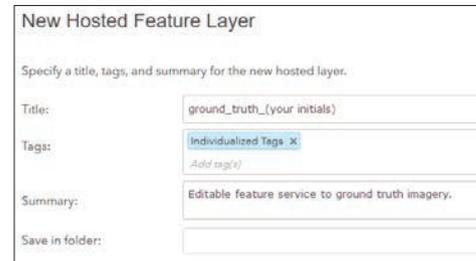
5. Click NEXT.

6. You want your feature layer to include the truth field, so click NEXT.

7. Accept the default map extent and click NEXT.

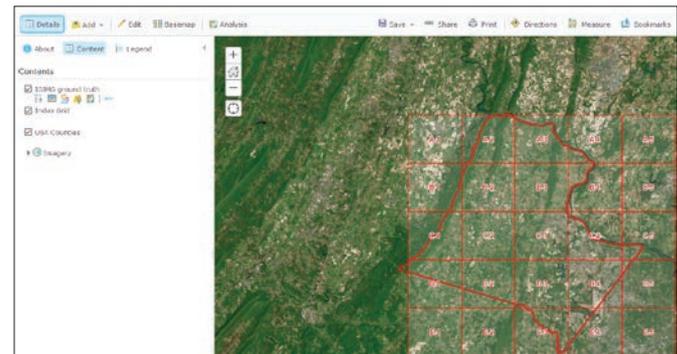
8. Use the following parameters:

- Title: **ground_truth_(your initials)**
- Tags: individual tags
- Summary: **Editable feature service to ground truth imagery**



9. Click DONE.

10. After the feature service has been created, click + Add>>Open in Map Viewer. This will open your map with your administrative boundary, your grid, and a ground truth editable feature service.



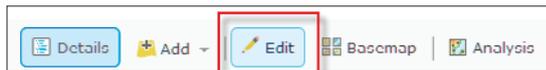
11. Click DONE.

12. Click Save.

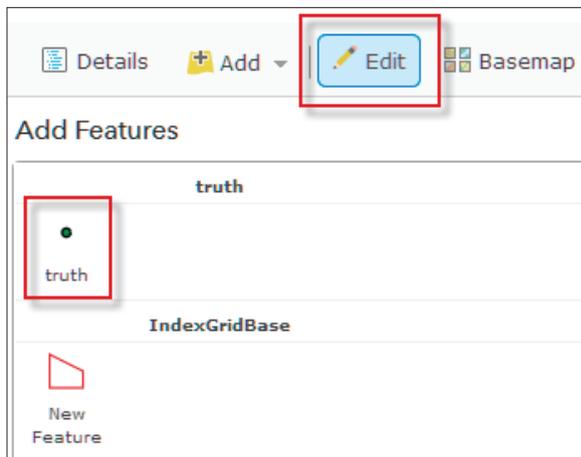
Collect data

Now the ground truth editable feature service can be used to collect data using aerial imagery. Remember, you created the grid to help with spatial distribution.

1. Add the grid feature service to your map. When you add the grid feature service, you will see the Edit icon on top of the page.



2. Click Edit.
3. Click the truth icon.



4. Click one point in each of the squares within the administrative unit. You should have 18 points. Do not worry about the ground truthing yet. Just digitize the points. You must select the truth icon every time you digitize a point. The process is as follows:

- Select the truth icon.
- Digitize a point.
- Click Close.
- Repeat the process.

Remember: Stay within the administrative boundary—in this case, Loudoun County.

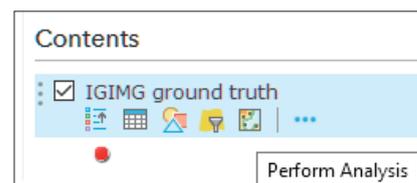


5. Click Save.

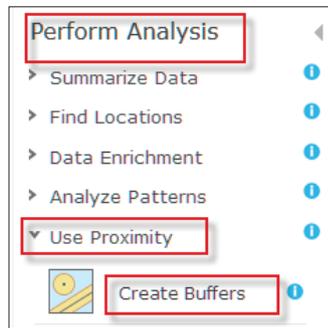
Buffer points

Because the land-cover accuracy that you will be evaluating has been classified from Landsat imagery, each pixel has a 30-meter spatial resolution. To replicate that resolution, you will now create a 30-meter buffer around the points. It is that 30-meter area that you will be ground truthing using the basemap imagery. Remember, ground truthing refers to validation of data. In this instance, you are validating the classified Landsat Imagery as compared to aerial imagery.

1. Click IGIMG ground truth and select Perform Analysis.



2. Click Use Proximity>>Create Buffers.

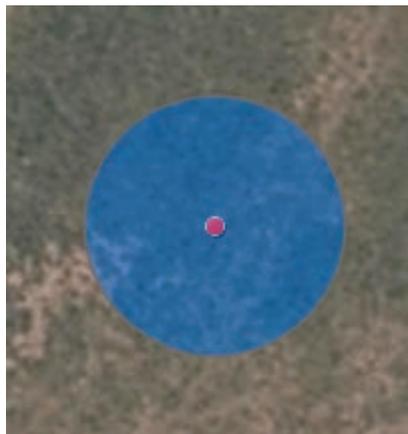


3. When the Create Buffers menu opens, use the following options:

- Choose layer containing features to buffer: IGIMG_ground_truth
- Enter buffer size:
 - Distance
- Enter buffer size:
 - 15 meters
- Result layer name: **buffer_points**

4. Click RUN ANALYSIS.

Zoom in on a point, and you will see a 30-meter buffer zone around each point.



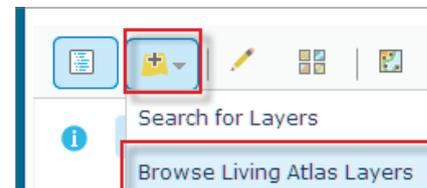
Add National Land Cover Data

In this section, you will add the classified land-cover data that has been derived from the Landsat satellite imagery. Remember: the satellite imagery has been classified to the following categories.

NLCD Land Cover Classification Legend

	11 Open Water
	12 Perennial Ice/ Snow
	21 Developed, Open Space
	22 Developed, Low Intensity
	23 Developed, Medium Intensity
	24 Developed, High Intensity
	31 Barren Land (Rock/Sand/Clay)
	41 Deciduous Forest
	42 Evergreen Forest
	43 Mixed Forest
	51 Dwarf Scrub*
	52 Shrub/Scrub
	71 Grassland/Herbaceous
	72 Sedge/Herbaceous*
	73 Lichens*
	74 Moss*
	81 Pasture/Hay
	82 Cultivated Crops
	90 Woody Wetlands
	95 Emergent Herbaceous Wetlands

1. Once again, go to the + Add button and select Browse Living Atlas Layers



2. Search for Landscape>>Land Cover.



3. Click USA NLCD Landscape>>Add layer to map



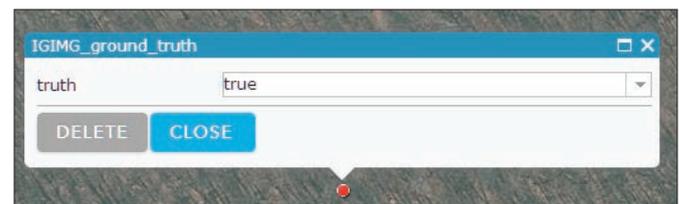
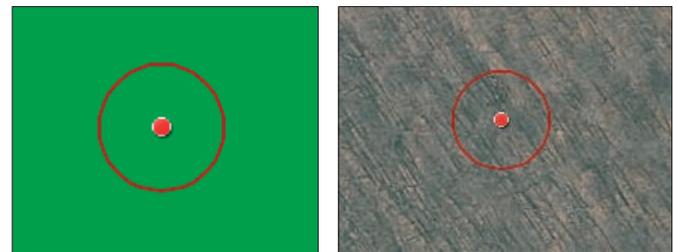
4. Click CLOSE.

Ground truth points

Zoom to each of the points and make a judgment call as to whether the land cover you are seeing is the same as the land-cover type. This section illustrates the process using an example point.

1. Zoom to the point.
2. See that the buffered area is green, which is 41, 42, or 43 which is forest.
3. Turn off USA NLCD Landscape.
4. If the image is forest, change the truth field to true as follows:

- Click the point.
- Click edit.
- Change the truth field to true.
- Click CLOSE.

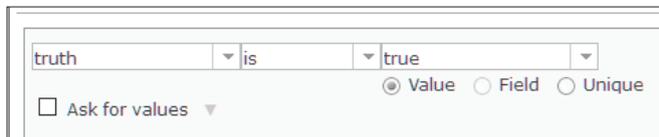


5. Repeat steps 1–4 for the remaining 17 points.

Calculate percentage

The percentage of the points that is true represents the accuracy of the classification.

1. Go to IGIMG ground truth, click Filter, and use the following expression.



The screenshot shows a filter expression interface. It consists of three dropdown menus: the first contains 'truth', the second contains 'is', and the third contains 'true'. Below these is a checkbox labeled 'Ask for values' which is unchecked. To the right of the checkbox are three radio buttons: 'Value' (which is selected), 'Field', and 'Unique'.

2. Record how many points are true.



The screenshot shows a table header. The top row is bolded and contains the text 'IGIMG ground truth (15 features, 0 selected)'. Below this is a single column header with the text 'truth'.

3. Calculate using the formula:

True/Total * 100.

$15/18 * 100 = 83\%$.

This case is completely subjective, but using these figures, the derived land-cover product would be 83 percent correct.

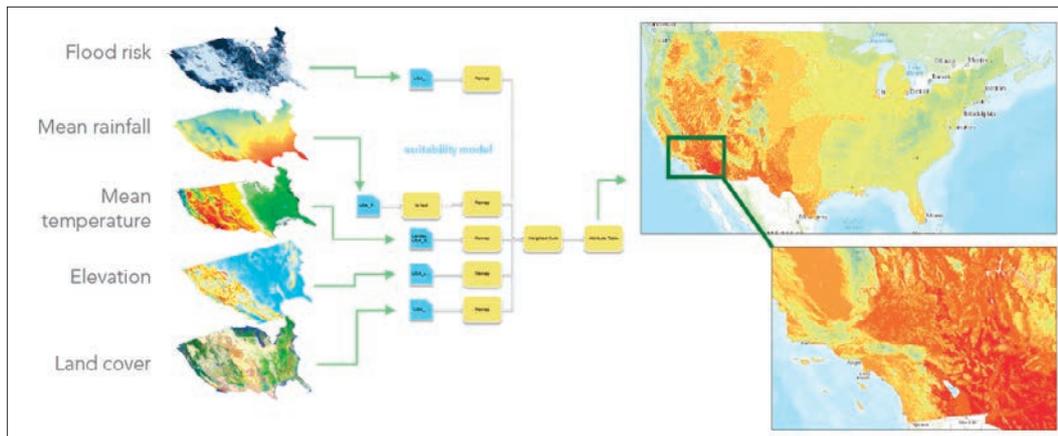
In this exercise, you have calculated the accuracy of a dataset that has been derived from a Landsat satellite scene. You have compared the actual data from basemap imagery to the derived product.

The ArcGIS Imagery Book, chapter 8

Questions for reading comprehension, reflection, and discussion

Teachers can use the items in this section as an assignment, introduction, or assessment, tailored to the sophistication of learners. Some learners can read all the sections at one time, while others are more comfortable with small segments. The questions and tasks are designed to stimulate thought and discussion.

1. “The Ultimate Big Data” is the title of this chapter. Write a paragraph explaining what this concept means. Include at least three of the following topics in your explanation:
 - AWS
 - Cloud computing
 - Petabyte
 - Mosaic datasets
 - Multiple scalable data
2. “The cloud changes everything” is a phrase used when talking about big data. Explain the phrase.
3. What is AWS Landsat?
4. What are the disadvantages of using compression for imagery?
5. To get a small insight into big data, solve the following problem: Landsat 8 collects 800 scenes/day. There are 11 bands in each scene, and, of course, there are 365 days in a year. How many bands of Landsat 8 data are collected in one year?
6. In chapter 8, there is a section titled “ArcGIS supports big imagery on demand.” In that section is a subsection titled “Big imagery enables big understanding.” The section explains scalable raster computing.



The analytical advantage of raster data is that it allows analysis at a pixel level. Each pixel contains a digital number of a value, and if the rasters are georeferenced analytical processes can take place involving all the rasters. To show your understanding of basic raster analysis, solve the following elevation and land-cover problem. The problem simply states that the user is looking for all areas that are 99 m in elevation with coniferous trees. In each case, the problem has been started. Your assignment is to reclassify both the elevation and the land-cover data. Put your numbers in each pixel. Then multiply the reclassified elevation times the reclassified land to get the final answer. Remember: $1 \times 1 = 1$ and $1 \times 0 = 0$.

Elevation in m					
34	34	34	99	99	99
26	25	12	99	99	25
25	24	10	99	99	25
99	99	10	13	13	25
99	99	11	13	13	25

Reclassify: 99 = 1, not 99 = 0					
0	0				
1					
		1			

Reclass elevation x Reclass land cover					
0	0				
1					
		1			

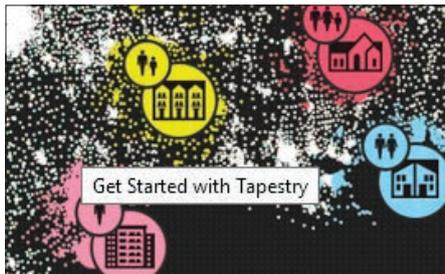
Land cover-Coniferous trees_52					
11	11	82	82	82	82
11	11	82	52	52	23
92	92	82	52	52	23
52	23	23	25	25	23
23	23	24	24	25	23

Reclassify: 52 = 1, not 52 = 0					
0	0				
1					
		1			

- After watching [video of bringing science to life](#) by thought leader Kathryn Sullivan, explain what she means when she talks about NOAA being an environmental intelligence agency.
- What are some of the advantages of a mosaic dataset?

Additional resources

Learn ArcGIS: Guided lessons based on real-world problems



Get Started with Tapestry

Using the ZIP Lookup tool

Finding key information

Identifying the best Tapestry segments for each scenario



Homeless in the Badlands

Adding ArcGIS Online data to ArcMap

Joining tabular data to spatial data

Publishing a layer to ArcGIS Online

Creating and symbolizing web maps

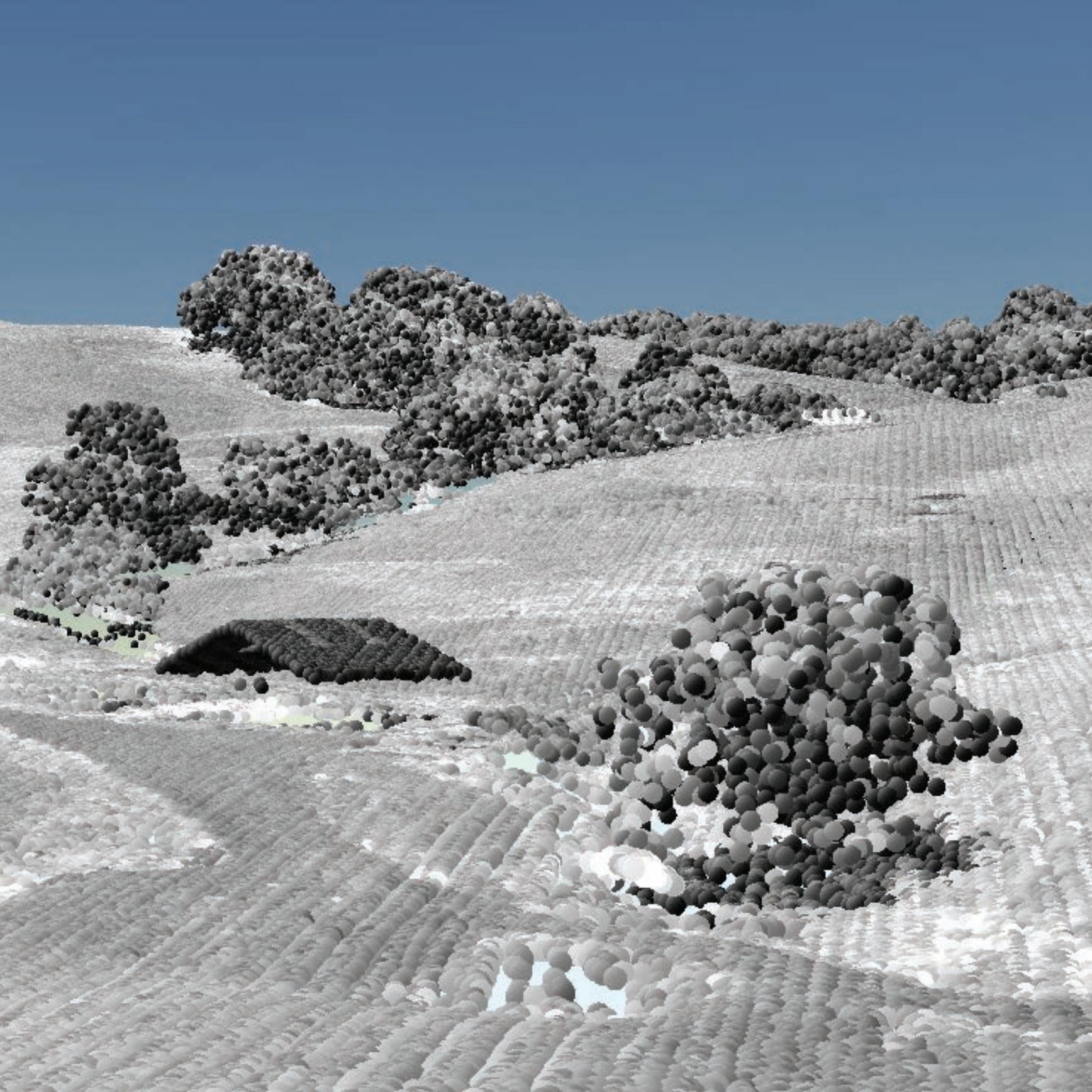


Get Started with Tapestry

Using the ZIP Lookup tool

Finding key information

Identifying the best Tapestry segments for each scenario



The Future Is Now

The map of the future is an intelligent image

The integration of GIS and imagery provides near real-time information about Earth, be it our own location or a location thousands of miles away. The invaluable capability to harness and share immediate information fosters informed and data-driven decision-making in arenas as diverse as disaster mitigation, traffic control, public health, and home security. Using data collected moments earlier by a drone, firefighters can assess the extent of fire in a canyon community without risking lives to do so. Ambulance drivers can determine the fastest route to the hospital with the help of real-time traffic data. Asthma sufferers can monitor levels of current atmospheric pollutants from the safety of their homes. While on vacation, at work, or anywhere in between, people can instantaneously check their home's status through cameras and sensors installed there. The exponential growth of this trend will impact every aspect of our lives. Soon we will manage our communities using custom drone missions to collect data as we track and analyze our bike rides with our smartphones. We live in a rapidly expanding geo-enabled world.



Introductory activities

Video

Esri pioneers problem-solving using GIS.



The Science of Where - Unlock Data's Full Potential

We believe digital transformation is leading business, government, and society into a new technological frontier. As the global market leader in geographic information systems (GIS)

Activity 9.1

Data, data everywhere

Modern GIS is about participation, sharing, and collaboration. Many governments at all levels are opening access to their geographic information, including their imagery collections, because they recognize the many benefits for their citizens. In this activity, you will investigate four government GIS databases (Australia, United States, Caribbean, and Virginia) recording the types of imagery available to the user. You will conclude by searching for your local administrative boundary GIS database, such as your state or county, and recording the available imagery. Record your findings in the table provided.

Investigate National Map Australian Government

National Map Australian Government is a website for map-based access to spatial data from Australian government agencies. It is an initiative of the Department of Communications and the Arts now currently managed by the Department of the Prime Minister and Cabinet, and the software has been developed by Data61 working closely with the Department of Communications and the Arts, Geoscience Australia, and other government agencies.

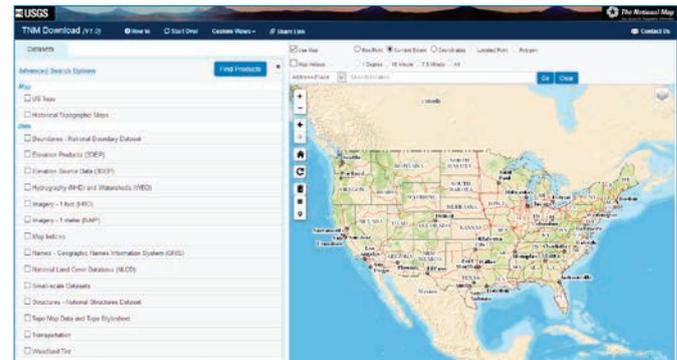
1. Click Map at the upper right.
2. Record the imagery basemaps.

Investigate The National Map of the United States: USGS

As one of the cornerstones of the US Geological Survey's (USGS) *National Geospatial Program*, *The National Map* is a collaborative effort among the USGS and other federal, state, and local partners to improve and deliver topographic information for the nation. It has many uses ranging from recreation to scientific analysis to emergency response. The National Map is easily accessible for display on the web, as products and services, and as downloadable data. The

geographic information available from The National Map includes orthoimagery (aerial photographs), elevation, geographic names, hydrography, boundaries, transportation, structures, and land cover. Other types of geographic information can be added within the viewer or brought in with The National Map data into a GIS to create specific types of maps or map views.

1. Record five examples of imagery shown on the left.



Investigate the Caribbean Landscape Conservation Cooperative

The Caribbean Landscape Conservation Cooperative is part of a national network of 22 Landscape Conservation Cooperatives (LCCs). An LCC is an applied conservation science organizations, universities, and other entities within a geographic area. LCCs are designed to inform resource management decisions in an integrated fashion across landscapes—at a broader scale than any individual partner’s responsibility.

1. Click the side panel and the Google Satellite tab (under Google Terrain) in the upper-right corner, and list five image sources.



Investigate Virginia’s statewide GIS clearinghouse

Virginia GIS Clearinghouse is hosted by the Virginia Geographic Information Network (VGIN) and the Virginia Information Technologies Agency (VITA). The GIS Clearinghouse is a repository of geospatial data produced and used by state agencies in Virginia, localities in Virginia, the state’s federal partners, nonprofits, and colleges and universities in Virginia.

1. Click Statewide Data Downloads and Statewide Data Services, and list five image sources.



Investigate local government

1. Search for your local administrative unit (state, county, region), find the geospatial clearinghouse, and list five image sources.

Australia	United States	Caribbean	Virginia	Local Government

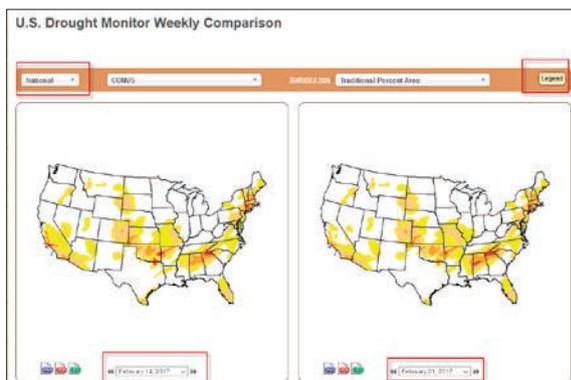
Activity 9.2 United States Drought Index

For several years, California was under drought and water restrictions in many areas. In 2013, Los Angeles, San Francisco, and Sacramento all hit record-low rain levels. California had seen some of its worst drought conditions in years. However, from the end of 2016 to the beginning of 2017, persistent precipitation and snowpack buildup lifted the severe levels of drought for most of the state.

In this exercise, you will use the US Drought Monitor to look at the drought over time in California. The US Drought Impact Reporter is an interactive tool developed by the National Drought Mitigation Center at the University of Nebraska-Lincoln to collect, quantify, and map reported drought impacts.

Check for drought

1. Go to [US Drought Monitor Weekly Comparison](#).



Take some time to familiarize yourself with the drought monitor interface.

- Notice that you can change views from National to Climate Region to State.
- You can pick the weekly time period.

- You can display the legend to show the severity of the drought.

2. Change the state to California.
3. Change the first date to February 25, 2014.
4. Be sure to look at the statistics displayed at the bottom of the interface.

Statistics Comparison						
Week	Rate	D0-D4	D1-D4	D2-D4	D3-D4	D4
2014-02-25	0.00	100.00	94.56	90.82	73.83	26.21
2017-02-21	61.66	38.34	19.87	4.19	0.00	0.00

The numbers shown in the chart indicate the percentage of the area that is in the particular drought phase as indicated by the legend available in the upper-right corner.



Q1 Write a paragraph explaining the difference between the spatial distribution of the drought in 2014 and 2017 and include statistical information.

5. Repeat steps 2–4 for New Mexico.
6. Repeat steps 2–4 for Arizona.

Q2 Write paragraphs for both New Mexico and Arizona.

Lesson 9-1: Warming Alaska with Map Notes

Remember, you can access ArcGIS Online for all the lessons in this guide, either with no sign-in to an organizational account required (the first set of lessons in each chapter) or by signing in to your organizational account (for the last set of lessons in each chapter).

In chapter 9 of *The ArcGIS Imagery Book*, there is a focused story map that offers convincing evidence about a warming Alaska. The story map is an example of shared imagery by the greater GIS community.

Build skills in these areas:

- ▶ Locating sites
- ▶ Adding Map Notes with description
- ▶ Adding links to Map Notes
 - Information links
 - Video links
 - Image links

What you need:

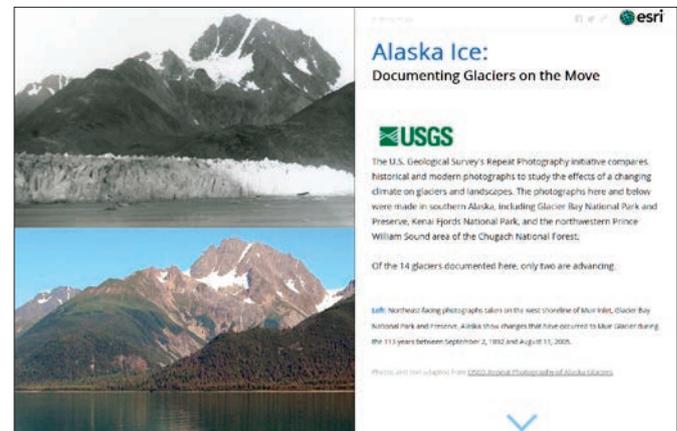
- ▶ No account needed
- ▶ Estimated time: 45 minutes

Scenario

After being inspired by observing the story map, Alaska Ice: Documenting Glaciers on the Move, you have decided to try your hand at adding Map Notes with links, images, and videos.

Locate the glacier

1. Open [Alaska Ice: Documenting Glaciers on the Move](#).



2. Investigate the story map and choose three glaciers that are particularly interesting to you. The three examples included here are

- Muir Glacier
- Pedersen Glacier
- Holgate Glacier

3. Open ArcGIS Online.

4. On the top ribbon, click Map.

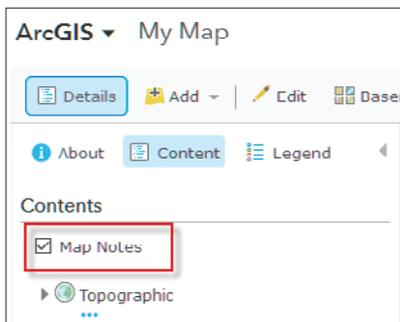
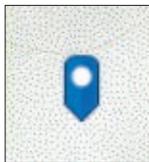
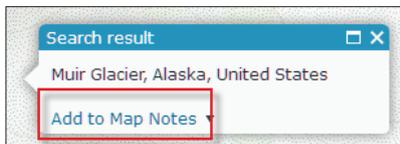
5. Click Modify Map.



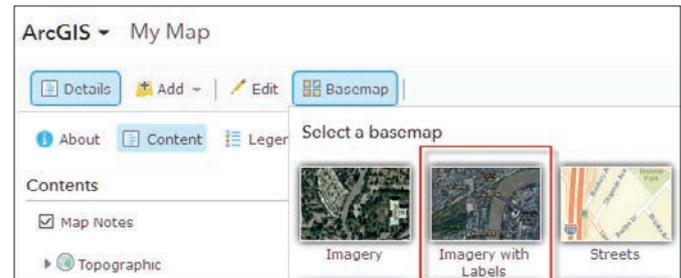
6. In the Search box, search for **Muir Glacier, Alaska, United States**.



7. Click Add to Map Notes. When you click Add to Map Notes, it adds a Map Notes graphic and adds a Map Notes layer to the Contents pane.



8. In the upper-left ribbon, change the basemap to Imagery with Labels.



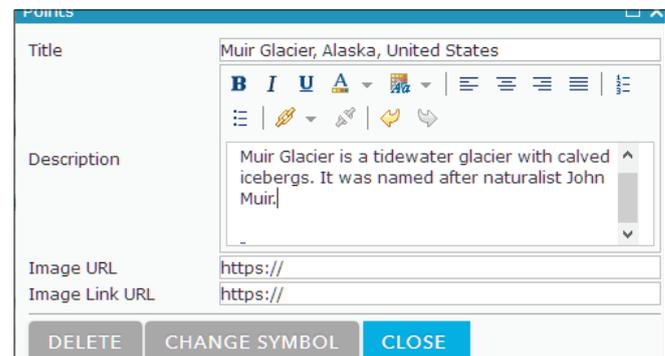
Add information to the Map Notes

1. Click the blue Map Notes icon.

2. Click Edit.

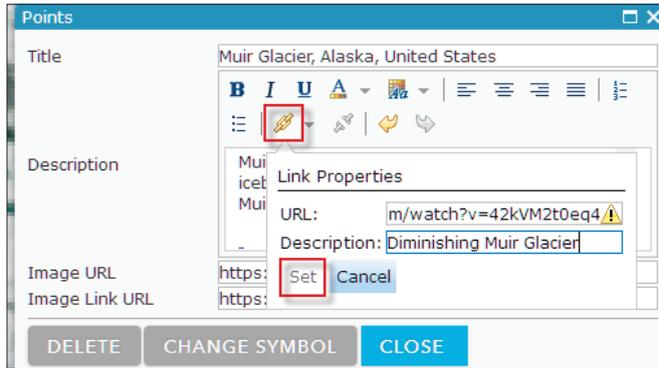
3. Write the following description:

Muir Glacier is a tidewater glacier with calved icebergs. It was named after naturalist John Muir.



4. Click the link icon and insert the following URL and title:

- <https://www.youtube.com/watch?v=42kVM2t0eq4>
- Title: **Diminishing Muir Glacier**



5. Click Set.

6. Click CLOSE.

Add information for additional glaciers

Doing your own research and following the instructions above, make Map Notes for Pedersen and Holgate Glaciers.

Lesson 9-2: Racing the High Mountains

The Haute Route Dolomites Swiss Alps is a multiday race starting from Venice, Italy, and finishing in Geneva, Switzerland. Featuring beautiful landscapes of the Dolomites and the Swiss Alps and a vertical gain of approximately 20,000 meters, the race lasts seven days and is 933 km in length. Stage 6 of 7 the race goes from Andermatt to Crans-Montana, Switzerland, and is a 142 km stretch, with a vertical gain of 3,100 meters. It has several significant cols (passes or saddles) and breathtaking scenery.

Build skills in these areas:

- ▶ Adding a modified GPS file
- ▶ Saving as a layer
- ▶ Publishing as a feature layer
- ▶ Showing in Scene
- ▶ Configuring layer to show elevation in 3D
- ▶ Investigating cols (passes, saddles)
- ▶ Creating viewsheds
- ▶ Comparing heart rate to elevation
- ▶ Comparing speed to elevation
- ▶ Creating a comparison app

What you need:

- ▶ Account required
- ▶ Estimated time: 1 hour



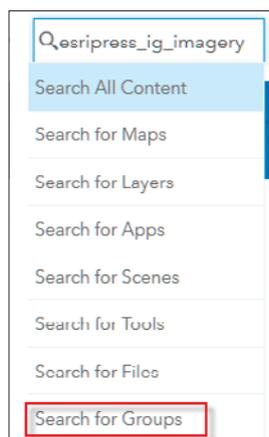
Scenario

GPS_FOR_EVERYONE, a website and mobile app used to track athletic activity via GPS, has asked you to create a 3D visualization using the GPS track from your Dolomite biking race. They are particularly interested in users comparing elevation to heart rate and speed.

Map the GPX, save as a layer, and publish as a feature layer

You have been given a GPS file of approximately three quarters of the Stage 6 2014 Dolomite race. The points have been thinned to 2,000 so they can be published to ArcGIS Online. The points were thinned for speed of processing.

1. Go to ArcGIS.com and sign into your organizational account.
2. In the upper-right Search box, type **esripress_ig_imagery** and click Search for Groups.



The default search returns results found only within your organization. To show all public results, you'll remove that filter.

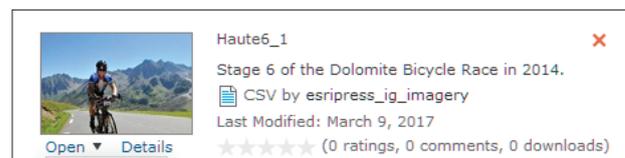
3. Clear the check box that says to only search in your organization.



4. Click **esripress_ig_imagery** to view the group content.



5. Click the Open arrow below the thumbnail for Haute6_1 and download.

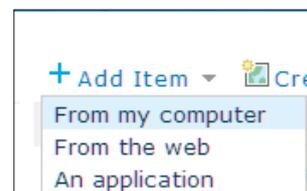


6. Save the file Haute6_1 to a location of your choice.



7. Within your organization, click My Content on top of the page.

8. Click + Add Item >> From my computer.



9. Browse to the Haute6_1 file and choose the file.

- Add Tags: individual tags
- Select the check box for Publish this file as a hosted layer
- Locate features using: Latitude/Longitude.
- Time Zone is (UTC) Coordinated Universal Time.

Item from my computer ?

Add an item from your computer.

File: Haute6_1.csv

Title: Haute6_1

Tags: Individualized Tags X
Add tag(s)

Publish this file as a hosted layer.
(Adds a hosted layer item with the same name.)

Locate features using:
 Latitude/Longitude Address None, add as table

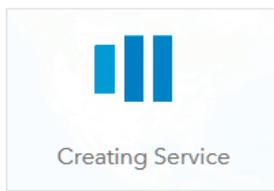
Review the field types and location fields. Click on a cell to change it.

Field Name	Field Type	Location Fields
Creator	String	Not used
Time	Date	Not used
Name	String	Not used
Latitude	Double	Latitude

Time Zone: (UTC) Coordinated Universal Time ?

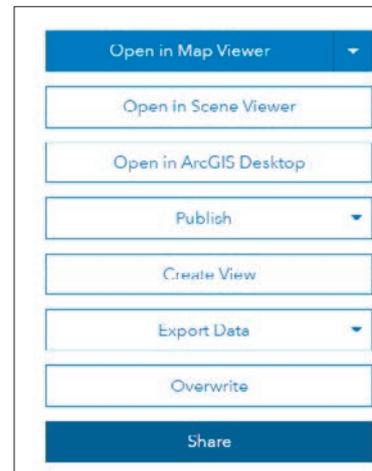
10. Click ADD ITEM.

If users are working within the same organizational account, they should rename the CSV file to an individualized name before trying to upload. It is suggested that they add their initials to the file name—i.e., Haute6_1initials.



11. Click Open in Map Viewer>>Share>>Share with Everyone.

12. Open in Map Viewer.

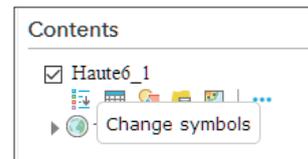


13. Choose an attribute to show location only.

14. Click DONE.



15. Click Haute6_1>>Change symbols.



16. Click OPTIONS.

17. Click Symbols.

18. Pick a colored dot of your choice.

19. Click OK.

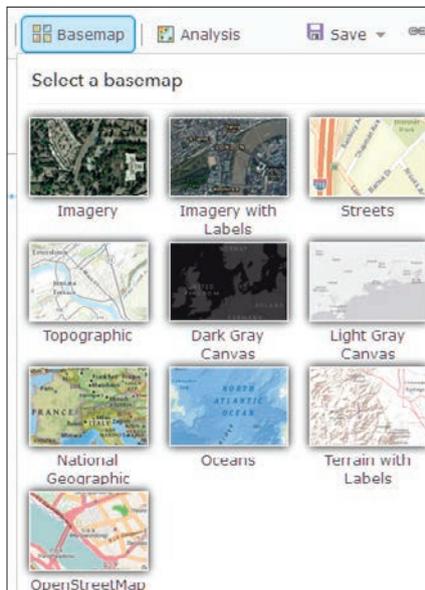
20. Click DONE.



Identify locations and cols along the route

In this section of the exercise, you will identify locations along the route. You will identify the starting point of Andermatt and Furkapass, which is one of the cols of Stage 6.

1. On the top ribbon, locate the Basemap tab. You will be using different basemaps during this section of the exercise.



2. Change the basemap to Imagery with Labels.

3. Zoom to the northeast to the beginning point of the race and identify Andermatt.



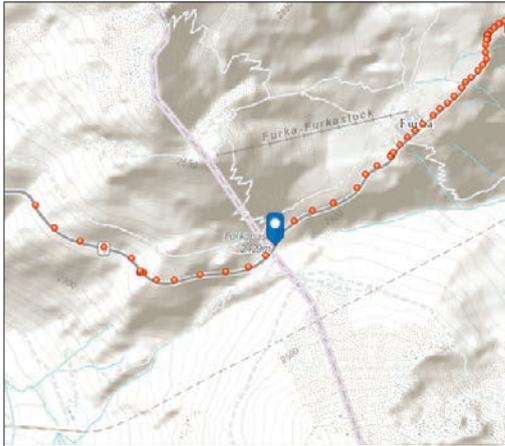
4. In the upper Search box, search for **Furkapass, Valais, Switzerland**

5. Click Add to Map Notes.



Furkapass is a col (notch, gap, saddle) located along the Stage 6 trail. A col is the lowest point on a mountain ridge between two peaks. It may also be called a *notch*, a *gap*, or a *saddle*. Standing within a col, you should be able to see downward on two sides and upward on two sides.

6. Change the basemap to Topographic.

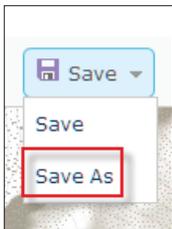


You can now see that the map note is within a notch on the map. The elevation goes up northwest to southeast, and it goes down northeast to southwest.

Save your map

This is a good time to save your map.

1. Go to the upper ribbon and click Save As.



2. Use the following documentation for your map:

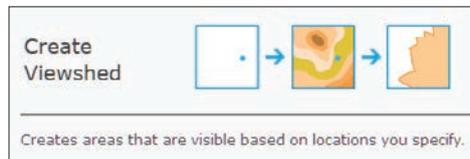
- Title: **Stage 6 of the Dolomite Ride**
- Tags: individual tags
- Summary: **Stage 6 of the Dolomite Ride**
- Save in folder: (Answers will vary.)

3. Click SAVE MAP.

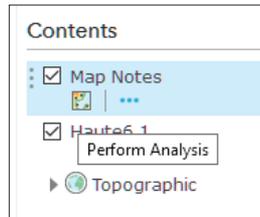
A screenshot of the 'Save Map' dialog box. The title is 'Stage 6 of the Dolomite Ride'. The tags are 'Individualized Tags'. The summary is 'Stage 6 of the Dolomite Ride'. The save in folder is '004IGb_Heat_Islands'. There are 'SAVE MAP' and 'CANCEL' buttons.

Create a viewshed at Furkapass

The Create Viewshed tool uses the Esri Elevation Analysis service to determine which areas are visible from specified observer points. The specified observer point for this exercise is Furkapass. The viewshed determines which areas can be viewed from Furkapass.



1. Under Map Notes, click Perform Analysis.



2. Choose Find Locations>>Create Viewshed, and use the following parameters:

- Point features that represent observer locations are Map Notes (Points).
- Visibility setting (optional) is 6 Feet (based on height of an individual).
- Maximum viewing distance is 9 Miles.
- Result layer name is **Furkapass visible areas**.
- Save result in (desired folder).
- Clear the check box for Use current map extent.

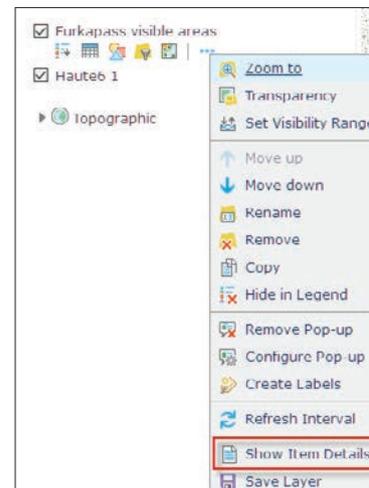
3. Click RUN ANALYSIS.

4. Zoom out to see the extent of the viewshed. The areas that you see are the areas that are visible from the Furkapass col.

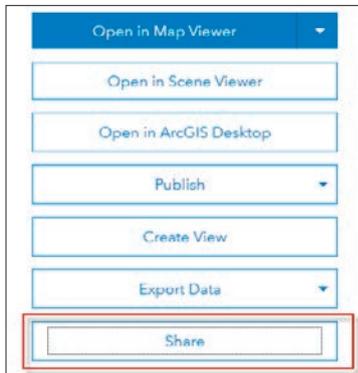


You will be using the viewshed in a subsequent 3D scene so it must be made public.

5. Click Furkapass visible areas and select Show Item Details

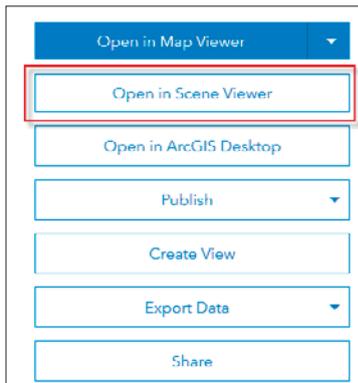


6. Click Share.



7. Click Share with Everyone.

8. Click Open in Scene Viewer.



Display the GPS track with elevation, heart rate, and speed in Scene

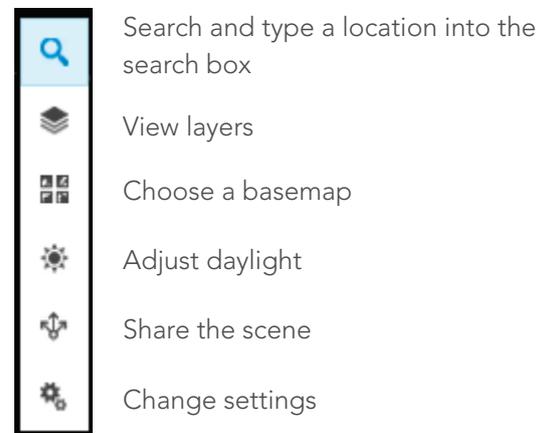
ArcGIS Online 3D Scene Viewer is an app that can symbolize 3D geospatial content that includes a multiscale basemap and a collection of 3D layers, styles, and configurations that allow you to visualize and analyze geographic information in an intuitive and interactive 3D environment. You can also create web apps with a scene by using a configurable app. Different configurable apps offer various bits of functionality.

Create a scene of elevation

1. In the upper-left corner of your screen are the navigation controls. Take a few minutes to familiarize yourself with the tools. Use all the tools.

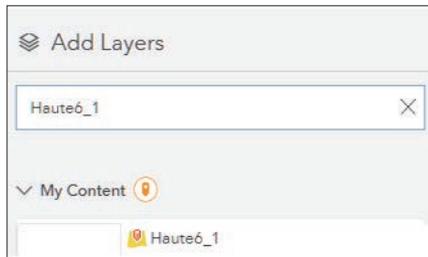


2. Pay particular attention to changing the basemaps.



3. Add a layer to the scene by clicking ADD LAYER.

4. Search for Haute6_1



5. Click the plus sign (+) and add a layer to the scene.

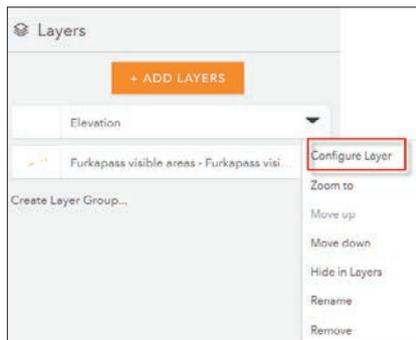
Notice that the point data for the Haute6_1 GPS track appears on the scene.

6. Click DONE.

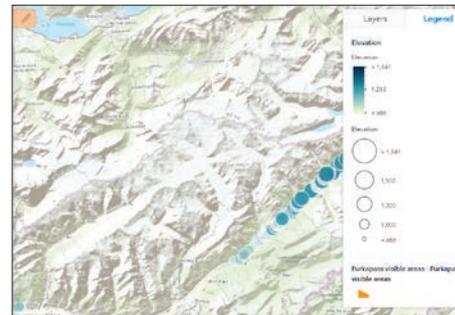
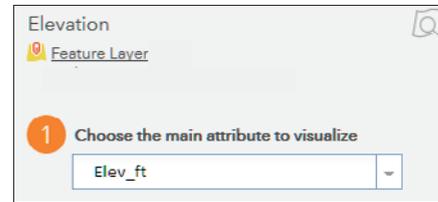
You will now configure the layer to show elevation.

The menus involved in configuring the layer can be accessed from the tab on the side of the feature.

7. Click Elevation>>Configure Layer. Rename Haute6_1 to **Elevation Dolomite Bicycle Race**.



8. Choose the main attribute to visualize as Elevation.



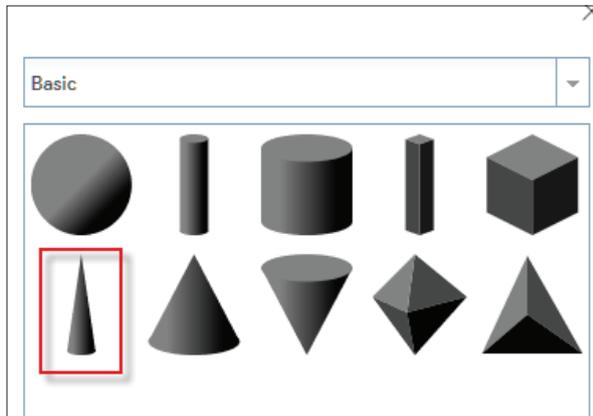
Notice that the elevation is now represented on the map both with graduated symbols and using a color ramp. The symbols are spheres, and the larger the sphere, the higher the elevation. The elevation is also shown as a graduated color ramp with the darkest blue indicating the highest elevation.

You will next choose a drawing style. You want to choose the Counts & Amounts 3D OPTIONS.

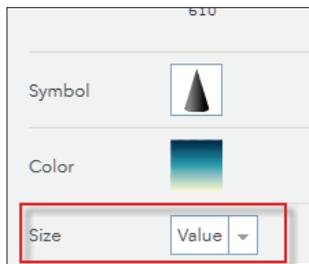
9. Click OPTIONS.



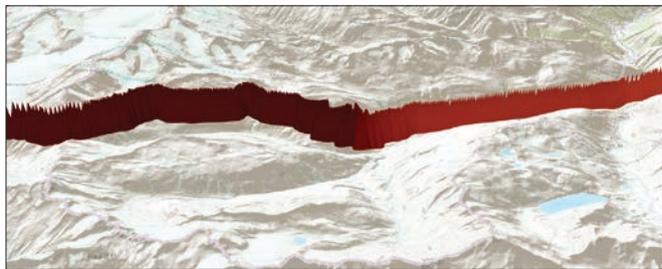
10. Click Symbol and change to cone.



11. Change Size to Value.



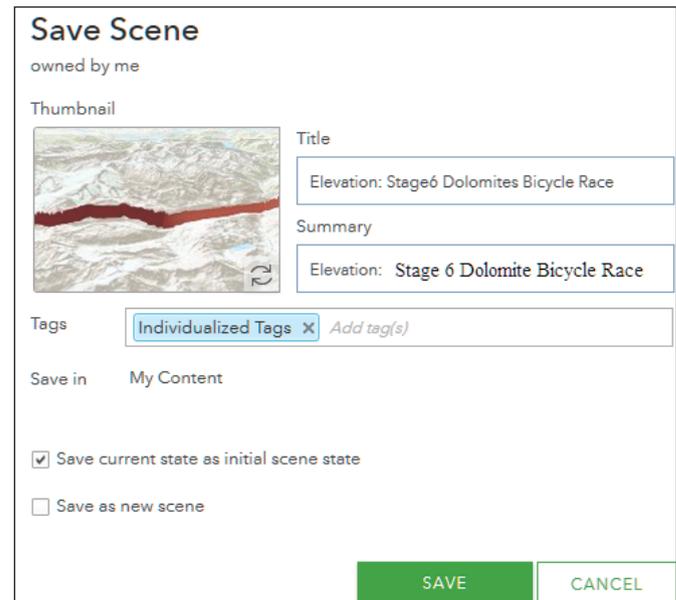
12. Click DONE.



13. Click DONE again.

14. Click SAVE SCENE AS, and enter the following metadata:

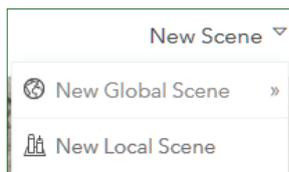
- Title: **Elevation: Stage 6 Dolomite Bicycle Race**
- Summary: **3D Visualization of Elevation**
- Tags: individual tags
- Click: Save as new scene (If previous scene has been saved).



You have successfully made a 3D scene showing elevation of the Dolomite Bicycle Race. You will now create two more maps, one showing speed and one showing heart rate of the racer.

Create maps showing speed and heart rate

1. In the upper-right corner, click New Scene>>New Global Scene.



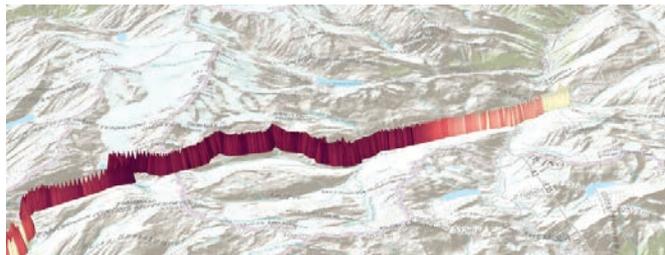
2. Repeat steps 7–14 from the previous section to create the heart rate map with the following exceptions:

- Rename the layer **Heart Rate Dolomite Bicycle Race**.
- Select red for the color.
- Select an inverted cone for the symbol.

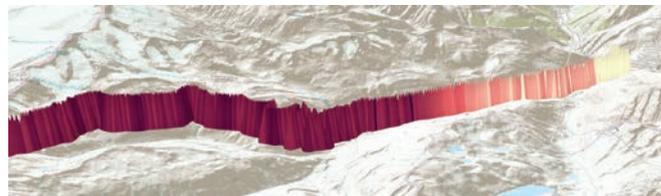
3. Click SAVE SCENE, and enter the following metadata:

- Title: **Heart Rate Dolomite Bicycle Race**.
- Summary: **3D Visualization of Heart Rate of the Dolomite Bicycle Racer**.
- Tags: individual tags.
- Click: Save as new scene.

4. Click SAVE.



5. Repeat steps 7–14 to create a speed map.



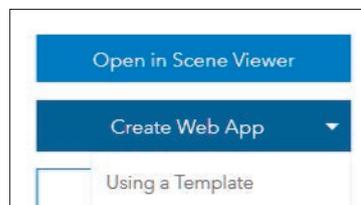
Create two comparison apps: elevation vs. heart rate and elevation vs speed

1. Go Home and click My Content.

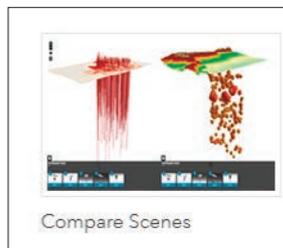


2. Click Elevation Dolomite Bicycle Race.

3. Click Create Web App>>Using a Template.



4. Select Compare Scenes and click to open.



5. Click CREATE WEB APP and enter the following metadata:

- Title: **Comparison of Elevation and Heart Rate**
- Tags: individual tags
- Summary: **3D Comparison of Elevation and Heart Rate of the Bike Racer**



6. Click DONE.

7. Click Select Web Scene(s).

8. Select Elevation and Speed.

9. Click OK.

10. Click SAVE.

11. Click Launch.



Q1 Write a summary comparing the variables of elevation, speed, and heart rate. Be sure to tell what sort of mathematical proportion is shown in both comparisons.

Lesson 9-3: Real-time data feeds



Real-time GIS gives you the ability to connect to data streams and receive real-time data. Once configured properly, real-time feeds can be brought into your maps and provide help in everyday decision-making. Traffic cams and cameras watching wildlife make for interesting feeds. Adding live feeds to your maps provides the locational information of the live feeds.

Build skills in these areas:

- ▶ Constructing and working with CSV files
- ▶ Mapping real-time data from live camera feeds

What you need:

- ▶ Account not required
- ▶ Estimated time: 30 minutes

Scenario

The City of Santa Clara, California, is doing a traffic study of a section of the Great America Parkway. The parkway is one of the major roads in the Santa Clara area with a lot of traffic congestion. City officials have decided to monitor the situation using live cameras. As a staff GIS analyst, you have been tasked with mapping the designated web cams.

Construct a CSV file

A CSV file stands for comma-separated values. It is a simple file format that can be created in a text editor, Microsoft Excel, or Open Office. In this exercise, you will make a CSV file in a text editor that includes the following headings:

Name – location of live-feed camera

URL – website of live-feed camera location

long – longitude

lat -- latitude

1. Open Microsoft Notepad or Excel and copy the data shown below and at right.. You may simply copy the values and paste into the text program if desired. It does not matter what software program you use, only that the file be saved as a CSV file.

name,URL,long,lat

*Bowers Ave @ SB101 Ramp,http://
trafficcamsantaclaraca.gov/TrafficCamera.
aspx?CIDBowers101,-121.977373,37.384592*

*Great America @ 101 Off-Ramp NB,http://
trafficcamsantaclaraca.gov/TrafficCamera.
aspx?CIDGA101,-121.97664,37.386749*

*Mission College @ Agnew,http://trafficcamsantaclaraca.
gov/TrafficCamera.aspx?CIDMissionCollegeAgnew
,-121.969663,37.388865*

*Mission College @ Mission College Circle,http://
trafficcamsantaclaraca.gov/TrafficCamera.
aspx?CIDGAMissionCollegeCircle,-121.97905,37.391569*

*Great America @ Mission College,http://
trafficcamsantaclaraca.gov/TrafficCamera.
aspx?CIDGAMissionCollege,-121.976868,37.392165*

*Great America @ Patrick Henry,http://
trafficcamsantaclaraca.gov/TrafficCamera.
aspx?CIDGAPatrickHenry,-121.978091,37.395813*

*Great America @ Old Glory,http://
trafficcamsantaclaraca.gov/TrafficCamera.
aspx?CIDGAOldGlory,-121.978134,37.400075*

*Great America @ Tasman,http://
trafficcamsantaclaraca.gov/TrafficCamera.
aspx?CIDGATasman,-121.978048,37.403088*

*Tasman @ Old Ironsides,http://trafficcams.
santaclaraca.gov/TrafficCamera.
aspx?CIDTasmanOldIronsides,-121.979904,37.403118*

*Tasman @ Convention Center,http://
trafficcamsantaclaraca.gov/TrafficCamera.
aspx?CIDTasmanConventionCenter,-121.975559,37.403642*

*Great America @ Bunker Hill,http://
trafficcamsantaclaraca.gov/TrafficCamera.
aspx?CIDGAParkwayBunkerHill,-121.977979,37.40547*

*Tasman @ Calle De Sol,http://trafficcams.
santaclaraca.gov/TrafficCamera.
aspx?CIDTasmanCalleDeSol,-121.96384,37.407428*

*Tasman @ Lick Mill,http://trafficcams.
santaclaraca.gov/TrafficCamera.
aspx?CIDTasmanLickMill,-121.961608,37.408417*

*Great America @ Old Mtn Alviso,http://
trafficcamsantaclaraca.gov/TrafficCamera.
aspx?CIDGAOldMtnAlviso,-121.977531,37.410654*

*Great America @ Great America Pkwy,http://
trafficcamsantaclaraca.gov/TrafficCamera.
aspx?CIDGAGAParkway,-121.97753,37.413632*

Map the CSV file

Now that the CSV file is constructed, you must map the data.

1. Click [ArcGIS.com](https://www.arcgis.com).
2. Sign into your organizational account.
3. Click Map on the upper ribbon.
4. Drag the camera.csv file to the map. The points will appear at the appropriate location.
5. Under Change Style>>Choose an attribute to show, click Show location only.



6. Click OPTIONS>>Symbols and change the symbol size to 15.

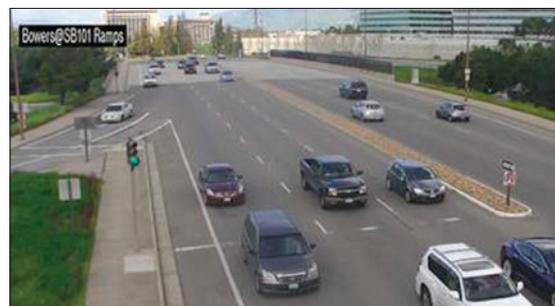


7. Click OK.
8. Click DONE.

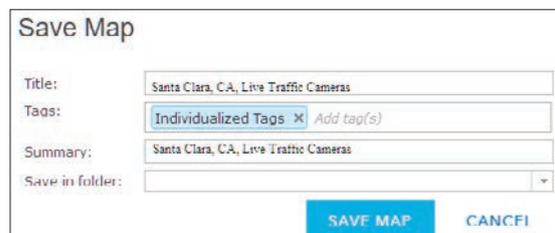
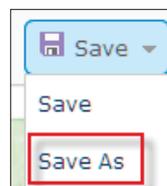


Display the live camera feed

1. Click a point.
2. Click More Info, and the live camera feed will appear.



3. On the top ribbon, click Save As and enter the proper documentation for the map.



4. Click SAVE MAP.

Additional exercise

The *Raptor Resource Project* deals with the preservation of raptors. The project maintains and observes some 40 nests and nest sites. The nests are observed by live camera feeds. Following is a text file that allows you to add the live camera feeds to an ArcGIS Online map by following the instructions in the previous section of this lesson.

name,lat,lon,camera

decorah eagles,43.2755,-91.7796,http://www.ustream.tv/embed/16981684?html5ui=1

peregrine falcons,43.87102,-91.3198,https://www.youtube.com/embed/uQAI12FkO5U?rel=0;&autoplay=1

north nest eagles, 43.333,-91.921,https://youtu.be/t2q89jtvEq8

The ArcGIS Imagery Book, chapter 9

Questions for reading comprehension, reflection, and discussion

Teachers can use the items in this section as an assignment, introduction, or assessment, tailored to the sophistication of learners. Some learners can read all the sections at one time, while others are more comfortable with small segments. The questions and tasks are designed to stimulate thought and discussion.

1. “Entering the human era of GIS” is a powerful statement. List at least three everyday technological products that are powered by location—for example, almost everyone uses a navigational map.
2. The term “geo-authorship” refers to a mashup of different sources. What different sources can be shown in a story map?
3. List the factors that make imaging the GIS of the future.
4. Discuss how on-board analytics and disappearing computing limits represent the future of GIS and imagery.
5. Drone data can be analyzed to provide both a DEM and a DSM. Explain both a DEM and a DSM and describe the mathematical procedure to extract height using these products.
6. As a final piece of information, we would like for you to enter a location and a piece of information about your educational identity on a collaborative map. We collected this information for the *Instructional Guide for The ArcGIS Book* and would like to continue this for users of the *Instructional Guide for The ArcGIS Imagery Book*. Follow the steps below to enter your location and information. Thanks. Kathryn and Lyn.
 - Go to [Collaborative Map](#).
 - On top of the page, click Edit.
 - In the table of contents, click Learners.
 - Click to add a point on your location on the map.
 - Fill out the information requested.

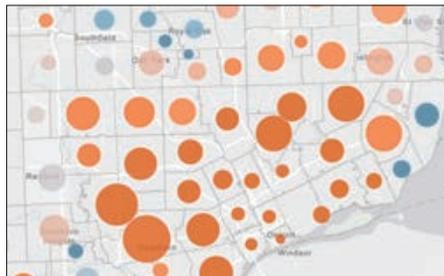
Additional resources

Learn ArcGIS: Guided lessons based on real-world problems



Evaluate Locations for Mixed-Use Development

- Enriching layers with on-demand attributes
- Filtering layers with logical queries
- Adding and calculating table fields
- Deriving new locations through analysis
- Creating time-based accessibility zones



Fight Child Poverty with Demographic Analysis

- Adding layers to a map
- Enriching layers with demographic data
- Styling layers with smart mapping
- Configuring pop-ups
- Editing item details
- Configuring a web app



Mapping the Public Garden

- Map Design
- Publishing large-scale tiled map services with additional close-up scales
- Publishing feature services
- Configuring an email notifier web app

Acknowledgments

Special thanks to Jack Dangermond and Clint Brown for the vision and inspiration that motivated us to write this guide. Their enthusiasm and encouragement made it a reality. We are grateful to Charlie Fitzpatrick, Angela Lee, and Joseph Kerski for their excellent support over the years and for their unflagging willingness to collaborate with us as educators. Such guidance has meaningfully influenced the way that we approach students in the classroom, helping us develop the effective teaching methodologies you see here. The assistance of the many members of Esri's software development and imagery team has been invaluable. We appreciate Esri Press's publishing professionalism and cheerful attitude. We would also like to acknowledge Bob Kolvoord and Paul Rittenhouse for their willingness to engage in constant dialog about geospatial technology education over many, many years. Finally, thanks to the James Madison University geospatial students for being the first testers of the *Instructional Guide to the ArcGIS Imagery Book*.

About the authors

Kathryn Keranen and Lyn Malone coauthored *The Instructional Guide for the ArcGIS Book*. (Esri Press, 2015).

Kathryn Keranen is a retired Fairfax County, Virginia, geosystems high school teacher. Currently an adjunct instructor at James Madison University, she has taught geospatial technology to both students and instructors for more than twenty years. She also coauthored (with Robert Kolvoord) the four-book series *Making Spatial Decisions* (Esri Press).

Lyn Malone is an educational consultant specializing in the classroom application of geospatial technologies. She is also the author of *Mapping Our World: GIS Lessons for Educators* (Esri Press, 2002) and *Community Geography: GIS in Action Teacher's Guide* (Esri Press, 2003).

Data and Image Credits

All screen captures are by Esri.

Chapter 1

NASA/Goddard Space Flight Center Scientific Visualization Studio; Landsat is a joint program of NASA and the US Geological Survey. <http://landsat.usgs.gov>; <http://www.nasa.gov>.

Esri, DigitalGlobe, Earthstar Geographics, CNES/Airbus DS, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS user community.

Esri, USDA, FSA, Microsoft.

U.S. Department of the Interior, U.S. Geological Survey

Esri, DigitalGlobe, Earthstar Geographics, CNES/Airbus DS, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS user community.

“Earth as Art” video by NASA/Goddard Space Flight Center Scientific Visualization Studio; Landsat is a joint program of NASA and the US Geological Survey. <http://landsat.usgs.gov>; <http://www.nasa.gov>.

Storymap, High Resolution Imagery - Additional Levels of Detail Available by Esri. Data sources: Esri, Earthstar Geographics, HERE, DeLorme.

Satellite imagery web map, Imagery with Metadata: Thumbnail, by Esri. Data sources: Esri, DigitalGlobe, Earthstar Geographics, CNES/Airbus DS, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS user community.

Satellite imagery web map, Imagery with Metadata: Full World View, by Esri. Data sources: Earthstar Geographics | Esri, FAO, NOAA.

Satellite imagery web map, Metadata: Eastern Africa, Kilimanjaro Ave, Nairobi by Esri. Data sources: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS user community | DigitalGlobe | Esri Eastern Africa, Esri, © OpenStreetMap contributors, HERE, Garmin, USGS

Satellite imagery web map, Imagery with Metadata: Administrative boundary of Nairobi (Satellite Web Map). Data sources: Earthstar Geographics, CNES/Airbus DS | Esri Eastern Africa, Esri, © OpenStreetMap contributors, HERE, Garmin, USGS.

Satellite imagery web map, Imagery with Metadata: Kenya (satellite web map). Data sources: Earthstar Geographics | Esri Eastern Africa, Esri, HERE, Garmin, FAO, NOAA, USGS.

Satellite imagery web map, Imagery with Metadata: Africa (satellite web map). Data sources: Earthstar Geographics | Esri, Garmin, FAO, NOAA.

Webscene, Interesting Places: Mont Blanc, Italy, by Esri. Data sources: DigitalGlobe, Microsoft | Source: USGS, NGA, NASA, CGIAR, GEBCO, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen, and the GIS user community.

Webscene, Interesting Places Meteor Crater Arizona, by Esri. Data sources: USDA FSA, Microsoft | Source: USGS, NGA, NASA, CGIAR, GEBCO, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen and the GIS user community.

Land of Terror, Earth as Art 4 Collection, U.S. Department of the Interior, NASA, USGS. Data source: Landsat 8.

Satellite imagery web map, Imagery with Metadata: Thumbnail, by Esri. Data sources: Esri, DigitalGlobe, Earthstar Geographics, CNES/Airbus

DS, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS user community.

Satellite imagery web map, Imagery with Metadata: Full World View, by Esri. Data sources: Earthstar Geographics | Esri, FAO, NOAA.

Satellite imagery basemap, Imagery with Labels [Metadata]: Rodonia, Brazil, by Esri. Data Sources: Esri, DigitalGlobe, Earthstar Geographics, CNES/Airbus DS, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS user community.

Satellite imagery web map, Rodonia, Brazil: Urban Areas, by Esri. Earthstar Geographics, CNES/Airbus DS | Esri, HERE, Garmin, USGS.

Satellite imagery web map, Rodonia, Brazil: Urban Areas by Esri. Earthstar Geographics, CNES/Airbus DS | Esri, HERE, Garmin, USGS.

The Landsat 8 Moisture Index web map By Esri. Data Sources U.S. Geological Survey (USGS), National Aeronautics and Space Administration (NASA), Esri.

Moisture Scale for The Moisture Index: How Hot or How Dry? By Learn ArcGIS, Esri. Data sources: U.S. Geological Survey (USGS), National Aeronautics and Space Administration (NASA), Esri.

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Imagery basemap by Esri; Central Park Tour by Kathryn Keranen and Lyn Malone. Data sources: Earthstar Geographics, New York City 1836 from the David Rumsey Historical Map Collection.

Imagery basemap by Esri; Central Park Tour by Kathryn Keranen and Lyn Malone. Data sources: Earthstar Geographics, New York City 1836 from the David Rumsey Historical Map Collection.

Image Source: New York City 1836, David Rumsey Historical Map Collection.

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<http://www.arcgis.com/apps/SimpleViewer/index.html?appid=c24f2796580b4602bd56d9379409ca54>.

<http://learn.arcgis.com/en/projects/oso-mudslide-before-and-after/>.

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Chapter 2

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Esri, Google Open Fonts.

Imagery with Metadata: Thumbnail web map by Esri, DigitalGlobe, Earthstar Geographics, CNES/Airbus DS, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS user community.

Imagery with Metadata: World View web map by Esri, DigitalGlobe, Earthstar Geographics, CNES/Airbus DS, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS user community.

Imagery with Metadata: Washington D.C. web map by Esri, DigitalGlobe, Earthstar Geographics, CNES/Airbus DS, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS user community.

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MODIS Aqua layer, Living Atlas of the World: Esri, HERE, DeLorme, NGA, USGS, DeLorme, NGA, USGS.

Precision Agriculture Analysis web map by Kathryn Keranen. Esri Interface. Data sources: USDA FSA, Microsoft.

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Precision Agriculture Analysis web map by Kathryn Keranen. Esri Interface. Data sources: USDA FSA, Microsoft.

Precision Agriculture Analysis web map by Kathryn Keranen. Esri Interface. Data sources: USDA FSA, Microsoft.

Precision Agriculture Analysis web map by Kathryn Keranen. Esri Interface. Data sources: USDA FSA, Microsoft.

Precision Agriculture Analysis web map by Kathryn Keranen. Esri Interface. Data sources: USDA FSA, Microsoft.

Precision Agriculture Analysis web map by Kathryn Keranen. Esri Interface. Data sources: USDA FSA, Microsoft.

Precision Agriculture Analysis pH web map by Kathryn Keranen. Esri Interface. Data sources: USDA FSA, Microsoft.

Precision Agriculture Analysis Phosphorous web map by Kathryn Keranen. Esri Interface. Data sources: USDA FSA, Microsoft.

Precision Agriculture Analysis Potassium web map by Kathryn Keranen. Esri Interface. Data sources: USDA FSA, Microsoft.

Precision Agriculture Analysis-Filter Analysis web map by Kathryn Keranen. Esri Interface. Data sources: USDA FSA, Microsoft.

Precision Agriculture Analysis-Filter pH web map by Kathryn Keranen. Esri Interface. Data sources: USDA FSA, Microsoft.

Precision Agriculture Analysis P web map by Kathryn Keranen. Esri Interface. Data sources: USDA FSA, Microsoft.

Precision Agriculture Analysis K web map by Kathryn Keranen. Esri Interface. Data sources: USDA FSA, Microsoft.

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<http://learn.arcgis.com/en/projects/analyze-volcano-shelter-access-in-hawaii/>.

Chapter 3

A Landsat Flyby, video courtesy of NASA/Goddard Space Flight Center.

USA National Land Cover Database web map, Esri. Data sources: USA Land Cover 2011: Esri, HERE, Delorme, NGA, USGS.

Seasonal Change web map, Esri. Data Sources: Blue Marble Next Generation imagery produced by Reto Stöckli, NASA Earth Observatory (NASA Goddard Space Flight Center) Earthstar Geographics/Esri, HERE, Garmin.

A Landsat Flyby, video courtesy of NASA/Goddard Space Flight Center.

USA National Land Cover Database web map by Esri. Data sources: Esri, HERE, Garmin, NGA, USGS, NPS | Source: USGS, Esri | Esri, HERE.

USA National Land Cover Database web map legend by Esri.

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Seasonal Change web map, Esri. Data Sources: Blue Marble Next Generation imagery produced by Reto Stöckli, NASA Earth Observatory (NASA Goddard Space Flight Center) Earthstar Geographics/Esri, HERE, Garmin.

Seasonal Change web map Search Function, Esri.

Imagery with Labels, Jordan base map-ArcGIS Online, by Esri. Data sources: Earthstar Geographics | Esri, HERE, Garmin.

Imagery with Labels, Mafraq, Jordan base map-ArcGIS Online, by Esri. Data sources: Earthstar Geographics, CNES/Airbus DS | Esri, HERE, Garmin.

Imagery with Labels, Mafraq, Jordan base map with pin-ArcGIS Online, by Esri. Data sources: Earthstar Geographics, CNES/Airbus DS | Esri, HERE, Garmin.

Open Street Map, Mafraq, Jordan base map with pin-ArcGIS Online, by Esri. Data sources: Map data © OpenStreetMap contributors, CC-BY-SA.

Landsat 8 layer-ArcGIS Online, Esri. Data source: NASA/Landsat 8.

Landsat 8 layer-Zoomed in view, ArcGIS Online, Esri. Data source: NASA/Landsat 8.

Topographic base map-Los Padres National Forest, Esri. Data sources: Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NPS.

Topographic base map-Los Padres National Forest with Soberanes Perimeter Layer, Esri. Data sources: Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NPS.

Topographic base map-Los Padres National Forest with Soberanes Perimeter layer (rendered display, pre-fire), Esri. Data sources: Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NPS.

Topographic base map-Los Padres National Forest with Soberanes Perimeter layer (rendered display, post-fire), Esri. Data sources: Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NPS.

Topographic base map-Los Padres National Forest with Soberanes Perimeter layer (rendered display, infrared), Esri. Data sources: Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NPS.

Gibson Fires, by Kathryn Keranen and Lyn Malone. Imagery with Labels, Longitude: 127.859769, Latitude: -23.284888-ArcGIS Online, by Esri. Data sources: Earthstar Geographics | Esri, HERE, Garmin.

Pre-Gibson Fires by Kathryn Keranen and Lyn Malone. Imagery with Labels, Longitude: 127.859769, Latitude: -23.284888-ArcGIS Online, by Esri. Data sources: Earthstar Geographics | Esri, HERE, Garmin, Landsat 8.

Post-Gibson Fires by Kathryn Keranen and Lyn Malone. Imagery with Labels, Longitude: 127.859769, Latitude: -23.284888-ArcGIS Online, by Esri. Data sources: Earthstar Geographics | Esri, HERE, Garmin, Landsat 8.

ArcGIS Online Interface-polygon measurement tool, Esri, over Post-Gibson Fires by Kathryn Keranen and Lyn Malone. Imagery with Labels, Longitude: 127.859769, Latitude: -23.284888-ArcGIS Online, by Esri. Data sources: Earthstar Geographics | Esri, HERE, Garmin, Landsat 8.

Post-Gibson Fires by Kathryn Keranen and Lyn Malone. Imagery with Labels, Longitude: 127.859769, Latitude: -23.284888 with Landsat 8 Views layer, Stretch Type Deviation-ArcGIS Online, by Esri. Data sources: Earthstar Geographics | Esri, HERE, Garmin, Landsat 8.

Fires on the Island of Madere, Madeira, Portugal by Kathryn Keranen and Lyn Malone. Imagery with Labels base map-ArcGIS Online, by Esri. Data sources: Earthstar Geographics, CNES/Airbus DS | Esri, HERE, Garmin.

Fires on the Island of Madere, Madeira, Portugal (Natural color view) by Kathryn Keranen and Lyn Malone. Imagery with Labels base map-ArcGIS Online, by Esri. Data sources: Earthstar Geographics, CNES/Airbus DS | Esri, HERE, Garmin, Landsat 8.

Fires on the Island of Madere, Madeira, Portugal (Infrared view) by Kathryn Keranen and Lyn Malone. Imagery with Labels basemap-ArcGIS Online, by Esri. Data sources: Earthstar Geographics, CNES/Airbus DS | Esri, HERE, Garmin, NASA/Landsat 8.

ArcGIS Online Interface-polygon measurement tool, Esri, over Fires on the Island of Madere, Madeira, Portugal (Infrared view) by Kathryn Keranen and Lyn Malone. Imagery with Labels basemap-ArcGIS Online, by Esri. Data sources: Earthstar Geographics, CNES/Airbus DS | Esri, HERE, Garmin, NASA/Landsat 8.

Fires on the Island of Madere, Madeira, Portugal (with Normalized Burn Index (NBR) display) by Kathryn Keranen and Lyn Malone. Imagery with Labels basemap-ArcGIS Online, by Esri. Data sources: Earthstar Geographics, CNES/Airbus DS | Esri, HERE, Garmin, NASA/Landsat 8.

Aral Sea map by Kathryn Keranen and Lyn Malone. Imagery with Labels basemap-ArcGIS Online, by Esri. Data sources: DigitalGlobe | Esri CIS, Esri, HERE, Garmin.

Aral Sea map by Kathryn Keranen and Lyn Malone. Imagery with Labels basemap-ArcGIS Online, by Esri. Data sources: DigitalGlobe | Esri CIS, Esri, HERE, Garmin, NASA/Landsat 8.

Aral Sea map by Kathryn Keranen and Lyn Malone. Imagery with Labels basemap-ArcGIS Online, by Esri. Data sources: DigitalGlobe | Esri CIS, Esri, HERE, Garmin, NASA/Landsat 8.

Aral Sea map with Island Digitization map by Kathryn Keranen and Lyn Malone. Imagery with Labels basemap-ArcGIS Online, by Esri. Data sources: DigitalGlobe | Esri CIS, Esri, HERE, Garmin, NASA/Landsat 8.

Aral Sea map with 1984 perspective map by Kathryn Keranen and Lyn Malone. Imagery with Labels basemap-ArcGIS Online, by Esri. Data sources: DigitalGlobe | Esri CIS, Esri, HERE, Garmin, NASA/Landsat 8.

Aral Sea map with colorized historical symbology map by Kathryn Keranen and Lyn Malone. Imagery with Labels basemap-ArcGIS Online, by Esri. Data sources: DigitalGlobe | Esri CIS, Esri, HERE, Garmin, NASA/Landsat 8.

Aral Sea Story map by Kathryn Keranen and Lyn Malone. Imagery with Labels basemap-ArcGIS Online, by Esri. Data sources: DigitalGlobe | Esri CIS, Esri, HERE, Garmin, NASA/Landsat 8.

Aral Sea Tabbed Series by Kathryn Keranen and Lyn Malone. Imagery with Labels basemap-ArcGIS Online, by Esri. Data sources: DigitalGlobe | Esri CIS, Esri, HERE, Garmin, NASA/Landsat 8.

Aral Sea final results map by Kathryn Keranen and Lyn Malone. Imagery with Labels basemap-ArcGIS Online, by Esri. Data sources: DigitalGlobe | Esri CIS, Esri, HERE, Garmin, NASA/Landsat 8.

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Elevation in Oaxaca, Mexico web map by the Kathryn Keranen and Lyn Malone. Data sources: Esri, HERE, Garmin, INCREMENT P, USGS, METI/ NASA, NGA.

Elevation in Oaxaca, Mexico web map by Kathryn Keranen and Lyn Malone. Data sources: Esri, HERE, Garmin, INCREMENT P, USGS, METI/ NASA, NGA.

Elevation in Oaxaca, Mexico (with overlay of Transparency tool) web map by Kathryn Keranen and Lyn Malone. Data sources: Esri, HERE, Garmin, INCREMENT P, USGS, METI/NASA, NGA.

Elevation in Oaxaca, Mexico web map by Kathryn Keranen and Lyn Malone. Data sources: Esri, HERE, Garmin, INCREMENT P, USGS, METI/ NASA, NGA.

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Chapter 4

Top Earth Images of 2016 video courtesy of NASA Johnson used under YouTube Standard License.

A World of Circles web map by Esri. Data sources: Earthstar, Geographics, CNES/Airbus, DS

Landsat App by Esri. Data sources: HERE, City of Riverside, County of Riverside (opening scene), Esri, HERE, Garmin, NGA, USGS.

Landsat Explorer App by Esri. Data sources: HERE, City of Riverside, County of Riverside (opening scene), Esri, HERE, Garmin, NGA, USGS

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A World of Squares, New Orleans map by Kathryn Keranen and Lyn Malone, derived from A World of Circles web map by Esri.Earthstar, Geographics, CNES/Airbus, DS.

A World of Squares, New Orleans pivot map by Kathryn Keranen and Lyn Malone, derived from A World of Circles web map by Esri.Earthstar, Geographics, CNES/Airbus, DS.

A World of Squares, New Orleans pivot map B by Kathryn Keranen and Lyn Malone, derived from A World of Circles web map by Esri.Earthstar, Geographics, CNES/Airbus, DS.

A World of Squares, New Orleans (with Item Details dropdown menu) by Kathryn Keranen and Lyn Malone, derived from A World of Circles web map by Esri.Earthstar, Geographics, CNES/Airbus, DS.

Landsat Explorer App (with Time tool overlay) by Esri. Data sources: HERE, City of Riverside, County of Riverside (opening scene), Esri, HERE, Garmin, NGA, USGS.

Landsat Explorer App, Washington D.C. (natural color) by Esri. Data sources: HERE, City of Riverside, County of Riverside (opening scene), Esri, HERE, Garmin, NGA, USGS.

Landsat Explorer App, Washington D.C. (Infrared view) by Esri. Data sources: HERE, City of Riverside, County of Riverside (opening scene), Esri, HERE, Garmin, NGA, USGS.

Wadi As-Sirhan, Saudi Arabia (Vegetation Index) map by Kathryn Keranen and Lyn Malone. Derived from Landsat Explorer App by Esri. Data sources: HERE, City of Riverside, County of Riverside (opening scene), Esri, HERE, Garmin, NGA, USGS.

Abu Dhabi, United Arab Emirates map by Kathryn Keranen and Lyn Malone. Derived from Landsat Explorer App by Esri. Data sources: HERE, City of Riverside, County of Riverside (opening scene), Esri, HERE, Garmin, NGA, USGS.

Landsat Explorer App by Esri. Data sources: HERE, City of Riverside, County of Riverside (opening scene), Esri, HERE, Garmin, NGA, USGS.

Shenandoah National Park map derived from Landsat Explorer App (overlayed by layer selector tool) by Esri. Data sources: HERE, City of Riverside, County of Riverside (opening scene), Esri, HERE, Garmin, NGA, USGS.

Shenandoah National Park map derived from Landsat Explorer App by Esri. Data sources: HERE, City of Riverside, County of Riverside (opening scene), Esri, HERE, Garmin, NGA, USGS.

Shenandoah National Park map derived from Landsat Explorer App (overlayed by Details dialogue box) by Esri. Data sources: HERE, City of Riverside, County of Riverside (opening scene), Esri, HERE, Garmin, NGA, USGS.

Shenandoah National Park map derived from Landsat Explorer App (overlayed by Search for layers tool) by Esri. Data sources: HERE, City of Riverside, County of Riverside (opening scene), Esri, HERE, Garmin, NGA, USGS.

Shenandoah National Park (with Rendering tool overlay) map derived from Landsat Explorer App (overlayed by Search for layers tool) by Esri. Data sources: HERE, City of Riverside, County of Riverside (opening scene), Esri, HERE, Garmin, NGA, USGS.

Landsat Explorer App (with Story Map tool overlay) by Esri. Data sources: HERE, City of Riverside, County of Riverside (opening scene), Esri, HERE, Garmin, NGA, USGS.

Shenandoah National Park map derived from Landsat Explorer App (overlayed by Search for layers tool) by Esri. Data sources: HERE, City of Riverside, County of Riverside (opening scene), Esri, HERE, Garmin, NGA, USGS.

Landsat Explorer App by Esri. Data sources: HERE, City of Riverside, County of Riverside (opening scene), Esri, HERE, Garmin, NGA, USGS.

Les Cayes, Haiti map derived from Landsat Explorer App (overlaid by Search for layers tool) by Esri. Data sources: HERE, City of Riverside, County of Riverside (opening scene), Esri, HERE, Garmin, NGA, USGS.

Les Cayes, Haiti map (with Infrared Render tool) derived from Landsat Explorer App (overlaid by Search for layers tool) by Esri. Data sources: HERE, City of Riverside, County of Riverside (opening scene), Esri, HERE, Garmin, NGA, USGS.

Les Cayes, Haiti map (with Date Selector tool overlay) derived from Landsat Explorer App (overlaid by Search for layers tool) by Esri. Data sources: HERE, City of Riverside, County of Riverside (opening scene), Esri, HERE, Garmin, NGA, USGS.

Les Cayes, Haiti map (with Time Slider tool overlay) derived from Landsat Explorer App (overlaid by Search for layers tool) by Esri. Data sources: HERE, City of Riverside, County of Riverside (opening scene), Esri, HERE, Garmin, NGA, USGS.

Les Cayes, Haiti map (with Difference Mask tool overlay) derived from Landsat Explorer App (overlaid by Search for layers tool) by Esri. Data sources: HERE, City of Riverside, County of Riverside (opening scene), Esri, HERE, Garmin, NGA, USGS.

Les Cayes, Haitimap (with Polygon Selection tool overlay) derived from Landsat Explorer App (overlaid by Search for layers tool) by Esri. Data sources: HERE, City of Riverside, County of Riverside (opening scene), Esri, HERE, Garmin, NGA, USGS.

Landsat Explorer App by Esri. Data sources: HERE, City of Riverside, County of Riverside (opening scene), Esri, HERE, Garmin, NGA, USGS.

Cedar Rapids, Iowa map by Kathryn Keranen and Lyn Malone derived from Landsat Explorer App by Esri. Data sources: HERE, City of Riverside, County of Riverside (opening scene), Esri, HERE, Garmin, NGA, USGS.

Cedar Rapids, Iowa with Render tool overlay-(Infrared View) map by Kathryn Keranen and Lyn Malone derived from Landsat Explorer App by Esri. Data sources: HERE, City of Riverside, County of Riverside (opening scene), Esri, HERE, Garmin, NGA, USGS.

Cedar Rapids, Iowa with Mask tool overlay-(Infrared View) map by Kathryn Keranen and Lyn Malone derived from Landsat Explorer App by Esri. Data sources: HERE, City of Riverside, County of Riverside (opening scene), Esri, HERE, Garmin, NGA, USGS.

Cedar Rapids, Iowa with Mask slider dialogue box overlay (Infrared View) map by Kathryn Keranen and Lyn Malone derived from Landsat Explorer App by Esri. Data sources: HERE, City of Riverside, County of Riverside (opening scene), Esri, HERE, Garmin, NGA, USGS.

Cedar Rapids, Iowa with Time Slider tool overlay-(Infrared View) map by Kathryn Keranen and Lyn Malone derived from Landsat Explorer App by Esri. Data sources: HERE, City of Riverside, County of Riverside (opening scene), Esri, HERE, Garmin, NGA, USGS.

Cedar Rapids, Iowa with Record Masked Area tool overlay-(Infrared View) map by Kathryn Keranen and Lyn Malone derived from Landsat Explorer App by Esri. Data sources: HERE, City of Riverside, County of Riverside (opening scene), Esri, HERE, Garmin, NGA, USGS.

Cedar Rapids, Iowa with Masked Area tool overlay (Infrared View) map by Kathryn Keranen and Lyn Malone derived from Landsat Explorer App by Esri. Data sources: HERE, City of Riverside, County of Riverside (opening scene), Esri, HERE, Garmin, NGA, USGS.

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Chapter 5

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A World of Circles by Esri. Data sources: Earthstar, Geographics, CNES/Airbus, DS.

Landsat App by Esri. Data courtesy of HERE, City of Riverside, County of Riverside (opening scene), Esri, HERE, Garmin, NGA, USGS.

Landsat Explorer by. Data Sources: Esri, HERE, City of Riverside, County of Riverside (opening scene), Esri, HERE, Garmin, NGA, USGS.

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Great Lakes Region Land Cover Report, A NOAA O-CAP story map. Data sources: NOAA Office for Coastal Management | Earthstar Geographics | Esri, HERE, Garmin.

Regional Land Cover Change Reports, 1996 - 2010, Great Lakes Region Land Cover Report, A NOAA O-CAP story map. Data sources: NOAA Office for Coastal Management | Earthstar Geographics | Esri, HERE, Garmin.

Explore a Tapestry of World Ecosystems a story map by Esri. Data sources: Esri, GEBCO, DeLorme | Source: USGS, Esri, Metzger, et.al., 2012, ESA, GEO | Source: Esri, USGS, ESA, GEO, WorldClim.

Explore the Ecological Tapestry of the World a story map by Esri. Data sources: Esri, GEBCO, DeLorme | Source: USGS, Esri, Metzger, et.al., 2012, ESA, GEO | Source: Esri, USGS, ESA, GEO, WorldClim.

Explore the Ecological Tapestry of the World (showing contributing layers) a story map by Esri. Data sources: Esri, GEBCO, DeLorme | Source: USGS, Esri, Metzger, et.al., 2012, ESA, GEO | Source: Esri, USGS, ESA, GEO, WorldClim.

Explore the Ecological Tapestry of the World (showing Great Lakes Region) a story map by Esri. Data sources: Esri, GEBCO, DeLorme | Source: USGS, Esri, Metzger, et.al., 2012, ESA, GEO | Source: Esri, USGS, ESA, GEO, WorldClim.

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Landscape base map, Living Atlas; TopBathy Layer, Living Atlas.

Landscape layer, Living Atlas; TopBathy Layer, Living Atlas by Esri. Data sources: Esri, FAO, NOAA | USGS, NGA, NASA, CGIAR, GEBCO, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen, and the GIS user community.

Landscape base map, Living Atlas; TopBathy Layer, Living Atlas; Highest Structures layer, Living Atlas; Lowest Structure in the Ocean, Living Atlas; Structures Below Sea Level, Living Atlas. by Esri. Data sources: Esri, FAO, NOAA | USGS, NGA, NASA, CGIAR, GEBCO, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen and the GIS user community.

Terrain layer, by Esri. Data sources: Data sources: Terra Mapping the Globe Ltd, Esri, HERE, Garmin, INCREMENT P, USGS, METI/NASA | USGS, NGA, NASA, CGIAR, GEBCO, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen and the GIS user community. Terrain Slope map layer by Esri. Data Sources: Terra Mapping the Globe Ltd, Esri, HERE, Garmin, INCREMENT P, USGS, METI/NASA | USGS, NGA, NASA, CGIAR, GEBCO, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen and the GIS user community | USGS, NGA, NASA, CGIAR, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen and the GIS user community. Terrain Hillshade map layer by Esri. Data sources: Terra Mapping the Globe Ltd, Esri, HERE, Garmin, INCREMENT P, USGS, METI/NASA | USGS, NGA, NASA, CGIAR, GEBCO, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen and the GIS user community | USGS, NGA, NASA, CGIAR, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen and the GIS user community.

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USGS National map layer, by USGS. Data Sources: Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, AAFC, NRCan | USGS,NGA,NASA,CGIAR,GEBCO,N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen and the GIS user community | USGS, NGA, NASA, CGIAR,N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen and the GIS user community | USGS The National Map: National Boundaries Dataset, National Elevation Dataset, Geographic Names Information System, National Hydrography Dataset, National Land Cover Database, National Structures Dataset, and National Transportation Dataset; U.S. Census Bureau - TIGER/Line; HERE Road Data.

Terrain: Aspect map layer, Living Atlas by Esri. Data sources: Terra Mapping the Globe Ltd, Esri, HERE, Garmin, INCREMENT P, USGS, METI/NASA | USGS, NGA, NASA, CGIAR, GEBCO, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen and the GIS user community | USGS, NGA, NASA, CGIAR,N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen and the GIS user community.

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Chapter 6

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Katrina Track by NOAA, National Hurricane Center: NHC Data in GIS Formats. Data Source: NOAA.

Detailed Water geodatabase by Esri. Data sources: Esri, USGS.

Kathryn Keranen.

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ArcGIS Online: Scene Basics, produced by Esri.

3D Across All Scales scene by Esri. Data. Data sources: Earthstar Geographics | Source: USGS, NGA, NASA, CGIAR, GEBCO, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen and the GIS user community.

Precipitation Pattern of South Americaby NOAA. Data sources: Earthstar Geographics | Source: USGS, NGA, NASA, CGIAR, GEBCO, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen and the GIS user community | WorldClim, CIAT.

ArcGIS Online-Details dialogue box by Esri.

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ArcGIS Online-3D Across All Scales Scenes Full Screen version by Esri. Data sources: Data sources: Earthstar Geographics | Source: USGS, NGA, NASA, CGIAR, GEBCO, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen and the GIS user community.

Katrina Track map by NOAA, National Hurricane Center: NHC Data in GIS Formats. Data Source: NOAA.

Katrina Track Windspeed map by NOAA, National Hurricane Center: NHC Data in GIS Formats. Data Source: NOAA.

Katrina Track Windspeed map by NOAA, National Hurricane Center: NHC Data in GIS Formats. Data Source: NOAA.

Katrina Tracker Speed and Pressure map by NOAA, National Hurricane Center: NHC Data in GIS Formats; overlay of Configure App Scene tool by Esri. Data Sources: NOAA.

House Sites in Lake Junaluska, NC map Layer by Kathryn Keranen. Data source: Kathryn Keranen.

House Sites in Lake Junaluska, NC map Layer by Kathryn Keranen. Data source: Kathryn Keranen.

House Sites in Lake Junaluska, NC map Layer by Kathryn Keranen. Data source: Kathryn Keranen.

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House Sites in Lake Junaluska, NC map Layer by Kathryn Keranen. Data source: Kathryn Keranen.

ArcGIS Organizational Account by Esri. 3D Map Scene, by Esri. Map Scene data sources: Esri, HERE, FAO, NOAA | Source: USGS, NGA, NASA, CGIAR, GEBCO, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen and the GIS user community

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Learn ArcGIS Lesson, Get Started with Drone2Map for ArcGIS, Esri. Data sources: Pix4D, Ascending Technologies.

Learn ArcGIS Lesson, I Can See for Miles and Miles, Esri. Data sources: DoBH, OS, Esri, HERE, Garmin, USGS, NGA.

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Chapter 7

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National Consortium for the Study of Terrorism and Responses to Terrorism (START). (2016). Global Terrorism Database [Data file]. Retrieved from <https://www.start.umd.edu/gtd>.

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Sea Level Rise and Coastal Flooding Impacts, New York City zoom by NOAA. Data sources: United States Department of Commerce | National Oceanic and Atmospheric Administration | National Ocean Service | USA.gov.

Sea Level Rise and Coastal Flooding Impacts, New York City circled in red by NOAA. Data sources: United States Department of Commerce | National Oceanic and Atmospheric Administration | National Ocean Service | USA.gov.

Sea Level Rise and Coastal Flooding Impacts, New York City zoom by NOAA. Data sources: United States Department of Commerce | National Oceanic and Atmospheric Administration | National Ocean Service | USA.gov.

The Landsat Change Matters Viewer, Changes to Lake Urmia, Iran by Esri. Data sources: USGS, NASA, Global Land Survey (GLS) Landsat Imagery, Kass Green & Associates, Tukman Geospatial, dtsagile.

The Landsat Change Matters Viewer, Changes to Bear Glacier, Alaska by Esri. Data sources: USGS, NASA, Global Land Survey (GLS) Landsat Imagery, Kass Green & Associates, Tukman Geospatial, dtsagile.

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USGS Historical Topographic Map Explorer, Johnson Space Center by USGS. Data sources: City of Houston, Texas Parks & Wildlife, Esri, HERE, Garmin, USGS, NGA, EPA, USDA, NPS.

USGS Historical Topographic Map Explorer, Johnson Space Center by USGS. Data sources: City of Houston, Texas Parks & Wildlife, Esri, HERE, Garmin, USGS, NGA, EPA, USDA, NPS.

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Esri. Data sources: Earthstar Geographics, CNES/Airbus DS | source: National Hydrography Dataset - USGS.

Esri. Data sources: Esri, TomTom, U.S. Department of Commerce, U.S. Census Bureau.

Esri. Data sources: Esri, TomTom, U.S. Department of Commerce, U.S. Census Bureau.

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Landsat Global Land Survey Esri. Data sources: Landsat Global Land Survey Esri, USGS, NASA Landsat.

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Chapter 9

The National Map: USGS: United States by the U.S. Department of the Interior | U.S. Geological Survey

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The U.S. Drought Monitor is produced through a partnership between the National Drought Mitigation Center at the University of Nebraska-Lincoln, the United States Department of Agriculture, and the National Oceanic and Atmospheric Administration.

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