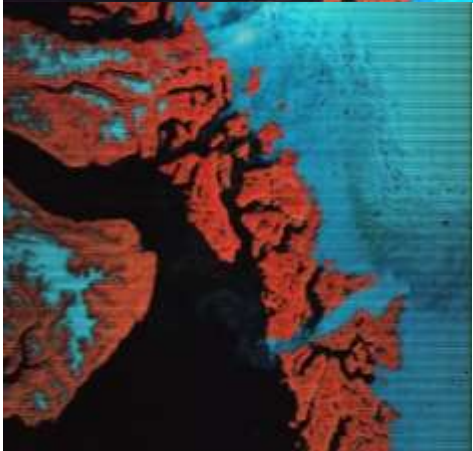


GloVis

USGS Global Visualization Viewer



More Lessons from the Sky
Satellite Educators Association
<https://SatEd.org>

Please see the Acknowledgements section for historical contributions to the development of this lesson plan. This form of “GloVis USGS Global Visualization Viewer” was published in November 2014 in “More Lessons from the Sky,” a regular feature of the SEA Newsletter, and archived in the SEA Lesson Plan Library. Both the Newsletter and the Library are freely available on-line from the Satellite Educators Association (SEA) at this address: <https://SatEd.org>.

Content, Internet links, and support material available from the online Resources page revised and updated March 2022.

SEA Lesson Plan Library Improvement Program

Did you use this lesson plan with students? If so, please share your experience to help us improve the lesson plan for future use. Just click the Feedback link at <https://SatEd.org/library/about.htm> and complete the short form on-line. Thank you.

GLOVIS

Global Visualization and Analysis

Invitation

Since artificial satellites first orbited Earth in 1956, scientists, both amateur and professional, have collected and studied the vast amounts of observations made by, and transmitted to us, from sensors on those satellites. Most of these data are archived in databases that have been used only by expert investigators trained in the use of specialized retrieval techniques and analysis tools.

More recently, the National Aeronautics and Space Administration (NASA), the National Oceanic and Atmospheric Administration (NOAA), and the U.S. Geological Survey (USGS), among others, have developed online tools for easy retrieval of archived data in various forms that serve the needs of every level of scientific research including middle and high school grade levels.

This hands-on tutorial guide is an introduction to **GloVis**, the USGS Global Visualization Viewer (GloVis), a quick and easy online search tool for selected satellite and aerial data. GloVis provides access to imagery from aerial surveys, EO-1, and Landsat satellites among others. Following the tutorial steps, learners will experience the value and utility of GloVis for themselves while becoming familiar with its "look and feel" as they investigate changes in Greenland's Jacobshavn Glacier.

Grade Level:	6-12
Time Requirement:	2 class periods
Prerequisites:	None
Relevant Disciplines:	All

Student Learning Outcomes

By the end of this lesson, students should be able to do the following:

- Use GloVis, an online data retrieval and visualization tool from USGS
- Access satellite-based remote sensing data from USGS archives
- Demonstrate knowledge of how to use GloVis independently
- Analyze and interpret sequences of images
- Construct explanations for the interpretations
- Assess the value of various graphical displays of data generated with GloVis
- Communicate findings with others

Lesson Description

GloVis is a web application that provides an easy way to “view, order, and download remotely sensed data.”

<https://www.usgs.gov/centers/eros/science/glovis-short-and-simple-tutorial>

This tutorial lesson is intended to supplement existing curriculum in order to add GloVis to the student's toolbox of data acquisition skills. By way of introduction to GloVis,

Teaching Notes

learners will take a built-in tour of GloVis, and, following this tutorial guide, they will access, visualize, and analyze selected data. Learners are then invited to explore the available image collections by repeating the process to retrieve data of their own choosing. They will access image metadata from which they will extract source and parameter information related to their selected data and enhance their explanations of the generated imagery and use of GloVis. Throughout the tutorial, learners will encounter questions to be answered on a separate answer sheet.

This is a web-based activity that requires computer terminals with Internet access for each student or group of students. It is recommended that no more than two to four students be assigned to a computer at one time.

While no prerequisite is listed for this activity, the tutorial would be much more meaningful if students had a reason for learning how to use GloVis. For example, learners may want to access and visualize satellite imagery of polar ice to determine how the ice extent is changing. Some knowledge of satellite remote sensing and remotely sensed datasets ahead of time would be valuable.

Important Terms

Calving (glaciers)	Interpolate	Longitude
Glacier	Landsat	Metadata
GloVis	Latitude	Terminus (glacier)

Assessment Suggestions

Summative assessment: correct completion of the answer sheet and determination of whether learners are able to use GloVis to obtain sufficient data relevant to their own investigations. This is best determined when individual learners are able to complete the Your Turn extension activities on their own. Formative assessments can be made while learners work through the tutorial and the teacher circulates to monitor student-computer and student-student interactions.

Next Generation Science Standards

The Next Generation Science Standards present performance expectations for assessment of learning. Each suggested assessment task bundles together a disciplinary core idea, science and engineering practice, and crosscutting concept that are to be connected in the same lesson. The National Research Council (NRC) states that standards must take into account that students cannot fully understand scientific and engineering ideas without engaging in the practices of inquiry. At the same time, they cannot show competence in practices except in the context of specific content. Following that line of reasoning, the NRC identified eight practices of science and engineering that are essential for all students to learn:

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking

6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

The tutorial guide in this lesson plan is meant to augment curriculum and instruction of other content by providing broader access to specific data that may otherwise not be available to middle and high school students in the course of learning about that other content. Therefore, this lesson plan does not emphasize any specific core content, but rather supports the learning of appropriate practices associated with many content core ideas. Of the eight identified science and engineering practices listed by the NRC, this lesson plan supports the learning and teaching of these specifically:

- 3. Planning and carrying out investigations**
- 4. Analyzing and interpreting data**
- 5. Using mathematics and computational thinking**
- 8. Obtaining, evaluating, and communicating information**

Components of each of these practices can be found in the Next Generation Science Standards at all grade levels K-2, 3-5, 6-8, and 9-12 and associated with disciplinary core ideas and performance expectations for all subject areas.

Preparation

An Internet enabled computer for each learner or group of learners is needed for this activity. Most of the exercise can be accomplished online. It is recommended that learners work in groups of two to four at each computer.

The tutorial guide in the Student Activity pages should be duplicated and distributed one copy per learner group or one to each student for reference if desired. The answer sheet in the Student Activity section should be duplicated and distributed to each student.

The lesson plan document is supplied in portable document format (PDF). An acceptable PDF viewer such Adobe Reader (<https://get2.adobe.com/reader/>) or equivalent is required to read and print the document. The Student Activity pages are also available in Microsoft Word document (DOCX) format to allow teachers greater flexibility in easily adapting those pages to meet the varying needs of curriculum, students, and classroom situations.

GloVis is a web-based application made available by the United States Geological Survey (USGS). It requires an Internet enabled computer and a competent, up-to-date web browser.

You may decide to register a username and password with the USGS so you can log-in and download scenes. Experience of those in the classroom suggests it is faster to download lesson specific files ahead of time and have them available to the local student computers when needed. If teams or individual learners are doing independent research, the teacher will have to decide how best to handle the username and password or student accounts. Perhaps, learners can request specific files that the teacher downloads and makes available at a later time.

Teaching Notes

A decompression and extraction program is required to access files in the **.zip** or **.tar.gz** folders once downloaded. While later versions of Windows have some decompression (expansion) capability, 7-Zip (PC) and Stuffit Expander (Mac) have been remarkably reliable for decompression and extraction. Both are free of charge, easy to install, and very easy to use. 7-Zip is available in 32- and 64-bit configurations for multiple operating systems from <https://www.7-zip.org/>. Stuffit Expander is available from <https://www.stuffit.com/>.

ImageJ was used to process the image described earlier. ImageJ is a powerful, high-quality, scientific image processing program originally developed by the National Institute of Health for medical imaging and research. Now in the public domain, it is downloadable from <https://imagej.nih.gov/ij/>. It is available for both Windows and Macintosh at no charge. Full documentation and extra plug-ins are also available at the same site. Additionally, the ImageJ User Guide is also available from the SEA Lesson Plan Library's Analysis Toolbox at <https://SatEd.org/library/Tools.htm>.

It is recommended that Windows users install ImageJ in its own folder outside of the default Program Files folder. Protection protocols built into this folder do not allow ImageJ updates in Windows Vista and later versions.

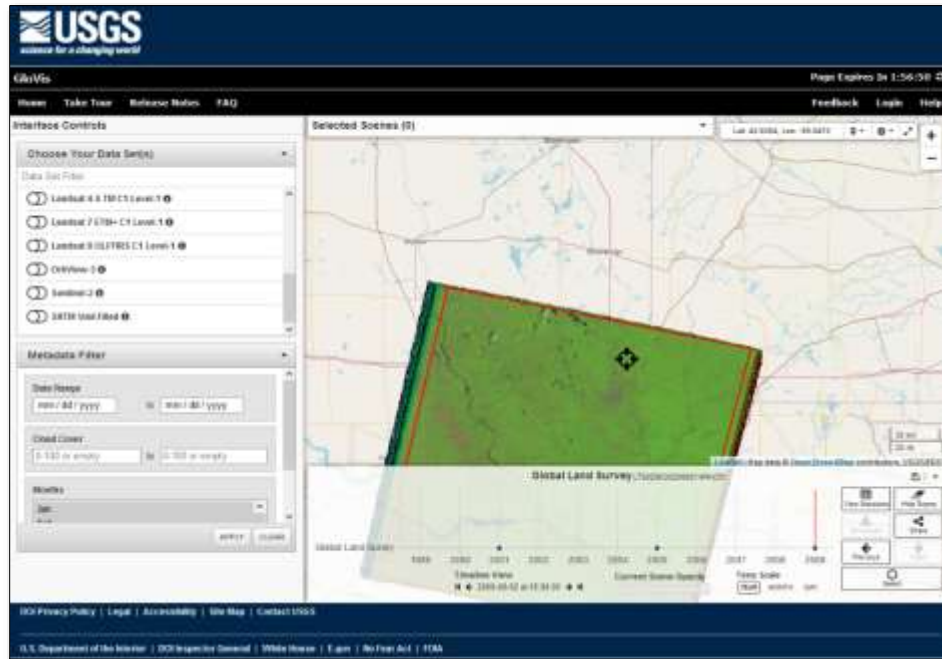
Background

Throughout this edition of Teaching Notes and the associated Student Activity, it has been assumed that learners have already been introduced to environmental satellites, some of their remote sensors and products. If needed, an introduction to satellites including environmental satellites, remote sensing, remote sensing datasets, and no-cost, high quality, professional software packages for visualization, analysis, and interpretation can be found in the article, "Environmental Satellites in Your Classroom, Incorporating Satellite-Based Data When Planning Lessons." The article was first published in the online Newsletter of the Satellite Educators Association. The article can be read online or downloaded in PDF from this web address:

<https://SatEd.org/library/Tools.htm>.

GloVis is an acronym of the U.S. Geological Survey that stands for **Global Visualization Viewer**. It is an easy-to-use graphical user interface related to the USGS Earth Explorer. It allows easier access to the satellite and aerial survey scenes in the USGS Earth Resources Observation Science Center (EROS) inventory. You can access GloVis at <https://glovis.usgs.gov/>. When the web page opens, the user is given the choice of launching GloVis or launching GloVis in full screen mode. It is recommended that GloVis be launch initially in standard mode (not full screen) to allow the user to become accustomed to the peripheral information in the screen header and footer. Additionally, the login button is in the header. Although not required, it may be helpful to look at that page now while reading through the following material.

When planning to use GloVis as a data search and retrieval tool, consideration should be given to the type of data available in the EROS collections, including their sources, and the data format.



Collections and Data Sources

Selecting a data collection for use depends on the research question or hypothesis under consideration including the time period of interest. For example, if the question relates to land cover in 1990, the investigator might access Global Land Survey imagery. On the other hand, an investigation of global cryospheric changes might lead an investigator to more recent Landsat imagery. The data collections accessible with GloVis are listed below. Click the **i** next to each on screen for more information.

- ▶ **DOQ** (Digital Orthophoto Quadrangles) – computer generated images of aerial photography in 3.75 minute and 7.5 minute quadrangles.
- ▶ **EO-1** – Advanced Land Imager (10 spectral bands) and Hyperion (220 spectral bands) on Earth-Observing One (2000-2017)
- ▶ **Global Land Survey** – from Landsat imagery (1972-2012)
- ▶ **IRS** – Advanced Wide Field Sensor (AWiFS) and Linear Imager Self-Scanning Sensor (LISS-3) on Resourcesat-1 and Resourcesat-2 (USGS partnership with Indian Space Research Organization) (2003-present)
- ▶ **Landsat 1-5 MSS** – Multispectral Scanner on Landsat 1-5 (1972-1992)
- ▶ **Landsat 4-5 TM** – Thematic Mapper on Landsat 4 and 5 (1982-2012)
- ▶ **Landsat 7 ETM+** – Enhanced Thematic Mapper Plus on Landsat 7 (1999-2003; 2003-present with data gaps)
- ▶ **Landsat 8 OLI/TIRS** – Operational Land Imager and Thermal Infrared Sensor on Landsat 8 (2013-present)
- ▶ **OrbView-3** – commercial, high resolution imagery; panchromatic (black & white) and multispectral (color) (2003-2007)
- ▶ **Sentinel-2** – land and sea monitoring, natural disaster mapping, sea ice observation, ships detection; ESA Copernicus Programme, (2015-present)
- ▶ **SRTM** – Shuttle Radar Topography Mission (February 11-22, 2000)

Teaching Notes

Data Format

Data retrieved with GloVis are displayed on-screen in compressed JPEG images of 100-300KB. They can be saved to your local computer by screen capture. High resolution JPEG and TIFF images (~12MB and 250MB, respectively) can be ordered and downloaded. These images have already been processed to Level 1, 2, or 3. The chart below summarizes image processing levels as defined by NASA.

Level	Description
0	Reconstructed, unprocessed instrument and payload data at full resolution, with any and all communications artifacts removed.
1a	Reconstructed, unprocessed instrument data at full resolution, time-referenced, and annotated with radiometric and geometric calibration coefficients and georeferencing parameters computed and appended but not applied to Level 0 data. Level 0 data are recoverable from 1a data.
1b	Level 1a data that have been processed to sensor units; not all instruments have Level 1b data; Level 0 data are not recoverable from Level 1b data.
2	Derived geophysical variables at the same resolution and location as Level 1 source data.
3	Variables mapped on uniform spacetime grid scales, usually with some completeness and consistency (e. g., missing points interpolated, complete regions composited from multiple orbits, etc.).
4	Model output or results from analyses of lower level data (i. e., variables that were not measured by the instruments but instead are derived from these measurements).

Learners are encouraged to use the screen capture method in this lesson. If the need arises to download high resolution images, an account with username and password is required. The registration process to create an account is very quick online, and there is no cost. Click the Login button on the GloVis home page. Register a username and password to create an account. It is suggested that only the teacher create an account and then download images when requested by students.

More than one file is available for download for each Landsat scene. For example, the download list for Landsat 7 scene, Path 10 Row 11, in June of 2000 looks like this:

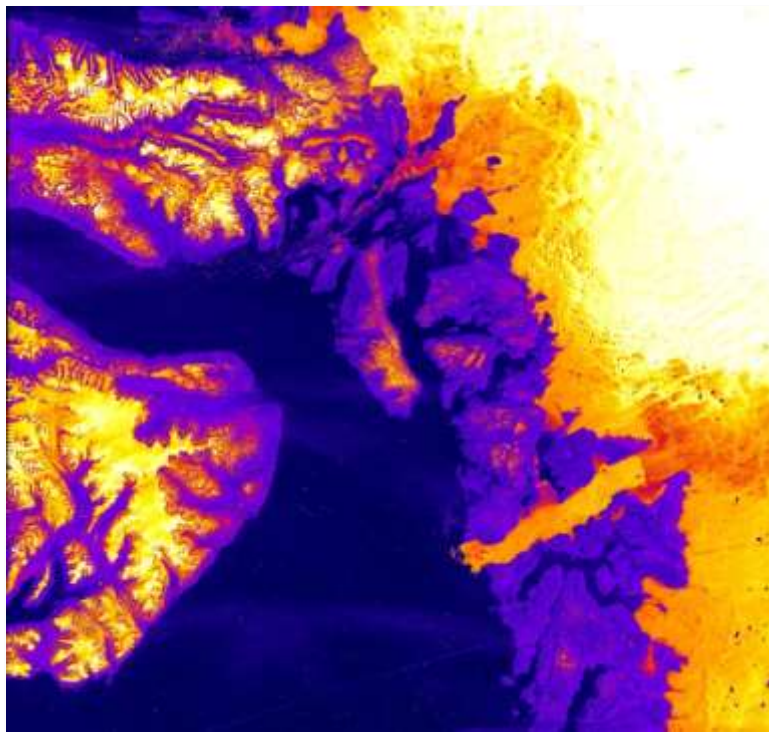


- **LandsatLook Natural Color Image** is a single JPEG image file. This image is 8701x8261 pixels in size and 8.30MB. In this Arctic scene, "natural color" is almost like false color where snow and ice appear light blue, water appears very dark blue, and bare ground appears reddish brown to brown.
- **LandsatLook Thermal Image** is a single JPEG image file. The image is 8701x8261 pixels in size and 3.95MB. This infrared image appears in negative

gray tones where brighter (whiter) is warmer and darker is cooler.

- **LandsatLook Quality Image** is a Level 1 Quality band image providing a quick view of the quality of the pixels within the scene.
- **LandsatLook Images with Geographic Reference** is a zipped archive containing two images similar to those listed above along with metadata and georeferencing files allowing display in a geographic information system (GIS).
- **Level 1 GeoTIFF Data Product** is a G-zipped TAR archive containing 14 files (more for Landsat 8): a README file with information about the other files, 3 text files that could be read into specialized visualization programs to produce images, and 10 image files – one for each waveband: 3 visible and 5 infrared (2 files for Band 6), and a quality image.

Learners are asked to download only the natural color image in this lesson. The teacher is encouraged to explore other image types to determine best fit to their curricula.



For example, the JPEG above is the Band 8 image from the Level 1 GeoTIFF Data Product download. It was extracted from the G-Zip compression and the TAR collection with 7-Zip. The high-contrast between land, water, snow, and ice in this gray-tone infrared image was further enhanced with ImageJ to produce these striking color differences for easy identification of features. It was also rotated and cropped with ImageJ.

Some background information about glaciers may be helpful here. Alison Giffoni, teaching about the Physics of Glaciers at the University of Alaska, Fairbanks, defines a glacier as "any perennial body of ice that flows under its own weight due to gravity" on this class web site:

http://fden-2.phys.uaf.edu/webproj/212_spring_2014/Alison_Giffoni/alison_giffoni/Index.html

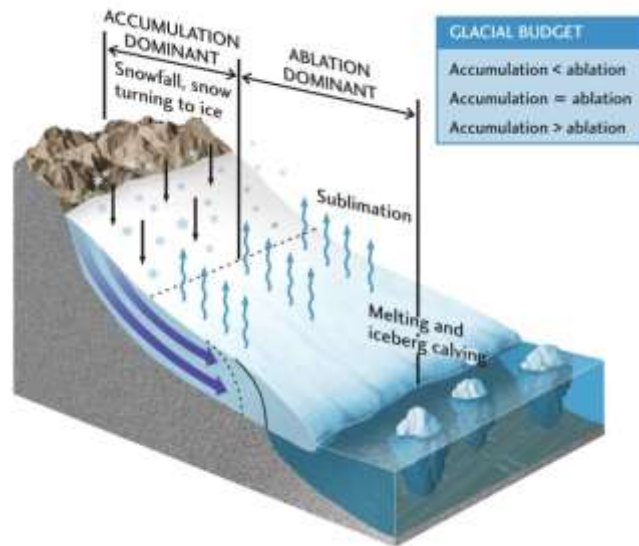


Image: http://ffden-2.phys.uaf.edu/webproj/212_spring_2014/Alison_Giffoni/alison_giffoni/Slide2.html

As illustrated above, a glacier has two general parts, the accumulation zone and the ablation zone. The accumulation area is where the snow turns to ice and adds to the glacier. In the ablation zone, the total rate of sublimation, melting, and calving (chunks of ice breaking off and floating away as icebergs) is greater than the rate of accumulation. The terminus is the edge of the glacier where the ablation zone meets the water. If there is more ice removed from the glacier than is added, the glacier is said to be retreating.

The image of the Jacobshaven Glacier obtained with GloVis and processed with ImageJ can be downloaded for printing or projection from this lesson's online resources page at <https://SatEd.org/library/Resources.htm>. (NOTE: USGS requires that any USGS scenes that have been modified by further processing be accompanied by mention of the modifications.) Coupled with the data scenes obtained by learners, this image could be used for engagement in a 5E inquiry about glacial movement. Can learners identify the accumulation and ablation zones in the scenes they obtain with GloVis? Can they locate the terminus? Is this glacier advancing, retreating, or neither? What further evidence is needed to reach reasonable answers to these questions?

On the other hand, remember, the point of the lesson is learners developing familiarity with GloVis in order to use it again for other lessons or their own research. As mentioned in the Assessment section, you will know that learners have developed said familiarity when they can use GloVis to obtain desired scene images on their own. Generally, that skill is demonstrated in the Your Turn activities. It should be required that every learner complete at least two (2) of the Your Turn activities for this lesson.

Regarding the graph in the first Your Turn activity, it is recommended that learners use a computer-based graphing program such as Microsoft Excel or Vernier's Graphical Analysis. Since the glacier seems to be moving from east to west (changing longitude), it is suggested the graph be constructed with the time (year) as independent variable and the longitude as dependent variable.

The second Your Turn activity examines imagery from other sensors and satellites. The

Jacobshavn Glacier is more difficult to see clearly in scenes from other satellites. This is due in part to the ground paths, the sensors' viewing angles and fields of view compared to Landsat. In sample image above, the Landsat satellite was almost directly overhead whereas satellite ground paths are more often farther east or west.



Jacobshavn Isbræ in West Greenland. Photo: Konrad Steffen

To help cultivate an awareness of ground path and row numbers related to satellite orbits, an animated NASA video clip illustrating the scan path of Landsat sensors is found at <https://svs.gsfc.nasa.gov/11475>. A complete description of the Worldwide Reference System (WRS) of the path and row pattern of Landsat scans is available at <https://landsat.gsfc.nasa.gov/about/worldwide-reference-system>.

The subject of Greenland glaciers and polar ice (both Arctic and Antarctic) was selected as the exemplar for use of GloVis in this lesson. Many other possible subject areas can provide focus for this tutorial exercise. Landsat was selected because it is the longest continuous global record of the Earth's surface in existence – 1972 to present day. Landsat datasets alone provide a global perspective on:

- Natural changes such as flooding from swollen rivers and river delta changes
- Close-up view of human impacts such as oil fires
- Ecosystems
- Urban growth
- Agricultural land use and crop health
- Water resources
- Human health such mosquito habits
- Energy issues and oil exploration
- Natural disasters such as volcanic eruptions, sever storm aftermath, tornado and tsunami damage
- Climate change such as cryospheric changes including glaciers

Any of these topic areas could make a valid research project supported by imagery from the Landsat archive accessed with GloVis. Applications can be found in every subject area.

Teachers are encouraged to check out these resources related to Landsat:

Teaching Notes

- USGS Landsat Missions (with many resource links)
<https://www.usgs.gov/landsat-missions>
- NASA Goddard Media Studios "A Landsat Flyby" (video, 1:46)
<https://svs.gsfc.nasa.gov/10513>
- *More Lessons from the Sky* lesson plan "How Landsat Works"
<https://SatEd.org/library/LESSONS/Landsat/Landsat.pdf>

At this point, teachers are invited to experience GloVis by trying the tutorial in the Student Activity pages themselves and, if applicable, discover the Landsat archive with specific topics in mind in addition to glaciers and climate change.

Acknowledgements

All satellite-based images in this lesson came from the USGS Earth Resources Observation and Science Center (EROS) archives and were accessed using GloVis.

The image on page 7, as stated in the text, is a Band 8 gray-tone image from the Level 1 Product download from GloVis for the Landsat 7 scene, Path 10, Row 11, June 2000. It was further processed by the author with ImageJ by changing the lookup table (color palette), rotating and cropping.

Background information about glaciers was taken from an online posting of Alison Giffoni at the University of Alaska, Fairbanks, teaching about the Physics of Glaciers. The accompanying diagram of glacier parts was produced by Outcrop. The photograph of the Jacobshavn Glacier by Konrad Steffen was also included in that posting.

The table of image processing levels is based the one published by NASA at science.nasa.gov. The map of flight paths for Arctic Campaign 2014 was produced M. Studinger for NASA Operation IceBridge. The map of Landsat paths and rows over Nebraska was produced at University of Nebraska, Lincoln. The "Landsat Flyby" video and the WRS-2 map of Landsat paths and rows comes from Landsat Science at NASA's Goddard Space Flight Center.

This edition of Teaching Notes and the material in the Student Activity pages were developed as part of *More Lessons from the Sky* by J.P. Arvedson for the non-profit Satellite Educators Association, Inc. *More Lessons from the Sky* has its roots in an original collection of more than fifty lessons compiled by Satellite Educators Association and published in *Lessons from the Sky*, © 1995 by Amereon, Ltd. *More Lessons from the Sky* is a regular feature of the free, on-line Satellite Educators Association Newsletter. More information about the Satellite Educators Association, its annual Satellites & Education Conference for teachers, international student environmental research collaborative, and access to the Newsletter can be found at <https://SatEd.org>.

All *More Lessons from the Sky* lesson plans are archived in the on-line SEA Lesson Plan Library available at <https://SatEd.org>. The web site features a description of the library contents, Next Generation Science Standards addressed, several search tools for finding lessons easily, separate resource files for lessons where needed, and the library's Analysis Toolbox.

When duplicating or otherwise using any portion of this lesson or its associated

materials, full credit to all contributors to the lesson and its associated materials must be included.

Resources

Note: All of these URLs were current and active as of this writing. If any are unreachable as printed, the use of on-line search engines such as DuckDuckGo, Ask, Google, or Bing is suggested to find current links.

- _____. "ASTER Search Data Catalog." Land Processes Distributed Active Archive Center, NASA EarthData. Retrieved March 2022 from https://lpdaac.usgs.gov/product_search/?collections=Terra+ASTER&view=list
- _____. "The Sentinel Missions." European Space Agency. Retrieved March 2022 from https://www.esa.int/Applications/Observing_the_Earth/Copernicus/The_Sentinel_missions
- _____. "Data Processing Levels." NASA Science. Retrieved March 2022 from <https://science.nasa.gov/earth-science/earth-science-data/data-processing-levels-for-eosdis-data-products/>
- _____. "Global Land Surveys (GLS)." Landsat Missions, U.S. Geological Survey. Retrieved March 2022 from https://www.usgs.gov/core-science-systems/nli/landsat/global-land-survey-gls?qt-science_support_page_related_con=0#qt-science_support_page_related_con
- _____. "Welcome to GloVis." U.S. Geological Survey. Retrieved March 2022 from <https://glovis.usgs.gov/>.
- _____. "Vernier Graphical Analysis." Vernier Software & Technology. Retrieved March 2022 from <https://www.vernier.com/products/graphical-analysis/>
- _____. "How Landsat Works." More Lessons from the Sky, SEA Lesson Plan Library, Satellite Educators Association Newsletter, March 2014 (updated October 2019). Retrieved March 2022 from <https://SatEd.org/library/LESSONS/Landsat/Landsat.pdf>
- _____. "IceBridge Data." NASA Distributed Active Archive Center at National Snow & Ice Center. Retrieved March 2022 from <https://nsidc.org/data/icebridge/>
- _____. "IceBridge." National Aeronautics and Space Administration. Retrieved March 2022 from https://www.nasa.gov/mission_pages/icebridge/index.html
- _____. "ImageJ Image Processing and Analysis in Java," National Institute of Health. Retrieved March 2022 from <https://imagej.nih.gov/ij/>
- _____. "Landsat Science." National Aeronautics and Space Administration. Retrieved March 2022 from <https://landsat.gsfc.nasa.gov/>
- _____. "MODIS." National Aeronautics and Space Administration. Retrieved March 2022

Teaching Notes

from <https://modis.gsfc.nasa.gov/>

_____. "MODIS Overview." Land Processes Distributed Active Archive Center, U. S. Geological Survey, NASA EarthData. Retrieved March 2022 from <https://lpdaac.usgs.gov/data/get-started-data/collection-overview/missions/modis-overview/>

_____. "Resources for Lessons." SEA Lesson Plan Library, Satellite Educators Association, Inc. Retrieved March 2022 from <https://SatEd.org/library/Resources.htm>

_____. "Stuffit." SmithMicro Software, Inc. Retrieved March 2022 from <https://www.stuffit.com/>

_____. "The Worldwide Reference System." Landsat Science, National Aeronautics and Space Administration. Retrieved March 2022 from <https://landsat.gsfc.nasa.gov/about/worldwide-reference-system>

_____. "Data Management and Information Distribution." U.S. Geological Survey. Retrieved March 2022 from <https://landsat.gsfc.nasa.gov/wp-content/uploads/2013/01/wrs2.gif>
For "UTM Zone" and "WRS-1" and "WRS-2" definitions.

Giffoni, Alison. "The Physics of Glaciers." University of Alaska, Fairbanks. Retrieved March 2022 from http://ffiden-2.phys.uaf.edu/webproj/212_spring_2014/Alison_Giffoni/alison_giffoni/Index.html

Simmon, Robert. "Elegant Figures – How to make a True-color Landsat 8 Image." NASA Earth Observatory, October 22, 2013. Retrieved March 2022 from <https://earthobservatory.nasa.gov/blogs/elegantfigures/2013/10/22/how-to-make-a-true-color-landsat-8-image/>

National Research Council. *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Washington, DC: The National Academies Press, 2012. Retrieved March 2022 from <https://www.nap.edu/catalog/13165/a-framework-for-k-12-science-education-practices-crosscutting-concepts>

National research Council. *The Next Generation Science Standards, Next Generation Science Standards For States, By States*. Washington, DC: The National Academies Press, 2013. Retrieved March 2022 from <https://www.nap.edu/catalog/18290/next-generation-science-standards-for-states-by-states>

Pavlov, Igor. "7-Zip." Retrieved March 2022 from <https://www.7-zip.org/>

Answers to Questions in the Student Activity

1. What is the first step in finding data with GloVis?
The first step is selecting a data set.

2. To help refine your data search, what metadata filters can be applied?
Metadata filters include a date range, cloud cover range expressed in percent of image masked by clouds, and months of the year.
3. When you zoom-in, several scenes become visible and may overlap. Which one is the currently selected scene?
The currently selected scene is outlined in red.
4. Where are the controls located for changing from the current scene to an earlier or later scene?
The Scene Navigator, with controls for changing the current scene to an earlier or later one, is located in the bottom right corner of the display.
5. How can you find the metadata for the currently selected scene?
To open the metadata for the currently selected scene, click the metadata icon in the Scene Navigator or the Selected Scenes list.
6. What sorts of information are found in a scene's metadata?
Answers will vary. Metadata is information about the data used to create the scene image. The metadata file includes information like date of acquisition, specific location, identification codes, and more.
7. Describe what happens in the image window when the Current Scene Opacity is changed.
The transparency of the current scene changes. Drag all the way to the left for 0% opacity (fully transparent), all the way to the right for 100% opacity (non-transparent), or somewhere in between.
8. Using the mouse cursor, determine the current latitude and longitude of the Map Center Point crosshair in the default street map.
Answers may vary slightly. The Map Center Point crosshair is over latitude 43.7433 (or 43.7433° N) and longitude -96.6467 (or 96.6467° W).
9. The Map Center Point crosshair marks what special location on the map?
The default position for the Map Center Point crosshair is the USGS Earth Resources Observation and Science Center in Sioux Falls, South Dakota.
10. List the ways available in GloVis for defining an area of interest?
An area of interest can be defined using zoom and pan controls as well as the Jump To... options.
11. Which band numbers are combined to make the "True Color" basemap layers?
"True Color" refers to visible light colors: red, green, and blue (RGB). Band 1 is visible blue, band 2 is visible green and band 3 is visible red. A true color image might be designated 3,2,1 (for RGB).
12. Describe what changes took place on-screen when you clicked **Take Tour**, **OK**, and **End Tour**, respectively?
This is the sequence of steps to reset the image display to the default street map and clear all selected scenes. The Map Center Point crosshair returns to Sioux Falls, South Dakota.

Teaching Notes

13. Scroll down the metadata list and record the Values for these scene attributes. (Hint: Fill in the metadata for the 2013 scene. You will access the metadata for the 2000 scene later.)

Dataset Attribute	2013 Scene	2000 Scene
Landsat Scene Identifier	LE70100112013196EDC00	LE70100112000177EDC00
Date Acquired	July 15, 2013	June 25, 2000
WRS Path and Row	Path 10, Row 11	Path 10, Row 11
Station Identifier	EDC	EDC
Daytime or night	Day	Day
Cloud Cover	0.09%	0.08%
Center Latitude dec	69.60743°N	69.61000°N
Center Longitude dec	50.95096°W (or -50.95096°)	51.04650°W (or -51.04650°)

14. Describe what you see in the scene.
The image shows a bay on the west coast of Greenland with a large island in the bay. The coast line is uneven with at least one large glacier extending from inland, through the coastal range and into the sea. The water is displayed in a very dark shade of blue, the land near the coast is reddish brown in color, snow is light blue and ice (glacier) is a slightly darker shade of blue.
15. Compare the scene identifier of this scene with the scene identifier of the last scene (recorded in Question 13). Is this the same scene?
There is no difference in the scenes. They are exactly the same. The scene identifiers are identical. The difference is not in the scene but with the method of accessing the scene.
16. The Landsat scene identifier for this scene is LE70100112013196EDC00. Refer to the scene's metadata and your answer to Question 13 to interpret this coded identifier. What does it mean?
With a little detective work, students should be able to glean most of this from the metadata file. Landsat scene identifiers are encoded this way: LXSPPPRRRRYYYYDDDGSI VV where
L = Landsat
X = Sensor (M = MSS, T = TM, E = ETM+, O = OLI, C = Combined OLI and TIRS)
S = Satellite (such as Landsat-7)
PPP = WRS Path
RRR = WRS Row
YYYY = Year of Acquisition
DDD = Day of Acquisition Year (For example: the 196th day of 2013 is July 15th.)
GSI = Ground Station Identifier
VV = Version
So, LE70100112013196EDC00 is a scene scanned by the Enhanced Thematic Mapper Plus (ETM+) instrument on the Landsat 7 satellite, Path 10 Row 11, on the 196th day of 2013. The signal was received by an unidentified station and provided to the collection by EROS Data Center (EDC) in South Dakota. Version number is 00.
17. Why is the clearest portion of the image in the center? Why does the clear portion extend from top to bottom instead of left to right?
The satellite orbit moves the scanning instrument from north to south or south to north over the scene. The remote sensor scans from side to side. The center line of the image is where the scanner looks directly down at the surface whereas the edges of the image are scanned at an angle. The center of the image is the zone of greatest clarity and accuracy.

18. Compare and contrast the appearance of Jacobshavn Glacier in June 2000 with its appearance in July 2013.
At first, the glacier in both scenes appears to be solid. However, in the 2013 scene, the terminus seems to have receded significantly extending the ablation zone with increased calving.
19. Does your comparison suggest Jacobshavn Glacier has retreated significantly between 2000 and 2013?
Yes. The condition of the glacier in the 2013 scene compared to that in the 2000 scene suggests the glacier may be retreating.
20. Is this evidence sufficient to support a conclusion of melting glaciers and rising sea level? Why or why not? Explain.
That the glacier is melting can only be suggested, not confirmed, by just two scenes. Two scenes are not enough evidence to support a conclusion that the glacier is melting. Much more evidence is needed to reach a concrete conclusion. Evidence such as 20 to 30 years of scenes and measurements of the terminus position in each for comparison could be a possible starting point. Also, a change in average sea level cannot be detected from just two images.

GloVis

USGS Global Visualization Viewer

Introduction

Since artificial satellites first orbited Earth in 1956, scientists, both amateur and professional, have collected and studied the vast amounts of observations made by, and transmitted to us, by instruments on those satellites. Most of those data are archived in databases that have been used only by expert investigators trained in the use of specialized retrieval techniques and analysis tools.

More recently, the National Aeronautics and Space Administration (NASA), the National Oceanic and Atmospheric Administration (NOAA), and the U.S. Geological Survey (USGS), among others, have developed online tools for easy retrieval of archived data in various forms that serve the needs of every level of scientific research including middle and high school grade levels.

This hands-on tutorial guide is an introduction to **GloVis**, the USGS Global Visualization Viewer, a quick and easy online search tool for selected satellite and aerial data. GloVis provides access to imagery from Earth-Observing One and Landsat satellites, among others. Following the tutorial steps, you will experience the value and utility of GloVis for yourself while becoming familiar with its "look and feel" as you investigate changes in Greenland's Jacobshavn Glacier.

What is GloVis?

GloVis is the short name for U.S. Geological Survey's **Global Visualization Viewer**. According to the USGS, "GloVis is a quick and easy online search and order tool for selected satellite and aerial data. The Viewer allows user-friendly access to browse images from the multiple EROS data holdings." The USGS Earth Resources Observation and Science Center (EROS) *data holdings* are listed in these collections:

- ▶ **DOQ** (Digital Orthophoto Quadrangles) – computer generated images of aerial photography in 3.75 minute and 7.5 minute quadrangles.
- ▶ **EO-1** – Advanced Land Imager (10 spectral bands) and Hyperion (220 spectral bands) on Earth-Observing One (2000-present)
- ▶ **Global Land Survey** – from Landsat imagery; surveys in 1975, 1990, 2000, 2005, 2010)
- ▶ **IRS** – Advanced Wide Field Sensor (AWiFS) and Linear Imager Self-Scanning Sensor (LISS-3) on Resourcesat-1 and Resourcesat-2 (USGS partnership with Indian Space Research Organization) (2003-present)
- ▶ **Landsat 1-5 MSS** – Multispectral Scanner on Landsat 1-5 (1972-1992)

- ▶ **Landsat 4-5 TM** – Thematic Mapper on Landsat 4 and 5 (1982-2012)
- ▶ **Landsat 7 ETM+** - Enhanced Thematic Mapper Plus on Landsat 7 (1999-2003; 2003-present with data gaps)
- ▶ **Landsat 8 OLI/TIRS** – Operational Land Imager and Thermal Infrared Sensor on Landsat 8 (2013-present)
- ▶ **OrbView-3** – commercial, high-resolution imagery; panchromatic (black & white) and multispectral (color) (2003-2007)
- ▶ **Sentinel-2** - land and sea monitoring, natural disaster mapping, sea ice observation, ships detection; ESA Copernicus Programme, (2015-present)
- ▶ **SRTM** -- Shuttle Radar Topography Mission (February 11-22, 2000)

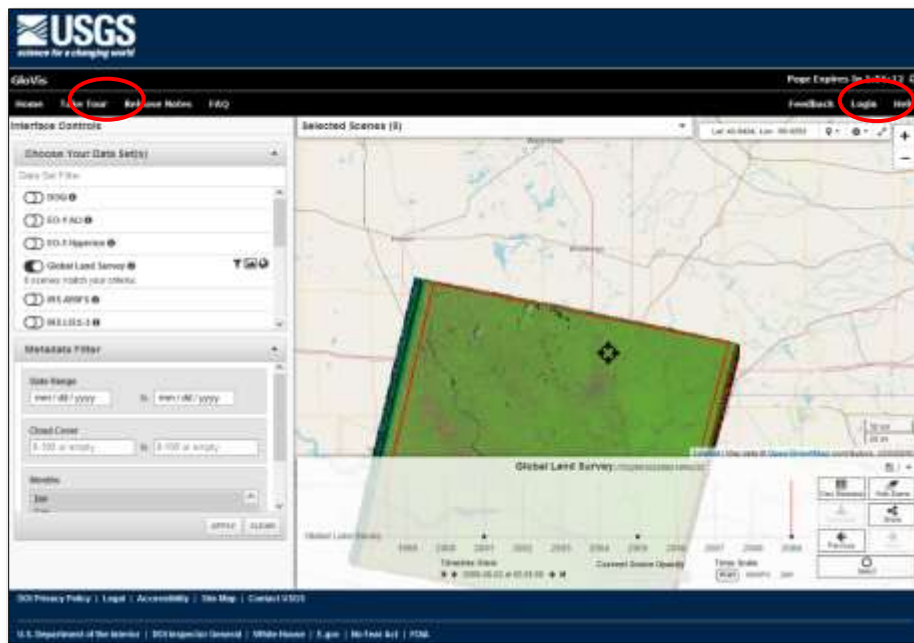
GloVis offers a graphic map display allowing you to view requested scenes of specific areas of interest from selected collection datasets. You can browse to adjacent scenes or select an entirely new one. You will discover many special features such as the ability to view only images with up to a specified amount of cloud cover.

Get started now on a venture to discover how views from above can help us better understand the Earth beneath our feet.

GloVis - Getting Started

GloVis is easy to use!

- 🖥️ Ensure your computer is Internet enabled. Launch your browser. Point the browser to the GloVis home page at this address: <https://glovis.usgs.gov/>.
- 🖥️ On the Welcome to GloVis page, click Launch GloVis. This GloVis home page is displayed. (NOTE: Be patient! Wait for the current scene to load and display before proceeding!)



The built-in quick tour will help you become familiar with fields and switches on the home page screen.

- 🖥️ Click the Take Tour link near the left end of the menu bar above the map display or in the initial pop-up on the screen.

Answer these questions as you take the tour.

1. What is the first step in finding data with GloVis?
2. To help refine your data search, what metadata filters can be applied?
3. When you zoom-in, several scenes become visible and may overlap. Which one is the currently selected scene?
4. Where are the controls located for changing from the current scene to an earlier or later scene?



5. *How can you find the metadata for the currently selected scene?*
6. *What sorts of information are found in a scene's metadata?*

When the tour ends, the map is reset to the default display. The Map Center Point crosshair is centered on the map display.




 **Find the Current Scene Opacity slider at the bottom of the Scene Navigator. Slowing slide the control from right to left and back again.**

7. *Describe what happens in the image window when the Current Scene Opacity is changed.*
8. *Using the mouse cursor, determine the current latitude and longitude of the Map Center Point crosshair in the default street map.*
9. *The Map Center Point crosshair marks what special location on the map?*

What are you looking at in this scene? These tools may help:

-  **Try zooming-in and -out using the + and – buttons in the upper right of the image.**
-  **Now try panning by placing the cursor on the image and holding down the left mouse button. While holding the mouse button, drag in any direction.**

When more help is needed, try these steps:

-  **Click Help in the menu bar. A new browser tab/window opens.**
-  **Notice Contacts on the right. It shows how to contact Customer Service at the USGS Earth Resources Observation and Science Center. Remember where to find this.**
-  **Find the bulleted list of help topics and click Glovis Next Tutorial. Briefly, scan through the tutorial to become familiar with the type of help available here.**

10. *List the ways available in GloVis for defining an area of interest.*

 **Close the browser tab for the tutorial. Close the browser tab for the Help Index.**

Feel free to refer to the Help section at any time while using GloVis.

Adjusting the View

You can adjust the map view by changing the following settings at any time:

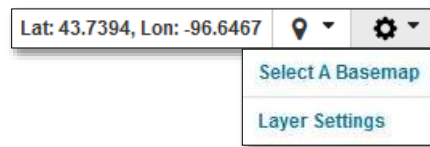
- To see more of the map...

Student Activity

- Click the full screen double arrow to change to full screen mode; click again to show both upper and lower screen information bands.



- To change the basemap...
 - Below the menu bar in the upper right of the map display, click the settings wheel and select Select a Basemap. Using the drop-down arrow in the popup, select a new basemap, and click Apply and Close.



The Band numbers in parentheses indicated which wavelength bands are combined to produce each basemap layer. Bands 1, 2, and 3 are visible blue, green, and red, respectively. The others are infrared wavebands.

11. Which band numbers are combined to make the “True Color” basemap layers?

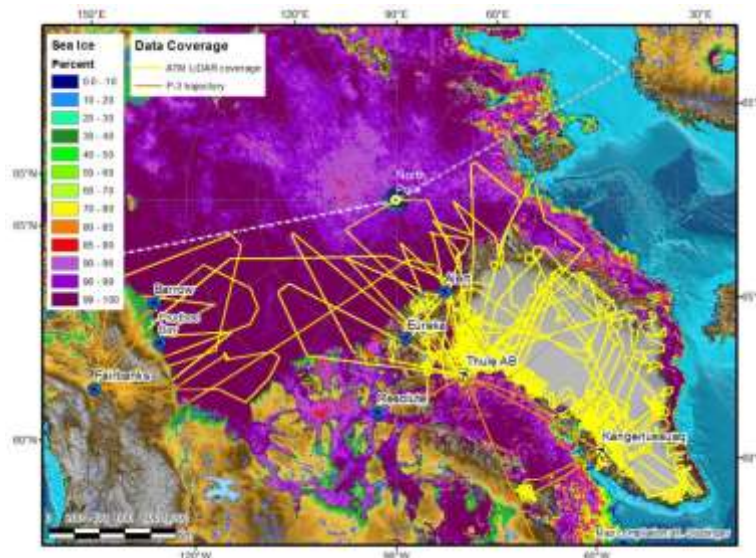
- To change the color of the Map Center Point crosshair...
 - Click the settings wheel and select Layer Settings. Use the drop-down arrow in the popup to select Map Center Point. Click the Stroke Color color swatch. In the Color dialogue, select a color and click OK. Then click Apply and Close.
- To reset the map to the default view...
 - In this order: click Take Tour, OK, and End Tour. Do not take the tour.

12. Describe what changes took place on-screen when you clicked **Take Tour**, **OK**, and **End Tour**, respectively? (HINT: Be patient! Wait for the server to complete the reset task.)

Accessing Data

Let's try a simple example. Suppose you are interested in glaciers in Greenland and whether they are advancing or retreating. NASA's ICESat satellite monitored the cryosphere especially in polar ice regions from 2003 to 2009. ICESat 2 was launched in 2018. Operation IceBridge was a six-year mission to survey the Earth's polar ice from the air beginning in 2009. It produced three-dimensional views of Arctic and Antarctic ice sheets, ice shelves, and sea ice. Multiple instruments on these flights provided annual looks at the behavior of ice in Greenland and Antarctica. IceBridge was extended to continue “bridging the gap” in cryospheric data between the functional lives of the two IceSat satellites.

We will focus our attention on a glacier north of Kangerlussuaq, Greenland. The Jacobshavn Glacier was surveyed extensively each year from 2010 to 2014. The fly-over pathways of the 2014 Arctic Campaign are shown in yellow on this map.



Operation IceBridge: Arctic Campaign 2014
https://www.nasa.gov/sites/default/files/arctic_2014_map.jpg

Icebridge data are from instruments on aircraft flying at relatively low altitudes compared to satellites. Satellite-based remote sensing data of polar ice are also available. Landsat Earth-observing satellites have been in orbit since 1972. The orbital path of each satellite is configured so that the entire Earth is scanned every 16 days. As the satellite orbits on a generally north-south path (colored columns in the left image below), its sensors scan the Earth's surface one scene at a time (squares in each column). Each successive scene is called a row in that path. Therefore, in GloVis, scene locations can be identified by **path and row** as well as by the **latitude and longitude** at the center of the scene.



Example of Landsat Paths and Rows
https://www.researchgate.net/figure/Landsat-ETM-scenes-path-and-row-for-the-5-state-region_fig2_249963497



WRS-2 Paths and Rows for Landsat 4, 5, 7
<http://landsat.gsfc.nasa.gov/wp-content/uploads/2013/01/wrs2.gif>

The sensors onboard Landsat satellites scan the Earth in three visible and at

Student Activity

least four infrared wavebands. Surface features on the Earth reflect solar radiation. By studying the amount of energy in each waveband reflected by various surface features, scientists are able to identify specific surface features in Landsat imagery. The USGS maintains an archive of Landsat imagery that can be accessed by the general public using the GloVis online tool.


For our example, use an atlas or world globe to determine the position of Jacobshavn Glacier in Greenland located between the towns of Ilulissat to the north and Claushavn to the south of the glacier.

 In **Choose Your Data Set(s)**, click the switch for Landsat 7 ETM+.

 In the **Metadata Filter**, set Date Range from 07/15/2013 to 07/15/2013. Click Apply.

 Click the drop-down arrow next to the location finder. Select Lat/Lng.



 In the **Jump to Lat/Lng** dialogue, type 69.160 in the latitude field and then -51.094 in the longitude field. Click Jump to Location.

 While GloVis prepares the Landsat scene for display, look at the scene's metadata. Click the **View Metadata** button. Answer **Question 13**.



13. Scroll down the metadata list and record the Values for these scene attributes. (Hint: Click any field name in the list for more information about that field.)

- Landsat Scene Identifier
- Acquisition Date
- WRS Path and Row
- Station Identifier
- Day/Night Indicator
- Cloud Cover (Land and Scene)
- Scene Center Latitude (decimal degrees)
- Scene Center Longitude (decimal degrees)

 Close the **Metadata** window.

14. Describe what you see in the scene.

 **If needed, zoom-in by clicking the plus sign in the upper right of the image display, Click the minus sign to zoom out.**

 **Locate the Jacobshavn Glacier. Check with your teacher to be sure you are on target.**

You can also locate Landsat scenes by path and row numbers, if you know them.

 **Reset the map display to the default view.**

 **Once again, select Landsat 7 with a date range of 07/15/2013 to 07/15/2013. Then Click the location finder and select WRS Path/Row.**



 **Type in the path and row numbers you recorded in Question 13. Click Jump to Location.**

15. Compare the scene identifier of this scene with the scene identifier of the last scene (recorded in Question 13). Is this the same scene?

16. The Landsat scene identifier for this scene is LE70100112013196EDC00. Refer to the scene's metadata and your answer to Question 13 to interpret this coded identifier. What does it mean?

Viewing the Scene Image

Before examining the scene in more detail, would it be helpful to be able to move the map display in its window?

 **Left-click and hold on the display map and drag it in any direction to better see your area of interest. Release.**

In this image, ice and snow appear light blue, sea water appears very dark blue, and bare land appears reddish to brown. Can you locate the terminus or leading edge of the glacier as it moves into the bay? Can you spot where the glacier is calving – that is, where large chunks of ice are breaking off the glacier and becoming icebergs as they float away in the current?

You may notice there are periodic lines from side to side in the image. These are

Student Activity

areas of missing data. The area in the center contains no missing data, but areas closer to the edges of the image frame have more missing data. Missing data have been interpolated to produce an image that appears more complete. The orbiting satellite carries the scanning instrument from north or south over the scene while the instrument scans from side to side. The center of the image is where the scanner looks directly down at the surface whereas the edges of the image are scanned at an angle. The center of the image is the zone of greatest clarity and accuracy.



Source: Lockheed-Martin

17. Why is the clearest portion of the image in the center? Why does the clear portion extend from top to bottom instead of left to right?

Save a copy of this scene image for later reference and comparison...

 **Before saving the scene, be sure to “select” it. Click the Select button in the lower right corner of the display.**








 **Right-click (PC) or Ctrl-click (Mac) the scene image and select View Browse. The image will be displayed in a new browser tab (depending on your browser settings).**

 **Right-click (PC) or Ctrl-click (Mac) the image and select Save Image As. Navigate to a location specified by your teacher and click Save. Close the browser tab.**

Melting glaciers and rising sea levels are concerns to be considered when discussing global change. Can melting glaciers or rising sea levels be detected in




Greenland using this Landsat image archive? Let's look at an earlier image of the same scene for comparison.

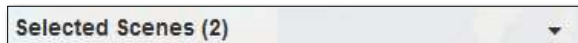
-  Show the **Interface Controls**. Change the **Date Range** to Jun 25, 2000. Click **Apply**.
-  When the scene is displayed, open its metadata file. Return to **Question 13** and complete the chart to compare the metadata of the two scenes.
-  Select this scene by clicking the **Select** button.
-  If instructed by your teacher. Save a copy of this scene image in the same location.
-  Open both scene images in your computer's default image viewer. Arrange the windows so you can examine both images side-by-side.

18. Compare and contrast the appearance of Jacobshavn Glacier in June 2000 with its appearance in July 2013.
19. Does your comparison suggest Jacobshavn Glacier has retreated significantly between 2000 and 2013?
20. Is this evidence sufficient to support a conclusion of melting glaciers and rising sea level? Why or why not? Explain.

Downloading Data (optional)

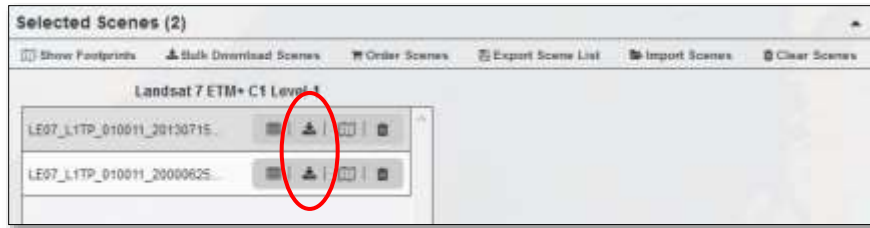
You have just captured and saved images from your screen display. Depending on your computer's operating system, the saved image is probably a JPEG image about 200KB in size. Higher resolution images can be downloaded if needed for deeper analysis with such programs as ImageJ or MultiSpec. As seen below, GloVis high-resolution images have a file size of 2MB to more than 240MB. That is 10 to 1000 times larger than the JPEG image you screen captured. It will take longer to download and occupy more storage space on your local computer.

-  Complete this section **ONLY** if instructed to do so by your teacher.
-  With your teacher's approval, login or ask your teacher to login for you.
-  Expand the **Selected Scenes** panel by clicking the drop-down arrow.

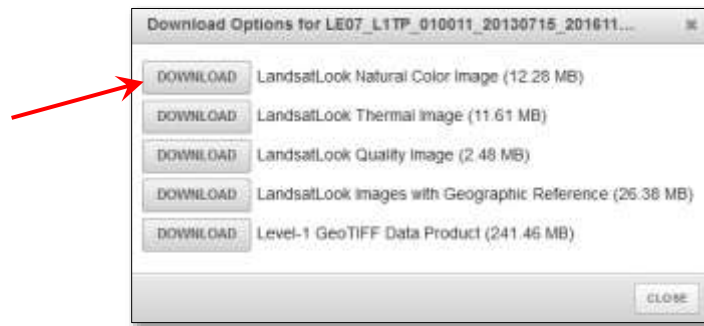


-  In the **Selected Scenes** panel, click the download icon for one of the scenes:

Student Activity



Notice 5 download options. The first is a natural color image. It will download in a compressed format called JPEG.



- 🖥️ Click Download for the **first image only**: LandsatLook Natural Color Image.
- 🖥️ When asked, select Save File and click OK. Wait while the scene image file is downloaded to your computer.
- 🖥️ When finished, close the Download Options dialogue.
- 🖥️ Click the download icon for the other scene to repeat the process until you have downloaded full image files for both scenes (June 2000 and July 2013).

Finishing Up

- 🖥️ When finished, click Clear Scenes in the Selected Scenes panel.
- 🖥️ Insure you are logged out.
- 🖥️ Close your browser.
- 🖥️ To view the image, find the file name in its stored location on your computer. Open the image in your computer's default JPEG image viewer.
- 🖥️ Proceed to the Your Turn activities. Follow your teacher's directions.

Your Turn

- ✚ To demonstrate change in Jacobshavn Glacier over time, more images are needed. Develop and carry out a plan to find and capture one image per year for a span of at least 20 years. Take into account the season of the year, the position of the sun, and the amount of cloud cover as you decide which images to use. Place the cursor over what appears to be the terminus or edge of the glacier where calving begins. Without moving the cursor, record the latitude and longitude of the cursor's location (shown in the upper right of the scene display). You will need to record latitude and longitude with at least 4 decimal places. Similarly record the positions of the glacier terminus in each successive image. Plot a scatter graph with line connecting the points. Plot the year on the x-axis and longitude on the y-axis. How has the glacier behaved over this span of time? How do you know? Share this information with your class. Be prepared to answer questions about your research.
- ✚ You have been working with data from the Enhanced Thematic Mapper Plus (ETM+) on Landsat-7. View the Jacobshavn Glacier from Global Land Survey (GLS) collection, sensors on Sentinel-2, the Thematic Mapper on Landsat-4-5, and the Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) on Landsat-8. Look for scene images for the month of July in various years. Can you locate the glacier in each image? For purposes of studying this glacier, compare and contrast these images with those from Landsat-7. What are the advantages and disadvantages of each? Consult your teacher to decide the best way to share this information with your class.
- ✚ Select a different glacier or surface feature of interest and perform a similar study with a sequence of images from the Landsat, Global Land Survey, or another collection using GloVis. Plan a sequence of imagery to demonstrate how that surface feature has changed over time and the importance of us being aware of those changes. Be sure to include in your plan a means of sharing your images and information with your class. Have your plan approved by your teacher and carry it out.
- ✚ An image's spatial resolution is the amount of surface area covered by each image pixel. Do all satellite-based images have the same spatial resolution? Take a look at Landsat satellites in particular. Perform an Internet search for information about the spatial resolution of instruments on each Landsat satellite (MSS on Landsat 1-5, TM on Landsat 4-5, ETM+ on Landsat 7, OLI/TIRS on Landsat 8, OLI2/TIRS2 in Landsat 9). Your search might start with USGS Landsat sites and NASA Landsat sites. Explain the spatial resolution of each and how they differ. Using GloVis, find sample imagery from the MSS, TM, ETM+, and OLI instruments to visually compare and demonstrate differences of each. Describe the advantages and disadvantages of higher spatial resolution imagery. For what purpose(s) might higher resolution be important? Consult your teacher to determine the best way to share your discoveries and conclusions.
- ✚ Can imagery accessed with GloVis be used to monitor sea level rise in coastal areas? Why or why not? Use GloVis to obtain imagery to demonstrate your answer. Ask your teacher to suggest a method to visually share this information with your class.
- ✚ Are you currently investigating something in your class that can be aided by using GloVis? If so, what is it? How will you use GloVis now?

GloVis

Answer Sheet

1. What is the first step in finding data with GloVis?
2. To help refine your data search, what metadata filters can be applied?
3. When you zoom-in, several scenes become visible and may overlap. Which one is the currently selected scene?
4. Where are the controls located for changing from the current scene to an earlier or later scene?
5. How can you find the metadata for the currently selected scene?
6. What sorts of information are found in a scene's metadata?
7. Describe what happens in the image window when the Current Scene Opacity is changed.
8. Using the mouse cursor, determine the current latitude and longitude of the Map Center Point crosshair in the default street map.
9. The Map Center Point crosshair marks what special location on the map?
10. List the ways available in GloVis for defining an area of interest.
11. Which band numbers are combined to make the "True Color" basemap layers?
12. Describe what changes took place on-screen when you clicked **Take Tour**, **OK**, and **End Tour**, respectively?

13. Scroll down the metadata list and record the Values for these scene attributes. (Hint: Fill in the metadata for the 2013 scene now. You will access the metadata for the 2000 scene later.)

Dataset Attribute	2013 Scene	2000 Scene
Landsat Scene Identifier		
Date Acquired		
WRS Path and Row		
Station Identifier		
Daytime or night		
Cloud Cover		
Scene Center Latitude		
Scene Center Longitude		

14. Describe what you see in the scene.

15. Compare the scene identifier of this scene with the scene identifier of the last scene (recorded in Question 13). Is this the same scene?

16. The Landsat scene identifier for this scene is LE70100112013196EDC00. Refer to the scene's metadata and your answer to Question 13 to interpret this coded identifier. What does it mean?

17. Why is the clearest portion of the image in the center? Why does the clear portion extend from top to bottom instead of left to right?

18. Compare and contrast the appearance of Jacobshavn Glacier in June 2000 with its appearance in July 2013.

19. Does your comparison suggest Jacobshavn Glacier has retreated significantly between 2000 and 2013?

20. Is this evidence sufficient to support a conclusion of melting glaciers and rising sea level? Why or why not? Explain.