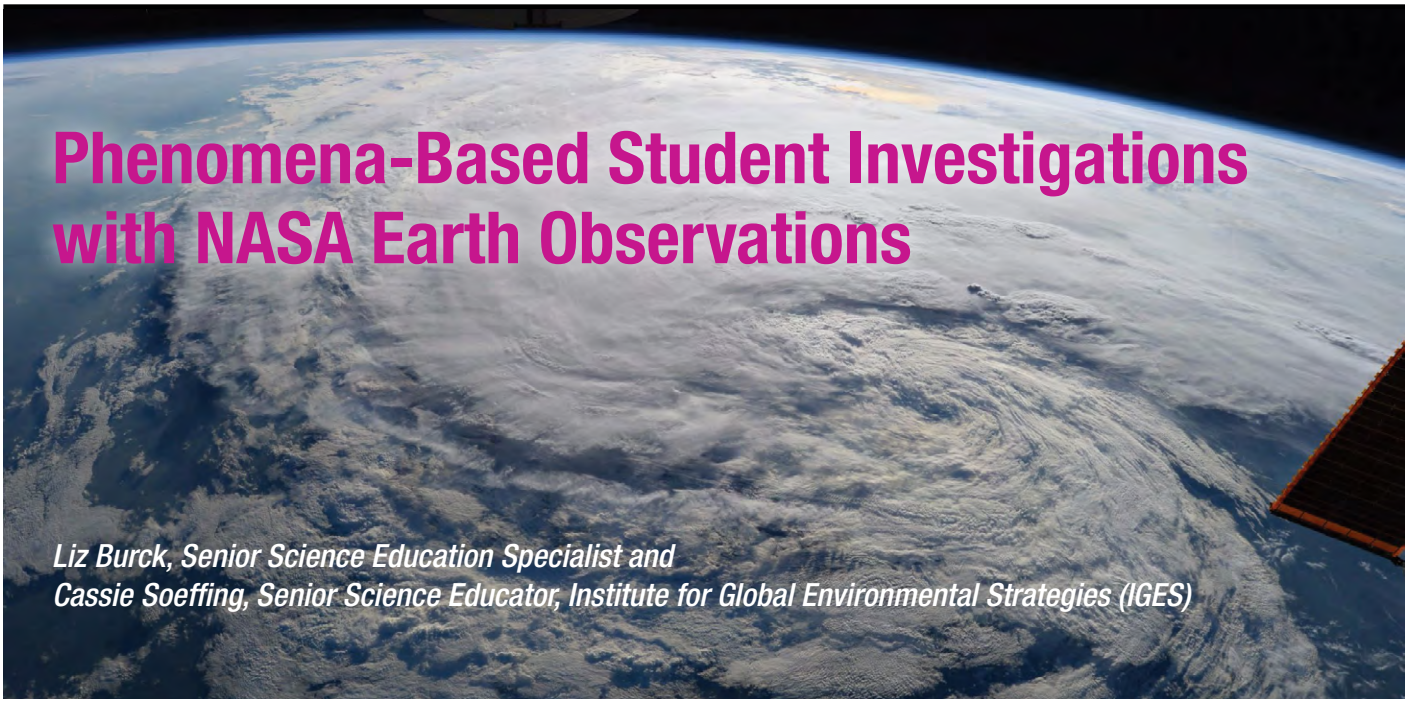

Phenomena-Based Student Investigations with NASA Earth Observations

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Abstract

Incorporating NASA satellite data in a student-centered classroom investigation promotes authentic research and allows students to engage in the practices of science. To encourage teachers at all grade levels to include NASA data in the classroom, the Institute for Global Environmental Strategies (IGES) has created an introductory guide to finding and using NASA datasets and imagery. The resource, Quick Start Guide to Finding Data/Imagery for Student Investigations, provides topical examples of Earth science data along with the links to online data sources that allow students to investigate related phenomena.

To demonstrate the use of the guide as well as the applicability of NASA data to a middle school science classroom, this article uses the Next Generation Science Standards (NGSS) aligned phenomenon of hurricanes. The extremely active 2017 Atlantic hurricane season provided constant reminders of the powerful forces, repeated patterns and devastating impacts of these natural hazards. From overhead, NASA Earth-observing satellites monitored each hurricane, collecting a continuous stream of related data. The visually compelling images and abundance of data gathered by those satellites are available for download and use at no cost. Investigating hurricanes through NASA images and data not only engages students in the practices of science but leads to a better understanding of Earth as an integrated system.

Introduction

Many events in nature are seasonal, including one of Earth's most powerful weather events: hurricanes. The Atlantic hurricane season runs from June 1 through November 30 and peaks in late summer. The 2017 season, the seventh most active since records began in 1851, produced hurricanes that were extraordinary in their frequency, destruction, and economic impacts. (NOAA, 2017)

- **Hurricane Harvey** first made landfall on August 25, battering the Houston, Texas region. The hurricane delivered an estimated 33 trillion gallons of water (the equivalent of a cube 3.1

miles wide and high) to the area. Harvey's rains, floods, and 130 mph winds impacted more than 13 million people.

- **Hurricane Irma** brought 185 mph winds to the Caribbean. Striking the Florida Keys on September 10, Irma destroyed 25% of the homes there.
- **Hurricane Maria** made landfall in Puerto Rico on September 20, with peak wind speeds of 175 mph. The island sustained widespread loss of both power and running water.
- **Hurricane Nate**, with 85-90 mph winds, made landfall on October 7 in Mississippi after forcing 92% of US Gulf of Mexico oil production to be temporarily taken offline.

NASA satellites monitored the life cycle of each hurricane, allowing both scientists and citizens to view and follow these incredible weather events. NASA satellites collected extensive data on surface wind speed, cloud height, rainfall rate, air temperature, air moisture, sea surface temperature and aerosols. Each of those data measurements was processed, visualized and analyzed by NASA scientists, and all of that data is freely available to the public (Figure 1).

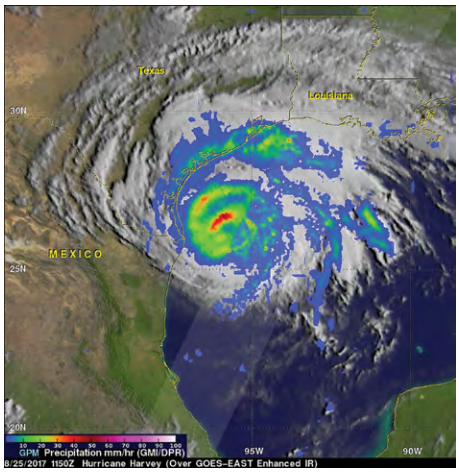

Figure 1. The Global Precipitation Measurement (GPM) Radar shows intense bands of rain from Hurricane Harvey.

Photo Credit: Hal Pierce (SSAI/NASA GSFC).

Because of the high level of interest in these events, hurricanes also provide an excellent learning opportunity for educators and students alike. The following article provides background and approaches for bringing the science of hurricanes, along with incredible NASA imagery and data, into the classroom.

Hurricanes as Anchoring Phenomenon

Hurricanes both captivate and frighten humans. Because they are fairly common, students have undoubtedly seen images and pictures of their appearance and read or heard reports of their impacts. Those images and reports prompt questions. Answering those questions requires multi-level investigations. Together, these components comprise the qualities of an anchoring phenomenon: hurricanes are engaging, observable, questionable and investigable. The study of hurricanes allows for the combination of investigative strategies and instructional activities. Incorporating NASA data allows students to conduct authentic research and engage in the practices of science.

Hurricanes are a natural hazard phenomenon included in the Next Generation Science Standards (NGSS) in the middle school Earth and Space Sciences (ESS) domain. The targeted Performance Expectation (PE), MS-ESS3-2, is shown in Table 1. Each of the three related dimensions (SEP, DCI, CCC) is listed below the PE. Using these NGSS standards along with the NASA tools found in the Quick Start Guide to Finding Data/Imagery for Student Investigations (sites.google.com/strategies.org/k12datapaths) described below will allow you to create a multi-investigative unit using hurricanes as the foundational phenomenon.

Table 1. Middle School Performance Expectation, SEP, DCI, and CCC related to Hurricanes

Performance Expectation – Earth and Human Activity

MS-ESS3-2: Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects.

Science and Engineering Practices

- Analyze and interpret data to determine similarities and differences in findings.

Disciplinary Core Idea

- MS-ESS3.B: Mapping the history of natural hazards in a region, combined with an understanding of related geologic forces, can help forecast the locations and likelihoods of future events.

Cross-Cutting Concepts

- Patterns: Graphs, charts, and images can be used to identify patterns in data.

Connections to Engineering, Technology, and Applications of Science:

- Influence of Science, Engineering, and Technology on Society and the Natural World
- The uses of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Thus, technology use varies from region to region and over time.

Student engagement with this phenomenon begins with observing and discussing NASA satellite images of hurricanes. Many captivating introductory videos and stills are found by searching for "hurricanes" on NASA Earth Observatory (earthobservatory.nasa.gov/). From those images, students should generate investigative questions and continue with the Claim® Evidence® Reasoning framework (Reiser, 2012).

Science begins with a question. After viewing the hurricane images, student questions might include:

- How does sea surface temperature influence hurricanes?
- How does warm ocean water help form clouds?
- Where do hurricanes get their energy?
- Why does the Atlantic hurricane season peak in late summer?

Students can begin answering those questions by using sources listed in the Quick Start Guide. Data related to their questions can be accessed, visualized, graphed, and analyzed. Based on that analysis, students develop a claim about the phenomenon using the data they gathered as evidence. Finally, students explain both the key science ideas behind their claim and how their evidence supports that claim. Teachers can extend the investigation by asking students to engage in two related science and engineering practices: 1) developing and using models to predict future storm recurrences, and 2) designing solutions for managing and/or mitigating the effects of hurricanes.

Using the *Quick Start Guide to Finding Data/Imagery for Student Investigations*

With an abundance of NASA data available to students, the initial challenge is finding the relevant source at the appropriate level. A resource created by the Institute for Global Environmental Strategies (IGES), entitled Quick Start Guide to Finding Data/Imagery for Student Investigations, will do both. The guide is available online at (sites.google.com/strategies.org/k12datapaths).

Figure 2. The Educator Toolkit features NASA resources for grades K-12 that can support and frame student investigations with NASA data and content.

The guide is broken down into three columns: the first column describes examples of data from the NASA focus area topics, the second column lists suggestions for investigable phenomena within those topic areas and connects to the NGSS content and practices, and the third column features seven online sources of data visualization which are bulleted to indicate applicability to the data example and phenomena. For example, NASA collects data on precipitation (column one) that can be used to investigate natural hazards and disasters such as severe storms (column two). Precipitation data is found in five of the seven online sources (column three).

This article features three Quick Start Guide sources, NASA Earth Observations (NEO), Precipitation Measurement Missions (PMM), and NASA Worldview. Each provides a gateway to precipitation data visualizations. The phenomenon of precipitation can be investigated as a scaffolded activity that builds toward an understanding of natural hazards/severe storms, such as hurricanes.

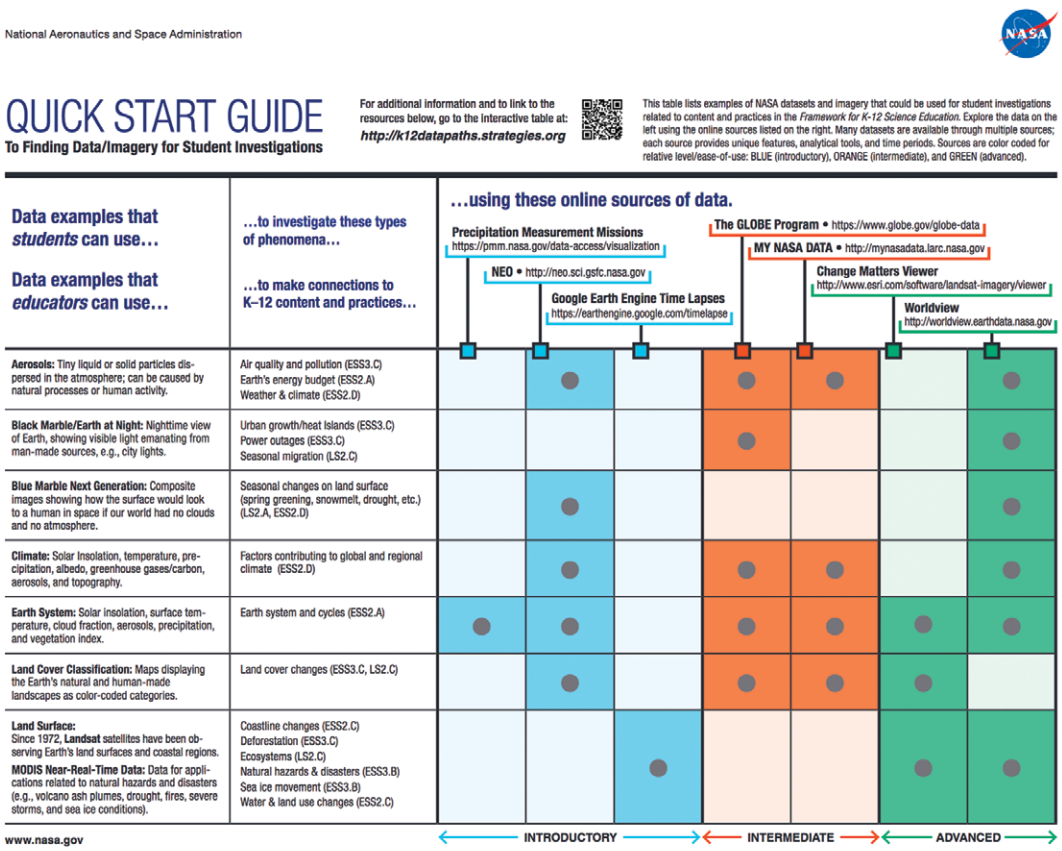

Figure 3. The Quick Start Guide to Finding Data/Imagery for Student Investigations.

NASA Earth Observations (NEO)

NEO's mission is to make global satellite imagery, particularly imagery featuring climate and environmental changes, as accessible as possible. To access NEO imagery, go to: neo.sci.gsfc.nasa.gov.

What it displays: Over 50 different global datasets are represented with daily, weekly, and monthly snapshots, and images are available in a variety of formats including JPEG, PNG, Google Earth, and GeoTIFF. One such dataset, sea surface temperature, is directly related to hurricanes.

Why this tool is relevant to a student investigation of hurricanes: Many of the questions generated by students at the beginning of their investigation of hurricanes, such as "Where do hurricanes get their energy?" or "Why does the hurricane season peak in late summer?" can be answered through research into one underlying variable- sea surface temperature.

Figure 4. NASA Earth Observations (NEO).

Using NEO to investigate Hurricane Harvey

Because hurricanes are fueled by warm ocean water, data on sea surface temperature is especially significant. Sea surface temperature is the temperature of the top millimeter of the ocean's surface- the ocean's skin. Slight changes in that temperature can have enormous impacts on hurricanes. Use the steps outlined below to explore the sea surface temperatures recorded in the Atlantic and Gulf regions before, during, and after Hurricane Harvey. To access NEO imagery, go to: http://neo.sci.gsfc.nasa.gov.

Follow these steps to access data on Sea Surface Temperature:

Ocean → Sea Surface Temperature 2002+ (MODIS)
Select Year → 2017
View by date: → 8 day → August 13-20 → Add to Analysis
View by date: → 8 day → August 21-28 → Add to Analysis
Analyze

Analysis Option allows you to select an area

Draw a box from the coast of Texas towards Africa
Keep the Mode to **Basic Exploration** and File size to **0.1 degrees** → Launch Analysis

The **Analysis Tool** displays the image dates you selected, in the order you selected them. Explore the following:

Click: → Data Probe and move within the image to see the values.
Click: → Plot transect and draw a line from right to left representing the path of Harvey.
Click: → Distance and draw a line from right to left to calculate the **distance** across an area.
Click: → Outline region to draw a polygon area, then choose **Scatter** or **Histogram** to see a plot of these values.

Want to know more about NASA NEO? Start with NEO Analysis in 10 Easy Steps: bit.ly/NEO_Analysis

Precipitation Measurement Missions (PMM)

Two separate but related missions make up the Precipitation Measurement Missions – the Global Precipitation Measurement (GPM) mission (2014 to present) and its predecessor the Tropical Rainfall Measurement Mission (TRMM) (1997-2015). The GPM mission, with its international network of satellites, provides global measurements of rain and snow allowing for improved forecasting of high-impact natural hazard events such as hurricanes. To access the PMM data visualization tools, go to: pmm.nasa.gov/data-access/global-viewer.

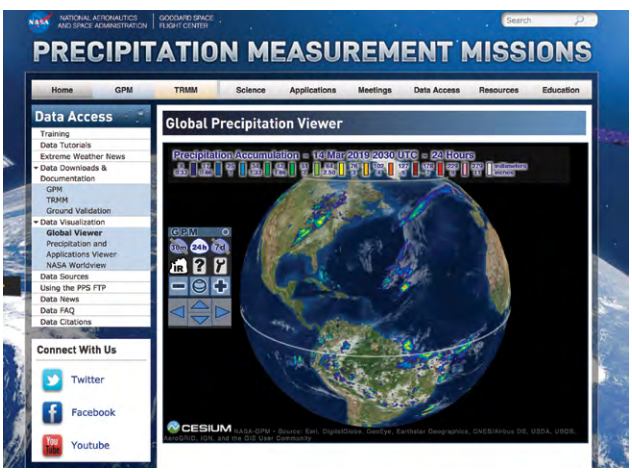

Figure 5. Precipitation Measurement Missions Global Precipitation Viewer.

What it displays: The data displayed will provide students with general information regarding global precipitation (any product formed by the condensation of water vapor that falls quickly out of a cloud). The GPM Global Precipitation Viewer is valued for its display of global precipitation estimates of rain and snow in near-real time (from as recent as the past 30 minutes, previous 24 hours and past 7 days). Hurricane Harvey was active in late August of 2017 and outside the range of the viewer's current data display. However, the Global Precipitation Viewer serves as a valuable resource for examining precipitation visualizations and discussing current precipitation events.

Why this tool is relevant to a student investigation of hurricanes: The PPM site is a valuable resource for middle school students seeking answers to general hurricane-related questions as well as sources of evidence to support their claims about hurricanes. Standard images of hurricanes feature a swirl of clouds; images of the aftermath of a hurricane's landfall prominently feature water. Students may ask: "Where did the clouds come from?" "Where did all of that water come from?" By providing background and insights into the roles of both atmospheric and hydrologic systems in the formation and strength of hurricanes, PMM data visualizations can lead to answers of those and other related questions.

NASA Worldview

This tool from NASA's Earth Observing System Data and Information System (EOSDIS) provides the capability to interactively browse global, full-resolution satellite imagery in near-real time. Imagery is generally available within three hours of satellite observation. To access NASA Worldview go to: worldview.earthdata.nasa.gov.

Note: The Worldview site opens to a link that provides a tour of the site features; it is highly recommended that new users complete the tour.

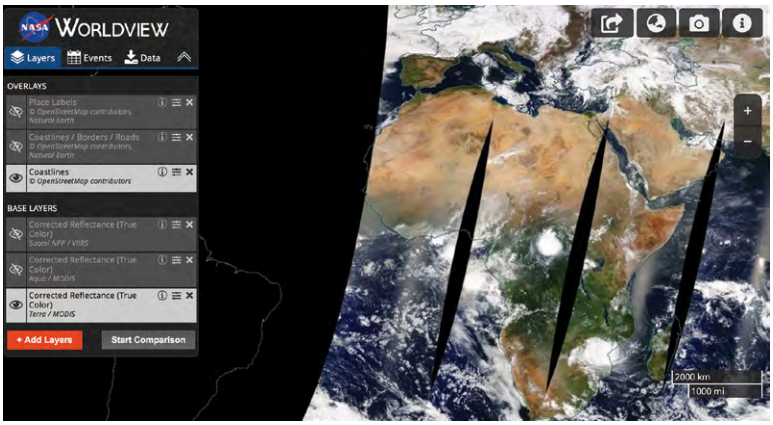

Figure 6. NASA Worldview.

What it displays: NASA Worldview displays full-resolution satellite images that essentially show the entire Earth as it looks "right now." The data related to the image can be downloaded. Many topics are catalogued under two general categories (Hazards and Disasters, and Science Disciplines) and can be perused using the "Add Layers" link in the left margin. For example, images and data related to hurricanes can be found under the Hazards and Disasters category in the topic areas of Severe Storms and Floods, and also under the category of Science Disciplines in the topic areas of Atmosphere and Oceans.

Why this tool is relevant to a student investigation of hurricanes: Data is available in near-real time. Students will be able to analyze, look for patterns and make predictions using data and tools that support unique science investigations.

Using NASA Worldview to investigate Hurricane Harvey

After touring the Worldview site features, follow these steps to get started:

Center the map view to include the Texas coast and the Gulf of Mexico to the west coast of Africa.
Set the **Timeline** to August 13, 2017. Hurricane Harvey made landfall on August 27.
Start by adding layers related to Sea Surface Temperature (SST)

Add layers → Hazards and Disasters à Severe Storms

Scroll through the list and select → Sea Surface Temperature (SST) → Terra/MODIS

This example uses **8 Day, Mid Infrared, 4km SST** data. MODIS (Moderate Resolution Imaging Spectroradiometer) is an instrument onboard both the Terra and Aqua satellites. The mid-IR channels are especially useful in high water vapor.

Add layers → Categories → Severe Storms → Precipitation Rate → IMERG → Rain Rate (Early).

IMERG is the Integrated Multi-satellitE Retrievals for the GPM data product. It is produced using data from the satellites in the GPM Constellation.

Make this the only visible layer.

Want to know the value of a particular location? Mouse over and look at the layers, they dynamically change in the legend.

Multiple layers may be added to the research area. Layers can be made visible by clicking the *'eye-shaped' button* to the left of the layer description.

j	Add layers
k	Select the date (year, month, day)
l	Layer visibility
m	Export layer to view in GoogleEarth

Many layers have extended information that is important to view with the "I" button. The temporal coverage may not include your specific timeframe, in which case, the viewer will not display the layer.

To see an animated series of imagery for comparison, follow these steps:

1. Use the buttons above and below the year, month and day to select your start date.
2. Click the animation button.
3. Choose how fast the animation should run by sliding left or right the frames-per second slider.
4. Click the play button.
5. Click to create an animated gif that you can download and save for presentations.

Extension: Using NASA Worldview data visualizations in other online tools: NASA Worldview visualizations can be exported to both GoogleEarth and ArcGIS. Each of these two online tools provides a uniquely different view of the original data.

Exporting to GoogleEarth

Why export to GoogleEarth? GoogleEarth is easy to use and presents the world in a 3D format. *Layers from NASA Worldview can be exported and saved in a .kmz format.*

- Click the camera icon → drag a box around the research area → Resolution: 5km → Format: KMZ → Download. Files are named using the following format: nasa-worldview-(image date).kmz
- Keep track of where the file is saved
- Open GoogleEarth → File → Open → find your file. GoogleEarth provides a spatial dimension to the investigation.

Exporting to ArcGIS Online

Why export to ArcGIS Online? Students will be able to explore, create and use their interactive web-based maps to reveal patterns, answers, and relationships and summarize the data.

Layers from NASA Worldview can be exported and saved in a .kmz format.

- Click the **camera** icon → drag a box around the research area → Resolution: 5km → Format: KMZ → Download. Files are saved in the following format: nasa-worldview-(image date).kmz
- Log in to www.arcgis.com (either a public or an organization account is required, both of which are free.)
- Click **Content** up top, → click **Add Item -- From my computer**, → **Browse** to the .kmz file on your computer and click it, → Give it a **title** and **tag,** i.e., Hurricane Harvey. Click **Add Item**.
- From the next screen, select **Open in Map Viewer**
- ArcGIS has additional data layers for investigations e.g. oil wells, transportation, population density, etc.

The ArcGIS for Schools Bundle is available at no cost for instructional use to individual US K–12 schools, school districts, and states direct from E. Beyond the United States, the bundle is available to schools worldwide through network of international distributors. Every public, private, home school, and youth-serving club is eligible (arcg.is/2pfOE0P).

A public account is another way to access ArcGIS Online. These accounts are not associated with an organization and offer a limited set of functionalities. A public account allows you to use and

create maps and share your maps and apps with others. Public accounts are for noncommercial use only (arcg.is/2BRbiPC).

Additional Tools

Online Resources: KEY FEATURES is a separate resource developed by IGES to accompany the Quick Start Guide. Image shots from seven online sources of Earth science data tools are shown, with the key features of the site highlighted. These are Google Earth Engine: Time Lapses, Precipitation Measurement Missions, NASA Earth Observations (NEO), The GLOBE Program: Visualization System and Advanced Data Access Tool (ADAT), MY NASA DATA, NASA Worldview, and ESRI Change Matters. The downloadable resource is available at bit.ly/2BI0whe.

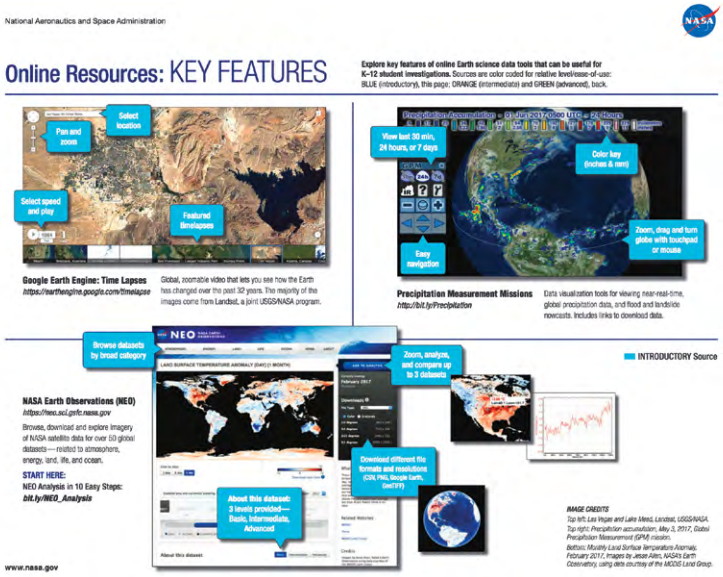

Figure 7. NASA Online Resources Key Features (bit.ly/2yTjJes).

NASA Wavelength – science.nasa.gov/wavelength – is a digital library of resources developed through funding of the NASA Science Mission Directorate (SMD). Search by Topic, Grade and Lessons. There are several hurricane event-based lessons using MYNASA DATA in Wavelength (mynasadata.larc.nasa.gov).

One of the most-used is **Hurricanes as Heat Engines** (mynasadata.larc.nasa.gov/lesson-plans/hurricanes-heat-engines) which guides students through an examination of sea surface temperature data exploring how hurricanes extract heat energy from the ocean surface. Use the keyword "hurricanes" in MYNASA DATA to bring up other resources..

Hurricanes: An Environment of Concern (http://bit.ly/2Dw4Cqw/) investigates the potential for future deadly and damaging hurricanes to impact the Gulf Coast area.

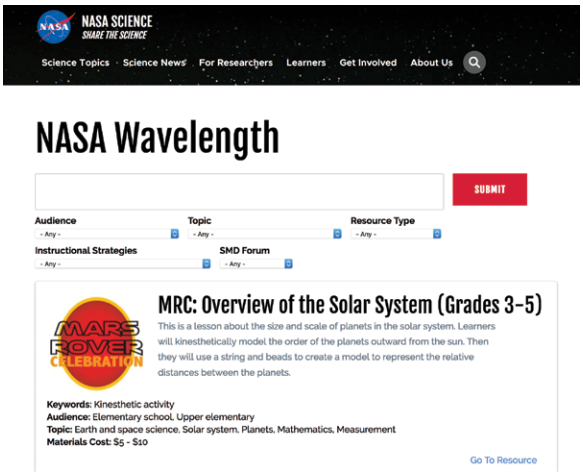

Figure 8. NASA Wavelength

Conclusion

Hurricanes are just one example of an anchoring phenomenon that can be investigated using NASA data. Middle school students can construct fundamental explanations of the science of hurricanes by using that data as part of their evidence and reasoning.

Constructing explanations using evidence and reasoning is one of the most important scientific practices a student can learn. Teachers play an essential role in developing that scientific practice. Teachers guide students through the Claim-Evidence-Reasoning process by introducing the phenomenon, providing a source of authentic and grade-appropriate data, and offering guidance on both selecting and incorporating evidentiary data in their explanations. The Quick Start Guide is a valuable resource for teaching students to use evidence and reasoning in constructing explanations. It lists many Earth science phenomena being studied by NASA, provides links to sources of that data, and makes connections to NGSS.

Using NASA data visualizations provides a pathway rich with multiple investigative opportunities. Frequent use of the Quick Start Guide- and the world of NASA data it opens up- will allow students to engage in the practices of science while developing a better understanding of Earth as an integrated system.

Acknowledgement

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This work builds on the 2013 Educators Guide to NASA Earth Science Data and Images that IGES created under NASA Cooperative Agreement: NNX09AQ09A. The 16-page booklet illustrates sample data sources as well as firsthand accounts of how these are being used in the classroom or informal education settings. (strategies.org/products/images-and-data-quick-start-guide/)

Please share your thoughts and how you've used the Quick Start Guide with us here: bit.ly/qs-guide

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Data Resources

Change Matters Viewer - esri.com/software/landsat-imagery/viewer

ESRI (Environmental Systems Research Institute), ArcGIS Online esri.com/software/arcgis/arcgisonline

Google Earth Engine Time Lapses – earthengine.google.com/timelapse

MY NASA DATA – mynasadata.larc.nasa.gov

NASA Earth Observations (NEO) – neo.sci.gsfc.nasa.gov/

Aerosol – neo.sci.gsfc.nasa.gov/view.php?datasetId=MYDAL2_M_AER_OD

NASA PMM Data Visualization Tools – pmm.nasa.gov/data-access/visualization

NASA Worldview – worldview.earthdata.nasa.gov

The GLOBE Program, Visualization and Advanced Data Access Tool – globe.gov/globe-data