Extreme Heat:

Heat Waves, Drought and Agriculture

Food and Agriculture
Center for Science Education

Educator's Guide

Welcome Educators!

Welcome to the "Extreme Heat: Heat Waves, Drought and Agriculture" educator's guide. This educator's guide brings together a series of activities developed by the education office at NASA's Jet Propulsion Laboratory, along with resources developed by the American Farm Bureau Foundation for Agriculture, to provide a comprehensive exploration of how weather and drought impact agriculture.

Before you jump in, take a moment to familiarize yourself with this resource!

Lesson 1: How Do We Collect and Interpret Data?

Lesson 2: Monitoring Our Planet's Health

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Lesson Snapshot

Throughout each lesson you will find:

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Links to Supporting Videos

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Link to NASA or AFBFA Activity Outline

AMERICAN FARM BUREAU FOUNDATION FOR AGRICULTURE®

The American Farm Bureau Foundation for Agriculture® is building awareness, understanding, and a positive public perception of agriculture through education.

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Lesson 1: How Do We Collect and Interpret Data?

Next Generation Science Standards

- 4-ESS2-2 Earth's Systems
- 5-ESS2-1 Earth's Systems
- MS-LS2-1 Ecosystems: Interactions, Energy and Dynamics
- HS-ESS2-2 Earth's Systems
- HS-ESS3-5 Earth and Human Activity

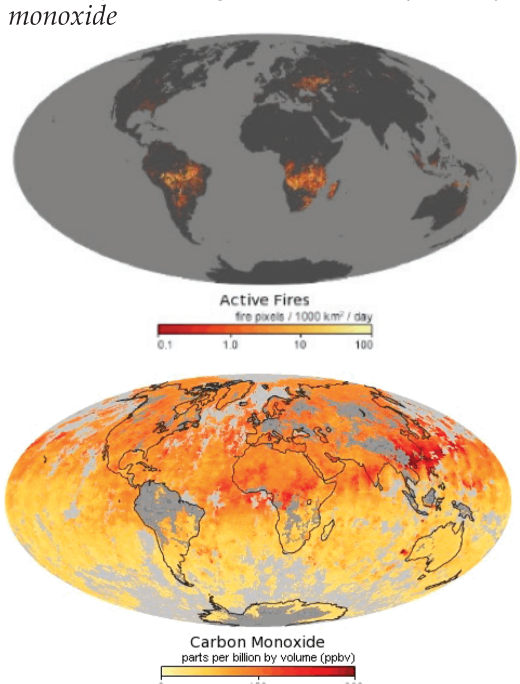
Overview

This activity shows students how to read and interpret a common data representation, the heat map. Students will examine heat map representations of Earth science data over time, discuss trends and compare data sets in order to assess potential correlation.

Background

Before we can be productive scientists exploring heat and drought, we first need to understand what it means to collect and interpret data. Often in experiments we use remote sensing and visualization techniques in order to represent data. Because we are looking at such large volumes of data over time, it can help to put the data into what is called a *heat map* to better understand trends over time.

Sample heat maps showing concentration of active fires and carbon monoxide



A heat map is a specialized chart that uses colors to represent data values in a table or physical map. Contrary to their name, heat maps don't necessarily map temperature. Instead, they map the amount or concentration of certain measurements. Heat maps are mostly used to plot large and complex data, such as Earth science measurements, so they can be viewed as a whole data set at once. Heat maps can take the form of a rectangular chart, the cells of which contain numerical data. Or, more commonly in Earth science applications, heat maps are colors overlaid on a map of Earth. The colors represent variations in the data. The values the colors represent are indicated in the map legend and can take the form of a color gradient (range) or discrete colors.

For example, "NASA | A Year in the Life of Earth's CO2" looks at the levels of carbon dioxide in our atmosphere over the years using heat maps.

View the video here: https://www.youtube.com/watch?v=x1SgmFa0r04

Carbon dioxide is a greenhouse gas emitted from burning fossil fuels, such as our automobiles, and results in the capturing of heat from the sun. Because the heat is captured in our atmosphere instead of released into space, we observe an increase in global temperature. At NASA, researchers use heat maps to track this data. This allows us to answer questions such as how temperatures of our oceans and our communities are changing over time as a result of increased greenhouse gas levels.

Classroom Activity: Earth Science Data Visualizations – How to Read a Heat Map
https://www.jpl.nasa.gov/edu/teach/activity/earth-science-data-visualizations-how-to-read-a-heat-map/

This lesson and related materials were created by the Education Office at NASA's Jet Propulsion Laboratory. For related lessons and to explore the complete collection of STEM lessons from NASA/JPL Edu, visit https://www.jpl.nasa.gov/edu/teach.

Lesson 2: Monitoring Our Planet's Health

Next Generation Science Standards

- 5-ESS2-1 Earth's Systems
- HS-ESS2-2 Earth's Systems
- HS-ESS2-4 Earth's Systems
- HS-ESS3-5 Earth and Human Activity

Overview

In this activity, students will use global temperature data to create models and compare short-term trends to long-term trends. They will then determine whether global temperature is rising based on the data.

Background

When we want to observe data in the short or the long term, it can help to graph the data. Now that we've discovered that the global temperatures of land and water are increasing, it is important to ask: How do we capture this and communicate it scientifically? It is also important to know if this is just a short-term observation or a larger historical trend.

For example, "NASA's Earth Minute: Earth Has a Fever" looks at Earth's average temperature over time.

View the video here: https://www.youtube.com/watch?list=PL9TFrgFq75552g7qVa-iTOeuo7Fy11o5f&v=nAuv1R34BHA

Much like what was found in Lesson 1, scientists have concluded that our climate is changing, that global temperatures are on the rise and that there are serious consequences to these rising temperatures. But in an age of plentiful yet opposing information, how do students separate fact from fiction? Examine the source data and do the math.

Weather and *climate* are two frequently confused terms that refer to events with broadly different spatial and time scales. ***Weather*** refers to atmospheric conditions that occur locally over short periods of time — from minutes to hours or days. Familiar examples include rain, snow, clouds, winds, floods or thunderstorms. Remember, weather is local and short-term. ***Climate,*** on the other hand, refers to the long-term regional or even global average of temperature, humidity and rainfall patterns over seasons, years or decades. Climate is regional or global and long-term; weather is local and short-term. Erratic weather in your neighborhood — whether rain or drought — may or may not be a symptom of global climate change. To know, we must monitor weather patterns over many years.

Two other terms that are often incorrectly used interchangeably are *global warming* and *climate change*.

Global warming refers to the upward temperature trend across the entire Earth since the early 20th century — and most notably since the late 1970s. Though there are many different greenhouse gases, carbon dioxide, or CO2, is the one that has been on the rise during the past century. Since the beginning of the Industrial Revolution, the concentration of CO2 in the atmosphere has increased by 39 percent. Increasing the concentration of greenhouse gases causes the Earth greenhouse to overheat. Worldwide since 1880, the average Earth surface temperature has gone up by about 1.4 degrees Fahrenheit (0.8 degrees Celsius) relative to the mid-20th-century baseline (measured between 1951 and 1980).

Learn more with "NASA's Earth Minute: Gas Problem."

View the video here: https://www.youtube.com/watch?v=K9kga9c0u2I&feature=youtu.be&list=PL9TFrgFq75552g7qVa-iTOeuo7Fy11o5f

Check out the online "Carbon Dioxide" tool here: https://climate.nasa.gov/vital-signs/carbon-dioxide/

Check out the online "Global Temperature" tool here: https://climate.nasa.gov/vital-signs/global-temperature/

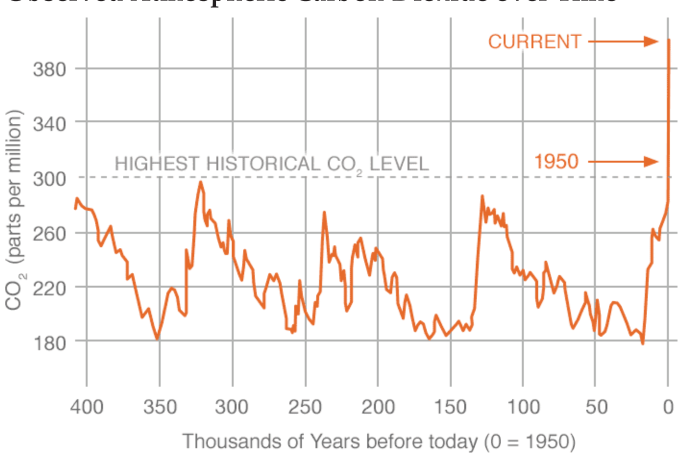
Climate change refers to a broad range of global phenomena created predominantly by burning fossil fuels, which add heat-trapping gases to Earth's atmosphere. These phenomena include the increased temperature trends described by global warming, but also encompass changes such as sea-level rise; ice-mass loss in Greenland, Antarctica, the Arctic and mountain glaciers worldwide; shifts in flower and plant blooming; and extreme weather events.

Learn more with "NASA's Earth Minute: Usual Suspects."

View the video here: https://www.youtube.com/watch?v=dLGbqjp78lE.

Climate change is driven by an increase in global temperature. But how do we know global temperatures are on the rise? We analyze temperature data, including daily temperature readings and monthly or annual average temperatures. The longest running record of directly measured temperature is the Central England temperature data series starting in 1659. The longest-running *global* record starts in 1880. Data are obtained from land stations and ships around the globe. More recently, satellites are used to measure temperature in the troposphere, the lowest level in our atmosphere.

Observed Atmospheric Carbon Dioxide over Time



It is possible to derive temperatures prior to the dates of these modern records by studying polar region ice cores and ocean sediment cores. Ice cores store records of millennia of climate data. Using ice cores, scientists have reconstructed climate data for the last 750,000 years, showing seven ice ages, each interspersed with a warm interglacial climate like our climate today. (The difference between those interglacial periods and today is the increased rate at which the climate is changing.) Ocean sediment cores add more data to the puzzle by way of marine fossils and sedimentary layers. Isotopic oxygen in marine fossils gives us information about ocean temperatures when the fossils were formed, and sedimentary layers provide data about historical events such as volcanic eruptions.

Classroom Activity: Graphing Global Temperature Trends
https://www.jpl.nasa.gov/edu/teach/activity/graphing-global-temperature-trends/

This lesson and related materials were created by the Education Office at NASA's Jet Propulsion Laboratory. For related lessons and to explore the complete collection of STEM lessons from NASA/JPL Edu, visit https://www.jpl.nasa.gov/edu/teach.

Lesson 3: Water and Drought

Next Generation Science Standards

- 3-ESS2-1 Earth's Systems
- 4-ESS2-2 Earth's Systems
- 5-ESS2-1 Earth's Systems
- MS-ESS2-4 Earth's Systems
- HS-ESS2-2 Earth's Systems
- HS-ESS3-6 Earth and Human Activity

Overview

In the activity "Modeling the Water Budget," students will use precipitation totals and evapotranspiration data to calculate and graph water deficits and surpluses. These spreadsheet models will help students understand droughts and the movement of water in the water cycle. In the activity "Fired up over Math," students will learn how scientists assess wildfires using remote sensing. Students then use some of the same techniques to solve grade-level appropriate math problems.

Background

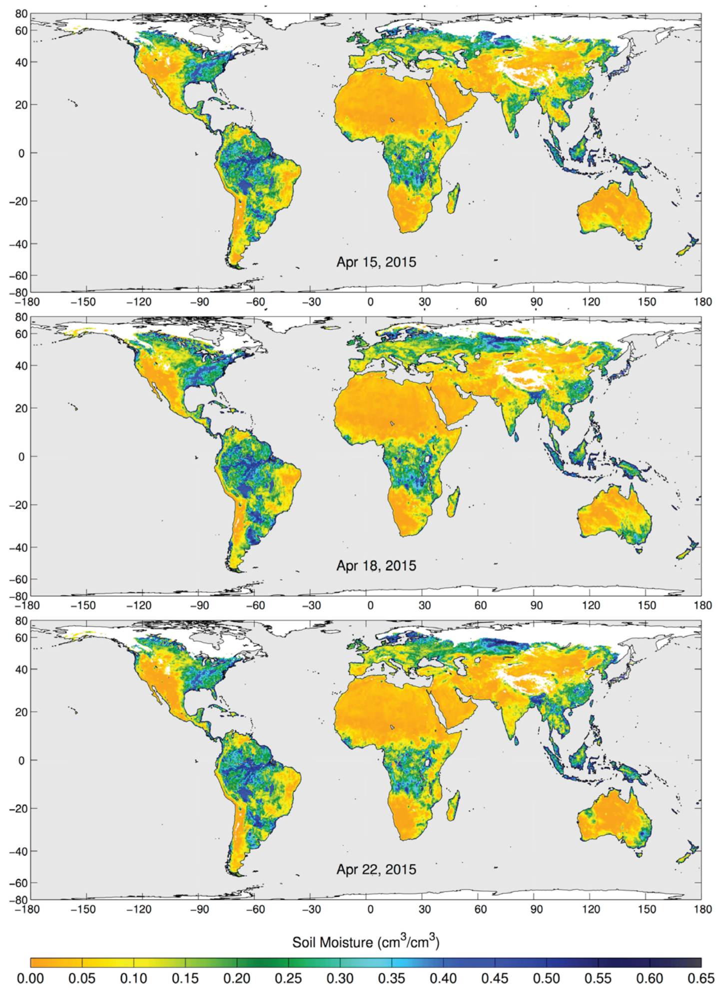
When we think about climate change and increasing global temperatures, we need to be concerned about a lot more than just how our bodies react. Remember, much like we are, the Earth is composed of large amounts of water. What does this increased global temperature mean for our oceans and lakes? What about our fresh water supplies on which we depend for drinking water and the means to grow our crops? Scientists explore this question by building a water budget: a mechanism to show where our water is going and whether or not the amount available is changing favorably or harmfully over time. Two ways we lose water are **evaporation** and **transpiration**, which can be combined as evapotranspiration. Evapotranspiration is influenced by solar radiation, temperature, relative humidity, wind, soil moisture and the density and type of vegetation in an area.

Due to the variety of climates, surface types and vegetation coverage in the United States, it is currently not possible to know the exact amount of water being lost to the atmosphere through evapotranspiration at a given time.

However, using climate data and hypothetical surface types for various regions, scientists have created a reference rate known as ***potential evapotranspiration.*** For example, in California there are 18 different potential evapotranspiration zones. These reference rates approximate the amount of water that could be lost through evapotranspiration during each month of the year for each zone.

Comparing potential evapotranspiration to actual rainfall data can provide a better understanding of the water balance in an area. During months when *more* rain falls than potentially evapotranspirates, there will be a water surplus. During months when *less* rain falls than potentially evapotranspirates, there will be a water deficit. Calculating these data is an important part of studying climate and drought.

Soil Moisture Data Collected from NASA's SMAP Satellite



As we lose water, the land becomes drier and is at risk of wildfires. Wildfire is a global reality. Improper forest management and the onset of climate change impact the rate of wildfires annually. The impacts of wildfires range from the immediate and tangible to the delayed and less obvious. The potential for loss of life, property and natural areas is one of the first threats that wildfires pose. From a financial standpoint, fires can lead to a downturn in local economies due to loss of tourism and business, high costs related to infrastructure restoration and impacts to federal and state budgets.

Measuring the effects of wildfires takes many forms, several of which use remote-sensing technologies. Remote sensing (observing and measuring an object without coming into contact with it) is performed by instruments on-board NASA aircraft and satellites. These instruments measure the radiation being emitted by or reflected off of an object, whether it's radio waves, visible-light waves or energy from another part of the electromagnetic spectrum. Infrared imagery is particularly useful in studying wildfires during the fire and in the aftermath.

The activities linked below reference a few recent fires including the 2014 King Fire, a fire NASA's Jet Propulsion Laboratory and the U.S. Forest Service have collaboratively studied in depth. The King Fire burned more than 100,000 acres in Placer County, California, in September 2014. It was a uniquely severe fire that produced a great deal of smoke threatening global air quality. Unprecedented fire data contributing to the advancement of science was acquired by a variety of sensors including the AVIRIS instrument flying aboard NASA's ER-2 aircraft high above the King Fire; the Moderate Resolution Imaging Spectroradiometer (MODIS) flown on two satellites, Aqua and Terra; and the Operational Land Imager (OLI) aboard *Landsat 8*.

Learn more in the article "Unprecedented Megafire Remote Sensing" here: https://wildfire.jpl.nasa.gov/

View a map of the California King Fire here: https://wildfire.jpl.nasa.gov/images/CaliforniaKingFire.png

Learn more about the AVIRIS here: https://aviris.jpl.nasa.gov/

Learn more about NASA's Airborne Science Program here: https://airbornescience.nasa.gov/

Learn more about MODIS here: https://modis.gsfc.nasa.gov/

Learn more about Aqua here: https://aqua.nasa.gov/

Learn more about Terra here: https://terra.nasa.gov/

Learn more about OLI here: https://landsat.gsfc.nasa.gov/operational-land-imager-oli/

Learn more about *Landsat* here: https://www.nasa.gov/mission_pages/landsat/main/index.html

The scorched area left after a fire is called a *burn scar*. A lot can be learned from burn scars. The most obvious is the amount of territory that was touched by the fire. Less obvious but more important to fire scientists is the severity of the fire. Wildfires are classified as burning at different levels of severity: low, medium and high. Severity is a function of intensity, or how hot the fire was, and its spread rate, or the linear (kilometers per hour) speed at which it travels. Fire severity describes how fire intensity affects an ecosystem. A high-severity fire is going to cause some irreparable damage to plant life, while a low-severity fire will be recoverable for many large trees. Severity is measured by the damage left after the fire but can be estimated during a fire event by calculating spread rate and measuring flame height, which indicates intensity.

Learn more about burn scars here: https://www.nasa.gov/feature/goddard/burn-scars-from-the-rocky-fire-california

Learn more about fire intensity by reading Jon Keeley's "Fire intensity, fire severity and burn severity: a brief review and suggested usage." View the peer-reviewed article here: https://www.fs.fed.us/postfirevegcondition/documents/publications/keeley_ijwf_2009.pdf

Classroom Activities

Modeling the Water Budget
https://www.jpl.nasa.gov/edu/teach/activity/modeling-the-water-budget/

Studying Wildfires from Space
https://www.jpl.nasa.gov/edu/teach/activity/fired-up-over-math-studying-wildfires-from-space/

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Lesson 4: How Much Water Do We Need?

Next Generation Science Standards

- MS-ESS3-1 Earth and Human Activity
- MS-ESS3-3 Earth and Human Activity
- MS-LS1-2 From Molecules to Organisms: Structures and Processes

Overview

Students will be able to communicate that different crops require varying amounts of water to be produced, crops are affected if watered incorrectly and farmers use new technology to responsibly manage water.

Background

Now that we understand how much of a commodity water can be, we must ask ourselves how much of that water do we need to grow the crops that feed our communities.

Water is essential for growing crops and raising livestock that provide food and fiber we depend on. American farmers and ranchers take stewardship of natural resources, like water, seriously. Careful stewardship by America's food producers spurred a 44 percent decline in erosion of cropland by wind and water since 1982. Strategies like contour farming, where farmers plant crops across the slope of the land, help farmers conserve water and protect the soil. New technology enables farmers to accurately measure soil moisture and provide direct application of water specifically when and where crops need it.

In this activity, students will compare the water budgets they created previously with the water demands of different crops, such as fruits, vegetables and nuts. It will also foster exploration of the technologies we have at our disposal to responsibly manage water.

Classroom Activity

Dive in! Exploring the Science of Water and Food Production
http://www.agfoundation.org/files/Dive_In_Ed_Guide.pdf

This lesson and related materials were created by the American Farm Bureau Foundation for Agriculture.

For related lessons visit www.agfoundation.org.

Lesson 5: Solutions

Next Generation Science Standards

- HS-ESS2-4 Earth's Systems
- HS-ETS1-2 Engineering Design

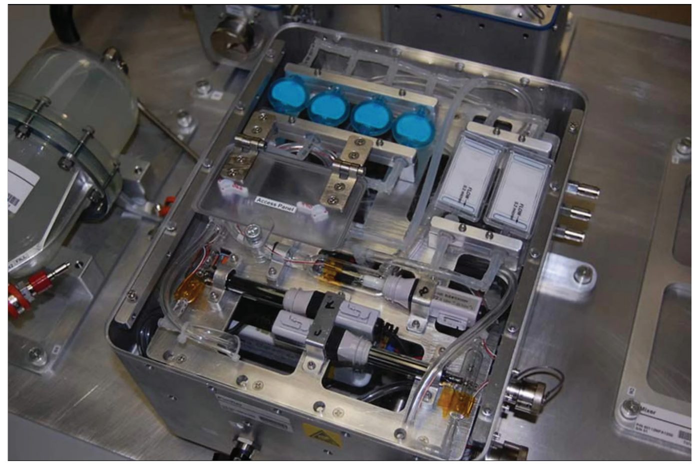
Overview

The process of switching to cleaner forms of energy is a complex issue. This activity allows students to break the issue down into more manageable pieces and to explore solar energy. Students will model solar energy inputs at different locations, analyze the cost effectiveness of installing solar panels and determine the appropriate locations for solar panels.

Background

As citizen scientists and engineers, it is our job not just to observe the effects of extreme heat and drought, but also to propose solutions. How can we solve some of these problems, ranging from mitigating the damage to dramatic changes in our actions capable of offsetting any damage done so far?

When it comes to water use, one immediate solution could simply be to better utilize this resource. This means being mindful of how much water we're using and how we recycle the water we do use. When we look at the polluted water in our communities, we are led to ask: ***Can we reclaim this water and reuse it? When we look at how water is used for agriculture, we are led to ask: Can we use it more efficiently?***



This IntraVenous Fluid Generation (IVGEN) system produces IV-grade water from space station drinking water.

Classroom Activity

Think Green: Utilizing Renewable Energy
https://www.jpl.nasa.gov/edu/teach/activity/think-green-utilizing-renewable-solar-energy/

This lesson and related materials were created by the Education Office at NASA's Jet Propulsion Laboratory. For related lessons and to explore the complete collection of STEM lessons from NASA/JPL Edu, visit https://www.jpl.nasa.gov/edu/teach.

Looking for More Resources?

For related lessons and to explore the complete collection of STEM lessons from NASA/JPL Edu, visit https://www.jpl.nasa.gov/edu/teach.

For related resources connected to agriculture from the American Farm Bureau Foundation for Agriculture, visit http://www.agfoundation.org/

Additional Suggested Sites

NASA Global Climate Change: https://climate.nasa.gov/

Climate Change Facts: https://climate.nasa.gov/evidence/

Orbiting Carbon Observatory 2: https://www.nasa.gov/mission_pages/oco2/index.html

Soil Moisture Active Passive: https://smap.jpl.nasa.gov/

USGS Water Data for the Nation: https://waterdata.usgs.gov/nwis

United States Drought Monitor: http://droughtmonitor.unl.edu/

Purple Plow Challenge Maker Space Program: http://purpleplow.org/

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