My NASA Data - Lesson Plans

Behavior Over Time: Analyzing Seasonal Soil and Air Properties

Grade Band

- 6-8
- 9-12

Lesson Duration

- 50 minutes

Sphere(s)

- Atmosphere
- Geosphere

Phenomenon

- Changing Air Temperatures
- Soil Moisture

NGSS Disciplinary Core Ideas

- ESS2A: Earth Materials and Systems
- ESS3A: Natural Resources

Science and Engineering Practices

- Developing and Using Models
- Constructing Explanations and Designing Solutions

NGSS Crosscutting Concepts

- Cause and Effect
- Systems and System Models
- Stability and Change

NGSS Performance Expectation

- MS-ESS2-1: Develop a model to describe the cycling of Earth's materials and the flow of energy that drives this process.

- MS-ESS2-4: Develop a model to describe the cycling of water through Earth's systems driven by energy from the sun and the force of gravity.
- MS-ESS3-1: Construct a scientific explanation based on evidence for how the uneven distributions of Earth's mineral, energy, and groundwater resources are the result of past and current geoscience processes.
- HS-ESS2-4: Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate.
- HS-ESS3-5: Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth's systems.

Common Core Math

- CC.6.SP.4 Summarize and describe distributions. Display numerical data in plots on a number line, including dot plots, histograms, and box plots.
- CC.6.SP.5 Summarize and describe distributions. Summarize numerical data sets in relation to their context.
- CC.9-12.S.ID.1 Summarize, represent, and interpret data on a single count or measurement variable. Represent data with plots on the real number line (dot plots, histograms, and box plots).*
- CC.9-12.S.ID.3 Summarize, represent, and interpret data on a single count or measurement variable. Interpret differences in shape, center, and spread in the context of the data sets, accounting for possible effects of extreme data points (outliers).*

Related Resources

- SMAP Mission Video

Student Handout(s)

- Student_Behavior Over Time_ Analyzing Seasonal Soil and Air Properties_Final (1).pdf

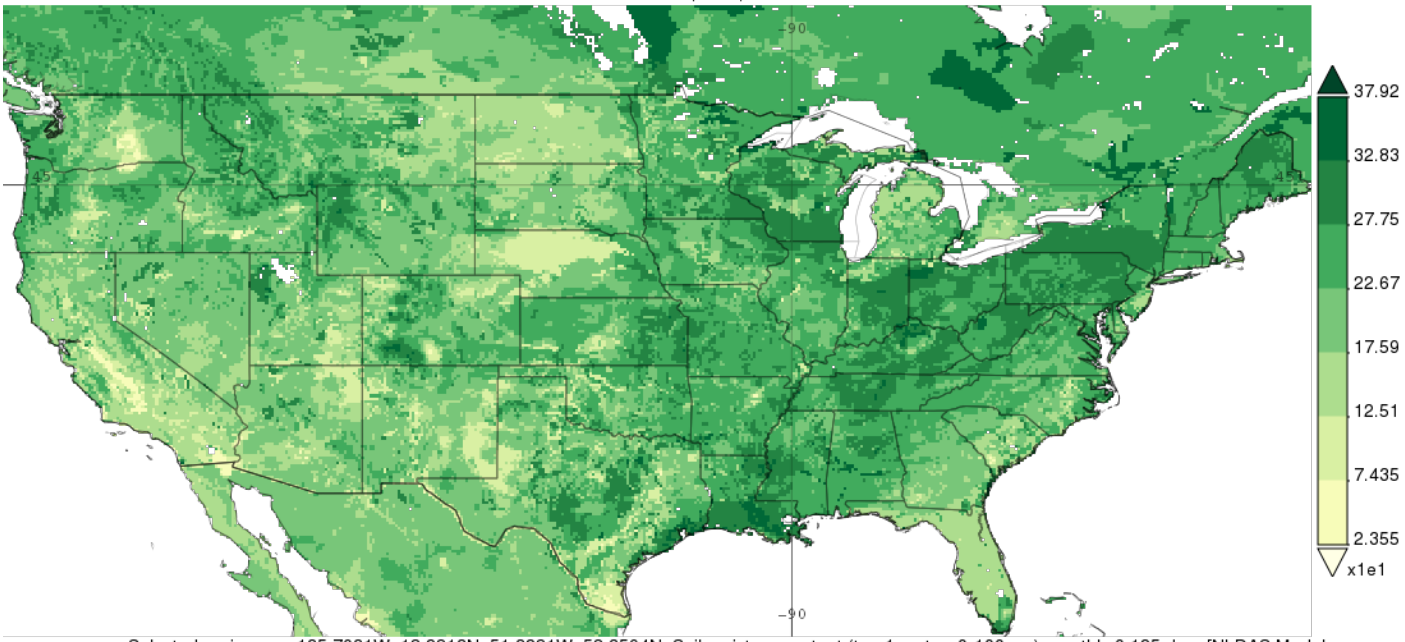
Key Vocabulary

- Soil moisture
- Surface Air Temperature
- Behavior Over Time Graph

NASA Data Types

- Soil moisture content
- Surface Air temperature

JJA (2017-Jun - 2017-Aug)
Soil moisture content (top 1 meter, 0-100 cm) monthly 0.125 deg. [NLDAS Model NLDAS_NOAH0125_M v002] kg/m^2 over 2017-Jun - 2017-Aug, Region 125W, 25N, 67W, 53N



- Selected region was 135.7031W, 18.2813N, 51.3281W, 58.3594N. Soil moisture content (top 1 meter, 0-100 cm) monthly 0.125 deg. [NLDAS Model NLDAS_NOAH0125_M v002] kg/m^2 has a limited data extent of 125W, 25N, 67W, 53N. The region in the title reflects the data extent of the subsetted granules that went into making this result.

Purpose

Students review Earth System phenomena that are affected by soil moisture. They analyze and evaluate maps of seasonal global surface air temperature and soil moisture data from NASA satellites. Building from their observations, students will select a location in the US to extract scientific data and then create Behavior Over Time graphs for each variable and communicate their findings.

Learning Objectives

- Use evidence to create an explanation.
- Observe the seasonal changes of surface temperature and soil moisture from across the United States during 2017.
- Analyze temperature and moisture values and infer relationships between these variables.
- Create Behavior Over Time graphs of two datasets.

NASA Phenomenon Connection

Scientists worldwide warn of increasing temperatures in the future. There is a relationship between soil moisture and surface air temperature and this plays an important role in climate change that involves not only weather and climate but also the entire Earth System. NASA scientists strive to better understand how water availability changes around the globe, as well as better predict floods and drought in weather models. As Earth's temperature rises, our soils dry out and affect crop production, drought extent, and forest fire to name a few. NASA also researches additional phenomenon connected to soil moisture properties including landslide risks and vector-borne diseases (i.e., include but are not limited to cholera, malaria, dengue fever, Zika, schistosomiasis, and West Nile fever).

Essential Questions

1. How does increasing atmospheric temperatures affect the Geosphere?

2. How does water connect the soil, the Atmosphere, and the Biosphere?

3. What role does the Sun's energy play in the hydrologic cycle? What evidence do you have?

Cross-Curricular Connections

National Geography Standards:

1. How to use maps and other geographic representations, tools, and technologies to acquire, process, and report information from a spatial perspective.

7. The physical processes that shape the patterns of Earth's surface.

STEM Career Connections

- Geoscientists - Research physical properties of the earth, such as rocks, soils, and other materials.

- Soil and Plant Scientists - Explore the breeding, production, and management of crops, trees, and plants.

- Conservation Scientists - Research, manage and protect natural resources like soil, forests, and water.

- Atmospheric and Space Scientists - Investigate weather and climate-related phenomena to prepare weather reports and forecasts for the public

- Earth Drillers, Except Oil and Gas - Explore minerals and soil properties through a variety of drilling and testing measures.

- Agricultural Engineers - Solve problems that are related to the way farms work.

- Computer and Information Scientists - Conduct research in the field of computer and information science

- Remote Sensing Scientists and Technologists - Research a variety of topics using techniques that allow the study of an object or phenomena without making contact directly with the object such as analyzing geological and geographical data. They typically work with aerial or satellite pictures.

Technology Requirements

- Standalone Lesson (no technology required)

Background Information

NASA actively monitors soil moisture and these measurements have practical applications that range from food availability to flood safety and weather forecasting. Water, energy and carbon exchanges between the land and the air are linked together through soil moisture. Detailed monitoring of soil moisture provides a view of how our whole Earth system works. The health of Earth's biosphere is dependent on the flow and storage of water, energy, and carbon. Our global climate and its future changes are dependent on how these major Earth cycles link and vary together. Global change is the major environmental challenge of our century, and its impacts can cause major shifts in how our societies will function in the future.

Through soil moisture data collection, NASA sensors provide critical information for drought early warning. In fact, a deficit in the amount of moisture in the soil defines agricultural drought. The measurements from Soil Moisture Active Passive mission, SMAP, are tools for mitigating drought in the future. Researchers forecast a threefold increase in drought frequency in many regions of the world by the end of the 21st Century. History shows that a sustained drought can result in crop failure, deaths of livestock, and ultimately deaths of people. There is an economic impact as well. It is estimated that the 2012 drought in the Midwest led to harvest failures costing an estimated $30 billion.

Soil monitoring is a critical factor for evaluating healthy plant growth, and will help improve crop yield forecasts and irrigation planning around the world. By indirectly monitoring global food production, NASA will improve targeting of humanitarian food assistance. Studies estimate that climate change will increase the number of undernourished people worldwide in 2080 by 5-26%.

Having a better understanding of soil moisture will also improve our ability to predict and warn residents about impending flood by assessing how wet the soil is before a rainstorm. Floods are the #1 natural disaster in the United States and they account for 40% of all natural disasters worldwide. Flooding is the leading cause of weather-related deaths in the United States. Flash flood guidance is updated at least every 24 hours based on surface soil moisture. Losses due to floods here average billions of dollars per year.

The amount of water available to evaporate from the land surfaces can be used by meteorologists to improve their forecasts of local and regional weather over spans of days to weeks. Forecasting the weather requires continuously observing the state of the atmosphere and including the level of moisture of the soil and water sources on the ground. Nearly 90% of the emergencies declared by the Federal Emergency Management Agency and approximately 70% of air traffic delays are caused by weather, at a cost of many billion per year.

Modified from [NASA SMAP.]

Behavior Over Time (BOT) Graphs:

Scientists in the 21st Century are forced to consider complex or "wicked" problems through interdisciplinary lenses and often utilize processes called Systems Thinking to level up their ability to understand the underpinnings of complex systems, such as climate change, water and food shortage, mass migration, etc. An important skill for systems thinkers is the process of documenting and evaluating Behavior Over Time (BOT). BOT graphs are not new to science teachers as graphing is often seen as the first step to better understanding complex systems. BOT graphs are line graphs that include time (x-axis) and one or more variables (y-axis). Processing the data in the BOT and then communicating findings is a critical part of the BOT process where students are encouraged to move beyond graphing variable/s where they begin to explain system's behavior of the system over time.

Connection Circles:

Connection Circles are useful for developing students' systems thinking abilities. These circles provide a graphic organizer for students to analyze parts of a system and how those parts affect one another. Write the parts of a system that change over time around edges of the circle. Draw lines from one part to the other to show that they are related to one another and cause/effect relationships. For more information on how to use Connection Circles, check out this video.

Prerequisites Student Knowledge

- Locating geographical locations using latitude and longitude and a world map
- Graphing
- Reading map legend

Student Misconception

- The majority of secondary students struggle with the idea that water vapor in air can come from water in plants and in the soil.

Credit: AAAS Science Links

Procedure

Part 1: Engaging Prior Knowledge of Common Phenomena Related to Soil Moisture

1. To engage prior knowledge, have students work in small groups to quickly describe phenomena related to soil moisture found on the Student Thinking Slips. Distribute a Student Thinking Slip to each student group. Student groups describe the phenomenon using the questions below and report out:
    1. A. Describe this phenomenon.

       B. What causes it? What sphere(s) does it relate to or are affected by it?

C. How does it trigger changes throughout other parts of the Earth System?

2. Draw a Connection Circle on the Board, and give out a copy to each student. As students are reporting out, students should draw connecting lines to the different phenomena provided. Model this with the students.

3. Now show the SMAP Mission Video to the students. Have them write in additional information provided in the video on the Connection Circle.

Part 2: Exploring Soil Moisture & Surface Air Properties

1. Ask students to describe soil moisture and how it is related to each of the phenomena.

Compared to the amount of water stored elsewhere on the planet, the amount in the soil is minuscule. But that small volume has great significance around the world. Soil moisture controls how much precipitation is soaked into the ground and how much turns into runoff. Average layer soil moisture is the depth-averaged amount of water present in a specific soil layer beneath the surface. Soil moisture content is reported in units of kg/m^2.

- Connection to the following Earth System phenomena:
- Drought Extent - Decreased soil moisture creates drier soils and often produces less runoff over longer periods of time.
- Landslide Risks - Landslides are natural disasters that cause enormous loss of physical property and human lives, are becoming more prevalent in mountainous region of many countries. Soil moisture, along with groundwater, are key variables in triggering slope failure causing landslides.
- Crop Productivity: Soil moisture plays a critical role in farming as it relates to plant growth and agricultural productivity, especially during conditions of water shortage and drought. Knowing moisture content in the soil is important before, during, and after the growing season.
- Forest Fire Risks - Soil moisture, along with temperature, relative humidity, wind speed, and vegetation (fuel density) are key factors contributing to fire frequency. Scientists recently modeled and calculated that dry areas are generally at higher risks for more frequent and larger fires over time. They also report that grasslands that have high moisture content in the spring result in more flammable environments during the summer.
- Flooding Potential - Seasonal cycles of soil moisture content and snowfall/snowmelt increase flooding potential along streams, rivers, and urban and coastal flooding.
- Vector-borne Diseases: Vector-borne diseases, caused by pathogens and parasites,

are transmitted through living organism carriers known as vectors. Mosquitoes, the most common disease vectors, transmit illnesses such as Zika, West Nile, chikungunya, malaria, dengue, and yellow fever, which affect millions of people across the world and kill more than one million people each year. Soil moisture is a condition that influence breeding habitats

2. Next, students observe data visualizations of SMAP data to create Behavior Over Time Graphs onto one sheet of graph paper using the mapped science data for the following variables:

    1. Soil Moisture

    2. Surface Air Properties

3. Briefly review Average Surface Air Temperature data with the students. Surface air temperature is the temperature measured approximately two meters (about 6 and a half feet) above Earth's surface.

4. Distribute the Student Data Sheet and review the sheet with the students.

5. Instruct students to develop a claim for 1 and describe predictions for each season in the two variables. Then distribute the mapped images, as well as two colored pencils to graph the data (e.g., Soil Moisture in green, Surface Air Temperature in yellow).

6. Walk through the following key points of the images with the students:

    1. Four images represent four different seasons throughout 2017 of each dataset

        1. Seasonal Averages of Surface Air Temperature in ?

        2. Seasonal Averages of Soil Moisture, 0 to 100 cm of the soil in kg/m^2

    2. Students begin preparing their graph by creating a title (e.g., 2017 Seasonal Soil Moisture, down to 100 cm in kg/m^2 Compared to Seasonal Air Surface Temperature ?)

    3. Review the range of values from each of the graphs. Tell students that they should note the full range throughout the entire year and will use these max and min values to create the values on the Y Axis.

    4. Time will be on the X Axis.

7. Using one of the images as a model, select a location in the US that is not close to their city's values to model the process. Note that students will observe the map's legend and the color shades as indicators for the scientific value. Students will graph these values on their graph paper. Direct students to observe the color legend and its values. What could the false

colors represent? units of measurement?

8. Now identify the location of your city on the map. Tell students that they will create a graph of the data for both datasets for the approximate location on the map. Note: Students should plot data on the graph using two different colored pencils for the two different datasets. Allow time for students to graph their data.

Part 3: Making Sense of the Data

1. Next, students should document their observations in the data table in the B. Section: Observed Evidence for each season.

2. Students should revisit their claim and predictions as compared to their evidence by completing 4. and 5. They describe any ideas that the evidence has sparked and any scientific principles that affect their findings.