2023

GLOBE LAC REGIONAL OFFICE – LAC ACADEMIC PEDAGOGICAL COMMITTEE

ATMOSPHERE

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LEARNING ACTIVITIES

THE GLOBE PROGRAM

The GLOBE program is an international hands-on science learning program that brings together students, educators and scientists from around the world in the study of Earth system science. The main goals of this program are to improve science education, raise environmental awareness, and create a greater understanding of the Earth as a system. For more information visit www.globe.gov

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Contenido

Air, surface and soil temperature. Is there a link among them?

GLOBE		Related SDGs:	Type of activity
Sphere	Protocols		
Atmosphere	Air Temperature Surface Temperature Cloud Protocol and Contrails Protocol.	13 (Climate Action) 15 (Life on Land)	Application Exploratory
Pedosphere	Soil Temperature		

Overview

The students will learn to relate three variables such as air temperature, surface temperature and soil temperature by making their own measurements. They will understand why surface and soil temperatures take longer to heat up than air temperatures and why they also take longer to cool down. In all three cases, the temperatures will reach their maximum and minimum at different times and will also be of different magnitude or thermal oscillation.

Prerequisites

Explain to the students what the Air Temperature Protocol, the Surface Temperature Protocol and the Soil Temperature Protocol at 5 and 10 cm depth are.

Time: one 90-minute class.

School Level
Sixth year of Primary and all Secondary school (11 to 18 years old).

Purpose

To demonstrate the students that objects, heat up depending on their ability to absorb heat and transmit it to other surfaces.

Student Outcomes
- To conduct air, surface and soil temperature measurements according to GLOBE protocols and instruments.

- To collect data from these protocols in spreadsheets and make daily temperature graphs with these data.
- To analyze the graphs to understand why the surface of the earth and the soil in its first centimeters of depth take longer to warm up than the air in the atmosphere.
- To explain this relation in class and communicate it through posters, reports, etc.

Introduction

Heat transfer is the process by which energy in the form of heat is exchanged between different bodies, or between different parts of the same body that are at different temperatures. Heat is energy in transit; it always flows from an area of higher temperature to an area of lower temperature, raising the temperature of the latter and lowering that of the former, as long as the volume of the bodies remains constant. Energy does not flow from a low temperature object to a high temperature object if no work is done (Beroa, n.d.).

Heat is transferred by convection, radiation or conduction. Although these three processes can take place simultaneously, it may happen that one of the mechanisms predominates over the other two. For example, heat is transferred through the wall of a house primarily by conduction and the Earth receives heat from the Sun almost exclusively by radiation.

Once the net radiation is absorbed at the soil surface and transformed into heat, it is transmitted to the depth, modifying the temperature of the different soil layers as it passes through. Temperature, together with humidity, generates the edaphic climate or soil climate. From the meteorological point of view, its importance lies in the fact that the soil is the source of heat for the air temperature, since it heats up or cools down in contact with the soil. The soil is a dispersed system consisting of a solid phase (50%), a gaseous phase (25%) and a liquid phase (25%). The movement of heat in the soil occurs from the hottest to the coldest layers, by molecular conduction in almost 95%; very little or almost none by convection (air) and processes of water state changes in the soil (Martínez, 2020).

Some factors that affect how heat is transmitted through the soil are the amount of water it contains, the composition and color of the soil, the type of vegetative cover and the organic content of the soil.

Soil will heat or cool in different patterns depending on soil depth. In the upper layers the difference or amplitude between the maximum temperature and the minimum temperature is very large, and the amplitude decreases with increasing depth. The daily variation of the amplitude can only be observed up to a depth of no more than 30-50 cm. In other words, on the daily scale, the heat exchange between the soil and the atmosphere only operates in this layer. Beyond this layer, as the depth increases, the soil temperature also increases at a rate of 1° C every 33 m, due to the type of heat emitted from the center of the Earth (Martinez, 2020).

Guiding Research Questions

- Which do you think will reach the maximum temperature record during the day: air temperature, surface temperature, or soil temperature? Why?
- At approximately what time will the current air temperature reach its maximum?
- Do all three temperatures peak at the same time? Can you explain?
- Do variables such as land cover type influence the measurements obtained?
- Will cloud cover affect the way the land surface and the soil heat up? How? What about precipitation?

- What would happen if, in addition to measuring soil temperature at 5 cm and 10 cm, it were also measured at 50 cm and 90 cm? Would the same trend continue?
- How do you think soil temperature would vary if we used sites with different soil types (more sandy, more clayey, with limestone)?

Scientific Concepts

- Air is a mixture of gases that conducts heat
- Soil absorbs radiation from sunlight
- Heat transfer between two bodies
- The land surface absorbs different amounts of heat depending on the type of ground cover
- Characteristics, color and composition affect how heat is transmitted through the soil thermal oscillation

Materials and Tools

- Alcohol or digital thermometer
- Surface temperature (infrared) thermometer
- Dial or digital soil thermometer or maximum and minimum probe thermometer
- Air temperature Field Guide (according to instrument)
- Surface Temperature Field Guide
- Soil Temperature Field Guide at 5 and 10 cm (2 and 3 inches)
- Air Temperature Data Sheet
- Surface Temperature Data Sheet
- Soil Temperature Data Sheet

What to Do and How to Do It

Beginning -

Determine a day when the students have a double shift at their school, or take the measurements yourself on a day when they are not at the school. Choose a site with bare soil and another with grass cover in the courtyard or garden of the school premises where students do not circulate during the day to prevent them from stepping on or damaging a thermometer. It is desirable that the sites are close to each other to supervise the activities of both groups or coordinate with another teacher to guide them to do them correctly. Make sure that on the chosen day there is no chance of precipitation, so that measurements can be taken under the same conditions throughout the day.

Development -

On the day of the activity, organize the students into groups of 4, with some groups going to the bare soil site and the others to the one with grass cover. Armed with the field guides, data sheets and instruments, both groups start taking measurements at the same time: 7 or 8 in the morning (the earlier the better). Conduct the measurements at each site in the following order:
- current air temperature
- surface temperature by taking the 9 required measurements and finding the average
- soil temperature at 5 cm from the surface
- soil temperature at 10 cm from the surface

Record these measurements with date and time on data sheets or in a science log. Repeat the same measurements throughout the day, within 1 to 2 hours between measurements, if classes permit. If not, do them during breaks between classes, e.g., every 1.30 hours or by rotating groups of students so that 2 groups of 4 students go out each time.

Take the measurements until the time the students leave the institution, and if possible, take one or two more measurements after that time (trying to get to 19 or 20 in the evening). In this way, at least 7 measurements can be taken in a period of approximately 12 hours.

Time: Measurements lasting 10-15 minutes every one-and-a-half to two hours throughout the day.

Ending -

Students bring the data sheets or science notebooks where they recorded the measurements of the different temperatures the previous class. Using grid sheets or Excel spreadsheets (depending on the age of the students) they make graphs for the different temperatures taken, taking into account the time of the measurement and the temperature recorded. They reflect on how the measurements were for each type of ground cover and what maximums and minimums were reached in each. They print out the four different graphs so that they can make comparisons in groups. An easy way to compare the temperatures with each other is to make the printouts on acetate sheets and superimpose them. This allows them to determine what the maximum and minimum temperatures reached for each variable, and at what time they occurred.

Ask them to analyze the graphs:
- Did all four variables reach their maximum temperature record at the same time?
- Which temperature peaked the fastest?
- In what order did the others occur?
- In what time span did the four maximum temperatures occur?
- Did the minimum temperatures behave in the same way? In what order did the recorded minimum temperatures occur?
- Did they occur in the same time frame as the 4 maximum temperatures? Why?
- What happened to the soil temperatures? Did they both behave in the same way with respect to each other?
- How was the thermal oscillation comparing the different land covers?

Alternative Practice:

If you do not have a full day to perform the previously proposed practice or want to perform it in less time, this alternative experiment is suggested.

Materials:
- Alcohol or digital thermometer
- Surface temperature (infrared) thermometer
- Dial or digital soil thermometer or maximum and minimum probe thermometer
- Air temperature Field Guide (according to instrument)
- Surface Temperature Field Guide
- Soil Temperature Field Guide at 5 and 10 cm

- Soil Temperature Data Sheet
- 2 floor lamps
- 2 containers of at least 15 cm deep
- Ruler

Procedure:

- Fill one container with soil only and the other with soil and grass on its surface.
- Place one soil thermometer at 5 cm and one at 10 cm in each container and measure the temperatures. Measure the surface temperature of both soil samples and measure the air temperature above the containers. It will be sufficient to measure the variables only once and record the time. Record the readings as Measurement 1.
- Remove the thermometers.
- Place a lamp over each vessel, approximately 7 cm above the surface. Turn on the lamps and wait 5 minutes. Place the thermometers in the containers with soil again and take all four temperatures. Record the time. Record the readings as Measurement 2.
- Continue recording temperatures every 5 minutes for 15 more minutes (Measurement 3, 4, and 5). Record the times.
- Turn off the lamps. Wait 5 minutes. Re-measure and record temperatures (Measurement 6) and take two more measurements at 5-minute intervals (Measurement 7 and 8). Record the hours.
- Make a graph for each variable with the temperature and time data (or at a more advanced level, make a single graph with the data for all four temperatures).
- Compare the heating and cooling times of the soil at the two depths indicated, the surface temperature of both soil covers and air, respectively.
- Use some of the questions from the previous exercise to help students think about how the heat emitted by the lamps influences the heating and cooling of the air, the surface, and the soil.

Frequently Asked Questions

What other type of surface can I use for the activity if there is no grass cover or bare soil in the schoolyard?

Some other places that can be used for the exercise can be a sand-covered soil (in elementary schools there are often places called "sandboxes" that are used for playground equipment for younger children) or a place with pebbles or gravel. What we cannot use is a surface with cement or asphalt since they will have to measure the temperature of the soil at 5 and 10 cm.

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s/natur_zientziak/DBH1Z-03-BEROA_TENP/1-DBH1Z-03-IRAKASLE/Beroa.pdf

Calculation of local solar noon

GLOBE		Related SDGs:	Type of activity
Spheres	Protocols		
All	Atmosphere protocols mainly, but it can be applied to all the spheres	13 (Climate action)	Exploratory

Overview

The local solar noon is decisive for many GLOBE measurements, mainly in the Atmosphere area. It is essential to know how to calculate it or to have the means to do so. Knowing the exact time of the local solar noon, we can know the two-hour window around it, when we have to perform the measurements so that they meet the GLOBE requirements.

Prerequisites
None

Time:

90 min.

School level
From the sixth year of Primary school and all Secondary school (12 to 18 years old).

Purpose

Students will learn about local solar noon, how to calculate it and how it differs from civil noon or local time.

Student outcomes

- To calculate the local solar noon using two different methods.
- To learn to use an application that calculates it automatically.
- To practice sexagesimal calculation

Introduction

Many of the GLOBE protocols require that they be performed at local solar noon, either because it is easier to compare data if all people take their measurements at approximately the same time in different parts of the world, or because, throughout the year, it is easier to compare data. Usually, the satellites make one of their paths or passages in the span of the

local solar noon and it is easier to compare when we have records of the satellites with which to check our measurements. The GLOBE Observer application allows us, for example, to set an alarm so that at the time of passage of a certain satellite (Aqua or Terra) we are notified so that we can go out to make our measurements at the same time it is passing over our observation point. It is also important for calculating the position of solar panels or collectors for energy saving, the location of the weather hut for taking measurements, the time of maximum sunlight incidence to protect livestock in summer, etc.

But what is local solar noon?
The local solar noon is not 12 o'clock noon, as some people believe, and it is not related to the time changes due to the advance or delay of the time in different countries to achieve energy saving. Nor is it related to universal time (Greenwich Mean Time or zero meridian).

Local solar noon is the instant when the solar azimuth is 0 somewhere on the globe; that is, when the sun has its maximum elevation above the horizon (time of transit of the sun) and the lengths of the shadows it produces are minimal because they coincide with the direction of the meridian. This solar time will vary with longitude, for example, on August 1, 2022, the transit time of the sun in Montevideo, Uruguay is 12:51 pm, while for Ezeiza, Buenos Aires, Argentina, it is 13:00 pm. This is due to the longitudinal distance between the two cities.
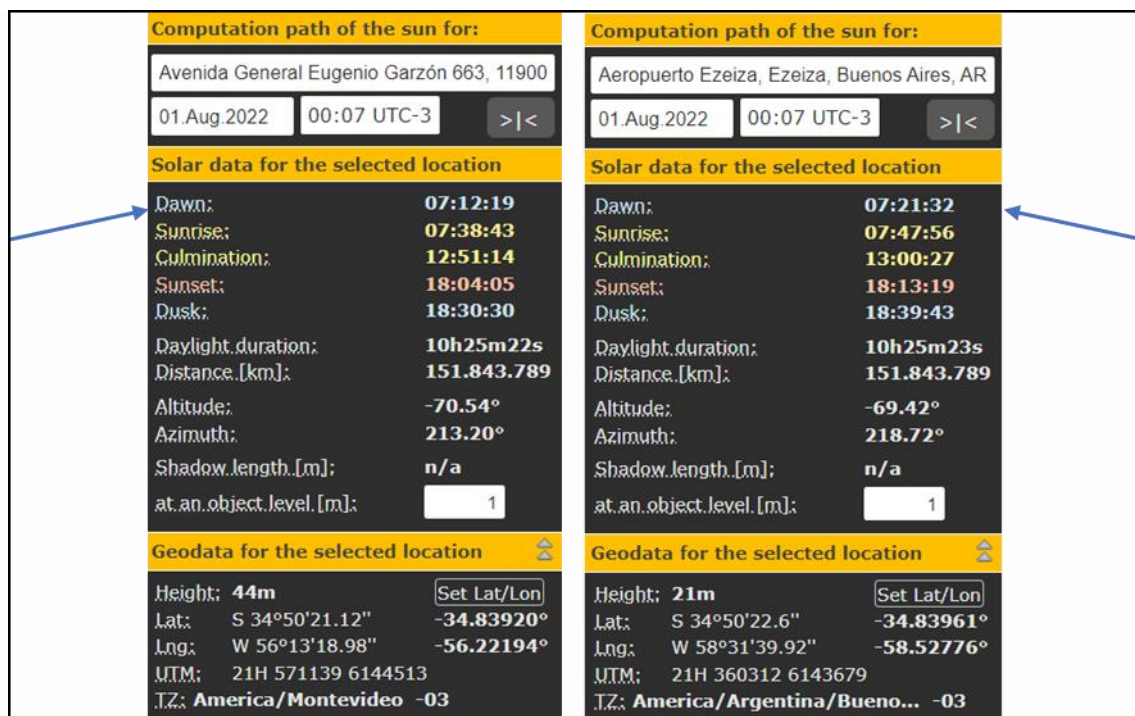

Fig. 1. https://www.suncalc.org

Only at certain times of the year the Sun is directly over your head at solar noon: at the Equator it occurs during the equinoxes, at the Tropic of Cancer (latitude 23° 26′11.4 ″ N) at the June solstice and at the Tropic of Capricorn (23° 26′11.4 ″ S) at the December solstice.

Guiding Research Questions

- Is 12 o'clock noon local solar noon?
- Does local solar noon occur at the same time every day in your location?
- How many hours of sunshine are there today for your geographic location? How can you find out?
- What other applications can have to know the local solar noon?
- What advantages do measurements taken at local solar noon have over measurements taken at other times of the day?
- How many hours of daylight are there usually in the month of the onset of winter and how many hours of daylight will there be in the month of the onset of summer? Does the local solar noon occur at the same time on those two days when the different seasons begin?

Science Concepts
- Solar noon vs. noon
- Latitude and longitude
- Mathematics / sexagesimal calculus

Materials and Tools
- *A world map*
- *Sunrise and sunset times for a given day*
- *Latitude and longitude for a chosen location*

What to Do and How to Do It

Beginning -
Instruct your students to research and bring as homework to class the sunrise and sunset times for that week. They can look on the Internet at weather websites, or get the data from the radio, television, daily news or the newspaper. Instruct them to record all the times on a spreadsheet and also to find the geographic location of their homes or school. This information can be obtained from Google Earth, by searching for their home address in the upper left window of the application, and it will give them the geographic location at the bottom right along with the altitude (Figure 2). Another way to do this is to download a GPS application from the Internet to their mobile devices and activate it at home or at the school to obtain the exact geographic location of the place.

You can review the concepts of latitude and longitude using the world map for this activity.
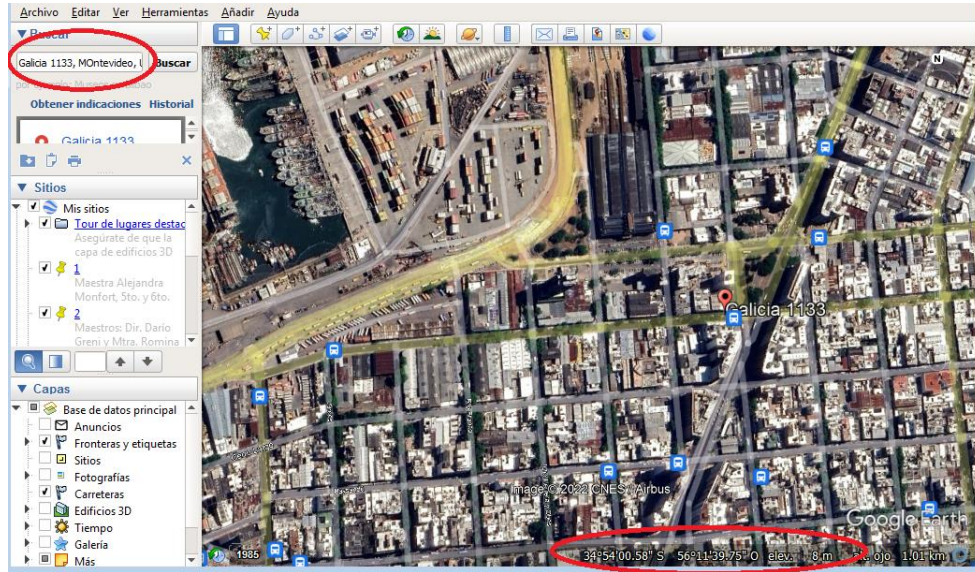
Fig. 2. Geographic location in Google Earth

Development -

In class, you will be taught three methods to calculate the local solar noon using sunrise and sunset times, two of them using calculations with the hours and the last one using a web page that calculates it automatically.

Method A. Assume we have the following data available:

Location: Cartagena de Indias, Colombia.

Geographical location: 10º23'35.62" N 75º28'59.63" S

Date: 01/08/2022

Time of sunrise: 5:51 a.m.

Time of sunset: 6.25 p.m.

They should subtract the sunrise time from the sunset time, divide the number of daylight hours we get by two, and the figure we get, add it to the sunrise time.

Note: Keep in mind that in this way the students will be making calculations with hours, so they will not use the centesimal method but the sexagesimal method.

Example:

18.25	−	5.51	=	12hs. 34'
Sunset Time		**Sunrise Time**		**Total daylight hours**

12 hs.34'	/	2	=	6 hs.17'
Total daylight hours				

5.51	+	6hs. 17'	=	12 hs. 08'
Sunrise Time				**Local solar noon**

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Method B: We must add the sunrise time to the sunset time and then divide the figure by two:

$$5.51 \quad + \quad 18.25 \quad = \quad 24 \text{ hs. } 16'$$
$$\text{Sunrise Time} \qquad \text{Sunset Time}$$

$$24 \text{ hs. } 16' \quad / \quad 2 \quad = \quad 12 \text{hs. } 08'$$
$$\text{Local solar noon}$$

Method C: They will use the page www.suncalc.org, where they will enter the latitude and longitude of the geographic location to determine the local solar noon. They will enter it where it says: "Set. Lat/Lon" (red circle) in either of the following ways: degrees and tenths, or degrees, minutes and seconds. If you enter it in the latter form, it will be automatically converted to degrees and tenths. You will also have to enter the exact day for which you are looking to find out the solar noon. For the example, the same data from the previous examples will be used to check if the three methods match.

Where it says "Culmination" the app will automatically show you the solar noon time for your location on that day.

https://www.suncalc.org
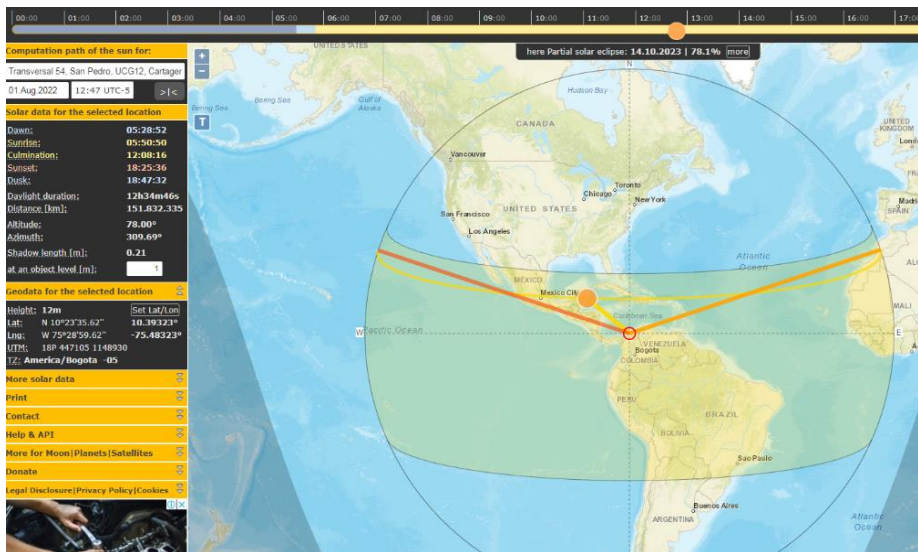
In any of the three methods, the solar noon time obtained should be the same, and once we have already calculated it, the time available for measurements in this window will be from 11:08 to 13:08 hours (a window of two hours).

Ending - Once the students have understood the three methods of calculating local solar noon, give them the following exercises:

a) Find the local solar noon for Escola Minas Gerais (GLOBE school) for September 16, 2022. The geographic location data are as follows:

Latitude: -22.9538° S Longitude -43.1689° W
Which method would you use?
Answer: 11:49 a.m.

b) Find the local solar noon time for the Universidad Agraria La Molina (GLOBE University) for October 3, 2022 with the following data:

Sunrise time: 05:49 am.
Time of sunset: 18.03 hs.
Which method would you use?
Answer: 11:56 a.m.

Frequently Asked Questions:

What if we cannot take measurements within the local solar noon time frame? You can still take measurements, but those taken at local solar noon on other occasions or at other schools may not be comparable to yours because they were taken at other times. In addition, GLOBE indicates that there are protocols that are advised to be taken at local solar noon and others that can be taken at other times of the day. See Introduction to Atmosphere (https://www.globe.gov/documents/10157/381040/atmo_chap_es.pdf) pp. 11-12.

Suggested resources for further information:

https://www.suncalc.org

Cloud Observation, Description and Identification

GLOBE		Related SDGs:	Type of activity
Sphere	**Protocols**		
Atmosphere	Cloud Classification and Contrails.	13 (Climate Action)	Application

Overview

The students observe and draw the clouds, describing their shape and using their own words. Initially, qualitative descriptions will be made and, later, a more scientific vocabulary will be used to deepen the analysis made. A relationship will be established among the students' descriptions and the standard classification of the ten types of clouds identified by GLOBE. Each student will have a personal cloud notebook to use along with the GLOBE Cloud Chart. Observation will be done over a period of days. At the end of this time, students make predictions about the weather and check them, using their observations.

Prerequisites
None.

Time: 10-minute observations (3 times a day) over the course of a week are discussed in a 40-minute class.

School level
Third year of Primary school onwards.

Purpose

To observe clouds, to describe them with everyday vocabulary and to compare this description with the official cloud names, stimulating students' interest to make observations about the type of clouds frequent in their area.

Student outcomes

- To identify the types of clouds in the students' locality using the standard cloud classification names.

- To study the relationship among cloud type, cloud cover and weather.
- To analyze the observed cloud types to make and attempt predictions.

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Introduction

Accurate weather forecasting begins with careful and systematic observations. The human eye represents one of the best (and the most inexpensive) meteorological instruments. Much of what we know about weather is the result of human observation over thousands of years. While being able to identify clouds is useful in itself, observing clouds regularly and recording the weather associated with certain clouds will show students the relationship between cloud types and weather. Recognizing cloud types can help in forecasting the type of weather to expect in the near future. These relationships are not described here, but there are many meteorology books that can help students learn about them. Inviting a local meteorologist into a classroom to talk to students is a sure way to stimulate their interest in the relationship between clouds and weather patterns.

This activity asks the students to look carefully at the clouds, draw them and describe them in their own words before using the official names. The activity can be repeated on different days, when there are different clouds. In fact, if possible, it would be good to take a break and do "cloud work" outdoors whenever a new type of cloud appears in the sky. Over time, students will gain considerable familiarity with cloud types. If it is not possible to go outdoors whenever an interesting cloud appears, perhaps they can be observed through a window.

Creation of a Personal Cloud Notebook.

A set of individual, personal notes about clouds and cloud types can be included in the GLOBE science notebooks or in separate booklets. A page in the GLOBE science notebooks should be devoted to each cloud type that is identified. This can include not only the students' own observations and descriptions, but also photographs of clouds that they take or obtain from other sources. If several cloud types are seen, each should be noted on a separate page in their notebooks and, if possible, each cloud type should be photographed to associate with the classification.

As a supplementary practice, the use of the GLOBE Observer application could be incorporated to the observations and registration, to acquire skills in the identification and data entry into the application. This has the possibility of identifying clouds manually or using an assistant for the guided identification of clouds, which is based on a dichotomous classification system that guides the observer to choose between two options until the most accurate classification is reached.

Guiding Research Questions

- Are all clouds the same?
- Are they at the same altitude?
- Do some clouds allow us to see the sun behind them and some don't? Why?
- Do all clouds produce precipitation?
- Can I predict what the weather will be like in the afternoon or tomorrow from the clouds I see now?

Scientific Concepts

- The weather can be described by qualitative observations.
- The weather changes from day to day and throughout the seasons.
- Clouds are formed by the condensation of water vapor in the atmosphere.
- Clouds affect the weather and climate.
- The nature and extent of cloud cover affects the characteristics of the physical geographic system.

Materials and Tools

- GLOBE Cloud Chart
- Photocopies of the clouds described in this activity.
- GLOBE Science Notebook / GLOBE Observer App
- Bibliography containing images of clouds
- Cell phone / Camera or video camera to take pictures of the clouds (optional)

What to Do and How to Do It

Activity 1: Identifying and classifying clouds on a daily basis

Beginning -

To begin the activity, students go outside with the teacher and spend 10-15 minutes observing the sky and describing it. Can they see clouds? What do they look like? What shape are they, what do they resemble? What colors are they? Can they see the sky and the sun through them? Are there any other elements in the atmosphere that prevent them from seeing the sky and the clouds? If so, can they identify what it is?

Then they describe the clouds in their own words, whether they appear to be high or low in the atmosphere and what approximate percentage of the sky they cover, if they can estimate it (remember the practice of the four cardinal points).

Using their field notebooks, they are invited to draw the clouds they observe, as realistically as possible.

Development –

In class the GLOBE Cloud Protocol is reviewed, in which ten common cloud types are recognized. The names used for clouds are based on three factors: their shape, the altitude at which they are found, and whether they produce precipitation.

The GLOBE Observer application also takes into account whether clouds are transparent, translucent or opaque, considering the light passing through them and whether it is possible to see the sky or the sun behind the cloud.

Clouds have three basic shapes:

> Cumulus (lumpy and swollen)
> Stratus (in layers)
> Cirrus (faint)

Clouds occur in three altitude ranges (cloud base altitude):

> High-level clouds (above 6000 m), called "cirrus or cirro-".
> > - Cirrus
> > - Cirrocumulus
> > - Cirrostratus
> Mid-level clouds (2000 - 6000 m), named by "alto-".
> > - Altocumulus
> > - Altostratus
> Low-level clouds (below 2000 m), without a prefix
> > - Stratus
> > - Nimbostratus
> > - Cumulus
> > - Stratocumulus
> > - Cumulonimbus

Note: Although both cumulus and cumulonimbus clouds may have bases starting below 2000 m, they often become large enough to reach into the mid to upper range. For this reason, they are generally referred to as "vertically developing clouds". Only high-level clouds are wispy, so the term cirrus has become synonymous with wispy, as well as high-level clouds.

- Clouds, whose names incorporate the word "nimbus" or the prefix "nimbus-" are clouds that produce precipitation.

- Contrails are linear clouds that form around small particles emitted by aircraft. They are directly caused by human activity, and are of great interest to researchers. Three subtypes are distinguished:
  - Short-Lived Contrails: Line that appears behind an aircraft; it does not remain after the aircraft has passed.
  - Persistent Non-Spreading Contrails: Noticeable contrails (linear and narrow) that do not appear to dissipate appreciably or show signs of spreading, and which remain well after the aircraft that created them disappears from the area. Each contrail subtends a narrow angle in the sky.
  - Persistent Spreading Contrails: Linear cirrus clouds with a diffuse appearance; each trail subtends a wider angle in the sky.
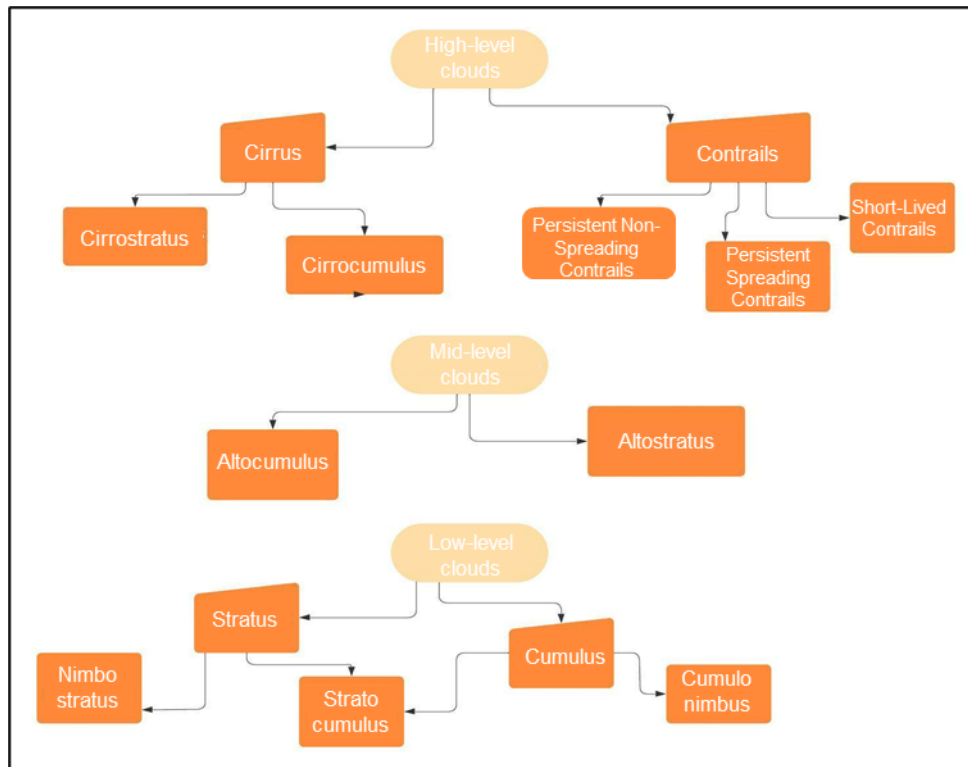
Fig. 1: Cloud types according to altitude range

Tips for Identifying Clouds

It is useful to know a few things to identify or name clouds according to official classifications: Clouds that are wispy and high in the sky are always cirrus clouds of one type or another. If cirrus clouds contain billows or puffs, then they are cirrocumulus. If they form continuous layers that seem to cover the sky, they are cirrostratus. Contrails also occur at high levels, and look like linear shaped clouds.

Clouds at medium altitudes are named with the prefix "alto-." If they are layered, they are altostratus; if they form piles or look puffy, they are altocumulus.

Clouds that form at low altitudes (below 2000 m) are of the cumulus or stratus family. Cumulus clouds are puffy and swollen. Clouds of the stratus family form layers or sheets that cover large areas of the sky.

Low-Level Clouds that are dark, threatening and rain-producing are called "nimbus". Nimbostratus clouds cover the entire sky with broad layers and produce continuous rain. Nimbostratus are more extensive horizontally than vertically. The precipitation associated with them is generally low to moderate in intensity, but falls over a wide area over a long period of time.

Cumulonimbus clouds have dark bases and swollen tops, often anvil-shaped, and are sometimes called "thunderheads". They usually produce heavy precipitation, usually accompanied by lightning and thunder.

Ask them to look for pictures of clouds in books, magazines, on the internet or their own pictures they have taken of landscapes. Additionally, you can ask them to take their own pictures of clouds, this will amuse them. Introduce this as a follow-up activity to drawing the clouds and describing them in their own words. Videotaping clouds in motion also introduces a new perspective on cloud formation and behavior, particularly if a tripod can be used and time-lapse photographs can be taken.

Closing -

Class display of the clouds observed through enlarged prints of the photos. Have the other students try to classify each other's clouds as they display them and guide them in identifying them.

They can even make three columns on the board and arrange the pictures according to the altitude range of the clouds to get used to classify them not only by their shape, but also by the height at which they develop in the atmosphere.

Activity 2: Observe the clouds several times a day to try to predict the weather.

Beginning –

- Over a period of five days, students are instructed to look closely at the clouds and record what they see in their science notebooks. If they do not yet know the names of the clouds, they can try to match them to those in the images above or the cloud chart, or they can write down what the clouds are shaped like.
- It would be best to observe the sky three times a day: once in the morning, once at local solar noon, and once in the late afternoon when it is still clear. The exact times of each observation are not critical, although it would help if the observations were made at the same time each day. For example, at 8 a.m., 1 p.m., and 5 p.m. If the student can make only one observation per day, it is best to choose a time within the local solar noon interval.

Development –

- Students should record the weather conditions at the time of each observation. Was it a rainy morning and a clear afternoon? Did it snow all day? Was it humid? The students do not have to quantify their weather information (they do not have to write down "21 mm of precipitation" or "79% relative humidity"), but they should describe the weather as thoroughly and clearly as possible. It is helpful to use a table like the one below to record day-by-day observations.

Table 1: Record of weather conditions

Day	It rained		Clouds (%)		Cloud type		Fog	
	Morning	Afternoon	Morning	Afternoon	Morning	Afternoon	Morning	Afternoon
Monday 14								
Tuesday 15								
Wednes. 16								
Thursday 17								
Friday 18								

- As cloud and weather observations are noted, look for any patterns. For example, are morning altocumulus clouds followed by afternoon thunderstorms? Are morning or

midday small puffy clouds ever associated with precipitation later in the day? Do they follow morning contrails, wide cirrus clouds, or altocumulus later in the day?

- Students can also develop their skills in observing the color of the sky (with their backs to the sun and matching the chart held up against the sky). They will be able to classify color into deep blue, blue, light blue, pale blue and milky blue. In addition, they can look at the visibility of the sky by taking a reference point on the horizon and working out whether it is hazy or not, and how clear the object looks in the distance; they can decide whether it is Unusually Clear, Clear, Somewhat Hazy, Very Hazy or Extremely Hazy.

Closing –

- After a week of recording clouds and weather, ask students to use their observations to predict the weather. Can they predict in the morning what the weather will be in the afternoon? Can they predict the weather the next day?
- Ask them to explain why they made the predictions they did. Each student will write down how they did in predicting the weather to develop and improve their skills. As a group, they will draw conclusions from what they observed.
- Posters can be made with the photos and drawings to display in the classroom or in the school corridors.

Frequently Asked Questions

What happens if the clouds and weather conditions are sustained for five days in a row?

This may occur in some places at certain times of the year. If you need to move on to other topics, you can have students comment on their observations without making predictions at that moment.

In weather forecasting, predicting that tomorrow will be the same weather as today is known as a persistence forecast, and it is usually correct more than half of the times. For a forecasting system to be useful, the forecast must be more accurate than a persistence forecast over a period of months and years.

Another approach would be to increase the observations made to more than five days, until more variety of cloud types and weather conditions are observed. Sometimes weather patterns stay in one place for a month or more, so you might have more success if you resume making measurements at a later date.

Suggested Resources

Different Types of Clouds

High-Level Clouds

Cirrus
These clouds look like delicate white feathers.
They usually have wispy shapes.
They contain ice crystals.

Cirrocumulus
These clouds are thin white layers with a texture that makes them look like a cotton field or waves without shadows. They contain mostly ice crystals and perhaps some very cold water droplets.

Cirrostratus
These clouds are a thin, almost transparent, whitish layer made up of ice crystals. They can cover all or part of the sky and create a halo appearance around the sun.

Short-Lived Contrails
Notice the short line of clouds above the streetlight. The plane is barely visible in this picture, but it is in front of the contrail.

Persistent Non-Spreading Contrails
These are different, with the ones on the right being persistent non-spreading, and the ones on the left being persistent spreading. Possibly all three types of aircrafts followed a similar path, but the high winds in the atmosphere blow from the right to the left and shift the older contrails to the left. The wake spreading on the left indicates that there is a fair amount of water vapor in the upper atmosphere.

Persistent Spreading Contrails.
Trails are shown in an area of heavy air traffic. As above, it is likely that the planes are following a similar path, but the trails are being spread by the wind. All of the contrails appear as wide or wider than those above, indicating the presence of abundant water vapor in the atmosphere. The cloud towards the center of the photo looks like the usual cirrus type, but from its position it would be likely that this cloud originated from a contrail.

Mid-Level Clouds

Altostratus
These clouds form a bluish or greyish veil that covers all or part of the sky. Sunlight can be seen through them, but there is no halo effect.

Altocumulus
These clouds look like white and gray sea waves and shadows. They contain mainly water droplets and maybe some ice crystals.

Low-Level Clouds

Stratus
These clouds are gray and are found very close to the Earth's surface. They usually look like a sheet but are sometimes found in patches. They rarely produce precipitation.

Stratocumulus
These clouds are gray or whitish in color. The bases of these clouds are usually round rather than flat. They may form from old stratus clouds or from spreading cumulus clouds. Their tops tend to be flat.

Nimbostratus
This is a dark or gray cloud layer that hides the sunlight. It is massive and produces continuous precipitation.

Cumulus
These clouds have a flat, dense base and a mound-shaped top reminiscent of a large cauliflower. When the sun shines on these clouds they are bright white. The base tends to be dark gray. They generally do not produce precipitation.

Cumulonimbus
They are large, heavy, dense clouds. They usually have a flat, dark surface, with very high and large tops resembling a large mountain or anvil. They often have associated lightning, thunder and sometimes hail. They can also produce tornadoes.

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Global temperature is rising - myth or reality?

GLOBE		Related SDGs:	Type of activity
Sphere	**Protocols**		
Atmosphere	Maximum and Minimum Air Temperature Precipitation	13 (Climate Action) 15 (Life on Land)	Application

Overview

Global temperature is increasing globally and the data that scientists collect, as well as what can be found in the GLOBE database with its 27-year records and other sources, can help estimate that increase over the years. Teachers and students can help produce data and establish temperature trends to help confirm the claim that the global temperature is rising and discover by how much it is rising locally.

Prerequisites
None

Time:
One month for measurements, two classes before and one class later. Measurements will require 5 to 10 minutes per day, but students can be rotated from day to day.

School level
Sixth Year of Primary and Secondary School (11 to 18 years old)

Purpose

Students will try to explain whether the global temperature increase is a myth or a reality. To do so, they will use scientific data that they will obtain from their study sites. Through this activity, students will develop their critical thinking and discernment to argue or debate beliefs or opinions related to popular knowledge, contrasting it with scientific information.

Student Outcomes

- To collect air temperature data for the coldest and warmest month(s) for the area where your school is located.

- To prepare graphs with daily temperatures recorded in your area (maximum, minimum average) and precipitation data.
- To obtain air temperature data from the GLOBE website or other reliable meteorological sources at the study site.
- To analyze the data collected and the data obtained from other institutions collectively to support or contradict the claim that the temperature is increasing.
- To communicate your results to the educational community
- To suggest a list of commitments that can be made from the school to contribute to mitigate and adapt to climate change, if it is verified indeed that what scientists say is true.

Introduction

The Intergovernmental Panel on Climate Change defines climate change as "A change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades of longer (IPCC, 2018) . Global warming is defined in that same report as "a global increase in combined air and sea surface temperatures over a period of more than 30 years".

There is a debate among many climate scientists that global warming is a fact, and that the global temperature is gradually increasing, and there are groups that proclaim that global warming has occurred cyclically over the years on Earth and that it is a natural process.

On this last statement, Juan Ramón Vidal Romaní, PhD in Geology from the University of A Coruña (2018), argues that climate change "has existed since the Earth is Earth, since the planet is solid. It is commonplace. Moreover, if climate change did not exist the Earth would be a dead planet. There is no climate change where there is no geological life. Planets that have no internal energy are dead, such as Mars, or the Moon. In his opinion, fighting against climate change is like fighting against windmills. Rising sea levels, for example, have nothing to do with climate change. We are in an interglacial era, where rainfall is higher, as is the temperature, and the sea level will rise, reaching in the next few years the height it was 135,000 million years ago during the previous interglacial, when the Earth's temperature was higher, CO2 was higher, and the sea level was one meter higher than it is today. Among geologists there is a large majority who think this way".

In contrast, Mark Maslin (2019) alludes to five myths that denialists argue against climate change, one of which is that "scientists manipulate the data to show an upward trend in temperature". Against this assertion, Maslin says that for this to be possible, thousands of scientists from more than 100 countries would have to agree to lie about the data obtained. What scientists do is to correct and validate the data collected, for example, by correcting historical temperature records, because measurement systems have varied over time.

The "naturalness of the changes" argument put forward by the denialists is based on the fact that the Earth's climate is still recovering from the cold temperatures of the Little Ice Age (1300 AD-1850 AD), and that the temperatures we have today are the same as those of the Medieval Warm Period (AD 900- AD 1300). The gap of this assessment is that both stages did not involve global changes, but regional ones, affecting northwestern Europe, eastern America, Greenland and Iceland. A study with 700 climate records has shown that the only time the climate has changed at the same time and in the same way worldwide during the last 2,000 years has been in the last 150 years, in which more than 98% of the planet's surface has experienced an increase in temperature (Maslin, M., 2019).

Scientists argue that global warming has increased especially since the period of the Industrial Revolution due to the increasing use of coal and oil in production. According to Johan Rockström "current CO_2 emissions suggest that the warming effect of GHG emission rates could rise up to 4°C above pre-industrial climate conditions. If this occurs, our climate would be as different from pre-industrial conditions as it was when the Earth began to emerge from the last Ice age 18,000 to 20,000 years ago. The world's governments have agreed that the average temperature increase should not exceed 2°C (compared to the pre-Industrial average), in order to avoid dangerous climate change (COP Cancun, 2010).

As a result of the many existing climate models, it is observed that the temperature could increase between 2° and 4.5°C (with an average of 3.1°C), if carbon emissions were doubled. All models show a significant increase in temperature if extra carbon dioxide is added to the atmosphere.
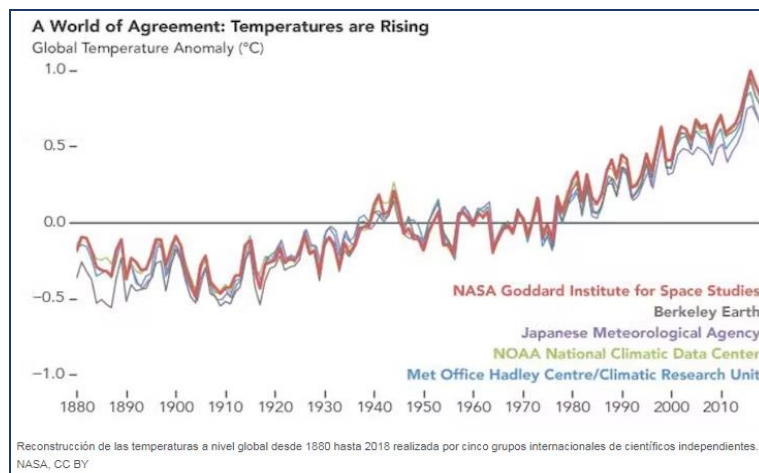

*Fig. 1: Global temperature reproduction
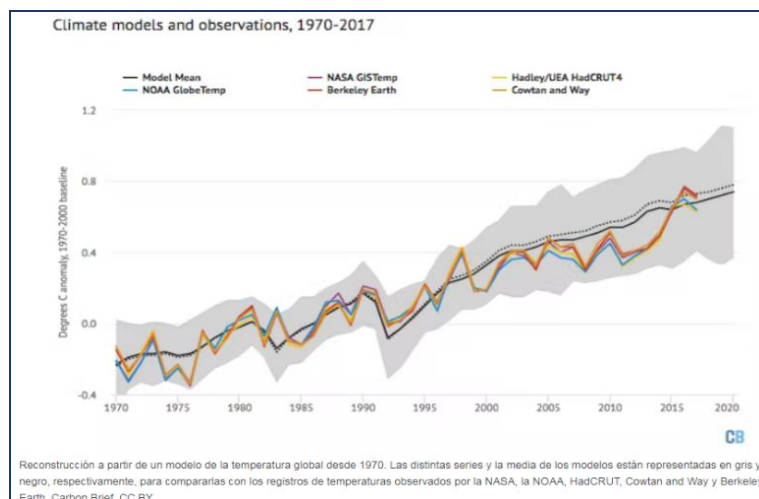from 1880 to 2018. Source: NASA*

*Fig. 2: Reproduction from a global temperature model based on various
sources that show a warming trend. Source: Maslin, 2019.*

In recent years, there has been an increase of almost 1% (0.85%) in both land and ocean temperatures, which has been evidenced in the heat waves experienced by many countries,

especially from 2016-2017, when the highest temperature peaks recorded for the month of July in the northern hemisphere occurred.
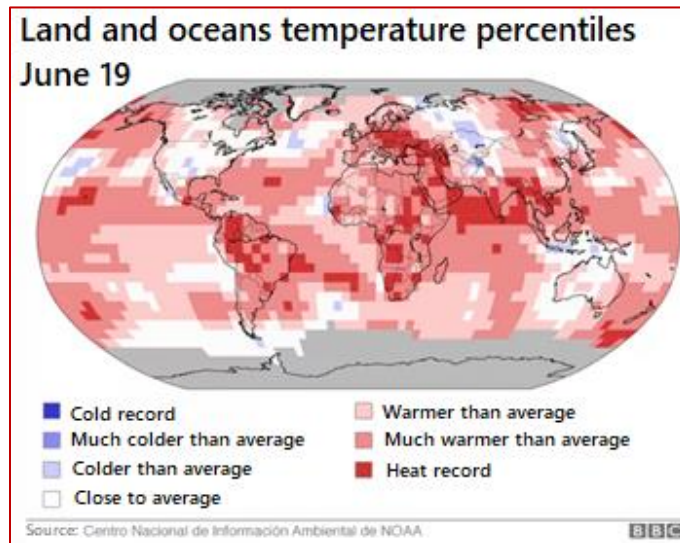

Fig. 3: Temperature in 2019. Source: NOAA.

Are these changes in the environment observable to people? The effects of global warming are visible to the human beings' naked eye: the North Pole ice extent has decreased and so has the glaciers´, the northern hemisphere snowfall has shrunk, and the sea level has risen -20 cm in the last century- (which can be seen mainly in coastal populations). Heat waves are becoming more frequent and summer temperatures are higher and higher, resulting in extreme and long-lasting droughts, forest fires and extreme weather phenomena, such as hurricanes and cyclones. There are also large and sudden floods that cause the displacement of animal species and populations, as well as destruction and death.

July 2016 is so far the warmest month since records began in 1880, according to the National Oceanic and Atmospheric Administration (NOAA).
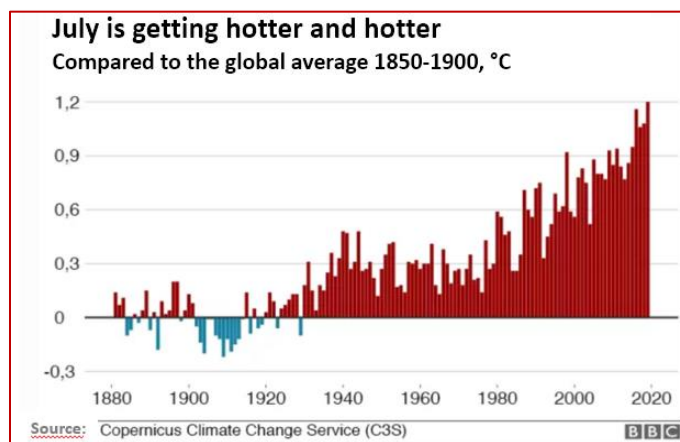

Fig. 4: Average temperature increase for the month from 1880 to 2020

Indicators continue to add up that we are heading for a much hotter world if we allow CO_2 emissions to continue to grow," said Katherine Kramer of the NGO Christian Aid. For many people in the developing world, these changes were already a reality, but now we are seeing heat records in the developed countries with the highest CO_2 emissions. (Source: https://www.bbc.com/mundo/noticias-49206050)

Guiding Research Questions

- What were the maximum temperatures recorded in your area last summer? And this summer?
- What were the minimum temperatures recorded last winter compared to this past winter?
- Do you expect future maximum temperatures to remain the same or increase?
- Is it possible to verify the climate change claim with data retrieved from the GLOBE website and local meteorological authorities?
- How many years of data would be sufficient to analyze climate change data?

Scientific Concepts
- Current air temperature vs. daily maximum and minimum
- Climate change
- Climate vs. Weather
- Global warming

Materials and Tools

- Digital thermometer for maximum and minimum temperatures / U-shaped thermometer
- Air temperature Field Guide
- Air temperature Data Sheet
- Weather shelter / automated station
- Optional: rain gauge

What to Do and How to Do It

Beginning -

- Ask your students to recall what they did last summer, where they were, whether they went to the beach or were indoors. What cooling systems did they use, what do they remember the weather was like: very hot, normal, cool?
- Then ask them to debate whether they consider that the Earth has been going through a process of global warming in recent years, or, on the contrary, it is a normal process that happens cyclically on the planet. Organize the class into two student groups and have each group argue for or against climate change and global warming, according to their knowledge and perceptions.
- Next, choose one of the following videos according to the students´ age and project it in the classroom to make them more aware of the topic and why it is a priority.

Videos for Primary School:

- *Global warming for Kids:* https://www.youtube.com/watch?v=AZxLIKIYac4
- *Climate Change for Kids (Educational videos for children):* https://www.youtube.com/watch?v=FeKld35Pxhg

Videos for Secondary School:

- *Climate change effects: (subheadings in English)* *https://www.youtube.com/watch?v=BFA-TcKA-w8*
- *Climate change and the greenhouse effect: https://www.youtube.com/watch?v=NM-sgVmBL_A*
- *What is global warming and what is its importance?:* https://www.youtube.com/watch?v=F2GCrL-K4t0
- *5 revelations of the UN report on climate change and what it says about Latin America:* https://www.youtube.com/watch?v=4QEW0DHWIIg

Development –

- In the second class, the teacher and students will choose a month of the year, the warmest or the coldest, depending on whether they are attending school in those months. For example, July is the coldest month in Montevideo, Uruguay, with an average minimum temperature of 7°C and an average maximum temperature of 14°C. The hottest month is January, but at this time students are on vacation. In Panama, April is the hottest month and it does coincide with the school year.

- The teacher will teach them the protocol of current temperature, maximum and minimum, and liquid precipitation (rainfall), how to record the data and upload it to the GLOBE website.

- They will set up the weather shelter at the atmosphere study site and place the digital maximum and minimum thermometer or U-shaped thermometer inside. They will also place a rain gauge at the back of the shelter or on the floor at a height of 60 cm if they prefer. Everything will then be ready for the students to start recording their measurements when the selected month begins.

- Once in the month the students are going to study, they will record the maximum, minimum and current temperatures, and the precipitation at local solar noon daily.

- At the end of the month, with all the records, they will make a graph of daily maximum and minimum temperatures, and note which was the coldest/hottest day recorded.

- They will calculate the averages of the maximum and the minimum temperature, separately or on the same graph.

- They will make another graph with the precipitation for the month and find the total precipitation for the month.

- The teacher will look for information in meteorological organizations of his/her country, which are the daily records of maximum and minimum temperature for that selected month, but from 10 and 30 years ago. He/she will bring graphs with the daily records, and with the averages for that month, both for maximum and minimum temperatures. If there is information from the GLOBE database from previous years, that can be used as well.

- In class the students will place the enlarged printed graphs on the board for the month in which they collected GLOBE data, and the teacher will place the graphs obtained from previous years' data for that month to their left.

- The teacher will ask them to compare the graphs and see if the trends stayed the same, or if the maximum and minimum temperatures were higher or lower.

- Then, they will identify the coldest/hottest day on the graph the teacher brought and compare with the data they took.

- Ask them to draw some conclusions as to whether recent data reflect higher temperatures and averages than previous years, whether minimums were also higher, or what changes they observe. What happened in these last 10 and 30 years?

Ending –

- The students will make a poster or video on what measures a child, an adult and the country governments (categories clearly differentiated by their degree of responsibility) can take to prevent global warming from continuing to worsen and its effects from becoming more and more drastic for life on Earth.

- The students will share the poster or video within the educational community with other groups of students, teachers, the administration and with the rest of the community (parents, relatives, friends) to raise awareness of what has been studied and the importance of not continuing to aggravate the effect of global warming.

Outreach Information Activity

- The teacher explains to the students how to make a climogram using one of the following videos:
  What is a climogram, and how to read and analyze it: https://www.youtube.com/watch?v=1r8uW_0Rcxk or
  How to make and analyze climograms (educ.ar)

- Suggest that they develop one for their city/locality, with data taken from the GLOBE website or from the official meteorological institutes of their country. They will need to download average temperature data for all months of the year and total precipitation data by month.

Frequently Asked Questions

What happens if the students are not attending classes in the coldest or hottest month?
If the classes do not coincide with either month, choose another month at random. The warmer or colder month is suggested, so that students can observe more extreme temperatures, but in fact, any month will do for the exercise.

Additional Resources for Further Information

What is a Climatogram and how can we make it? How are climates classified? | Professor BRUNO - YouTube

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Homemade instruments for meteorological variables

| GLOBE | | Related SDGs: | Type of activity |
Sphere	Protocols		
Atmosphere	Air Temperature Precipitation Atmospheric Pressure	13: (Climate Action)	Cognitive

Overview

The description of the meteorological conditions of a place is done with the help of measuring instruments that meet certain specifications and are previously calibrated. In order to learn more about the instruments for measuring meteorological variables and the physical principles behind them, students will make their own instruments with homemade materials and use them for educational purposes. In this regard, it is important to mention that the instruments that are made have no scientific value for taking real data, but they do have a lot of educational value.

Time
50 minutes

Prerequisites

To be familiar with GLOBE protocols for temperature, precipitation and barometric pressure.

School levels
Primary and Secondary

Purpose

To develop and test homemade measuring instruments with low-cost materials to measure temperature, precipitation and atmospheric pressure.

Student Outcomes

- To explain the importance of assessing the temperature, precipitation and atmospheric pressure of a location
- To develop homemade meteorological measurement instruments

LEARNING ACTIVITY

- To describe the functions of the instruments the students developed
- To take measurements with these instruments
- To compare the instruments the students developed with the actual instruments

Introduction

The engine that powers ecosystems is the sun. The sun´s energy flows into the ecosystem, driving its functioning. The angle at which the sun's rays reach the Earth's surface, which is tilted at approximately 23.5º as it rotates on its own axis and revolves around the sun, causes the planet to receive heat in different ways (Figure 1).
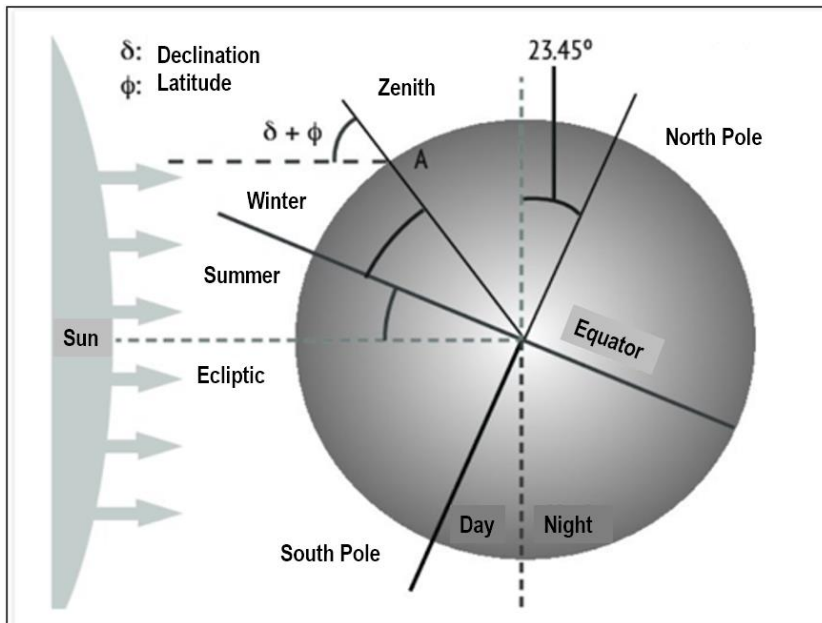
Fig. 1: Solar declination. This figure shows why the Equator receives the same amount of energy and gets warmer all year round, while the Poles only receive a considerable amount of energy in the summer. Source: (Cervantes, 2017)

The amount of solar energy received in a place and the amount of water it holds determines its evaporation capacity and the cloud formation. At the same time, the difference in the heat distribution of the planet creates high- and low- pressure systems. These elements are very important since the difference in pressure is what leads to winds, while winds and clouds combine to cause precipitation or rainfall, which in some parts of the planet are intense, while in others it does not rain (deserts). Figure 2 shows the dynamics that exist among radiation, temperature, cloud formation, precipitation and vegetation in different parts of the planet. The different climates that exist on Earth are only possible because, in addition to the angle of inclination at which the sun's rays reach the planet, the latter has a certain physiography that modifies the effect of radiation in each place on the planet.
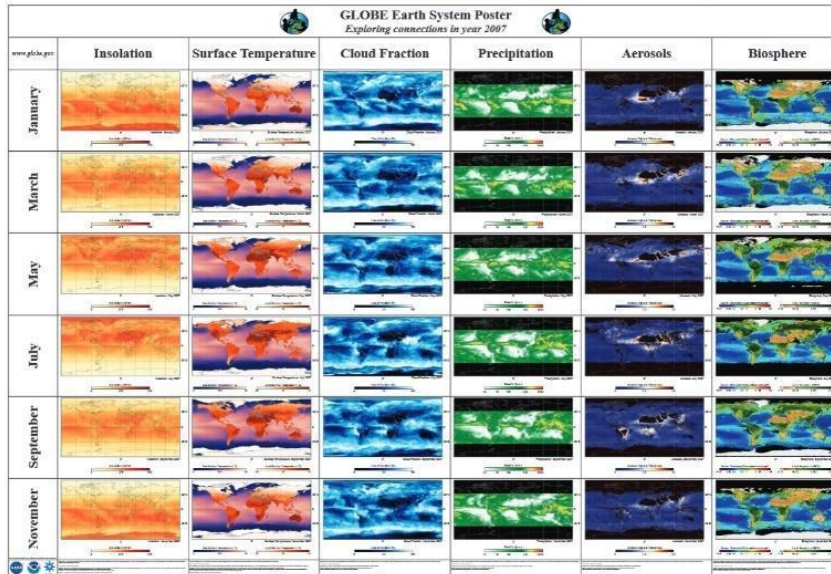
Fig. 2: Poster of the Earth as a System
Source: GLOBE Program

The Earth is also surrounded by gases that are divided into several layers (Figure 3), which form the atmosphere. This atmosphere exerts a certain weight per unit area, which is called atmospheric pressure and which is related to the availability of oxygen for living things to breathe, among other things.

Of all the atmosphere layers, the troposphere is the most important because this is where most of the atmospheric phenomena that are of interest to humans and their activities take place.
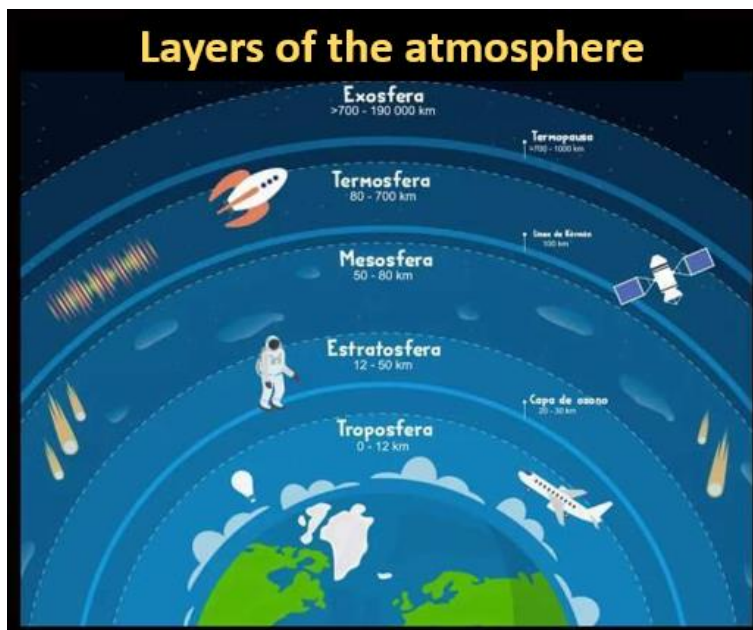
Fig. 3: Layers of the atmosphere
Source: GeologiaWeb

Climate, then, is a large system resulting from the interaction of the atmosphere and the Earth's surface. It can be defined as the average physical condition of an area, for at least 30 years, resulting from the interaction of the atmospheric elements and the planet's surface factors. It can also be defined as the diversity of atmospheric weather present in a given place for at least 30 years (Garcia, 1994). Therefore, what changes from one moment to the next, or from one day to the next, is not the climate but the atmospheric weather.

The climate elements are the variables (something that varies or changes) originated by the energy exchange between the Earth and its atmosphere. These are temperature, precipitation, atmospheric humidity, cloudiness, and wind, as the most important ones. Climate factors, on the other hand, are the variables that modify or control the magnitude or intensity of climate elements. These factors can be grouped into two categories: i) Permanent factors, which are those that are always present: Latitude, altitude, ocean and continent distribution, and mountains and earth movements. ii) Variable factors, such as ocean currents, high- and low- pressure centers, air masses, and atmospheric pollutants, among others (Garcia, 1994).

Among the most important meteorological variables measured to describe the atmospheric weather are temperature and precipitation. In addition, humidity, winds and atmospheric pressure are also recorded. The instruments to measure changes in these variables are not always available to everyone, and once they are, the principle by which they occur is not often understood; so, through this activity students will build some meteorological instruments, using materials they have within reach, to better understand what is the physical principle that makes real instruments work. They will also be able to take some measurements for educational purposes that can then be compared with the real data obtained with appropriate instruments.

The use of appropriate measuring instruments is essential to ensure accuracy and precision in taking meteorological data to describe the atmospheric conditions at a given location.

Scientific Concepts

- Temperature
- Precipitation
- Atmospheric Pressure
- Weather
- Atmospheric Weather
- Climate Elements
- Climate Factors

Guiding Research Questions

- What is a weather measuring instrument?
- What are the most commonly measured meteorological variables?
- What are the climate elements and what makes them differ from one location to another?
- What does a barometer measure and how does it work?
- What instruments are used to measure the temperature and precipitation of a location?

Materials and Tools

Making a thermometer
- A 250 ml glass bottle
- A transparent bottle tube to be used as a spray bottle
- Playdough of any color
- Water
- Cake dye (1 color)

Making a rain gauge
- A 2 lt. plastic beverage bottle
- A water measuring cup
- A ruler
- All purpose adhesive
- Scissors
- Playdough

Making a barometer
- A transparent bottle tube to be used as a lightweight spray bottle
- Scissors
- Cardboard, 10 cm X 35 cm
- A ruler
- A cardboard marker
- A glass jar
- 9 balloons
- An elastic band
- All purpose adhesive

What to Do and How to Do It

Beginning -

- The teachers tell their students that they are going on a field trip to a city in the country where they live and that they do not know what to pack in their suitcases because they do not know whether it will be hot, cold or rainy in that city yet. Then, they ask the students for ideas on how to solve these matters.

- The students offer ideas to help their teachers organize their trip based on the weather in the city they will be traveling to.

- The teachers and their students discuss the importance of weather and how they can get to know about it. It is suggested that it is important to measure at least the temperature and precipitation of a given location.

- The teachers suggest to their students the idea of making instruments to record changes in temperature, precipitation and pressure in the place where they live.

COMITÉ ACADÉMICO PEDAGÓGICO GLOBE LAC

- Next, the teachers divide the students into 3 groups and assign each group an instrument to make.

Development -

How to make a thermometer (Figure 4)

- Take a glass bottle and fill it halfway with water.
- Add two drops of cake dye.
- Place the plastic tube inside the bottle as if used for drinking the water.
- The plastic tube is secured to the bottle and the spout is hermetically sealed with playdough.
- It is observed how the water goes up or down through the plastic tube depending on whether the bottle is in contact with hot or cold surfaces.
- To enhance the experience, the bottle can be graduated and a real thermometer can be used to calibrate the measurements.
- The students are asked to develop some hypotheses about what they think makes the water go up or down through the plastic tube.
- The students are also asked to make inferences about what they believe is the heat sensitive element.
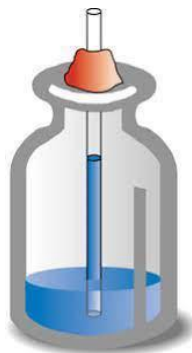

Fig. 4: A homemade thermometer

How to make a barometer (Figure 5)

- A balloon is torn off, leaving out its lip.
- The jar mouth is covered with the torn balloon, tightening it as much as possible and securing it to the bottle with the rubber band.
- The plastic or bamboo tube is glued to the center of the balloon that covers the jar.
- An arrowhead is drawn on the cardboard, cut out and glued to the other end of the plastic or bamboo tube.
- Lines are drawn on the cardboard every half centimeter. High pressure is written at the top and low pressure at the bottom
- Glue the jar to the cardboard and carefully observe what happens to the arrow.
- Hot and cold elements are brought near the jar and the pressure is observed.

Fig. 5: A homemade barometer

How to make a rain gauge (Figure 6)

- Cut off 1/3 of the plastic bottle at the top to make a sort of funnel.
- The cut top part is placed inside the bottle.
- That funnel is secured to the bottle with playdough.
- The bottle can be attached to a stable base, such as a chopping board or a wooden stick of about 1.50 m above the ground.
- Once it rains, the students can proceed in two ways:
  - The first way is to empty the contents of the bottle into a kitchen measuring jug to calculate the volume of rainfall in ml or cm.[3]
  - The second way consists of calibrating the volume of rainfall using a graduated ruler to mark the outside of the bottle with a permanent marker, verifying how many mm of rainfall is equivalent to one ml and using the formula in Figure 6.

Calculation of rainfall volume

$$\text{Rainfall v. (mm)} = \frac{10\ mm}{cm} \times \frac{\text{Rainfall v. } cm^3}{\text{Bottle area } (cm^2)}$$

$$\text{Bottle area} = \pi r^2$$

Fig. 6: Left: A homemade rain gauge. Right: Formula for calculating precipitation. It is important to mention that precipitation is measured in mm.

Ending -

- Each student group explains how they made their instruments and how they record meteorological variables.

- The students relate the changes occurred when the barometer and thermometer were exposed to heat and explain why these changes occur.

- The rain gauge is installed in a suitable place in the school to record precipitation every time it rains.

- The instruments can be calibrated and the data obtained with them can be compared with those obtained with real instruments.

Frequently Asked Questions

What causes changes in variables to be recorded?

All instruments have a sensitive element. This element is the one that reacts to the changes that occur in its environment most quickly through different processes, such as the expansion or contraction that alcohol undergoes in response to heat.

Can we use the instruments we developed to take our GLOBE measurements?

No, these instruments are only important pedagogically to understand the physical processes behind the measuring instruments, or to record some changes that may occur in temperature, atmospheric pressure and precipitation qualitatively. They will serve to motivate students to get closer to meteorological investigations.

Suggested Resources for Further Information:

Video on how to make a thermometer:
Homemade Thermometer. Very Easy to Make. Science Project. - YouTube

GLOBE Program thermometer activity
Building a Thermometer (globe.gov)

Earth as a System Poster of the GLOBE Program
Earth System Science Posters - GLOBE.gov

Video on how to make a rain gauge
HOMEMADE Rain Gauge - YouTube

Video on how to make a barometer
video how to make a barometer - YouTube

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Natural events and GLOBE protocol bundles

GLOBE		Related SDGs:	Type of activity
Sphere	**Protocols**		
Atmosphere	All	3 (Health and Well-being 4 (Quality Education) 11 (Sustainable Cities and Communities) 13 (Climate Action) 15 (Life of terrestrial ecosystems)	Exploratory
Bundles	All existing GLOBE learning activities already in place for various topics (e.g., Agriculture, Weather, Soils, etc.).		

Overview

Students will identify natural events that occur occasionally and often affect the environment where they occur, their negative and/or positive impacts and which ones occur in their community. They will select GLOBE protocols to study according to their characteristics using the idea of "bundles".

Prerequisites
None

Time:
1 class

School level
Third year of Secondary school onwards (15 years and older).

Purpose

Students will learn about natural events and the threat they can pose to the place where they occur. They will understand the difference between natural events and those caused by human action. They will be able to link them to a set of GLOBE protocols that will help them to study the phenomenon in an ecosystem-integrated way. They will learn to distinguish which protocols are appropriate for each type of event according to its characteristics. They will analyze the likely consequences of these events and how they can affect a community.

Student outcomes

- To learn to identify and use different sources of information to study natural events.

LEARNING ACTIVITY

- To identify possible causes and impacts of natural events on the community.
- To identify possible natural events that could affect their place.
- To relate GLOBE protocols to study natural events in their community.
- To develop models or drawings that represent the events and their impacts (before and after).

Introduction

A natural phenomenon is any manifestation, event, fact or occurrence derived from nature (International Strategy for Disaster Risk Reduction (www.eird.org/fulltext/ABCDisasters/glossary/home.htm#naturalphenomenon)
Due to inclement weather, natural hazards and disasters, and some natural events or phenomena that occur occasionally, such as eclipses, the environment can be changed or affected momentarily or permanently.

Natural hazards are defined as a natural or human-caused phenomenon or process that can endanger a group of people, their things and their environment, when they are not forewarned according to the ISDR. They can become a natural disaster, compromising the health and even the lives of the people who inhabit the place. A disaster is, according to the United Nations (2016), the serious disruption of the functioning of a community or society on any scale due to hazardous phenomena that interact with the conditions of exposure, vulnerability and capacity, causing one or more of the following: human, material, economic and environmental losses and impacts.

These events provide us with the opportunity to make observations and measurements that can later be consulted and used as historical data records, and also to compare them with a time of the year when these events do not occur in order to understand how these events can impact a region or country and the magnitude of the impact. Currently, it is necessary to recognize the risk and its factors in order to determine the procedures to be used (academics) due to the knowledge of the space where one lives (Abarca, 2019).

All these accumulated data will be useful for the processes of nature, their dimension, and when there is a risk of their occurrence, to be able to take preventive or mitigation measures once they have happened. Prevention plays a fundamental role in avoiding major destruction, damage to life and property, which takes a lot of economic and material resources to replace, especially in very vulnerable communities. Starting to deal with these issues at school is fundamental to acquire awareness, to be prepared and to spread the word to the rest of the community.

Some natural hazards are described next:

Avalanches: These occur when huge layers of snow break off the mountainside and shatter like broken glass as they hurtle downhill. These moving masses can reach speeds of 80 miles per hour in about five seconds. Avalanches are most common during and after 24 hours following storms that discharge 30 centimeters or more of fresh snow. This rapid pile-up overloads the accumulated snow, causing a weak layer under the large slab to fracture. The way the layers stick together will determine how easily one layer weakens and causes a slide (National Geographic).

Droughts: Period of time (months-years) during which an area of land suffers from a lack of rainfall. They cause serious damage to soil, crops, animals and even people, sometimes resulting in death (ISDR).

Earthquakes or telluric movements: These are Earth tremors produced by forces acting inside the planet. They are caused by the collision of tectonic plates, which are fragments of the lithosphere (the most superficial layer of the earth) that move as a rigid block, without internal deformation of the asthenosphere (layer immediately next to the lithosphere, which is located between 100 and 240 km below the surface). Another cause is the reorganization of the components of the earth's crust.

Floods: They are caused by the overflowing of a river due to rainfall, tropical storms, hurricanes, and sometimes by human actions, such as deforestation, the location of housing in low-lying areas and near rivers or in known flooding sites (ISDR).

Forest fires: Phenomenon that occurs when one or several combustible materials in forests, jungles and other vegetation areas are consumed in an uncontrolled manner by fire, which can get out of control and spread very easily over large areas (ISDR).

Hail: Frozen water falling from clouds in the form of grains of different sizes is called hail. It is a precipitation different from snow, which descends as flakes. Hail is a solid precipitation. It is composed of small ice spheres, usually between 5 and 50 millimeters in diameter. For hail to form, solid particles are carried by the rising winds into the cumulonimbus, where water particles adhere to them. As these particles ascend, the temperature drops and freezing occurs. Once the hail is formed, when it reaches the upper sector of the cumulonimbus, it falls towards the surface due to its weight (Definicion.de).

Hurricanes: Strong winds originating from the sea and rotating in large whirlwind-like circles, accompanied by rainfall. They are also called tropical cyclones. According to the Beaufort scale, the hurricane storm or hurricane is classified grade 12, and winds reach more than 118 km/h, produces abundant destruction and rain, gigantic waves over 14 m and completely null visibility.

Land subsidence: In geology, subsidence is described as the gradual and progressive downward settlement of the land surface in the absence of horizontal movements. In a simple way we could refer to the process as the gradual subsidence and collapse of the ground. Among the natural causes of land subsidence are permafrost thawing, karst phenomena such as the dissolution of limestone soils, oxidation of organic soils or the sinking of calderas or lava galleries of a volcano, among others. There are also man-made causes (National Geographic).

Landslides: Soil, rocks and vegetation that slide quickly or slowly downhill because the soil is not firm enough. They occur mainly during the rainy season or during seismic activity (ISDR).

Plagues: A major calamity that afflicts a village or community, e.g., large numbers of insects or animals that can destroy crops.

Snow and ice storms: A blizzard or snowstorm is a long-lasting storm with very strong winds and heavy snowfall. To have a snowstorm you need: cold air at the surface, large amounts of moisture and warm air rising above the cold air. An ice storm is a type of winter storm caused by freezing rain. The weather services define it as a storm that results in the accumulation of at least 0.25 inches of ice on exposed surfaces (Biopedia).

Tornadoes: Violent, rotating gusts of wind that spin over the earth. Also defined as a strong, funnel-shaped windstorm that rotates over the ground in a narrow path (ISDR).

Tsunamis: A series of giant sea waves caused by earthquakes, volcanic eruptions or submarine landslides. Tsunamis are also called tidal waves (ISDR).

Volcanic eruptions: Explosions or emanations of lava, ash and toxic gases from the earth's interior through volcanoes (ISDR).

There are also other types of natural phenomena that do not represent a natural threat and are occasional events, such as solar or lunar eclipses, sandstorms that cross the Atlantic bringing dust from the Sahara Desert to the Caribbean and the northern coasts of South America, and others. It is of extreme interest to study them, since their effects transcend a region or continent, and cause effects in other regions of the earth.

Sahara Sands: This phenomenon occurs because winds move, for more than 8,000 kilometers, about 14 million tons of particles from the Sahara Desert to Central America, the Caribbean and part of South America. It happens every year at the beginning of summer due to the action of the trade winds. While these particles affect air quality and, therefore, people's health, these clouds of sand or desert dust provide a good amount of minerals, mainly iron and phosphorus in the soils of the Amazon (Sustainable Territories, 2021).

Eclipse: occurs when a planet or moon gets in the way of the sunlight. We can experience two kinds of eclipses: solar and lunar. A solar eclipse occurs when the moon gets in the way of the sunlight and casts its shadow on the Earth. That means that during the day, the moon moves in front of the sun and it becomes dark. In a lunar eclipse, the Earth prevents the sunlight from reaching the moon. That means that at night, the full moon disappears completely, as the Earth's shadow covers it (NASA Science, 2022).

Guiding Research Questions

- Have any of these events occurred or are they likely to occur in your region?
- What are the most important natural events affecting your community?
- What environmental variables can be studied about them?
- How can they affect human or animal health?
- Could preventive and/or mitigation measures be implemented so that their impact does not greatly affect the community? Which ones?
- In order to study the event, what protocols would you choose that would allow you to measure the environmental consequences of the event?

Scientific Concepts

- Natural hazards and disasters
- Environmental and health impacts
- Environmental hazards
- Vulnerability
- Prevention / Mitigation

Materials and Tools

- Laptop with internet connection
- Colored pencils or markers
- White sheets of paper
- Depending on the event chosen, e.g. for flooding of a watercourse you will require:
  - a square or rectangular container to simulate a river bed, stones, soil, moss or grass, sticks, a jug of water, cell phone or camera

What to Do and How to Do It

Activity 1

Beginning –

- To learn more about the environment and know exactly if any of these events can happen in the locality of the educational center in question, one of the measures that can be taken is to study the place, its characteristics, how it is affected by the climate and other factors (sometimes also affected by the human factor). Some events can be foreseen, and others cannot, but we can study different environmental variables around any of them. To do this, you will choose two of the events described above, and taking a map of the region, you will identify the place of potential "risk" or a place where the event has already occurred.

- You will look for historical information, press releases on the internet about these events, before and after pictures, etc. Also, if it has been a recurring event, investigate when, how many times it occurred and what consequences it produced (for example, the eruption of a volcano, the flooding of a river that passes along the local riverbank or a tsunami that has reached the coast).

- A local expert can visit the school and explain to the students what the event consists of, what its (possible) causes are, what we should consider or anticipate when it occurs, and what its potential consequences and risks (negative and/or positive) are in order to know how to mitigate them.

Development –

- Ask students to draw two scenarios or build two models of such an event, for example, the scenario before an avalanche (the calm mountain landscape) and the one after it happens.

- The teacher will ask them to reflect on the potential damage that could occur and what preventive measures could be taken to minimize its effects.

- Possible questions for students: What was the area like before the event? What happened during and after the event? What happened to the rocks, trees, animals and vegetation? What about the soil? What would have happened if there had been crops or villages in the affected area?

- Afterwards, work with them on the concepts of vulnerability, mitigation and prevention. It is important to raise awareness and work on prevention with the students, especially in those areas that imply an imminent or very probable risk, in order to minimize the risks in their schools, homes and community in general.

Time: 45 minutes. An additional class in case of a visit from an expert.

Activity 2 (Advanced level)

- In the next class you will discuss examples of how an event can be analyzed from the approach of a group of protocols known as the GLOBE protocol bundles.
- You will either provide examples that can be associated with each of the two events that were worked on in the first class or simply choose others. A protocol bundle is defined as "a group of recommended GLOBE protocols". After presenting the examples, allow time for students to discuss whether they find them appropriate or what other bundle they suggest for studying such event.

Example 1. Bundle of suggested protocols to study a forest fire.
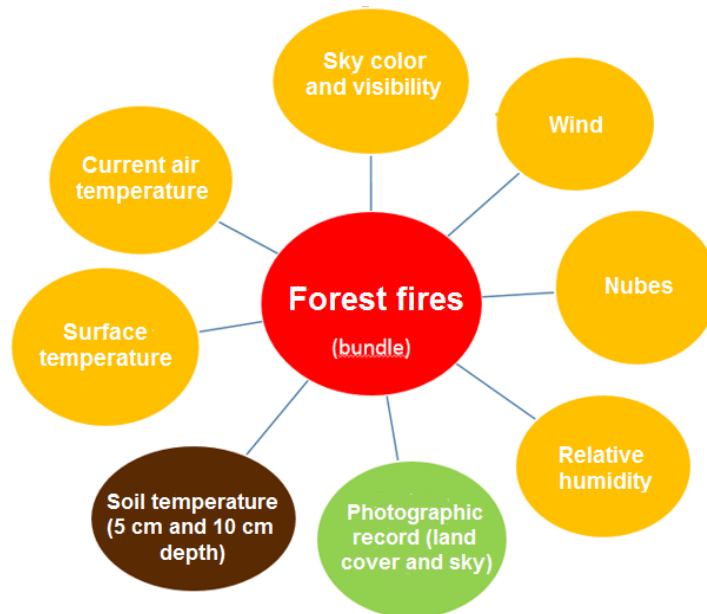
During the event, and as long as it is safe, all protocols can be performed in a nearby area, except for Soil Temperature. When the area has cooled and is safe, Soil Temperature can be added to the other protocols.

Example 2. Flooding of an area that is known from previous flooding events. Bundle of suggested protocols in normal flood season and after flooding has occurred and it is safe to approach the area:
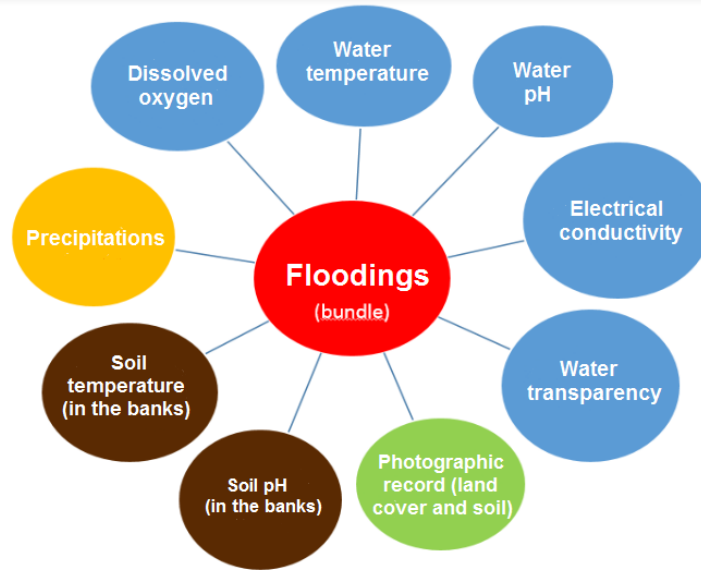
Example 3. Eclipse. The same protocol bundle will be applied for 3 days: the day before, the day of the eclipse and the day after.
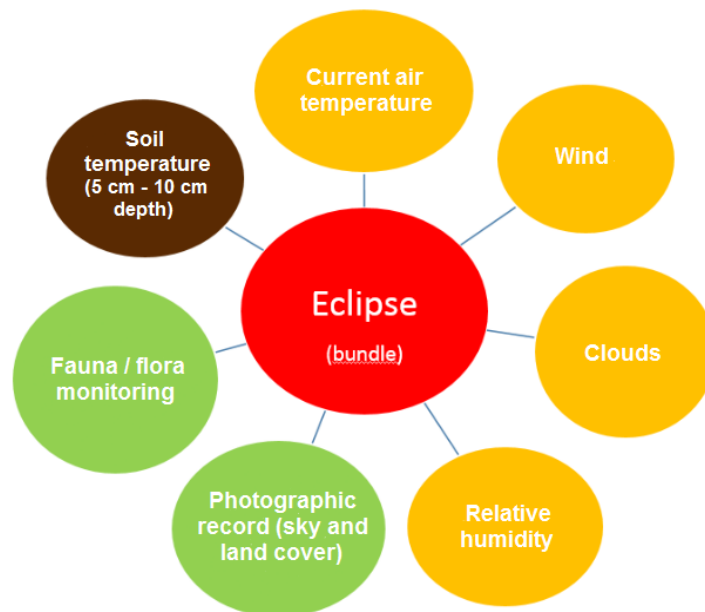
Note: Monitoring of fauna or flora species includes birds, domestic animals, sunflowers (Helianthus annuus), sunbeams (Lampranthus) and some other species that experience changes in the absence of sunlight.

Brown code: protocols corresponding to the Soil

Yellow code: protocols of the Atmosphere

Light blue code: protocols of the Hydrosphere

Green code: protocols of the Biosphere

- Students will then be asked to break into groups and take one of the examples of natural events and propose what protocols could be applied in that case, e.g., the arrival of the Sahara sands.

Ending –

- Each group will present their bundle of suggested protocols to the class and discuss with the other groups whether or not this set of protocols is adequate to study the event, which would be the correct ones, which would be the protocol that cannot be missing in this bundle, in what order they would apply them, etc. They should detail how often they will make the measurements, what instruments they will need, how they will organize themselves to make the measurements and recordings, etc.

Frequently Asked Questions

Can we address these events by studying a single protocol or with the tools we have at our disposal?

Yes, of course, the protocol bundles are a proposal to approach the subject with an integrated view of how it affects the entire environment, which is not a fragmented view of reality, approaching it only from the atmosphere or only from the ground, understanding the Earth as a system. If you have only one or two instruments, try to approach the protocols you can with them, and perhaps later you can incorporate other protocols for further study.

Suggested Resources for Further Information

https://espanol.epa.gov/espanol/desastres-naturales

Natural Disasters Video: https://www.youtube.com/watch?v=HdO02KGD86U

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Oscillation of Air temperature with Altitude

GLOBE		Related SDGs:	Type of activity
Sphere	**Protocols**		
Atmosphere	Air temperature Optional: -Barometric pressure -GPS	13 (Climate Action)	Exploratory

Overview

The students will learn to relate temperature to altitude and other variables that affect it. They will understand why the temperature is not the same in different places on Earth at the same time and at different altitudes and will be able to explain it.

Prerequisites

To have completed the Air Temperature Protocol or have it explained prior to the activity.

School Level

From the fifth year of Primary and Secondary (11 to 18 years old).

Purpose

To demonstrate to the students that the higher the altitude, the lower the temperature recorded at a given location will be (in the troposphere).

Student Outcomes

- The students will learn the relationship of temperature to altitude, winds, atmospheric pressure and latitude.
- They will develop ideas for measuring air temperature at altitude and present them to classmates.
- The students will make measurements and take data from sites in their region to compare temperatures at different altitudes.
- They will contact other schools and compare temperatures with students from schools located at different altitudes.

Introduction

The Earth receives energy from the Sun, which helps to warm it up, but on the other hand, it loses heat when it radiates it to the atmosphere, and this is called the Earth's energy balance. The closer we are to the ground, the warmer it generally gets. Clouds help to retain the heat from the surface, but the higher we ascend, the thinner and less dense the layer of clouds and air becomes, which causes it to get colder at higher altitudes.

The height measured from sea level is called altitude. As the altitude increases, the temperature decreases by one degree every 154 meters in the temperate zone and every 180 meters in the intertropical zone, this is due to the fact that in the temperate zone the insolation received is less and the atmosphere is thinner. When the latitude increases, the distance between the Earth and the Sun also increases, so the temperature gradually decreases. To give an example, if in a location at sea level (0 meters altitude) it is 24°C at noon, at 462 meters altitude on a nearby hill, at the same time it would be 21°C (3 degrees less). Keeping the same example for a location in the intertropical zone, 21°C would be recorded on the hill but at 540 m. altitude. This variation is known as the vertical thermal gradient.

But in some regions of the atmosphere just the opposite happens, that is, the temperature increases with altitude. In this case the vertical thermal gradient is said to be **negative**. This is influenced by issues such as the presence of mountains and the proximity to the sea.

The higher the altitude, the lower the atmospheric pressure. Atmospheric pressure is the weight exerted by the air in the atmosphere as a result of gravity on the Earth's surface or on one of its air layers.

Other factors that also influence the temperature are winds and relative humidity. In places where there is higher humidity, there is lower pressure and vice versa, where there is lower humidity there is higher pressure; this situation is closely related to the altitude.

But what happens in the other layers of the atmosphere?

http://www.atmosfera.cl/HTML/temas/estructura/estructura3.htm
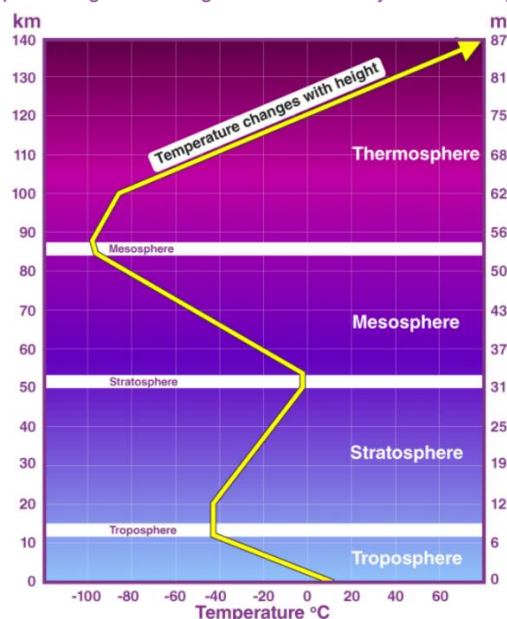
The atmosphere is composed of 5 layers: the troposphere, the stratosphere, the mesosphere, the thermosphere and the exosphere.

The vertical thermal gradient can be altered by several processes: sudden fall or rise of the ground temperature or strong winds. The temperature changes as we ascend.

In the troposphere it has an approximate value of 6º C per kilometer. This means that if, for example, the temperature at sea level is 15º C, at an altitude of approximately 5 km, it will reach the value of -15º C (a decrease of 30 degrees). At the upper limit of the troposphere, which is the tropopause, where the temperature stops decreasing, the temperature is close to -55°C.

Above the troposphere is the stratosphere, which extends up to about 45 km. There the temperature increases with altitude to a value close to 0°C at its upper limit called the stratopause.

In the mesosphere the temperature decreases on average as one ascends, i.e. the vertical thermal gradient is positive. This stops at about 80 km altitude where the temperature approaches -90°C (mesopause).

In the thermosphere, the temperature increases with altitude and, therefore, the vertical thermal gradient becomes negative again in this layer of the atmosphere.

An important issue to consider in the troposphere is thermal inversion, which happens when the ground is rapidly cooled by radiation, which in turn cools the air in contact with it. In turn, the cooler, heavier air in the upper layer cools even more. Thus, the rate at which the two layers of air mix abruptly decreases. This usually occurs in winter, causing persistent fog and frost in the layer closest to the ground.

Guiding Research Questions

- Is the assumption that the closer we get to the Sun, the higher the temperature will be, a correct assertion?
- If the ambient temperature is measured at the foot of a hill and at the same time at the top of the hill, will it be the same for both places?
- What other variables can influence temperature besides height when we measure temperature at different altitudes?
- If Mount Everest in the Himalayan range is 8,848 meters high, what temperature would be expected at the summit if no other variables were involved? Are there any sources/agencies that record the temperature at these altitudes? Which ones?

Scientific Concepts

- Soil absorbs radiation from sunlight
- Altitude / Latitude
- Atmospheric Pressure
- Thermal Gradient
- Layers of the Atmosphere

Materials and Tools

- Alcohol or digital thermometer
- Air Temperature Field Guide
- Air Temperature Data Sheet or field notebook
- GPS application on the mobile device.

What to Do and How to Do It

Activity 1.
Beginning -

Assign your students the task to take the temperature as close to local solar noon as possible at their homes (after school for the morning shift classes, before school for the afternoon shift classes) with an alcohol thermometer following the GLOBE protocol. Also ask them to record the exact location and altitude of where they are taking the temperature, and to record those three pieces of information and bring them to the next class. This assignment will be done by all students on the same day.

Development -

In the next class, on the board write the temperatures you recorded the previous day in one column, and in the other column write the altitude of your geographic location.
Did they all record the same temperature? Why? What factors do you think may have affected it?
Afterwards, ask your students to look up on their computers on the internet what the recorded temperature was for the same time and day they found, but for other locations in the region at different altitudes, for example, a city in the mountains or a town in a low valley.

Ending -

Ask your students to think about how temperature changes at different altitudes and the factors that also affect altitude. Also have them look for similarities in temperature among the different sites.

Outreach Activity

- Assuming that the temperature increases by 1°C for every 154 m. of altitude in temperate zones and every 180 m. in intertropical zones, ask your students to think and develop in writing or orally what ideas they can think of to measure the air temperature at these altitudes to see if there is indeed a change in temperature between the Earth's surface and the altitudes mentioned. For example, hang a liquid thermometer on a drone with a camera and raise it in an open area to record the temperature when it reaches 154 m. and 308 m. high.
- Ask your students to present their ideas to the whole group. Are any of the methods they put forward feasible? Why? Why not? Ask them to discuss options, evaluate possibilities and come to some conclusions.
- For example, you can measure the temperature at the bottom of a hill, then go up and measure the temperature as you reach the altitudes of 154 m. and then about 300 m. They can use the GPS application to determine the altitude at which they want to take the measurements. It can also be three people taking the measurement at the same time at the three different altitudes.
  What difficulties do they encounter? What other variables may play a role?

Ending –

Encourage students to develop some of the ideas or do it yourself and share the results with them afterwards.

Time: one 50-minute class.

Activity 2.
Beginning -

Using the GLOBE website, search for schools within your region that are at different altitudes from your school. Find out if any teachers at those schools are willing to do collaborative work.

Development –

- You can organize a Zoom or Google Meet session in class for students to connect, explain what activities they are doing and what they are interested in working on collaboratively to measure the temperature for the next class or for whenever they can schedule.
- Plan for both groups' measurements to be taken at the same day, at a site with similar characteristics (both in an open location, with grass cover, and if possible,

  on a clear day, or with similar cloud cover). If possible, they should be at local solar noon and may include more measurements at other times to provide more data for comparison.
- Have students record their data in the science notebook and in the next class they schedule to meet online and share the data, analyze the data each group recorded and discuss with the other group their conclusions about how altitude influences temperature.

Ending -

The students can elaborate a poster in each of the educational centers and deepen the research to present their work to the IVSS.

Time: at least two classes in connection with the other school.

Frequently Asked Questions

Why is temperature estimation at high altitudes important?

There are animals that are ectotherms (they depend on external sources of heat, as is the case of reptiles and arthropods) and altitude can affect both their reproduction and distribution, and even their survival. Studying the change in temperature at different altitudes can help to know the right conditions for the propagation and conservation of a species. Another concrete example can be in aviation, since aircrafts must avoid icing conditions (ice formation on the external surfaces of the aircraft) that are caused by low temperature and high humidity in the atmosphere, which would cause, among other things, the loss of the aircraft´s lift and increase its weight. Another applicable case would be for mountaineers: the altitude determines the type of clothing they must wear to withstand those

temperatures, the provisions they must make for sudden changes in weather conditions (blizzards, snowstorms), and even the lower amount of oxygen in the air as they ascend.

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Precipitation in the Latin America and Caribbean region. Patterns by regions and seasons

GLOBE		Related SDGs:	Type of activity
Sphere	**Protocols**		
Atmosphere	All Data Literacy Activity: Search, visualization and use of Precipitation data. Learning activity: Working with data in graphs.	13 (Climate Action) 15 (Life on Land)	Application

Overview

Students analyze precipitation data for several countries in Latin America and the Caribbean, including their own. They will identify rainfall patterns for these countries. They will identify factors that may influence differences in patterns (if any) and phenomena that may modify the patterns. Students will compare the data obtained with data from official meteorological agencies in their countries or internationally to find out if the patterns found coincide or not with the data investigated. Students will determine when and how much precipitation occurs in their countries in different seasons.

Prerequisites
- Knowledge of the Precipitation protocol. Use of the rain gauge.
- Precipitation measurement data taken in class (optional).
- Knowledge of Excel spreadsheet.

Duration:
45 min. – 1 hour

School Level
From the sixth year of Primary school and all Secondary school (12 to 18 years old).

Purpose
Students will learn about seasonal patterns in their country and elsewhere in the Latin America and Caribbean region using available rainfall precipitation from various sources.

Student outcomes
- To learn to identify and use different sources of precipitation data.
- To present in class and compare graphs from their country or region or from other regions to find patterns.

LEARNING ACTIVITY

- To analyze graphs and draw conclusions.
- To identify different climates according to temperature and precipitation (temperate zone, tropical zone, etc.) in the Americas.
- To find internet data of the El Niño/Southern Oscillation (ENSO) cycles for the data periods found and compare them with the graphs produced.

Introduction

Precipitation consists of all forms of liquid (rain and drizzle) or solid (snow and hail) water falling from the atmosphere and deposited on the earth's surface. The amount of precipitation that falls in a region, when it occurs, and the amount that falls in individual episodes define the climate of that region.

Precipitation is an element of climate, which is basic to life on Earth, and it is influenced by other factors, such as: latitude, ocean currents, proximity to a sea or lake, seasons, the presence of orographic barriers, etc.

Importance:

- It is an important part of the water cycle, vital for all life on earth.
- Rainfall is essential for recharging lakes, rivers, and subway aquifers.
- It allows dams to be filled, and dams produce electricity for various uses.
- It is necessary for plants in order to carry out the process of photosynthesis by which plants create their food.
- Provides water for animals and humans.
- Allows for cooling and humidification of the air.
- Regulates ambient temperature.
- Provides a free, regular, and relatively clean source of water.
- Cleans the air, which keeps the atmosphere fresh and clear.

Establishing precipitation patterns makes it possible to define the climate of a region to determine whether it is dry, humid, mild, etc. According to the precipitation and temperature flows, among others, it is possible to differentiate the seasons into summer, autumn, winter and spring, or between the wet and dry ones.

The landscape of a place can change throughout history, since it is subject to many factors and atmospheric events that can radically alter its physiognomy. For example, it can modify the normal course of a watercourse, the shape of the relief due to landslides produced by intense rainfall, the formation of gullies due to rapid erosion following rainfall, etc. How can we know what a region/site looked like a few years ago? Satellite images from two or three decades ago are available, as well as even older aerial photos that help us recognize the landscape of the study area.

We can study changes in precipitation in our region using GLOBE precipitation data, as well as other data obtained from national and international agency weather stations.

Guiding Research Questions

- What type of climate is there in your country or region?
- What elements contribute to the definition of a site's climate?
- In what other regions of the world might there be a climate similar to that of your region? Why?
- Can you identify any period/season of the year that does not rain in your region? Which one?
- How does precipitation in your country differ depending on whether it occurs in the coastal zone or the continental zone?

- Where do rainstorms generally come from when they arrive in your region? What other factors may play a role?

Science Concepts

- Weather vs. Climate
- Liquid and solid precipitation
- Weather changes from day to day and from season to season
- Weather varies on local, regional, and global scales
- Extreme events (floods, droughts, heavy rains)
- The amount of precipitation influences the characteristics of the physical and geographic system.

Materials and Tools

- Colored pencils, a black pencil, plain white paper, and ruler or graph paper
- A world map
- An Earth System Poster resource to introduce the topic. (https://www.globe.gov/documents/10157/334459/Earth_System_Poster_07_Activities.pdf)
- Acetates or tracing paper.
- Already printed graphs brought by the teacher of annual precipitation in your locality/country and other localities/countries.

What to Do and How to Do It

Beginning-

To understand and explain the climates of each region, the Köppen-Geiger Climate Classification can be used as a support, where the main climates are defined according to temperatures and precipitation (https://www.tiempo.com/ram/4585/mapa-mundial-de-la-clasificacin-del-clima-de-kppen-geiger-actualizado/).

Additionally, you can use the Earth System Poster to show the different environmental variables analyzed in it, including precipitation. Ask the students what they observe, how they think precipitation is related to the other variables presented (land cover, temperature, relative humidity, clouds, etc.), which are the regions where it rains the most, in which season the highest volume of precipitation occurs, etc. They will reflect on the global level and then turn focus on the regional and local level.

Duration: 20 minutes

Development -

In a second instance, provide printouts of graphs of precipitation data extracted from the GLOBE Data Visualization System, or from other official sites where annual cycles can be obtained (if possible), such as the official national meteorological institute website or data from NASA or other recognized agencies.

Organize groups of three or four students to analyze the graphs.

Two groups will analyze precipitation data from their locality/region, while the other groups will analyze data from other localities/regions in Latin America or the Caribbean in order to have several points of comparison. If possible, it is recommended to look for annual cycles or cycles as complete as possible, and another annual cycle from previous years to compare with the same site. In this way, each group will have two annual cycles per location/region. They can also compare graphs of seasonal cycles of several years accumulated with annual graphs (see figure 2).

They will identify the different seasons that correspond to their country by colors (see figure 1 as an example for Uruguay), where data for autumn, winter, spring and summer can be differentiated. This will also be the case for The Dominican Republic, Colombia and Panama, and in other cases, different models will be found; e.g. for Peru and Ecuador they will identify a dry season (summer) and a wet season (winter) instead of the four seasons mentioned above.

Some of these questions will be asked for the students to investigate and be able to answer the matters posed:
- Which is the rainiest month of the year? Which is the driest?
- What was the day with the highest rainfall according to the observed data? In which month was it?
- What was the longest period without precipitation? What season(s) of the year does it correspond to? Can it be identified with a dry season?
- What is the seasonal variation in precipitation?

Note: For a higher level of complexity of the activity, the raw data can be provided for the student to calculate the volume of precipitation by season (or month by month if preferred).

Provide students with copies of the graphs that the other groups have and they will copy the graphs using the acetate sheets, and draw the lines with markers. Precipitation patterns can be studied by overlaying graphs from two different years from the same site or by overlaying a graph from their locality/region with one from another region. Have them compare graphs obtained from different sources and in various formats (patterns from one station with an annual cycle, data from the same station over the cumulative of several years, etc.).

Here you will proceed with the following questions:
- Do the patterns repeat year after year or between non-consecutive years? Why do you think this happens?
- Does the pattern found for precipitation in your country match the pattern found for another country/region?
- Do you know of any phenomena/events that alter the precipitation patterns for your region?

Introduce the phenomena that affect the different regions of the Americas, for example, the El Niño Southern Oscillation (ENSO) phenomenon. This consists of three phases: El Niño (warming and precipitation), La Niña (cooling) and a neutral phase. This variability does not have a defined time interval, as events have been observed between periods that vary between 2 and 7 years, approximately. To qualify as an event, anomalous measurements must reach the ranges for at least three months. How do these events affect an annual precipitation cycle?

Take into account in these comparisons with other countries/regions the differences in altitude, orography, proximity to the coast, winds and the influence exerted by these

variables causing different patterns for each site. Explain what the "rain shadow" effect is in mountain areas and how it affects precipitation depending on the slope of the mountain. In the case of coastal regions, explain how precipitation differs in the continental zone from the coastal zone and in turn between different coastal zones, as they are subject to particular currents and winds.

Observe the sites they analyzed and according to their geographic location, find out if any of these variables can affect their region and how (use the Earth System Poster for this purpose or a world map to display on the board).

If you have more class time available, contact other schools in other regions of Latin America and the Caribbean to share the students' findings and have students from those schools share what precipitation patterns are like in their country/region.

Ending -

At the end of the activity, the student should have acquired clear skills in how to analyze and interpret data from previously provided graphs. He/she should also be able to identify rainfall patterns in his/her region and what factors influence these patterns. He/she can prepare a poster with the tables and graphs developed and the main conclusions to be displayed in class.
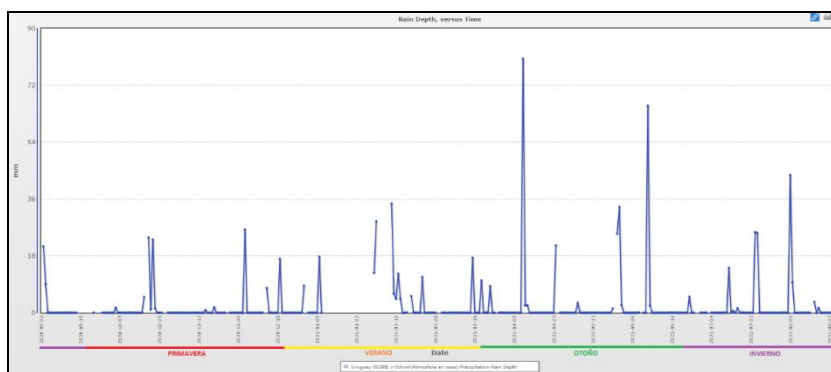
Fig. 1: Data extracted from www.globe.gov on precipitation in Uruguay GLOBE v-School, corresponding to one year (from 09/01/2020 to 08/31/2021).
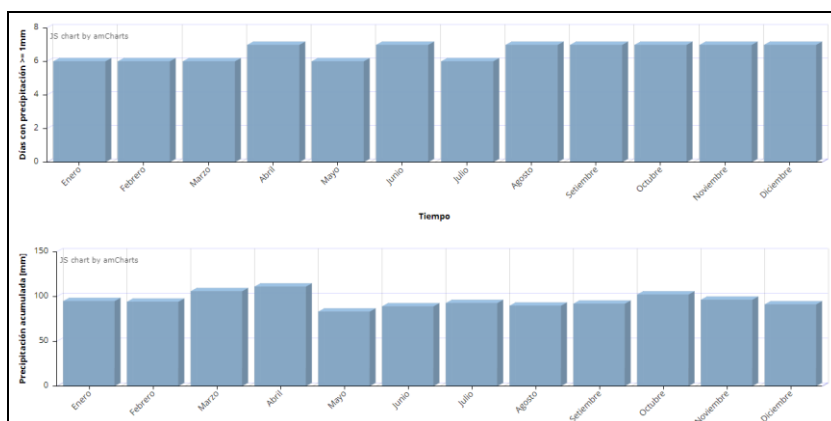
Fig. 2: Precipitation statistics graphs for the period 1991-2020 for 15 meteorological stations in Uruguay. Source: https://www.inumet.gub.uy/clima/estadisticas-climatologicas/graficas-estadisticas-pluviometricas

Frequently Asked Questions:

What if I don't have internet access to download graphics or access Earth Posters?
In this case, you can use a geography atlas where the precipitation models for different regions are described.

Suggested Resources for Further Information:

http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears.shtml

https://www.esrl.noaa.gov/psd/data/gridded/data.crutem4.html#detai

Ungerovich, M. & Barreiro, M. Seasonal Climate Prediction of Spring and Summer Accumulated Precipitation in Southern Uruguay. http://meteo.fisica.edu.uy/archivos/TrabajosEspeciales/TF_MAtildeUngerovich.pdf

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http://www.climate.gov/news-features/department/8443/all

NOAA. El Niño and La Niña: Frequently asked questions. Climate.gov https://www.climate.gov/news-features/understanding-climate/el-ni%C3%B1o-and-la-ni%C3%B1a-frequently-asked-questions

Urban heat islands / Surface temperatures

GLOBE		Related SDGs:	Type of activity
Sphere	**Protocols**		
Atmosphere	Temperature	4 (Quality education)	
Pedosphere	Temperature, Soil Characterization, Surface Temperature	11 (Sustainable Cities and Communities) 13 (Climate Action)	Research

Overview

The students will record a range of variations in temperature conditions, in different materials in their environment, deducing their varieties and projecting the overall integrated effect at their school level. On this basis, they will deduce associated environmental effects.

Time

One class period to discuss and plan the experiment, another one to set up the experiment, part of one class period at daily intervals (or any other day) to record the results, and two class periods four weeks later to observe and discuss the final results.

Prerequisites

Preliminary handling of concepts associated with energy and its forms.

School level

Upper primary school (From 8 to 12 years old)

Purpose

To understand the concept of Heat Island as a combined expression of heat energy transmission according to the characteristics of the materials and their environmental effects, comparing surface temperatures of different materials and deducing their effects as a whole.

L E A R N I N G A C T I V I T Y

Student outcomes

- To understand the concept of "Heat Island" as the combined effect of heat energy exchange and migration on different material substrates
- To identify environmental implications and effects of the heat energy we measure in temperature
- To determine the effects of heat manifestations on humans

Introduction - Context

The Heat Island has an urban phenomenon connotation of heat accumulation in an asymmetrically spatial form. In urbanization processes, the temperature control in larger areas of land is done by remote sensing or satellite sensors because when weather stations are *inside* the heat islands, they generate erroneous data because they do not record the region climate, but the forced one by the heat island regime. In its study, it is usually important to capture the radiance measurement from the temperature brightness in Kelvin degrees; and, by transforming it to degrees Celsius in order to correlate the Heat Islands with the different variables surrounding the urban environment, consider the instances of heat transfer of the materials present in the study area and identify the phenomenon collateral effects on the environment, specifically on the place biodiversity.

In the present activity we will approach the study of this phenomenon with the intention of studying it in more detail on larger surfaces than those considered on this occasion.

Scientific Concepts

- Forms of heat energy exchange (convection, radiation and conduction)
- Temperature scales and conversions (ºK,, ºC, ºF).
- To differentiate heat and temperature
- Thermal sensation
- Concepts of Albedo, reflection, thermal inversion, ground/atmosphere interface
- Rould's Law

Guiding Research Questions

- What is a Heat Island?
- How does the phenomenon occur?
- What are its main effects?
- What could be the options for mitigating their negative effects on human health?

Materials and Tools

- 30x20x5 cm. box mold (as a mold to make Adobe mudbricks or bricks).
- An infrared digital thermometer

What to Do and How to Do It

Beginning –

- With the help of the frame, make molds out of different materials, such as concrete, Adobe mud, pebbles, free soil, etc., and place them in an area that gets the most sunlight on your school grounds. For three days (ideally sunny), take the temperature of each block with a digital thermometer, three times each for three days at solar noon, two hours before and two hours after. Record the data and, with the above inputs, make comparative graphs, construct explanations together with your students and report the results. As a corollary, collectively construct an idea of a heat island as a result of heat energy transfer in a heterogeneous material set and the corresponding concepts associated with heat transfer.

Development -

Get a scale plan of your school floor plan and reproduce it on a larger scale (something like 50 x 90 cm). Identify areas of different materials and define measurement points according to the predominant material in the area of each measurement. Take the temperature of each block with a digital thermometer, three times each for three days at solar noon, two hours before and two hours after. Record the data.

Closing -

With the above inputs, draw up comparative graphs and assign colors to the different average temperatures, assign a color to each one and color the areas of the plane associated with them. Ask your students to relate the real areas with each average temperature determined and ask them to search for bibliographic material describing the collateral effects on the biodiversity installed in the vicinity of the heat island.

Frequently Asked Questions

How could we deepen and project our study on a larger scale?

Using GLOBE data tools over the city or county where the school is located, design an investigation ideally in the summer season over the entire territory, where using satellite data you can build conclusions at a larger scale and include statistically processed data to deduce effects on local biodiversity, especially birds and human health.

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Wildlife Monitoring with GLOBE Atmospheric Parameters

GLOBE		Related SDGs:	Type of activity
Sphere	**Protocols**	13 (Climate Action) 15 (Life on Land)	Research Application
Atmosphere	All		
Biosphere	Land Cover Classification (MUC) Migratory Birds Hummingbird		

Overview

To associate the atmospheric protocols to the sighting of wildlife species in order to study if these variables influence the presence of the species studied. To check if changes are recorded in the times of sightings, number of species, habitats visited, etc. according to what is defined in the reference guides on the species historically.

Prerequisites

Notions of Bird Migration and Ruby-Throated Hummingbird Protocols.

Total activity time:
4 months (one whole season for monitoring and one month for the other activities). Note: Monitoring can be repeated in another season or other seasons to compare data.

School Level
Fourth grade and above.

Purpose

To observe processes that occur in nature by applying environmental monitoring techniques (e.g., arrival of monarch butterflies in our region, sightings of migratory swallows, etc.). To determine when certain migratory species arrive or when others begin to be sighted. To determine what variables, influence their sightings or determine their presence.

Student outcomes

- To observe nature in order to understand its processes and dynamics.
- To apply Atmosphere and Land Cover Protocols to wildlife observation and monitoring.
- To determine an animal species of interest for study.

LEARNING ACTIVITY

- To develop a plan to study the chosen species.
- To conduct observation of a species over an entire season to monitor its behavior.
- To record both sighting and environmental variable data (temperature, humidity, precipitation, wind, clouds, surface temperature).

Introduction

How many times have we said or heard someone say: "Now you don't see as many butterflies as before", "This year the swallows haven't arrived", "You don't see light bugs (fireflies) in the field at night any more". Is it really like that or is it that we no longer pay attention to what surrounds us? We are immersed in a globalized world and technology often takes up all our free time and we do not spend time or spend very little time enjoying and observing nature.

Just as it is vitally important to conserve the quality of water, air and soil, it is also essential to pay attention to the state of wildlife populations in a given ecosystem for the survival of the species that inhabit it and those that depend on them. Many species are threatened by various factors in their habitats such as deforestation, cattle raising, agriculture, mining, hunting, the introduction of exotic species and the growth of cities. These factors, along with forest fires and climate change, have caused these species to be displaced, having to migrate to other territories, or directly to be eliminated from a habitat. "Nowadays we speak more of a dynamic conception of the flow of nature in which a constant change in ecosystems and biological reserves is defined" (Maza and Bonacic, 2013).

Therefore, it is a priority to know more about the animal and plant species in the habitat we live in (distribution, abundance and population dynamics) and thus contribute to their conservation and protection.

One of the criteria we can take when choosing our target species is to identify a native or endemic species (one that lives naturally in a region, that is, one that is believed to have originated or arrived naturally in the country, without human intervention) over an exotic species (a species from another part of the world that has been introduced mainly by human incidence, either voluntarily or accidentally). Another criterion could be to study a common species versus one that is considered at risk for our country or region. If you prefer to study the latter, you can consult the IUCN Guides and Red Data Books of Threatened Species (*) and others specific to each country where species are classified in categories such as "Critically Endangered" (CR), "Endangered" (EN) or "Vulnerable" (VU).

Why monitor? It allows us to determine the status of the species in a specific ecosystem or site, identify over time whether the population is growing or declining and what may be the factors that cause it, protect the sites where they stop after a migration or where they go to reproduce, develop a guide about the species of the site, obtain data on species as indicators of the state of the ecosystem, make databases for future studies available, etc.

From GLOBE's perspective we can collaborate through citizen monitoring, making our young people aware of the importance of contributing to the knowledge of what happens in the ecosystem, paying special attention to the observation of species and, in this case, to the atmospheric factors that accompany the observation. Temperature, relative humidity, cloudiness, precipitation and wind are factors that affect the sighting or appearance of species such as butterflies, hummingbirds, birds (including migratory ones), fireflies, etc.

- Temperature: it affects the presence or absence of species and their daily behavior and also on flowering or fruiting. Minimum, maximum, current and daily and

seasonal average temperature can be studied. Daily and monthly averages of high and low temperatures can also be taken. To measure this parameter, a liquid or digital thermometer is used.

- Precipitation: like temperature, it influences the presence and behavior of animals and the phenology of plants. Sightings can be studied depending on whether it rained that day or not, on what amount, and also on monthly and seasonal averages. It is also important to study it in the case of flooding of habitats of land species, since they can be displaced to other territories. The rain gauge is used to make precipitation measurements.

- Clouds: they are linked to precipitation and air temperature. A nimbostratus cover, for example, indicates probable precipitation, which will surely affect the presence of insects and birds. To estimate this variable, the GLOBE Cloud Chart and optionally the GLOBE Observer app are used.

- Wind: wind speed has an impact on some species in particular, e.g., butterflies and hummingbirds, and it will depend on the wind speed on a given day whether these species are sighted or not. It is measured with the anemometer and both wind speed and direction can be recorded on a daily basis.

- Relative humidity: days with low relative humidity and no precipitation, added to high temperatures, cause vegetation to dry out (causing animals to be unable to feed and migrate to other areas or die) and also increase the risk of fire. Humidity is measured with the hygrometer and can also be recorded daily and throughout the day.

- Surface temperature: linked to air and soil temperature, it influences the presence and behavior of insects and birds. It can be monitored throughout the day, but especially after local solar noon, when maximum temperatures usually occur. This measurement is done with the infrared thermometer.

Guiding Research Questions

- When do the monarch butterflies arrive in my region? Do they arrive on the same dates every year? And when do they stop being seen?
- What were the temperatures recorded this spring when the swallows began to arrive? Was it in the rainy or dry season?
- This spring was unusually rainy, did this result in that almost no hummingbird was sighted?

Scientific concepts

- Environmental monitoring
- Scientific names/Common names
- Risk of extinction
- Vulnerable
- Wealth
- Distribution
- Population
- Resident vs. migratory and native vs. exotic species

Materials and Tools:

- GPS App or GPS device

- Alcohol or digital thermometer
- Hygrometer or hygro thermometer
- GLOBE Cloud Chart / GLOBE Observer app
- Anemometer and wind vane or app for device (it can be Wind Compass)
- Rain gauge (optional)
- Infrared or surface temperature thermometer (optional)
- Field Guide with the step-by-step tour (student-designed)
- Science notebook or Excel spreadsheet (student-designed to record data)
- Pencil or pen
- Camera or electronic device
- Compass
- Wildlife Field Identification Guides
- Binoculars (optional) / Magnifying glass
- Ribbons, banners or other items to mark the observation trail

What to Do and How to Do It

Beginning -

In one visit or a series of visits by the teacher (probably more than one will be needed at different times or seasons), a monitoring site is determined, if possible, within the school grounds, or close to them and easily accessible, since the visits will be frequent (orchard, garden, field, forest or nearby park, botanical garden, protected area, etc.). The teacher can visit the site a second time with the students to see what species are present or can be seen in the habitat. Bibliography or identification guides that list the geographical distribution of species can also be consulted.

In a first class it is determined which species is of interest for observation according to the existing ones in the chosen site.

To do so, certain characteristics and conditions of the species should be taken into consideration in order to facilitate its observation at the chosen site:
- to be a frequent species at the site
- that is easy to observe and to record photographically
- that can be identified either by its colors, shape, flight, trill, etc.
- to consider that daytime habits species should be chosen, as the observation of students is likely to be done during school hours.
- if it is also attractive to the group of students it would be ideal, as it is a good stimulus for their study.

Examples:
- the monarch butterfly (*Danaus plexippus*) or any day butterfly;
- the white-browed swallow (*Tachycineta leucorrhoa*) which is migratory and moves over a large area of South America, or some other bird;
- the ruby-throated hummingbird (*Archilochus colubris*) or the one observed in our region
- ladybirds, St. Anthony´s ladybugs or ladybugs (*Coccinellidae*)

It is recommended to always prefer native species over exotic ones and the special protection species in particular.

White-browed Swallow
Image: Jorge
Barcala

Monarca
(Danaus plexippus)
Creative Commons

Ladybird
Creative Commons

Development -

1. In the second class, the students look for information about the characteristics of the chosen species, its behavior, ecology, geographical distribution, what type of habitat it lives in, when it is sighted, what it feeds on, etc. To do this, they use field guides to identify species in the country/region or ask a scientist, park ranger (or forest ranger) or local species expert to give them a talk in class.

2. The students determine what features to observe in the species under study that differentiate it from others of its genus, e.g. number of legs, wings, antennae, color patterns, etc.

3. According to the chosen species, the students discuss as a group and define which atmospheric parameters will be applied in the monitoring. For example, they can measure temperature, wind and precipitation. These will be the variables that will be determined as factors that influence the appearance or sighting of that species for this particular study. It should be noted that the variables to be studied will also depend on the instruments available at the school. The necessary instruments to study the atmospheric variables can also be obtained from a science museum, a university or the GLOBE Coordination in your country.

4. In the third class, the teacher teaches the protocols that were defined to study the species in question and such protocols are practiced in class beforehand.

5. On a new visit to the chosen site, the students and teacher plan an observation trail and mark it with flags, for example, or with ribbons on trees or whatever is most visible to them. The GPS protocol will be used to geolocate the site, either with the GPS device or with the app on the mobile device and is recorded in the science notebook along with a sketch of the trail and the site.

6. In the fifth class, a monitoring or observation plan is drawn up detailing what is going to be monitored, when, how, how often, for how long, who is going to do it (in groups or pairs, taking turns, etc.) and a schedule of activities with specific dates is made. All this will be recorded in a document and shared with all the students.

7. The students, guided by the teacher, will agree on a field guide, or step-by-step guide that they will follow in the field so that everyone follows the same procedure or protocol

for making observations and recording data. Please find an example of a Field Guide developed by the Butterflies and Environmental Variables Project Team for the Observation of Butterflies and Environmental Variables (see Figure 1).

8. All materials, instruments, data sheets and recording forms to be used are defined and recorded in a spreadsheet that will be consulted each time a site visit is made.

9. To keep records of data, it is convenient to develop a form (it can be on paper or Excel) that includes all the fields according to the protocols to be applied and the observations of the species to be taken into account (e.g. specimens are observed- yes or no, how many specimens are observed, what genus they are, what species they are, common name, activity being carried out, etc.). This form should clearly state the date, time and person responsible for the observation in order to keep a more rigorous record. Recording in spreadsheets makes it easier to systematize the information obtained and save time in the field. A simple form is presented as an example. The fields can be obligatory or optional (see example in Figure 2).

10. Accompanying the observation and monitoring with a photographic record is fundamental to help the students identify the species, and also the host or feeding species they visit. Having a camera for this purpose or several mobile devices for recording images helps, as well as instructing students to behave prudently in order to capture the species without disturbing them or scaring them away from their usual activity and habitat.

Fig. 1: Field Guide for Butterfly Observation. Courtesy of the Butterfly and Environmental Variables Project.

Date	Time	No. of specimens observed / NO specimen (0)	Specimen photo	Common name	Genus	Specie	Place (plant, fruit, trunk, soil, pot, grass)	Action: feeding, flying, resting, etc.)	Land cover	Current temp. (ºC)	Rainfall Yes/No (in mm)	Wind speed (km/h)	Student's name	Geographic coordinates (longitude, latitude, elevation)

Fig. 2: Recording Sheet (abbreviated example of the one used for the Butterfly Project). Courtesy of the Butterfly and Environmental Variables Project.

Ending -

At the end of the period determined for monitoring, the information obtained will be analyzed through tables and graphs, cross referencing variables of the observed species with atmospheric variables to determine how they influence their sighting / appearance / migration. The conclusions will be discussed as a group and a group report will be prepared for presentation at the GLOBE Virtual Science Symposium.

Optionally, historical information on that species and its behavior (if available) can be sought from various sources to compare students' findings and see if trends change or remain stable in terms of distribution, richness, habitats, sighting times, behavior, etc.

Frequently Asked Questions

What happens if the educational center where I work is in an urbanized area that has a closed courtyard among buildings where there are no wildlife species to be seen? Can I still carry out the activity?

Generally urban schools have fewer possibilities in terms of adequate space for green areas, but we can look for other options: create a space on the roof if it is accessible and safe; go out to the nearest square or park where we can see more wildlife; get and bring butterfly caterpillars to study the life cycle, etc.

Do I need to be an expert to study a certain species?

No, it is enough to read information about the chosen species and look for identification guides, applications that help us to identify them (e.g., iNaturalist for wildlife, Merlin Bird ID for birds, NatureID) or seek the advice of a specialist to help us throughout the study. What is important is to seek the support of a colleague or expert to accompany us throughout the activity or at least at the beginning and end (to analyze the results).

Suggested Resources for Further Information:

iNaturalist application: https://www.inaturalist.org/

Merlin Bird ID application: https://merlin.allaboutbirds.org/download/

NatureID Application:
https://play.google.com/store/apps/details?id=plant.identification.flower.tree.leaf.identifier.identify.cat.dog.breed.nature&hl=en_UY&gl=US

PictureThis application: https://www.picturethisai.com/es/

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How To Achieve Scientific Quality Data

GLOBE		Related SDGS	Type of Activity
Sphere	**Protocols**		
Atmosphere	All	4 (Quality Education) 13 (Climate Action)	Exploratory

Overview

Scientific measurements require certain conditions in both the procedure and the instruments used to obtain quality and scientifically valid data. In addition, prior practice of measurements in the classroom is required before making a field trip to take real data.

Time
1 lesson of 80 minutes

Prerequisites
None

School Level
Secondary

Purpose

To teach students that, in order for research data to have scientific value, they must be obtained following certain procedural criteria, which reduce the percentage of error to a minimum.

Student outcomes

- To explain the concept of calibration
- To deepen the concepts of accuracy, precision and the types and sources of error.
- To describe what a protocol is and the importance of following the established step-by-step procedure to achieve scientifically valuable data
- To understand the importance of instrument care and correct use for proper maintenance and conservation and to make the data usable.

- To promote students' critical thinking that translates into the ability to solve problems in and out of the classroom.

Introduction

When dealing with scientific data, it is essential to handle the most precise and accurate data we can, so that the percentage of error is minimal or zero and we are able to obtain quality research.

Precision and **accuracy** are two measures used in scientific studies to determine the **percentage of error**.

Precision is the detail with which an instrument or procedure can measure a variable while accuracy is how close this measurement is to the actual value. For example, if a person is weighed on the same scale every time, it will be accurate even if it is not his/her actual weight, but if he/she is weighed on different scales, it will be difficult to keep track of his/her actual weight because each scale will have a percentage error.

It is possible for a system to be highly precise, but not accurate, and vice versa. One way to represent the difference between precision and accuracy is with a dart board. If the center of the dartboard is the true value, the closer the darts are to the dartboard, the more accurate they will be, and the closer the darts are to each other, the more precise they will be (see Fig. 1).
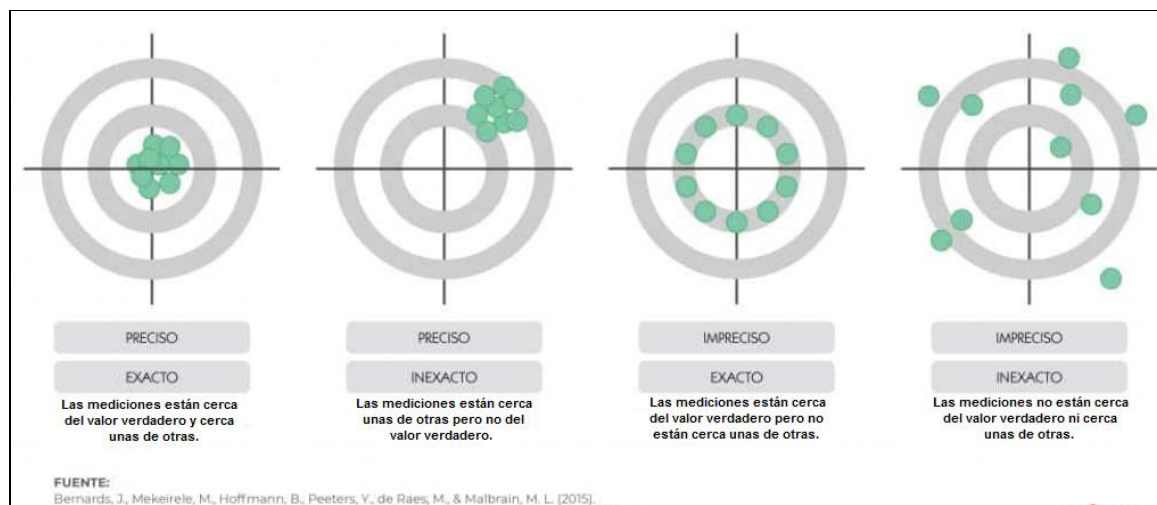

Fig. 1: Precision and accuracy

The measurement of variables always involves some degree of error. No method provides a measurement that corresponds 100% with reality. The *error* is the difference between the actual value and the measured value. However, since the actual value is never really known, the error must always be estimated.

In scientific research, two main errors are recognized, random error and systematic error.

Random error refers to the random difference between the observed and true values. It is a natural error, since there is always some variability in the measurements: fluctuations in the environment, the instrument or the interpretations themselves. The random error is known as "noise" because it blurs the true value of what is being measured. Keeping random error low will allow accurate data to be collected.

Systematic error or "bias" is the proportional difference between the observed and true values of something.

This is an error in the design or analysis of the study that produces an incorrect or invalid estimate of the method under study. An example of a systematic error is a poorly calibrated scale that constantly registers higher weights than they really are.

A systematic error affects the accuracy of a measurement, i.e. how close the observed value is to the true value.

Knowing what the source of error is will allow us to reduce its incidence and identify if our measurement is accurate and precise.
How is the error percentage calculated?

The word error just means an error or a deviation from what is expected. There is a way to quantify exactly what percentage error there is in a measurement. This is called percent error and is a ratio of the difference between the actual value of your measurement and the true value. This ratio is then multiplied by 100 to convert it to a percentage. A percentage error of less than 10% is acceptable (https://estudyando.com/mediciones-cientificas-exactitud-precision-y-porcentaje-de-error/).

It is calculated with the following formula:

$$\% \text{ error} = \left[\frac{\text{Medición} - \text{Valor real}}{\text{Valor real}}\right] \times 100$$

Example of an error calculation in temperature measurement:

$$\% \text{ error} = \left[\frac{16°C - 17°C}{17°C}\right] \times 100 = 5{,}88\%$$

Whether the measurement is greater than the actual value or the actual value is greater than the measurements, the percent error must be positive.

Guiding Research Questions

- What should we take into account when using the instruments?
- What is the proper procedure to follow to obtain scientific data?
- Is the data obtained in my measurement comparable to that of a student who took temperature in the Dominican Republic, for example?

Scientific concepts

- Calibration
- Accuracy / Precision
- Percentage of error
- Protocol

Materials and Tools

- Several thermometers of different types: mercury, liquid, probe, probe maximum/minimum/current, U-shaped thermometers; in different states of preservation and some with almost ran out batteries.
- Pencil
- Field notebook
- Calculator
- Stopwatch, watch or electronic device
- Ice
- A lab measurement cup
- A calibration thermometer
- Distilled water

What to Do and How to Do It

Beginning -

- As a trigger, the teacher instructs students at the beginning of class to write down the current time on a piece of paper and, reading aloud their notes, compare their records to see if they all wrote down the same value.
- The teacher instructs the students to get together into groups of four.
- The teacher assigns a role to each of the members, which will basically be: i) handling the instrument, ii) timing and iii) making the measurements, and iv) recording in the field notebook.
- Then, the teacher will instruct the students to take one thermometer per group, from an instrument box that the teacher will have reserved only with the thermometers designated for this activity. This box will have been previously prepared by the teacher with a digital thermometer working properly, one with a low battery and one not calibrated, a liquid thermometer with a separated liquid rod, one calibrated and one not calibrated, a U-shaped thermometer, and a mercury thermometer that has been stored unused for a year or more in a cupboard, without having been calibrated and in a horizontal position.

Development -

- The teacher will tell the students to go out to the school playground or the park and separate into groups spreading out in different parts of the place.

- Then the teacher will give them the instructions for the activity: they will have 5 minutes total, they will take a thermometer per group, the field notebook and a pencil. They will measure the ambient temperature. Then they will return to the classroom.

- Once in the classroom, one group at a time will write down the temperature data obtained in one column on the classroom blackboard, and in a second column, the type of thermometer used.

- When all the groups are finished, they will have a set of data (probably very disparate) about the temperature that they all recorded at the same time and study site.

- The teacher will ask why all (or most) of the measurements are different and why they think this might be. The teacher will give them a few minutes to think about their answers and then guide them with the next questions:

    - How do they know the thermometer was in the right condition to measure?
    - Did everyone use exactly the same procedure to measure?
    - Is one repetition enough to know that the measurement is correct?
    - Do the different thermometers measure the same way?

- The teacher will give them 5 more minutes to check the thermometers and look for possible sources of error based on the questions posed by the teacher. After the students come up with possible explanations for the sources of error, the teacher will explain the different sources of error in detail and give examples of each situation for a better student understanding:

- It is necessary to calibrate instruments before use (this applies to thermometers, infrared thermometers, pH meters, conductivity meters, soil thermometers, etc.) and the teacher will teach the students the method for calibrating air temperature thermometers. He/she will emphasize that thermometers should be calibrated periodically, after repair, when they have been stored for a long time without use, and especially before use.

- In the case of probe thermometers, it is important to store them without batteries so that they do not continue consuming energy, and if when the students turn on the instrument, they notice that the screen flickers, does not work well or does not even turn on, they should remember to change the battery in case it ran out.

- On the other hand, the teacher will also show the students how to store the thermometers, which should be kept vertically and in a place that is neither too humid nor too warm. The teacher can also point out to them, with a thermometer with a separated liquid rod, that the instruments can be damaged by ill use or storage, showing them the methods for rejoining a rod (shaking it vigorously with the hand up and down, or placing it over a heat source so that the liquid expands and rejoins the rod).

- The teacher will inform them that in order to ensure that all measurements are carried out under the same conditions and quality data is obtained, GLOBE uses a method called "Protocol", which is the standardized scientific process to take a measurement, and that the data obtained are comparable to those taken by any person in another part of the world, who has used the same instrument and protocol.

    - As part of the protocol, they will also be told why to take the measurement three times: one is not enough, if there are two, you may get two different values, but if there are three, surely the three are similar or at least two of them, which allows students to achieve a more accurate data by averaging the three measurements.

- Problems caused by the observer. The individual is a highly error-prone observer. Despite his/her best intentions, the human observer is limited by the sensitivity of his perceptual system, by the marks and categories available to him/her for the organization of his/her sensitive experience, as well as by motivational and psychological aspects.... From this, his/her inability to repeat an observation in exactly the same way and obtaining the same result is deduced (variability). Possible solution, to repeat the observation and take the average of the observed

values, use discriminating and measurable categories, etc. (http://www4.ujaen.es/~eramirez/Downloads/theme4).

- This can be reflected, for example, when looking at the thermometer to measure temperature, the observer's eye must be in a straight line with the thermometer, because if it is looked at from below or from above, the measurement will be incorrect (see Fig. 2). The same is true for the rain gauge, where it is the lower part of the meniscus in the measuring tube that should be measured, not the edges.
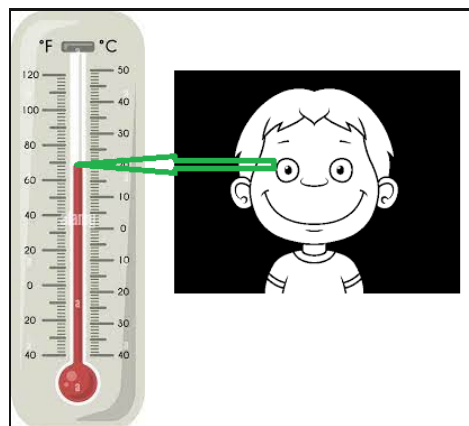

Fig. 2: Correct position of the observer's eye

- Another factor that will influence the measurement is the site chosen for the measurement. Therefore, if different groups measured in different places in the courtyard, some in the sun, others in the shade of trees, others in the shade of their body, they will probably have obtained different measurements. The protocol indicates that the ambient temperature is taken in the shade of the body of the person taking the measurement.

- The type of land cover on which the students are standing also affects the temperature value, for example, asphalt or cement store more heat on the surface than grass, which absorbs part of the sun's rays and reflects the rest). It is recommended to do it on natural cover, within the existing possibilities.

- The environmental conditions in which the measurements are taken are another element that affects the accuracy of the data. For example, in the case of outdoor temperature measurements, the fact of starting the measurement with sunshine and that during the three measurements required by GLOBE the sky is partially cloudy, will cause the temperature to drop slightly during the measurements; which will be changing the environmental conditions in the middle of the data collection. To avoid this type of effect on the measurements, it is best to make sure beforehand that all 3 measurements are taken under the same conditions: always sunny or always cloudy.

- Another stage where data management is important is data entry and analysis (organization in charts, graphs, etc.). Consistency and standardization of data handling is essential to avoid errors in data entry into a database. Consider establishing the format of the data beforehand to avoid generating inconsistencies among the different people who enter it. Example: the different formats for entering the date corresponding to the data collection: dd/mm/yy, mm/dd/yy, mm/dd/yyyy, etc.; the units of measurement in which the measurements are taken: temperatures in ºC, ºF, ºK; length in mm, cm, m, etc.

Ending -
- To end the activity, the teacher asks the students to go back out to the courtyard, once they have calibrated all the thermometers and learned the protocol, and following the steps in the Field Guide, take the temperature measurement again under the protocol requirements.
- Then, when the students return to the classroom, they again write down the data obtained on the blackboard and surely, the data values obtained will be much more accurate than the first time.
- Ask the students to discuss whether there might have been any errors and what might have caused them.

Frequently Asked Questions

What kind of thermometers can I use for this learning activity?
As this is a practice to understand the importance of calibration and to respect the protocol to obtain research quality data, any thermometer will do: broken, with a separated rod, uncalibrated, mercury thermometers (although GLOBE does not recommend them and they are no longer used in many countries, they are useful for this particular activity), alcohol, calibration, wall, probe, U-shaped thermometers.

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Search, visualization and use of Precipitation data

GLOBE		Related SDGs:	Type of activity
Sphere	**Protocols**		
Atmosphere	Precipitation **Associated learning activity:** Precipitation in the Latin America and Caribbean Region. Patterns by regions and seasons	13 (Climate Action) 15 (Life on Land)	Exploratory

Overview
Students will learn how to conduct data searches using the GLOBE Data Visualization System and other data sources to understand how precipitation is distributed throughout the year in their region or country, identify patterns if they exist, and understand how occasional events may cause those patterns to change or deepen.

Prerequisites

Operation of the GLOBE Data Visualization System. Elaboration of graphs. Knowledge of the Precipitation Protocol. Measurements taken and entered on www.globe.gov (optional). Teacher with a GLOBE user created and updated and/or who has previously created users for more than one student.

Time:
45 minutes.

School level
Secondary (13 years and older)

Purpose

To teach students how to search and visualize data, how to use the GLOBE website, how to create graphs from the downloaded data and how to interpret and explain what they have researched.

Student outcomes

- To understand the process of searching for data on the www.globe.gov website and its importance.
- To cross-reference, compare, interpret and explain data.

LEARNING - DATA ACTIVITY

- To download raw data to produce precipitation graphs.

Introduction

The GLOBE Data Visualization System allows searching by protocol, combining more than one protocol, and adding other layers of data to the search such as by study site name, teacher's name, delineating a region, by altitude of the region, and also selecting the time period of data we wish to access.

The data visualization allows, for example, to determine if there is data for our region or a particular site, since when there is data for that region, if there are regular measurements or only isolated data, which schools entered data, to access the data for that school (in case we want to contact them for our research), or to search for data worldwide for a specific day, among other possibilities.

Just as it is important for the student to know how to develop a protocol and perform its measurements, it is equally useful for the student to learn how to enter the data obtained and conduct searches to visualize it, or to visualize data from other educational institutions to understand the importance of contributing to a worldwide scientific database. These data operations will give the student another insight into the application of data and its subsequent use in research.

Visualizing precipitation data on a global or regional scale will help them understand the global concept and then apply it locally.

Guiding Research Questions

- Is there a period/season of the year when it does not rain in your region? How can you identify it?
- How does a long period of drought affect your particular region/city?
- How does a period of heavy and prolonged rainfall affect your region/city?
- Does the type of soil in your region affect the consequences of precipitation in any way? How does it affect it?

Materials and Tools

- Several laptops with internet access
- Printer to print graphs and data (or the teacher brings printed graphs and data to class)
- Acetate sheets
- Colored markers

### *What to Do and How to Do It*

Beginning -

Arrange students in groups of 3 or 4 in separate locations in the classroom. Instruct them to go to www.globe.gov on their laptop and enter the Data Visualization System and then search by Precipitation Protocol. Here they should choose one or more criteria within the protocol, the options for which are: Type of Occurrence, Precipitation Depth, New Snow Depth, Equivalent Total Liquid and Precipitation pH.

They will only indicate Precipitation Depth and will not filter the search using any other parameters. It will let them visualize the data displayed for today for the whole world (see figure 1). At this point you will explain that the database can potentially contain data from 127 countries (GLOBE partners), so there will be countries from which they will not be able to get GLOBE data. Also, explain that not all teachers are active teachers, so some will enter data and some will not.

Ask students to enter one of the sites that has data by standing over the raindrop icons, and read the screens that pop up showing what the study site is called, what school it belongs to, what measurements the school has entered, etc.
Then use questions to encourage them to understand what the data means and what it represents on the map:
- Which continent/region seems to have entered the most data for today?
- Does that mean it has rained more than in other regions? Why?
- Why is it important to enter precipitation data even when it didn't rain?
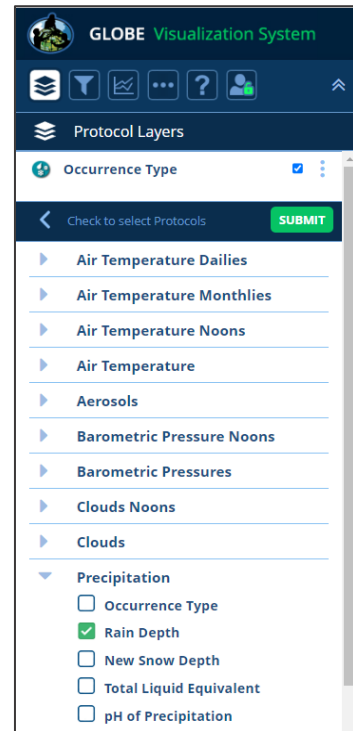
You will now ask them to display the legend bar (bottom right in blue) to understand what the different shades of color of the raindrop icon mean, and to reinterpret the map according to the amount of precipitation indicated in the legend.

Fig. 1 GLOBE Data Visualization screen for precipitation.

How accurate were their first conclusions? Do they now know that they can interpret the meaning of the colors in the captions?

If there is still class time left, you can have them practice other searches using the other precipitation parameters (e.g., Type of Occurrence).

Development -

Now that the students have some command of the data visualization system, ask two of the groups to look up precipitation data for their country/city if data is available. If not, they can choose another country/city in the region. If possible, have them look for a current annual rainfall cycle and one for the previous year or several years ago at the same site. Show them how to view the graph for the data period set or available and how to download it (see examples in Figures 2 and 3).
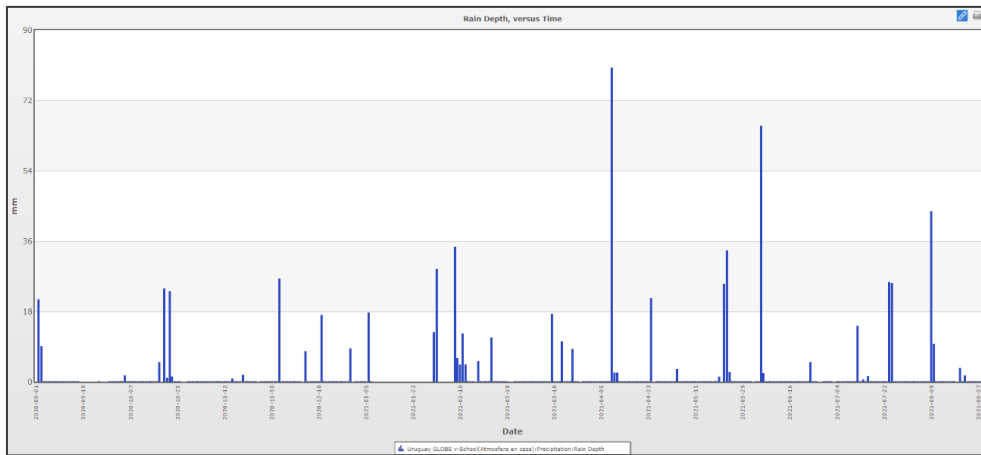

Fig. 2: Data extracted from www.globe.gov on precipitation in Montevideo, Uruguay, corresponding to one year (from 09/01/2020 to 08/31/2021). Study site: Atmosfera en casa.
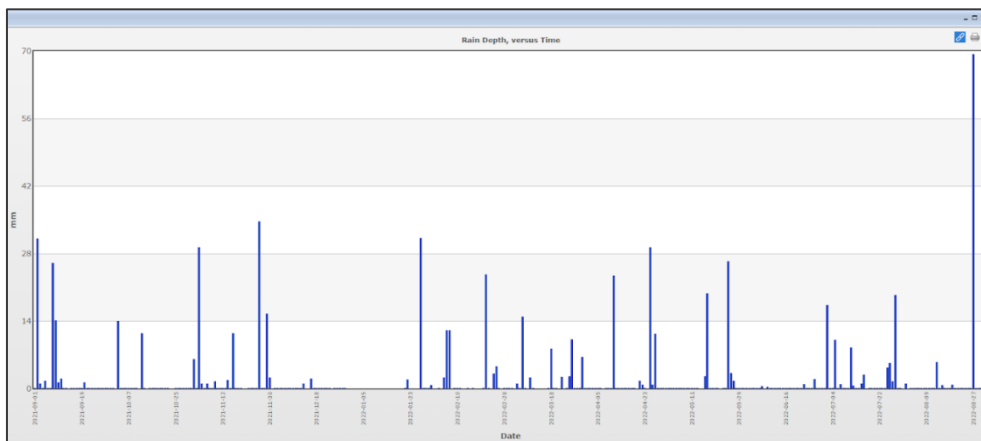

Fig. 3: Data extracted from www.globe.gov on precipitation in Montevideo, Uruguay, corresponding to one year (from 09/01/2021 to 08/27/2022). Study site: Atmosfera en casa.

Have them think about what would happen if graphs were made that collected average precipitation information for each month instead of each day. The graph would have much less data and you would not be able to see the variations from day to day. You would be able to learn general trends in precipitation over the year. What would you not be able to determine? You would not be able to determine the effects of short-term events, such as storms, or short periods of drought, which days had precipitation and which days did not, and how often it rained. Have them look at the option for the graph to get monthly/yearly averages to explore different ways of looking at the same data.

If data from two annual cycles from the same site or at least two equal seasonal cycles from two different years are available for the same site, the teacher will proceed with the following questions:

- Do the patterns repeat year after year, and month after month, and why do you think this happens?
- Having data from a previous year, could you predict what the approximate precipitation averages would be for a year where there is no data entered? Or approximately how many days it rained if it followed a similar pattern?
- What other phenomena/events may affect precipitation patterns for your region?

At this point, explain that there are phenomena that affect the region, such as the El Niño Southern Oscillation (ENSO), the permanent Atlantic anticyclone (which affects Uruguay and Argentina), the Pampero wind (which affects the Patagonian Andes), etc.

- How might these events affect precipitation at these locations?

Ending -

As a closing activity, instruct students to collect precipitation data for the next month at the school, record it in their science notebooks and enter it into the GLOBE database. They will then create a graph for the month and make it into a poster or presentation for the rest of the class.

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http://www.climate.gov/news-features/department/8443/all

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Regional wind variability and relationship with rainfall in Montevideo and sea level on the coast. https://www.gub.uy/ministerio-ambiente/sites/ministerio-ambiente/files/2020-08/Producto%203.pdf

The impact of the Sun on the Earth. The case of Eclipses

GLOBE		Related SDGs:	Type of activity
Sphere	**Protocols**		
Atmosphere	All	4 (Quality Education) 13 (Climate Action)	Exploratory
Pedosphere	Soil Temperature Protocol		

Overview

Eclipses are sporadic events, which occur more frequently than we think. Taking measurements of atmospheric and other related protocols under such particular circumstances can produce very significant data for each location and for the observer who is recording this type of phenomena. Linking the environmental variables that occur in these circumstances helps to produce valuable information on the changes that occur on the Earth's surface due to the effect of the eclipse.

Time
Three 45-minute classes.

Prerequisites

To have data that has been taken on any occasion that eclipses have been observed in your region following the GLOBE protocols. If you do not have data, you can download it from the GLOBE website (www.globe.gov).

School level
Secondary

Purpose

To evaluate the impact of the phenomenon on the environment and on living beings (e.g. birds, flowers that close, even in people's mood).

Student outcomes

- To review literature on eclipses and atmospheric variables and identify those that may be affected by the eclipse effect.
- To search the GLOBE website for data corresponding to any date where an eclipse has been recently recorded.

LEARNING ACTIVITY - DATA

- To download data from at least two different study sites where the same eclipse has been sighted to compare data according to the degree of eclipse cover.
- Analyze the data to determine which environmental variables are altered when an eclipse occurs and how it impacts the Earth's surface.

Introduction

Life on Earth depends on energy from the Sun. The Sun controls the weather, ocean currents and the hydrological cycle. Thanks to the Sun's heat, there is liquid water on our planet, which most forms of life (bacteria, plants, animals and humans) need to survive.

The Sun's activity rises and falls according to 11-year cycles, along which magnetic field lines that meander and curl inside the Sun periodically cross the surface, producing sunspots, which move across the outer face of the Sun. The increased magnetic activity associated with sunspots can cause solar flares, coronal mass ejections, and other powerful electromagnetic phenomena. Aurora Borealis (northern lights) and Aurora Australis (southern lights) are visible manifestations of space weather (WMO, 2019).

But there are also other phenomena outside of human activity, which impact on the Earth and at times leave some places on the Earth's surface in complete darkness. These are solar eclipses.

GLOBE began collecting temperature and cloud data measured during eclipses a few years ago through observing campaigns that included GLOBE students and teachers, but also citizen scientists through the GLOBE Observer app. The first time the app was used to record data was during the eclipse of August 21, 2017, which crossed North America from west to east.

This eclipse viewing and measurement device is activated in the application a few days before an eclipse occurs, it is not permanently available as are Cloud, Tree Height, Data Entry, Mosquito Habitat Mapper, and Land Cover.

The Eclipses app provides alarms to warn at what times measurements should be taken; the more frequently measurements are taken, the more data will be available to analyze and draw more accurate conclusions. Measurements begin to be recorded a few hours before the total eclipse in normal atmospheric conditions, during the eclipse, and after the eclipse for a few hours. The measurements that the app can record so far are air temperature, cloud cover and cloud type.

Other variables can also be measured, but the Eclipse application does not yet allow them to be recorded. They can be uploaded into the GLOBE web or Data Entry app.

At the end of the observations, the application automatically generates a graph of the measurements taken before, during and after the eclipse, which looks like the following:
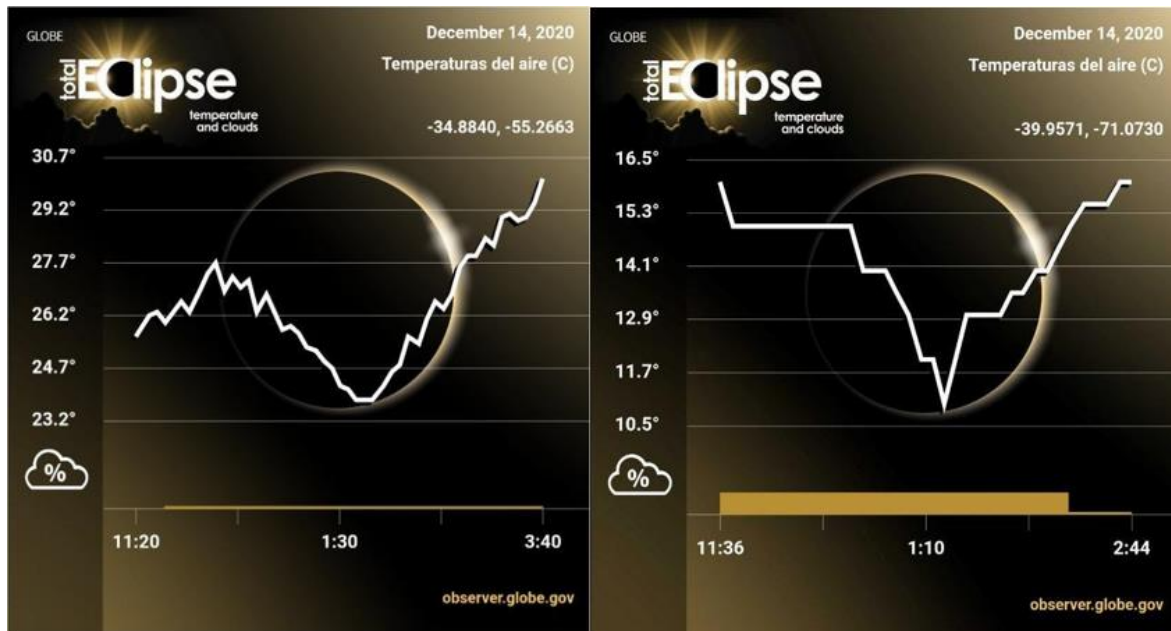
Fig. 1 and 2: Measurements in San Francisco, Uruguay, (on the left) and Junín de los Andes, Argentina (on the right) during the eclipse of December 14, 2020.
Sources: Andrea Ventoso and Huechulafquen Science Club.

In these figures you can see the differences recorded for air temperature taking into account a site where the eclipse was observed partially (74% cover), and another site where it was seen in its totality (100% cover).

The environmental variables that can be investigated during an eclipse can be the following:
- Atmospheric:
  - air temperature
  - surface temperature
  - cloud cover
  - relative humidity
  - wind speed and direction
  - barometric pressure
- Pedosphere:
  - soil temperature at 5 cm and at 10 cm depth
- Other qualitative variables:
  - observation of the behavior of wildlife species (domestic animals, farm animals and birds, in particular)
  - observation of flora behavior (species such as sunflower -*Heliantus annuus*, daisy -*Bellis perennis*- and others).

It is advisable, school time permitting, to also take measurements the day before and the day after the eclipse, to have points of comparison with respect to the changes that may occur during the eclipse. Sometimes it is even useful to take data one day in the week prior to the day of the eclipse for the same purpose.

On the day of the eclipse, it is important to record measurements from a few hours before the point of maximum obscuration (time of greatest sun cover) to a few hours after the maximum point, which will show if there are increases or decreases in the value of the variables when it gets dark, or if some other type of change occurs. Figure 3 shows the changes in air temperature with respect to surface and soil temperature during the eclipse

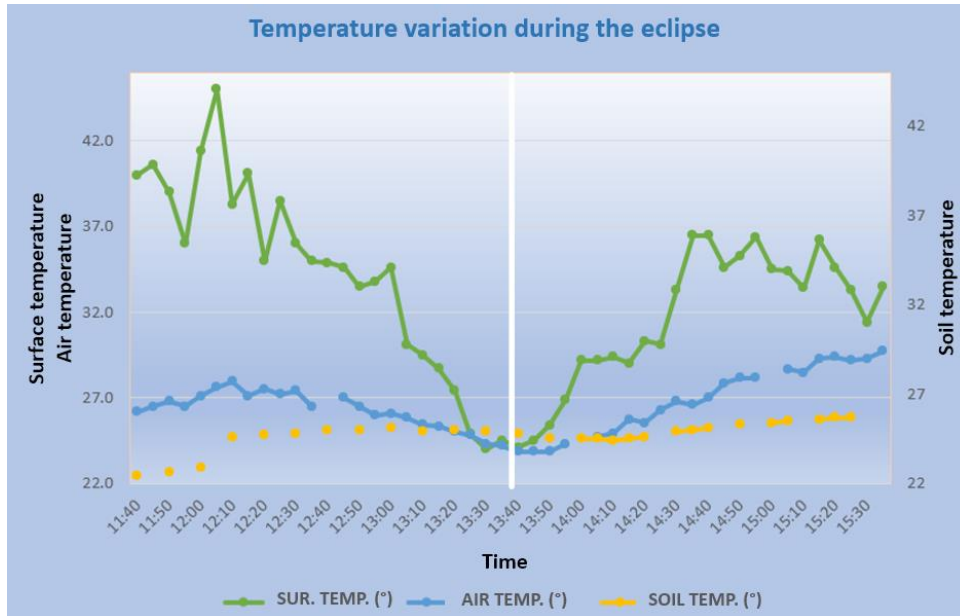of December 14, 2020, based on data collected at a study site in San Francisco, Maldonado, Uruguay.

Fig. 3: Relationship of the variables air, surface and soil temperature during the December 14, 2020 eclipse. Source: Andrea Ventoso

Guiding Research Questions

- What facts should we look for about eclipses?
- Does it make a difference whether it is a total or partial solar eclipse?
- What other aspects of nature do you think are affected by the shadow or darkness effect of the eclipse?
- How does the air temperature change during an eclipse? What about the wind?

Scientific Concepts

- Total solar eclipse
- Annular solar eclipse
- Partial solar eclipse
- Lunar eclipse

Materials and Tools

- Laptop
- GLOBE user for the web search: www.globe.gov

What to Do and How to Do It

Beginning -

- The teacher will present in class what an eclipse is, what types of eclipses can be seen, and how they occur.

- As a homework assignment, the teacher will instruct students to read two scientific journal articles on what atmospheric variables may be affected during an eclipse and provide a brief summary of which they are and how they may be affected (several articles are suggested in the bibliography for this activity).

Development –

- The next class students will present the review of the articles and discuss in class what the key variables to measure are.

- The teacher will instruct the students to organize themselves into groups and each group will be in charge of searching for data for a different variable (e.g. group 1 will work on air temperature, group 2 on relative humidity, etc.) in the GLOBE data retrieval system (www.globe.gov). (Tutorial at: https://www.globe.gov/globe-data/data-tutorials).

- As an alternative to facilitate the task, or depending on the ages of the kids, the teacher can provide them with the following air and surface temperature data obtained during the eclipse of December 14, 2014 (Table 1).

Table 1: Downloaded data from the Alfred Nobel School in Canelones, Uruguay. (Location: -34.567075, -56.298089, altitude 34 m.)

Measured on Coordinated Universal Time (UTC)	Air temps: solar measured at	Air temps: current temp (deg c) Air temperature in degrees Celsius	Surface temperature (deg c) Average surface temperature (degrees C)
14/12/2020	11:09:00 a.m.	25,3	
14/12/2020	12:40:00 p.m.		
14/12/2020			
14/12/2020	12:35:00 p.m.	25,3	
14/12/2020			
14/12/2020	11:59:00 a.m.	26,3	
14/12/2020	12:29:00 p.m.	25,6	
14/12/2020	11:30:00 a.m.	26,6	
14/12/2020	12:18:00 p.m.	26	
14/12/2020	10:59:00 a.m.		
14/12/2020	11:49:00 a.m.	26,3	
14/12/2020	12:09:00 p.m.	26,3	
14/12/2020	11:38:00 a.m.		
14/12/2020	11:20:00 a.m.		
14/12/2020			
14/12/2020	12:45:00 p.m.		
14/12/2020	12:36:00 p.m.		26,1
14/12/2020	1:01:00 p.m.		23,5
14/12/2020	2:26:00 p.m.	26,3	33,7
14/12/2020	11:26:00 a.m.	26,7	38,9
14/12/2020	1:56:00 p.m.	26,7	32,4
14/12/2020	12:06:00 p.m.	26,3	34,8
14/12/2020	1:21:00 p.m.		25,3
14/12/2020	12:26:00 p.m.	25,7	26,7
14/12/2020	12:51:00 p.m.	24,8	25,9
14/12/2020	1:16:00 p.m.	25,1	25,9
14/12/2020	11:16:00 a.m.		
14/12/2020	3:02:00 p.m.	27,7	
14/12/2020	12:41:00 p.m.	24,7	25,9
14/12/2020	11:56:00 a.m.		36,7
14/12/2020	1:46:00 p.m.	26	
14/12/2020	11:06:00 a.m.	25,3	36,7
14/12/2020	2:56:00 p.m.		33,7
14/12/2020	1:06:00 p.m.		
14/12/2020	12:56:00 p.m.	24,3	
14/12/2020	2:16:00 p.m.		34,6
14/12/2020	11:46:00 a.m.	26,3	38,3
14/12/2020	12:31:00 p.m.	25,3	27,8
14/12/2020	1:36:00 p.m.		30
14/12/2020	12:46:00 p.m.	24,3	24,4
14/12/2020	1:11:00 p.m.	24,3	
14/12/2020	10:56:00 a.m.		38,8
14/12/2020	2:46:00 p.m.	27,3	31,5
14/12/2020	2:36:00 p.m.	28,2	32,1
14/12/2020	11:36:00 a.m.	26	42,2
14/12/2020	1:26:00 p.m.		28,2
14/12/2020	2:06:00 p.m.	26,7	31,4
14/12/2020	12:16:00 p.m.	26	30

- With the data obtained (either through the search or those provided in Table 1), the students will create a graph for these variables.

- The teacher can explain what the trend line () on a graph means and ask the students to include it in the graphs they are making. Figure 4 shows the trend line (dotted in

blue) for the air temperature recorded during the 14 th December. It shows the tendency for the temperature to increase as the morning progresses and local solar noon arrives, and even later in the early afternoon. However, in the line graph of temperature on day 14 th (in blue), the data show a decrease at the hour of maximum darkness of the eclipse after solar noon, which alters the trend.
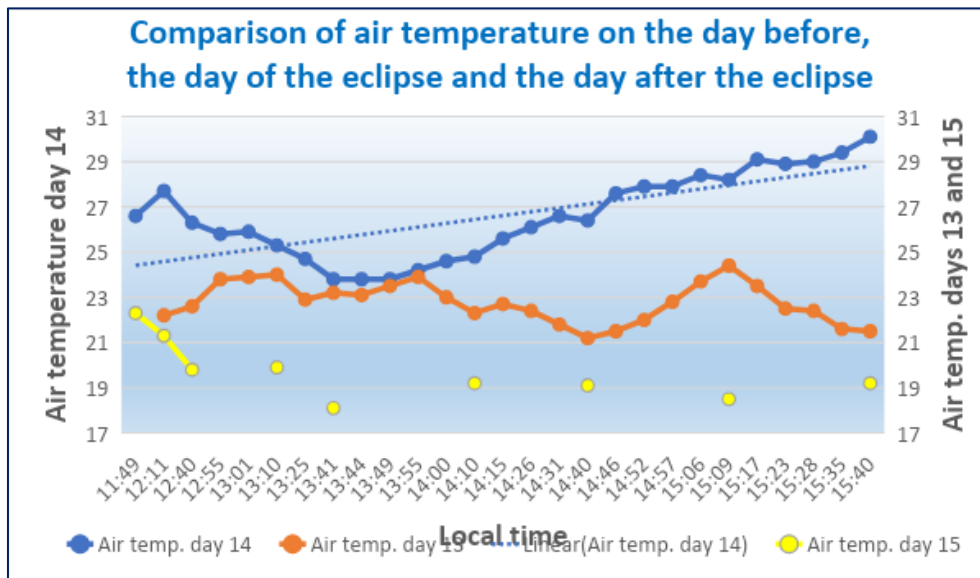

Fig. 4: Air temperature on 13th, 14th and 15th December 2020 with the trend line for the 14th.

- Each group of students will print out their graph and stick it on the board to discuss with the whole class what they analyzed with respect to the variable they studied and what conclusions they can draw.

- Then the teacher will ask them to discuss, by looking at the graphs on the board, which variables they might cross to analyze, e.g., air temperature vs. surface and soil temperature (see Fig. 3); relative humidity vs. air temperature; or cloudiness vs. temperature. The ideal conditions to observe the influence of the eclipse on these variables is a completely clear, cloudless day. In case it was a cloudy day, the students should take into account this variable that will influence the others, and also, if during the eclipse it was completely overcast and the eclipse could not be observed, the measurements of the variables will not have been as altered as would have been expected with a sunny day.

Ending –

- The teacher works in class with one or two of the articles suggested to the students, and together they analyze whether the variables they studied maintain the same trends as those analyzed in the articles. They draw conclusions and analyze what the possible factors that altered the trends are, for example, measurements taken at a site where a total eclipse was observed versus another where a partial eclipse was observed, or a site where it was sunny versus another that had significant cloud cover.

Outreach Activity:

- The teacher asks the students the following questions: Has there ever been an eclipse where you lived or live? Have you had the opportunity to see one?
- Discuss whether the students have seen one or remember their parents or grandparents seeing one in their lifetime and where they saw it.
- The teacher presents several options for finding dates of past and future eclipses such as:

  - https://eclipse.gsfc.nasa.gov/SEcat5/SEcatalog.html#cattab.
    NASA page containing information on solar eclipses for five millennia.

  - http://xjubier.free.fr/en/site_pages/SolarEclipsesGoogleMaps.html
    Webpage showing eclipse paths for Google Earth

- https://www.eclipsewise.com/solar/SEdecade/SEdecade2021.html
  Displays solar and lunar eclipses for the current decade (2021 to 2030)

- timeanddate.com/eclipse. App that presents the paths, eclipse types, time of the maximum shadow point for your location, eclipse magnitude and percentage of cloud cover (approximate) according to averages of recent years for that date. In figure 6 you can see what the percentage of eclipse cover in a specific location will be, taking into account the geographic coordinates of the site.
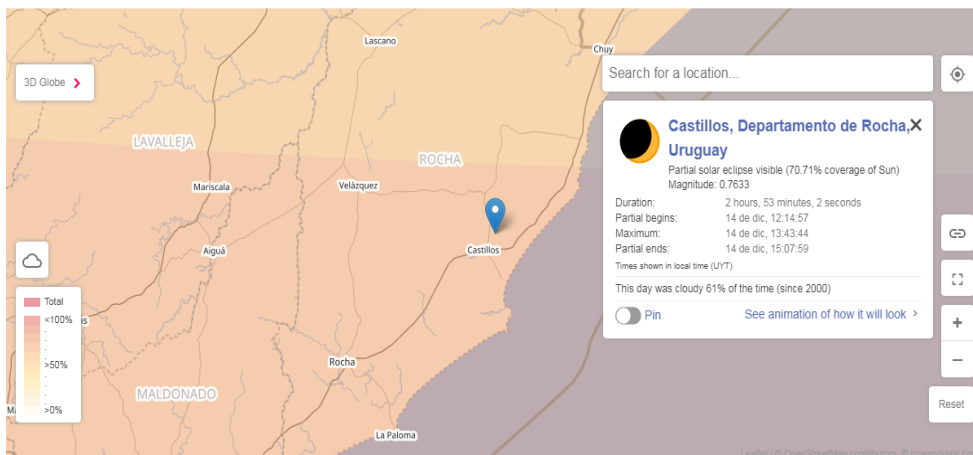

Fig. 6: Visualization of how an eclipse was observed in Castillos city, Rocha, Uruguay.

- The teacher asks them to open one of these applications to determine the date of a past or future eclipse in the LAC region, and the countries in which it will be observable, and to record some locations where it will be observed partially and totally, and how it will be seen.

Frequently Asked Questions

What if students do not find data taken in South America and the Caribbean during eclipses?

You can use data from other regions, but ideally, even if it is scarce, data from this region should be used for the activity. Having consistent data in the region is critical for future student research.

Additional Resources for Further Information

- https://solarsystem.nasa.gov/eclipses/home/

- timeanddate.com/eclipses

- Video made by Andrea Ventoso about the eclipse observed from Montevideo, Uruguay (partial view) on December 14, 2020: https://youtu.be/nvHO6CKdHGg

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Working with data in graphs

GLOBE		Related SDGs:	Type of activity
Sphere	Protocols		
All	All protocols	4 (Quality Education)	Evaluation Communication

Overview

Understand the importance of data analysis through charts and graphs in order to communicate the results of an investigation in an appropriate way.

Time
One double lesson or two 40-minute lessons.

Prerequisites

Notions of Excel or other applications that allow the elaboration of graphs.

School level
Fifth grade and above (Secondary school)

Purpose
To stimulate teachers to apply data analysis through charts and graphs with their students and to develop skills for their formulation and correct interpretation by the reader.

Student outcomes

- To understand how a chart is composed
- To create graphs from data tables
- To present the data in an appropriate way so that the graph represents exactly what we want to convey.
- To recognize the essential and non-essential data in a graph to select what is indispensable for the understanding of what wants to be conveyed.

Introduction

A **graph** is a type of representation of data, generally quantitative, by means of visual resources (lines, vectors, surfaces or symbols), to show the mathematical relationship or statistical correlation among them.

The graph is of high value to both the analyst and the end user, to whom we are communicating a data-driven story. (See Fig. 1).
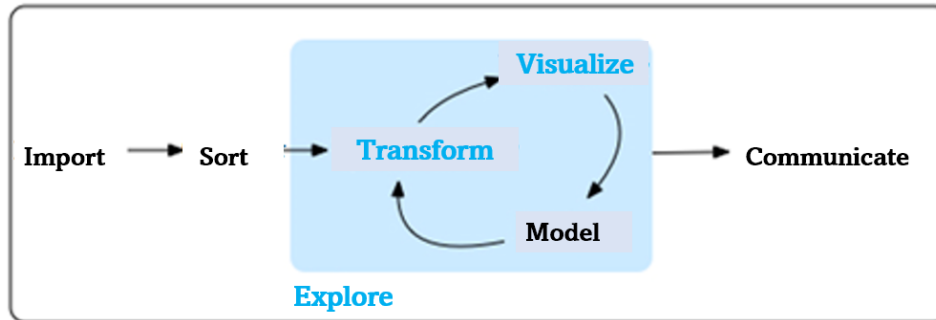
LEARNING ACTIVITY - DATA

Fig. 1. Representation of a standard process in advanced data analytics. Source: datos.gob.es

Data represents variables (something that changes in space or time) at a particular time and place. They can be qualitative or quantitative. Qualitative data are used to describe the quality of something or qualify the appearance of something, these can be opinions or thoughts that are usually described in words. Quantitative data are those that are obtained from figures, numerical values that can be analyzed using mathematics.

When you define a research based on the hypothesis, the first thing it must be defined are the variables. A variable is a property of the research subject that can assume two or more values. If this does not occur, the observed characteristic is not a variable but a constant. You will have dependent variables then.

The independent variable is defined as the variable that changes or is controlled to see its effects on the dependent variable. For example, in a study investigating the effect of temperature over the course of a day, the hours of the day (or time) will be the independent variable and the temperature recorded will be the dependent variable. The independent variable is not affected by what the experimenter does or by any other variable within the same study; therefore, it is called "independent", controlled or predictive.
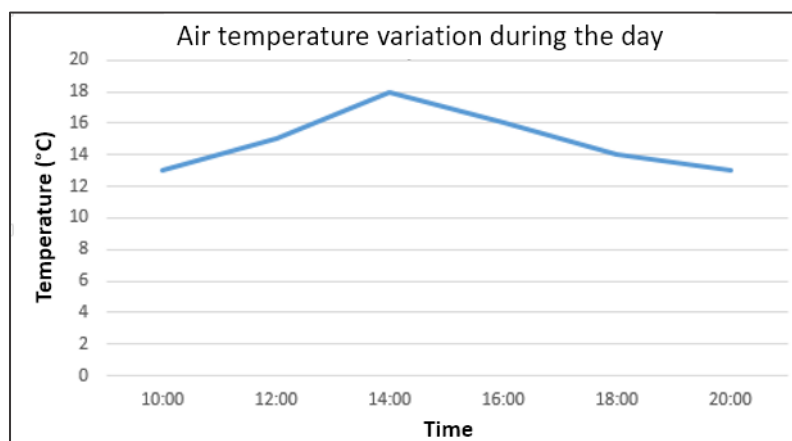

Fig. 2. Graph of air temperature variation
on September 23rd, 2020, in Montevideo, Uruguay.

It is represented on the abscissa axis (x) in a graph. Generally, only one independent variable is chosen in a chart to clearly establish that only that variable is the one that will influence the dependent variable; if we had more than one it would complicate the interpretation since the dependent variable would be influenced by more than one cause and we would not be able to determine exactly to what extent each one is influencing it and how it does so.

The dependent variable represents a quantity whose value depends on how the independent variable is modified. It is about the effect, what is measured. It is represented on the y-axis of a graph. It is also known as the experimental, measurement or response variable. For example, in a graph where you want to represent the rainfall that was recorded throughout the month, the dependent variable will be the amount of rainfall recorded, and the independent variable will be the days of that month.
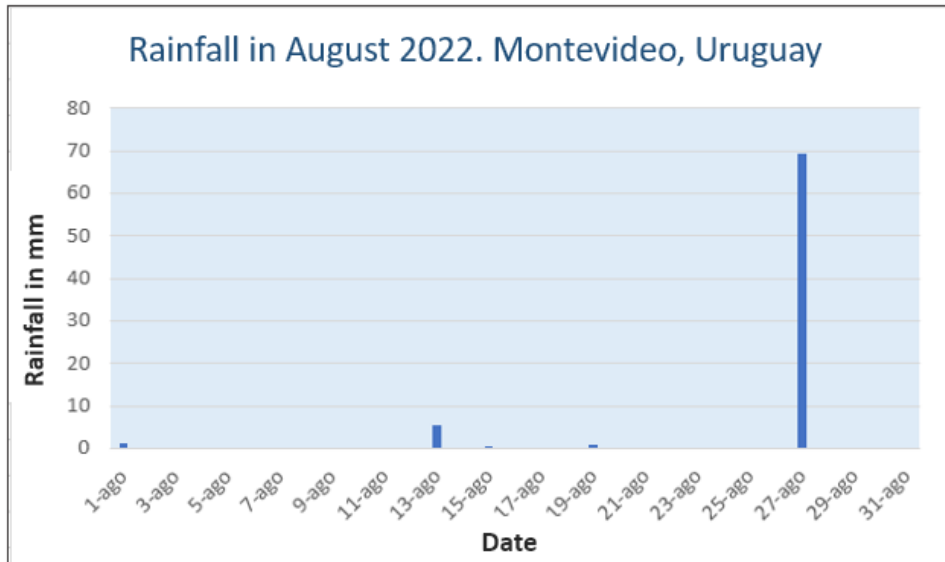

Fig. 3: Graph that shows the rainfall during August 2022.

In the elaboration of the graphs, we must consider including some basic data that contribute to the understanding of the graph:

Title of the graph: it is the presentation of the graph and the indicator of what we expect to find in it. It should be brief, clear and concise. It should be placed at the top in a larger font than the titles of the axes so that it stands out and is centered in the image. It is essential for the understanding of the graph in the context of the report or research.

Axis titles: these are the names of the dependent and independent variables, which will go on the respective axes. In the case of the dependent variable, it will go vertically to the left. In the case of the independent variable, it will be horizontal, below the values of the variable.

Units used: Special care should be taken to clarify the units of measurement in which the variable has been recorded correctly, so as not to leave it to free interpretation and to avoid drawing an erroneous conclusion. For example, in Fig. 3 it is made clear that rainfall was taken in mm (and not in liters). For the previous case in Figure 2 (temperature vs. time), it is clarified that the temperature was taken in Celsius degrees (and not in Fahrenheit).

Scales: The scales of the axes should start at 0 and cover the whole range of data present in the table: for example, if the minimum precipitation value is 3 mm, the graph will show the scale from 0 mm and not from 3 mm onwards. You will also need to scale the axes proportionately to the measurements taken, for example, instead of unit by unit, you may require it to be 50 by 50 or 100 by 100, or 0.5 by 0.5.

Data labels: optionally you can add the label to the data. This means that once we select it, the value of the data will appear above the corresponding bar. All these options are offered by Excel by selecting the area of the chart and clicking on the + symbol that will appear in the pop-up window.

Trendline: it is additional information that we can add to the chart. It is an analysis tool that allows us to visualize points on a chart that go beyond the actual data and represent possible future values according to their trend. It offers several layout options: linear, linear extrapolate, two-period moving average, logarithmic, polynomial, exponential.

Grid lines: it is an accessory. We can add horizontal or vertical lines, or both, as the background of the graphic. In papers it is recommended not to add them to make it more easily read.

By selecting the chart area and clicking on the brush symbol, different styles and colors to apply to the chart will appear in the pop-up window. Finally, by selecting the funnel symbol in the pop-up window, you can select which data points and names are visible on the chart and modify the data series and categories.

According to what we want to emphasize in the graph or the type of data handled, different types of graphs will be used. This will allow us to adequately visualize what we want to communicate to the reader. We can choose between the following types of graphics:

- **Bar charts:** or column charts. They only consist of two axes, X and Y. On one of the axes the items to be compared are placed, and on the other one the values of each one are presented. They are easy to understand. An example of a bar chart: figure 3. A variant of the bar charts are the **histograms:** the difference is that in this type of chart you can only see the variation of a variable with respect to the data being analyzed. They have the particularity that there is no separation between the bars.

- **Line graphs:** in these graphs the points will vary on each X-axis, and then are joined with straight lines to show the increase, decrease or equality from one axis to the next. It is one of the most useful because it allows you to analyze and understand how a variable change over time. Example: Fig. 2 shows the rise and fall of temperature over the course of the day.

- **Circular, pie, cake or sectorial:** it is used when you already know the absolute value or quantity of what you are measuring, but you need to know how many parts the total is divided into. It has a geometric style that stands out for its visual simplicity, it is very easy to remember. Example: Fig. 4 highlights the predominance of Eucalyptus over other species in the study site.
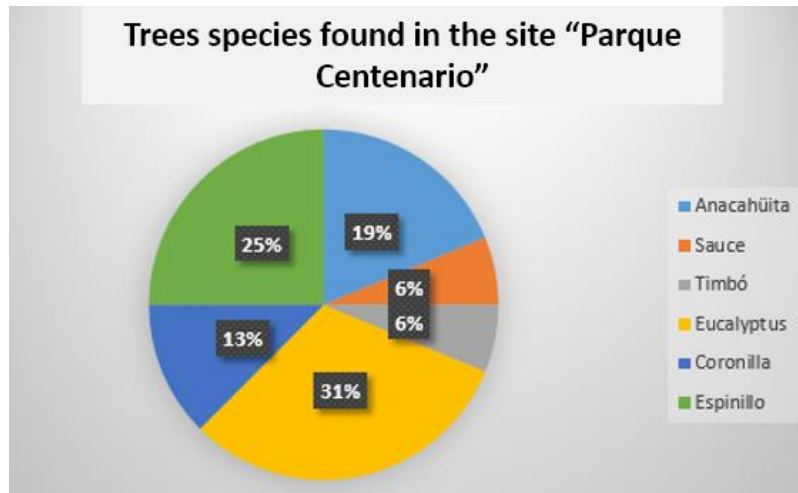
Fig. 4. Example of a pie chart: Distribution of Tree species in the site "Parque Centenario".

- **Scatter plot:** it represents the data obtained through observation, in the form of dots, to then compare them with certain trends**.** It is also known as XY graph and it is used in cases of ordered pairs to know the type of relationship established between variables or when a large number of observations are available.
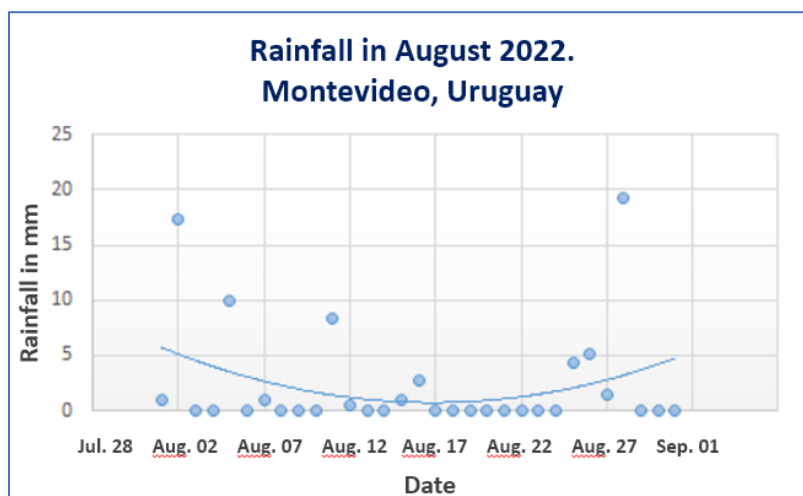

Fig. 5: Rainfall scatter plot.

- **Area graph:** it is used to see the behavior of two or more variables in a period of time. Two axes are used to make it, one vertical and the other horizontal. On the horizontal axis the time measures are placed, and on the vertical axis the values of each variable are placed. First, the variable with the highest value is placed and the points are joined by means of lines or curves, then the other variables are added, from highest to lowest. For a better visualization, the resulting areas among the curves are painted with different colors.

- **Stacked Area Chart:** Used to compare total magnitudes and to show the distribution of a known total. It allows both actions to be achieved at the same time,

combining the bar chart and the pie chart. It can be used to visualize, for example, monthly or yearly accumulated rainfall (see example in Figure 6).
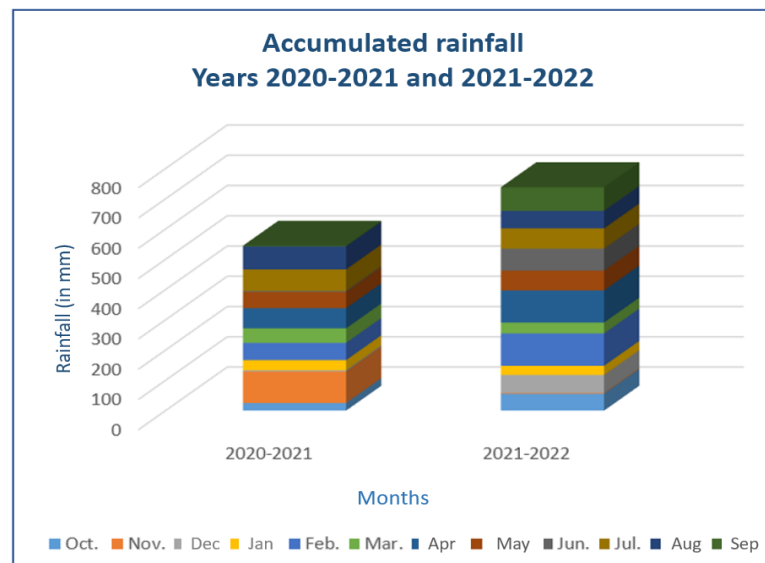

Fig. 6. Accumulated rainfall graph in the site
Atmósfera en casa, in Montevideo, Uruguay.

- **Other graphics**: **pyramid (**to represent characteristics of a population of a city or country), **cartogram** (it is made on maps and different marks or references are used to show the results of a certain event or situation), **fluctuation graph**, **bullet graph**, **highlight table** or color map, **tree map**, **box and whiskers diagram**, **candlestick graph, pictogram, arc diagrams, spider graph, 2D and 3D graphics,** etc.

Guiding Research Questions

- What data can we represent in a graph? What are dependent and independent variables? How are they applied in a graph?
- Should the chart have a title? Why?
- What do the X and Y axes represent on a graph?
- Are all charts suitable for all data or are there chart formats that are more suitable for each thing?

Scientific concepts

- Dependent vs. independent variables
- Bar chart, pie chart, line graph, etc.

Materials and tools

- Excel Spreadsheet App
- Legos or other stackable, colorful materials to represent data

What to Do and How to Do it

Beginning -

Depending on the age of the students, you can introduce them to graphing through representation with Legos or any other nesting cubes. It is also popular to graph with food, but other teachers, school administrators, and parents may not like the idea of using food for teaching purposes. Another way to start working on graphing with young children can be to use an open abacus.

Fig. 7. Open abacus for working with graphics with children.

In the case of older students, graph paper will be used for making graphs or, in secondary school, the Excel calculation program can be used in its graphing options.

Development -

- Organize the students into groups, and armed with tape measures and science notebooks, go out to the school yard or a park to measure the height and circumference of the trees in a 10 x 15m pixel. If you already use a site for different biosphere measurements, use the same one as it will be useful to have these measurements in the future.
- Each group chooses a tree, tries to identify it with the help of the teacher or a local flora identification guide, and will measure the height and circumference of the chosen tree. Try to organize as many groups as there are trees, or have some groups measure 2 trees until all the specimens in the pixel are complete. It is advisable to mark each marked tree with a tape or a flag so as not to repeat the specimens already measured.
- To estimate the height, they can use the GLOBE Tree Observer app, and record the circumference there as well. In addition, have students record them in the science notebook.
- Return to class with the students and ask each group to record on the board the height of the tree they measured in one column and the circumference of the same tree in another column. They will make a table with the data of the specimens measured, the heights, and the circumferences.
- Then, in pairs, some students will make graphs comparing species to tree height, and others will make other graphs using the circumference measurements. They can use graph paper or the Excel spreadsheet.

Ending -

All students will display their printed graphs on the board and look at the different ways they each chose to lay out their graph (types of graphs they chose, colors, how they used titles, how they moved data from the charts to the axes of the graph, etc.).

Guided by the teacher, they will decide which graphs were the most appropriate to communicate the information they want to convey: the heights and circumferences of the trees according to the respective species. They will detect errors and lack of relevant information for the correct communication of the data. They will draw conclusions about what they have worked on.

You can create a Padlet and upload the photos of the measured trees, along with their heights and circumferences, and the graphs you created with the measurement data. It will be a record for future research and for the field portfolio.

Frequently Asked Questions

Can I work with graphs with younger children?

Yes, but make sure you use Legos or something similar, that it is easy for them to represent the measured objects and that the measurements are in whole numbers to transfer the data to the Lego cubes.

Suggested resources for further information:

https://www.experimenta.es/uncategorized/build-chrome-juego-construccion-google-lego/

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Air Quality. Changes due to natural and anthropic events

GLOBE		Related SDGs:	Type of activity
Spheres	**Protocols**		
Atmosphere	Aerosols, Air Temperature, Surface Temperature, Barometric Pressure, Clouds, Sky Color, Precipitation, Relative Humidity	3 (Good health and well-being) 9 (Industry, innovation and infrastructure) 15 (Life on land)	Exploratory
Biosphere	Land Cover		
Bundle	Air Quality Bundle		

Overview

Satellite images, maps, videos and articles are analyzed to interpret the sources of aerosols (volcanic ash, airborne dust, smoke from forest fires and pollution from industries, transportation, etc. in cities) and their impact in Latin America and the Caribbean. Finally, the Air Quality Index is presented to link the number of aerosols with health risks.

Time

4 classes

Prerequisites

Basic knowledge of meteorology, ecosystems and ICT. Ability to interpret satellite images and maps. Ability to locate points using latitude and longitude.

School level

Upper Primary School, High School and University students

Purpose

To understand the interaction of aerosols in the exchange of matter and energy between the spheres of the Earth System and their impact on very distant regions.

LEARNING ACTIVITY - SATELLITE IMAGES

Student outcomes

- To interpret satellite imagery and maps to draw conclusions about the impact of different types of aerosols in different regions.
- To analyze satellite imagery and other data sources to look for evidence of volcanic activity, dust clouds, forest fires, and industrial and urban pollution as sources of aerosols.
- To relate changes in emissions of some aerosols due to the Covid-19 pandemic shutdown.
- To use information to design an air quality outreach campaign.

Introduction

Air pollution is caused by a mixture of solid particles and gases in the air. These tiny particles are called aerosols and can come from different sources: natural or anthropogenic. Watch the video: My name is aerosol, Aerosols are transported by the wind over long distances. Watch the video summary of the movement of aerosols.
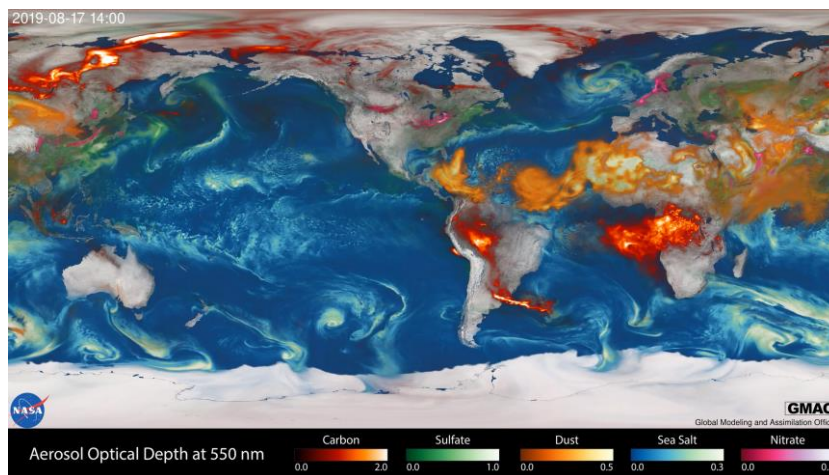

Fig. 1. Global movement of aerosols. The colors represent different aerosols: dust (orange), sea salt (blue), nitrates (pink), sulfates (green) and carbon (red). Bright regions correspond to higher amounts of aerosol. Video: https://svs.gsfc.nasa.gov/31100

Volcanic eruptions produce large amounts of aerosols that can be transported over long distances. For example, in the eruption of the Puyehue-Cordón Caulle Volcanic Complex in 2011 and of the Calbuco Volcano in 2015, large amounts of ash were spewed into the atmosphere and the winds transported them long distances, affecting air traffic (Watch the video of the Calbuco volcano ash tracking. In addition, the wind removes the ash deposited on the ground and redistributes it affecting visibility, transportation, health, etc. Another source of particulate matter is large deserts. Southern North America, northern South America and the Caribbean are periodically affected by Saharan dust. These small dust particles transported thousands of kilometers can be composed of metal oxides, clays and carbonates and generate various impacts: they fertilize the ocean and rainforests, scientists suggest that they could slow down hurricanes, but they can also cause respiratory health

problems, darken the sky causing accidents. Forest fires are also a major source of aerosols, releasing large amounts of smoke into the atmosphere and then carried by the wind over long distances (Watch the video of smoke from fires in Latin America and the Caribbean Jun-Dec 2021). Industrial activity, transportation and other human activities emit aerosols. The shutdown of activities at the beginning of the Covid-19 pandemic exposed the aerosols produced by human activity. E.g., NO_2 concentrations decreased dramatically and, in many cities, it was possible to see blue skies. See satellite images in Latin American and Caribbean cities and the video summarizing the changes in emissions.

Some aerosols are toxic and can cause health problems. For this reason, the Air Quality Index (AQI) has been created. This index indicates acceptable levels and those that can cause health problems.

Daily AQI Color	Levels of Concern	Values of Index	Description of Air Quality
Green	Good	0 to 50	Air quality is satisfactory, and air pollution poses little or no risk.
Yellow	Moderate	51 to 100	Air quality is acceptable. However, there may be a risk for some people, particularly those who are unusually sensitive to air pollution.
Orange	Unhealthy for Sensitive Groups	101 to 150	Members of sensitive groups may experience health effects. The general public is less likely to be affected.
Red	Unhealthy	151 to 200	Some members of the general public may experience health effects; members of sensitive groups may experience more serious health effects.
Purple	Very Unhealthy	201 to 300	Health alert: The risk of health effects is increased for everyone.
Maroon	Hazardous	301 and higher	Health warning of emergency conditions: everyone is more likely to be affected.

©EPA. Air Quality Index Scale - Source: https://www.airnow.gov/aqi/aqi-basics/

Fig. 2. Air Quality Index (AQI).

Guiding research questions

- How do different sources of aerosol emissions influence air quality?
- How does wind direction affect air quality?
- How can satellite and meteorological imagery be used to explain different changes in air quality?
- How does the amount and type of aerosols affect the ecosystems, human activities and health in Latin America and the Caribbean and in your locality?

Scientific concepts

- Weather and climate
- Atmospheric circulation
- Volcanic eruptions
- Air pollution
- Environmental hazards and vulnerability

Materials and tools

Satellite images of: Worldview, Earth.nullschool.net, Copernicus Sentinel-5P, Hot Spots, Forest Cover

Videos: My name is aerosol, aerosol movement, volcanic ash dispersion, smoke from Amazon fires, air quality during pandemic shutdown

Map: Volcanoes, Flightradar24, Air quality map

Articles: Calbuco volcano eruption, Impacts of Amazon dust, Air quality

What and how to do it

- *Beginning*

1. Ask students to watch the video "My Name is Aerosol" and note the sources of aerosols, their interactions in the atmosphere and their health impacts.
2. Divide the class into groups and ask them to watch the video summary of the aerosol movement around the world.
3. Each group will pay special attention to one of the colors representing a type of aerosol to answer the following questions:
    a. What type of aerosol are you observing?
    b. What source does this aerosol come from?
    c. What patterns do you see in this visualization from satellite data?
    d. What evidence do you see of the interaction of the Earth System (between the spheres: Atmosphere, Hydrosphere, Biosphere, Pedosphere)?

- *Development*

Each group will take an aerosol source to analyze, then a panel will be structured to report back to the rest of the class.

Case 1. Volcanic Ashes

1. Consult the map of volcanoes in Google Earth. Is the year of their last activity known?
2. Check out the report on the impacts of the 2015 Calbuco Volcano eruption in Chile.
3. Watch the video of the volcanic ash dispersion.
4. Answer the questions:
    a. What impact does volcanic ash have on ecosystems and human activities?
    b. How far back can the impact of ash from Calbuco Volcano be traced?
    c. How are the pedosphere, atmosphere, hydrosphere and biosphere connected in this example?
    d. Do you know of other volcanoes that have erupted in recent years and ash has reached your region? Describe the event.
5. With this information, prepare a presentation to inform the rest of the class.

Case 2. Dust in Suspension

1. Read the article about the impacts of Amazon dust.

2. Check the extent and intensity of the different events on Earth.nullschool.net with the links in the table below.
3. Which areas were most affected? What size particles reached such areas in the greatest quantity?

Particle Size	Events
Very fine dust, less than 550 nm	June 2018 - June 2020 – May 2022
Particles smaller than 1 μ (PM$_1$)	June 2018 - June 2020 – May 2022
Particles smaller than 2.5 μ (PM$_{2.5}$)	June 2018 - June 2020 – May 2022
Particles smaller than 10 μ (PM$_{10}$)	June 2018 - June 2020 – May 2022

4. Consult the area where you live. Did particles reach this area? What size were they?
5. Scroll through different days to find out how long the dust storm lasted.
6. What is special about the location where the dust originates?
7. Which way does the dust travel, and can it vary in direction?
8. How does the dust get from one place to another?
9. How are the pedosphere, atmosphere, hydrosphere, and biosphere connected in this example?
10. With this information prepare a presentation to report back to the rest of the class.

Case 3. Forest Fires

1. Watch the video of smoke from fires in the Amazon and other areas of Latin America and the Caribbean.
2. See satellite-detected hotspots from Jun to Sep. 2021 in Latin America and the Caribbean and the record on 7/25/21. See for other time periods.
3. Check the aerosol emission (Particles smaller than 10μ - PM10) produced by the fire on 23/9/21. Look up information also on other days.
4. In which months are forest fires more frequent in Latin America and the Caribbean?
5. Has your region suffered fires or received smoke from other fires?
6. Look for news of the impact of smoke in cities in Latin America and the Caribbean.
7. Look up changes in forest cover in the last 20 years in Latin America and the Caribbean.
8. Has your region had a loss or gain of forest cover?
9. With this information prepare a presentation to inform the rest of the class.

Case 4. Air Quality in the Cities

1. See the article "What does air quality tell us about Latin America and the Caribbean's response to the coronavirus crisis?" and the video that summarizes the changes in NO_2 concentration between 2019 and 2022.
2. Compare current NO_2 emissions at Earth.nullschool.net with real-time flights from Flightradar24
3. What patterns do you observe?
4. Compare emissions of other gases CO, CH_4, SO_2 during the shutdown by Covid-19 and today.
5. In some cities the air quality is of concern, that is why the Air Quality Index (AQI) has started to be used. Is it used where you live? Can you identify the sources of aerosol emissions in your town? Consult the world map to visualize the different air quality in some cities in Latin America and the Caribbean.
6. With this information prepare a presentation to inform the rest of the class.

- ***Ending***

Bring all groups together and form a panel with 1 representative from each group to report on their research. Conduct a final discussion and conclusion on the types of aerosols that could be present in the air in your area and the possible impacts they would produce.

Because of the relevance of this issue to society, ask your students to design a public awareness campaign on this issue.

Frequently asked questions

Where can I find satellite images of aerosols? - Worldview, Earth.nullschool.net, Copernicus Sentinel-5P

How can I measure aerosols on the ground? - While there are specific sensors, one of the easiest and cheapest ways is to measure sky color with the GLOBE Observer App.

Why does NASA study aerosols? - NASA studies the different sources of aerosols that affect air quality. As the impacts of climate change increase so can other risks such as forest fires or dust clouds. The data can be used to design mitigation actions and early warning systems for the public and disaster response teams.

NASA is studying this phenomenon to better understand how smoke from fires affects people's quality of life even at great distances.

Suggested resources for further information

Another suggestion is to measure the color of the sky around you when a particular event occurs (e.g., fire smoke) or on a regular basis. This allows you to compare with satellite

imagery information to understand the impact at local, regional and global scales. The relevant protocols for measurements are: 1) Atmosphere: Aerosols, Air Temperature, Precipitation, Clouds and Sky Color, Atmospheric Pressure, Humidity. 2) Biosphere: Land cover.

Other resources:

AirNow (2022) *Air Quality Index (AQI) Basics* https://www.airnow.gov/aqi/aqi-basics/

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NASA Earth Observatory (2022) *No Breathing Easy for City Dwellers: Nitrogen Dioxide*. https://go.nasa.gov/3Jwz9qP

NASA Earth Observatory (2022) *No Breathing Easy for City Dwellers: Particulates*. https://go.nasa.gov/3Sn7YCG

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Impacts of ENSO
(El Niño-Southern Oscillation)

GLOBE		Related SDGs:	Type of activity
Spheres	**Protocols**		
Atmosphere	Air Temperature, Surface Temperature, Precipitation	6 (Clean water and Sanitation) 13 (Climate Action) 14 (Life Below Water) 15 (Life on Land)	Exploratory
Pedosphere	Soil Moisture, Soil Temperature		
Hydrosphere	Water Temperature		
Bundle	ENSO Bundle		

Overview

Satellite images and maps are analyzed to determine the impacts of the ENSO phenomenon at a local, regional and global scale with examples of the 2015 El Niño and the 2010 La Niña events. Students analyze the local and regional impacts and develop an outreach campaign to help the population learn about the ENSO phenomenon and prepare for future impacts.

Time

4 classes

Prerequisites

Basic knowledge of meteorology, ecosystems and ICT. Ability to interpret satellite images and maps. Ability to locate points using latitude and longitude.

School Level

Upper Primary School, High School and University students

LEARNING ACTIVITY - SATELLITE IMAGES

Purpose

To understand the interrelationship of energy exchange between the spheres of the Earth System during the ENSO phenomenon and its impact on human activities.

Student outcomes

- To interpret satellite images and maps to draw conclusions about the impact of the ENSO phenomenon in different regions.
- To give examples of how ENSO events affect different human activities in different regions of Latin America and the Caribbean.
- To use geographic information to develop a public awareness campaign to help the population prepare for ENSO events.

Introduction

In Latin America and the Caribbean, the ENSO phenomenon produces negative effects on the sustainability of ecosystems (coral bleaching, changes in phytoplankton that affect the food web), on agricultural production systems (coffee, sugarcane, cocoa, bananas, tubers, soybeans and other cereals, etc., reduced pastures for livestock) and on fishery resources (fish deaths) that affect prices, the economy, social security, food security and health. For example, the 2015-16 El Niño had very significant social and economic impacts, such as worsening droughts in The Caribbean and northern South America, with some extreme precipitation events and floods in Central and Southern South America. The humid zone of Argentina, Uruguay and Southern Brazil tends to record above-normal rainfall during El Niño phase, mainly in spring and summer, while during La Niña phase, this zone tends to record below-normal rainfall, particularly during the winter. Studying the ENSO phenomenon and predicting it in time helps society to develop adaptation actions to face these effects.
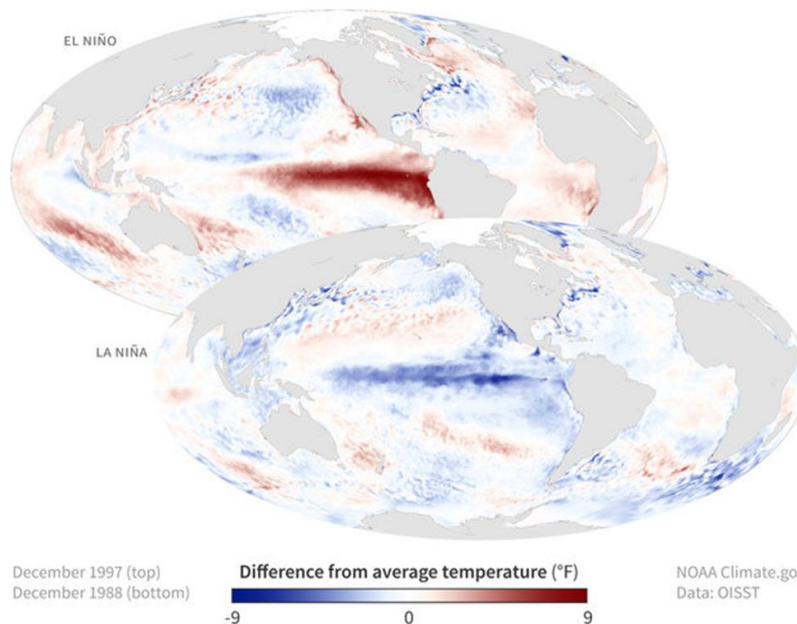

Fig. 1. Temperature anomalies during the 1997 El Niño and 1998 La Niña events

Temperature anomalies (above-normal increase or decrease) in the surface waters of the Pacific Ocean produce the El Niño-Southern Oscillation (ENSO) phenomenon. This event directly affects the distribution of rainfall and temperatures in tropical areas and can have a strong influence on the climate in other parts of the world, causing extreme weather events such as heat waves, droughts, floods and other associated problems such as diseases, fires, etc. These interactions around the world are called teleconnections.

El Niño and La Niña are the extreme phases of the ENSO cycle; between these two phases there is a third phase called Neutral. See animations. For several years now, satellites have provided a global view of ocean surface temperatures.

El Niño: occurs when the trade winds are weaker than they usually are. The warm water accumulates along the equatorial zones and moves toward the coasts of Central and South America. As the surface of the water is warmer than normal, the atmosphere also warms, causing moist air to rise, forming clouds and storms.

La Niña: is an inverse phase because the trade winds become stronger, cold water accumulates on the coasts of Central and South America. As a consequence, the atmosphere is cooled by the contact with the cold surface waters of the ocean, for this reason very little water evaporates and the air does not rise. This causes an anomalous decrease in precipitation and storms in that region.
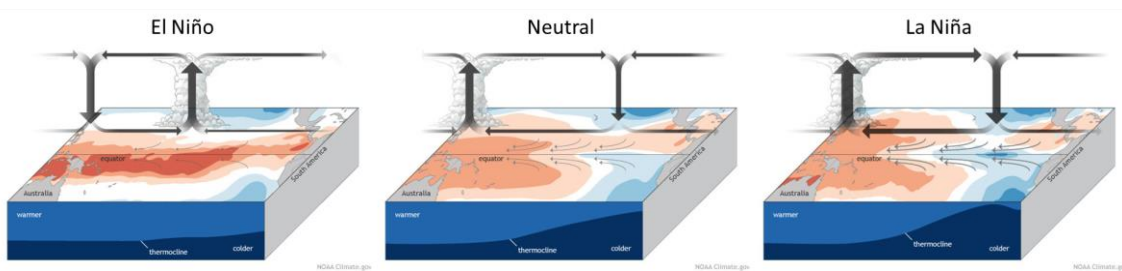

Fig. 2 Atmosphere-ocean feedback during the ENSO phenomenon. El Niño, Neutral and La Niña phases.

Oceanic Niño Index: known by its acronym in English as ONI (Oceanic Niño Index) represents the deviation of the quarterly average surface temperature of the Pacific Ocean. It is the main measure for predicting the phenomenon and is composed of 3 phases: 1) El Niño with positive values equal to or greater than +0.5ºC for three consecutive months; 2) La Niña with negative values less than or equal to -0.5ºC for three consecutive months; and 3) the Neutral phase with ONI values between -0.5 and +0.5. These events vary in intensity. See animation of the index and the map. (Interactive ONI chart in degrees Celsius and Fahrenheit)
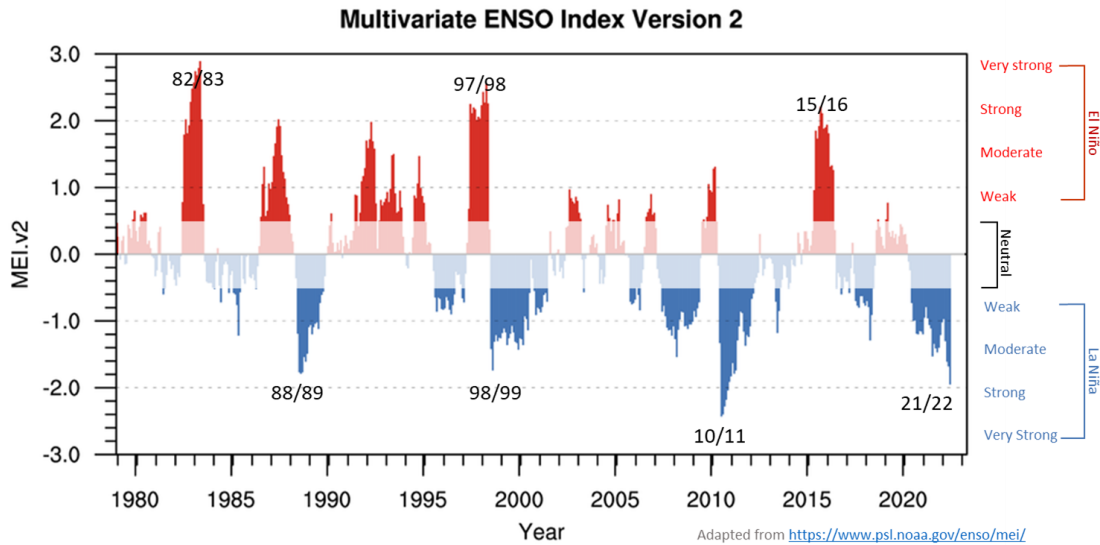
Multivariate ENSO Index Version 2

Fig. 3. El Niño Oceanic Index. The red area indicates El Niño events and the blue area indicates La Niña events. Years with very strong events are shown.

Each ENSO event is different and occurs in conjunction with other weather events. Not all impacts occur in all events, and may not be limited to the regions indicated. The maps show areas where impacts are likely to occur, based on historical evidence.
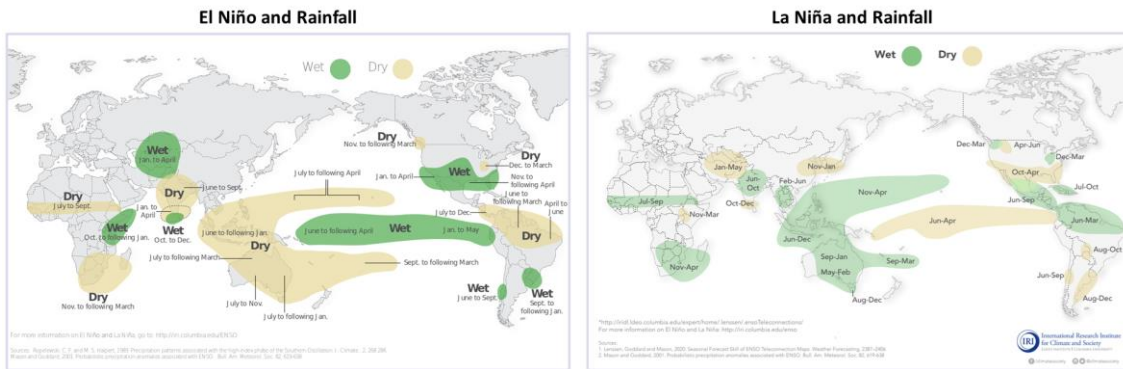

Fig. 4. Changes in precipitation patterns during El Niño and La Niña events.

El Niño and La Niña conditions in the tropical Pacific change precipitation and temperature patterns in many parts of the world. These changes vary in intensity from one event to the next, but are maintained with some consistency in the regions and months shown on the maps.
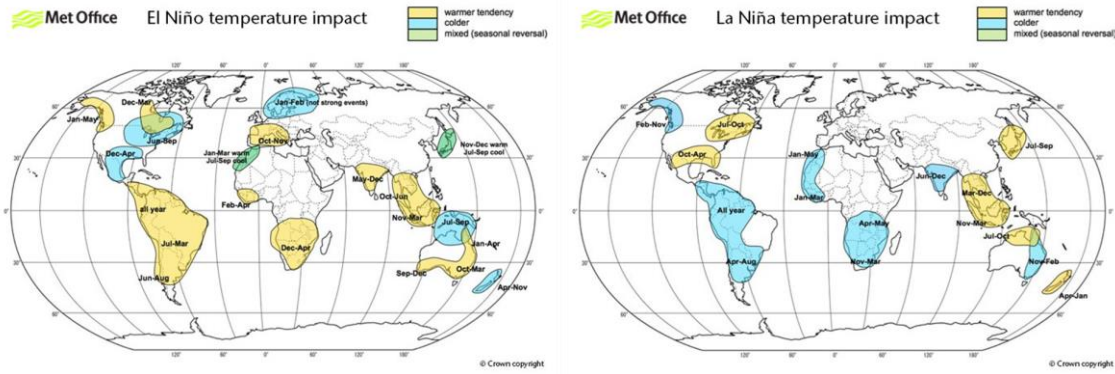
Fig. 5. Changes in temperature patterns during El Niño and La Niña events.

Guiding research questions

- What are the main differences between a normal phase (neutral) and El Niño and La Niña phases?
- How does the impact of El Niño and La Niña vary in different parts of the world?
- What changes occur in temperature and precipitation patterns during the ENSO phenomenon in your country and locality?
- How did these changes affect ecosystems, human activities, and health in your country?

Scientific concepts

- Weather and climate
- Atmospheric circulation
- Ocean currents
- Environmental hazards and vulnerability

Materials and tools

Satellite images of:

1. Sea surface temperature anomalies (El Niño: 1 Nov 2015, Neutral 1 Mar 2014 and La Niña: 14 Dec 2010)
2. Total precipitation (monthly average) (Mar 2014, Nov 2015 and 14 Dec 2010)
3. Daytime soil surface temperature (monthly average) (Mar 2014, Nov 2015 & 14 Dec 2010)
4. Impacts: Floods from El Niño (Jan 2016), fires (Feb 2022) and droughts (Oct 2020 groundwater and soil moisture) from La Niña.

What and how to do it

- **Beginning**

Ask your students to look for news about the impact of the ENSO phenomenon in their country. (Consider the ONI index with significant events). Generate a discussion with your students and gather the information in the following table.

Month/Day/Year	News	El Niño	La Niña

- *Development*

1. Ask students to read the introduction to this activity and make a concept map with the information. Add to the concept map the examples of impacts in their country that they found in the news.

2. Divide the class into groups and assign a Worldview satellite image to each group (Sea Surface Temperature Anomalies and Total Precipitation). Students should answer the following questions: What does each color represent in the different images? In which regions are the colors more intense?

3. Gather all the groups and ask them to explain the images analyzed, consult the information on the concept map and determine to which ENSO phase each image corresponds.

4. Project the surface temperature images to compare with the previous ones. What happened in your region during the 2015 El Niño and the 2010 La Niña phase?

5. Consult the images of some El Niño and La Niña impacts and compare them with the impacts in your region.

- *Ending*

Due to the relevance of the ENSO phenomenon in society, it is important to develop outreach materials for your area. Ask your students to elaborate a story with maps (Story Map), a video, or flyers to post on social media.

Frequently asked questions

Where can I find satellite images? – Worldview

Why is NASA studying the ENSO phenomenon? – This phenomenon can be investigated from space to complement measurements on the ground. Oceanography from space provides relevant information for research. The ENSO phenomenon produces changes in temperature, sea level height, winds, ocean currents, salinity, phytoplankton, sea ice. Combining satellite data with on site measurements makes it possible to analyze the events and their impacts in order to implement adaptation actions.

Suggested resources for further information

As an extension of this activity, students can consult satellite images from different dates during the ENSO events mentioned to investigate the phenomenon from beginning to end, or investigate other ENSO events that have occurred in the past. Worldview has about 20 years of satellite images stored.

Another suggestion is to make measurements in your environment (whether you are in a Neutral phase or in a La Niña or El Niño phase). This allows comparison with satellite image information to understand the impact at a local, regional and global scale. The relevant protocols for measurements are: 1) Atmosphere: Air and Surface Temperature, Precipitation. 2) Pedosphere: Soil Moisture and Temperature. 3) Hydrosphere: Water Temperature.

Other resources:

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WMO (2014) *El Niño/Southern Oscillation*. WMO–No 1145. https://bit.ly/3WvSLAR

WMO (2022) *State of the Climate in Latin America and the Caribbean 2021*. WMO-No 1295. https://bit.ly/3GsLBI6

Precipitation

GLOBE		Related SDGs:	Type of activity
Sphere	**Protocols**		
Atmosphere	Air temperature. Surface temperature. Wind direction and speed. Precipitation. Relative humidity	6 (Clean water and sanitation) 13 (Climate action) 14 (Life below water) 15 (Life of land)	Exploratory
Biosphere	Land cover. Biometrics. Phenology.		
Pedosphere	Soil characterization. Fertility. Moisture. pH. Temperature.		
Hydrosphere	Water temperature. pH. Alkalinity. Electrical conductivity. Transparency. Salinity. Nitrates.		
Bundle	Agriculture Air Quality ENSO. Mosquito Water cycle. Water Quality Weather. Soils		

Overview

Rainfall and other dependent variables, such as soil moisture, temperature, etc., are analyzed using satellite images and satellite data to characterize the type of vegetation cover that can grow on a site. Students study cases of different types of vegetation cover in Latin America and the Caribbean. Extensions of the activity are suggested by carrying out field measurements to complement the satellite information.

Time

4 o 5 classes

Prerequisites

Basic knowledge of ecosystems, photosynthesis, meteorology, and TIC. Ability to interpret satellite images and maps. Ability to locate points using latitude and longitude.

School level

High school and university students

LEARNING ACTIVITY - SATELLITE IMAGES

Purpose

To understand the influence of precipitation on the environmental conditions that allow the development of different types of forests, grasslands, crops and the trends of short and long-term changes considering the impact of climate change.

Student Outcomes

- Identify different types of land cover in satellite images.
- Characterize environments where forests, grasslands, or deserts are found according to freshwater availability from precipitation.
- Analyze the response of vegetation to changes in precipitation and other dependent variables, such as soil moisture, temperature, etc., through satellite imagery.
- Analyze precipitation anomalies and impacts such as droughts, fires, floods, etc.

Introduction

Precipitation is part of the hydrological (water cycle) and represents the most critical source of freshwater for terrestrial ecosystems. But rainfall is distributed unevenly worldwide, allowing the development of large rainforest areas in places with abundant rainfall or deserts where rainfall is scarce or almost non-existent. But even sometimes, it also rains in deserts, as happened in Atacama in 2015 and in 2017, which provided enough moisture for plants to grow and flourish. Rainfall is also irregular throughout the year, with seasonal variations, very marked in some places.
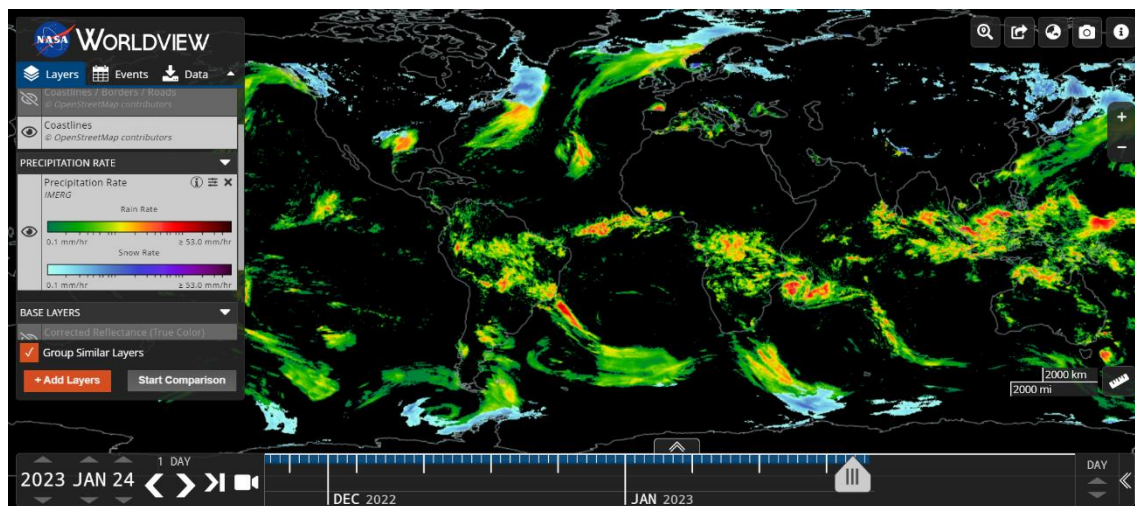

Fig. 1. Precipitations January 24, 2023. Fuente: NASA – Worldview https://go.nasa.gov/3XIXX5g

Ecosystems depend on rainfall for their functioning; many birds and mammals migrate following rain because they will have greater food availability due to vegetation growth. The NDVI (Normalized Difference Vegetation Index) and other similar indices are used to monitor vegetation with satellite images. Soil moisture depends on rainfall and is essential for plant growth. When soil moisture is scarce in some places, irrigation is used to sustain crops. Water for irrigation is usually drawn from nearby water bodies or aquifers.

In many cases, the irrigation of large extensions causes the reduction of river flows or the depletion of aquifers. Soil moisture influences hydrological, ecological, and meteorological

processes. For example, observe in Fig. 2 how precipitation is concentrated in the Amazon in January and September in Central America and the Caribbean. This coincides with changes in temperature and soil moisture. Snow is only found in high altitudes or Patagonia in September.
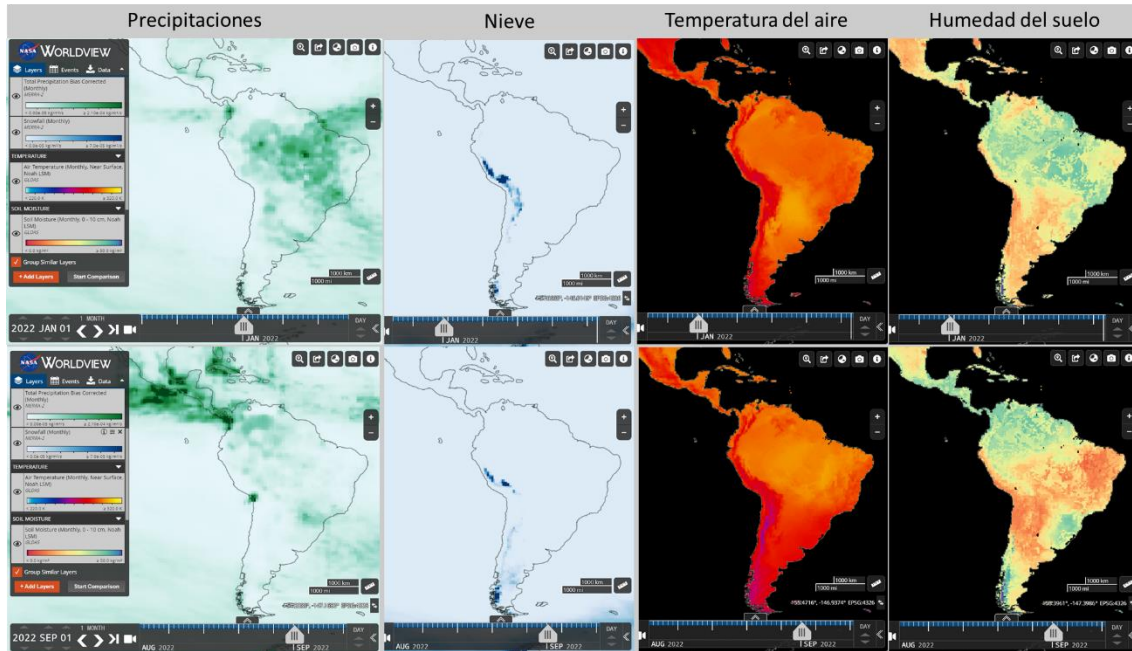

Fig. 2. Comparison of precipitation with air temperature and soil moisture in Latin America and the Caribbean. January and September 2022. Source: NASA - WorldView.
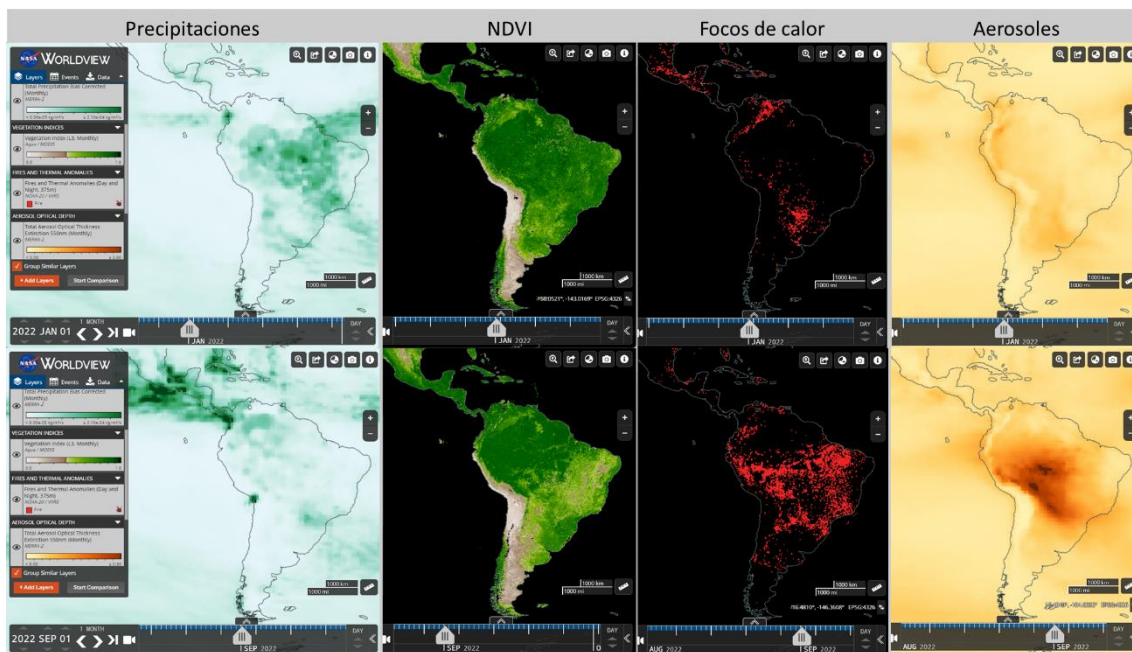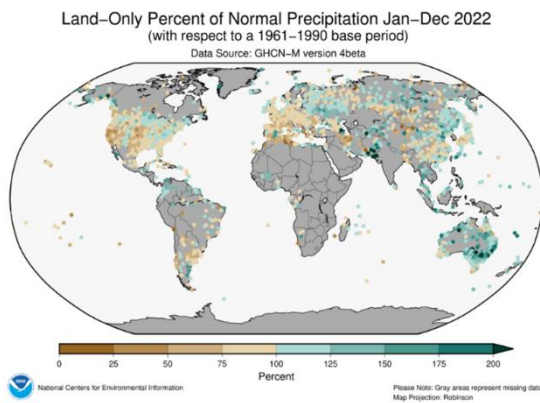

Fig. 3. Comparison of precipitation with NDVI, hot spots (which can cause fires), and aerosols in Latin America and the Caribbean. January and September 2022. Source: NASA - WorldView.

Rainfall is significant for agriculture, food production, and food security, and much of the electricity we use daily comes from hydroelectric power plants that use water reservoirs to produce it. These reservoirs are recharged by rainfall. Excessive rainfall causes flooding

(creating conditions for the proliferation of vector-borne diseases such as dengue, malaria, cholera, etc.). Heavy rains can cause landslides with risks to people and damage to infrastructure. Conversely, when it does not rain, prolonged droughts can cause economic, environmental, and health-related impacts (allergies, heat exhaustion, etc.). Dry vegetation is more susceptible to fires, which release aerosols into the atmosphere that spread over long distances in addition to local disturbances. The ENSO phenomenon can influence by changing the standard rainfall patterns causing floods or droughts. In Fig. 3, note the changes in NDVI and hot spots in the Amazon, Central America, and the Caribbean compared to rainfall.

Fig. 4. Normal precipitation and anomalies during 2022. Source NOAA https://bit.ly/3Y0N5zf

Knowing rainfall patterns, making accurate measurements on the ground, and monitoring large areas from satellites are essential as the population grows and more water is consumed. In many countries, water consumption is rapidly depleting water resources, and rainfall is failing to replenish them. Human activities and climate change now influence the natural variability of water movement worldwide. Climate change is modifying rainfall patterns, increasing in some places and decreasing in others (Fig. 4); the IPCC Interactive Atlas predicts future temperature and precipitation changes. Sustainable freshwater management is currently of concern, and alternatives are being studied to optimize water use.

Guiding research questions

- How much rain does it rain in my locality? Is there a period where rainfall is concentrated? Are there arid periods?
- What economic activities depend on rainfall in my region/country?
- Has land cover changed in my region?
- Have precipitation anomalies occurred in the past or currently? Have there been droughts, fires, floods, etc.?
- Are there indications of changes in precipitation patterns due to climate change? What is the climate change prediction for your region?

Scientific concepts

- Ecosystems. Tropical, subtropical, and temperate forests, grasslands, and deserts.
- Land cover
- Water cycle
- Satellite images

Materials and tools

1. ArcGIS StoryMaps https://storymaps.arcgis.com/

2. To consult satellite information data of different types of land coverage:

Case 1. *Tropical forest. Estado do Amapá, Brasil:*

- Google Map – Location
- Google Earth (Sequence 1985 2020)
- Copernicus. Land Cover. Types of land cover
- Meteoblue (Climate diagrams)
- Total monthly Precipitation
- Surface Temperature – Promedio mensual
- Soil moisture - Monthly average– 0 a 10 cm.
- Snow days
- NDVI. Monthly average.
- Fires. The monthly total of heat sources
- Aerosols. Monthly average

Case 2. *Bosque subtropical. Santa Catarina, Brazil:*

- Google Map - Location
- Google Earth (Sequence 1985 to 2020)
- Copernicus. Land Cover. Types of land cover
- Meteoblue (Climate diagrams)
- Total monthly Precipitations
- Surface Temperature – Monthly average.
- Soil moisture. Monthly average – 0 a 10 cm.
- Snow days
- NDVI. Monthly average.
- Fires. The monthly total of heat sources
- Aerosols. Monthly average.

Case 3. *Temperate forest. Parque Nacional Corcovado, Chile:*

- Google Map - Location
- Google Earth (Sequence 1985 to 2020)
- Copernicus. Land Cover. Types of land coverage
- Meteoblue (Climate diagrams)
- Total monthly Precipitations
- Surface temperature – Monthly average.
- Soil moisture. Monthly average – 0 to 10 cm.

- [Snow days.](#)
- [NDVI](#). Monthly average.
- [Fires](#). Total monthly heat sources.
- [Aerosols](#). Monthly average.

Case 4. Mangrove Forest. Panama City:

- Google Map - [Location](#)
- Google Earth (Sequence [1985 to 2020](#))
- [Copernicus. Land Cover](#). Types of land coverage
- Meteoblue ([Climate diagrams](#))
- Total monthly [Precipitations](#)
- [Surface Temperature](#) – Monthly average.
- [Soil moisture](#). Monthly average – 0 to 10 cm.
- [Snow days](#)
- [NDVI](#). Monthly average.
- [Fires](#). Total monthly heat sources.
- [Aerosols](#). Monthly average.

Case 5. Herbaceous vegetation. Uruguay

- Google Map - [Location](#)
- Google Earth (Sequence [1985 to 2020](#))
- [Copernicus. Land Cover](#). Types of land coverage
- Meteoblue ([Climate diagrams](#))
- Total monthly [Precipitacions](#)
- [Surface Temperature](#) – Monthly average
- [Soil moisture](#). Monthly average – 0 to 10 cm.
- [Snow days](#)
- [NDVI](#). Monthly average
- [Fires](#). Total monthly heat sources.
- [Aerosols](#). Monthly average

Case 6. Dessert. Atacama

- Google Map – [Location](#)
- Google Earth (Sequence [1985 to 2020](#))
- [Copernicus. Land Cover](#). Types of land coverage
- Meteoblue ([Climate diagrams](#))
- Total monthly [Precipitations](#)
- [Surface temperature](#) – Monthly average
- [Soil moisture](#). Monthly average – 0 to 10 cm.
- [Snow days.](#)
- [NDVI](#). Monthly average
- [Fires](#). Total monthly heat sources.
- [Aerosols](#). Monthly average

What to do and how to do it?

- *Beginning*

  - Show your students the water cycle infographic and analyze the water movement after rainfall. Then show the following videos a) [Seasonal Global Precipitation Variation from the Global Precipitation Measurement Constellation](), b) [Chile – The Mega Drought](), c) [Fires in South America, Jun to Dec 2021](), d) [Devastating floods and mudslides in Brazil leave scores dead]() y e) [Chile's newest national park is a blossoming natural phenomenon]()
  - Conduct a short discussion on rainfall, average rainfall, and the consequences of lack or excess rain.

- *Development*

  1. Ask the students to read the introduction to this activity and create a concept map with the information.
  2. Divide the class into groups and assign a case to each group for analysis
      a. Look at the current satellite image on Google Maps. What do you see in that picture (forest, desert, cities, roads, rivers, etc.)?
      b. Open the Google Earth sequence and note the changes each year. Note the changes you observe or if it remains unchanged.
      c. Consult Copernicus for the land cover types of the site you are analyzing.
      d. In Meteoblue, consult the climate diagrams, especially the first seismogram with temperature and precipitation information.
      e. Consult the environmental data for each month during the year 2022 (precipitation, temperature and soil moisture, snow days, NDVI, fire, and aerosols), and record the most common values for the analyzed site in each season.
          Note: In WorldView, you can change the date bottom left; making a video with sequences of images is also possible. E.g., temperature changes per month during the year 2022.
      f. Compare the Meteoblue seismogram with the Worldview monthly data for the year 2022. Is the precipitation similar to the site average? Were there anomalies due to a lack of rainfall or excess?
      g. In case of anomalies: Were there changes in soil moisture or NDVI? Were there fires and increased aerosols at any time during the year?
  2. Ask your students to develop a presentation on the case study. They can make a story with maps (using ArcGIS StoryMaps), a slide presentation, or a video. To elaborate on the production, consider the following questions: What is the precipitation like at the site analyzed? Does rainfall occur similarly throughout the year, or is it concentrated in some periods? What happened in 2022 with the environmental variables? Did they continue as expected, or were there anomalies? Were the changes in precipitation reflected in vegetation, the number of fires, or the amount of aerosols?Si registraron cambios: ¿podrían atribuirlos a cambios estacionales normales?
  3. Bring all the groups together and ask them to explain the cases analyzed and compare their similarities and differences: Tropical forest, sub-tropical forest, temperate forest, mangrove forest, herbaceous vegetation, and desert.
  4. Complete the conceptual map with the main characteristics of each case analyzed.

- *Closing*

Due to the relevance of this problem, it is essential to develop dissemination materials. Students can elaborate a story with maps (Story Map), a video, or flyers to post on social networks summarizing the cases analyzed and highlighting the importance of quantifying and analyzing rainfall patterns to improve water management.

Frequently asked questions

Where can I find satellite images? - Worldview - Google Earth - Google Map

Where do I find precipitation data? Government agencies in each country have information from weather stations (sometimes limited to a few sites) and satellite imagery. You can also consult Wundermap, which has data from individual weather stations, and Meteoblue, which provides information based on satellite data. To visualize where it was raining in the last 30 minutes, one day ago, or seven days ago, you can consult IMERG.

Suggested resources

As an extension of this activity, students can consult satellite images from different dates and locations to explore other sites of interest or evaluate trends over the last 20 years for the same areas analyzed. Worldview has had this type of satellite imagery available for over 20 years.

You can use the GLOBE Program protocols to measure your environment or visit nearby sites manually. You can also make land cover measurements of your environment and surface temperature. You can complement this information with other biosphere measurements such as phenology (measuring the advance and retreat of green) or atmosphere, pedosphere, and hydrosphere measurements.

Websites

- Copernicus. Global Land Cover http://lcviewer.vito.be/2019
- FAO. Earth Observation https://www.fao.org/giews/earthobservation/asis/index_2.jsp?lang=en
- IPCC WGI. Interactive Atlas. Short version https://interactive-atlas.ipcc.ch/ Version with many variables. https://bit.ly/3XFwh13
- Meteoblue: Climate diagrams https://bit.ly/3kPFuW8
- NASA - FIRMS https://firms.modaps.eosdis.nasa.gov/map/#d:24hrs;@0.0,0.0,3z (current and historical hot spots)
- NASA Earth Observatory. Global Maps. https://earthobservatory.nasa.gov/global-maps (Interactive maps with satellite images from the year 2000 to the present)
- NASA Global Precipitation Measurement (GMP) https://gpm.nasa.gov/
- NASA GPM - IMERG https://gpm.nasa.gov/data/visualization/global-viewer (Rainfall in the last 30 minutes, 1 day ago, or 7 days ago)
- NOAA. GHCN Gridded Products. https://bit.ly/3Dkjg4W (Annual maps of global temperatures and precipitations)
- SERVIR AMAZONIA: https://servir.alliancebioversityciat.org/

– SERVIR GLOBAL: https://www.servirglobal.net/
– Wundermap https://www.wunderground.com/wundermap (Data from weather stations)

Videos:

– DW (2022) *Brazil: Deadly landslides and flooding.* Youtube: https://www.youtube.com/watch?v=9ao9QE1BJsM

– EuroNews (2022) *Chile's newest national park is a blossoming natural phenomenon.* Youtube: https://youtu.be/1KrMvnI8nm0?si=PN3iqbXRUFd9gbsR

– My NASA Data. (2018) *NASA: Freshwater Movements Around the World.* https://youtu.be/JFEpBgX192Q

– PrensaCR2 (2016) *La megasequía en Chile.* Youtube: https://youtu.be/pkdigxhRpZs

– SVS (2021) *Seasonal Global Precipitation Variation from the Global Precipitation Measurement Constellation.* https://svs.gsfc.nasa.gov/4897

– Earth NullSchool. (2022) *Fires in South America, Jun to Dec 2021.* Youtube: https://youtu.be/j3xQRH_d3Wc

– UNESCO (2020) *Chile – The Mega Drought / Droughts in the Anthropocene.* Youtube: https://www.youtube.com/watch?v=dnRkjyMI0UA

Infographics:

- USGS. *The Water Cycle.* https://www.usgs.gov/media/images/water-cycle-png

Articles

– SVS (2018) *Landslide Activity in the Americas for the Cover of Earth's Future.* https://svs.gsfc.nasa.gov/4633

Other resources:

- Tutoriales de: Worldview, Story Map, OpenAltimetry (infographic)

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McCullum, A.; Torres-Pérez, J.; Beaudry, B.; Pippin, H. (2022). *Using Earth Observations for Pre- and Post-Fire Monitoring.* NASA Applied Remote Sensing Training Program (ARSET). https://go.nasa.gov/3Y49Get

Mehta, A and Melton, F. (2022) *Applications of Remote Sensing-Based Evapotranspiration Data Products for Agricultural and Water Resource Management*. NASA Applied Remote Sensing Training Program (ARSET). https://go.nasa.gov/3j7UnT8

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NASA Earth Observatory (2021) *Research Shows More People Living in Floodplains.* https://go.nasa.gov/3DgjrOE

NASA Earth Observatory (2022) *Coniferous Forest.* https://go.nasa.gov/3OEXBbQ

NASA Earth Observatory (2022) *Desert. https://go.nasa.gov/40fNQgj*

NASA Earth Observatory (2022) *Grassland. https://go.nasa.gov/3WBVp7l*

NASA Earth Observatory (2022) *Rainforest.* https://go.nasa.gov/3u2MjET

NASA Earth Observatory (2022) *Temperate Deciduous Forest.* https://go.nasa.gov/3XAP4L8

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Remote Sensing – Atmosphere: Precipitations

GLOBE		Related SDGs:	Type of activity
Sphere	**Protocols**		
Atmosphere	Air temperature. Surface temperature. Wind direction and speed. Precipitation. Relative humidity	11 (Sustainable Cities and Communities) 13 (Climate action) 15 (Life of Terrestrial Ecosystems)	Exploratory
Biosphere	Terrestrial coverage. Biometry. Phenology		
Pedosphere	Soil characterization. Fertility. Humidity. pH. Temperature		
Bundle	Agriculture Air Quality Soils Cities Meteorology		

Overview

Basic remote sensing concepts are explained to analyze satellite images of a mega forest fire in Chile and the Atacama Desert blooming after extraordinary rains. Satellite images processed with a combination of bands and indices are used. In addition, students can try different band combinations and apply other specific indices to highlight some features.

Time

4 or 5 classes

Prerequisites

Basic knowledge of ecosystems, photosynthesis, meteorology, waves, electromagnetic spectrum, and ICT. Analysis of bar charts, line graphs, and histograms. Ability to interpret satellite images and maps. Ability to locate points using latitude and longitude.

School Level

High school and university students

LEARNING ACTIVITY - SATELLITE IMAGES

Purpose:

To understand the application of wave properties, satellite sensors, and satellite images to obtain information about the Earth's process to observe changes, trends, and interrelationships between the biosphere, atmosphere, hydrosphere, and pedosphere.

Student outcomes

- Know the types of electromagnetic waves satellite sensors use to obtain information from the Earth system.
- Identify changes and trends in satellite imagery.
- Apply combinations of the bands by assigning the colors Red (R), Green (G), and Blue (B) to identify specific features on the ground.
- Apply specific indices to analyze satellite image information.
- Analyze land cover impacts caused by wildfires.
- Analyze the relationship between temperature, rainfall, and flowering in the Atacama Desert.

Introduction

Remote Sensing

Remote sensing is acquiring information from a distance using remote sensors. For example, a camera is a sensor that allows us to obtain information about an object from space (when we take a photograph), and our eyes are sensors that enable us to get information about our surroundings when we look at something. To study the Earth, sensors placed on satellites, the international space station, airplanes, drones, balloons, and others are used to detect and record reflected or emitted energy—fig. 1.

Fig. 1. Different types of remote sensors that obtain information from the Earth. Source:
https://svs.gsfc.nasa.gov/30892

Remote sensors provide a global perspective and a large amount of atmospheric, hydrosphere, pedosphere, and biosphere data that allow us to know the current state, study trends with historical information (e.g., 20-year record of rain and snow), and use them for data-driven decision making. NASA has its fleet of satellites orbiting the Earth, and some satellites operate in consortium with other countries (several of them belong to the Latin

American and Caribbean region). An example of this is the International Afternoon Constellation, formed by a coordinated group of satellites from different countries that travel in a synchronized orbit with the sun, passing at approximately 13:30 local solar time, with a difference of seconds to minutes between them (for this reason it is called the Afternoon Constellation). This constellation of satellites performs near-simultaneous observations with a wide variety of sensors that are of great utility for conducting research, issuing warnings, making decisions, etc. Fig. 2.
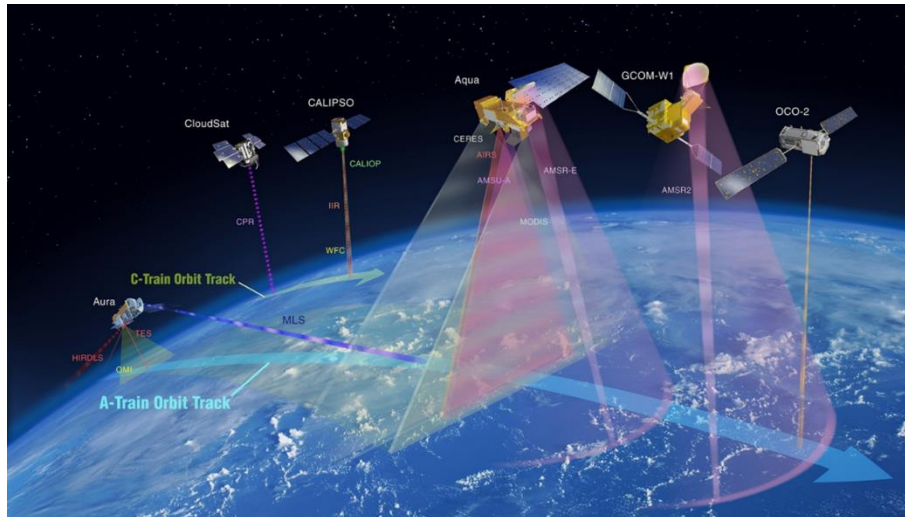

Fig. 2. International Afternoon Constellation. Source: https://atrain.nasa.gov/

Some sensors are passive, i.e., they detect electromagnetic waves reflected from the earth's surface when illuminated by the sun or when it emits light (e.g., city lights at night). Most passive sensors operate in the electromagnetic spectrum's visible, infrared, and microwave portions. Passive sensors measure land and sea surface temperature, vegetation properties, cloud properties, aerosols, and soil moisture. However, they have limitations because they cannot penetrate the dense cloud cover that regularly covers the tropics. Active sensors emit waves that bounce off the Earth's surface and return. Most operate in the microwave band of the electromagnetic spectrum, allowing them to penetrate the atmosphere (e.g., radar). These sensors measure aerosol vertical profiles, forest structure, precipitation and winds, sea surface topography, and ice.

The Sun is the primary source of energy observed by satellites. Different types of surfaces reflect different amounts of solar energy. The albedo is the property of anybody to reflect incident radiation. For example, snow is a light surface and has a high albedo (it reflects up to 90% of incoming solar radiation). The ocean is dark, with low albedo (it reflects only about 6% of incoming solar radiation and absorbs the rest). When energy is absorbed, it is re-emitted, usually at longer wavelengths. In the case of the ocean, the absorbed energy is re-emitted as infrared radiation. The amount of energy surfaces reflect, sponge, or transmit varies with wavelength.

Spectral bands and signatures

As the reflected energy goes according to the surface type, it can be used to identify different characteristics of the Earth; it works just like our fingerprints and is called a spectral signature. Thanks to the spectral signature, it is possible to identify different types of rocks and minerals, clear and turbid water, soil moisture, different types of vegetation, vegetation conditions, etc.). Fig. 3.
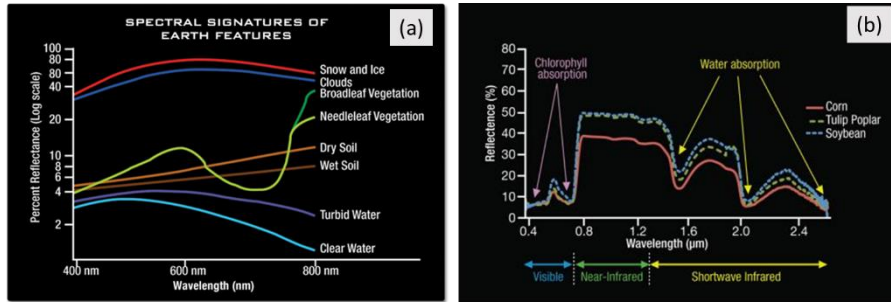
Fuente: NASA - Jeannie Allen https://go.nasa.gov/3DnmbK2   Fuente: NASA - Eric Brown de Colstoun https://go.nasa.gov/2Pk20k8
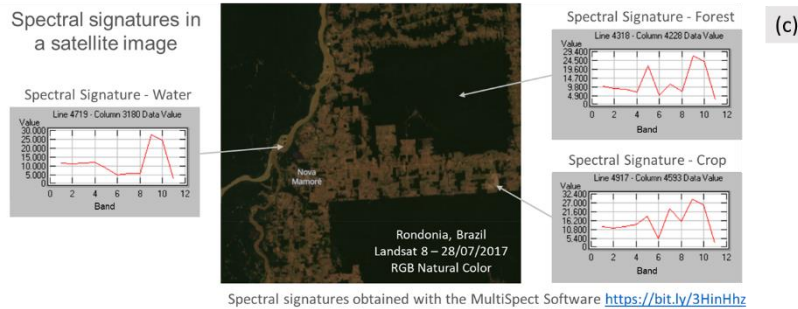
Spectral signatures obtained with the MultiSpect Software https://bit.ly/3HinHhz

Fig. 3. Spectral signatures: (a) of different Earth features. (b) of vegetation. (c) Examples of spectral signatures in different pixels of the satellite image of Rondônia, taken by the Landsat 8 satellite on 27/07/17.

A digital image comprises pixels (or squares) whose color represents a number each. Thus, a picture is a matrix of grayscale numbers ranging from 0 (white) to 255 (black). Any other value within that range is a variation of gray (Fig. 4).
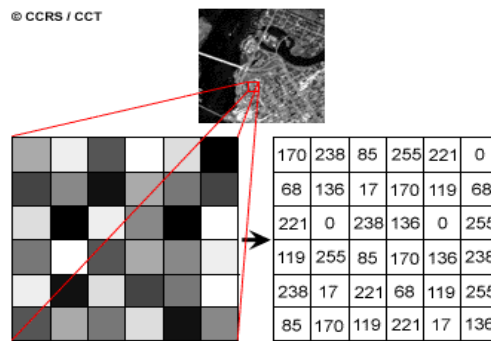

Fig. 4. Satellite image and numerical matrix of a Landsat 7 satellite image band. Each pixel (or square) represents a land area of 30m x 30m and a specific brightness color. Source: https://www.nrcan.gc.ca/

Each satellite image has multiple bands representing different electromagnetic spectrum wavelengths [Fig. 5 (a)]. Sensors on most satellites use infrared to ultraviolet, including visible light. The bands represent data from the visible and infrared (shortwave infrared, near-infrared, and mid-infrared) regions. [Fig. 5 (b)] When we combine the bands in an RGB image to obtain a color similar to natural color, we work with three matrices, one per color channel: Red, Green, and Blue. [Fig. 5 (d)] As in the grayscale images, 0 represents the absolute absence of color, and 255 is the total presence of the hue corresponding to a particular channel. One of the RGB colors is assigned, and the false color is obtained to observe other aspects reflected in infrared bands or different wavelengths that are not perceived by our eyes. [Fig. 5 (c)
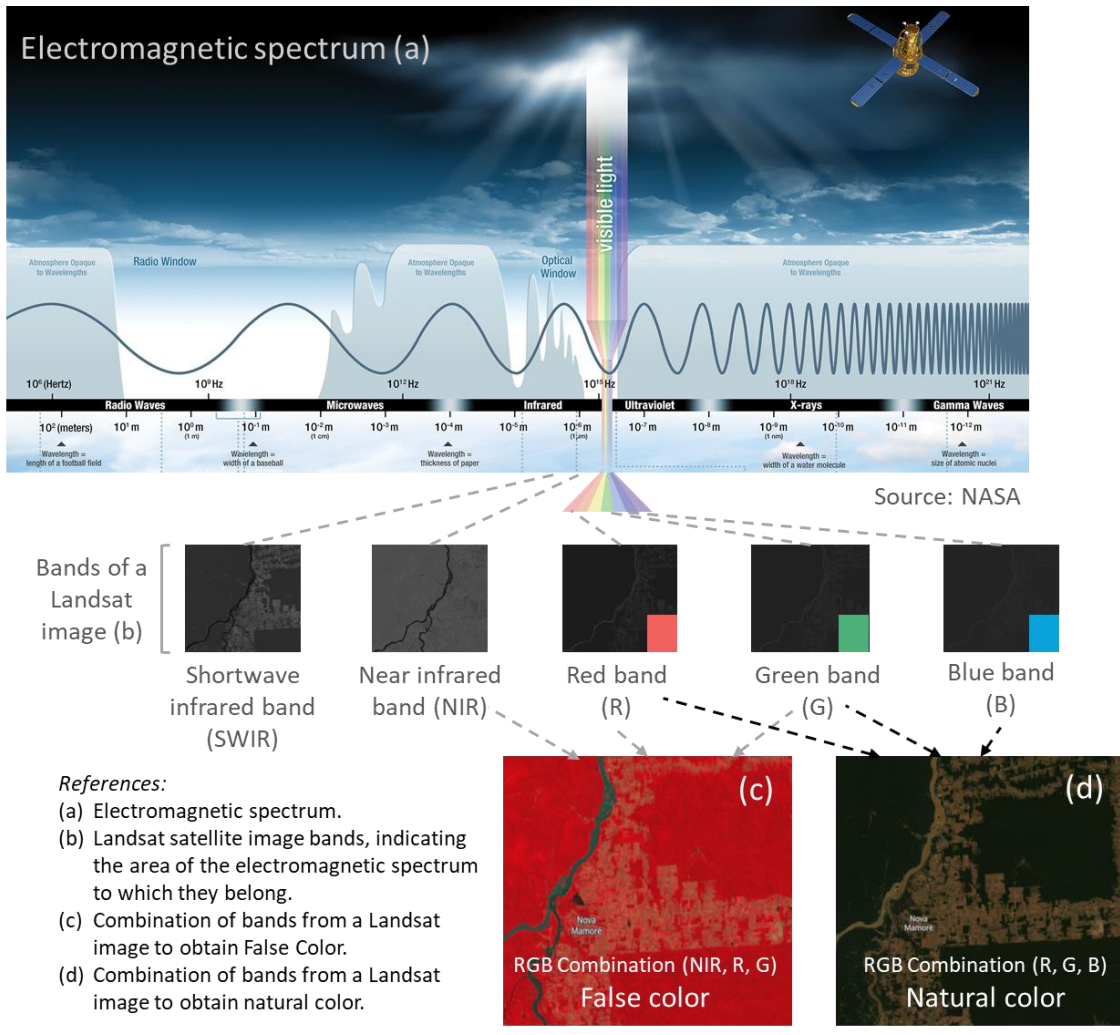
Fig. 5. Combination of Landsat satellite image bands to visualize various aspects. Sources: NASA and Landsat.

As the satellite images are matrices, it is possible to perform calculations to detect other elements not visible with the color combination. The indexes are obtained from calculations with the matrices that form each band of the satellite images. This calculation is performed using specific software, and as a result, a new image is obtained where the pixels related to the parameter, we are measuring are graphically highlighted. E.g., vegetation indices emphasize parameters of vegetation cover: density, leaf area index, chlorophyll activity, and others. For example, details of changes in vegetation cover are easily analyzed by applying indices. The Normalized Difference Vegetation Index (NDVI) is the most commonly used, but several similar indices exist. The NDVI allows estimating vegetation quantity, quality, and development based on measuring the radiation intensity of some bands of the electromagnetic spectrum that foliage emits or reflects. The bands vary according to the type of satellite. Some images automatically generate the most common indices. High NDVI values indicate healthy vegetation; low values indicate that the vegetation is drying out (may be due to water stress, disease, fire, etc.) - Fig. 6.
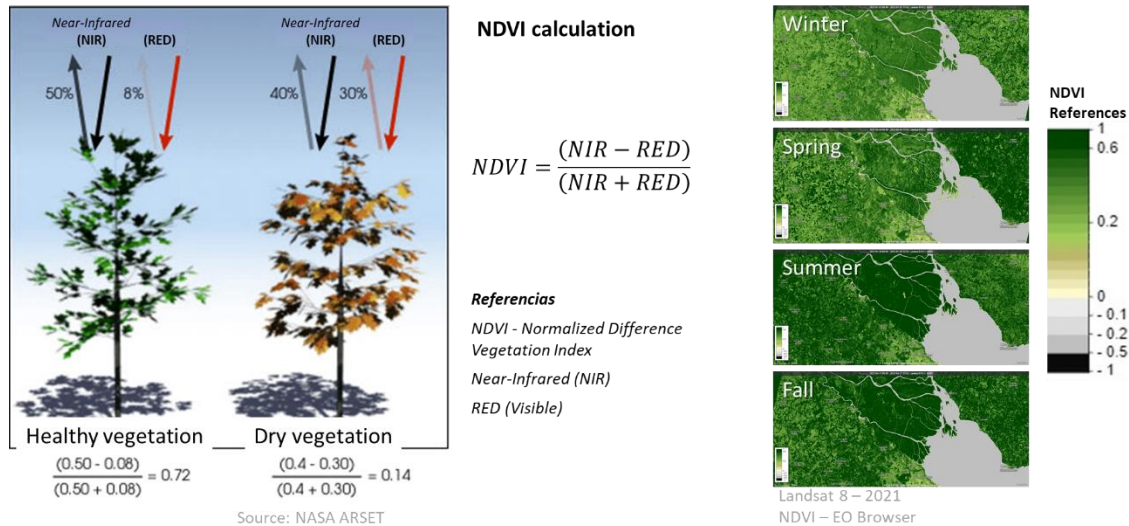
Fig. 6. Calculation and satellite images of the Paraná River Delta processed with the NDVI index. Seasonal changes in vegetation are detected with different color intensities.

Spectral indices have been developed to analyze various aspects of satellite images that have applications in ecology, agriculture, disasters (floods, fires, etc.), aquatic resources, geology, etc. All of them use calculations using different bands of satellite images.

Guiding Research Questions

- Why do some areas catch fire more often than others?
- What is the relationship between precipitation and vegetation type? What vegetation type is in my local environment, and how is precipitation distributed throughout the year?
- What happens when precipitation patterns change in my environment? Are there any known local/regional consequences related to the ENSO phenomenon?
- What conditions allow a massive flowering of plants in the desert? Where do desert blooms occur besides the Atacama?

Scientific concepts

- Ecosystems. Forests. Grasslands. Deserts.
- Land cover.
- Waves and electromagnetic spectrum.
- Graphs. Histograms
- Satellite images

Materials and Tools

1. ArcGIS StoryMaps https://storymaps.arcgis.com/
2. Worldview https://worldview.earthdata.nasa.gov/
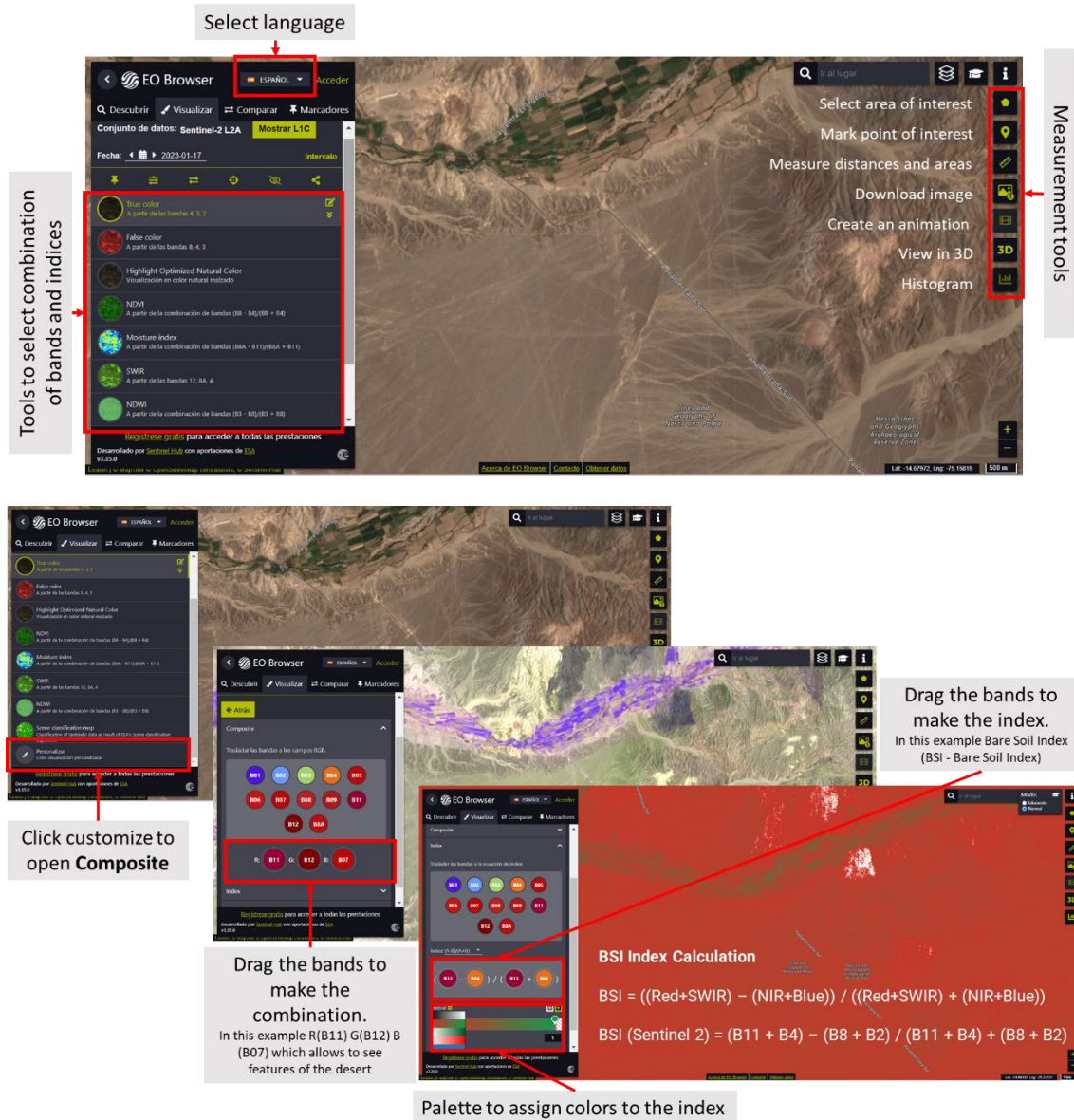3. EO Browser App https://apps.sentinel-hub.com/eo-browser/

Fig. 7. EO Browser App tools infographic. Source: Own elaboration based on screenshots of the app.

Case analysis:

Case 1: *Analysis of burned areas (forest and the city of Villa Santa Olga) Chile. January 2017.*

- Google Map - Location
- Climogram of average temperature and precipitation.
- Tree cover. Gain and loss.

Worldview
- Hot spots, smoke, and fire lights at night (consider that city lights also appear; change dates to differentiate with fire lights). City fire 01/26/17: Check days before

and after the fire. Observe fires near the city and use the ruler (right, below the screen) to measure distances to hot spots.
- Environmental conditions: a) Precipitation, b) Temperature.
- Generate a video in Worldview with each data set queried.

EO Browser (see tools in Fig. 7):
Sentinel image False color before the fire 19/01/2017 2.
2. Sentinel image False color after the fire 20/03/2017 3.
● Use the ruler (on the right of the screen) to measure the burned area and distances from nearby cities to the boundary of the burned area.
3.　　　Sentinel Image False color after six years 01/28/2023.

On the EO Browser images, perform the following:
1. View the false color images and analyze the changes.
2. Select the NDVI index (on the left side of the screen) and then the histogram (on the right side of the screen). Compare the results of the images. You can draw the site and then select the histogram to measure a specific area.
   a. Do the same for NDMI (Soil Moisture Index) and SWIR (for water present in vegetation and soil).
   b. Refer to the **histogram** (on the right side of the screen), open the menu of the index you are observing (on the left side) to see the color reference. Analyze the histogram by comparing the values with those of the reference.
   c. You can draw an area and do the same analysis for that particular sector.
3. To make a new **band combination,** go to customize (left below) and select **composite**.
   a. Drag the bands to the circles to make the RGB combination: (R) 11, (G) 8 and (B) 3.
   b. Compare the sharpness with which you observe the burned area concerning previous visualizations.
4. **Generate an index.** To improve the analysis, use the Normalized Burned Ratio Index (NBRI), which is sensitive to changes in vegetation and is used to detect burned areas and subsequently monitor ecosystem recovery.
   a. Go to Customize (bottom left) and select **Index**. The formula for placing the bands will appear. Place A lace band B8) and in place B (place band B12) correspond to the following calculation:

$$NBRI = (NIR - SWIR) / (NIR + SWIR)$$

$$NBRI\ (Sentinel\ 2) = (B8 - B12) / (B8 + B12)$$

   b. Then, go to **Threshold** and select a color palette to colorize the image.
5. Make a presentation comparing the results obtained before and after the fire to analyze the impact and after six years to evaluate if it has recovered.

Case 2: Analysis of the "flowering desert". Rapid flowering after rains in the Atacama Desert.
- Google Map - Location
- Climogram of average temperatures and rainfall.

1. Flowering 2017. Worldview:

   o NDVI - Flowering from June to November (maximum in August).
   o Environmental conditions: a) Precipitation, b) Temperature.

- Generate a video in Worldview with each dataset queried.
- EO Browser (see tools in Fig. 7):
- False color, NDVI, Moisture Index (NDWI - Soil Moisture), SWIR (Short Wave InfraRed - amount of water present in vegetation and soil).

EO Browser (see tools in Fig. 7):
o: False color, NDVI, Moisture Index (NDWI - Soil Moisture), SWIR (Short Wave InfraRed - amount of water present in vegetation and soil).

2. *Flowering 2021*
   Worldview:
   - NDVI - Flowering from August to October (maximum in August - September).
   - Environmental conditions: a) Precipitation, b) Temperature,
   - Generate a video in Worldview with each dataset queried.

      EO Browser (see tools in Fig. 7):
      o: False color, NDVI, Moisture Index (NDWI - Soil Moisture), SWIR (Short Wave InfraRed - amount of water present in vegetation and soil).

3. Desert without flowers:
   Worldview:
   - NDVI - Desert without flowers
   - Environmental conditions: a) Precipitation, b) Temperature,
   - Generate a video in Worldview with each data set queried.

   EO Browser (see tools in Fig. 7):
   - False color, NDVI, Moisture Index (NDWI - Soil Moisture), SWIR (Short Wave InfraRed - the amount of water present in the vegetation and in the soil).

On the images in the EO Browser of the blooms (2017 and 2021) and the desert without blooms, perform the following:
1. View the false-color images and analyze the changes.
2. Select the NDVI index (on the left side of the screen) and then the histogram (on the right side of the screen). Compare the results of the images. You can draw the site and then select the histogram to measure a specific area.
   a. Do the same for NDMI (Soil Moisture Index) and SWIR (to know the water in vegetation and soil).
   b. Refer to the **histogram** (on the right side of the screen), open the menu of the index you are observing (on the left side) to see the color reference. Analyze the histogram by comparing the values with those of the reference.
   c. You can draw an area and do the same analysis for that particular sector.
3. To make the **combination of bands,** go to customize (left below) and select **composite**.
   a. Drag the bands to the circles to make the RGB combination: (R) 8A, (G) 11, and (B) 12. Also, try with the combination of RGB bands: (R) 8, (G) 4, and (B) 3.
   b. Compare the sharpness with which you observe the vegetated area concerning the previous visualizations.
4. **Generate an index.** Indices have been developed to visualize flowers (for application to canola crops and their yellow flowers), but they do not apply to this type of flowers. Instead, the Normalized Difference Infrared Index (NDII) measures

the water content of vegetation canopies and is more precise for detecting the area with plants in the desert.

    a. Go to Customize (bottom left) and select **Index**. The formula for placing the bands will appear. Site A (place band B8) and at site B (place band B11) correspond to the following calculation:

$$NDII = (NIR - SWIR\ 1) / (NIR + SWIR\ 1)$$

$$NDII\ (Sentinel\ 2) = (B8 - B11) / (B8 + B11)$$

    b. Then, go to the **threshold** and select a color palette to colorize the image.

5. Make a presentation comparing the results in both blooms and of the desert without flowers.

What to do and how to do it

- **Beginning**

Show your students the following videos: a) NASA Remasters Nearly 20 Years of Global Rain, b) *Climate Change Could Affect Global Agriculture Within 10 Years* y c) *Introduction to the Electromagnetic Spectrum* Also, the websites: a) Eyes on the Earth, b) Sentinel 2 Bands and Combinations

Then share ideas about the usefulness of satellite information for making decisions in daily life. Also, about the use of different waves of the electromagnetic spectrum to obtain information about the Earth.

- **Development**
  1. Ask students to read the introduction to this activity and make a concept map with the information. *(The introduction provides the basic fundamentals of remote sensing with links to further information or clarification.)*
  2. Divide the class into groups and assign a case to each group to analyze.
     a. Look at the current satellite image on Google Maps. What do they see in that image (forest, desert, cities, roads, rivers, etc.)?
     b. Analyze the climogram of rainfall and temperature averages for that location.
     c. Look up the environmental conditions during the events analyzed and make a video in Worldview.
        i. *Note*: In WorldView, you can change the month and year at the lower left.
     d. Consult the EO Browser images and analyze the band combinations and indices. Use the combinations and indexes shown (if you wish, you can try different bands and analyze the display).
  3. Ask your students to prepare a presentation on the analyzed case. They can make a story with maps (using ArcGIS StoryMaps), a slide presentation, or a video.
  4. Bring all the groups together and ask them to explain the cases analyzed.
  5. Complete the concept map with the main characteristics of each case analyzed.

- **Closing**

Due to the relevance of both events, it is essential to develop dissemination materials. Students can elaborate a story with maps (Story Map), a video, or flyers to post on social networks summarizing the cases analyzed.

Frequently asked questions:

Where can I find satellite images? - Worldview - Google Earth - Google Map

Where do I find forest cover information? Global Forest Watch (GFW) has a wealth of information on forests.

Where do I find information on global environmental conditions and population? ResourceWatch brings together information from different sources.

Suggested Resources

As an extension of this activity, students can consult satellite images from different dates and locations to explore other sites of interest and even different events. You can use the GLOBE Program protocols to make manual measurements in your environment or download data from measurements made by others. You can also make environmental measurements to complement your research based on satellite imagery.

Websites:

– Esri. (2023) *Indices gallery.* ArcGIS Pro 3.0 https://pro.arcgis.com/en/pro-app/latest/help/data/imagery/indices-gallery.htm
– GISGeography (2022) *Sentinel 2 Bands and Combinations.* https://gisgeography.com/sentinel-2-bands-combinations/
– NASA. (2023) Eyes on the Earth. https://eyes.nasa.gov/apps/earth/#/
– USGS (2021) *Common Landsat Band Combinations.* https://on.doi.gov/3wAKJvd
– USGS (2022) *What are the best Landsat spectral bands for use in my research?* https://on.doi.gov/3HEMdLf

Videos:

– NASA Climate Change (2021) *How NASA Satellites Help Model the Future of Climate.* Youtube: https://youtu.be/iAUFVUzZIhI
– NASA Climate Change. (2021) *NASA's Earth Minute: Dishing the Dirt.* Youtube: https://youtu.be/hgsIFyITvJE?si=zBZXPyvjRbi5wIvy
– NASA Climate Change. (2021) *NASA's Earth Minute: Earth Has a Fever.* Youtube: https://youtu.be/nAuv1R34BHA?si=AJHU9ZxNf6qDu2pj
– NASA Climate Change. (2021) *NASA's Earth Minute: Cloudy Forecast.* Youtube: https://youtu.be/UCVn_IODeys?si=jyecSHoKZHf-w0WK
– NASA Climate Change. (2021) *NASA's Earth Minute: Blowin' in the Wind.* Youtube: https://youtu.be/UCVn_IODeys?si=jyecSHoKZHf-w0WK
– NASA Climate Change. (2021) *NASA's Earth Minute: My Name is Aerosol.* Youtube: https://youtu.be/4eh6IKahbok?si=QISVr_NmynXoqWQm
– NASA Climate Change. (2021) *NASA's Earth Minute: Mission to Earth?* Youtube: https://youtu.be/R8hh_l3l9Ao?si=WBOWIpw23UkhyREB
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– NASA (2019) *Two Decades of Rain, Snowfall from NASA's Precipitation Missions.* https://youtu.be/qNlRQgACTFg?si=c95YgYXQ3yXQDb-P
– NASA en Español (2021) *Climate Change Could Affect Global Agriculture Within 10 Years.* Youtube: https://youtu.be/-NZIvvhGlR0?si=av2opPTE48KSuwCT
– ScienceAtNASA (2011) *Tour of the Electromagnetic Spectrum 3. Microwaves.* Youtube: https://youtu.be/UZeBzTI5Omk [Español. Traducido por: Antenas y Salud (2015) *El espectro electromagnético 3. Microondas.* Youtube: https://youtu.be/OCxFv_KDdZE]
– ScienceAtNASA (2011) *Tour of the Electromagnetic Spectrum 4. Infrared Waves.* Youtube: https://youtu.be/i8caGm9Fmh0 [Español. Traducido por: Dpto. Electricidad Electrónica (2017) *El espectro electromagnético 4. Infrarrojo.* Youtube: https://youtu.be/DgZKWfRRxKw]
– ScienceAtNASA (2011) *Tour of the Electromagnetic Spectrum 5. Visible Light Waves.* Youtube: https://youtu.be/PMtC34pzKGc [Español. Traducido por: Dpto Electricidad Electrónica (2017) *El espectro electromagnético 5. Luz visible.* Youtube: https://youtu.be/BVbbkzygf94]
– ScienceAtNASA (2011) *Tour of the Electromagnetic Spectrum 6. Ultraviolet Waves.* Youtube: https://youtu.be/QW5zeVy8aE0 [Español. Traducido por: Eldador (2011) *El espectro electromagnético 6. Luz ultravioleta.* Youtube: https://youtu.be/lOKEbZgB2lI]
– ScienceAtNASA (2011) *Tour of the Electromagnetic Spectrum. Introduction 1.* Youtube: https://youtu.be/lwfJPc-rSXw [Español. Traducido por: Antenas y Salud (2015) *El espectro electromagnético. Introducción 1.* Youtube: https://youtu.be/K-up0o96Vhw]

Other resources:

Tutoriales de: Worldview (short video, Complete video, Website, ideas for the classroom) EO Browser (Website o video, infographic), Story Map

Traducción automática: Videos, Website

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