teach with space

→ INVESTIGATING SNOW

Mini Case Study for Climate Detectives

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FAST FACTS

Subject: Science; Biology; Chemistry; Earth Science

Age range: 12-17 years old

Type: Project activity

Keywords: Snow; Climate Change; Cryosphere; Earth Observation; Science; Biology

LEARNING OBJECTIVES

- Be able to work scientifically by collecting data, making careful observations, looking for patterns and relationships.
- Gaining knowledge about snow and its characteristics
- Understand the relation between Snow cover and Climate Change
- Identify the consequences of changes in the snow cover
- Understand how Earth observation satellites can be used to monitor changing snow cover and snowing events during several years

Brief description

The mini case Studies for Climate Detectives are intended to help teachers identifying the topic that their Climate Detectives team will investigate and to guide them during the different phases of the project. In the template, teachers will find suggestions of different types of data that students could collect and analyse. The suggestions are not exhaustive, and the teachers may decide on their own specific focus within a given research area. The mini case study should be used in conjunction with the teacher guide and not as a standalone document.

This case study is dedicated to the topic of **Snow and Climate** and students will investigate the links between snowing events, snow cover and climate change.

About Climate detectives

Climate Detectives is a school project for school students run by the European Space Agency (ESA) in collaboration with the national European Space Education Resource Offices (ESEROs) throughout Europe.

In this project students will embrace the role of Climate Detectives while learning about Earth's environment. For that they will identify a local climate problem (Phase 1), investigate it by using real satellite images or their own ground measurements (Phase 2), and finally propose actions to help reduce or monitor the problem (Phase 3).

RESEARCH QUESTION PLANNER

START HERE

Does the question fit the theme of the investigation?

Yes. Snow and snow cover themes are relevant from both climate and climate change perspectives.

Topic: Snow and Climate

Research Question

Last winter, how long did the snow cover last in your area? Are there differences when comparing several years?

Yes. The data on global and national snow coverage and snow situation are freely available, and there are several options for gathering primary data depending on time and resources.

Is the question feasible (consider timeframe, access to resources, student capability)?

No. It involves data search and interpretation and use of Earth Observation monitoring data.

Is the answer to the question too readily available?

Yes. It is clearly defined and testable in school.

Is the question clear and concise?

No, because the main research question focuses on comparing the duration of snow cover over a few years, and with additional research questions you can broaden the topic even further.

Is the question too broad or too narrow?

Yes. It is focused on snow coverage and duration of the snowy season.

Is the question focused on a single problem or issue?

Additional Research Question

For younger ages:
If Santa didn´t have a magic sled, how far/how close to your home would he have gotten last Christmas?

Teams from an area with no snow could investigate changes in snow cover on a global level and try to answer the question:
What could the impacts of a snow-free winter be (increase of temperature; impact on water resources and water bodies and biodiversity; socio-economic impacts)?

A – Introdution to the topic (PHASE 1)

"Seasonal snow cover is the largest single component of the cryosphere (*), covering 50% of the northern hemisphere's land surface during mid-winter, and is an important component of the climate system. (...) Snow is also a major, if not dominant, freshwater source in many alpine, high- and mid-latitude regions [and] an important contribution to the global water cycle." **ESA CCI Snow Project**

(*) Cryosphere refers to the regions on Earth where it is possible to find snow or ice. The different components of the cryosphere are snow, sea ice, lake and river ice, glaciers, permafrost, icebergs, ice caps, ice sheets and ice shelves.

Background information

According to the European Environment Agency, over the period 1967–2015, snow cover extent in Europe has decreased by 13 % on average in March and April and by 76 % in June (1), with the biggest changes taking place in summer. Snow cover is the land area blanketed in snow at a given time and its very sensitive to changes in temperature and precipitation. Snow cover cools the climate, as it effectively reflects the sun´s radiation i.e. it has high albedo (reflectivity). Due to its impact on Earth's climate, snow cover is specified as an Essential Climate Variable (ECV) by the Global Climate Observing System (GCOS). Teachers can introduce the topic of albedo with this game from the ESA Climate Change Initiative (CCI).

The following classroom resources can also be used to introduce students to the concept of albedo:
- The ice is melting (Primary education)
- The greenhouse effect and its consequences: Investigating global warming (Secondary Education)

These additional resources can also be used to learn more about:
- Weather vs climate
- Climate Change: The evidence from space
- Snow and ice
- Snow: why it matters

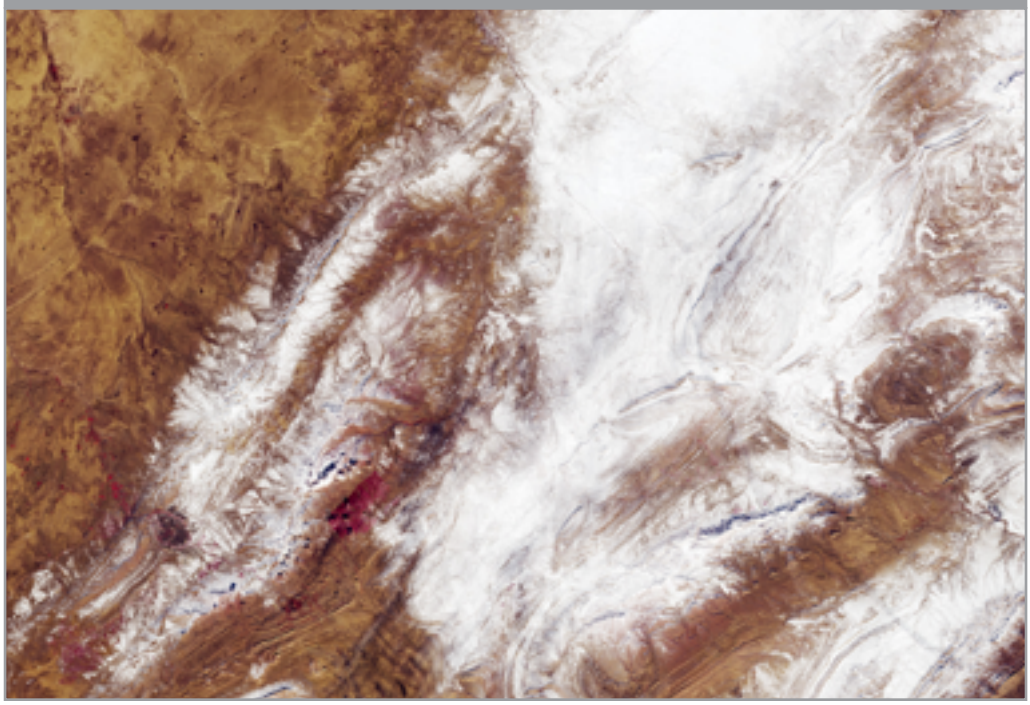
Engage students

To start the discussion in the classroom and stimulate students' prior knowledge about the topic, the following small facts can be discussed:
- **What is snow?**
  Snow is precipitation made up of ice crystals that forms when water vapor freezes. When the crystals get heavy enough, they fall as snowflakes. Snow is not frozen rain such as sleet.
- **Is it true that no two snowflakes are alike?**
  The form of each snowflake is different because they all have a different whirling, spinning route down to the ground. There is only the tiniest possibility of similarity. Since there are countless numbers of snowflakes, it is difficult to check them all! Physicist Kenneth Libbrecht of the California Institute of Technology showed that snowflakes can also create twins. See here for more information.
- **How many molecules are there in a snowflake?**
  Even if a snowflake starts with only six water molecules, even the tiniest snowflake typically ends up with 1 000 000 000 000 000 000 water molecules.

(1) https://www.eea.europa.eu/data-and-maps/indicators/snow-cover-3/assessment/#_edn1

- **How dense is snow?**
  Water density is 1 kg /liter, but the density of snow varies greatly. In severe frost with no wind, snowflakes can be very fluffy and light (0,05 kg /liter), but in warmer temperatures and hard wind, snow can be very wet and thus heavy (0,8 kg / liter).
- **Where can we find snow?**
  Although we associate snow with high latitudes, snow falls all over the world, even near the equator at high elevations. It is even possible to find snow in the Sahara Desert.

Figure 1



↑ Sentinel-2A satellite happened to be in the right place at the right time to record a rare snowfall event in the Sahara Desert. This image contains modified Copernicus Sentinel data (2018), processed by ESA, CC BY-SA 3.0 IGO.

- **Why is snow important?**
  Snow plays a big role in Earth's climate. As snow is white, it reflects almost all the heat from the Sun back into space, preventing it from warming the planet. Without snow cover, the ground absorbs about four to six times more of the Sun's energy. On a more local scale, snow cover is important for many plants and animals. Snow also impacts water supply, hydropower generation and local economies.

The following hands-on activity can also be done to engage students on the topic:

→ Activity 1 – Do-it-yourself snow

Location: Indoors/ Regular classroom
Equipment: Shaving foam, baking soda, corn flour or potato flour, bowls, spoon, tablespoon, food colouring (optional)

1. Add 2 large spoons of corn flour or potato flour to bowl number one. Add about the same amount of shaving foam.
2. Add 2 tablespoons of baking soda to bowl number two. Add about the same amount of shaving foam.

3. Stir both bowls with a spoon. Once you have mixed the ingredients, use your hands to play with the mixtures. Which one feels more like snow?

Additional information: There are different types of snow. For example, it can be wet or dry. Both versions in this experiment are more like wet snow, although with corn flour the snow will be a bit firmer and not as fluffy. A wet snow or slush occurs when the air temperature near the surface is above freezing. This causes the snowflakes to partially melt before reaching the surface. Wet snow is more sticky than dry snow, so it is easier to construct snowballs with it than with dry snow. Dry snow is powdery, fluffier, and not sticky, and it occurs when the air temperature is below freezing. Dry snow is light and easy to handle, but in windy weather can cause poor visibility.

This experiment can also be used to start a discussion around the fact that ski resorts increasingly rely on artificial snow and that changes in snow can also have economic impacts. Students can also discuss the ecological impact of artificial snow and its impact on climate change: *What is the energy and CO_2 assessment of artificial snow?* This image of snowless ski slopes from space can be used to trigger the discussion.

Did you know?

Up north in the Sápmi region (north of Norway, Sweden, Finland, and Russia) live the Indigenous people called the Sami. In the Northern Sami language, they have more than 200 words to describe the quality and condition of the snow. But they do not have a word for artificial snow.

Investigation plan

Now that your team is engaged in the topic and has decided on a research question, it is time to plan which data your team needs to collect. The final step in Phase 1 of Climate Detectives is submitting an investigation plan. Teachers can find ideas for data collection in section B.

B – Data collection and analysis (PHASE 2)

Data to be analysed

To investigate the topic of snow, students can collect and analyse data from several sources. Depending on time availability, teams can choose from one or more data sources listed below to conduct their research. There are two types of methods to monitor snow cover: ***in situ*** measurements and **remote sensing** observations, for example from satellites. In-situ means "situated in the original place". These measurements are provided by institutions and agencies at the regional, national and global level. Teams can also make their own observations and collect data from their own measurements. We call this **primary data**.

Global Satellite Data

The use of satellite imagery represents a useful support for snow cover mapping as some of the areas covered with snow are very isolated and inaccessible. Satellite data can be accessed online in different platforms:

- Climate from Space - interactive website (esa.int) - The Climate from Space app provides a graphical visualisation of archived satellite data and offers an overview of the different climate variables that scientists use to study climate change. It is possible to see the evolution of snow cover at a global level over time (1979-2017).
- EO Browser's Education mode gives the option to access specific satellite data tailored to a selected theme. Students can select Theme Snow and Glaciers and choose one of the visualisation options available: *True color, Highlight Optimized Natural Color, Normalised Differentiate Snow Index (NDS) or Snow Classifier.* They can use a timelapse function to see the difference in glacier sizes or snow coverage during the years. You can find a QuickStart guide for EO Browser here.
- https://climate.rutgers.edu/snowcover/ includes various data from the Rutgers University Global Snow Lab. Students can find tabular data, maps, graphic products, and information regarding global snow cover extent across the Northern Hemisphere, daily, weekly or monthly. Here students can find data regarding the weekly area of snow extent (1966-2022).
- The European Environment Agency shows satellite-derived time series of snow cover extent for the period 1967–2015 over the Northern Hemisphere and Europe.

Figure 2

↑ This Copernicus Sentinel-3 image shows the snow cover in the Alps. Students can access Sentinel-3 data using EO browser. This image contains modified Copernicus Sentinel data (2022), processed by ESA, CC BY-SA 3.0 IGO

Teams are also encouraged to find and analyse data from national and international agencies and institutions relative to their countries/area of investigation.

Primary data/hands-on-activities

Snow can be studied from several perspectives, and students can collect their own measurements. Scientists study different properties of snow, such as the different structures of snow crystals, the snow height, the layer structure, the snow water equivalent /density, or even the purity of the snow, to name a few. The activities below are suggestions of measurements that can be done by students to investigate some of the properties of snow.

Figure 3

↑ Snow profile measurements during a field experiment campaign. Ground measurements are very important to validate and better interpret satellite data.

→ Activity 2 – Investigate your own snow crystals

Location: Outdoors - nice, snowy weather
Equipment: Snow traps, which are plates and loupes cut from dark cardboard, magnifying glasses

Students can use dark cardboard to catch falling snowflakes, and then observe them using the magnifying glass. The shapes of snow crystals stand out best when examined against a dark surface. A magnifying glass can be placed on top of the snow trap, making the details stand out.

Did you know?

A crystal is a solid material that has an organized structure. When a snowflake, or snow crystal, is blown through the air, it gathers more water molecules and continues to grow. The structure of each snowflake can give scientists information about the weather conditions it was experiencing while being formed.

→ Activity 3 – Snow height

Location: Outdoors - nice, snowy weather
Equipment: Snow measuring stick

Students measure the height of snow cover in a few areas and calculate the average of the height of the snow cover. When using the measuring stick, make sure the stick is pushed vertically into the snow until the bottom of the stick rests on the ground. Try to select areas where the snow has not been disturbed by human activities.
Students can make measurements through the winter and investigate how the height of the snow cover varies in time and space.

→ Activity 4 – How much does snow weigh and how much water is in snow?

Location: Indoors and outdoors in nice, snowy weather
Equipment: Snow, two similarly sized glass jars or measuring glasses, weighing scale, pen

5 centimetres of snow is not the same as 5 centimetres of water. This easy experiment measures the amount of water found in snow.
Students start by collecting samples of snow, if possible, from different locations. Next, they fill the two glass jars with the collected samples. Use a pen to mark the glass jar at the snow line and measure both glass jars' weight. Students should hypothesise how much water comes out of the snow as it melts.

Did you know?

The same amount of wet snow can contain 2 to 3 times more water than the same amount of the dry snow, meaning wet snow is much heavier than dry snow. In extreme cases, wet snow can cause some structural damage, for example by collapsing roofs. Due to its weight, wet snow can also destroy burrows under the snow used by small animals.

→ Activity 5 – How clean is the snow?

Location: Indoors and outdoors in nice, snowy weather
Equipment: Snow, filter paper, magnifying glasses, hot water

Students start by collecting samples of "clean" and "less clean" snow. They then put each sample in a coffee filter and melt it with hot water. The used filter paper can be cut into pieces with scissors and examined with a magnifying glass. Usually, dust particles remain on the paper. Sand, pollen, hair, and debris from trees are often found in snow taken from the ground.

Additional information: To form, a snowflake needs a particle for compaction, around which snow crystals begin to form. These particles can be, for example, air pollutants, bacteria, sea salts or nitrates. In addition to this, birds frolicking on top of the snow, cars driving by, domestic animals and we humans pollute the snow after it lands on the ground.
Snow pollution can have negative impacts on the environment. Sometimes you can see snow which has a black color which is snow that has been contaminated by pollutants such as soot, oil, and other materials. This can happen when snow falls in areas with high levels of air pollution, or when snow is contaminated by industrial activities. Pollution generated by burning fossil fuels causes snow to

darken, which reflects less solar energy and melts faster. Polluted snow can also be harmful to plants and animals.

Did you know?

Sandstorms from the Sahara can sometimes travel all the way to Europe. When snowfall hits, a snow crystal forms around a particle of Sahara sand. The resulting snowdrifts look orange, their dirtiness observable with the naked eye. The phenomenon happens more often in Southern Europe, for example in the snow resorts of the Alps, but it is possible for the phenomenon to happen almost every year or several times a year in Northern Europe as well.

Teams can also collaborate with research institutions and research projects at European level as for example the CHARTER Project that created a very complete "Snow Protocol" available here.

Analysing data

After collecting data it's important to analyse findings. Students may use the following questions to evaluate whether their findings answer their research question:

- What does the data show? Are there obvious trends/patterns?
- Are there any readings that don't seem to make sense? Can they be explained?
- Can any conclusions be drawn from the findings?
- Is further research required?

C - It is time to MAKE A DIFFERENCE! (PHASE 3)

What actions could students take as individuals or as a community to make a difference regarding the topic of their investigation? Actions do not need to be limited to school time; for example, students could take home ideas and involve their families to put them into practice in their everyday lives or give a presentation or host a campaign at their school or local community to raise awareness.

→ TASKS AS CLIMATE DETECTIVES

Student Worksheet

A – Introduction to the topic to be investigated (PHASE 1)

- *What do you know about the topic of snow and snow cover?*
- *What would you like to know about the topic of snow and snow cover?*
- *How does the topic that you will investigate affect/relate to you, your community or your local environment?*
- *What is the role of snow in Earth´s climate?*
- *Describe how you plan to investigate the climate problem and which data you plan to analyse. (For the Investigation Plan)*

B – Data collection and analysis (PHASE 2)

- *Investigate how snow cover varies over time in Earth Observation pictures and in the data sources suggested by your teacher.*
- *What does the data show? Does the data match the Earth Observation imageries?*
- *Interview people living around the area of your investigation to discuss the evolution of snow cover over the years.*
- *What is the impact of climate change in snow coverage? And what is the impact of changing snow coverage on climate change?*

C - It is time to MAKE A DIFFERENCE! (PHASE 3)

Your work as a Climate Detective is now complete. What actions could you propose, as individuals and as a community, to make a difference regarding the topic of your investigation?

→ Links

ESA resources

Climate Detectives Teacher Guide
https://climatedetectives.esa.int/wp-content/uploads/2023/09/Climate-detectives_teacher-guide_2023.pdf

Climate Detectives classroom resources
https://climatedetectives.esa.int/resources/?_categories=classroom-resources

Climate for schools – Resources from the Climate Change Initiative
https://climate.esa.int/en/educate/climate-for-schools/

Background information

What is Climate and Climate Change
https://climate.esa.int/en/evidence/what-is-climate-and-climate-change/

Climate Change: the evidence from space
https://climate.esa.int/en/evidence/observations-change/

ESA CCI Snow project
https://climate.esa.int/en/projects/snow/

Snow and ice — snow, glaciers and ice sheets
https://www.eea.europa.eu/publications/europes-changing-climate-hazards-1/snow-and-ice/snow-and-ice-snow

National Snow and Ice Data Center
https://nsidc.org/learn

Data collection and analysis

Climate from Space app
https://climate.esa.int/en/explore/climate-from-space/

EO Browser
https://apps.sentinel-hub.com/eo-browser-education/

Rutgers University Global Snow Lab
https://climate.rutgers.edu/snowcover/

European Environment Agency
Data visualisations — European Environment Agency (europa.eu)

CHARTER Research Project
CHARTER research project homepage: Drivers and Feedbacks of Changes in Arctic Terrestrial Biodiversity (charter-arctic.org)

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