THE GLOBE PROGRAM

GLOBE TY: Weather

Description: This module introduces the atmosphere; it includes a classroom discussion and outdoor based hands-on activities to investigate weather

Age: Designed for Transition Year

Time Required: Variable – 1 x 45-minute class ideal for each activity (cloud, rainfall, wind)

Purpose: Learn about the atmosphere through cloud and weather observations

Tools required: Please see individual activities for activity specific tools

Optional extras: Weather station, weather recording equipment

Supporting documents: Are you a registered GLOBE teacher? See the GLOBE weather protocols

Teacher Training/Guide: https://www.globe.gov/get-trained/protocol-etraining/etraining-modules/16867642/12267

https://observer.globe.gov/do-globe-observer/clouds/taking-observations

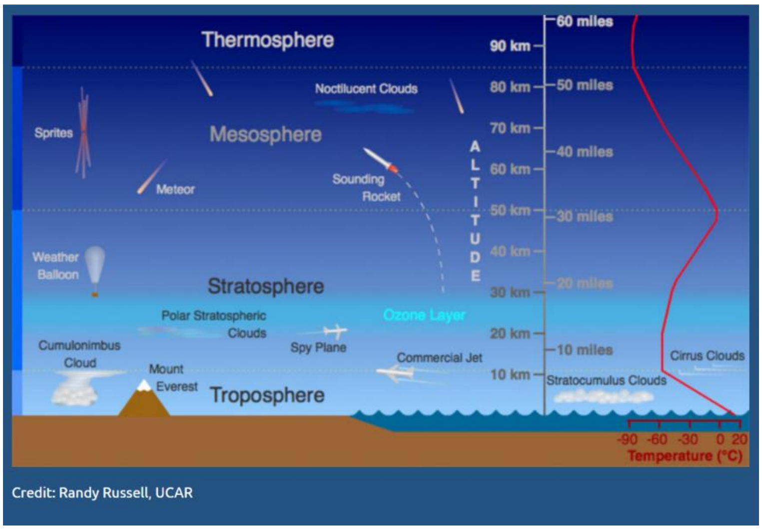
Introduction to the Atmosphere (sourced UCAR center for science education)

The Earth's atmosphere is an extremely thin sheet of air extending from the surface of the Earth to the edge of space. The Earth is a sphere with a roughly **12,742 km diameter**; the atmosphere, in comparison has a thickness of approximately **400 km**.

The Earth's atmosphere has a series of layers, each with its own specific traits. The layers are the: troposphere, stratosphere, mesosphere, thermosphere, and the exosphere (not all scientists include this layer!)

Over 99% of the mass of the Earth's atmosphere is contained in the two lowest layers: the troposphere and the stratosphere.

Most of the Earth's atmosphere (80 to 90%) is found in the troposphere, the atmospheric layer where we live. Gravity is the reason the atmosphere is denser closer to the Earth's surface, in fact, **Earth’s gravity is why we have an atmosphere at all!**



Credit: Randy Russell, UCAR

Moving upward from ground level, these layers are named:

- Troposphere
- Stratosphere
- Mesosphere
- Thermosphere
- Exosphere (uppermost reaches, not all scientists count this layer!)

Let us begin with examining the **troposphere**, this is where we see clouds and where almost all the weather takes place. It is also the wettest part of the atmosphere. The troposphere is the air we see and breathe!

Student/Teacher discussion: Brainstorm knowledge around the atmosphere and what we can see from the Earth’s surface. Suggestions for questions to answer include:

- What is the driving force behind the weather we observe?

The answer is **unequal heating**! The equator receives more energy from the sun per km sq. This unequal heating drives the movement of energy (heat) from the warm equator to the northern and southern hemispheres. Air masses and ocean circulate around the globe to reach a state of equilibrium.

- What causes the sky to change colour?

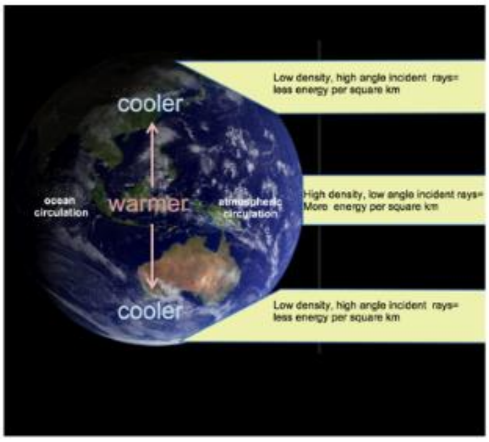
Sky colour is an indication of the number of **aerosols in the atmosphere**. Aerosols are very small liquid or solid particles suspended in the atmosphere. Aerosols tend to scatter all wavelengths of light, making the sky become whiter, while deep blue suggests very few aerosols present. A milky sky suggests there are lots of aerosols. Common natural aerosols include salt, water droplets, pollen, and dust.

Uneven Heating of the Earth Drives Air and Ocean Circulation

The unequal heating of the Earth's surface drives air and ocean circulation and causes climate to vary by latitude.

Air and water circulation is initiated at the equator, where insolation is greatest. Masses of air and ocean transport heat energy from areas of high concentration to low concentration.

The movement of these masses of air and ocean establish an equilibrium state of heat distribution which we determine the general climate bands, or zones that we see at different latitudes.



At the higher latitudes, solar energy reaches the Earth as Low density, high angle incident rays, so there is less energy reaching the Earth's surface per km2, compared to the equator. Image: Blue Marble from NASA Earth Observatory

Why do Clouds form?

Clouds are created when water vapor, an invisible gas, turns into liquid water droplets. It happens when water vapor encounters cold air and condenses, turning into liquid water. We see it on the ground as clouds. When the tiny water droplets become too heavy, they start to fall to the ground as rain. Clouds are an indication of a change in air pressure or temperature. It is interesting to study clouds as they tell us something about the current atmosphere conditions.

Short Activity on Ireland’s climate, and weather versus climate meaning!

1. **Ask students to discuss or write 1-3 sentences describing Ireland’s Climate – see below for a description from Met Eireann**

   The dominant influence on Ireland’s climate is the Atlantic Ocean. Consequently, Ireland does not suffer from the extremes of temperature experienced by many other countries at similar latitude. The warm North Atlantic Drift has a marked influence on sea temperatures. This maritime influence is strongest near the Atlantic coasts and decreases with distance inland. The hills and mountains, many of which are near the coasts, provide shelter from strong winds and from the direct oceanic influence. Winters tend to be cool and windy, while summers, when the depression track is further north and depressions less deep, are mostly mild and less windy.

2. **Ask Students to discuss the difference between weather and climate**

Weather is a description of short-term changes in the atmosphere, over minutes, hours, or days. It is described with words like sunny, cloudy, rainy, or windy.

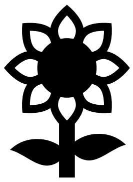
Climate is a longer-term description of typical atmospheric conditions around a defined geographical area. To determine what the climate of a place is like, scientists average at least 30 years of weather data (also called long-term averages or ‘Normals’). The period of 30 years is considered long enough to smooth out year-to-year variations. For more information check out NOAA (US National Oceanic and Atmospheric Administration) article and resources.

Why Study Clouds?

Clouds affect the temperature and energy balance of the Earth and play a significant role in controlling the planet’s long-term climate.

Cloud observations made by people, such as GLOBE participants, are an important part of the ground truth activity (or validation of observations by satellites) and contribute to our larger understanding of the role clouds play in our weather and climate.

Observing clouds can help students connect with nature as they spend time looking at the ever-changing sky.



Time for an outdoor activity!

Outdoor Classroom Activity 1: Identify cloud type and height in the sky

Difficulty Rating: Easy

GLOBE Teacher e-training on Clouds: https://www.globe.gov/get-trained/protocol-etraining/etraining-modules/16867642/12267 and instructions for taking observations using the GLOBE observer app https://observer.globe.gov/do-globe-observer/clouds/taking-observations

Tools Required: You may record your observation using the attached cloud worksheet or the GLOBE Observer App. If manually recording you will need a pencil, and the recording worksheet, otherwise bring your phone and use the Clouds protocol on the GLOBE Observer app.

Activity Learning Outcomes: Develop observational skills, estimating, and recording accurately

Method:

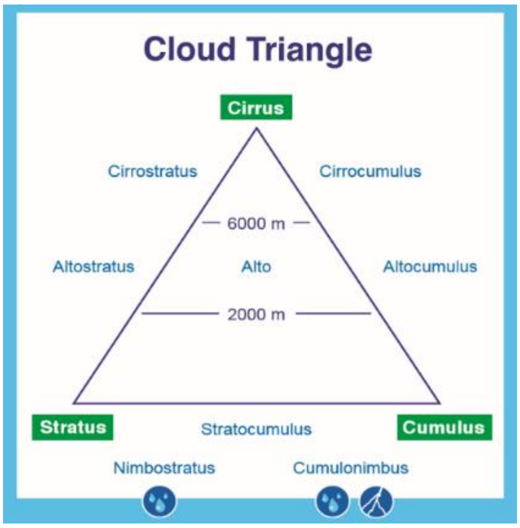
- Before you leave the classroom, review the cloud shape identification slide below and tips on determining cloud cover and level (height)
- Find an appropriate location to observe the sky, try to move away from any obstructions such as nearby buildings
- Encourage students to take their time and begin by observing all parts of the sky (5-10 minutes)
  - Do students think they have a good view of the sky?
  - How many cloud types can they observe?
  - Sketch the shape of the different clouds
- When you are ready, begin completing the cloud observation worksheet or use the GLOBE Observer app to record your observations (10 minutes)

Cloud Types: there are 3 main cloud shapes

Cumulus (Puffy): Made of water, cumulus clouds can be associated with fair weather. They are usually not very tall and they are separated from each other with lots of blue sky in between.

Stratus (Layered): Made of water. These clouds can be found from Earth's surface to 2,000 m high. When you see the Sun's disk through them, the edges look sharp.

Cirrus (Wispy): Made of ice crystals and are considered "high clouds", forming above 5,000m. They generally indicate fair to pleasant weather. The reason for the long tail is primarily due to high speed winds at high altitudes.



The Cloud Triangle is a useful memory device

Clouds can be defined according to:

- Their shape
- The cloud base altitude
- Whether they are producing precipitation

How to Observe: Cloud Cover

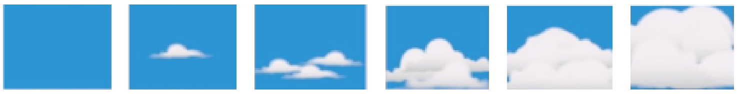
You will estimate the total cloud cover of the whole sky and at each level (high, mid, and low levels).

It may be helpful to divide the sky in 4 quadrants (North, South, East, and West) and estimate cloud cover in each, then take the average to get the whole sky value.

Tip:

Observe the sky overhead, excluding the horizon. This can be done by:

- observing above 14°,
- or holding your arms out in a "V", hands even with the height of the top of your head, and observing between your hands,
- or holding your fist out at arm's length, even with the horizon; putting your second fist on top of the other; observing the sky from above the top of your second fist.



No Clouds (0%)	Few (0-10%)	Isolated (10-25%)	Scattered (25-50%)	Broken (50-90%)	Overcast (>90%)

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How to estimate cloud cover for the whole sky at each level. People tend to over-estimate cloud cover, if you are close to a transition between two categories, perhaps choose the lower category!

Cloud Level – useful tips from GLOBE to help determine cloud level (height) for cumulus and stratus clouds

Tip:

For Cumulus (puffy) clouds, use fist/thumb/pinky finger strategy to estimate cloud height.

High clouds (cirrocumulus) appear comparable in size to pinky finger held at arm's length.

Mid-level clouds (altocumulus) appear comparable in size to thumb held at arm's length.

Low clouds (cumulus) appear comparable in size to fist held at arm's length.

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Tip:

For stratus (layered) clouds, look for clues near the Sun.

NEVER look directly at the Sun!

Cirrostratus is the only cloud type which can produce a halo around the sun or moon. The halo will have all the rainbow colors in it.

Altostratus will produce a thinly veiled Sun or moon, and will often be darker in appearance, a medium gray color. The Sun looks dimly lit behind these clouds.

Stratus will usually be very gray and often very low to the ground. They tend to cover a lot of the sky.

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GLOBE Cloud Observation Worksheet (if NOT using GLOBE Observer app)

Student Name:
Today's Date and Time:

1. **What does your sky look like?**

No Observable Clouds ☐

Observable Clouds ☐

Or the view of your sky and clouds is obscured ☐

2. **Cloud cover**

Go to a location where you have a good view of the sky. How much of the sky is covered by clouds? **Select one of the boxes below**. If you hesitate between two boxes, choose the lower value as we tend to overestimate cloud cover.

None ☐
Few (<10%) ☐
Isolated (10%-25%) ☐
Scattered (25%-50%) ☐
Broken (50%-90%) ☐
Overcast (90%-100%) ☐

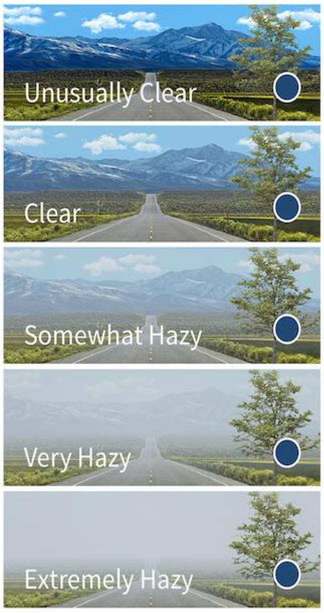
3. **What Colour is the deepest shade of blue in the sky?**

Remember to look at the sky, not the clouds, if no sky is visible tick cannot observe.

Deep Blue ☐
Blue ☐
Light Blue ☐
Pale Blue ☐
Milky ☐
Cannot Observe ☐

4. **What is the sky visibility across the horizon?**

Sky visibility is an indication of the amount of the aerosols/particulate matter close to the surface of the ground. The more aerosols there are, the hazier it will appear. Pick a landmark in the distance and choose the most appropriate description below.



Unusually clear ☐

Clear ☐

Somewhat Hazy ☐

Very Hazy ☐

Extremely Hazy ☐

5. **Observe cloud details according to height in the sky**

High-Level Clouds

Are there any high-level clouds? _________ % cover ______

Type of high-level clouds observed (cirrus (wispy), cirrocumulus (puffy) or cirrostratus (layered))

____

What is the visual opacity of the high-level clouds? (opaque (can't see through), translucent (lets some sun through) or transparent (see through)) ______________________________________

Mid-Level Clouds

Are there any mid-level clouds? _________ % cover ______

Type of mid-level clouds observed (altocumulus (puffy) or altostratus (layered))

____

What is the visual opacity of the mid-level clouds? (opaque (can't see through), translucent (lets some sun through) or transparent (see through)) ____

Low-Level Clouds

Are there any low-level clouds? _________ % cover _______

Type of low-level clouds observed (stratocumulus (layered and puffy), stratus (layered - blanket) or cumulus (tend to have flat base and puffy top), nimbostratus (overcast with steady rain) and cumulonimbus (heavy rain/thunderstorm clouds))

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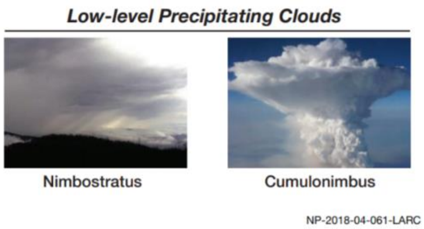
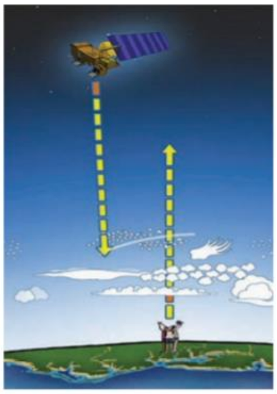


Is it raining? Clouds that precipitate have names with nimbo prefix/suffix. Precipitation can be in any form such as rain, snow, hail, etc. Cumulonimbus clouds are known as thunderstorm clouds and are sometimes called anvil clouds because of their shape. Nimbostratus clouds often bring steady, ongoing precipitation. In Ireland, we see plenty of nimbostratus, the classic drizzly day 😊

What is the visual opacity of the low-level clouds? (opaque (can't see through), translucent (lets some sun through) or transparent (see through) ____

You now have made a complete cloud observation!



Your reports from the ground looking up help NASA better understand our atmosphere and the views from the satellite looking down.

If you have a GLOBE account you can upload your observations here: https://www.globe.gov/globe-data/data-entry

Introduction to the Hydrosphere

Earth is the only planet in our solar system where significant amounts of liquid water flow on the surface. All life depends on water. The water in the atmosphere, which plays an essential role in determining the weather, is part of the larger hydrologic cycle.

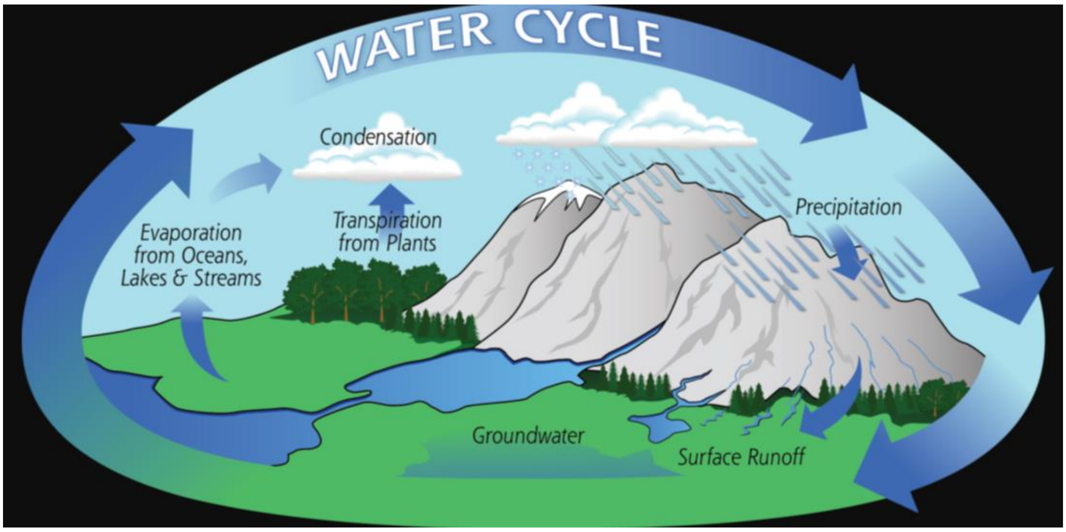


Image source: NASA

Why Record Rainfall?

- Water is essential to life on Earth.
- Precipitation varies greatly from place to place.
- Measuring and mapping precipitation helps us understand weather, climate, and ecological systems.
- Precipitation affects our daily life.
- Rain can wash pollutants out of the atmosphere to the ground surface

Rain gauge measurements sample the amount of precipitation that falls. To get the total amount, we assume that the same depth of water fell over the area surrounding the rain gauge. Prior to the actual placement of the rain gauge, take a walk with your students around the school grounds to locate the best places to put the gauge. As you walk around the school grounds, you could have the students draw a map of the area, including details such as the surface (e.g. paved or grassy). Observing and making a map of the area around the instruments is good scientific practice. Ask “What could be influencing my observations and giving me inaccurate or unrepresentative data?” Remember that your data should be representative of the surrounding area, so using an open area with no obstacle such as trees or buildings would be a suitable site.

Time for an outdoor activity!

Outdoor Classroom Activity 2: **Measuring Precipitation – Rainfall**

Do you have a weather station with a rain gauge at school? If so, recording rainfall is simple! If you do not have a rain gauge you can make your own in class. It is easy, all you will need is a plastic bottle (1 or 2L is ideal), paper clips, and scissors. Please see the appendix for how to make your own rain gauge.

Difficulty Rating: Moderate - more time required if making and installing own gauge (1 class period) and time required to check rain gauge daily (5 minutes)

GLOBE Teacher e-training on Precipitation: https://www.globe.gov/get-trained/protocol-etraining/etraining-modules/16867642/12267

Where do you place your rain gauge?

Method:

- Choose a location away from building and trees
- If you attach your rain gauge to a post, remember to bury the post deep in the ground (approximately 0.2-0.3m)
- Make sure the top of your rain gauge funnel is above the post level
- We recommend that students check the rain gauge daily during the week – record rainfall, empty contents and ensure no debris is in the funnel as this will affect your measurements. For periods where that is not possible, such as over the weekend or holidays, you can record the accumulated rainfall (this will affect accuracy)

Instructions:

1. Build your own rain gauge following instructions in the appendix.
2. Install your rain gauge:

The rain gauge will be attached to a post using a cable tie with the top of the funnel above the post, so that the post does not shadow it from the rain. To ensure that your rain gauge is level, you need to put a carpenter's level across the top of the funnel of the gauge in two directions.

Bury the post 0.2-0.3m based on height of the post.

Image courtesy of the GLOBE Programme.

3. Record your Rainfall amounts using the Rainfall recording sheet

Rainfall Recording Sheet

- **Days of accumulation**: ______
  (Note how many days since the instrument was last emptied. For example, if it was yesterday, note “1” for one day. If it was a week ago, note “7” for seven days, etc.)

- **Accumulated rainfall:**

If you are using a purchased rain gauge: Simply record the **accumulated rainfall** here (in millimetres): ______mm.

Otherwise, if you are using a homemade rain gauge:

- Record the **amount of water present** (in millilitres): _______ml.
- Calculate the **accumulated rainfall** in mm using these steps:
  i. Calculate a constant (c) that will be applied to each rainfall measurement. The formula to find this is:
  $c = 3.142 \times (\text{radius of funnel of homemade rain gauge})^2$
  ii. Divide the amount of water by the constant. This gives you the accumulated rainfall in cm.
  iii. Change this value from cm into mm by multiplying it by 10.
  iv. Record this value here: ______mm. **This is the accumulated rainfall in mm.**

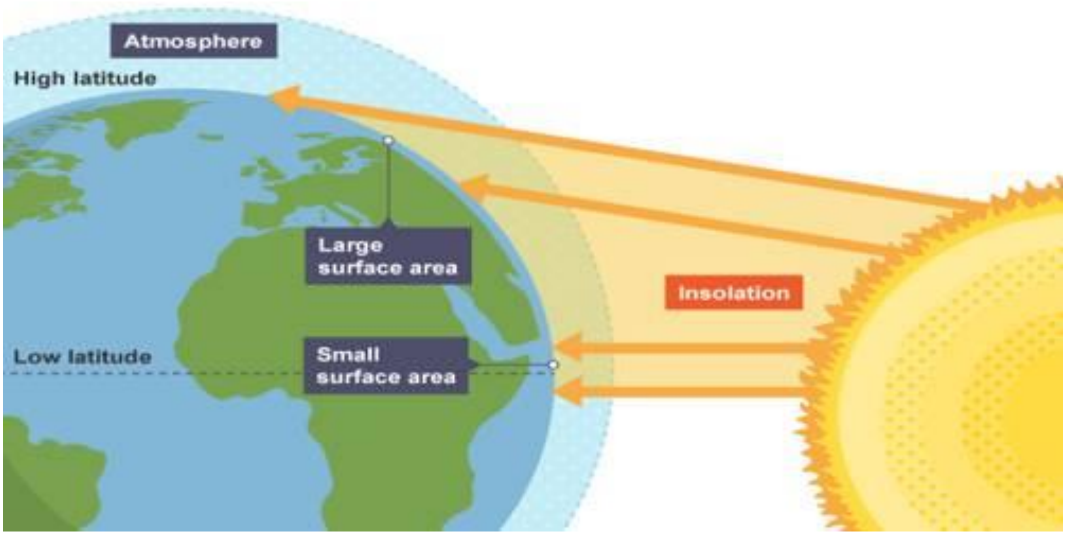
Once the measurement is complete, please empty the rain gauge and place it back in its spot to monitor rainfall.

4. Record rainfall over a period and graph your results. How do your rainfall measurements at your school compare with recorded rainfall at Met Eireann weather stations?

5. If you have a GLOBE account you can upload your observations here: https://www.globe.gov/globe-data/data-entry

Introduction to Wind

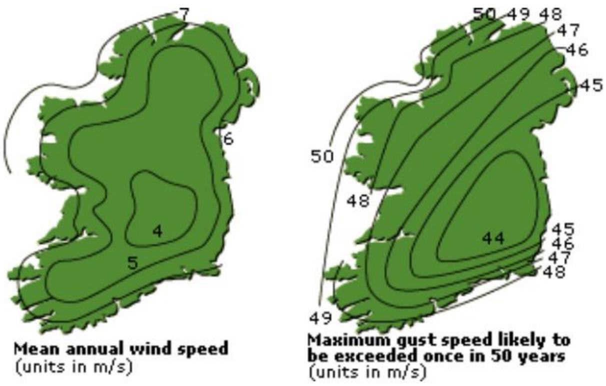
We have already learned that unequal heating drives the weather that we experience day to day. Air circulation begins at the equator where insolation (quantity of sun's radiation received on a horizontal surface area with time) is greatest.



(From: https://www.qsstudy.com/geology/insolation)

WIND OVER IRELAND

The wind at a particular location can be influenced by a number of factors such as obstruction by buildings or trees, the nature of the terrain and deflection by nearby mountains or hills. For example, the rather low frequency of southerly winds at Dublin Airport is due to the sheltering effect of the mountains to the south. The prevailing wind direction is between south and west. Average annual wind speeds range from 3m/s in parts of south Leinster to over 8 m/s in the extreme north. On average there are less than 2 days with gales each year at some inland places like Carlow, but more than 50 a year at northern coastal locations such as Malin Head.



https://www.met.ie/climate/what-we-measure/wind

What about wind energy in Ireland?

Watch: This is an excellent 25-minute Eco Eye programme on Ireland's green energy potential. Watch here

Time for an activity!

Outdoor Classroom Activity 3: Measuring Wind Speed

Do you have a weather station with an anemometer at school? If so, recording wind speed and direction is simple! If you do not have an anemometer you can make your own in class, you will find instructions here: https://www.scientificamerican.com/article/bring-science-home-wind-speed/ - this is a basic device using small cups, it's a good hands-on building experience.

Difficulty Rating: Moderate - time required if making your own anemometer (1 class period), followed by outdoor time to measure wind speed.

Method:

- Choose a location away from buildings and trees
- Count how many times a single cup rotates for a 15 second interval and multiply by 4 to get your revolutions per minute (rpm)
- To convert from **rpm to kilometres per hour (kph)**: To determine this:
    - Calculate the circumference of the circle in centimetres made by the rotating cups by measuring the distance around the circle that they make (using a tape measure or a piece of string you can measure with a ruler)
    - Convert the circumference to km where 1 cm = 0.00001 km
    - Multiply the circumference (km) by your rpm, this will give you km per minute
    - Convert from km per minute to km per hour by multiplying by 60, now you have kph
- Ask students to discuss how accurate this tool is?

Instructions for measuring wind speed:

Build your anemometer in class following instructions here:
https://www.scientificamerican.com/article/bring-science-home-wind-speed/

Additional GLOBE Atmosphere Protocols

If you have your own school weather station or additional weather monitoring equipment, there is e-training on how to measure the following atmosphere protocols on GLOBE

- Aerosols
- Air Temperature
- Relative Humidity
- Barometric Pressure
- Surface Temperature

Don't forget to share your measurements with GLOBE here!

Appendix:

Homemade rain gauge

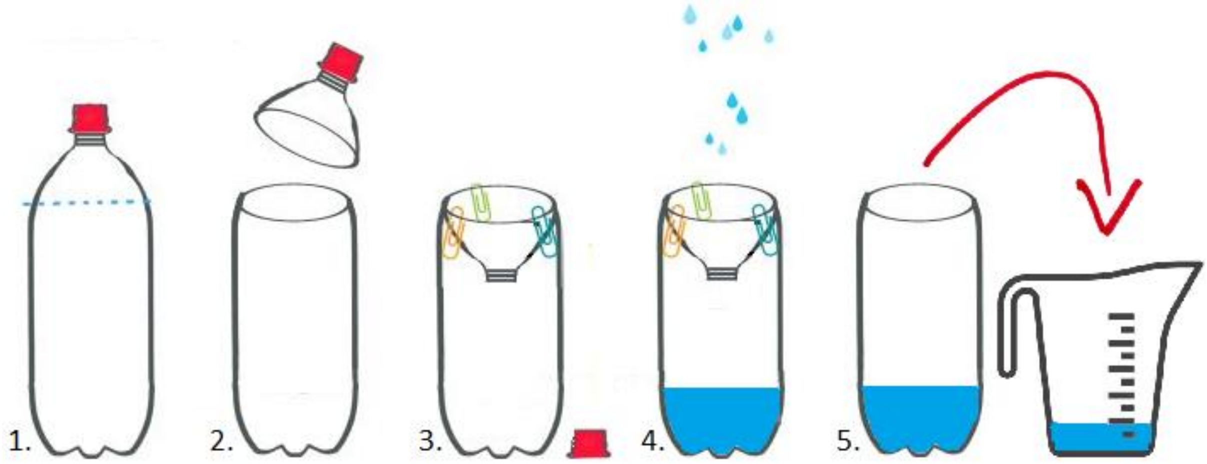


Illustration: Homemade rain gauge.

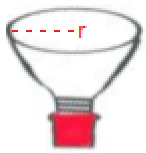
What you will need:

- 1L or 2L Bottle (clean & dry)
- 3 x Paperclips
- measuring jug
- Scissors

Calculate the constant for your rain gauge: you only need to do this once (so keep it safe!).

The formula is:

c = 3.142 x (radius of funnel)^2



where radius of funnel (r) = Half of the diameter of the funnel

Take the measurement:

Step 1: Empty any water present into a measuring jug/ graduated cylinder to measure it. Record the volume (V) in millilitre (ml).

Step 2: Calculate the accumulated rainfall for the period the rain gauge was left outside. This is done in two parts:

Part (i): *Calculate the accumulated rainfall (in cm): t*he amount of rainfall is calculated by dividing the volume of water collected (recorded in step 1) by the constant c. This gives you the amount of rainfall in cm.

Part (ii): convert the accumulated rainfall from cm into mm. To change this value into mm, simply multiply it by 10. You now have the amount of rain that fell (in mm) over the number of days the rain gauge was left out.

Here is an example:

The radius of our homemade rain gauge is 5cm and 20ml of rainwater were collected over 3 days.

Prerequisite - Calculate the constant for the rain gauge:

$c = 3.142 \times (r)^2$

We know r = 5cm, so: $c = 3.142 \times (5)^2 = 78.55$

Part (i) Calculate the amount of rainfall:

We know the volume of water = 20ml, so:

Divide the volume of rainwater by the constant (78.55): 20ml/ 78.55 = 0.25cm

Part (ii) Convert this value for cm into mm: 0.25cm x 10 = 2.5mm