Earth Science

2024

Thank you to our chapter sponsor: Seaspan Shipyards

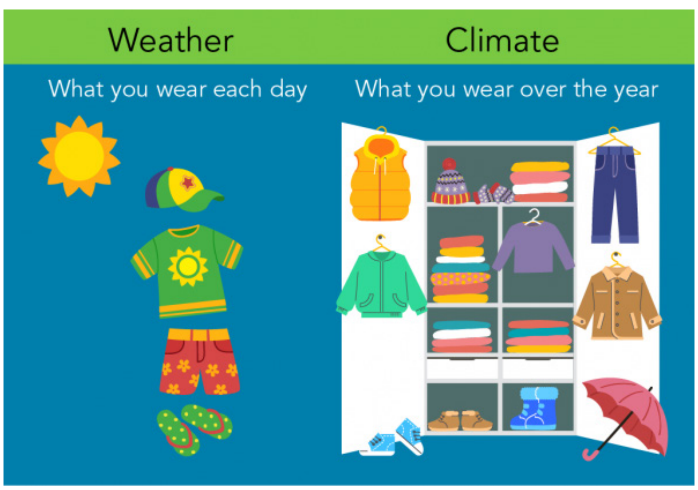
Introduction to Climate Change

What is climate change?

Climate change is a change in the usual weather patterns in a region over time. Temperatures on Earth have been rising dramatically for many years. This change is impacting local climates all around the world.

Changes in weather happen all the time. But weather and climate are not the same thing. **Weather** is the day to day change in temperature and precipitation in a place. You can describe the weather in your community by looking outside. If it's cold and snowy right now, that's today's weather.

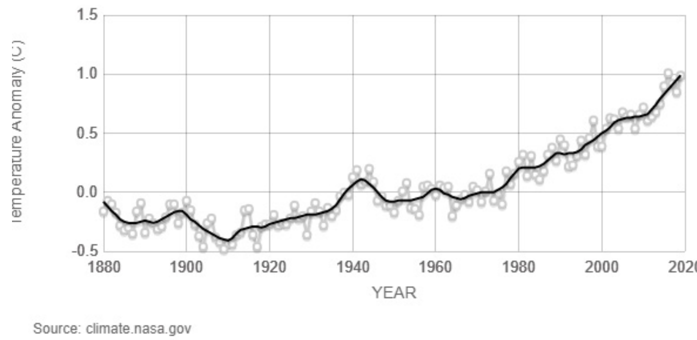
Climate, on the other hand, is the usual weather in a place over a long period of time. Weather can change quickly. It might be sunny in the morning and rainy in the afternoon. Climate changes much more slowly. Until recently, Earth's climate had been about the same for 9000 years.



Weather versus climate as shown by your clothes (Let's Talk Science using images by Kubkoo, nataka and vectorikart via iStockphoto based on an image by the NOAA).

How do we know the world's climate is changing?

The world's average temperature has changed throughout history. Sometimes the world's temperature has been warmer and sometimes it has been colder. Factors like ocean currents and volcanic eruptions caused these shifts. They are part of a natural cycle of heating and cooling. This usually happens over tens of thousands of years.



Global temperatures from 1880 to 2020 (Source: Global Climate Change, NASA).

But now Earth's climate is changing faster than it ever has during human history. Earth's average temperature has increased by at least 1.1 °C since 1880. And most of that warming has happened since 1975. In fact, 2023 will probably be the warmest year ever recorded.

This trend of rising global temperatures is called **Global warming**. Global warming is one of the ways that Earth's climate is changing. Climate change also involves changing global weather patterns, ocean currents, and other systems.

We are already experiencing these changes. Scientists have observed rising sea levels, melting ice and increasing extreme weather events. These changes affect each region differently. For example, snow and ice are melting so quickly that the Arctic could have no summer sea ice by 2030. Coastal areas are experiencing more flooding. These are all evidence of climate change.

Why is the climate changing?

These changes to Earth's climate are not natural shifts. Scientists are confident that human activities are the leading cause of climate change. Human activities release gases that change Earth's atmosphere. These gases are making our atmosphere better at trapping the Sun's heat. We call this the **greenhouse effect**.

2023 SUMMER MINIMUM

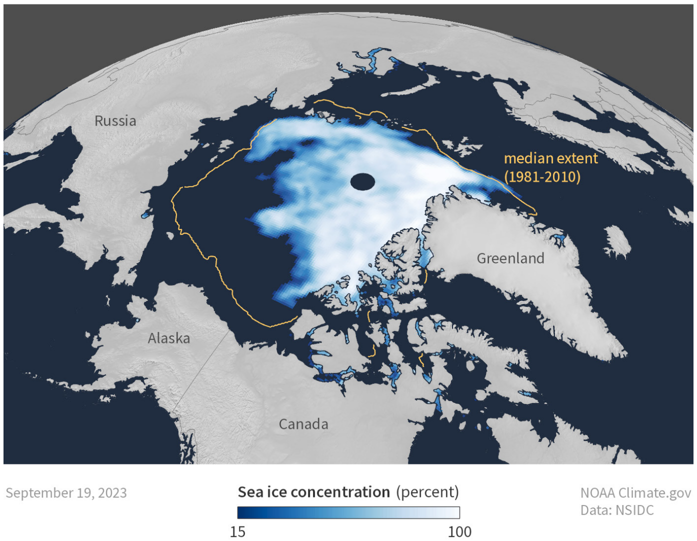


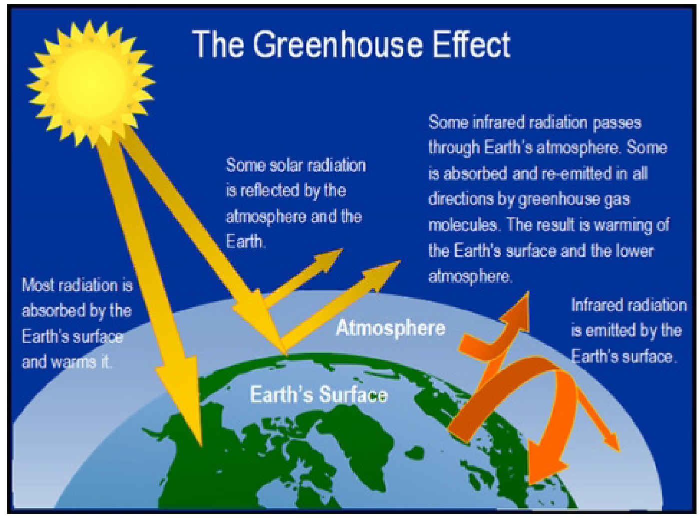
Image from the National Oceanic and Atmospheric Administration (NOAA) comparing the area of sea ice in summer 2023 to the median area from 1981-2010 (Source: NOAA).

The greenhouse effect is the main cause of rising temperatures on Earth.

So what is the greenhouse effect? Plants can grow better in a greenhouse because it stays warmer than the outside air. This is because heat from the Sun enters through clear glass or plastic, then gets trapped inside. This heat keeps the greenhouse warm.

A greenhouse traps heat (Source: NASA/JPL-Caltech).

Earth's atmosphere also acts like a greenhouse. Sunlight reaches our planet and warms it. Some of this heat is reflected back into space. Some of it is trapped by gases in Earth's atmosphere. These **greenhouse gases** include carbon dioxide (CO_2), water vapour, methane, and nitrous oxide.



The Greenhouse Effect (Source: Wikimedia Commons).

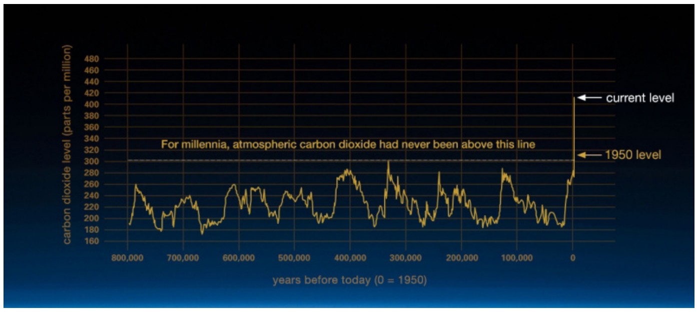
The greenhouse gases in our atmosphere help keep our planet warm enough for us to survive. Too little greenhouse gas would make Earth too cold for humans. But, too much greenhouse gas makes Earth too warm. Over the past century, humans have added a lot of greenhouse gases to our atmosphere.

> Did you know?
> The average temperature on Earth would be -18°C without the greenhouse effect.

Carbon dioxide is the most common greenhouse gas in our atmosphere. Carbon moves between the Earth, living things, and the atmosphere in the **carbon cycle**. Like all animals, humans add carbon dioxide to the atmosphere when we breathe. We also emit a lot more carbon dioxide when we burn **fossil fuels**. These are fuels we dig up like oil, gas and coal which are made of plant and animal remains from millions of years ago. We burn fossil fuels when we drive cars, heat our homes, and generate electricity. Humans have burned large amounts of fossil fuels over the last century.

The amount of carbon dioxide in the air is now nearly 50% more than in 1750. About 25% of that change has happened since 2000. Carbon dioxide concentrations haven't been so high for over three million years.

Methane (CH_4) is the next most common greenhouse gas. Methane has about 80 times the warming power of carbon dioxide. This makes methane an important gas to keep an eye on. The main sources of methane in Canada are from fossil fuels use, farming, and waste.



Carbon dioxide levels over time (Source: NASA).

What are the impacts of climate change?

Increasing the global temperature by a few degrees may not seem that bad. But think about how you feel when you have a fever. Raising your body temperature by just a couple degrees can make you feel terrible. Like our bodies, Earth is a series of intertwined systems. Rising global temperatures have complex and sometimes unexpected impacts that affect us all. These can already be felt in Canada and around the world.

The impacts of climate change are complex. And they are different for every region. In some places, higher temperatures have already led to **megadroughts** and **heat waves**. They are also causing **extreme rain** and **snowstorms** in some places. Climate change could continue causing melting sea ice, glaciers, warming oceans, and rising sea levels. These changes impact people, plants, and animals. Additionally, climate change will continue to affect our planet for a long time. Carbon dioxide stays in the atmosphere for hundreds of years. It could take some time for Earth's complex systems to respond to changes.

How can we tackle this problem?

Our response will determine how much our climate will change. There are two main ways to deal with climate change. These are adaptation and mitigation. **Adaptation** is about finding ways to cope with our changing climate. For example, cities could adapt to rising sea levels by building walls or using pumps to prevent flooding.

Dry lake bed (Source: piyaset via iStockphoto).

Flood protection sandbags with flooded homes in the background (Source: Marc Bruxelle via iStockphoto).

Mitigation is about finding ways to reduce greenhouse gas emissions. For example, we could burn less fossil fuel by using cars and other gas-powered vehicles less. We can also use solar or wind power, instead of fossil fuels, to generate electricity. These changes need work and cooperation from people around the world.

Solar panels and wind turbines (Source: zhongguo via iStockphoto).

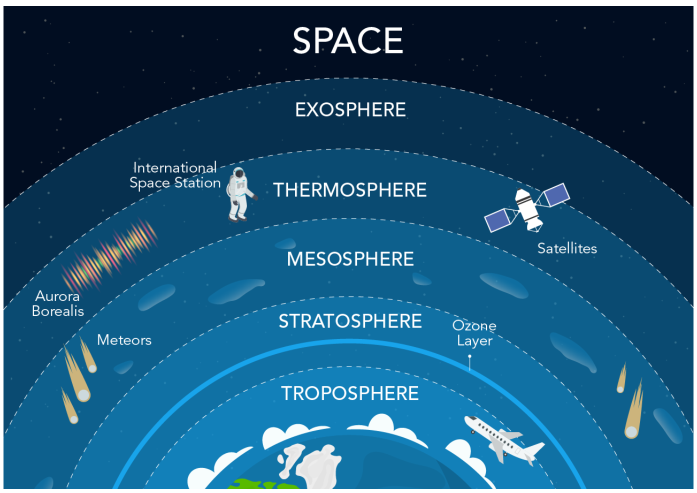
Climate change is a difficult issue to solve because of its global scale and complexity. Luckily, many people are concerned about climate change. Young people in particular are encouraging governments and businesses to take action. Many organizations are trying to reduce greenhouse gas emissions. Government plans, international agreements, and emerging technologies will all need to play a role. There is a lot of work and research that still needs to be done. But we humans are up for it!

Weather: Atmospheric Pressure

There is a layer of gases around Earth. This is our atmosphere.

Did you know?
The word atmosphere comes from two Greek words. Atmós means vapour and sphaîra means ball.

Scientists who study our atmosphere describe it with five major layers.



Layers of the atmosphere including some of the things you can find there (Let's Talk Science using an image by Bigmouse108 via iStockphoto).

Did you know?
Earth's atmosphere actually includes the Moon!

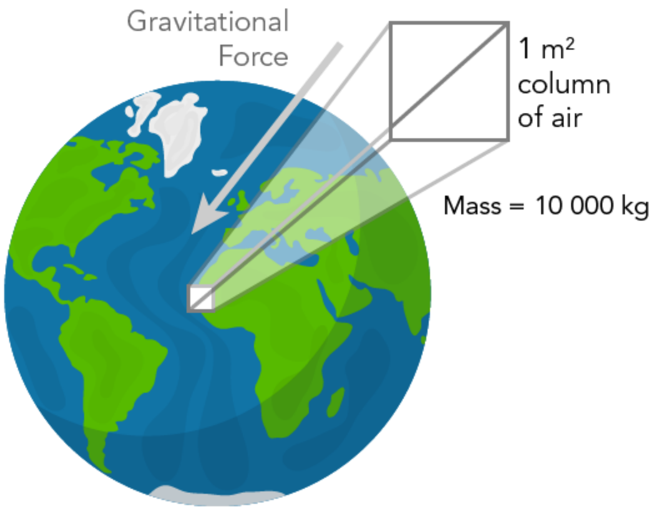
Atmospheric Pressure

Our atmosphere plays an important role in weather and wind patterns. It may seem invisible and weightless. But the gases that make up the atmosphere have both **mass** and **weight**.

Misconception Alert
Mass and weight do not mean the same thing. Mass is a measure of the number of atoms in an object. Weight is a measure of gravity acting on it.

Atmospheric pressure is the downward force caused by the molecules of air in the atmosphere. Imagine a one square metre column of air that reaches from sea level to the top of the atmosphere. This weighs about 10 000 kilograms! The exact weight of an air column depends on the number and types of molecules it contains.

Layer	Height	Description
Troposphere	0 - 14 km	This is the part of our atmosphere that we experience every day. The troposphere is almost 80% of the total mass of the atmosphere. Most of Earth's weather occurs in the troposphere.
Stratosphere	14 - 50 km	This is a very stable layer. The air in the stratosphere is very dry. Because of this, there are few clouds here. The **ozone layer** is in the stratosphere. The ozone layer is very important. It helps protect us from ultraviolet (UV) radiation from the Sun.
Mesosphere	50 - 85 km	Mesosphere comes from the Greek word meso, meaning middle. Most **meteors** burn up in the mesosphere. Reddish lightning called **sprites** can sometimes be seen above thunderstorms. These are in the mesosphere.
Thermosphere	85 - 600 km	The **Northern Lights (aurora borealis)** and the **Southern Lights (aurora australis)** happen in the thermosphere. This is also where the International Space Station orbits.
Exosphere	600 - 1000 km	The exosphere is the furthest from the surface of the Earth. Its edge marks the edge of space. It contains gas molecules like hydrogen and helium, but they are very far apart. Auroras sometimes happen in the lower exosphere.



A one metre-squared column of air has a mass of 10 000 kg (Let's Talk Science using an image by Bigmouse108 via iStockphoto).

Air is made of gas molecules. The more gas molecules there are in an area, the more dense the air is. More molecules also mean the air has more weight and pressure. Fewer molecules mean the air has lower density, weight and pressure.

Like all molecules, molecules of gases in the atmosphere are always moving. At higher temperatures, the molecules move quickly and spread out more. This means there are fewer molecules in that area. Fewer molecules result in lower air pressure. The opposite is true at lower temperatures. The molecules stay closer together and the air pressure is higher.

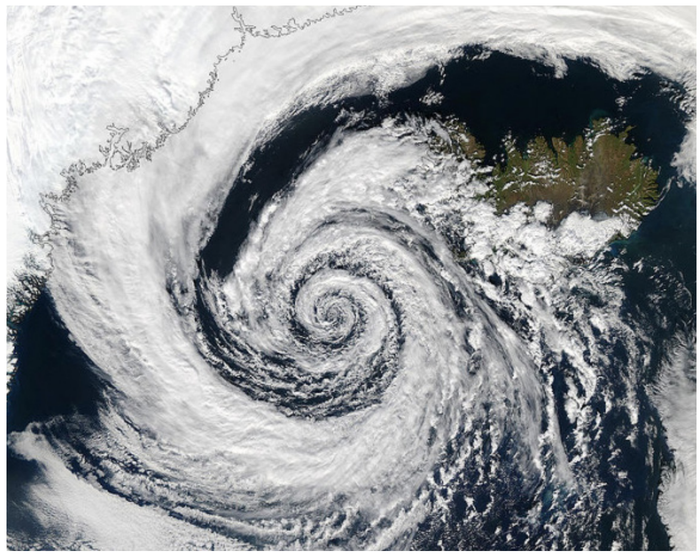
Air pressure is measured with a tool called a **barometer**.

A barometer (Source: connect11 via iStockphoto).

High and Low Pressure Systems

Atmospheric pressure changes from day to day and from place to place. You might hear a weather forecaster talk about a **pressure system** or **pressure area**.

A **low pressure system** is an area of low pressure surrounded by higher pressure. Air with low density and high temperature is surrounded by air with high air density and low temperature. This causes the air to form an inward **spiral**. You can see this shape in the picture below.

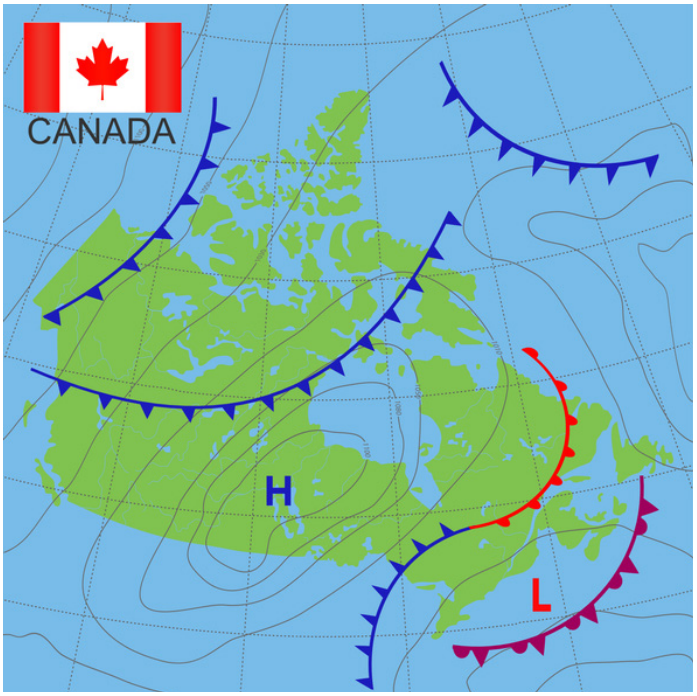


Low pressure system over Iceland (Source: NASA [public domain] via Wikimedia Commons).

Usually, low pressure systems have warm, humid air. They often create clouds and sometimes **precipitation**. This happens mostly when they run into high pressure systems.

A **high pressure system** is an area of high pressure surrounded by lower pressure. This means there is cold, dense air surrounded by warmer, less dense air. This causes the air to form a spiral outward. High pressure systems usually cause weather with cool temperatures, dry air and few clouds.

On a weather map, low pressure areas are labelled with a capital L. High pressure areas are labelled with a capital H.



Weather map of Canada showing high and low pressure systems (Source: YULIYA SHAVYRA via iStockphoto).

Weather Fronts

Weather fronts are the border areas between air of different densities and temperatures.

Cold fronts happen where a mass of colder air is moving towards a mass of warmer air. The colder, denser air quickly pushes the warmer, less dense air up into the atmosphere. The air then cools and condenses. This often causes short-lived showers and thunderstorms.

Warm fronts are where a mass of warmer air is moving towards a mass of colder air. The warm air slowly moves over the cold air and up into the atmosphere. There, it condenses and causes precipitation. Precipitation caused by warm fronts lasts much longer than the precipitation caused by cold fronts.

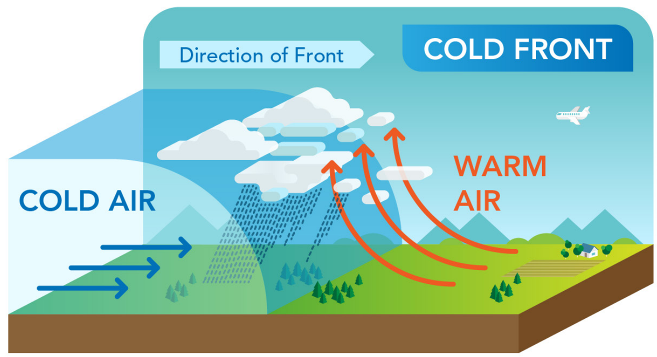
On a weather map, the symbol for a cold front is a blue line with blue triangles. The triangles point in the direction the front is travelling.

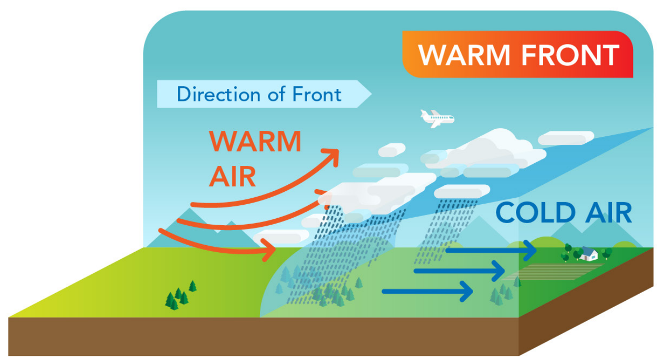
Weather map symbol for a cold front (Source: Public domain image via Wikimedia Commons).

The symbol for a warm front is a red line with red half-circles. The half-circles point in the direction the front is travelling.

Weather map symbol for a warm front (Source: Public domain image via Wikimedia Commons).

Sometimes you will see a purple line with both triangles and half-circles. This shows the location of an **occluded front**. An occluded front is where three air masses come in contact with each other. The shapes point in the direction of the colder air.





Movement of air masses in a cold front (left) and warm front (right) (Let's Talk Science using an image by VectorMine via Getty Images).

Weather: Temperature

Temperature

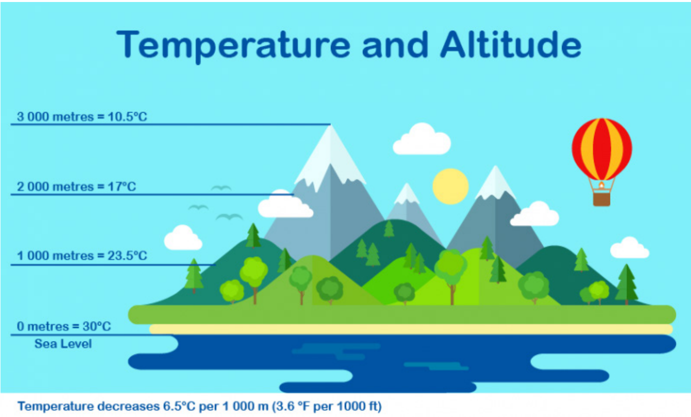
Why is there sometimes snow on the top of a mountain but not at the bottom? And why is the Arctic always cold while the Tropics are always hot? Let's find out!

Elevation and Altitude

The vertical distance between **sea level** and where you are is your **elevation**. The greater your elevation, the less air there is above you. This means the **air pressure** is lower. The less pressure there is on the air, the more it expands. And the gases that make up the air get cooler as they expand. So, the air temperature drops about 6.5 °C for each kilometre you climb.

> Did you know?
> **Elevation** is how high land is above sea level.
> **Altitude** is how high an object is above sea level.

You can even feel this without climbing at all! Try using a can of compressed air, or let the air out of a tire. The air inside is under pressure. But when it comes out, it suddenly expands, so it is colder than the air around you.



Temperature decreases 6.5ºC for every 1 000 metres of altitude (Let's Talk Science using an image by Sentavio via iStockphoto).

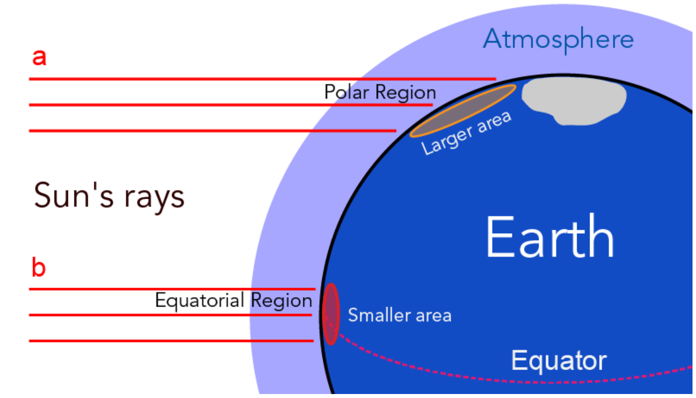
> Did you know?
> The cruising altitude of commercial airliners is about 11 km above Earth. At that altitude, the air pressure is about 25% of what it is on the ground. The temperature outside the plane is about -55 °C!

Latitude

Places on Earth can have very different temperature patterns. This is because of the Sun. The more sunlight that shines on a place, the hotter it will be.

The Earth is a **sphere**. The places where sunlight hits the Earth at a **right angle** get a lot of sun in a small area. This area is close to the **equator**. It's called the **equatorial region**. The places where sunlight hits the Earth at a **shallow angle** get the same amount of sunlight, but it's spread over a much larger area. Areas like this are close to the north pole or the south pole. They're called the **polar regions**.

In the picture below, you can see that the same amount of sunlight covers a large area **(a)** at a polar region and a small area of **(b)** at the equatorial region. Because area b is smaller than area a, the sunlight is more **concentrated** there. This means there are warmer temperatures at b than at a.



How the Sun's rays strike the Earth (Let's Talk Science using an image by Peter Halasz [CC SA] via Wikimedia Commons).

Seasonal Temperatures

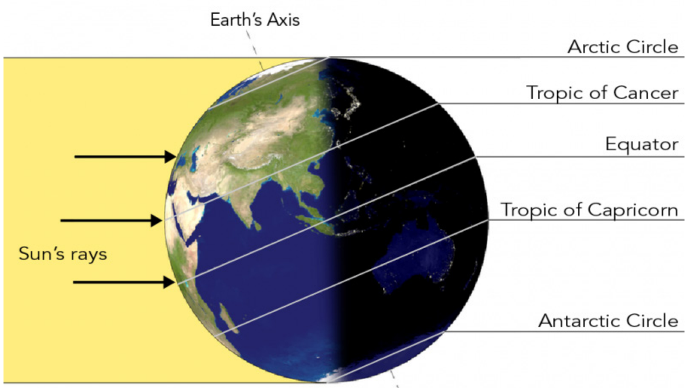
The Earth spins on its **axis**. If that axis stood straight up, Earth's equator would always face the Sun as the planet **orbited** around it. But this would mean that the **Northern Hemisphere** would stay cold all year round. We know that that doesn't happen. In North America, winter is colder and summer is warmer. Spring and autumn are in between.

The Earth has seasons because it is tilted at an angle of **23.5°**. As the Earth moves around the Sun, the planet is tilted either towards, or away from the Sun. Let's see how this works in different seasons.

Did you know?
The northern end of the Earth's axis always points to basically the same place in space. This explains why the North Star can always be used to find north in the Northern Hemisphere.

In the Northern Hemisphere summer is from June to September. This is when the area north of the Equator is tilted towards the Sun. In North America, calendars are set so that the Sun is directly overhead at its furthest north position on June 21 or 22. This is called the **Summer Solstice**.

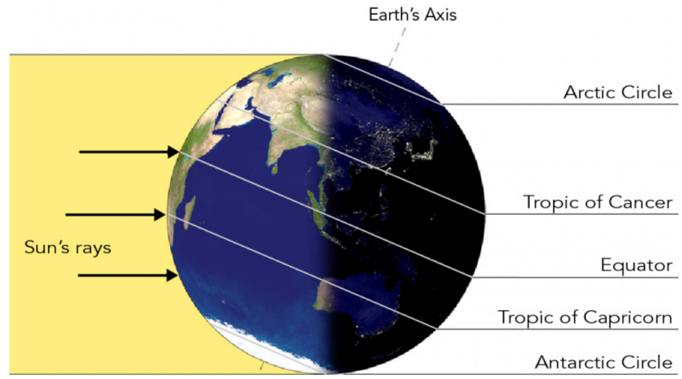
The picture below shows the Earth at the Summer Solstice. You can see which part of the Earth is lit and which part is in shadow. More of the Northern Hemisphere is in the light half than in the dark half. This is why days are longer in the summer. In fact, above the **Arctic Circle**, there are 24 hours of daylight at the Summer Solstice!



Lighting of the Earth at the Summer Solstice (Let's Talk Science using an image by Przemyslaw "Blueshade" Idzkiewicz [CC By] via Wikimedia Commons).

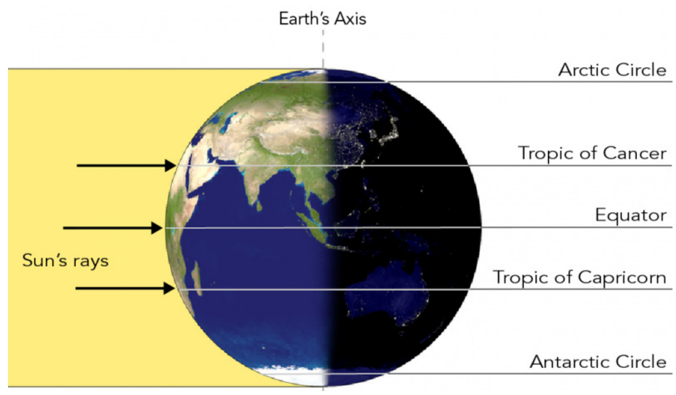
The opposite happens in winter in North America. During this part of the Earth's orbit, the Northern Hemisphere is tilted away from the Sun. The picture below shows the Earth at the **Winter Solstice** on December 21 or 22. More of the northern hemisphere is in the dark half than the light half.

This is why the days are shorter in winter, and why the nights are longer. Winter Solstice is the longest night of the year. And as you may have guessed, above the Arctic Circle, there are 24 hours of darkness at the Winter Solstice!



Lighting of the Earth at the Winter Solstice (Let's Talk Science using an image by Przemyslaw "Blueshade" Idzkiewicz [CC By] via Wikimedia Commons).

The picture below shows the Earth at the Autumnal Equinox and at the Spring Equinox, which is also called the Vernal Equinox. The Northern Hemisphere is not tilted towards, or away from the sun. These dates are when day and night are exactly the same length.



Lighting of the Earth at the Winter Solstice (Let's Talk Science using an image by Przemyslaw "Blueshade" Idzkiewicz [CC By] via Wikimedia Commons).

Equinoxes and solstices are points in time. They are moments when the Earth's angle is perfectly aligned with the Sun's rays. But people sometimes use these names for the whole day on which these times fall.

Perceived temperature vs real temperature

The temperature outside is not the only thing that makes you feel cold or warm. This is why weather forecasts sometimes give you a second temperature. This is based on how people feel. You might feel colder on a windy day. This perceived temperature is called **wind chill**. You might feel hotter on a humid day. This perceived temperature is often called **humidex**.

Weather: Clouds

Clouds are made up of water droplets or tiny ice crystals. As part of the **water cycle**, water **evaporates** from oceans, rivers and lakes. This water rises up into the **atmosphere**. The farther up it travels, the colder the air around it gets. When the air gets cold enough, the water starts to **condense** around small particles of dust and pollen in the air. This condensation creates visible **clouds**.

> Did you know?
> Although clouds float in the air, they can still be very heavy. A single cumulus cloud can weigh hundreds of tons!

Clouds are classified by shape and **altitude**. Clouds often have two-part names that describe both these features.

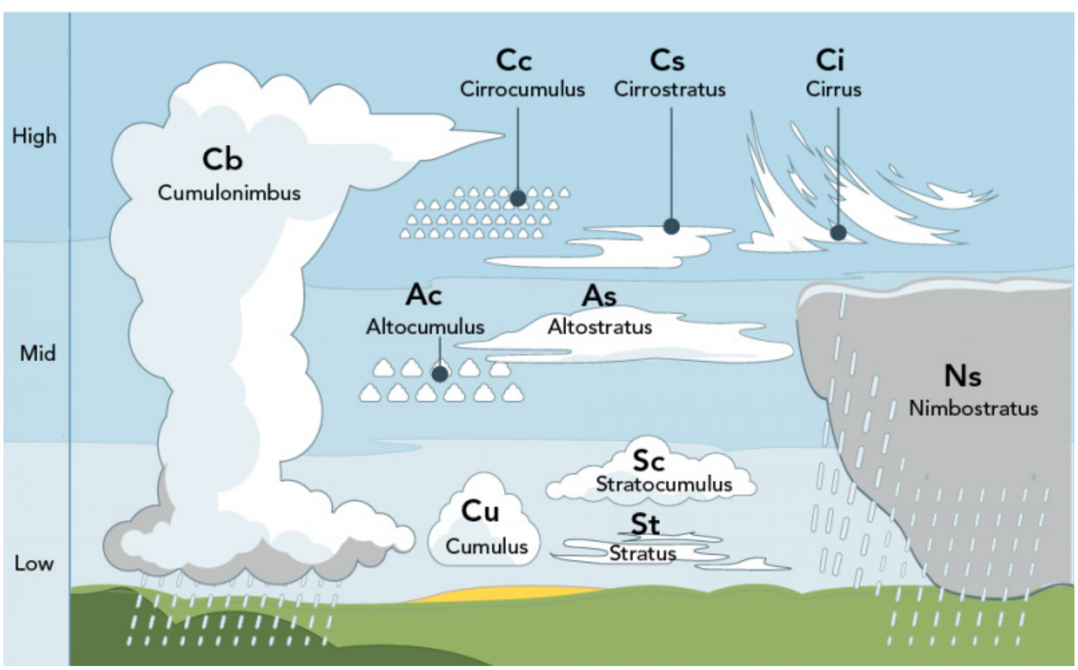
Most clouds form in the **troposphere**. That's the lowest layer of the Earth's **atmosphere**. The height of the troposphere varies depending on where you are on Earth. The average height at the **equator** is 18 km (11 mi; 59,000 ft). The average height at the north and south poles is 6 km (3.7 mi; 20,000 ft). We'll use measurements based on the height of the troposphere in an area between the equator and the poles.

Locations of Clouds

Clouds can be grouped based on the altitude where they form.

- **Low-level clouds** form at an altitude of less than 2 000 m. This group includes ***stratus***, ***cumulus***, ***stratocumulus*** and ***cumulonimbus*** clouds. Although they form below 2 000 m, some low-level clouds can grow very tall. The tops of cumulonimbus can reach an altitude of up to 20 000 m!
- **Mid-level clouds** form at an altitude between 2 000 m and 7 000 m. This group includes ***altocumulus***, ***altostratus*** and ***nimbostratus*** clouds.
- **High-level clouds** form at an altitude between 5 000m and 13 000 m. This group includes ***cirrus***, ***cirrocumulus*** and ***cirrostratus*** clouds.

> Did you know?
> Along with the height of the troposphere, cloud heights vary in different parts of the world. In warmer regions near the equator, the top of the troposphere is much higher. As a result, clouds form much higher in the sky!



Location and names of different cloud types (Source: Valentin de Bruyn / Coton [CC BY-SA 3.0] via Wikimedia Commons).

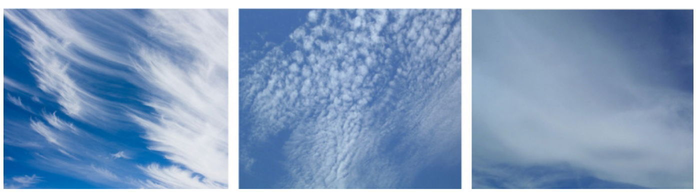
Shapes of Clouds

Based on their appearance, most clouds fall into ten types in four categories.

Cirro-form

From the Latin word for hair. These are thin, wispy, high-level clouds. They include:

- **Cirrus** clouds, which are delicate, feathery, and always made of ice. They light up in yellow or red before sunrise and after sunset.
- **Cirrocumulus** clouds are grainy or ripply and made mostly of ice. They appear in thin, patchy rows and don't last long in the sky.
- **Cirrostratus** clouds are also made of ice crystals. They appear in a thin sheet that seems to cover the sky. You can usually see the Sun through these clouds.



Examples of cirrus (left), cirrocumulus (centre) and cirrostratus (right) clouds (Sources: Fir0002/Flagstaffotos [GFDL 1.2] via Wikimedia Commons, LivingShadow [CC-BY-SA 3.0] via Wikimedia Commons, and Simon Eugster [CC-BY-SA 3.0] via Wikimedia Commons).

Cumulo-form

From the Latin word for pile, these look like puffy white cotton balls with flat bases. They can stretch high up into the atmosphere. They include:

- **Cumulus** clouds can look like domes or towers in the sky. They can be made of ice crystals, water droplets, or both. Many people call them fair weather clouds.
- **Stratocumulus** clouds are grey or whitish and appear in a patchy sheet across the sky. They are usually made of water droplets, but sometimes include ice crystals. They usually have a dark honeycomb, or lumpy or rolled texture.
- **Altocumulus** clouds appear in white or grey patchy layers of round shapes or rolls. They can be made of water droplets or ice crystals. You often see them with other types of clouds, and they can cause coronas around the Sun and Moon.

Examples of cumulous (left), stratocumulous (centre) and altocumulous (right) clouds (Sources: Fir0002/Flagstaffotos [CC BY-NC] via Wikimedia Commons, Ronan268 [CC BY-SA 4.0] via Wikimedia Commons and Rubinstein Felix [CC BY-SA 3.0] via Wikimedia Commons).

Strato-form

From the Latin word for layer, these are widespread and can look like a blanket. They include:

- **Stratus** clouds are flat and greyish. They can be made of water droplets, ice crystals, or both. They extend over large sections of the sky and sometimes bring drizzle or light snow. When stratus clouds touch the ground they are called fog.
- **Altostratus** clouds appear in a grey or bluish sheet that covers the entire sky. They are made of a mixture of water droplets and ice crystals and sometimes bring light precipitation. You can see the Sun through these clouds, but it often appears blurry.

Examples of stratus (left) and altostratus (right) clouds (Sources: Vipin Vasudeva [CC BY-SA 3.0] via Wikimedia Commons and Famartin [CC BY-SA 4.0] via Wikimedia Commons).

Nimbo-form

From the Latin word for rain, most precipitation comes from nimbo-form clouds. They include cumulo, cirro and strato forms, and they are generally the thickest type. They include:

- **Nimbostratus** clouds form when altostratus clouds get thick and dark enough to blot out the sun. They are mostly made of water droplets, but can also contain ice crystals. They often bring rain or snow.

Weather: Precipitation

- **Cumulonimbus** clouds form heavy, dense towers. They are often anvil-shaped, with very dark bottoms. They are made of water droplets and ice crystals. These clouds are responsible for thunderstorms, lightning, hail, and even tornadoes.

Examples of nimbostratus (left) and cumulonimbus (right) clouds (Sources: Simon Eugster [CC BY-SA 3.0] via Wikimedia Commons and Greg Lundeen [Public domain] via Wikimedia Commons).

Did you know?
"Contrails" is short for "condensation trails." At high altitudes, cold air temperatures cause water vapour to condense around the particles in hot, humid airplane exhaust. This creates the line-shaped clouds you see in the sky.

So the next time you look at clouds, see if you can figure out what type they are!

Clouds seen from an airplane (Kaushik Panchal, Unsplash)

Humidity

Humidity is the amount of water vapour in the air. **Dew**, **frost** and that 'muggy feeling' on hot days are all signs of water vapour in the air. Humidity is an important part of any habitat. It determines which plants and animals can thrive there.

People are also affected by humidity. When we **sweat**, the sweat **evaporates** from our skin. This is what keeps us cool on a hot day. But when it is humid, our sweat evaporates slowly. This is because the air around our bodies is already filled with water vapour. If the humidity is high enough, people can develop **heat stroke**.

Sometimes people use **air conditioners** to cool the air inside buildings. But air conditioners also lower the humidity. They have cooling elements that cool the air around them. When water vapour hits these elements, it **condenses** into liquid water. This removes it from the air.

Microorganisms like **bacteria** and **mould** can grow when it's too humid indoors. Some of these microorganisms can be bad for people's health. This is why many people use **dehumidifiers** to remove moisture from the air.

Precipitation

Precipitation is an important part of the Earth's **water cycle**. **Drizzle**, **rain**, **snow**, **sleet** and **hail** are all different kinds of precipitation. All precipitation starts as water vapour. This condenses into droplets that fall from the sky. Some droplets stay liquid. Other droplets freeze.

Rain

Raindrops start when water vapour condenses on tiny dust particles. Then, these small water droplets bump into each other to form larger droplets. Eventually, they become so heavy that they begin falling to Earth, gathering more water as they go. When the air is unstable, more and more droplets collide, resulting in bigger raindrops.

Raindrops can measure from 0.1 mm all the way to 9 mm. That's a pretty big raindrop!

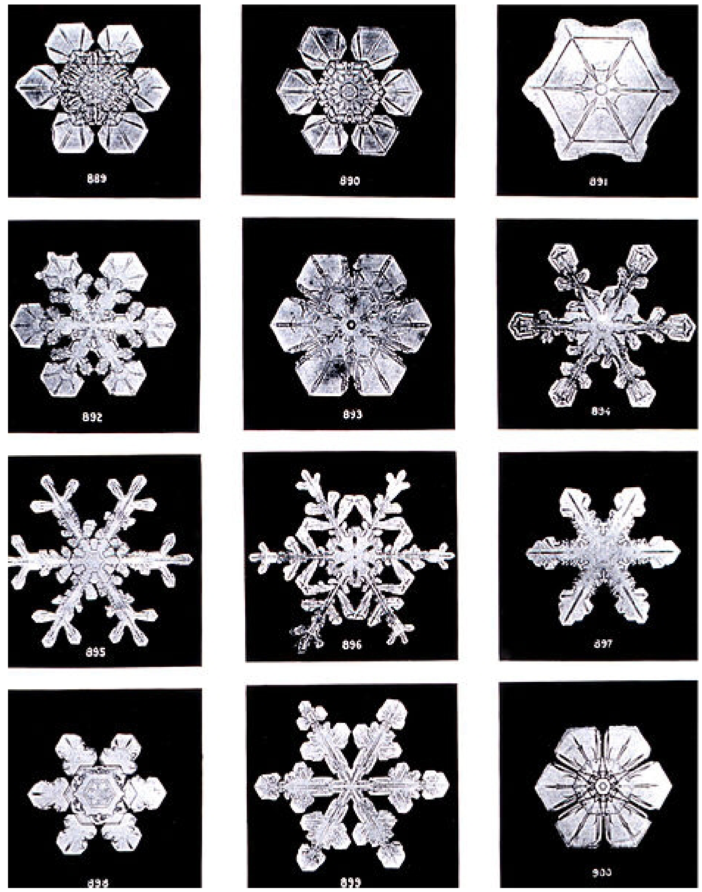
Late summer rainstorm (Source: Malene Thyssen [CC SA 3.0] via Wikimedia Commons).

Freezing rain can happen when the temperature near the ground is close to 0°C, but the air above is warmer. The rain does not have enough time to freeze as it falls, but it turns to ice the instant it lands.

Snow

Sometimes water droplets in clouds freeze around dust or pollen particles and form **ice crystals**. One kind of ice crystal is the snow crystal. Snow crystals form when droplets become **supercooled**. Then they form a six-sided **crystal lattice**. These snow crystals bump into water droplets in the clouds and grow bigger and bigger. Just like raindrops, when snowflakes get heavy enough, they fall to Earth. They might collide and stick to other snowflakes on the way down. Sometimes, around −2 °C, snowflakes can be 3-dimensional!

You may have heard that no two snowflakes are alike. This is very difficult to prove. Snow crystals form in many different shapes. They are also sensitive to temperature changes. Each one falls from a cloud at a different time, changing shape as it encounters different temperatures along the way. **Wilson Alwyn Bentley** photographed thousands of snowflakes using a microscope. He didn't find two identical ones. But his photographs helped scientists understand different snowflake types.



Photographs of snowflakes taken by Wilson Bentley in 1902 (Source: Wilson Bentley [Public domain] via Wikimedia Commons).

Did you know?
Scientists think snowflakes can be sorted into eight general categories, 39 intermediate categories, and as many as 121 elementary categories! That means there are up to 10^{158} possible shapes.

Hail and Sleet

Hail is when ice crystals fall to the Earth on warm days. Warm air rises inside clouds. It pushes water droplets up into the colder air above the clouds. This happens over and over again. During this time, the ice crystals collide with more water droplets and grow. These ice chunks, or hailstones, drop to Earth once they are heavy enough to fall through the warm air. Hailstones are larger than 5 mm across. And there have been hailstones the size of golf balls and baseballs!

Weather: Wind

A large hailstone (Source: Public domain image from the National Severe Storms Laboratory (NSSL) Collection via Wikimedia Commons).

Did you know?
The largest hailstone ever measured was between 18.8 cm and 23.6 cm in diameter!

Ice pellets are also called _____. They are small, almost see-through, balls of ice. They are usually smaller than hail. Sometimes you can see ice pellets bounce when they hit the ground.

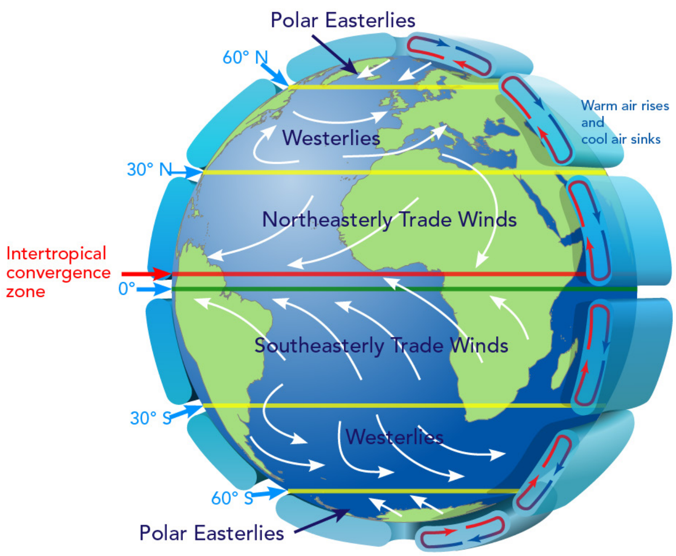
Wind is the movement of air across the surface of the Earth. Winds are named after the direction from which they blow. So, **northeasterly winds** blow from the northeast. And a **land breeze** blows from the land towards the ocean.

Air moves because the Sun does not warm the surface of Earth evenly. If Earth did not rotate, hot air at the Equator would rise up into the atmosphere. Then it would push cold air from the poles towards the equator. But the Earth's spin causes something called the **Coriolis Effect**. This makes things travelling long distances around Earth appear to curve as they go. Even though the object travels in a straight line, we observe it from the moving surface of Earth. And different spots on Earth's surface move at different speeds. Because Earth is a sphere, a town at the Equator spins faster than one near the North Pole, because it has further to travel in a day. A cannonball shot straight north from the Equator will actually land to the east! And winds travelling around the globe appear to blow in certain curved patterns. This is because air is flowing from a region that is moving faster to one that is moving slower.

A **prevailing wind** is a surface wind that blows mostly from a particular direction.

Have a look at the image on the next page. In the area close to the equator, the winds blow mostly from the east. These winds are called the **Prevailing Easterlies**. North of the equator they blow from the northeast and are called the **Northeasterly Trade Winds**. South of the equator they blow from the southeast and are called the **Southeasterly Trade Winds**.

Between 30° to 60°N and 30° to 60°S the winds blow mainly from the west. These are called the **Prevailing Westerlies**. Near the North and South Poles, the Coriolis force produces winds from the east, called **Polar Easterlies**.



Global wind patterns showing the locations of polar easterlies, westerlies and trade winds (Let's Talk Science using an image by Kaidor based on an image by NASA [CC SA 3.0] via Wikimedia Commons).

Wind patterns can also be seen on a smaller scale in different regions of the world. In western Canada you could experience a **Chinook**. Chinooks are winds that become warm and dry as they are pushed down the eastern side of the Rocky Mountains. Chinooks can change the temperature in southern Alberta from -20ºC to over 15ºC in a few hours! On the other side of Canada, some areas are always exposed to very high winds. This is the case for the **Wreckhouse** area in Newfoundland. And the "Les **Suêtes**" winds will blow you over in Nova Scotia.

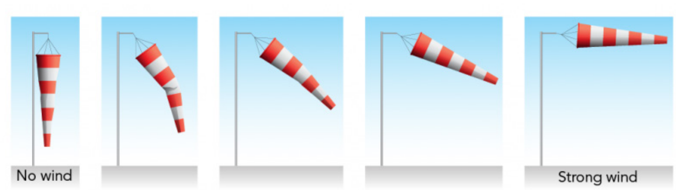
Measuring Wind

Wind strength is the speed that wind blows. Most of us have experienced short bursts of high-speed wind. These are called **gusts**. Winds that blow non-stop for more than a minute are called **squalls**. Winds that last longer have different names, according to their average strength. These include **breeze**, **gale**, **storm**, **hurricane** and **typhoon.**

People have created a number of tools to measure the wind. A metal rooster with the symbols for north, south, east and west on the top of a building is a **weather vane**. It pivots in the wind to show what direction the wind is coming from.

Weather vanes show the direction that wind comes from (Source: Nevit Dilmen [CC SA 3.0] via Wikimedia Commons).

At airports, pilots use **windsocks** to determine wind direction. They can also use them to estimate the speed of the wind. Wind socks are conical tubes of thin material that move easily. The wind blows into the wide end of the tube and escapes out the narrow one. So, the narrow end always points in the opposite direction from where the wind is blowing. When the wind isn't blowing, the sock hangs straight down. When the wind is strong, the sock is parallel to the ground.



Wind sock showing no wind to strong wind (Let's Talk Science using an image by jack0m via iStockphoto).

You can use an anemometer to measure the wind more precisely. Basic anemometers are made of cups mounted on arms connected to a rod. The faster the wind blows, the faster the cups rotate and spin the rod. Other anemometers look more like propellers with tails. The speed of the propeller indicates wind speed, and the tail shows wind direction.

A propeller-type anemometer (Source: tzahiV via iStockphoto).

Did you know?
The word anemometer comes from the Greek word anemos meaning 'wind' and metron meaning 'measure.'

The speed of wind can be described using the Beaufort Scale.

The Beaufort Scale

The **Beaufort Scale** was created by Sir Francis Beaufort in 1805. He did not use wind speeds for each level. Instead he used descriptions of how a sail on a ship moves in different winds. In the 1850s, wind conditions on land were added. Later, meteorologists added the number of turns of an anemometer to each level. The Beaufort Scale is still used to estimate wind strength today. But meteorologists usually describe wind speed in kilometres per hour or miles per hour.

In Canada, **maritime** winds forecast to be in the range of 6 to 7 on the Beaufort Scale are called **strong**. 8 to 9 are called **gale force**, 10 to 11 are called **storm force**, and 12+ is called **hurricane force**. Wind warnings are issued by Environment Canada.

Did you know?
Wind can be used to generate electricity. Wind turbines are structures placed in windy areas to harness the energy of wind.

Beaufort Number	Description	Wind speed
0	Calm	0-1 km/hr
1	Light Air	2-5 km/hr
2	Light Breeze	6-11 km/hr
3	Gentle Breeze	12-19 km/hr
4	Moderate Breeze	20-28 km/hr
5	Fresh Breeze	29-38 km/hr
6	Strong Breeze	39-49 km/hr
7	Near Gale	50-61 km/hr
8	Gale	62-74 km/hr
9	Strong Gale	75-88 km/hr
10	Storm	89-102 km/hr
11	Violent Storm	103-117 km/hr
12	Hurricane	≥118 km/hr

The Beaufort Wind Force Scale (often shortened to the Beaufort Scale) (Source: Let's Talk Science using an image by ttsz via iStockphoto).

How can we build a structure that protects toy people from wind?

Consider using the Design & Build Process with this challenge.

This activity will help build skills related to the Plan, Create, Create, Test & Evaluate, and Reflect & Share phases of this process. It also highlights the iteration needed during this process.

Materials:

- Two small toy people, approx. 5 cm (2”) tall (e.g., LEGO® people)
- Craft sticks
- String
- Paper
- One small piece of stick tack (about the size of your fingernail) or tape
- One piece of cardboard
- Scissors
- One electric fan

Tropical island where the people are shipwrecked (Source: deezaat via iStockphoto)

What to do!

Two toy people have been shipwrecked on a tropical island. Your challenge is to design and build a shelter for them. It needs to stand up to the wind from an electric fan.

1. **Plan** – Create drawings for what you want your structure to look like. Think about how moving air will affect the different materials and how you attach them together. There are several criteria for the design. Your plan must include these.
   - The cardboard is the base.
   - You must attach your structure to the cardboard using the stick tack or tape. You cannot use the stick tack or tape for anything else.
   - The toy people must be able to fit inside the structure.
2. **Create** - Build a prototype. This is a working model that you will be able to test. You can only use materials from the materials list.
3. **Test** - When you are satisfied with your prototype, it is time to test it!
   - Place the structure 60 cm (~2’) away from the electric fan. Point the fan at the structure.
   - Turn the fan on its lowest setting for 30 seconds.
4. **Evaluate** – How well did the structure stand up to the wind?
   - If your structure withstands the lowest setting, turn the fan up to the next setting for 30 seconds. Continue until the fan is at its maximum setting.
   - If your structure failed before reaching the maximum setting, think about which parts failed. Go back to your design. How can you make it better?
   - If you have time, keep trying. See if you can make the structure strong enough so the toy people remain inside, and it does not fall apart when blown by the fan at the highest setting for at least 30 seconds.
5. **Reflect & Share** – How well did you do? What would you do differently next time? Would this design work in real life? Why or why not?

What’s happening?

It is important to think about the climate and environmental conditions of a region when designing structures. Important things to consider include wind, temperature and precipitation patterns. Knowing the chance of extreme weather events, such as floods and hurricanes, is also important.

Wind happens when air flows from an area of high pressure to an area of low pressure. Tropical islands can have very strong winds during hurricanes. Hurricanes form when warm, moist air over the ocean rises quickly. This creates an area of low pressure. Then, air blows into this area of low pressure. This new air gets warmer and rises as well. This cycle can lead to violent winds that can batter islands and coastal areas.

For this activity, you created a model of a structure on a tropical island. Your materials were limited to materials or objects like what you might find there. For example, you might be able to use wood from trees. That's why you had wooden craft sticks. You also might be able to braid rope from leaves or grasses. This is why you had string.

Why does it matter?

While many regions experience regular extreme weather events, climate change is making these events more severe and more frequent. Some parts of the world that rarely experience extreme weather are now experiencing it more often and more intensely. Structures are not always designed for extreme weather, which can cause them to fail. One way that people can adapt to climate change is to make sure that the structures they design are ready for extreme weather.

Tropical island where the people are shipwrecked (Source: deezaat via iStockphoto)

Investigate further!

- If you are doing this with other teams, compare your designs. Was there anything in common between the successful designs? What about designs that failed?
- Can your structure withstand the wind from all directions? Rotate your structure so that each side is exposed to the wind. How would you change your design to make this better?
- What if it started raining? How would you change your design to protect your toy people from water as well?

Keven Bruce

Tactical Weather Specialist
Canadian Armed Forces

I was born in Kingston, Ontario, but grew up in South Western Ontario, around Sarnia and Windsor Ontario. I now live in Oromocto, New Brunswick. I graduated from the University of Windsor, with a Bachelor's of Science in Biology. I also graduated from Niagara College's Geomatics program. Formal meteorological training took place at the Canadian Armed Forces School of Meteorology in Winnipeg.

What I do at work

My work involves the gathering, analyzing and sharing of weather-based intelligence. This involves reporting on weather and supporting artillery through upper air soundings. This is done through hourly weather observations, collection of weather data, and by launching weather balloons.

Hourly weather observation is simply detailed observations of ongoing weather throughout the day. This includes precipitation types, amounts, cloud types and cloud cover, etc. This aspect of the job means we have to keep an ongoing watch on the weather and to keep an eye on weather systems moving into the observing region.

The larger part of the job is the gathering of weather intelligence. We do this through the use of weather forecasting tools, weather prediction software, and various international government sites. We use the information we collect to advise command staff of weather systems and how those weather systems may impact their planned missions, flight routes, or other available assets. This involves a fair amount of computer work. It also requires an understanding the weather forecasting tools and software, and remote sensing using satellite imagery and radar. Reporting on these weather effects, and advising command staff also requires being comfortable with public speaking.

Although my job title is Tactical Weather Specialist, I also advice on Earth Systems impacts, from volcanoes, and earthquakes to potential tidal waves. For some tasks, I even report on space weather events.

While most of the work is done individually, sometimes it is done in a team environment. But depending on where the weather office is located, it can also be very isolated (e.g., working shifts alone). This job is a good mix of both engaging office work, and fieldwork depending on the career path chosen. Experience with the French language is beneficial while working in a military environment.

My career path

I can honestly say this is not where I expected to end up in my career! I graduated high school, and went to university for biology intending to become a veterinarian. However, after completing my degree, taking courses in earth sciences, as well as geomatics and geographic information systems, I ended following advice from family members and applying to the armed forces as a meteorological technician.

While a university degree is not required for this career, the extra learning does help with the meteorological course at the Canadian Armed Forces School of Meteorology. In fact, many tactical weather specialists have university degrees in a science fields.

I am motivated by

I enjoy that my work allows me to work in both a field environment and an office environment. As well, tactical weather specialists, while working mostly from the background, are involved in general operations making sure of the safety of both civilians and military personnel. This includes such things as accurate mission planning, to timely reporting of natural disasters, and the direct assistance we give for search and rescue operations.

This career gives you many opportunities. These can be in terms of a career advancement or in terms of traveling to locations not often visited by people; locations such as CFS Alert on the northern end of Ellesmere Island, to more common locations, like Europe and Hawaii. Then there is the job security, full benefits, and government pension.

How I affect peoples' Lives

Weather has an impact on everything. This is particularly important in a military environment, where much of my work is used for planning purposes. Either planning for military operations, or just for general flight safety. As a tactical weather specialist, I am involved in the operation planning of missions (e.g., advising command staff on how weather might affect their assets during any giving mission). Weather reports are also important for pilots as weather systems, such as severe storms, icing, or other weather phenomena can affect flight safety.

Besides the military aspects, we are often the first point of contact for global environmental disasters that require a rapid disaster response team. This includes monitoring phenomena such as hurricanes and typhoons, to reporting on earthquakes, tidal waves and volcanic eruptions.

My advice to others

I would say, get a science degree, even though it's not required. There is still a fair amount of technical and meteorological theory to understand for this career. Become comfortable with public speaking (at least 80% of this career is public speaking). Finally, getting an early start on physical training or adopting an active lifestyle will go a long way towards making basic training and the other field/military training courses much easier. Apart from the more formal, class room style meteorology course, all applicants will have to undertake the CAF basic training program, as well as further training including Soldier Qualification course, and Navy Environment Training Program.

References

Introduction to Climate Change

Climate Reality Project. (November 7, 2019). Climate Adaptation vs.Mitigation: What's the Difference and Why Does it Matter?

NASA. (n.d.). Global Climate Change.

NASA. (n.d.). How do we know the climate is changing?

NASA. (n.d.). What is the greenhouse effect?

NASA. (February 27, 2020). Why Milankovitch (Orbital) Cycles Can't Explain Earth's Current Warming – Climate Change

NOAA. (August 7, 2020). Climate is what you expect, weather is what you get

Weather: Atmospheric Pressure

Met Office. (n. d.). High and low pressure.

NASA. (2013). Earth's Atmospheric Layers.

Rutledge, K. et al. (2011). Atmospheric pressure. National Geographic.

Science Struck. (n. d.). Easy Explanation of an Occluded Front With Diagram

University Corporation for Atmospheric Research. (n. d.). The Highs and Lows of Air Pressure.

University Corporation for Atmospheric Research. (n. d.). Weather Fronts.

Weather: Temperature

Canadian Centre for Occupational Health and Safety. (2019). Humidex Rating and Work : OSH Answers.

Deziel, C. (2018), How Does Latitude Affect Climate? Sciencing.com.

Eldridge, A. (n. d.) What's the Difference Between a Solstice and an Equinox? Britannica.com.

Government of Canada. (2019). Guide to public weather forecasts: weather elements.

Kozlowski, R. (2020). How to Calculate a Wind Chill Factor. Sciencing.com.

NASA Space Place. (2020). What Causes the Seasons?

UCAR Center for Science Education. (2013). Change in the Atmosphere with Altitude.

Weather: Clouds

Braun, S. (n.d.). What are clouds made of? Are they more likely to form in polluted air or in pristine air? NASA.

Encyclopaedia Britannica. (2019, March 18). Cloud.

National Oceanic and Atmospheric Administration. (2023, March 28) The Four Core Types of Clouds.

National Oceanic and Atmospheric Administration. (2023, March 28) Ten Basic Clouds.

UCAR Center for Science Education. (2012). Cloud types.

Zuckerman, C. (2019, April 24). Clouds, explained. National Geographic.

Weather: Precipitation

Bradač, M. (2015). The science of snowflakes.

Cenedese, C., Mason, B. and others. (2020, March 21) Climate - Types of precipitation. Encyclopedia Britannica.

Library of Congress. (n. d.) Is it true that no two snow crystals are alike?

National Oceanic and Atmospheric Administration. Freezing Rain and Sleet. Weather.gov

National Oceanic and Atmospheric Administration, National Severe Storms Laboratory. (n. d.) Severe Weather 101: Hail Basics.

Rutledge, K., Ramroop, T. et al. (2011, January 21) Hail. National Geographic

United States Geological Survey. The Fundamentals of the Water Cycle.

YouTube. National Geographic.(2011). Humidity.

Weather: Wind

Environment Canada. (2020). Criteria for public weather alerts: Wind.

EOceanic.com. (n. d.) Understanding the Beaufort Scale.

National Geographic. (2011). Coriolis Effect.

National Geographic. (2012). Wind.