EXPERIMENT MANUAL

Weather & Climate Lab

THAMES & KOSMOS

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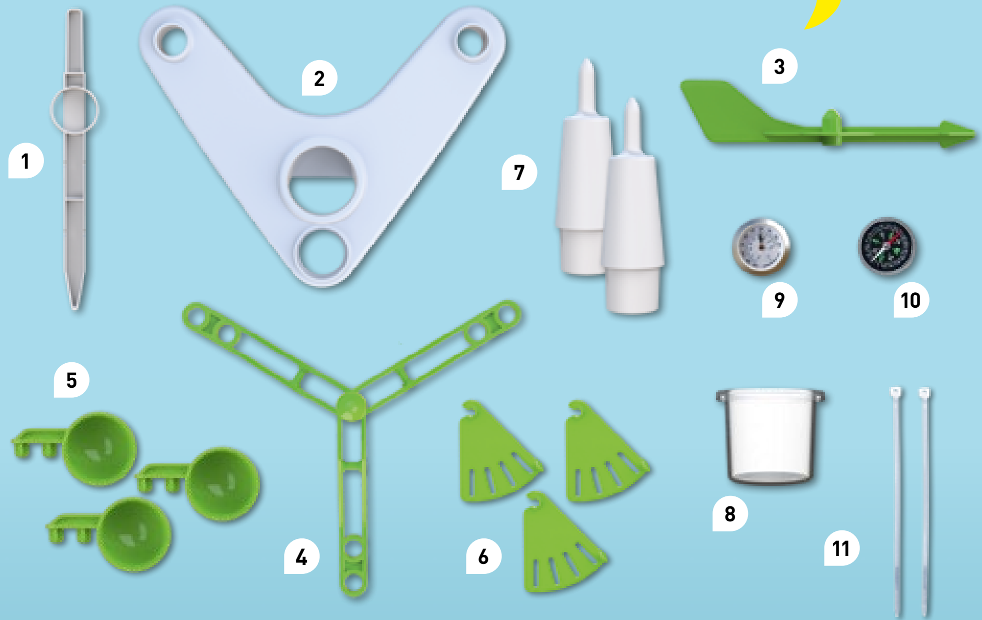
KIT CONTENTS

What's inside your experiment kit:

Good to know!

Do you have any questions or are you missing any parts? Our tech support team will be happy to help you!



Checklist:

✓	No.	Description	Quantity	Part No.
○	1	Weather station peg	1	728519
○	2	Weather station base	1	728513
○	3	Wind vane	1	728568
○	4	Anemometer base	1	728569
○	5	Anemometer wind catcher	3	728570
○	6	Anemometer blade	3	728571
○	7	Wind gauge spindle	2	728572
○	8	Rain gauge, transparent	1	728573
○	9	Thermometer	1	728575
○	10	Compass	1	728576
○	11	Cable tie	2	728574

Parts not included in the box are listed under "You Will Need" in italics.

YOU WILL ALSO NEED:

Scissors, water, ruler, pen, markers, balloon, drinking straw, wooden post, paper, rubber band, empty Mason jar or similar, toothpick, transparent plastic or glass basin/vessel (e.g. a salad bowl or storage box), thermos, flashlight, paper towel, empty plastic bottle, water kettle

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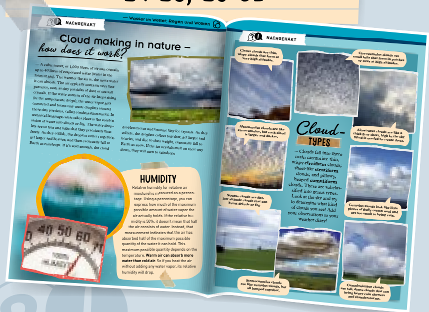
TIP

ADDITIONAL INFORMATION CAN BE FOUND IN THE CHECK IT OUT SECTIONS ON PAGES 7-9, 13, 17-19, 24-25, 28-31



Ready? — let's go!

550049-02-160124

Warning!
Not suitable for children under 3 years. Choking hazard — small parts may be swallowed or inhaled. Keep the packaging and instructions as they contain important information.

Dear Explorers,

With this kit, you will build an outdoor weather station that you can use to observe and study your environment! Included in your weather station is a rain gauge, a wind vane, a thermometer, a compass, and a tool called an "anemometer" to measure wind speed.

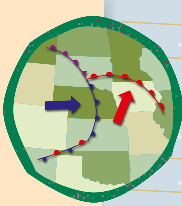
In this manual, you will also find lots of fun weather experiments that will help you learn what causes rain, wind, and clouds.

Let's go! In just a few steps you can assemble the station and you'll be ready to start your weather observations! Ask an adult for help installing or mounting the station outside.

If there is severe weather outside, do not go out to your weather station. You could get injured. It's best for you to pay attention to weather forecasts in your area and bring your weather station inside before strong winds, storms, or heavy rainfall are predicted.

IMPORTANT INFORMATION

Dear Parents and Supervising Adults



Children want to explore, understand, and create new things. They want to try things and do it by themselves. They want to gain knowledge! They can do all of this with Thames & Kosmos experiment kits. With every single experiment, they grow smarter and more knowledgeable.

This experiment kit will give your child their own functional outdoor weather station that they can use to measure precipitation, track temperatures, and observe wind speed and direction. In addition, you will find exciting experiments in this manual exploring weather phenomena like clouds and meteorological terms like air pressure.

Support your little meteorologist in setting up and installing the weather station and in conducting the experiments described in the manual. Find a place outside together to install and secure the weather station, such as a balcony or your front yard. If you install the weather station on a balcony, please take care that your child does not risk falling when using the station; for instance if they have to climb up on something in order to access it. The weather station should be set up somewhere exposed to the elements that will allow for collection of rainwater and where it will be in the path of the wind. The wind vane and the anemometer must be able to spin without obstruction. Ideally, the station should be visible through a window from indoors. To avoid damage, store the station safely during severe weather, hail, and storms. Check, dry, and clean the station after heavy rain or snow. Take care that your child does not stay outside with the weather station during hazardous weather conditions (storms, hail, or heavy rain).

This experiment kit is not suitable for children under 6 years of age and should therefore be kept out of their reach. Supervise your child when handling the weather station and experimenting. Please read and follow these instructions and the description of the steps of the experiments and keep them handy for reference. Discuss the safety information and the possible hazards with your child. A solid table without a sensitive surface is the best place to experiment. There should be good lighting and access to a water tap. There must be no sockets or electrical devices near the workplace.

We wish you and your child lots of fun with the weather station!

Enjoy!

Your WEATHER STATION...

... is quick to assemble, and then it's time to get started: Measure rainfall and the wind's speed and direction, and track changes in temperature over one day or several weeks. With your weather station, you can easily observe and study the weather right outside your door!

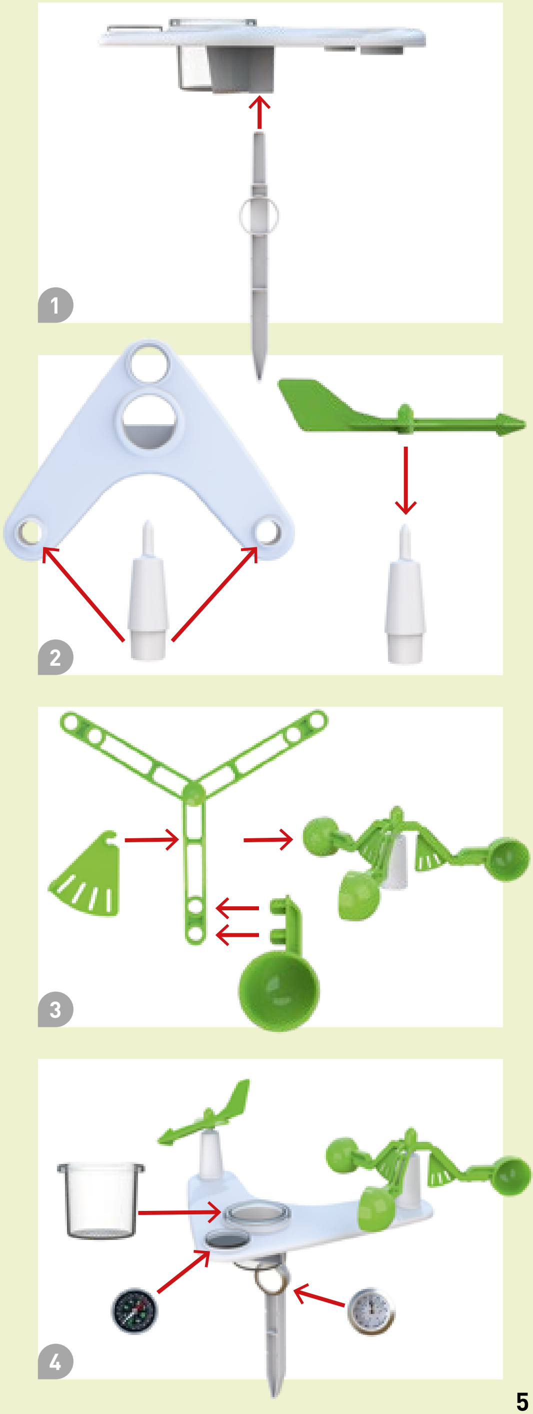
Assembling the weather station

You will need

- Weather station base and peg
- Wind gauge spindles
- Wind vane
- Anemometer pieces
- Rain gauge
- Thermometer & compass
- Cable ties

Here's how

1. Insert the weather station peg into the designated hole in the bottom of base.
2. Insert the two wind gauge spindles into the designated holes on the top of the base. Place the wind vane on the tip of one of the spindles.
3. Snap the three anemometer blades onto the pivots in the arms of the anemometer base. Insert the posts of the three wind catchers into the holes at the ends of the base's arms. The bowls of all three wind catchers should face in the same direction. Place the assembled anemometer onto the second spindle.
4. Place the compass into the designated slot on the top of the weather station. Insert the thermometer into the round slot in the peg. Ensure that the display is facing out so that you can read it. Place the rain gauge into the top of the weather station so that you can see the scale in the front.



Setting up the station outside

You will need

– Cable ties

Here's how

1. Read through the information in the green box on the right.
2. With an adult, find a good place for your weather station, keeping in mind all of the information in the green box.
3. If you are putting the weather station in a flower pot or the ground: drive the peg far enough into the soil that the station stands securely upright.
4. If you want to mount the station with the cable ties: Ask an adult for help. Place the cable ties across the notches designed for that purpose on the weather station peg. The cable ties must go around both the peg and the material that the station will be attached to. Cinch the cable ties tight. You can re-open the cable ties with the small clips on the ends.

PLACING YOUR WEATHER STATION

In order to ensure that your weather station works, keep the following things in mind when choosing where to set it up:

– The weather station should be **elevated and free of obstructions.** The wind vane needs to be able to spin freely. Ideal locations include a spot in the garden, a balcony planter, or a terrace railing.

– For the compass to work, the weather station must be set up **parallel to the ground**. Do not stick the station into the ground crookedly or attach it at an angle.

– To measure temperature accurately, the weather station should be at least **1-2 meters away from the building exterior.**

– To measure rain, the weather station must be placed **under the open sky.** It should not be beneath plants or an overhanging roof. If you are putting the weather station on a balcony, check if there is another balcony or a shade over it. If this is the case, hang the weather station on the exterior side of the balcony rail. Have an adult help you with this!

– The weather station should be **easily accessible** so that you can take measurements regularly. Locations such as a garage roof are not suitable.

CHECK IT OUT

Actually, what is *weather?*

The Climate System

Earth's **CLIMATE SYSTEM** is awesome and complicated. It consists of several systems, called spheres, such as the envelope of air around Earth, called the **atmosphere,** and the layer of water composed of oceans, seas, rivers, and groundwater, called the **hydrosphere.** Earth's areas of snow and ice, the **cryosphere,** and its expanses of soil, the **pedosphere,** and of rock, the **lithosphere,** are other parts of the climate system. All these systems affect one another. They store water and heat, and they exchange water and heat with each other. The sun is the driving force behind the interactions between the different systems.

THE TERM "CLIMATE"...

... refers to the environmental conditions in a particular region over a long period of time. It also includes daily and seasonal fluctuations — for example, whether it is usually cool and dry or hot and muggy in a given location in summer. Several factors influence the climate: the sun's radiation, the distribution of land and ocean masses, the height above sea level, the composition of the atmosphere, and wind systems. The interaction of these factors determines when and for how long the sun shines, and whether it is warm, cold, cloudy, rainy, stormy, or snowy.

TALKING ABOUT "WEATHER"

When people talk about weather, they mean the state of the atmosphere at a given moment and place. The weather is directly perceivable as sunshine, cloudiness, rain, heat, or cold. So weather and climate describe similar characteristics, but climate is general to a region over a period of time, and weather is specific to a particular location and time.

CHECK IT OUT

Summer and Winter

As addressed on the previous page, solar radiation is a major factor influencing the weather — and here is why: You have probably noticed how strong an effect the sun's angle can have on the temperature over the course of a single day. If you are sitting in the sun at noon on a summer day, you will quickly get hot. With the approach of evening on the same day, as the sun gradually sinks to the horizon and its rays are coming from the side rather than above, it will be just pleasantly warm.

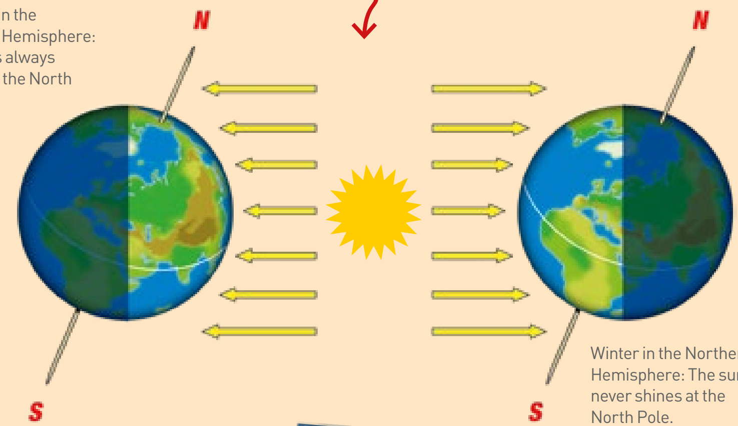
At the North and South Poles, the varying paths of the sun have the greatest effect. There, half a year will go by without the sun sinking under the horizon or rising above it. This is called **polar night** or **polar day** and lasts for months. At the equator, on the other hand, the sun's position hardly varies over the course of a year. There are practically no seasons, and for the entire year, day and night are almost equally long, namely about 12 hours each.

KEYWORD

Meteorology

The term "meteorology" refers to the science that deals with the processes in Earth's atmosphere, such as weather and climate. Like you, meteorologists observe and record data about atmospheric pressure, wind, temperature, and more using a weather station. They prepare weather forecasts and research weather phenomena like cloud formation. They also concern themselves with the climate, and create things like climate maps or climate diagrams. To do these things, meteorologists use mathematics, chemistry, physics, geography, and biology.

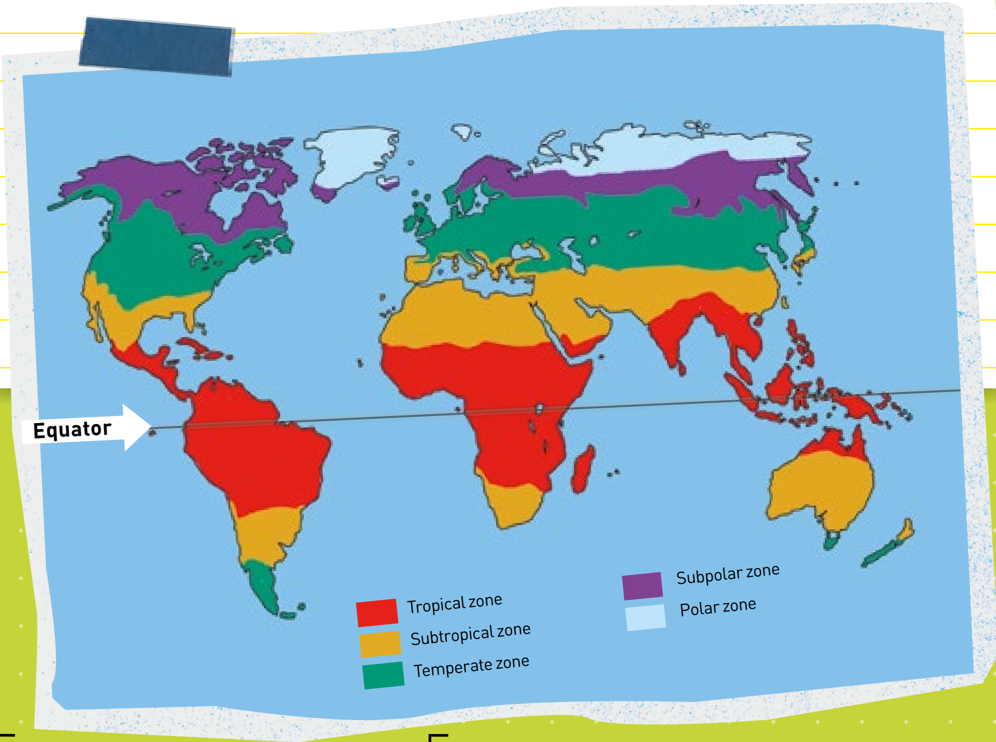
Summer in the Northern Hemisphere: The sun is always shining at the North Pole.



Winter in the Northern Hemisphere: The sun never shines at the North Pole.

Climatic zones

The Earth is divided into climatic zones based on various climatic conditions. The reason the climatic conditions are not all the same has to do with the different degrees of intensity of solar radiation. The climatic zones run from the North Pole to the South Pole, more or less parallel to the lines of latitude. The zones are mirror images of each other in the Northern and Southern Hemispheres.



The most extreme seasonal temperature differences are found near the poles. Overall, the climate there is very cold, and only gets above freezing in summer if at all. Closer to the equator, the climate is warmer. At the equator, the weather is hot and humid all year around. The seasons are less pronounced at the equator compared to other zones.

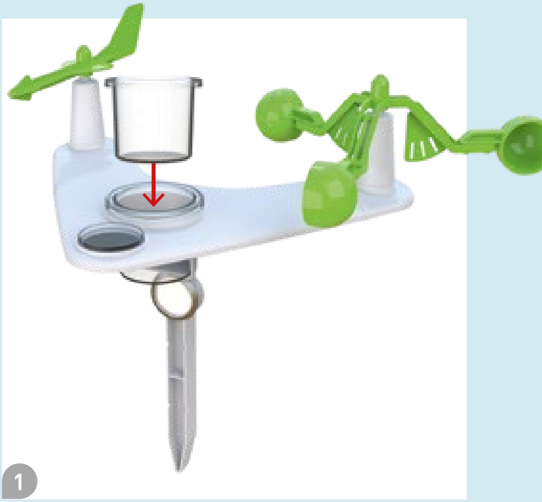
Most of North America is in the temperate zone. The temperate zone is characterized by four distinct seasons and differences between day and night that vary considerably with the seasons. Temperature, humidity, and precipitation are also quite variable. The temperate zone can be divided into many smaller zones, and is not the same everywhere. The most important factor in dividing the temperate zone into smaller zones with similar climatic conditions is the proximity of the region to the ocean.

Water in Weather

Water is fundamental to life on Earth, and without water there would also be no weather. Not only is more than 70% of the Earth's surface covered by water, but the atmosphere that surrounds us also contains water in the form of water vapor. We experience this as precipitation in weather events as rain, snow, or hail. With your weather station, you can measure the amount of precipitation where you live.

EXPERIMENT 1

Measure rainfall



You will need

- **Weather station with rain gauge**
- *Pen*
- *Ruler*
- *Paper*

Here's how

1. Ensure that your weather station with the rain gauge is positioned so that rain can fall into the container.
2. To compare rainfall quantities, read the rainfall in millimeters at the same time every day. Take notes about the rainfall in a weather journal. You can find a template for this on the last page of this manual.
3. Empty the rain gauge completely after your measurement and place it back in the station.

IMPORTANT! Do not go outside in a storm or heavy rain to read or empty the rain gauge!

A professional rain gauge

WHAT'S HAPPENING?

Fallen precipitation is **measured in millimeters.** One millimeter of rain in the rain gauge is equivalent to one liter of rain per square meter. That means if you measure 10 mm of precipitation, ten liters of precipitation have fallen in your area on every square meter of ground. Rain is not the only form of precipitation. Hail and snow are also measured with precipitation gauges.

EXPERIMENT 2

Make it rain

You will need

- *Water, water kettle, ice cubes*
- *Vessel with a rounded base, (e.g. small bowl)*
- *Heat-resistant glass jar or vessel, (e.g. Mason jar)*

Here's how

1. This step should be performed by an adult: heat water in a kettle. Place a heat-resistant glass jar securely on a stable, waterproof surface. Let the water cool to just below boiling, then fill the jar with approximately two finger-widths of water.
2. Carefully place the small bowl on the opening of the jar of water. It must completely close the opening of the jar. Place a handful of ice cubes into the bowl.
3. Now observe what happens at the bottom of the bowl. After a little while, you should start to observe some raindrops inside the jar! If you're patient, you can watch more raindrops form for another 10–15 minutes.


1


2


3

WHAT'S HAPPENING?

The hot, almost boiling water releases steam. The steam rises and stays trapped in the jar, because the bowl is blocking the opening. Meanwhile, the ice drastically cools the bottom of the bowl. So the water condenses, or becomes liquid, on the underside of the cold bowl. Soon, you can see tiny droplets forming that slowly combine into larger drops. At some point, when the larger, heavier drops can no longer stick to the bottom of the bowl they fall again into the water at the bottom of the jar. It's raining in the jar!

CHECK IT OUT

The Water Cycle

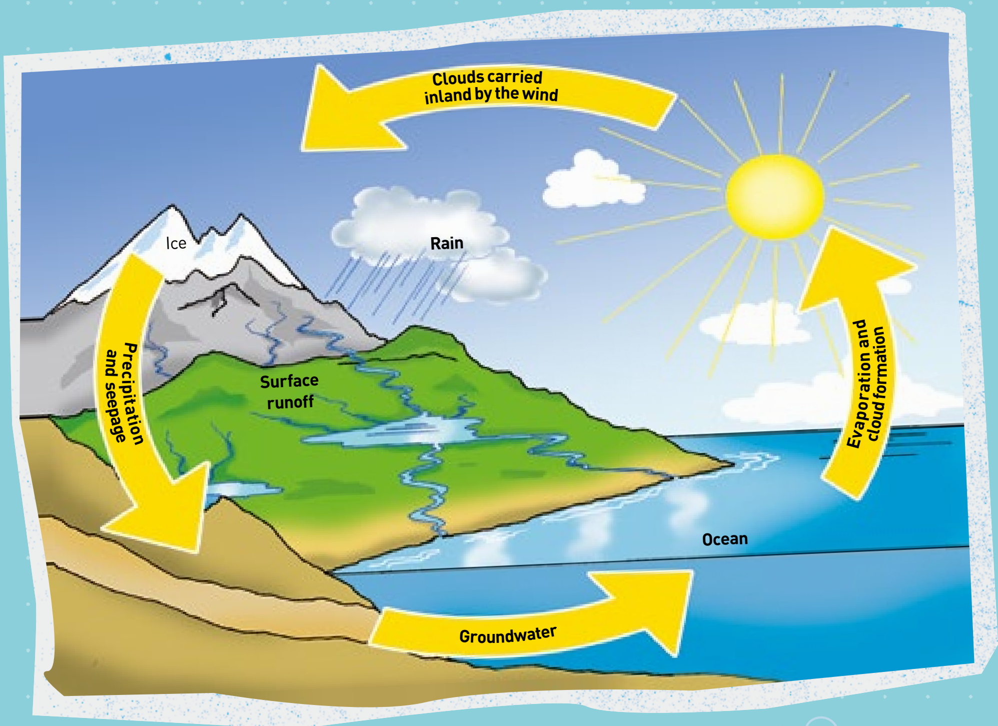
The oceans, rivers, seas, and groundwater form the **hydrosphere,** or the layer of water covering Earth. But that is only the water that sits on and under the Earth's surface. Water also shows up in lots of other forms. The forms that you probably know best are the rain and snow that fall from the sky. Water is also contained in the air, even though you don't see it because it is present as invisible vapor. All of these forms interconnect and create a continuous, natural water cycle.

Some rain seeps into the ground becoming groundwater, and some of it flows directly across the surface into rivers. Groundwater also feeds into the rivers that empty into the oceans after their long journeys.

If it's hot on Earth's surface, the water vaporizes and enters the atmosphere as water vapor. This process is called **evaporation.**

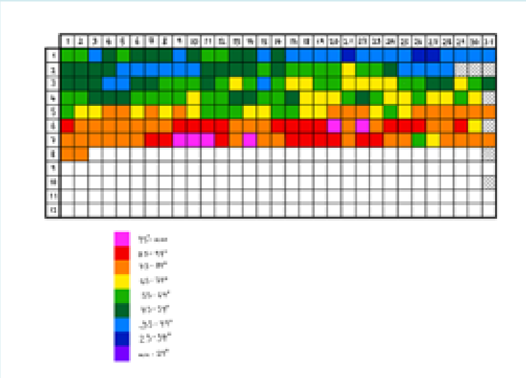
The water vapor then forms clouds by a process known as **condensation.** The water in the clouds falls to Earth in the form of rain or snow. Snow and ice melt and flow into the groundwater, rivers, or the ocean. Through this cycle, water changes its state several times, but none of it is lost. The water we have on Earth now is the same water that surrounded dinosaurs millions of years ago!

Precipitation is the most important means of water supply in most regions of the world. The quantity of precipitation decides how much vegetation can be supported in a region.



EXPERIMENT 3

A year of weather in pixels



You will need

- **Weather station thermometer**
- **This template**
- *Markers or pens*

Here's how

1. Choose a time when you will check the temperature on the weather station thermometer each day (or have someone else check for you if you aren't home). It would be best to measure the temperature in the afternoon, since that's usually when the day reaches its highest temperature.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
January														
February														
March														
April														
May														
June														
July														
August														
September														
October														
November														
December														

2. **Choose a color scheme:** First find out what the maximum and minimum temperatures are in your area. Divide the temperature range in between into even segments. Don't make the segments bigger than 10 degrees! Write them down in the template to the right and assign a color to each segment. You can use the example on the left to help.

3. After reading the temperature each day, color in the pixel for that day with the corresponding color.

	Degree:

Of course, you can also record other weather phenomena at the same time, for instance with little symbols drawn in the squares after they're colored:

~ WIND
★ SNOW
∴ RAIN

15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31

EXPERIMENT 4

Cloud making

You will need

- *Transparent plastic or glass basin/vessel (e.g. a salad bowl or storage box)*
- *Water*
- *Insulated flask or glass jar*
- *Towel*
- *Flashlight*

4

Here's how:

1. Place an empty, uncapped insulated flask in the freezer for one hour.
2. Fill the basin/vessel about halfway with warm water.
3. Take the flask from the freezer and immediately cover the opening with a towel or cloth. Quickly bring the flask over to the basin and tip the flask over the basin as if you were trying to pour water out of it. As you do this, the flask opening must be quite close to the surface of the water. Watch the surface of the water beneath the flask opening very closely! For even better results conduct this experiment in a darkened room with the beam of a flashlight pointed at the vessel. What do you see?

WHAT'S HAPPENING?

The heavy cold air from the insulated flask pours onto the warm air above the basin and cools it. The air's capacity to absorb water decreases, some of the water contained in it condenses, and small clouds form. **You can see these wisps of cloud particularly clearly in the beam of a flashlight coming from the side in a darkened room.**

Rain clouds are likely to form when cold air masses slide under warm and humid ones and lift them up, and when damp ocean air gets pushed up and cooled by mountains and hills. But it also happens when damp air that is warmed during the day cools off at night. This is typical in tropical rainforests.

CHECK IT OUT

Cloud making in nature
how does it work?

A cubic meter, or 1,000 liters, of air can contain up to 40 liters of evaporated water (water in the form of gas). The warmer the air is, the more water it can absorb. The air typically contains very fine particles, such as tiny particles of dust or sea salt crystals. If the water content of the air keeps rising (or the temperature drops), the water vapor will be converted to form tiny liquid droplets around these particles, called condensation nuclei. In technical language, what takes place is the condensation of water into clouds or fog. The water droplets are so fine and light that they practically float freely. As they collide, the droplets collect together, get larger and heavier, and then eventually fall to earth as raindrops. If it's cold enough, the cloud droplets freeze and become tiny ice crystals. As they collide, the droplets collect together, get larger and heavier, and due to their weight, eventually fall to earth as snow. If the ice crystals melt on their way down, they will turn to raindrops.

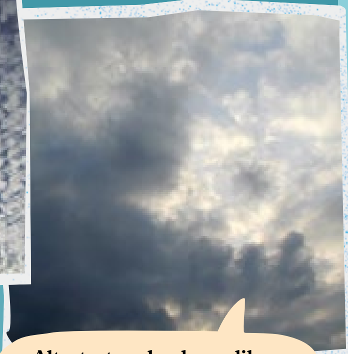
HUMIDITY

Relative humidity (or relative air moisture) is measured as a percentage. Using a percentage, you can express how much of the maximum possible amount of water vapor is being held in the air. If the relative humidity is 50%, it doesn't mean that half the air consists of water. Instead, that measurement indicates that the air has absorbed half of the maximum possible quantity of the water it can hold. This maximum possible quantity depends on the temperature. **Warm air can absorb more water than cold air**. So if you heat the air without adding any water vapor, its relative humidity will drop.

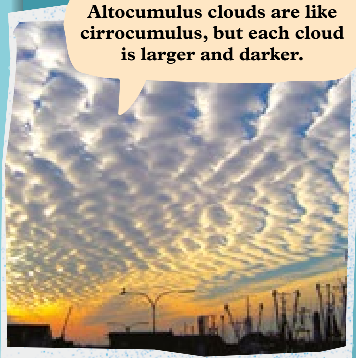
CHECK IT OUT

Cirrus clouds are thin, wispy clouds that form at very high altitudes.

Cirrocumulus clouds are small tufts that form in patches or rows at high altitudes.



Altostratus clouds are like a thick gray sheet, high in the sky. Wind is needed to create these.



Altocumulus clouds are like cirrocumulus, but each cloud is larger and darker.

Cloud TYPES

Clouds fall into three main categories: thin, wispy **cirriform** clouds; sheet-like **stratiform** clouds; and pillowy, heaped **cumuliform** clouds. These are subclassified into genus types. Look at the sky and try to determine what kind of clouds you see. Add your observations to your weather diary.

Cumulus clouds look like little pieces of fluffy cotton wool and are too small to bring rain.

Stratus clouds are flat, low altitude clouds that can bring drizzle or fog.

Stratocumulus clouds are like cumulus clouds, but all lumped together.

Cumulonimbus clouds are tall, dense clouds that can bring heavy rain showers and thunderstorms.

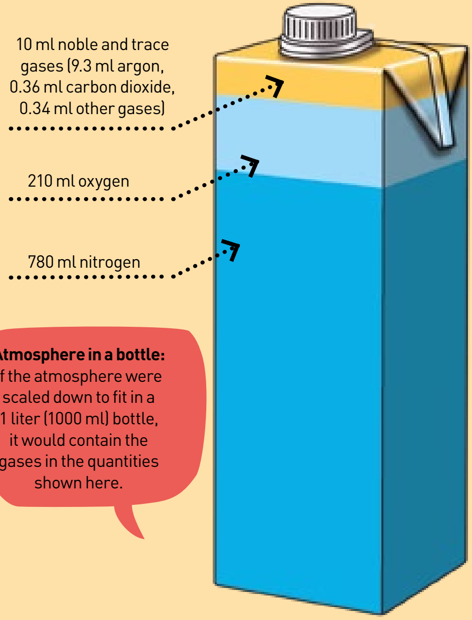
EARTH'S ATMOSPHERE

The air that we breathe is a mixture of various gases. The largest component is nitrogen. If you could capture just a tiny quantity of the particles, four out of five of them would probably be nitrogen. The fifth would be oxygen. Besides nitrogen and oxygen, there are noble gases and other trace gases contained in the air. But just one out of a hundred particles is a noble gas. Air also contains a small, variable proportion of water vapor, which is responsible for clouds and other weather patterns.

If you look at 10,000 particles, fewer than four of them would be carbon dioxide. Because it is only present in quite small quantities, carbon dioxide belongs to the group of trace gases. Other members of that group are methane, ozone, and CFCs, which stands for chlorofluorocarbons. Even though they make up only a small part of the air, they are of great importance to our climate.

Together, all of these gases form a thin envelope around the Earth called the atmosphere. Like all objects on Earth, the atmosphere is attracted and held in place by the Earth's gravitational field. Altogether, the atmosphere is about 640 kilometers (400 miles) thick and weighs about 5×10^{18} kilograms — that's a 5 with 18 zeros after it. That is about 11×10^{18} pounds.

The atmosphere is composed of several layers, and the density of the air molecules, i.e. the mass of air molecules in a given volume of air, becomes less and less as you go higher. The lowest 10–15 kilometers, called the troposphere, is where clouds are formed and weather patterns play out. The next layer, called the stratosphere, extends 11–50 km above Earth's surface and contains the ozone layer, which converts dangerous ultraviolet light into heat.



Atmosphere in a bottle: If the atmosphere were scaled down to fit in a 1 liter (1000 ml) bottle, it would contain the gases in the quantities shown here.

A Protective Layer of Air

Our atmosphere protects us in two ways. For one thing, it prevents the full energy of the sun from heating the Earth. If that were to happen, temperatures would get much too high to permit life as we know it to exist. At the same time, the atmosphere keeps the heat from the sun that does reach the Earth from being completely given off (reflected or radiated) back into space. If this were to happen, nights on Earth would be bitterly cold.

Pressure and Temperature

Like most physical bodies, air reacts to being warmed by expanding. Cold air is heavier than warm air, because in the same volume of space there are more air molecules in cold air than in warm air. Understanding this relationship between pressure and temperature is critical to understanding how Earth's climate and weather systems work.

EXPERIMENT 5

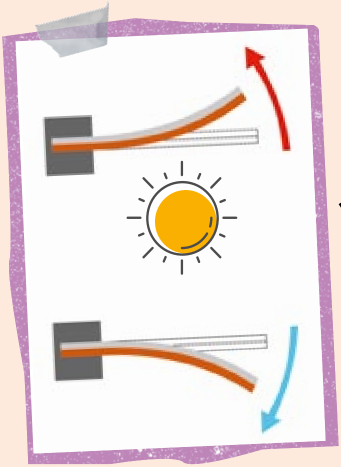
Measure temperature

You will need

- **Weather station thermometer**
- **Weather journal and "A year of weather in pixels" template**
- *Pen and paper*

Here's how:

1. Always measure the temperature on the thermometer of your weather station **in the shade!** Relocate your weather station if you see that the thermometer is in the sun.
2. In order to compare temperatures in your area, check the temperature daily once in the early morning and once in the afternoon. Usually these are the coldest and warmest times of the day.
3. Record both temperatures in a weather journal like the one you can find on the last page of this manual.
4. Record the afternoon temperature in the "A year of weather in pixels" template.



WHAT'S HAPPENING?

Your weather station's thermometer is a **bimetallic thermometer.** There is a bimetallic coil inside of it. This coil is made up of two different strips of metal that are bonded together. When the temperature changes, the two metals contract or expand differently, which bends the coil. This causes the pointer attached to the bimetallic coil to move and point to the temperature. There are other kinds of thermometers, such as mercury thermometers. Different units are used to measure temperature in different countries, so the thermometer shows the temperature in both Celsius (C) and Fahrenheit (F).

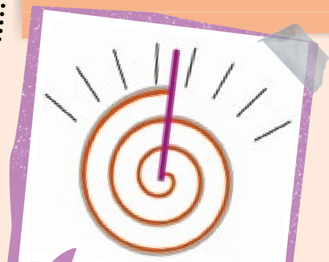


Diagram of a bimetallic thermometer

Warm and cold air

You will need

- *latex balloon*
- *empty plastic bottle*
- *water*
- *refrigerator*

Here's how:

1. Pull the balloon over the mouth of an empty plastic bottle, and hold the bottle under warm running water. Make sure you don't turn the water on too hot and scald yourself! After a little while, the balloon will expand.
2. You will get the opposite effect if you tightly screw the top onto the bottle and leave it overnight in the freezer. The next morning, the bottle will be crumpled.

WHAT'S HAPPENING?

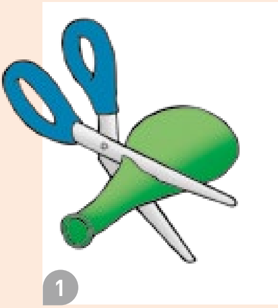
Under warm water, the air in the bottle is warmed. Warm air expands and spreads out into the balloon, which offers resistance and is stretched tight. When air cools, its volume decreases. So in the bottle left in the freezer, a vacuum forms and its walls crumple inward.

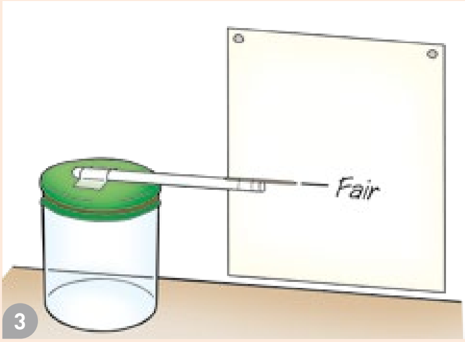
EXPERIMENT 7

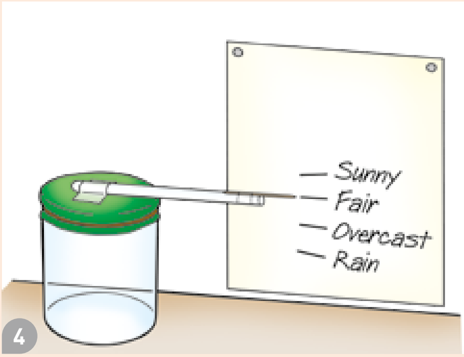
Build a simple barometer

You will need

– empty glass jar, or empty coffee or soup can
– scissors, latex balloon, rubber bands
– pin or toothpick, drinking straw
– paper and pen







Here's how:

1. Blow up the balloon a few times to stretch it out. Cut the neck off of the balloon. Stretch the larger top portion over the top of the jar, creating an airtight seal.
2. Secure the balloon in place with a couple of rubber bands.
3. Tape the pin (or toothpick) onto one end of the drinking straw. Tape the other side of the straw securely to the center of the balloon. Place a piece of paper on the wall and move your barometer next to it. Set this away from direct sources of heat and sunlight. Record your initial measurement by marking the paper at the exact pin point and noting the day's weather.
4. Continue to mark the weather periodically throughout the week. Do you see any patterns? What is the weather usually like when the pin points upward, and what is the weather usually like when it points downward?
5. Add your observations to your weather diary.

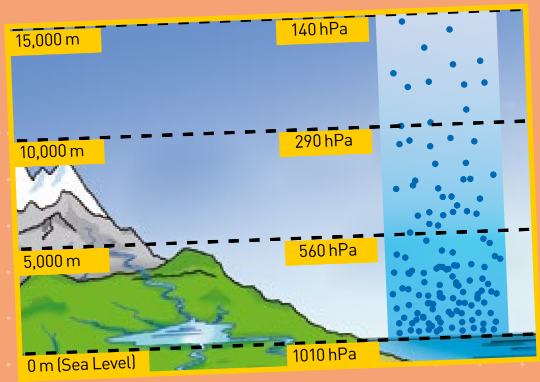
WHAT'S HAPPENING?

Higher pressure pushes the balloon into the jar and moves the pin point upward. Lower pressure does the opposite. You should see that higher pressure relates to nicer weather, while lower pressure relates to stormy or rainy weather. See the next page for an explanation of why this happens.

CHECK IT OUT

Air pressure

As you learned in Experiment 6, air is not nothing. Air is made up of tiny molecules that take up volume and have weight. Air pressure is the force exerted on objects by the combined weight of all these tiny molecules above them. Air can be compressed into smaller volumes. The more air molecules there are in a space with a set volume and temperature, the higher the air pressure in that space.



Because of the force of gravity, there are more air molecules at sea level than there are at high altitudes. The air pressure is highest at sea level, and steadily decreases as altitude increases. The standard air pressure at sea level is 1013.25 hPa or 29.92 inches of mercury. At approximately 9,000 meters, or the height of Mt. Everest, the air pressure is only 320 hPa. At 100 km above sea level, the air pressure is virtually zero.

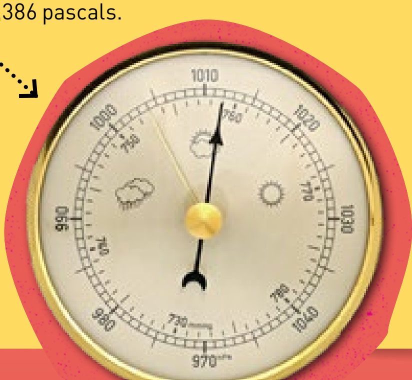
HOW IS AIR PRESSURE MEASURED?

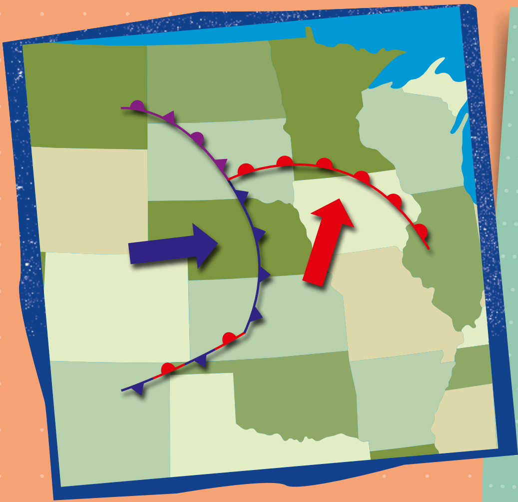
The air pressure surrounding us is about 1,000 hPa. You can check this on a barometer, a device that measures air pressure. If you do not have one at home, you can find the current barometric pressure in the weather forecast.

"Pa" stands for Pascal, the unit for pressure in the metric system. The "h" stands for hecto, a prefix that means 100. 1,000 hPa is, therefore, 1,000 x 100 Pa, or 100,000 Pa. The atmospheric pressure varies somewhat. Inside a high-pressure area it can be around 1,050 hPa, whereas inside a low-pressure area, it may only be 960 hPa.

The pressure in a car tire is about 2,000 hPa above the atmospheric pressure. In a bicycle tire, there may be an overpressure of up to 7,000 hPa. The pressure also increases rapidly under water. For every centimeter that you dive down, the pressure rises by about 1 hPa. Therefore, at the bottom of a 2 meter deep swimming pool, the pressure is 200 hPa higher than at the surface.

In the U.S., air pressure is often measured and reported in "inches of mercury" in weather reports. One inch of mercury equals 3,386 pascals.





FORECASTING THE WEATHER

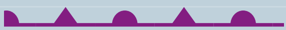
Analyzing changes in air pressure can help you forecast changes in the weather. Generally speaking, the weather will be nicer when pressure increases, and it will be rainier or stormier when pressure decreases. When a low pressure air mass is on its way, it is likely that rain or snow will follow. This is because the low pressure air is lighter, so it rises up into the atmosphere where it is colder, and condenses to form precipitation. Conversely, when a high pressure air mass is on its way, it's more likely that there will be clear skies.

WEATHER FRONTS

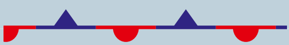
Meteorologists, or scientists who study the atmosphere, use special symbols and maps to track weather patterns. These weather maps show the positions of large masses of air in which the conditions — temperature, pressure, and humidity — are consistent. Monitoring the movement of these air masses allows them to forecast the weather. The air masses move at different speeds around the globe. When one air mass meets another, the boundary between them is called a front. There is often precipitation or stormy weather along fronts. There are four major types of fronts.

When a cold air mass moves into a warm air mass, a cold front forms. Cold air is denser than warm air, so it sinks under the warm air, pushing the warm air up. This creates cumulus clouds, precipitation, and storms along the front. As the front passes, the temperature drops and the skies become clear. Cold fronts move about twice as fast as warm fronts.

A warm front forms when a warm air mass moves into a cold air mass. The warm air is less dense, and thus flows over the cold air. This forms cirrus or stratus clouds along the front, and sometimes precipitation. As the front passes, the temperature rises and the skies clear.



An occluded front occurs when a cold front overtakes a warm front, because it was moving more quickly. The weather can be unpredictable here.



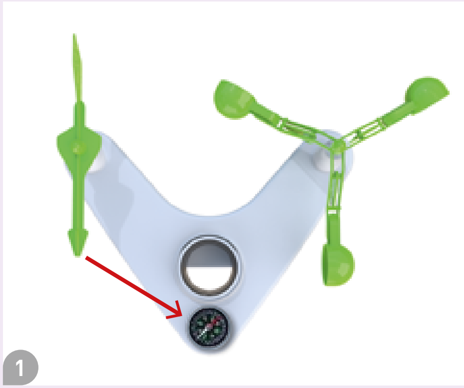
A front that does not move for a period of time is called a stationary front. Mild winds and precipitation occur along stationary fronts.

Wind and Climate Change

The air in our atmosphere is not like a rigid shell. Its movements range from soft breezes to heavy storms. The main cause of wind is differences in air pressure between different air masses. Air particles from areas with a higher air pressure flow into areas with lower air pressure. You can measure the resulting wind with your weather station in two ways: Wind speed and wind direction.

EXPERIMENT 8

Measure wind speed and direction

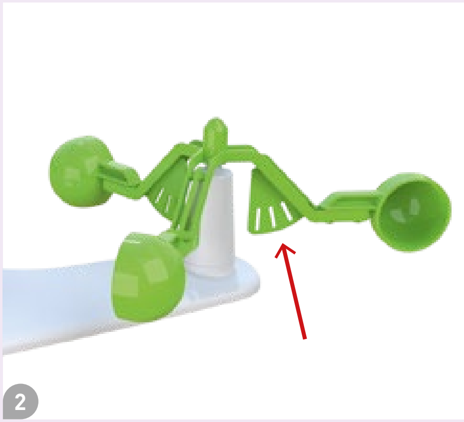


You will need

- **Weather station with wind vane and anemometer**

Here's how

1. The wind vane combined with the compass will help you to figure out the direction of the wind: Observe where the tip of the wind vane is pointing and use the compass to find the corresponding cardinal direction. Write down the result in your weather journal.
2. With the anemometer, you can estimate the wind speed. Depending on the wind speed, the blades will show one, two, or three stripes. Record this in your weather journal.
3. If you would like to use the official wind speed scale, called the **Beaufort scale,** refer to the table on the next page.



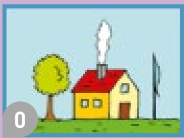
WHAT'S HAPPENING?

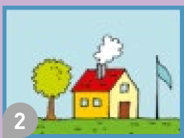
Both the anemometer and the wind vane rest on a point of a spindle. The minimal friction between the surfaces ensures that the wind can move both instruments easily.

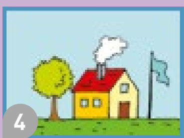
CHECK IT OUT

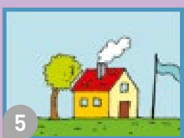
MEASURING WIND SPEED

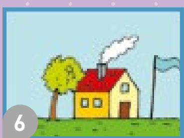
Wind speed is measured in Beaufort numbers (bft), named after the British admiral who created this multi-part scale in 1806.



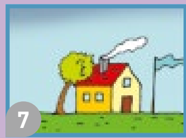


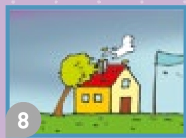


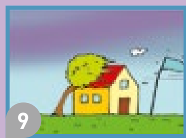


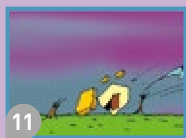


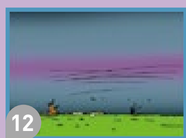
Beaufort	Name	Description
0	Calm	Smoke rises straight up
1	Light air	Leaves move in the treetops
2	Light breeze	Smoke blows, light movement in the tips of grasses
3	Gentle breeze	Smoke blows quickly, flags, grasses, and the tips of bushes move lightly
4	Moderate breeze	Wind can be felt, tops of trees and bushes move and make a soft rustling sound
5	Fresh breeze	Wind is clearly felt, tops of trees and bushes obviously move with rustling sound
6	Strong breeze	Trees and branches move strongly, waves and white foam form on water's surface
7	Near gale	Trees make whooshing noise, leaves are torn off, water forms whitecaps
8	Gale	Entire trees in motion, twigs break, the wind starts to howl, high waves on the water
9	Severe gale	Thin branches break, the wind howls, strong whitecaps on the water
10	Storm	Trees are uprooted, significant damage occurs
11	Violent storm	Heavy storm damage
12	Hurricane	Catastrophic hurricane damage









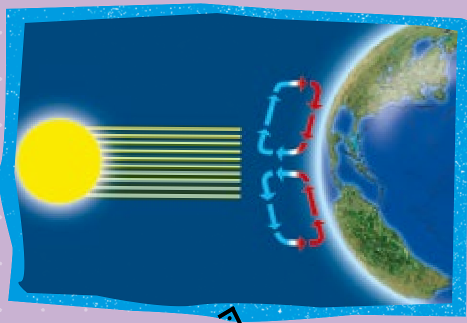


Huh!
Stormy weather!

Global Circulation

Air doesn't just circulate within small areas. If you look at Earth as a whole, large-scale wind patterns may be observed, stretching over the entire planet. This is known as global circulation. The source of energy for these global wind movements is, once again, the sun. Due to the spherical shape of Earth, the overall radiation of the sun lessens as you get closer to Earth's poles. Radiation from the sun is strongest at the equator, so a lot of energy is delivered to areas near the equator.

At the equator, warm air rises up. At sea level there, a low pressure region develops, and a high pressure region develops much higher up. At the poles, on the other hand, the cold air lies heavily on the ground. A high pressure region forms there, while a low pressure area forms above it. So the temperature gradient between the equatorial tropics and the poles gives rise to a difference in pressure, called a pressure gradient, that is equalized by large-scale wind movements. Warmed air moves near the ground from the poles to the equator, and rises at the equator. When it rises, it cools and moves higher up back towards the poles, where it sinks again. These movements of air create the air mass exchange of the global wind system.

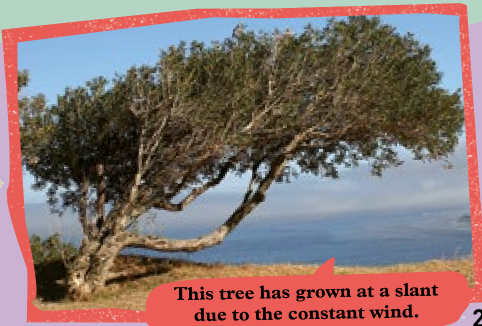


Planetary circulation

Local winds

If a given landscape is heated more strongly by the sun than the area around it, the warm air will rise, because it is lighter than the surrounding cold air. That can happen, for example, where a ripe field of grain borders on a forest. At ground level, cold air follows the warm air, and is in turn warmed and rises up. In this way, a tunnel of constantly upward-moving warm air is formed. This is known as an updraft or thermal. Birds and gliders like to take advantage of thermals to get a free elevator ride high up into the air.

Because mountains and valleys have differences in elevation and temperature, they also have differences in air pressure. When air masses flow over a mountain range, this difference in air pressure usually causes so-called fall winds. This is nothing other than an exchange between cold and warm air, and happens, for example, along seacoasts where the land is mountainous and colder than the ocean.



This tree has grown at a slant due to the constant wind.

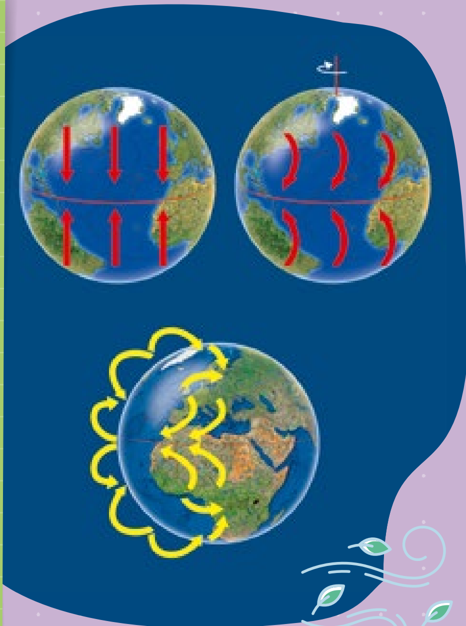
CHECK IT OUT

THE CORIOLIS FORCE

If Earth ever stood still, the global air currents would always run parallel to Earth's axis from bottom to top, as described on the previous page. According to this principle, near the ground in the northern hemisphere you would only ever get a north wind and in the southern hemisphere only a south wind.

However, as the Earth rotates from west to east, the air currents will be deflected in the direction of this movement. A mass of air flowing toward the equator will be turned into a northeasterly wind in the northern hemisphere, or a southeasterly wind in the southern hemisphere. The force responsible for this is known as the **Coriolis force.** At high altitudes, in the region of moderate or middle latitudes between pole and equator, we also get an opposing air current. The cause of this is, once again, the Coriolis force. The winds there are diverted parallel to the lines of latitude into a very powerful westerly wind current, which is known as the **jet stream.**

The **jet stream** is a strong high-altitude wind, which can pull the lower layers of air with it, causing turbulence. This gives rise to dynamic high and low pressure regions that influence the weather. High pressure regions are known as **anticyclones,** while low pressure regions are called **cyclones.** They rotate in a virtually circular manner. When viewed from space, cyclones in the northern hemisphere rotate in a counterclockwise direction, while anticyclones rotate the opposite way.



A typical tropical hurricane rotating in a counterclockwise direction

The current patterns of the atmosphere are easily recognizable in clouds seen from space.

Climate change

You have probably heard of the **greenhouse effect** in connection with climate change. It is often claimed that the greenhouse effect is caused by humans. But that isn't the whole story. There is a natural greenhouse effect, without which life on Earth as we know it wouldn't even be possible in the first place!

This natural greenhouse effect is responsible for the fact that the heat reflected back from Earth's surface doesn't simply leave the atmosphere. Instead, it is first absorbed by trace gases in the atmosphere, known as greenhouse gases, and also by clouds.

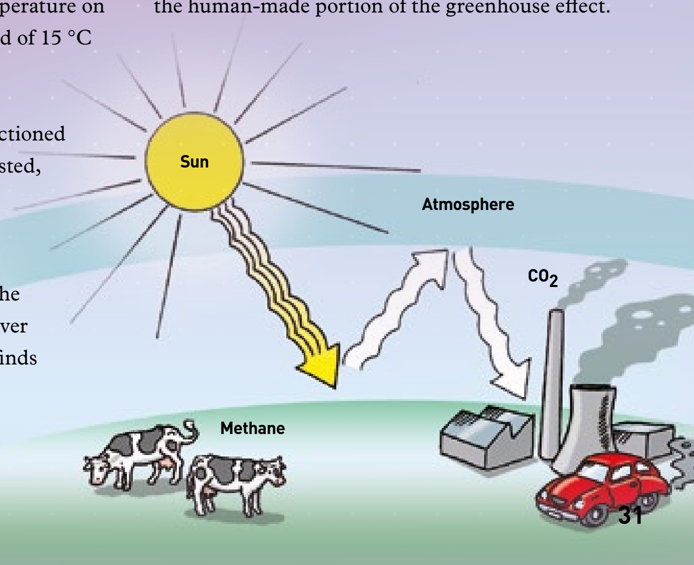
The trace gases and clouds then give some of this energy off into space, and also radiate some energy back in the direction of Earth's surface. This warms the Earth's surface even more.

The accumulation of heat brought about in this manner in the lower atmosphere creates a natural greenhouse effect. Without it, the temperature on Earth would be much colder, and life as we know it would not be possible. Without the greenhouse effect, the average temperature on Earth would be -18 °C (-0.4 °F) instead of 15 °C (59 °F). Pretty cold, right?

The natural greenhouse effect has functioned since the Earth and its atmosphere existed, and it has its own mechanisms of self-regulation. In other words, natural variations in temperature — both increases and decreases — caused by the natural greenhouse effect occur only over very long periods of time, and nature finds ways to react and adjust to them.

Since the beginning of the Industrial Revolution, humans have contributed to an increase in the concentrations of natural greenhouse gases — such as **carbon dioxide** (CO_2), methane (CH_4), nitrous oxide (N_2O), and ozone (O_3) — and have added new greenhouse gases in the form of CFCs. The increase in greenhouse gases has intensified the greenhouse effect and led to a noticeable increase in Earth's surface temperature.

The greatest and most important recent change in the atmosphere is in its carbon dioxide content. During the last 100 years, the concentration of CO_2 in the atmosphere has risen by over a third. Current levels are the highest they've been in the last 650,000 years. It is believed that carbon dioxide is responsible for more than half (60%) of the human-made portion of the greenhouse effect.



My Weather Journal

My Location: ....

Date	Morning temperature in C°/ F°	Afternoon temperature in C°/ F°	Precipitation in mm	Wind direction	Wind speed	Air pressure	Type of clouds	Other (snow, hail, fog?)

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