SPACE awareness

THE INTERTROPICAL CONVERGENCE ZONE

Discover how the sun drives the winds on Earth

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Tema del plan de estudio
Atmosphere, surface

La gran idea de la ciencia
Earth is a system of systems which influences and is influenced by life on the planet

Palabras clave
Equator. Atmosphere, Updraft, Winds, Convection

Edades
8 - 16

Nivel del sistema educativo
Middle School, Secondary School, Informal

Tiempo
1h

Tamaño del grupo
Group

Supervisión de seguridad
Supervised

Gasto
Average (5 - 25 EUR)

Ubicación
Indoors (small, e.g. classroom)

Competencias básicas
Asking questions, Developing and using models, Planning and carrying out investigations, Constructing explanations, Engaging in argument from evidence, Communicating information

Tipo de actividad de aprendizaje
Full enquiry

BREVE DESCRIPCIÓN

The students learn that warm air rises over cold air. They will understand that this basic phenomenon is the cause for the large scale air circulation systems on Earth and the warm and humid climate near the equator.

OBJETIVOS

The students will learn how the Sun drives the main engine of atmospheric circulation. They will experience hands-on, how irradiation and heat can drive convection. A minor aspect is the seasonal change of the global circulation system.

OBJETIVOS DE APRENDIZAJE

The students will learn how the Sun drives the main engine of atmospheric circulation. They will experience hands-on, how irradiation and heat can drive convection.

Desired Student Outcomes for Activity 1
After this activity, the students will understand that warm air rises above the surrounding cooler air. The uplift can be strong enough to launch objects up into the air.

Desired Student Outcomes for Activity 2
After this activity, the students will understand that a continuous convection stream can be produce, provided the energy source injects heat constantly. They will also understand that fresh needs to be replenished to keep the engine going.

Desired Student Outcomes for Activity 3
This worksheet helps the students to transfer the knowledge to the situation on Earth, where the Sun is the main heat source. They will understand that the Intertropical Convergence Zone is only a part of a larger air circulation system that is the cause for the climate zones between the Tropics and the Subtropics.

EVALUACIÓN

The teacher starts off with some introductory remarks. The students are stipulated by a series of questions and possible answers that lead through the various aspects to be learned. The answers given by the students – partially stimulated by discussion – are the gauge by which the teacher can evaluate the learning outcome.

Q: Where are the poles? Where does the equator lie relative to the poles?
A: The equator is the line or circumference on the globe half way between the poles.

Q: Can you name countries that touch the equator? Do you know any cities close to it?
A: e.g. Ecuador (Quito, Galapagos), Brazil, Gabun (Libreville), Kongo, Uganda (Kampala), Kenia, Malaysia, Indonesia

Q: What is the typical vegetation there? A closer look at the satellite images helps to answer the question.
A: Rainforest

Q: What is the typical weather there (humid or dry, cold or warm)?
A: humid and warm, lots of rain

Q: Can you think of a reason, why it is so warm there all year? Show them a model of the Sun-Earth-System.
A: The Sun is the main heating source. Near the equator, it is always almost directly above.

Q: The air is heated up by the hot surface of the Earth. What happens with hot air? Imagine a hot-air balloon.
A: Warm/hot air rises above cold air.

The final activity, a worksheet, summarises the learning achievements and puts into the perspective of a global system on Earth. From this, it should be straightforward to judge, to what degree the individual elements have been understood.

Activity 1: Flying flames

Q: What happened to the air around the burning paper?
A: It was heated.

Q: What happens with heated air?
A: It rises.

Q: Can you explain why in the end the burning paper lifted off?
A: It was dragged along with rising air.

Activity 2: Updraft tower

Q: Why does the fan rotate?
A: The air inside the tower is heated up and streams upward.

Q: How is the air heated? Remember that the lamp does not shine inside the tower.
A: The lamp heats the black tower, which in turn heats the air inside.

Q: What are holes at the bottom for?
A: They permit replenishing the tower with fresh air.

Q: If you compare this with the situation on Earth, what does the Sun do in the belt around the equator? What happens with the surface and the air above?
A: The Sun heats the ground which, in turn, heats the air. Just like the model of the updraft tower, the heated air rises and produces a continuous up-current of air.

Q: Can you imagine what happens with the air, when it climbs to high altitudes?
A: The air cools down and moisture condenses to rain.

Q: Coming back to the updraft tower: it had flaps at the bottom to allow replenishing the air. The same happens on Earth. What do we call horizontal air flows?
A: wind

Activity 3: Worksheet

The answers expected from the last activity with the worksheet are as follows:

Q: Look at Fig. 1. Where on Earth does the Sun heat most efficiently?
A: around the equator

Q: Heating the air directly is quite inefficient. When you think about the updraft tower experiment, the lamp did not heat the air. Describe the process, how eventually the solar energy heats the air.
A: The irradiation from the Sun heats the ground, which in turn heats the air. This is more efficient next to the surface as compared to higher altitudes.

Q: Which part of the atmospheric layers is heated strongest?
A: The one next to the surface.

Indicate the correct attributions:
The air close to the surface of the Earth is warm
The air at high altitudes above ground is cold.

Q: What happens with the air close to the surface? Consider the temperature differences between low and high altitudes.
A: It rises above the cooler air.

Q: Warm air can store more water than cold air. What happens, when the air rises into higher layers of the atmosphere? Think of boiling water at home, when the hot air meets the cold air or cold surfaces.
A: The water vapour condenses. First to clouds, eventually to larger drops and rain.

Q: Can you explain why the equator regions of the Earth experience so much rain during the year?
A: Warm humid air is driven up to cooler atmospheric layers, where the water condenses to rain. This is a process that works almost all year.

Q: This region around the equator is also called the Intertropical Convergence Zone, abbreviated ITCZ. At some point, the air cannot rise any higher. It is diverted north and south. At those high altitudes, the air constantly cools down. What happens with cold air?
A: Cold air drops.

Q: We just mentioned that cold air can store less water than warm air. Can you explain why the desert areas north and south of the equator are so dry? What happens with the air, when it drops back to the surface?
A: When the warm air rises up to cooler layers, it cannot store water as efficiently and rain falls down. The air is dried by that process. When this air drops, it is heated up and potentially can store more water. Without replenishment with humid air, the air dries even more.

Q: Back at the surface, the air streams towards the equator region, where they converge (ITCZ). Those are winds we call the Trade Winds. Can you imagine, why?
A: The Trade Winds are a fairly constant phenomenon that helped cargo ships to sail long distances. Its direction is fairly stable as well, so ships didn't get lost so often.

For a solution for the drawing, see Fig. 3 in the background information.

MATERIALES

The activities are carried out best in groups by two. The items listed below are indicated per group.

Common items:

- paper handkerchief, napkin or dual chamber tea bag
- matches or lighter
- plate (or any other non-flammable flat surface)
- strong lamp (common bulb or tungsten halogen bulb, min. 100 W)
- scissors
- flat nose pliers, if available
- glue (for cardboard)
- pencil or similar pointed object
- aluminium wrap of a tea light
- drawing pin

For either of the following alternatives:

Alternative 1

- cardboard tube (inner part of a kitchen roll)
- black paint and brush or black coloured paper
- one piece of cardboard (approx. 1 cm wide, 8 cm long)

Alternative 2

- construction template provided with this sheet
- black cardboard (22 cm x 20 cm)
- one piece of card board (approx. 1cm wide, 12 cm long, see template)

INFORMACIÓN DE REFERENCIA

The Sun is the main engine and energy source to all weather phenomena we see on Earth. When it irradiates the surface of the Earth, the light is absorbed and heats the ground. Infrared radiation is re-emitted that heats the layer of air directly above. Since warm air has a lower density than cool air, it produces an updraft which by convection drags the air up into the highest layers of the troposphere about 10 - 15 km above ground.

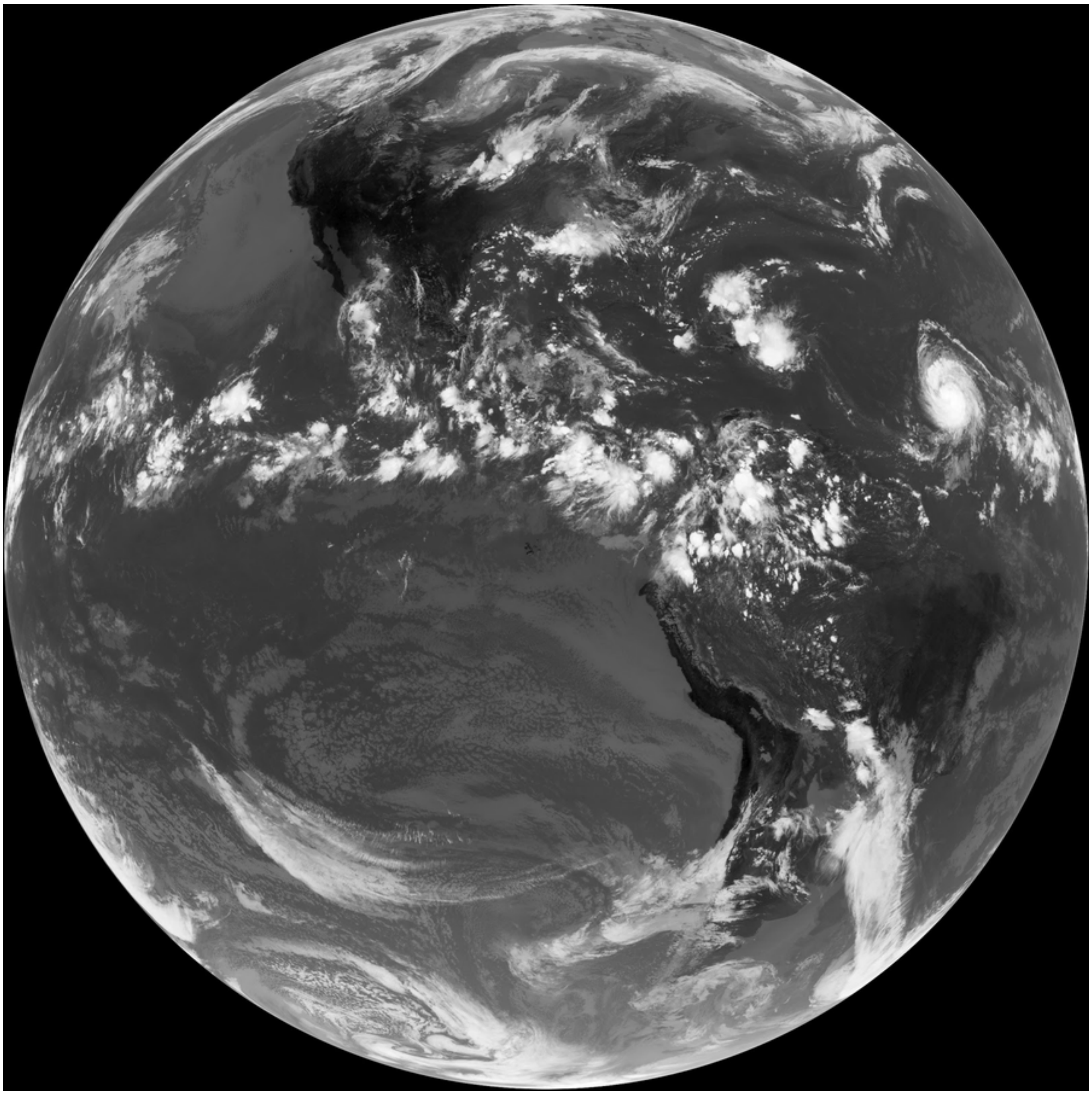


Figure 1: Image obtained with the GOES 14 satellite. The belt of cloud formation around the ITCZ is well visible (Credit: NASA, http://eoimages.gsfc.nasa.gov/images/imagerecords/39000/39848/hemisphere_goe_2009229_lrg.jpg).

This process is most effective at latitudes where the Sun is at Zenith, i.e. in a belt around the equator. This area is called the Intertropical Convergence Zone (ITCZ). It follows the Sun northward and southward during the seasons. Since the air cools down with increasing altitude, its ability to store water is continuously reduced. This leads to the formation of clouds and, consequently, thunderstorms. In extreme cases, the convection can lead to severe weather phenomena like cyclones and hurricanes. Eventually, the humidity is released via precipitation leaving the air dry. This is the reason, why the low latitudes around the equator are strongly affected by a humid, tropical climate with low pressure areas and lots of rain. On satellite images, the ITCZ is very prominent due to a global cloud belt along the equator (see Fig. 1). This demonstrates that satellite imagery can be an important tool to monitor the climate of the Earth.

The convection zone at the ITCZ is only a part of a much larger and global air circulation system (see Fig. 2). Locally, it belongs to a circulation unit called the Hadley cell. The air can only rise up to an altitude of 10 to 15 km above ground, where it is diverted poleward while it cools down again. At latitudes around 30° north and south, the already dried air drops, heats up, and is dried even more. This gives rise to the arid, subtropical climate we find there.

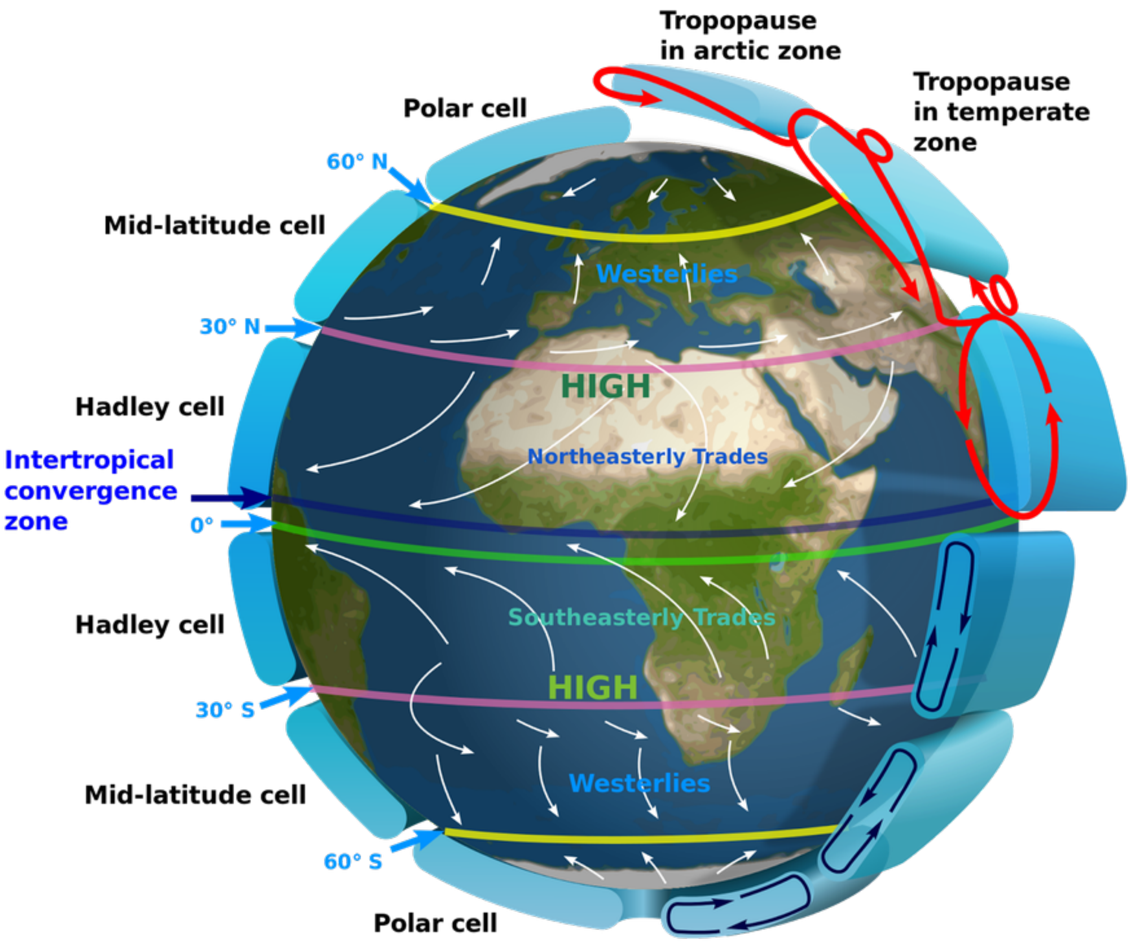


Figure 2: Global circulation of Earth's atmosphere (Credit: Kaidor, improved by the Wikigraphists of the Graphic Lab (ru), https://commons.wikimedia.org/wiki/File:Earth_Global_Circulation_-_en.svg, https://creativecommons.org/licenses/by-sa/3.0/legalcode).

The cycle of the circulation of the Hadley cell closes with the air currents flowing back to the equatorial region and the ITCZ where they feed the convection again. Because of the Coriolis force, which is caused the rotation of the Earth, those winds cannot blow directly north or south, but they are diverted westward. Since wind directions indicate their origin, this produces the wind phenomena known as the Northeasterly and Southeasterly Trade Winds.

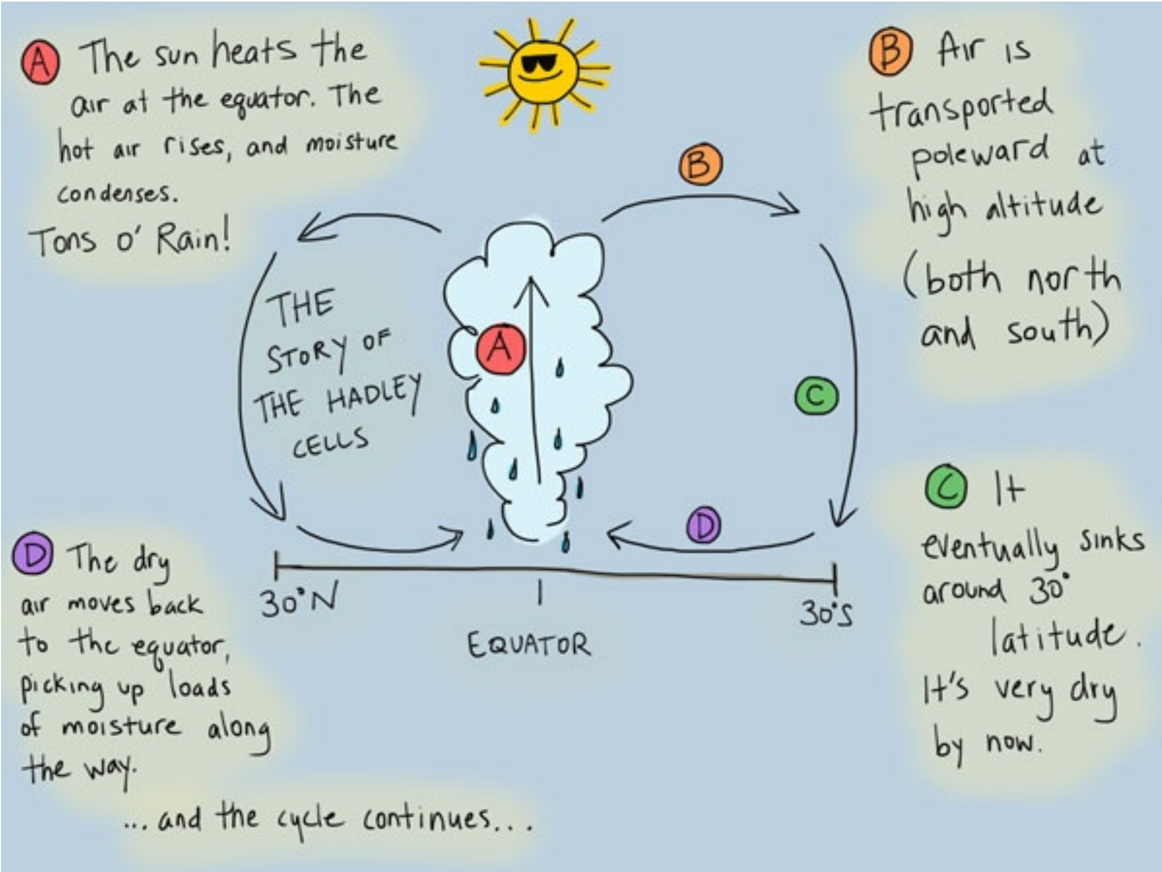


Figure 3: Schematic of the Hadley cell (Source: "The Waveform Diary" blog, The mystery of the shifting tropical rain belt, http://www.michw.com/blogwp/wp-content/uploads/2013/05/Hadley-Cells_600px.jpg, credit: M. Weirathmueller, permission for reproduction granted).

DESCRIPCIÓN COMPLETA DE LA ACTIVIDAD

Introduction: Questions and Answers

Show the students an Earth globe or a global map and ask them, if they can identify the equator.

Q: Where are the poles? Where does the equator lie relative to the poles?

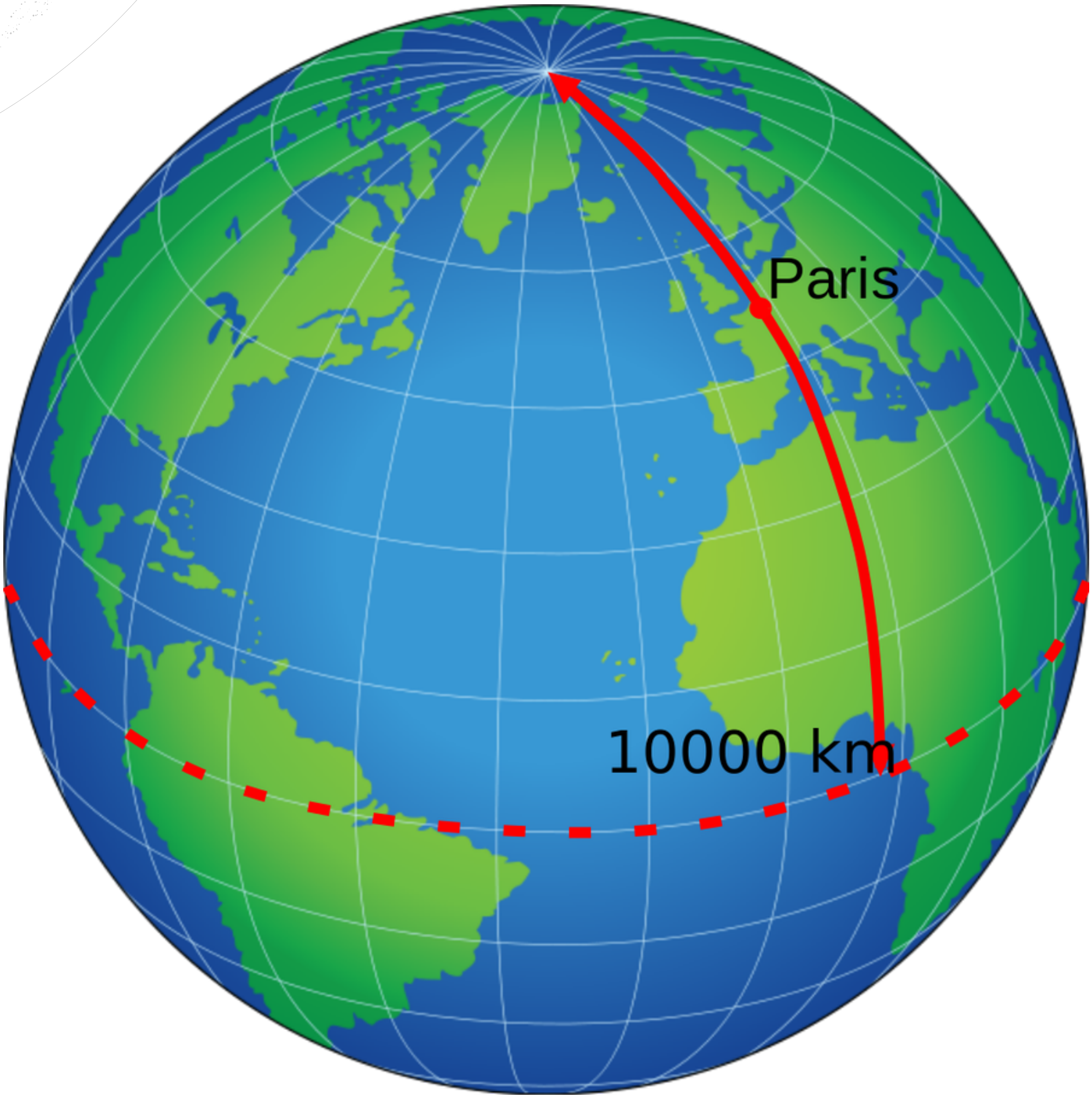


Figure 4: Illustration of the Earth globe and the position of the equator relative to the North Pole (Source: Wikimedia commons, licence: public domain).

If possible, let the students use an online map tool to investigate the geography and satellite images of the equator region.

Q: Can you name countries that touch the equator? Do you know any cities close to it?

Q: What is the typical vegetation there? A closer look at the satellite images helps to answer the question.

Q: What is the typical weather there (humid or dry, cold or warm)?

Q: Can you think of a reason, why it is so warm there all year? Show them a model of the Sun-Earth-System?

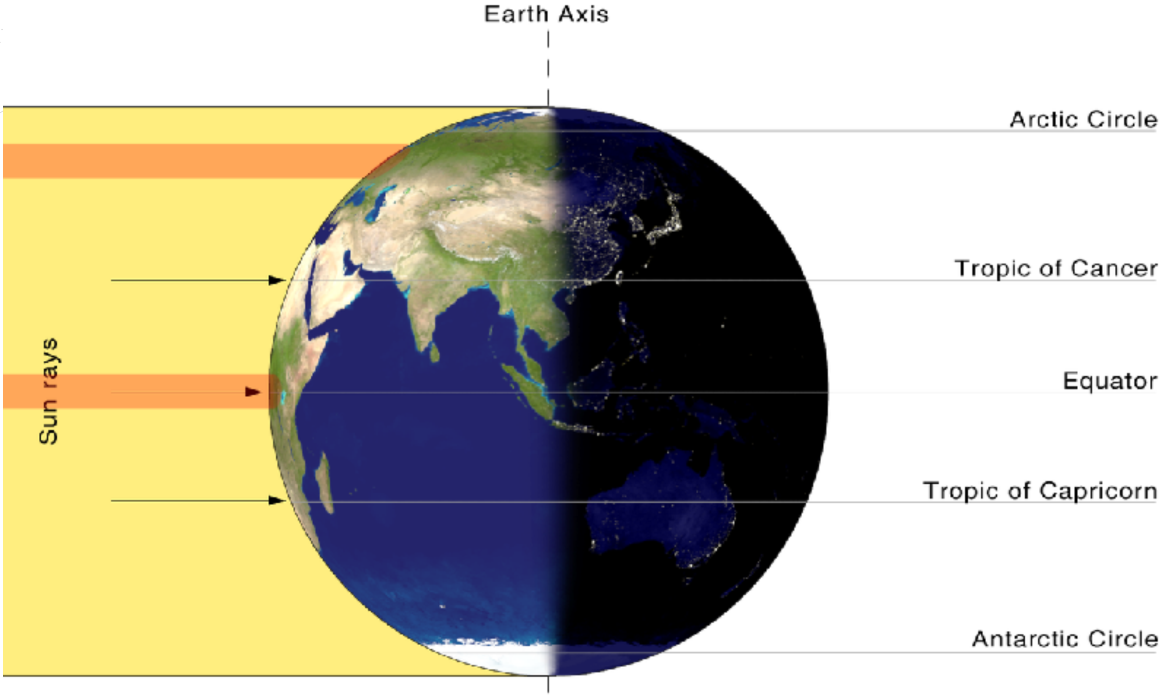


Figure 5: Illustration of the Earth by the Sun. Looking from the equator, the Sun is almost always directly above (Source: adapted from Wikimedia commons, credit: M. Nielbock, P. Idzkiewicz, https://creativecommons.org/licenses/by-sa/2.0/legalcode).

Q: The air is heated up by the hot surface of the Earth. What happens with hot air? Imagine a hot-air balloon.

Activity 1: Flying flames

WARNING! This activity is only suitable for students that are confident enough to handle a flame. If in doubt, the experiment should be demonstrated by the teacher.

Smoke detectors may have to disabled for this.

In this activity, the students will experience, how warm air rises above cooler air. The hot air produced by a burning piece of very light paper produces its own uplift and rises up in the air. This experiment should give rather a qualitative result meaning that the exact uplift force is not so important.

Gather the following items, one set per group (or one for the teacher only, if carried out as a demonstration):

- paper handkerchief, napkin or dual chamber tea bag
- matches or lighter
- plate

- scissors

Distribute the students in groups of two (suggested).

1. Prepare the wick:
   - Paper handkerchiefs and napkins consist of several layers. Take only one and cut off one quarter.
   - If a tea bag is used, cut off the top and empty the bag. Unfold it.
2. Form a tube (napkin, handkerchief, tea bag) of a few centimetres and put it on the plate, standing upright. It should stand stably. Avoid abrupt and fast movements to prevent moving air from blowing the wick away.
3. Light it.

Discuss with the students what happened. Let the students describe in detail what they saw. While the wick burns down, it lifts off at some point.

Q: What happened to the air around the burning paper?

Q: What happens with heated air?

Q: Can you explain why in the end the burning paper lifted off?

Activity 2: Updraft tower

This activity demonstrates how heated air rises. As long as the heating source is present, a continuous updraft of the heated air is generated. The students will experience this phenomenon by building a model of an updraft tower. Afterwards, the concept of air circulation can be used to explain the process of terrestrial atmospheric circulation systems and the Intertropical Convergence Zone.

Gather the following items, one set per group:

- scissors
- flat nose pliers, if available
- glue (for cardboard)
- pencil or similar pointed object
- aluminium wrap of a tea light
- drawing pin

For either of the following alternatives:

Alternative 1

- cardboard tube (inner part of a kitchen roll)
- black paint and brush or black coloured paper
- one piece of cardboard (approx. 1 cm wide, 8 cm long)

Alternative 2

- construction template provided with this sheet
- black cardboard (22 cm x 20 cm)
- one piece of card board (approx. 1cm wide, 12 cm long, see template)

Figure 6: Items needed for building an updraft tower model (Source: M. Nielbock).

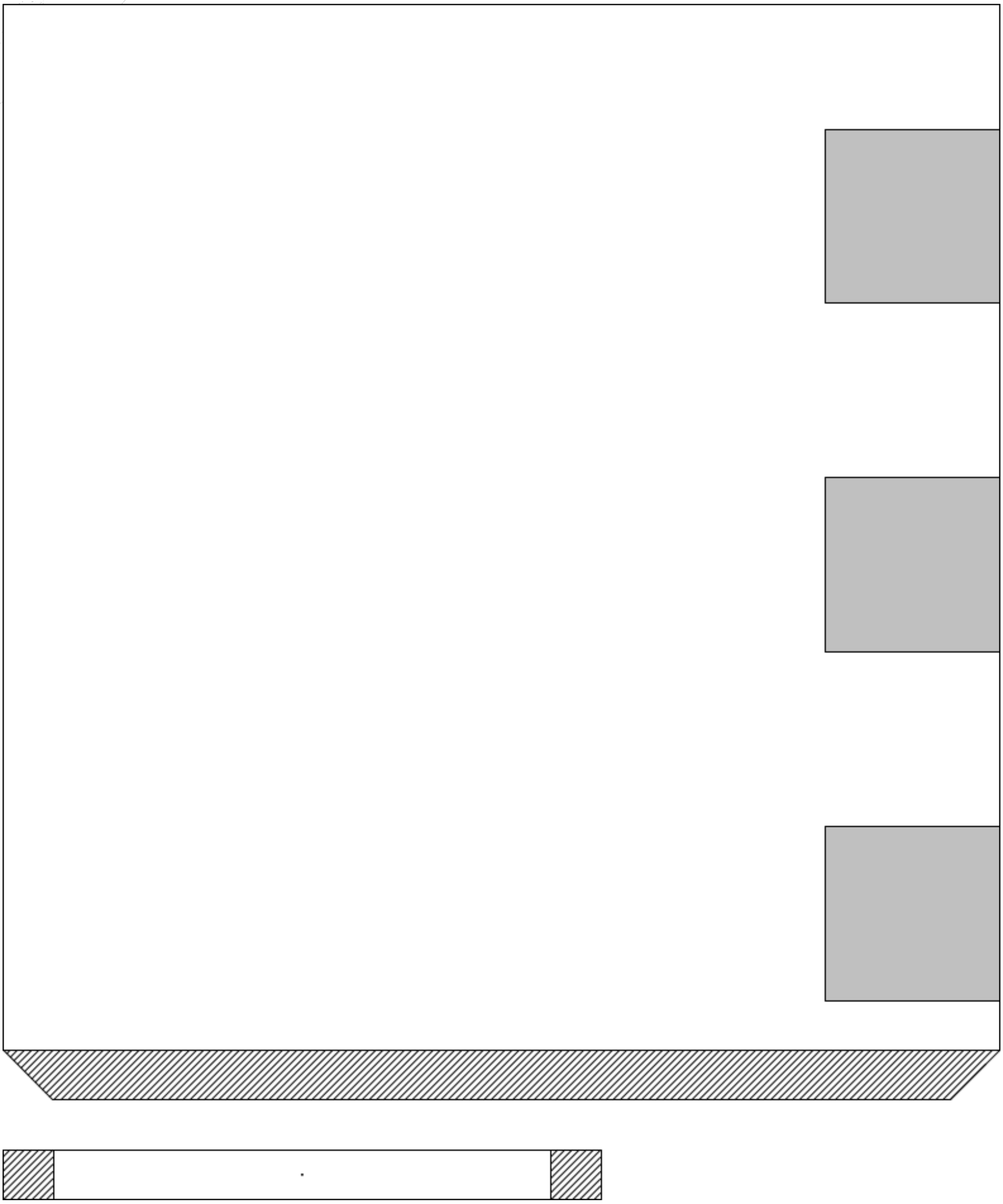


Figure 7: Construction Template (scaled down version, original version to be attached).

Building Instructions

Alternative 1:
The first version may be somewhat simpler to produce, but might be not that effective, because the cardboard tube used in this example may a bit too narrow.

1. Paint the outside of the cardboard tube black or glue it with black paper.

Alternative 2:
The second version is especially designed to match the diameters of the tower and the fan.

1. Prepare the black cardboard according to the construction template provided.
2. Roll the cardboard perpendicularly to the hashed area.
3. Glue the tube at the hashed area.
4. Cut out the grey areas or cut them from bottom to top and fold them up to form flaps.

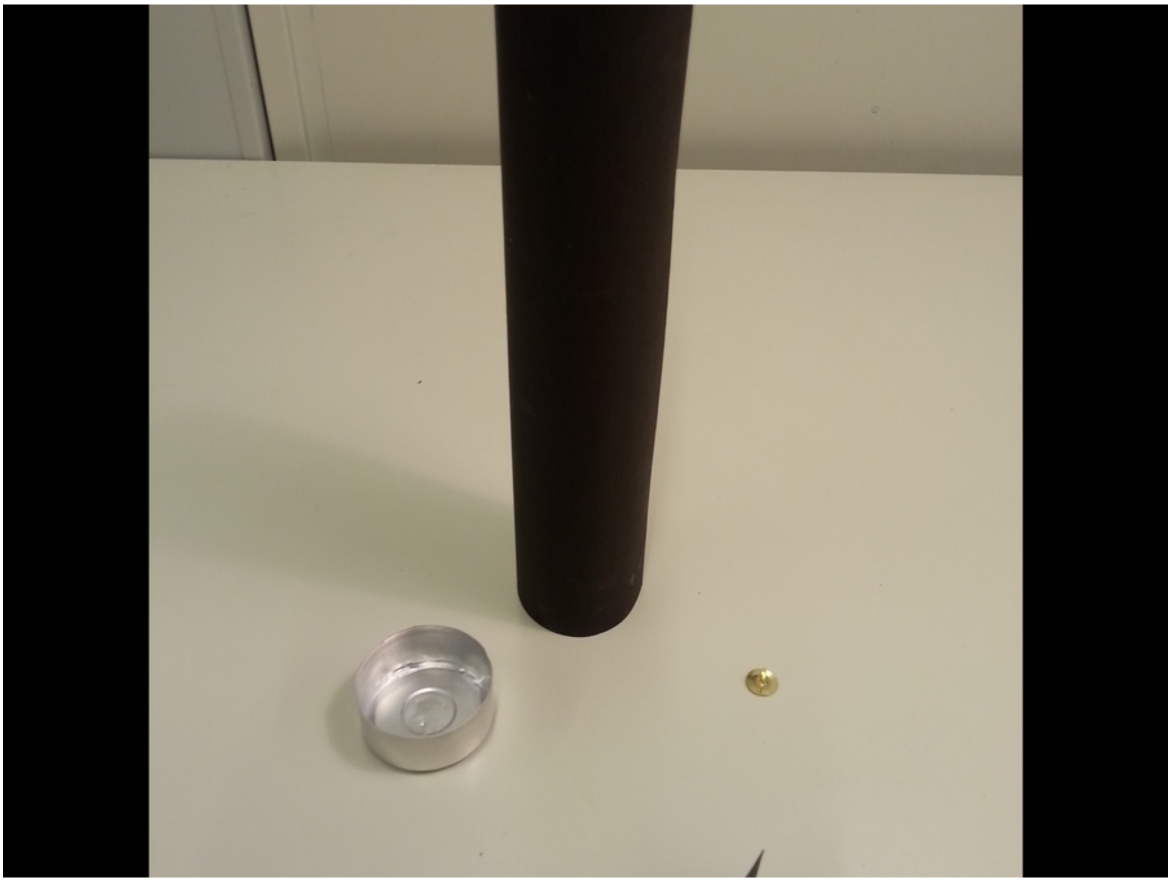


Figure 8: Set of items with the tower already built (Source: M. Nielbock).

Common steps:

1. Now we produce the fan using the tea light wrap. This part is quite delicate and has to be done very carefully.
2. Cut the walls of the tea light wrap into 16 equal sections.
3. Flatten the sections outside to the bottom of the wrap.
4. Extend the cuts to the inner circle of the bottom of the wrap.

5. Press the pencil exactly at the centre of the fan to form a small dent. Be careful not to punch a hole.
6. Bend all 16 wings of the fan around an axis from the centre to the edge. Use the pliers if available.
7. Punch the drawing pin through the centre and from the back of the small piece of cardboard.
8. Glue the small piece of cardboard to the inside at the top of the tube. It should form an arc.

Figure 9: Set of items with the tower and the fan (Source: M. Nielbock).

1. Put the fan on top of the drawing pin.
2. Balance the fan by bending the winds up and down.

Figure 10: The finished updraft tower model (Source: M. Nielbock).

1. Illuminate the tower with a strong lamp.
2. Watch the fan rotate.

Discuss the results with the students.

Q: Why does the fan rotate?

Q: How is the air heated? Remember that the lamp does not shine inside the tower.

Q: What are holes at the bottom for?

Q: If you compare this with the situation on Earth, what does the Sun do in the belt around the equator? What happens with the surface and the air above?

Q: Can you imagine what happens with the air, when it climbs to high altitudes?

Q: Coming back to the updraft tower: it had flaps at the bottom to allow replenishing the air. The same happens on Earth. What do we call horizontal air flows?

Activity 3: Worksheet: The Wind Engine of the Earth

We have seen in the experiments that a heat source can heat up the air and cause an upward flow. The very same process happens on Earth.

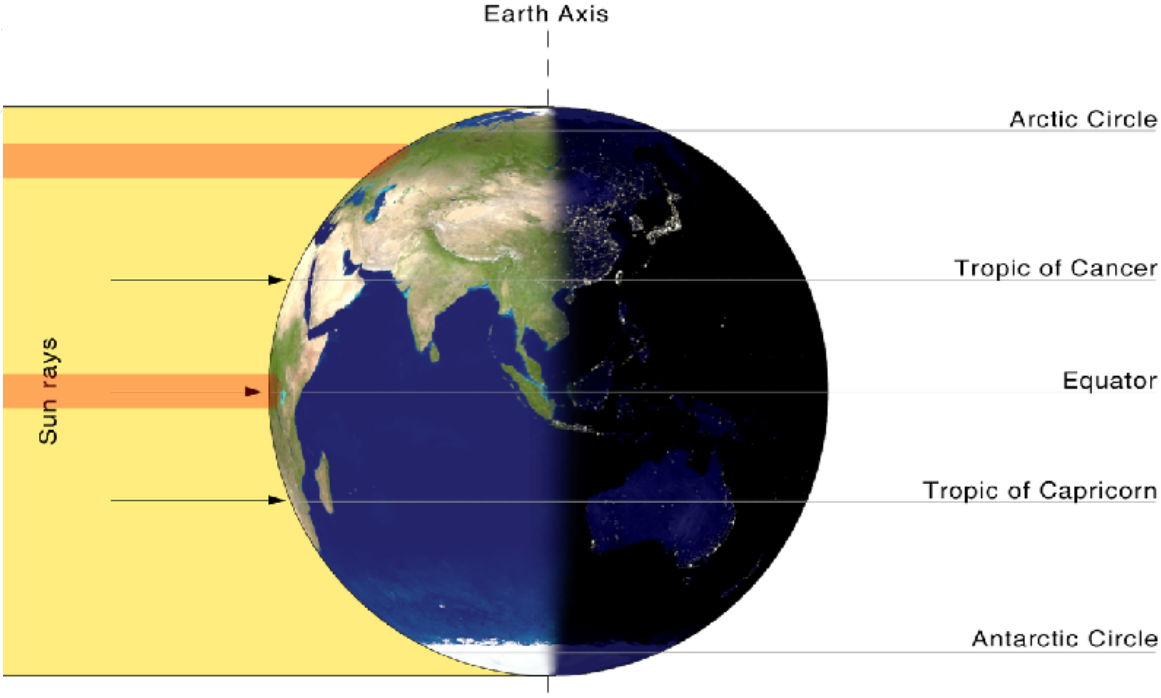


Figure 11: Illustration of the Earth by the Sun. Looking from the equator, the Sun is almost always directly above (Source: adapted from Wikimedia commons, credit: M. Nielbock, P. Idzkiewicz, https://creativecommons.org/licenses/by-sa/2.0/legalcode).

Q: Look at Fig. 1. Where on Earth does the Sun heat most efficiently?

Q: Heating the air directly is quite inefficient. When you think about the updraft tower experiment, the lamp did not heat the air. Describe the process, how eventually the solar energy heats the air.

Q: Which part of the atmospheric layers is heated strongest?

Indicate the correct attributions:
The air close to the surface of the Earth is warm/cold.
The air at high altitudes above ground is warm/cold.

Q: What happens with the air close to the surface? Consider the temperature differences between low and high altitudes.

Q: Warm air can store more water than cold air. What happens, when the air rises into higher layers of the atmosphere? Think of boiling water at home, when the hot air meets the cold air or cold surfaces.

Q: Can you explain why the equator regions of the Earth experience so much rain during the year?

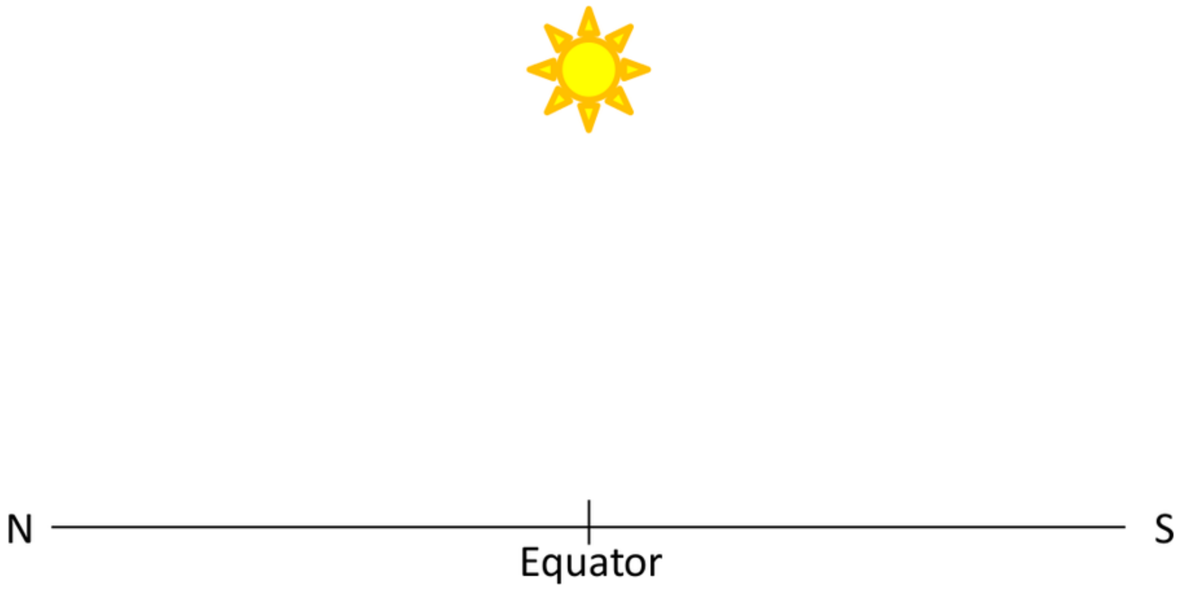
This region around the equator is also called the Intertropical Convergence Zone, abbreviated ITCZ. At some point, the air cannot rise any higher. It is diverted north and south. At those high altitudes, the air constantly cools down.

Q: What happens with cold air?

Q: We just mentioned that cold air can store less water than warm air. Can you explain why the desert areas north and south of the equator are so dry? What happens with the air, when it drops back to the surface?

Q: Back at the surface, the air streams towards the equator region, where they converge (ITCZ). Those are winds we call the Trade Winds. Can you imagine, why?

Q: We have constructed an entire circulation system that begins and ends at the equator region. This system is called the Hadley cell. Can you draw a schematic with the most relevant elements and processes? Use the prepared sketch below as a starting point.



PLAN DE ESTUDIO

Space Awareness curricula topics (EU and South Africa)

Our fragile planet, Atmosphere, surface

CONCLUSIÓN

This learning package consists of three activities that, in a stepwise approach, illustrates the power of the Sun driving a global air circulation system that is also responsible for tropical and subtropical climate zones. In addition to an introduction, the activities comprise:

- An experiment that demonstrates how heated air rises above cool air.
- An experiment that shows how a continuous heat source produces air convection streams that can even drive a propeller.
- A worksheet that presents the big picture of the global air circulation system of the equator region by transferring the knowledge from the previous activities into a larger scale.

This resource was selected and revised by Space Awareness. Space Awareness is funded by the European Commission's Horizon 2020 Programme under grant agreement n° 638653