





# Worksheet: The Intertropical Convergence Zone

# **Background Information**

## Temperature, density and buoyancy

We all know from experience that the density of gases depends on their temperature. Cold air is denser than warm air. This is the reason why hot air balloons can fly and even lift cargo.



Figure 1: Heating and inflating a hot-air balloon (<u>Mike Pennington</u>, <u>http://www.geograph.org.uk/photo/3605709</u>, <u>https://creativecommons.org/licenses/by-sa/2.0/legalcode</u>).

So whenever we have warm air next to cold air, the warm air rises above the other. This vertical wind is also called 'updraft'.

#### The Sun and the global wind system

The atmosphere of the Earth consists of air. We know that whenever it is heated, it rises up (see above). The atmosphere is heated by the Sun, mainly as it heats the surface first, and this in turn heats the air close to the ground. Since warm air has a lower density than cool air (that is, it is lighter), it produces an updraft which drags the air up into the atmosphere about 10–15 km above the ground. While the air rises, it constantly cools down, which reduces the buoyant force. At some point, the uplift stops and the air is diverted horizontally north and south.









| 10,000 km     | 1                        |            |          |                         |                  |        |              |          |                  |
|---------------|--------------------------|------------|----------|-------------------------|------------------|--------|--------------|----------|------------------|
|               |                          |            |          |                         |                  |        |              |          |                  |
|               |                          |            |          | Exosphere               |                  |        |              |          |                  |
| 965 km        |                          | 20         |          |                         |                  |        |              |          |                  |
|               |                          |            |          | lonosphere              |                  |        |              |          |                  |
| <u>600 km</u> |                          |            | TI       | ermopause               |                  |        |              |          |                  |
|               | Space shuttle            |            |          |                         |                  |        |              |          |                  |
|               |                          |            | 1        | hermospher              | re               |        |              |          |                  |
|               |                          |            | Aurora   | 5                       |                  |        | Pola         | r mesos  | spheric clouds   |
| 85 km         |                          |            |          | 2 2000                  |                  |        | (Noc         | tilucent | clouds)          |
|               |                          | Meteors    | - 1      | Mesopause<br>Mesosphere | e                |        |              |          |                  |
| 50 km         | Stratonaugo              | -          |          |                         |                  | Dalar  | stratechoria | cloud    |                  |
| 10 km         | Stratopause Stratosphere |            |          |                         | (Nacreous cloud) |        |              |          |                  |
| Alex          |                          | •.*•       | Troposph | ere                     | 🔁 Tropop         | ause 🗧 | Comercial ai | rliner   | 1990             |
| Layers        | of the                   | atmosphere | (The     | High                    | Fin              | Sperm  | Whale,       | http     | s://commons.wiki |

Figure 2: Layers of the atmosphere (The High Fin Sperm Whale, <u>https://commons.wikimedia.org/wiki/</u> <u>File:Layers of the atmosphere.PNG</u>, 'Layers of the atmosphere', altitudes according to NASA (<u>https://www.nasa.gov/</u> <u>mission\_pages/sunearth/science/atmosphere-layers2.html</u>) added by M. Nielbock, <u>https://creativecommons.org/licenses/by-</u> sa/3.0/legalcode).

This process is most effective at latitudes where the sun is at the zenith, i.e. in a belt around the equator (Figure 3). This area is called the Intertropical Convergence Zone (ITCZ). It follows the sun northward and southward through the seasons.



Figure 3: Illustration of the Earth irradiated by the Sun. Looking from the equator, the Sun is almost always directly above (Przemyslaw '<u>Blueshade'</u> Idzkiewicz, <u>https://commons.wikimedia.org/wiki/File:Earth-lighting-equinox\_EN.png</u>, 'Earth-lighting-equinox EN', irradiation columns added by M. Nielbock, <u>https://creativecommons.org/licenses/by-sa/2.0/legalcode</u>).









Just like hot steam condenses to water as soon as it hits a cold surface, humid, warm air produces clouds when cooling down (Figure 4).



Figure 4: Cooling towers of the nuclear powerplant Cattenom in France. In this powerplant, water is heated until it forms steam and it is then fed into turbines that generate electrical power. The remaining heat is released through cooling towers as the water evaporates. When contacting the ambient cooler air, the water condenses into clouds (Stefan Kühn, https://commons.wikimedia.org/wiki/File:Nuclear\_Power\_Plant\_Cattenom.jpg, 'Nuclear Powerplant Cattenom', https://creativecommons.org/licenses/by-sa/3.0/legalcode).

Cool air can store less water than warm air. Therefore, the rather humid air that rises in the ITCZ continuously loses its ability to store water. As a result, clouds form, from which eventually water is released as rain. On satellite images, the ITCZ is very prominent because it appears as a cloud belt along the entire equator (Figure 5). This demonstrates that satellite imagery can be an important tool to monitor the Earth's climate.











Figure 5: Image obtained with the GOES 14 satellite. The belt of cloud formation around the ITCZ is clearly visible (NASA/GOES Science Team).

The air now becomes dry. While it is pushed north and south to latitudes around 30° north and south, the dry air drops, heats up, and is dried even more. This is why we find deserts in this area (Sahara, Atacama and the Australian Outback).



Figure 6: Schematic of the Hadley Cell (M. Weirathmueller, <u>http://www.michw.com/2013/05/the-mystery-of-the-shifting-tropical-rain-belt/</u>, 'The Waveform Diary' blog, 'The mystery of the shifting tropical rain belt', permission for reproduction granted)

Finally, the air that has again reached the ground flows back to the equatorial region to close the cycle (Figure 6). We have seen that the heat released by the Sun is an engine that drives wind vertically and horizontally. In es-









sence, this can be regarded as a conveyor belt that circulates air between the equatorial region and the subtropics. This system is called the 'Hadley Cell'.









# **Activity 1: Flying Flames**

WARNING! You may have to be able to handle a flame responsibly. Carefully listen to the teacher's instructions.

List of materials:

- paper handkerchief, napkin or dual chamber tea bag
- matches or lighter
- plate or/and tinfoil
- scissors



Figure 7: Illustration of the instructions (M. Nielbock).

If you use a tea bag, cut off the top and empty it. Unfold it. If you use a paper handkerchief or napkin, take only one thin layer and cut out one quarter. Form a tube of a few centimetres and put it on the plate standing upright.

Avoid abrupt and fast movements to prevent blowing away the paper tube.

Light it from the top.

Describe your observation.

What happens to the air around the burning paper?

What happens with the heated air?

Can you explain why the burning paper lifts off in the end?









# **Activity 2: Updraft Tower**

#### List of materials:

- strong lamp
- 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 two 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 × 20 cm)
- one piece of card board (approx. 1 cm wide, 12 cm long, see template)



Figure 8: Items needed for building an updraft tower (M. Nielbock).









## **Building instructions**

There are two alternatives for building the updraft tower. The second option is preferred.

#### 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. The template can be printed on black cardboard. The markings should still be visible.
- 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 9: Set of items with the tower already built (M. Nielbock)

#### Common steps:

- 5. Now we produce the fan using the tea light wrap. This part is quite delicate and has to be done very carefully.
- 6. Cut 16 equal sections into the walls of the tea light wrap.
- 7. Flatten the sections outside to the bottom of the wrap.
- 8. Extend the cuts to the inner circle of the bottom of the wrap.
- 9. Press the pencil exactly at the centre of the fan to form a small dent. Be careful not to punch a hole.
- 10. Bend all 16 wings of the fan around the axis from the centre to the edge. Use the pliers if available.











Figure 10: Set of items with the tower and the fan (M. Nielbock)

- 11. Punch the drawing pin through the centre and from the back of the small piece of cardboard.
- 12. Glue the small piece of cardboard to the inside at the top of the tube. It should form an arc.
- 13. Put the fan on top of the drawing pin.
- 14. Balance the fan by bending the wings up and down.



Figure 11: The finished updraft tower model (M. Nielbock).

- 15. Illuminate the side of the tower with a strong lamp.
- 16. Watch the fan rotate.









Explain what you observe.

Why does the fan rotate?

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

What are the holes at the bottom for?

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?

Can you imagine what happens with the air when it reaches high altitudes?

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









## **Activity 3: 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 same process happens on Earth.

Look at Figure 3. Where on Earth does the Sun heat most efficiently?

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 by which solar energy eventually heats the air.

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 the ground is warm/cold.

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

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

Can you explain why the Earth's equatorial regions experience so much rain during the year?

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

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?









Back at the surface, the air streams towards the equatorial region, where they converge (ITCZ). These are the winds we call the 'trade winds'. Can you imagine why?

Try to predict what would happen with the winds and the weather in general if the temperature continues to rise.

This is actually happening right now. It is called 'global warming'. Explain what would happen if we do not stop this process.

We have constructed an entire circulation system that begins and ends at the equatorial 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.



Ν

Equator

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