SPACE awareness

WATER IS A HEAT SINK

Learn how oceans absorb heat from the atmosphere

Markus Nielbock, Space Awareness

Temat z programu nauczania
Oceans, atmosphere

Ważna koncepcja nauki
Earth is a system of systems which influences and is influenced by life on the planet

Słowa kluczowe
thermic radiation, heat capacity, oceans, atmosphere, global warming, balloons, expansion, air, gas

Wiek
8 - 14

Poziom kształcenia
Middle School, Secondary School

Czas trwania
30min

Rozmiar grupy
Group

Nadzór ze względów bezpieczeństwa
None

Koszt
Low (< ~5 EUR)

Lokalizacja
Indoors (small, e.g. classroom)

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

Rodzaj zajęć edukacyjnych
Full enquiry

KRÓTKI OPIS

Balloons filled with air and water are used as simple models to demonstrate how those substances react on administering heat. Candles are placed beneath the balloons and the results are observed and discussed. The balloon filled with air bursts instantly, while the water balloon remains inert. The pupils will learn that the reactions are a consequence of different heat capacities and the resulting expansion.

CELE OGÓLNE

This activity demonstrates how very different certain materials react on heat. The pupils will learn that water can store large amounts of heat very quickly without changing its properties very much. However, air – like any gas – is altered quite drastically. The experiment provides a direct and vivid approach to the properties of heat capacities of different substances. When generalising the observations and transferring them to the global processes on Earth, the pupils will understand that oceans can absorb heat more effectively than the atmosphere, which helps mitigating the global warming.

CELE OPERACYJNE

The pupils are supposed to

- realise that water can absorb heat effectively which leads to a relative small temperature increase.
- discover that the heating process results in a smaller and slower temperature increase than for air.

EWALUACJA

Pupils are supposed to give an explanation in their own wording for the phenomenon witnessed. In case the necessary physical basic concepts have not been reviewed yet the pupils should be able to explain their observations in their own wording.

Task 1:

Boiling a pot of water on a stove takes a certain amount of time. However, if you take away the pot and put your hand above the hot plate, the air heats up considerably faster.

Task 2:

A balloon filled with air bursts immediately whereas the balloon filled with water can be positioned above a flame any length of time.

Given the same energy supply, air warms up much faster than water. Therefore, air attains temperatures and pressures to let the balloon burst earlier than water. Water can store more heat per volume than air.

On Earth, the Sun is the main heat source on the surface. The oceans store heat more effectively than the atmosphere without changing its properties too much. As such, the oceans help to reduce global warming as much of the heat that could warm up the atmosphere is absorbed by water.

MATERIAŁ

The list of items is needed for one experimental set-up. Depending on whether it is carried out as a demonstration by the teacher or by the students themselves, the total number of items has to be assessed accordingly.

- water (preferably water tab for filling)
- pocket lighter
- matches
- 2 balloons
- candle

PODSTAWOWE INFORMACJE

The oceans as a heat sink

The global warming caused by the Greenhouse Effect is one of the biggest challenges of mankind. Different to other planets in the solar system, the Earth is covered by large oceans that make up for 2/3 of the total surface area. Therefore, they are an important player in the budget of heating and cooling. Oceans act as a heat sink, as they react slower and with less a temperature change than land masses do.

The temperature distribution of the waters on Earth is efficiently monitored from space by remote sensing Earth observation satellites. Monitoring the sea is one of the key objectives of Europe’s Copernicus Earth observing programme.

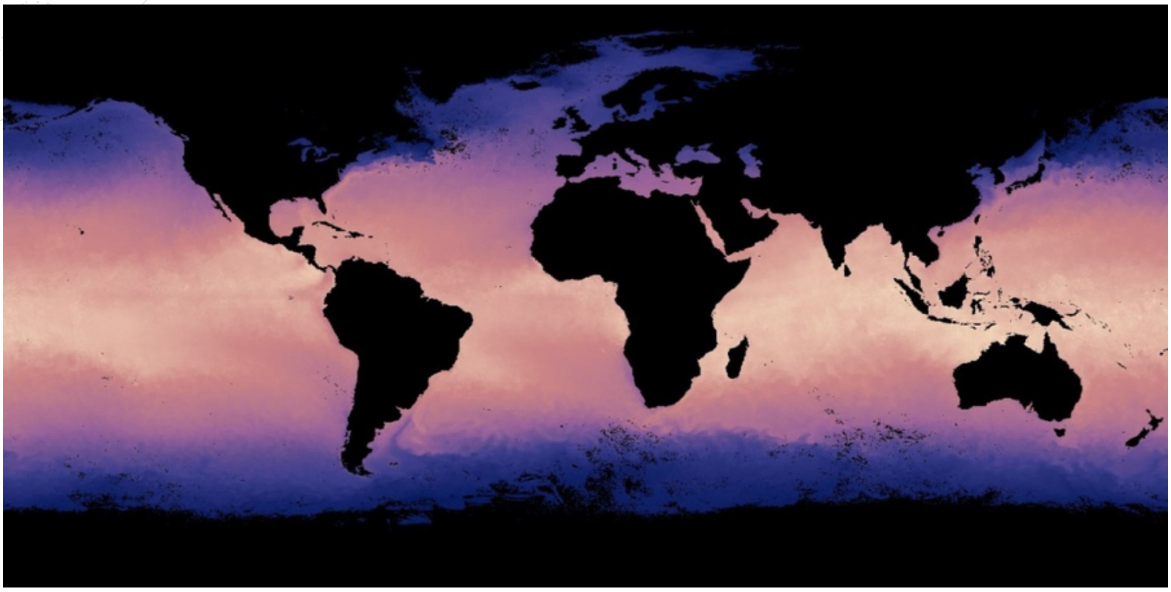

Figure 1: Averaged global land surface temperature map for March 2016 obtained with the MODIS spectrograph on board NASA's Aqua satellite of the EOS programme. The colour code indicates temperatures between -2°C and +35°C (Credit: NASA Near Earth Observations, http://neo.sci.gsfc.nasa.gov/view.php?datasetId=MYD28M).

Heat capacity

If heat Q is added to liquids (or other material in general), their temperature T rises. Both increases (ΔQ, ΔT) are directly proportional to each other.

$\Delta Q \propto \Delta T$

Demonstration experiment
An immersion heater with the radiative power P within a certain period of time Δt will add energy to the liquid according to:

$\Delta Q = \kappa \cdot P \cdot \Delta t$

In this case κ is a dimensionless quantity with $\kappa \in [0;1]$, corresponding to the percentage of the energy transformed and absorbed by the liquid.

$\Delta Q \propto P \cdot \Delta t$

means that the energy needed by the immersion heater is directly proportional to the temperature change ΔT.

Remark: This experiment also works with a water filled paper cup, positioned over the flame of a Bunsen burner.

If you double the amount of liquid with m being the mass, you find the following correlation:

$\Delta Q \propto m$

In summary, the following is valid

$\Delta Q \propto m \cdot \Delta T$

with a proportionality constant

$c = \Delta Q / (m \cdot \Delta T)$

The quantity c is called specific heat capacity. It depends on the material. The dependence on the temperature is neglected in this example. The unit of the specific heat capacity is:

$[c] = 1\ J/(kg \cdot K)$

It is commonly listed in units of:

$1\ kJ/(kg \cdot K) = 1\ J/(g \cdot K)$

With a value of c_W = 4.182 kJ/(kg·K) water has a high specific heat capacity and thus is an excellent heat reservoir due to its simple and low priced availability.

Air on the other hand consists of 78% nitrogen and approx. 21% oxygen. Both gases have a specific thermic capacity of

$$c_{N_2} = 1.040 \frac{kJ}{kg \cdot K}$$

$$c_{O_2} = 0.920 \frac{kJ}{kg \cdot K}$$

thus achieving a first approximate thermic capacity for air of:

$$c_{air} \approx 0.78 \cdot c_{N_2} + 0.21 \cdot c_{O_2} \approx 1.0 \frac{kJ}{kg \cdot K}$$

This shows that air has a four times lower heat capacity than water. In addition, it has to be taken into account that one litre of air has a mass of approx. 1.2 g, while the same volume of water has a mass of about 1 kg. This means that warming up water by ΔT=1K needs about 4.000 times the energy as air of the same volume.

In turn, with a given heating power, one litre of air warms up considerably faster to higher temperatures than one litre of water. In terms of theory, the conclusion can be expressed as:

$\Delta T = \Delta Q / (c \cdot m)$

with $c_{air} \approx 1/4 \cdot c_W$, as well as $m_{air} \approx 1/1000\ m_W$. In summary, this corresponds to $\Delta T_{air} \approx 4000 \cdot \Delta T_W$, i.e. the temperature increase for air is about 4000 bigger than for water. This statement is valid given ideal conditions, i.e. air is warming up evenly and the specific heat capacity remains constant.

Balloons with air and water

We have seen that water can store much more heat than air without changing its temperature too much. Applying this to air and water enclosed inside a balloon, we understand why the air balloon bursts while the water balloon remains relatively inert – provided the heating rate exerted onto the balloon is small enough so that it can be absorbed by the water before it damages the balloon.

PEŁNY OPIS ZAJĘĆ

Task 1

Describe from your own experience what happens when boiling a pot with water on a stove. How long does it usually take? Compare this with your experience when placing your hand at a certain distance above the plate after switching on the plate. How long does it take until the air gets warm?

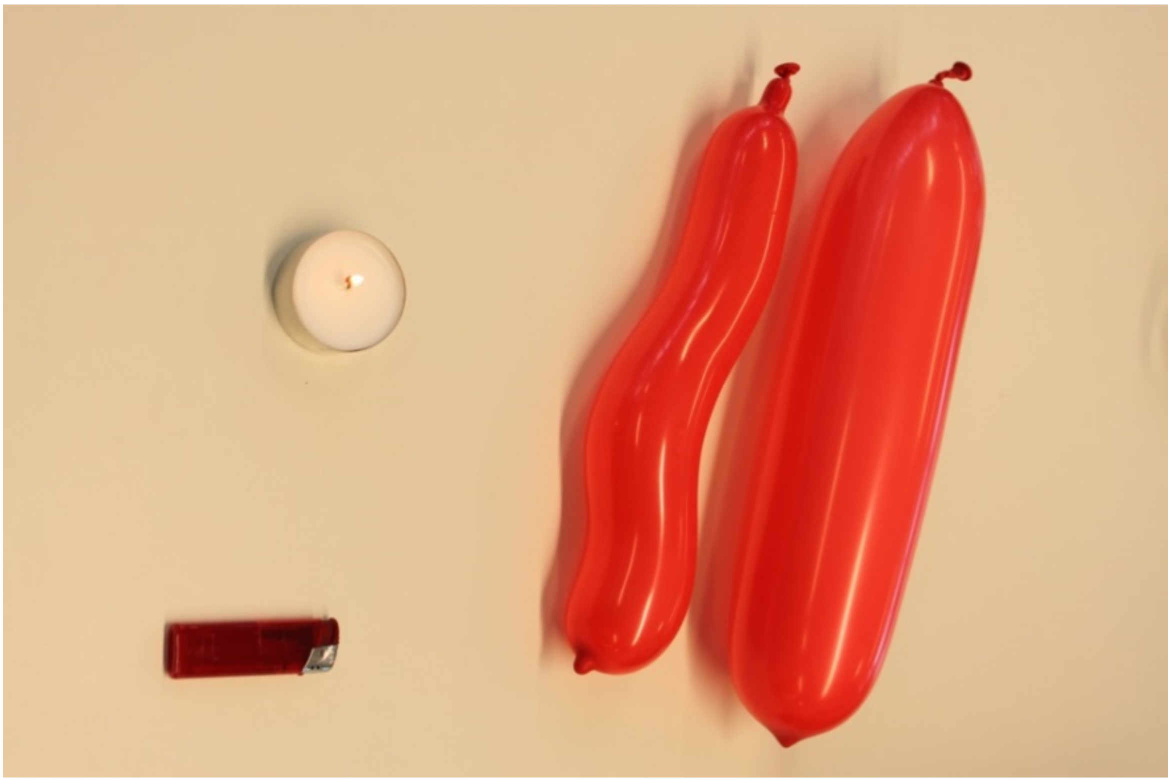

Figure 2: Experimental set-up of the activity.

Experimental set-up

1. Fill one balloon with water, the other with air.

2. Light the candle.

Experimental procedure

Put the balloons above the flame one after the other.

Task 2

Write down your observations and try to find an explanation for the phenomenon. What does the heat from the flame do to the air and the water? Which of both can store more heat?

Task 3

Consider the activity as a simple model for the Earth with oceans and an atmosphere. Where does most of the heat go to?

PROGRAM NAUCZANIA

Space Awareness curricula topics (EU and South Africa)

Our fragile planet, Oceans, atmosphere

ZAKOŃCZENIE

This activity provides a feeling for the effects of different heat capacities. Water can store heat much more effectively than air without a drastic temperature increase. Two balloons filled with air and water simulate the atmosphere and the oceans on Earth. When heated by a flame, the air balloon burst immediately while the water balloon remains inert. This demonstrates the heat storage capability of water compared to air. Transferred to the situation on Earth, it becomes obvious that oceans play an important role in capturing and storing heat that cannot contribute to the global warming.

This resource was selected and revised by Space Awareness. Space Awareness is funded by the European Commission's Horizon 2020 Programme under grant agreement nº 638653