

## An experimental model to understand temperature regulation

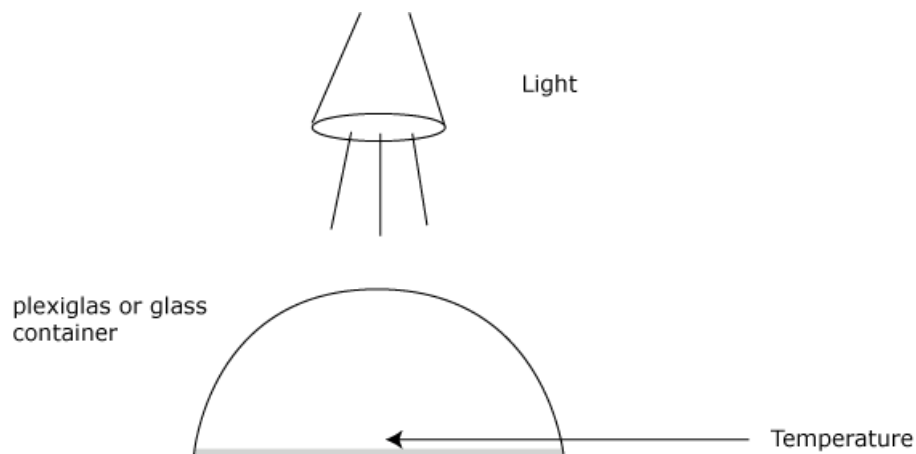
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### Introduction

This is a simple first experiment to introduce pupils to climate change.

The following experimental set-up summarises well temperature regulation at the Earth's surface.



**Challenge:** how to change the temperature inside the container?

The lamp represents the sun, the soil or sand represents the Earth's surface, and the container represents the greenhouse gases (but NOT the atmosphere). The container represents the greenhouse gases because the glass or plexiglass have the same transparency and absorption properties in relation to the light; transparent to visible light but opaque to infrared radiation. This experimental set-up also illustrates the origins of the name "greenhouse gas/effect" as we are creating in effect creating a greenhouse.

### Aim

To help students understand the phenomena involved in temperature regulation at the Earth's surface.

### Prior knowledge

Some background information about greenhouse gases and atmosphere

## Materials

- Transparent containers such as salad bowls (glass or plexiglass), which can fit into each other
- Thermometers
- Different coloured sand and soils, white and black paper
- Desk lamps

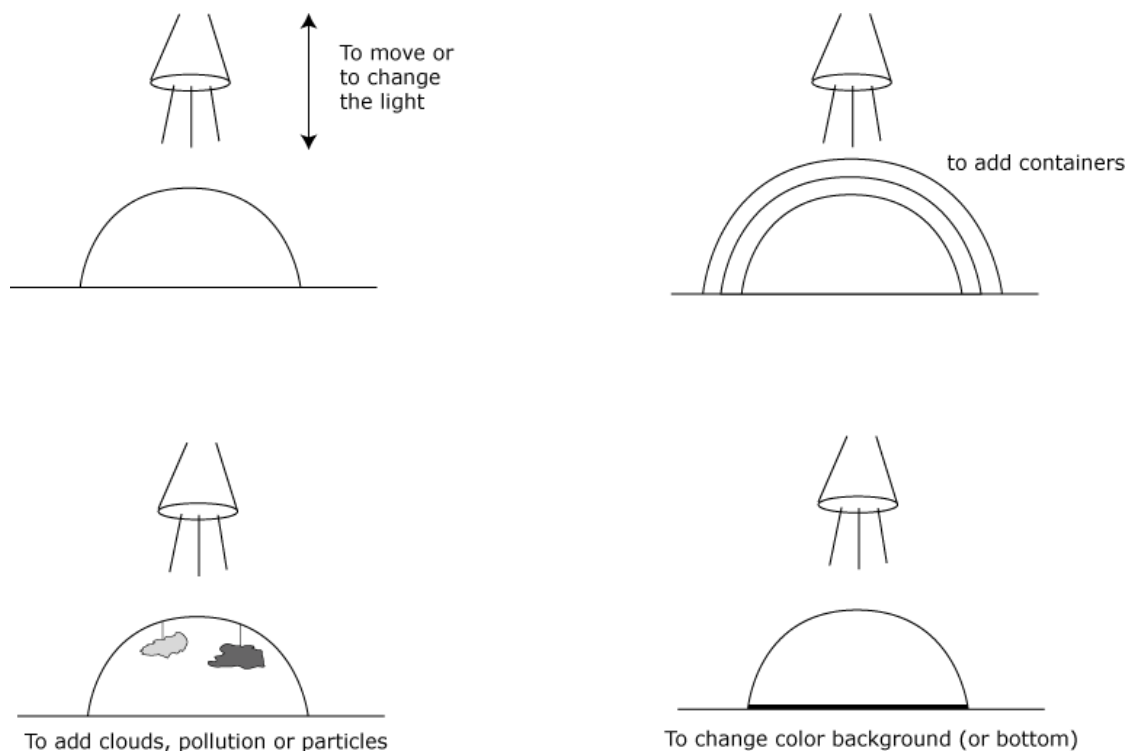
## Duration

A good two hours to give pupils time to experiment

## Procedure

1. Set-up the experiment with just the up-turned container, lamp and thermometer as shown above.
2. Set the following challenge to the pupils: Change the temperature inside the container, not forgetting that the set-up represents the Earth and sun etc, thus they must find realistic solutions (for example, switching the lamp off to reduce the temperature would be the same as extinguishing the sun, which is not possible).
3. If you wish, set a more precise challenge to the pupils: increase the temperature by 1 degree by suggesting different solutions. This is interesting as it shows the pupils that different phenomena can have the same results; the temperature at the Earth's surface can vary as a result of different processes, which is true.

## Possible solutions (but let the pupils find them on their own first)



- Placing the lamp further away or nearer to the container corresponds to when the Earth is further away from or nearer the sun depending on its trajectory, or when the sun is stronger or weaker. Changing the power of the lamp can also be accepted as it represents the same phenomenon.
- Increasing the number of containers corresponds to an increase in greenhouses. In order to observe a temperature gradient similar to that in the atmosphere (the troposphere to be precise), place a thermometer between each container.
- Changing the background colour corresponds to the changes in general atmospheric colour (presence of clouds, for example), or in Earth surface colour (the average colour of the Earth's surface is darkened as a result of melting ice, or is lightened due to the spreading of deserts).
- Adding clouds or aerosols (pieces of paper or aluminium foil) is interesting because the results are unpredictable. Clouds and aerosols are big unknowns in climate change prediction models.

### How to carry out the measurements?

The problem with this experiment is that the temperature under the container(s) takes time to stabilise (more than 50 minutes). This means that is either necessary to wait for stabilisation in order to obtain comparable temperatures, or to start the experiments with the same initial temperature conditions and to take good notes of the temperature changes. The second solution is easier to carry out in class, allowing the pupils to quickly see the differences in temperature (between 2 and 5 minutes).

### Some examples of experimental set-ups

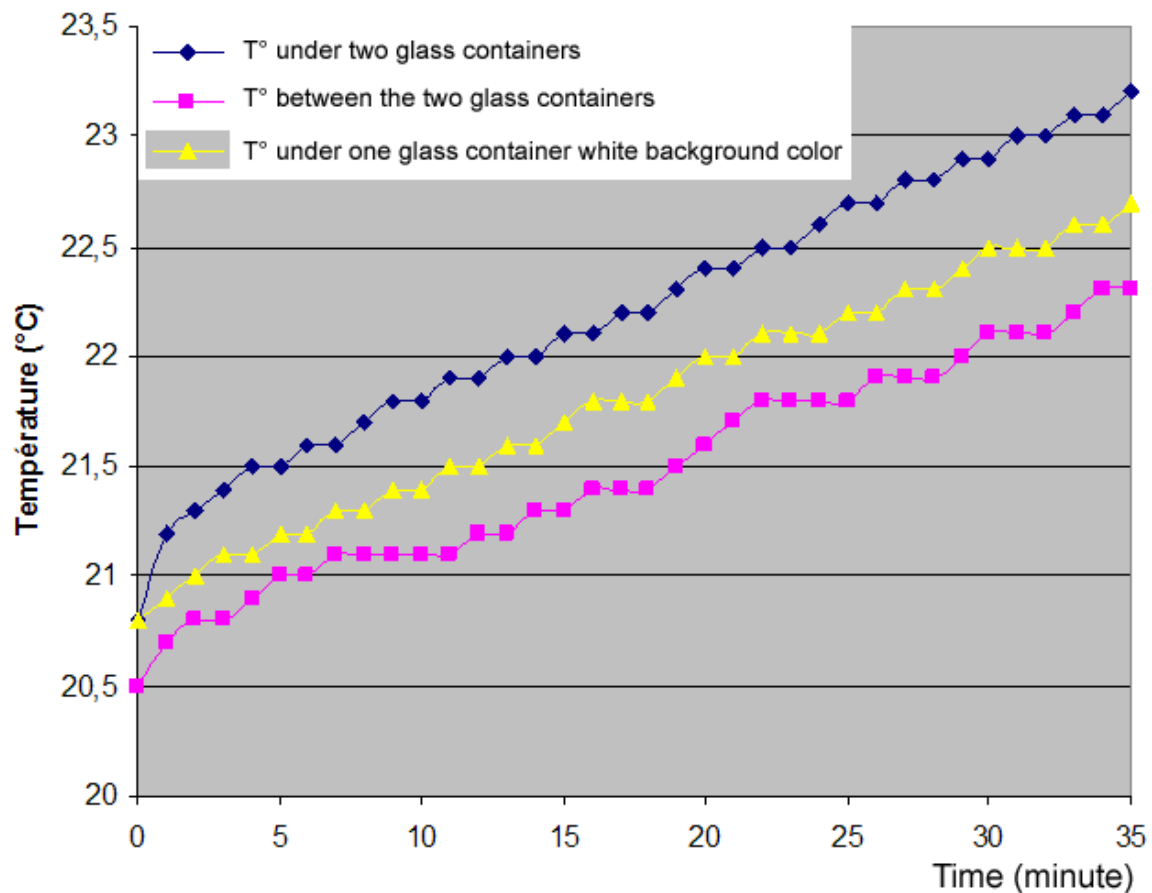
These examples are taken from the work carried out by a secondary school class (Lycée de Vilgenis, Massy) in their Natural Sciences class. The activity was carried out in two one and a half hours sessions, including the time needed to take photos and to make the posters. They opted for the second measurement solution (noting the temperature changes), as they didn't have time to wait for the temperature to stabilise.

#### 1) Increase in greenhouse gas concentration



*Experimental model: the pupils chose to put two glass containers inside each other. The temperature was measured under both containers (blue curve in the graphs below), and also between the two (pink curve)*

## Rise in temperature

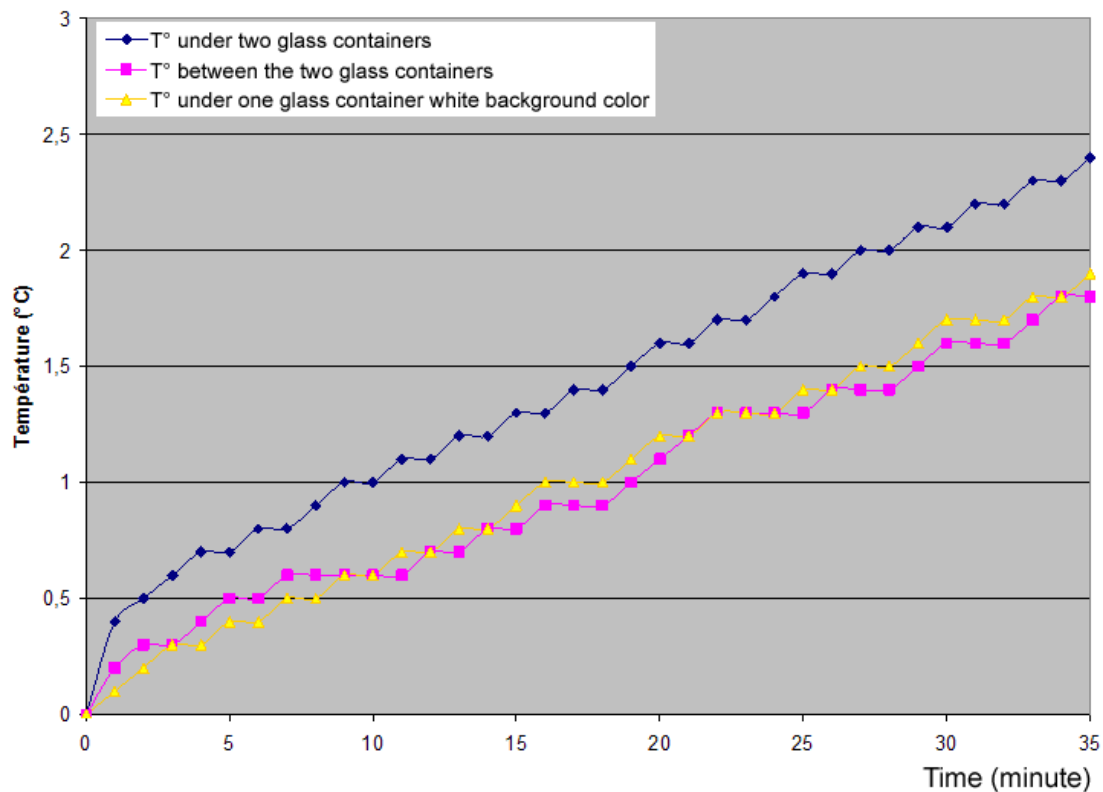


### Results :

- *Yellow curve : temperature under one glass container, control experiment*
- *Blue curve : temperature under two glass containers (corresponding to a situation where greenhouse gas concentration is higher)*
- *Pink curve: temperature between the two glass containers (corresponding to the temperature taken in the middle of the troposphere)*

*We can see in the graph that the temperature varies at the beginning of the experiment. In order to obtain more comparable results, the pupils produced a graph showing the rise in temperature in relation to the start of the experiment (see graph below).*

## Rise in temperature in relation to initial conditions



### Rise in temperature, in relation to initial conditions over time

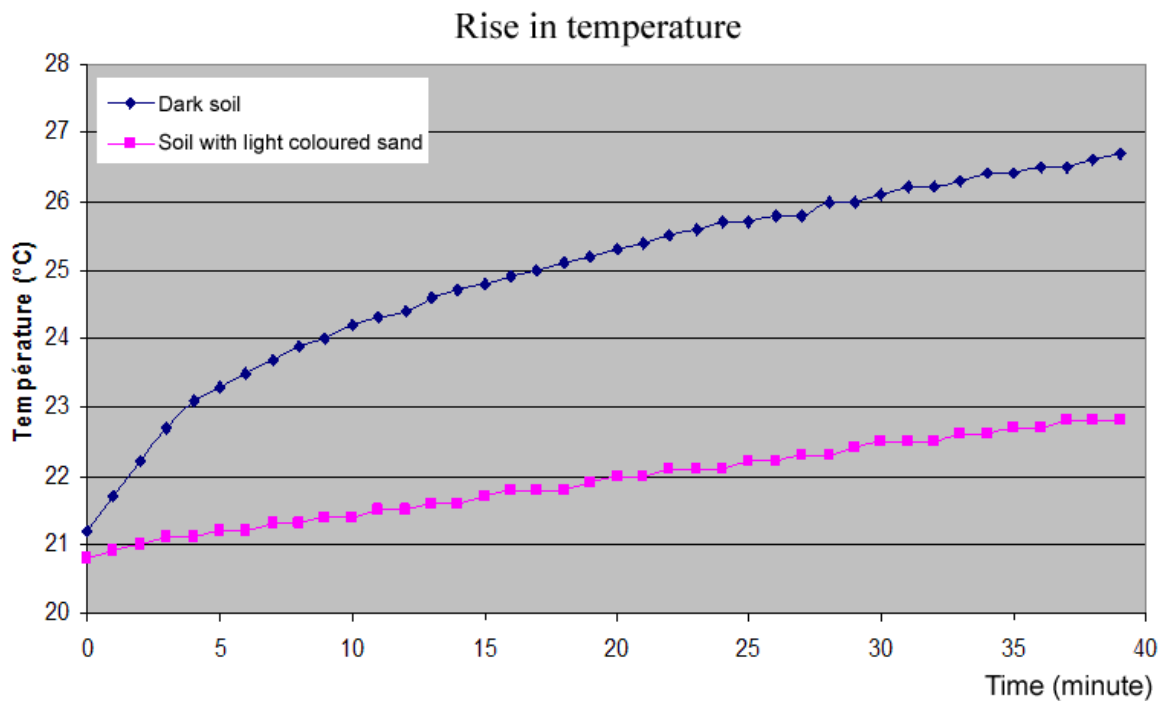
- *Yellow curve : temperature under one glass container, control experiment*
- *Blue curve : temperature under two glass containers (corresponding to a situation where greenhouse gas concentration is higher)*
- *Pink curve: temperature between the two glass containers (corresponding to the temperature taken in the middle of the troposphere)*

*These experiments show that as the number of glass between the source of light and the ground is increased, the ground temperature increases. Furthermore, a temperature gradient is created by increasing the layers of glass. Thus, this experimental model is a good analogy for greenhouse gases.*

## 2) Changing the colour of the Earth's surface



Experimental model : (i) under a container with dark soil, (ii) under a container with light coloured sand

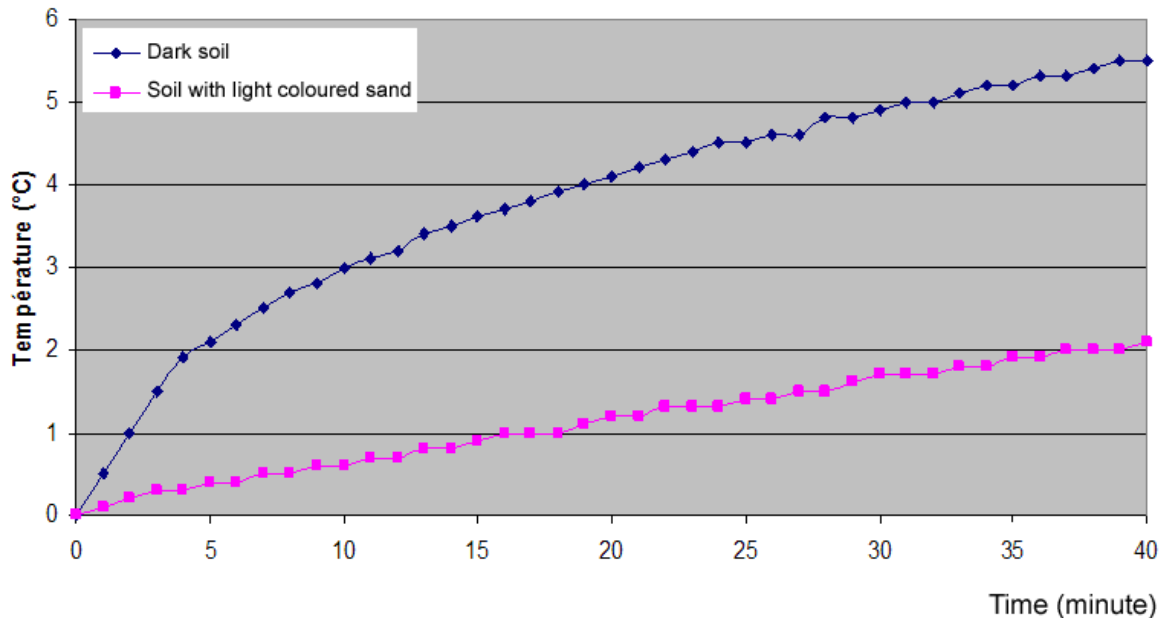


### Results

- Pink curve : temperature measured with light-coloured sand
- Blue curve : temperature measured with dark soil

Once again, as the initial temperature conditions differed a little, the pupils produced a second graph to show the rise in temperature in relation to that measured at the beginning of the experiment.

### Rise in temperature in relation to initial conditions



### Rise in temperature in relation to initial conditions over time

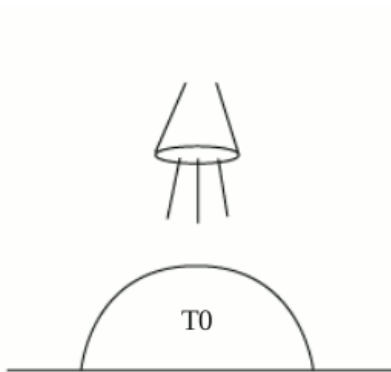
- Pink curve : temperature measured with light-coloured sand
- Blue curve: temperature measured with dark soil.

These experiments show that the colour of the ground has an influence on its temperature: the darker the ground, the higher the temperature. This phenomenon can be explained by the fact that dark soils/surfaces have higher visible light energy absorption.

During a discussion with the pupils, it was highlighted that the melting of ice has a serious effect on the increase of temperatures: a rise in temperatures leads to the melting of polar ice caps, the Earth's average colour darkens (white is replaced by the dark blue of the oceans or by the brown of the continents), and consequently the energy absorbed by the Earth increases, thus leading to an increase in surface temperature and the subsequent melting of ice etc. A vicious circle has been started (what is known as "positive feedback").

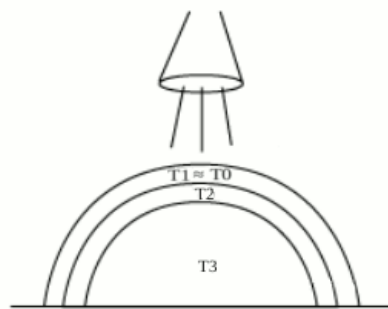
## Summary of experiments carried out at lycée de Vilgenis

Control experiment,  
temperature  $T_0$

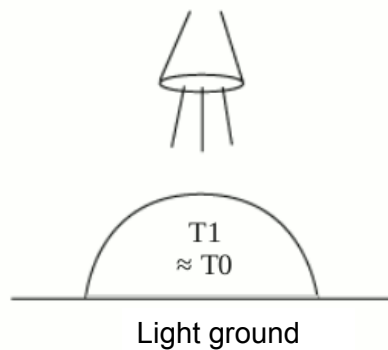
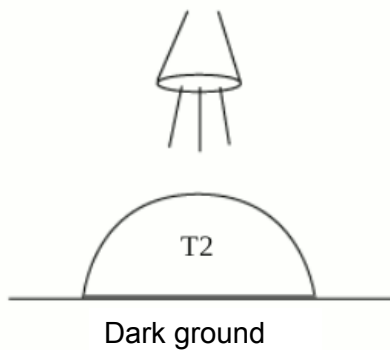


Layers of glass containers: creation of  
a temperature gradient

$$T_0 \approx T_1 < T_2 < T_3$$



Change of ground colour  
 $T_2 > T_1 \approx T_0$



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