Notes for teachers

An introduction to climate modelling

This activity presents basic ideas about the Earth's climate and the greenhouse effect, and how a simple model can allow us to understand how the Earth's temperature may be determined.

There are two parts:

An introduction to the greenhouse effect and to scientific modelling (using powerpoint or overhead transparencies)

A computer-based activity (using an Excel spreadsheet); this activity can also be carried out using paper and calculators.

We suggest that students study at least the first half of the introduction before tackling the computer-based activity.

The activities are designed for science lessons in Years 12 and 13 (pupils aged 16-18).

Part 1

KS5intro.pdf

This presentation introduces the greenhouse effect and how a model can be used to represent it.

Throughout the presentation, questions are posed and there is an opportunity to stop and spend time thinking and discussing the points raised.

Slide	Pupil activity	Notes	Approx time
1	Objectives		
2	Consider why an understanding of temperature is important. How might people's lives be affected by changes in climate?	Broaden this beyond pupils' local perspective and think about global issues e.g. effects on people in low lying areas (Tuvalu, Bangladesh) or those in drought-affected areas.	10mins
3	Start to relate the Earth's temperature to energy flows.	Pupils should think about: absorption by oceans, land and atmosphere; reflection from clouds and land. Relate absorption, reflection, emission to light and dark areas.	5 mins
4	To compare their ideas with this chart. Discuss what the figures might mean for the temperature of the Earth and atmosphere.	The Sun emits mainly infrared, visible and ultraviolet radiation. The incoming solar radiation varies with time – there are day-night variations, and variations with latitude. The tropics receive much more radiation than the poles (energy is	5 mins

		redistributed by the atmosphere and oceans). The Sun itself varies: sunspot activity varies on an 11 year cycle, the Earth's orbit varies slowly in time – giving us ice ages when less solar radiation is intercepted.	
5	Extend the ideas to include the greenhouse effect.	Arrive at the idea that because the Earth radiates energy, some of which is reabsorbed, the Earth stays warm. The rate of arrival of radiation = rate of loss of energy.	2mins
6 & 7	Identify models which they have come across in science, eg kinetic model of matter.	Consider 'model' in its broader sense, and in its scientific sense. In science, many types of model are used. One type, amenable to computing, is a mathematical model based on equations.	5 mins
8	The energy balance model intro	This introduces the basis of a very simple mathematical model. Note that we ignore the fact that the Earth is spherical, spinning etc. We consider an 'average Earth'.	5 mins
9, 10	The energy balance model - numbers	The model is based on 'global means' i.e. averaging the incoming and outgoing energy over the surface of the Earth. In reality, the Tropics receive most energy whereas the mid-latitudes lose most.	5-15 mins
11	Summing up, introducing the desirability of computing.	The calculation on Slide 10 is the first step in an iterative calculation. This can be readily extended using a spreadsheet – see the exercise which follows.	5 mins

Part 2 – practical, a simple energy balance climate model

This in an example of an 'energy balance model'. If the amount of energy the Earth gets is the same as the amount of energy it loses, the temperature of the Earth will stay the same – it is in a **steady state**.

Paper version

This leads students through the basic ideas of a simple climate model, and asks them to perform an iterative calculation to see how the temperature of the Earth will change in response to a sudden increase in the rate at which energy arrives from the Sun.

Here is the table they should obtain:

Time / years	Incoming radiation / $Js^{-1}m^{-2}$	Outgoing radiation / $Js^{-1}m^{-2}$	Change in temperature / K	Temperature of Earth / K

0	-	-	-	283
1	382.2	364	1.4	284.4
2	382.2	370.9	0.9	285.3
3	382.2	375.7	0.5	285.8
4	382.2	378.3	0.3	286.1
5	382.2	379.9	0.2	286.3
6	382.2	381.0	0.1	286.4
7	382.2	381.5	0.1	286.5
8	382.2	382.0	0.0	286.5
9	382.2	382.0	0.0	286.5

The temperature of the Earth increases rapidly to start with, then slowly settles at a new temperature, 286.5 K, 3.5 K warmer than it was to start with. This is a new 'steady state' which will not change unless the amount of incoming radiation changes again.

Even as energy balance models go, this model is very simple. In reality, the atmosphere has a number of effects:

- It reduces the amount of solar radiation that reaches the surface.
- It absorbs some of the infrared radiation emitted by the surface.
- It emits infrared radiation, some of which is absorbed by the surface.
- It makes possible the loss of energy from the surface via convection and evaporation.

Also the energy balance is never constant for long enough for a steady state to be achieved.

Excel version

This activity allows students to play with a model and to see how it can be used to test the effects of different starting conditions on the outcome. They can also vary the length of the time steps. It is good preparation for the work on a real climate model where there are many more variables. It is a good way of demonstrating in a simple way the time the Earth takes to reach a new equilibrium temperature when a change is made to the system.

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