Simple Climate Model – Teachers' Notes

2 Versions of this activity are available:

1) Excel based, for which the students will need access to a PC, and some basic knowledge of using Excel
climatemodel_instructions.pdf
climatemodel_worksheet.xls

2) Paper based, for which the students will need a calculator
climatemodel_paper.pdf

Suggested Answers to the Questions

1a) The Earth's temperature is never constant, but changes slowly through the day, season, year, decade…
b) It is affected by whether it is day or night, winter or summer (because the Earth is not symmetrical – the Southern Hemisphere has more water than the Northern), the composition of the atmosphere – gases and particles (pollution, volcanic ash), etc.

2) The amount of energy the Sun emits, the distance between the Sun and the Earth, the relative sizes of the Sun and Earth and the amount of energy reflected by the Earth (by clouds, ice etc.)

3) The correct answer is that the temperature of the Earth and the amount of outgoing radiation will increase, but this will be demonstrated in the exercise, so getting the answer wrong is ok!

4) The temperature is more or less stable after 15 years, at 286.47

5) A time increment that it between 2 and 8 times bigger gives you the same answer but with fewer iterations (so the total time it takes to reach the new equilibrium is the same). However, with a time increment that is 9 times or more larger (4.5 years or more) the model is unstable – temperatures oscillate from timestep to time step and never reach an equilibrium. This is because the modelled Earth gains/ loses more heat than is needed to take it to the new equilibrium temperature in one timestep, and it overshoots. This is an artefact of the model - the correct solution is not reached because of numerical instability (bad model). So clearly, computer models have to be a compromise between getting the right answer and making as few calculations as possible. A full climate model has to solve many thousands of equations at every time step, so finding the optimal time step size is important

6a) With an 8% increase, the new equilibrium temperature is 288.50K – warmer. Reduce the incoming radiation by 5%, a new equilibrium temperature of 279.4 K is reached.

6b) Much easier to see what's going on

7a) The ability to simplify things is valuable – investigate the relationship between some things without other things going on and masking the effect. Also, by, definition, there is no data for the future, so the only thing scientists can do is find a model that does a good job of replicating the past, and then use it to produce a forecast for the future.

7b) The greenhouse effect – outgoing radiation is absorbed and reemitted by carbon dioxide etc., latent heat release (water evaporating and condensing) etc. etc.

Excel model notes.doc

Notes on the model:

Cells in Row 1 contain values of constants:

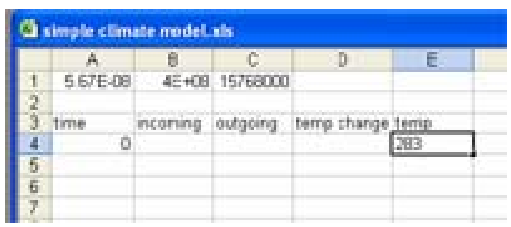
A1 = Stefan-Boltzmann constant σ = 5.67*10^-8

B1 = heat capacity of the Earth per square metre = 4*10^8

C1 = time increment = half a year = 60*60* 24*182.5

Cells in Row 3 contain headings.

Cell E4 = initial temperature of the Earth = 283 K



Calculations

Column A calculates the time (in years) at half-yearly intervals:

A5 = $A4 + $C$1/(60*60*24*365)

Column C calculates the rate at which energy leaves, using the Stefan-Boltzmann law:

C5 = $A$1 * $E4^4

Column B shows the rate at which energy arrives. Initially, this is equal to C5.

B4 = C$5

At the first time step, we increase the incoming radiation by 5%:

B5 = $B$4*1.05

This stays the same in the future, so you can copy this cell down to B20.

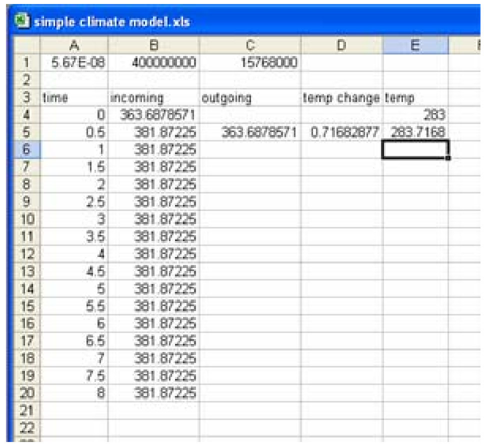
Column D calculates the temperature change:

D5 = ($B5-$C5)*$C$1/$B$1

Column E calculates the new temperature:

E5 = $E4 + $D5

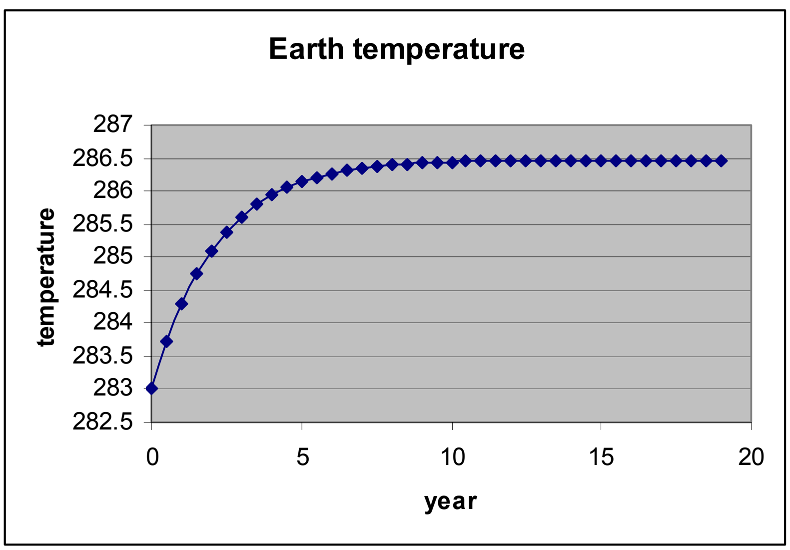
Your table should look like this:



simple climate model.xls

	A	B	C	D	E
1	5.67E-08	400000000	15768000		
2					
3	time	incoming	outgoing	temp change	temp
4	0	363.6878571			283
5	0.5	381.87225	363.6878571	0.71682877	283.7168
6	1	381.87225			
7	1.5	381.87225			
8	2	381.87225			
9	2.5	381.87225			
10	3	381.87225			
11	3.5	381.87225			
12	4	381.87225			
13	4.5	381.87225			
14	5	381.87225			
15	5.5	381.87225			
16	6	381.87225			
17	6.5	381.87225			
18	7	381.87225			
19	7.5	381.87225			
20	8	381.87225			
21					
22					

The model reaches a new equilibrium temperature of 286.47K by year 13.



climateprediction.net