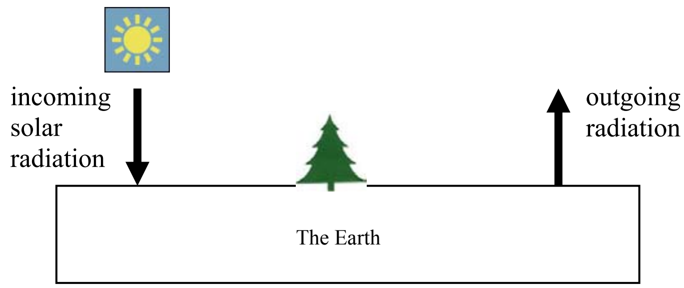
A very simple energy balance climate model

At the most fundamental level, the temperature of the Earth is governed by the difference between the amount of **energy** the Earth receives from the Sun, and the amount of energy the Earth loses to space.



Assume the incoming radiation is **364Js^{-1}m^{-2}** (364J of energy arrives on every square metre of the Earth's surface every second). What determines this quantity?

The outgoing radiation depends only on the temperature of the Earth. The amount of outgoing radiation is given by the Stefan-Boltzman Law
Outgoing radiation = σT^4
where **σ= 5.67 x 10^{-8} Js^{-1}m^{-2}K^{-4}**

The temperature of the Earth depends on the difference between in the incoming and outgoing radiation and the heat capacity of the Earth (**4 x 10^{8} JK^{-1}m$^{-2)}$**.

Start a new Excel spreadsheet. First define the constants – put σ in cell A1, the heat capacity of the Earth in cell B1 and the time increment in cell C1 – lets set this to half a year for now (make sure this is in seconds)

Now put table headings 'time', 'incoming', 'outgoing', 'temperature change' and 'temperature' in cells A3 to E3.

Specify the initial temperature of the Earth, at time 0, to be 283K.

Consider the time column first. Write a formula in cell A5 so that the time is the time in cell A4 (0) plus the time increment. Copy the formula down at least 20 cells in the A column. This should give you a series of times at half yearly intervals.
The time is displayed in seconds – a big and not very meaningful number, so change the formula (not the constant!) to display the time in years

Now consider the outgoing radiation (column C) at time = 0.5years. Construct a formula for the outgoing radiation based on the constant in cell A1 and the temperature of the Earth at time 0.

If we assume the Earth is in a steady state before we do anything to the radiation, you can make the incoming radiation at time 0 equal this, so in cell B4 put

=C5

What could change the amount of incoming radiation?

Consider the case where the incoming energy increases by 5% at time = 0.5 years, and then stays constant with time. Fill in column B accordingly.

Now, in cell D5, you can calculate the temperature change
= (incoming radiation – outgoing radiation) x time increment / heat capacity

and in cell E5 you can calculate the new temperature
= old temperature + temperature change

You can now extend the series in columns C, D and E down to row 20 and see how temperature evolves in your model.

Use the chart wizard to plot an appropriate graph of temperature against time for the Earth.

Try playing with the time increment (do you get the same new equilibrium temperature if you use a bigger or smaller time increment? Why?) and with the amount you change the incoming radiation by – if you reduce the incoming radiation by 5%, does the model reach a new equilibrium, steady state temperature? If so, is it higher or lower than the old one?