# Excel Climate Model - Worksheet

The aims of this practical are to

- See how greenhouse gas concentrations relate to temperature in very simple models.
- Investigate how volcanoes, changes in the Sun's energy output, the 'climate sensitivity' and 'global dimming' affect the temperature of the Earth, using a simple climate model.

You will investigate the data produced by a climate model which is a numerical representation of how the atmosphere behaves.

The model is very simple. It does not even try to represent many of the processes operating in the atmosphere, and greatly simplifies some others. This means that it is easier to see how a change in one factor impacts another.

It is an 'Energy Balance Model'; a zero or one dimensional model which predicts sea-surface temperatures based on the energy balance of the Earth. Because it does not attempt to calculate the complete dynamical structure of the atmosphere, by solving the appropriate equations of motion, it can produce results almost instantaneously.

Full GCMs (General Circulation Models/ Global Climate Models), which try to represent all the significant processes operating in the atmosphere, would take weeks of computer time to produce the equivalent results.

This model is based on the equation

$$C\,(d\Delta T/dt) = \Delta F(t) - \lambda \Delta T$$

Where

C = heat capacity of the Earth

T = temperature

t = time

F = the forcing
(through greenhouse gases, solar energy, volcanic emissions and sulphate aerosol etc.)

$\lambda$ = the feedback parameter

If this equation makes sense to you, consider the effect of having a positive change in forcing (e.g. due to an increase in greenhouse gas) or a negative change (e.g. due to a volcanic eruption)

1) On the graphs, the purple line shows the temperatures calculated by the model, and the green triangles show the observed global mean temperature. The temperature shown is always relative to the average of 1961-1990, so, whatever you do to the model, the temperature anomaly will always be closest to 0 in this period and most different at the edges of the graph.

2) Even this simple model can do a remarkably good job at reproducing the temperatures observed in the past.

3) There are 3 worksheets, use the tabs at the bottom of the page to change between them. Each worksheet uses a different greenhouse gas emissions scenario (SRES scenarios A2 and B1 and IS92a).

**What are the SRES scenarios?**

The **A1** storyline and scenario family describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity-building, and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. The A1 scenario family develops into three groups that describe alternative directions of technological change in the energy system.

The three A1 groups are distinguished by their technological emphasis:
- fossil intensive (**A1F1**),
- non-fossil energy sources (**A1T**)
- a balance across all sources (**A1B**)

(Note: A1B where balanced is defined as not relying too heavily on one particular energy course, on the assumption that similar improvement rates apply to all energy supply and end use technologies.)

The **A2** storyline and scenario family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing population. Economic development is primarily regionally oriented and per capita economic growth and technological change more fragmented and slower than other storylines.

The **B1** storyline and scenario family describes a convergent world with the same global population that peaks in mid-century and declines thereafter, as in the A1 storyline, but with rapid change in economic structures toward a service and information economy, with reductions in material intensity and the introduction of clean and resource-efficient technologies. The emphasis is on global solutions to economic, social and environmental sustainability, including improved equity, but without additional climate initiatives.

The **B2** storyline and scenario family describes a world in which the emphasis is on local solutions to economic, social and environmental sustainability. It is a world with continuously increasing global population, at a rate lower than A2, intermediate levels of economic development and less rapid and more diverse technological changes than in the B1 and A1 storylines. While the scenario is also oriented towards environmental protection and social equity, it focuses on local and regional levels.

The **IS92a** scenario came out of the previous IPCC report.

4) Compare the different temperatures predicted by this model in 2100 for each of the 3 scenarios.

**a) Volcanoes**

Choose one worksheet, and switch the Earth's volcanoes off by typing 0 in cell D6, moving the cursor over the bottom right hand corner of the cell, so that it turns into a cross, and right click and dragging down to the bottom of the sheet.

You should see that very little changes on the graph – although large volcanoes (such as Mount Pinatubo) have had a significant influence on the climate for a couple of years, nothing has had an effect for much longer.

Pressing Control-Z twice will return all the values to the cells and switch your volcanoes back on.

**b) Climate Sensitivity**

'Climate sensitivity' is a theoretical quantity, which measures how sensitive the Earth's climate system is to changes. We don't know what the 'true' value of climate sensitivity is, but many people are trying to work it out! The larger the value, the bigger the climate change we will see for the same increase in carbon dioxide in the atmosphere.
Climate sensitivity is formally defined as the difference between the global mean temperature in a world with pre-industrial $CO_2$ and the global mean temperature in a world with doubled $CO_2$, given enough time to adjust.

From the equation in the box above, it is possible to see that, at equilibrium when the rate of change of temperature with time is zero,

$$\lambda = \Delta F / \Delta T$$

where $\Delta F$ is the change in forcing associated with a doubling of $CO_2$, and $\Delta T$ is the temperature change associated with it – the climate sensitivity.

This parameter is set in cell B3.

The climate sensitivity could be between 1.9 – 11°C , with the most likely value being 3-4°C.

Try changing the value of the climate sensitivity.

You should see that changes within this range have relatively small impacts on the modelled temperature in the recent past and near future, but much bigger differences can be seen in the more distant past and future. It is for this reason that the climate sensitivity can be constrained by observations of the past, an area of active research.  It is also why, if the Earth actually has a high climate sensitivity, any small changes in the atmospheric composition now could result in large temperature changes in over a hundred years time.

**c) Global Dimming**

The scaling factor in cell E4 relates to how much the forcing due to sulphate aerosol is scaled by in the total forcing – so the default is 1.
What happens if the sulphate aerosol is turned off?

> Change the number in E4 from 1 to 0, effectively removing sulphate aerosol from the model.

The temperature curve should now be steeper. This demonstrates the so-called 'global dimming' effect – the fact that increasing concentrations of sulphate aerosol in the atmosphere may have masked, to some extent, global warming due to increasing concentrations of greenhouse gases. The Earth's atmosphere didn't warm much in 1950-1980 partly because of the amount of sulphate aerosol in the atmosphere – mostly coming out of industrial chimneys. Clean air acts and legislation designed to reduce acid rain have removed a lot of sulphate from the atmosphere, at least over Europe and America.

Alternatively, try doubling the amount of sulphate aerosol by changing the number in E4 to 2.

The curve is now much shallower.

**d) Solar forcing**

There have been some suggestions amongst climate sceptics that the observed temperature of the Earth in the recent past could be entirely due to natural forcing mechanisms (solar, volcanic).

Try turning off the changes in greenhouse gas (ghg) and/ or sulphate concentrations (to do this, click on cell B6, move the cursor over the bottom right hand corner so that it turns into a cross, right click and drag down to the bottom of the worksheet, and/ or change E3 to 0 ).

Can you do anything to make the modelled temperature curve match observations as well as it did with greenhouse gas etc. emissions turned on? You could try changing the values in the solar forcing column, E, by changing the scaling factor on the solar forcing, which is currently set to 1.0 in cell H2. You could also change the effective depth of the ocean in cell B4.

Again, to return the chart to its original condition press control-Z repeatedly.