# Information on obtaining and using GENIE

Information and documentation about the GENIE earth simulator can be found on the project wiki site:

https://source.ggy.bris.ac.uk/wiki/GENIE

For further information and the relevant password to obtain the code please contact the GENIE project team:

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After you have obtained a username and password follow the weblink below to download the code.
https://source.ggy.bris.ac.uk/wiki/GENIE_GENIELab#Downloads

## System requirements and additional prerequisites

Note that in addition to the source code, GENIE makes use of several applications and packages. You must have the following list of prerequisites installed on your computer, before you can run GENIE:

- Python.
- Perl (for the automatically generated documentation).
- GNU make.
- The BASH shell.
- The NetCDF libraries. See the using netCDF page for more information about downloading and installing netCDF.
- A C++ compiler, such as that from the GNU Compiler Collection (GCC).
- A Fortran compiler (including support for Fortran90). Compilers which are known to work with GENIE include: Intel, PGI, Pathscale, Sun, GNU gfortran, g95

GENIE can also be built for Windows platforms with a suitable build environment.

Follow link below for information on creating a build environment in Windows.
https://source.ggy.bris.ac.uk/wiki/GENIE_WindowsCompilation#Prerequisites

# SOES3015 Palaeoclimate Change

## Modelling Practical (non-assessed) – Introduction to GENIE & CO2 experiments

## *Answers to stages 4 and 5*

You will be carrying out experiments with the GENIE earth system model of intermediate complexity (EMIC). Once you are basically familiar with the model, you will carry out CO2-forced experiments that are designed to investigate:

- Anthropogenic Forcing of Climate, 1800-2100
- Equilibrium Climate Sensitivity

The forcing is prescribed as $CO_2$ emissions. The purpose of this practical is to give you some direct experience of an EMIC: how fast (slow!) it runs; the kind of experiments that we carry out with such models; the kind of data produced. The practical takes 2.5 hours however the model may run slowly so be patient throughout - you're running an Earth System Models with a dynamical 3-D ocean and a closed carbon cycle!

### *4. Anthropogenic $CO_2$ forcing (3.00-3.30)*

Now run 300-year experiments that mimic the greenhouse gas emissions associated with the industrial revolution and subsequent global development, spanning 1800-2000, and an IPCC scenario for 2010-2100. The total global emissions data in selected years, should again be typed in under “Adjust emissions” as tabulated.

Observe selected time series (e.g., Atmospheric pCO2) and evolving anomaly maps (e.g., air temperature). [In the first decade or so, you will notice slight reduction of CO2 and associated cooling – this is a very minor transient re-adjustment of the model after continuation from the end of a spin-up that was carried out on a different computer – the subsequent $CO_2$ rise and warming soon swamps this initial small transient.]

What is the $CO_2$ concentration in 2000? How does it compare with the actual concentration at this time (369.47 ppmv, observed at Mauna Loa observatory)? What is the $CO_2$ concentration in 2100? What has happened to air temperature? Is there a pattern to the warming?

When the experiment is complete (if time permits): From the results folder, extract the time series of atmospheric $CO_2$ concentration. Plot this and compare it with the historic time series of $CO_2$ (see above website). How well does model $CO_2$ compare with observed $CO_2$ up to 2000? Also extract the time series of NH and SH air temperature. Combine these (average them) to get global mean air temperature and subtract the initial (year 0 = 1800) value to get the anomaly (global warming). How well does model global warming compare to observed global warming in 2000 (estimated at 0.7°C)?

***$CO_2$ rises slowly at first, but the rate of increase picks up steadily. As a consequence, $CO_2$ concentration barely changes in the early decades, and much of the rise to the year 2000 value is accomplished post-war. The time series compares closely with observations, and the year 2000 concentration is very close to the observed value. The same is true of the simulated global warming at 2000. Warming is greater over land due to the much smaller heat capacity there (compared to the ocean, where much excess heat is advected and mixed into the deep ocean – hence surface warming is somewhat less).***

### *5. Climate Sensitivity Experiments (3.30-5.00)*

Based on the experience you gained in stages 3 and 4, run a multi-centennial experiment (at least 500 years, longer if you have time – work out how long you can run for, based on the 300 years in stage 4). Specify an initial pulse of $CO_2$ emissions: immediately increase emissions to a large value, sustain this for 50 years, then “switch off” – i.e., back to zero, and keep emissions at zero for at least 450 years. You will see the $CO_2$ concentration peak at the end of the pulse, after which the climate-carbon system equilibrates towards a new “high $CO_2$” state. A fraction of the pulse-emitted $CO_2$ remains in the atmosphere on a multi-centennial timescale (note the difference between peak and final $CO_2$ concentration).

You should cooperate in this stage! Work in groups of ~5 pairs, each pair undertaking a different pulse experiment (agree the pulse amplitude before you start). Share the experimental results within the group, completing sufficient runs in the time available to determine the relationship between $CO_2$ and temperature, as outlined below.

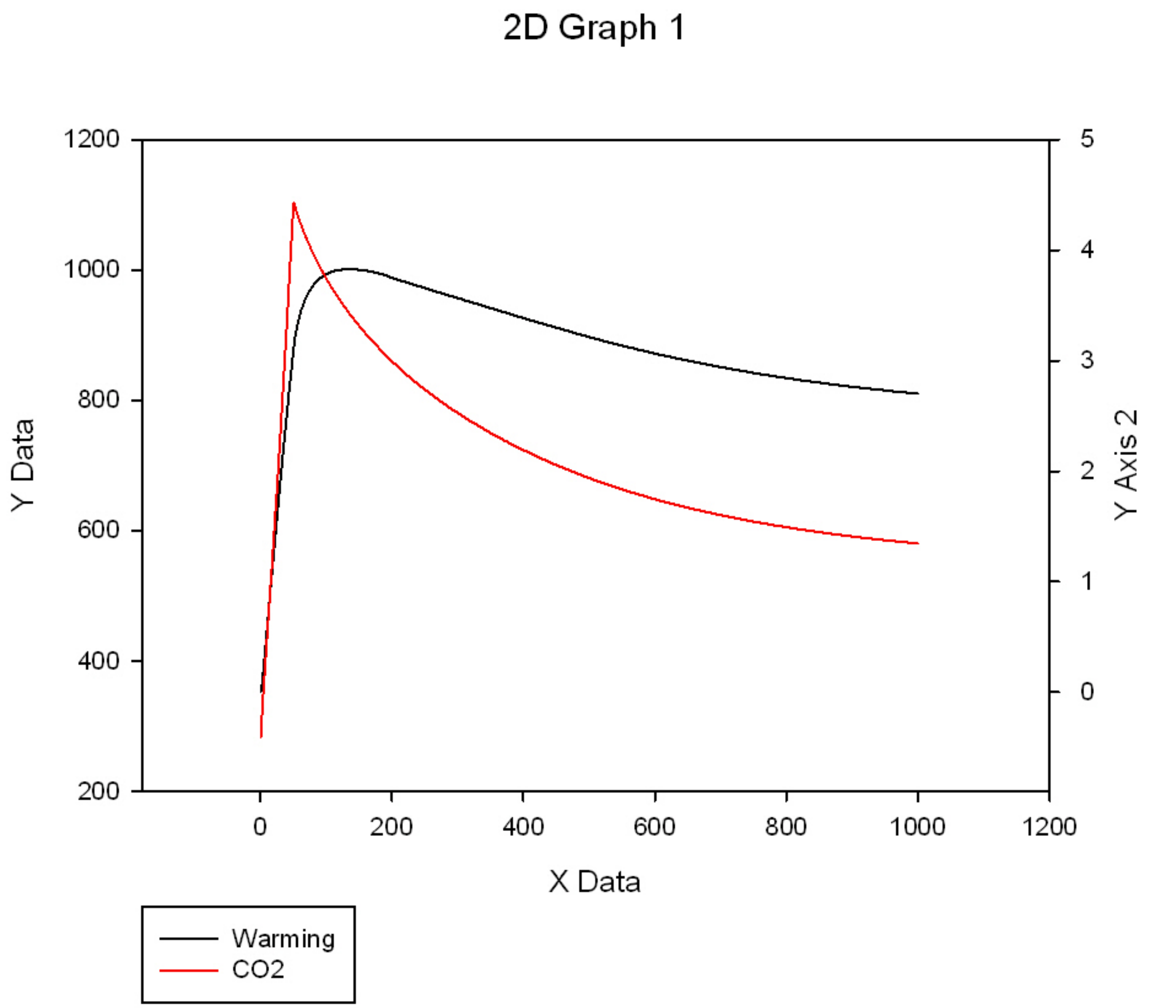
The general concept of climate sensitivity was introduced earlier. Here we want to determine the long-term global warming as a function of the long-term $CO_2$ concentration. Increasing the “height” of the $CO_2$ emissions pulse in a range of experiments, plot the warming as a function of the ratio of increased $CO_2$ to initial $CO_2$ (modern pre-industrial = 279 ppmv). Aim to get end-of-run CO2 concentration equilibrating towards values in the range x1.5 (Pliocene?) to x8 (PETM?) pre-industrial concentration. A clear relationship should emerge, from which you can ascertain a rough functional relationship between warming and $CO_2$.

Caveat: full equilibrium may only be approached after around 1000 years (mixing timescale of the global ocean, with implications for readjustment of the carbon cycle), and the long-term carbon cycle continues to remove $CO_2$ from the atmosphere over timescales of O(10,000) years.

*Hint 1 : the "equilibrium climate sensitivity" of a climate model (or the real climate system) is often defined as the rise in global-mean temperature for a doubling of $CO_2$.*

*Hint 2. Start with 20 Gtonne C per year, for first 50 years, followed by zero emissions over years 51-500.*

***This result is courtesy of Darlington et al., who chose a pulse of 50 Gt C per year:***

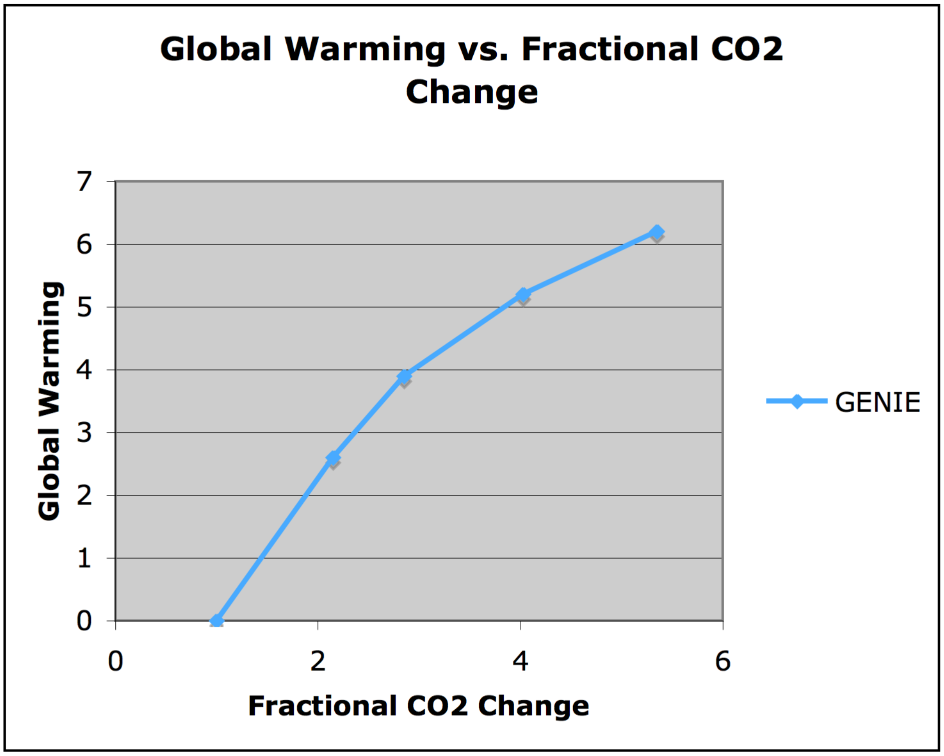


***Note that $CO_2$ increases approximately linearly over years 0-50, thereafter adjusting exponentially to a new high-$CO_2$ equilibrium as the oceans sequester***

***some of the atmospheric $CO_2$. In the 50 Gt C per year example, global-mean temperature closely follows $CO_2$, but "overshoots" by about 0.4°C after year 50 – this is because the ocean (with large thermal inertia) is still coming into equilibrium with the perturbed radiation balance. By year 1000, $CO_2$ and global-mean temperature difference (from initial state) are ~600 ppmv and ~2.6°C respectively. So the ratio of final/initial $CO_2$ ("fractional $CO_2$ change") is ~600/279 = ~2.15.***

***To appreciate the relationship between equilibrium global warming and $CO_2$ (relative to Holocene pre-industrial), another three experiments are sufficient (in addition to zero warming for no pulse, by definition): pulses of 75, 100 and 125 Gt C per year. For larger/smaller pulses, equilibration is slower/faster, so necessary simulation time varies between 1500 and 3000 years.***

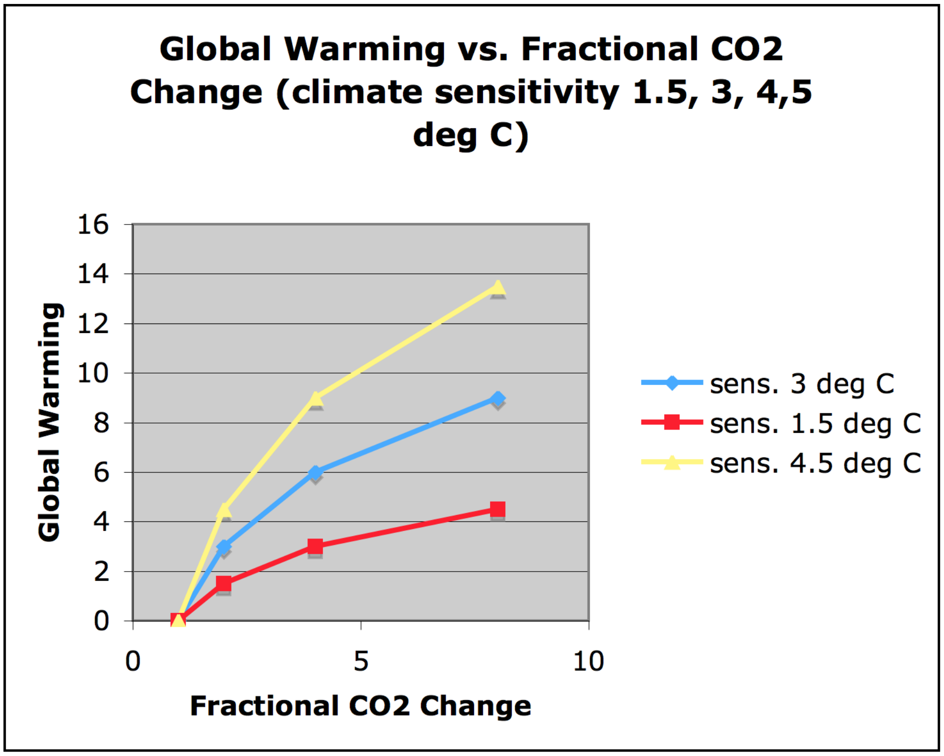
***The results are summarized below:***



***Note that the curve bends over – this suggests that $CO_2$ is having proportionately less warming effect as it is increased. In fact, it is known that constant incremental warming is obtained per doubling of CO2. This is supported by the GENIE results, although it is largely specified by a parameterization for the radiative forcing of $CO_2$, a fixed incremental flux ($Wm^{-2}$) per $CO_2$ doubling.***

***From the results obtained here, we estimate the climate sensitivity of GENIE to be around 2.4 deg C. This is close to 3 deg C, perhaps the most likely actual value, intermediate between IPCC extremes 1.5 and 4.5 deg C (see below).***

***Hypothetical curves for climate sensitivity of 1.5, 3 and 4.5 deg C:***



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