4.4.2 Problem Set: Introduction

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In this pset, we consider the impact of anthropogenic (i.e. the result of human activity) production of greenhouse gases on the atmosphere. As much as we attempted to make the model realistic, please keep in mind that it did not undergo peer review and is fairly simplistic. Please do not attach too much significance to the specific numerical values that you obtain. However, we do believe the general trends and timescales of the evolution of the atmosphere are representative. The overall goal of this problem set will be for you to implement a Monte Carlo method to simulate the uncertainty involved in this simple climate model.

Overview of climate model

This will be a three state ($\boldsymbol{M = 3}$) model with:

- $\boldsymbol{u_0 = T}$ being the average atmospheric temperature near the ground
- $\boldsymbol{u_1 = [H_2O]}$ being the average concentration of water vapor in the atmosphere
- $\boldsymbol{u_2 = [CO_2]}$ being the average concentration of carbon dioxide in the atmosphere

The model's main idea is that the atmospheric temperature adjusts until there is an energy balance between the incoming solar radiation and the outoing radiation into space. This can be written as:

$$C\frac{dT}{dt} = (1-\alpha)\ \frac{S_0}{4} - \left(1 - \frac{1}{2}\epsilon\left(T, [H_2O], [CO_2]\right)\right)\ \sigma\, T^4, \tag{4.51}$$

where (in SI units) each term is in $\mathbf{W/m^2}$, and

- C is the climate's effective heat capacity. A typical value would be $C = 4.5 \times 10^8\ \mathbf{J/(Km^2)}$.
- T is the atmospheric temperature near the ground, measured in degrees Kelvin ($\mathbf{K}$), assumed uniform in space.
- t is the time in $\mathbf{s}$.
- The first term in the right-hand side is the incoming heat flux.
- S_0 is the solar irradiance, $S_0 = \mathbf{1370\,W/m^2}$.
- α is the average albedo of the Earth. A typical value would be $\mathbf{0.3}$.
- The second term in the right-hand side is the outgoing heat

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flux resulting from (nearly) black-body radiation (Stefan's law).

- ϵ is the Earth's effective emissivity, i.e., the extent to which the Earth departs from a perfectly radiating black body. A black body would have $\epsilon = 0$, while a typical value for the Earth
- 0
temperature, $[H_2O]$, and $[CO_2]$. The following model will be used for these dependencies:

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an approximate value is currently around 10 ppm/yr.

- For carbon dioxide,