Global Carbon Cycle Mixture Model and Carbon Capture

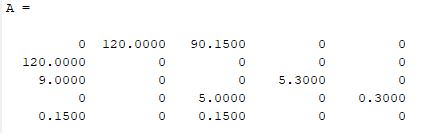
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[Intro]

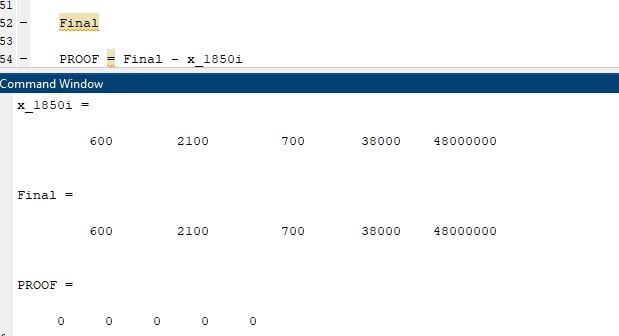
Ever since the industrial revolution in the mid-1800s, human activities have accumulated many carbon dioxide (CO2, or carbon for short), especially from the geological reservoir into the atmosphere. It is of our best interest to find out what methods can we implement to offset the carbon emissions and maintain the carbon balance in the earth system. One of the methods we can use is carbon capturing, which involves in transferring the atmospheric carbon back into its geological form for future sustainability. In this project, we will be using computer programs to simulate the mathematical model behind the earth’s carbon cycle and how the interactions between the different carbon reservoirs might give us insights on how to solve this issue.

[Question 1]

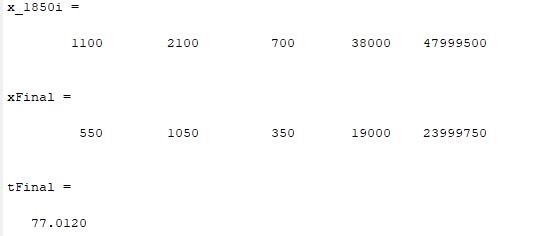
In order to answer any of our questions, it would be necessary for us to set up a mathematical model that captures the behavior of the carbon cycle on earth first. The earth’s carbon cycle system can be modulated by the following differential equation:

where the matrix x is the amount of CO2 in five different areas that we will look at primarily: atmosphere, biosphere, surface ocean, deep ocean and geological carbon reservoirs, and a(t) is the “forcing term”, which indicates the human impact of carbon emissions. First, we need to figure out what the matrix A is, which means the transferring of carbon between different carbon reservoirs. According to the pre-conditions, the matrix A should look like:

Assuming most carbon emissions caused by human activities after the industrial revolution at 1850, we will set the year 1850 as our starting point and that Ax(1850) = 0, without human interactions. From our MATLAB program, we are able to verify so:



Therefore, if we assume a(t) = 0 at 1850, the initial condition is indeed in equilibrium, as the net transferring of carbon between the different reservoirs should add up to zero. However, at year 2020, the initial condition changes to such that the atmosphere has an additional 500 Gt of carbon, which is transferred from the geological reservoir. Now, we want to find the time in years it takes for the additional carbon to be reduced to 50%. This is done by



As the results suggest, the carbon goes under natural decay in around 77 years. All reservoirs have their carbon reserve reduced by 50% and the one with the least amount of carbon taken up is the surface ocean reservoir.

[Question 2]

[Question 3]

[Question 4]

[Question 5]