CO_2 Sequestration
As means of fighting global warming
A MathCAD experiment

ABSTRACT

Climate change, more specifically global warming, has been found to have a direct connection to the amount of carbon dioxide (CO_2) in the earth's atmosphere. The increasing amounts of CO_2 in the atmosphere are making the atmosphere less permeable to blackbody radiation. Blackbody radiation is the heat that is radiated from the earth back out into space, causing the earth to warm (Agrawal). The earth's natural carbon cycle can move carbon (CO_2) from the atmosphere into the deep ocean where it can be stored, and more importantly removed from the atmosphere. With the increase of CO_2 production, due to human action, more attention is being paid to the carbon cycle in measuring how much carbon it can move. Along with reducing carbon emissions, carbon sequestration (movement of carbon from the atmosphere to the deep ocean) appears to be another tactic to fight global warming. Whether carbon sequestration is a viable method for reducing atmospheric carbon was the focus of this week's lab session. Carbon sequestration was determined to be a valid method for removing carbon from the atmosphere. However, with the large amount of atmospheric carbon that would be needed to be removed, carbon sequestration would not be very efficient. Reducing emissions appears to be a much more direct and effective way of controlling the amount of carbon in the earth's atmosphere.

INTRODUCTION

Carbon dioxide is a green house gas produced by the burning of fossil fuels. Since the industrial revolution the amount of CO_2 produced by human action has increased the amount of atmospheric carbon to levels never seen before. With the increase of atmospheric carbon global warming has occurred due to thicker atmosphere not allowing radiation to escape as easily as when less carbon was present. The carbon cycle allows carbon to be transported between the atmosphere, Land and shallow oceans, and the deep oceans. In a simplified carbon model, used for this experiment, several inputs and outputs were used. Industrial emissions are the main current source for placing carbon in the atmosphere, mainly in the form of CO_2. The atmosphere on average holds about 735 Gt (giga tons) of carbon. Through the processes of fixation and respiration carbon can be exchanged between the atmosphere and the earth's surface (land and shallow oceans). Fixation is the removal of carbon from the atmosphere to the earth's surface usually stored in organic forms, trees, plants, animals etc… Respiration is the release of carbon from the earth's surface to the atmosphere through the biologic processes of burning of organic matter and breathing. Another exchange occurs between the shallow oceans (which include the carbon found on land in this simplified model) and the deep ocean. Around 781 Gt of carbon can be stored in the shallow oceans, compared to the massive 19,230 Gt's that can be stored in the deep ocean. Downwelling and upwelling are the two major exchange processes that occur between the shallow and deep ocean. A minor amount of carbon is deposited in the deep ocean floor, but the small amount is not a primary focus of this experiment. This simple model is the bases for the MathCAD program used.

Carbon sequestration is the process by which carbon is moved by the cycle and stored within the deep ocean. The deep ocean has a large capacity to hold more carbon than any other part of the carbon cycle. With the increase of carbon in the atmosphere leading to global warming, it is in our best interests to store carbon in a place where it will not have such a strong effect on our earth's climate. Carbon sequestration appears to be a reasonable way to remove the carbon from the atmosphere and aid in lessening the effects of global climate change the earth will be facing in the future. In looking at the variables we can use to move the bulk of the atmospheric carbon to the deep oceans we have fixation, downwelling and deposition. Going against the movement of carbon from the atmosphere to the deep oceans are respiration, upwelling and emissions. Controlling emissions has been a main concern ever since we have realized the problems that are caused by the increased CO2 in the atmosphere. Special organizations and regulations such as the Kyoto protocol (Kyoto) have been initiated in trying to manage the amount of CO2 emissions produced by industry. To return the global carbon balance back to how it was prior to the increase in CO2 emissions, humans would have to cut carbon emissions by 80% (Agrawal). A stabilization point where we are producing the maximum amount of carbon the natural cycle can handle was also found. This value would be around a concentration of 500 ppm of carbon in the atmosphere. Due to the difficulty in the market and political world of cutting emissions, carbon sequestration is viewed as a way to fight global warming without reducing emissions to their lowest levels. MathCad was used to project what the levels of carbon would be in the atmosphere when different degrees of emission controls were used. Also the sensitivity of the atmospheric CO2 levels to the different carbon transporting variables was viewed as to how they function in the global carbon cycle.

METHODS

In the first section of the lab experiment, emission levels were changed and CO2 levels were graphed and recorded for each emission change. The time scale was also varied throughout the experiment. Time ranged from a span of 340 years to up to 1000 years time, to view the reaction of atmospheric CO2 levels to the change in the level of emissions. The second section on the experiment focused on the sensitivity of atmospheric CO2 to different processes. Five variables were altered in this experiment, fixation, upwelling, respiration, downwelling and deposition. The five variables were altered either by decreasing by 50% or by doubling the rate at which they are able to move carbon through the global carbon cycle. The response of the concentration of atmospheric CO2 was recorded after each individual variable was changed. Each variable was changed independently of all other variables, in order to record the direct effect each variable had on the atmospheric concentration of CO2. The mathCAD program was based on a simple equation, that resembled the simple global carbon cycle mentioned in the introduction. MathCAD took the five variables, as well as emissions and combined them in groups as they effect the three main areas of carbon storage (atmosphere (At), land / shallow oceans (St), and deep oceans (Dt).) The equation can be seen as Figure 1.

Fig. 1 MathCAD equation for carbon cycle

$$\begin{pmatrix} A_t \\ S_t \\ D_t \end{pmatrix} := \begin{bmatrix} \left(\text{respiration}\cdot S_{t-1} + \text{emission}_{t-1}\cdot dt - \text{fixationA}_{t-1}\right)1 + A_{t-1} \\ \left(\text{fixationA}_{t-1} + \text{upwellingD}_{t-1} - \text{respiration}\cdot S_{t-1} - \text{downwellingS}_{t-1}\right)1 + S_{t-1} \\ \left(\text{downwellingS}_{t-1} - \text{upwellingD}_{t-1} - \text{deposition}\cdot D_{t-1}\right)1 + D_{t-1} \end{bmatrix}$$

RESULTS

When changes were made to the amount of emissions produced overtime the level of atmospheric CO2 in Giga tons of carbon were graphed overtime. In the most complex example, emissions prior to the year 2100 were set at 20 GtC (giga ton of carbon) and emissions after 2100 were set at 10 GtC. The results showed a steady increase in giga tons of carbon until the year 2100, then after the emissions were reduced to 10 ppm??? the amount of carbon in the atmosphere was maintained at around 1560 Gts. The concentration of atmospheric CO2 followed a similar trend. This trend occurred over a 340 year span. The CO2 concentration increased from 280ppm to about 840ppm prior to the year 2100. After the year 2100, the CO2 concentration held constant at about 820ppm (Figure 2).

Fig. 2 Atmospheric CO2 concentration and Giga Tons of carbon in the atmosphere over a 340 year period in relationship to 20(PPM????) emissions prior to 2100, and 10 PPM??? emissions after 2100.

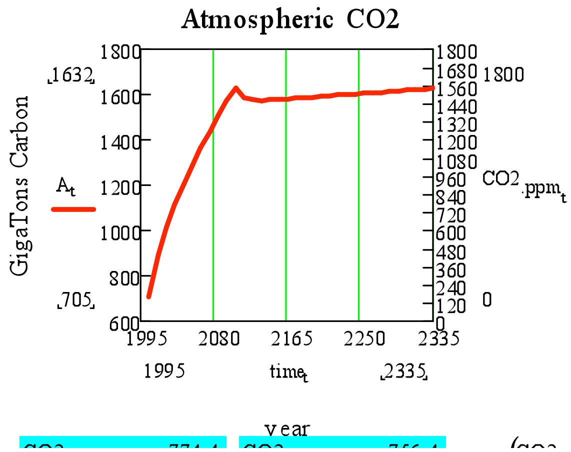
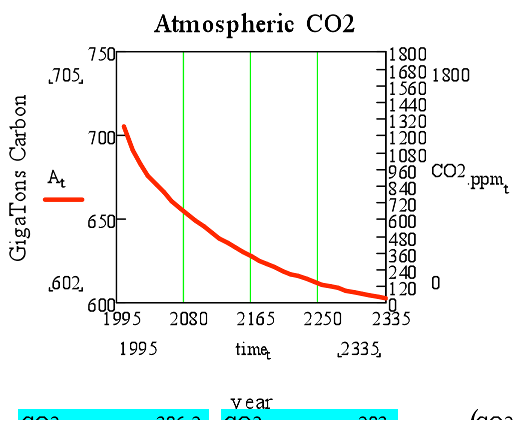


Figure 2 can be compared to figure 3 which shows the same data when emissions were set to zero. In figure 3, the tons of carbon in the atmosphere fall steadily to zero, and the CO2 concentration holds constant at about 280ppm during the entire time span.

Fig. 3 Atmospheric CO2 concentration and Giga Tons of carbon in the atmosphere over a 340 year period in relationship to zero emissions after year 2100.



For the second section of the lab experiment the sensitivity of atmospheric CO2 concentration were measured as a result of independently changing each of the five emission variables. The CO2 concentrations were measured for two specific time periods. The first set of sensitivity was measured at the year 2200, the second set was measured to find the maximum concentration the CO2 would reach over the 1995 – 2335 time period. The results followed general increasing or decreasing trends, when considering which variable was manipulated. When variables that work to remove carbon from the atmosphere such as; fixation, downwelling, and deposition, were decreased by 50% the concentrations of CO2 were found to increase in the atmosphere. Counter to that point when the variables that increase the amount of carbon in the atmosphere such as; respiration, upwelling and emissions, were decreased by 50%, the CO2 concentration in the atmosphere declined. All results can be seen in Table 1.

Table 1. Atmospheric CO2 concentrations (ppm) in relationship to increasing and decreasing the levels of fixation, respiration, upwelling, downwelling, deposition, and emissions, during the year 2200, and the maximum level found over a 340 year period (1995-2335)

		Fixation	Respiration	Upwelling	Downwelling	Deposition	Emission
2200	0.5**	1681	801	1014	1338	1113	702
	1	1112.9	1112.9	1112.9	1112.9	1112.9	1112.9
	2	653	1567	1300	865	1112	1932
Max*	0.5	2633	1178	1542	2096	1667	976
	1	1667.5	1667.5	1667.5	1667.5	1667.5	1667.5
	2	948	2414	1901	1255	1667	3049

*Max = highest concentration from 1995-2335
**0.5, 1, 2 = halving, same, or doubling of emissions over entire 340 year time period

It was also found that if emissions were cut to 25% of original levels then the atmospheric CO2 concentrations were found to be 498ppm for year 2200, and 631ppm for the maximum over the 340 year period. When fixation was increased 3 fold, the 2200 CO2 concentration was found to be 460ppm, and the maximum for the 340 year period was 660. Also if respiration was reduced to 25% of original level the CO2 concentration was found to be 615ppm for year 2200, and a CO2 concentration of 895 was found as the maximum over the 340 year span.

DISCUSSION

In terms of setting a optimal CO2 emission limit, I feel that finding the balance point at which the natural carbon cycle would be able to cycle all our emissions would be the ideal amount. This would be more profitable then working to reduce CO2 emissions to zero, and would also allow the natural process of carbon cycling to not be overwhelmed with the amount of carbon released by our emissions. To reduce emission rates our way of life must change. Our current emission rates if not controlled and reduced will have us facing devastating effects of global climate change. Ways to reduce our overall emissions include standards and regulations for industrial companies and engineering more fuel efficient vehicles. Simple life changes such as using a programmable thermostat or turning off unused lights would also greatly reduce human carbon emissions.

When looking at using carbon sequestration to reduce the amount of carbon in the atmosphere, the data suggests that it could be done by adjusting the rates of the variables that effect how the carbon moves through the cycle. The costs and energy needed to for example increase the fixation rate, should then be compared to the costs and energy needed to reduce emissions to reach the same CO2 concentration in the atmosphere. The overall amounts of carbon that is exchanged between the atmosphere, shallow oceans, and deep ocean is very small when compared to the amounts of carbon that is held in each area, especially when considering the deep ocean. This suggests that the large amount of CO2 we would want to remove from the atmosphere by sequestration would take an extremely long time. It would be much more effective to focus our attention and energy on reducing carbon emissions. This would have a more direct effect on the amount of CO2 in the atmosphere. Controlling CO2 emissions would also allow us to engineer greater technologies to help us continue to reduce emissions for the future, rather than just shifting the bulk of the carbon to the oceans from the atmosphere.

The effects of carbon sequestration have not been thoroughly studied. How the oceans will react to the increased amount of carbon are greatly unknown. From a human standpoint it seems that we want to use carbon sequestration as a way to put the CO2 and excessive carbon out of sight, and out of mind. With CO2 emissions we didn't worry about the affects of putting excess carbon in to the atmosphere until we started to see complications arise as in global warming. Moving excessive carbon from the atmosphere ultimately to the deep oceans will be difficult and the results are not certain. Focus should be placed on holding more carbon in fixation in forests and plant life on land and coastal areas, as well as reducing overall emissions. Carbon sequestration though it would reduce the amount of CO2 in the atmosphere seems like just sweeping dirt under the rug. We know the carbon is still there, we are not worried about it currently, but at some point we will have to deal with it.

Works Cited

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