MODEL SIMULATIONS OF DIRECT CARBON INJECTION IN THE NORTHWEST PACIFIC

Katsumi Matsumoto[1], and Bryan K. Mignone[2]

[1]*Department of Geology and Geophysics, University of Minnesota, Minneapolis, MN 55455-0219; katsumi@umn.edu; katsumi@ni.aist.go.jp*

[2]*Department of Geosciences and Woodrow Wilson School of Public and International Affairs, Princeton University, Princeton, NJ 08544; bmignone@princeton.edu*

ABSTRACT

An ocean general circulation model (OGCM) is used to simulate the direct injection of CO_2 near Tokyo. Our results confirm that direct injection can sequester large amounts of CO_2 from the atmosphere when disposal is made at sufficient depth but show that the calculated efficiency is sensitive to the choice of physical model. Moreover, we show, in an OGCM and under a reasonable set of economic assumptions, that sequestration effectiveness is quite high for even shallow injections. However, the severe acidification that accompanies injection and the impossibility of effectively monitoring injected plumes argue against the large-scale viability of this technology. Our coarse-grid models show that injection at the rate of 0.1 Pg-C/yr lowers pH near the site of injection by as much as 0.7-1.0 pH-unit. We also show that, after several hundred years, one would effectively need to survey the entire ocean in order to accurately verify the inventory of injected carbon. These results suggest that while retention may be sufficient to justify disposal costs, other practical problems will limit or at best delay widespread deployment of this technology.

INTRODUCTION

Increasing demand for energy is accelerating the world-wide consumption of fossil fuel and the release of CO_2 into the atmosphere. The possible severity of climate change due to the emission and atmospheric accumulation of this greenhouse gas has encourage the development of a number of "geo-engineering" strategies designed to mitigate the rapid build-up of CO_2 in the atmosphere. One such strategy is the direct disposal of CO_2 in the interior of the ocean, as first suggested by *Marchetti* [1977]. Since then, a number of studies have further examined the scientific and technological viability of deliberate ocean sequestration, and today one can find many variations and extensions of his basic idea. Here, we present injection simulation results, following the OCMIP-2 injection protocol [*Aumont and Orr*, 1999] (100 years of injection at the rate of 0.1 Pg-C/yr starting from the year 2000) from a single carbon-cycle model coupled to a family of three ocean general circulation models. Specifically, we are interested in the spatial and temporal evolution of the dissolved inorganic carbon (DIC) plumes and seawater pH anomalies that result from injecting CO_2 off the coast of Tokyo. Our focus on Japan is partly based on the fact that carbon sequestration is a pressing issue for Japan, as it will have relatively few easy options to exploit if it is forced to reduce emissions under a global climate change agreement. The country already relies heavily on non-fossil sources, and other mitigation options (e.g., geologic sequestration) are less plentiful than in larger nations like the United States.

RESULTS

In our simulations, the injected DIC is transported passively by ocean circulation, and the plume of DIC anomaly spreads largely to the east and south from the point of injection off Japan. When the anomaly reaches the surface, its high pCO_2 drives carbon out of the ocean and into the atmosphere, which is the source of the "leakage" problem. The "sequestration efficiency", the fraction of injected carbon that remains in the ocean after some period of time, is highest for the least "diffusive" model and for the deepest injection. After the 100 year injection period, 10-20% of the carbon injected at 800 m is lost to the atmosphere, while 70-90% of the injected carbon is lost by the year 2500. By contrast, no carbon is lost in the 3000 m injection by the year 2100. The pH lowering (or acidification) that accompanies DIC injection depends on the competition between the rates of injection and of dispersion by circulation. In our simulations, the change in pH during the 100 year injection period exceeds -0.7 pH-unit for the 800 m injection, -0.8 pH-unit for 1500 m injection, and -1.0 pH-unit for the 3000 m injection. These pH changes are quite high compared to the typical range of experiments that expose marine organisms to pH fluctuations. In reality, the maximum pH reduction at the very point of injection would be much higher, because our coarse-grid models spread the pH perturbation over large model cells. The dispersal of DIC anomaly would make it difficult to monitor it over time, but this is a critical piece of information for properly giving credit for the amount of carbon actually sequestered. Our 1500 m-depth injection simulation shows that 50 years after the termination of the injection, a mere 10% of the injected DIC can be captured by integrating in the model (or equivalently surveying the ocean) over waters near the injection site. In the same year, integrating the entire eastern half of the North Pacific would still only capture about 70% of the injected carbon remaining in the ocean. This suggests that accurate monitoring is practically very difficult. Finally, we address the benefit of direct carbon injection into the ocean, given that it is a "leaky" system. Following *Herzog et al*.[2003], we calculated the "sequestration effectiveness", defined as the ratio of the net benefit of temporary storage to the net benefit of permanent storage, by using an economic concept called the net present value. Using the "usual" 3% discount rate and two scenarios of future carbon price, we show that a large benefit is often associated with temporarily storing anthropogenic carbon in the ocean near Tokyo even for shallow injections. This result is driven by the time preferencing of the discount rate which favors the near term (when there is sequestration) over the long term (when there is leakage).

REFERENCES

Aumont, O., and J. Orr, (1999). Injection-HOWTO, in *Internal OCMIP Report*, pp. 17, LSCE/CEA Saclay, Gif-sur-Yvette, .

Herzog, H., K. Caldeira, and J. Reilly (2003). An issue of performance: Assessing the effectiveness of temporary carbon storage, *Climate Change*, *59*, 293-310, .

Marchetti, C. (1977). On geoengineering and the CO_2 problem, *Climatic Change*, *1*, 59-68,