GROUNDWORK

Furthering the Influence of Earth Science

Facing major challenges in carbon capture and sequestration

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INTRODUCTION

Anthropogenic emission of greenhouse gases, notably CO_2, contributes significantly to global warming (IPCC, 2007). Economic growth in developing countries, increasing reliance on non-conventional oil, and use of coal as a power source are all leading to increased emissions of CO_2 (Kerr, 2008). Carbon Capture and Sequestration (CCS) is often viewed as a panacea. The U.S. Department of Energy (DOE) has made $3.4 billion available for fossil fuel research, a significant fraction for CCS (Charles, 2009), and DOE supports a number of trial projects for CO_2 sequestration (Litynski et al., 2008).

Injecting CO_2 in the subsurface has an out-of-sight, out-of-mind appeal because injecting the waste makes the problem "go away." This approach is, however, not without its drawbacks, and research needs to focus on making CCS effective both technically and economically on the scale needed to mitigate anthropogenic contributions to global warming. In order to assess this issue, it is essential to look at the numbers involved in CCS.

HOW MUCH CO_2 DO WE NEED TO SEQUESTER IN ORDER FOR CCS TO HAVE A SIGNIFICANT EFFECT?

Pacala and Socolow (2004) studied what steps can be taken to cap the CO_2 concentration at 550 ppm, this is twice the pre-industrial level of CO_2. They propose to select seven steps from fifteen possible options that include increased energy efficiency and conservation, more nuclear energy, increasing the use of renewable energy, more efficient forest and land use, and CCS. The amount of CO_2 to be sequestered worldwide as one of these seven actions is 3 Gt CO_2/year. To put this amount into perspective, this is about one-eighth of the current global CO_2 production. It is about the same mass as the total annual global oil production (http://www.eia.doe.gov/neic/infosheets/crudeproduction.html). To sequester such an amount in the subsurface may require an infrastructure that is comparable to the one used now for petroleum production worldwide.

Currently, CO_2 is injected at a number of pilot projects in countries that include Canada (Weyburn), Norway (Sleipner), and Algeria (In Salah). Through these projects, and the new ones planned by DOE in the continental U.S., typically ~1 Mt CO_2/year is to be injected. Therefore, the pilot-project technology currently used must be replicated or upscaled by a factor of 1000 to be effective for mitigating global climate change. The current cost of CCS is between $40 and $70 per ton CO_2 (Metz et al., 2005). The annual cost of sequestering 3 Gt CO_2/year at a cost of $50 per ton CO_2 is $150 billion per year. Even though this is not a large amount compared to the global expenditure for energy, one may question whether society is willing to cover an expense of this magnitude in order to mitigate climate change. Moreover, the recent McKinsey report, *Reducing U.S. greenhouse emissions: How much at what cost?* (McKinsey&Company, 2007), showed that the United States can avoid ~40% of its CO_2 emissions by taking actions such as driving more efficient cars and trucks and implementing combined heat and power generation. Most of the actions proposed in the report are cheaper than CCS and actually pay for themselves in the long term. Over the time scale of several hundred years, CO_2 has the potential to react with the host rock in some geologic formations and to become permanently stored in the subsurface (Metz et al., 2005). In order for CCS to be effective, CO_2 must be sequestered for several hundred years. Losing 0.5% of the CO_2 per year over 200 years due to leakage amounts to a total loss of 64%. This means that in order to ensure that CCS is effective, one must be able to contain the CO_2 and to predict and measure extremely low leakage rates.

IN ORDER FOR CCS TO BE A VIABLE OPTION, IT IS ESSENTIAL THAT THE FOLLOWING QUESTIONS BE ANSWERED

1. How do we reduce the cost of CCS? Currently, CCS is not financially competitive with other options for avoiding CO_2 emissions (McKinsey&Company, 2007), many of which also save energy. The current cost of CCS (between $40 and $70 per ton of CO_2) (Metz et al., 2005) makes it unlikely for this technology to be used at a scale that will make a difference in curbing global warming.
2. How do we upscale current technology by a factor of 1000? If pilot studies demonstrate the successful sequestration of 1 Mt CO_2/year with current technology, how do we upscale the technology so that it is feasible to inject several Gt CO_2 per year? Perhaps we simply need a thousand times as many injection sites, but is this the optimal way to implement CCS?

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3. How can we predict and monitor extremely low leakage rates? In order for CCS to be effective, leakage rates of a fraction of a percent per year must be predicted and monitored. Monitoring such low leakage rates is beyond our current capability (Wells et al., 2006).

It is essential that CCS research addresses these questions. If not, CCS projects and related research may serve to provide valuable insights and develop useful expertise but ultimately fall short of cost-effective implementation on the scale needed to significantly reduce greenhouse gas emissions. Because CCS is among the most expensive options for avoiding CO_2 emissions compared to alternative approaches that actually save energy and pay for themselves (McKinsey&Company, 2007), we may run the risk of repeating a mistake from the 1970s in the diversification of our energy portfolio; that is, developing technical solutions that are not economically viable and therefore in the long run do not succeed. A critical evaluation of the various options for avoiding CO_2 emissions is essential for formulating and implementing a holistic policy that is successful not only in reducing CO_2 emissions, but also in saving energy and creating jobs in the economy of the twenty-first century. By using appropriate CCS appropriately, but not placing too much emphasis on "injecting ourselves" out of the climate change problem, we will avoid being lulled into a sense of complacency that may prevent us from starting to work on additional approaches to reduce CO_2 emissions that may cost less and also save energy.

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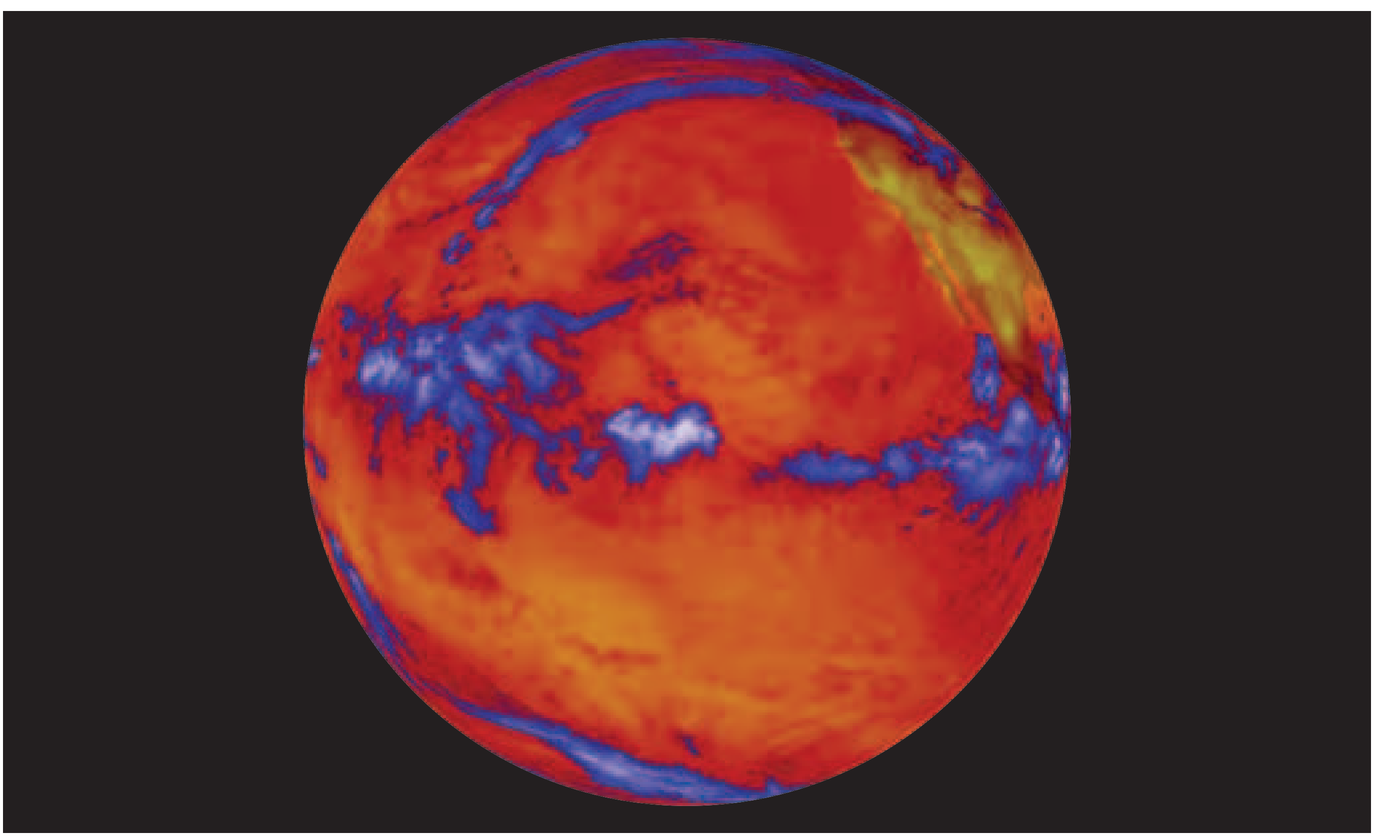

"Watching the World Rev its Heat Engine." This false-color image of Earth was produced 30 Sept. 2001 by the Clouds and the Earth's Radiant Energy System (CERES) instrument flying aboard NASA's *Terra* spacecraft. The image shows where more or less heat, in the form of longwave radiation, is emanating from the top of Earth's atmosphere. Image courtesy Barbara Summey, NASA Goddard Visualization Analysis Lab, based upon data processed by Takmeng Wong, CERES Science Team, NASA Langley Research Center (http://visibleearth.nasa.gov/view_rec.php?vev1id=11546).