Progress in Carrying Out Ocean CO_2 Perturbation Experiments

Peter G. Brewer & Edward T. Peltzer
Monterey Bay Aquarium Research Institute
7700 Sandholdt Road, Moss Landing, CA 95039

OUTLINE

Introduction

- Ocean carbon sequestration was first proposed by Marchetti, 1977.
  - The ocean is a big place = 1.4 x 10^9 km^3.
  - It already contains 50 times the atmospheric burden of CO_2.
  - Seawater is strongly buffered and is slightly basic so CO_2 uptake is the "natural" reaction.
- Current situation:
  - 1/3rd of anthropogenic emissions (2 Gt C equivalent to 7 Gt CO_2) is absorbed annually.
  - As atmospheric levels rise absorption will increase.
  - > 80-90% of anthropogenic emissions will go there.
  - Over 500 Gt CO_2 absorbed to date.
- Ocean CO_2 "Disposal" Today (see: Sabine et al., Science, 2004.)
  - Fossil fuel signal has penetrated to >1000m.
  - Surface values reach 50 μmol/kg (2.2 mg/kg).
  - The inventory of anthropogenic CO_2 in the ocean (1800 to 1999) is:
    - 155 billion tons of C.
    - 568 billion tons of CO_2.
  - Global surface ocean CO_2 "disposal" is now about 1 million tons per hour.
- Problems:
  - Natural carbon sequestration processes are slow.
  - If uptake faster, atmospheric CO_2 rise minimized.
  - Internal circulation of ocean is slow and stratified.
  - 1/2 of anthropogenic CO_2 uptake has remained in the upper 400m of the ocean.
  - Sea surface pH already reduced by 0.1
- Technological fixes:
  - Iron fertilization to enhance biological pump.
  - Purposeful sequestration by industrial means.
- Future Problems
  - All future CO_2 production scenarios predict higher levels of CO_2.
  - Higher levels of atmospheric CO_2 mean lower ocean pH.

Small-scale Experiments at MBARI

- Peter Brewer, et al., have been doing small-scale release experiments since 1996:
  - Kinetics of CO_2 & CH4 hydrate formation.
  - Rates of liquid CO_2 & CO_2 hydrate dissolution.
  - Amount and extent of pH disturbances around CO_2 pools.
  - In collaboration with biologists (J. Barry and M. Tamburri), have looked at the impact on biota.
- Problems:
  - Limited control of experimental conditions.
  - Observed novel but not reproducible results.

OACE Experiment

- Research interests by group:
  - MBARI:
    - Develop and deploy new technology for controlled seafloor CO_2 release experiments.
    - Liquid CO_2 and CO_2 hydrate dissolution rates.
    - CO_2 hydration / dehydration kinetics.
  - NMRI:
    - Develop and conduct pressure tank experiments.
    - Hydrate skin strength and growth rates.
    - Liquid CO_2 / sediment interactions.
  - University of Bergen:
    - Fluid-dynamics & chemistry of liquid CO_2 in deep sea.
- Hardware
  - Benthic Flume.
  - Elevator Deployment.
  - ROV Tiburon.
  - 56 L CO_2 Accumulator.
- Experiment conducted in Monterey Bay

Video Highlights

- Dye injection experiments at various flowrates.
- Wave generation by "bottom currents."

Summary of Observations

- pH and conductivity show opposite sense suggesting a disequilibrium between CO2 and bicarbonate.
- Dissolved CO_2 (un-reacted with water) "dilutes" salinity of seawater.
- Results confirmed by kinetic studies using closed cell at depth:
  - Acid addition experiment.
  - CO_2 addition experiment.
  - Kinetics faster at pressure than at one atmosphere.

Future research

- Beyond climate cabled experiments (FOCE)
- FOCE prototype
  - Elevator deployment.
  - Use HCl instead of CO_2 during algorithm development phase.
  - Control pH using sensor feedback.

Acknowledgements

- David and Lucille Packard Foundation.
- New Energy and Technology Development Organization (Japan).
- US Department of Energy (DE-FC26-00NT40929).