

It is now commonplace to carry out large-scale CO2 enrichme nt experiments on land, but no equivalent experiments have yet been carried out in the ocean. Why is that, is there a compelling need, and what are the conflicts and challenges? The ocean is the largest sink for fossil-fuel CO2 emissions, now absorbing some 21 million tons of CO2 per day. Without this vast present and future sink the world would have an insurmountable greenhouse gas problem. We have already reduced the pH of ocean surface waters worldwide by ~ 0.1 pH units, and when CO2 levels reach 600 ppm in mid-century we will have reduced the pH by 0.3. All future energy scenarios have continued fossil fuel usage, and thus a lower pH ocean is inevitable with only the time scale at issue. Significant declines in calcification rates of coral reefs and marine plankton, and changes of the deep-ocean lysocline, are predicted. Innovative experiments on deep-ocean CO2 sequestration have lead to concerns over the physiological performance of deep-sea species in a lower pH ocean, yet the present day surface fluxes already vastly exceed any possible sequestration strategy. If the ocean can continue to absorb mankind's industrial CO2 without significant environmental harm then existing energy scenarios may be reasonable; if there are limits then the challenge is enormous. How might we find out?

We report on experimental techniques newly developed that s hed light on this problem, and propose their extension to CO2 enrichment studies comparable to those on land. We present results from small-scale deep-sea biogeochemical experiments that locally perturb the oceanic CO2 environment. These are necessarily of short duration since the CO2 is now supplied in batch mode. With technological innovations now being investigated it should be possible to greatly extend the longevity and range of the studies, and to control the CO2 perturbations within the experimental area by sensor feed-back techniques that compensate for currents as is done for wind on land. Challenges include sensor stability, CO2 hydræ formation, and sampling and data recovery techniques. Butwithout such studies we will not know the limits to the changing ocean of the 21st century.



Atmospheric CO2 and average ocean pH

Data = historic CO2 (1750 –2000), IS92a emissions (2000-2100), and logistic CO2 emissions (2100-3000) (~5700 GtC total). Calculated using LLNL ocean GCM assuming neutral land biosphere. (Ken Caldeira, unpublished data)

How does elevated CO2 affect marine animals?

- CO2 injection causes;
- 1 – Elevated CO2 levels
 - 2 – Elevated Seawater Acidity (reduced pH)

Physiological Effects

Respiratory Stress
Increased acidity reduces the level of oxygen-binding and transport by respiratory proteins, leading to reduced aerobic capacity.
Acidosis (reduced internal pH)
Disruption of the acid/base balance of animal tissues impairs function and requires energy to restore or maintain optimal internal pH levels.
Metabolic suppression (Torpor)
Elevated CO2, reduced pH, or both can cause some animals to enter a state of reduced metabolic rate and semi-hibernation, reducing their activity, protein synthesis, growth, reproduction, etc.

Healthy

Degraded

pH Perturbations at

Spiking due to currents and tide
experimental results to be quest
experiment will address these inaccur
accurately represent a

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Putin Aide Rules Out Russian Approval of Kyoto Protocol

By THE ASSOCIATED PRESS

Filed at 11:13 a.m. ET MOSCOW (AP) -- A senior adviser to President Vladimir Putin said Tuesday that Russia cannot ratify the Kyoto Protocol limiting greenhouse gas emissions, dealing a mortal blow to the pact that required Russia's ratification to take effect. "In its current form, the Kyoto Protocol places significant limitations on the economic growth of Russia," Putin's economic adviser, Andrei Illarionov, told reporters in the Kremlin. "Of course, in this current form this protocol can't be ratified." Putin had previously cast doubts on Moscow's willingness to ratify the protocol, but hadn't ruled out ratification completely. The 1997 Kyoto Potocol calls for countries to reduce their level of greenhouse-gas emissions, which are seen as a key factor behind global warming. To come into force, the pact must be ratified by no fewer than 55 countries, accounting for at least 55 percent of global emissions in 1990. Under the treaty's complex rules, the minimum can now only be reached only with Russia's ratification because the United States and several other nations have rejected the treaty. At a U.N. climate conference in Milan, Italy, a Greenpeace official insisted that Russia's decision would not stop other nations' efforts to reduce greenhouse gases. "The encouraging news about this is that countries are going ahead with reducing their emissions without having Russia ratify," Steven Guilbeault said. Guilbeault said he thought Illarionov's stand was "a political comment in light of upcoming Duma elections" Sunday in the lower house of Russia's legislature. The conference opened Monday, gathering government officials, activists and scientists, but doubt over Russia cast a cloud over it. Participants say they doubt any major breakthroughs will be achieved and that alternative strategies at keeping emissions cuts alive would be discussed in the corridors. Russia's reluctance to ratify the pact despite its earlier pledge to do so has vexed Kyoto's European and U.N. backers, who warned Moscow that it would lose politically and economically if it fails to ratify Kyoto. But Illarionov, who made his commentson the sidelines of Putin's meeting with European business executives in the Kremlin, said firmly that the pact was against Russian interests. "It's impossible to undertake responsibilities that place serious limits on the country's growth," Illarionov said. He added that it would be unfair to Russia to curb emissions and stymie its own growth while the United States and other nations which account for the bulk of global emissions refuse to join the pact. The protocol's proponents see Kyoto as a vital first step in cutting emissions, warning that failure to quickly put it into force would trigger a dangerous, steep rise in greenhouse gas concentrations that would be far more difficult to control in the future.

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Face Experiment Structure

