DECADAL CHANGES IN OCEAN CARBON UPTAKE

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ABSTRACT

There is growing evidence that the rate of anthropogenic CO_2 uptake in the ocean is changing over time. Several programs are poised to assess current and future ocean CO_2 uptake rates, but there are issues with how to extrapolate these measurements to decadal-scale changes over entire ocean basins. One possibility is to exploit the growing network of ARGO floats that are collecting profiles throughout the global oceans. We explore the viability of this approach and make recommendations for how the ARGO network might be made more useful for biogeochemical applications.

GLOBAL BUDGET

By combining a recent estimate of the anthropogenic CO_2 that has accumulated in the ocean between 1800 and 1994 together with a synthesis of uptake estimates over the last 20 years, we can begin to evaluate potential changes in the decadal-scale uptake rate of anthropogenic CO_2 by the ocean [*Sabine et al.*, 2004a,b]. Table 1 shows the change in inventories during the first 180 years of the anthropocene versus the inventory changes over the last 20 years. These estimates suggest that the ocean uptake of net CO_2 emissions decreased from ~44% during the first period to ~36% over the last two decades. Although this difference is not statistically significant, there is a suggestion that the ocean uptake efficiency is decreasing with time.

Table 1. The Global Carbon Budget [Pg C]. Positive values represent atmospheric increase (or ocean/land sources), negative numbers represent atmospheric decrease (sinks).

	1800-1979	1980-1999
Atmospheric increase	+116 ± 4	+65 ± 1
Emissions (f. fuel, cement)	+156 ± 20	+117 ± 5
Ocean Inventory	–90 ± 19	-37 ± 8
Net terrestrial	+50 ± 28	-15 ± 9
Land-use change	+82 to +162	+24 ± 12
**Resid. terrestrial sink*	–32 to -112	-39 ± 18

MONITORING DECADAL CHANGES

Several countries have initiated programs to evaluate decadal-scale changes in ocean CO_2 uptake. Within the U.S., the Hawaii Ocean Time-series (HOT) and Bermuda Atlantic Time-Series (BATS) programs have been measuring carbon concentrations in the water column for over 15 years. These projects have focused most of their attention on seasonal to inter-annual variability, but are beginning to have long enough records to see longer-term variability in CO_2 uptake [e.g. *Bates*, 2001; *Gruber et al.*, 2002; *Dore et al.*, 2003; *Keeling et al.*, 2004].

Changes in the carbon concentrations along hydrographic sections sampled several years apart can also provide useful information on decadal-scale CO_2 uptake. The U.S. CLIVAR/CO_2 Repeat Hydrography Program has outlined 19 cruises that will re-occupy sections that were last sampled in the 1990s. To date, six lines have been run. Preliminary results have suggested interesting basin to basin differences in the inferred uptake rates on these lines (e.g. 0.7 moles m^{-2} yr^{-1} in the North Atlantic versus 1.1 moles m^{-2} yr^{-1} in the North Pacific; see *Wanninkhof et al.* and *Feely et al.* abstracts in this volume).

A NOVEL APPROACH FOR ESTIMATING BASIN-SCALE DECADAL CO_2 CHANGES

One concern with the measurement approaches mentioned above is how to meaningfully extrapolate the results to basin and global scales. We will explore the possibilities of fitting the carbon data collected as part of these programs as a function of physical properties, then using the profile data from the ARGO array to estimate the basin-scale carbon distributions.

We fit the dissolved inorganic carbon (DIC) data from three cruises run in the North Atlantic (A16N, A20, A22) in 2003 as a function of potential temperature, salinity, potential density, and spiciness. Separate fits were made for tropical, subtropical, and subpolar waters. In the year surrounding these cruises (4/1/03 to 3/31/04) there were ~7,000 ARGO profiles collected in the upper 2000m of the North Atlantic. Preliminary results suggest that the physical parameters measured by the standard ARGO float are marginally sufficient for characterizing the carbon distributions in the North Atlantic. The uncertainty in the estimates can be significantly reduced, however, by adding oxygen sensors to the ARGO package and including dissolved oxygen in the fits. Based on substantially better fits of alkalinity to the physical parameters, another approach for the future would be to measure pH on the ARGO floats and then use empirical fits of alkalinity to fully constrain the carbon distributions in the ocean.

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