TWO DECADES OF OCEANIC CO_2 VARIABILITY AND THE INFLUENCE OF WIND AND STORMS ON AIR-SEA FLUX IN THE NORTH ATLANTIC OCEAN NEAR BERMUDA

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ABSTRACT

Two decades of continuous oceanic CO_2 observations in the North Atlantic Ocean near Bermuda at Hydrostation S (32°50'N, 64°10'W; 1983-1988) and BATS (Bermuda Atlantic Time-series Study; 32°10'N, 64°30'W; 1988-2003) sites are examined for long-term trends, changes in the oceanic sink of CO_2, and the influence of atmospheric changes and short-term hurricane wind events. Over the 1983-2003 period, surface DIC and alkalinity increased at a rate of +1.18 + 0.19 µmoles kg^{-1} $year^{-1}$ and +0.69 + 0.14 µmoles kg^{-1} $year^{-1}$, respectively. The observed rate of surface ocean salinity normalized DIC (nDIC) was +0.79 + 0.13 µmoles kg^{-1} $year^{-1}$ and similar to that expected from oceanic equilibration with increasing CO_2 in the atmosphere. The upward trend in oceanic p CO_2 (1.53 + 0.13 µatm year-) is also identical to the rate of atmospheric CO_2 increase (1.59 + 0.02 µatm $year^{-1}$) over the last 20 years. The ocean near Bermuda has also become more acidic, with a decrease in seawater pH of 0.0012 + 0.0006 pH units year-1. This represents a decline of ~0.025 pH units (~8.125 to ~8.100) over the last 20 years, about one third of the ocean acidity increase observed since pre-industrial times [*Sabine et al.*, 2004]. For the 1984 to 2003 period, the mean net annual rate of air-to-sea flux was -0.63 + 0.22 mol CO_2 m-2 yr^{-1} (negative CO_2 flux values denote net air-to-sea CO_2 flux) with an interannual range of -0.32 to -1.34 mol CO_2 m-2 yr^{-1}. If extrapolated over the North Atlantic subtropical gyre, the peak-to-peak interannual variability of oceanic CO_2 sink was ~0.1 Pg C yr^{-1}. As important modulators of air-sea CO_2 flux, severe hurricanes in 1995 and 2003 enhanced the summertime efflux of CO_2 from the ocean by 30-71%. Over the 1984 to 2003 period, the annual rate of net air-to-sea CO_2 flux increased by ~33% primarily in response to an increase in wind speed by ~1.6 m s^{-1}. This coincided with other reports of gyre scale changes (e.g., salinity, Gulf Stream position, gyre volume) that presumably reflect an increased thermal gradient and enhancement of wind stress over the subtropical North Atlantic Ocean.