Carbon Monoxide and Methane in Surface Seawater of the Tropical Pacific Ocean

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Abstract—Methane and carbon monoxide in the surface seawater and the overlying atmosphere were measured in the equatorial Pacific from 160°E and 160°W. Both gases were supersaturated with respect to the atmosphere. The longitudinal distribution of oceanic methane showed an interannual variation between 1987 to 1990. This variation suggested that the production and/or transport of methane were largely changed by a strong upwelling during the 1988/89 La Niña event. The measurements of oceanic carbon monoxide in 1994 showed higher concentrations in the central and eastern regions than in the western region. This longitudinal distribution was mainly related to the solar radiation intensity. Carbon monoxide concentrations showed clear diurnal cycles that had a phase delay of 3-4 hours against the solar radiation cycle. However, the change rate of carbon monoxide concentration with time coincided well with the solar radiation pattern with no phase lag, suggesting that the rate of photochemical production quickly responded to the solar radiation intensity. A higher carbon monoxide concentration was observed in a water depth of 3 m rather than 5 m, suggesting a steep concentration gradient. From these results, it is concluded that longitudinal, interannual and vertical variations of the both gases are important for more accurate estimation on total oceanic fluxes in the tropical Pacific.

INTRODUCTION

Atmospheric methane (CH₄) is an important greenhouse gas that influences the radiative balance and climate of the Earth by warming the troposphere and cooling the stratosphere. Recent increases in atmospheric methane concentrations and interannual variations in these concentrations have been observed during the past two decades by several research groups (Blake and Rowland, 1988; Scheel et al., 1990; Aoki et al., 1992; Fraser et al., 1992; Khalil et al., 1993; Dlugokencky et al., 1994; Lowe et al., 1994; Sugawara et al., 1994; Matsueda and Inoue, 1996; Matsueda et al., 1996). Atmospheric carbon monoxide (CO) is not itself a greenhouse gas, but can influence the oxidative capacity in the atmosphere (Thompson, 1992). Recent changes in global atmospheric CO mixing ratios have
been measured by several research groups (Scheel et al., 1990; Fraser et al., 1992; Brenninkmeijer, 1993; Derwent et al., 1994; Khalil and Rasmussen, 1994; Novelli et al., 1994). Such CO concentration changes could affect the future atmospheric CH₄ increase (Thompson and Cicerone, 1986), since the main sink of the both gases is an oxidative reaction with OH radicals in the atmosphere (Cicerone and Oremland, 1988). Thus, an understanding of both CH₄ and CO is needed for better prediction of a future climate changes due to the greenhouse gases.

The ocean acts on a source of atmospheric CH₄ and CO, since it is generally supersaturated with respect to the atmospheric concentrations. The oceanic CH₄ source was estimated to be less than 10% of the total sources of CH₄ to the atmosphere (Intergovernmental Panel on Climate Change, 1994). Oceanic CO is also a minor source to the atmosphere, but recent model sensitivity calculations suggest that the oceanic CO flux may significantly affect the CO pool in the marine boundary air (Erickson and Taylor, 1992; Springer-Young et al., 1996). It is suggested that the oceanic source change could affect the chemical cycles in the marine boundary air. However, large uncertainties still remain on the estimation of global oceanic fluxes of both CH₄ and CO (Intergovernmental Panel on Climate Change, 1994). Thus, it is necessary for more measurements in the surface seawater to evaluate the impact of oceanic sources on the atmosphere.

Oceanic CH₄ and CO play an important role in the carbon cycle in seawater, because both gases are produced by the degradation of organic matter. CH₄ is mainly produced by biological degradation in anoxic marine environments such as the digestive track in zooplankton (Traganza et al., 1979; de Angelis and Lee, 1994) and sinking particles (Karl and Tilbrook, 1994). Karl and Tilbrook (1994) reported that CH₄ associated with the sinking particles was vertically transported and released in the water column. On the other hand, the major production process of CO is a photochemical degradation of organic matter in the surface seawater. Several studies have shown that the photochemical production of CO is a large sink of bio-refractory organic matter in the deep water (Mopper et al., 1991; Valentine and Zepp, 1993; Miller and Zepp, 1995). Both gases in the surface seawater are removed mainly by microbiological oxidation and air-sea exchange. The generated CO₂ from the CH₄ and CO oxidation is re-utilized by photosynthesis in the euphotic zone and converted to organic matter. Thus, the production and consumption of these trace gases are important processes in the understanding of the global carbon cycle in the ocean.

Since the 1960’s, CH₄ distributions in the surface seawater have been observed in various oceanic environments (see the summaries by Lambert and Schmidt (1993) and Bange et al. (1994)). Surface CO concentrations have been measured in several oceanic environments such as the Pacific Ocean (Lamontagne, et al., 1973; Bates et al., 1993), the Atlantic Ocean (Conrad et al., 1982), the Southern Ocean (Williams and Bainbridge, 1973) and the Arabian Sea (Owens et al., 1991). Systematic measurements of CH₄ and CO in surface seawater were made between 1987 and 1994 to obtain consistent regional and temporal variations in the North and South Pacific (Bates et al., 1995, 1996). These results