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Key Points:
- The upwelling rate of anthropogenic carbon from the thermocline to the surface layer is almost twice as large as air-sea fluxes
- Diffusion has a major impact on reemergence of anthropogenic carbon in the Equatorial Pacific
- Reemergence of anthropogenic carbon decreases dramatically during the El Niño events

Supporting Information:
- Supporting Information S1

Correspondence to:
P. Zhai,
pzhai@princeton.edu

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Mechanistic Drivers of Reemergence of Anthropogenic Carbon in the Equatorial Pacific

Ping Zhai[1], Keith B. Rodgers[1], Stephen M. Griffies[2], Richard D. Slater[1], Daniele Iudicone[3], Jorge L. Sarmiento[1], and Laure Resplandy[4]

[1]AOS Program, Princeton University, Princeton, NJ, USA, [2]NOAA/GFDL, Princeton, NJ, USA, [3]Stazione Zoologica Anton Dohrn, Naples, Italy, [4]Geosciences and PEI, Princeton University, Princeton, NJ, USA

Abstract Relatively rapid reemergence of anthropogenic carbon (C_{ant}) in the Equatorial Pacific is of potential importance for its impact on the carbonate buffering capacity of surface seawater and thereby impeding the ocean's ability to further absorb C_{ant} from the atmosphere. We explore the mechanisms sustaining C_{ant} reemergence (upwelling) from the thermocline to surface layers by applying water mass transformation diagnostics to a global ocean/sea ice/biogeochemistry model. We find that the upwelling rate of C_{ant} (0.4 PgC yr^{-1}) from the thermocline to the surface layer is almost twice as large as air-sea C_{ant} fluxes (0.203 PgC yr^{-1}). The upwelling of C_{ant} from the thermocline to the surface layer can be understood as a two-step process: The first being due to diapycnal diffusive transformation fluxes and the second due to surface buoyancy fluxes. We also find that this reemergence of C_{ant} decreases dramatically during the 1982/1983 and 1997/1998 El Niño events.

1. Introduction

To date, subpolar and high-latitude regions have been the main focus of studies of ocean carbon-climate feedbacks, over both the North Atlantic (Halloran et al., 2015; Schwinger et al., 2014) and the Southern Ocean (Hauck & Völker, 2015; Le Quéré et al., 2007; Sarmiento et al., 1998). It was originally expected that waters comprising deep, intermediate, and subpolar water masses should dominate anthropogenic carbon (C_{ant}) accumulation (Sabine et al., 2004). However, more recent consideration of C_{ant} accumulation revealed that 34% of the WOCE (the World Ocean Circulation Experiment) era inventories resided in waters shallower than the base of the directly ventilated thermocline (potential density $\sigma < 26.6$ kg m^{-3}) (Iudicone et al., 2016). One of the most important overturning structures within the thermocline are the subtropical cells (STCs), which link subtropical subduction regions with equatorial upwelling regions. These STC structures could support rapid (decadal) reemergence of C_{ant} from the ocean interior back into the surface layers, in particular, in the Equatorial Pacific (Bopp et al., 2015; Iudicone et al., 2016; Nakano et al., 2015), with potentially important implications for carbon-climate feedbacks. The potential for strong re-emergence on decadal time scales is already in evidence with the evolution of the bomb-radiocarbon transient in the Equatorial Pacific (Guilderson & Schrag, 1998; Rodgers et al., 2004). For the case considered here, high dissolved inorganic carbon (DIC) waters resulting from C_{ant} reemergence in obduction or upwelling regions would perturb the Revelle factor of local surface waters and thereby inhibit local uptake of C_{ant} via gas exchange.

Lévy et al. (2013) and Bopp et al. (2015) demonstrated the importance of net upwelling of DIC into the mixed layer in the Equatorial Pacific and identified as well a nontrivial role for diffusion of DIC across the base of the mixed layer, by applying instantaneous kinematic subduction and obduction diagnostics to a global model of the carbon cycle. However, they did not identify a specific connection to the shallow overturning circulation structures in which the Equatorial Pacific carbon cycle is embedded.

Our objective is to build upon these previous efforts to identify the mechanisms that sustain the reemergence of C_{ant} in the Equatorial Pacific. We examine the processes controlling the upwelling, or reemergence, of C_{ant} using a water mass transformation framework that isolates the contributions from surface buoyancy forcing, tracer diffusion, and other processes. In this context, upwelling is defined as the net upward diapycnal transport of C_{ant}, which can have both vertical and horizontal components depending on the local isopycnal slopes. A principal advantage of applying the water mass transformation diagnostics is to provide an intrinsic connection between the diapycnal transport of C_{ant} and the overturning circulation that is not provided by kinematic subduction/obduction diagnostics. Iudicone et al. (2011) illustrated the utility of this