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Strong CO_2 outgassing from high nutrient low chlorophyll coastal waters off central Chile (30°S): The role of dissolved iron

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ABSTRACT

Carbonate system parameters (pH and alkalinity) were used to estimate the coastal water CO_2 fluxes off central Chile (30°S) during September 2007. Coastal waters rich in nitrate and silicate were strongly CO_2 supersaturated and normally poor in chlorophyll *a*. MODIS satellite chlorophyll *a* data suggest that phytoplankton biomass remained particularly low during September 2007 although coastal waters were highly fertilized with nitrate and silicate. The phytoplankton gross primary productivity in macronutrient-rich waters was very low with the exception of shallow waters (e.g. within or near bays). Several iron-enrichment bottle experiments show that fCO_2 rapidly decreases during iron-enrichment treatments compared to controls. This suggests that iron limitation of phytoplankton growth (mainly diatoms) plays a role in maintaining high-CO_2 outgassing by preventing rapid interception of upwelled CO_2.

1. Introduction

The role of dissolved iron in the sequestration of atmospheric CO_2 over large portions of the open ocean (Martin, 1990) has been greatly debated during the last two decades (Jickells et al., 2005). However, much less attention has been paid to its effect on the intensity and variability of coastal air–sea CO_2 fluxes. Coastal areas affected by intense upwelling are often described as sources of CO_2 (Borges et al., 2005). Certainly, the deep upwelling of normally cold and already CO_2-supersaturated subsurface waters leads to an immediate outgassing of CO_2 at the coastal divergence (Torres et al., 1999). However, the high macronutrient (nitrate and phosphate) content of the upwelled water can stimulate intense blooms of phytoplankton that sequester inorganic carbon, reducing the fugacity of CO_2 (fCO_2) and thus reducing or even reversing the CO_2 flux at the air–sea interface (Simpson and Zirino, 1980). High spatial and temporal variability in coastal CO_2 air–sea fluxes has been attributed to coastal circulation (Torres et al., 1999) and/or biological activity (Simpson and Zirino, 1980). Due to the 'pulsed' nature of the forces driving upwelling (often referred to as events, i.e. Upwelling Favorable Wind Events, UFWE), coastal upwelling is also variable and a rapid interception of the upwelled carbon by phytoplankton may require a close coupling between macronutrient fertilization and phytoplankton productivity. In the last decade, a growing amount of evidence suggests that a decoupling between macronutrient fertilization and the generation of phytoplankton blooms (typically characterized by diatom proliferation) can occur in coastal upwelling areas due to non-optimal concentrations of dissolved iron in the water that supplies the upwelling (Bruland et al., 2005, and references there in).

Coastal upwelling HNLC (High Nutrient Low Chlorophyll) areas and/or periods associated with low levels of dissolved iron have been reported for California (Hutchins and Bruland, 1998; Hutchins et al., 1998; Johnson et al., 1999; Bruland et al., 2001; Firme et al., 2003), Peru (Hutchins et al., 2002; Bruland et al., 2005), and recently off Coquimbo, Chile (Torres et al., submitted for publication). Suboptimal levels of dissolved iron for diatom growth have been ultimately linked to physical features that prevent additional iron inputs into the upwelled water, for example: a narrow continental shelf, little or no fresh water input, and air mass trajectories that would minimize dust inputs from surrounding land masses (Hutchins et al., 1998; Johnson et al., 1999; Bruland et al., 2005). The Coquimbo upwelling system (~30°S, Central Chile) exhibits all the aforementioned characteristics as well as consistently low levels of dissolved iron in nitrate-rich recently upwelled waters (~1 nM total dissolved iron; Torres et al., submitted for publication).

In this paper, we will suggest that suboptimal levels of dissolved iron in highly CO_2-supersaturated coastal water off Central Chile (30°S) prevent a rapid interception of the upwelled CO_2.

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