Modelling long-term changes in pCO_2 within the Coral Sea

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Introduction

The present study investigates the possible long-term changes in pCO_2 and pH within the Coral Sea using the coupled regional model ROMS-PISCES. As a result of increased atmospheric pCO_2, oceanic geochemistry has already significantly changed since 1880, with pH levels in the surface ocean having decreased by 0.1 units as a result of higher oceanic pCO_2. The effects of higher atmospheric pCO_2 will likely be further aggravated by shallower mixed layer depths as a result of reduced upper ocean mixing due to warmer sea surface temperatures.

Study Site

The present study has been undertaken for the entire Coral Sea (142-170°E; 8-30°S). The Coral Sea is a marginal sea located in the southwest Pacific off the northeast coast of Queensland, Australia (142°48'E), and is bordered by the Solomon Islands and Papua New Guinea to the north (9°22'S), New Caledonia and the New Hebrides Islands to the east (170°13'45"E), and the Tasman Sea to the south (30°S).

Numerical Modelling

The biogeochemical and physical characteristics of the Coral Sea are investigated with two coupled models. The physical properties of the Coral Sea are explored using a version of the Regional Ocean Model System (ROMS) model, which originally has been developed at Rutgers university. ROMS is a free-surface, terrain-following, hydrostatic ocean model (Marchesiello *et al.*, 2003). The present version (ROMS-Agrif) has been tested previously for areas within the Pacific Ocean (e.g. Marchesiello *et al.*, 2003), including coastal areas around New Caledonia. The biochemistry of the Coral Sea is represented with the Pelagic Interaction Scheme for Carbon and Ecosystem Studies (PISCES) biogeochemical model (Bopp *et al.*, 2003).

Methods

Various IPCC scenarios for predicted atmospheric pCO_2 were used to determine likely changes in the biogeochemistry of the Coral Sea during the 21st century. At present, the atmospheric CO_2 concentration is around 380 ppmv. It is forecast that CO_{2atm} will increase to 650-1000 ppmv by the end of the 21st century. To investigate how future rises in atmospheric pCO_2 might impact on the Coral Sea, ROMS-PISCES was forced with atmospheric pCO_2 ranging from 380 ppmv to 1000 ppmv.

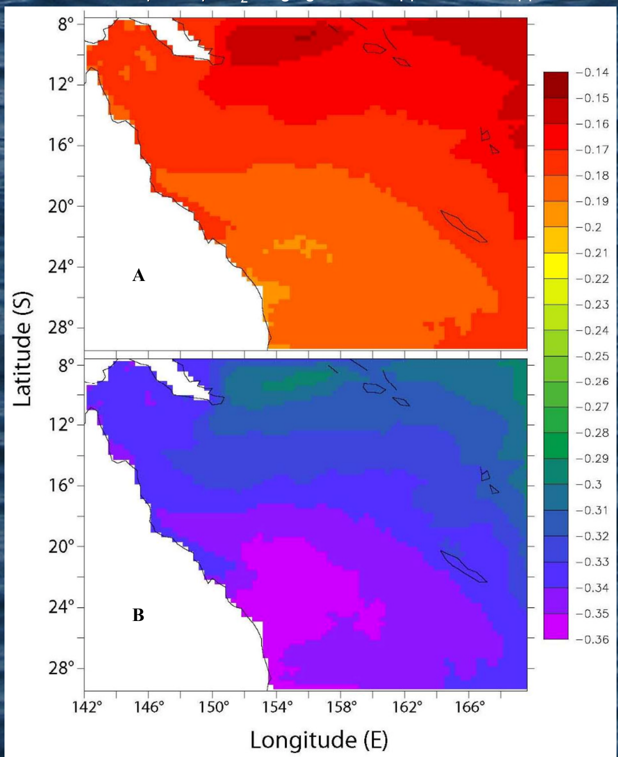

Fig. 1 Predicted change in pH for an increase of atmospheric CO_2 from 380 ppmv to A) 650 ppmv and B) 1000 ppmv. pH for both scenarios decreases throughout the study area, with greatest declines occurring in the south-west.

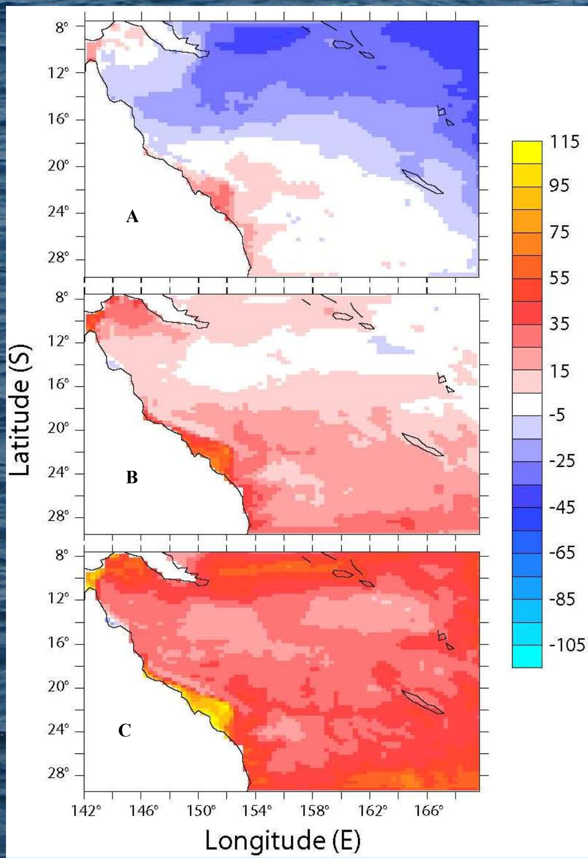

Fig. 2 Yearly average of ΔpCO_2 (atmosphere-ocean) within the Coral Sea for atmospheric CO_2 levels of A) 380 ppmv, B) 650 ppmv and C) 1000 ppmv. Presently, the tropical ocean constitutes a source of CO_2 to the atmosphere as a result of high sea surface temperatures (SSTs), whereas the subtropics act as a seasonal sink during the cooler months. With increasing CO_{2atm}, the Coral Sea progressively develops into a net sink in all regions, albeit not during all seasons.

Results

Increases of atmospheric pCO_2 to 650-1000 ppmv results in a decrease of sea surface pH by 0.14-0.36 units within the Coral Sea in the model (Figure 1). The difference between atmospheric and oceanic pCO_2 ($\Delta pCO_{2atm-oc}$), in turn, would mostly increase by 0-50 ppmv, resulting in the Coral Sea changing from a source of pCO_2 in the equatorial region, and from a seasonal source in the subtropical area (mainly during late summer and autumn), to a predominant sink in the entire Coral Sea (Figure 2). Concurrent with increased ocean acidification and pCO_2, the saturation state of aragonite and calcite will decline significantly, which would have wide-reaching effects on the coral calcification rates and the general health, and structural strength, of calcifying organisms. To this date, there has been surprisingly little effort to monitor the changes in biogeochemistry within the Coral Sea and, specifically, within the GBR as a result of increased atmospheric pCO_2. Further large-scale studies are required throughout the entire Coral Sea in order to accurately determine the long-term trends in oceanic pCO_2, CO_3^{2-} saturation state and pH.

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