OCEAN CARBON CYCLING AND CO_2 AIR-SEA EXCHANGE ALONG THE U.S. WEST COAST

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ABSTRACT

The eddy-resolving physical-biogeochemical ocean circulation model ROMS is used to study the climatological mean coastal ocean carbon budget for the U.S. West Coast, with a focus on the central upwelling region off California. This region is dominated by intense coastal upwelling, highly turbulent flow, and high biological productivity. We investigate (1) the air-sea CO_2 gas exchange and its variability, and (2) the euphotic zone inorganic and organic carbon budgets, in particular the lateral and vertical fluxes to and from the euphotic zone. Model results are compared to available data and observation-based estimates.

CONCLUSIONS

The air-sea flux of CO_2 constitutes only a small component of a very active and dynamic carbon cycle in the euphotic zone. The central California upwelling region is nearly balanced with regard to CO_2 air-sea gas exchange. This is a consequence of upwelling-driven CO_2 outgassing nearshore and biologically-driven CO_2 uptake offshore, often associated with filaments originating at topographical features along the coast. Lateral transport of organic carbon associated with mean horizontal fluxes induced by persistent meso- and submesoscale circulation structures and to lesser degree by the mean lateral offshore transport induced by Ekman transport is found to be substantial, thereby fuelling heterotrophic activity in the open Pacific ocean. As a consequence, new and export production are strongly decoupled locally nearshore.

(1) CALIFORNIA CURRENT SYSTEM

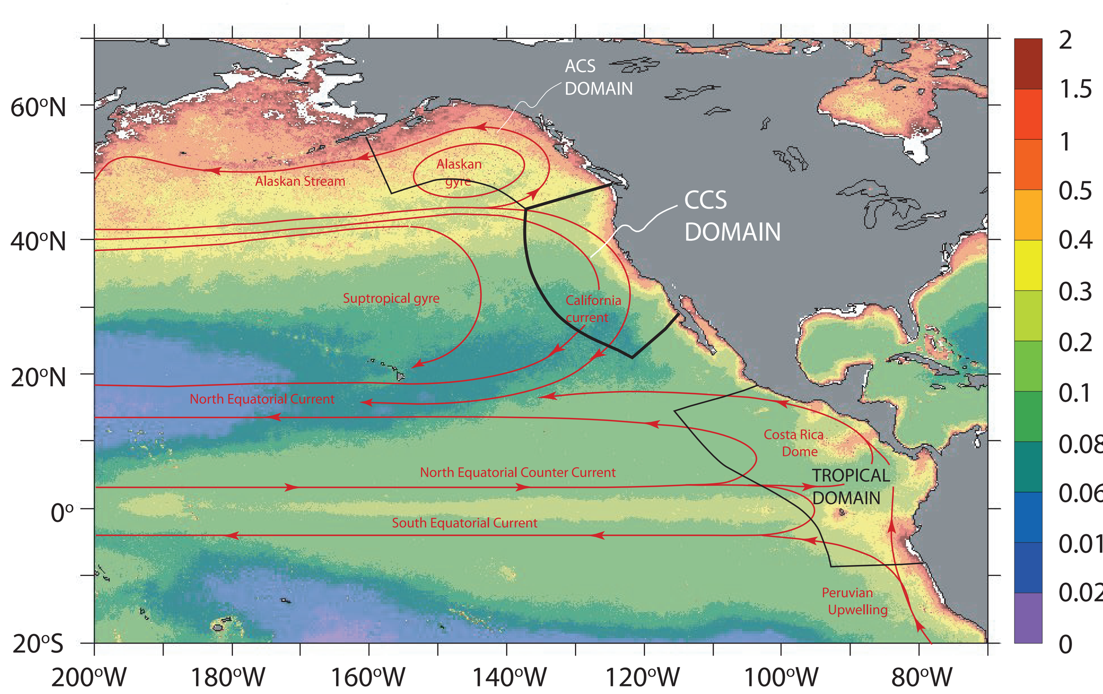

Fig. 1: The California Current System in relation to the large-scale circulation of the North Pacific. The colors indicate the annual mean surface ocean chlorophyll concentrations (in mg Chl-a m^{-3}) as observed by satellite (SeaWiFS), emphasizing the high biological productivity in the CCS domain (indicated by thick black lines).

(2) ECOSYSTEM-BGC MODEL

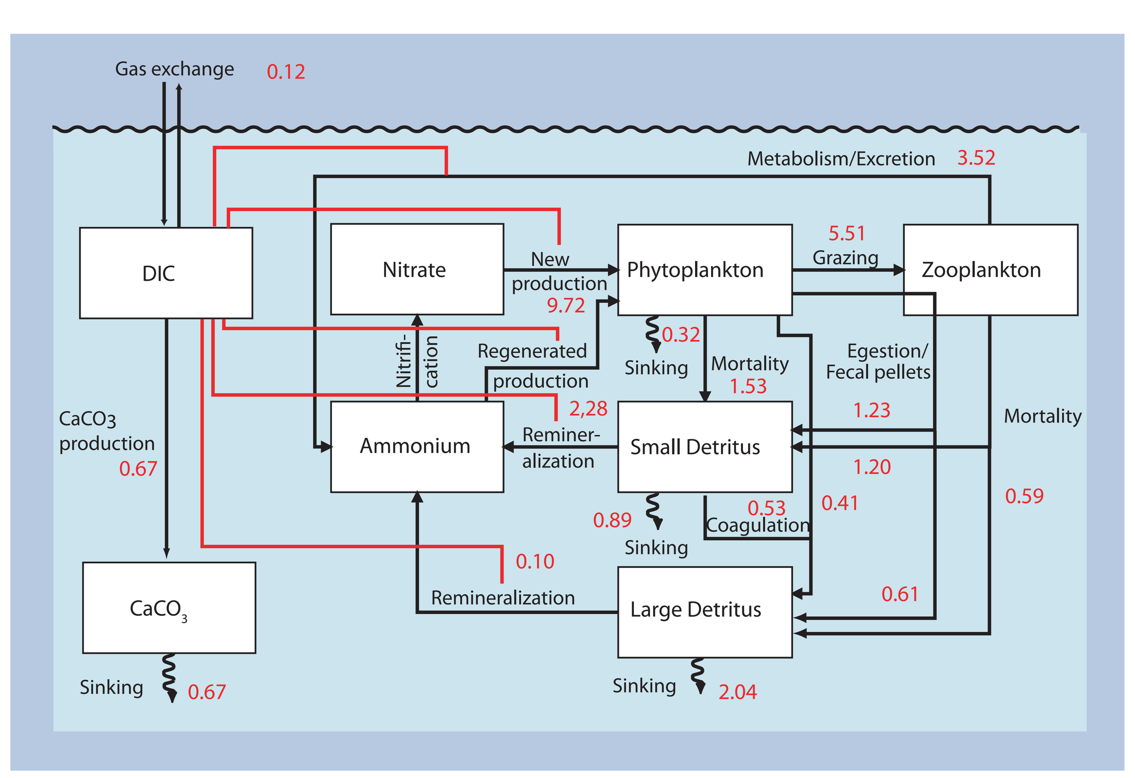

Fig. 2: Schematic representation of the nitrogen-based NPZD ecosytem and carbon cycle models within ROMS (Plattner et al., 2005; Gruber et al. , 2006). Numbers are for the annually averaged C budget (mol C m^{-2} yr^{-1}) of the euphotic zone in a 300 km wide nearshore region off the central California coast from the 5km ROMS setup.

(3) MEAN SEA-AIR CO_2 FLUX

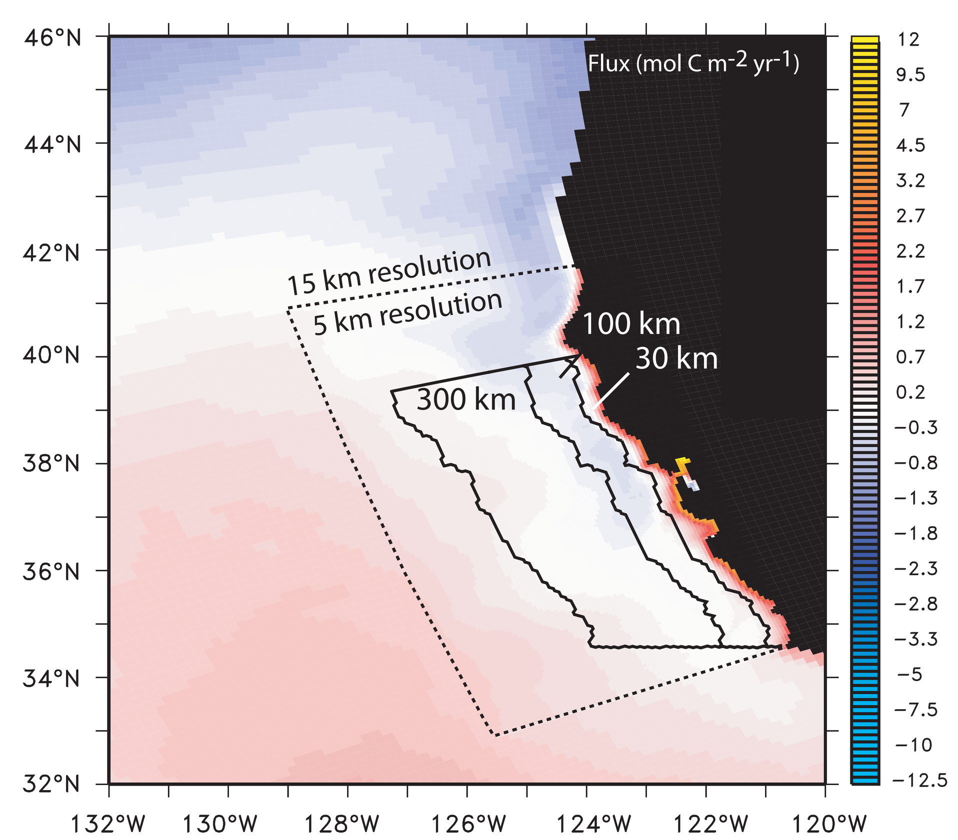

Fig. 3: Modeled annual mean sea-air CO_2 flux in the CCS (mol C m^{-2} yr^{-1}) from the climatologically forced 15+5km ROMS setup. Upwelling-driven CO_2 outgassing nearshore and biologically-driven uptake further offshore can be seen within about 100 km from the coast. Further offshore, the temperature effects dominate the signal. Thin lines indicate the focus regions of this study. The dotted line depicts the boundary of the 5 km child grid, embedded in the 15 km U.S. West Coast parent grid.

(4) VARIABILITY IN SURFACE pCO_2

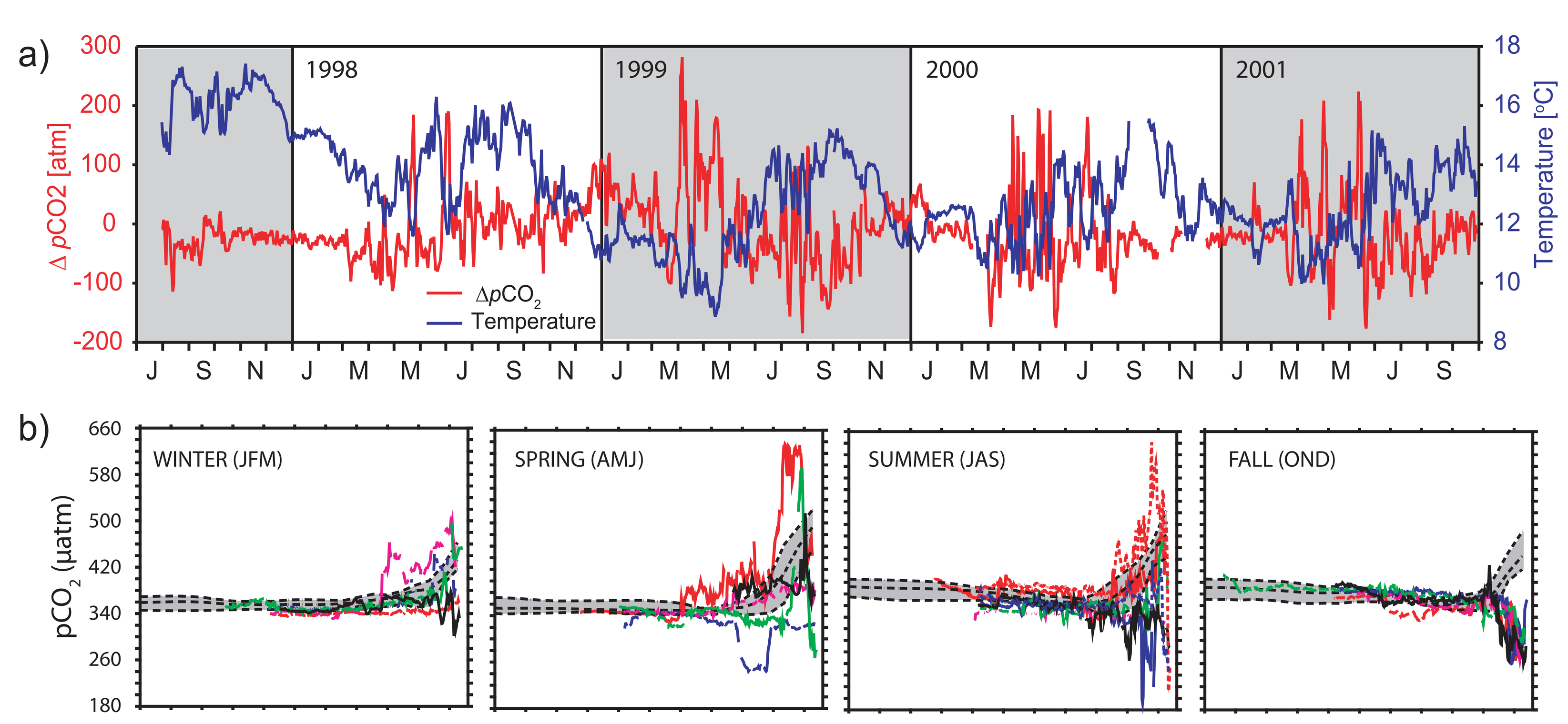

Fig. 4: Illustration of the variability in oceanic surface pCO_2 as observed and modeled within the CCS. (a) Time series of $\Delta pCO2$ (pCO_2,oce - pCO_2,atm) and SST from Monterey Bay from 1997 to 2001 (Friederich et al., 2002). (b) Observed and model simulated pCO_2 transects along CalCOFI line 67 at approximately 36°N. The plot covers distances to about 450 km offshore. The grey shaded range covers minimum and maximum pCO_2 values simulated by the 15+5km version of ROMS. Observations are courtesy of Gernot Friederich and Francisco Chavez (MBARI, Pennington et al., 2006); different colors indicate different cruises during 1997-2001.

(5) CARBON BUDGET OF THE CCS

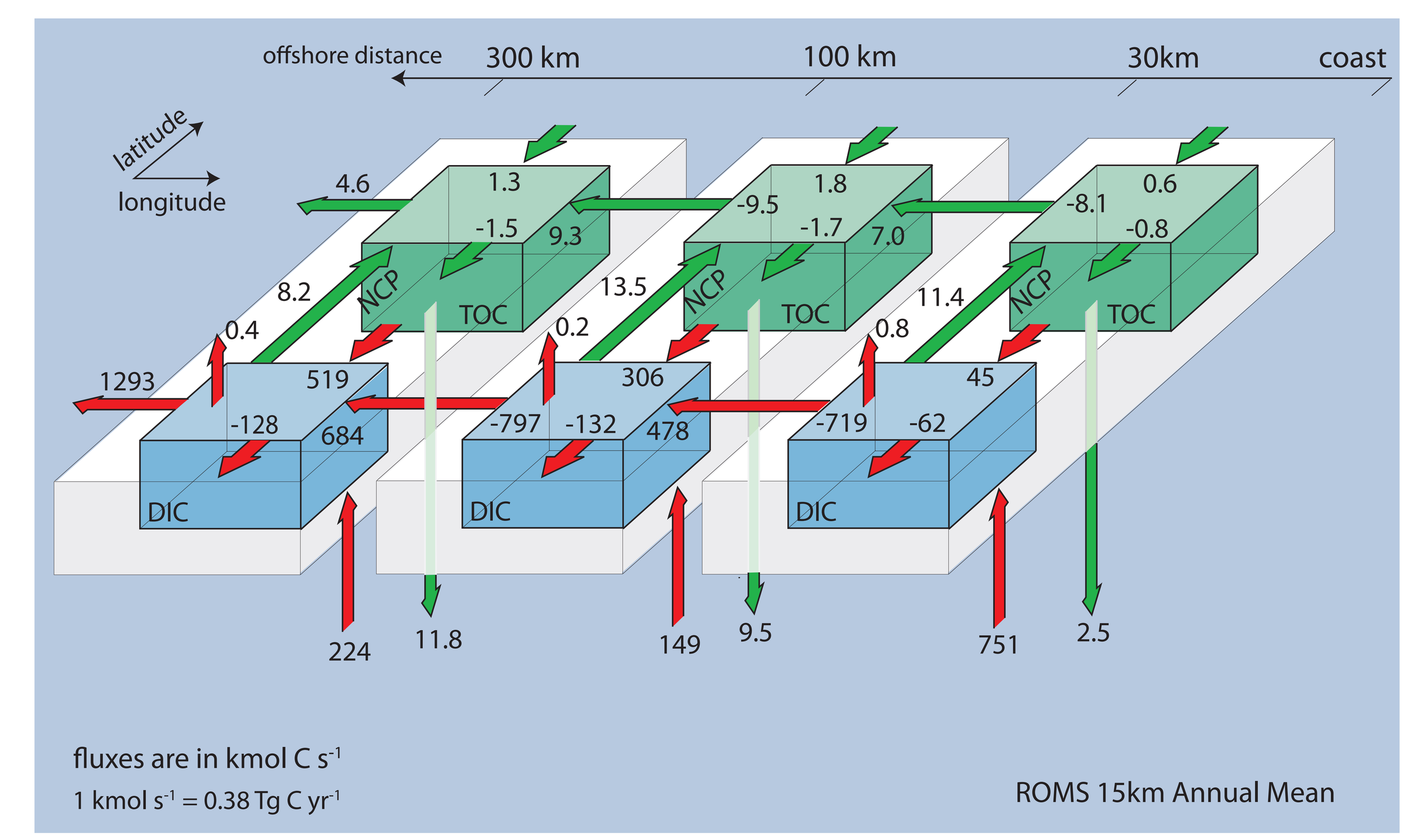

Fig. 5: Euphotic zone carbon budget for the CCS (given in kmol C s^{-1}). The averages have been calculated over the regions shown in Fig. 3, extending to 30, 100, and 300 km from the coast. The inorganic (DIC) and organic (TOC) carbon fluxes are given with red resp. green arrows. Substantial offshore and vertical fluxes for both organic and inorganic C are modeled. In contrast, air-sea CO_2 fluxes are small.

(6) OFFSHORE TRANSPORT OF ORGANIC CARBON

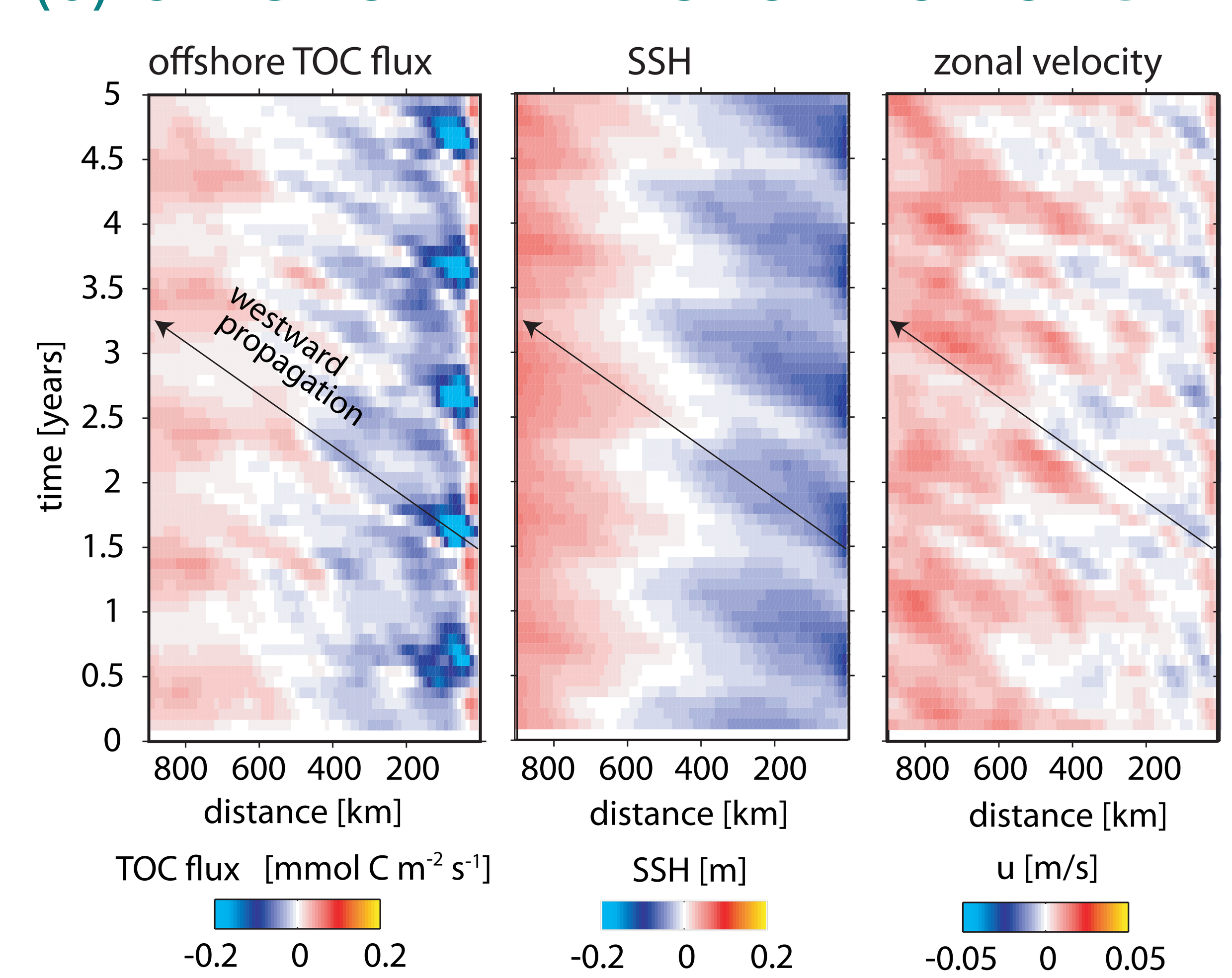

Fig. 6: Hovmoeller plots showing offshore distance versus time for a meridionally averaged section off the central California coast (see Fig. 3). Shown are a) offshore fluxes of organic carbon (in mmol C m^{-2} s^{-1}; left), b) SSH (in m; center), and c) zonal velocity (in m s^{-1}; right). A westward propagation at a phase speed of about 2 cm s^{-1} can be seen in physical and biogeochemical quantities in the model (Nagai et al., in prep.). This transport is associated with meso- and submesoscale eddies and filaments originating from capes and other topographical features along the coast- (Nagai et al., in prep.; Plattner et al., 2005).

REFERENCES & CONTACT

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