A Model of Carbon and Nitrogen Fluxes in the Gulf of Mexico with a Simple Zooplankton Cohort Structure

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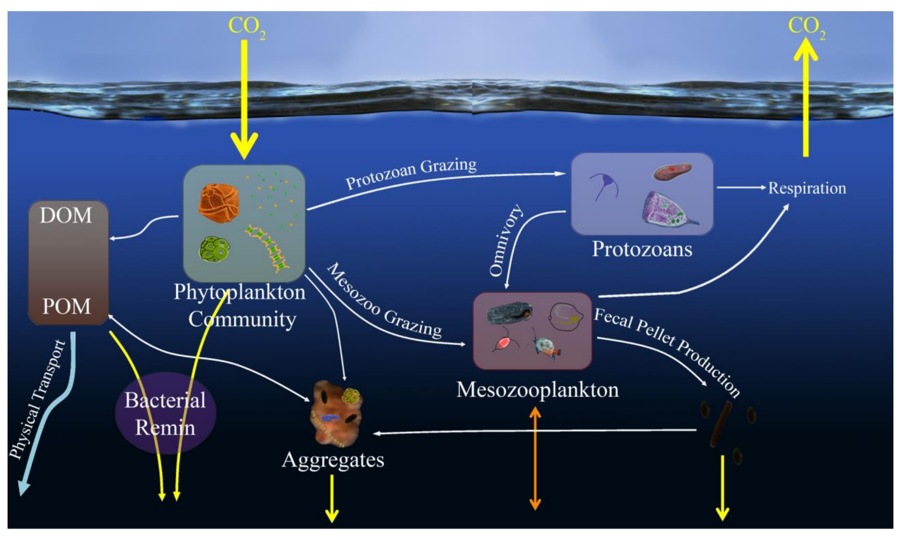
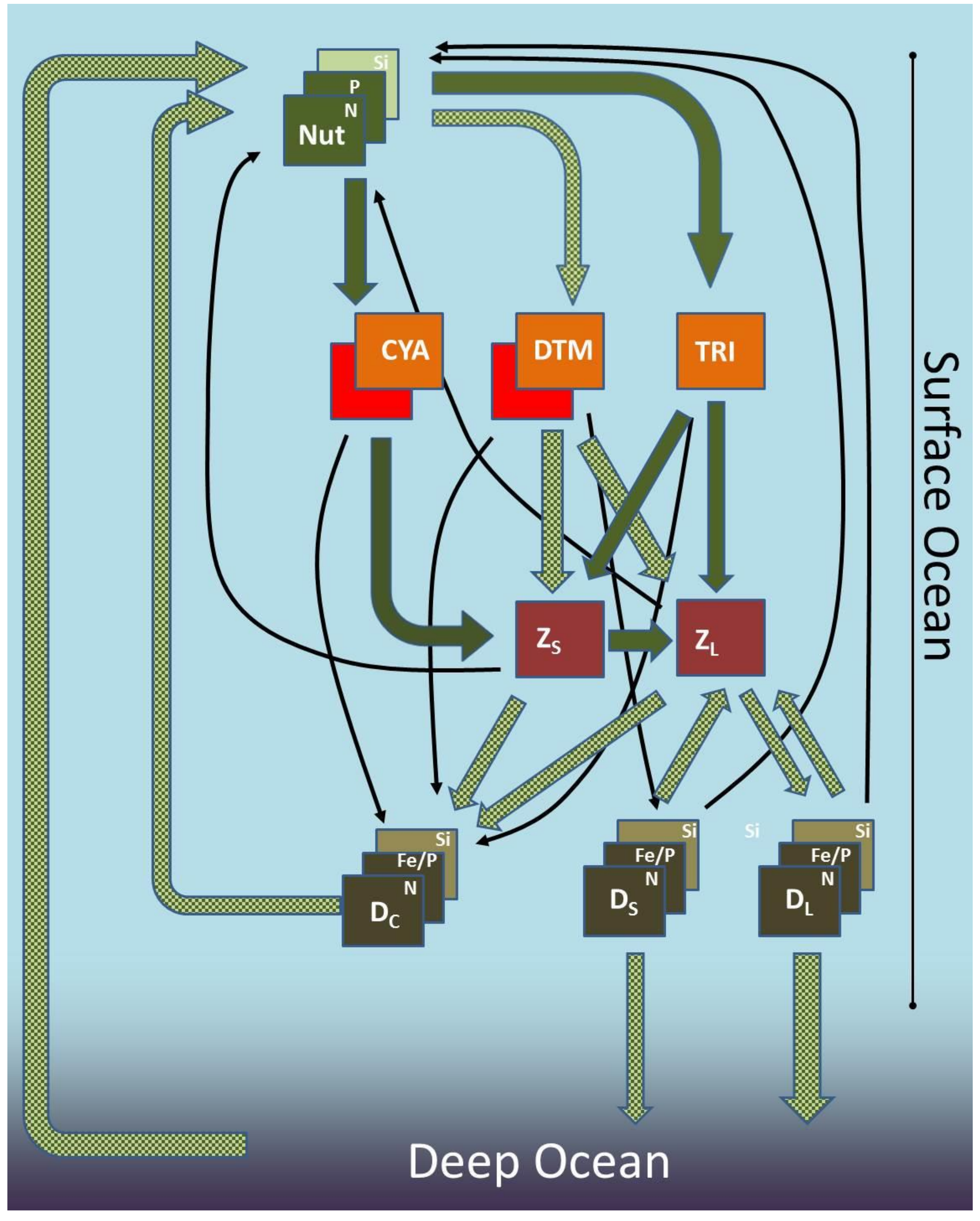
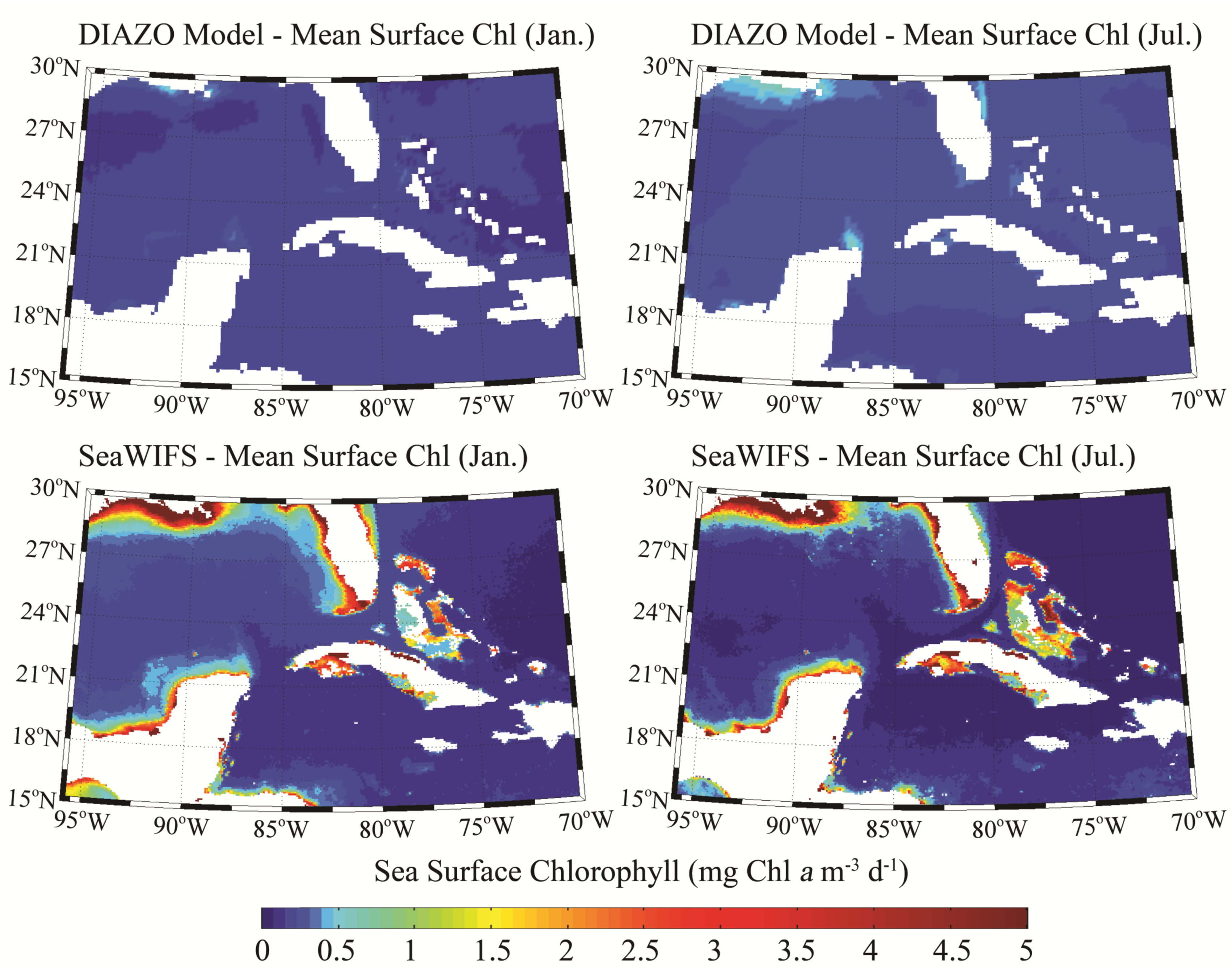


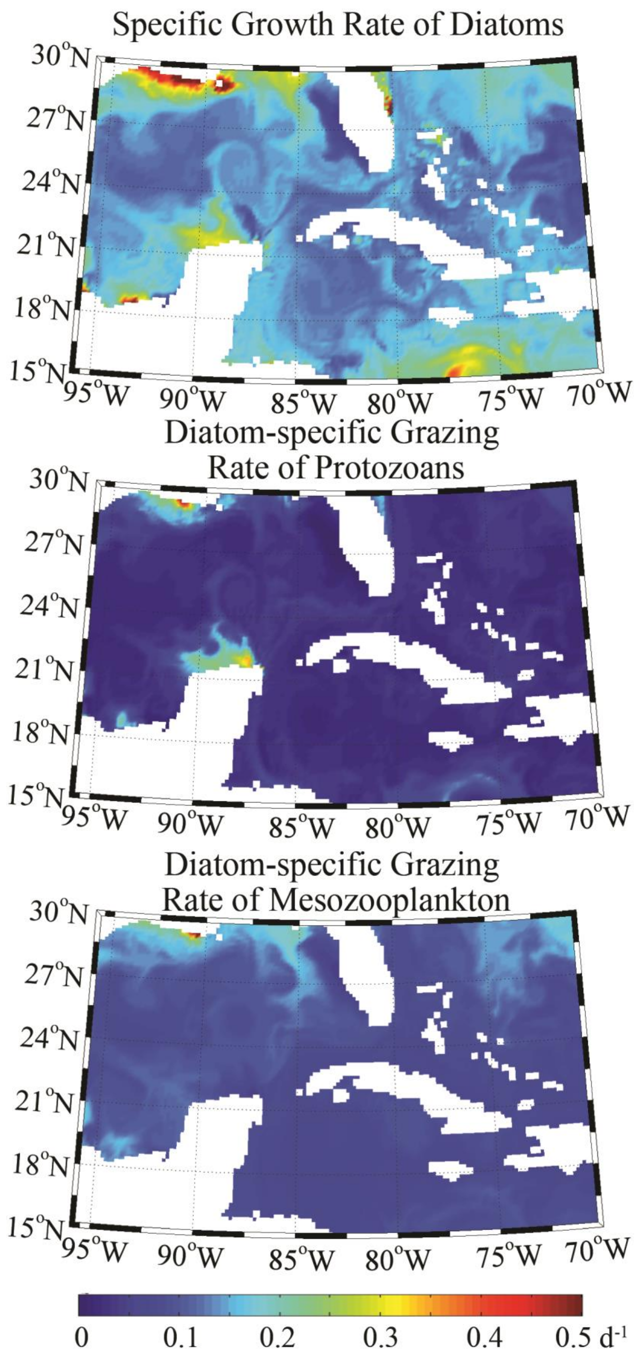
Introduction: Marine phytoplankton are responsible for half of global photosynthesis. However, most of the CO_2 fixed by these microscopic organisms gets respired in the surface ocean and released back into the atmosphere. Removal of this CO_2 from the atmosphere for periods of decades to millennia relies on a suite of processes (known as the biological pump, see figure above right) that transport carbon to depth. Mechanisms of export include gravitational flux of sinking particles (which depends on phytoplankton production, mesozooplankton fecal pellet production, particle size spectra, mineral ballasting, upwelling and nitrogen fixation), subduction, vertical mixing and active transport by vertically migrating zooplankton). Estimates of the magnitude of the contemporary biological pump range from 5 – 20 Pg C yr^{-1} and our ability to predict future change in this globally important process is hindered by the absence of a mechanistic understanding of the driving processes.

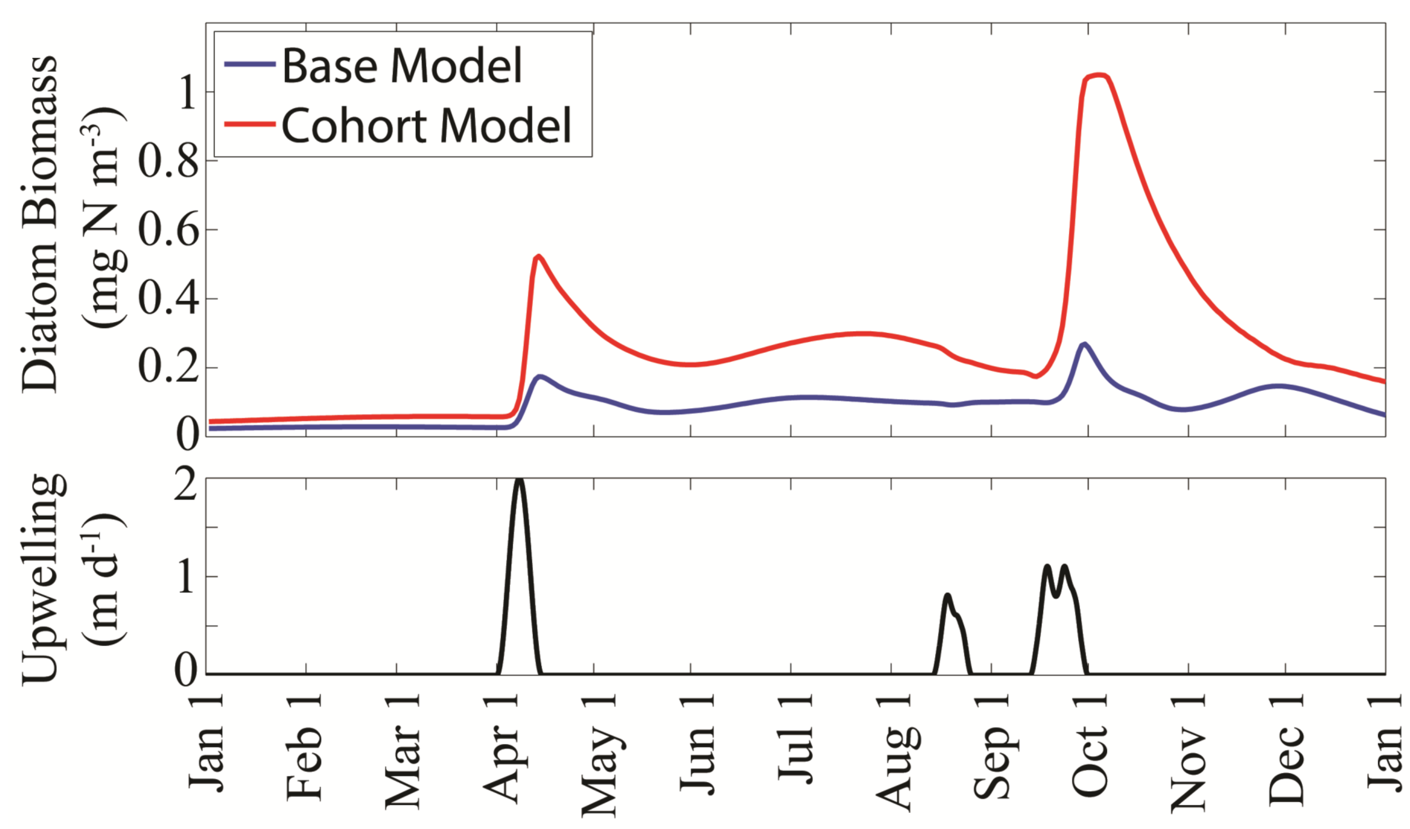


Approach: In order to investigate the processes driving carbon export in the Gulf of Mexico – and predict regional variability – I modified the DIAZO plankton model to allow tracking of nitrogen sources (bottom figure) and configured it to run in the Gulf of Mexico domain. I then compared model results to sea surface chlorophyll estimates made with the SeaWIFS satellite (below) and found that while the model accurately predicted chlorophyll concentrations in the oligotrophic regions and also correctly determined which regions have high productivity, it substantially underestimated chlorophyll concentrations in the high biomass, coastal regions.



Modeling zooplankton cohorts: The model underestimation of phytoplankton biomass (and primary production) in coastal regions is a common feature of many marine biogeochemical models, and is particularly important to overcome, because it impacts flows of carbon in the most dynamic regions of the ocean. To discern its cause in my model, I looked at both growth and grazing rates of diatoms in the model (diatoms are the phytoplankton taxa that typically respond by blooming after nutrient input). While growth rates of the diatoms were quite high in the coastal region (as expected), grazing by mesozooplankton was higher than expected during the early stages of the bloom and prevented the phytoplankton from reaching high biomass (top, right figure). This overly intense coupling in the model likely results from differences between the biology of protozoans and mesozooplankton that is not reflected in typical biogeochemical models. Specifically, while protozoans reproduce by binary fission, with growth rates that are of the same order of magnitude to their pico- and nanoplankton prey, the mesozooplankton that predominantly feed on diatoms have complex life histories that involve multiple larval and juvenile stages. Thus in the ocean (but not in our models) these metazoan grazers are incapable of responding rapidly to pulsed nutrient input in coastal regions, and their prey forms blooms that can persist for weeks before zooplankton population growth catches up. To simulate this behavior, I created a simple zooplankton cohort structure model in which adult mesozooplankton biomass production yields non-feeding larvae with a two-week maturation time. I then ran this model in a simplified 1-D physical framework with pulses of upwelling to assess the impact on phytoplankton responses to upwelling (below).





The cohort model shows substantially greater (and more realistic) response of diatoms to upwelling pulses. It is also a simple modification that can be introduced to many biogeochemical models to more accurately represent carbon and nutrient cycling in dynamic coastal regions.

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