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Effect of Ocean Iron Fertilization on the Phytoplankton Biological Carbon Pump

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Abstract. It has been proposed that photosynthetic plankton can be used as a biological carbon pump tp absorb and sequester carbon dioxide in the ocean. In this paper, plankton population dynamics are simulated in a single stratified water column to predict carbon dioxide sequestering due to surface iron fertilization in deep ocean. Using a predator-prey model and realistic parameter values, iron fertilization was found to only cause temporary blooms up to 5 months in duration, and relatively small increases in adsorption of atmospheric CO_2.

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Key words: Phytoplankton, carbon dioxide, iron fertilization, carbon pump.

1 Introduction

A recent initiative for combating climate change is using photosynthetic plankton (phytoplankton) as a biological carbon pump to absorb and sequester carbon dioxide within the ocean. Iron fertilization has the potential to dramatically increase the potency of phytoplankton blooms, leading to an increased uptake of the greenhouse gas. The use of iron fertilization in high nitrogen, low chlorophyll (HNLC) oceans has the potential to increase the carbon storage capacity of the oceans.

Plankton population dynamics have been explored quite thoroughly in the past; both in theory and practice. While experiments on small scales have proven relatively successful, increasing the carbon processing ability of phytoplankton cultures, the effect of long term iron fertilization on large oceanic blooms has remained unevaluated

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to date. However, several short term iron experiments have been carried out over various HNLC oceans.

More recently, the Indo-German expedition LOHAFEX [8] was carried out with the intention of testing whether iron fertilization was a feasible means of increasing phytoplankton yield of the Southern Ocean. Over 300 square kilometers of ocean was fertilized with 20 tonnes of iron sulfate. The expedition lasted 45 days. The results [10] of the expedition showed that there was little increase in overall phytoplankton population with respect to additional iron, and the researchers noted that the predator species in the system (mainly zooplankton and cephalopods) reacted to the initial spike in phytoplankton population, consuming additional phytoplankton and damping what would otherwise have been a population boom.

While iron models have already been developed [3–5], they have not been applied to the problem of evaluating iron fertilization. The existing models have only been applied to naturally occurring systems [6,7]. In addition, there is no model to describe the actual sequestering of carbon dioxide into the ocean, which currently can only be estimated from other environmental parameters. To complement the field studies currently being carried out, we use a modeling approach to further investigate the effect of iron fertilization on phytoplankton in terms of carbon sequestering.

2 Methodology

Two existing models form the basis of the mathematical model of the system. The first one, developed by Huisman et al. [3, 4] gives a one dimensional stratified water column, wherein turbulent diffusion dominates above the thermocline. The Huisman model provides a good physical basis for the system, but does not take into account predator interaction. Therefore, the growth model in their model is not sufficiently realistic. The KKYS model [6], and its advancement, the KKYS-Fe model [9], on the other hand, provide the relevant biological processes including iron. As the KKYS (-Fe) models are designed to function as part of a three dimensional ecological simulation, the governing equations and thus simulation techniques used are unnecessary for the purposes of this study, and the physical model used by the KKYS-Fe model are replaced by one dimensional counterparts. Together they form the basis of the model in this paper.

2.1 Mathematical model

A single, one dimensional, stratified water column of depth z_m is assumed. Within this column, there are multiple compartments, or species, simulated. The compartments are as follows: Phytoplankton (PHY), Zooplankton (ZOO), Particulate Organic Matter (detritus, or POM), Dissolved Organic Matter (DOM), and Iron Nutrient (FE). The material flow and interaction of the compartments is illustrate by Fig. 1.

Each compartment has its own governing equations, which relate to other compartments. Let $[\cdot]$ denote the concentration of various quantities, we have the follow-