Modeling Phytoplankton New Production in the Peru Upwelling from Nitrate Reductase Activity and Light.

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ABSTRACT

Oceanic New Production is limited by nitrate (NO_3^-), ammonium (NH_4^+), and light. Measuring it by $^{15}NO_3^-$ incubations is the current gold-standard, but the data acquisition rate is slow. Calculating it from plankton nitrate reductase activity (NR) is an inexpensive alternative with a higher data acquisition rate. Here, we calculate phytoplankton new production for the Peru upwelling ecosystem from measurements of NR activity using an enzyme kinetic model based on light-limitation. Calculations for the C-Line section at 15°S find new production ranging from 0.1 to 0.4 micro M N h^{-1} at the shelf edge and compares well to gross primary productivity when Redfield equivalents are used for N-C conversion. JASON-CUEA expedition data for September 1976 were used.

INTRODUCTION

Nitrate Reductase (NR) is responsible for reducing NO_3^- to nitrite (NO_2^-), in phytoplankton (Eq. 1)

$$\mathbf{NO_3^- + NADH + 2e^- + H^+ \rightarrow NO_2^- + NAD^+ + H_2O} \quad \text{(Eq. 1)}$$

In diatoms, chlorophytes, and cyanobacteria, NR can be found in the plasmalemma and other cellular membranes; in dinoflagellates NR can be found in chloroplasts; and in

Chlorophytes it can be found in pyrenoids [1]. NR is a sensitive enzyme because if NO_3^- is not present or if NH_4^+ is present in seawater, NR is inactivated. In the dark, NR is inactivated. If NO_3^- is present, NR activity is characterized by a diel cycle. As a result NR is not measureable in the oligotrophic ocean, but easily measured in coastal upwelling areas. Around zooplankton it is repressed by their NH_4^+ excretion and deep in a nitrate-rich water column by the low light.

But, because of these sensitivities, NR activity is a useful oceanographic indicator, of new production. This production is the part of the primary productivity driven by NO_3^- uptake as opposed to regenerated productivity that was driven primarily by NH_4^+ uptake [2]. Here we develop a light-dependent model of new production based on NR activity that predicts strong new production off Peru (Fig. 1 and 2).

The model was based on measurements from the Coastal Upwelling Ecosystem Analysis (CUEA) JASON expedition [3]

MATERIAL & METHODS

Sampling procedures: Water samples were taken along the line ("C"-Line) extending from the coast of Peru to 182 km offshore, during R/V Eastward Leg IV. Four L samples were taken from the morning productivity rosette [4] and filtered using a Gelman glass fiber filter (4.25µm pore size). The samples were assayed for NR activity by nitrite detection [5]. The new production model was based on: (1) the knowledge that the first step in the phytoplankton NO_3^- assimilation processes is controlled by NR and its Vmax gives the potential New Production rate [6]; and (2) the well-known direct dependence of NR activity on light and NO_3^-, and its inverse dependence on NH_4^+ [1].

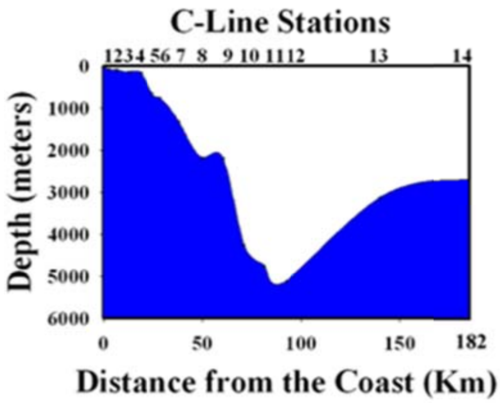

Fig. 1. CUEA C-Line through the Peru upwelling and Trench at 15°S Peru coast on the left.

In the euphotic zone along the C-Line in September 1976, the NO_3^- was always above 4 micro M and the NH_4^+ was always below 0.1 micro M. Accordingly, the NR activity was dependent on the light levels in the euphotic zone and a single-substrate kinetic model was constructed to calculate the New Production Rate (NPR):

$$\mathbf{NPR = -(\partial[NO_3]/\partial t) = [NR][h\nu]/(K_{Lt} + [h\nu])} \qquad \mathbf{(Eq.\ 2)}$$

Where K_{Lt} = the NR Michaelis constant for Light. NR is the V_{max} of NR. Light [hν] was measured and reported in Langleys. A K_{lt} of 21.4 ly min^{-1} (2.5% I_0), from a previous upwelling study (Martinez et al, 1987) was used here.

RESULTS & DISCUSSIÓN

Results in the distribution of NR along the water column show high values in surface waters, where there is no limitation by light (Fig. 2). These results are consistent with gross carbon productivity measurements (Fig.3) from [4] when compared using a Redfield ratio for C:N of 06.6 [7].

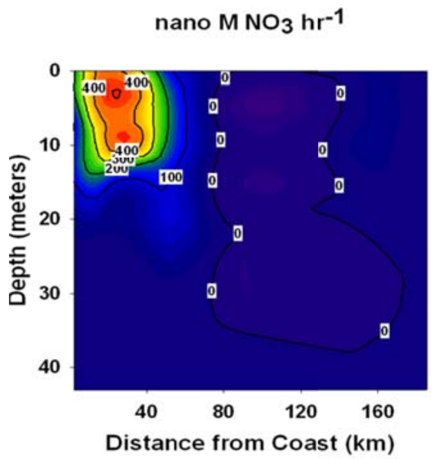

Fig. 2. New Production along the C-Line (12-18 September, 1976) as calculated from nitrate reductase activity in the phytoplankton.

Results in the carbon distribution, as well, show high values in surface water, which correlate with the NR values (Fig. 3), arguing that new production based on the reduction of NO_3^- is equivalent to carbon production.

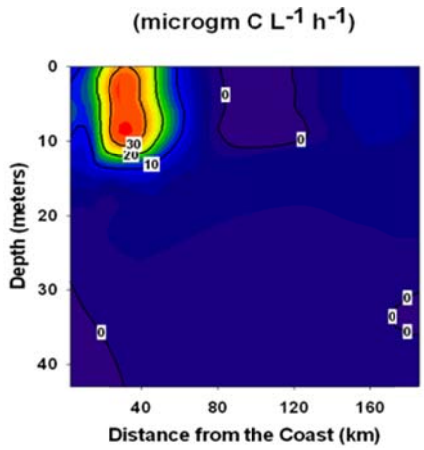

Fig. 3. ^{14}C-Productivity (gross) along the C-Line (12-18 September, 1976) as calculated from 6-hr deck-incubated bottled phytoplankton.

ACKNOWLEDGMENTS

We thank J. Ammerman, J. Kogelshatz, G. Freidrich, L.A. Codispoti, P. Coble, and J. Topinka, for their help at sea, in all phases of the expedition, with sample analysis, and data processing. This study was supported by CUEA-12 (OCE75-23718) to ttp and BIOMBA (CTM2012-2729-MAR) to mg.

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