Effect of in-situ Iron Fertilization on Phytoplankton Growth and Biological Carbon Fixation in the Ocean

Background

We have demonstrated that iron is the limiting factor of biological carbon fixation by phytoplankton in high nutrient and low chlorophyll regions. Since iron fertilization could have potential to increase phytoplankton growth, hence increase air to sea CO_2 flux, iron fertilization has attracted interest as a strategy against global warming. However, the response of marine ecosystem to iron fertilization is largely unknown. Thus, mesoscale in-situ iron fertilization experiments should be conducted and then the information about phytoplankton response to iron fertilization should be examined.

Objectives

In order to reveal the response of phytoplankton and the amount of carbon fixation to iron fertilization, in-situ iron fertilization experiments were conducted in the Southern Ocean and the subarctic North Pacific.

Principal Results

1. Results of in-situ iron fertilization experiments in the Southern Ocean and the subarctic North Pacific

We conducted four mesoscale in-situ iron fertilization experiments in the Southern Ocean and the subarctic North Pacific during 2001 and 2004 (Fig.1). Iron fertilization stimulated phytoplankton growth in all experiments. The water mass fertilized with iron was found to turn into absorption area of atmospheric CO_2. The quickness of response, increase of stock and responding species of phytoplankton were quite different among the experiments. The response of increase in phytoplankton stock to iron fertilization in the subarctic North Pacific was larger than that in the Southern Ocean (Fig.2). The amount of decrease in nutrient concentration and fugacity of carbon dioxide (fCO_2) of the surface waters were also different among the experiments (Fig.3). It was demonstrated that there were large differences in the amount of biological carbon fixation in each experiment.

2. Factors for controlling the response of phytoplankton to iron fertilization

As a result of the examination of the difference in phytoplankton response among the experiments, the following three factors were cited.

(1) Biological factor: the phytoplankton species responding to iron fertilization.
(2) Physical factor: the depth of surface mixed layer.
(3) Chemical factor: the retention time of fertilized iron.

3. Estimates of the amount of carbon fixation

The amounts of biological carbon fixation were estimated quantitatively by the observed results of organic carbon stock and organic carbon flux in each experiment (Table 1). When vertical organic carbon flux at 100 m depth was assumed to be the amount of carbon fixation, the amount of carbon fixation was estimated to be approximately 16% of the increased organic carbon stock with iron fertilization.

Future Developments

The amount of carbon fixation by in-situ iron fertilization should be estimated more accurately by identifying the factors controlling phytoplankton growth and carbon fixation efficiency. Additionally, the amount of carbon fixation and the change in ocean environment by repeated iron fertilization should also be estimated with consideration of global ocean circulation.

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Reference

Tsuda, A. et al. (2003) A mesoscale iron enrichment in the western subarctic Pacific induces large centric diatom bloom. Science 300, 958-961.
Boyd, P.W. et al. (2004) The decline and fate of an iron-induced subarctic phytoplankton bloom. Nature 428, 549-553.

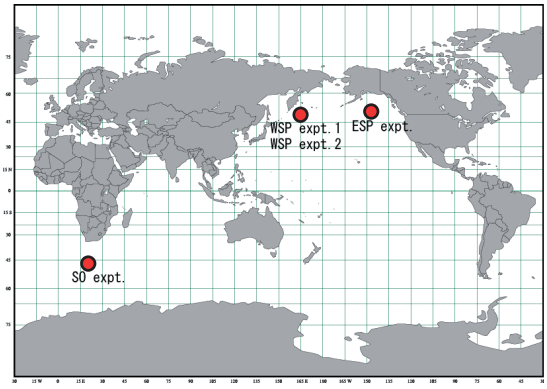

Fig.1 Locations of the iron fertilization experiment site; Southern Ocean (SO), Western subarctic Pacific (WSP) and Eastern subarctic Pacific (ESP).

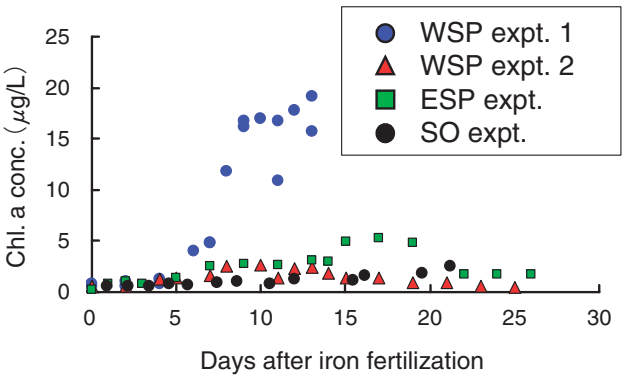

Fig.2 Changes in chlorophyll *a* concentration in surface mixed layer during iron fertilization experiments.

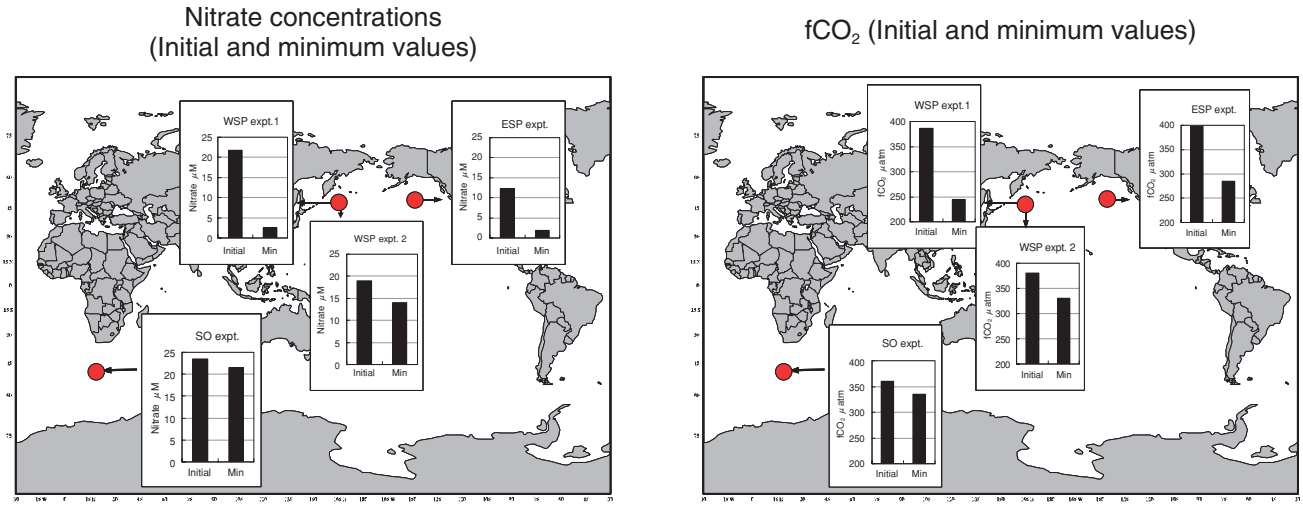

Fig.3 Changes in nitrate concentration and fugacity of carbon dioxide (fCO_2) of the surface waters during iron fertilization experiments.

Table 1 Comparison of observation periods, amount of fertilized iron and organic carbon fixation among the iron fertilization experiments.

	WSP expt. 1	ESP expt.	WSP expt. 2
Observation periods (days)	13	26	26
Fertilized iron (kg Fe km^{-2})	4.4	6.1	6.3
Organic carbon budget ($g\ C\ m^{-2}$ = 10 kg C ha^{-1})			
Maximum accumulation	13.0 (day 13)	6.8 (day 17)	2.8 (day 8)
Particulate organic carbon (%)	11.4 (88%)	5.5 (81%)*	2.5 (91%)*
Dissolved organic carbon (%)	1.6 (12%)	1.3 (19%)	0.2 (9%)
Accumulation at the end of the experiment	13.0	1.0	0.1
Vertical export flux	0.5 (4%)	1.1 (16%)	0.4 (16%)**

*estimated from chlorophyll *a*, **estimated from total particulate flux