PICES XIV W3-2536 Oral
Modelling the ocean iron cycle – The major uncertainties

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The importance of iron as a limiting nutrient for oceanic ecosystems is now indisputable. The iron cycle in the ocean impacts the biogeochemical cycles of carbon, nitrogen, phosphorus and silica, but the cycle of iron itself is poorly understood. There are few if any robust estimates of residence time, and the sources and pathways by which it reaches the oceans, cycles within the water column, and ultimately is lost to the sediments, remain uncertain, and in some important areas current data appear contradictory or paradoxical. The rapid disappearance of dissolved iron in open-water fertilization experiments, for example, is difficult to reconcile with scavenging rates that allow deep and mid-depth concentrations to be maintained at observed levels. This paper will identify critical points of uncertainty about iron in the ocean, including the variability and concentration-dependence of scavenging rates, regulation of dissolution of aeolian iron, and lower limits to phytoplankton iron requirements. We will discuss approaches to using models and observations to reduce the uncertainties, especially with respect to climate projections.

PICES XIV W3-2220 Invited
The importance of iron speciation and kinetics in understanding iron biogeochemical cycling in the open ocean: Effects on budget estimates from meso-scale tracer release experiments

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The role of iron in limiting primary productivity in HNLC regions of the global ocean is now well established principally through meso-scale iron fertilization experiments. However our present understanding of the chemical processes affecting iron distribution, speciation and bioavailability still needs to be dramatically improved. One approach to this has been the development of budgetary schemes for the iron released during the meso-scale iron enrichment experiments performed to date. Experimental results from the Southern Ocean (SOIREE, EISENEX, SOFeX, EIFEX) have highlighted the importance of redox cycles and the kinetics of transformation between soluble, colloidal and particulate iron phases to the residence time of iron in the surface mixing layer. Similar processes were also found to be important in unperturbed HNLC South West Pacific waters during the recent meso-scale tracer experiment (FECYCLE), though more experiments of this type are needed. This study will examine the state of our present knowledge, identify the key mechanisms involved, and outline future schemes for improving our understanding of iron biogeochemical cycling in the open ocean.

PICES XIV W3-2551 Oral
Lower trophic ecosystem model including effect of iron in the Okhotsk Sea and adjacent areas

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A three dimensional physical-ecosystem coupled model, including effect of iron, is applied to the Okhotsk Sea and adjacent areas. In order to investigate sources of iron, we have modified a nitrogen-based ecosystem model (with six compartments of phytoplankton, zooplankton, DON, PON, NO_3, and NH_4, Kawamiya *et al.* (1995)) by including iron cycle with four iron components. We assume there are four main sources of iron to sea water: 1) atmospheric loading from Northeastern Asia; 2) riverine input from the Amur River; 3) solution from sediment; and 4) biological process of zooplankton and bacteria in the water column. The physical-ecosystem model simulation was conducted for one year period, from 1 January 2001 to 31 December 2001. After spring

phytoplankton bloom, the ecosystem model without iron cannot reproduce the observed surface nitrate distribution. But, the simulation with iron cycle shows good agreement with the observed sea surface nitrate in the Northwestern Pacific. During spring, dominated iron source to the surface ocean is from the atmosphere. The atmospheric iron loading contributes about half of iron needed for supporting primary production in Okhotsk Sea.

PICES XIV W3-2363 Oral
Modelling the ecosystem response to iron fertilization during SERIES

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We present results from a one-dimensional model designed to explore the planktonic ecosystem and biogeochemical response to the 2002 SERIES iron fertilization experiment in the subarctic NE Pacific. The ecosystem model simulates with the same parameter set both the 'average' annual cycle at ocean station Papa and the SERIES experiment. We seek to understand the role of iron fertilization in changing (i) planktonic ecosystem structure and function, (ii) the macronutrient fields of N and Si, and (iii) the inorganic carbon system (including surface ocean $p\mathrm{CO_2}$). The model captures the initial bloom of small phytoplankton followed by the large bloom of diatoms, accompanied by a strong draw-down of the nutrient silicic acid. Generally this sequence proceeds more rapidly in simulations than in situ. It took considerable tuning of parameter values to obtain a high enough peak biomass of diatoms before they crashed. Key parameters were the sinking speed of diatoms, the scaling coefficient for aggregation, the relative preference of microzooplankton for diatoms, and the 'normal' or background degree of iron limitation of the diatoms. We discuss the sensitivity of model results to the assumed fraction of small phytoplankton that are calcifiers and to the uptake ratio by diatoms of silicic acid and nitrogen.

PICES XIV W3-2526 Invited
Development of a marine ecosystem model including intermediate complexity iron cycle

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Iron is an important micronutrient for marine phytoplankton, and it controls primary productivity and phytoplankton community structure. Development of iron cycle model, including interaction of chemical species, biological uptake and utilization of iron, will advance understanding the role of iron in regulating marine ecosystem and biogeochemical cycles. We have developed a marine ecosystem model explicitly including intermediate complexity iron cycle. The iron cycle component of the model consists inorganic iron species Fe(II)' and Fe(III)', iron complexed with organic ligands (FeL), and particulate iron ($\mathrm{Fe_P}$). Biological compartments of the ecosystem model are based on NEMURO (North Pacific Ecosystem Model Used for Regional Oceanography), which developed by the CCCC/MODEL task team of PICES. The ecosystem model with iron cycle has been applied to station A7 (41°30'N, 145°30'E) in the western North Pacific, where diatom bloom occurs regularly in spring. Model simulations reproduced the time series of observed dissolved-iron concentration. We will discuss some other recent model studies regarding mesoscale iron fertilization experiments in the subarctic Pacific (Subarctic Pacific Iron Experiment for Ecosystem Dynamics Study (SEEDS; 48.5°N, 165°E) and Subarctic Ecosystem Response to Iron Enrichment Study (SERIES; 50°N, 145°W)).

PICES XIV W3-2513 Oral

Simulated biogeochemical responses to iron enrichments in three high nutrient, low chlorophyll (HNLC) regions

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We applied a fifteen-compartment ecosystem model to three iron-enrichment sites, SEEDS (the Subarctic Pacific Iron Experiment for Ecosystem Dynamics Study; 48.5°N, 165°E) in the Northwestern Pacific, SOIREE (the Southern Ocean Iron RElease Experiment; 61°S, 140°E) in the Southern Ocean, and IronExII (the second mesoscale iron experiment; 3.5°S, 104°W) in the Equatorial Pacific. The ecological effects of iron in the model were represented by changing two photosynthetic parameters during the iron-enrichment period. The model results successfully reproduced the observed biogeochemical responses inside and outside the iron patch at each site, such as rapid increase in biological productivity and decreases in surface nutrients and CO2 inside the patch. However, the modeled timing and magnitude of changes differed among the sites because of differences in both physical environments and plankton species. After the iron enrichment, the productivity by diatoms was strongly restricted by light at SOIREE and by silicate at IronExII. Light limitation due to self-shading by the phytoplankton was significant during the bloom at all sites. Model sensitivity to duration of the iron enrichment revealed that long-term multiple infusions over more than a week would not be effective at SEEDS because of strong silicate limitation to diatom growth. Model sensitivity to water temperature showed that export production was higher at lower temperatures, because of slower recycling of particulate organic carbon. Therefore, the e-ratio had a negative linear correlation with temperature. Through this study, we conclude that ecosystem modeling is a powerful tool to help design future iron-enrichment experiments and observational plans.