Numerical Simulation of Dissolved Iron Concentrations in the North Pacific: Importance of the Sedimentary Iron Source

Kazuhiro Misumi

(Central Research Institute of Electric Power Industry)

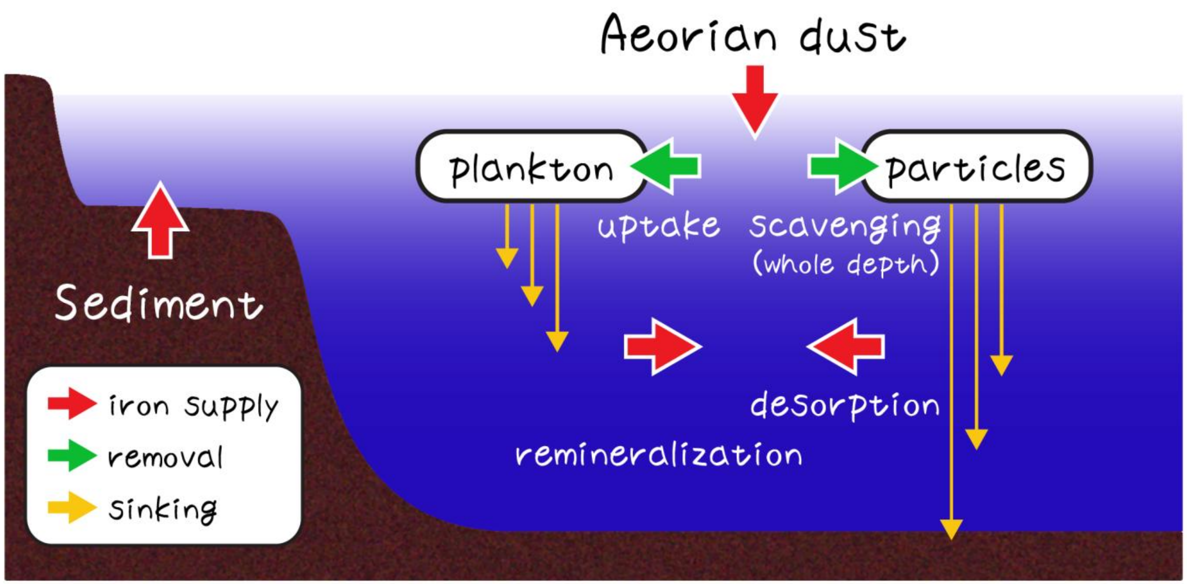
Importance of iron to the global carbon cycle

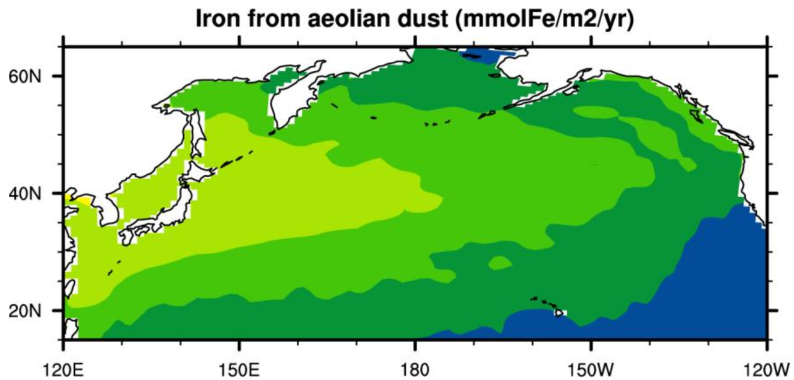
- Iron is an essential nutrient for marine phytoplankton.

- However, it tends to deplete in the surface water even in upwelling areas.

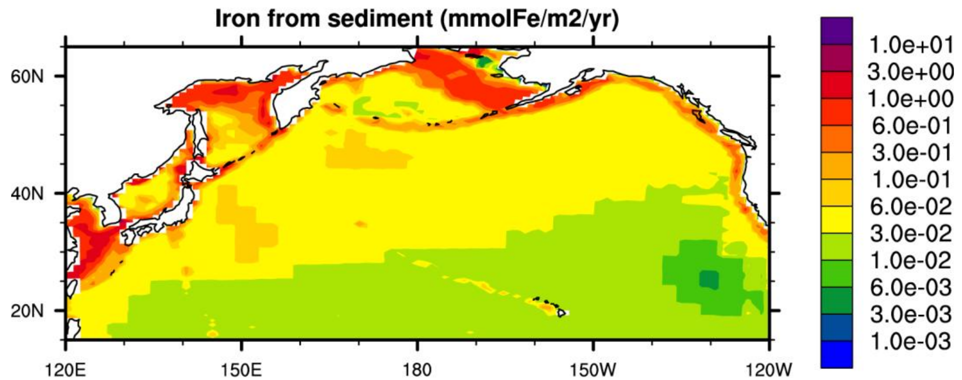
→ Controls oceanic CO_2 uptake

Iron cycle in the ocean



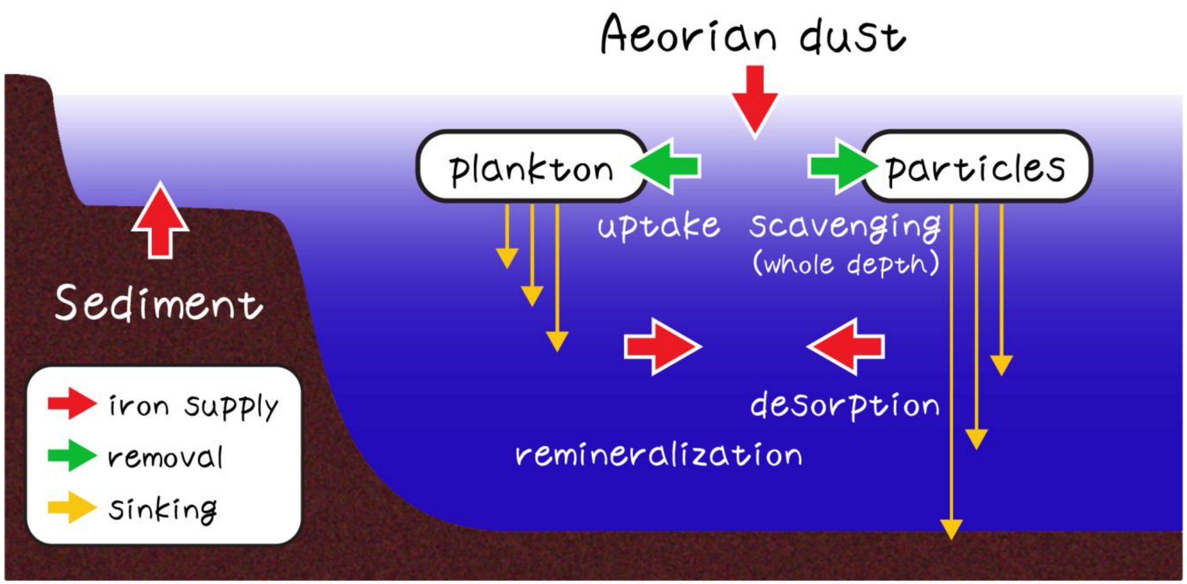


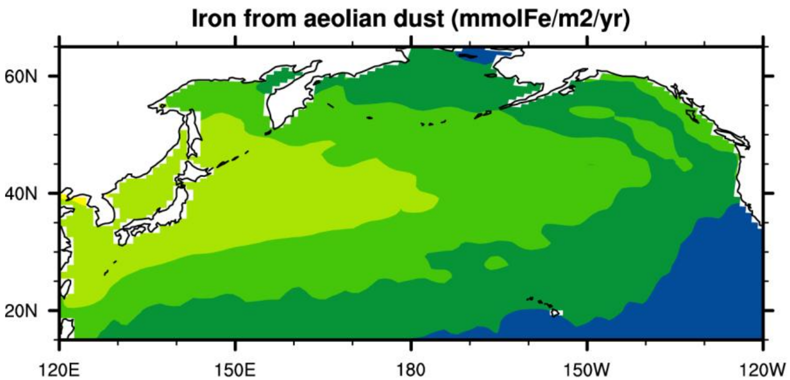
Luo et al., (2003)



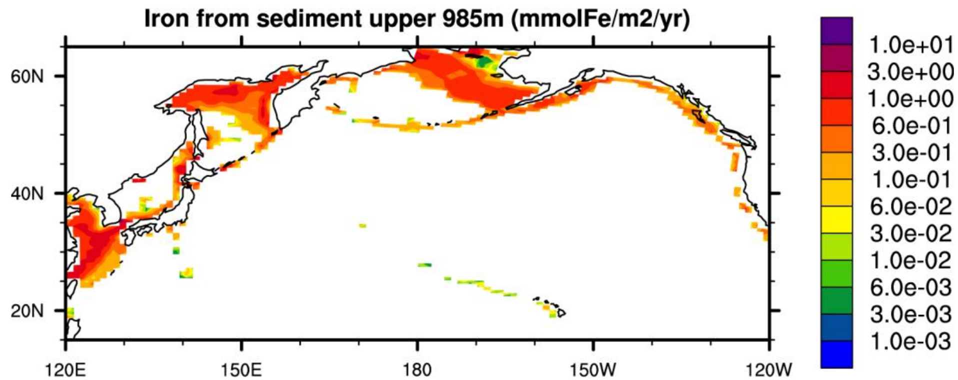
Moore & Braucher (2008)

Iron cycle in the ocean





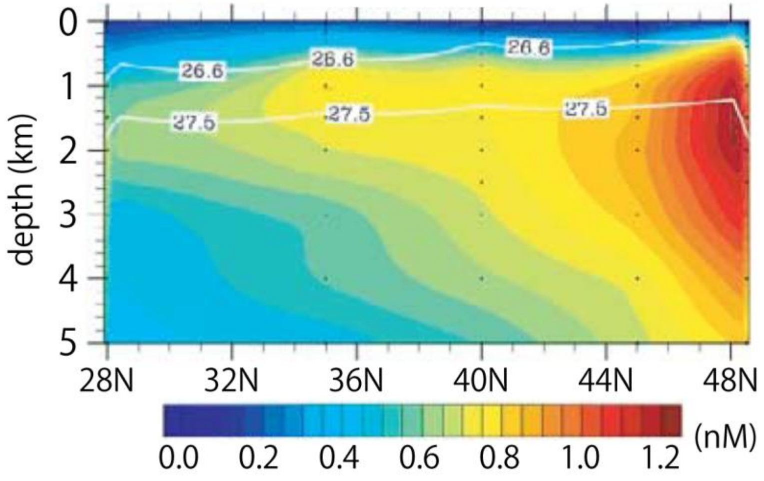
Luo et al., (2003)

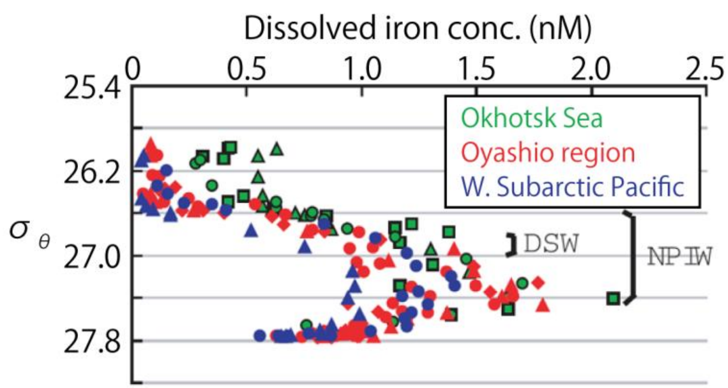


Moore & Braucher (2008)

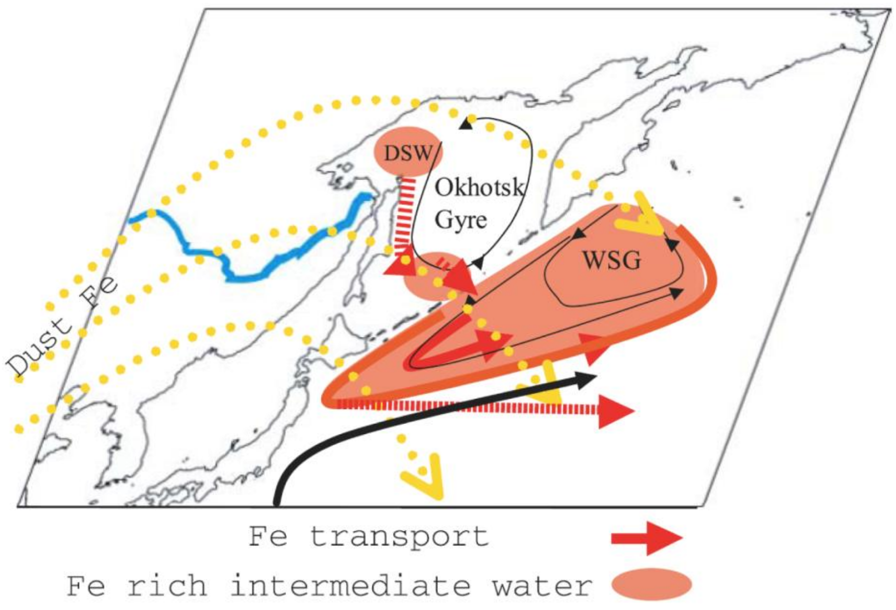
Importance of sedimentary iron source

Latitudinal cross section along165°E





Schematic of sedimentary iron transport to the Western Subarctic N Pacific



All figures are from Nishioka et al. (2007)

Purpose of this study

Investigate role of iron supplied in sea floor sediment on iron cycle in the N Pacific.

My answer

- Sedimentary iron significantly affect iron distribution in the N Pacific, especially in the western Subarctic region and off coast of California.

CCSM-BEC model
(ccsm3.5 beta19, compset C w/ ecosys)

Ocean Part
- POP 2.0.1

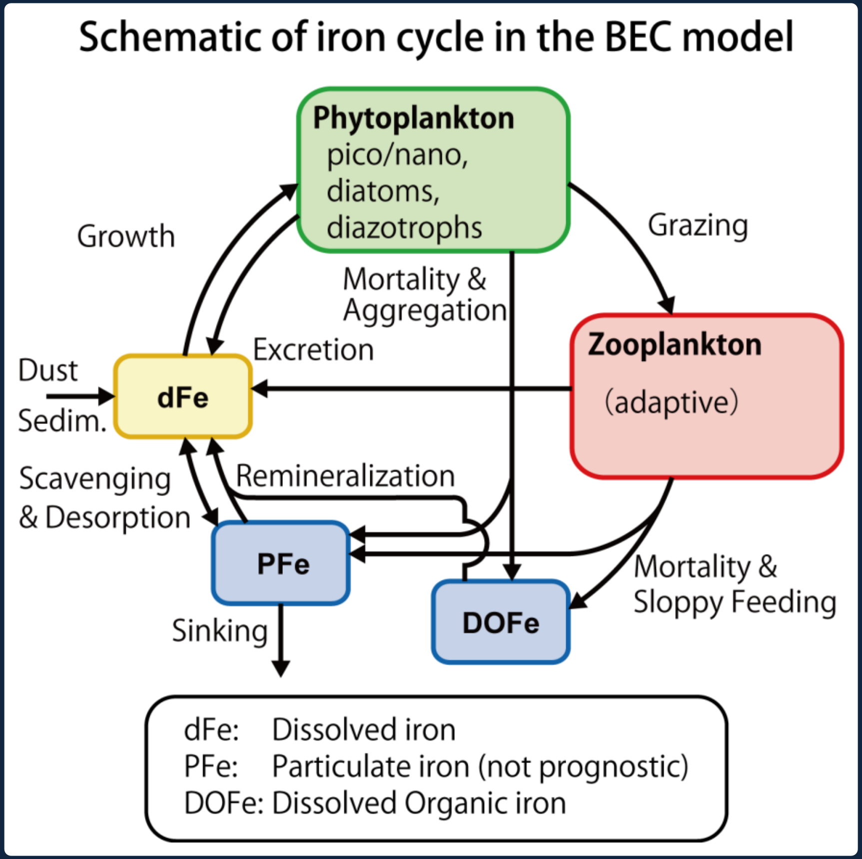
  (Smith and Gent, 2004)
- gx1v5 with 60 levels

Marine Biogeochemical Part
- BEC model

  (e.g., Moore & Braucher 2008)

Initial conditions
- PHC2 (Steele et al., 2001), WOA98, GLODAP (Key et al., 2004), Moore & Doney (2007)

Surface Forcings
- NYF (Large & Yearger, 2004)



Scavenging paremterization in the BEC model

$$\frac{\partial dFe}{\partial t} = phys + bio + scav + desorp$$

$$scav = -Sc \times dFe$$

$$Sc = Sc_b \qquad (\text{where} \quad dFe \leq L)$$

$$Sc = Sc_b + (dFe - L) \times C_{high} \qquad (\text{where} \quad dFe > L)$$

$$Sc_b = Fe_b \times (6 \times sPOC + sDust + sbSi + sCaCO_3)$$

Sc	: scavenging rate	Sc_b	: base scavenging rate
dFe	: dissolved iron conc.	L	: ligand conc.
Fe_b	: base scavenging coeff.	C_{high}	: proportional constant

Values indicated in red are parameters.

(Moore & Braucher 2008)

Experimental Settings

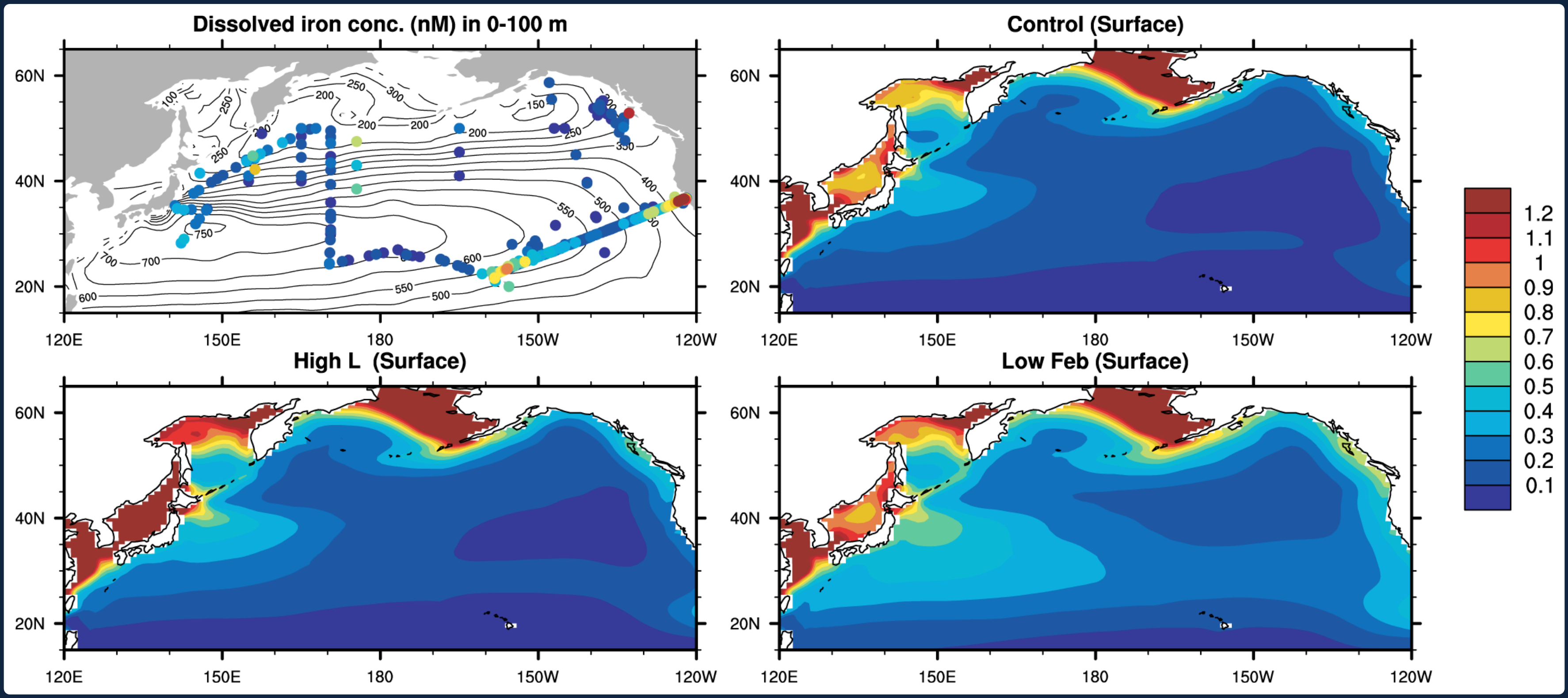
Name	Scavenging Parameters			Iron Source	
	L	Feb	Chigh	Dust	Sediment
Control	1	1	1	On	On
High L	2	1	1	On	On
Low Feb	1	0.5	1	On	On

Values are indicated by factors from the original values used in Moore & Braucher (2008).
Model has spun up for 120 years with parameters of the Control case.
Then it calculated for 50 years for each case with different parameters.

Horizontal distribution of iron conc. in the surface water (nM)

Field data

Control



High L

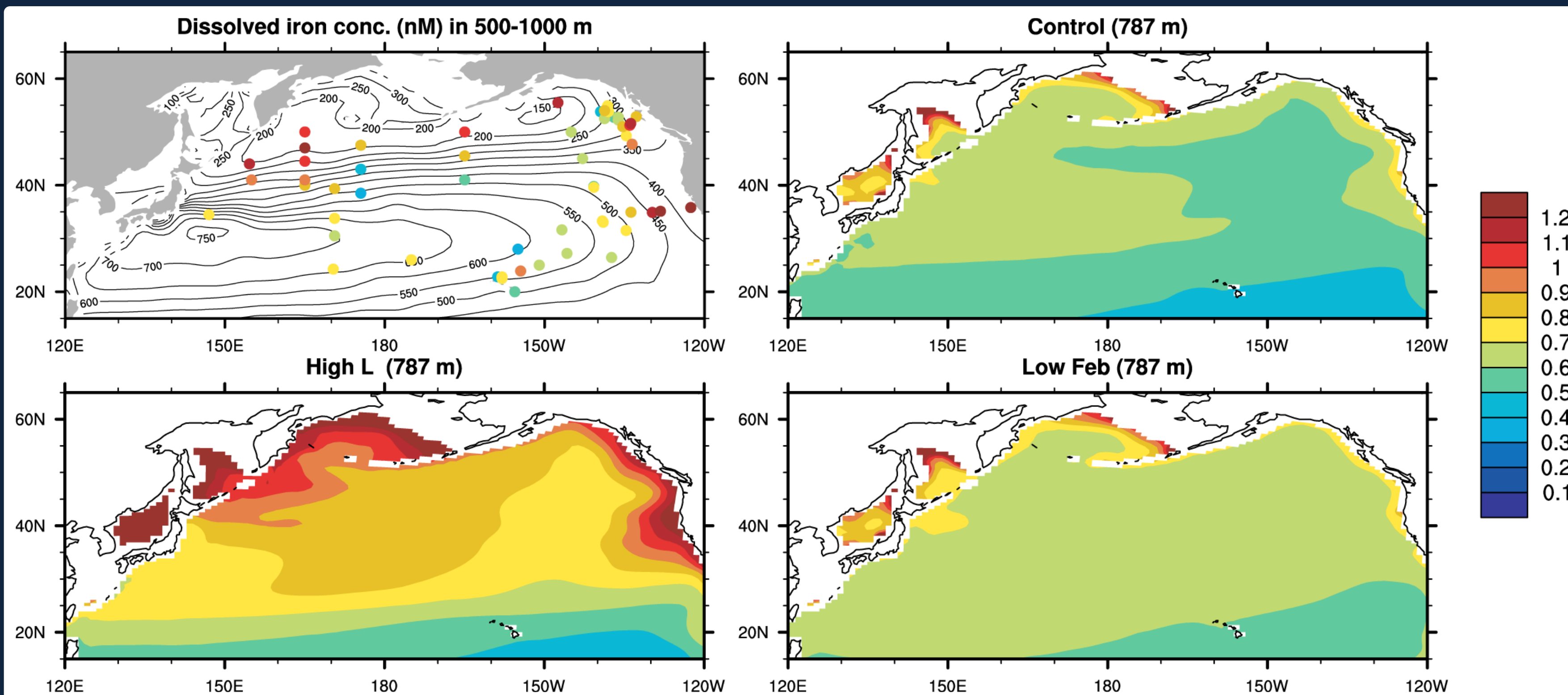
Low Feb

Field data used here are compiled data from Moore & Braucher (2008).

Horizontal distribution of iron conc. in the deep water (nM)

Field data

Control

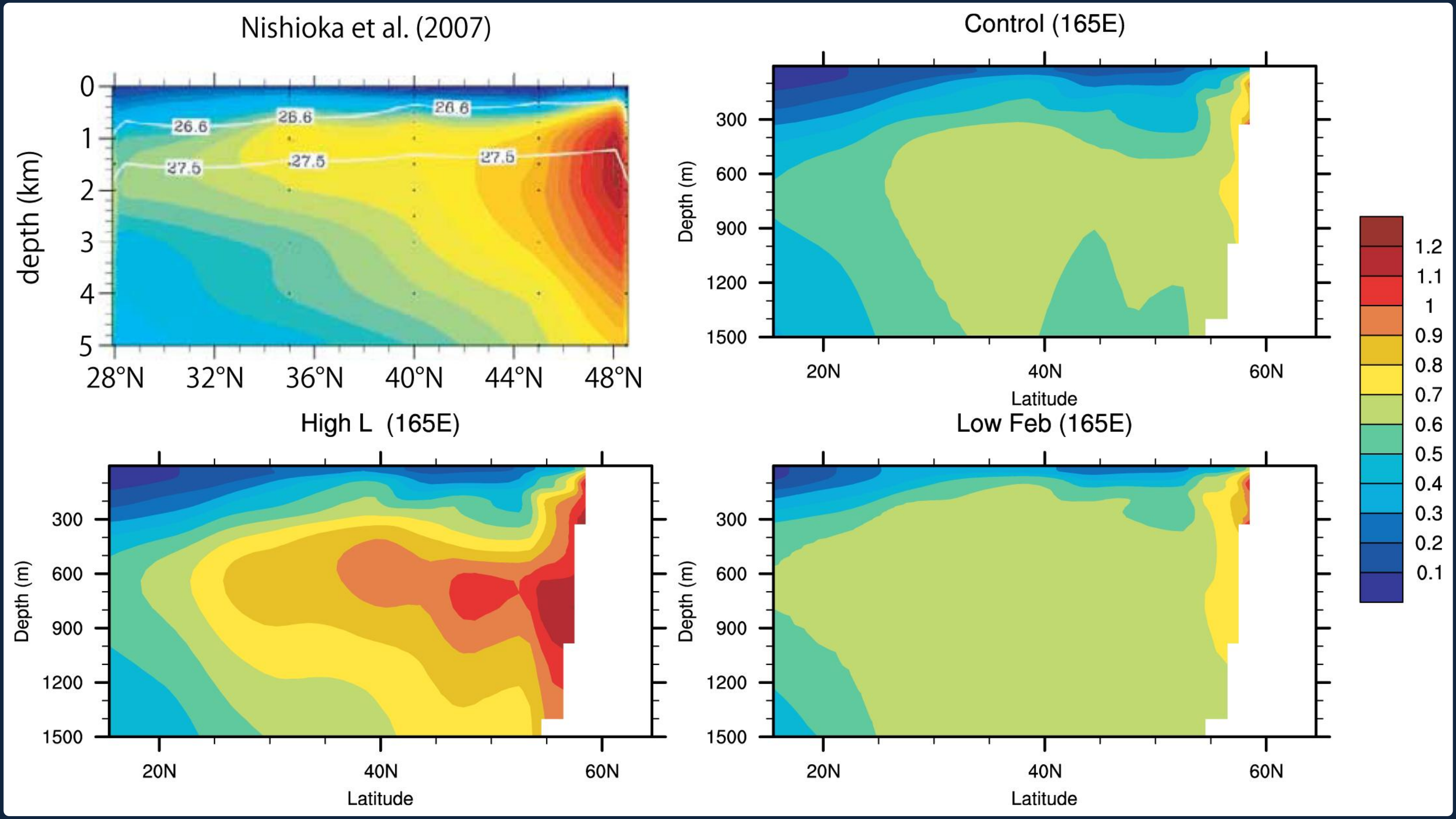


High L

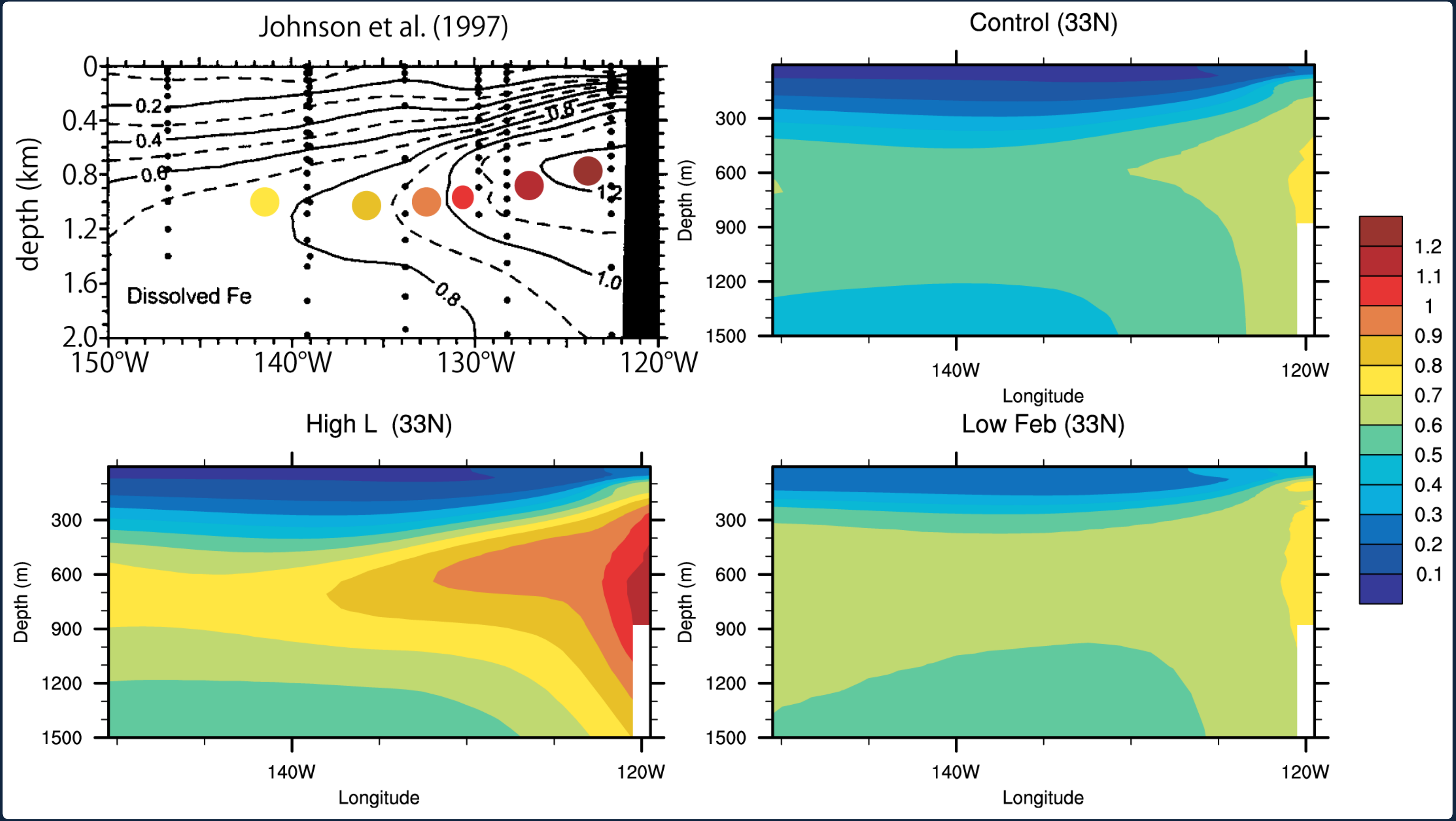
Low Feb

Field data used here are compiled data from Moore & Braucher (2008).

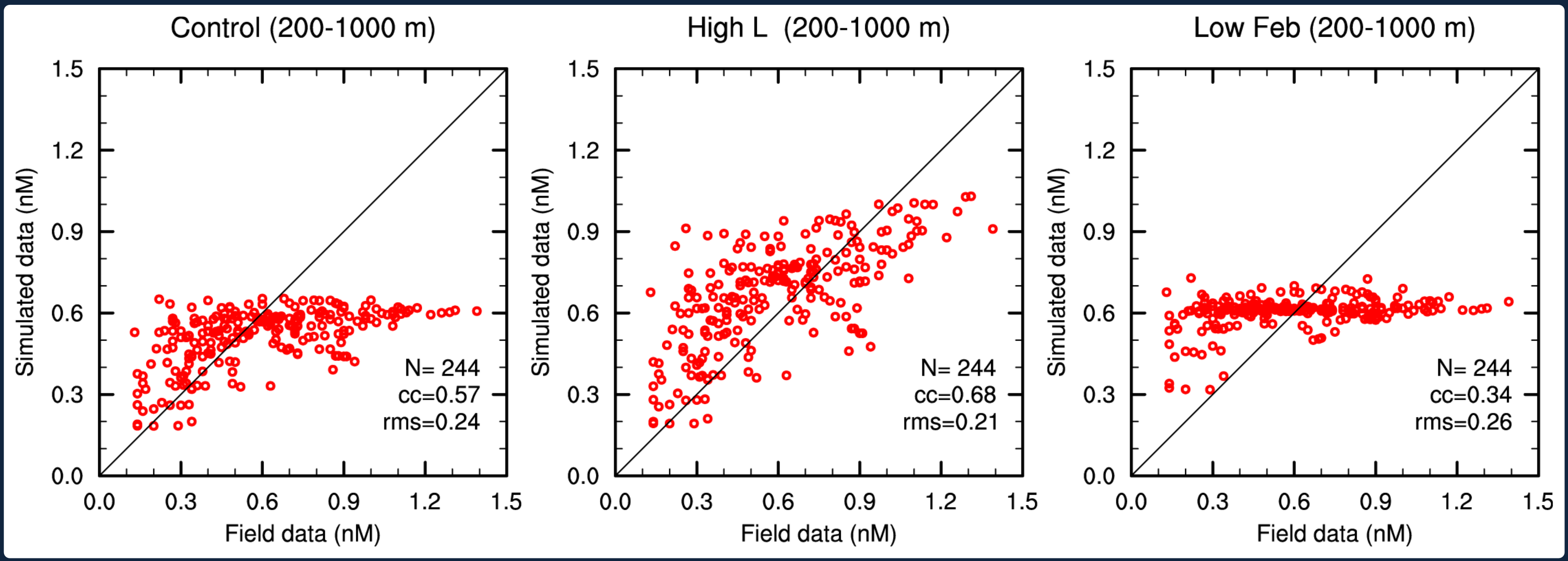
Cross section of iron distribution along 165° E (nM)



Cross section of iron distribution along 33° N (nM)



Field data vs. Simulated data

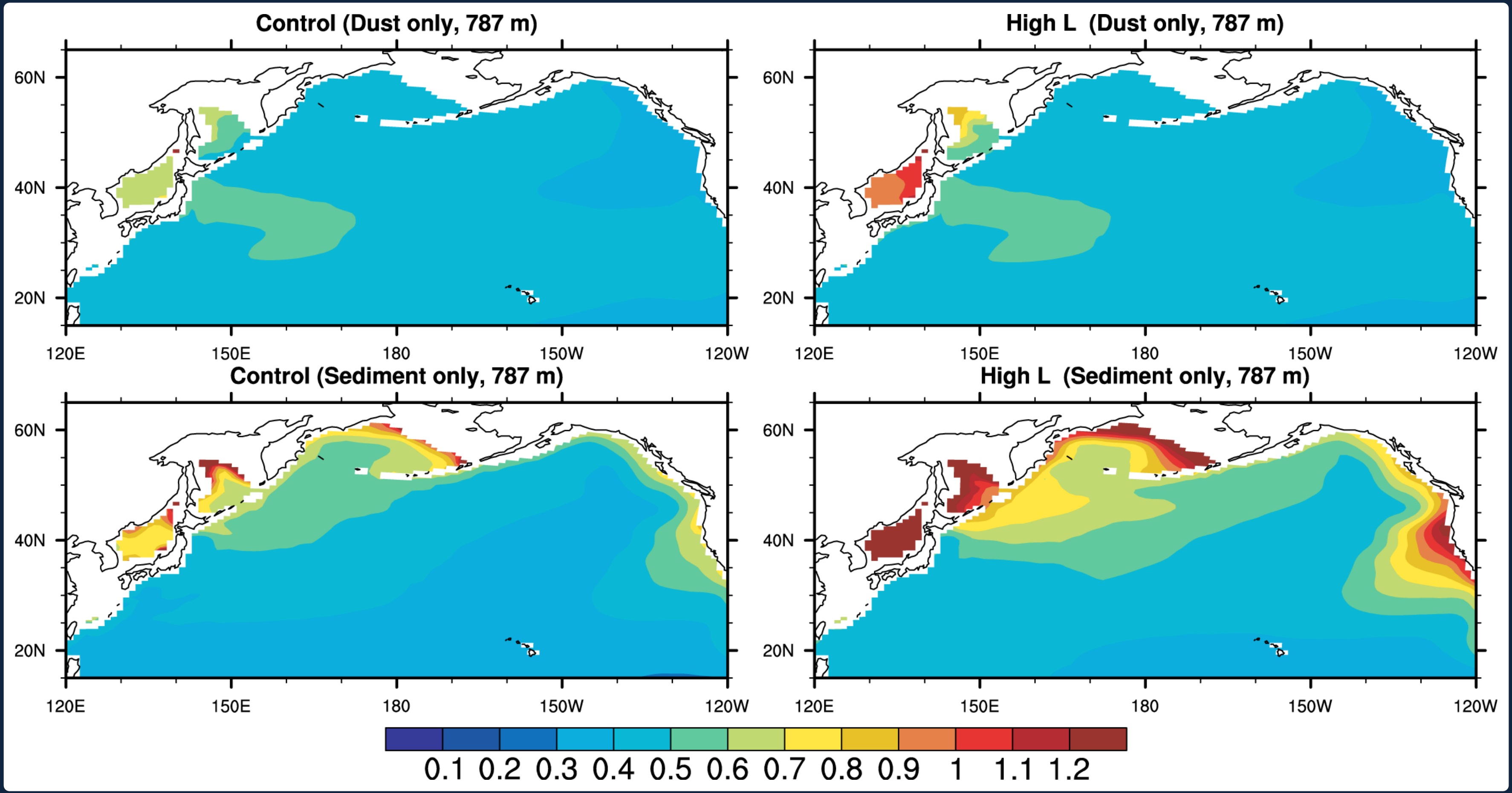


Field data used here are compiled data from Moore & Braucher (2008)

* Data near the coast (< 500 km) were excluded

Horizontal distribution of iron conc. in the deep water (nM)

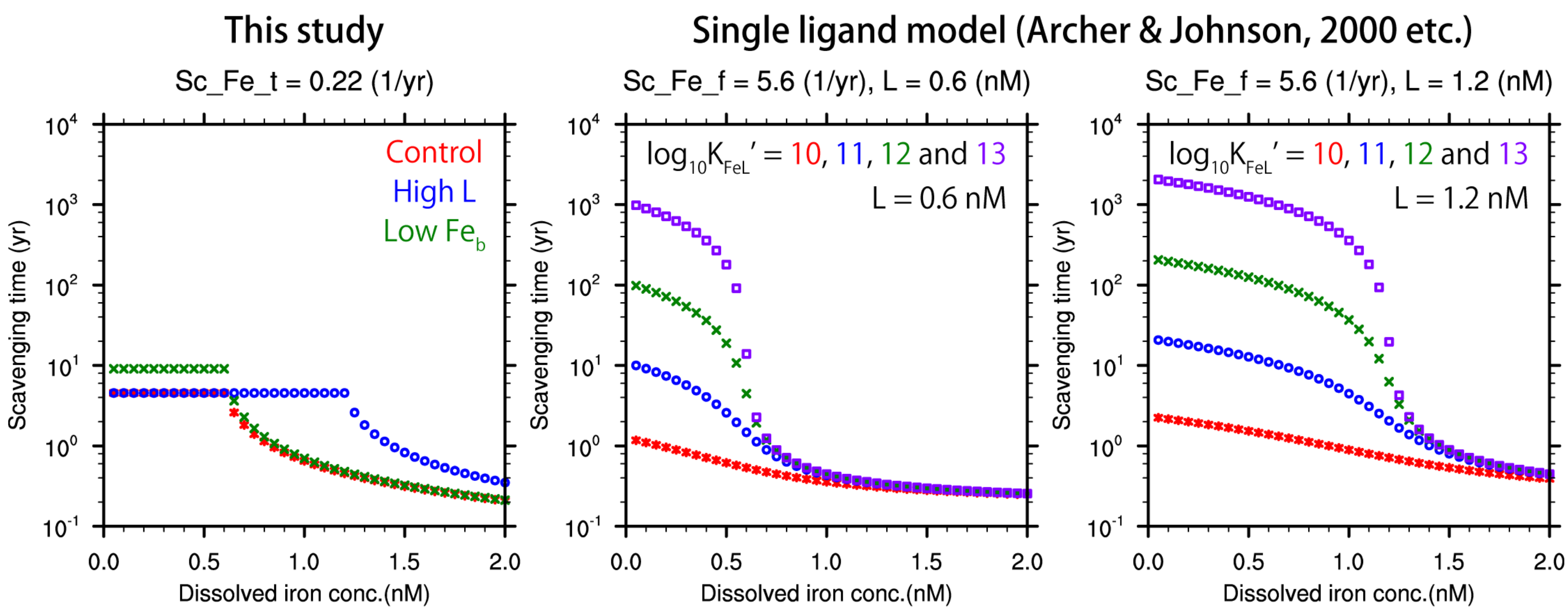
Control (Dust only) High L (Dust only)



Control (Sed only) High L (Sed only)

Why does increase in ligand conc. increase sedimentary iron transport

$$Scav_{time} \equiv -\frac{dFe}{scav}$$



Sc for this study is assumed as an average simulated scav. rate in the N Pac at 500 m detph (0.22 yr^{-1}).

Sc for single ligand model is assumed as 5.6 yr^{-1} referring to Doney et al. (2006).

Summary

- Ligand conc. strongly controls sedimentary iron transport to the open ocean, though it is not fully constraint by direct observations (0.5～6 nM; Parekh et al., 2004).
- Experiment with a relatively high ligand conc. (～1.2 nM) well simulates dissolved iron concentrations in the N Pacific, suggesting a validity of such a high ligand conc. in the N Pacific.
- If it is true, significant amount of sedimentary iron is transported to open ocean in the N Pacific, especially in the Western Subarctic and off coast of California.

APPENDIX

Iron scavenging in single ligand model

$$\frac{\partial Fe}{\partial t} = phys + bio + scav + desorp$$

$$scav = -S_c \times Fe'$$

$$Fe = Fe' + FeL$$
$$L = L' + FeL$$

$$Fe' + L' \rightleftharpoons FeL$$

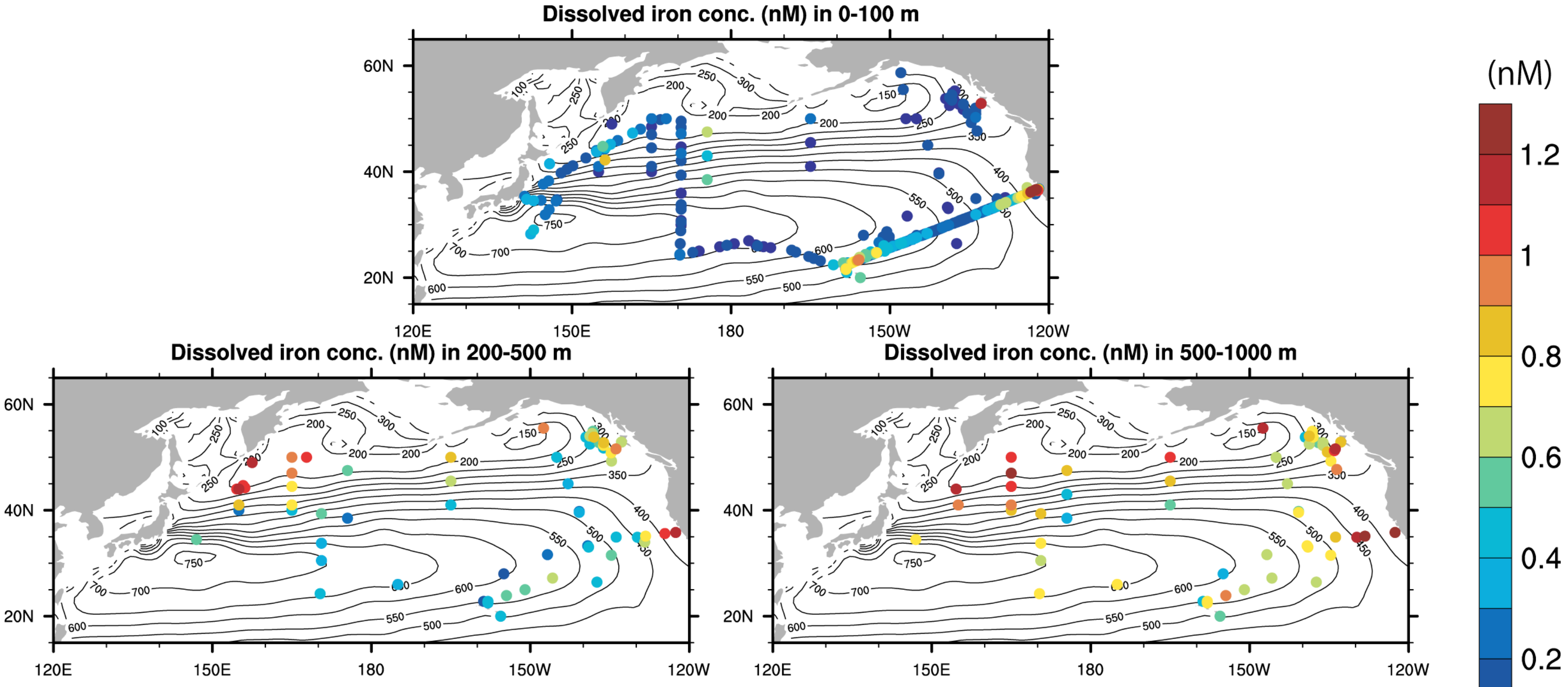
$$K'_{FeL} = \frac{[\mathrm{FeL}]}{[\mathrm{Fe}'][\mathrm{L}']}$$

S_c	: scavenging rate	FeL	: complex form iron
Fe	: total dissolved iron	L	: total ligand
Fe'	: free form dissolved iron	L'	: free form ligand
K'_{FeL}	: cond. stability constant		

(Archer & Johnson, 2000; Parekh et al., 2004; 2005; Aumont et al. 2006; Doney et al., 2006)

The BEC model also implicitly incoporate this process (Moore et al., 2004; Moore & Braucher 2008).

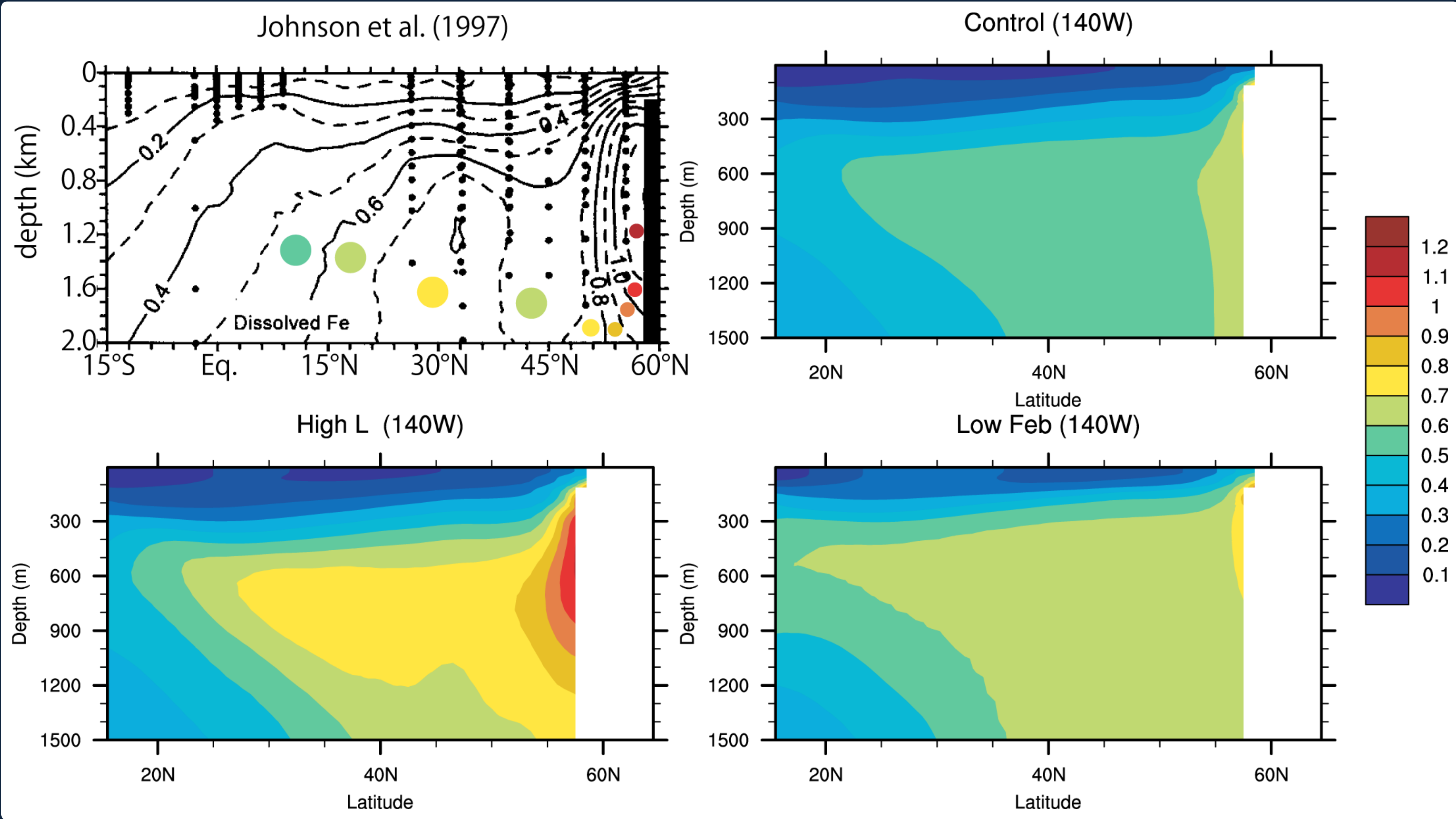
Field data



Color: dissolved iron concentration from compiled data (Moore & Braucher, 2008)

Contour: depth of 26.8 σ_θ in meters (WOA2005; Locarnini et al., 2006)

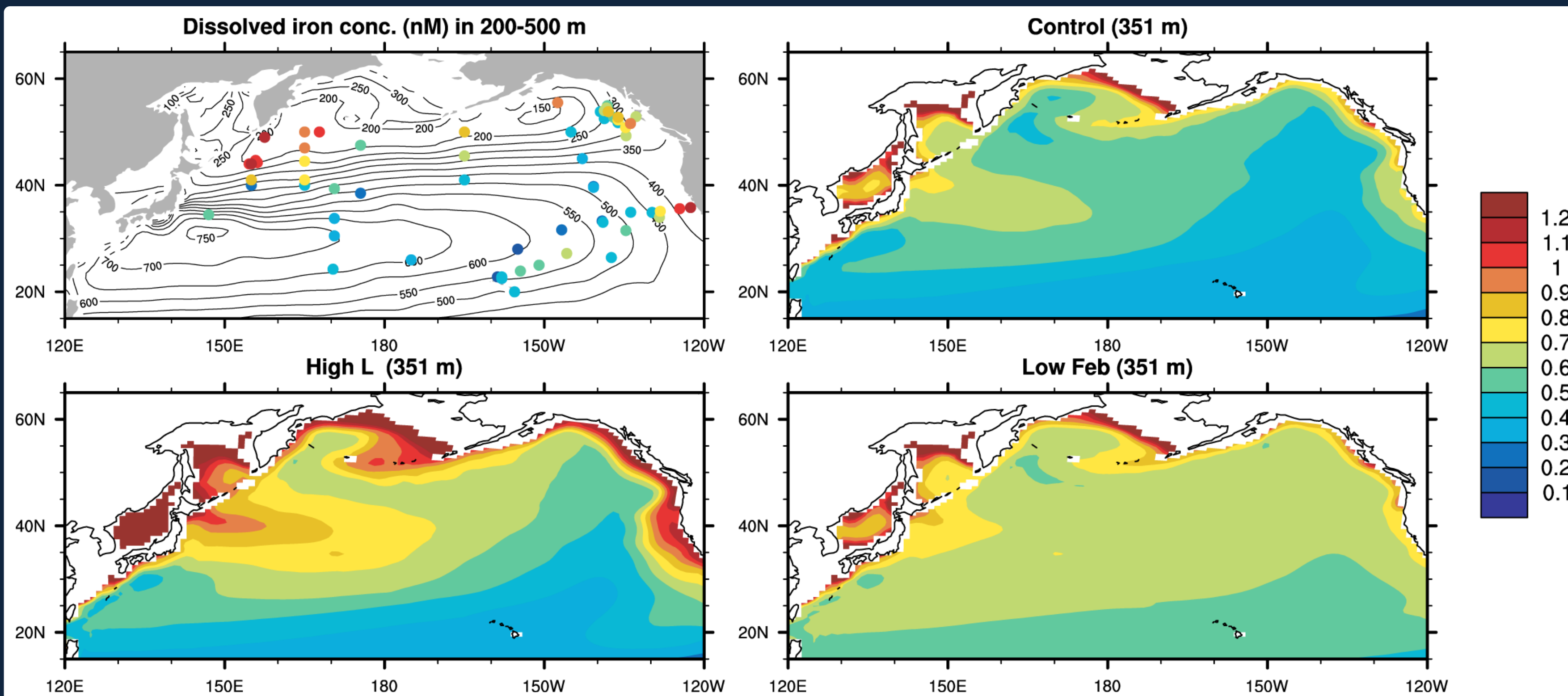
Cross section of iron distribution across 140° W



Horizontal distribution of iron conc. in the intermediate water (nM)

Field data

Control



High L

Low Feb

Field data used here are compiled data from Moore & Braucher (2008).

Additional Experiments

Name	Scavenging Parameters			Iron Source	
	L	Feb	Chigh	Dust	Sediment
Control (Dust only)	1	1	1	On	Off
Control (Sed only)	1	1	1	Off	On
High L (Dust only)	2	1	1	On	Off
High L (Sed only)	2	1	1	Off	On

Parameters are indicated by factors from the original values used in Moore & Braucher (2008).

What controls the spatial variability?