ESSAS Open Science Meeting, Seattle, 23rd May, 2011

Mechanisms controlling dissolved iron distribution in the North Pacific: A model study

K. Misumi[1,2], D. Tsumune[1], Y. Yoshida[1], K. Uchimoto[3], T. Nakamura[3], J. Nishioka[3], H. Mitsudera[3], F. O. Bryan[2], K. Lindsay[2], J. K. Moore[4], S. C. Doney[5]

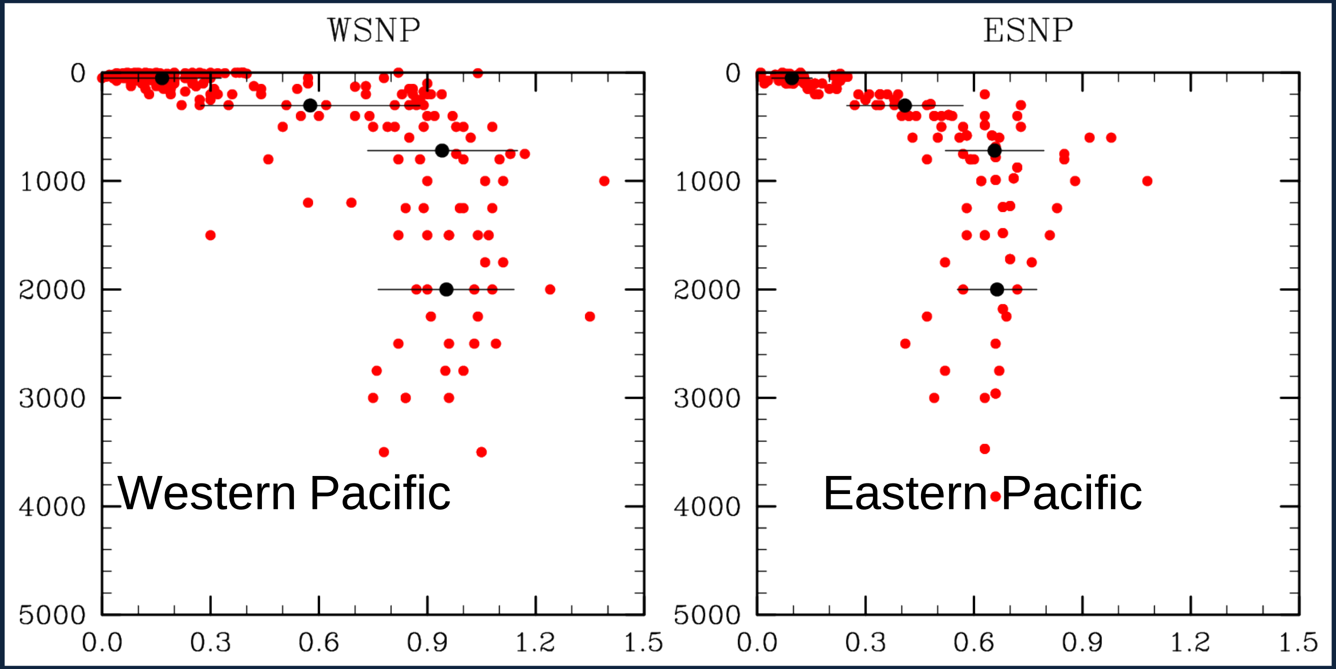
1. Environmental Science Research Laboratory, Central Research Institute of Electric Power Industry
2. Climate and Global Dynamics Division, NCAR
3. Pan-Okhotsk Research Center, ILTS, Hokkaido U.
4. Department of Earth System Science, UCI
5. Department of Marine Chemistry and Geochemistry, WHOI

JGR – biogeochemistry in press

Thanks to support by NEDO

Motivation: Larger iron concentration in the intermediate layer of western North Pacific

What controls intermediate-layer iron concentration?



Vertical distributions of iron concentration (nmol/L) in the western and eastern North Pacific (>40 N) (data from Moore et al. (2008))
Red dots ; Observation,
Black dot ; Averaged values (0-100, 100-506, 506-932, 932- m)

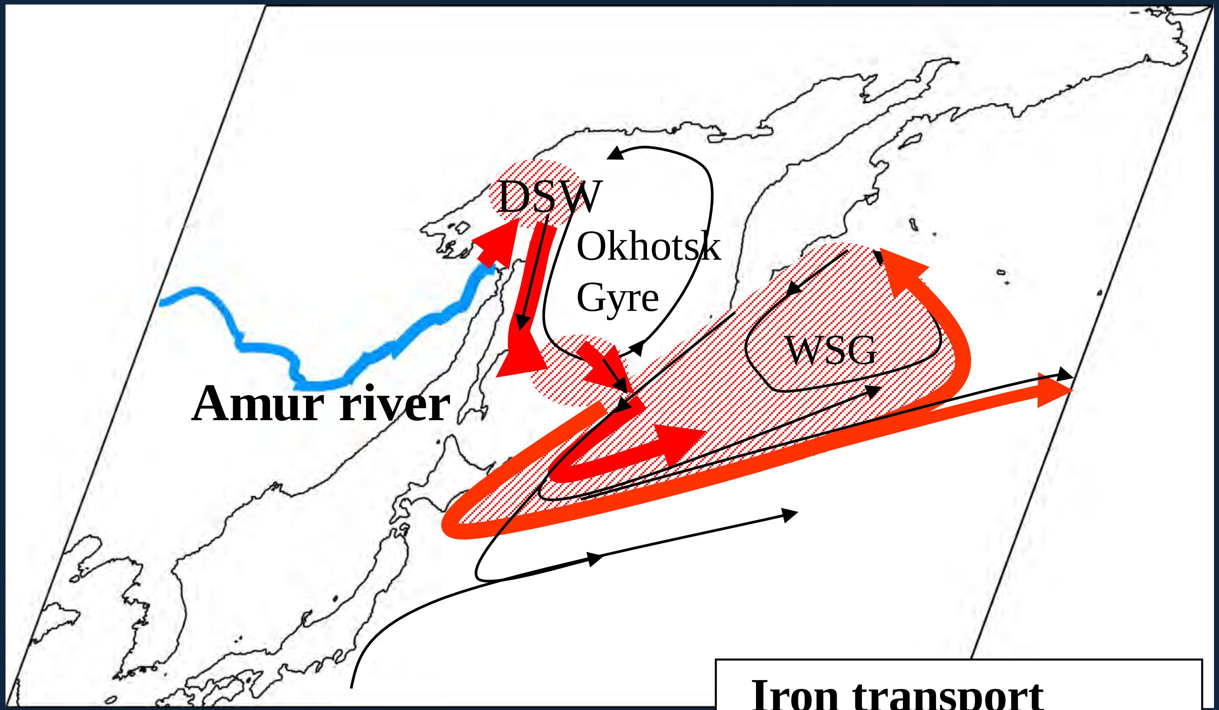
Importance of sedimentary iron source from the Sea of Okhotsk

Sedimentary iron source

Dense shelf water during ice production (DSW) →

Okhotsk Intermediate water →

Oyashio area and western North Pacific



Nishioka et al. (2007)

Iron transport
- **pathway**
- **distribution**

Currents

Uchimoto's talk in this session addresses this subject directly

Question: What controls penetration of the dissolved iron into North Pacific via intermediate layer circulation?

Outline

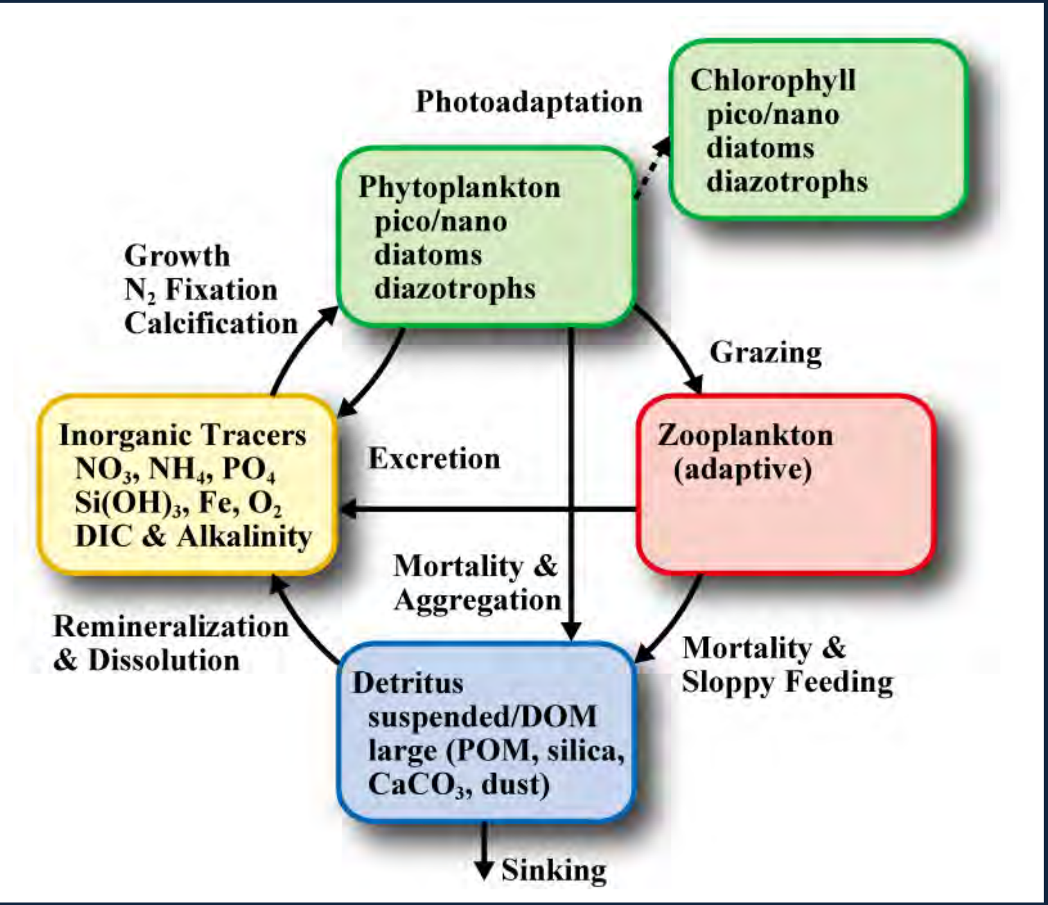
- CCSM-BEC model (global) developed by NCAR, which includes sedimentary iron source. CRIEPI Japan improved the intermediate layer iron distribution through the following experiments
- Experiment I: Changing scavenging parameters. Ligand concentration is important in reproducing intermediate-layer iron of the North Pacific
- Experiment II: Aeorian source (dust) vs Sedimentary source of iron

CCSM-BEC Model

Physical model

- POP (Parallel Ocean Program)
- Horizontal; about 1 degree, Vertical; 60 layers
- 3rd order upwind advection scheme
- KPP scheme
- Momentum; anisotropic GM scheme
- Tracer; GM scheme
- Ice model is not coupled. Dense shelf water is represented by restoring T and S in the Okhotsk.

CCSM-BEC Model

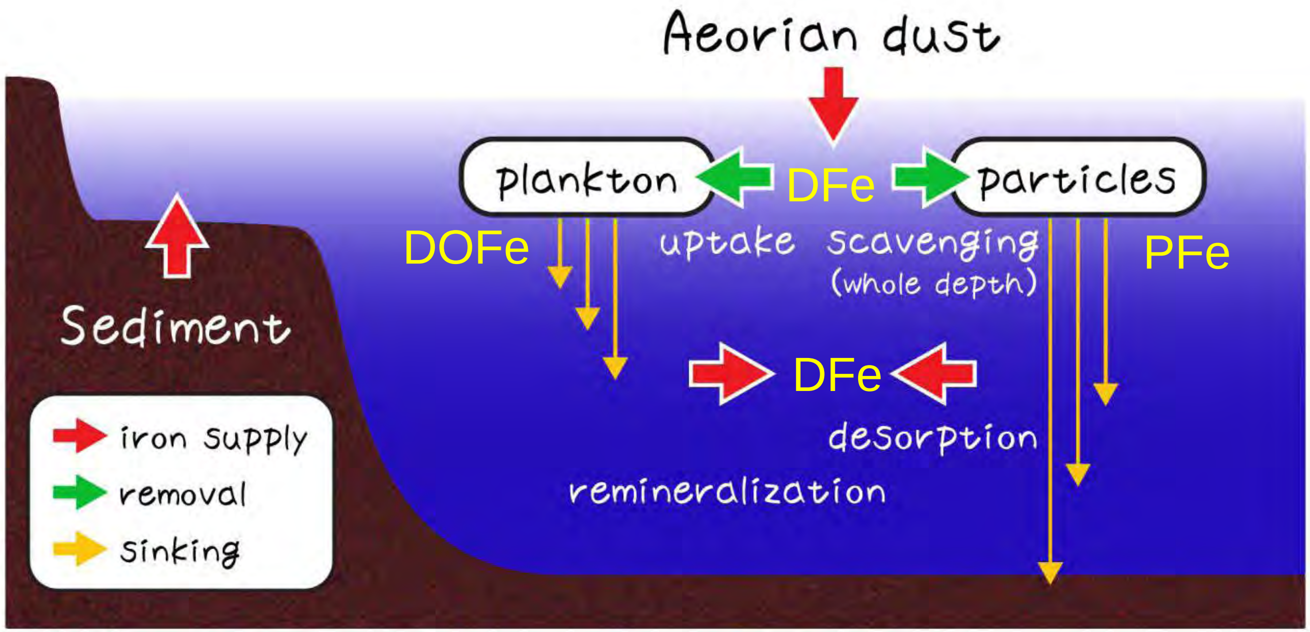


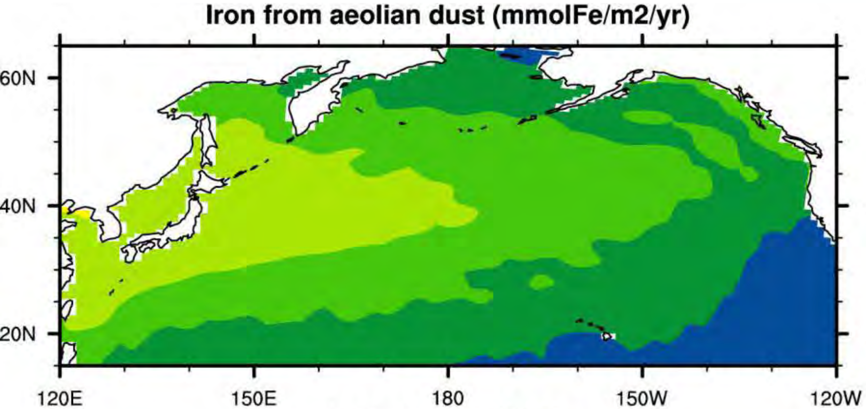
Modified from Doney et al. (2008)

Biogeochemical model is based on NPZD

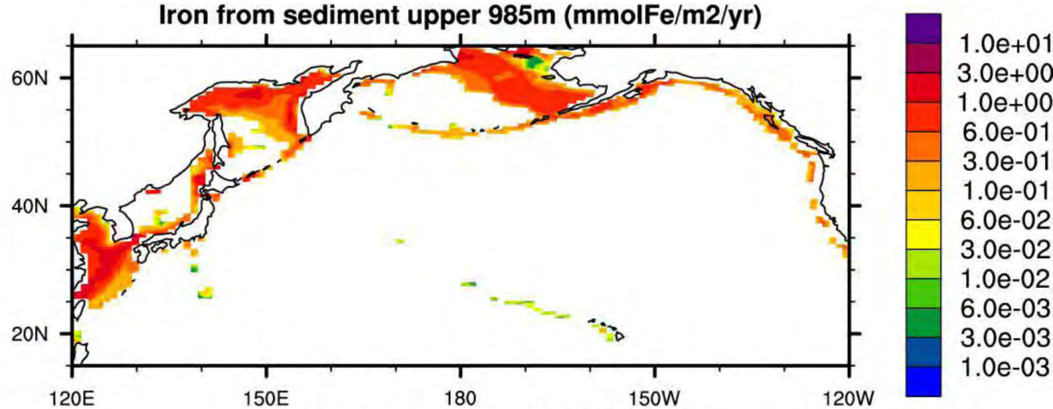
- 5 types of nutrients
- Carbonate system
- 4 types of phytoplankton (coccolithophores are implicitly included in pico/nano plankton)
- Chlorophyll synthesis
- 1 type of zooplankton
- 2 types of detritus

Iron cycle





Luo et al., (2003)



Moore & Braucher (2008)

Iron flux from shelves is estimated by sedimentation of organic matters

Scavenging parameterization

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

$$scav = -Sc \times dFe$$

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

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

0.6 nM in CTL

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

0.00384 $cm^2 ng^{-1}$

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

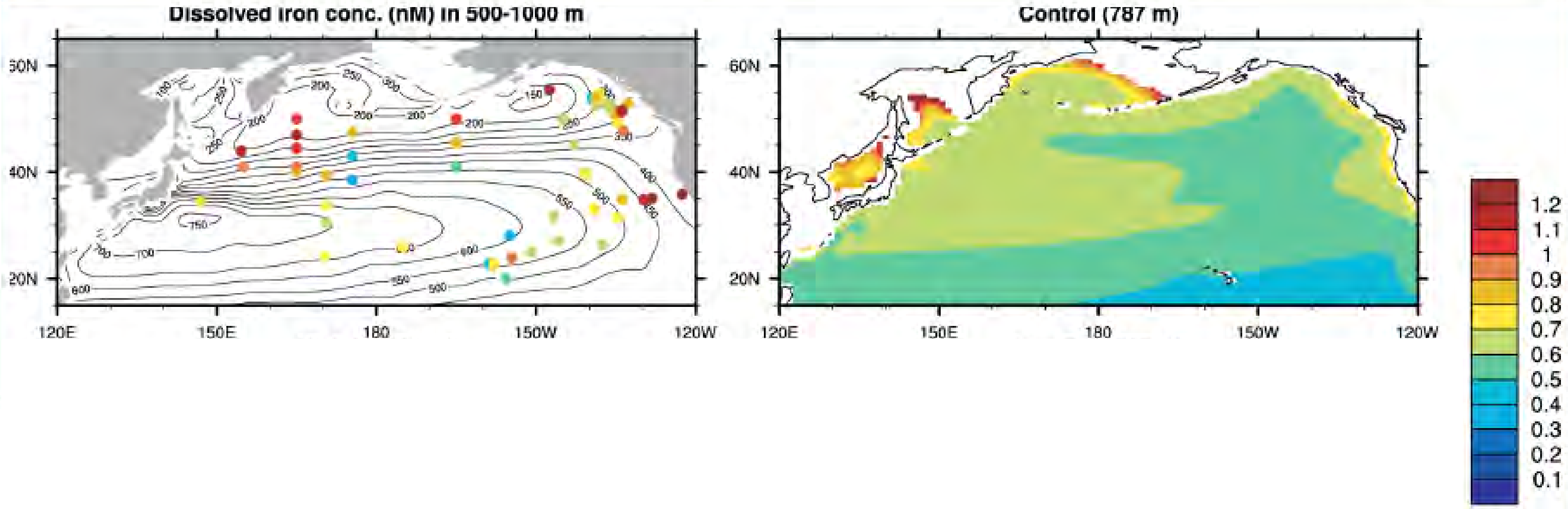
Values indicated in red are parameters.

(Moore & Braucher 2008)

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

Field data

Control



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

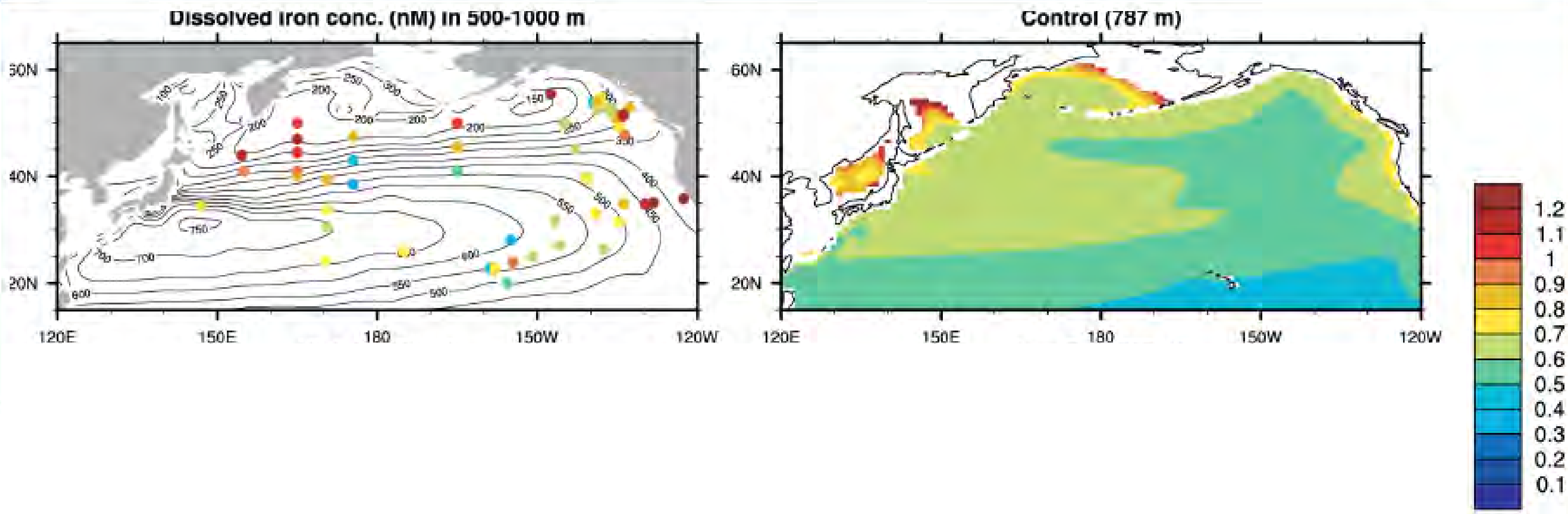
Experiment I: Scavenging parameters

Name	Scavenging Parameters			Iron Source	
	L	Feb	Chigh	Dust	Sediment
Control Moore and Braucher (2008)	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 deep water (nM)

Field data | Control

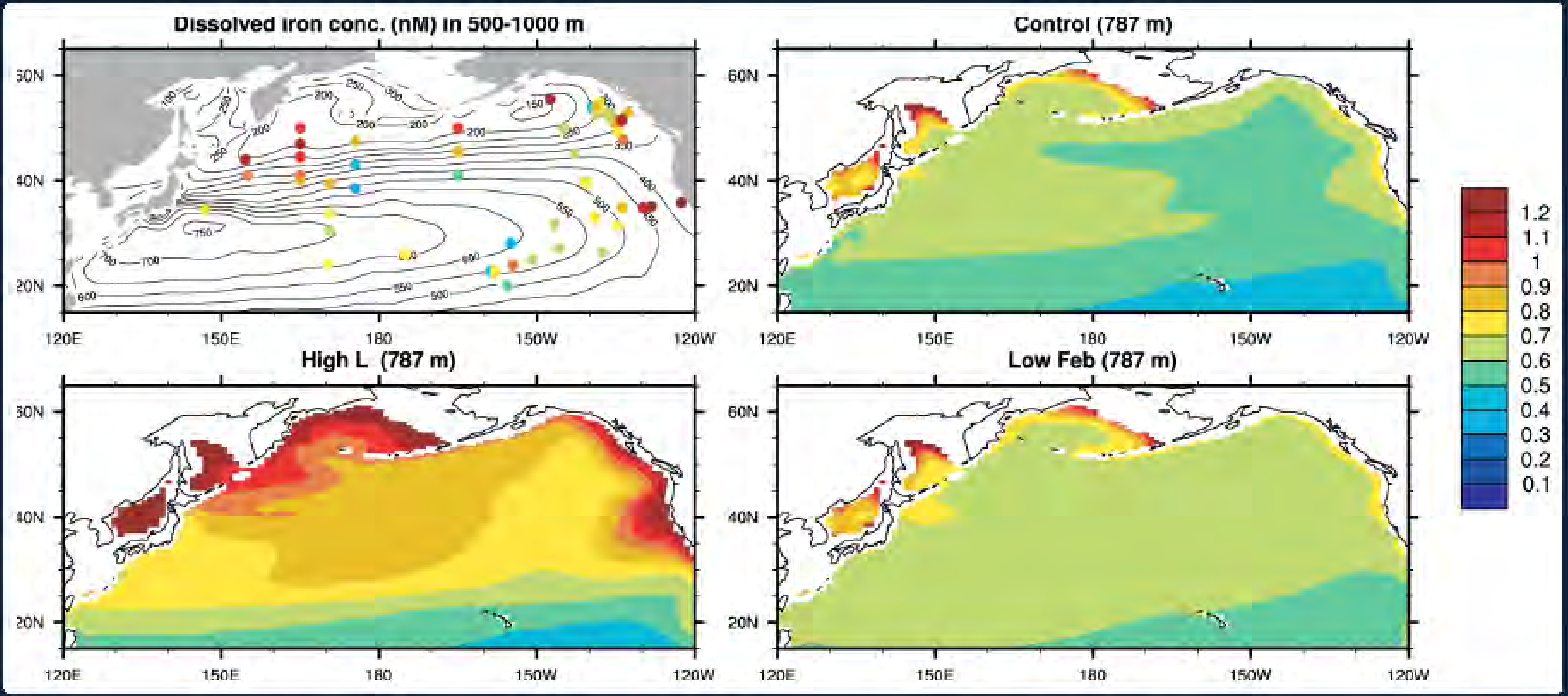


Field data used here are compiled data from Moore & Braucher (2008).

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

Field data

Control

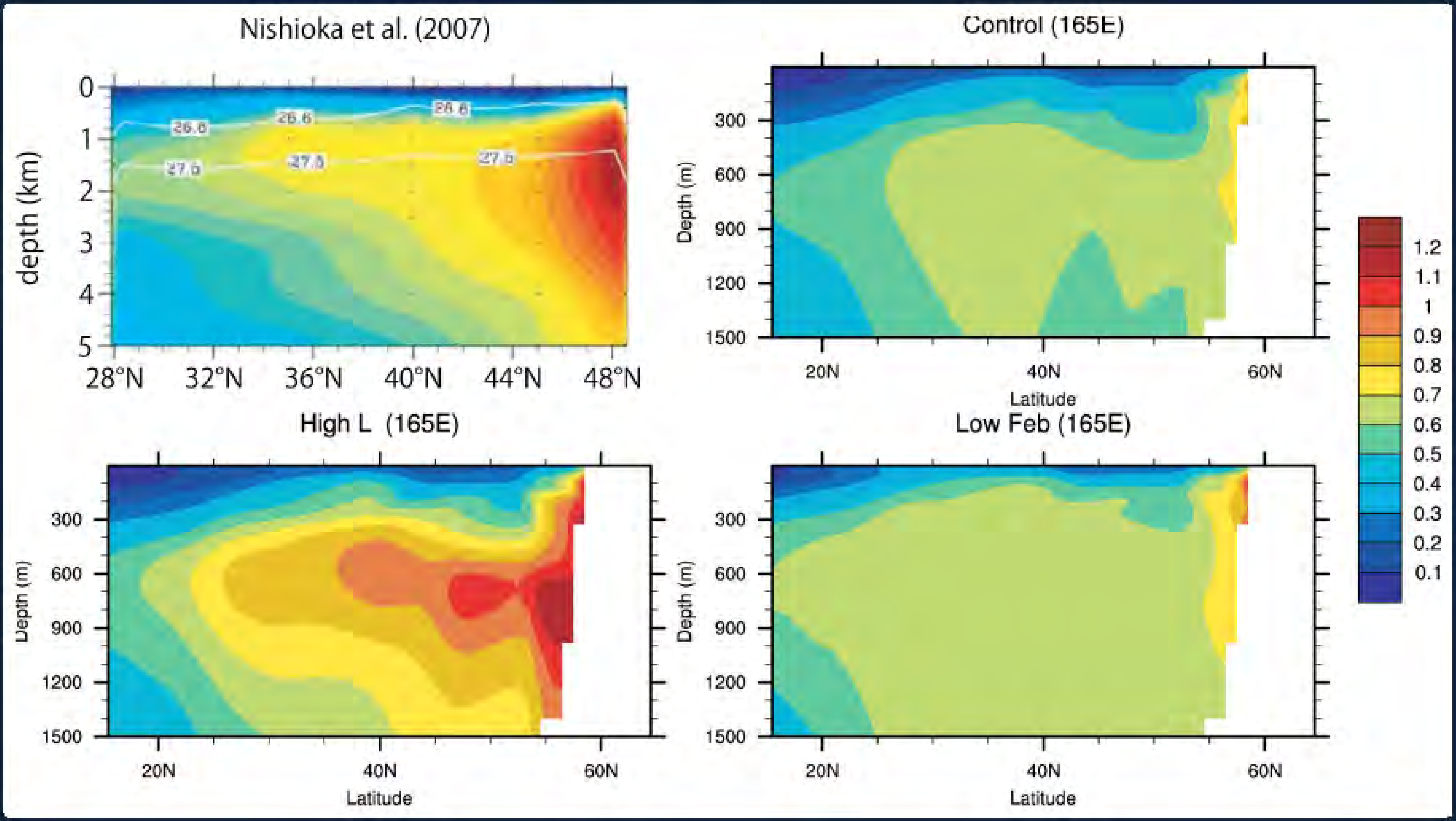


High L

Low Feb

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

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



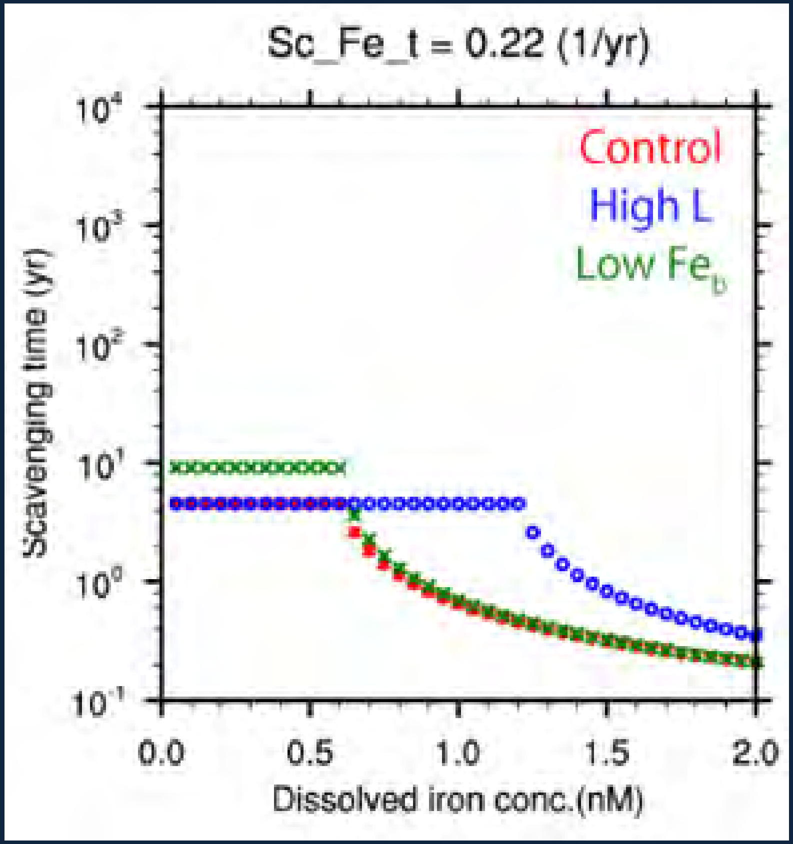
Effects of scavenging parameterization

- High ligand conc. case

Scavenging time becomes longer in high iron concentration regime, resulting in long-range penetration of SED Fe into the central Pacific.

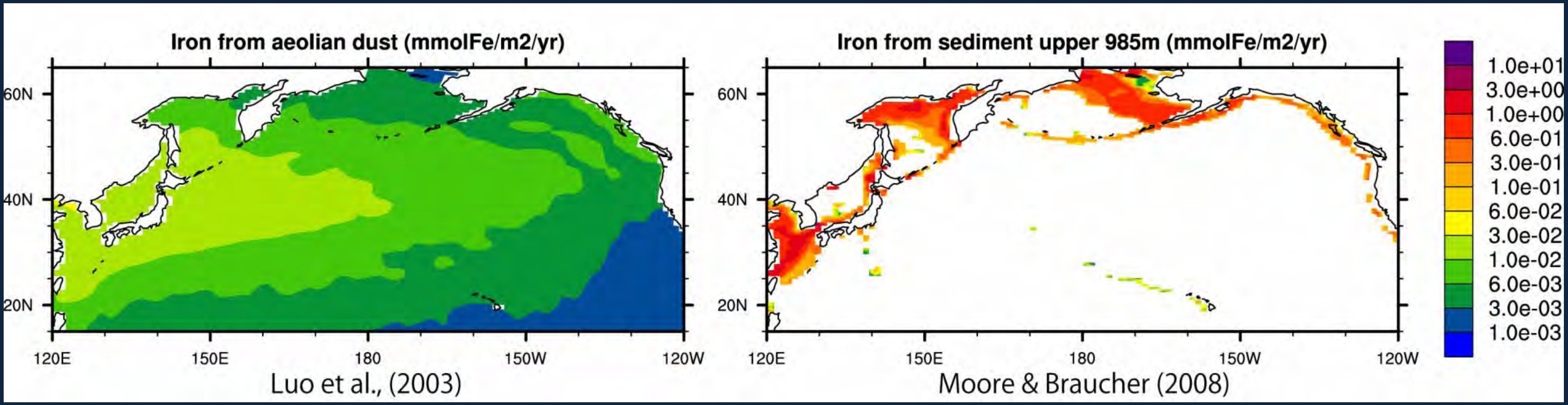
- Low Fe_b case

Scavenging time becomes longer in whole regimes of iron concentration, although it is not effective for the high iron concentration regime.



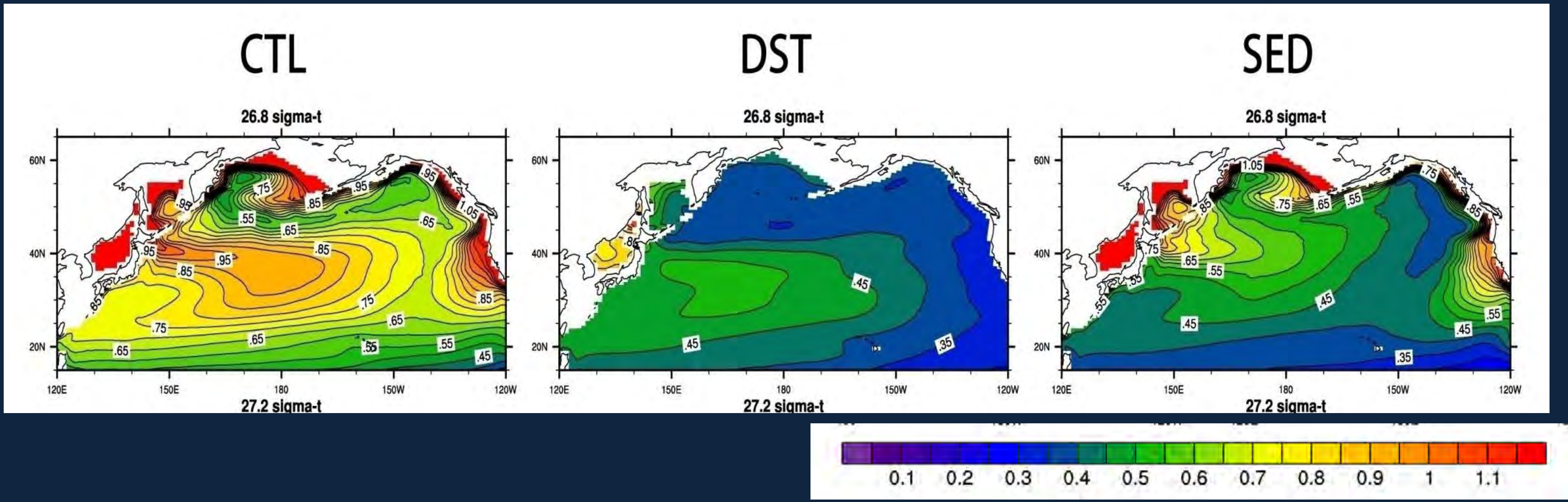
Experiment II: Dust vs Sediment

DST SED



Case	Iron source	
	Dust	Sediment
CTL (ligand 1.2 nM)	○	○
DST	○	×
SED	×	○

Results: Intermediate layer iron

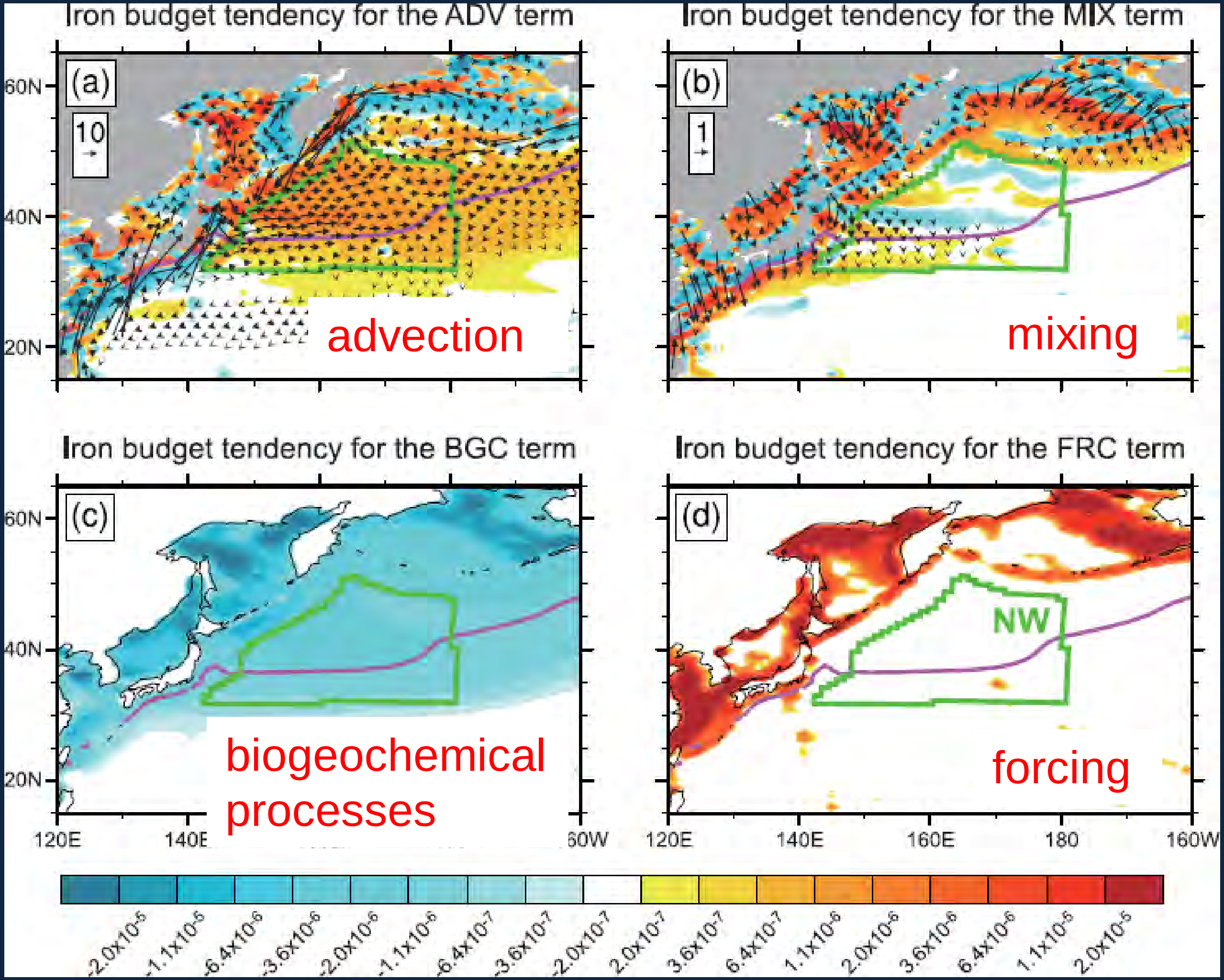


Misumi et al. (2011)

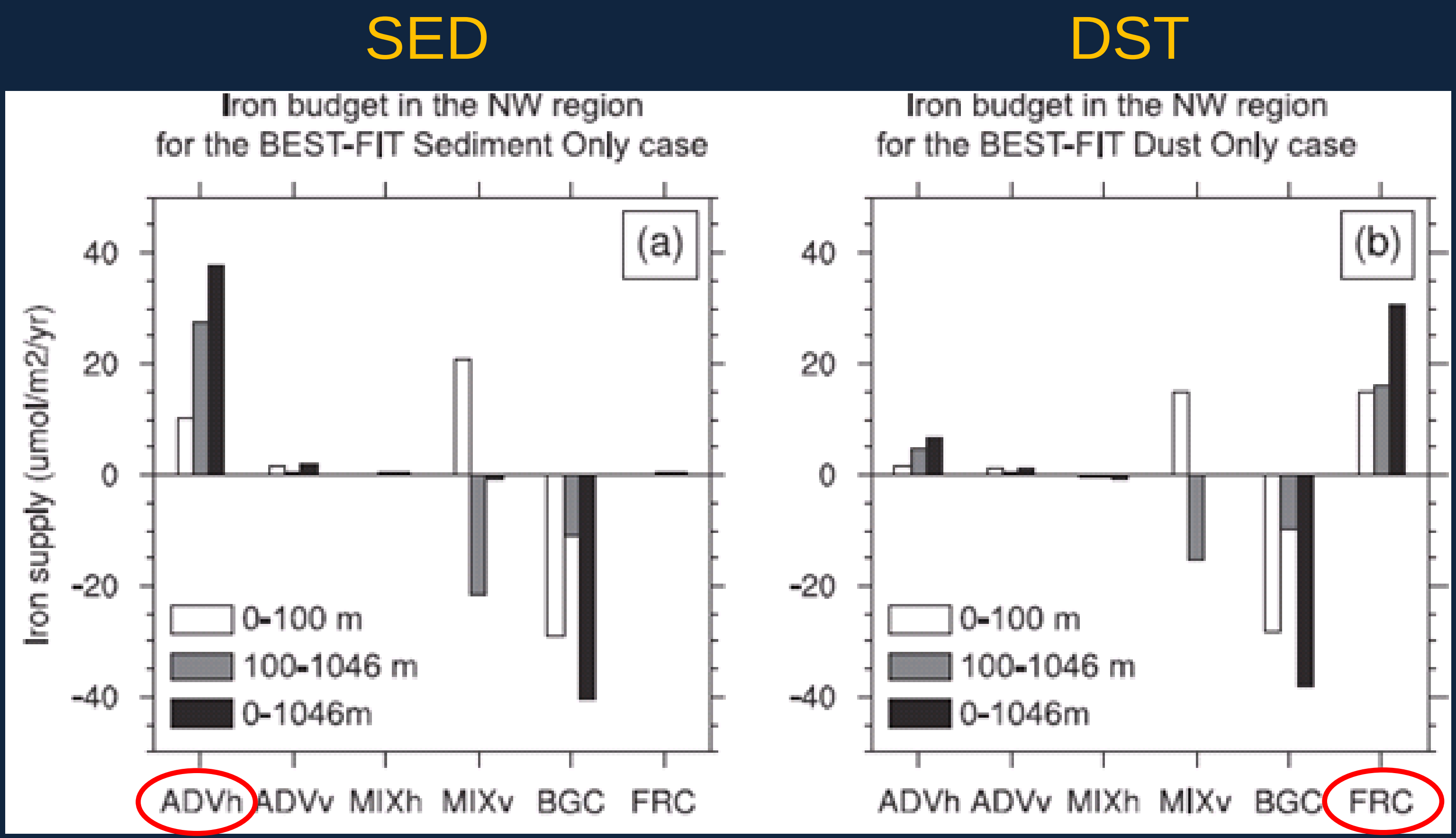
- Iron penetrates eastward from the Oyashio region in the SED case
- Iron is distributed in the subtropics in the DST case

What controls Iron budget?

SED case



Iron Budget in NW Pacific



- Advection is important in the Sediment Case: 3-D process
- Forcing is important in the Dust Case : 1-D process

Summary

- Ligand concentration strongly controls sedimentary iron transport to the open ocean, although it is not yet fully constrained by observations.
- Experiment with the high ligand concentration (1.2nM) well reproduces the observed Fe concentration by long-range penetration into the North Pacific.
- Sedimentary iron is likely to contribute to biological production in the western north Pacific via advection.
- Intermediate layer transport driven by ice production is not represented well in the model, so that the sedimentary iron from Okhotsk may be underestimated. Uchimoto’s talk later in this session directly addresses the transport processes by dense shelf water.