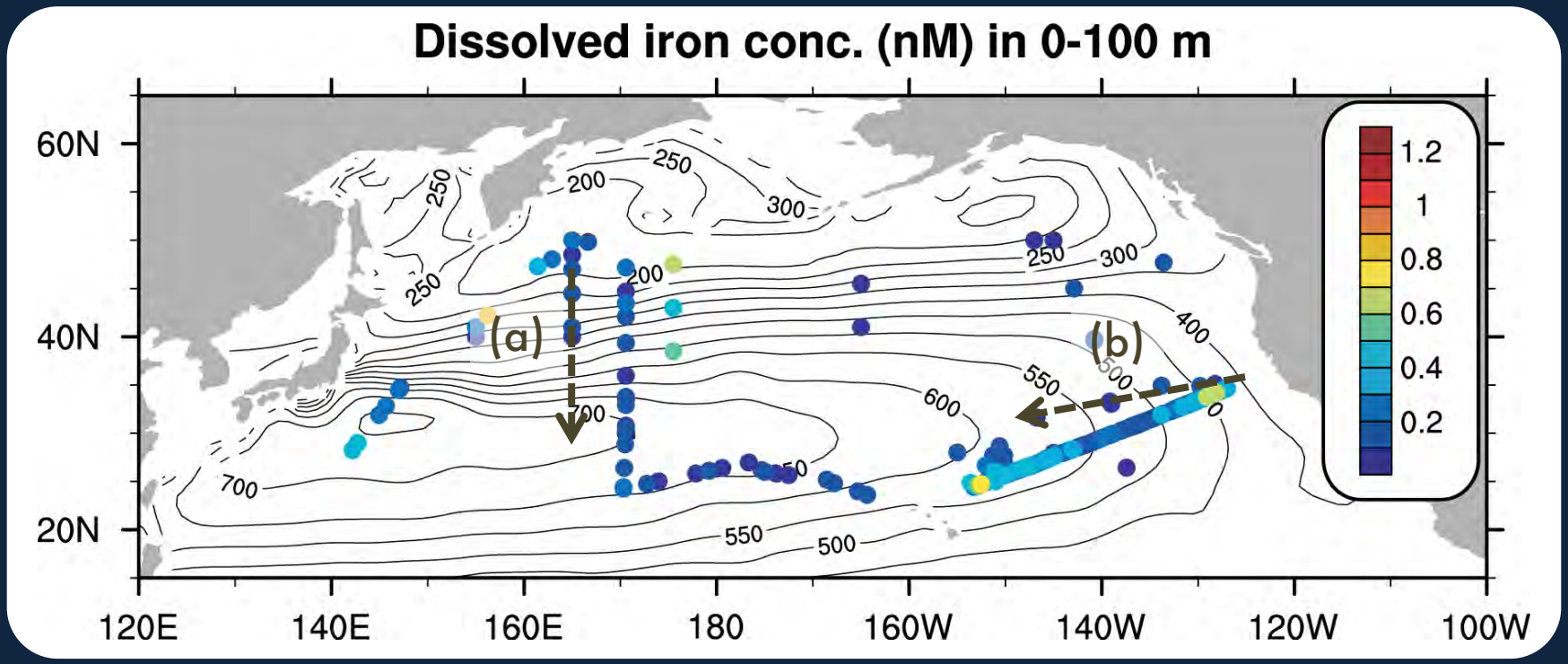
Mechanisms controlling dissolved iron distribution in the North Pacific: A model study

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

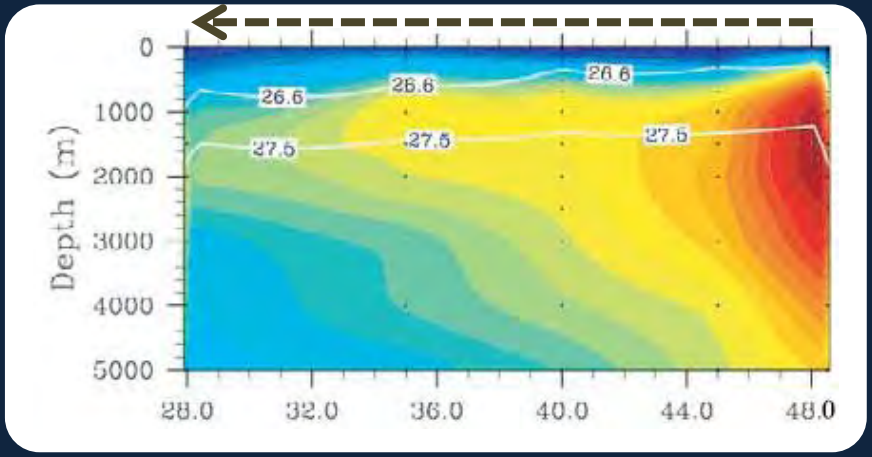
1. Central Research Institute of Electric Power Industry, Japan
2. Hokkaido University, Japan
3. National Center for Atmospheric Research, U.S.A.
4. University of California at Irvine, U.S.A.
5. Woods Hole Oceanographic Institution, U.S.A.

(Submitted to JGR –biogeosciences)

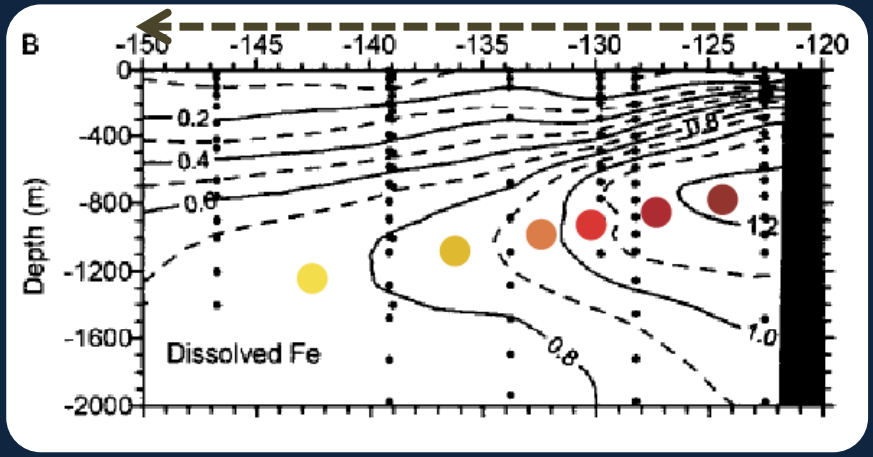


Contour lines are depth of 26.8σ_θ surface. Compiled dFe data are from Moore & Braucher (2008).

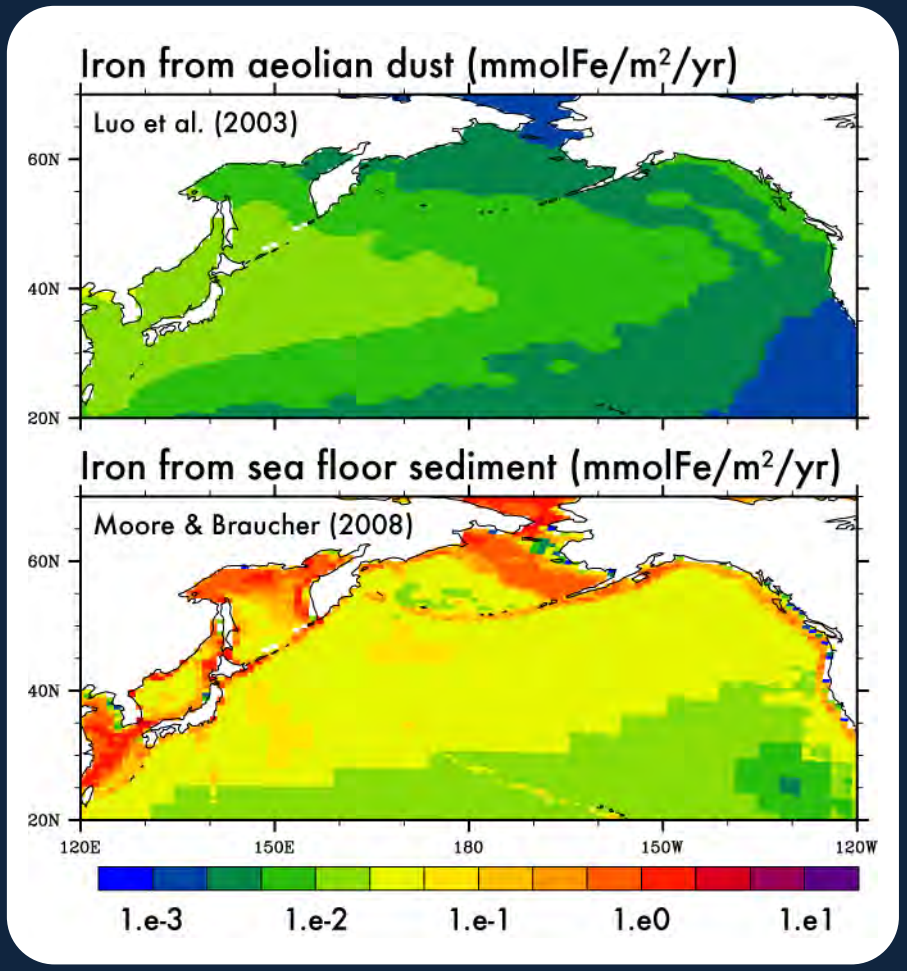
(a) Nishioka et al. (2007)

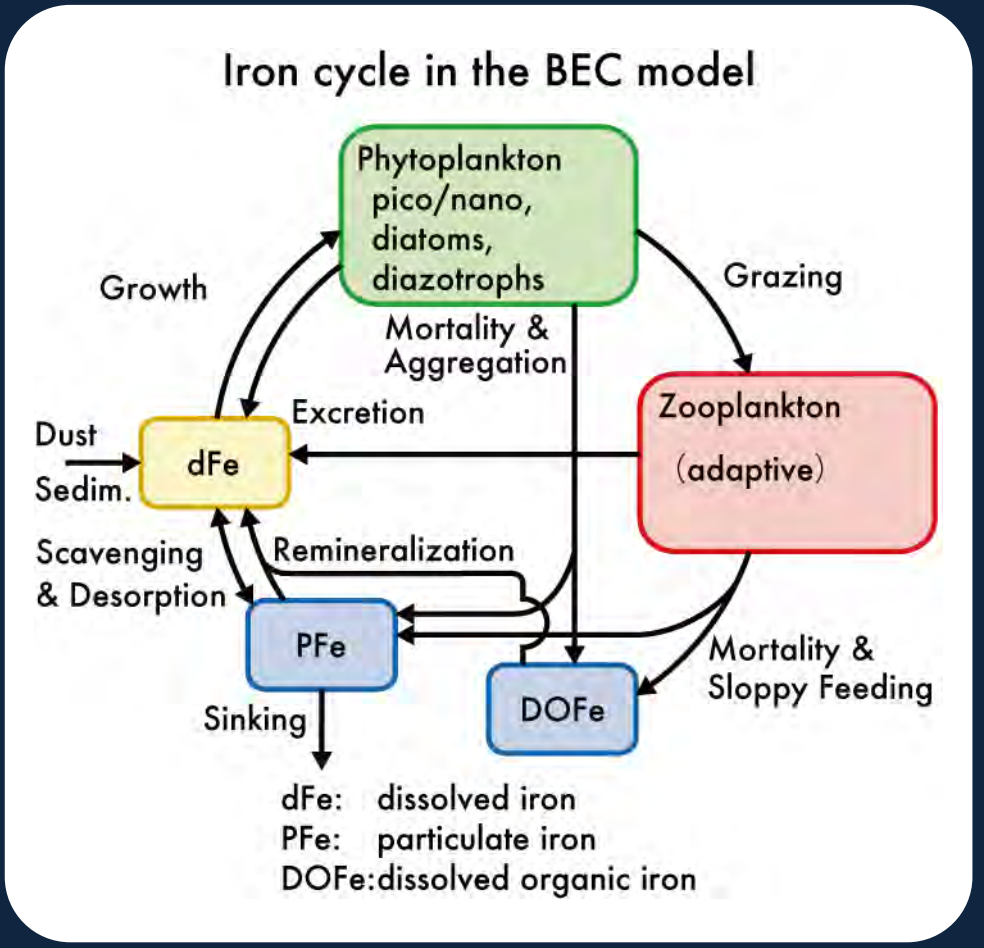


(b) Johnson et al. (1997)



Model


Iron from aeolian dust (mmolFe/m²/yr)
Luo et al. (2003)
60N
40N
20N
Iron from sea floor sediment (mmolFe/m²/yr)
Moore & Braucher (2008)
60N
40N
20N
120E
150E
180
150W
120W
1.e-3
1.e-2
1.e-1
1.e0
1.e1


Iron cycle in the BEC model
Phytoplankton
pico/nano,
diatoms,
diazotrophs
Growth
Grazing
Mortality &
Aggregation
Excretion
Zooplankton
(adaptive)
Dust
Sedim.
dFe
Scavenging
& Desorption
Remineralization
PFe
Mortality &
Sloppy Feeding
DOFe
Sinking
dFe: dissolved iron
PFe: particulate iron
DOFe: dissolved organic iron

$$scav = -Sc \times dFe$$

$$Sc = Sc_b, \qquad where\ dFe \leq L$$

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

$$Sc_b = Fe_b \times (sinking\ particle\ fluxes)$$

Ctrl : The same parameters as in Moore & Braucher (2008): L=0.6 nM, Fe_b=0.0384 $cm^2\ ng^{-1}$

High L : L is increased by a factor of two (high ligand conc.)

Low Fe_b : Fe_b is decreased by a factor of two (low affinity to particles)

scav: tendency of dFe owing to iron scavenging

Sc: scavenging rate

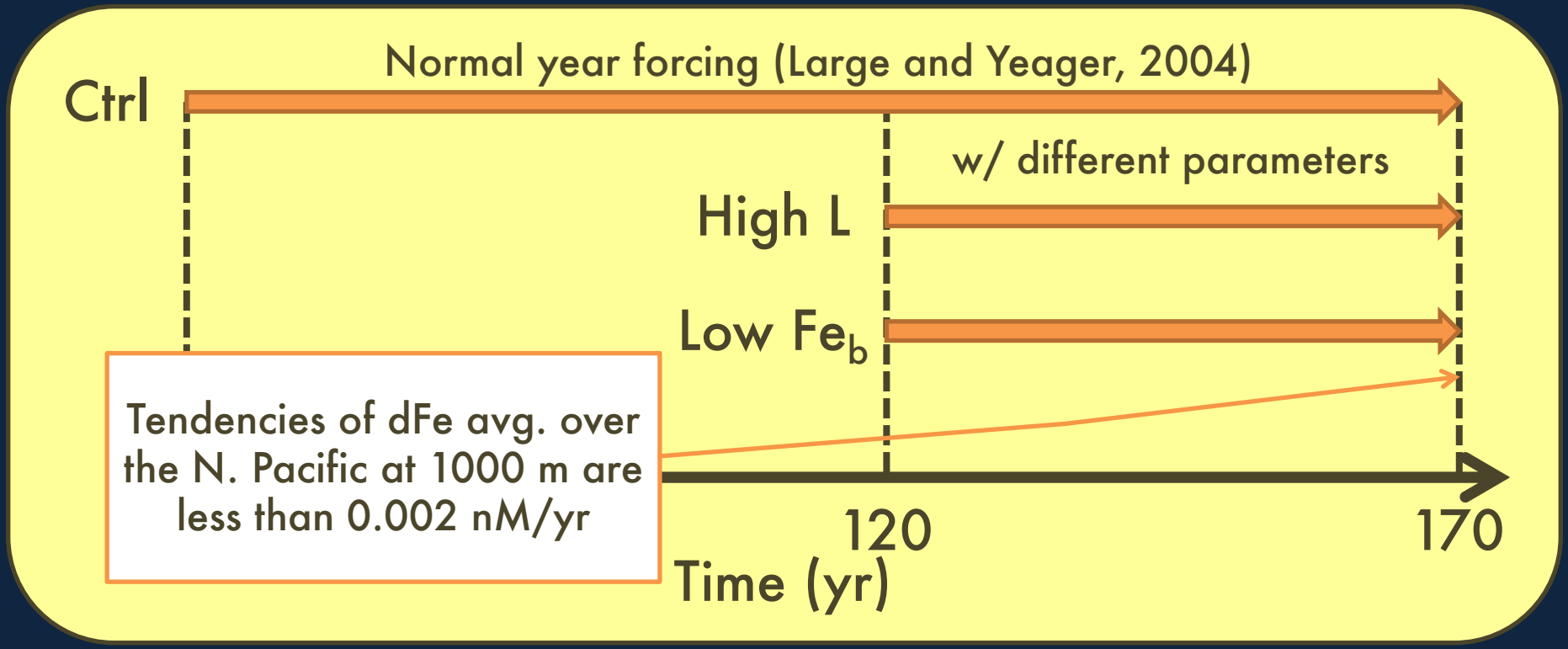
L: ligand conc.

Fe_b: base scavenging coefficient

Sc_b: base scavenging rate

C_{high}: proportional constant

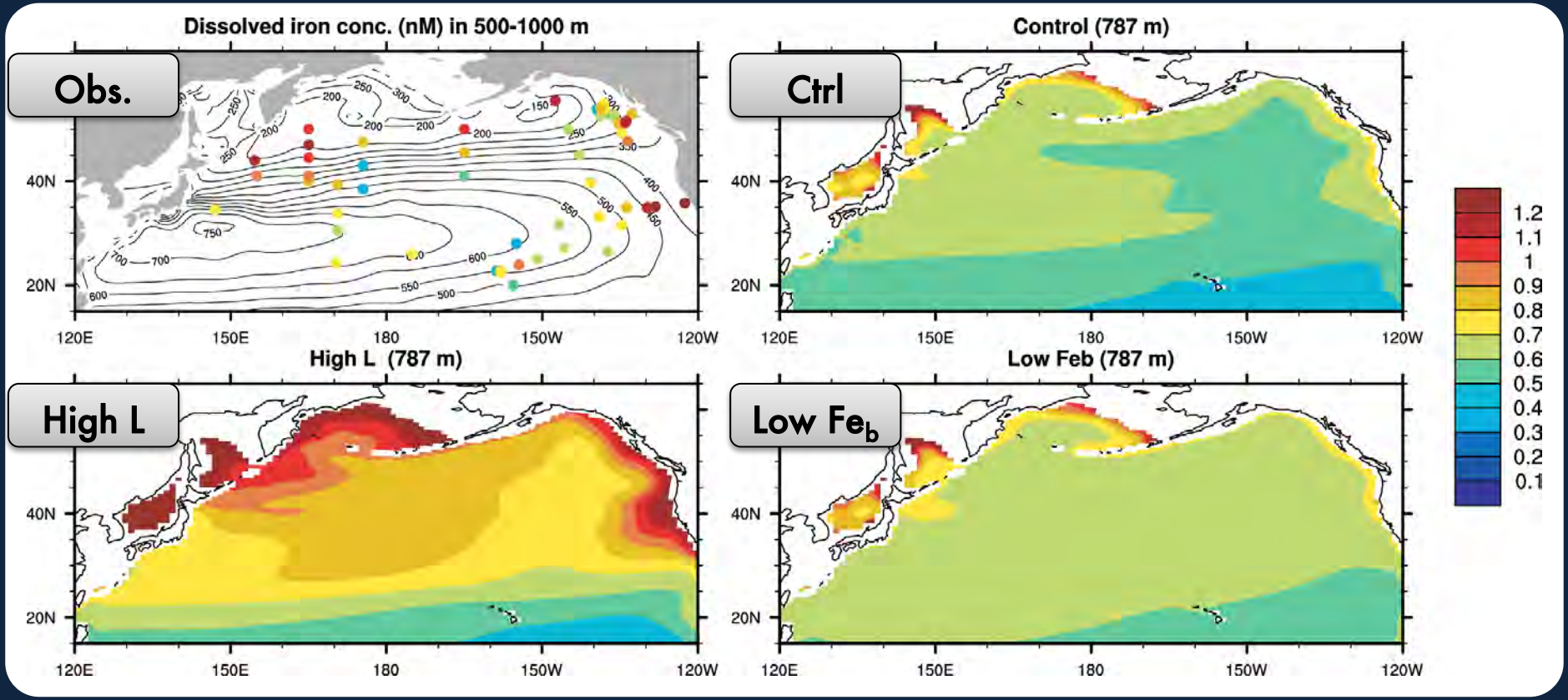
Experimental design



I.C.: T, S (PHC2, Steele et al., 2001); Macro nutrients (WOA98, Conkright et al., 1998); DIC & Alk (GLODAP, preindustrial, Key et al., 2004); Iron (Moore and Doney, 2007).

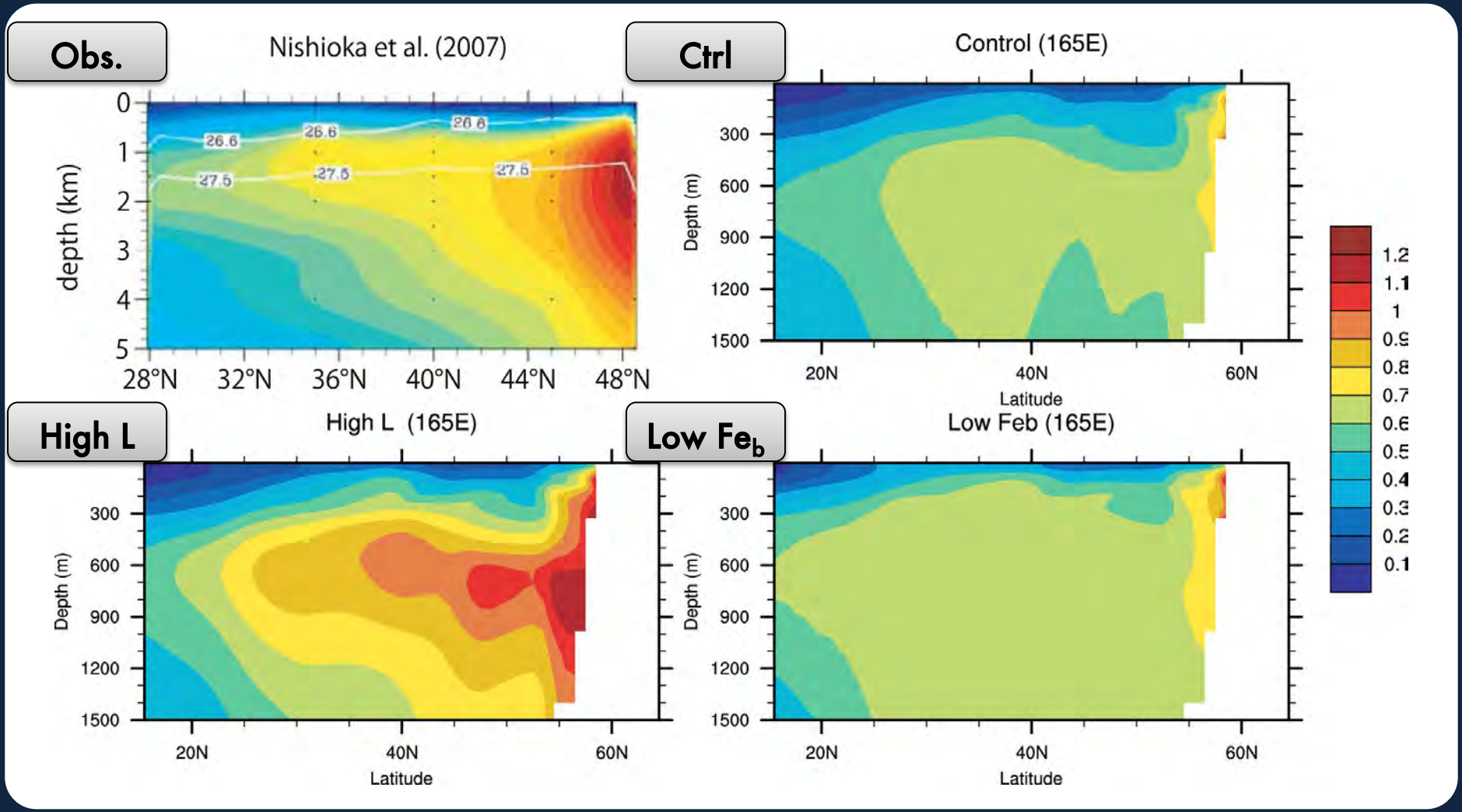
Normal year forcing: 6-hourly atmos. state based on NCEP reanalysis (Kalnay et al., 1996); Daily satellite radiation data (Zhang et al., 2004); Monthly prec. from Xie & Arkin (1996) & GPCP (Huffman et al., 1997).

Comparison of horizontal distribution



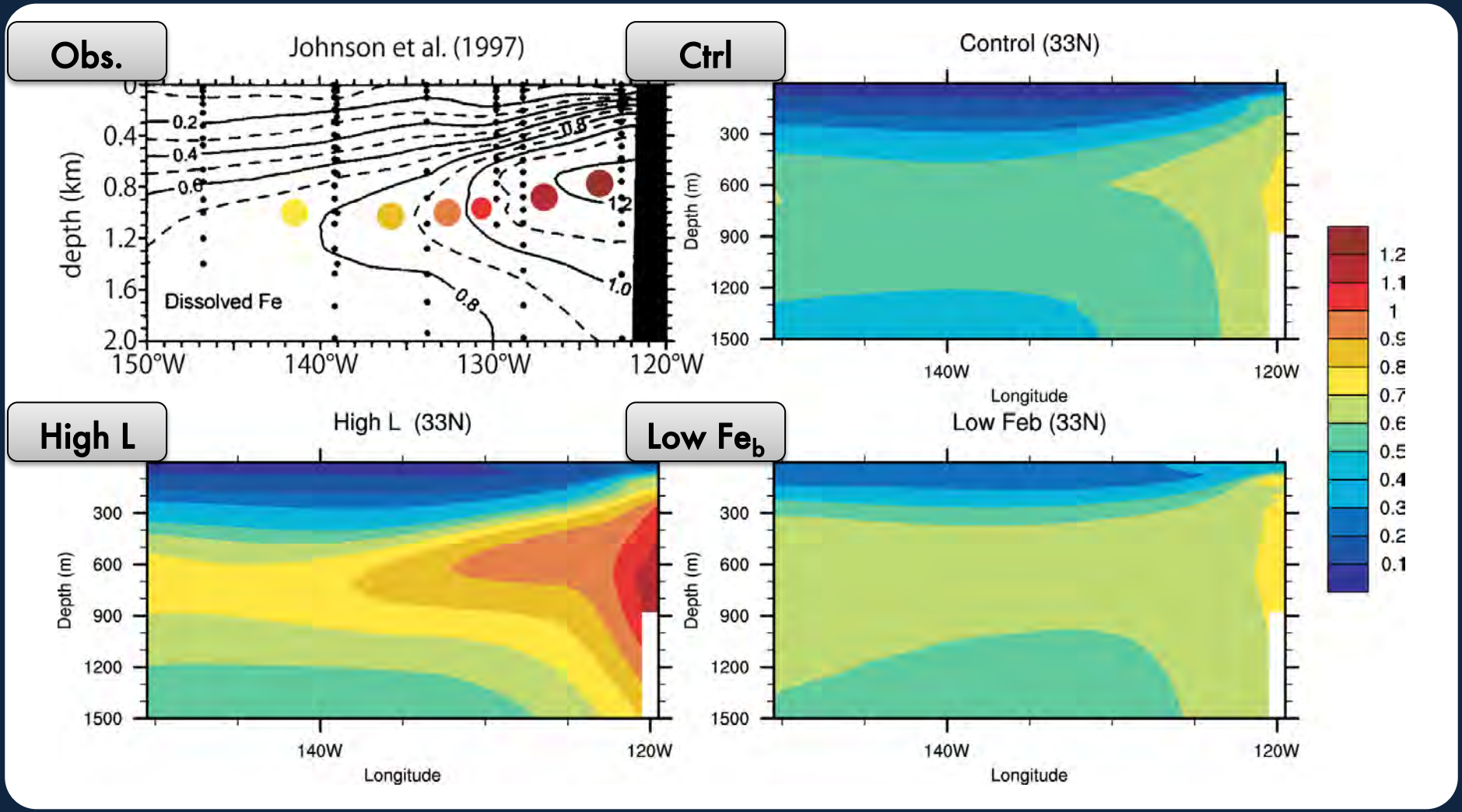
Field data used here are compiled data from Moore & Braucher (2008).

Comparison along 165° E



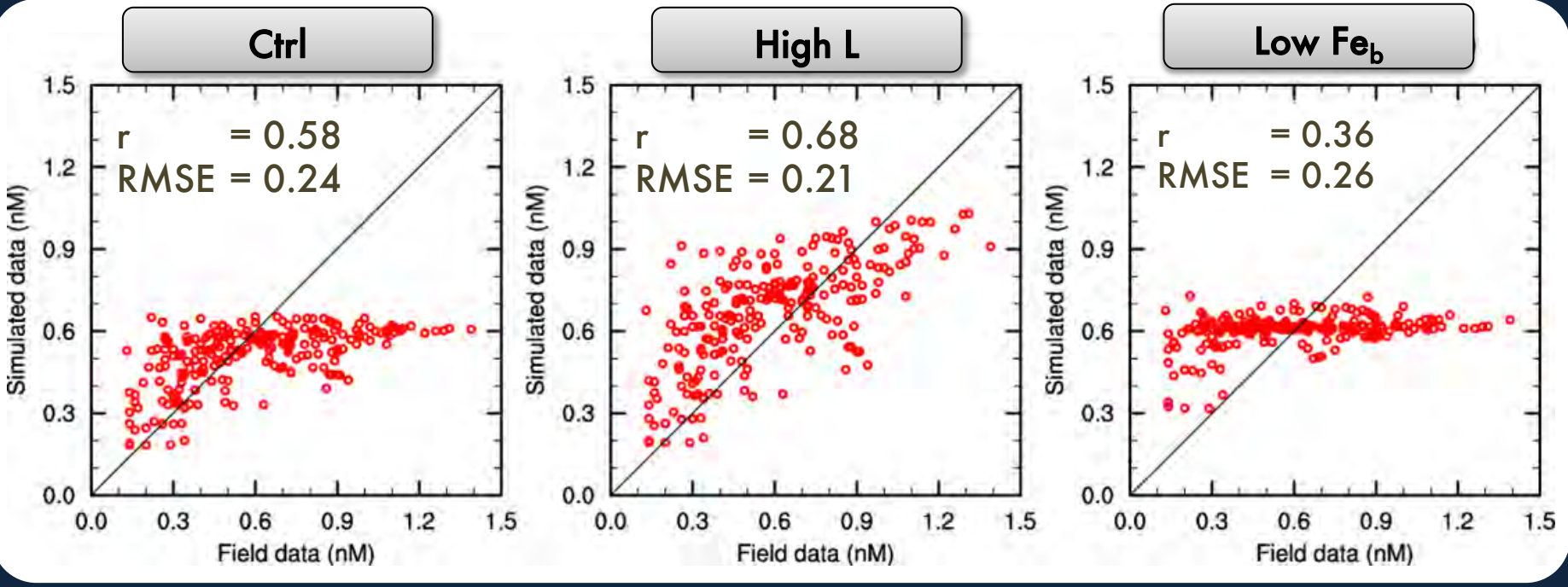
Field data used here are from Nishioka et al., (2007).

Comparison along 33°N



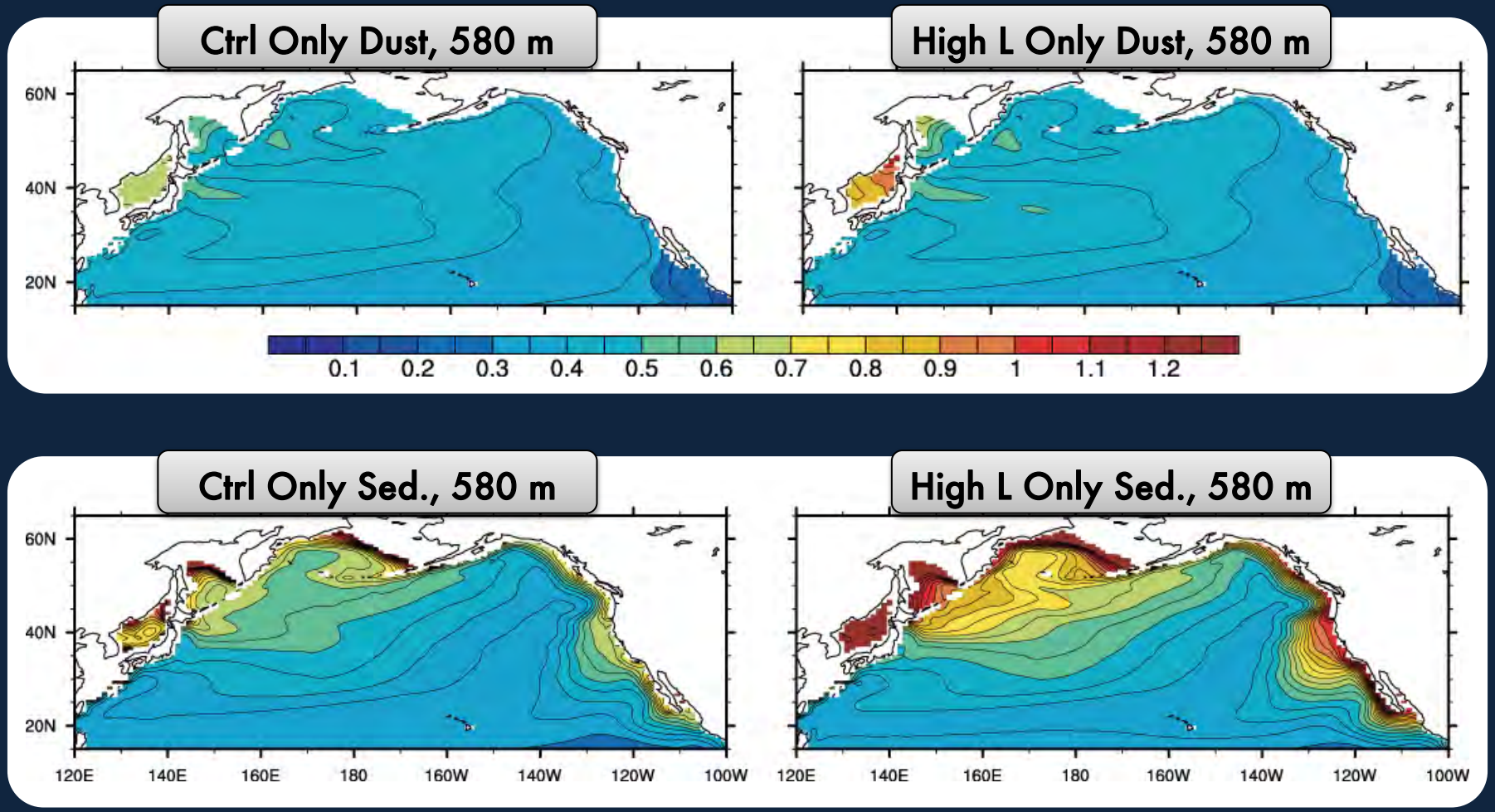
Field data used here are from Johnson et al., (1997).

Field data vs. Simulated data
(data between 200 m and 1000 m, N=244)



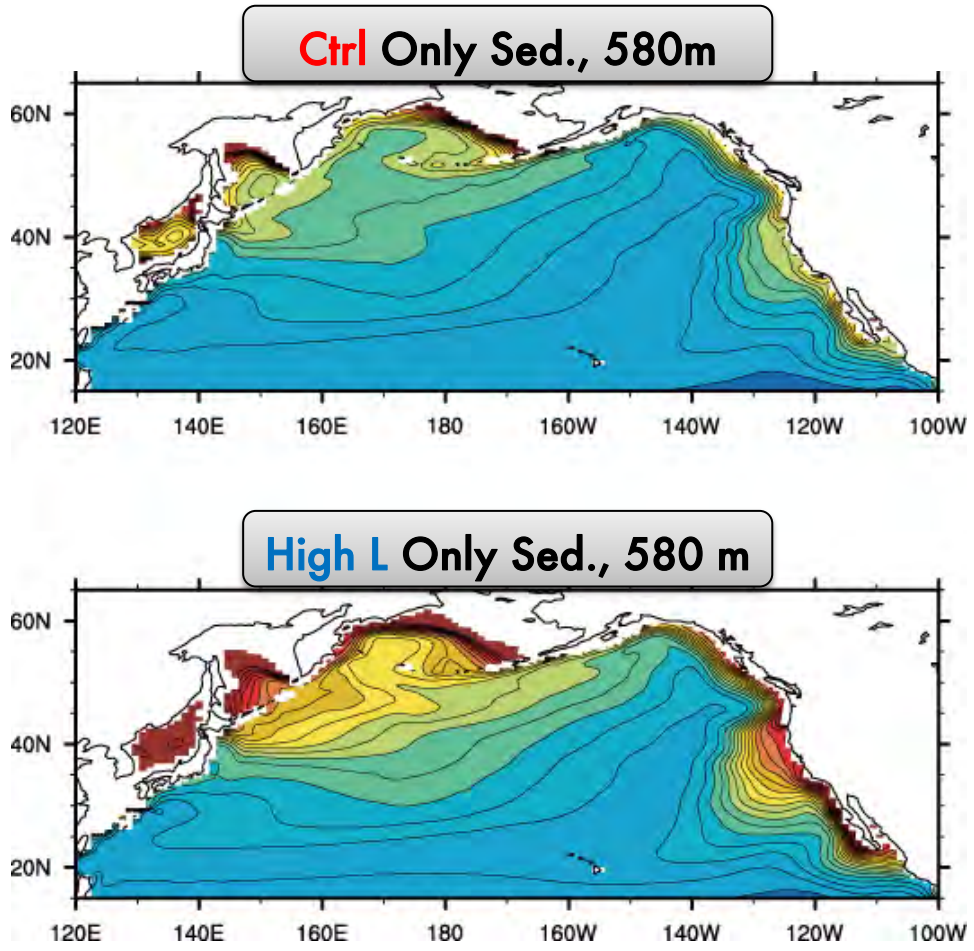
The High L case better simulates
the spatial variations of dFe in the N. Pacific.

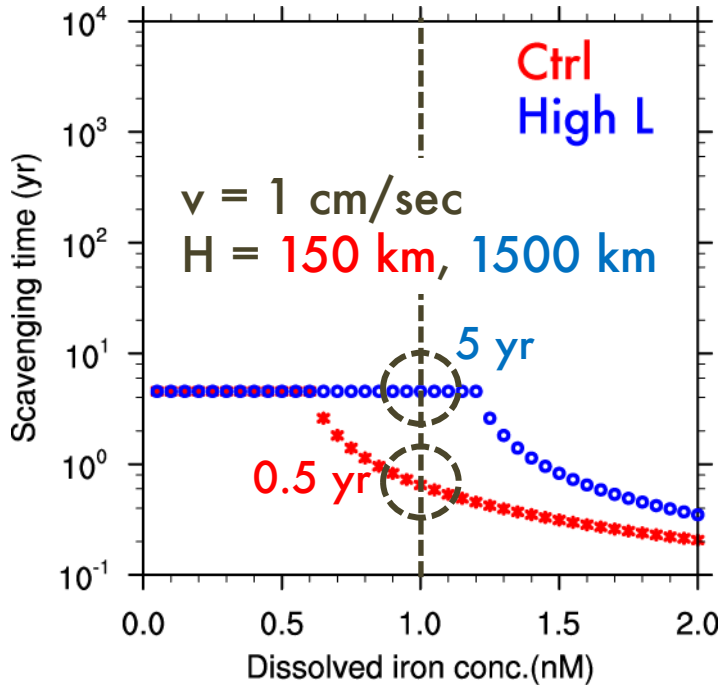
Field data used here are compiled data from Moore & Braucher (2008).
Data near the coast (< 500 km) were excluded.
Simulated data are sub-sampled from the same month, location, and depth as the field data.



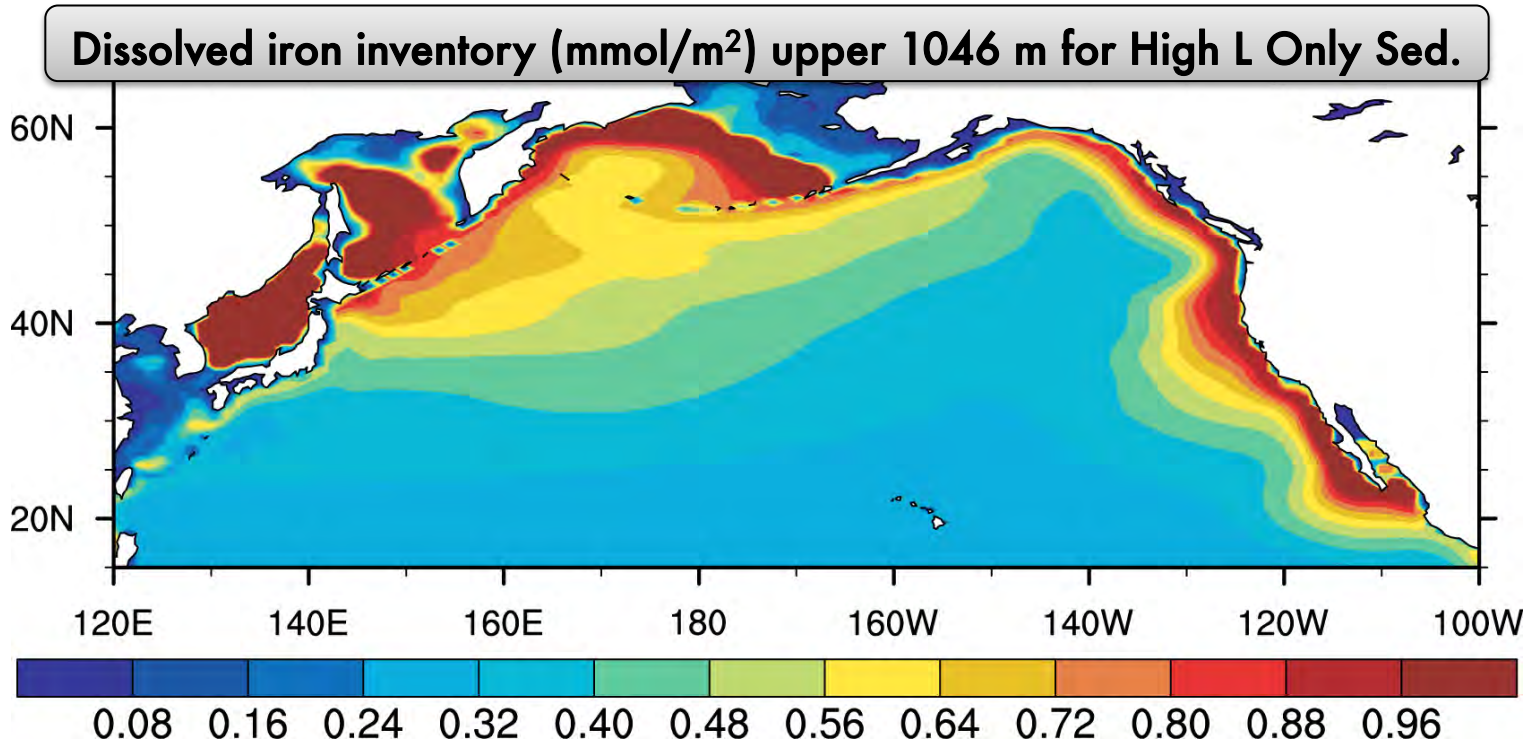
The increase in "L" facilitates sedimentary iron transport to the open ocean, resulting in the better skill in the High L case.

Why does increase in "L" facilitate sedimentary iron transport ?

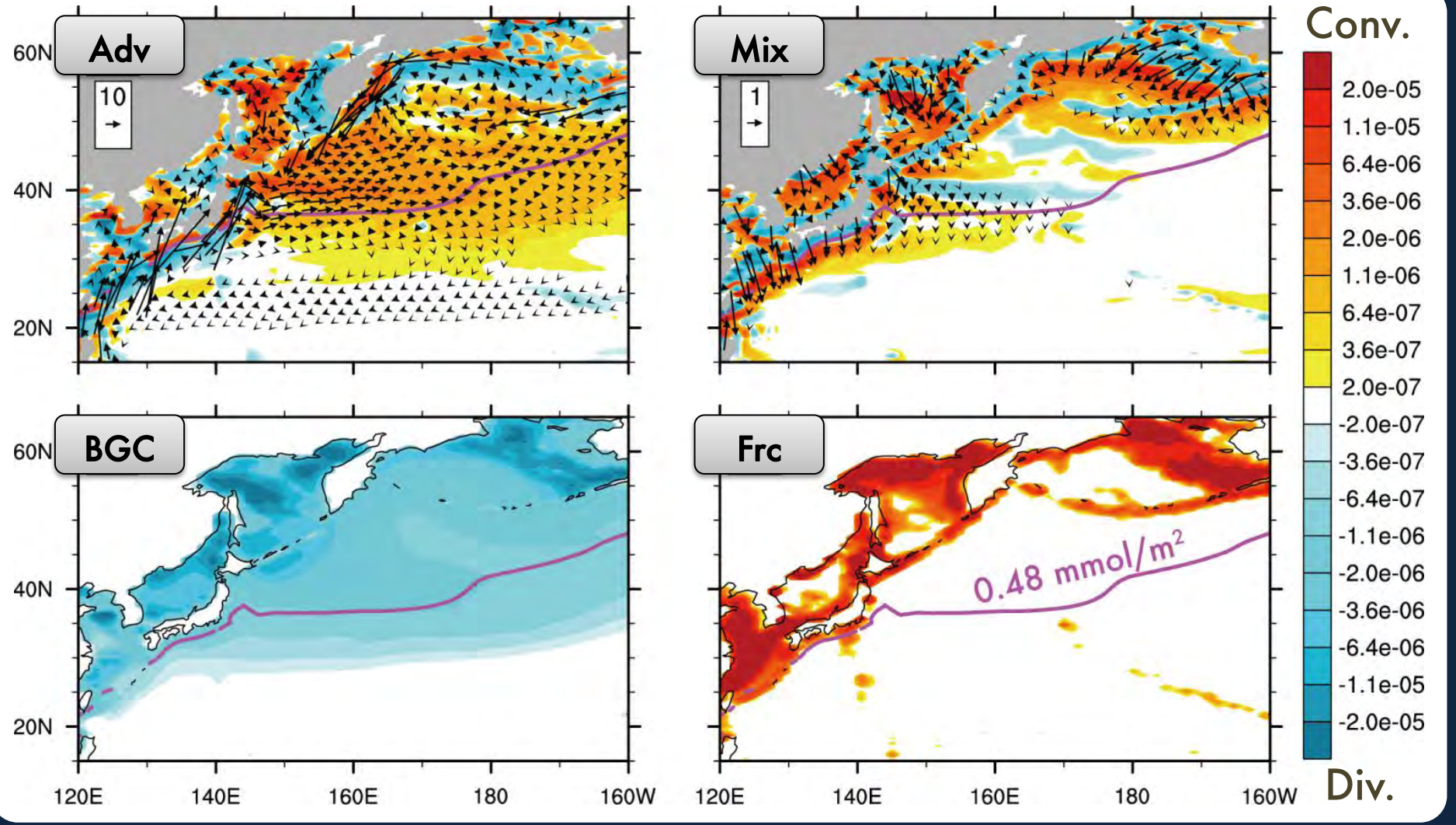


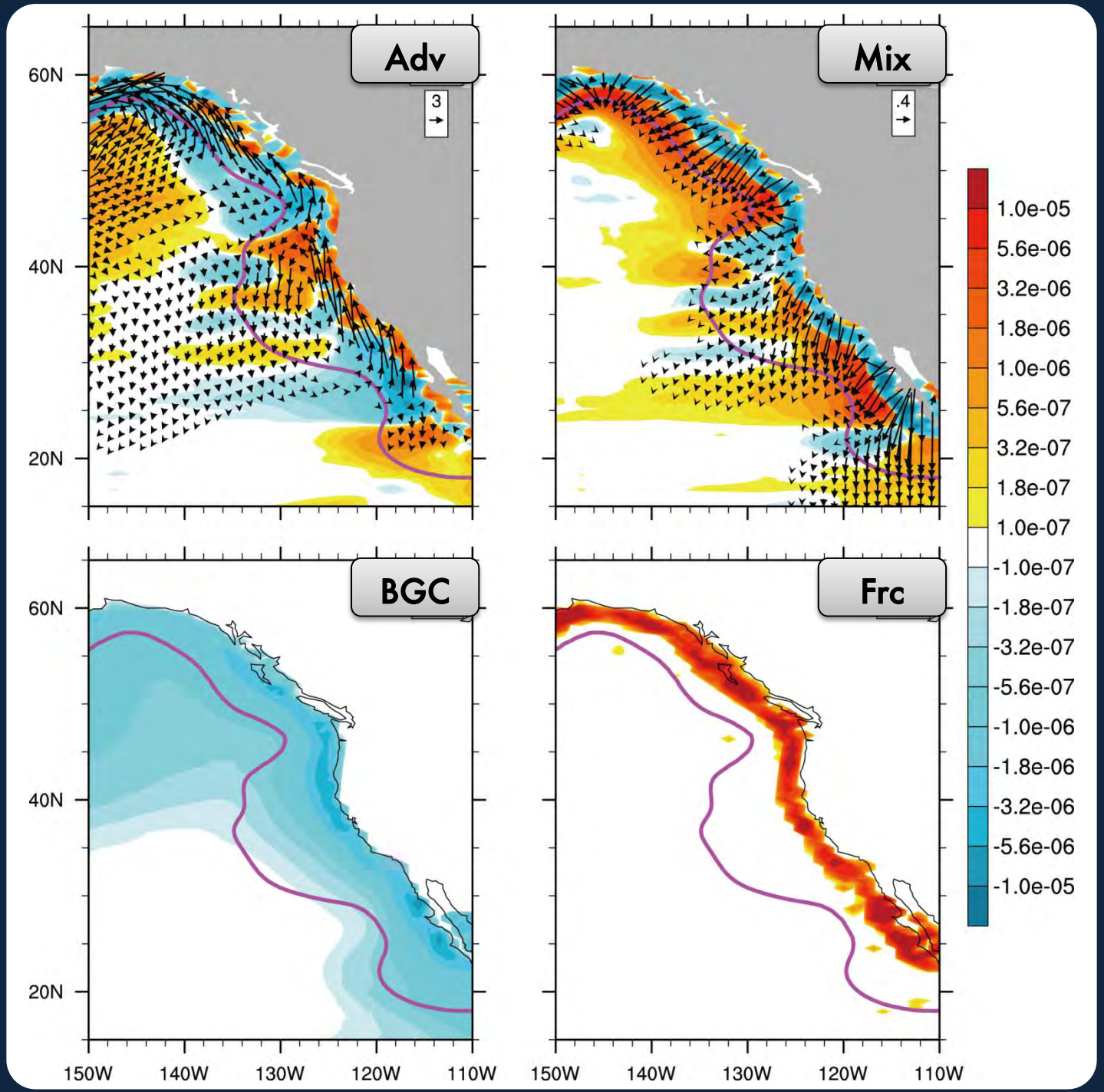


What determines the spatial pattern?



Vectors are horizontal dFe fluxes (nmol m^{-2} sec^{-1});
Colors are flux convergence (supply) and divergence (removal) (nmol m^{-3} sec^{-1}).




Adv
3
Mix
.4
BGC
Frc
60N
40N
20N
150W
140W
130W
120W
110W
1.0e-05
5.6e-06
3.2e-06
1.8e-06
1.0e-06
5.6e-07
3.2e-07
1.8e-07
1.0e-07
-1.0e-07
-1.8e-07
-3.2e-07
-5.6e-07
-1.0e-06
-1.8e-06
-3.2e-06
-5.6e-06
-1.0e-05

Summary

- Mechanisms controlling dissolved iron distributions in the N. Pacific are examined using the BEC model; the model reproduces well the major features in the iron distribution of the N. Pacific.

- We reveal a plausible iron scavenging regime in the N. Pacific:
  - high iron concentrations (1 nM) have long residence times (O(years)),
  - low iron concentrations (below L) are subject to a moderate scavenging.

- Sedimentary iron is transported to the open ocean by the following processes:
  - horizontal mixing transports it to offshore and into currents along the coast,
  - it penetrates into the open ocean in regions where alongshore currents leave the margin.
- For this reason, high concentrations are observed especially in the northwestern N. Pacific and off of California.