Oceanic iron supply mechanisms supporting the spring diatom bloom in the Oyashio region, western subarctic Pacific

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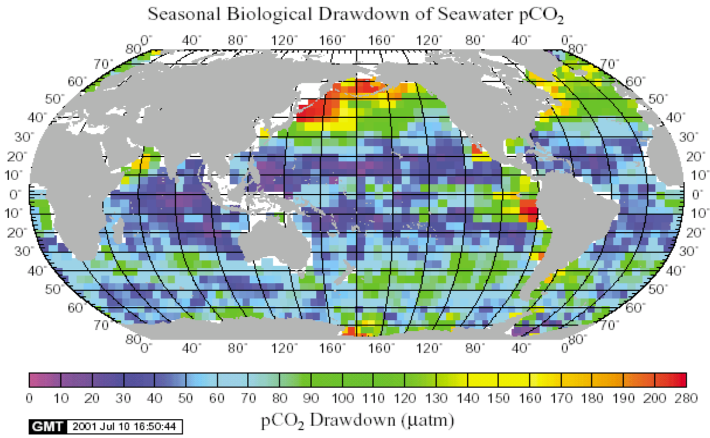
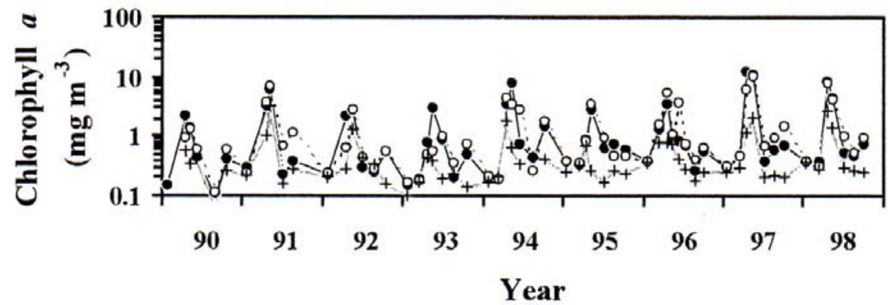
Iron limits phytoplankton growth in the subarctic North Pacific.

However, WSP is often more productive ....



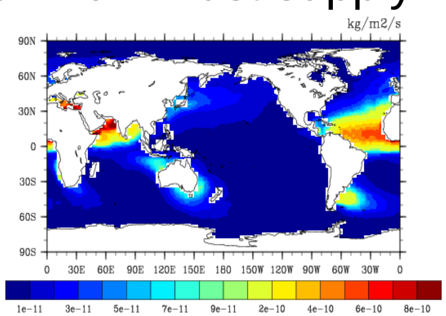
High biological drawdown in pCO_2 in the Oyashio, Oyashio-Kuroshio transition zone (Takahashi et al., 2002)



Oyashio time series data in Chl.a concentration from 1989-1998 （Saito et al., 2002)

What is major Iron supply processes for the seasonal production in WSP

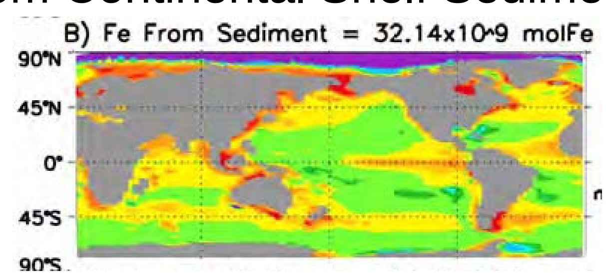
Iron from Dust supply



Mahowald et al., 2005、GBC

and/or

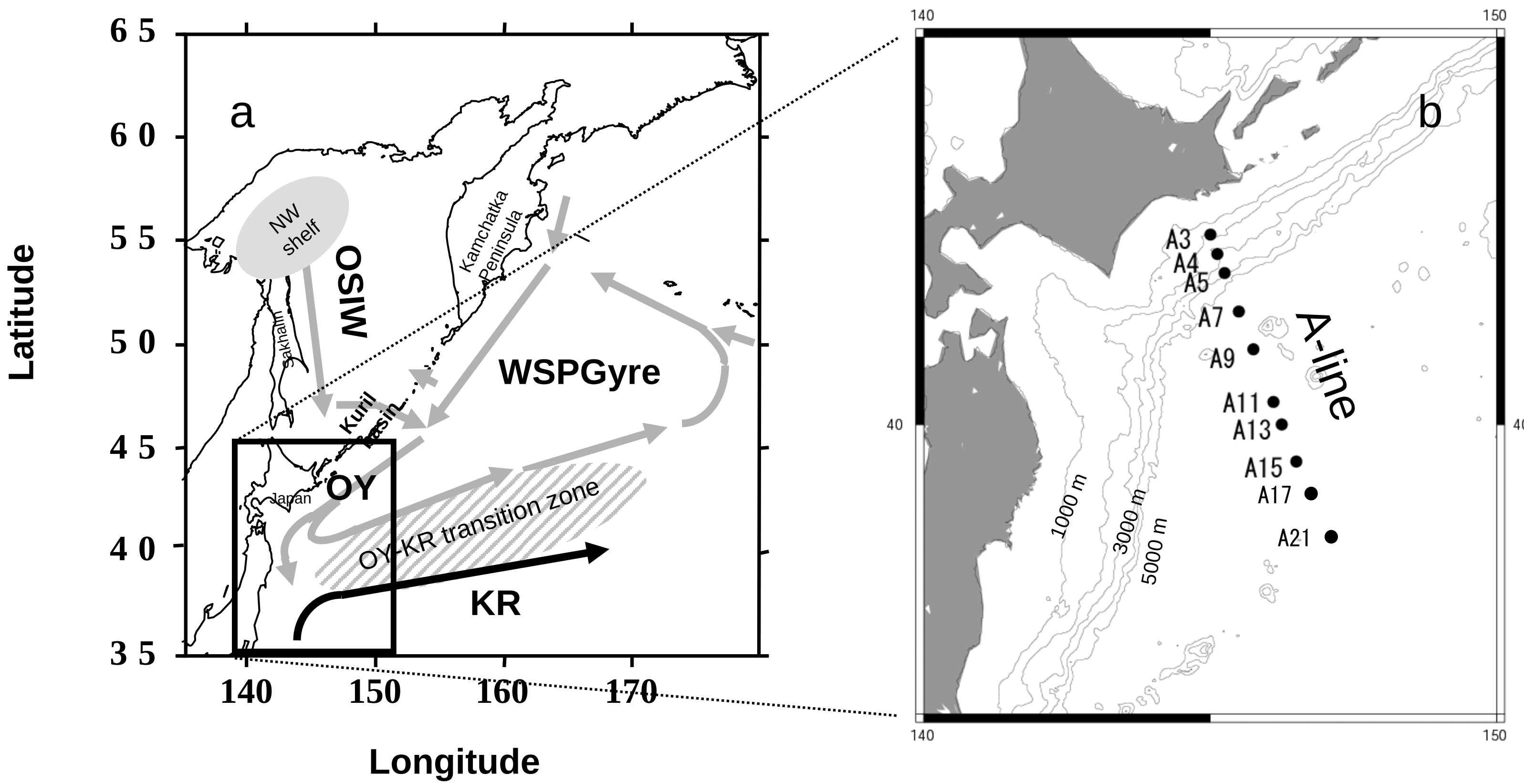
Iron from Continental Shelf Sediment



Moore and Braucher., 2008、Biogeosciences

Time series iron observation in the western subarctic Pacific (WSP)

Observation site



Temporal variability of Fe concentration is one of important information on **determine the source and seasonal timing of Fe input**

Time series iron observation in the western subarctic Pacific (WSP)

Frequency

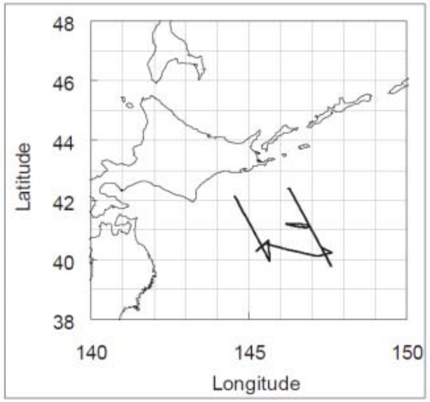
2003	J	F	M	A	M	J	J	A	S	O	N	D
2004	J	F	M	A	M	J	J	A	S	O	N	D
2005	J	F	M	A	M	J	J	A	S	O	N	D
2006	J	F	M	A	M	J	J	A	S	O	N	D
2007	J	F	M	A	M	J	J	A	S	O	N	D
2008	J	F	M	A	M	J	J	A	S	O	N	D

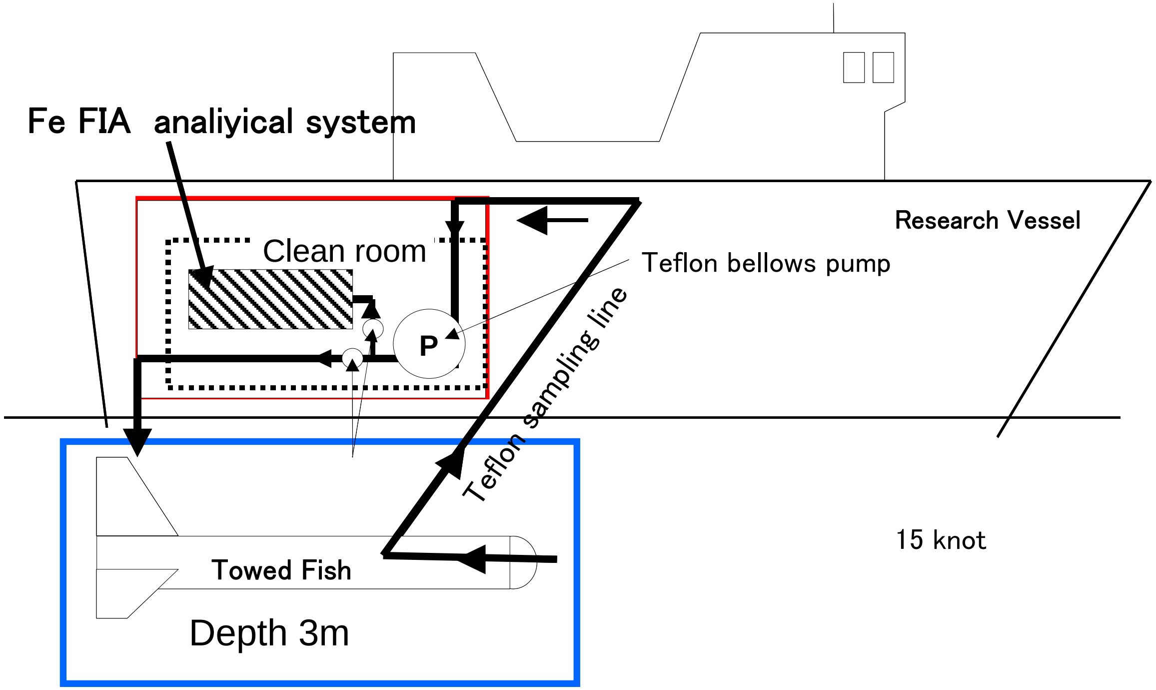
Vertical section observation along A-line

Underway diss-Fe observations in the winter surface layer

Details of the spatial distribution of diss-Fe concentration in the winter surface is important information on……….

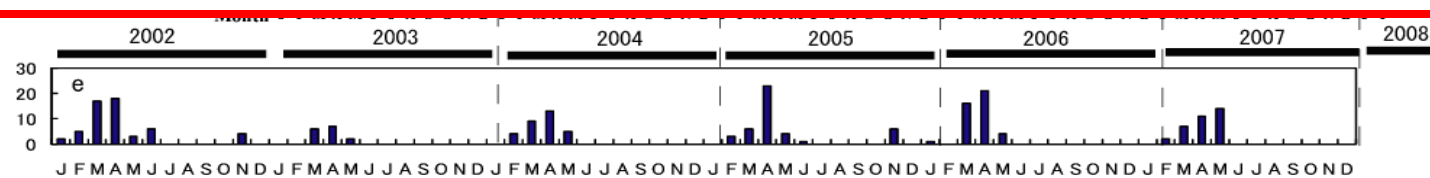
"What is the processes controlling surface diss-Fe concentration".

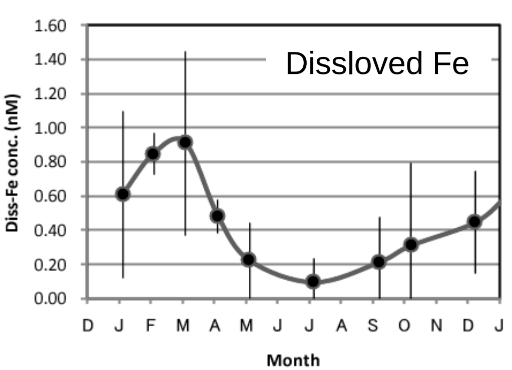


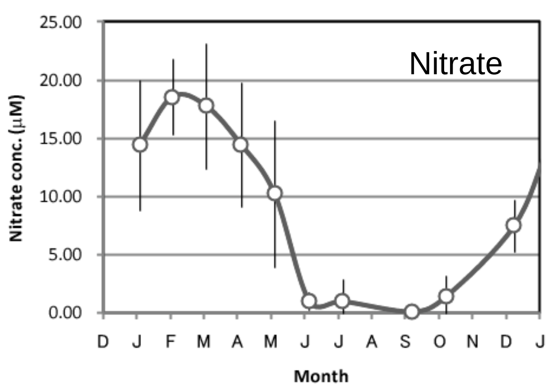


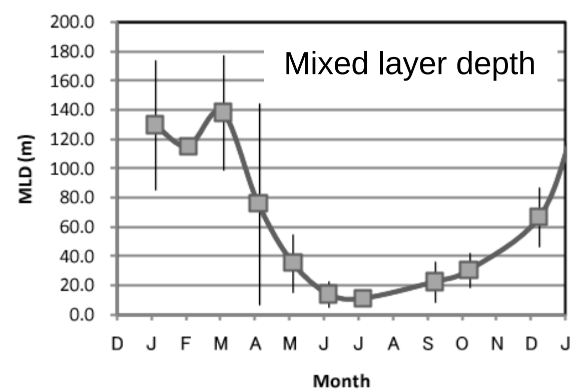
underway-auto-sequence sampling and analytical system.

- **An annual cycle of surface diss-Fe occurs every year**
- **The pattern of seasonal change in diss-Fe concentration in the surface mixed layer was similar to that of macronutrients.**
- **Maximum value is recorded in March when the surface mixed layer became deepest**
- **Diss-Fe and nitrate concentration decreased during the spring phytoplankton bloom**
- **Dust events were rare in autumn to winter, and this is the period during which the surface diss-Fe concentration increased.**



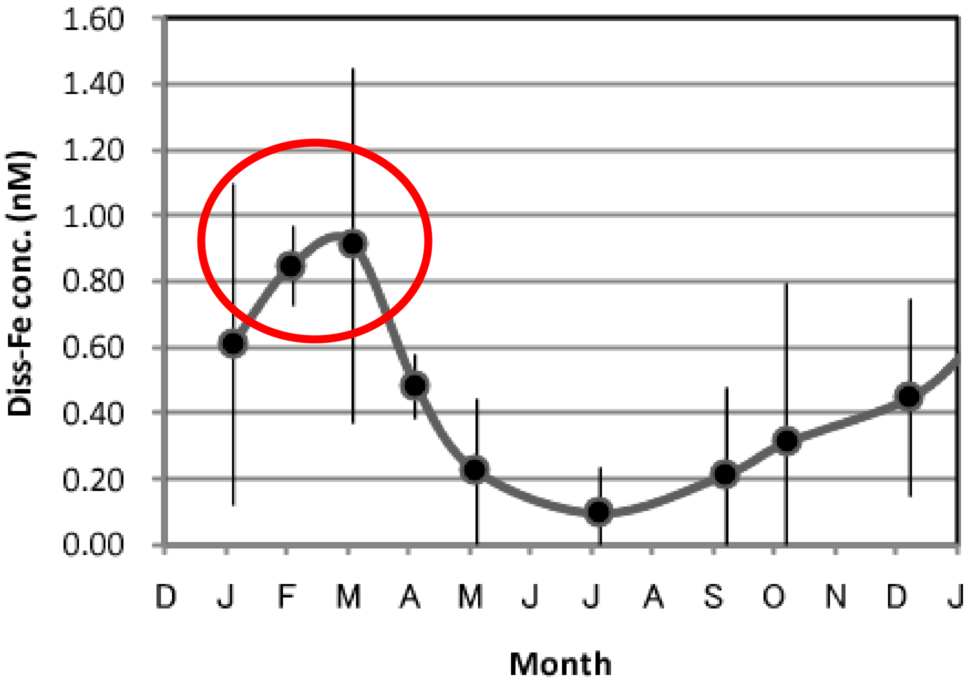




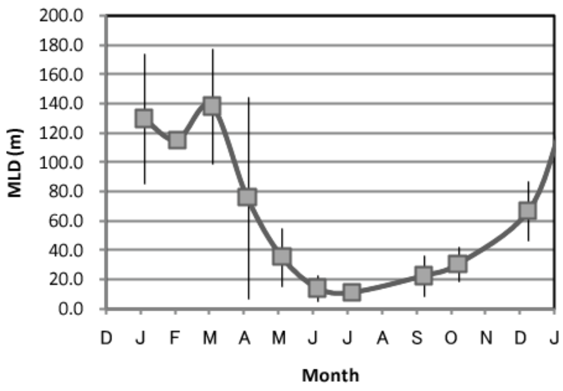


What is important processes for explaining high diss-Fe concentration in winter surface?

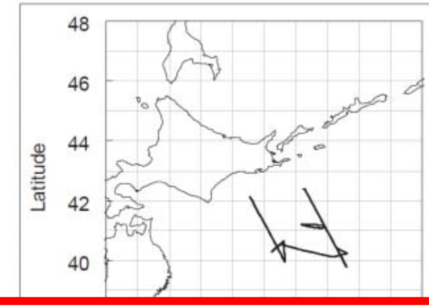
Seasonal variation of Dissolve Fe



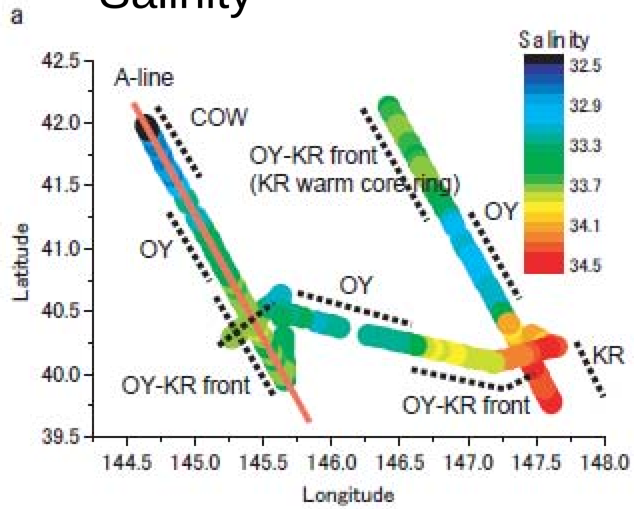
Seasonal variation MLD



Results of underway survey in winter surface, Jan. 2008



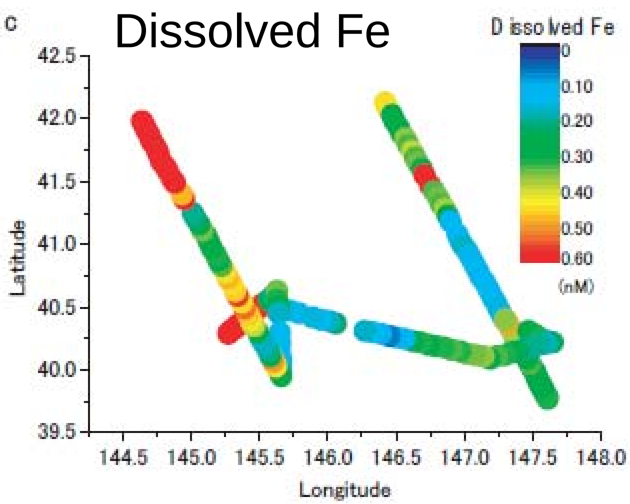
Salinity



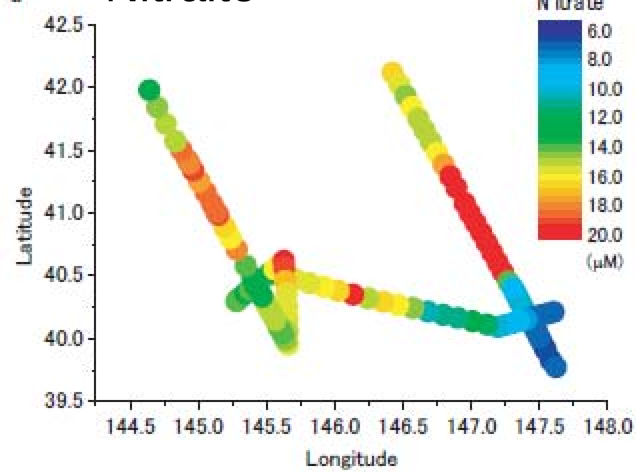
Temperature

- The diss-Fe varied with the mesoscale water mass hydrographic features
- The Oyashio front water generally showed relatively-high diss-Fe values.
- Spatial distribution of diss-Fe was not consistent with the spatial scale of atmospheric dust events

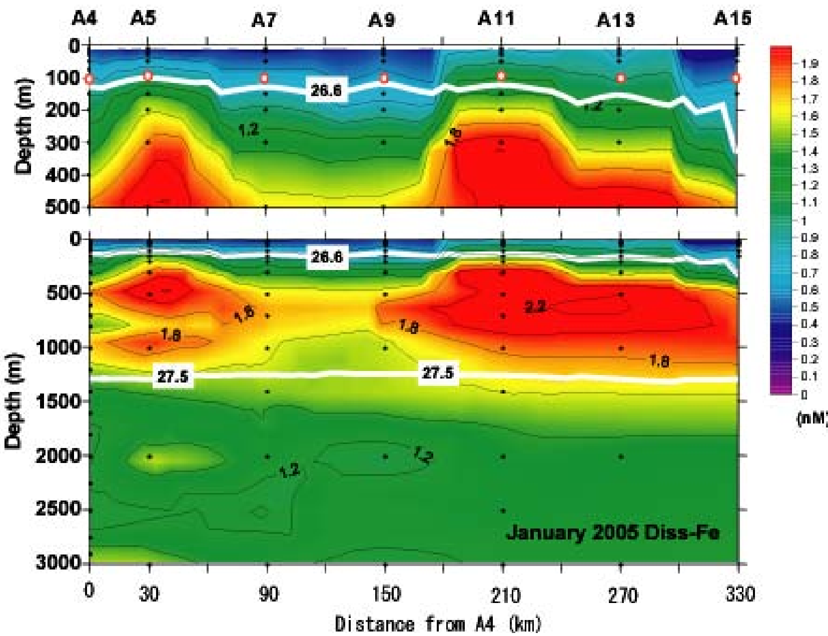
Dissolved Fe

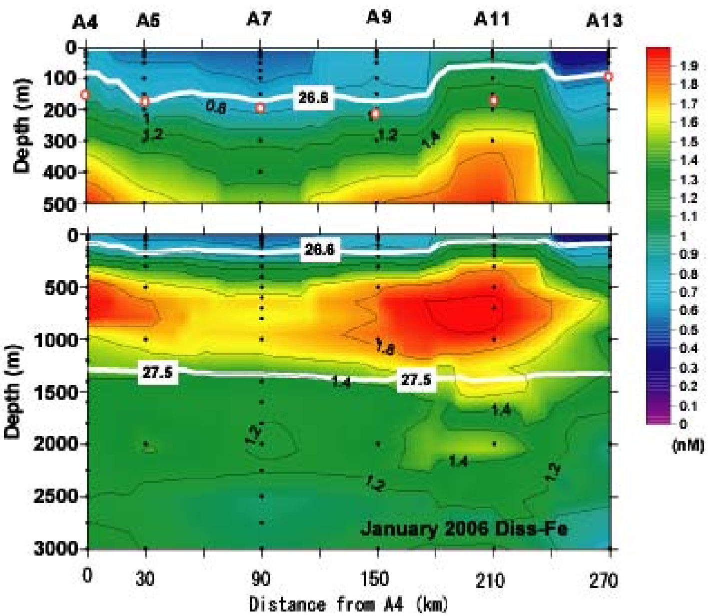


Nitraite



Fe supply from the Fe-rich intermediate water to winter surface





Maximum surface density in winter

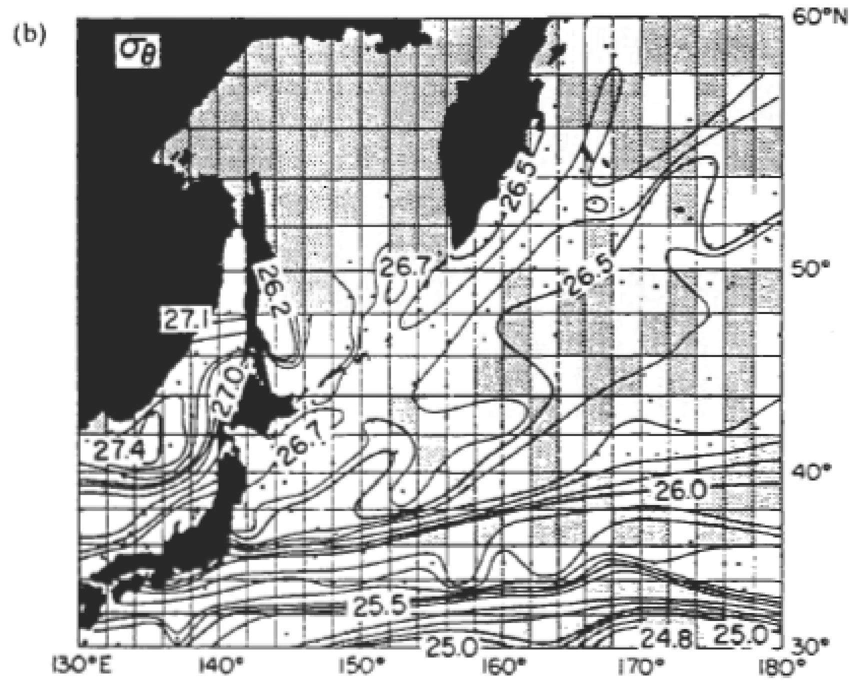
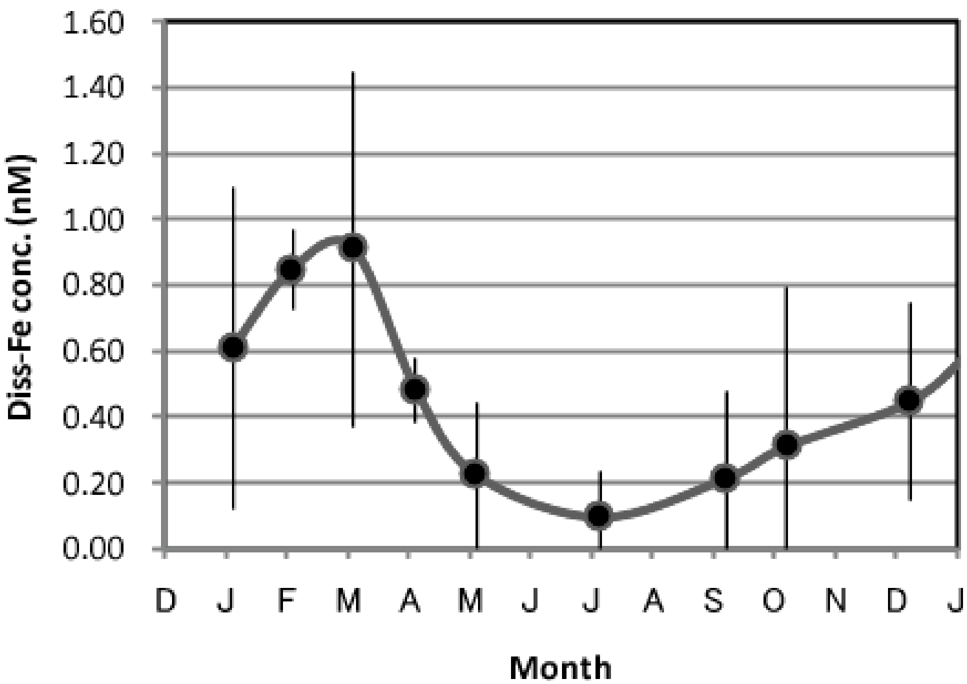


Fig. 4. (a) Distribution of all available Japanese and U.S. quality-controlled, hydrographic stations from February, March and April. (b) Nominal maximum surface density using these stations.

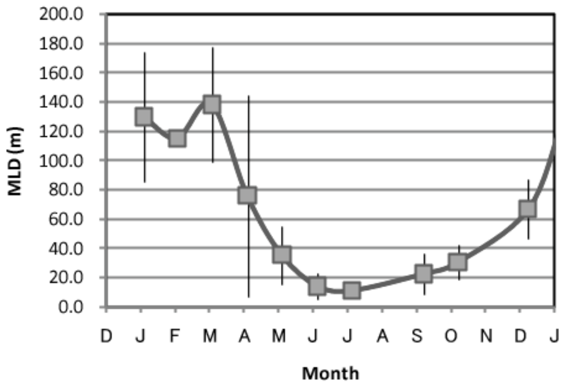
Dense water (26.6-26.7 σ_θ) appears in winter surface in the Oyashio and Oyashio-Kuroshio transition zone, Tally et al, 1991

Important factor for driving the annual cycle of surface diss-Fe concentration

Seasonal variation of Dissolve Fe



Seasonal variation MLD



- The occurrence of Fe-rich intermediate water is important
- Diss-Fe supply from the Fe-rich intermediate water by winter mixing
- Diss-Fe decrease by biological interaction (uptake and aggregation)

The diss-Fe/NO_3 ratio in winter surface layer in the studied region

(nM Fe / μM N)

- Fe-rich intermediate water has a higher diss-Fe/NO_3 ratio :
  0.040 ± 0.014, mean ± 1SD

- In the winter surface layer diss-Fe/NO_3 ratio :
  0.036 ± 0.028 (mean ± 1SD)

- The diss-Fe/NO_3 ratio in other HNLC region
  ~ 0.010 in ESP [Nishioka et al., 2007],
  0.010 ~ 0.025 in the Southern Ocean [Ellwood et al., 2008])

The winter surface water in the Oyashio and the Oyashio-Kuroshio transition zone has a high potential to stimulate phytoplankton growth

Comparison of Fe flux between oceanic upward and dust deposition

Oceanic upward diss-Fe flux

● **Diss-Fe flux from the intermediate layer to the surface**
＝28.6 μmol Fe/m²/yr （**57% is caused by winter mixing** ）

$F1 = W*R*215_{days} + Kz*(dFe/dz)*215_{days}$, $F2 = (C1-C2)*D1$

Total annual upward diss-Fe flux = F1 (Ekman advection and Eddy diffusion flux) + F2 (Winter mixing flux) (μmol/m²/yr).

Dust deposition diss-Fe flux

● **Estimates of atmospheric dust Fe deposition**
＝3.2~ 20.4 μmol Fe/m²/yr

Results of the ocean global model including Fe, suggest that the total atmospheric dust flux in the western North Pacific is 929 mmol Fe/m²/yr (ave. value for 40ºN, 170ºE, [Fung et al. 2000]) . Annual dust deposition in the WSP is 267 mmol Fe/m²/yr [Measures et al., 2005]. Reported solubility of air-born Fe in the WSP 1.2 ~ 2.2 % [the bulk aerosol sample value, Ooki et al., 2009].

Summary of Fe supply processes

Image of Diss-Fe supply via intermediate transport and winter mixing

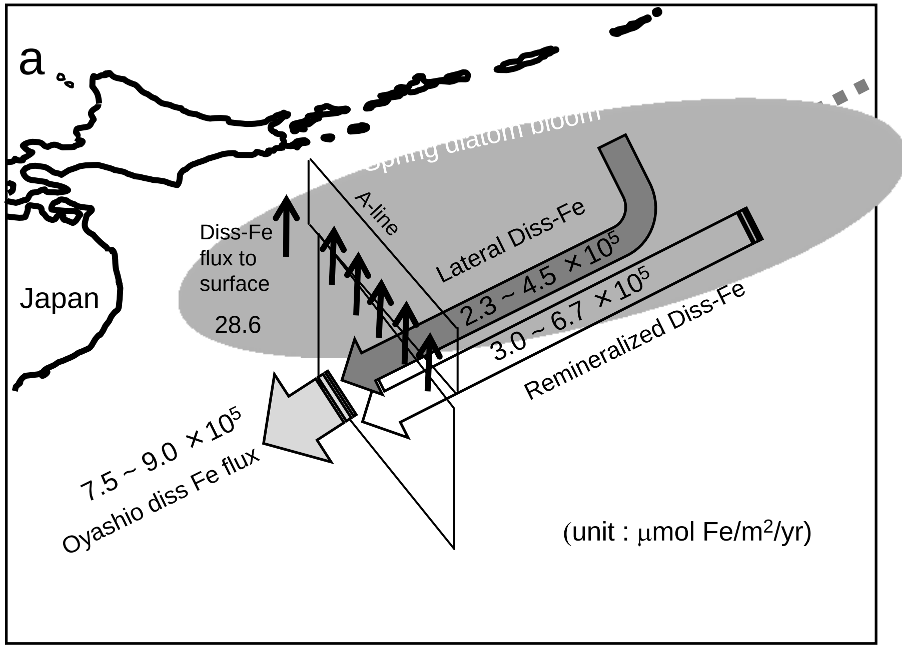
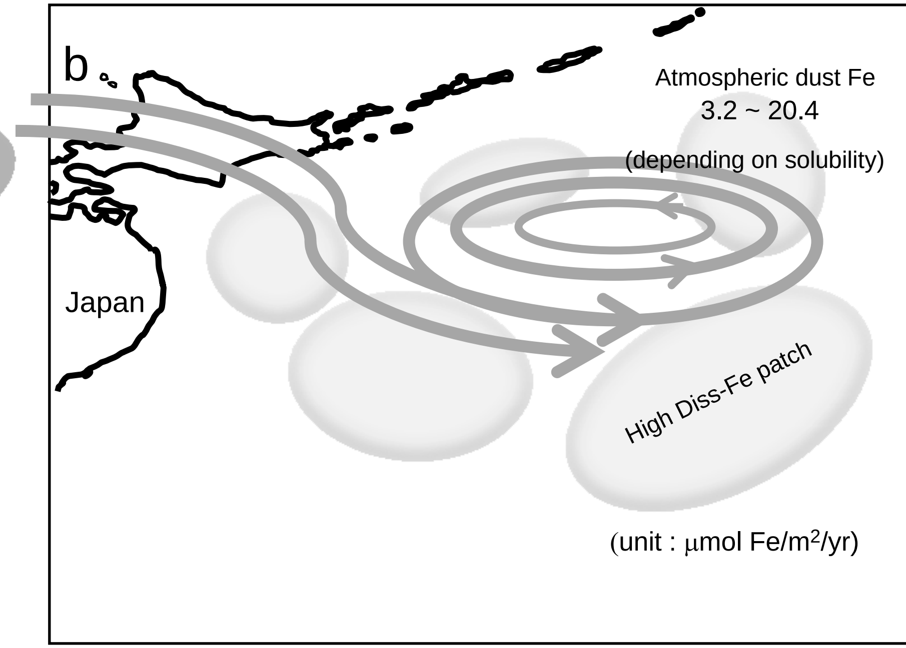


Image of Diss-Fe supply via atmospheric dust ??



Contribute to consistently occurring spring diatom bloom in the Oyashio and the Oyashio-Kuroshio transition zone

Contribute to spatially unstable and sporadically occurring phytoplankton blooms in the wide area of WSP.

A different source of Fe fuels different phenomenon of biological production in this region