Effects of Melting Sea Ice in the Tatarskiy Strait on Spring Bloom along the Primorye coast in the East/Japan Sea

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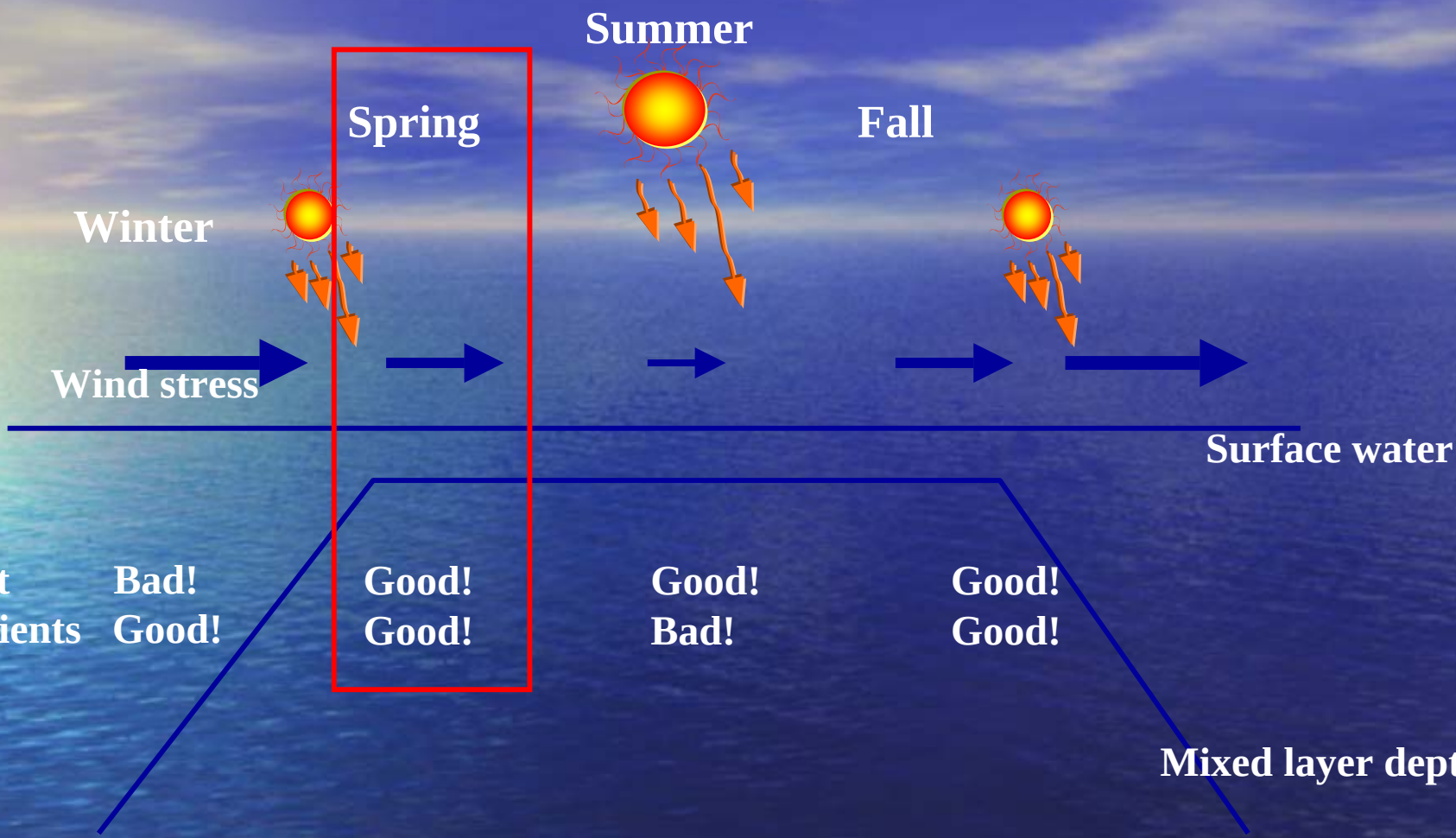
Background – Conditions for Spring Bloom

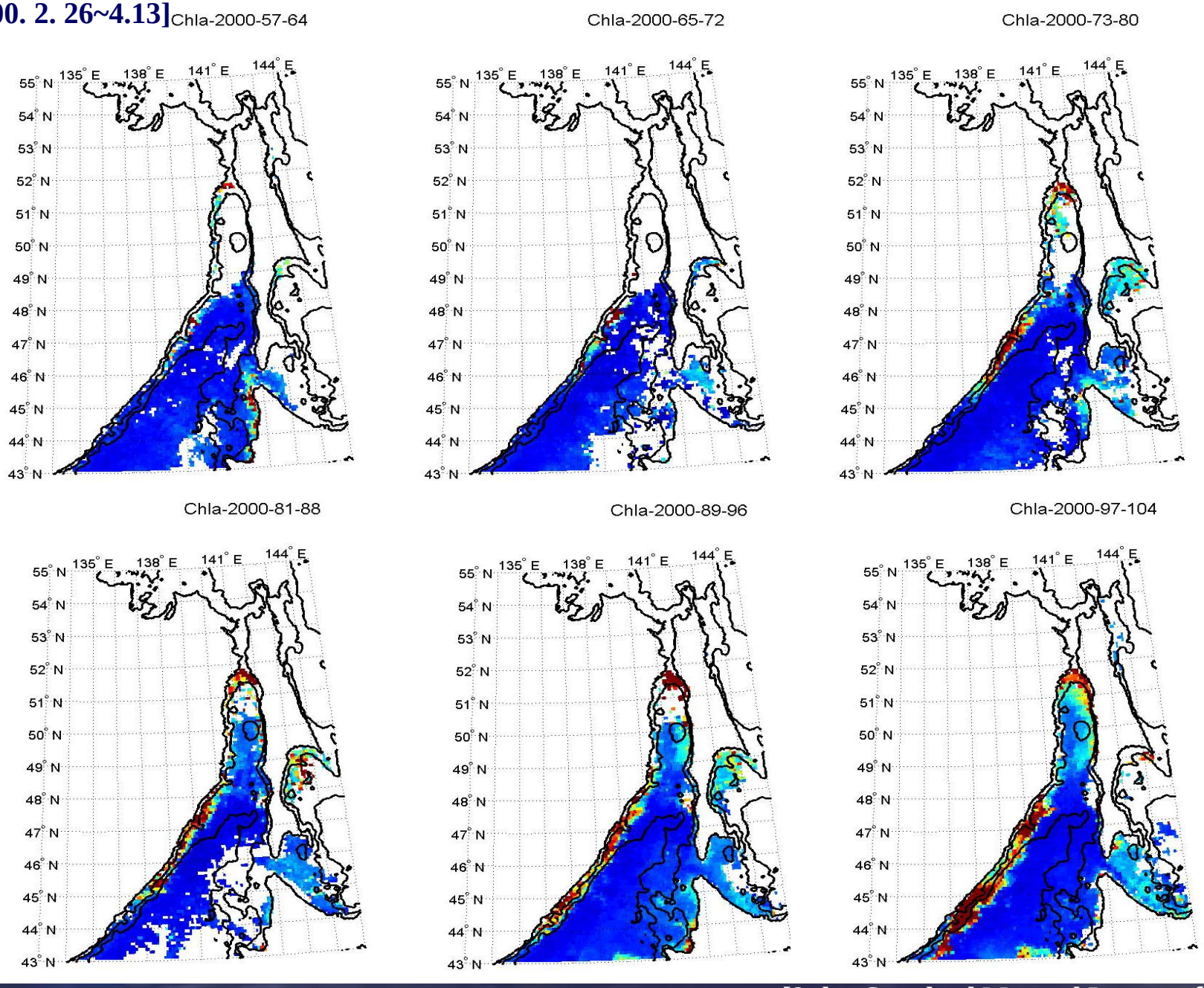


- Spring bloom in the East/Japan Sea usually occurs in April and/or May (Kim *et al*., 2000; Yamada *et al*., 2004).

- Nutrients are enough due to winter mixing. Water column stratification is formed by temperature increase and wind stress decrease.

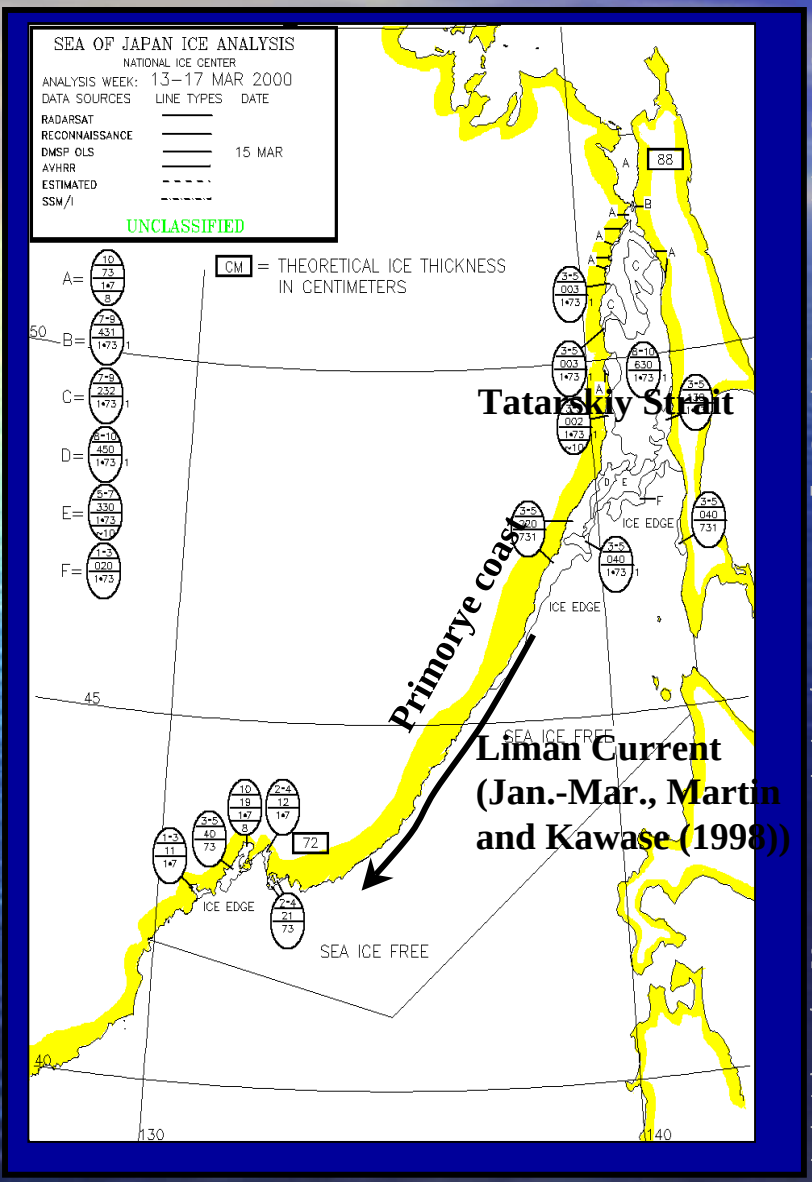
Background -Early Spring Bloom

[2000. 2. 26~4.13]



[8-day Standard Mapped Images of SeaWiFS]

Background – Roles of Sea Ice Melt Water



• During the beginning of March, nutrients could be enough due to winter mixing. So water column stratification is needed for the early bloom formation.

• Martin and Kawase (1998) suggested that the Liman Current that flow along the Primorye coast is low salinity water from sea ice in the Tatarskiy Strait from January to March.

• Advection of sea ice melt water can decrease water density and promote water column stability.

• On the basis of these facts, Yamada *et al*. (2004) suggested that timing of melting of sea ice and wind stress play important roles synergist-ically for timing of the early spring bloom along the Primorye coast.

Study Purpose

• **We investigated that the relationship between spring bloom along the Primorye coast and sea ice in the Tatarskiy Strait.**

- Conditions for early spring bloom formation

- Spring bloom timing and melting timing of sea ice

- Spring bloom intensity and sea ice melt water volume

Hydrochemical Data and Satellite data

Hydrochemical data : Observation data of R/V Professor Khromov from March 13 to 15, 2000 (*http://japansea-atlas.ucsd.edu*)

Satellite data : 1998~2003

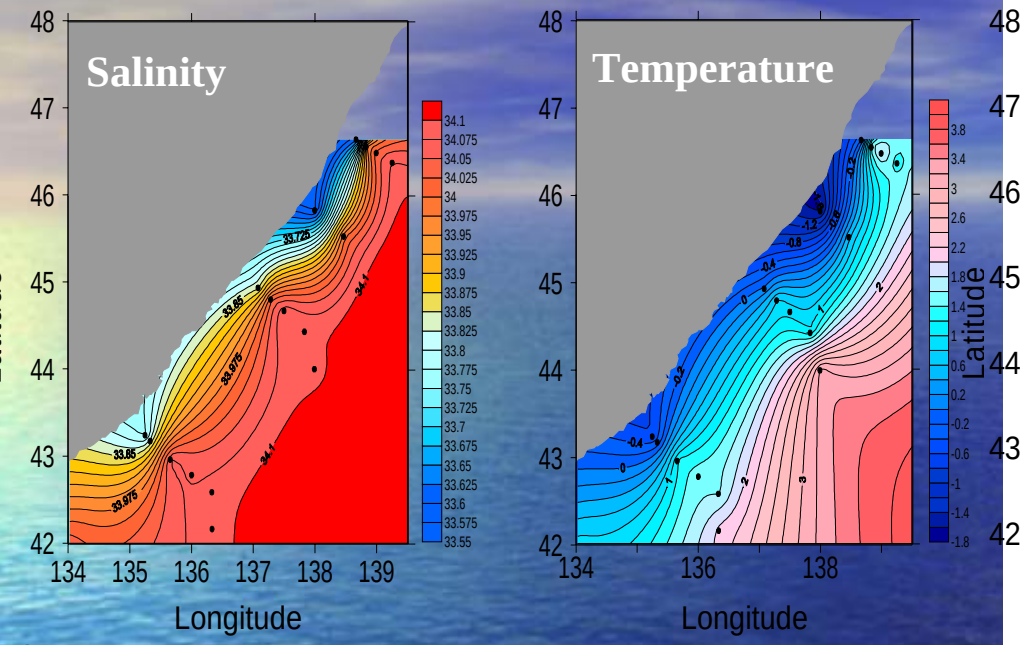
Parameter	Sensor name	Spatial/temporal resolution
chlorophyll *a*	SeaWiFS	9km/8-day
sea ice concentration	SSM/I	25km/daily
wind speed	QuikScat *	0.25^{o}/daily

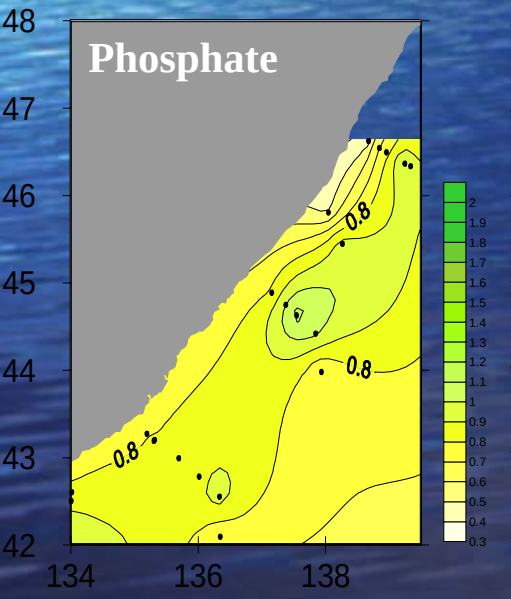
* QuikScat data: 2000~ 2003

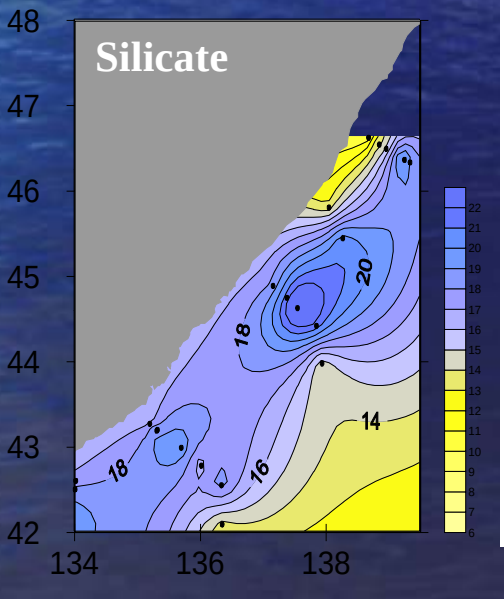
- **Sea ice concentration: percentage of ice coverage in a certain area.**
- **Sea ice area: area where sea ice concentration exceeds 15%**
- **Sea surface wind: wind speed at 10 m height from sea surface**

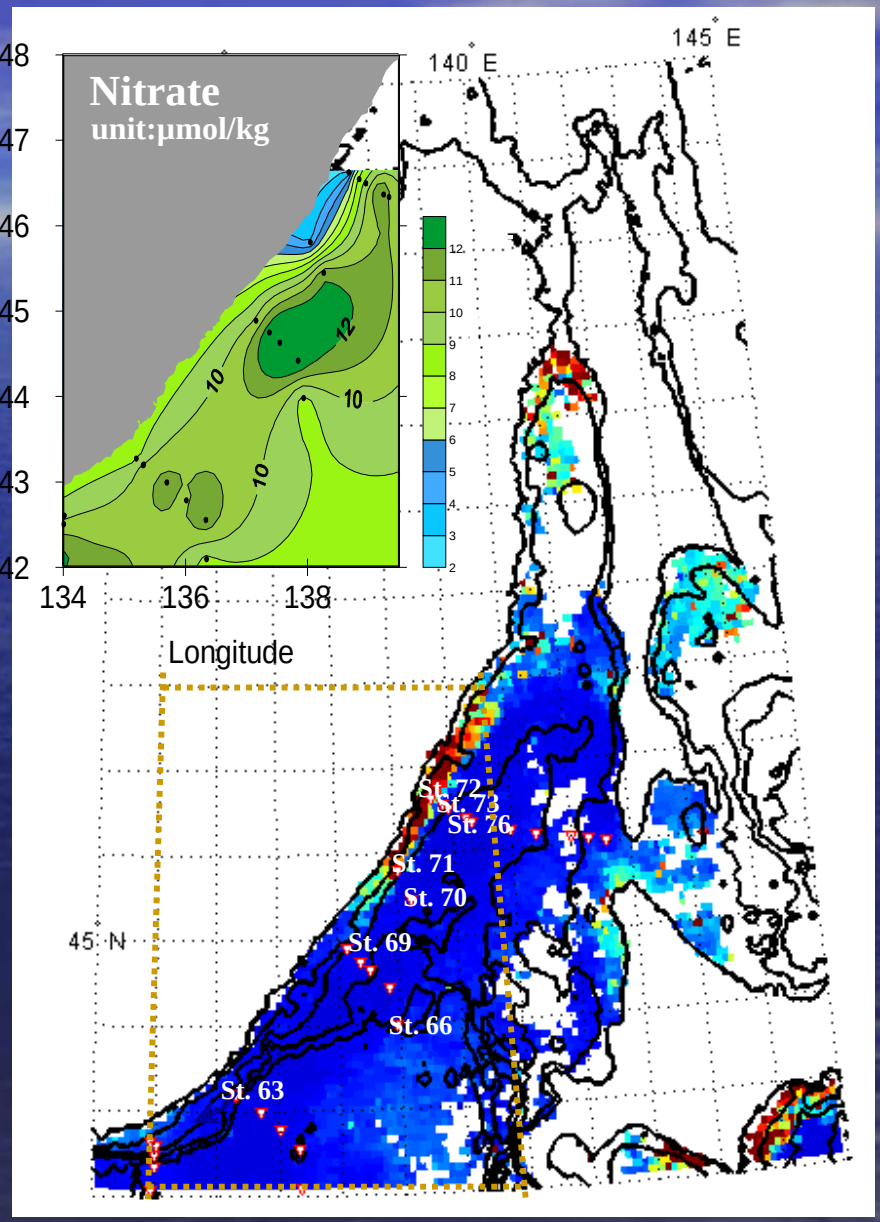
Formation of Stratification

Observation Period : 2000. 3.13~15

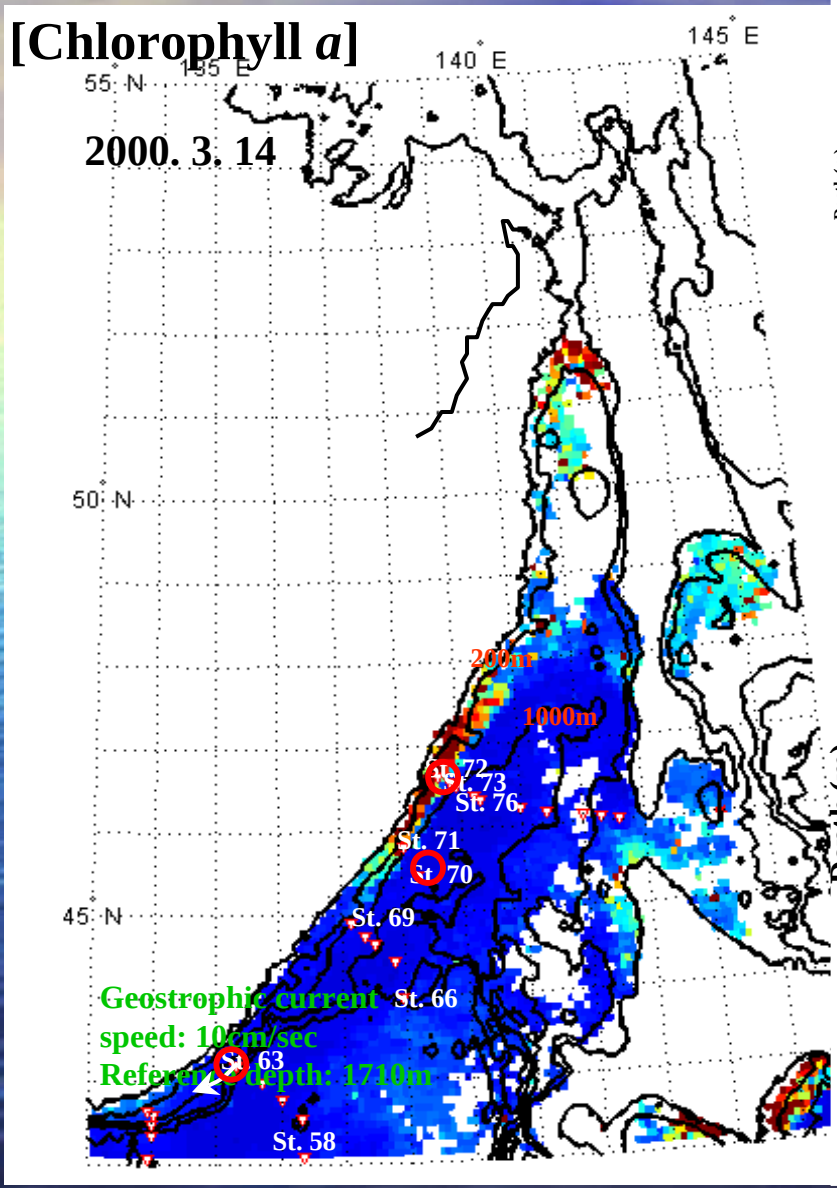


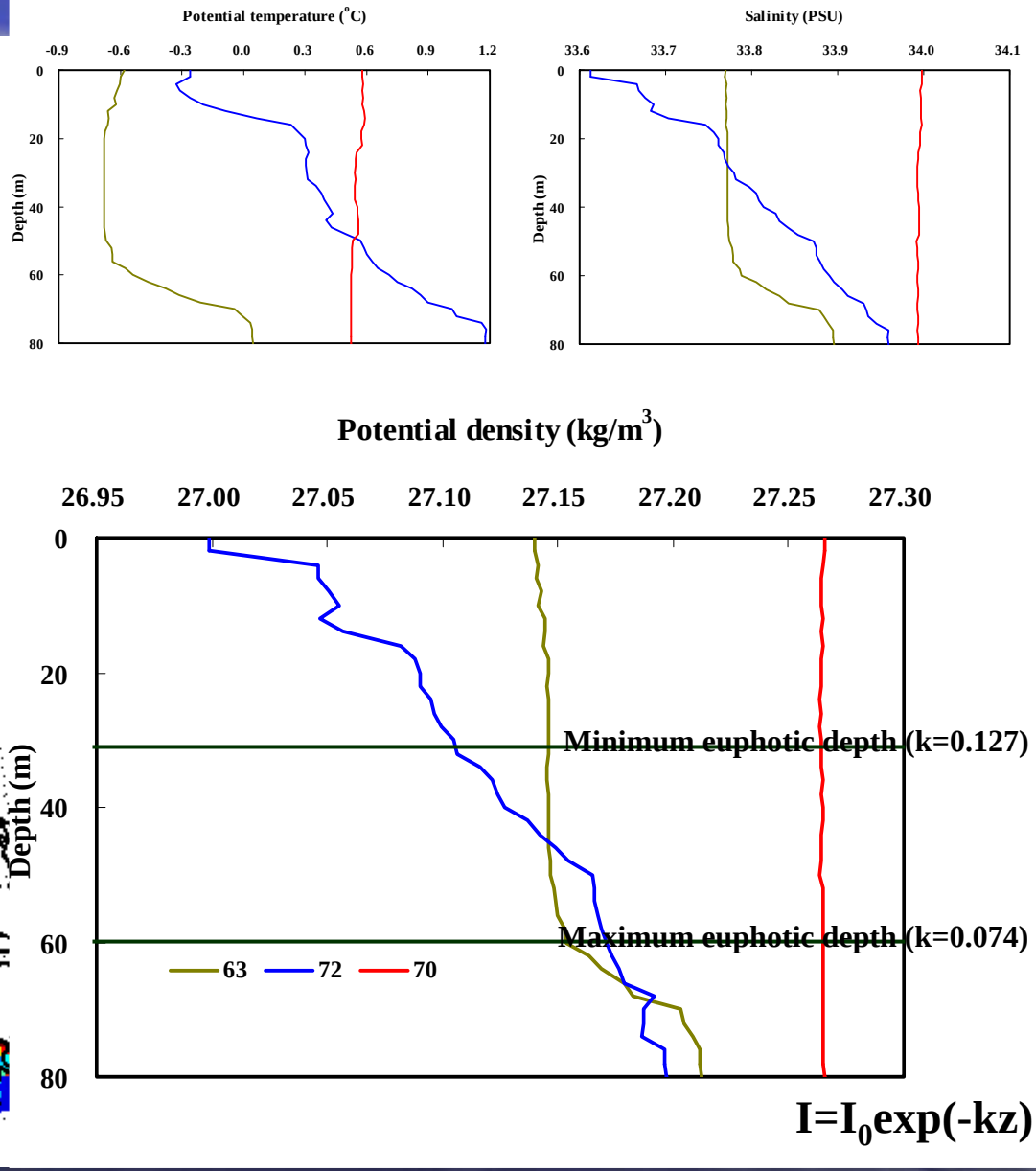




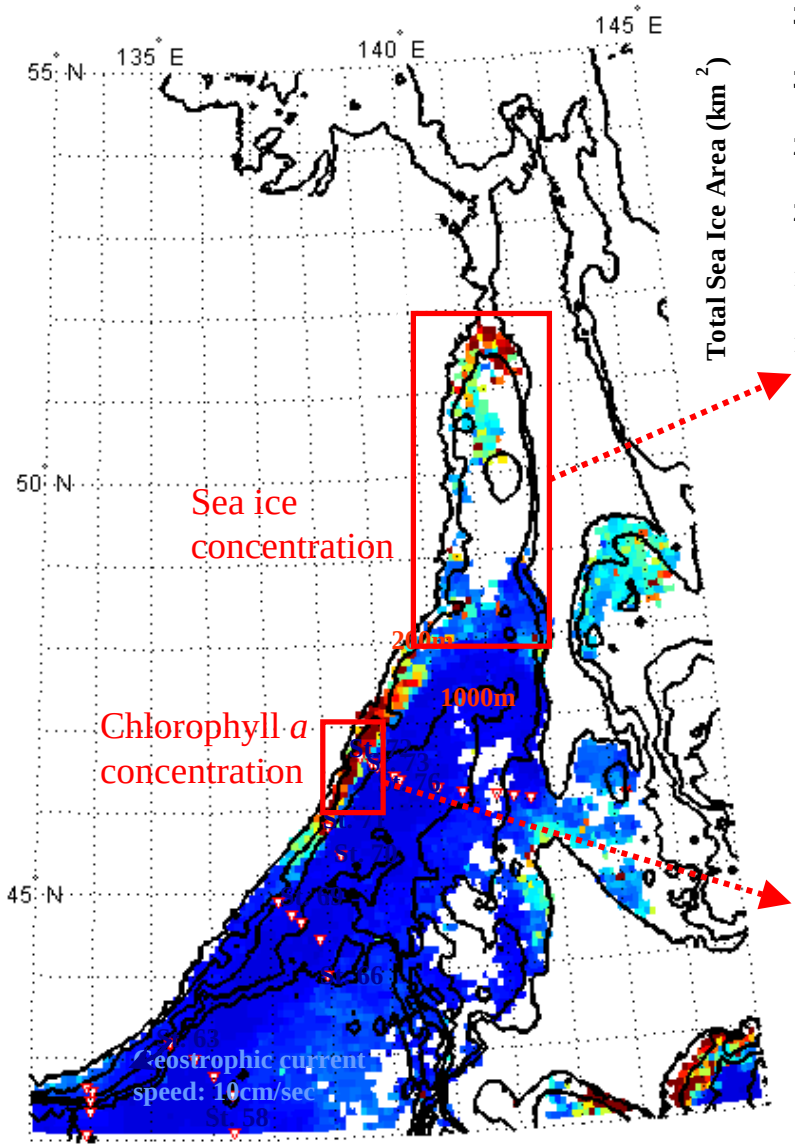


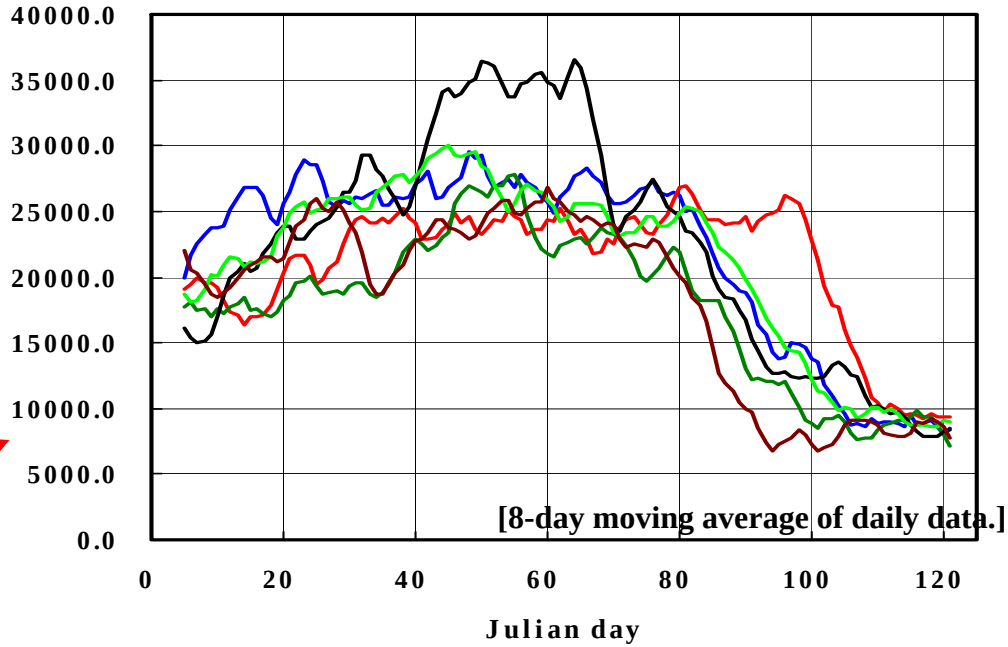
Formation of Stratification

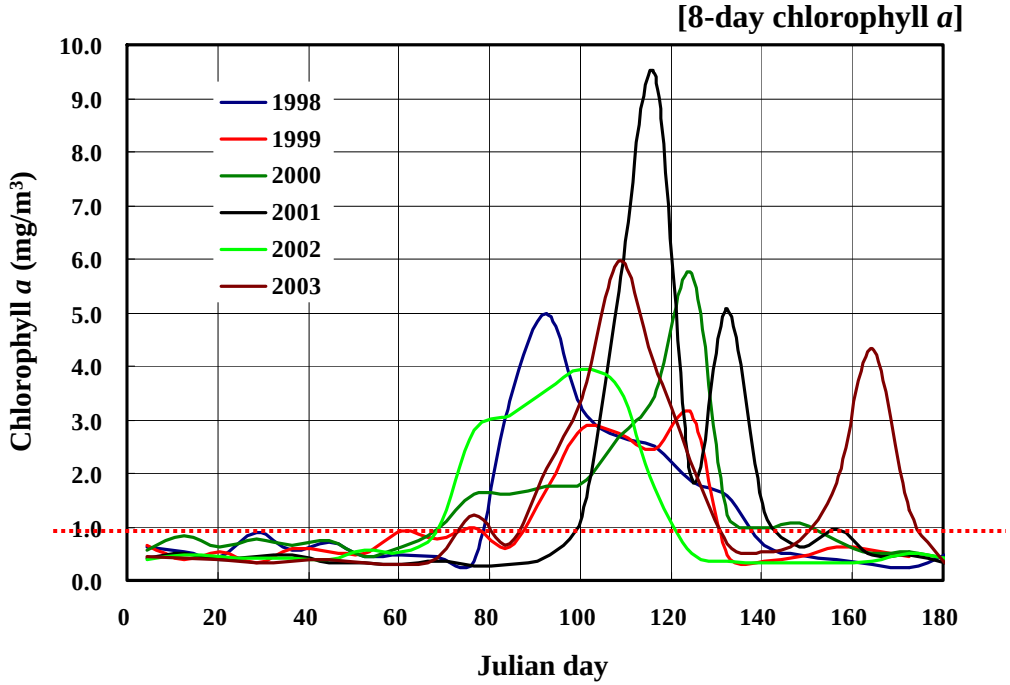




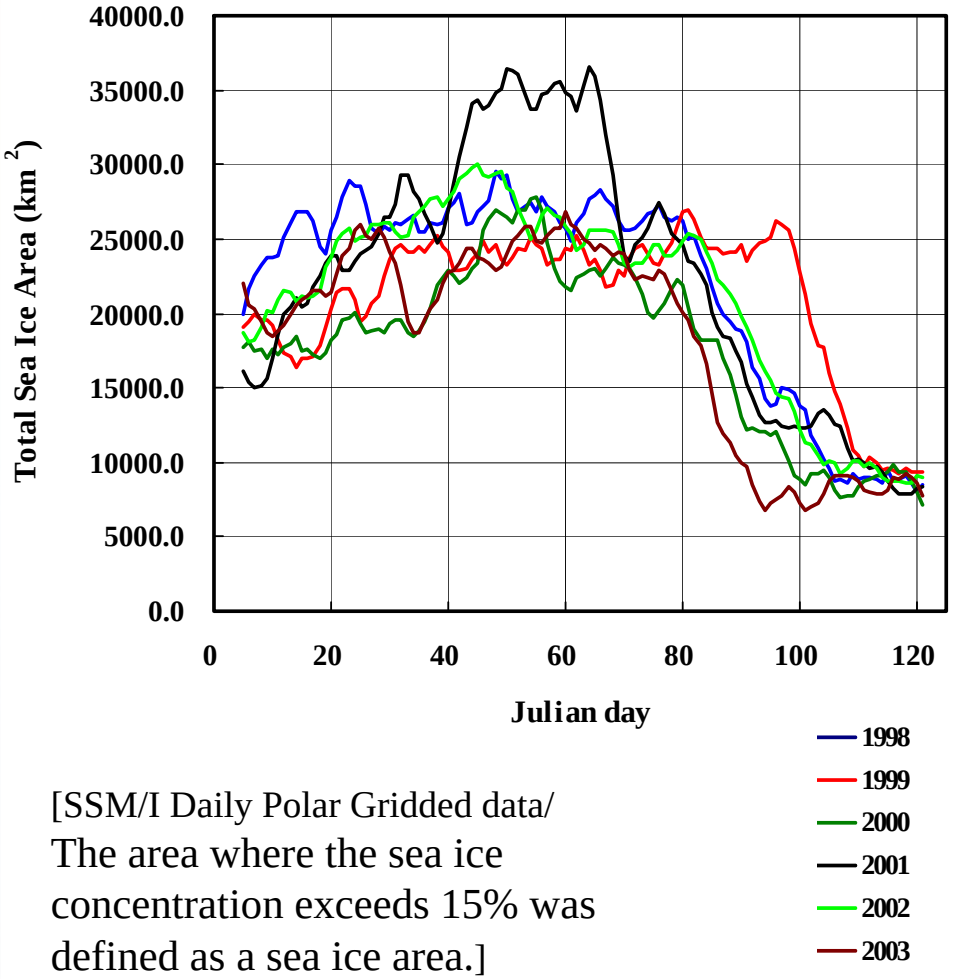
Interannual Variations





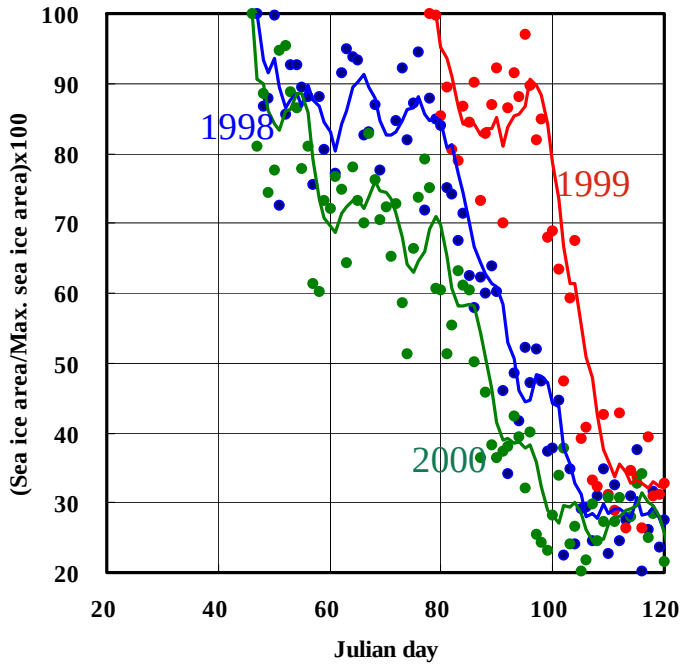


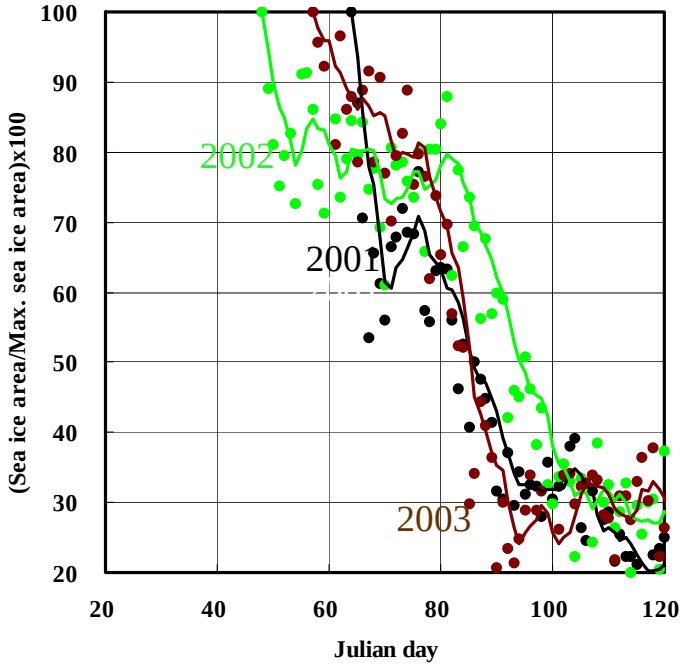
Melting of Sea Ice



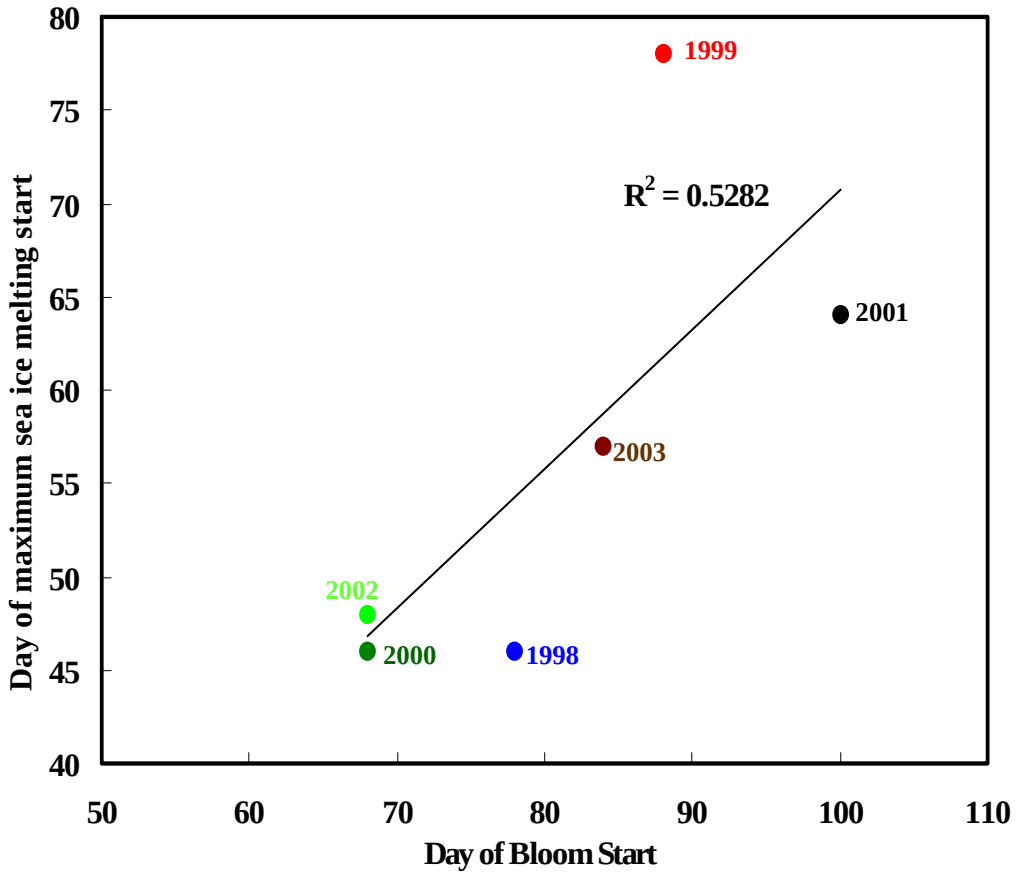
[SSM/I Daily Polar Gridded data/
The area where the sea ice concentration exceeds 15% was defined as a sea ice area.]

[All lines are 8 day moving average of daily data.]



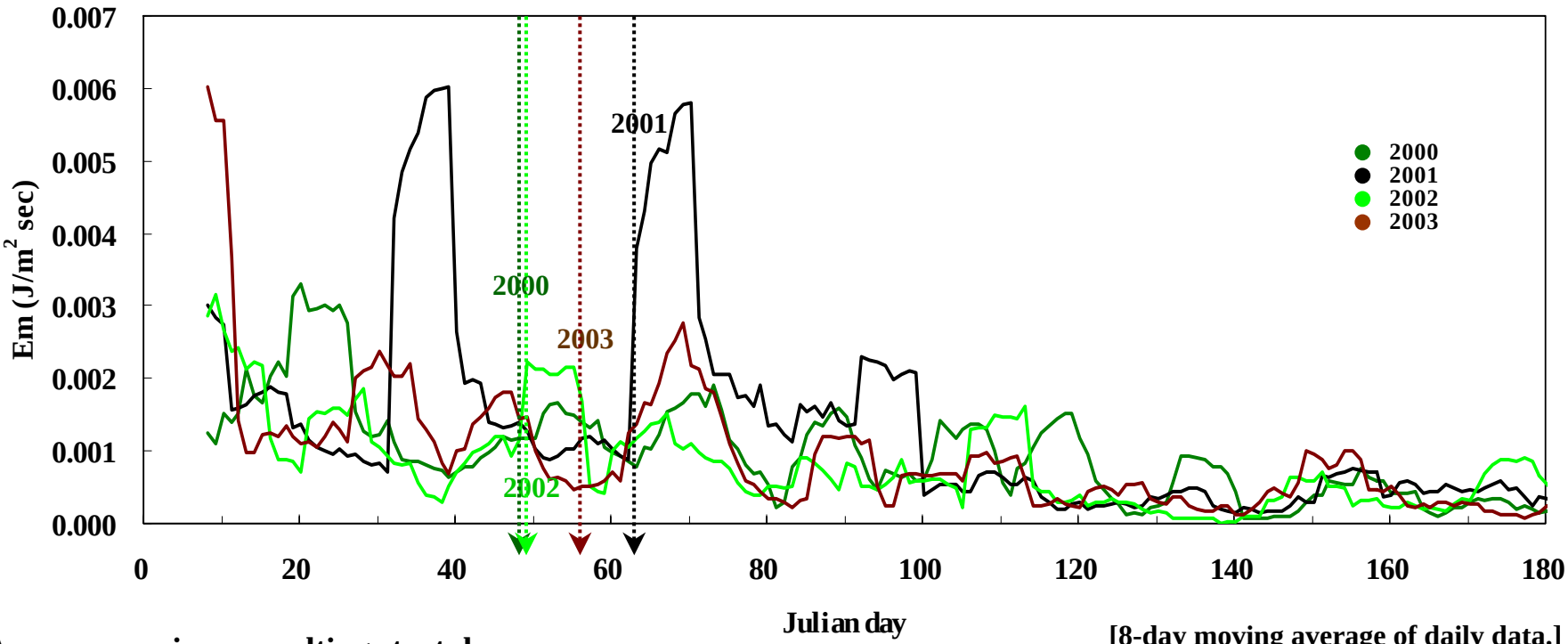


Melting Timing of Sea Ice and Spring Bloom Start Timing



Geostrophic current speed: 10cm/sec
Travel time from the sea ice edge to the study area of Primorye coast about 20days

Delay of Spring Bloom Timing by Wind



Arrows: maximum melting start day

[8-day moving average of daily data.]

Em (Denman and Miyake, 1973) : the rate at the energy in the wind becomes available for increasing the mixed layer thickness

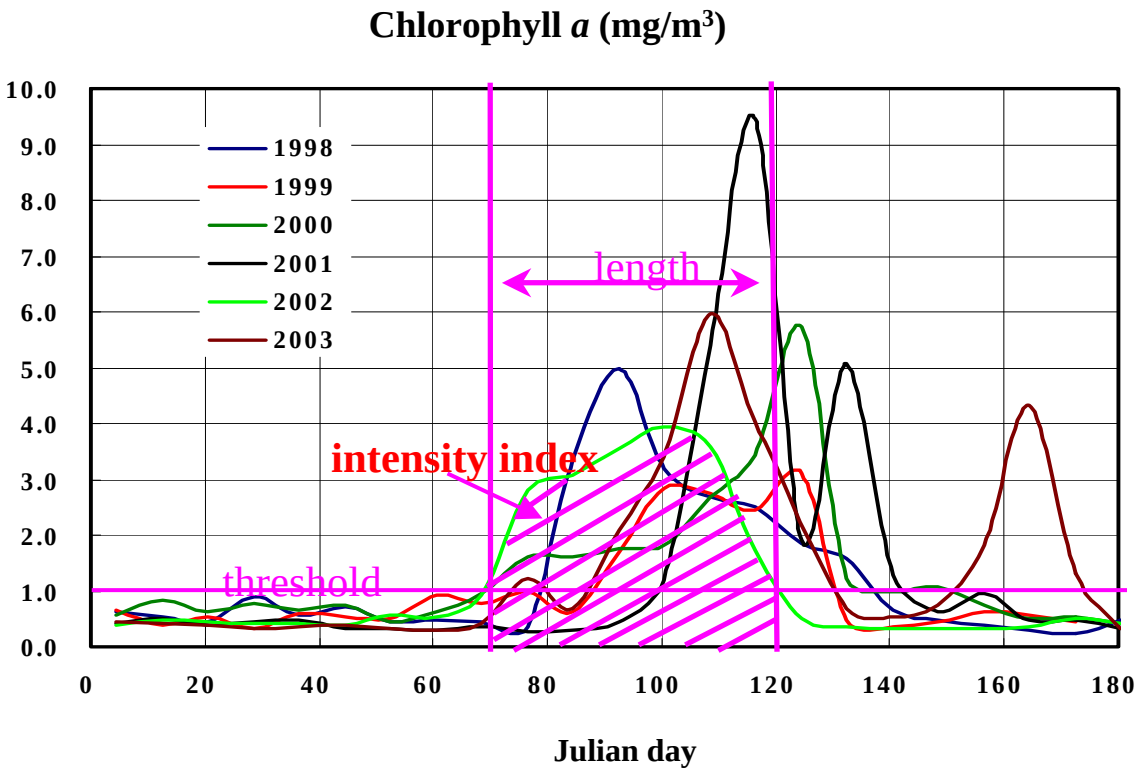
$Em=0.015\rho a C_{10} U_{10}^{3}$

ρa: air density ($1 kgm^{-3}$)

U_{10}: wind speed measured

C_{10}: drag coefficient to be used with 10m winds (0.001, Smith 1980)

Bloom Intensity Index



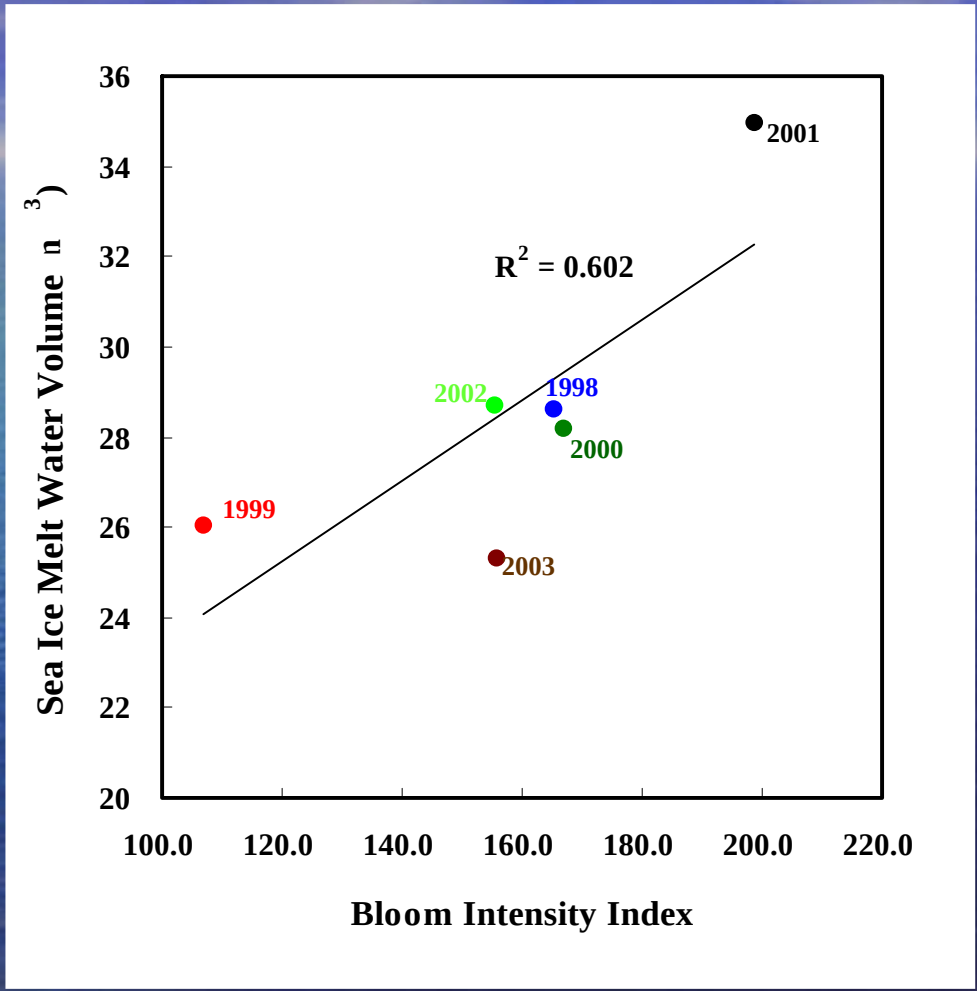
Sea Ice Volume: Sea ice area X Sea ice thickness

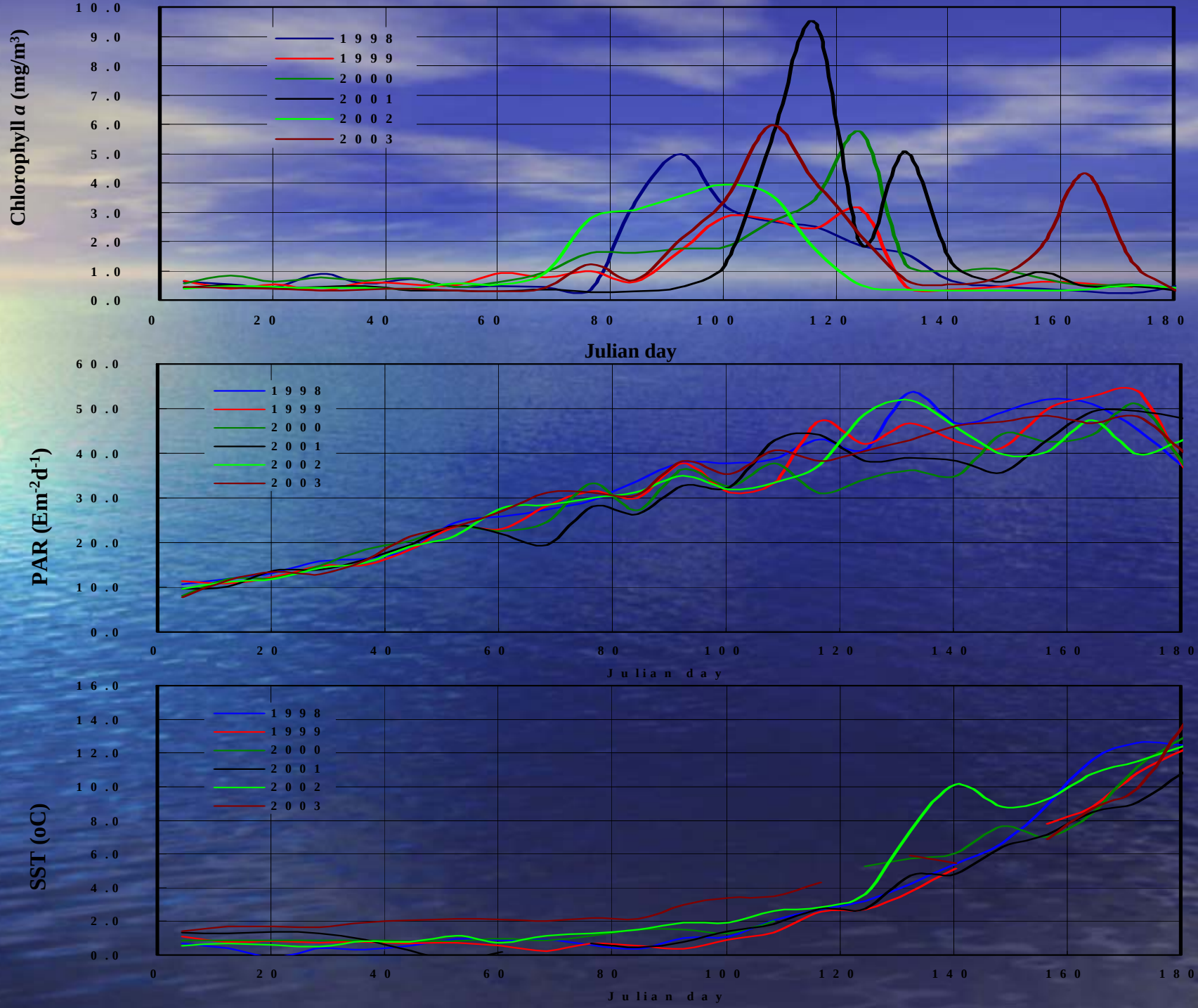
$\eta^2+5.1\eta=6.7\Sigma\ \Delta T$

η : the ice thickness (cm)

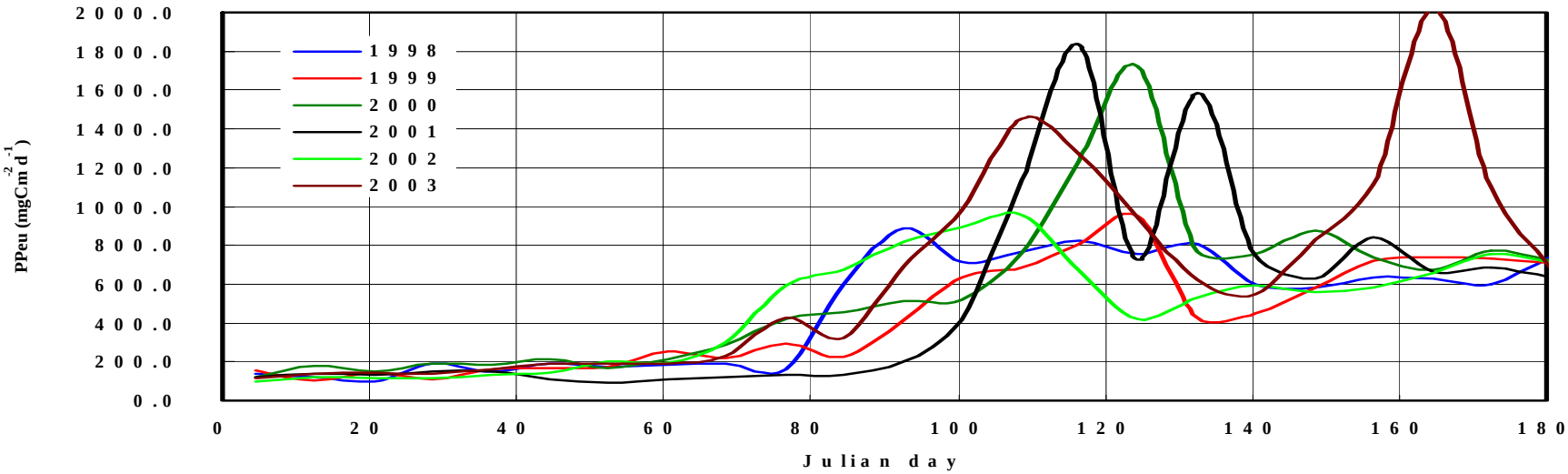
$\Sigma\ \Delta T$: the cumulative degree-days below 0◦C

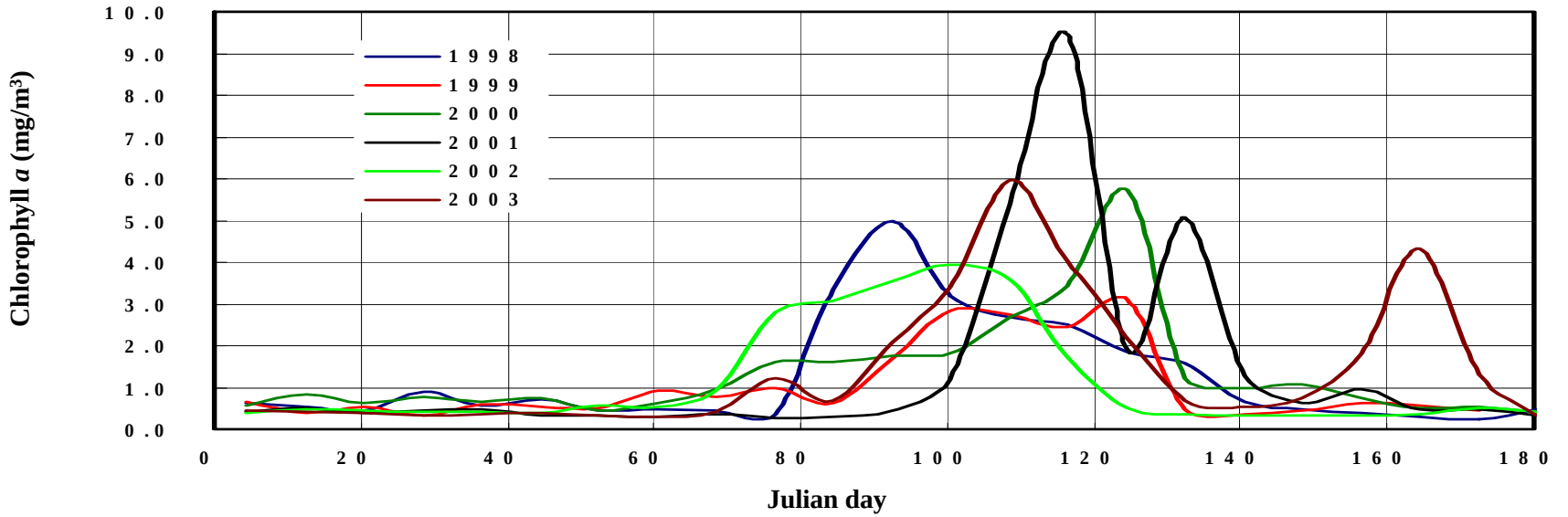
Sea Ice Melt Water Volume and Spring Bloom




Chlorophyll a (mg/m3)
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
1998
1999
2000
2001
2002
2003
0
20
40
60
80
100
120
140
160
180
Julian day
PAR (Em-2d-1)
60.0
50.0
40.0
30.0
20.0
10.0
0.0
1998
1999
2000
2001
2002
2003
0
20
40
60
80
100
120
140
160
180
Julian day
SST (oC)
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
1998
1999
2000
2001
2002
2003
0
20
40
60
80
100
120
140
160
180
Julian day

Integrated Primary Production

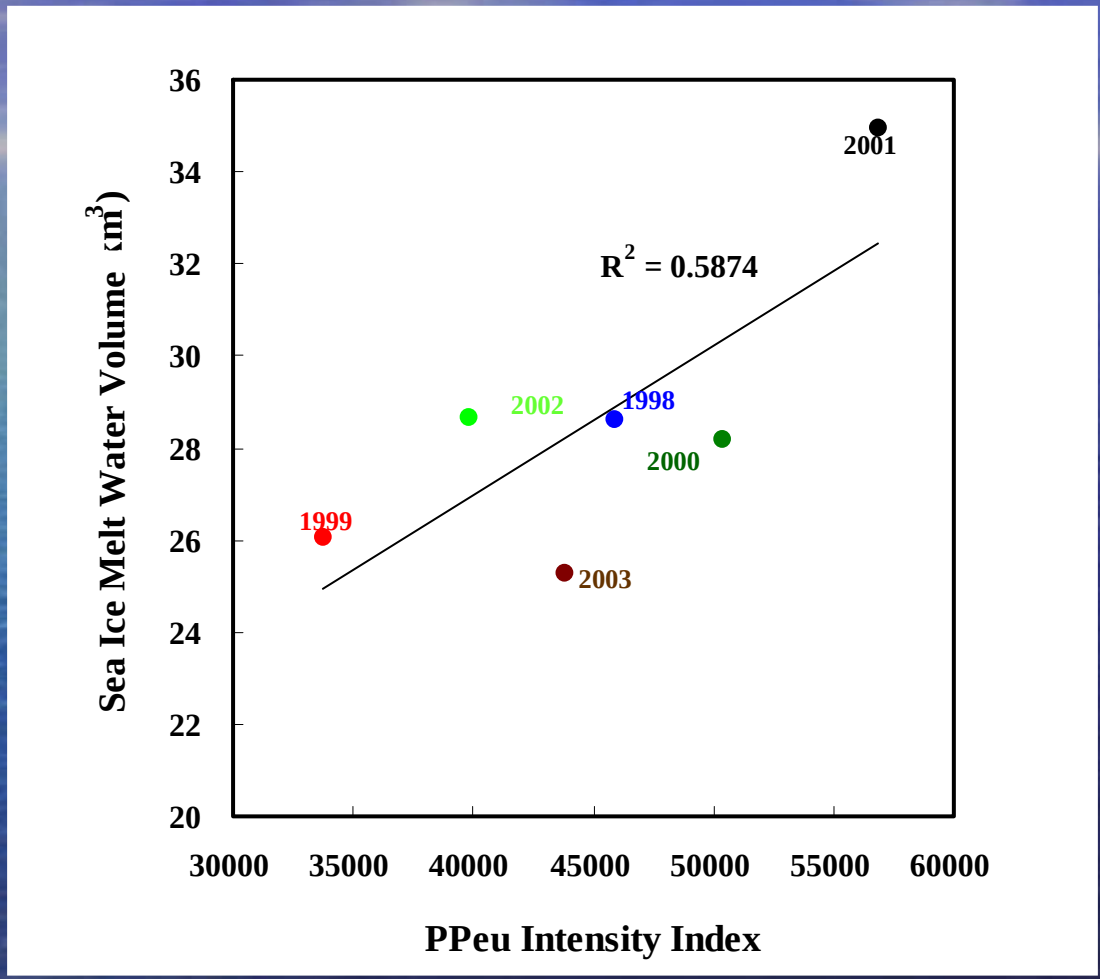




A modified Vertically Generalized Production Model (Yamada, 2004)

PPeu: integrated primary production in the euphotic zone ($mgCm^{-2}d^{-1}$)

Sea Ice Melt Water Volume and Primary Production



Summary

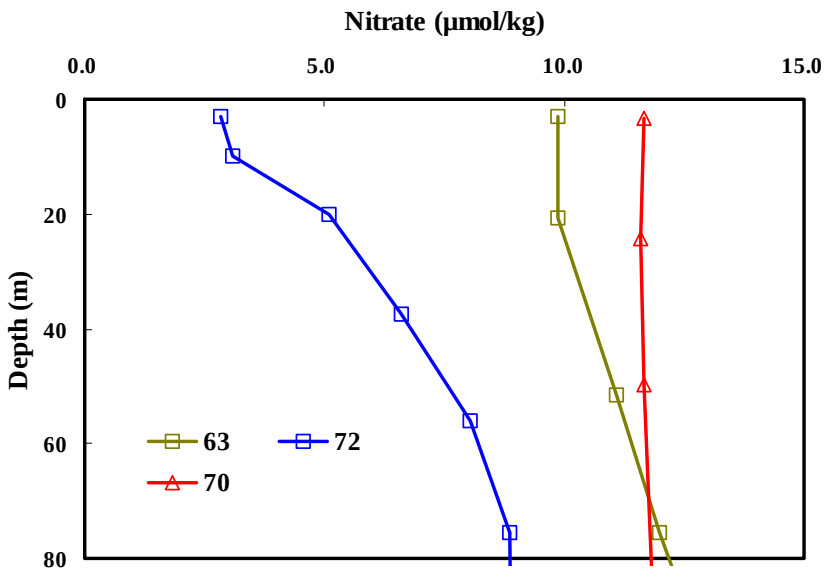
• Sea ice melt water from the Tatarskiy strait was supplied into the Primorye coast and stratification was formed by the sea ice melt water.

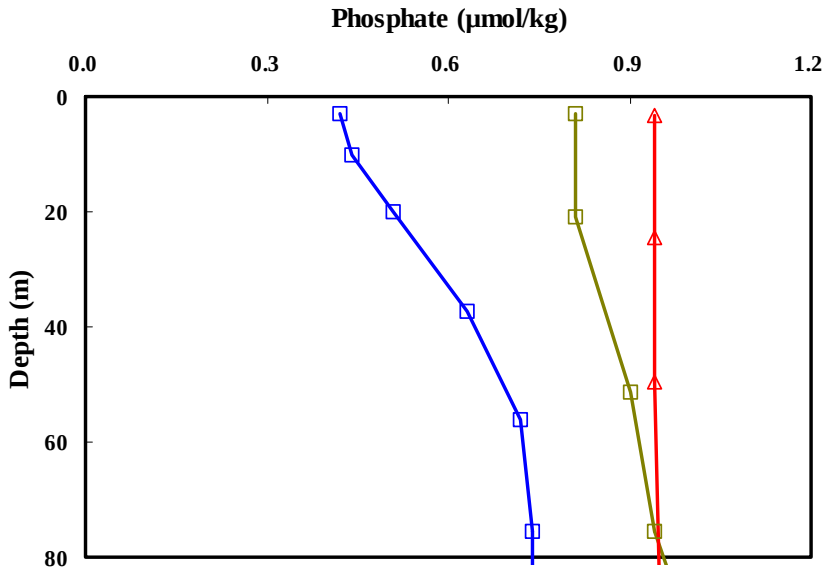
• Early spring bloom occurred due to this stratification.

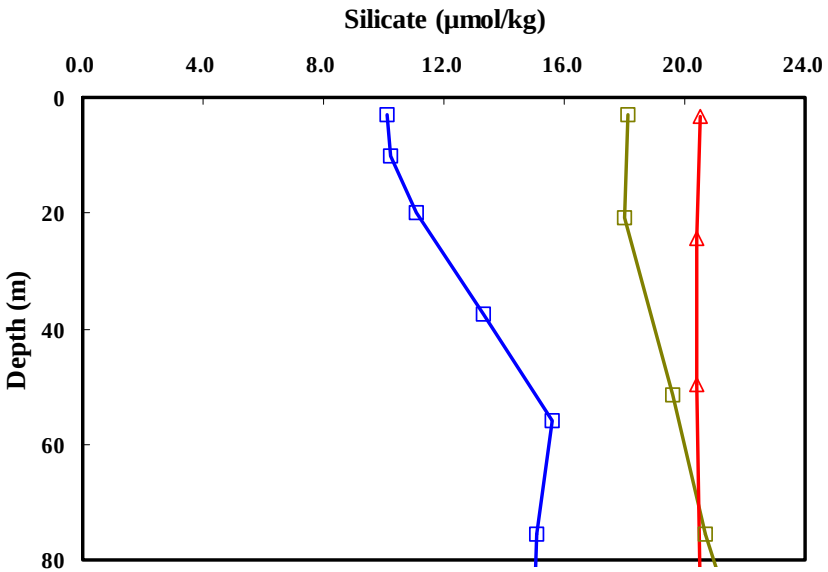
• Spring bloom started after maximum melting of sea ice. However, the bloom timing was delayed when wind stress was strong after maximum melting.

• The bloom intensity and primary production were associated with the volume of sea ice melt water.

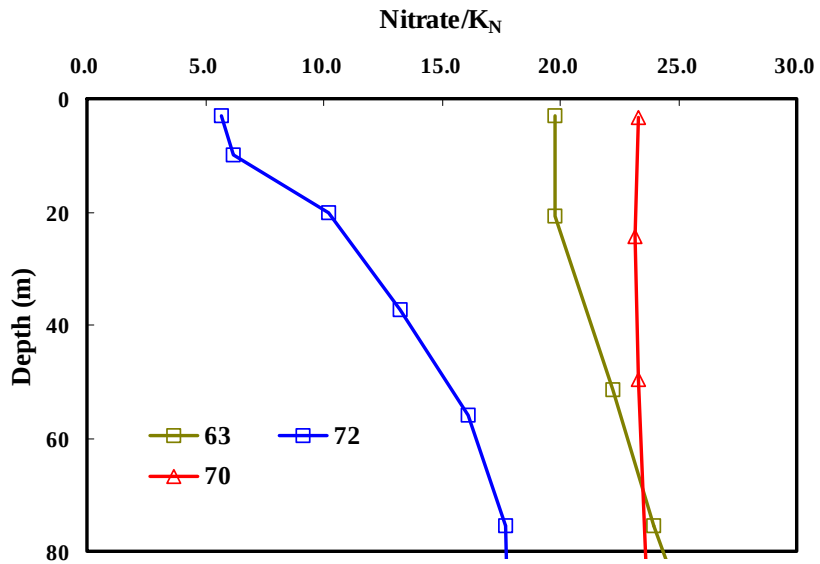
Vertical profiles of nutrients

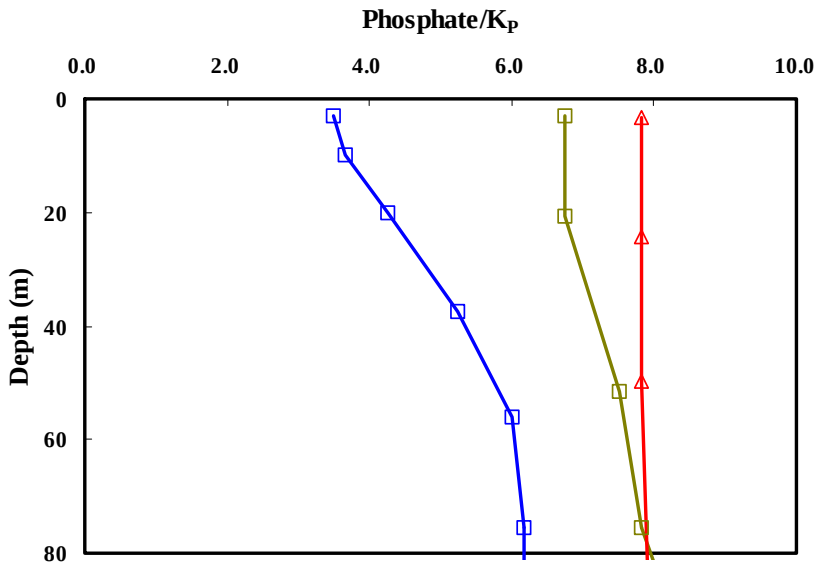


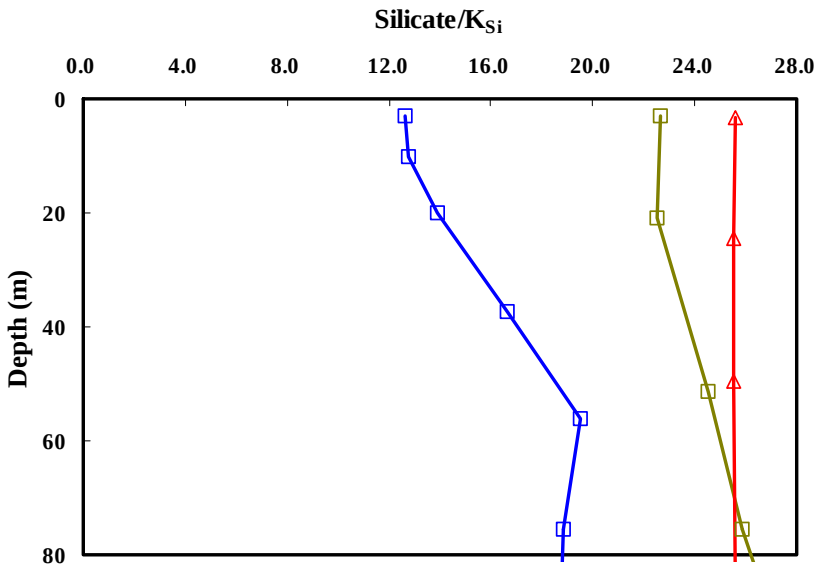




Vertical profiles of nutrients







K_N, K_P and K_{Si}: typical diatom half saturation constants for nitrate, phosphate and silicate.