Relationship between phytoplankton blooming and windstress in the sub-polar frontal area of the Japan/East Sea

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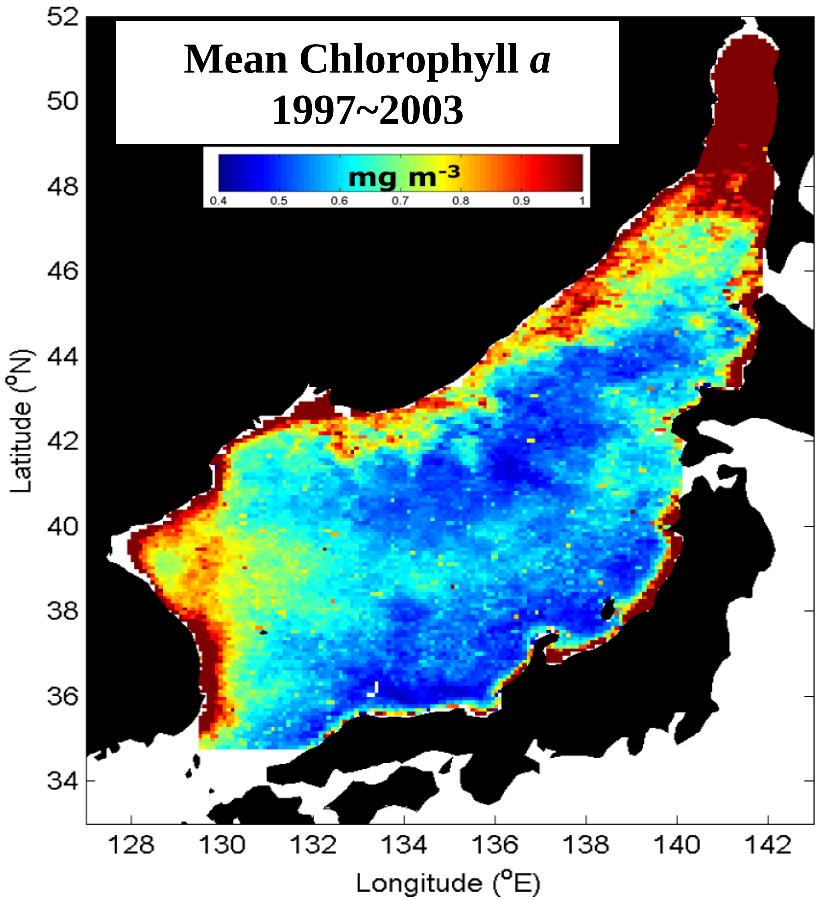
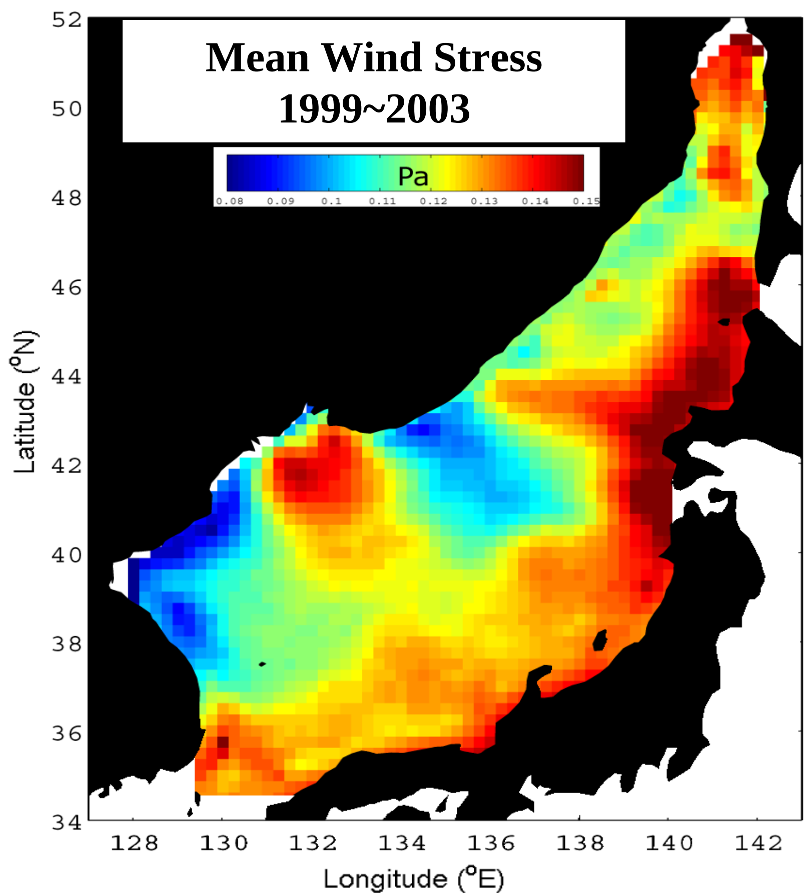
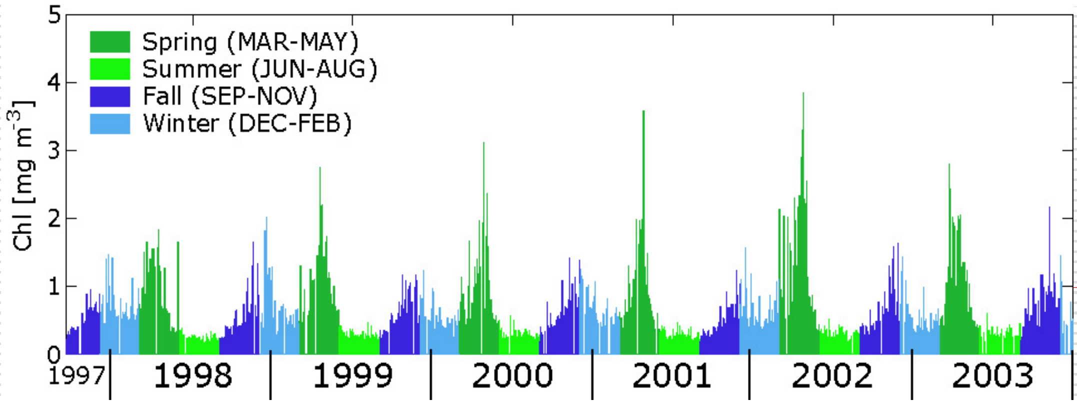
Background & Objective

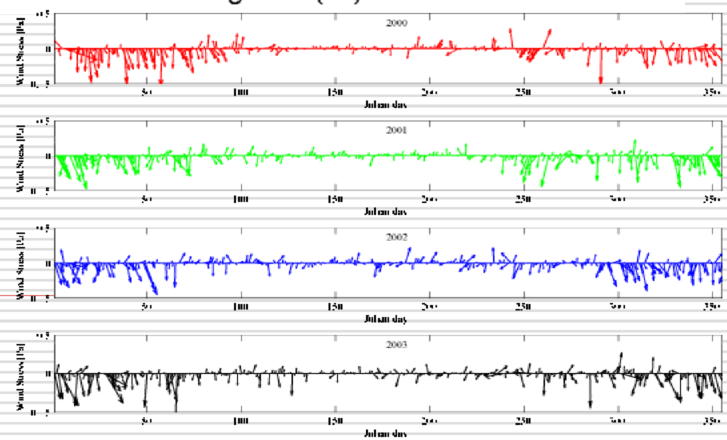
- Yamada *et al*. (2004). "Seasonal and interannual variability of sea surface chlorophyll *a* concentration in the Japan/East Sea (JES)"
  - There are remarkable springs blooms and fall blooms in the Japan/East Sea, as was observed from SeaWiFS chlorophyll *a* during 1997 to 2003
  - There are interannual variability in the start timing of the spring blooms and fall blooms and of their spatial distributions.
  - Among many forcing variables, wind plays an important role in determining the vernal stratification process, which in turn determines bloom timing in temperate water.
- In this presentation, We try to reveal the relationship between bloom process and wind with two hypotheses.

Variability of Chlorophyll *a* & Windstress in the Japan/East Sea

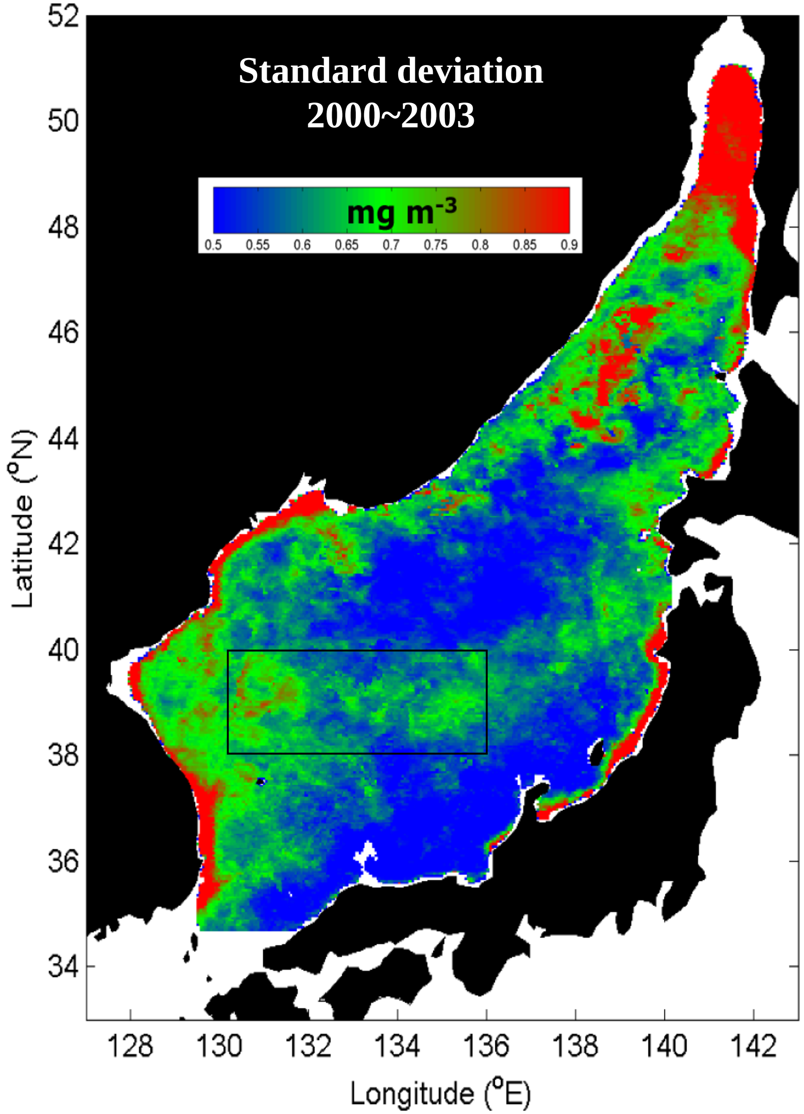






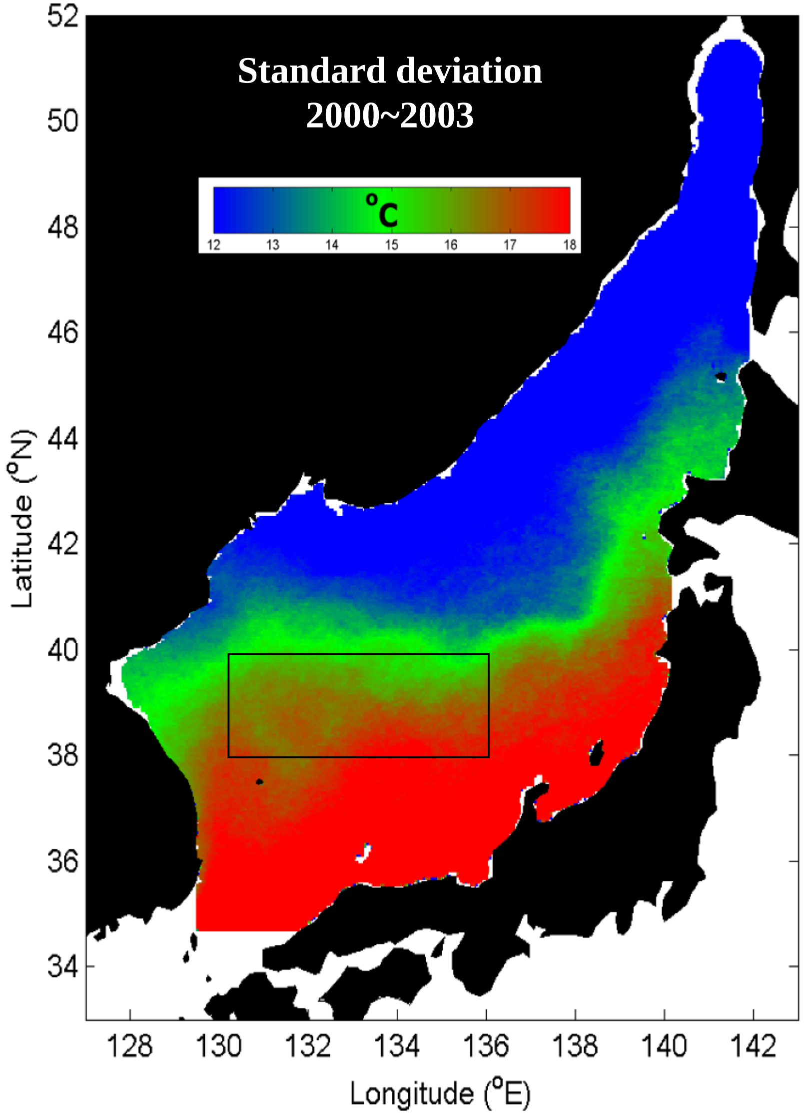


CHL



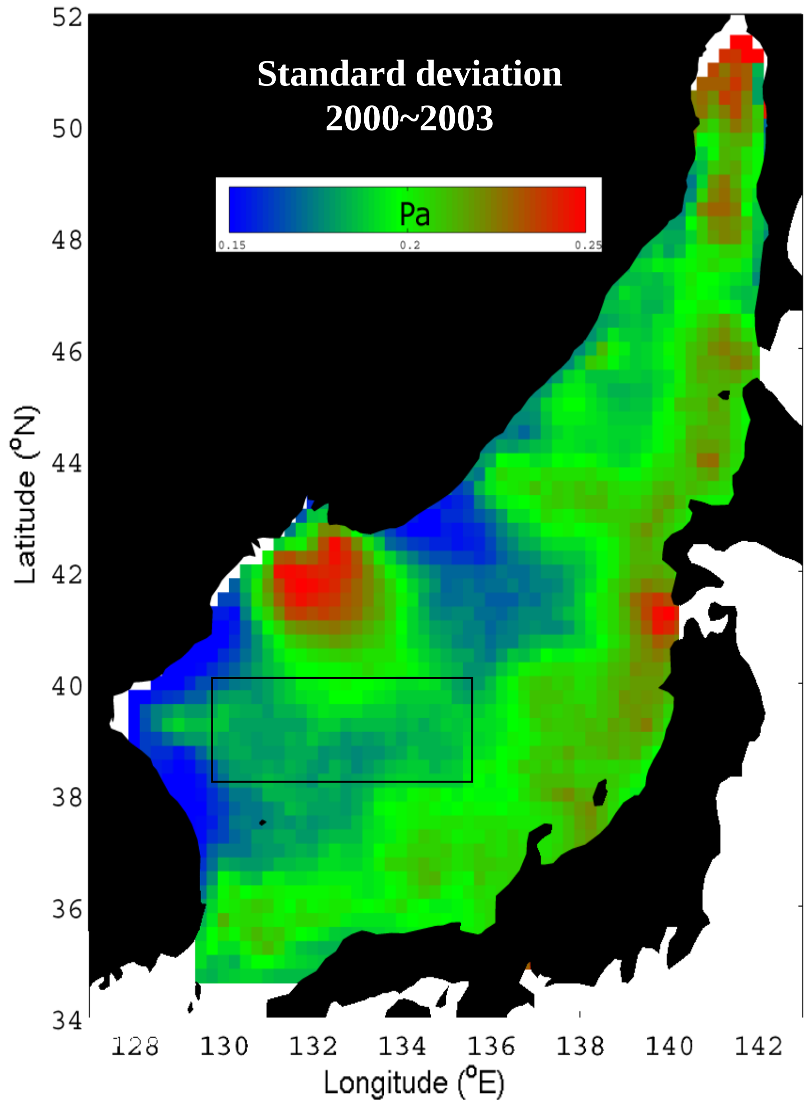
Standard deviation
2000~2003
mg m-3
0.5 0.55 0.6 0.65 0.7 0.75 0.8 0.85 0.9
Latitude (°N)
Longitude (°E)
52 50 48 46 44 42 40 38 36 34
128 130 132 134 136 138 140 142

SST

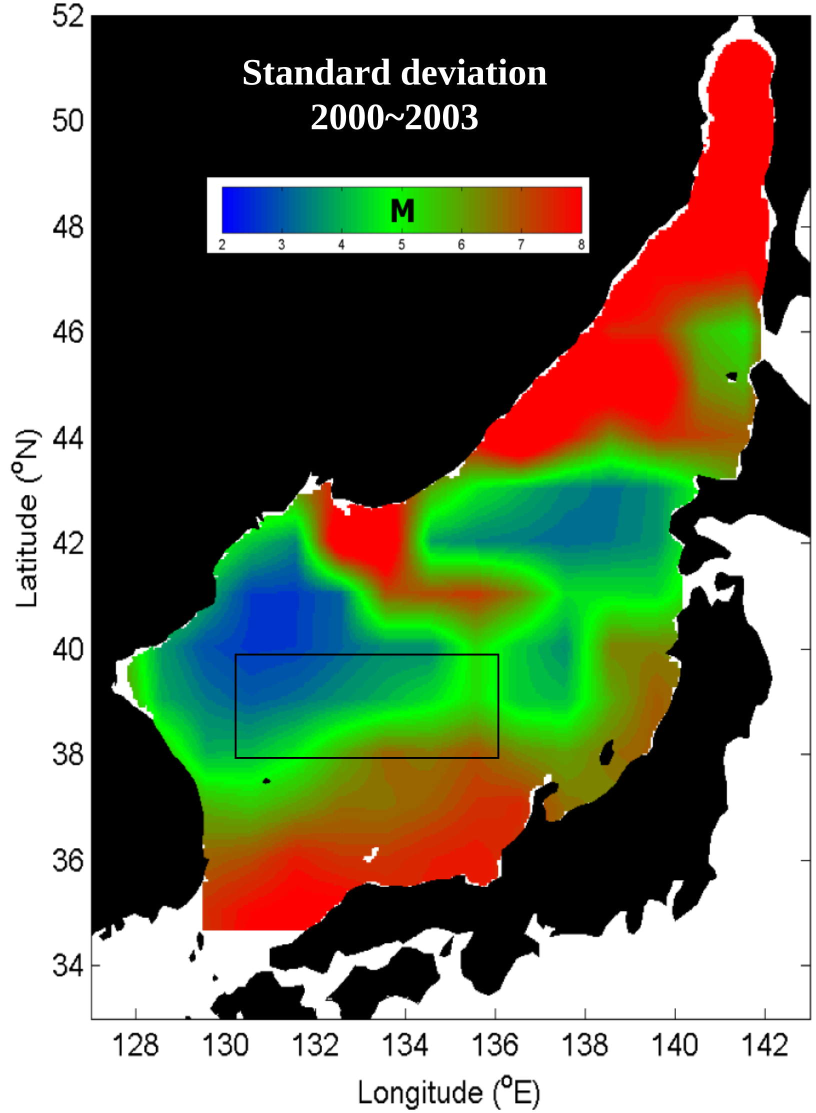


Standard deviation
2000~2003
°C
12 13 14 15 16 17 18
Latitude (°N)
Longitude (°E)
52 50 48 46 44 42 40 38 36 34
128 130 132 134 136 138 140 142

WIND

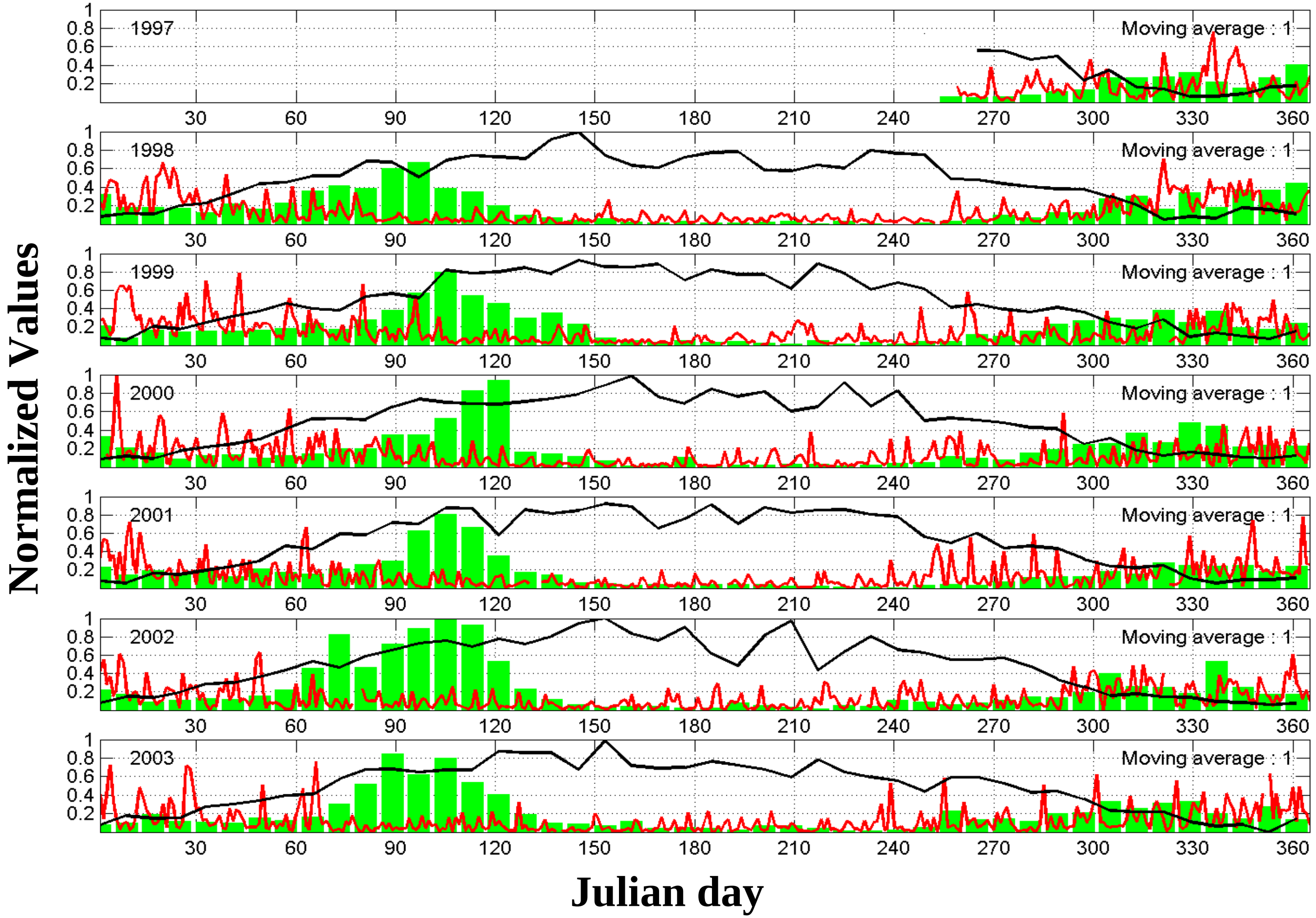

Standard deviation
2000~2003
Pa
0.15
0.2
0.25
52
50
48
46
44
42
40
38
36
34
Latitude (°N)
128 130 132 134 136 138 140 142
Longitude (°E)

MLD


Standard deviation
2000~2003
M
2 3 4 5 6 7 8
52
50
48
46
44
42
40
38
36
34
Latitude (°N)
128 130 132 134 136 138 140 142
Longitude (°E)

Variability of CHL, Wind and PAR 1997~2003

Green Bar : Weekly CHL, Red line : Daily Wind stress, Black line : Weekly PAR



Hypotheses

Hypothesis 1: The timing of spring bloom

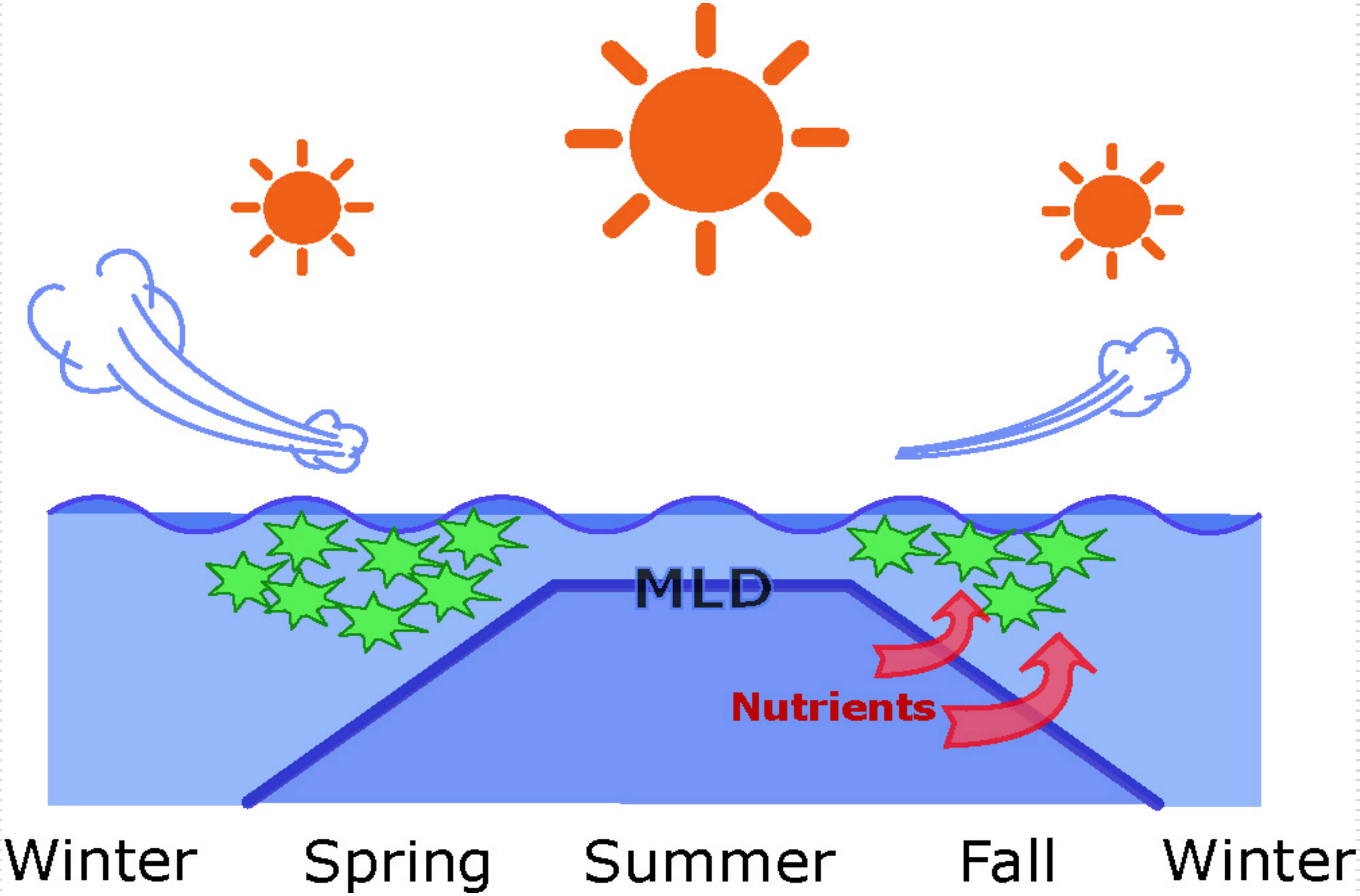
- **As the season progresses, the wind in spring becomes weaker and solar radiation gets stronger than in winter.**
- **These will accelerate thermal stratification in the upper layer.**
- **Stronger wind events in spring could delay the timing of blooming, while weaker wind events could advance the timing.**

Hypotheses

Hypothesis 2. The timing of fall bloom

- **During summers, the phytoplankton biomass in the upper layer is kept low by grazing and low growth rate limited by nutrients due to stratification.**
- **Monsoon wind is reversed in direction and gets stronger in fall.**
- **The water column is destratified by stronger wind and weakened solar radiation and nutrients are supplied to the upper layer. Growth are activated.**
- **<u>Stronger wind events in fall could advance the timing of blooming, while weaker wind events could delay the timing.</u>**

Light-nutrient hypothesis and seasonal growth cycles in the temperate waters



Previous studies

- **The stirring of the upper layers, by convective overturn and winds, is the major mechanism for regulating phytoplankton growth**
  - Sverdrub(1953), Cushing(1962), Evans and Paslow(1985), Yentsch(1990)

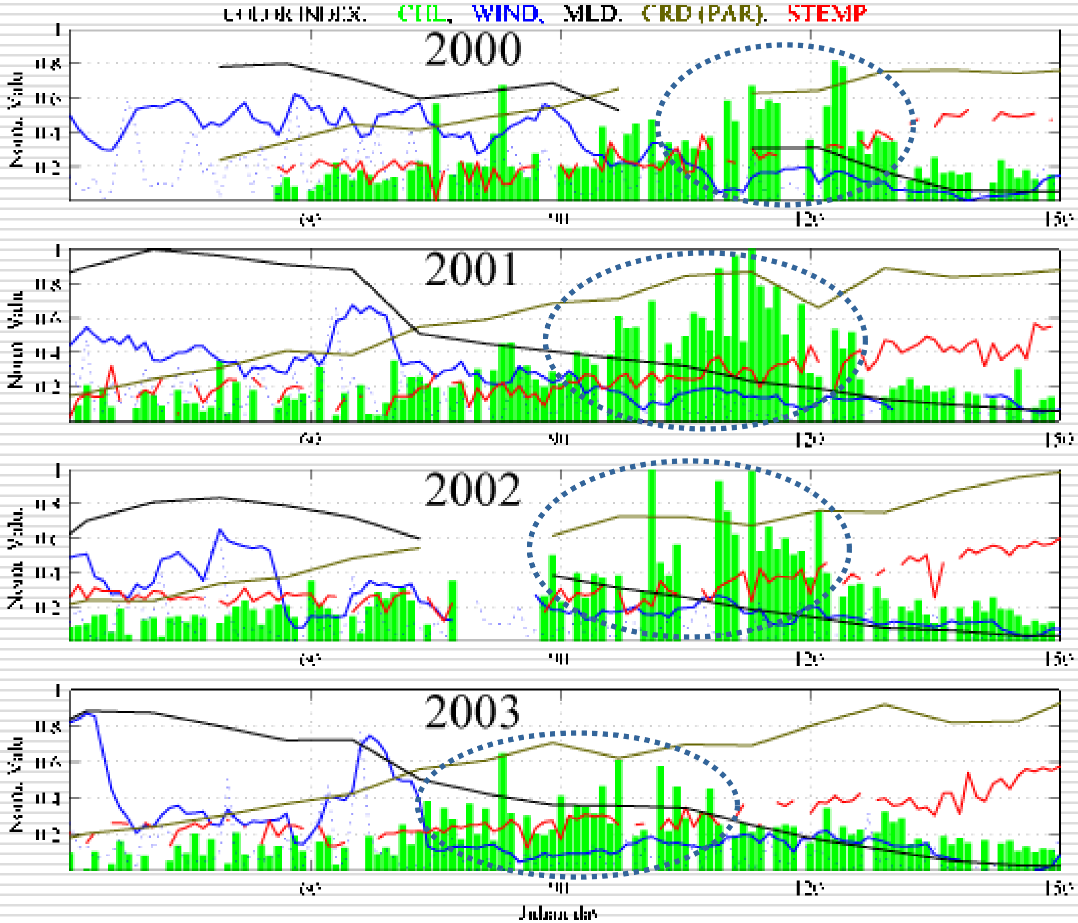
- **The role of wind stress in the spring bloom**
  - Goffart *et al*.(2002), Saitoh *et al*.(2002), Smayda (2002), Weise *et al*.(2002), Eslinger *et al*.(2001), Babaran *et al*.(1998), Tester *et al*.(1998), Lancelot *et al*.(1997), Brooks *et al*.(1993), Brooks *et al*.(1985)

- **Wind-driven Upwelling (nutrient resupply to the euphotic zone)**
  - Tang *et al*.(2003), Ryan *et al*.(2002), Roegner *et al*.(2002), Trainer *et al*.(2002) .

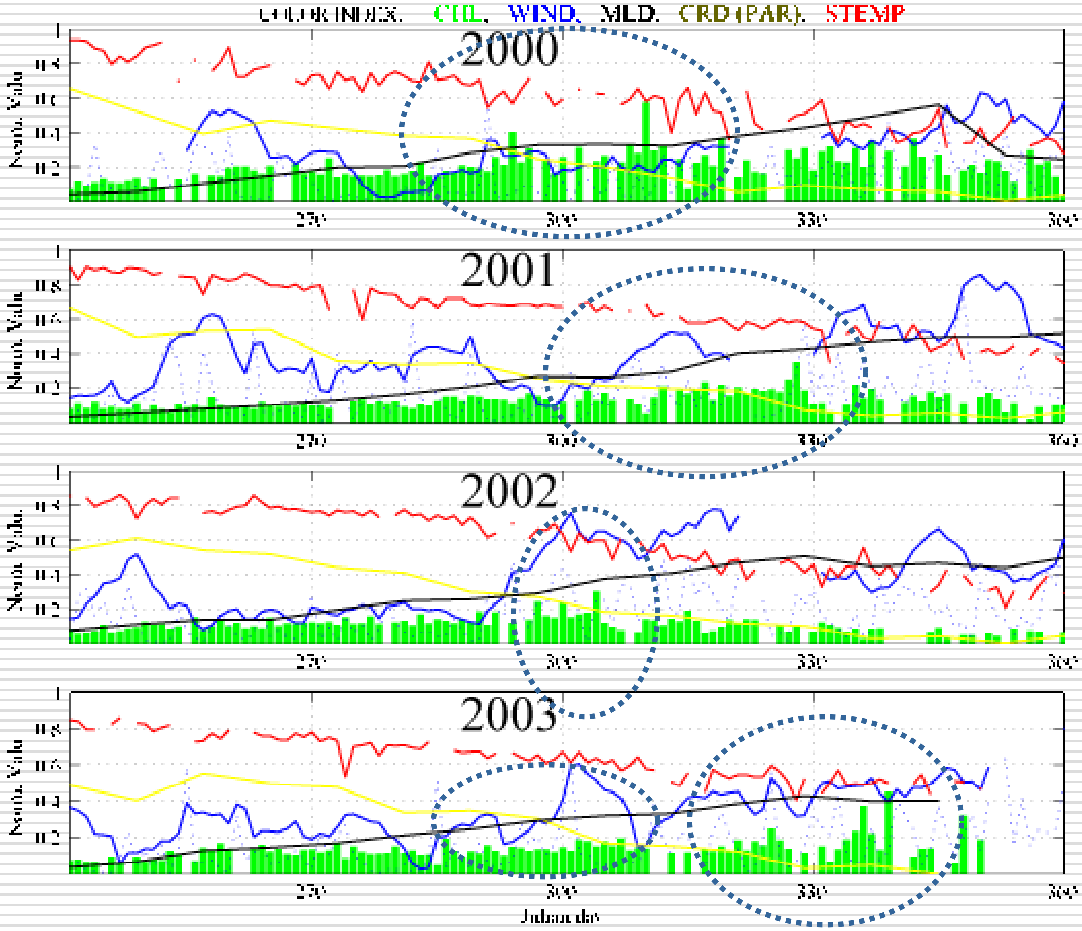
Data

- Ocean Color
  - SeaWiFS (SeaStar:1997~2003)
  - MODIS (Terra:2000~2003)
- SST
  - MODIS (Terra:2000~2003)
- Windstress (MWF)
  - AMI-Wind,NSCAT (ERS,NSCAT:1991~1998)
  - SeaWinds (QuickSCAT:1999~2003)
- MLD (model)
  - FNMOC (U.S.Navy's Fleet Numerical Meteorogy and Oceanography Center: 2000~2003)
- PAR
  - SeaWiFS(1997~2003)
  - MODIS(2000~2003)
  - NCEP reanalysis 2.
- KODC

Spring

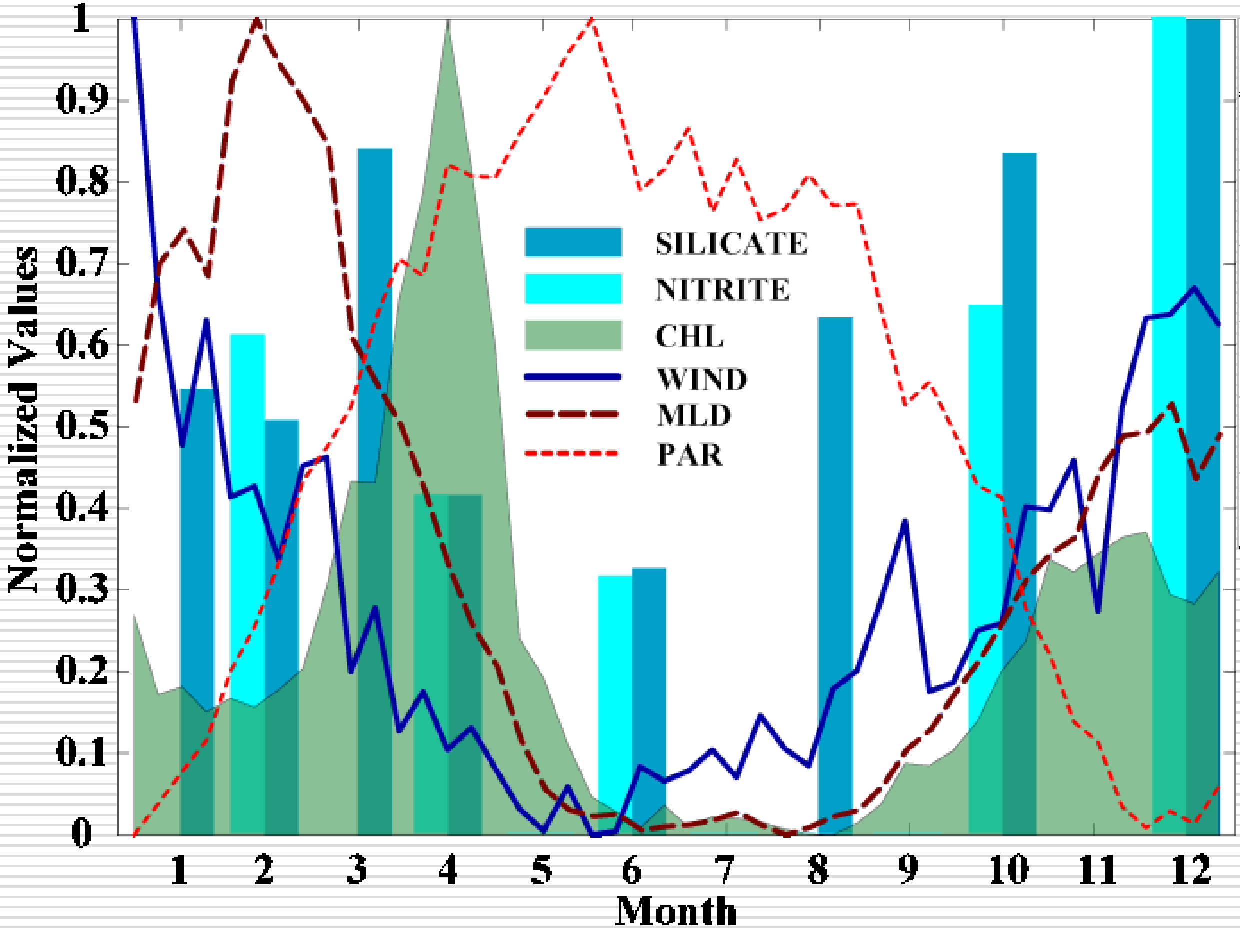

COLOR INDEX: CHL, WIND, MLD, CRD (PAR), STEMP
2000
2001
2002
2003
Norm. Value
Julian day

Fall



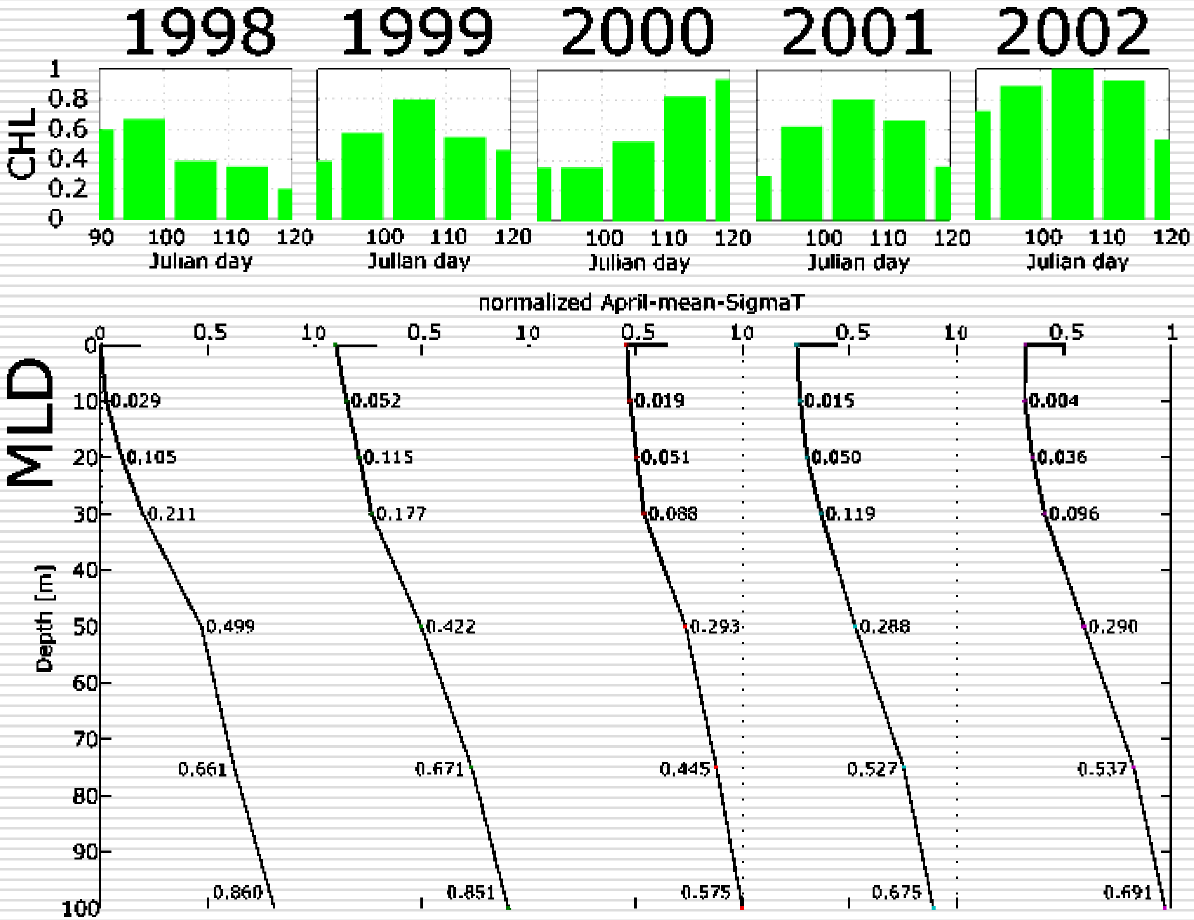
COLOR INDEX: CHL, WIND, MLD, CRD (PAR), STEMP
2000
2001
2002
2003
Norm. Value
Julian day

Averaged Monthly Trends (1997 – 2003)



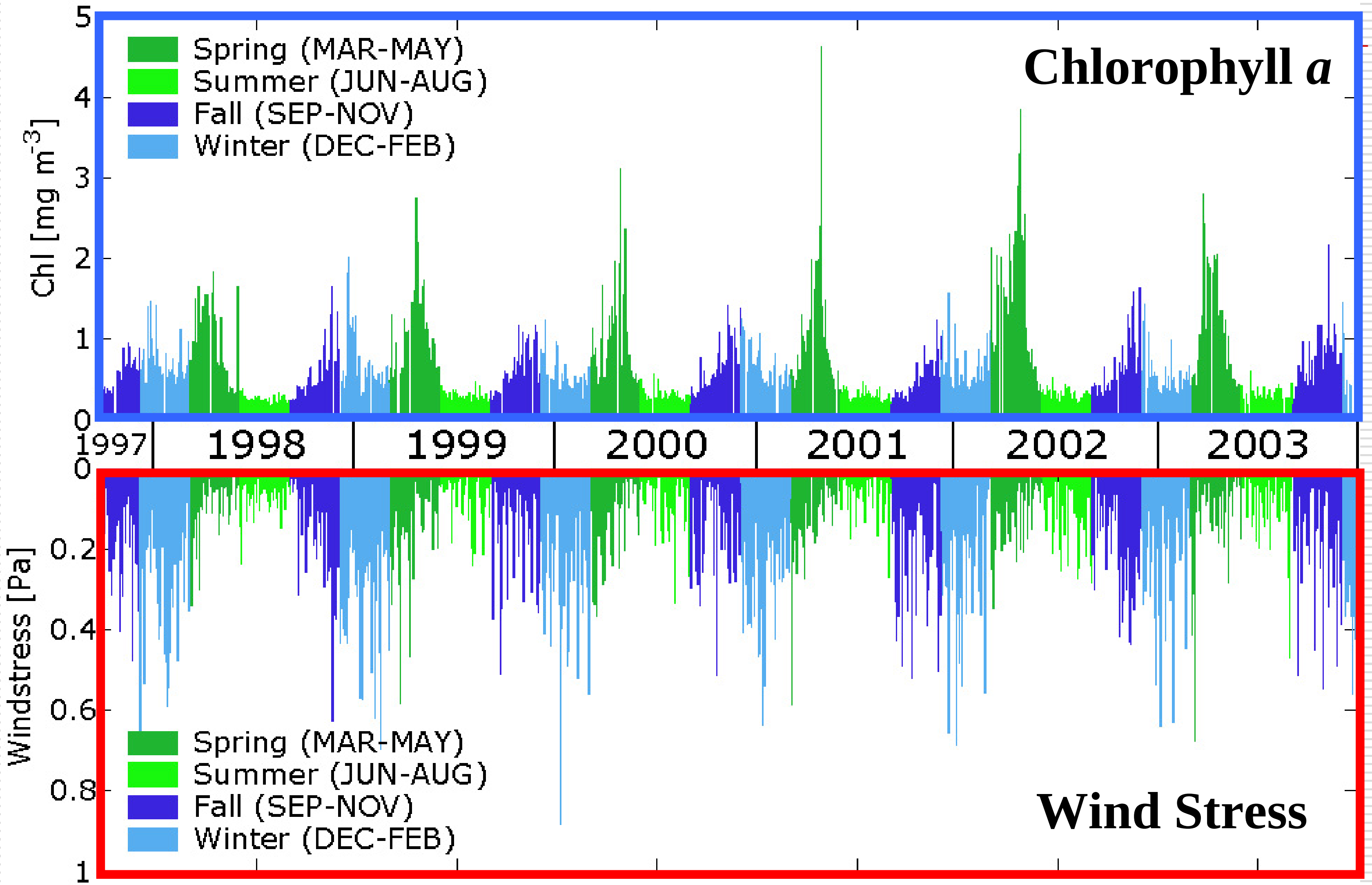
	Min	Max	Del.(0.1)
Silicate [um/l]	6.805	13.495	0.669
Nitrite [um/l]	0.249	0.558	0.0309
CHL [ug/l]	0.254	1.733	0.1479
Windstress [Pa]	0.033	0.297	0.0264
MLD [m]	4.862	67.805	6.2943
PAR [W/m^2]	10.193	51.729	4.1536

CHL (SeaWiFS) and MLD (KODC) in APRIL

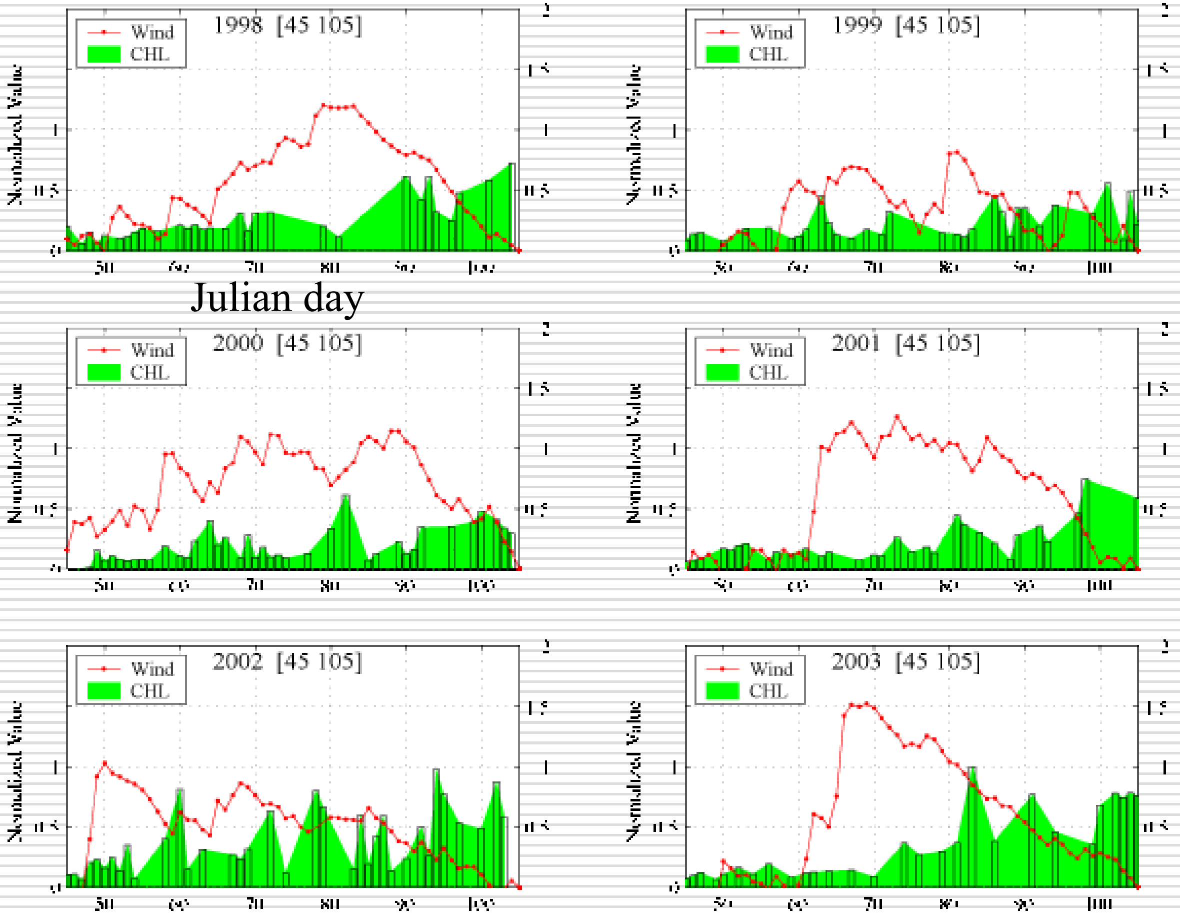


sub-polar frontal area of the Japan/East Sea

Daily CHL and Windstress
1997-2003



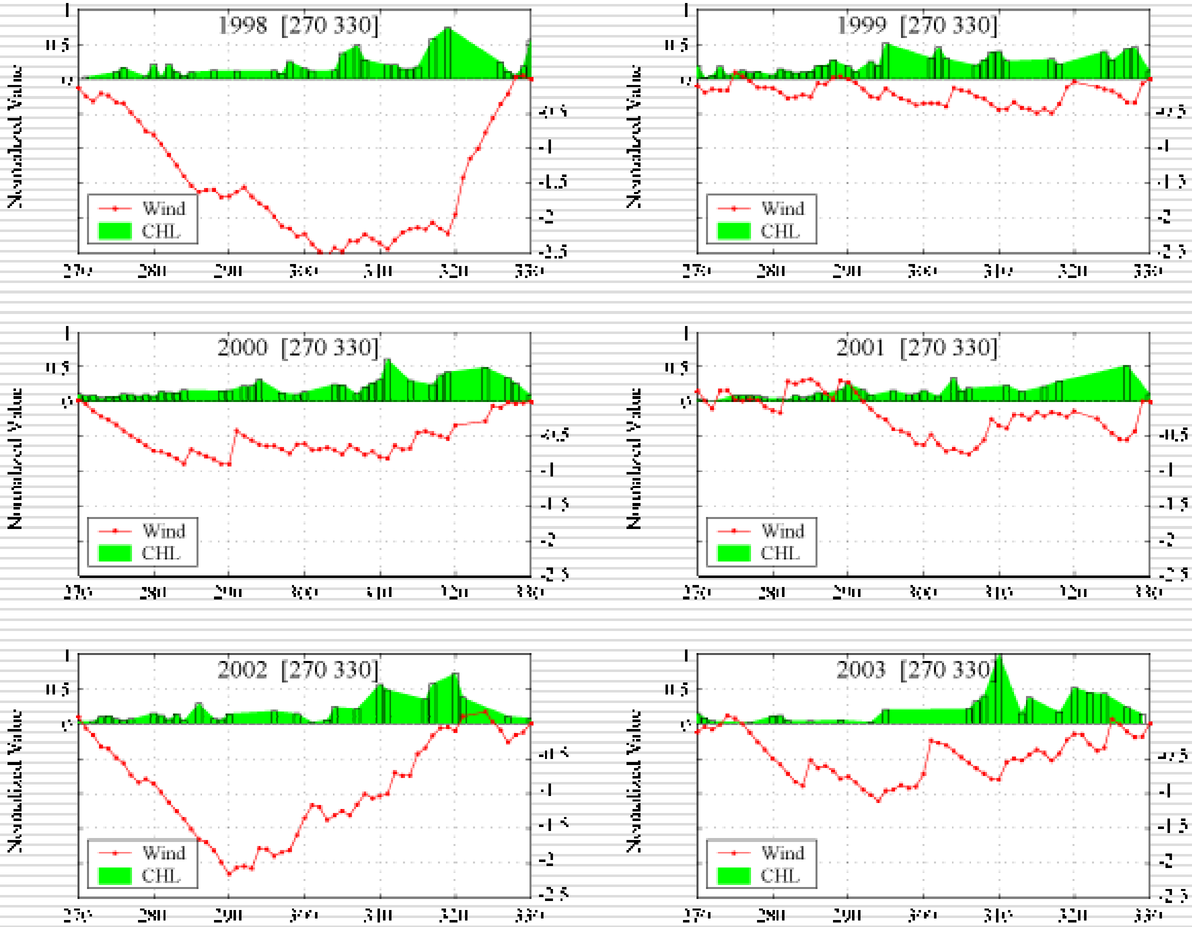
Time lag between Wind anomaly and CHL response in Spring



•Red line is CUSUM of wind anomaly

CUSUM: Cumulative Sum

Time lag between Wind anomaly and CHL response in Fall



* Red line is CUSUM of wind anomaly

Previous studies about time lag

The role of wind stress in the spring bloom

- Weise *et al.*(2002): wind>8m/s disrupt blooms.
- Yin *et al*. (1996): wind speed > 4m/s interrupt the spring bloom.
  Wind decrease ► NO_3 decreased after 5 days
  ► bloom occurred after 9 days.
- Bleiker and Schanz (1997): wind decrease ► growth occurred after 7 to 10 days

Wind-driven Upwelling (nutrient resupply to the euphotic zone)

- Yin *et al.*(1997): bloom occurred soon after the wind.
- Marra *et al.*(1990): wind increase
  ► increase in nitrate concentration in the euphotic zone
  ► bloom over the next 2days

Light & Nutrient MODEL (Yentch, 1990)

- The light limiting part
  - $P(z) = P_{max} \tanh \alpha I(z) / P_{max}$
  - $R = a P_{max}$
  - $P/R = \int^{Zm} Pdz / \int^{Zm} Rdz$

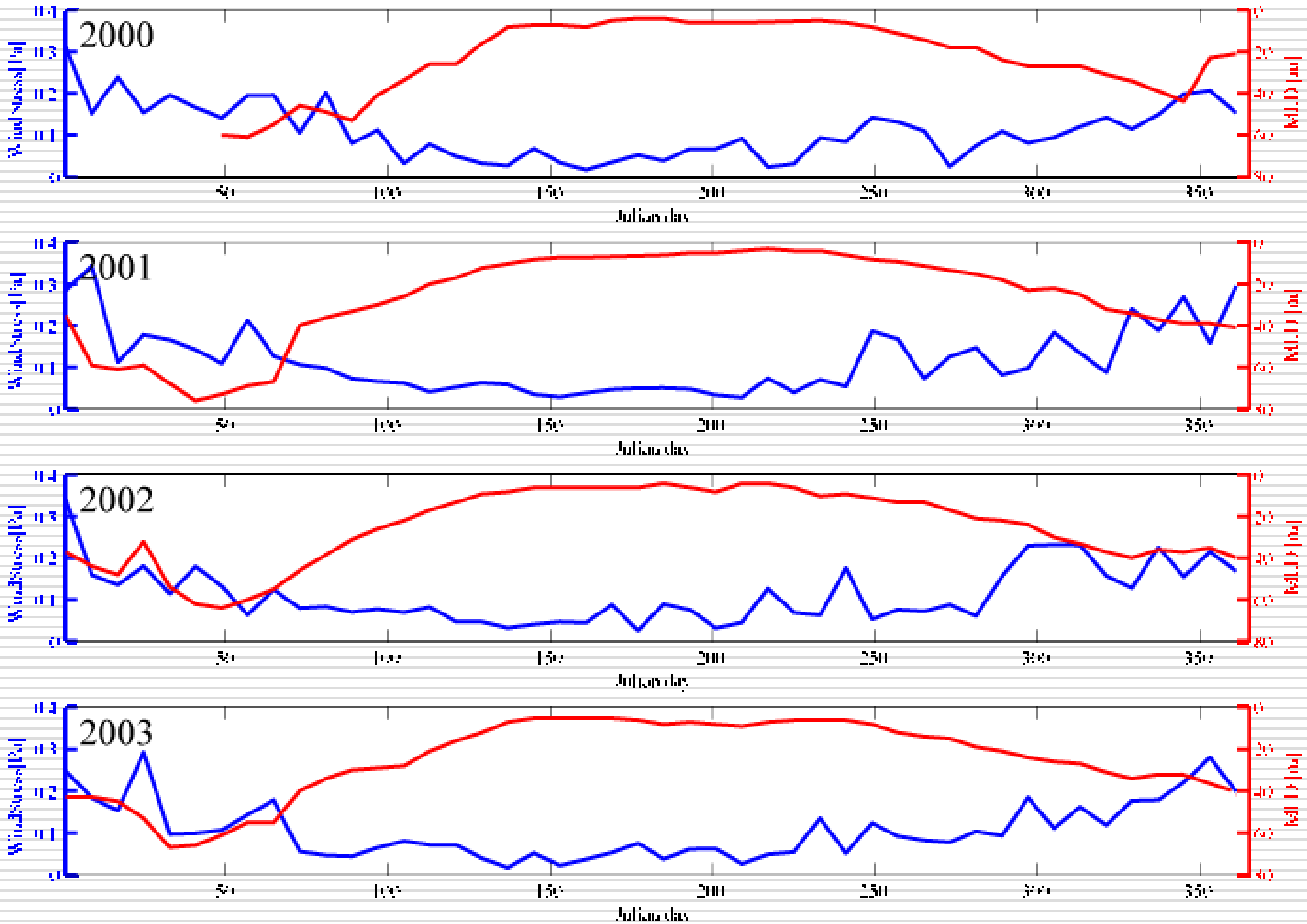
- The nutrient limiting part
  - $NZm = \int^{Zm} N(z)dz$
  - $PN = [(P/R-1)/5]\ NZm$

P: Phytoplankton Photosynthesis
R: Respiration
N: Nitrate concentration
Zm: Mixed layer depth
a: respiration ratio

Windstress & Mixed layer depth

Blue line:
Windstress

Red line:
Mixed layer depth



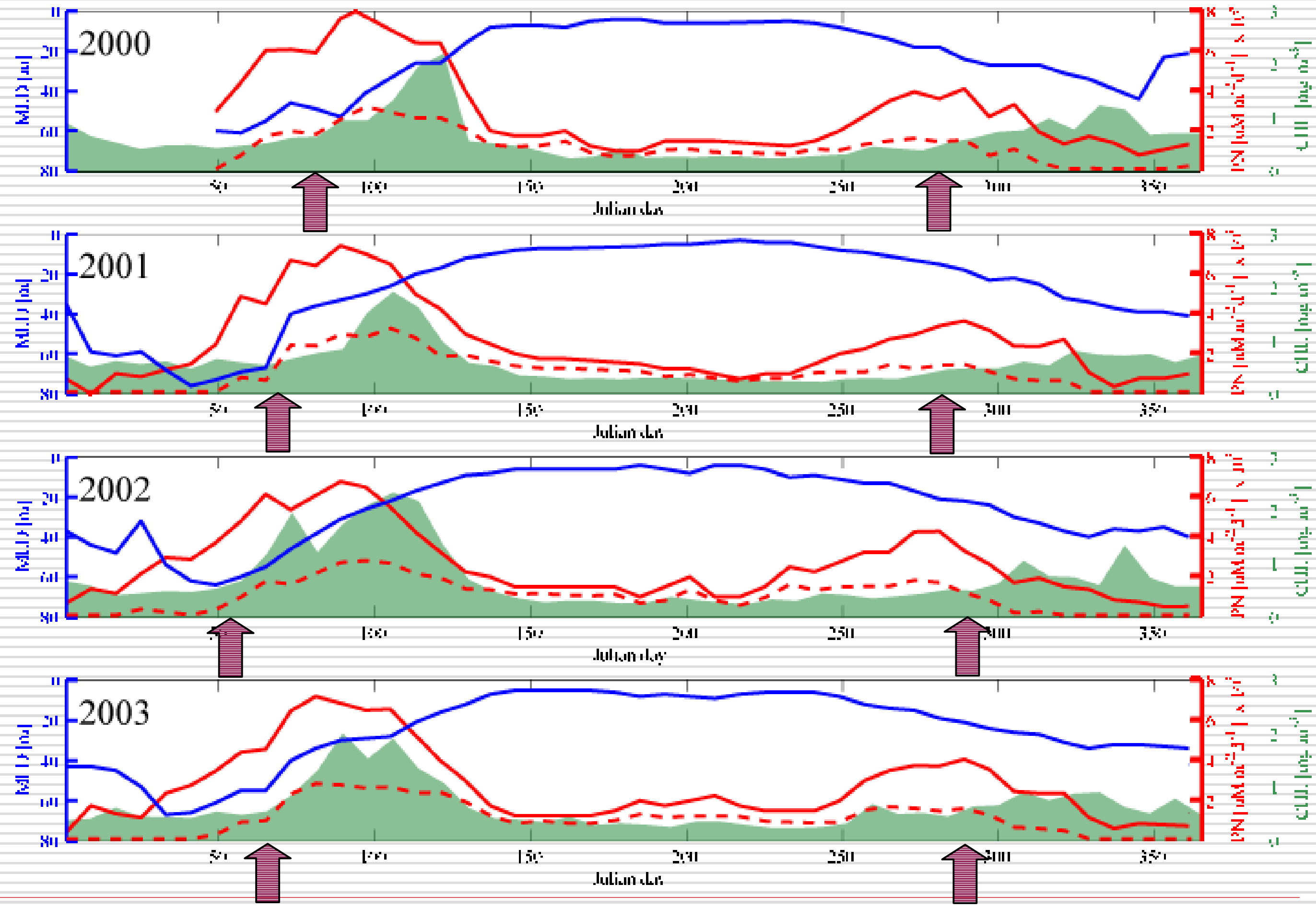
Chlorophyll *a* & PN & Mixed Layer depth

(Respiration ratio : bold line = 10 %, dashed line = 20%)

Blue line:
Mixed layer depth

Red line:
Particulate nitrate

Green area:
Chlorophyll

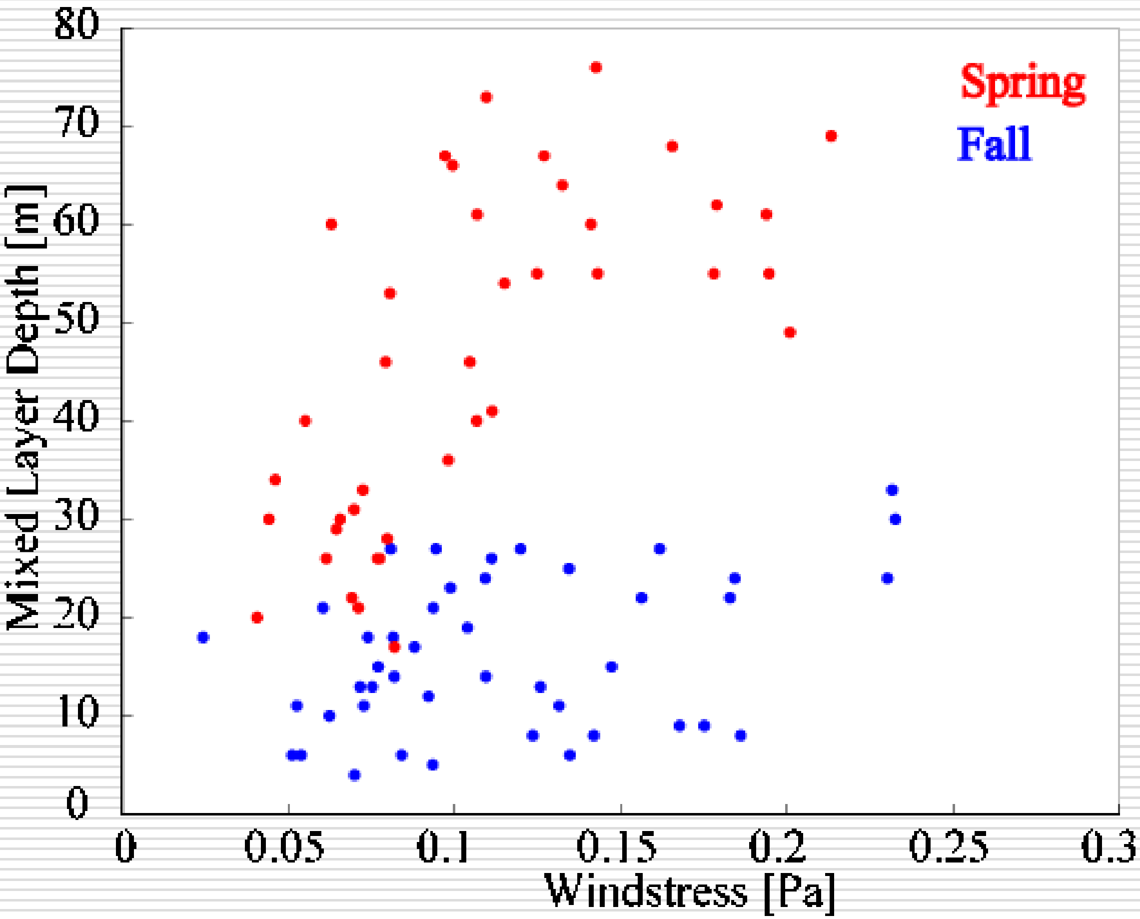


Conclusion

From above results, our hypotheses are well supported as follows.

- In the sub-polar front of the Japan/East sea
  - **Hypothesis 1: <u>Stronger wind</u> events in spring could <u>delay the timing of blooming</u>, while weaker wind events could advance the timing**
    - Spring bloom occurs in 7 to 10 days after wind .
  - **Hypothesis 2: <u>Stronger wind</u> events in fall could <u>advance the timing of blooming</u>, while weaker wind events could delay the timing.**
    - Fall bloom occurs after 1 to 4 days with increasing seasonal wind.

Thank you.



Spring
Fall
Mixed Layer Depth [m]
Windstress [Pa]
0
10
20
30
40
50
60
70
80
0
0.05
0.1
0.15
0.2
0.25
0.3

Result: Light limiting
Chlorophyll *a* & P/R & Mixed Layer depth

Blue line:
Mixed layer depth

Red line:
P:R ratio

Green area:
Chlorophyll