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Relationships of interannual variability in SST and phytoplankton blooms to giant jellyfish (*Nemopilema nomurai*) outbreaks in the Yellow and East China Seas(YECS)

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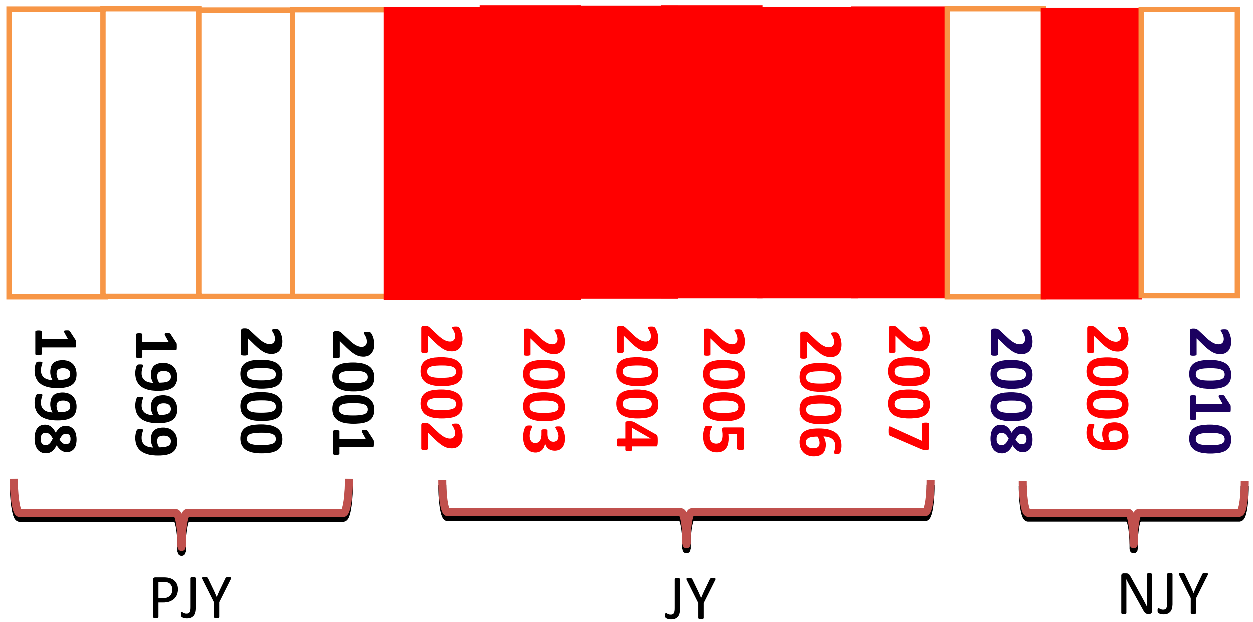
Photo modified from Itayama

Jellyfish outbreaks



More frequent outbreaks in 21 century

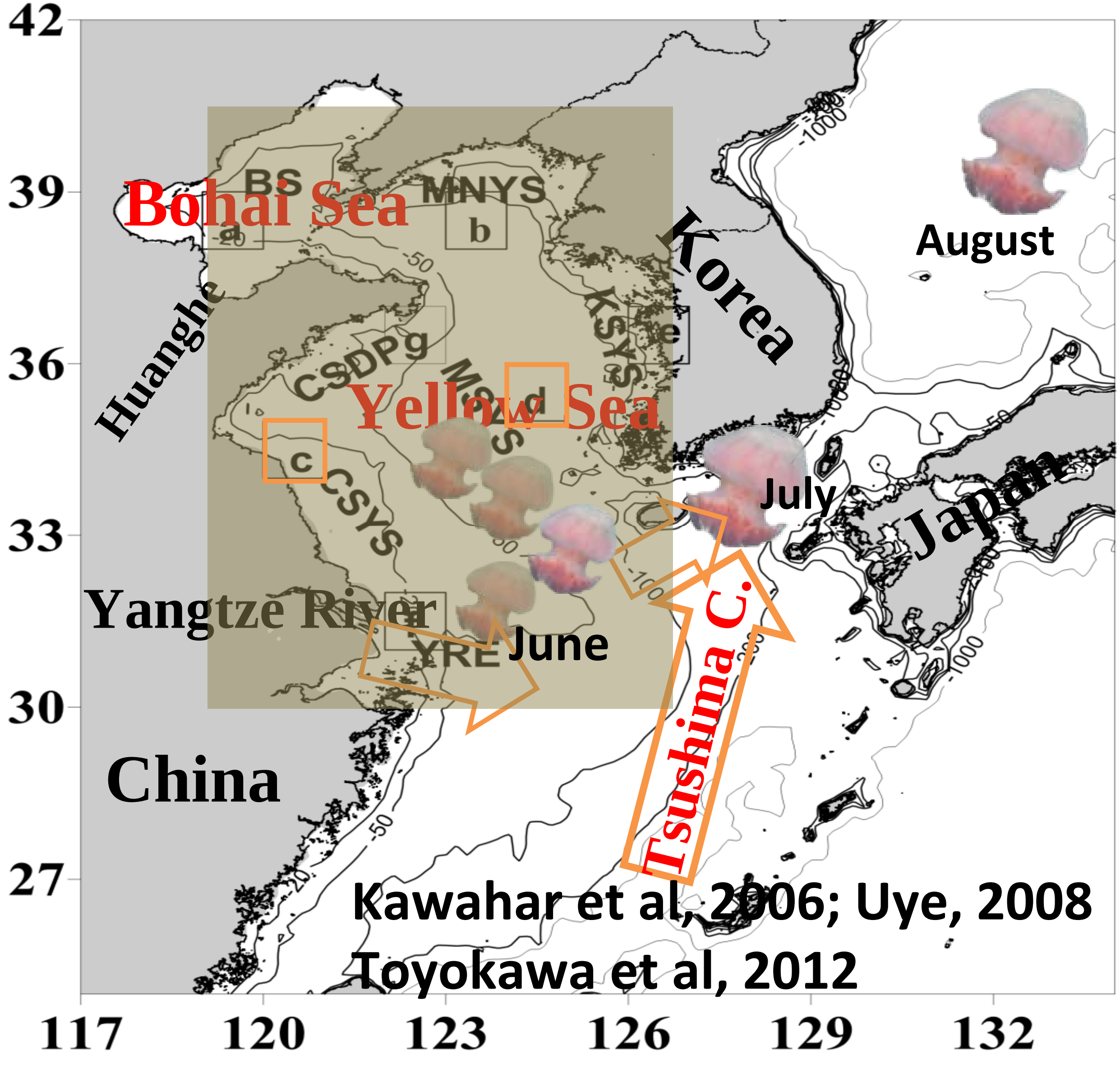
Pre-jellyfish year, PJY: **Absence of outbreaks**

Jellyfish year, JY: **Jellyfish outbreaks**

Non-jellyfish year, NJY: **Absence of outbreaks**

Annual report of FRA, Japan:
http://jsnfri.fra.affrc.go.jp/Kurage/kurage_top.html

Jellyfish distribution



Three hypotheses

1.Warming/cooling
of seawater ⇨ **Favorable/unfavorable for outbreaks**

2.High/low
eutrophication level ⇨ **Favorable/unfavorable for outbreaks**

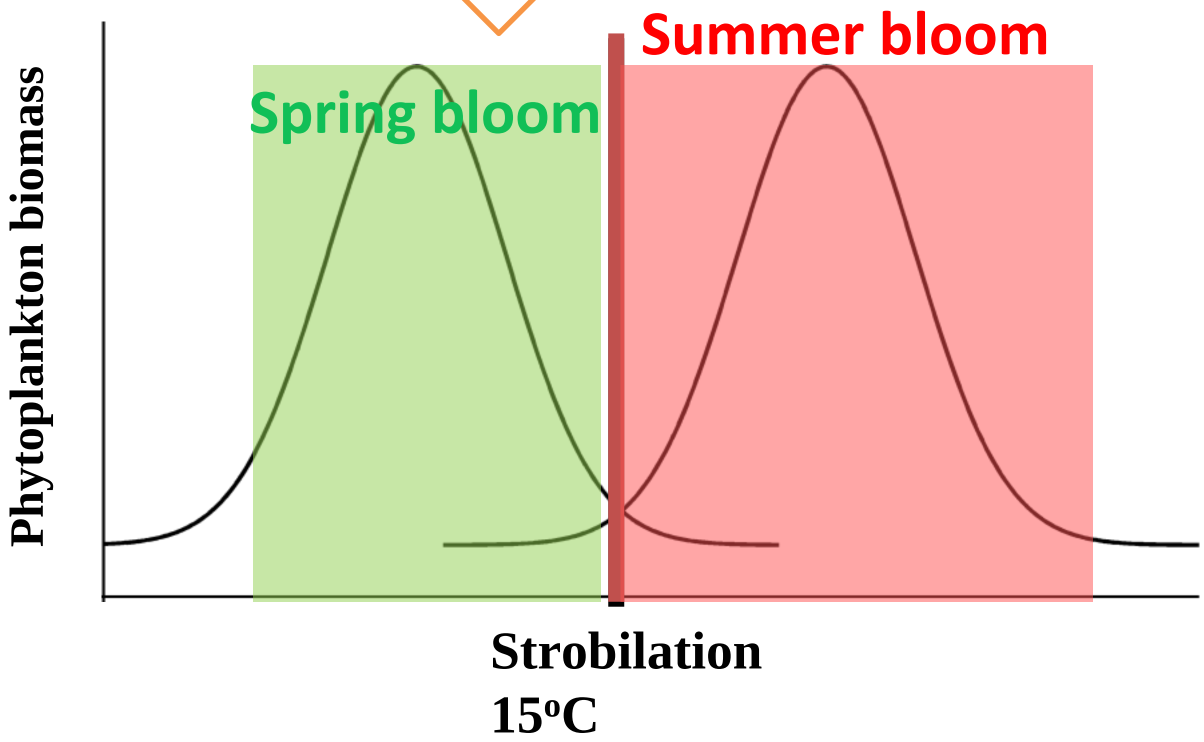
3.Match/mismatch
Between time to reach SST 15 °C and timing of phytoplankton blooms ⇨ **Favorable/unfavorable for outbreaks**

Gaussian fitting for phytoplankton blooms

$$CHL(t) = B_s \cdot t + B_i + a \cdot \exp\left\{ -\left[\frac{(t - t_p)^2}{2\sigma^2} \right] \right\}$$

Yamada and Ishizaka. GRL. 2005
Zhai et al. ICES J. 2011

1×1° grid in YECS,
totally 144 grids



Methods

1.Wilcoxon rank-sum (W-R) test:

SST difference among PJY, JY and NJY

- **SST(Weekly/monthly): 1998-2010 (AVHRR, MODIS)**

2.Correlation analysis:

The long-term trend in average Chl-a and peak Chl-a

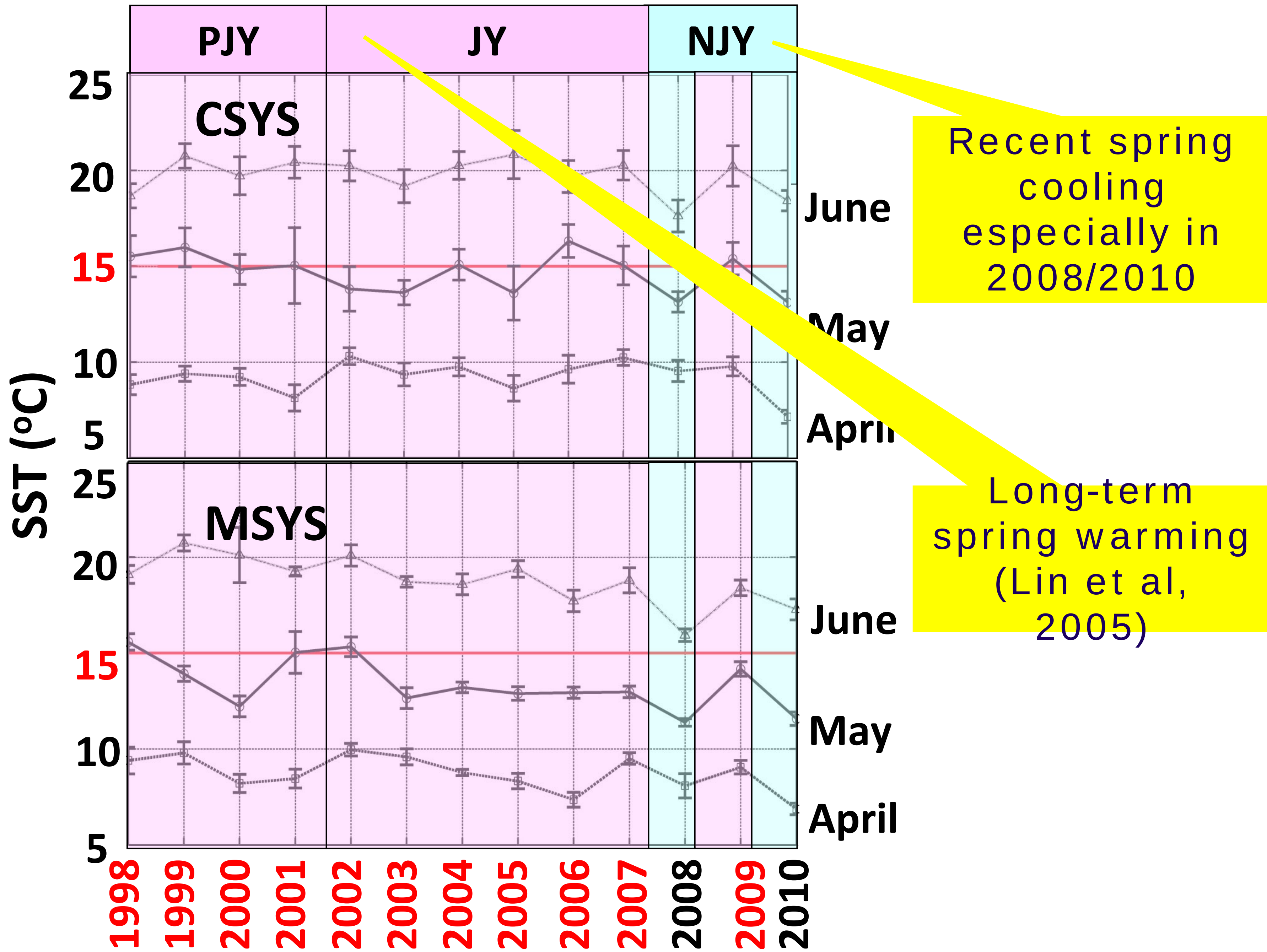
- **New Chl-a datasets(weekly): 1998-2010 (SeaWiFS, MODIS)**

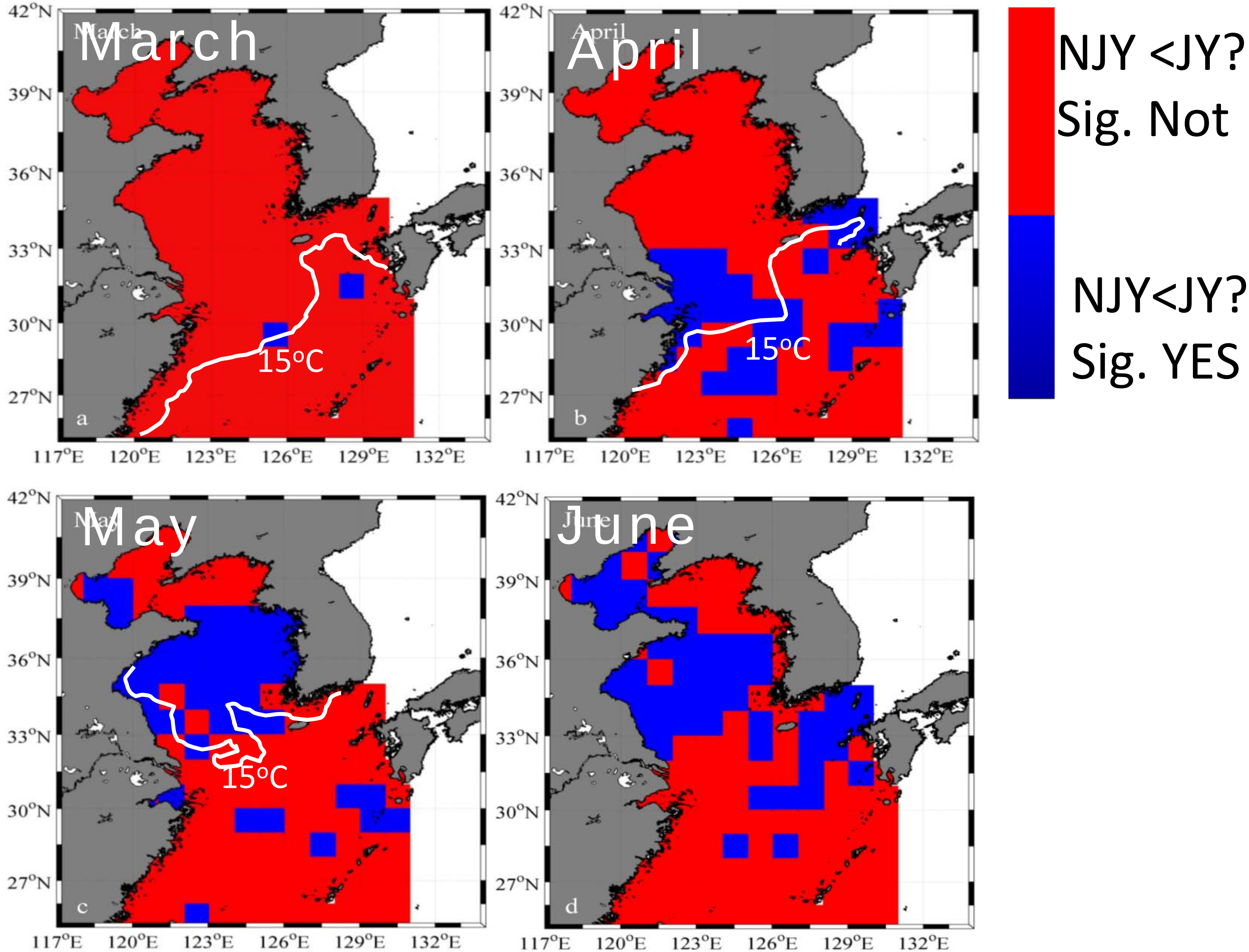
  (Siswanto et al. JO, 2011; Xu et al, submitted)

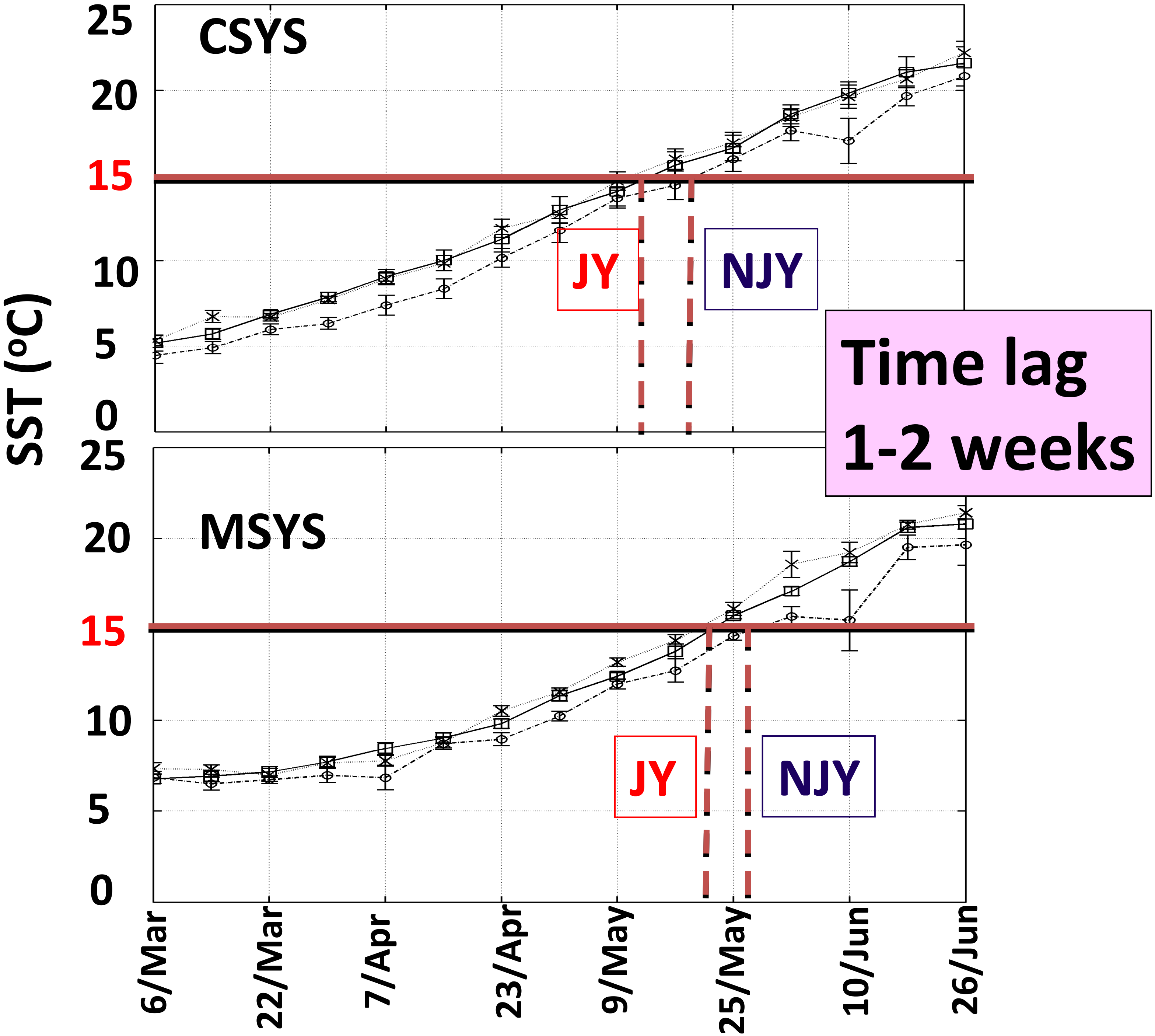
3.Match/mismatch

Timings of blooms and timing of SST reaching 15°C (strobilation)

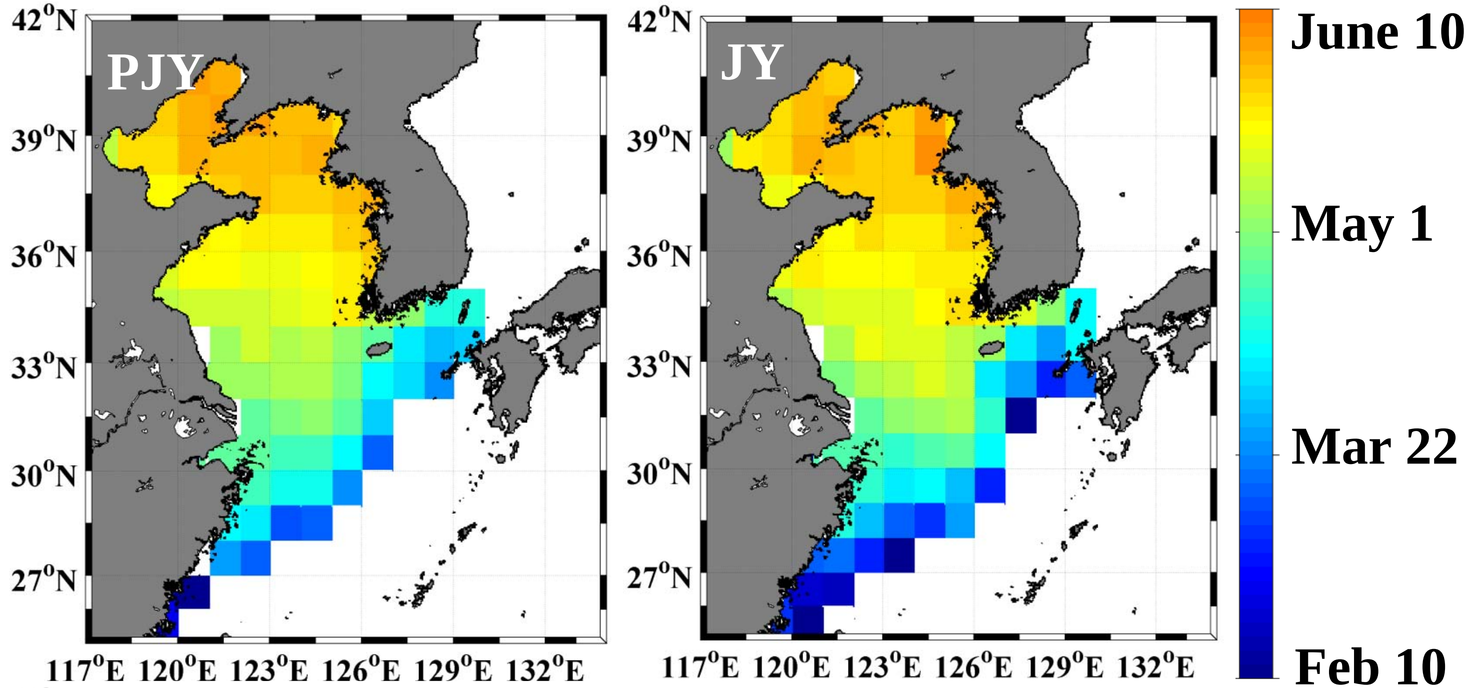
13-years satellite time series

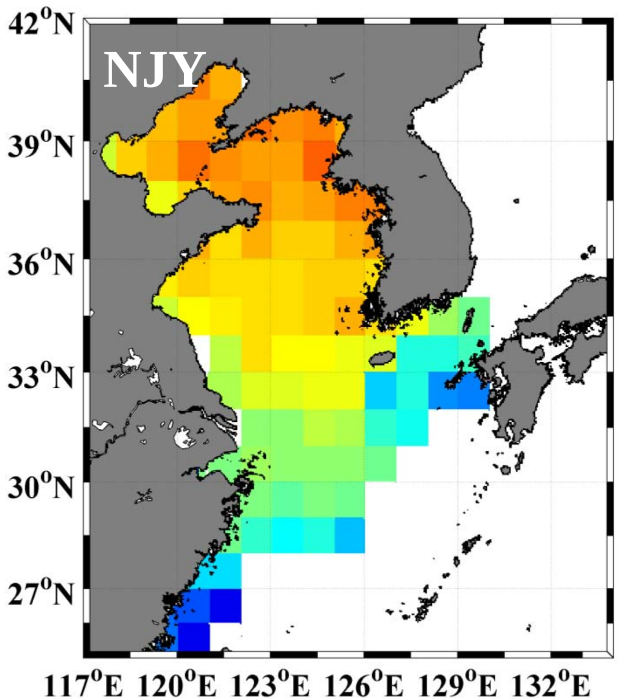

PJY
JY
NJY
CSYS
MSYS
SST (ºC)
25
20
15
10
5
June
May
April
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
Recent spring cooling especially in 2008/2010
Long-term spring warming (Lin et al, 2005)


March
April
May
June
15°C
15°C
15°C
a
b
c
d
42°N
39°N
36°N
33°N
30°N
27°N
117°E
120°E
123°E
126°E
129°E
132°E
NJY <JY?
Sig. Not
NJY<JY?
Sig. YES



CSYS
MSYS
SST (°C)
25
20
15
10
5
0
JY
NJY
Time lag
1-2 weeks
6/Mar
22/Mar
7/Apr
23/Apr
9/May
25/May
10/Jun
26/Jun





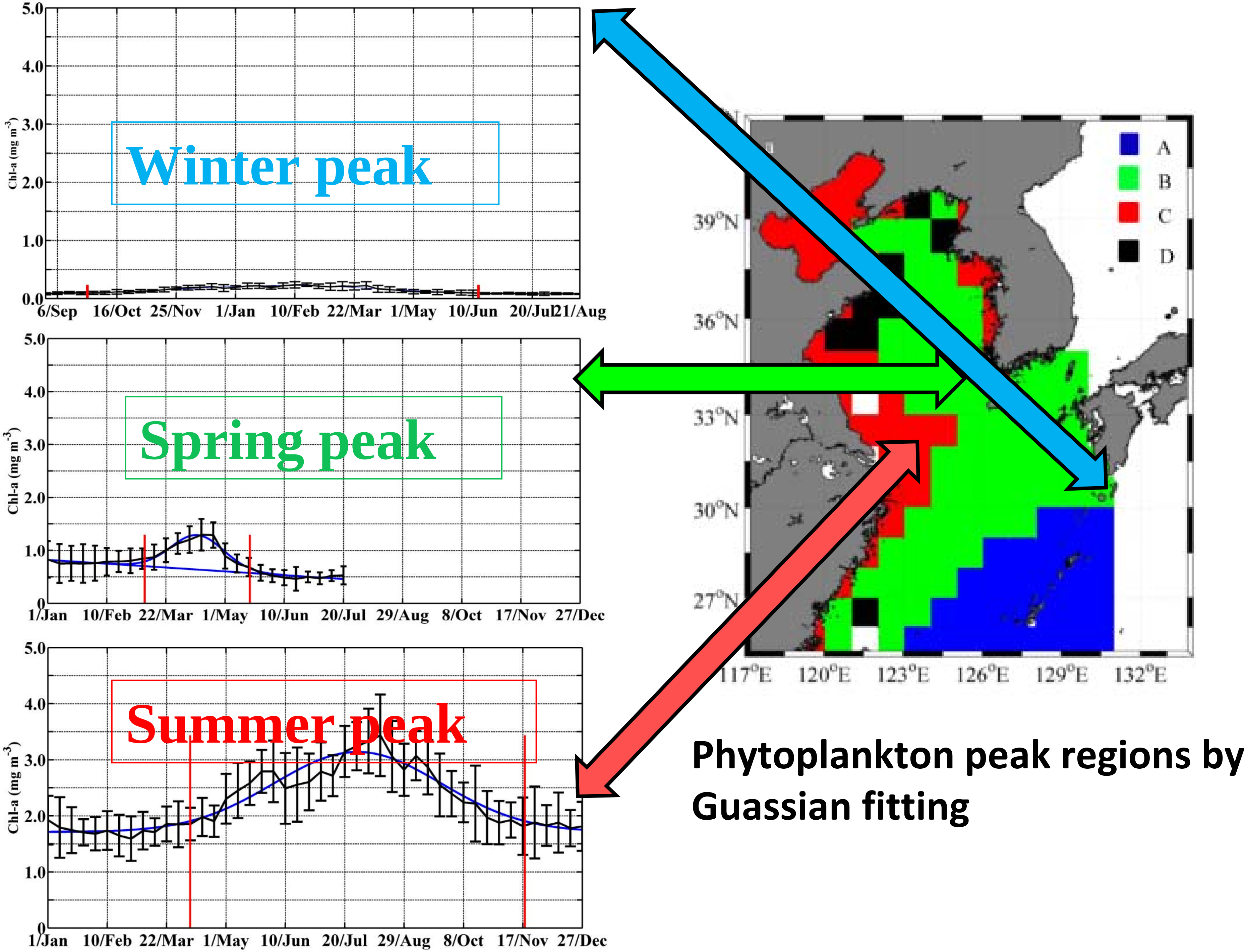
Time to reach 15°C:

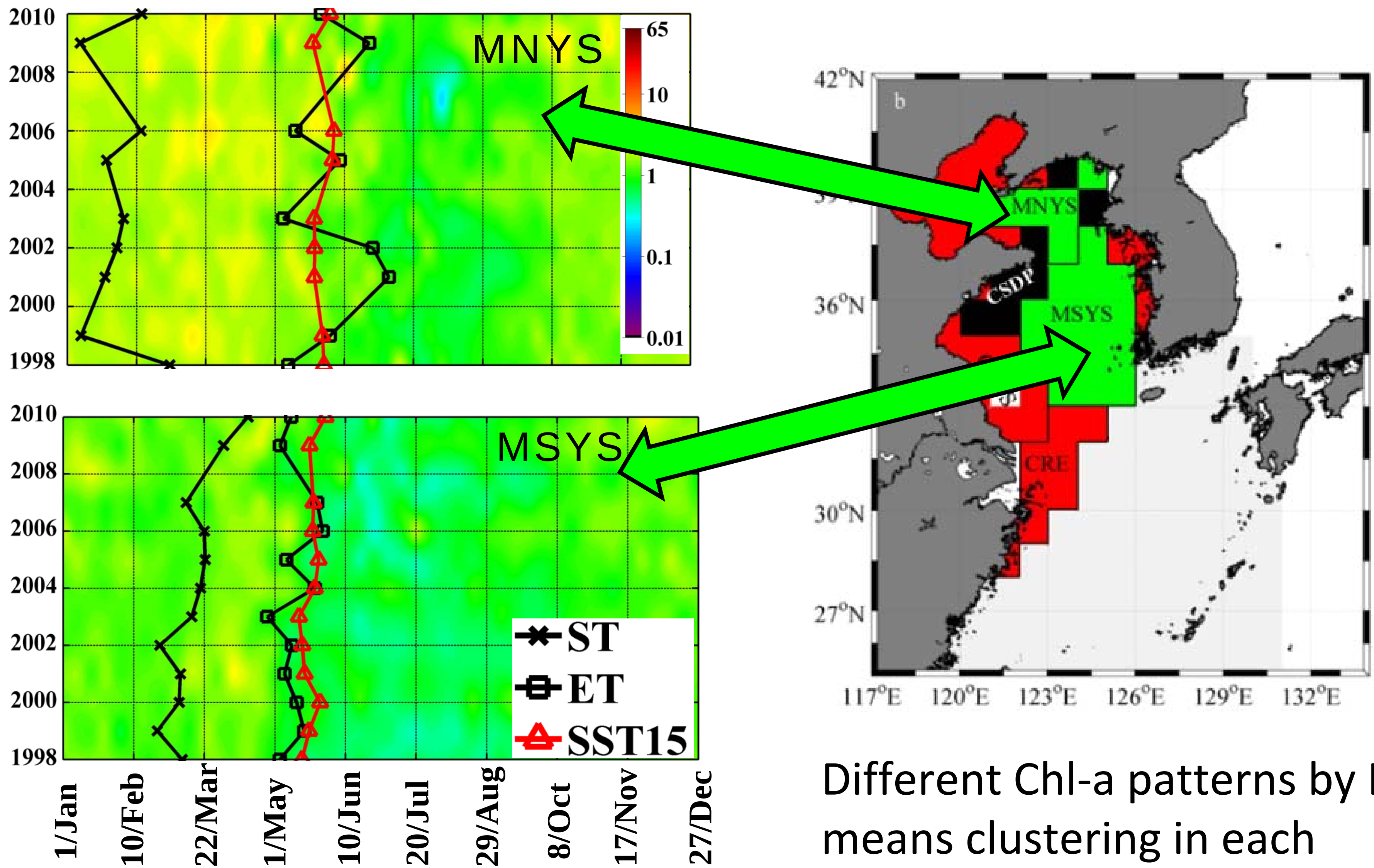
CSYS: early-May in JY/PJY

North YS and BS: late-May in JY/PJY

Delay in NJY: **2 weeks**

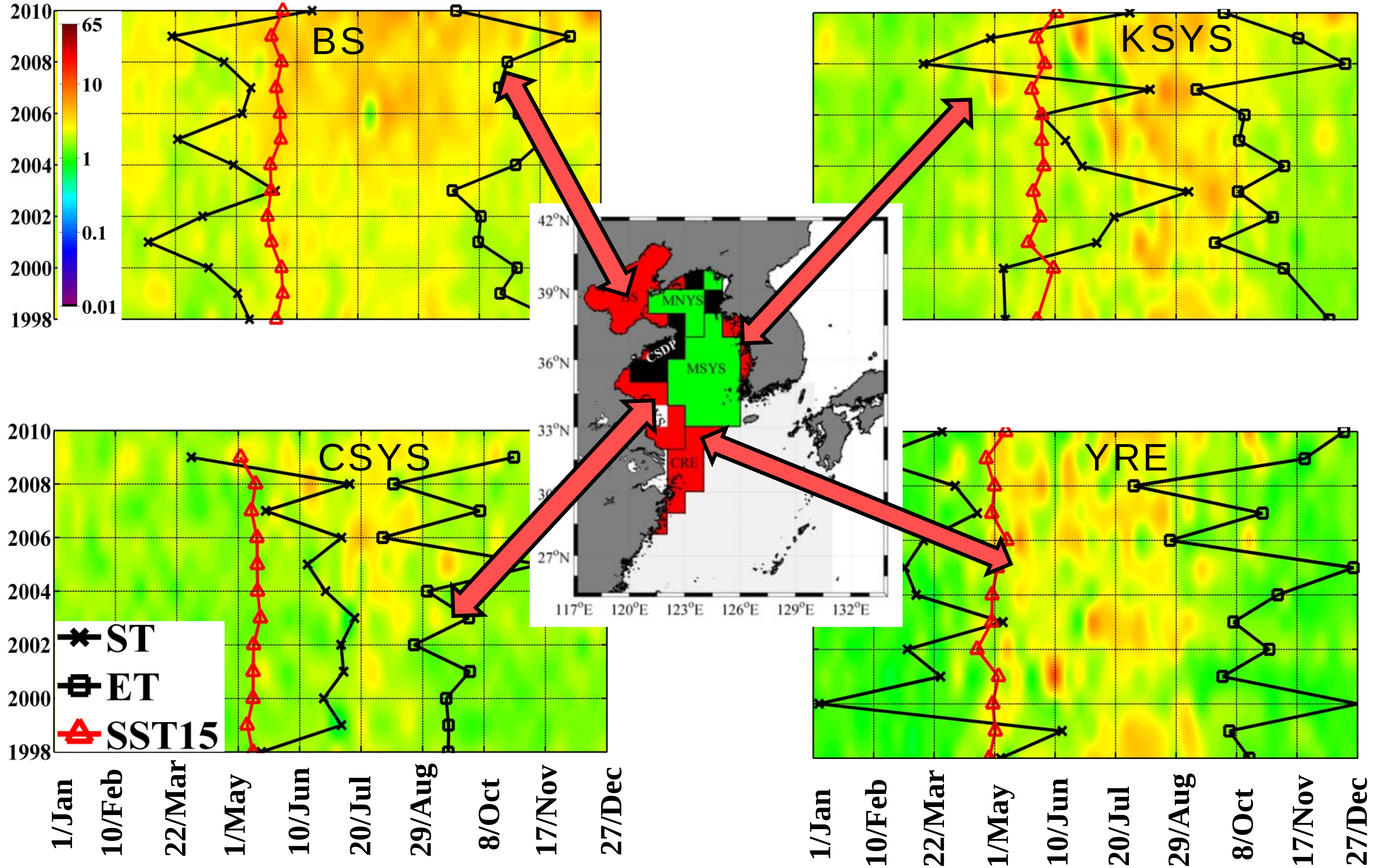
PJY≈JY<NJY


Winter peak
Spring peak
Summer peak
Chl-a (mg m⁻³)
6/Sep 16/Oct 25/Nov 1/Jan 10/Feb 22/Mar 1/May 10/Jun 20/Jul 21/Aug
1/Jan 10/Feb 22/Mar 1/May 10/Jun 20/Jul 29/Aug 8/Oct 17/Nov 27/Dec
A
B
C
D
39°N
36°N
33°N
30°N
27°N
117°E 120°E 123°E 126°E 129°E 132°E
Phytoplankton peak regions by Guassian fitting



Different Chl-a patterns by K-means clustering in each bloom regions

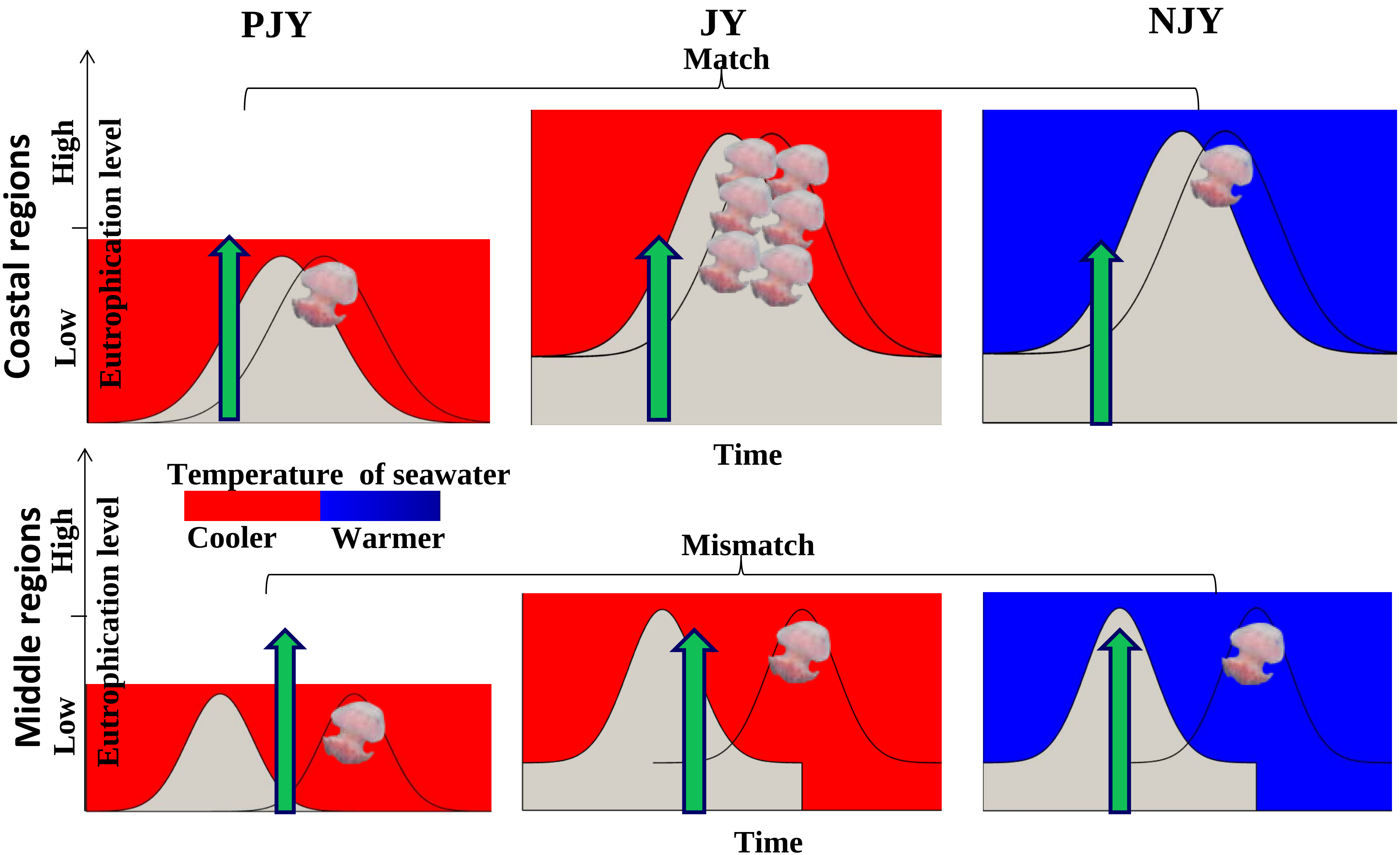
Mismatches



Matches and Eutrophication

Locations	Chl-a pattern	13 years increasing trend in average Chl-a	13 years increasing trend in Peak Chl-a
BS	**Summer bloom**	**55% ($r = 0.884$, $p < 0.05$), with 19% from PJY to JY**	**80% ($r = 0.882$, $p < 0.05$), with 31% from PJY to JY**
MNYS	**Spring bloom**		
CSYS	**Summer bloom**	**35.8% ($r = 0.831$, $p < 0.05$), with 14% from PJY to JY**	**60% ($r = 0.55$, $p < 0.05$), with 18% from PJY to JY**
MSYS	**Spring Bloom**	**18% ($r = 0.61$, $p < 0.05$), with 4% from PJY to JY**	**55% ($r = 0.66$, $p < 0.05$), with 8.2% from PJY to JY**
KSYS	**Summer bloom**	**35.7% ($r = 0.85$, $p < 0.05$), with 14.5% from PJY to JY**	**38% ($r = 0.75$, $p < 0.05$), with 26% from PJY to JY**
YRE	**Summer bloom**	**9.5% without significant trend, with 5% from PJY to JY**	**8-10% without significant trend, with 5% from PJY to JY**

Eutrophication were observed in most of coast regions and MSYS region


PJY
JY
NJY
Match
Coastal regions
High
Low
Eutrophication level
Time
Middle regions
Temperature of seawater
Cooler
Warmer
Mismatch
Time

Summary

1. **High eutrophication level and the warming of seawater favored the long-term increase in *N. nomurai* outbreaks in JY**
2. **Lower SST was an important factor preventing the outbreaks of jellyfish in NJY**
3. **Lower SST did not cause mismatch. It may directly affect the survival rate of jellyfish larvae**
4. **Mismatch maybe the main factor to cause absence of outbreaks in middle regions**
5. **Match in coastal regions and mismatch in mid regions were observed in all the years, indicating coastal regions provide better environments than mid regions for jellyfish ephyrae**