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May 19-22, 2008, Xiamen China

Effects of Winds on Hypoxia Formation in the Pearl River Estuarine Coastal Waters

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Outline

Global and Regional Hypoxia Perspectives

Nitrogen Enrichment in the Pearl River

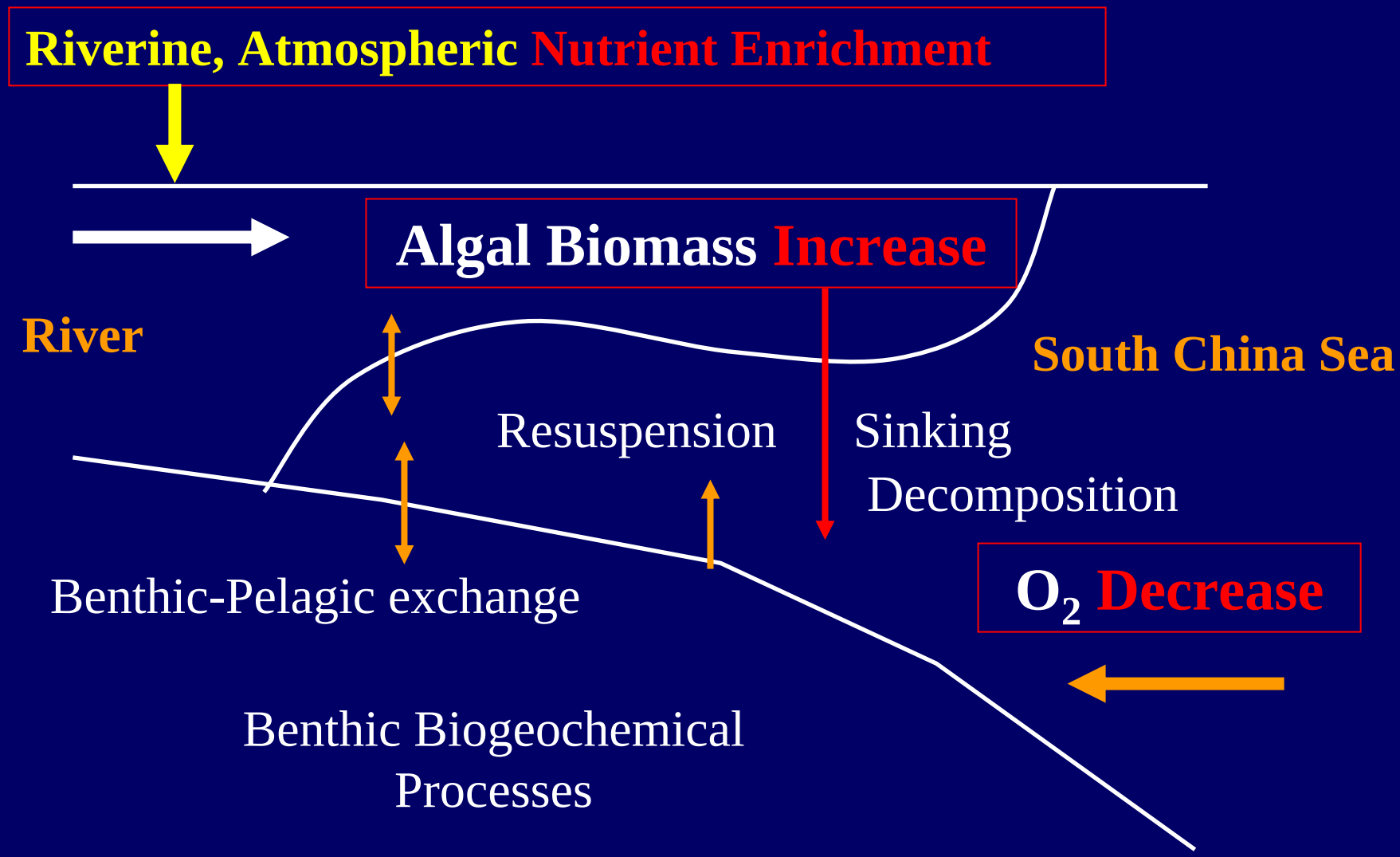
Variability of Dissolved Oxygen in Hong Kong

Oceanography Processes

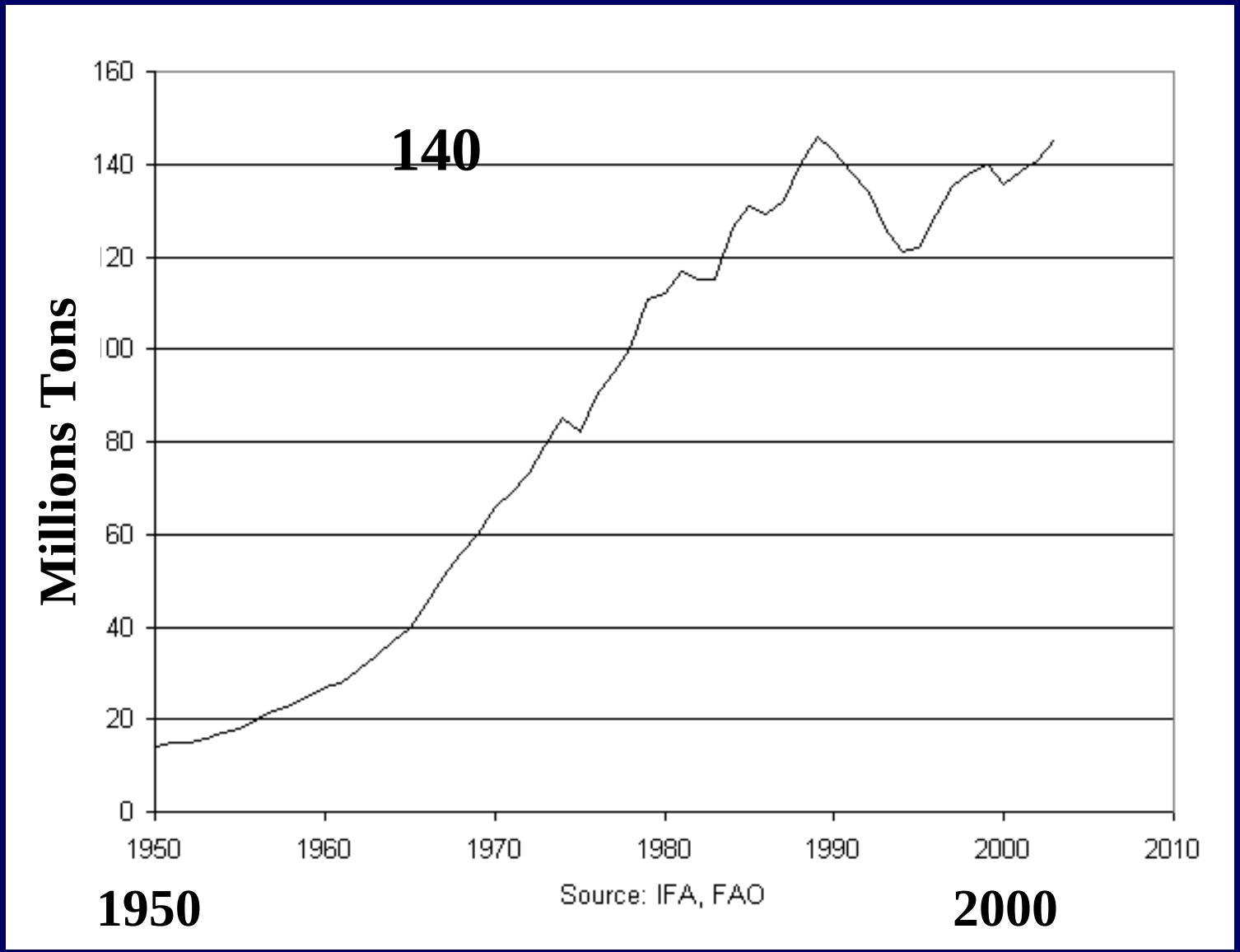
- Monsoons
- River Outflow

Effects of winds in preventing hypoxia formation in Hong Kong

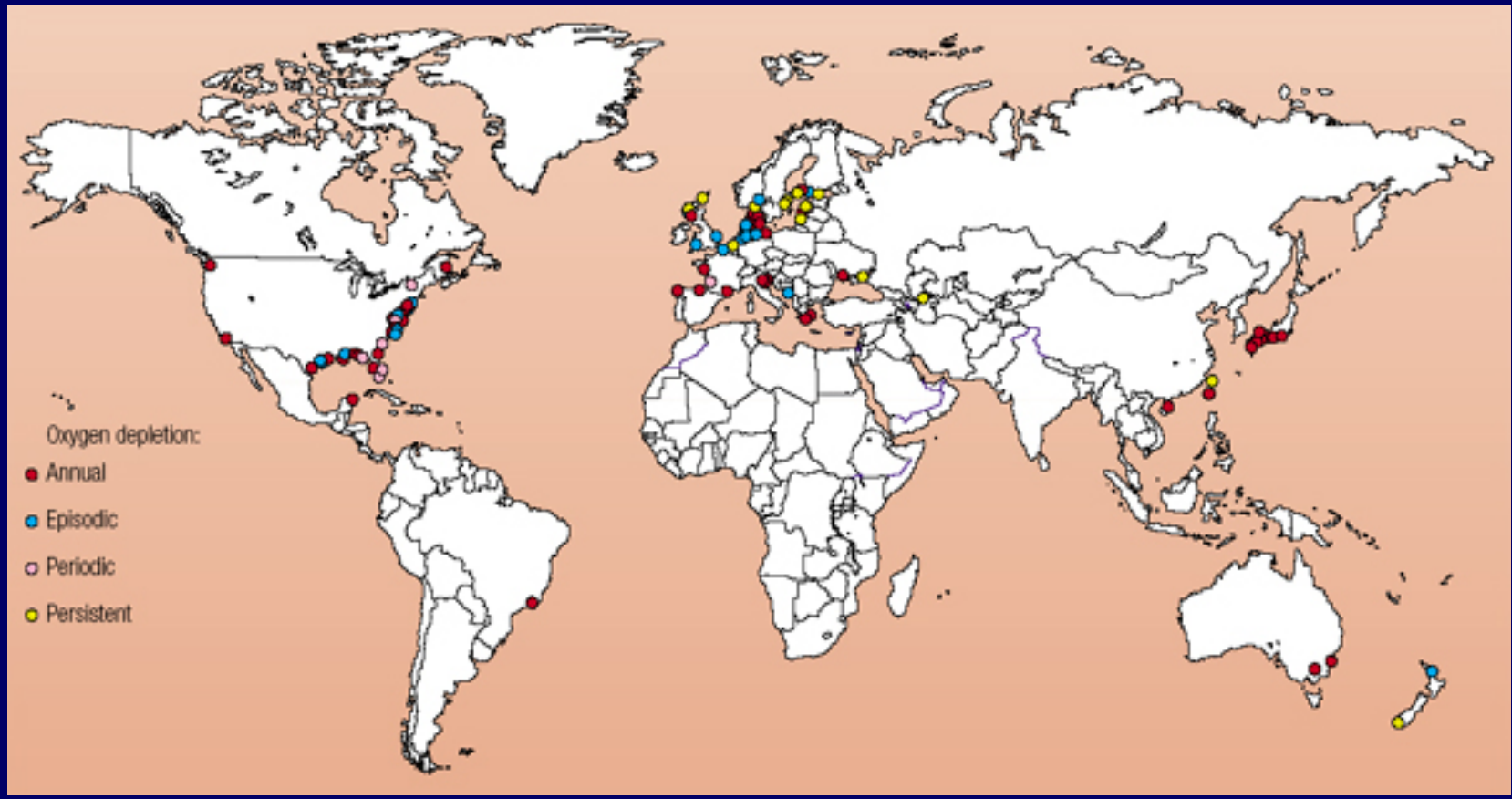
Eutrophication Symptoms for Input of Anthropogenic Nutrients



World Fertilizer Consumption 1950-2003



Global perspective: Dead Zones

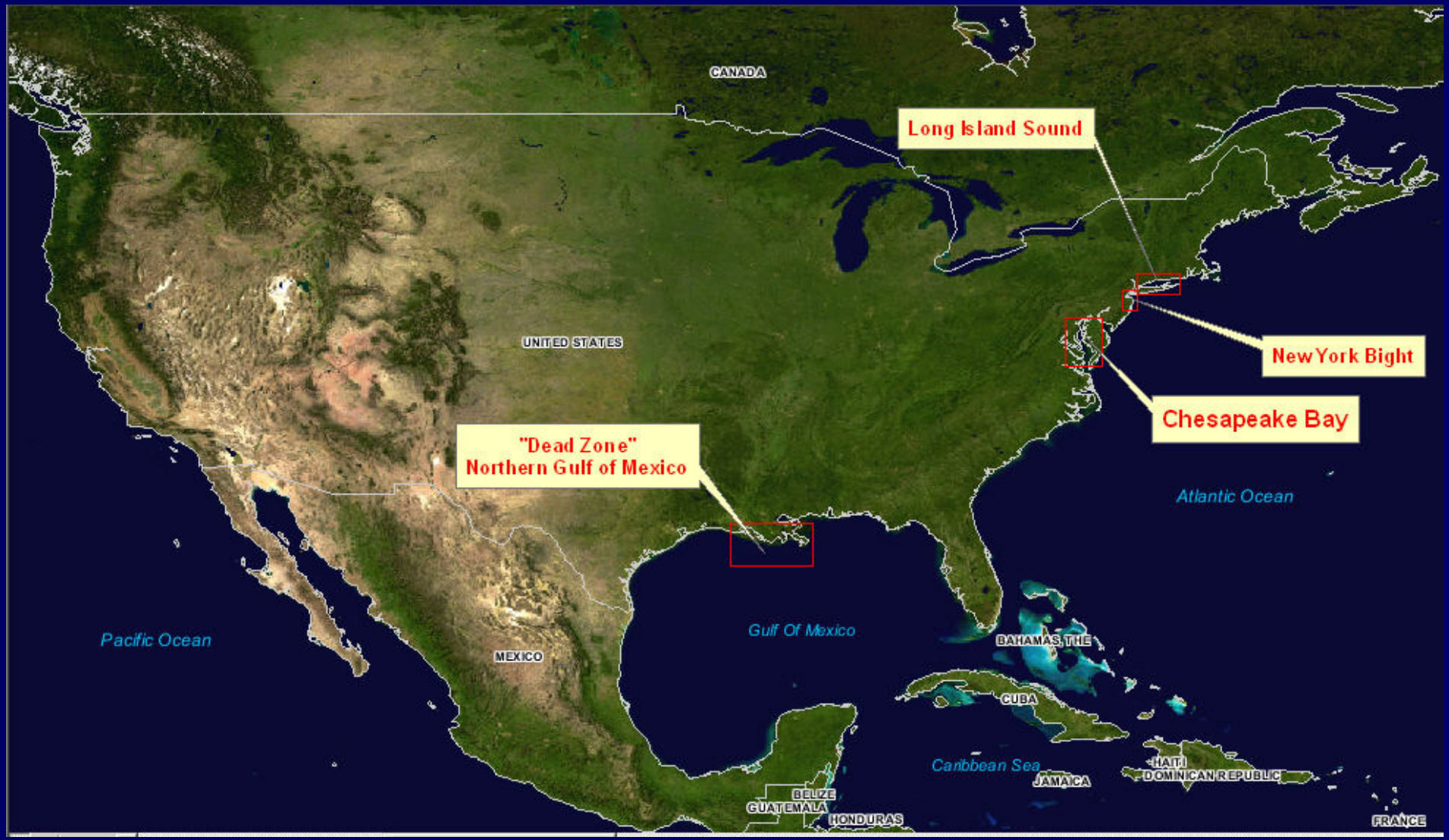


Source: UNEP, GEO Yearbook 2003 (Nairobi: 2004)

Dead Zone: Dissolved oxygen is < 2 ml/L

UNEP (2006) estimated, ~200 dead zones in 2007.

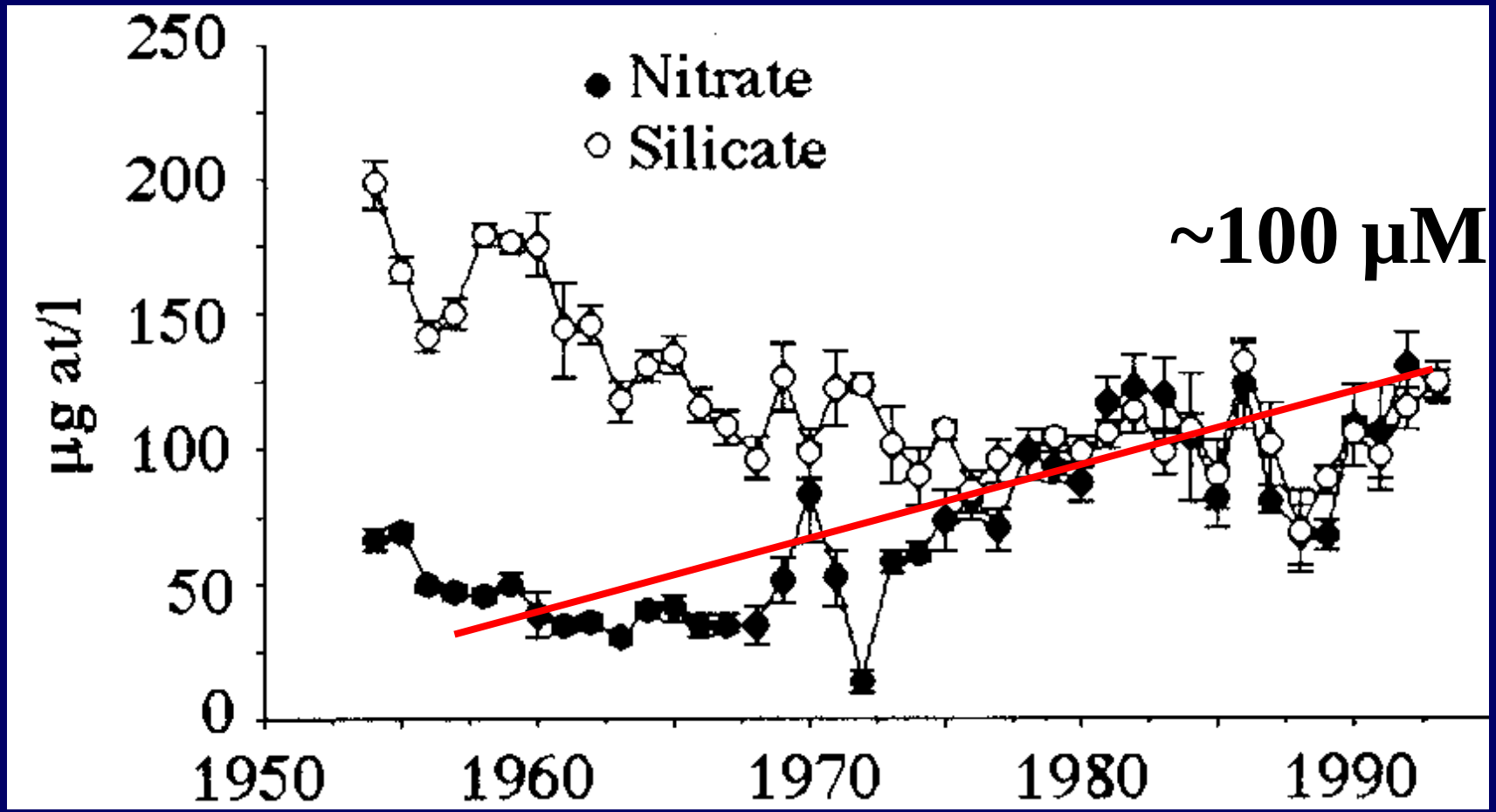
Places suffered from Persistent Hypoxia




Mississippi River Delta
Yangtze River
Pearl River
Guangzhou
Hong Kong

Mississippi River: Average annual concentrations

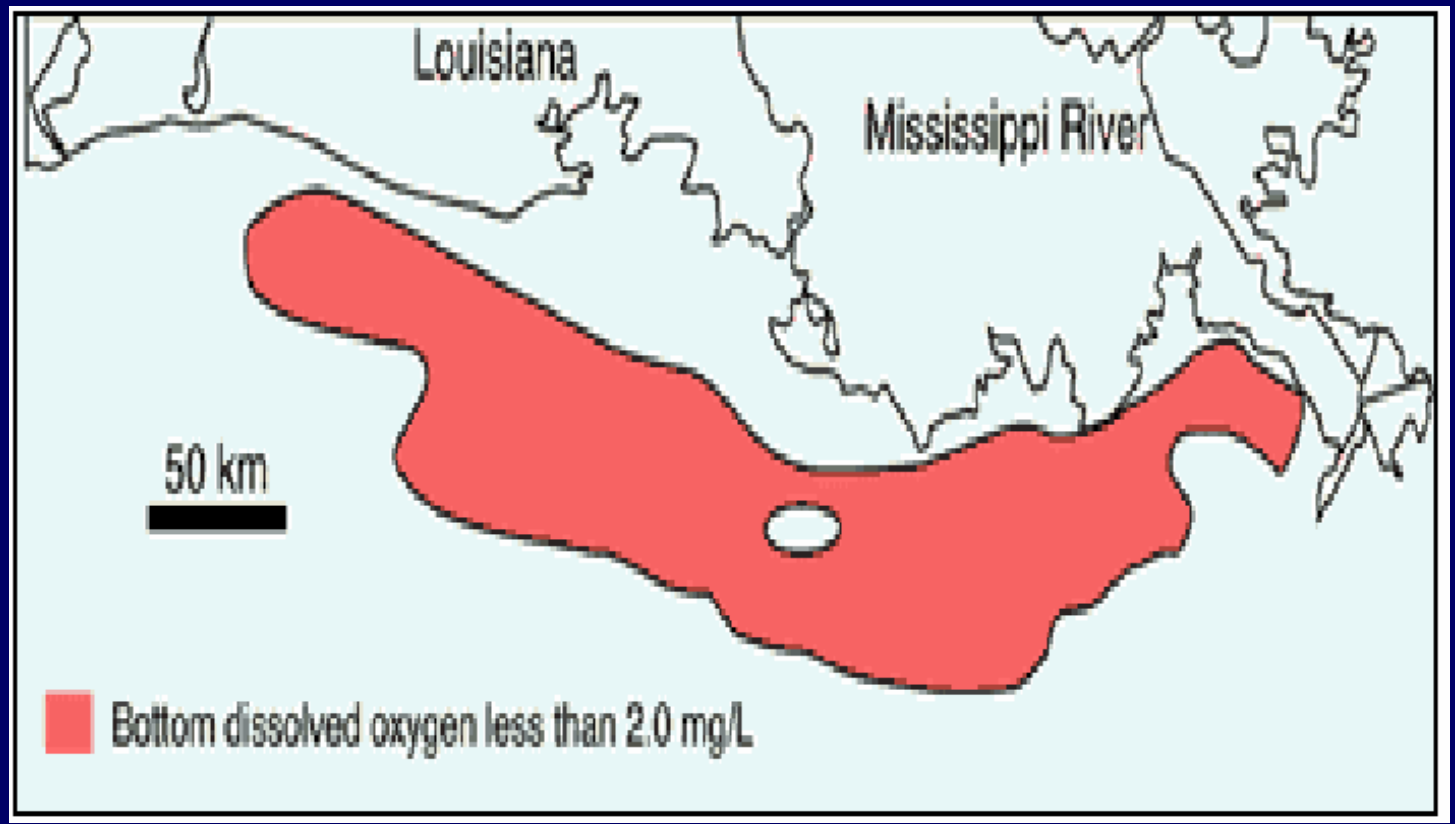
Turner et al. 1998. Proc. Natl. Acad. Sci. USA



Northern Gulf of Mexico:

a large area of hypoxia "dead zone" (20,000 km^2)

(<2 O_2 mg/L)



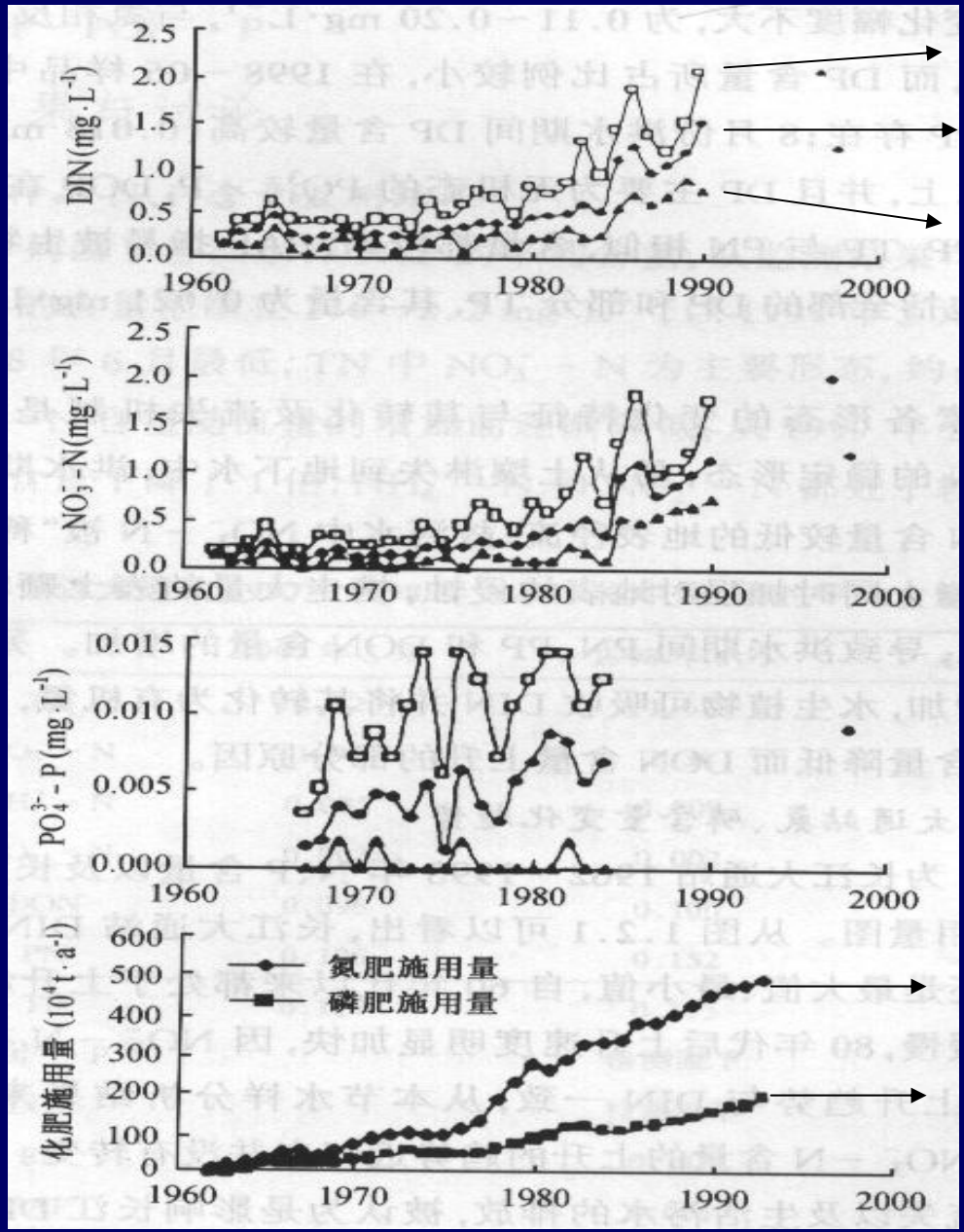
Science 281, 1998

Historic Trend of Nutrients in Yangtze River

DIN

NO_3-N

PO_4-P



Maximum

Mean

Minimum

N- fertilizer

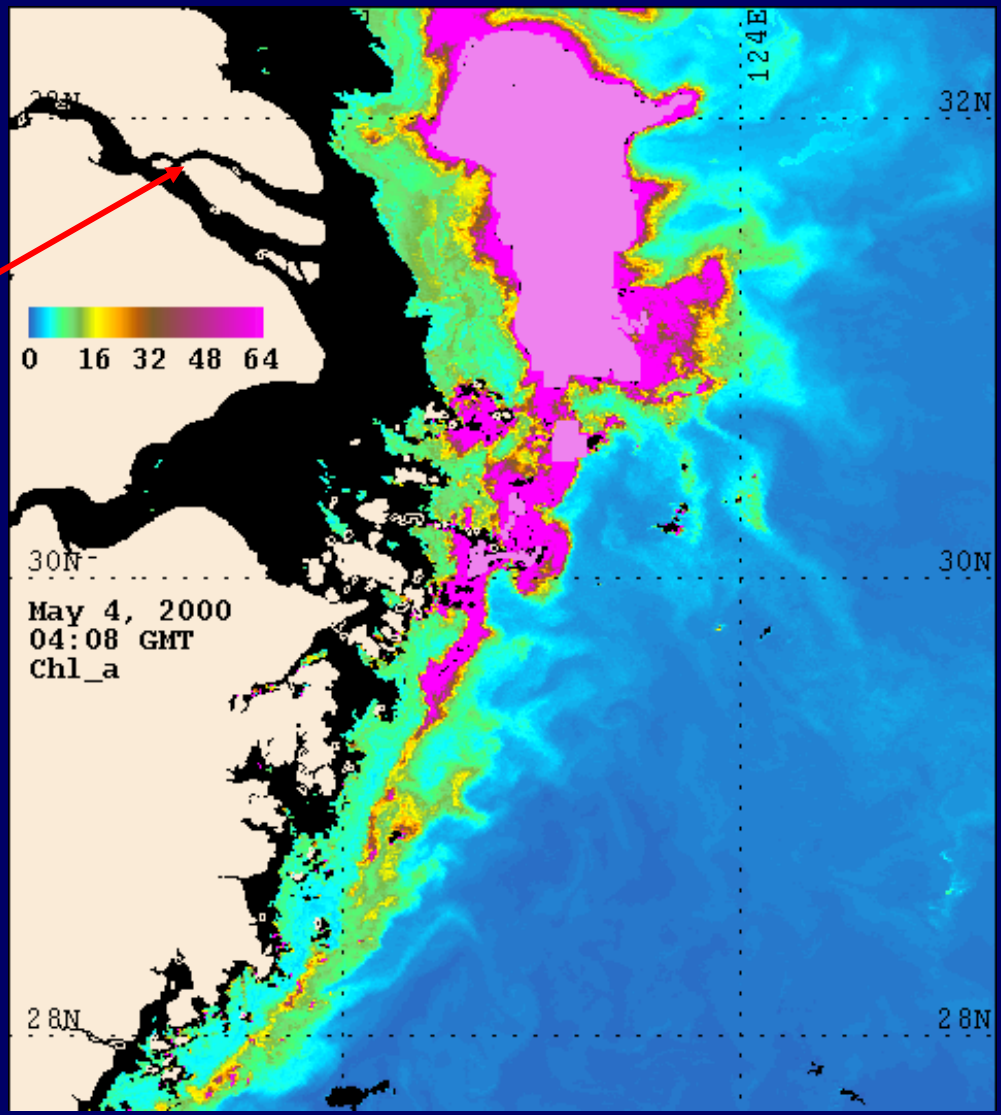
P- fertilizer

Persistent Cyanobacterial Blooms in Dianchi Lake in Kunming

Harmful Algal Blooms in East China Sea off the Yangtze River Estuary (Satellite View)

May 4, 2000

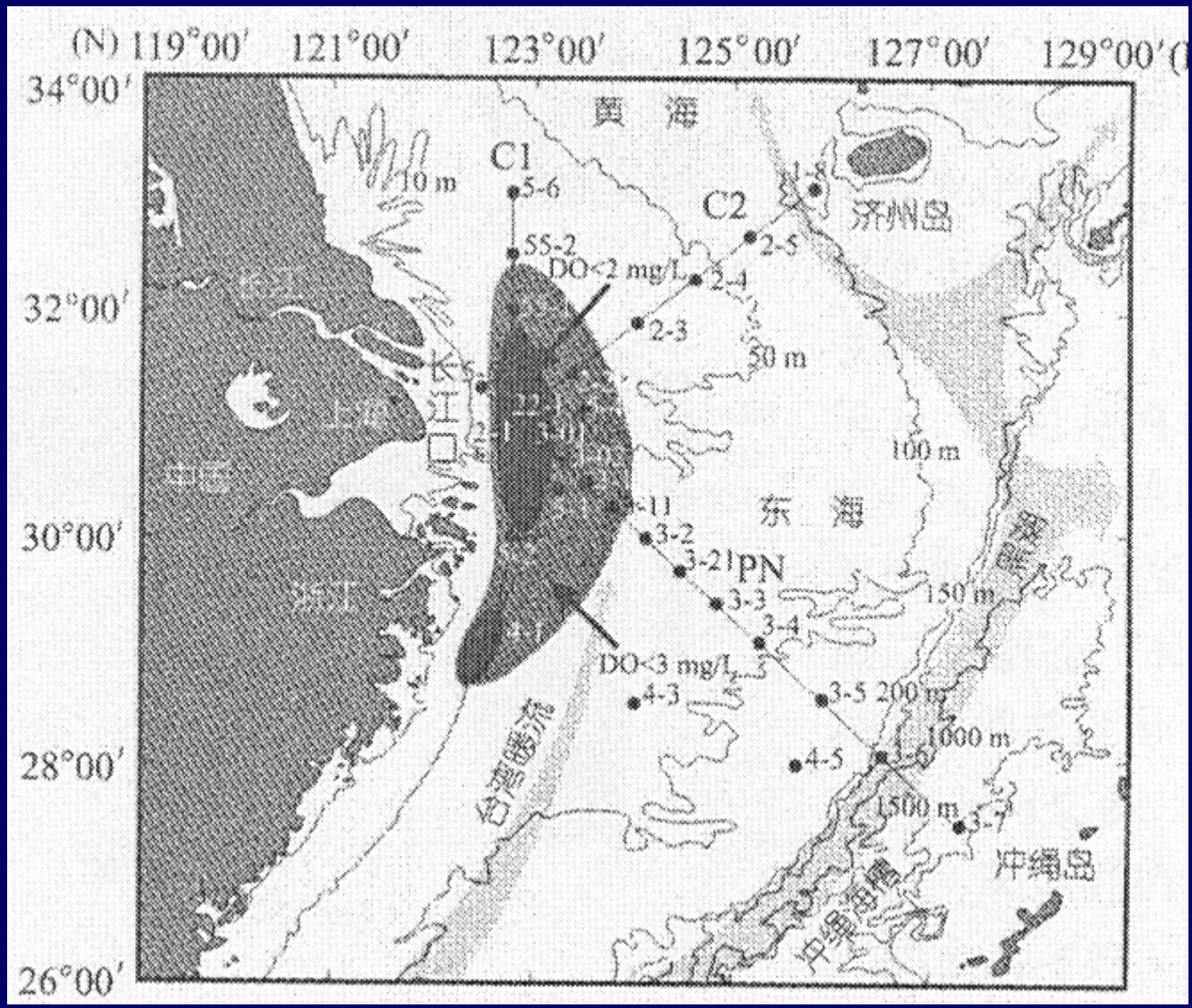
Yangtze River



About 2 times size of the “dead zone”

The "Dead Zone" in the Chang Jiang Estuary-East China Sea

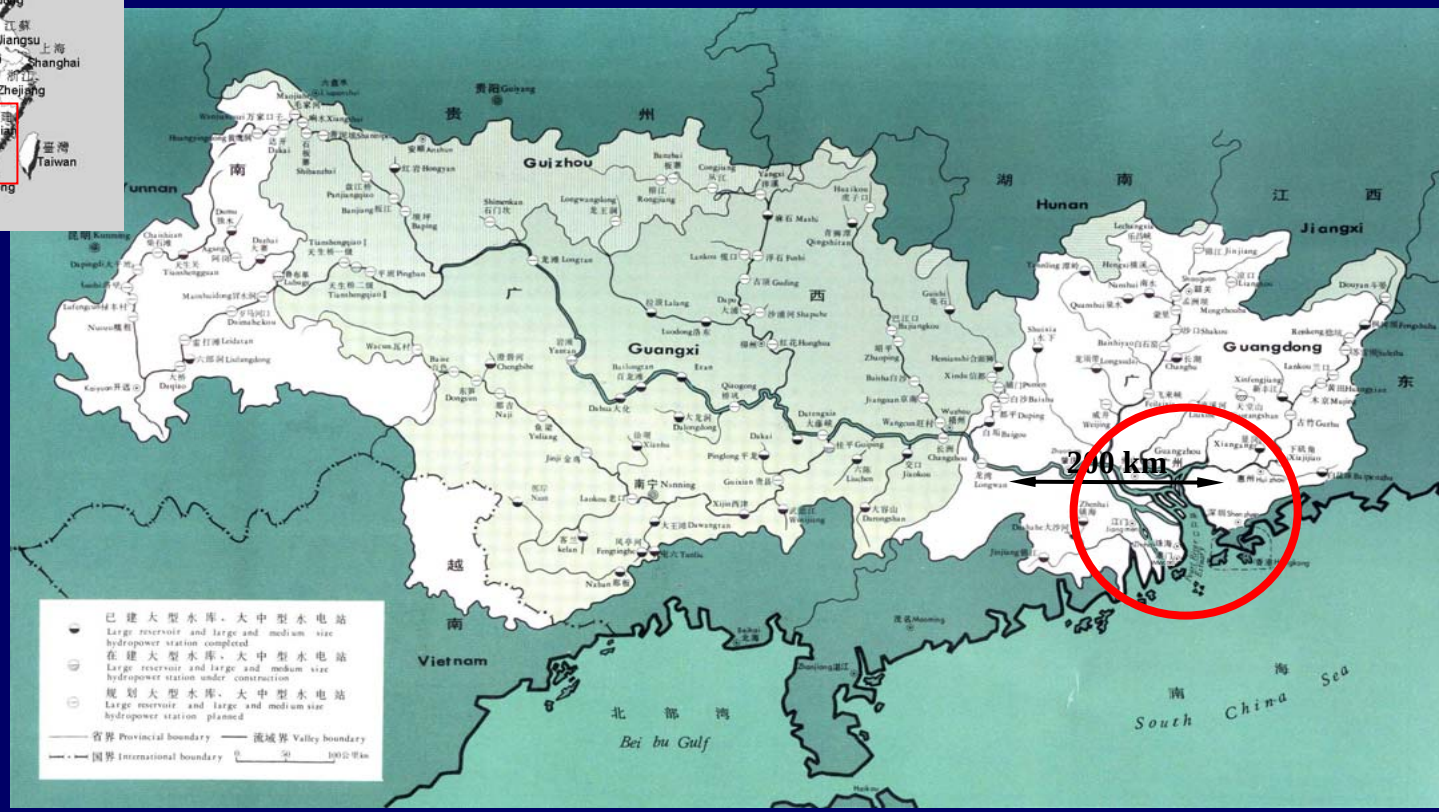
Li et al., 2002



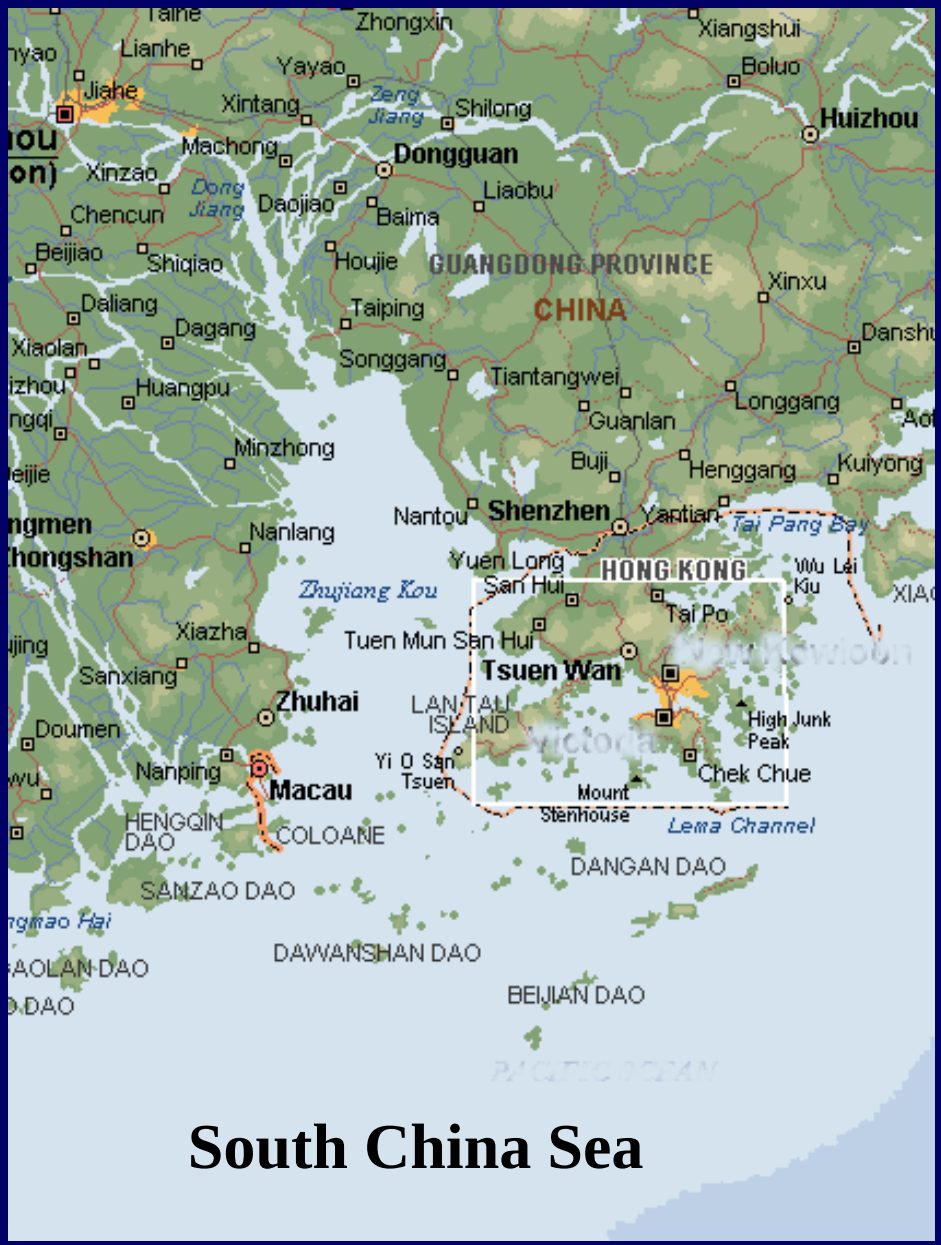
13,700 km^2

Pearl River Drainage Basin

- River-2, 200 km long
- Area -454, 000 km^2
- 100 million people



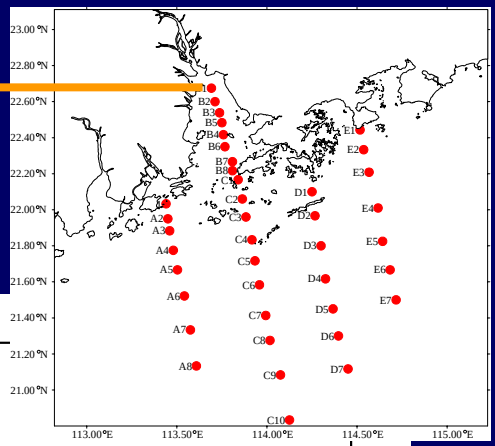
Pearl River Estuary

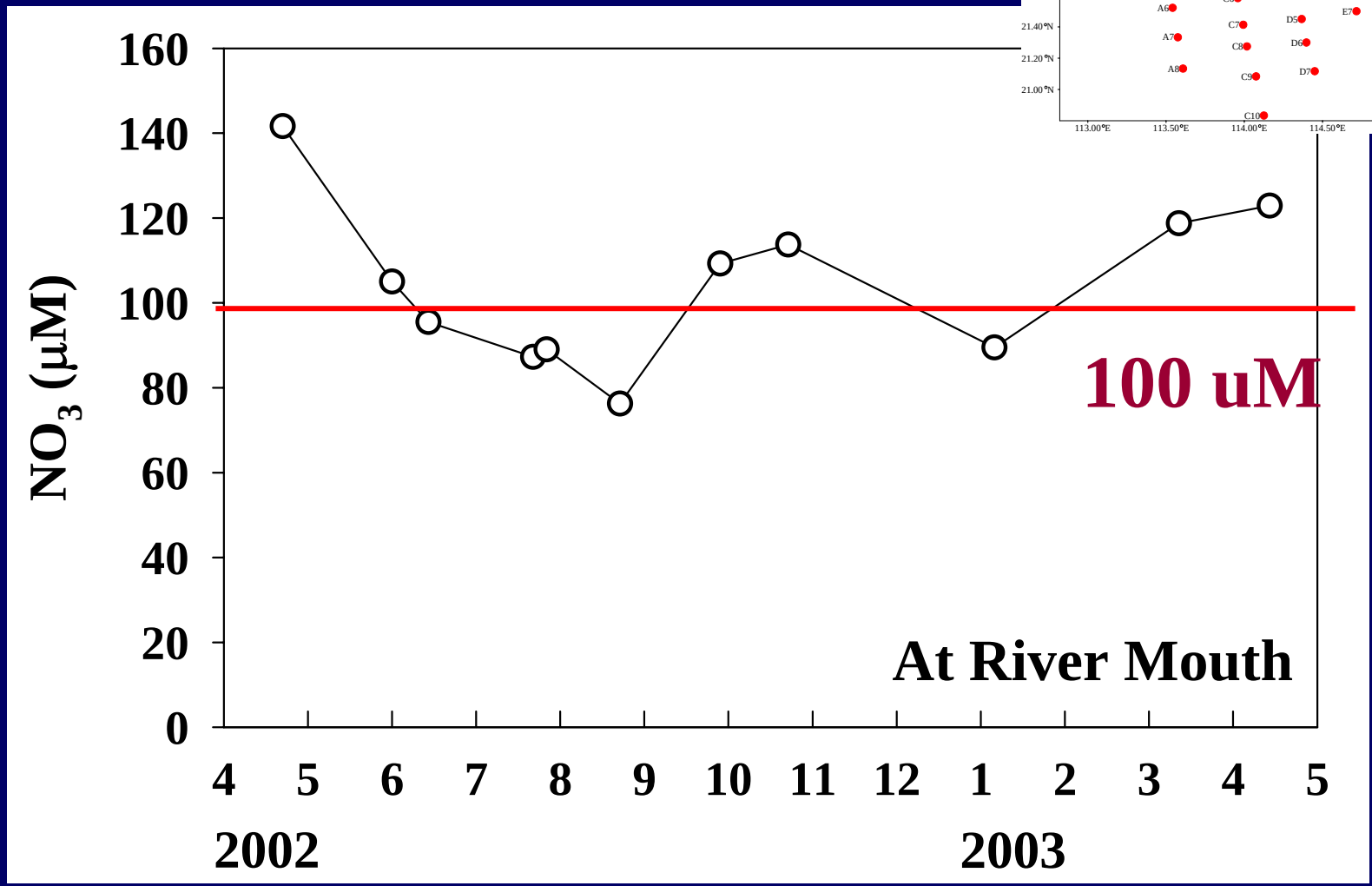


Pearl River

- 2nd largest river in China
- 13th largest river in the world

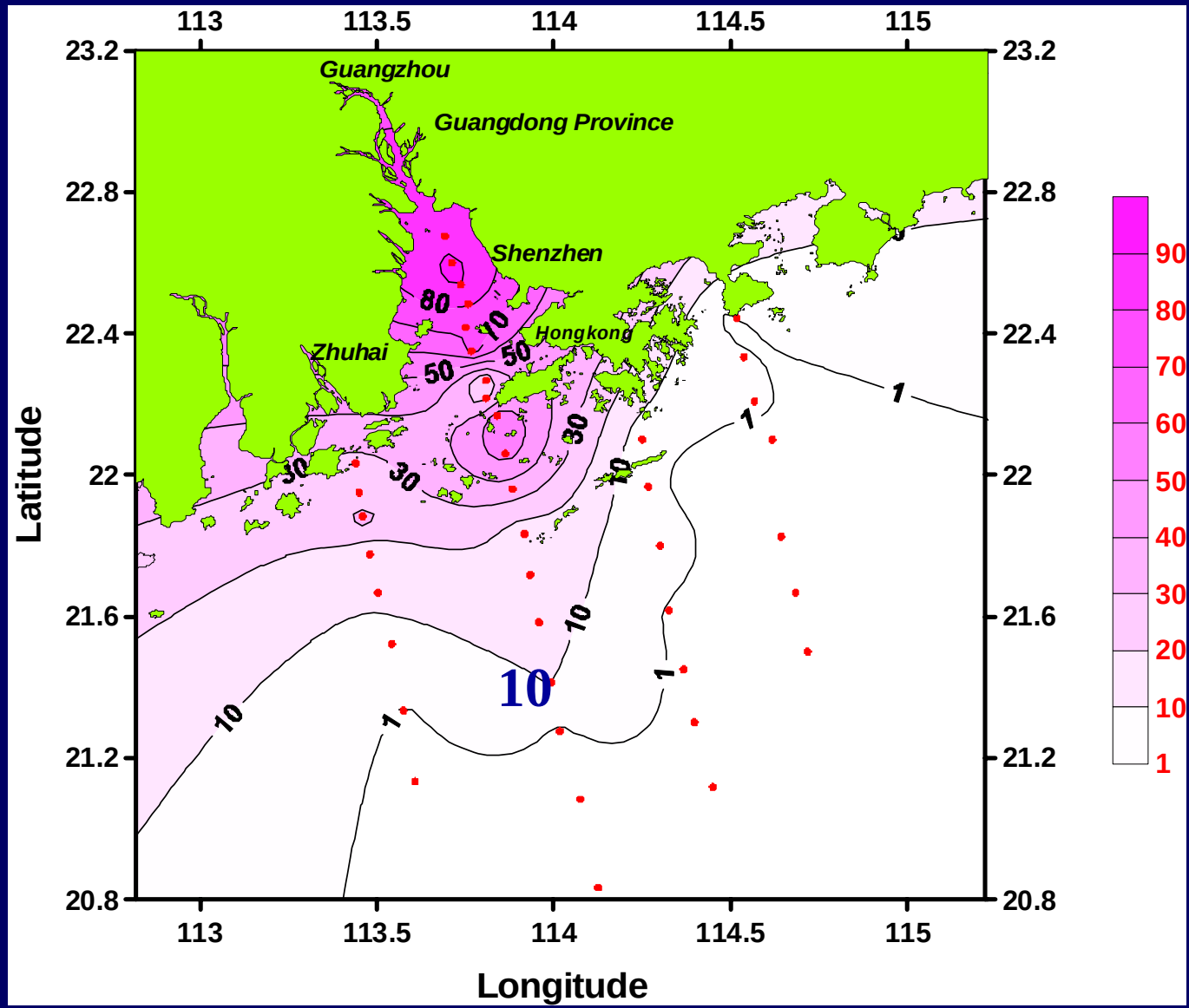
NO_3 at a PR mouth





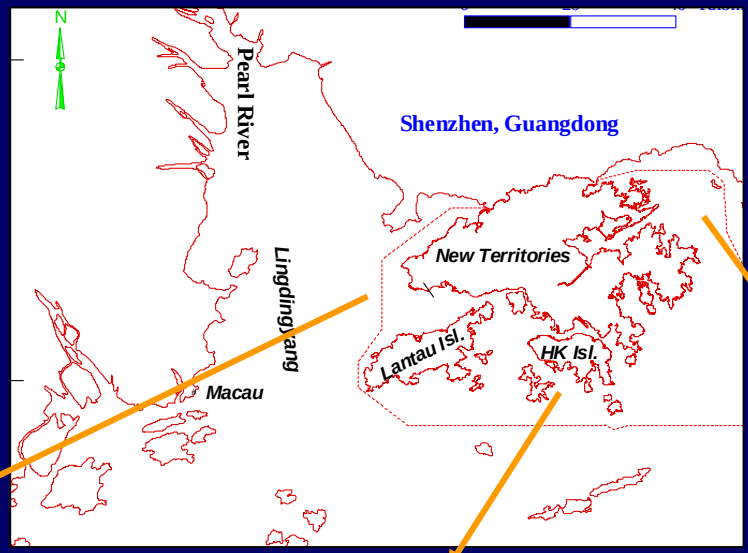
Huo and Yin unpub

NO3 Distribution during summer



Huo and Yin unpub

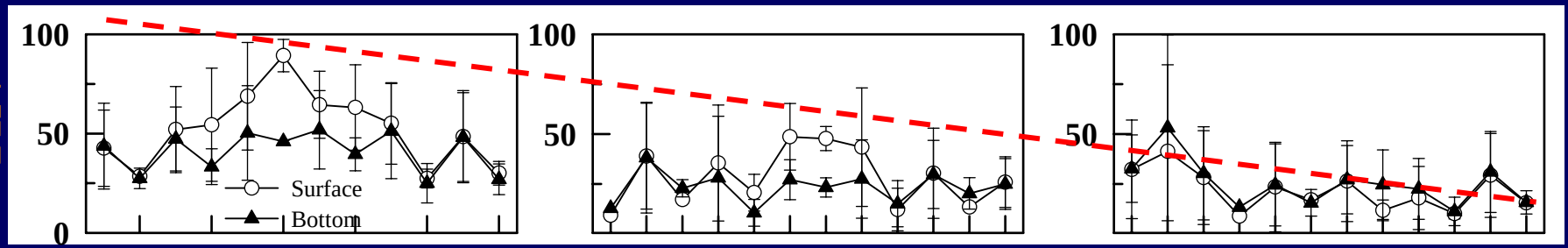
Monthly Average of total inorganic nitrogen during 1991-2000 (Yin 2002)



PR estuary waters

Southern Water

Mirs Bay



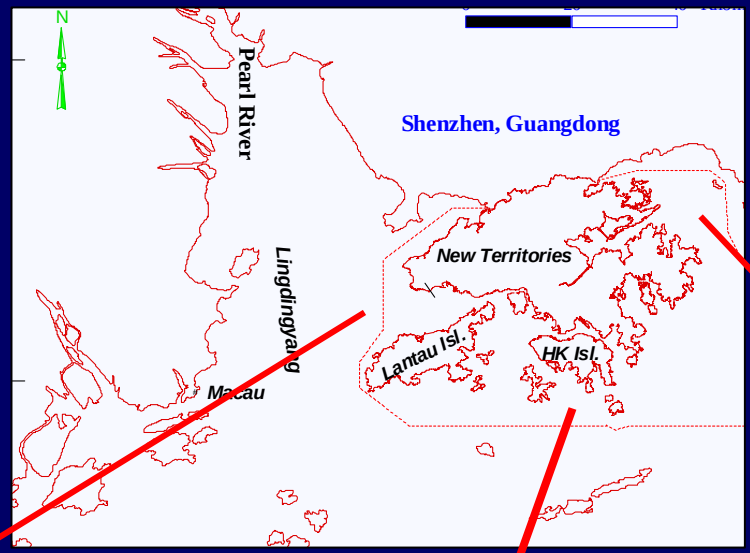
- **Nitrogen is high in the Pearl River estuarine coastal waters**
- **has increased 3 times in the past**

comparable to Mississippi and Yangtze which leads to hypoxia

What about dissolved oxygen in the Pearl River estuarine influenced coast?

Monthly Average of Dissolved O_2 during 1991-2000

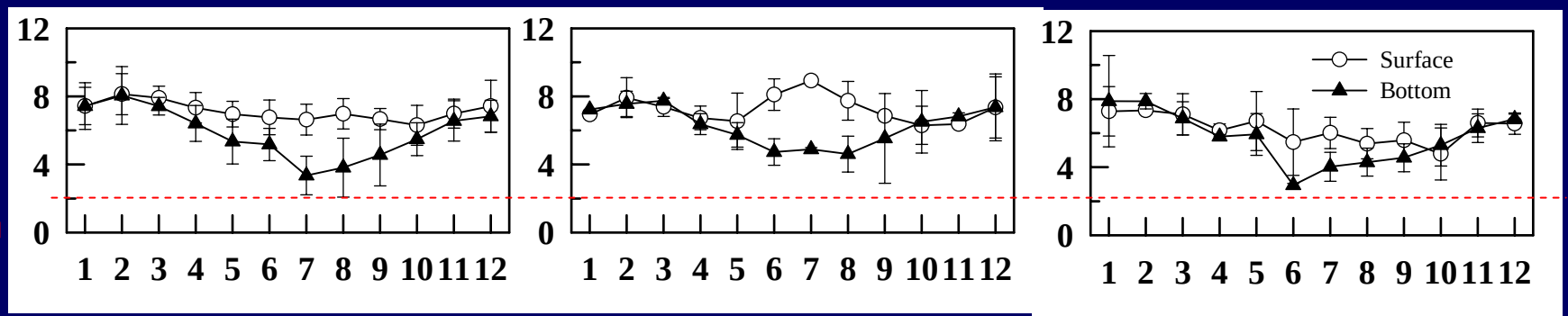
Dissolved O_2 does not drop to hypoxia!



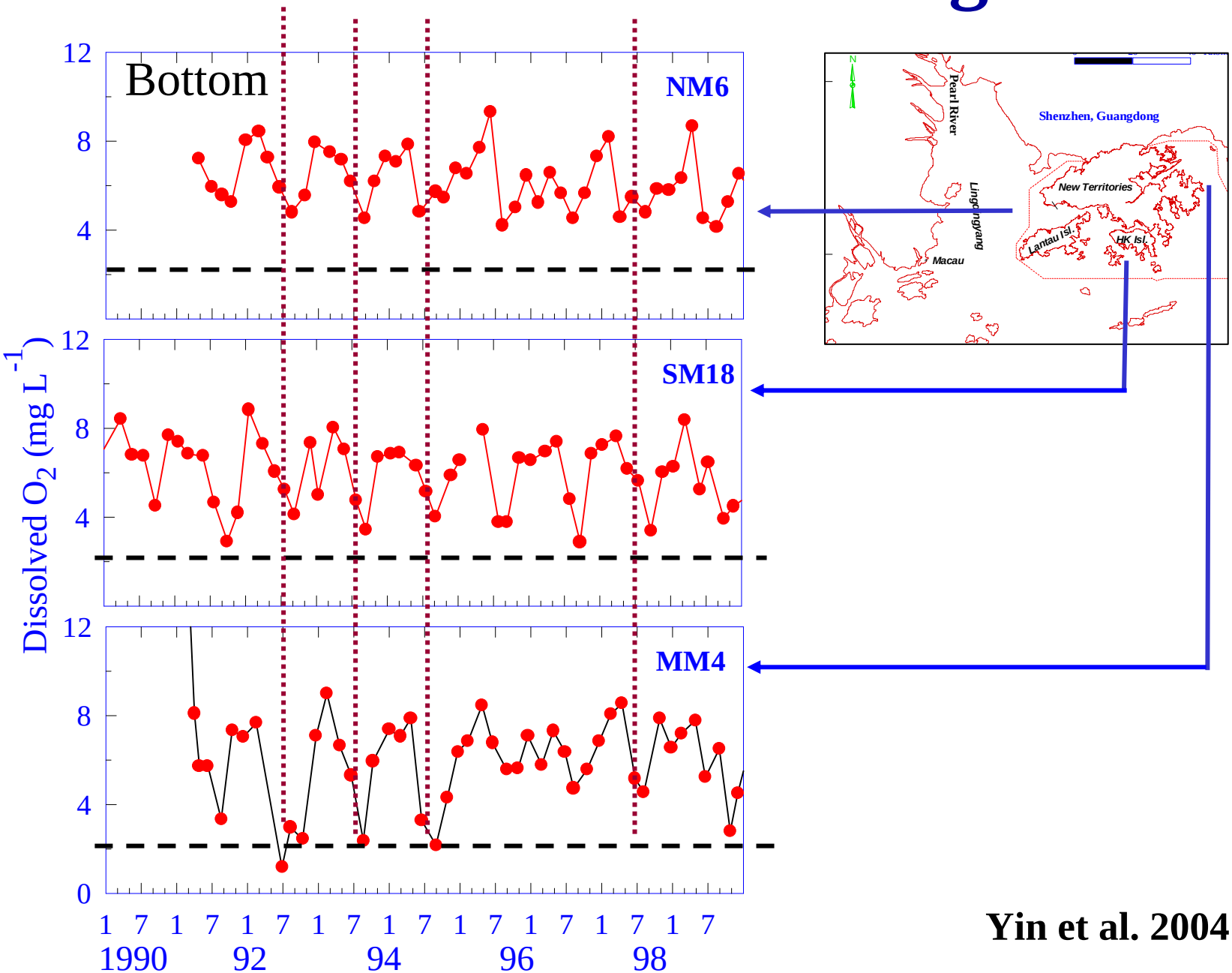
Western waters

Southern Water

Mirs Bay



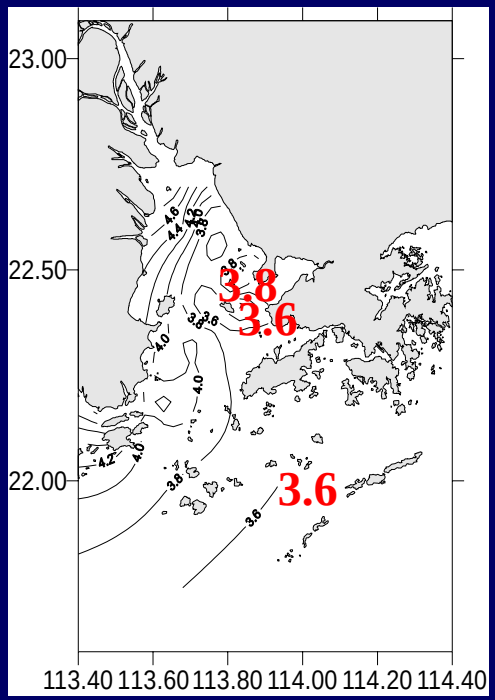
Lack of the decreasing trend!



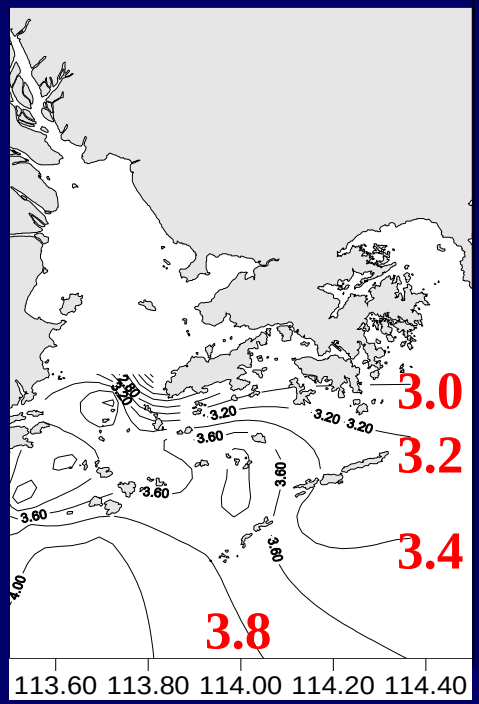
Yin et al. 2004

Bottom Dissolved O_2 in 1980s

August 1984



July 1981



Summer 1968

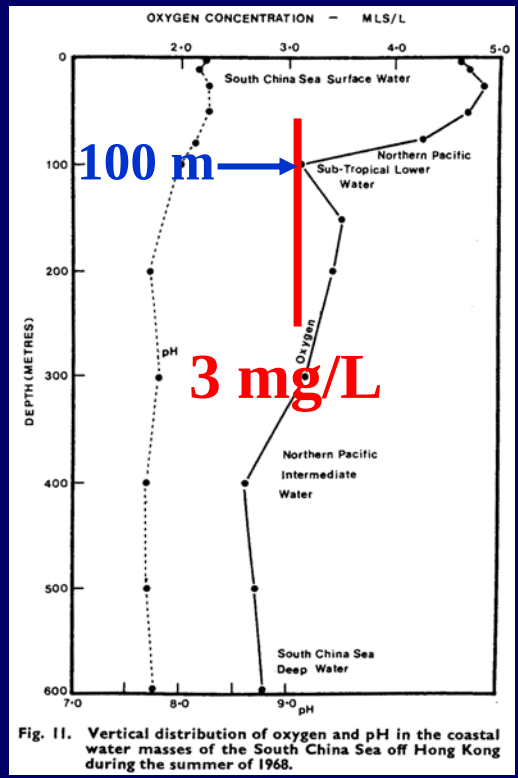
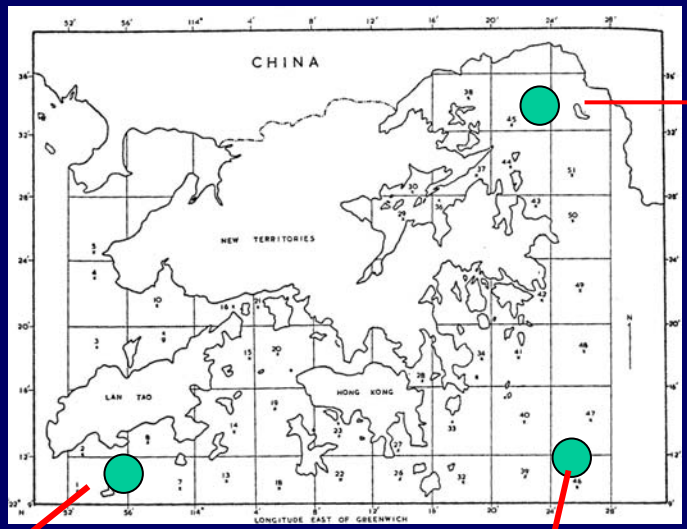


Fig. 11. Vertical distribution of oxygen and pH in the coastal water masses of the South China Sea off Hong Kong during the summer of 1968.

Yin et al. 2004 CSR

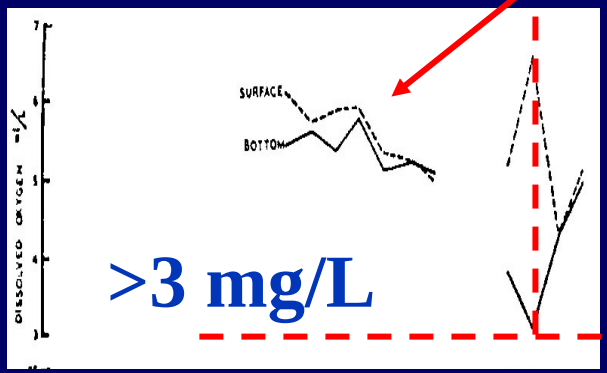
DO in Hong Kong waters, back in 1954-55

(Chau & Abessor 1958, HKU Fish. J. No.2: 43-57, Fig. 11)

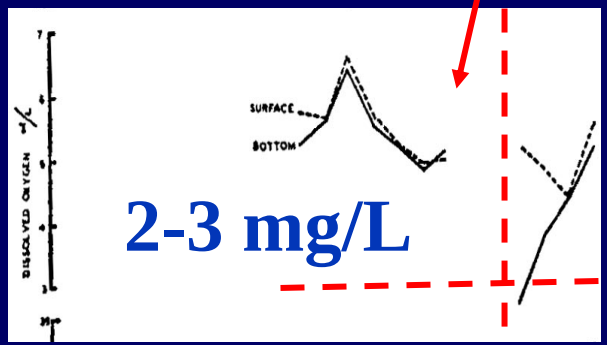


Bottom

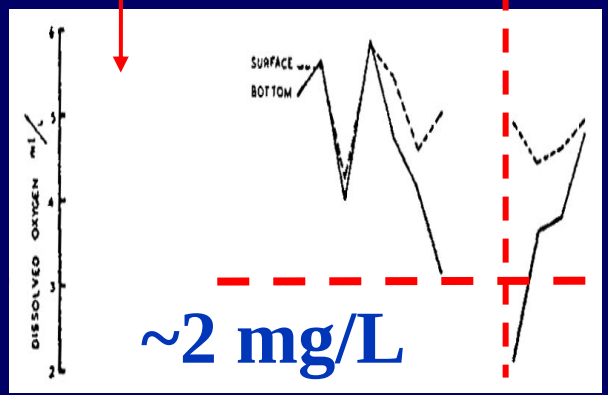
August



>3 mg/L



2-3 mg/L



~2 mg/L

1954 **1955**

Seasonal hypoxia does not appear to occur over the coastal scale of the Pearl River estuarine influenced waters in South China Sea

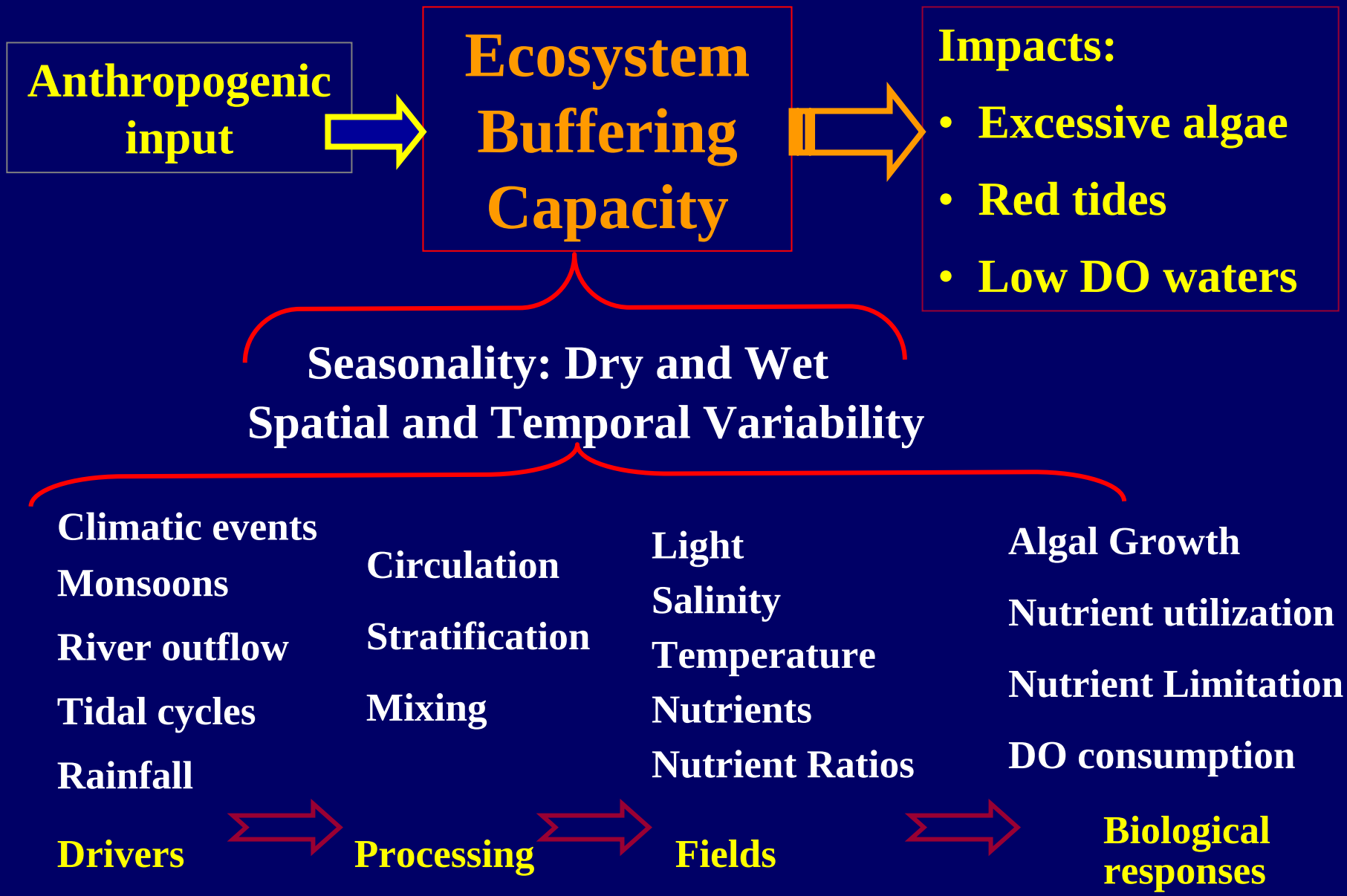
However, there are local episodic events of hypoxia

Some ecosystems can accommodate a nutrient enrichment without showing apparent eutrophication symptoms.

So, what makes the Pearl River Estuary "robust" to N enrichment?

- **Ecosystem Buffering**

Ecosystem Buffering



Ecosystem Buffering

Effects of winds

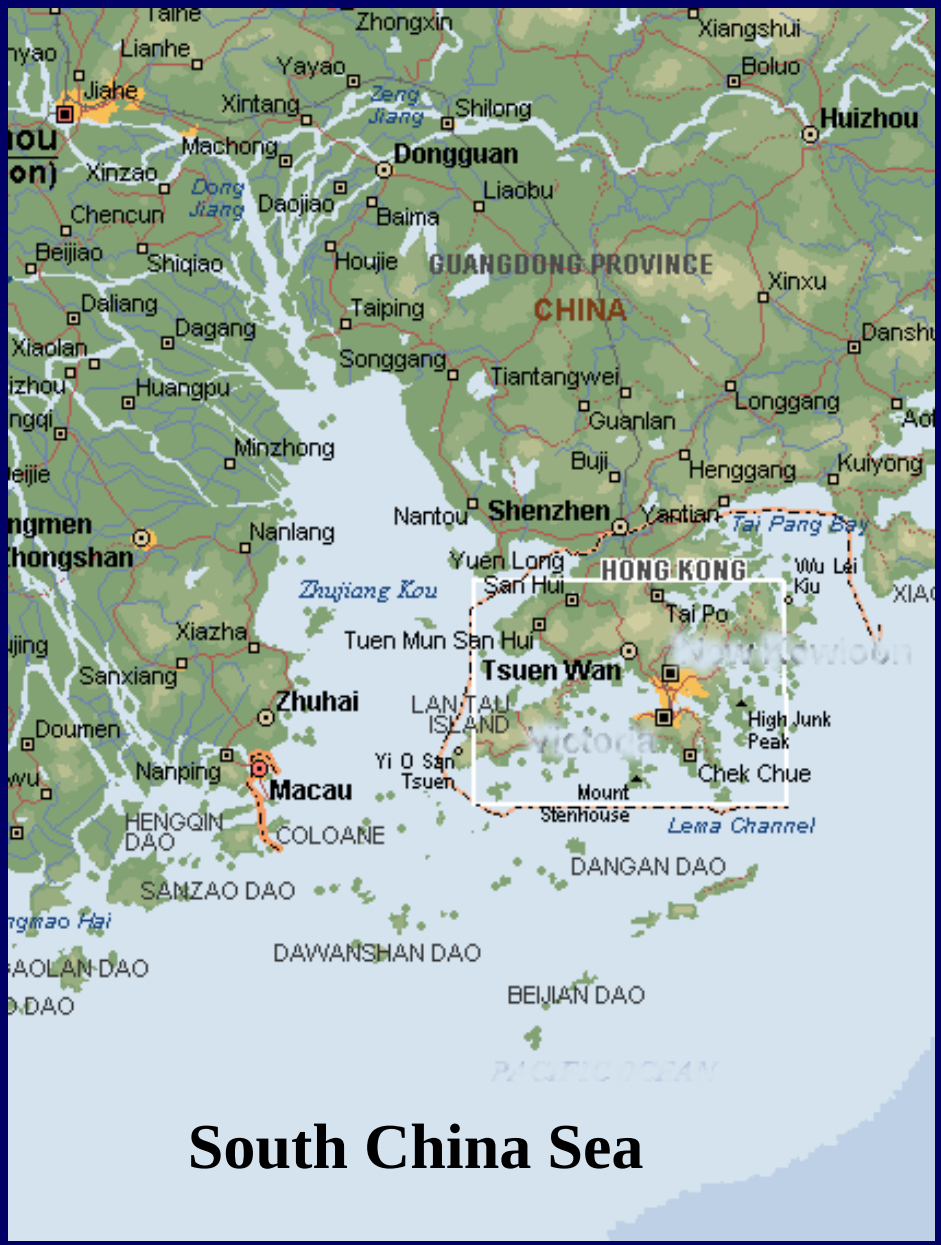
- Seasonal scale event
- Episodic events

Seasonal Scale Event

South China Sea

- 3 million km^2
- Largest inland sea after 4 open Oceans
- 3 times as large as the total of other China coastal seas

Pearl River Estuary



Pearl River

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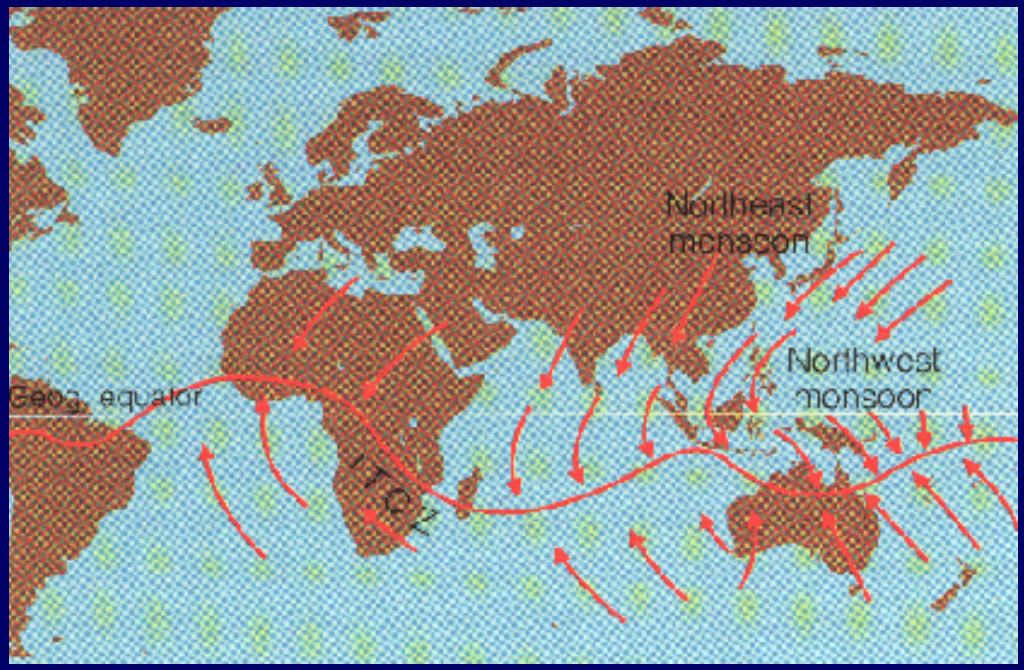
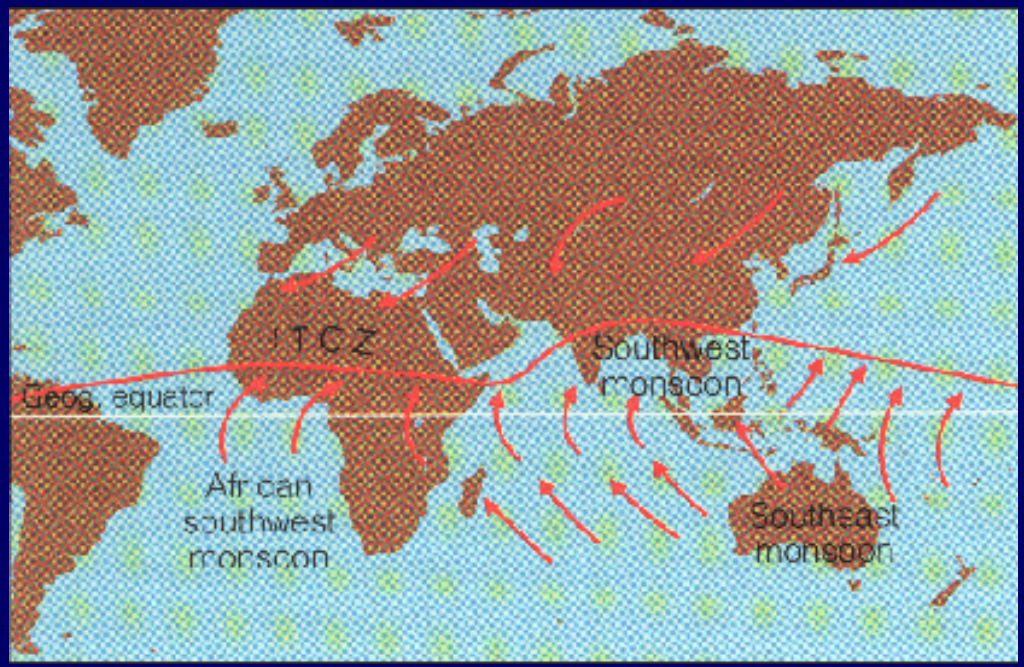


Northeast Monsoons

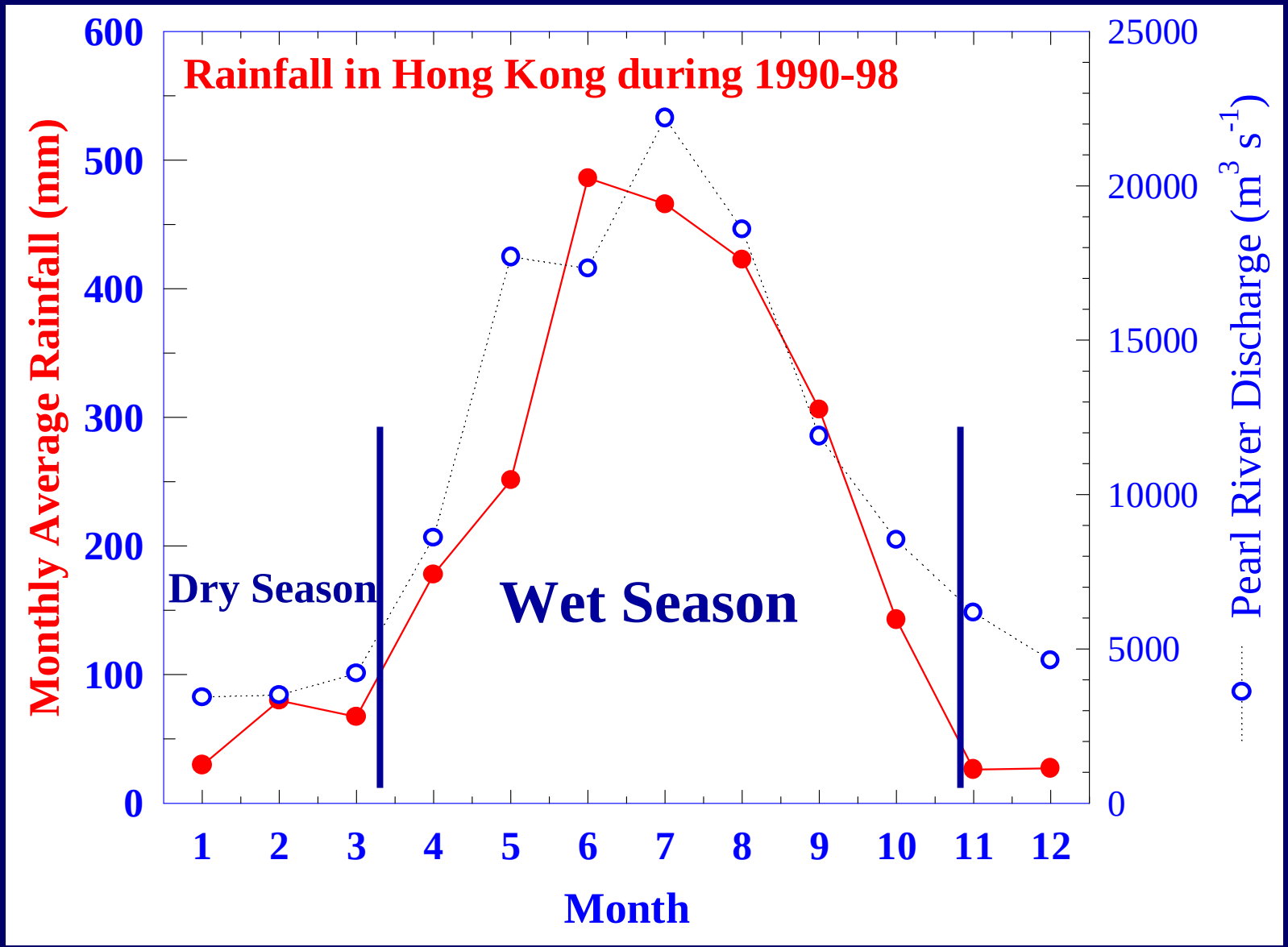
January



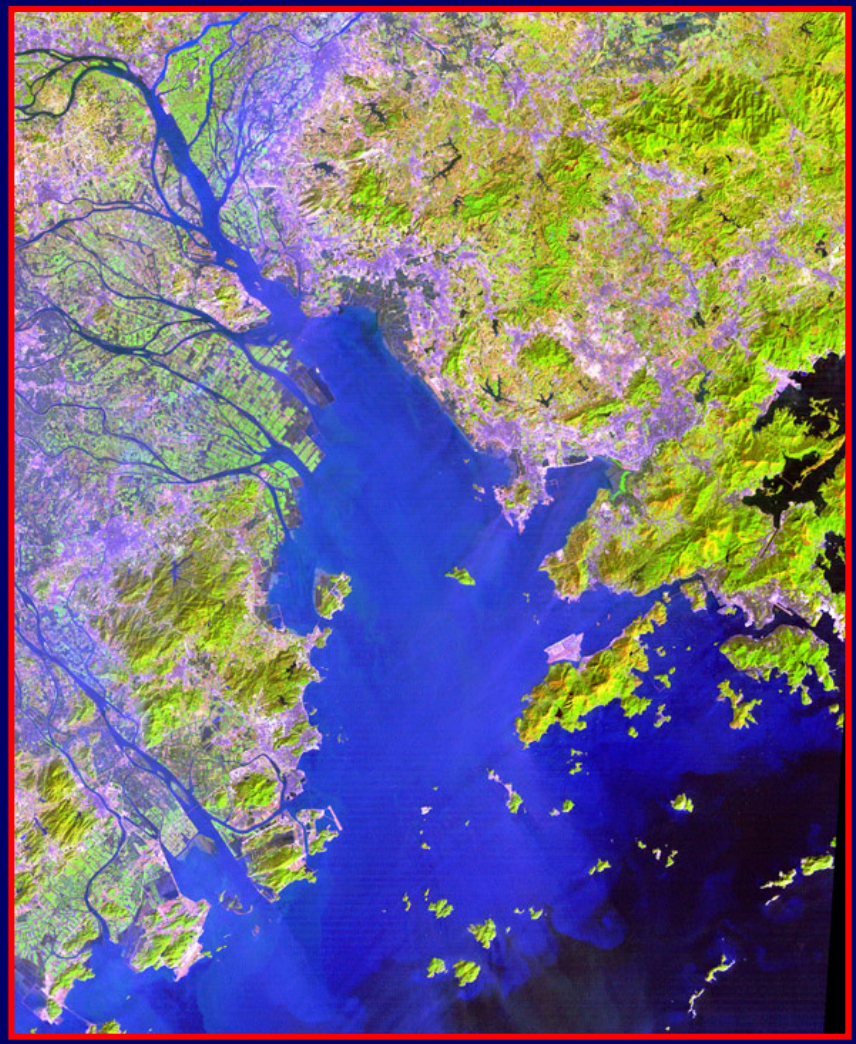
Southwest Monsoons

July

Pearl River Discharge & Rainfall

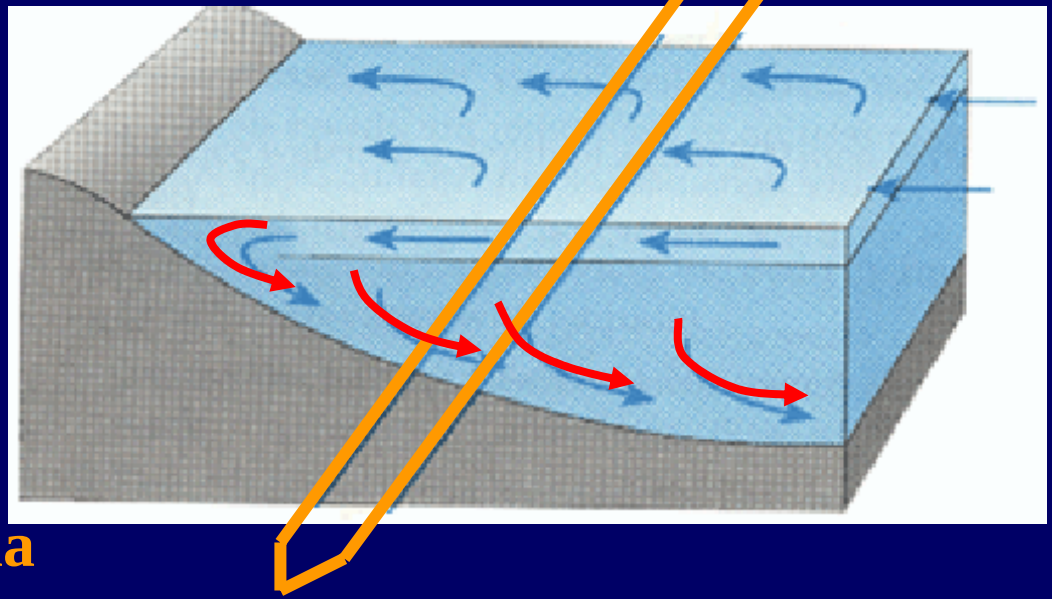


Pearl River Estuarine Coastal Plume



Physical processes induced by monsoons and Pearl River discharge

Northeast Monsoon

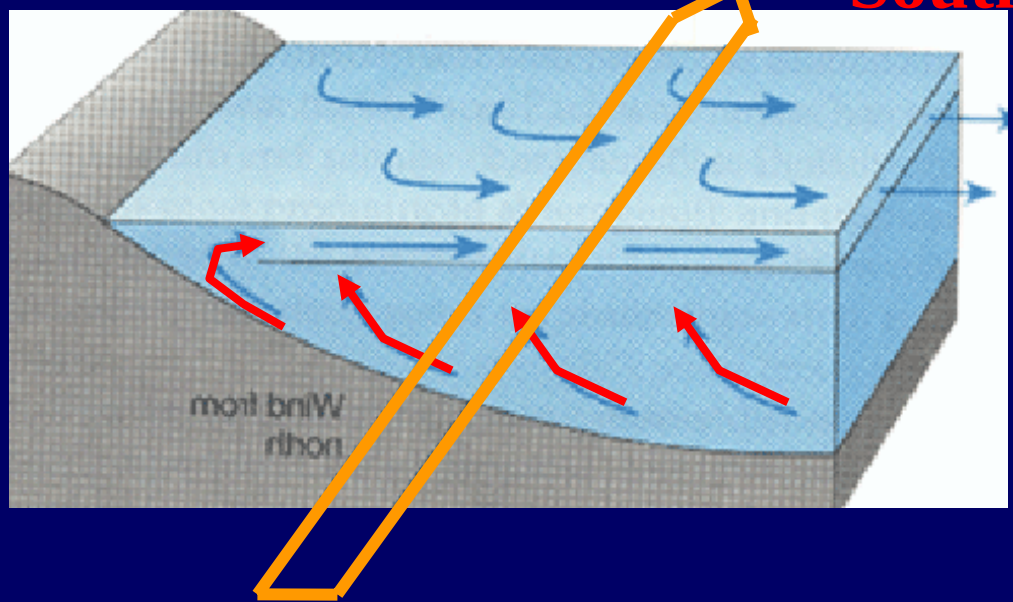


Coriolis effect

Coastal Downwelling

China south coast

Southwest Monsoon

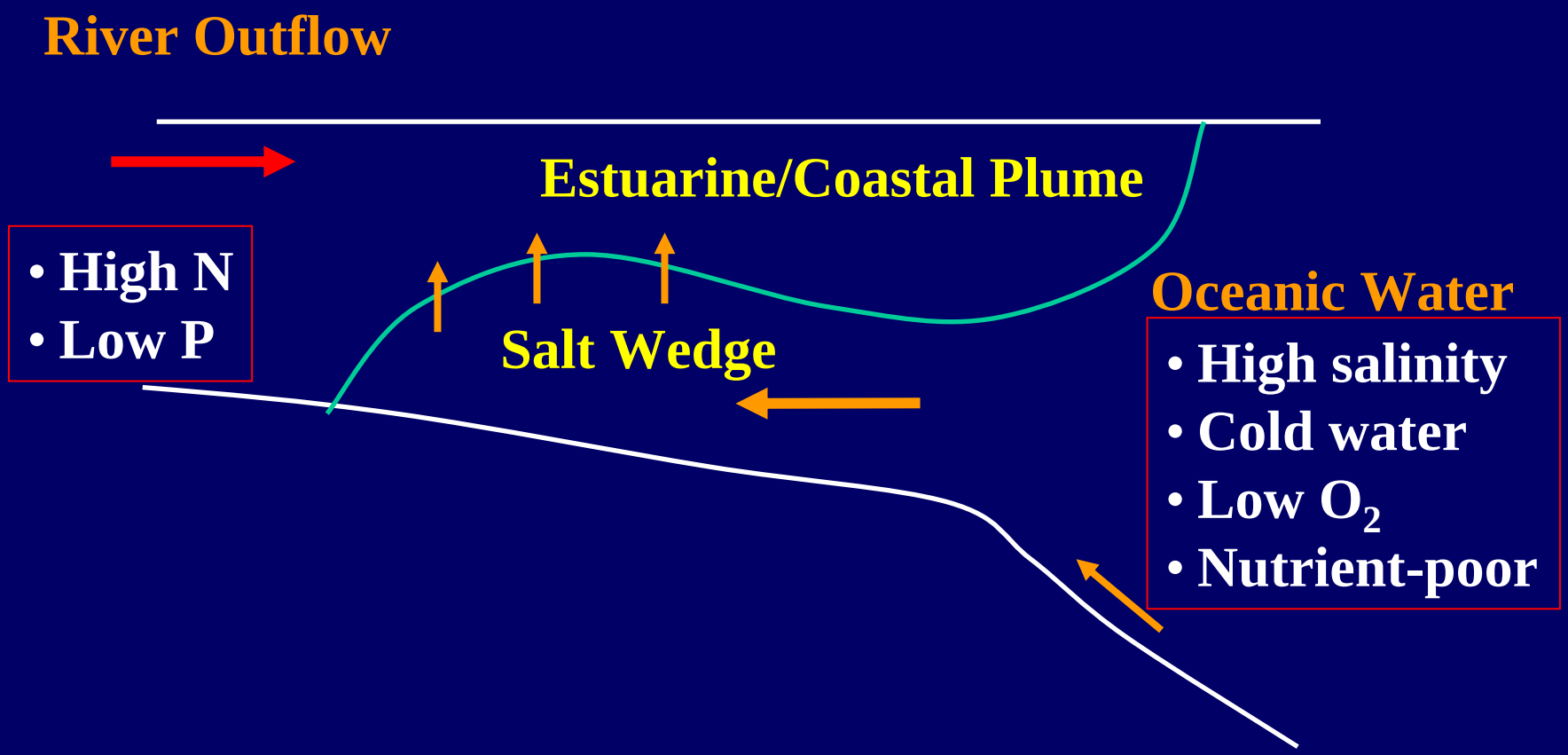


Coriolis effect

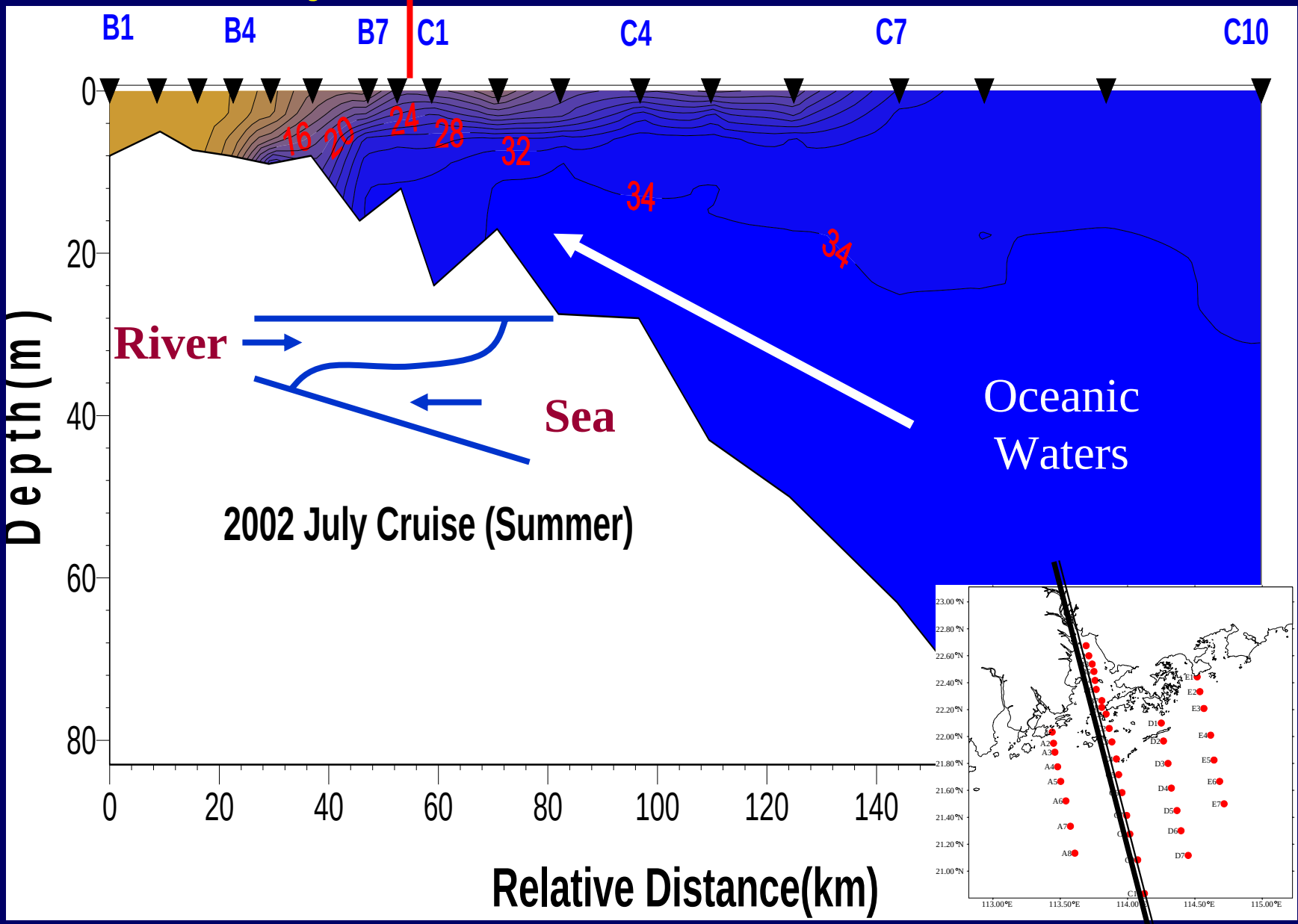
Coastal Upwelling

Estuarine Circulation in the Pearl River Estuary and Coastal Waters

Two Layer Opposite Flow Circulation



Salinity in Summer



Role of Monsoon Induced Physical Oceanographic Processes in Eutrophication

Winter

Water Masses:	**Offshore water dominates due to low river discharge**
Circulation:	**Downwelling**
Residence time:	**Longer**

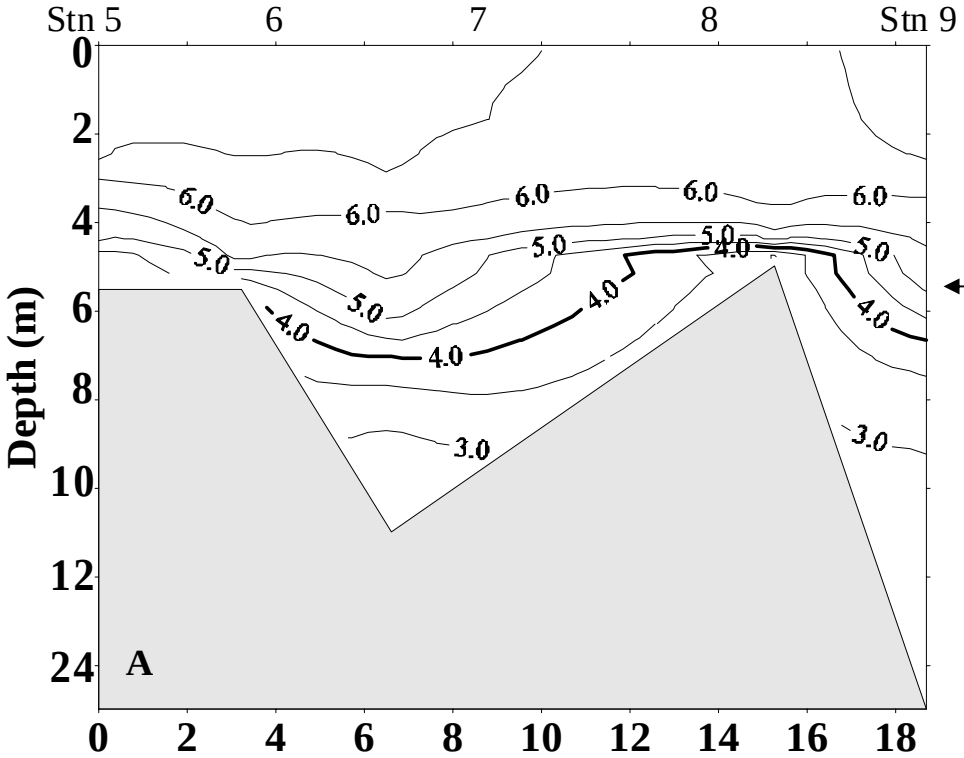
- **Annual flushing mechanism to reduce the accumulative effects of nutrients**

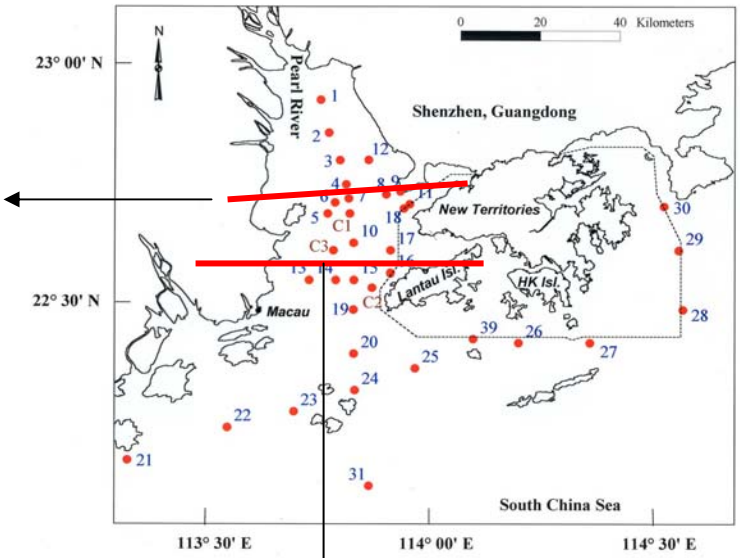
Summer

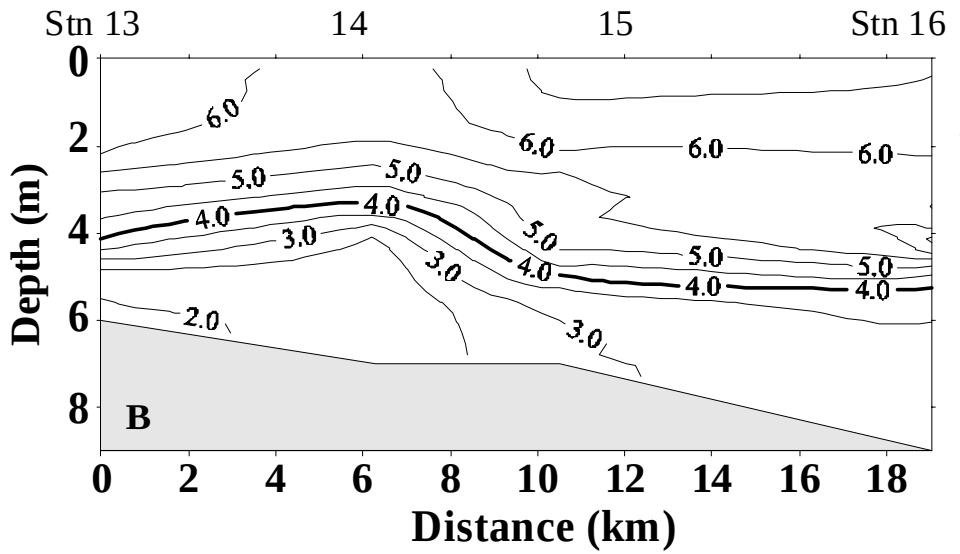
Water Masses:	**Freshwater influence dominates at the surface, oceanic waters dominate at the bottom**
Circulation:	**Two layer flows**
Residence time:	**Shorter**

- **Within-season flushing mechanisms**

Wind Episodic Events

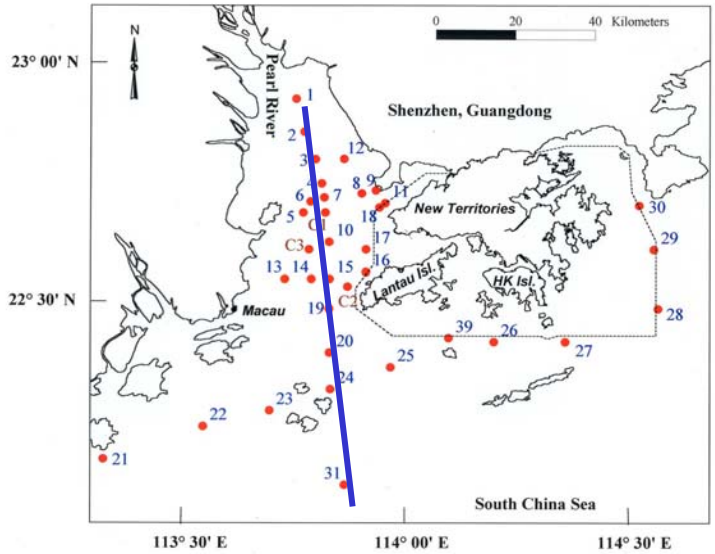


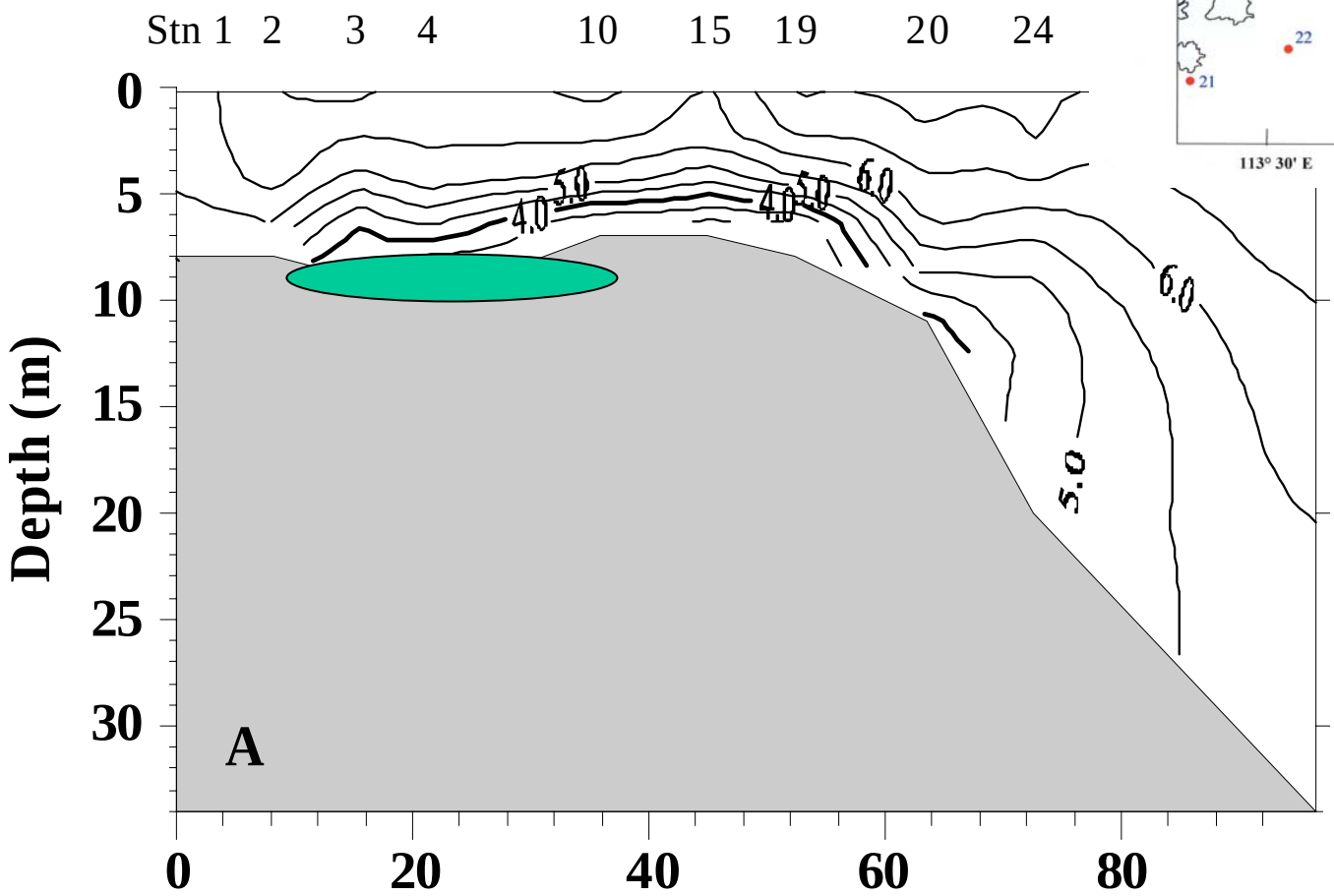




Local Episodic Hypoxia

Localized hypoxia





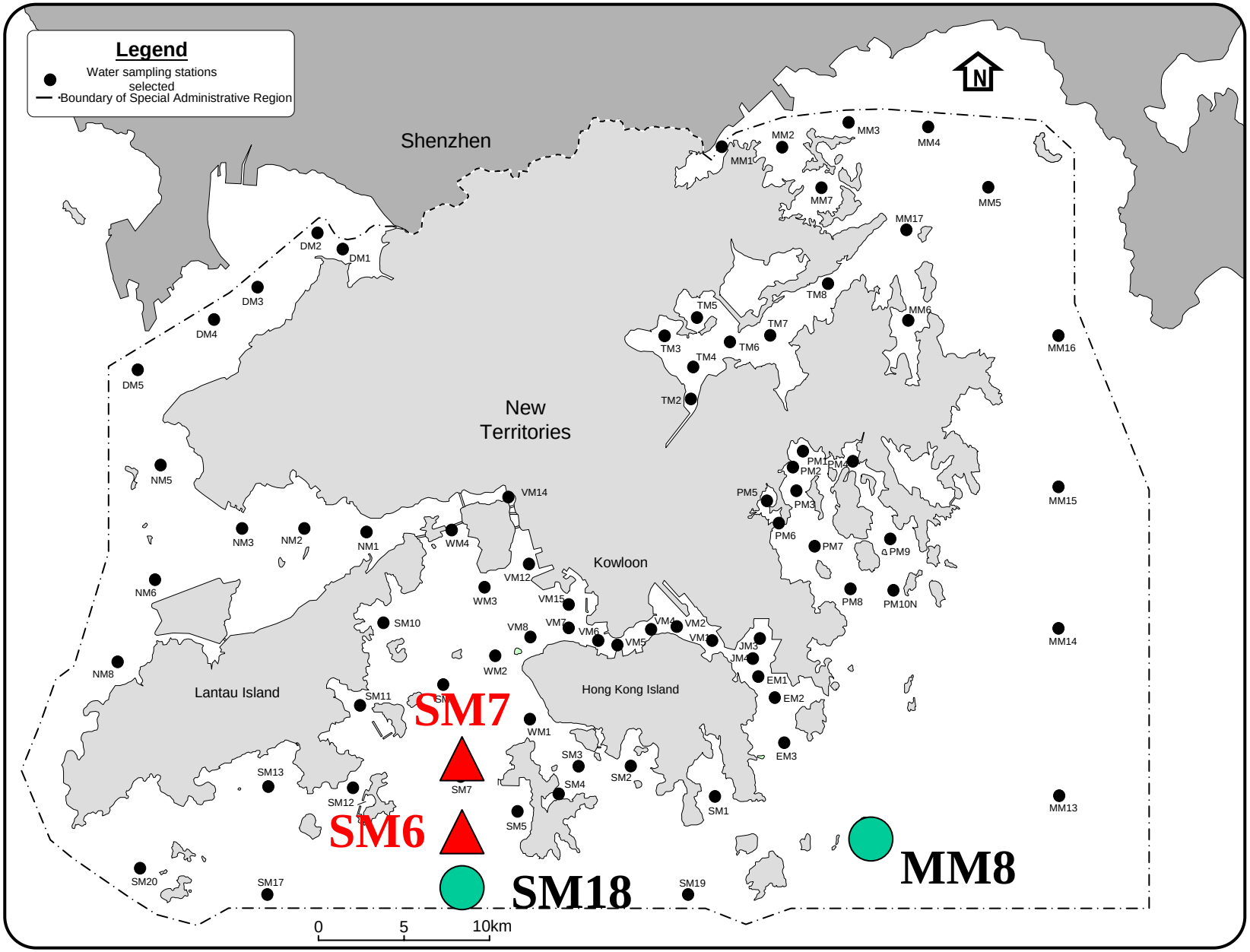
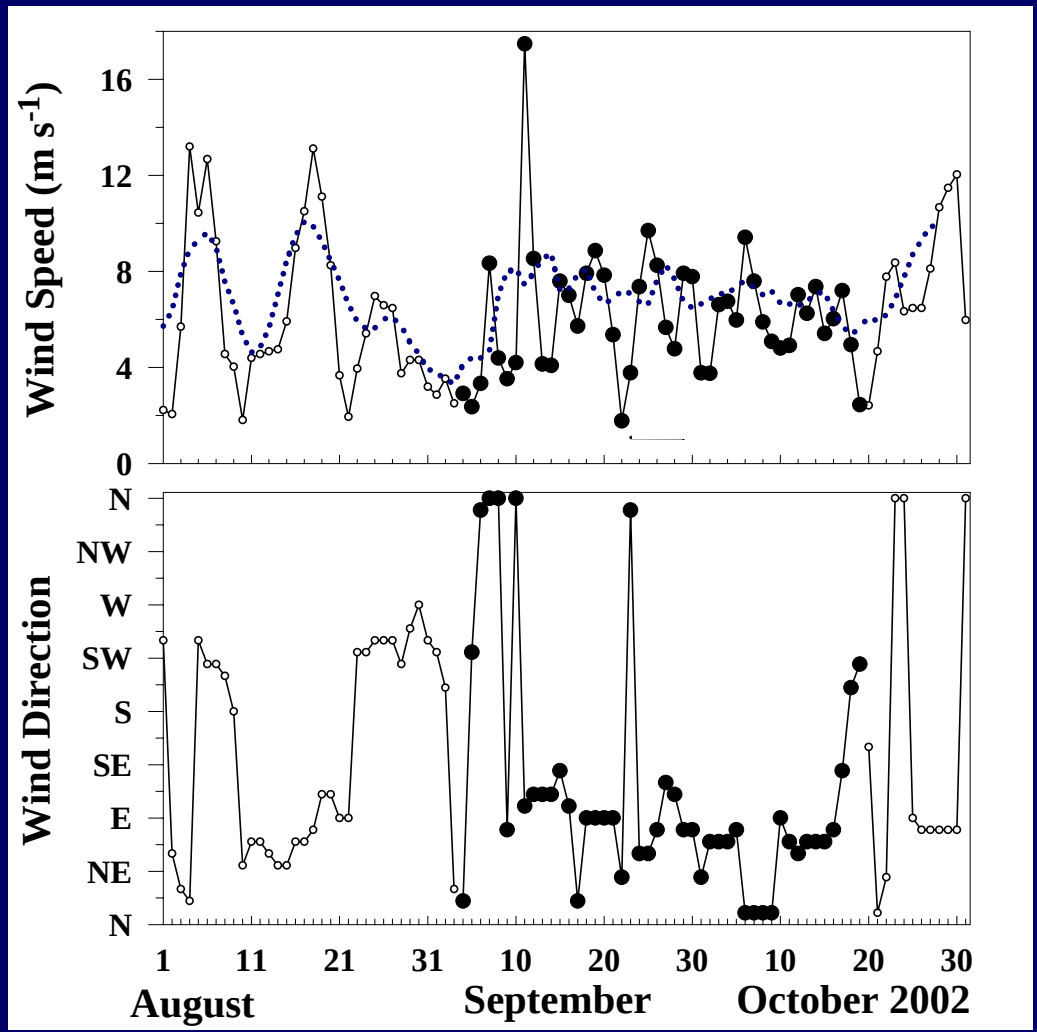
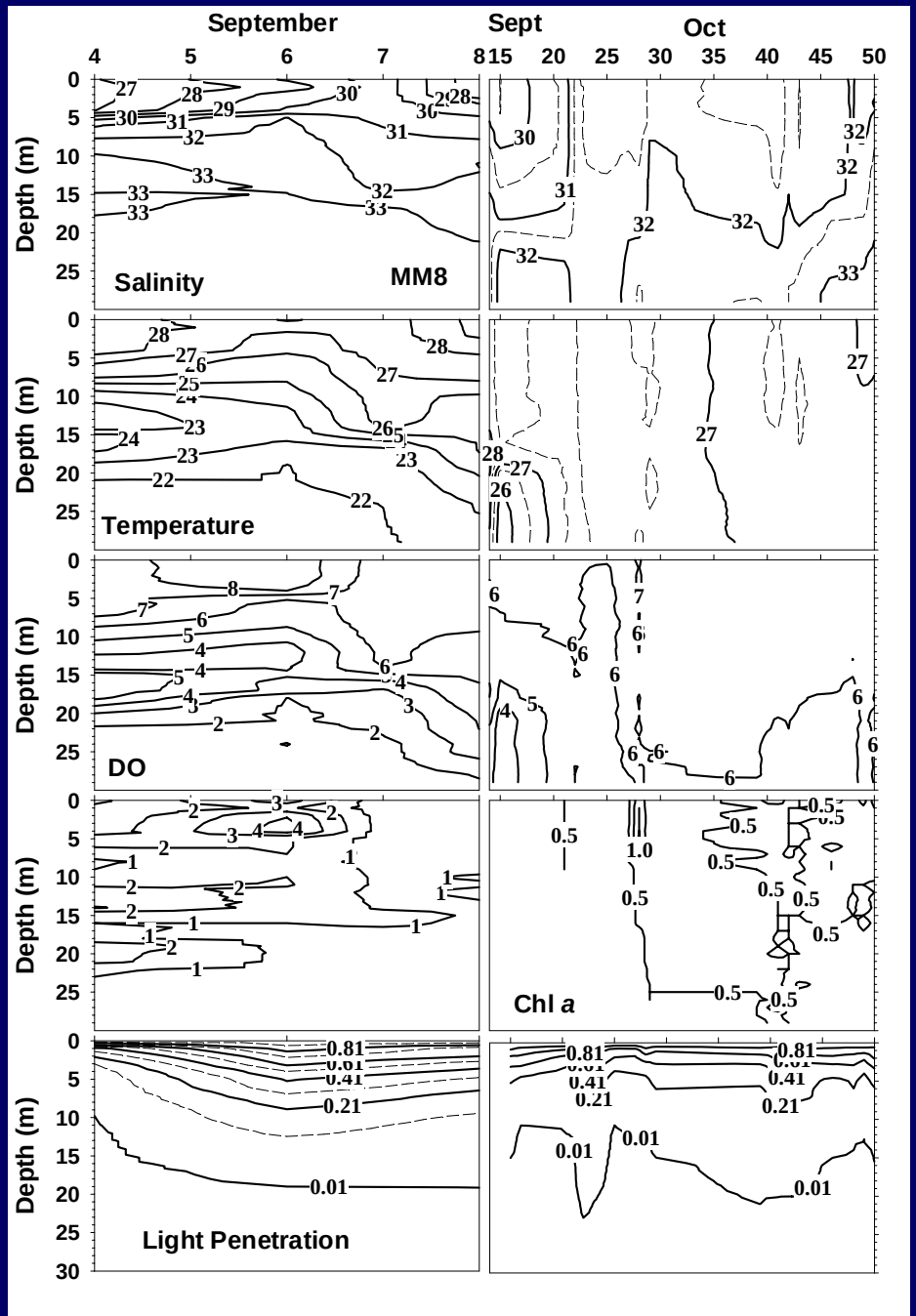
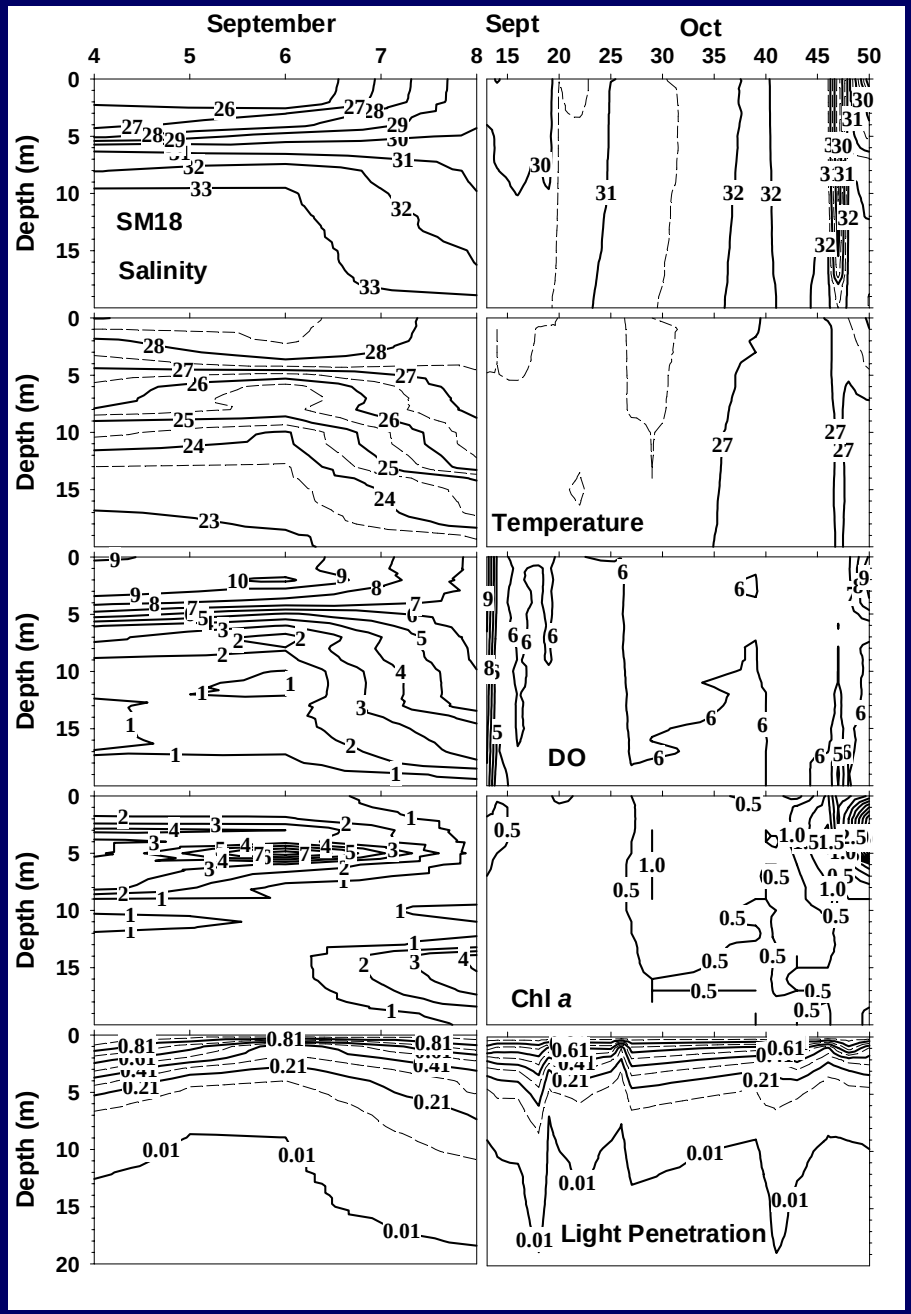
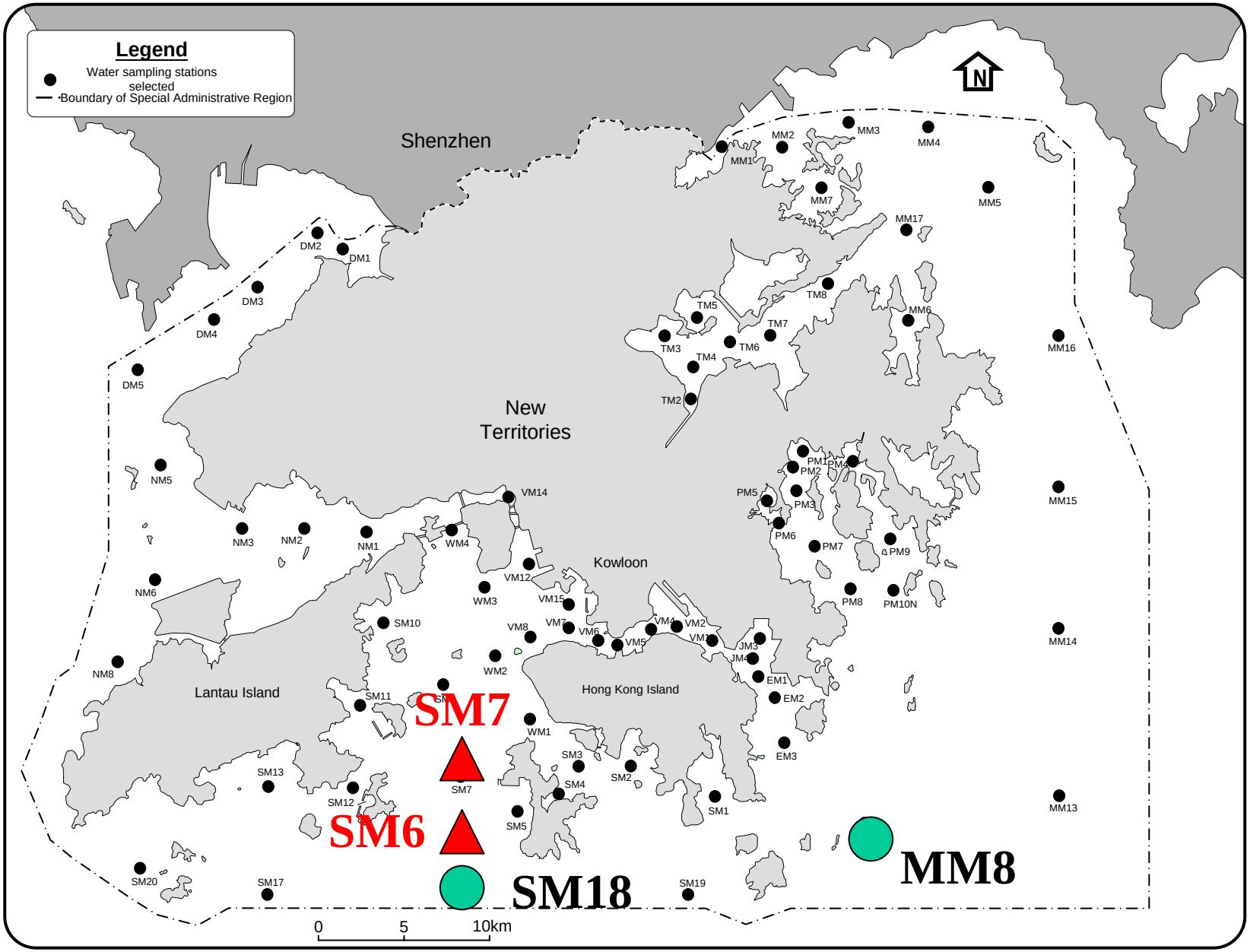


Figure showing EPD routine water sampling stations


Wind Speed (m s-1)
16
12
8
4
0
Wind Direction
N
NW
W
SW
S
SE
E
NE
N
1
11
21
31
10
20
30
10
20
30
August
September
October 2002


September
Sept
Oct
4
5
6
7
8
15
20
25
30
35
40
45
50
Depth (m)
Salinity
MM8
Temperature
DO
Chl a
Light Penetration


September
Sept
Oct
4 5 6 7 8
15 20 25 30 35 40 45 50
Depth (m)
SM18
Salinity
Temperature
DO
Chl a
Light Penetration



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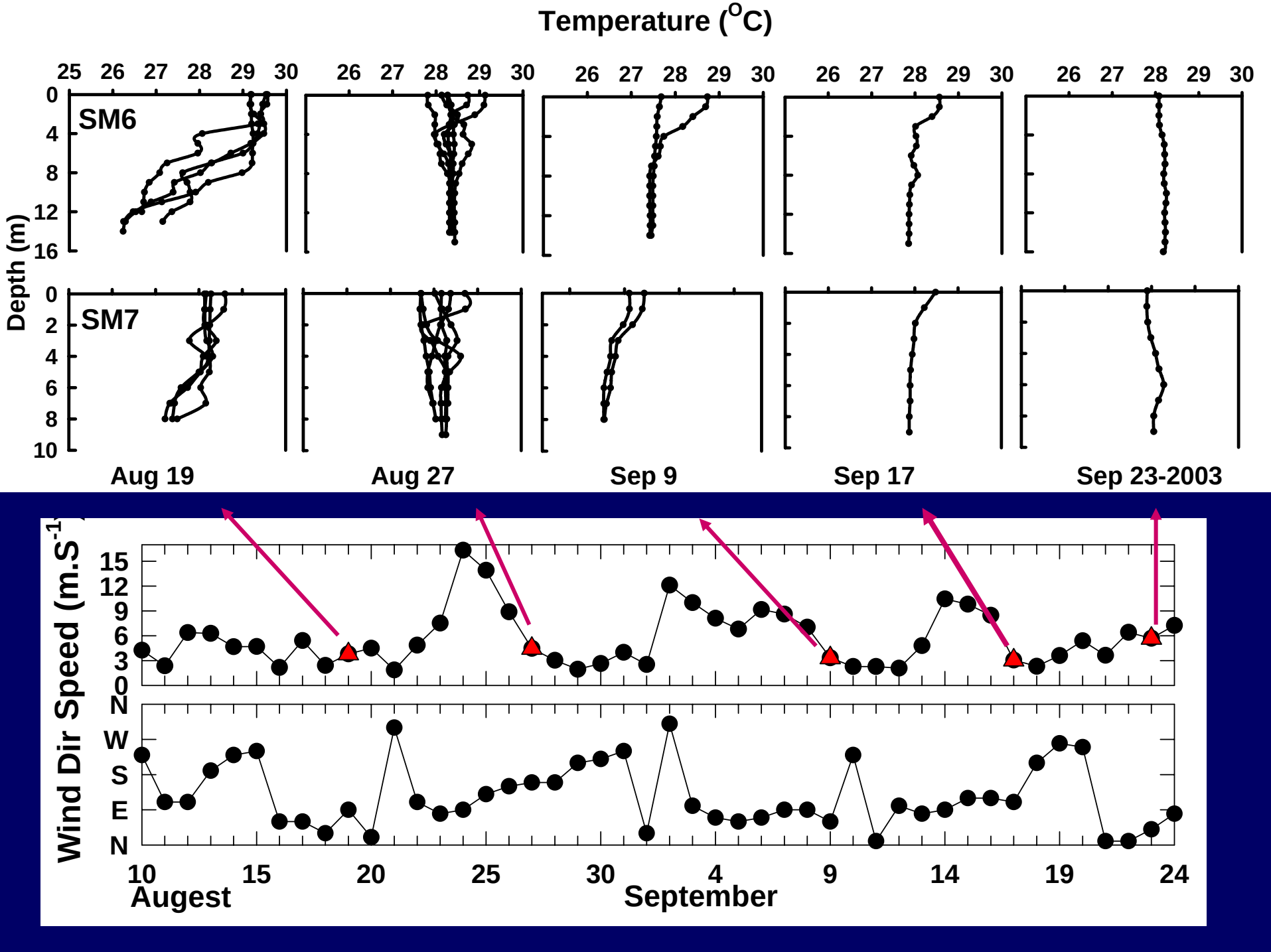
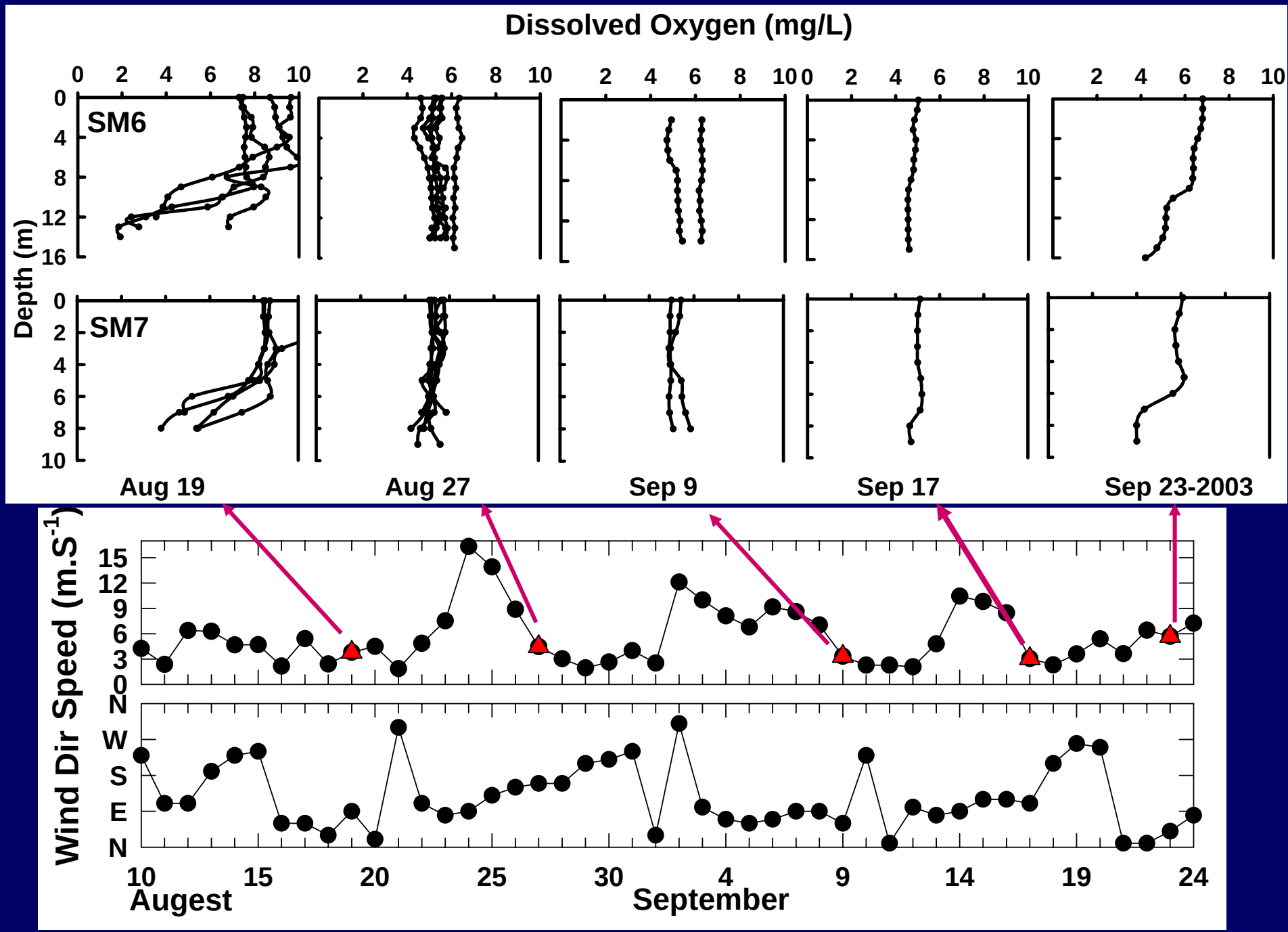
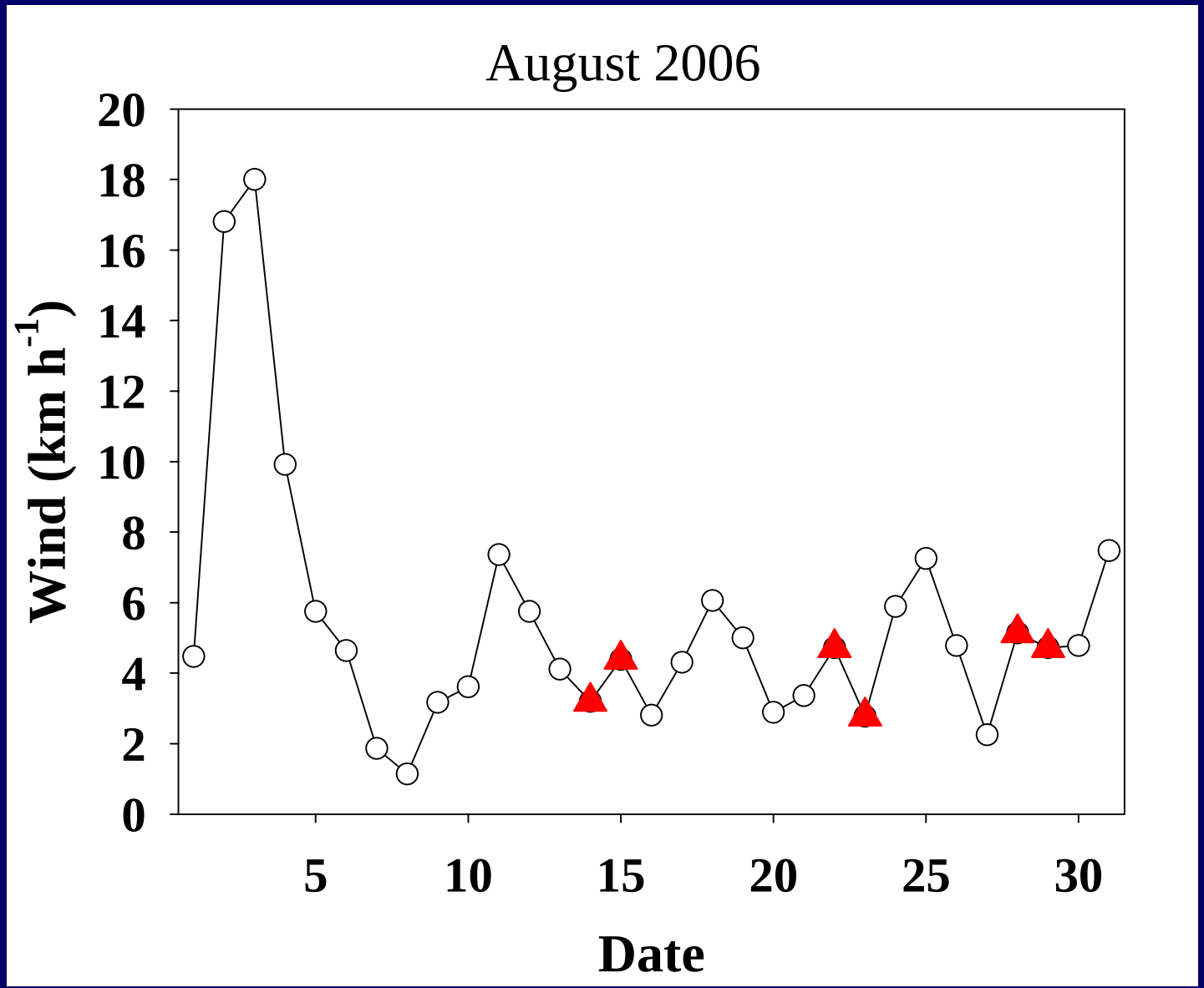

Temperature (°C)
25 26 27 28 29 30
26 27 28 29 30
26 27 28 29 30
26 27 28 29 30
26 27 28 29 30
Depth (m)
SM6
SM7
0 4 8 12 16
0 2 4 6 8 10
Aug 19
Aug 27
Sep 9
Sep 17
Sep 23-2003
Wind Dir Speed (m.S-1
15 12 9 6 3 0
N W S E N
10 15 20 25 30 4 9 14 19 24
Augest
September


Dissolved Oxygen (mg/L)
SM6
SM7
Depth (m)
Aug 19
Aug 27
Sep 9
Sep 17
Sep 23-2003
Wind Dir Speed (m.S-1)
N
W
S
E
N
10
15
20
25
30
4
9
14
19
24
Augest
September

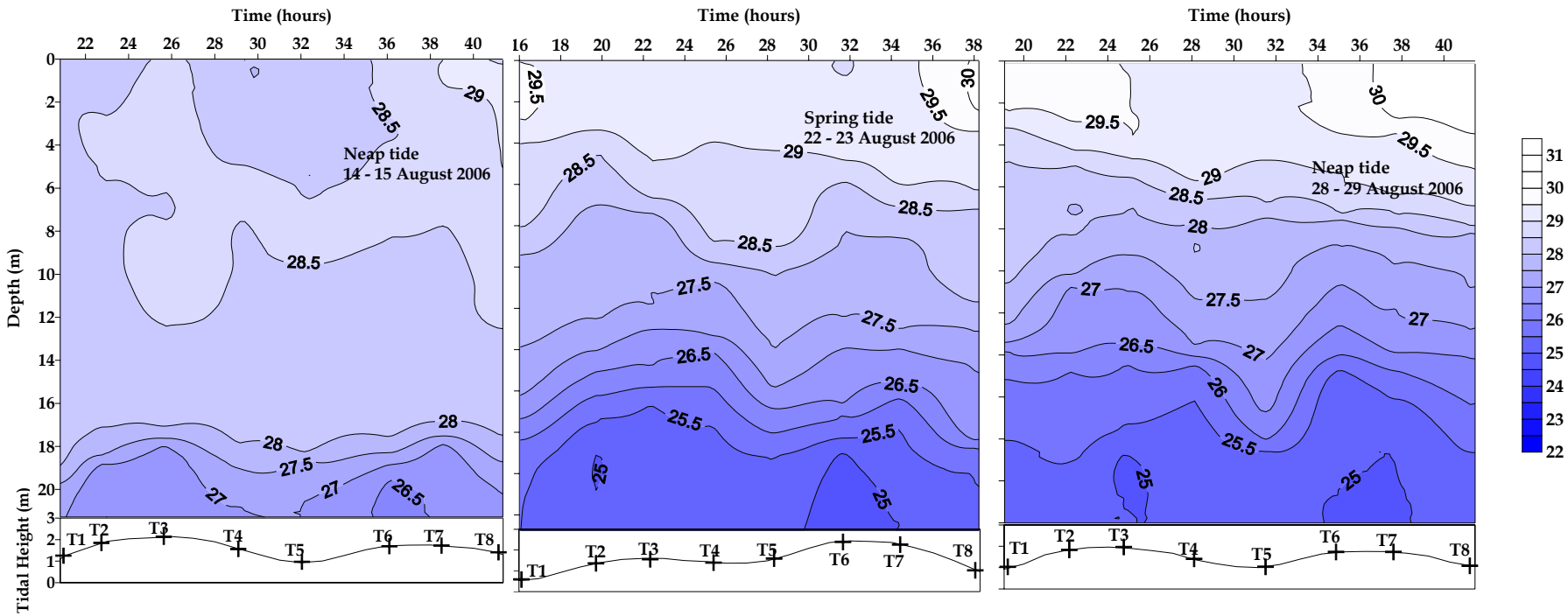

August 2006
Wind (km h-1)
0
2
4
6
8
10
12
14
16
18
20
5
10
15
20
25
30
Date

SM18, 24 h time series, August 2006: Temperature

Aug 14-15

Aug 22-23

Aug 28-29

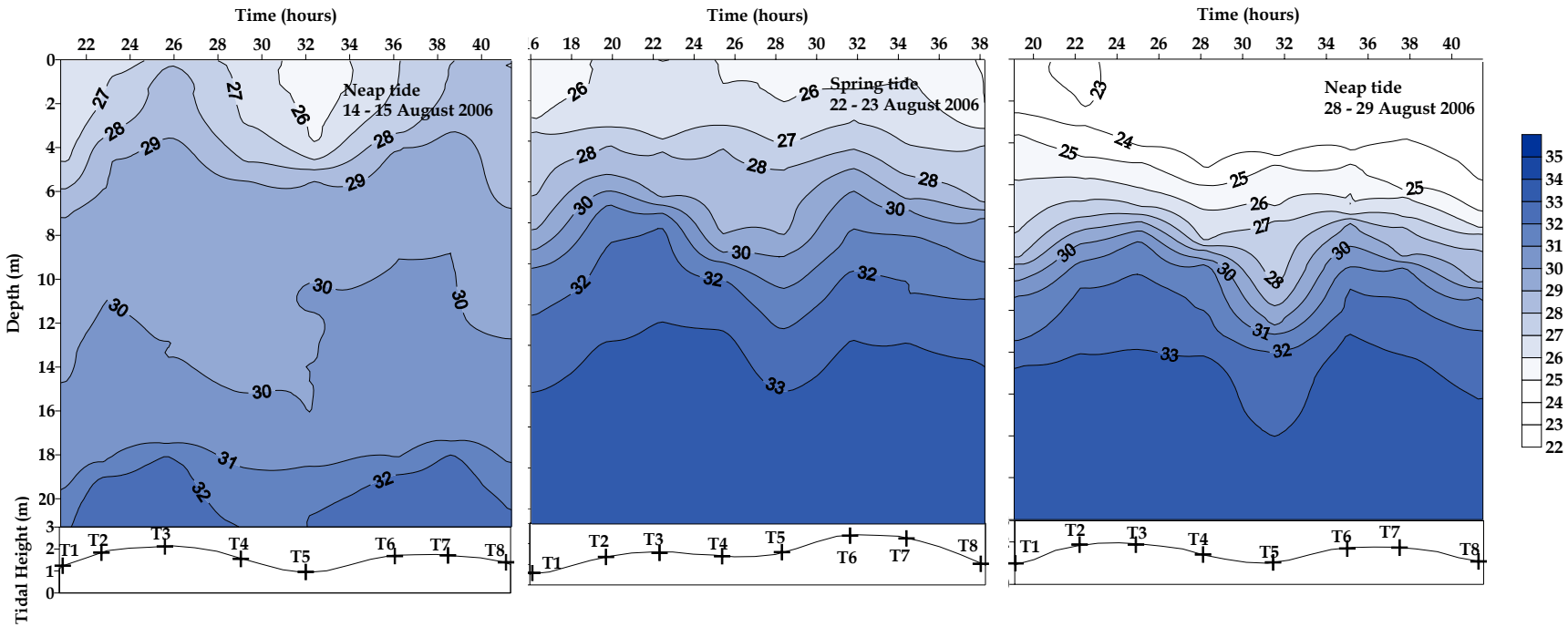


SM18, 24 h time series, August 2006: Salinity

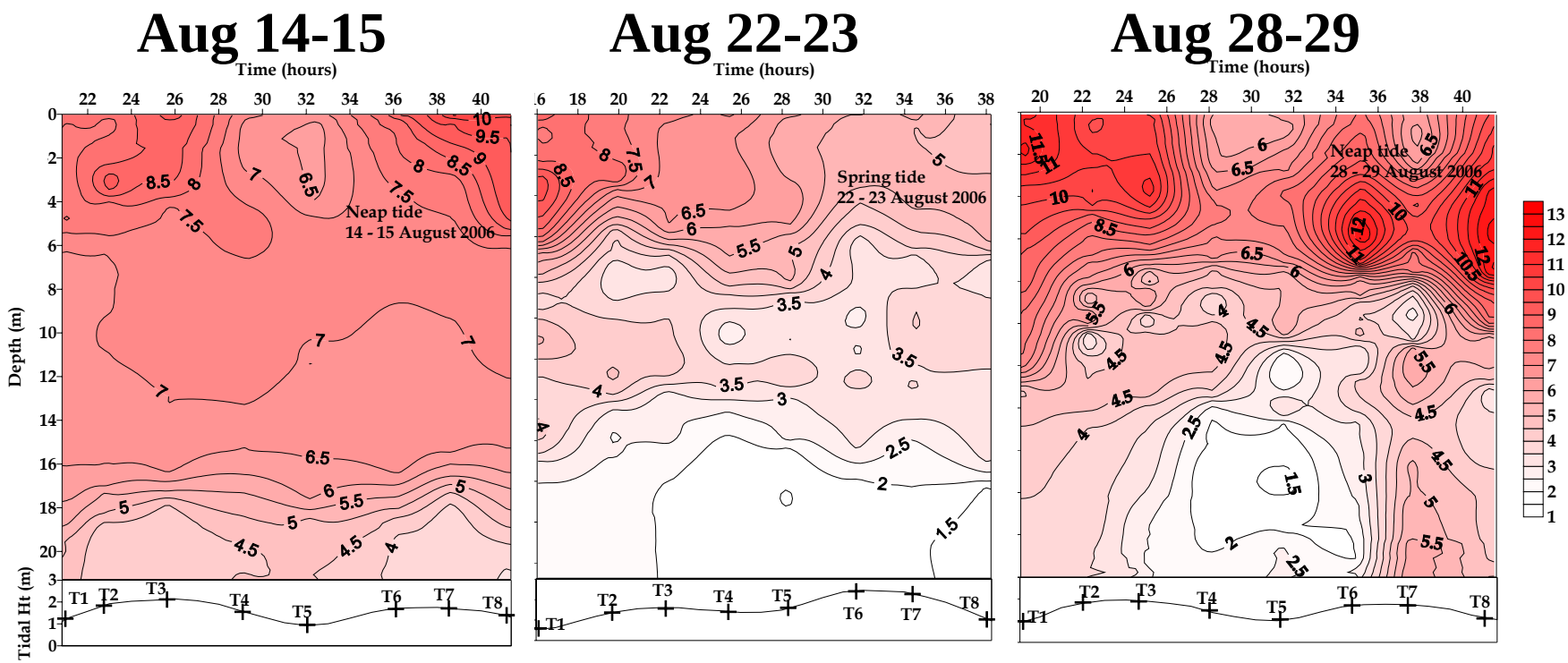
Aug 14-15

Aug 22-23

Aug 28-29



SM18, 24 h time series, August 2006: Dissolved Oxygen



Effects of winds during summer :

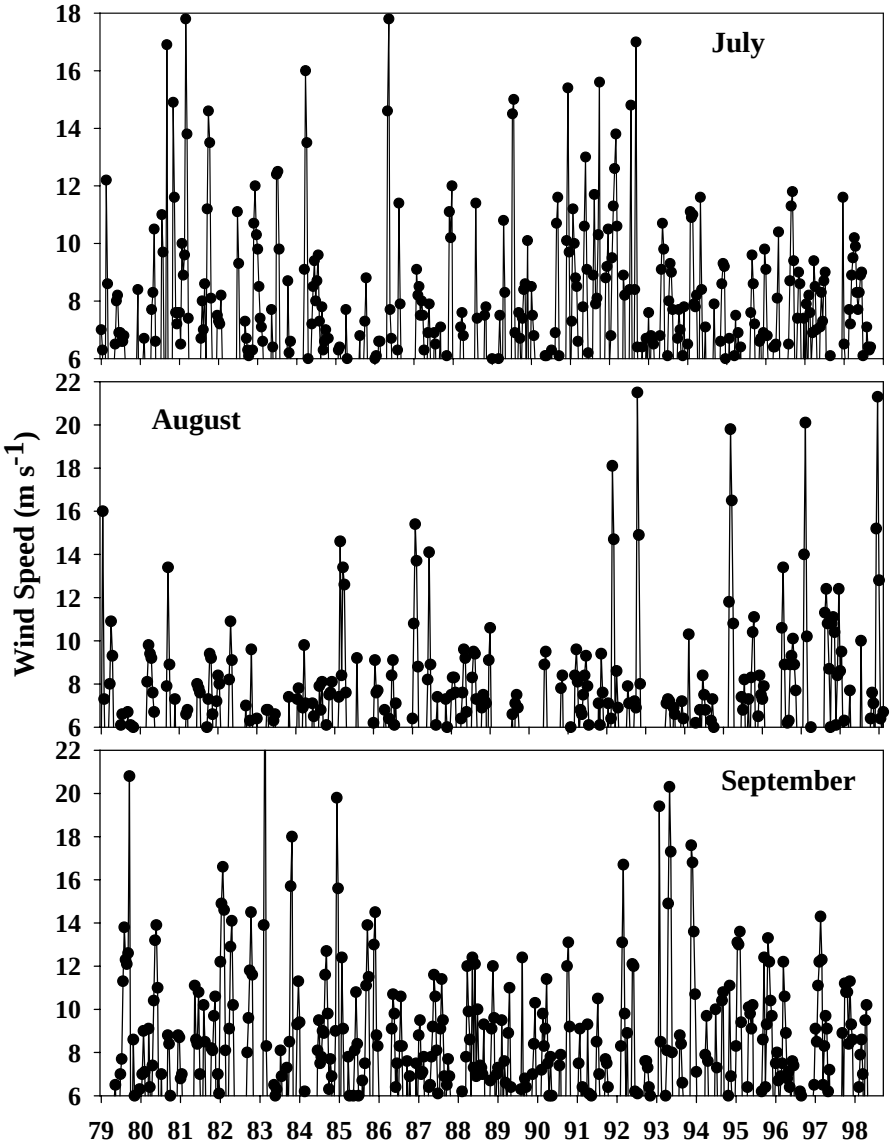
Winds >6 m s^{-1} was found to be a wind event, which

--mixed the water column and nutrients

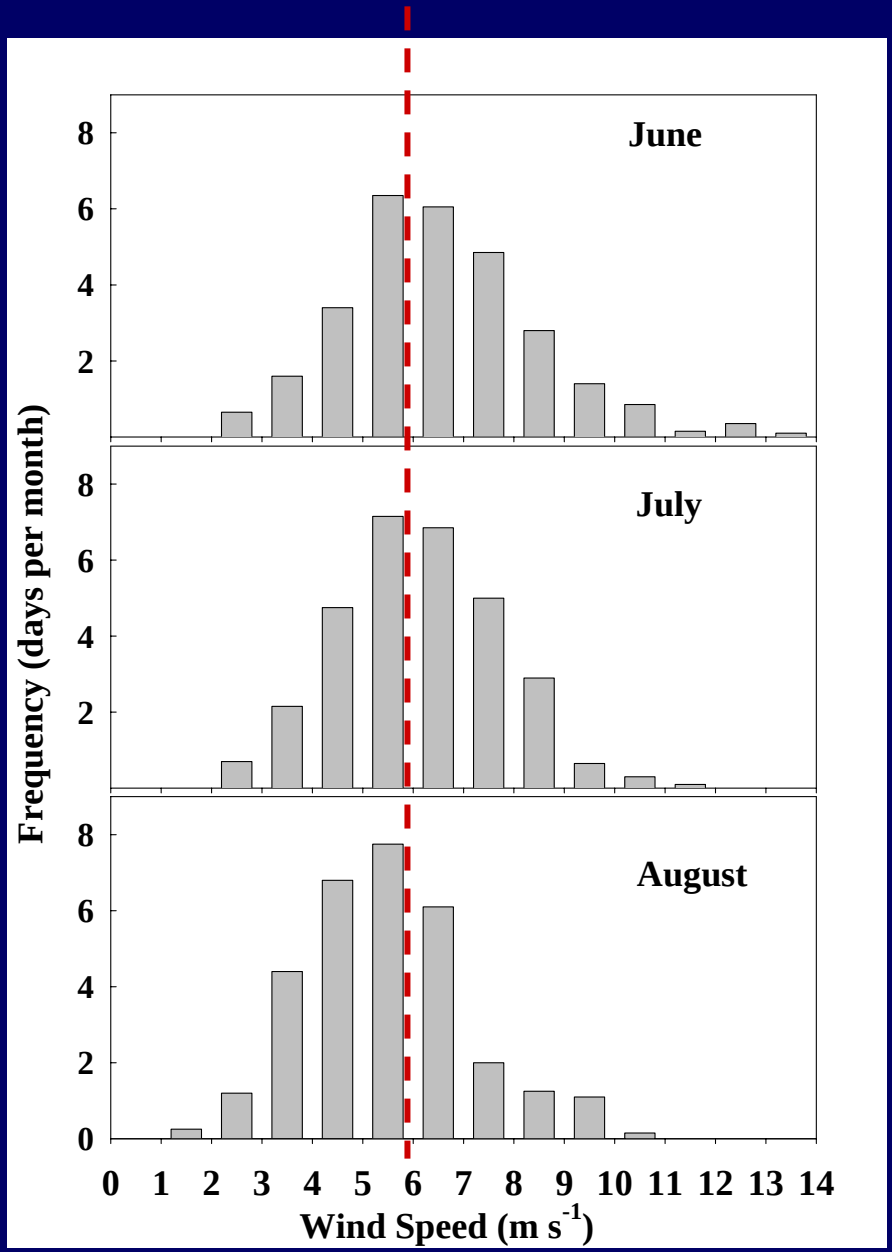
--caused a phytoplankton bloom in summer in the Strait of Georgia

(Yin et al. 1997 MEPS).

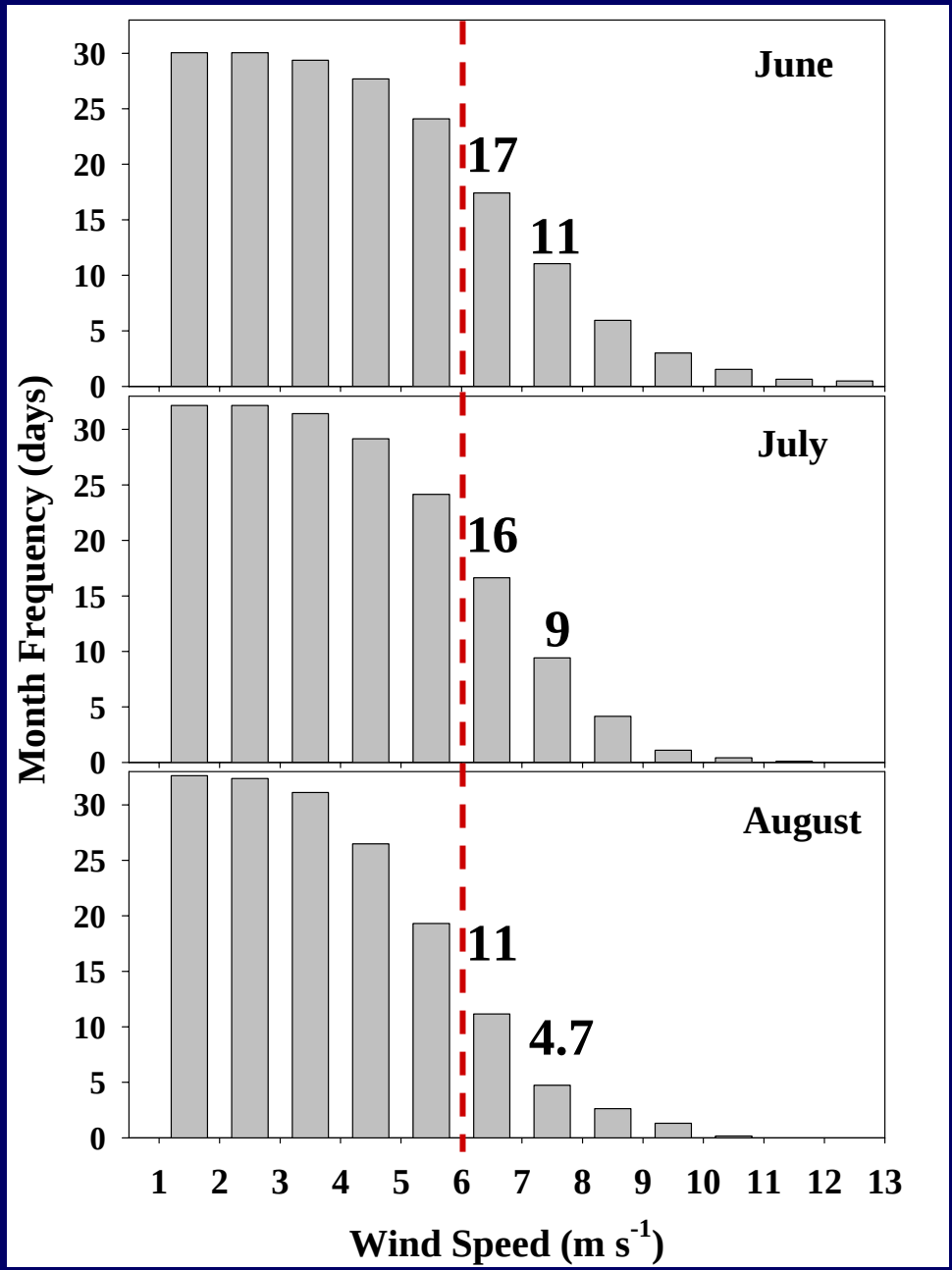
Wind speed above 6 m s^{-1} during 1979-1998



Frequency for the month during 1979-1998



Monthly accumulative frequency during 1979-1998



Effects of winds during summer :

Winds >6 m s-1

- frequently interrupts the water column stratification, and mixes oxygen downwards
- prevents the formation of seasonal hypoxia in the Pearl River influenced coastal waters.
- However, August is vulnerable to episodic events of hypoxia

Climate change – wind speed change: may trigger more frequently occurrences of hypoxia events

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