The 1st GloboLakes Project Workshop

太湖湖泊生态系统研究站

Taihu Laboratory for Lake Ecosystem Research

An overview of lake optics and remote sensing in Lake Taihu

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Outline

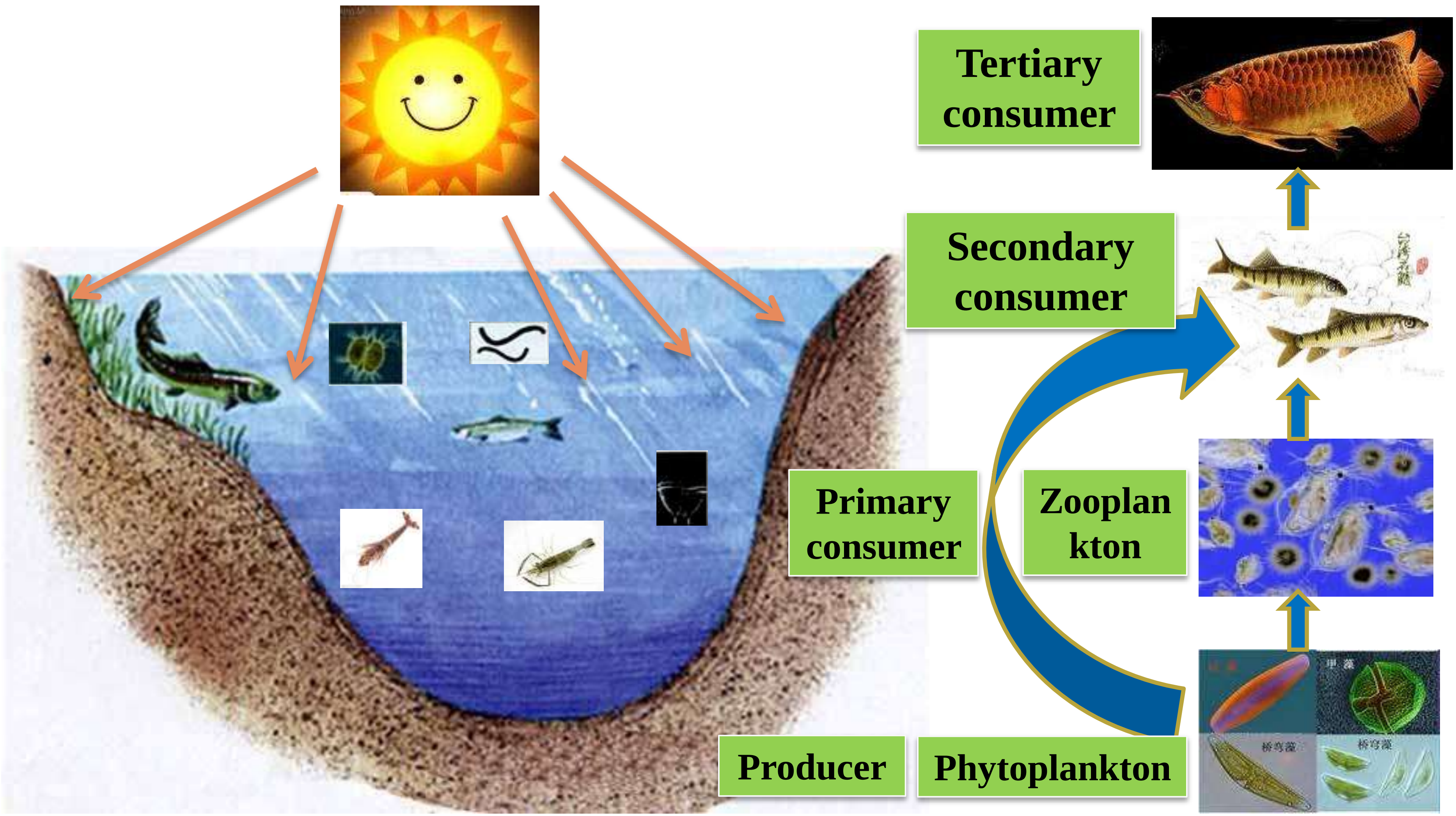
1 Background

2 Study regions

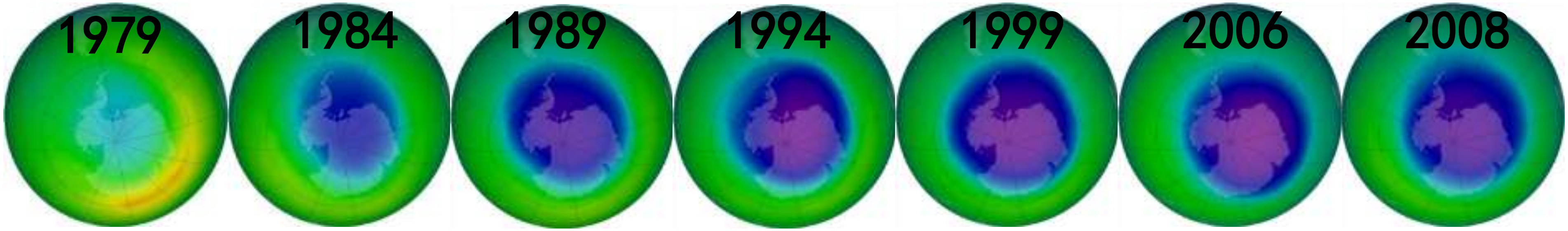
3 Main progresses

1. Background

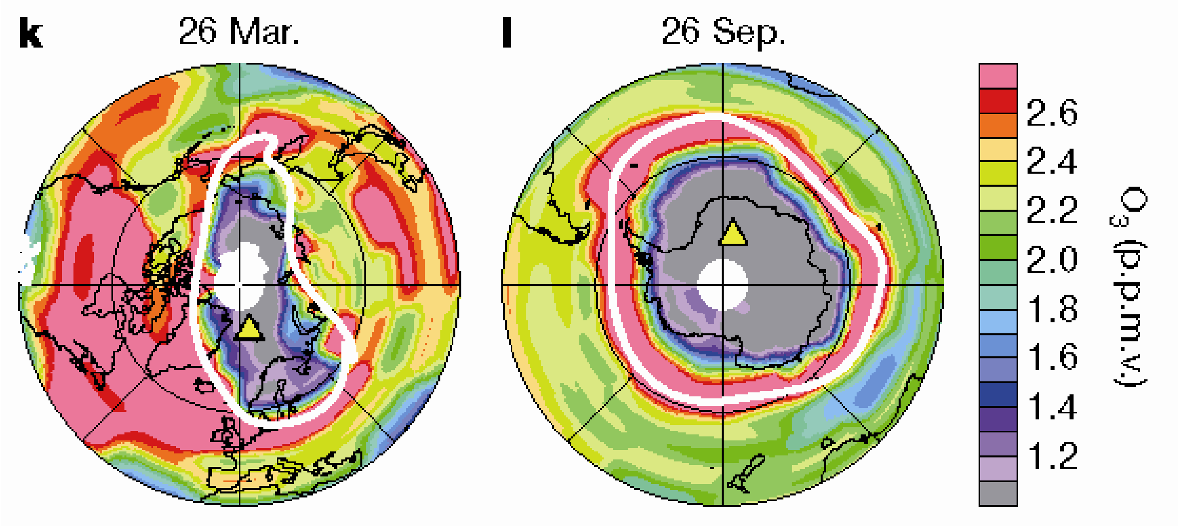
Solar radiation drives the lake ecosystem



Effect of increased UV-B radiation on lake ecosystem



The ozone hole in Antarctica in October



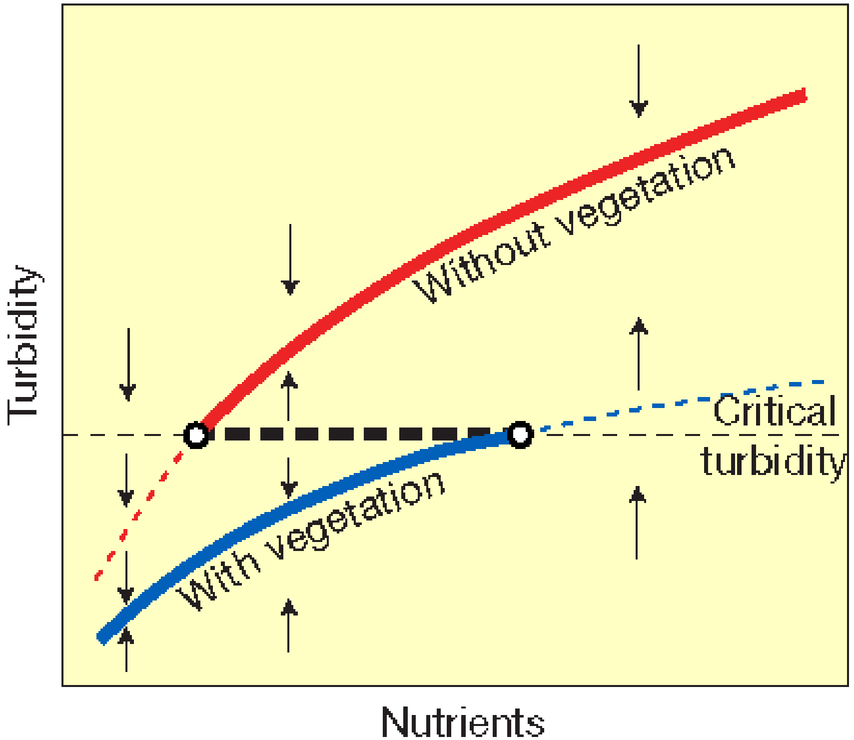
The ozone hole in Arctic in 2011

Zooplankton irradiated by UV-B

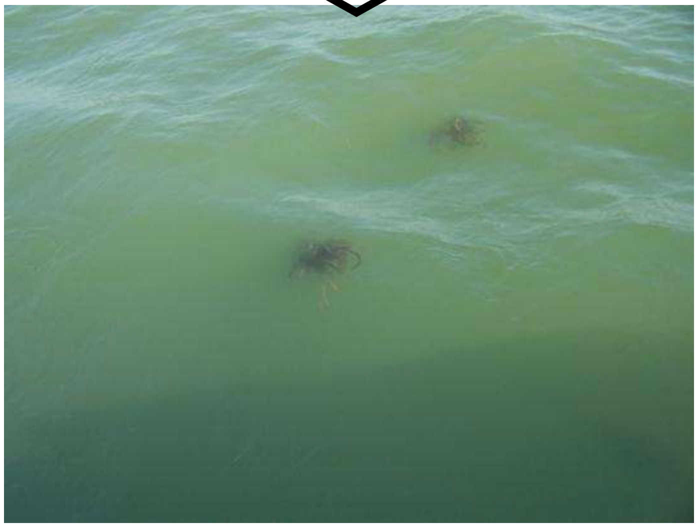
Manney et al, Nature, 2011; Balskus et al., Science, 2010

Water waste event and frequent algal bloom urging water color remote sensing

Turbidity increase due to eutrophication causing the disappearance of SAV

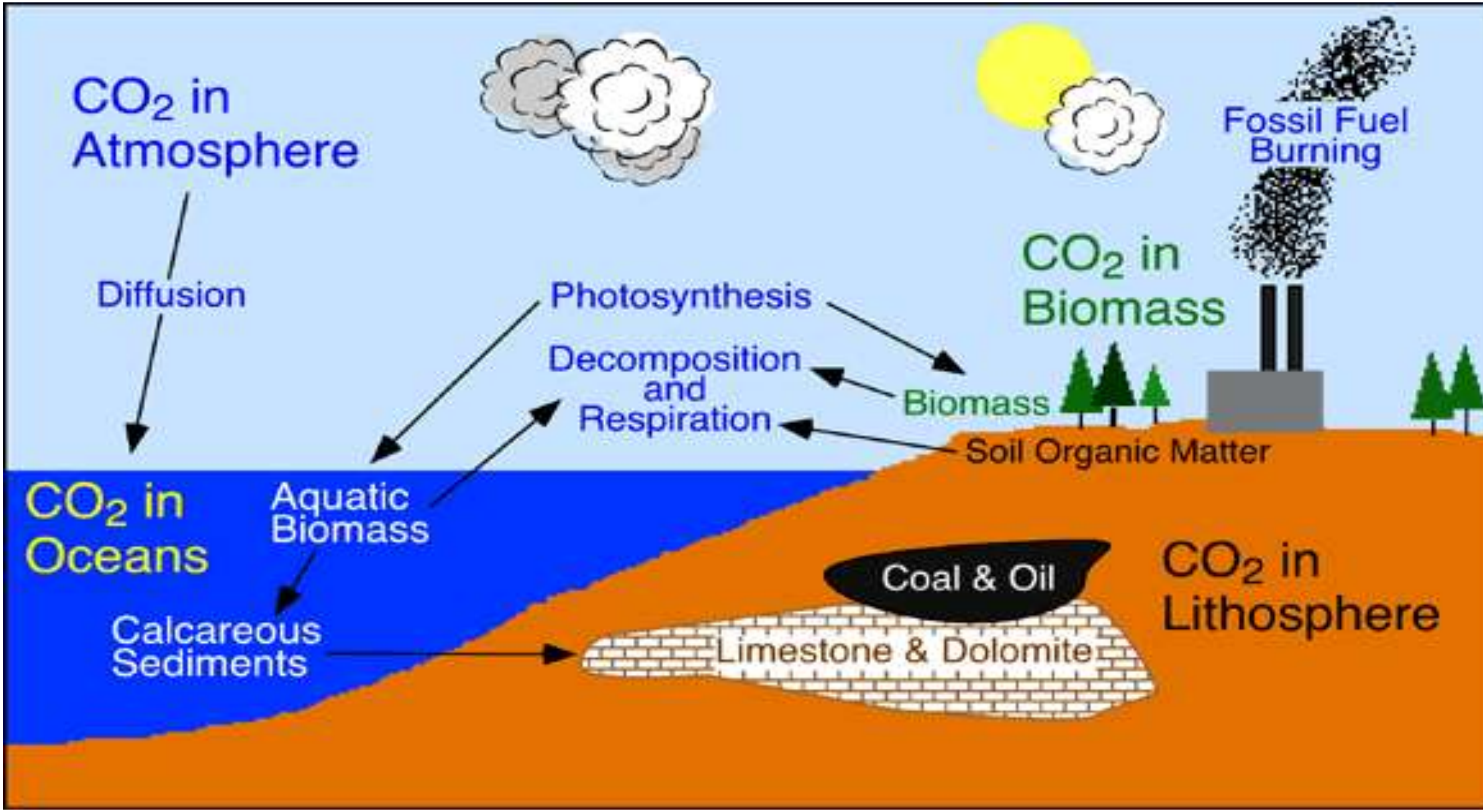


SAV distribution with turbidity and nutrients increases (Scheffer, Nature, 2001)

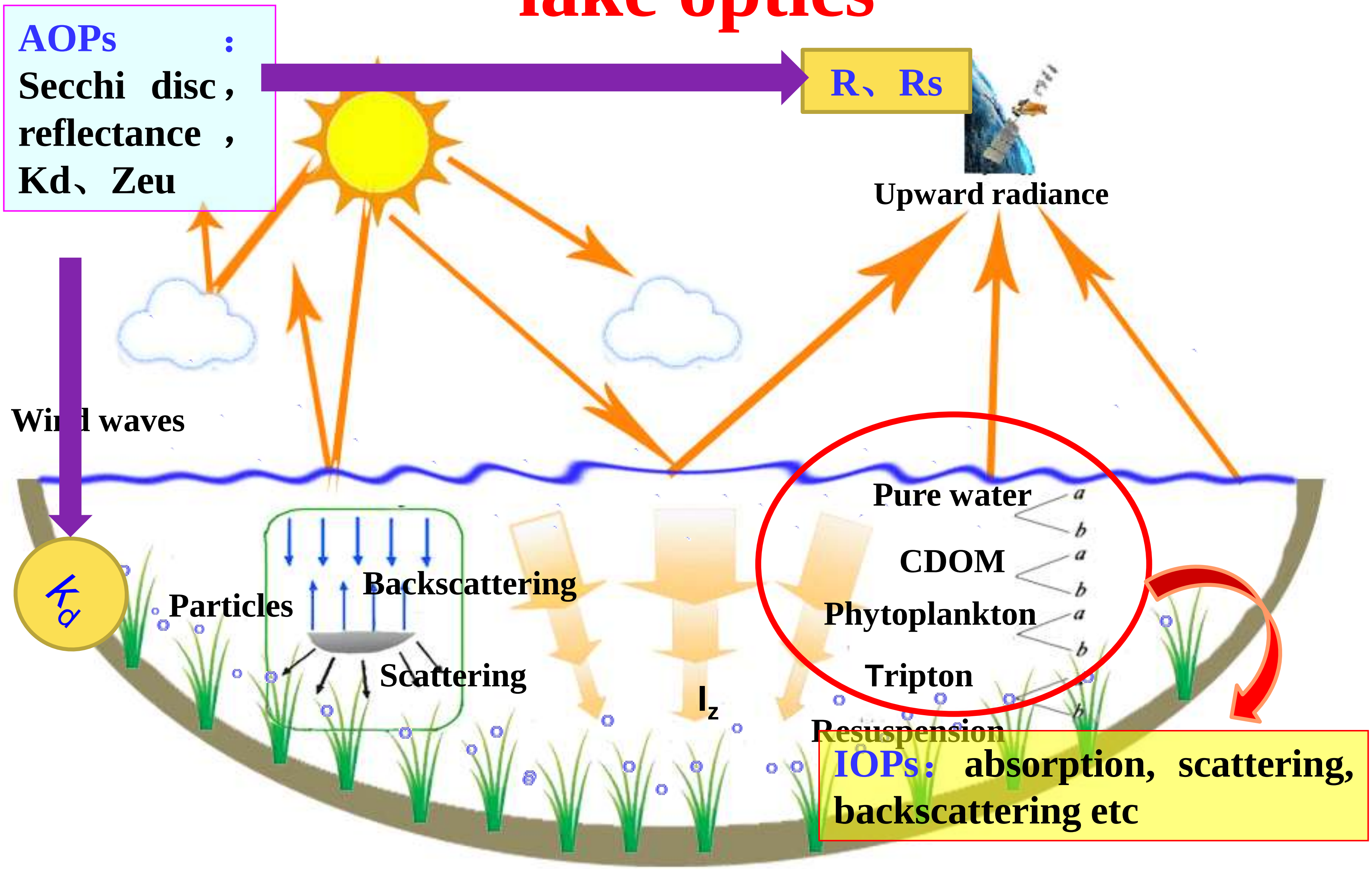


SAV disappearance

CDOM plays an important role in the global carbon cycle and estimation



Concept and theory framework of lake optics



Main contents and key scientific question

- Investigation
- Optical parameters measurement
- Water color remote sensing
- Processes observation
- Laboratory simulation
- Numerical model

Spatial-temporal pattern：

1. Typical lakes
2. Large lake

Processes study：

1. Hydrodynamic process
2. SAV growth and death
3. Algal blooms process
4. community succession

1. **Spatial-temporal pattern and driven mechanism of lake optics**
2. **Coupling process and mechanism of optics, thermodynamics and hydrodynamic**
3. **Water color parameters, primary production and phytoplankton community remote sensing**

Methods **Results** **Scientific question**

2. Study regions

Total Lakes: 2742(> 1 km^2)

Total Area: 91020 km^2

- Number of lakes (Area>1km^2): 651
- Total area:16558 km^2 (60% of total freshwater lake areas of China)
- Characteristics: shallow and eutrophication

Morphologic Map of Lake Taihu Catchment

Lake Taihu has multi-functions:

- **Drinking water supply**
- **Tourism**
- **Flood control**

Hydrography of Lake Taihu

• Area	2338	km^2
• Catchment	36500	km^2
• Mean Depth	1.9	m
• Max. Depth	2.9	m
• Lake Volume	44×10^8	m^3
• Max. Level	4.81	m a.s.l.
• Min. Level	2.02	m a.s.l.
• Retention Time	300	days

Characteristics 1: Diverse ecosystem types

Phytoplankton-dominated ecosystem

SAV-dominated ecosystem

Characteristics 2: Frequent algal bloom

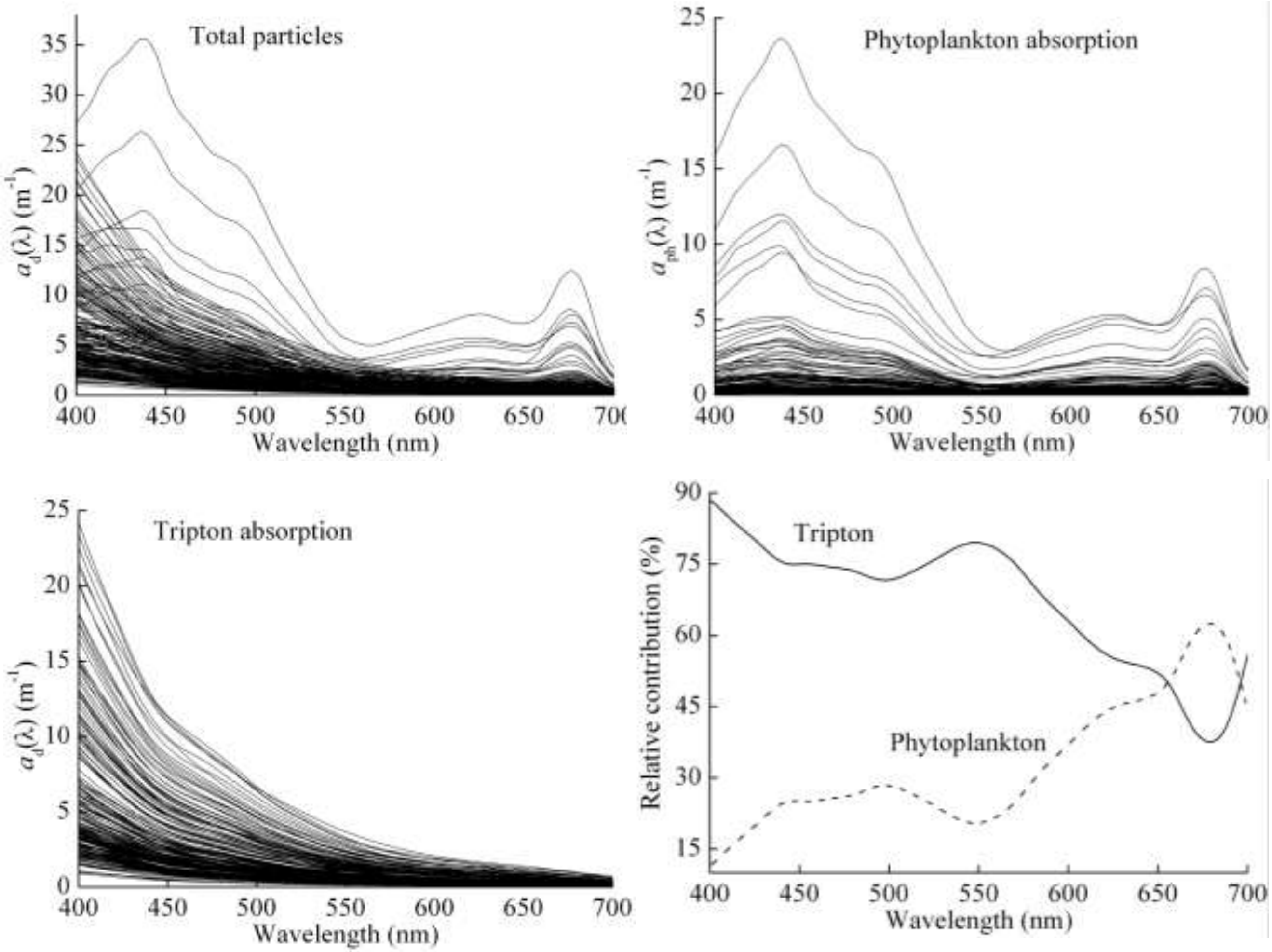
Characteristics 3: Strong wind waves and sediment resuspension

3. Main progresses

1. Development and innovation of lake optics study methods

Methanol soaked

NaclO bleaching



Absorption and relative contribution rate

Zhang et al., 2007, Hydrobiologia

1. Development and innovation of lake optics study methods

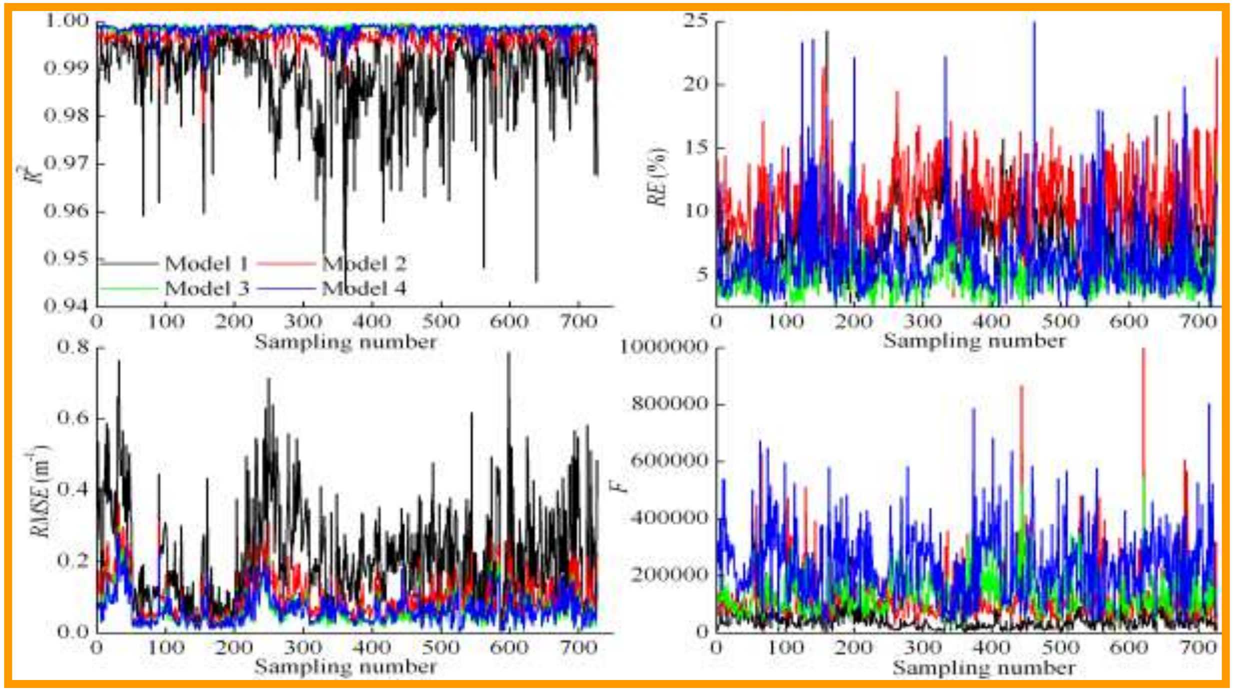
Optimization model of tripton spectral absorption

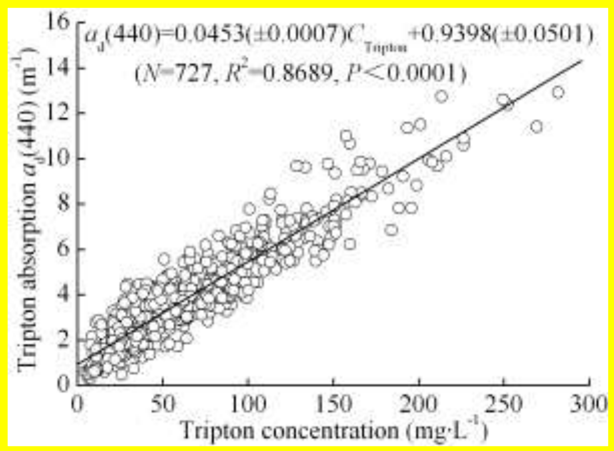
$\ln a(\lambda)=a_1-S_1\lambda$

$a_d(\lambda)= a_d(\lambda_0)\exp[S_d(\lambda_0-\lambda)]$

$a_d(\lambda)= a_d(\lambda_0)\exp[S_d(\lambda_0-\lambda)]+K$

$a(\lambda)=a_4(\lambda/440)^{-S_4}$





Zhang et al., 2011, IJRS

Phytoplankton numerical partition models

$a_d(\lambda) = a_d(\lambda_0)\exp[S_d(\lambda_0-\lambda)]$

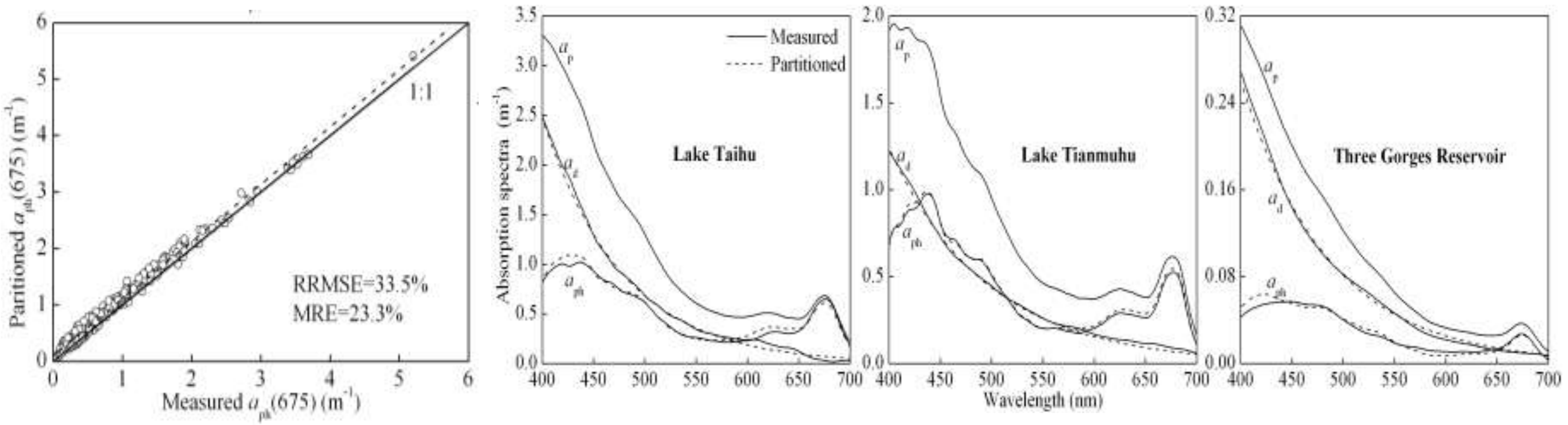
$a_{ph}(505): a_{ph}(380)=0.99$

$a_{ph}(580): a_{ph}(692.5)=0.92$

$a_d(\lambda) = a_d(\lambda_0)\exp[S_d(\lambda_0-\lambda)]+K$

$a_{ph}(490): a_{ph}(412)=0.919\mathrm{Chl}a^{0.012}$

$a_{ph}(510): a_{ph}(412)=0.581\mathrm{Chl}a^{0.047}$



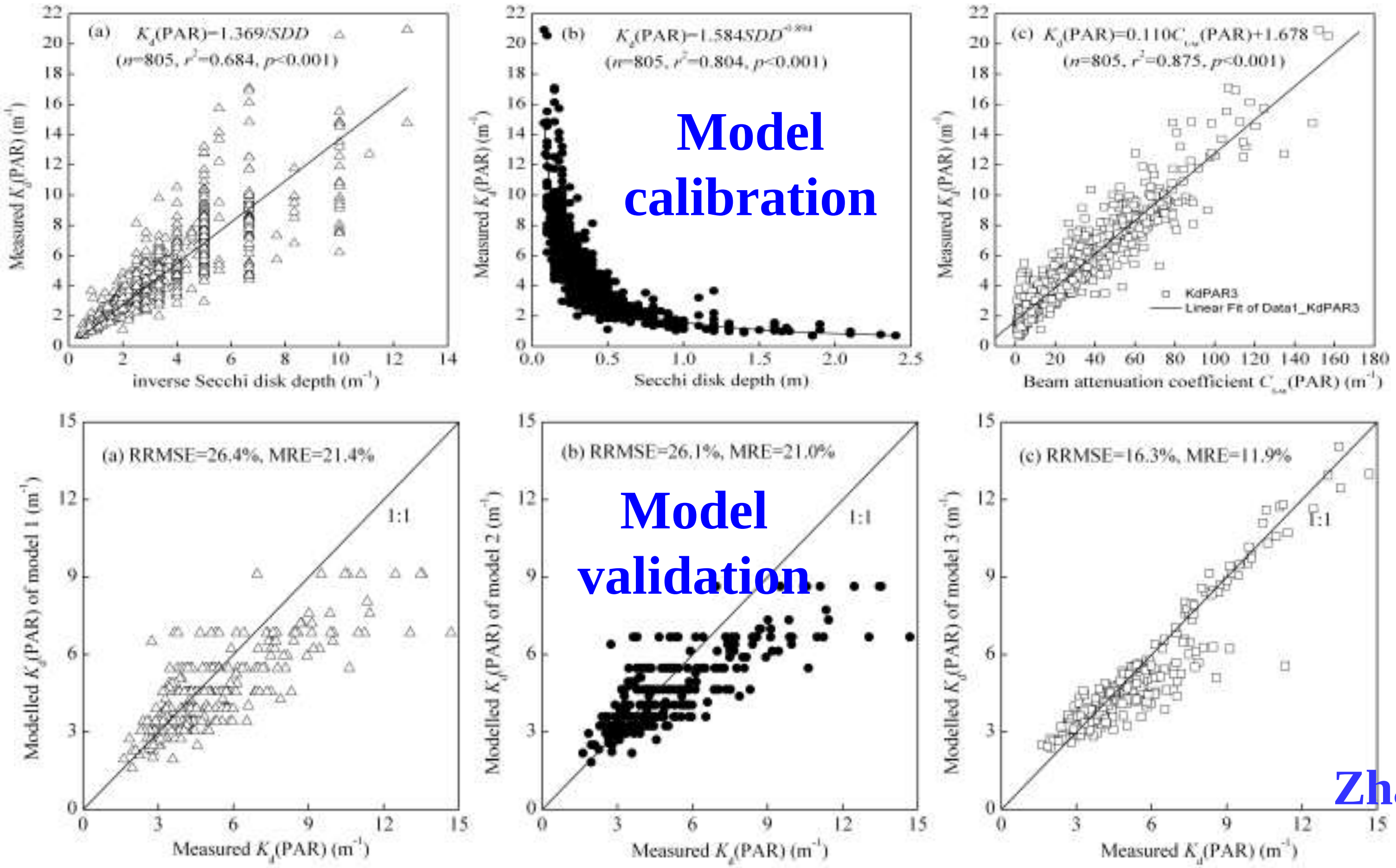
With the determination coefficient larger than 0.9 and relative error less than 25%

Zhang et al., 2009, JPR

1. Development and innovation of lake optics study methods

PAR diffuse attenuation coefficient prediction model

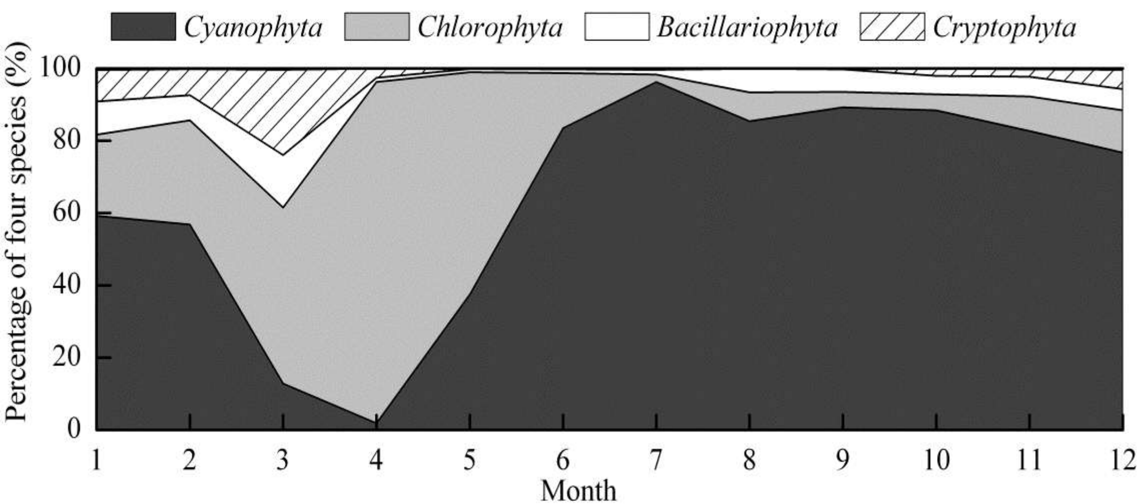
$$K_d(\mathrm{PAR}) = \frac{a}{\mathrm{SDD}} \quad K_d(\mathrm{PAR}) = b \cdot \mathrm{SDD}^c \quad K_d(\mathrm{PAR}) = d \cdot C_{t\text{-}w}(\mathrm{PAR}) + e$$



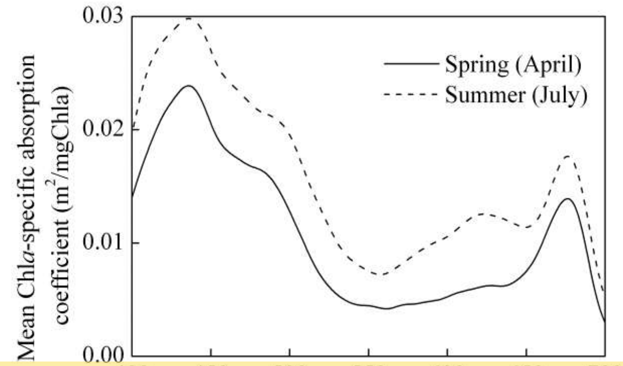
K_d(PAR) prediction model using, beam attenuation coefficient with the relative error less than 12%.

Zhang et al., 2012, Hydrobiologia

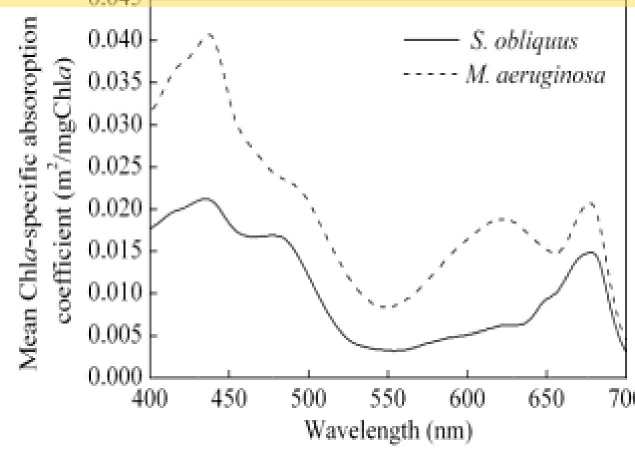
2. Lake bio-optical properties and affecting mechanism

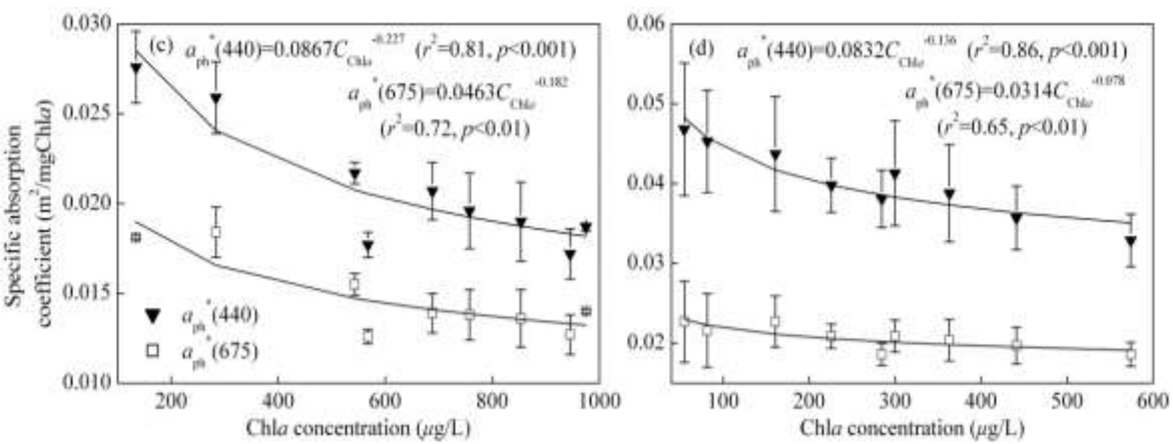


Phytoplankton community succession in Lake Taihu



Chla-Specific absorption





Chla-Specific absorption with Chla concentration

Zhang et al., 2012, OE

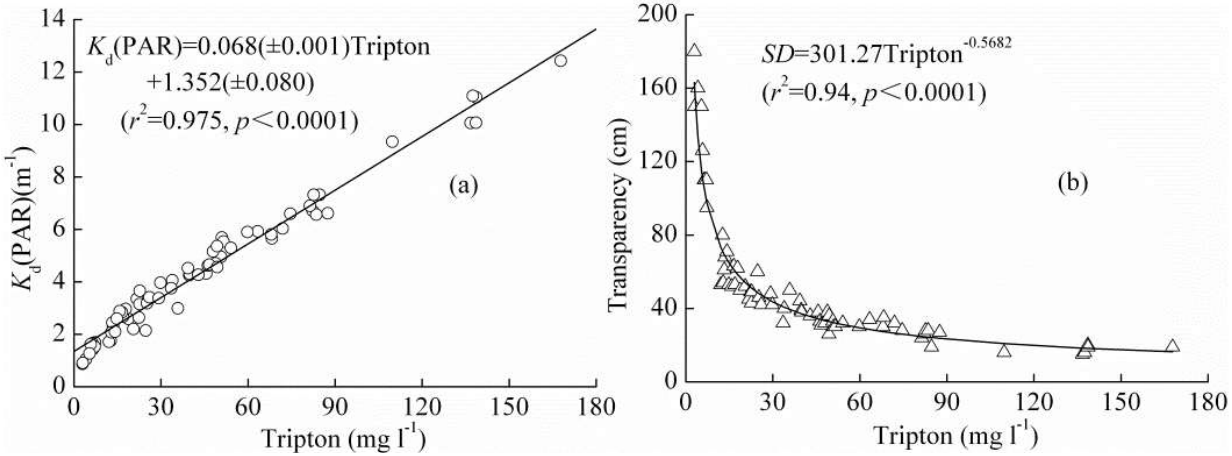
$$a_{ph}(675)=0.051D^{-0.256}C_{Chla}^{0.884}$$

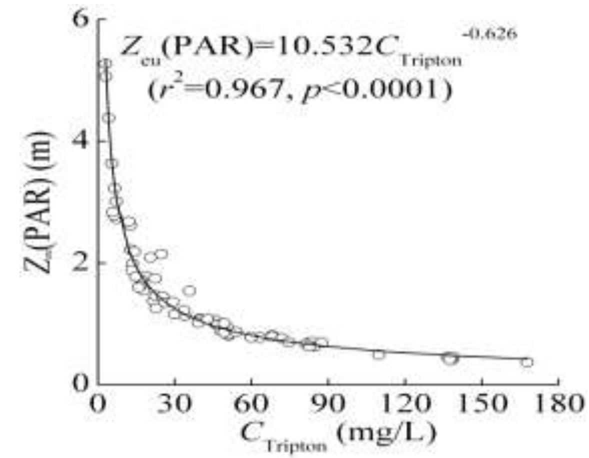
$$a_{ph}(440)=0.186D^{-0.555}C_{Chla}^{0.829}$$

$$a_{ph}^*(675)=0.053D^{-0.263}C_{Chla}^{-0.121}$$

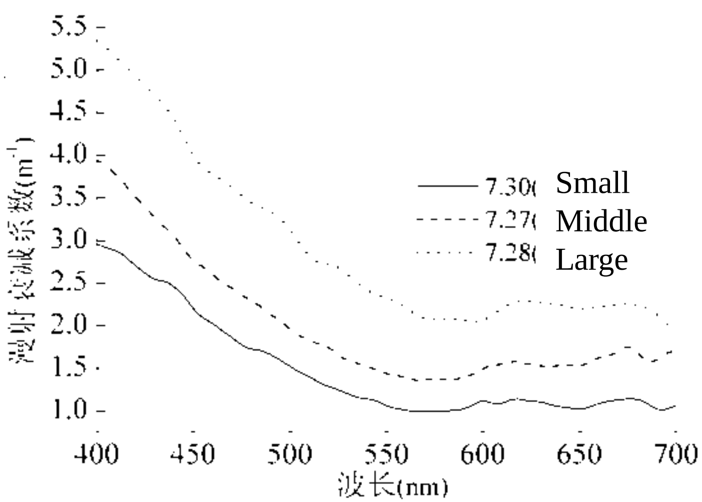
$$a_{ph}^*(440)=0.193D^{-0.567}C_{Chla}^{-0.173}$$

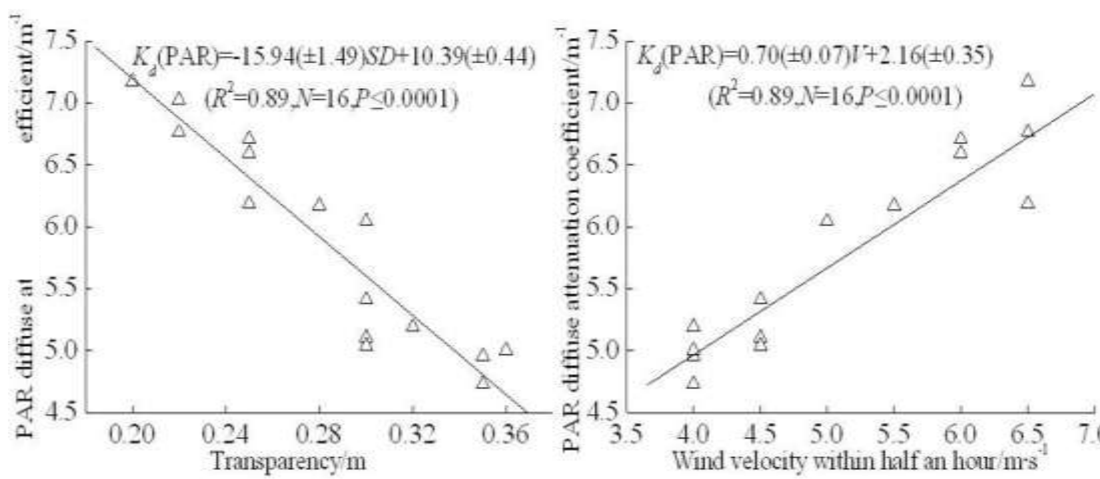
2. Lake bio-optical properties and affecting mechanism





Tripton was the dominant factor affecting K_d(PAR), SD and Z_{eu} in Lake Taihu

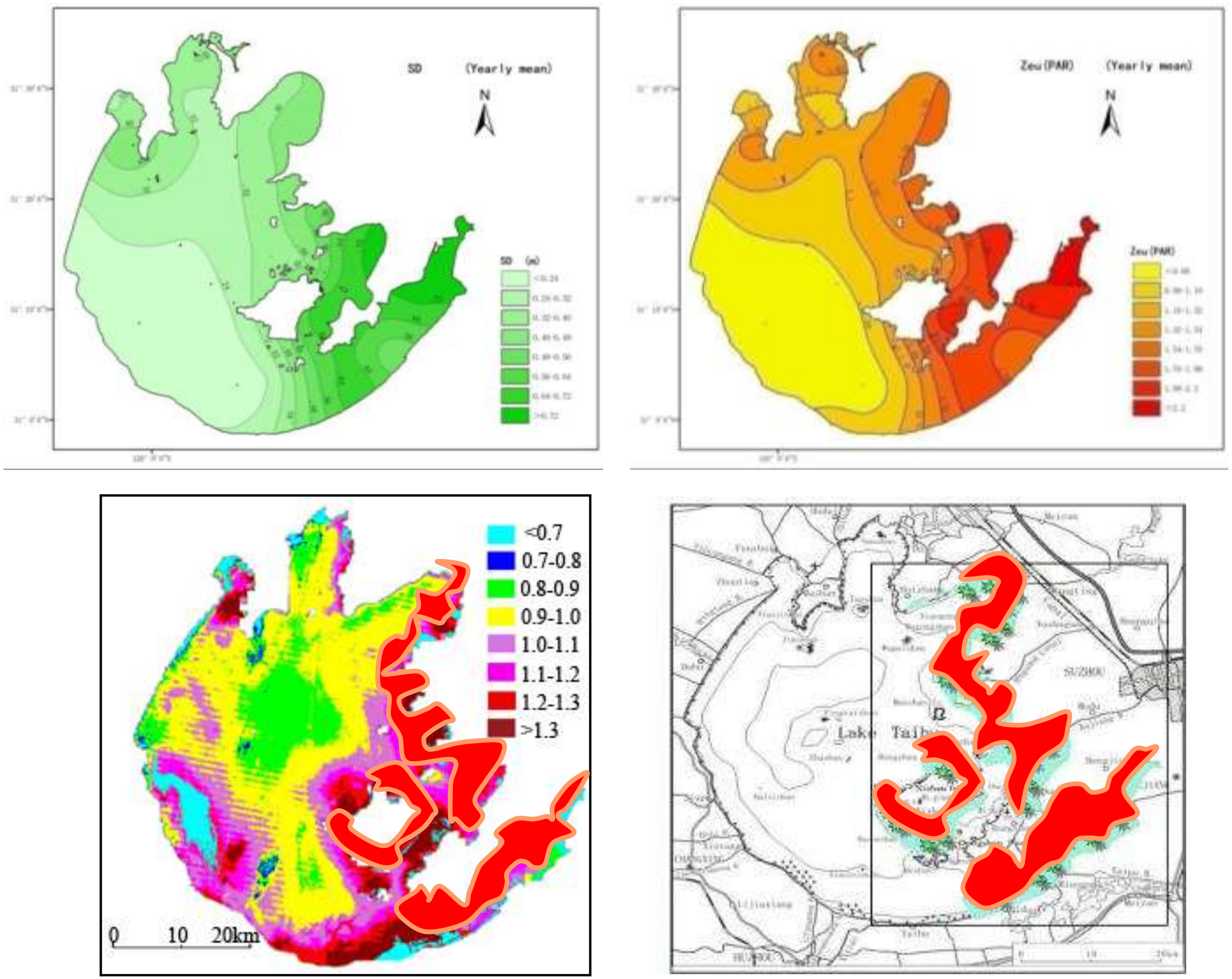




K_d variation with wind waves **Relationship between K_d(PAR) and wind speed**

Zhang et al., 2006, SC-SDEC; Zhang et al., 2007, FLA

2. Lake bio-optical properties and affecting mechanism

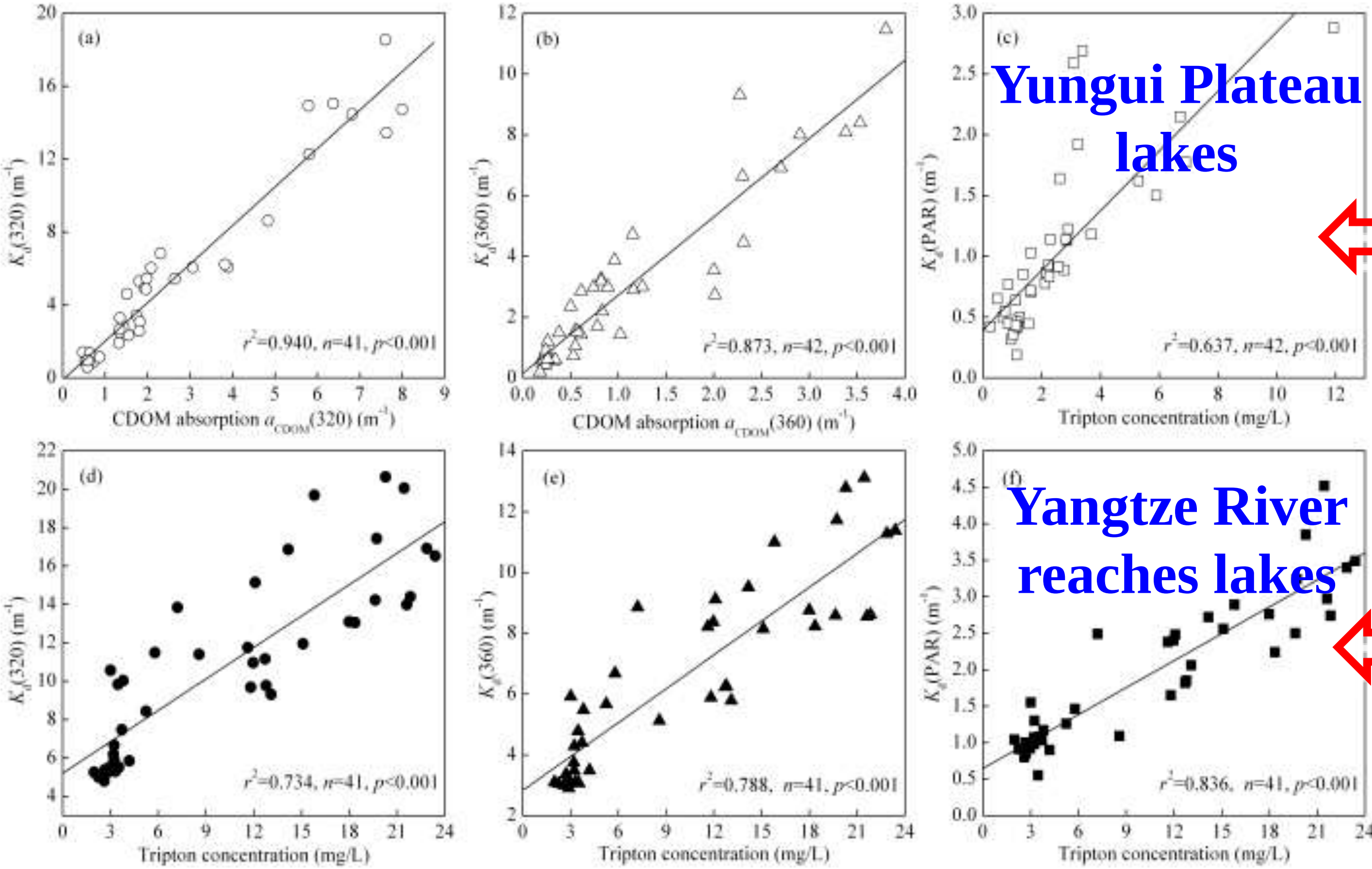


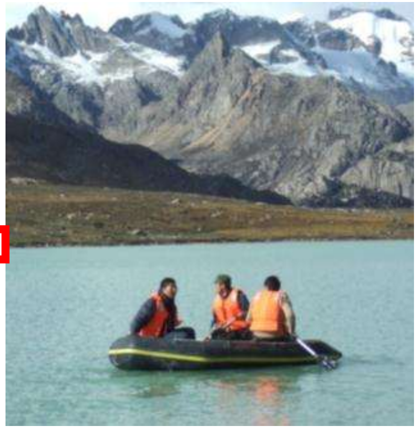
Spatial pattern of SD, Zeu, and SAV distribution

Tripton was the dominant affecting factor of Z_{eu}. SAV was distributed in these regions with the ratio of Z_{eu} to water depth > 0.8.

Zhang et al., 2007, FLA

2. Lake bio-optical properties and affecting mechanism

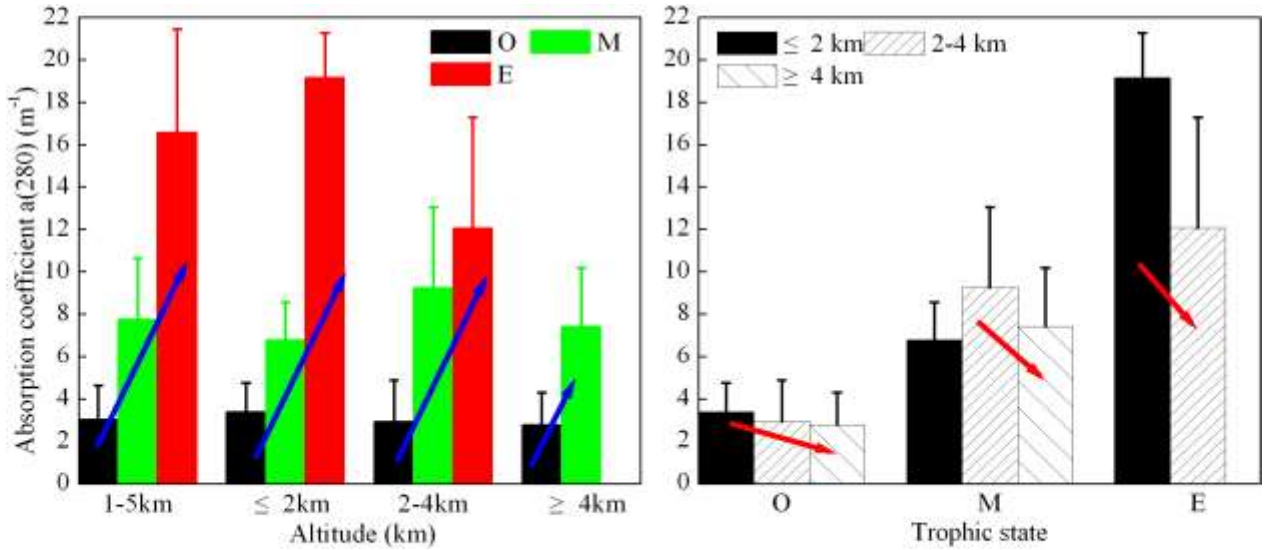




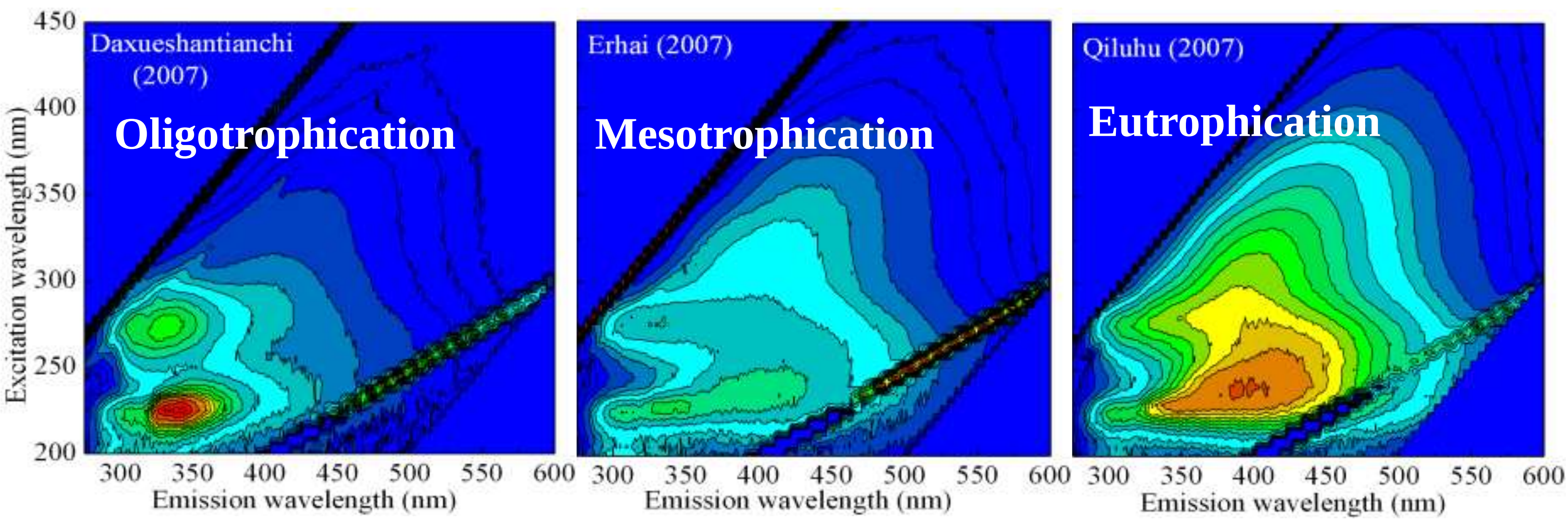
CDOM controls UVR attenuation but tripton controls PAR attenuation in Yungui Plateau lakes. In contrast, tripton controls UVR and PAR attenuation in Yangtze River middle and lower reaches lakes

Zhang et al., 2011, PPS

3. CDOM distribution, sources, composition and removal mechanism



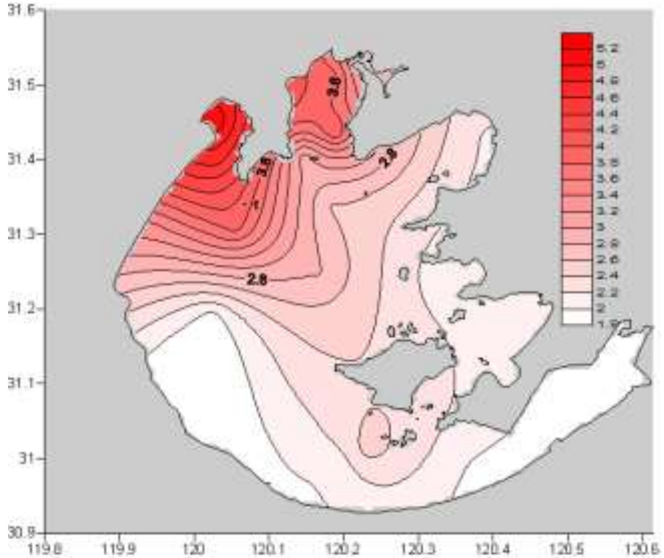
CDOM absorption increase with trophic level but decrease with altitude increase



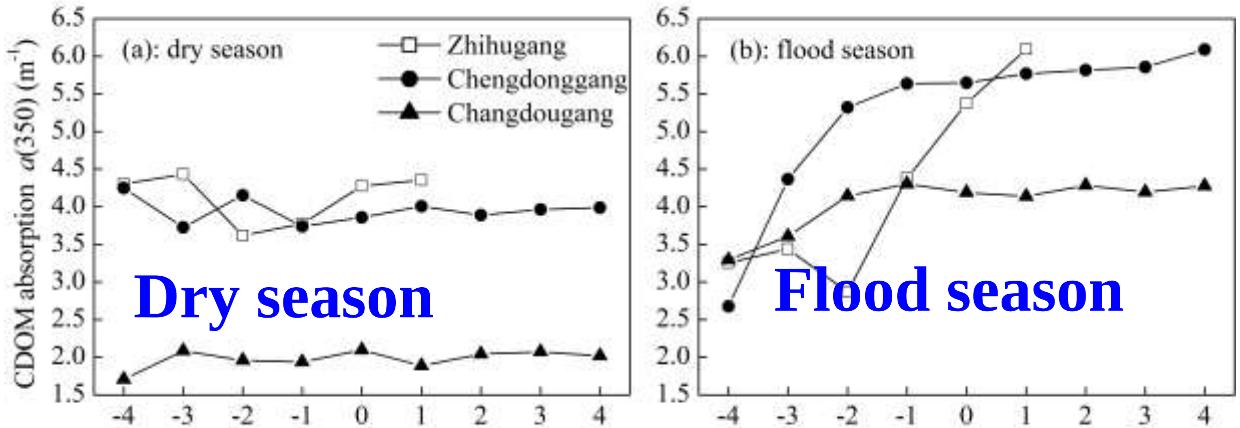
CDOM EEMs of different trophic level

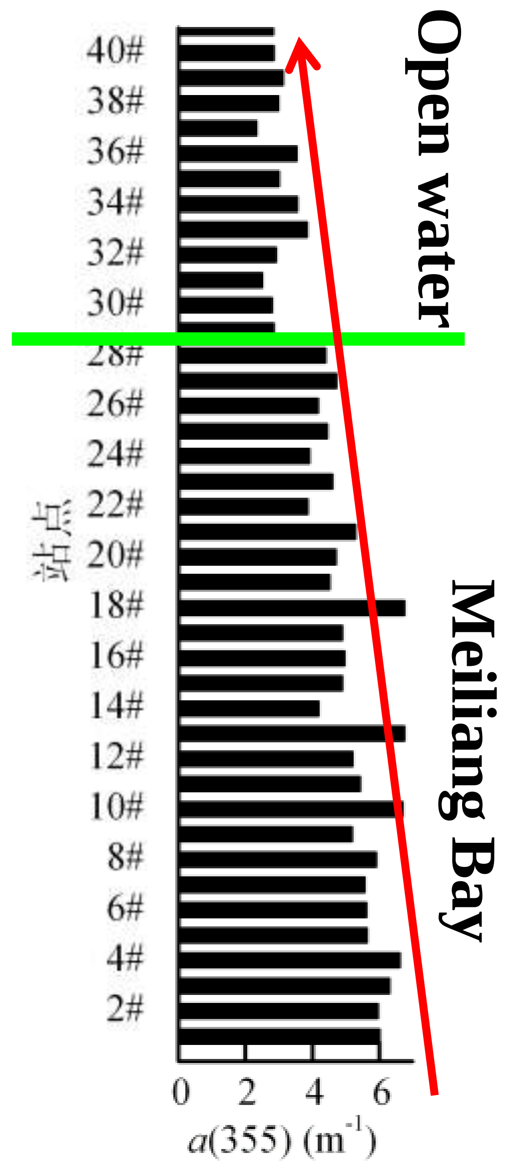
Zhang et al., 2010, L&O

3. CDOM distribution, sources, composition and removal mechanism



Spatial pattern of CDOM in Lake Taihu

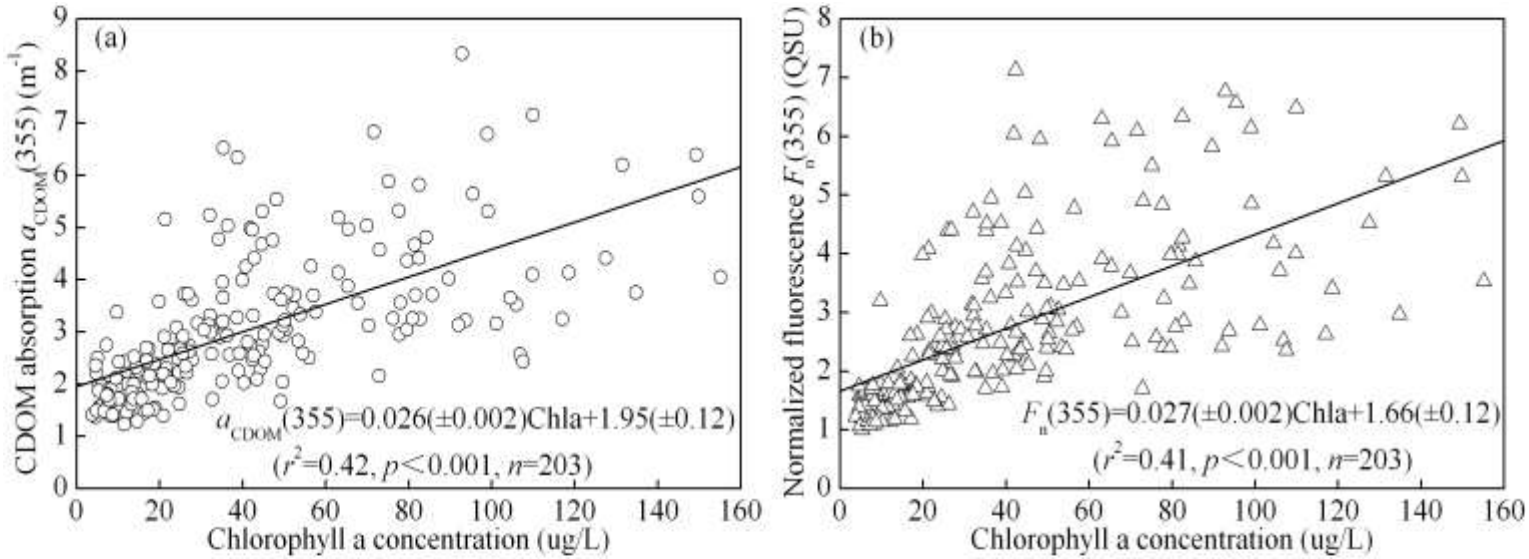




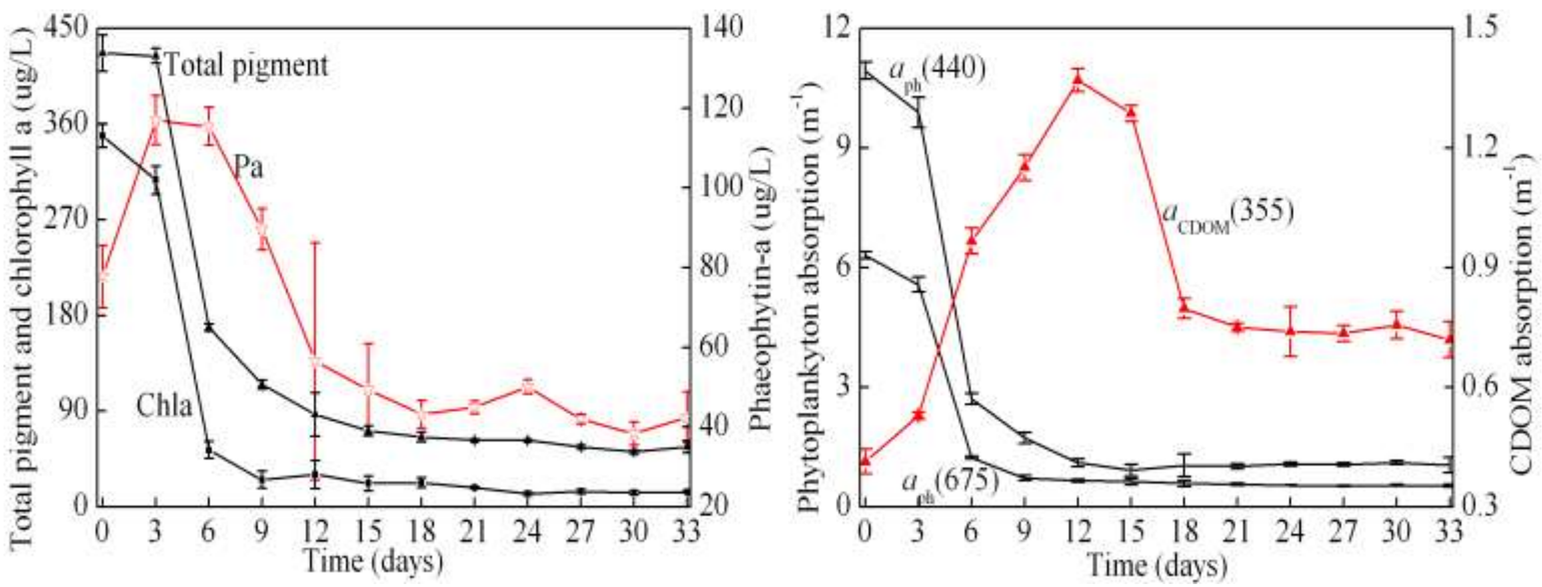
In the flood season, CDOM decreased from the river to the mouth and further to the open water

Zhang et al., 2011, OG

3. CDOM distribution, sources, composition and removal mechanism



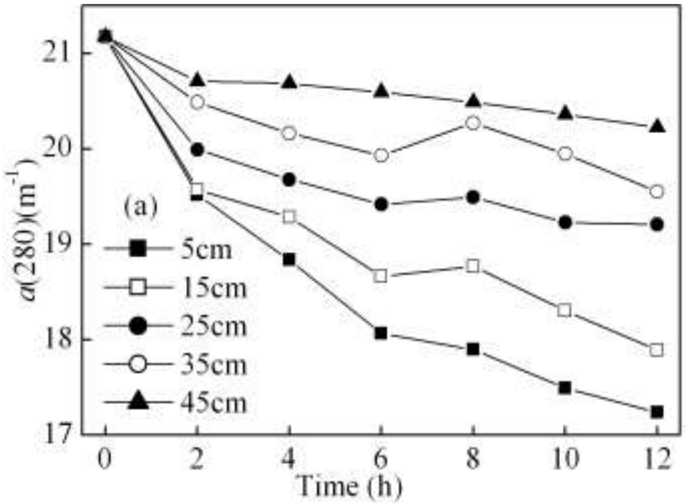
Correlation between Chla and CDOM absorption, fluorescence

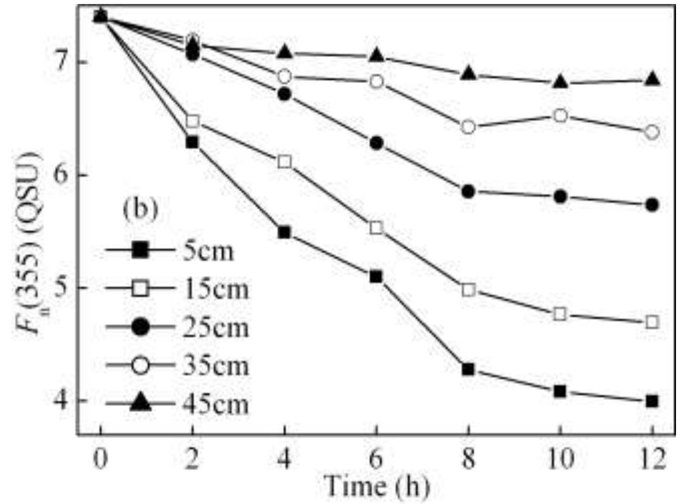


CDOM increased during the phytoplankton degradation

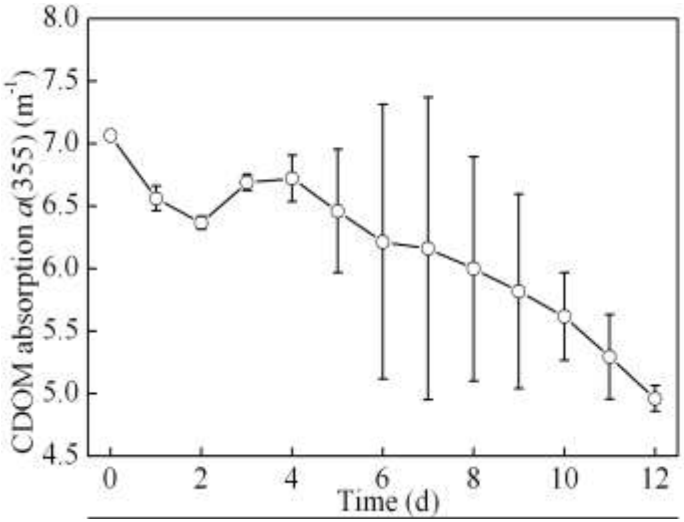
Zhang et al., 2009, WR

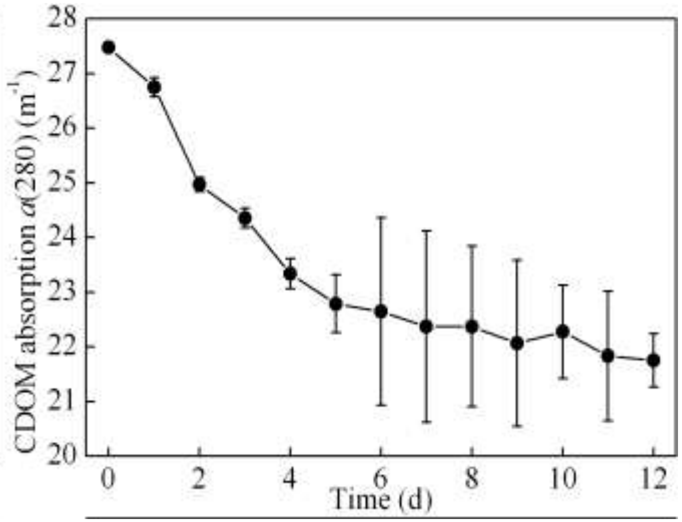
3. CDOM distribution, sources, composition and removal mechanism





Simulated UVR



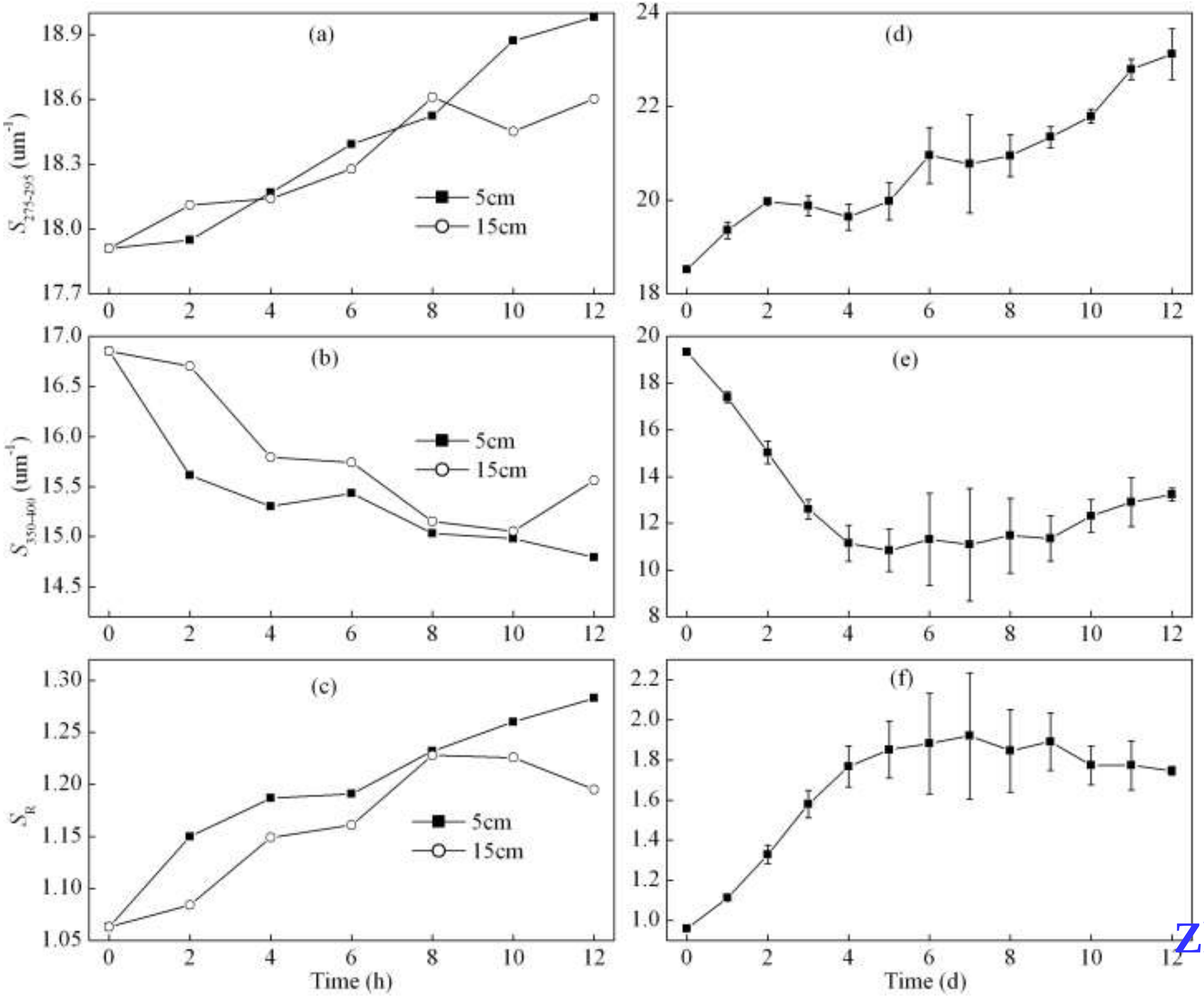


Natural solar radiation

Photobleaching causes CDOM decrease as the first-order kinetics

Zhang et al., 2009, Hydrobiologia

3. CDOM distribution, sources, composition and removal mechanism

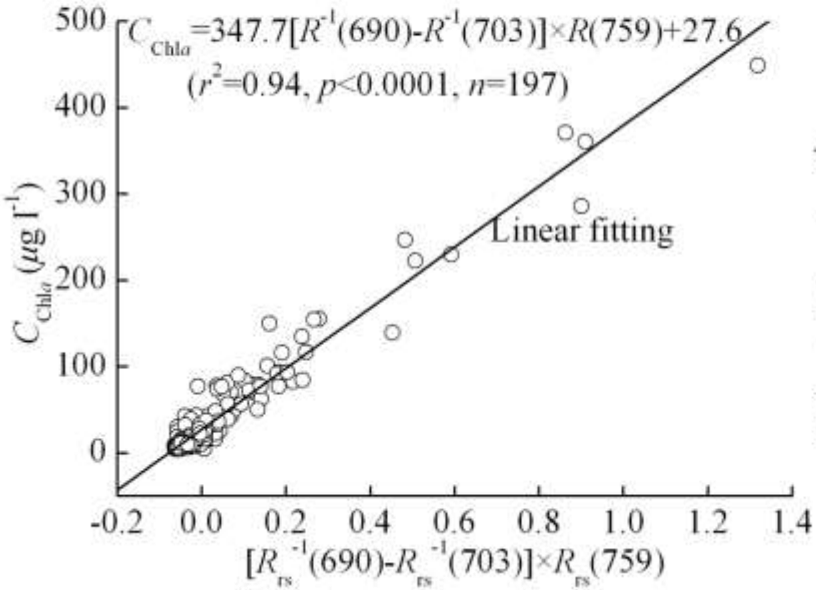


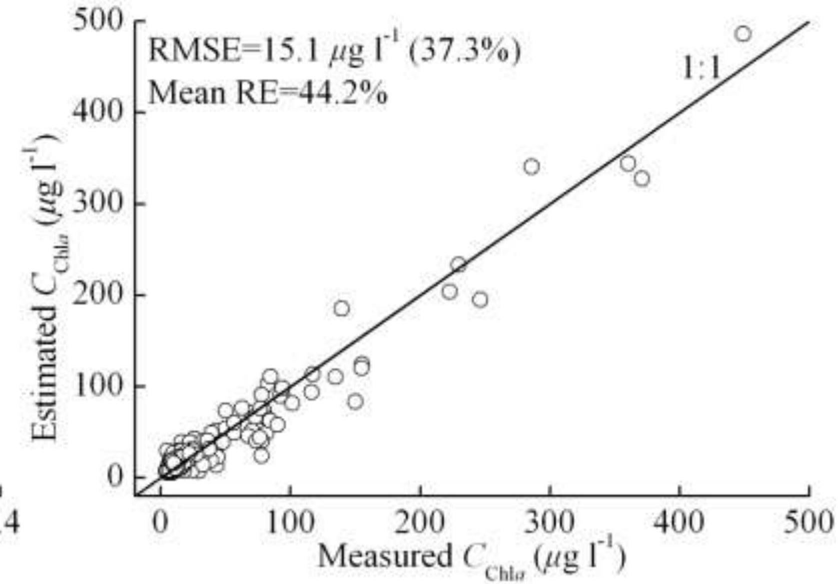
CDOM composition parameters change under natural solar radiation irradiation

Zhang et al., 2009, Hydrobiologia

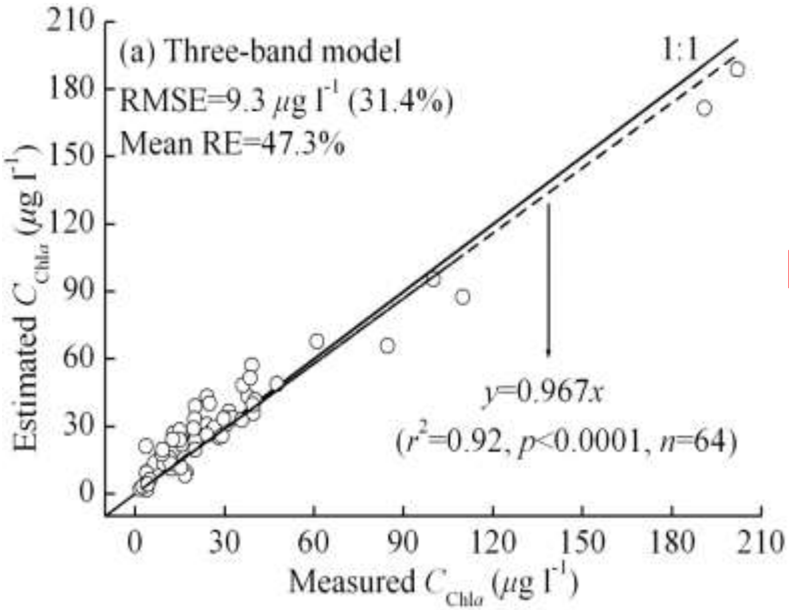
4. Water color parameters and primary production estimation

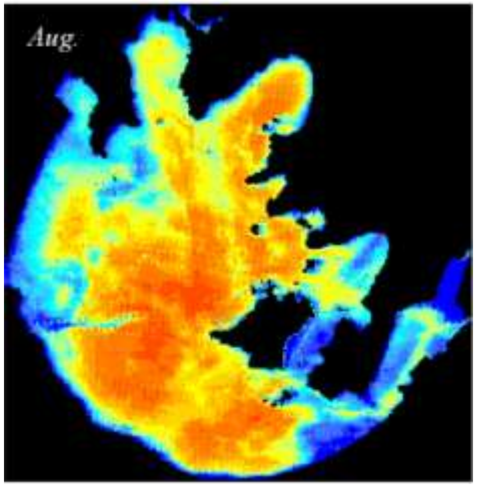
Chla three-band model calibration





Chla three-band model validation

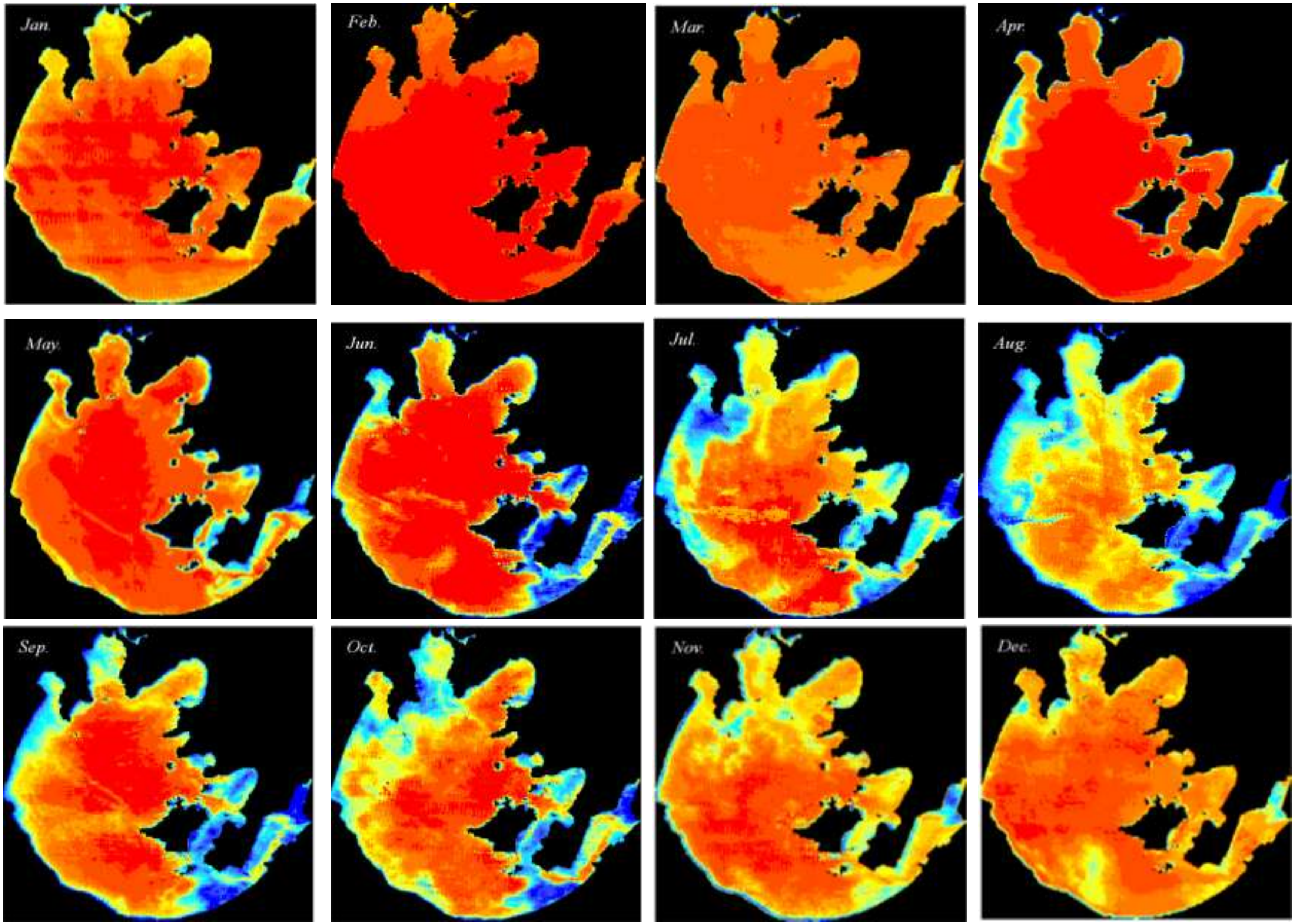




Chla spatial pattern

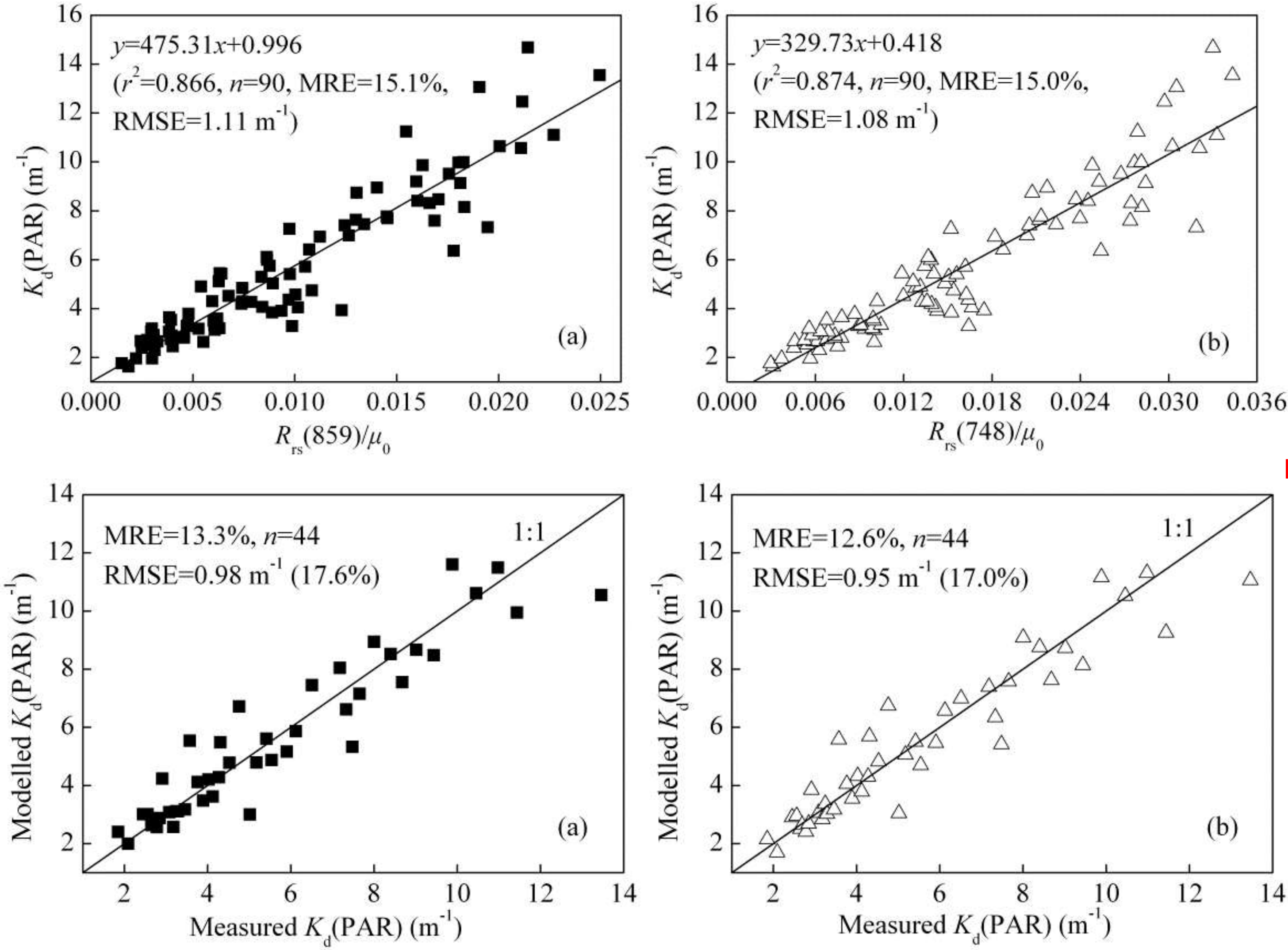
Zhang et al., 2009, IEEE TGRS

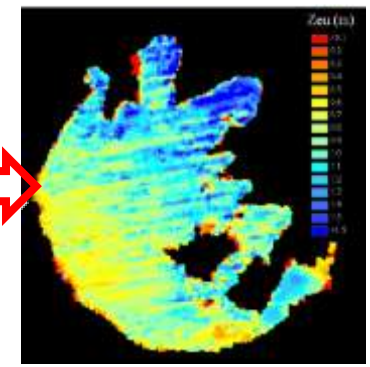
4. Water color parameters and primary production estimation



Chla spatial-temporal pattern

4. Water color parameters and primary production estimation



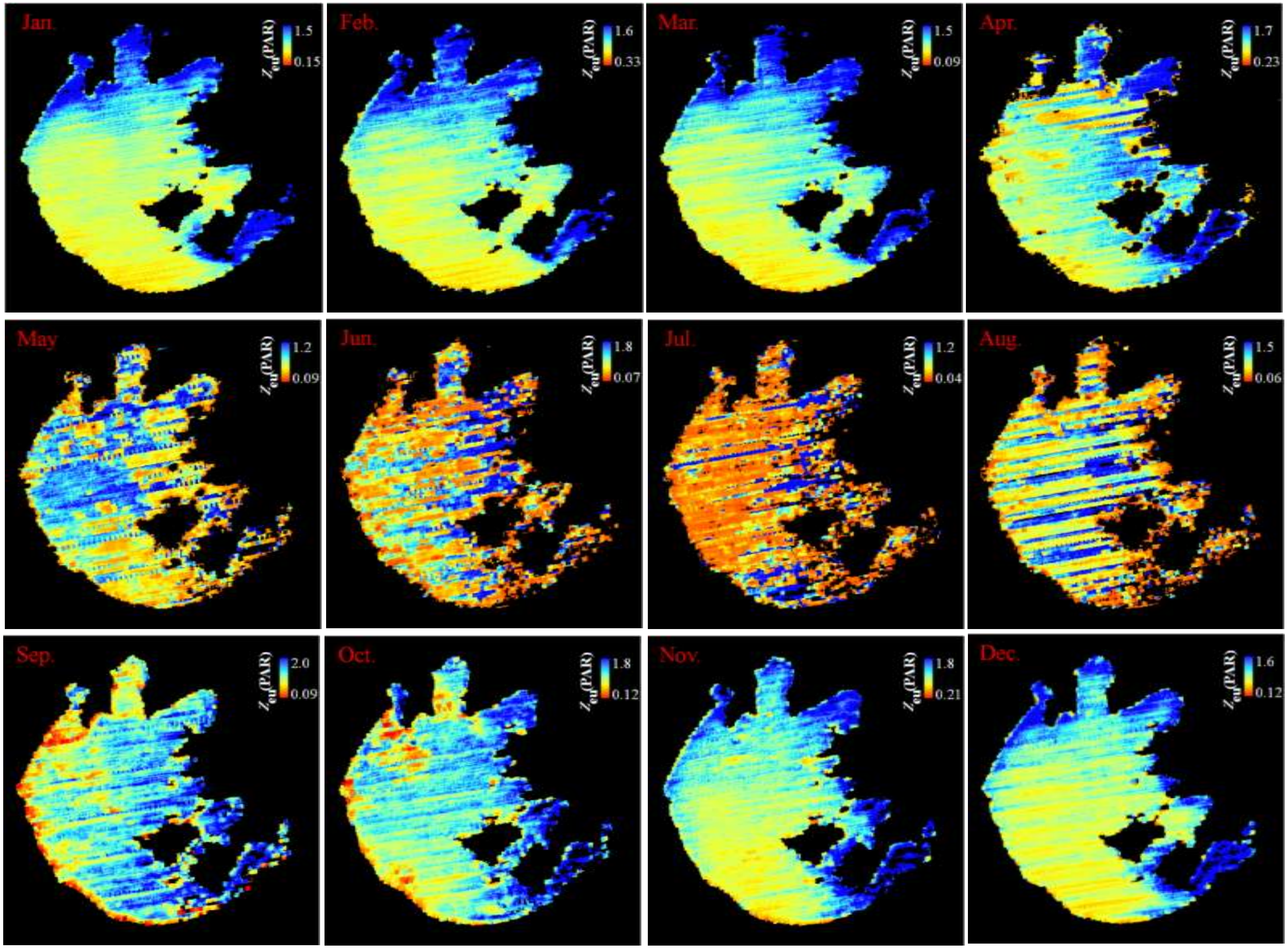


Euphotic depth spatial pattern

Calibration and validation of PAR diffuse attenuation coefficient

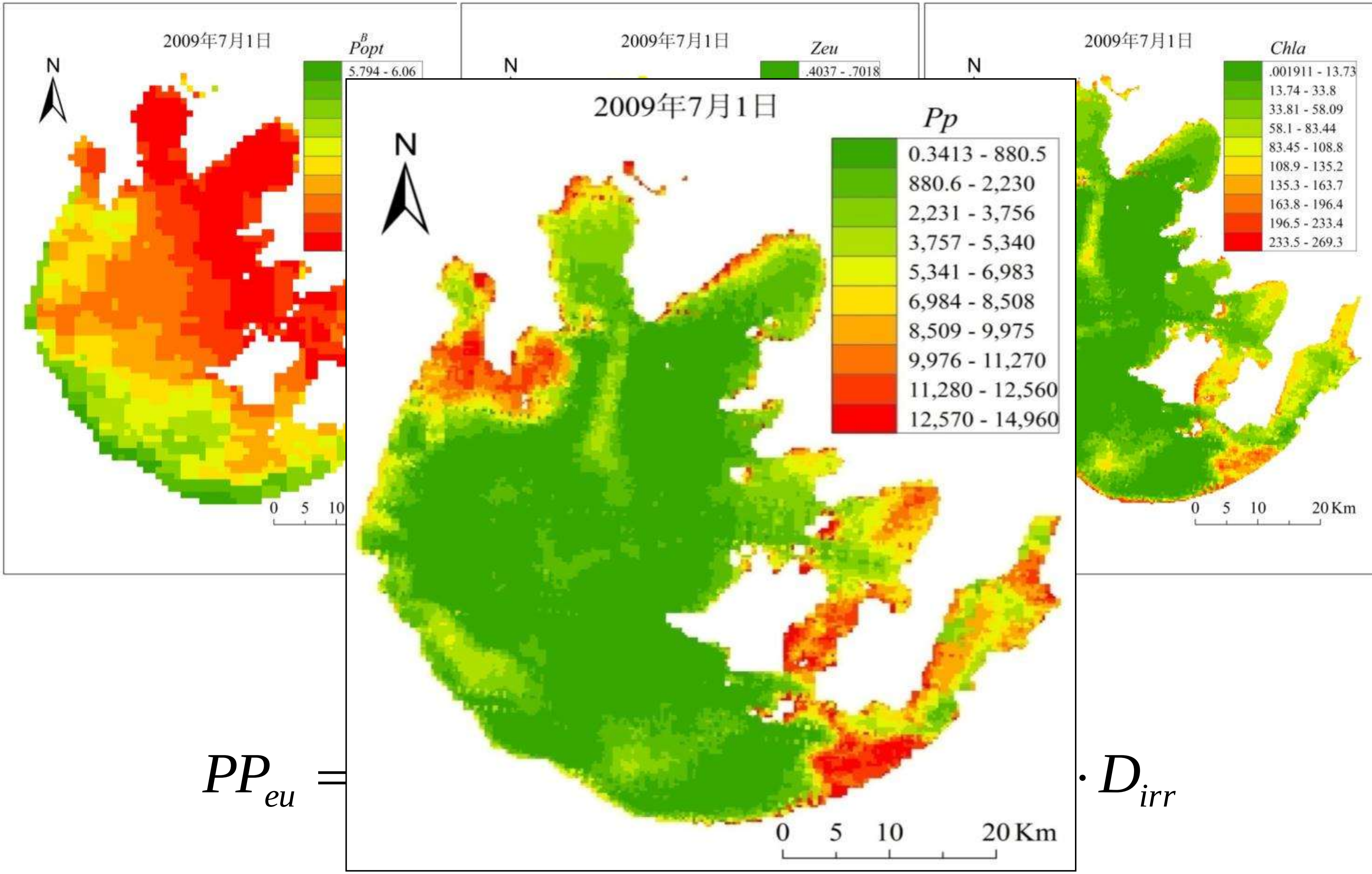
Zhang et al., 2012, OE

4. Water color parameters and primary production estimation



Euphotic depth spatial-temporal pattern

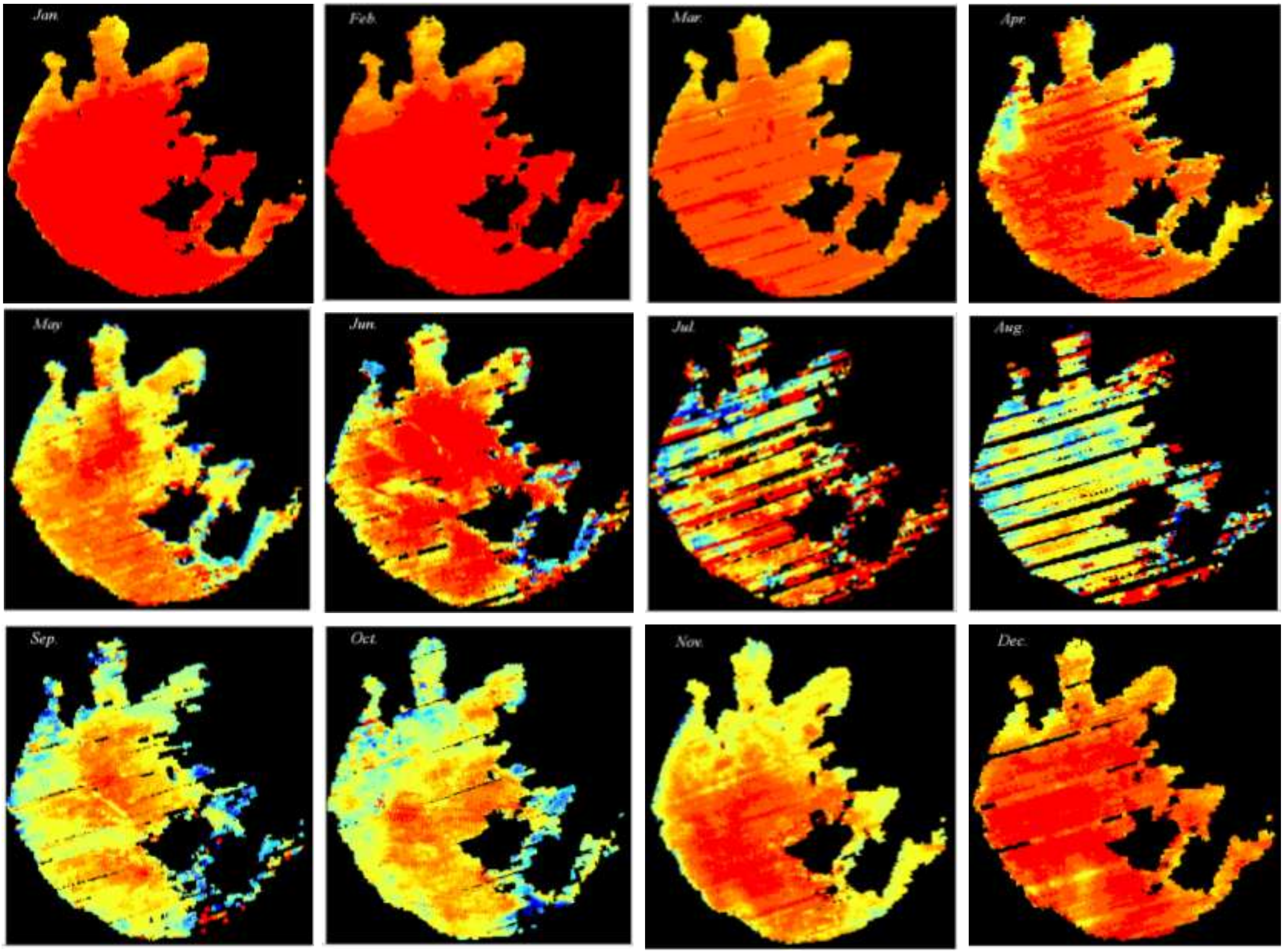
4. Water color parameters and primary production estimation



$$PP_{eu} =$$

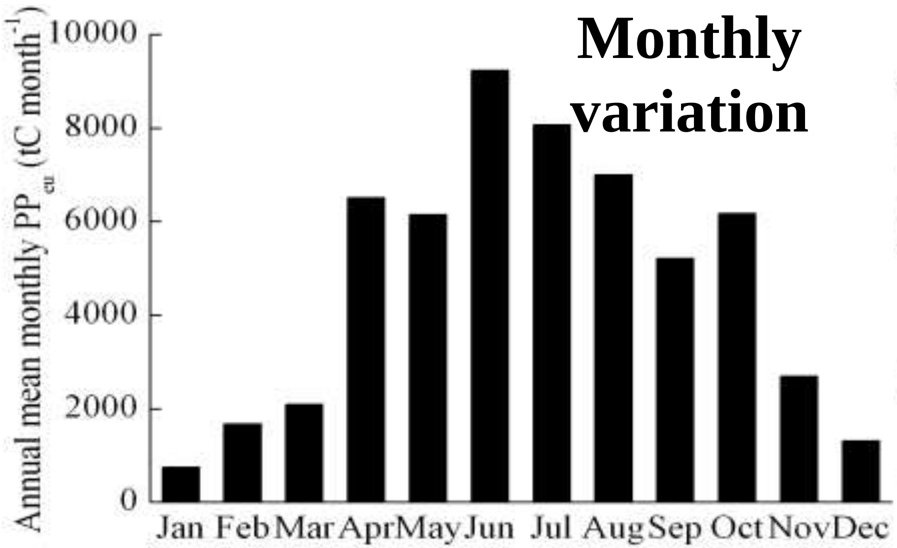
$$\cdot D_{irr}$$

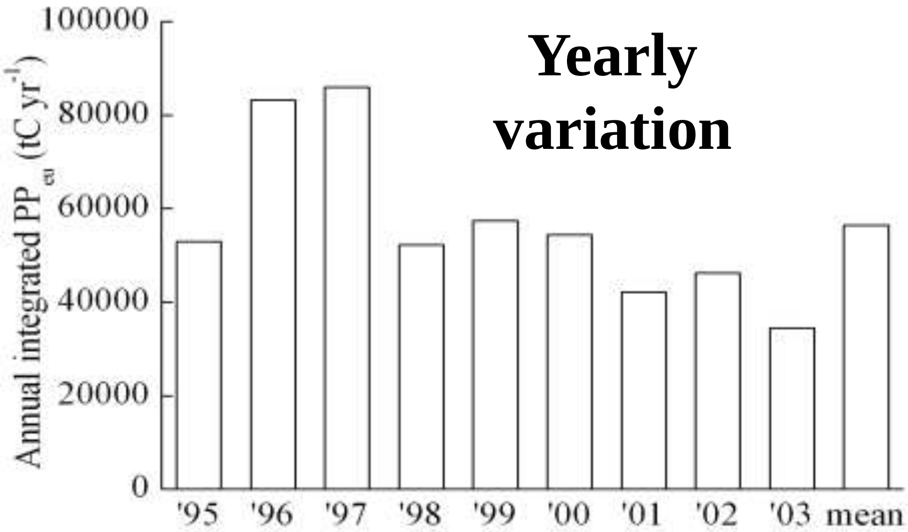
4. Water color parameters and primary production estimation

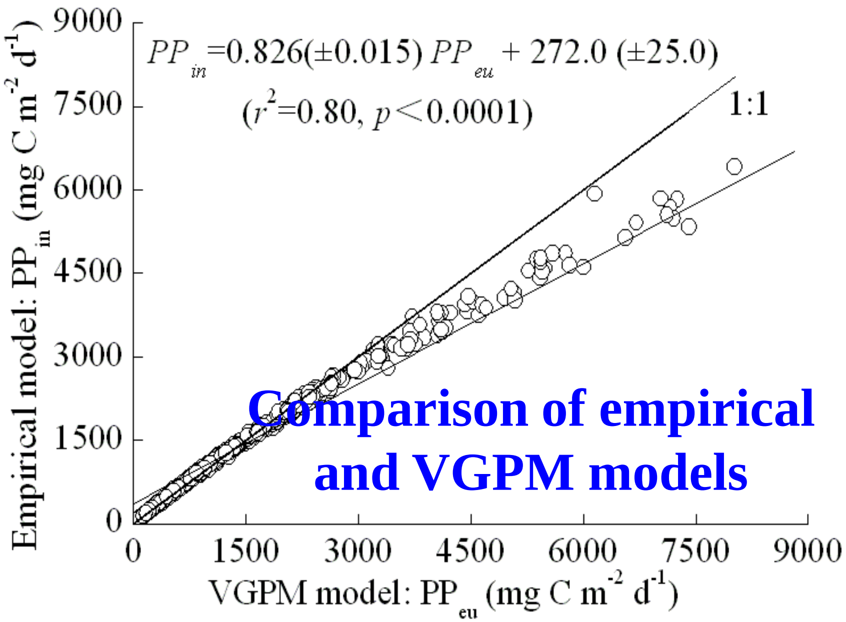


Primary production spatial-temporal pattern

4. Water color parameters and primary production estimation







Determination coefficient between empirical and VGPM models was higher than 0.80. The yearly mean phytoplankton primary production was 1172.6 mgC·m^{-2}·d^{-1} and the summer accounted for 43.0%.

Zhang et al., 2007, JPR

Summary

Development of physical limnology and lake optical remote sensing

Method development and innovation

Underwater light climate and affecting mechanism

- **blue-green algae light competition**
- **SAV spatial pattern**

CDOM distribution, source, composition and removal mechanism

- **Relationship with DOC**
- **Carbon cycle**
- **Characterizing DOM**

Water color and primary production remote sensing

- **Chla, TSM, CDOM, Kd, Zeu estimation**
- **Primary production and SAV estimation**

Thanks for your attention

Welcome to Lake Taihu

References

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16. **Zhang YL et al. *Science in China: Series D Earth Sciences*, 2006, 49: 114–125.**