Lake Color/Environment Remote Sensing in China

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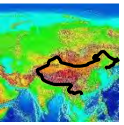
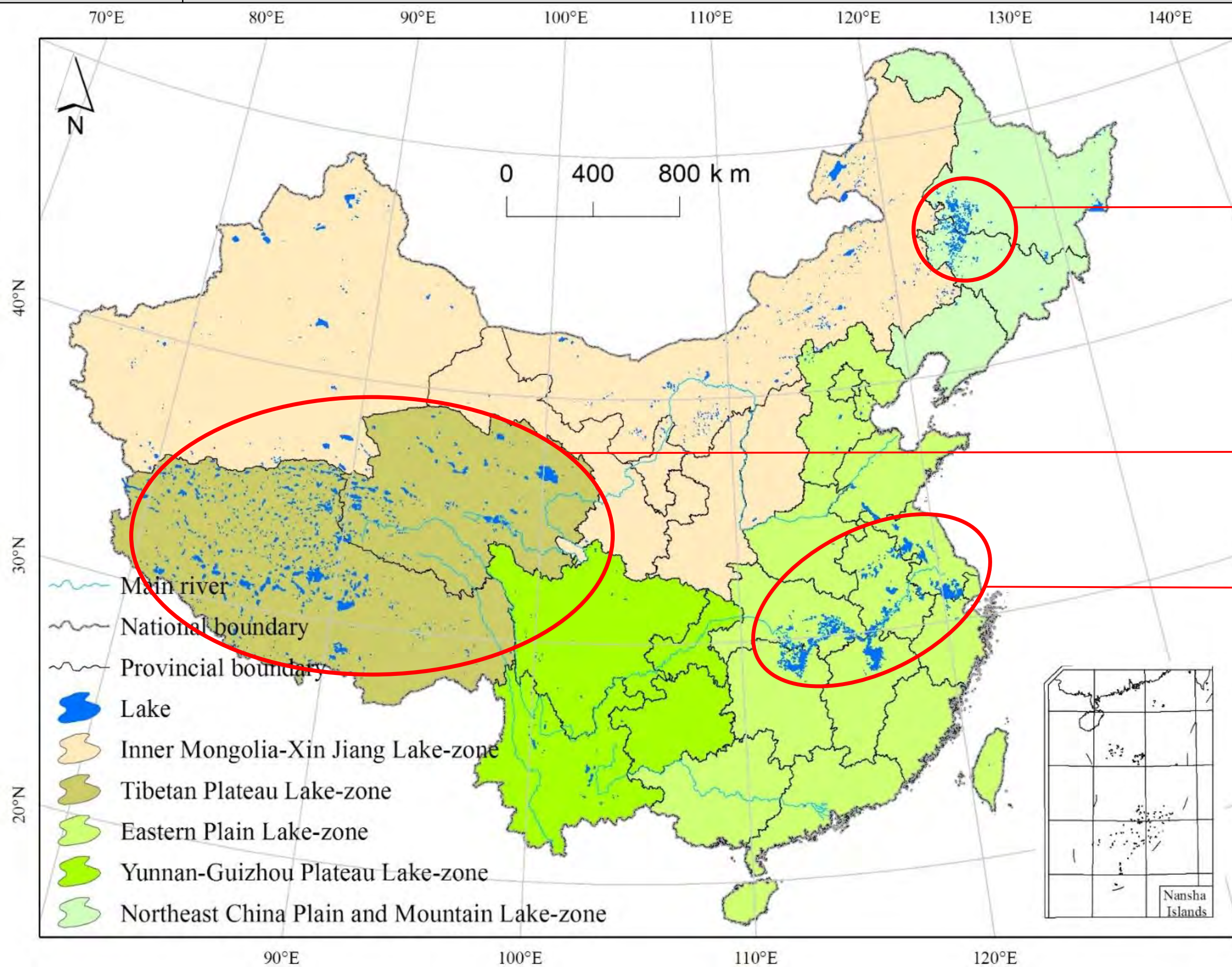
- Lake number & spatial distribution
- IOPs & AOPs of lake waters
- Pigments retrieval in surface waters
- Phytoplankton biomass estimation
- Cyanobacterial bloom remote sensing

Lake Color/Environment Remote Sensing in China

Area classification	>1000 km^2	500-1000 km^2	100-500 km^2	50-100 km^2	10-50 km^2	1-10 km^2	In total
Number	10	17	109	101	456	2000	2693
Area (km^2)	75050					6364	81414





Three main lake groups/zones

Northeast Plain and Mountain Lake Zone

Tibetan Plateau Lake Zone

Eastern Plain Lake Zone

Ma et al. A half-century of changes in China's lakes: Global warming or human influence? Geophysical Research Letters, 2010, 37: L24106, doi:10.1029/2010GL045514

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Lake Color/Environment Remote Sensing in China

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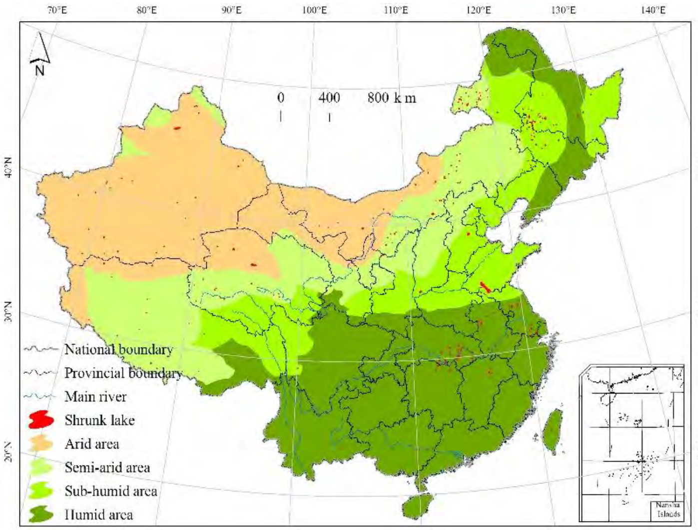
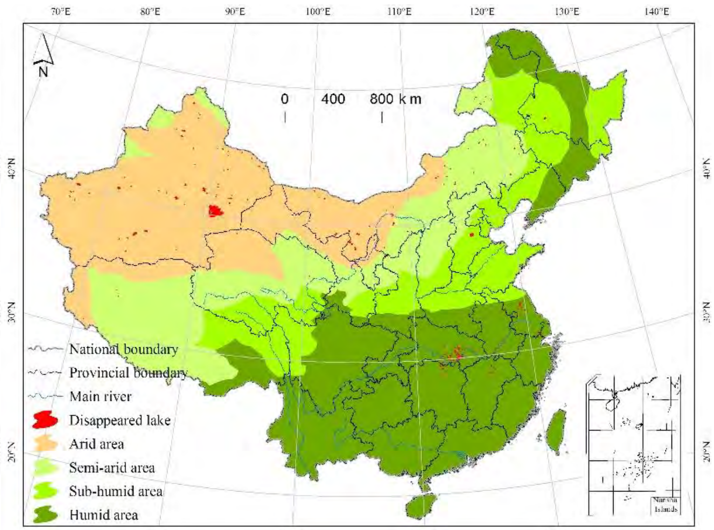
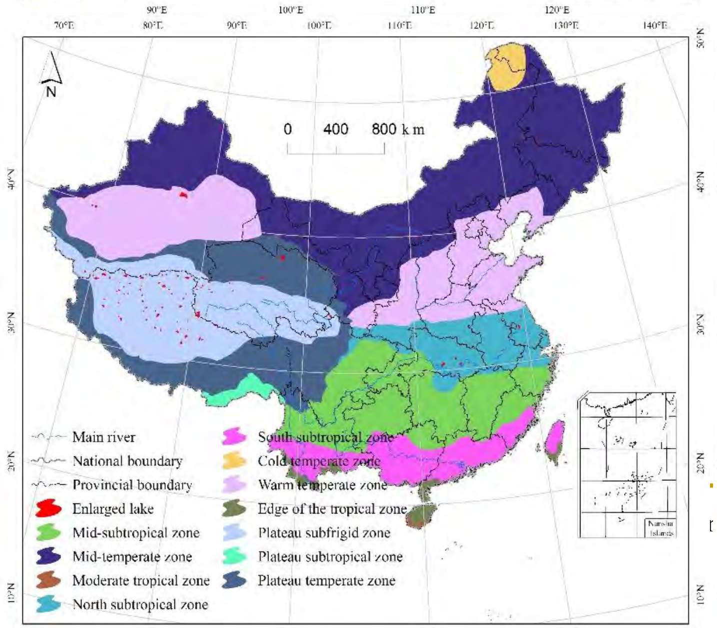
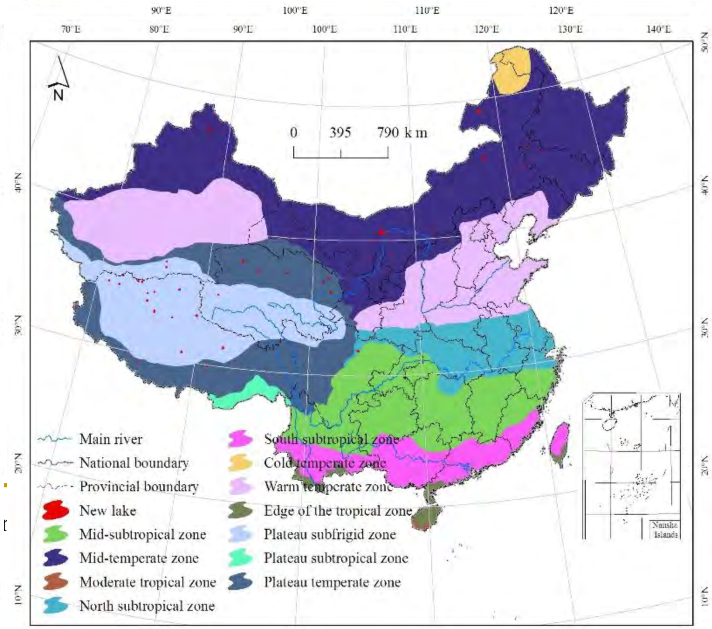








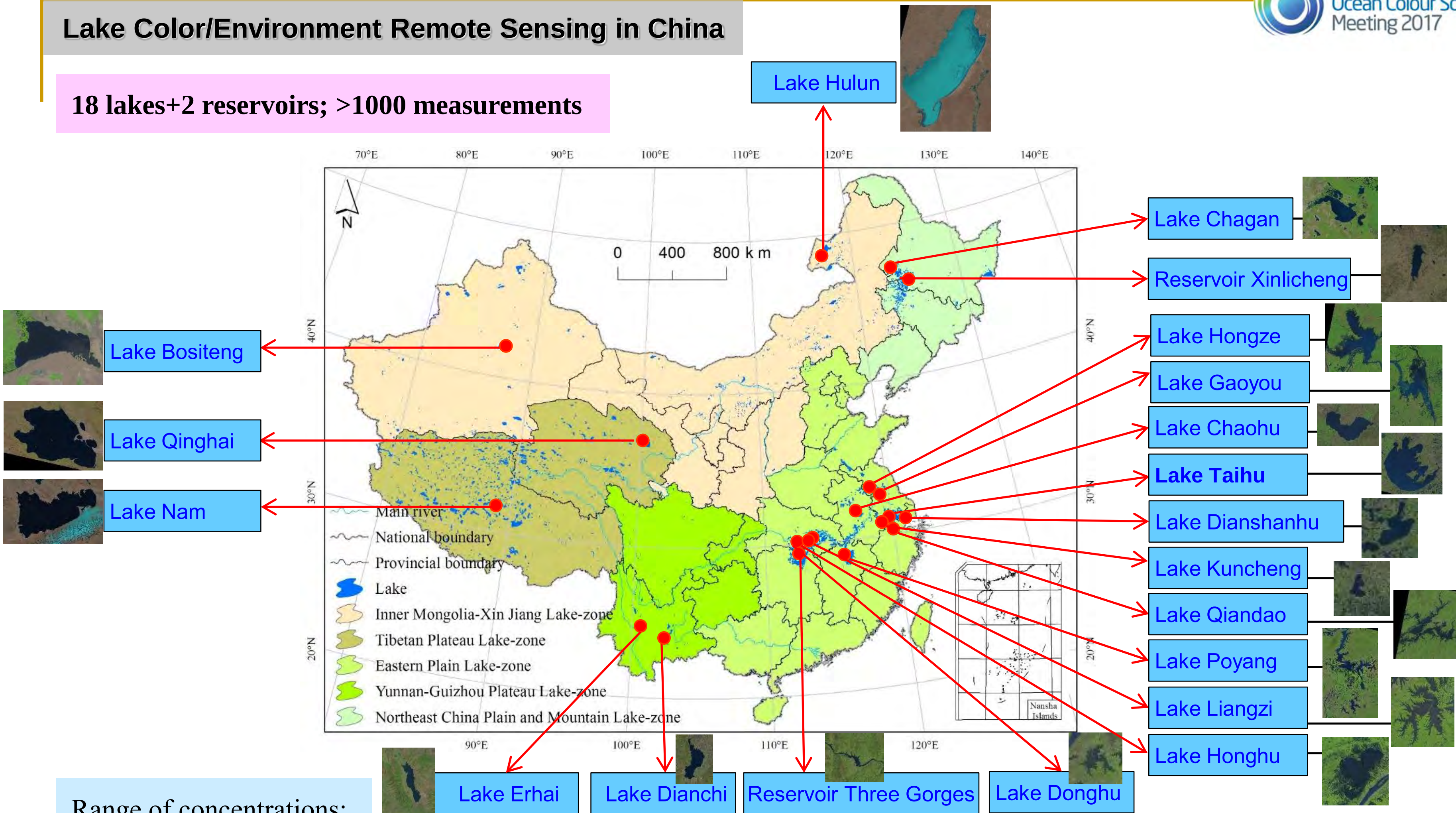
Over the last half century (from 1950s to 2000s), dramatic changes occurred to China's 2928 lakes (>1 km² in size), where 243 lakes vanished, 60 new lakes appeared, 254 lakes were downgraded in class, and 98 lakes were upgraded in class.

:10.1029/2010GL045514

- Lake Number & spatial distribution
- IOPs & AOPs of lake waters
- Pigments retrieval in surface waters
- Phytoplankton biomass estimation
- Cyanobacterial bloom remote sensing

Lake Color/Environment Remote Sensing in China

18 lakes+2 reservoirs; >1000 measurements



Range of concentrations:

Chlorophyll-a (CHL): 1.26 - 165.76 μg/L

Suspended Particulate Matter (SPM): 2.67 - 222.5 mg/L

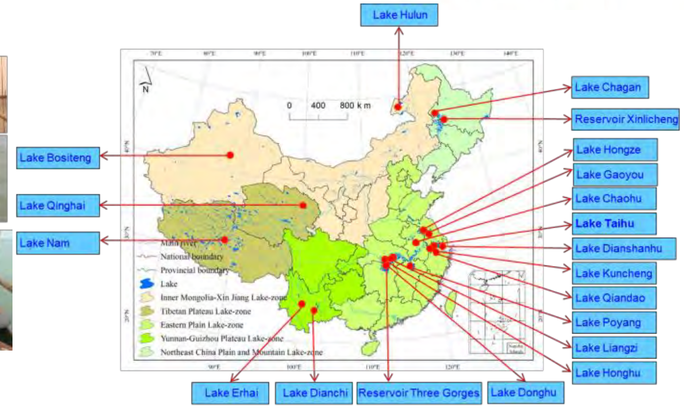
Absorption of Colored Dissolved Organic Matter at 440 nm ($a_g(440)$): 0.068-2.286 m^{-1}

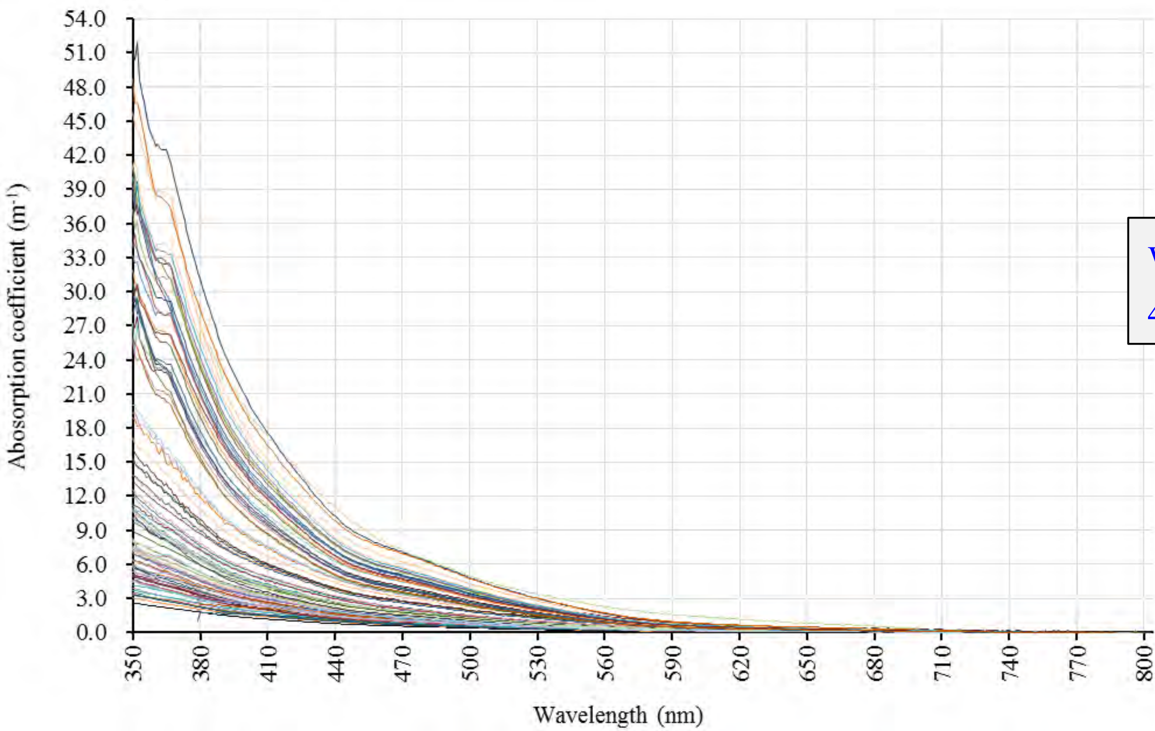
Xue et al., 2016; Cao et al., 2016; Li et al., 2016; Qi et al., 2016; Yin et al., 2014; Liu et al., 2011; Shi et al., 2011; Gai et al., 2010; Li et al., 2009; Ci et al., 2009; Song et al., 2007; Zhou et al., 2005; Ma et al., 2010; 2009; 2005; Duan et al., 2009; Zhang et al., 2009; 2005

Lake Color/Environment Remote Sensing in China

18 lakes+2 reservoirs; >1000 measurements

Absorption of the non-algal particulate matter





Reference wavelength (λ_0): 440nm

Wavelength range (λ): 380-750, 400-650, 400-700, 400-750, 380-600, 400-550

$$a_d(\lambda) = a_d(\lambda_0) \times e^{-S_d \times (\lambda - \lambda_0)}$$

$a_d(\lambda_0)$: 0.0049~0.0157 m^{-1}

S_d: 0.017~15 m^{-1}

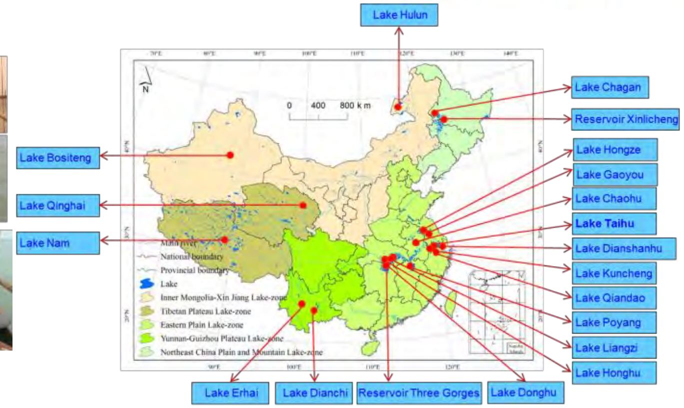
by QFT (Quantitative Filter Technique)

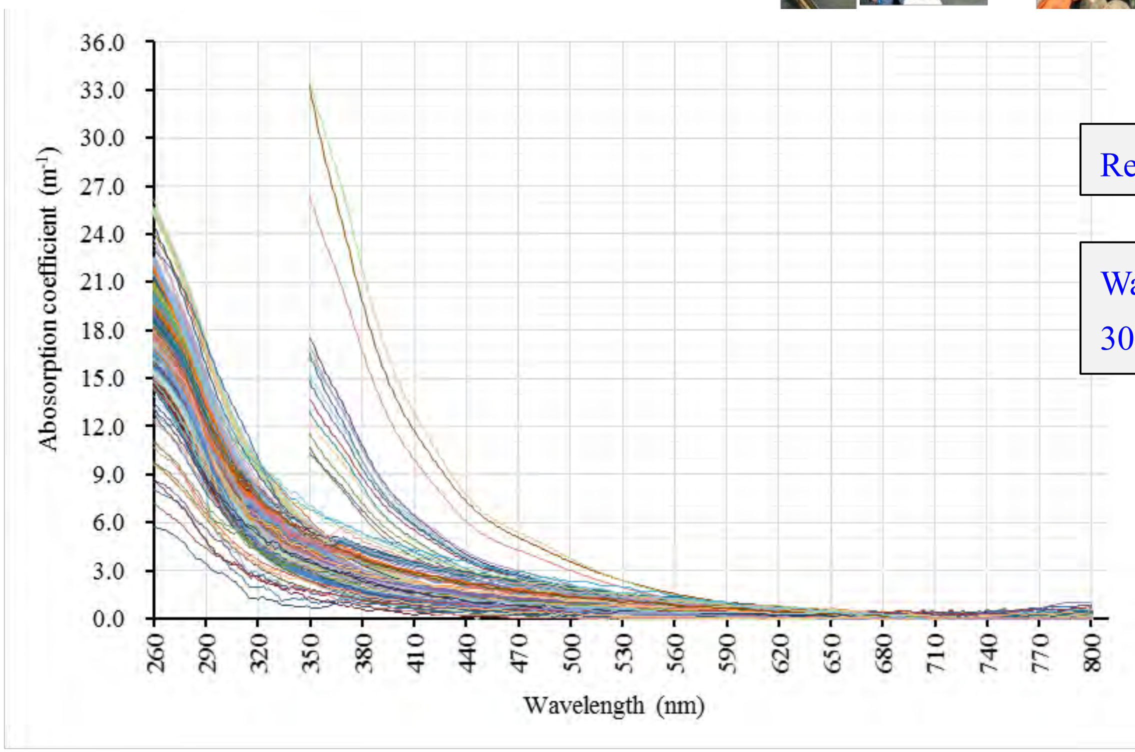
Xue et al., 2016; Cao et al., 2016; Li et al., 2016; Qi et al., 2016; Shen et al., 2014; Yin et al., 2014; Liu et al., 2011; Shi et al., 2011; Gai et al., 2010; Li et al., 2009; Ci et al., 2009; Song et al., 2007; Zhou et al., 2005; Ma et al., 2010; 2009; 2005; Duan et al., 2009; Zhang et al., 2009; 2005

Lake Color/Environment Remote Sensing in China

18 lakes+2 reservoirs; >1000 measurements

Absorption of the colored dissolved organic matter





Reference wavelength (λ_0): 375, 380, 400, 440 nm

Wavelength range (λ): 280-500, 380-550, 280-650, 300-600, 350-600, 300-500, 300-550, 350-550 nm

$$a_{CDOM}(\lambda) = a_{CDOM}(\lambda_0) \times e^{-S_{CDOM} \times (\lambda - \lambda_0)}$$

0.04~12.87 nm^{-1}

0.0053~0.0338 nm^{-1}

by QFT (Quantitative Filter Technique)

Xue et al., 2016; Cao et al., 2016; Li et al., 2016; Qi et al., 2016; Shen et al., 2014; Yin et al., 2014; Liu et al., 2011; Shi et al., 2011; Gai et al., 2010; Li et al., 2009; Ci et al., 2009; Song et al., 2007; Zhou et al., 2005; Ma et al., 2010; 2009; 2005; Duan et al., 2009; Zhang et al., 2009; 2005

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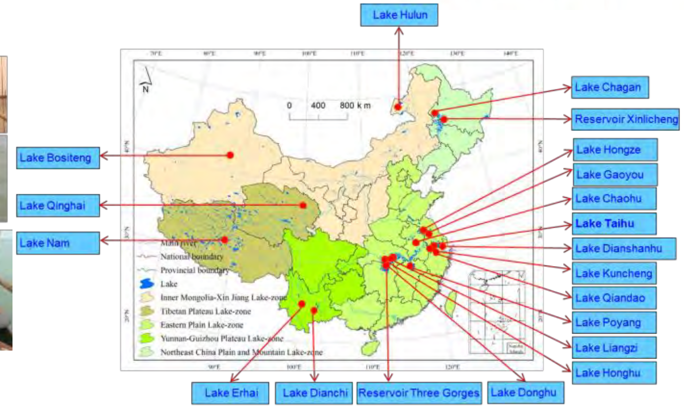
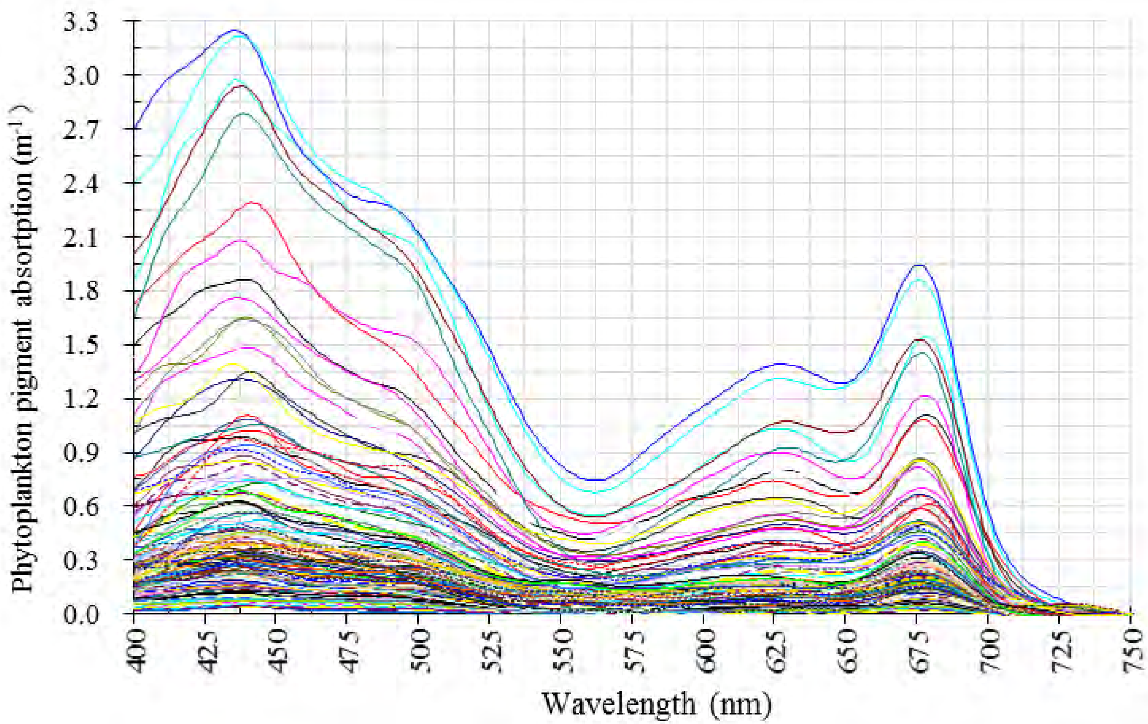
18 lakes+2 reservoirs; >1000 measurements

Absorption of the phytoplankton pigment

by QFT (Quantitative Filter Technique)





$$a_{ph}(\lambda) = \sum_{i=0}^{n} C_i a_i'(\lambda)$$

$a_{ph}(440)$: 0.044-14.41 m^{-1}

a_{ph}^{*} (440): 0.02051-0.424 m^2/mg

$a_{ph}(675)$: 0.01-6.43 m^{-1}

a_{ph}^{*} (675): 0.0105-0.339 m^2/mg

$a_{ph}(440)/a_{ph}(675)$: 1.67-2.5

17 pigments: chl-a, chl-b, chl-c, fucoxanthin, peridinin, hexanoyloxy, fucoxanthin, butanoylozy, fucoxanthin, alloxanthin, zeaxanthin, xanthophylls (diadinoxanthin, diatoxanthin), 19'-hexanoyloxyfucoxanthin, 19'-butanoyloxyfucoxanthin, divinyl chlorophyll-b, zeanthin

Xue et al., 2016; Cao et al., 2016; Li et al., 2016; Qi et al., 2016; Shen et al., 2014; Yin et al., 2014; Liu et al., 2011; Shi et al., 2011; Gai et al., 2010; Li et al., 2009; Ci et al., 2009; Song et al., 2007; Zhou et al., 2005; Ma et al., 2010; 2009; 2005; Duan et al., 2009; Zhang et al., 2009; 2005

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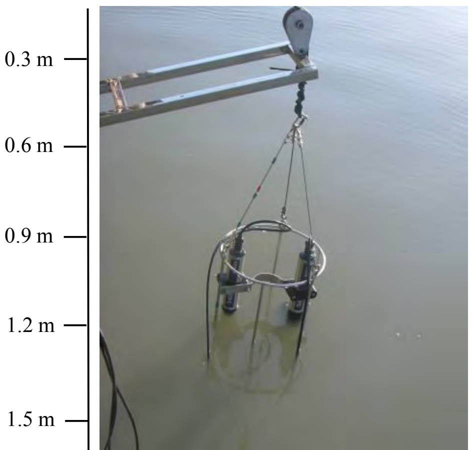
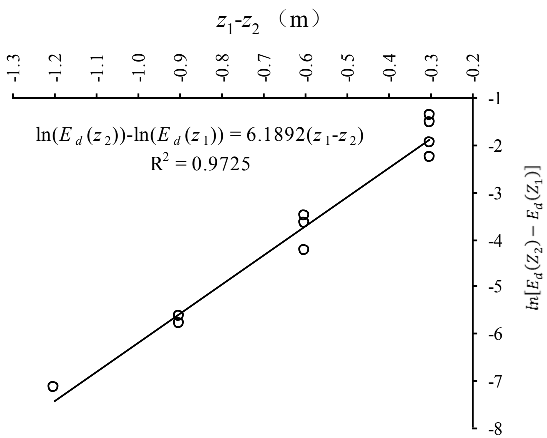
2 lakes; >20 measurements

Underwater light field

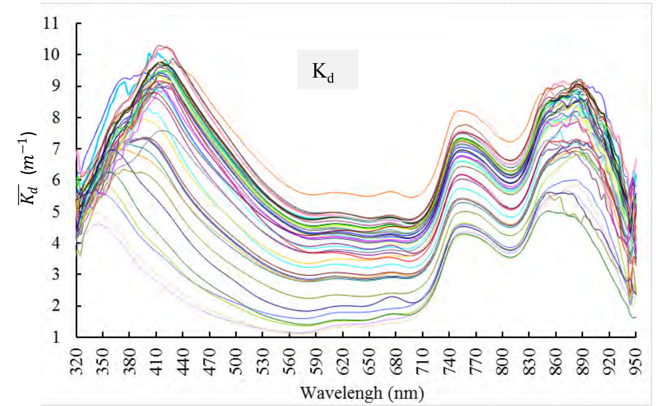
by TriOS

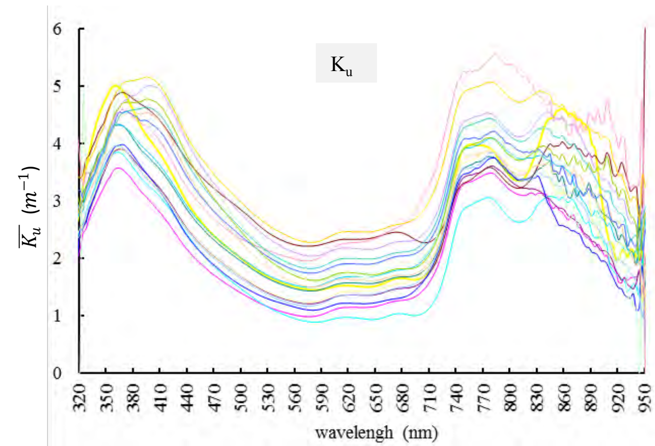
Germany Trios Corp.

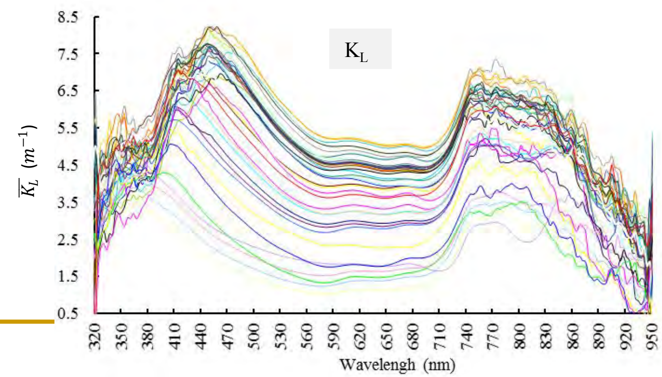




E_u, E_d, L_u → K_d, K_u, K_L







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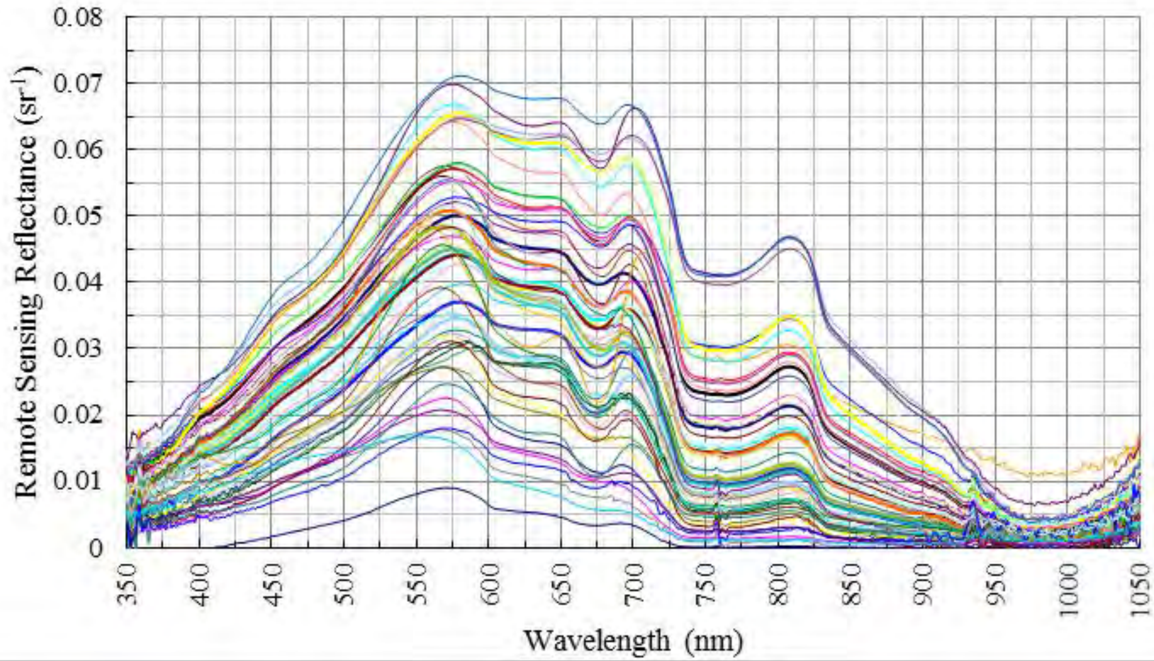
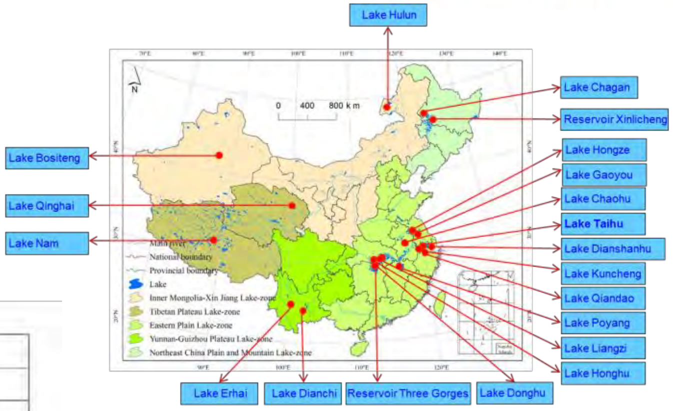
18 lakes+2 reservoirs; >1000 measurements

Remote Sensing of Reflectance





17 pigments: chl-a, chl-b, chl-c, fucoxanthin, peridinin, hexanoyloxy, fucoxanthin, butanoylozy, fucoxanthin, alloxanthin, zeaxanthin, xanthophylls (diadinoxanthin, diatoxanthin), 19'-hexanoyloxyfucoxanthin, 19'-butanoyloxyfucoxanthin, divinyl chlorophyll-b, zeanthin

Xue et al., 2016; Cao et al., 2016; Li et al., 2016; Qi et al., 2016; Shen et al., 2014; Yin et al., 2014; Liu et al., 2011; Shi et al., 2011; Gai et al., 2010; Li et al., 2009; Ci et al., 2009; Song et al., 2007; Zhou et al., 2005; Ma et al., 2010; 2009; 2005; Duan et al., 2009; Zhang et al., 2009; 2005

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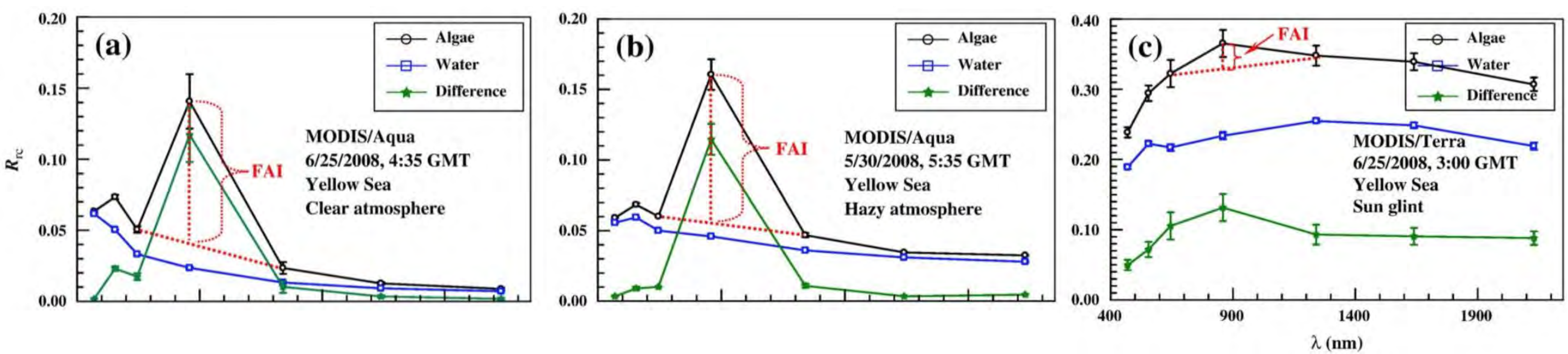
Lake Color/Environment Remote Sensing in China

a. to remove the atmospheric effect
b. to remove the covered-cyanobacterial bloom waters
c. to remove the effected-aquatic vegetation waters
d. to implement the optical classification of waters
e. to develop the algorithm of Chl, PC, SPM/TSS, etc

FAI: the difference between Rayleigh-corrected reflectance in the NIR and a baseline formed by the red and SWIR bands

$$R'_{rc,NIR} = R_{rc,RED} + \left(R_{rc,SWIR} - R_{rc,RED}\right) \times (\lambda_{NIR} - \lambda_{RED})/(\lambda_{SWIR} - \lambda_{RED})$$

$$\text{FAI} = R_{rc,NIR} - R'_{rc,NIR}$$



Hu. A novel ocean color index to detect floating algae in the global oceans. Remote Sensing of Environment, 2009, 113: 2118-2129

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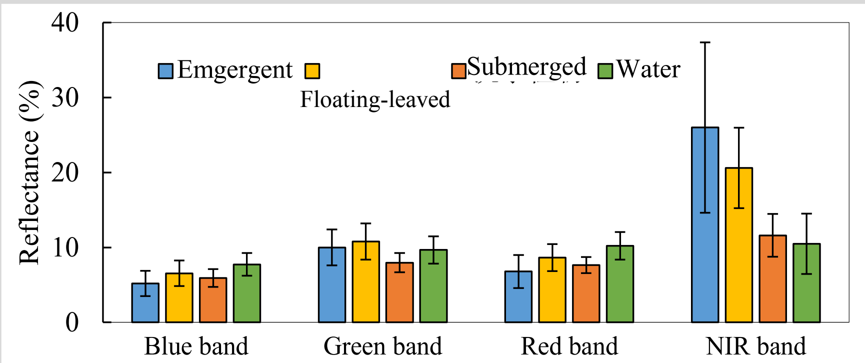
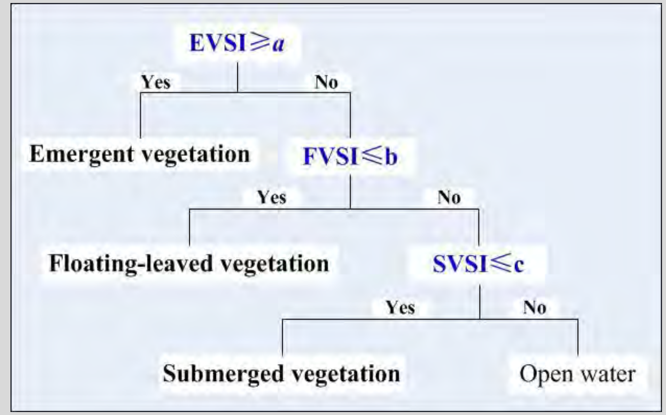
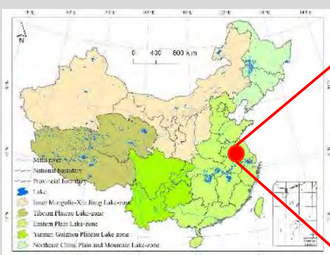
Method

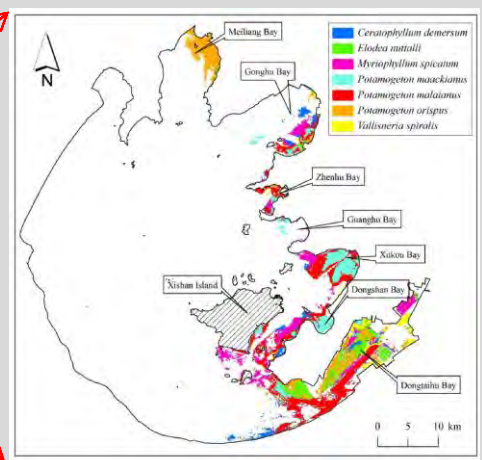




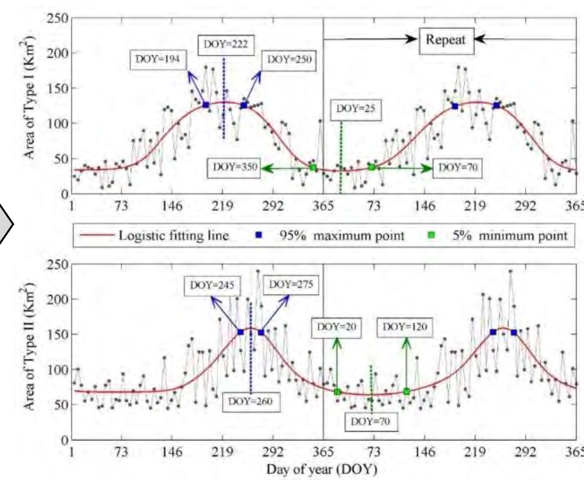
挺水植物 浮叶植物 沉水植物 水体

Result





Time-series



Luo J., Duan H., Ma R., Jin X., Li F., Hu W., Shi K., Huang W. Mapping species of submerged aquatic vegetation with multi-seasonal satellite images and considering life history information. Internation Journal of Applied Earth Obserbation and Geoformation, 2017, 57: 154-165

Lake Color/Environment Remote Sensing in China

Distinguish between surface cyanobacterial scums and aquatic macrophytes by MODIS

a. to remove the atmospheric effect
b. to remove the covered-cyanobacterial bloom waters
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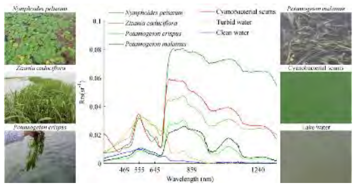
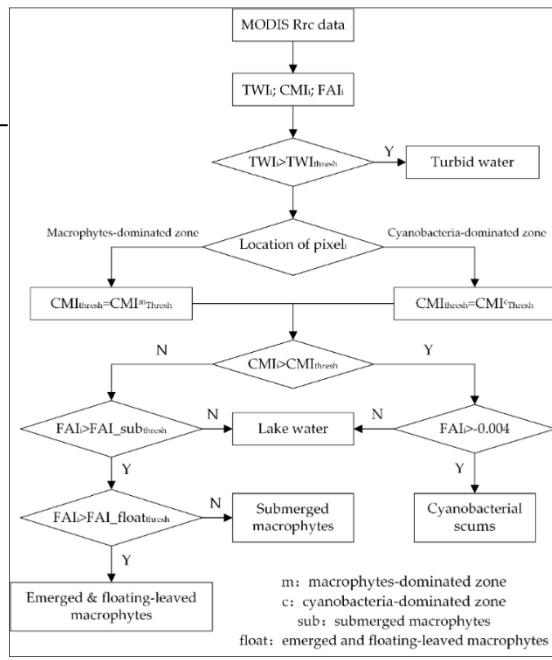


$$TWI = R_{rc,RED} - R_{rc,SWIR}$$

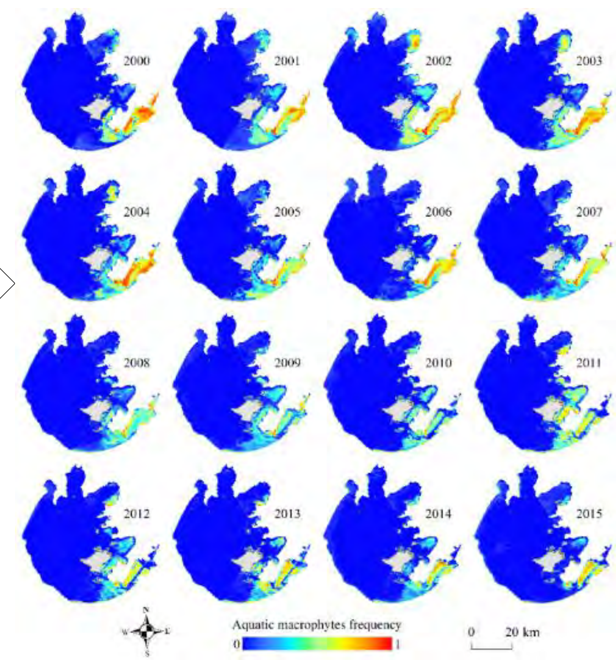
$$FAI = R_{rc,NIR} - R_{rc,RED} - [R_{rc,SWIR} - R_{rc,RED}] \times (\lambda_{NIR} - \lambda_{RED})/(\lambda_{SWIR} - \lambda_{RED})$$

$$CMI = R_{rc,GREEN} - R_{rc,BLUE} - [R_{rc,SWIR} - R_{rc,BLUE}] \times (\lambda_{GREEN} - \lambda_{BLUE})/(\lambda_{SWIR} - \lambda_{BLUE})$$

Method



Result



Liang Q., Zhang Y., Ma R., Steven L., Li J., Hu M. A MODIS-based novel method to distinguish surface cyanobacterial scums and aquatic macrophytes in Lake Taihu. Remote Sensing. 2017, 9, 133: doi://10.3390/rs9020133

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a. to remove the atmospheric effect
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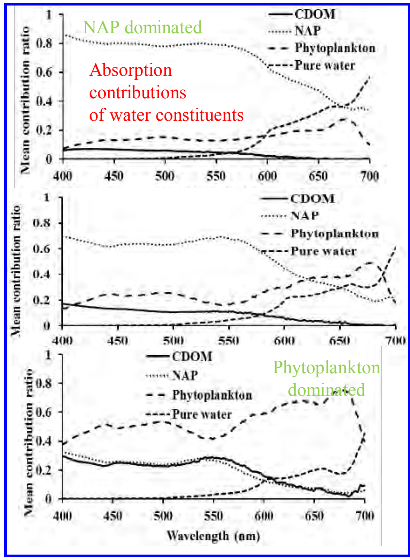
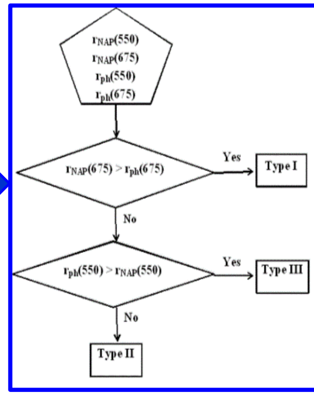
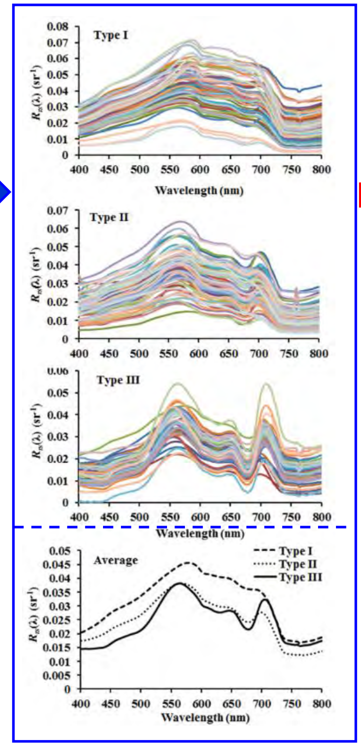
Classification by the contribution of the prominent constituent



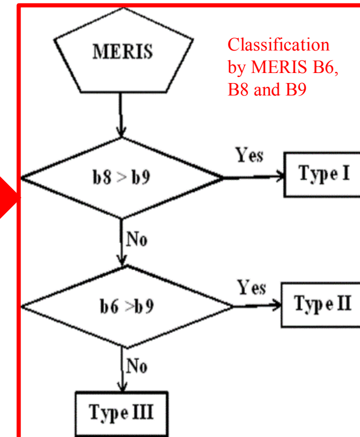
Classification by the contribution of $a_{NAP}(550)$ and $a_{Ph}(675)$

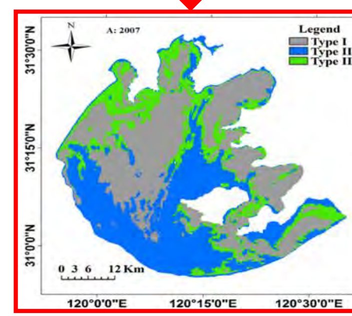


Spectral features of each class



Classification by MERIS bands





Shi K, Li Y, Li L, et al. Absorption characteristics of optically complex inland waters: Implications for water optical classification. Journal of Geophysical Research-Biogeosciences, 2013, 118:860–874

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NGRDI (Normalized Green-Red Difference Index) by MERIS

a. to remove the atmospheric effect
b. to remove the covered-cyanobacterial bloom waters
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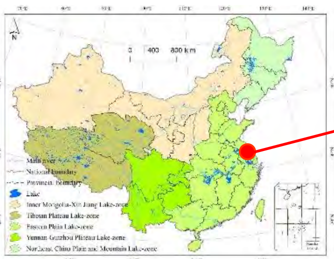
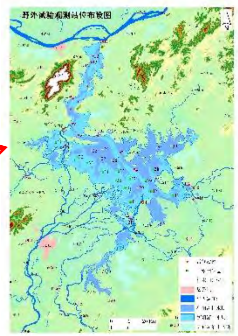
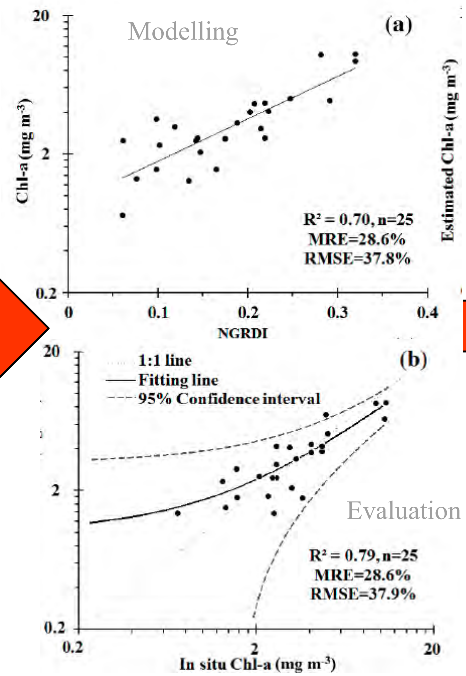
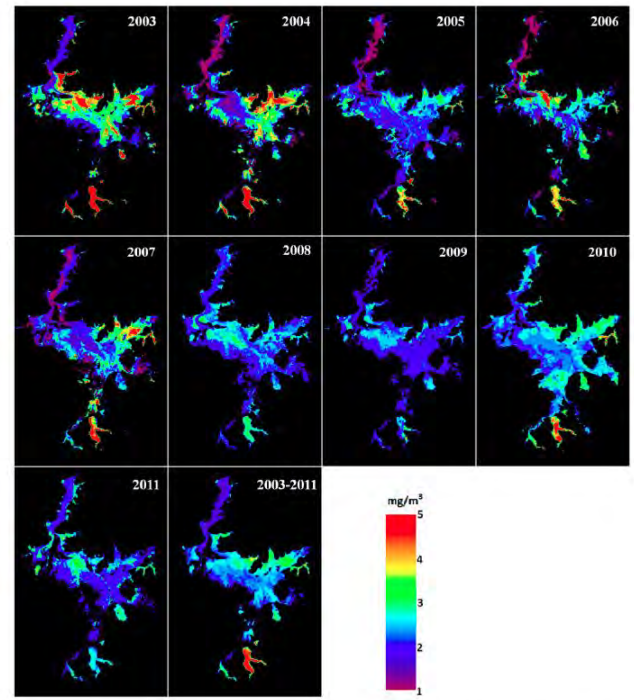
d. to implement the optical classification of waters
e. to develop the algorithm of Chl, PC, SPM/TSS, etc



Lake Poyang







$$\mathrm{NGRDI}=(R_{rs,560}-R_{rs,681})/(R_{rs,560}+R_{rs,681})$$

$$\mathrm{NGRDI}'=(\mathrm{R}_{rc,560}-\mathrm{R}_{rc,681})/(\mathrm{R}_{rc,560}+\mathrm{R}_{rc,681})$$

$$\text{Chl-a }(\text{mg}\cdot m^{-3})=0.8724\exp(7.0508\times NGRDI')\times 1.25\ [\text{NGRDI} > 0.06]$$

Feng L., Hu C., Han X., Chen X, Qi L. Long-term distribution patterns of chlorophyll-a concentration in China's largest freshwater lake: MERIS full-resolution observations with a practical approach. Remote Sensing. 2015, 7: 275-299

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Lake Color/Environment Remote Sensing in China

Key problems:
(1) to reduce the effect of atmosphere; (2) to reduce the effect of turbid water

a. to remove the atmospheric effect
b. to remove the covered-cyanobacterial bloom waters
c. to remove the effected-aquatic vegetation waters
d. to implement the optical classification of waters
e. to develop the algorithm of Chl, PC, SPM/TSS, etc

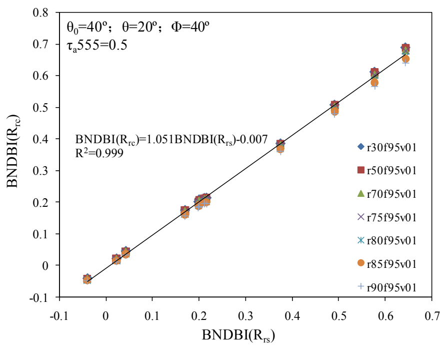
BNDBI (Baseline Normalized Difference Bloom Index) by MODIS

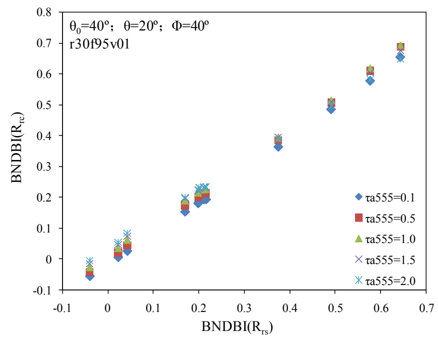
$$BNDBI = (R'_{rs}(555) - R'_{rs}(645))/(R'_{rs}(555) + R'_{rs}(645))$$

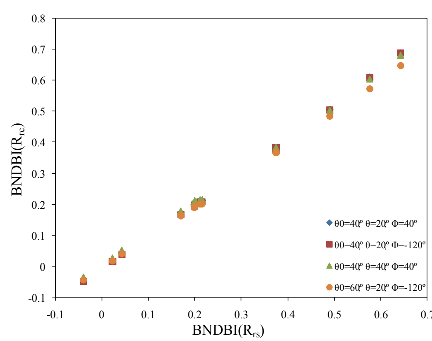
$$R'_{rs}(555)=R_{rs}(555) - \left[R_{rs}(469) \times \frac{(859-555)}{(859-469)} + R_{rs}(859) \times \frac{(555-469)}{(859-469)}\right]$$

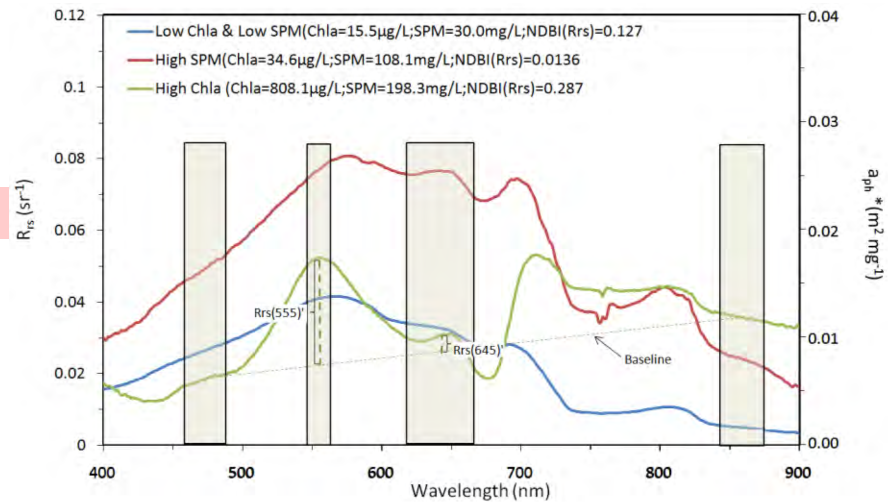
$$R'_{rs}(645)=R_{rs}(645) - \left[R_{rs}(469) \times \frac{(859-645)}{(859-469)} + R_{rs}(859) \times \frac{(645-469)}{(859-469)}\right]$$

$$\text{Chla} = 982.3 \times BNDBI^4 + 71.86 \times BNDBI^3 + 562.4 \times BNDBI^2 + 79.05 \times BNDBI + 6.6$$

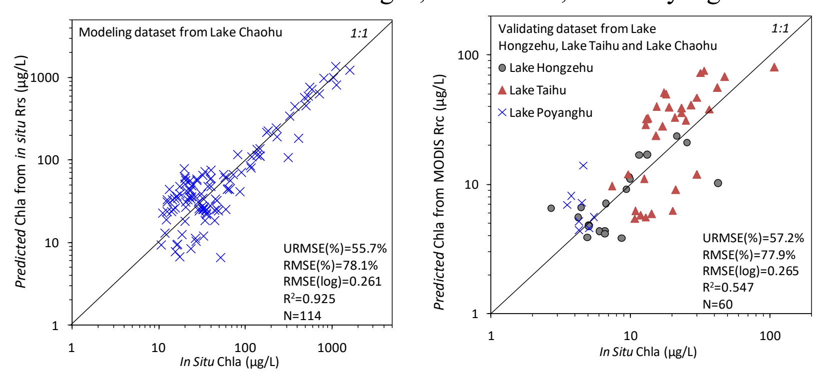








Validation in Lake Hongze, Lake Taihu, Lake Poyang



Zhang Y., Ma R., Duan H., Loiselle S., Zhang M., Xu J. A novel MODIS algorithm to estimate chlorophyll a concentration in eutrophic turbid lakes. Ecological Indicators. 2016, 69: 138-151

Lake Color/Environment Remote Sensing in China

Key problems:
(1) to reduce the effect of atmosphere; (2) to reduce the effect of turbid water

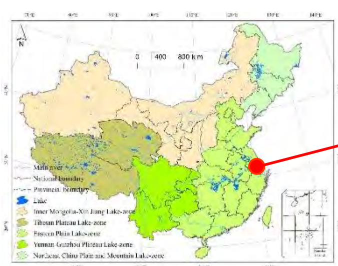
a. to remove the atmospheric effect
b. to remove the covered-cyanobacterial bloom waters
c. to remove the effected-aquatic vegetation waters
d. to implement the optical classification of waters
e. to develop the algorithm of Chl, PC, SPM/TSS, etc

PCI (Phycocyanin index) by MERIS

$$PCI = R'_{rs}(620) - R_{rs}(620)$$

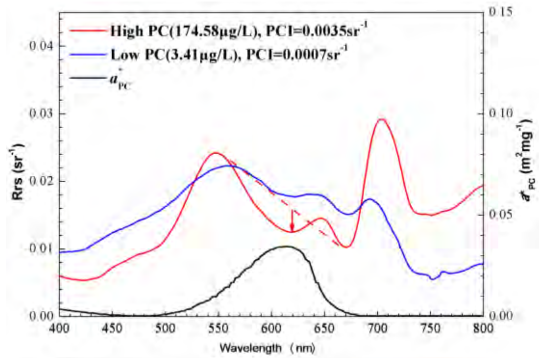
$$R'_{rs}(620) = R_{rs}(560) + \frac{620-560}{665-560} \times \left(R_{rs}(665) - R_{rs}(560)\right)$$

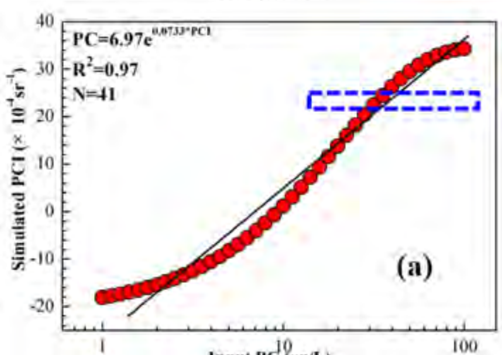
- PCI is sensitive to PC, but insensitive to CDOM or atmospheric perturbations;
- PCI is nearly immune to sun glint, thick aerosols, thin clouds, CDOM, turbidity;
- The valid satellite data rate is increased from <1% to 50%.



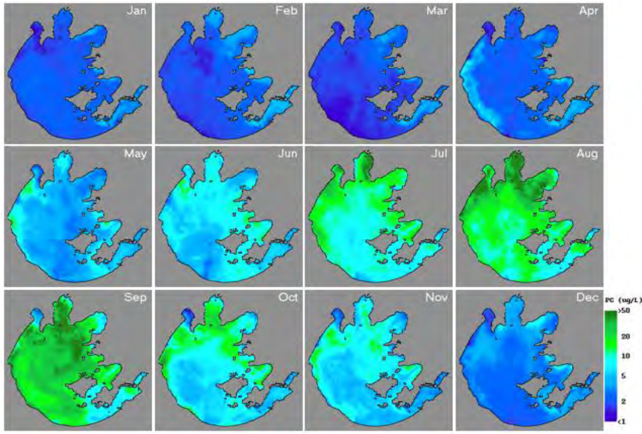
Lake Taihu

Lake Taihu: an area of 2427.8 km^2, a mean depth of 1.9 m and max. of 2.6 m

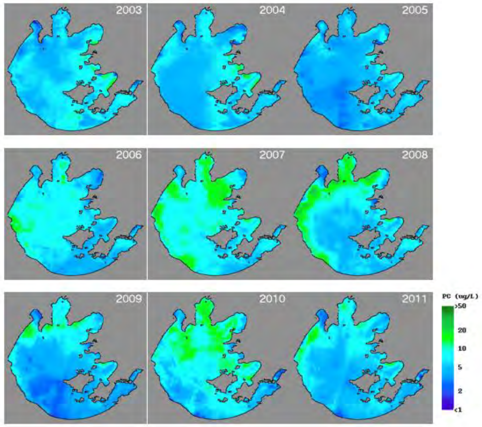




Climatology monthly mean PC distributions



Annual mean PC distributions



Qi L., Hu C., Duan H., Cannizzaro J, Ma R. A novel MERIS algorithm to derive cyanobacterial phycocyanin pigment concentrations in a eutrophic lake: Theoretical basis and practical considerations. Remote Sensing of Environment. 2014, 154: 298-317

Lake Color/Environment Remote Sensing in China

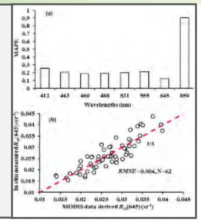
International Ocean Colour Science Meeting 2017

a. to remove the atmospheric effect
b. to remove the covered-cyanobacterial bloom waters
c. to remove the effected-aquatic vegetation waters
d. to implement the optical classification of waters
e. to develop the algorithm of Chl, PC, SPM/TSS, etc

TSM (total suspended matter) by MODIS

Atmospheric correction

a. To select the dense dark vegetation targets;
b. To calculate the surface reflectance at 469nm;
c. To inverse the aerosol optical depth at 550nm;
d. To retrieve Rrs(λ) from MODIS



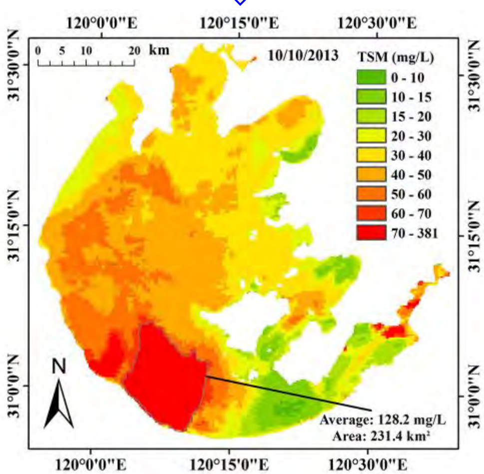
$$[TSM] = 9.65 \times \exp[58.81 \times R_{rs}(645)]$$

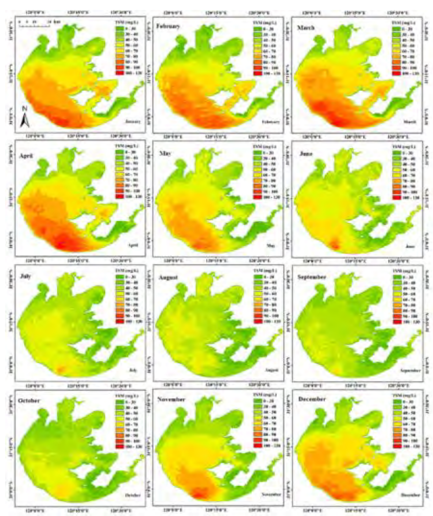
Daily
Oct. 10, 2013

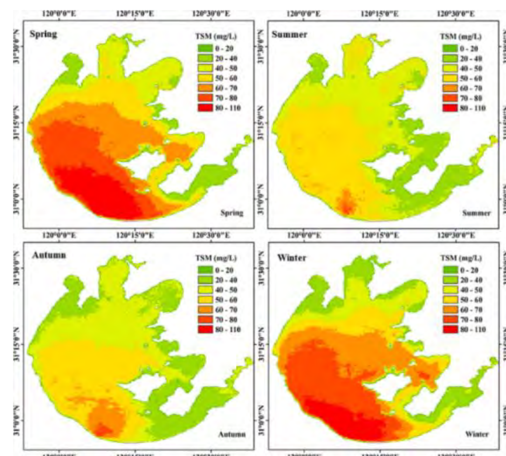
Monthly
Jan.-Dec.

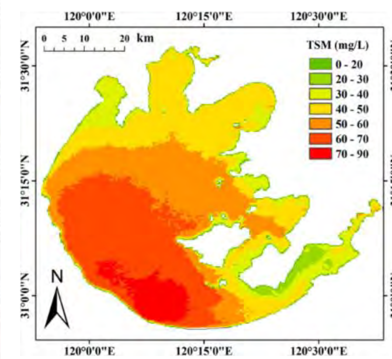
Seasonal
Spr., Sum., Aut., Win.

Yearly average
2003-2013









Shi K., Zhang Y., Zhu G., Liu X., Zhou Y., Xu H., Qin B., Liu G., Li Y. Long-term remote monitoring of total suspended matter concentration in Lake Taihu using 250m MODIS-Aqua data. Remote Sensing of Environment. 2015, 164: 43-56

NIGLAS 1940

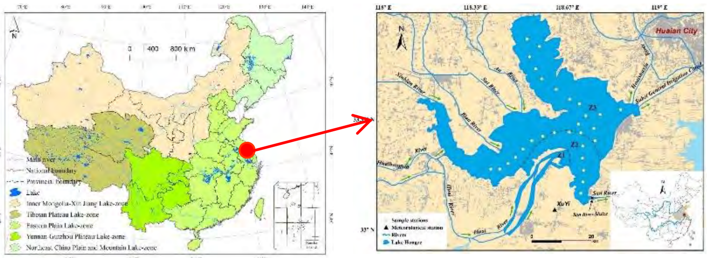
Lake Color/Environment Remote Sensing in China

Key problems: to reduce the effect of atmosphere

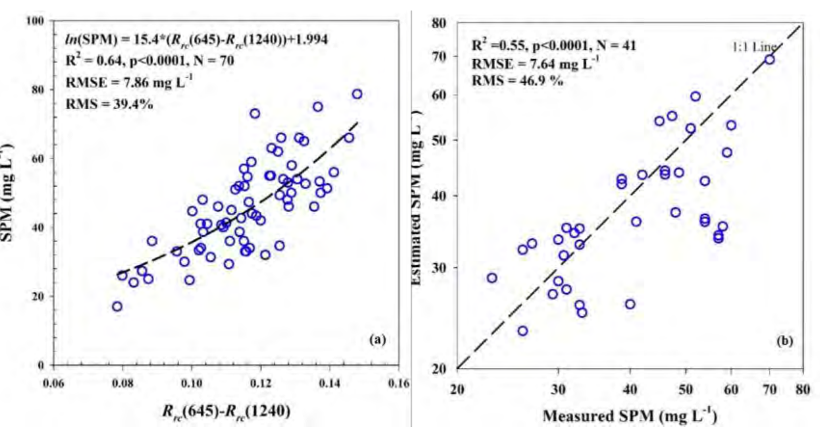
- a. to remove the atmospheric effect
- b. to remove the covered-cyanobacterial bloom waters
- c. to remove the effected-aquatic vegetation waters
- d. to implement the optical classification of waters
- e. to develop the algorithm of Chl, PC, SPM/TSS, etc

SPM (suspended particulate matter) by MODIS Aqua

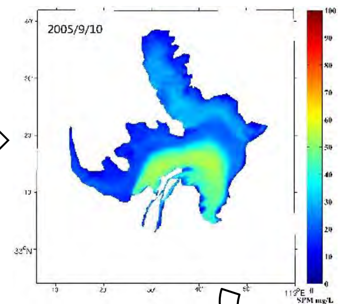
Lake Hongze



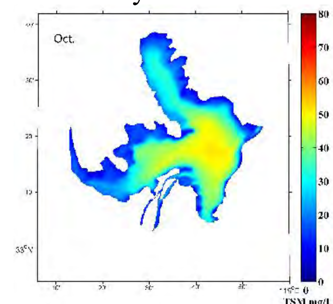
$$[SPM] = \exp(15.4 \times [R_{rc}(645) - R_{rc}(1240)]) + 1.994$$



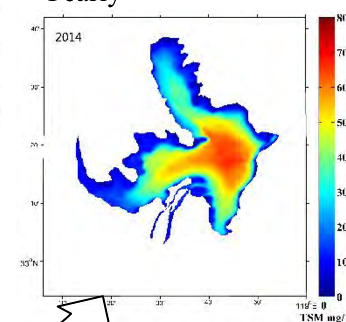
Daily



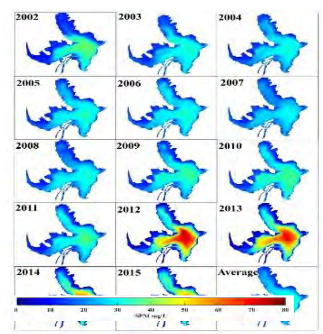
Monthly



Yearly



Time series in year



Cao Z., Duan H., Feng L., Ma R., Xue K. Climate- and human-induced changes in suspended particulate matter over Lake Hongze on short and long timescales. Remote Sensing of Environment. 2017, 192: 98-113

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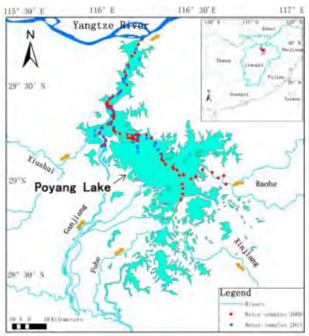
Lake Color/Environment Remote Sensing in China

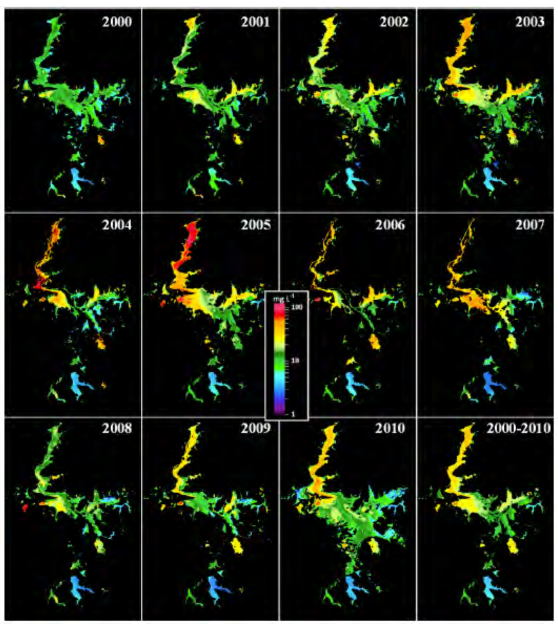
2000–present for Terra MODIS
2002–present for Aqua MODIS

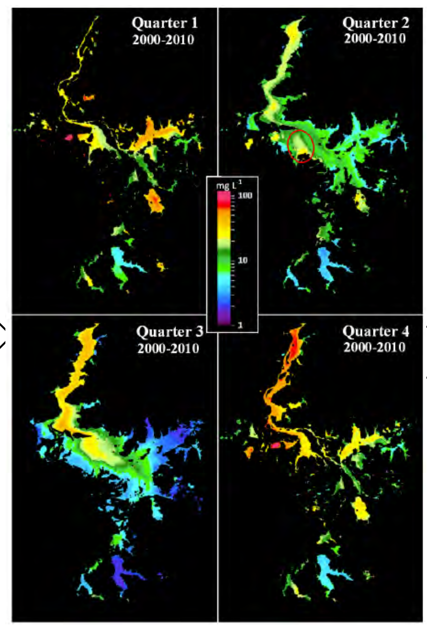
a. to remove the atmospheric effect
b. to remove the covered-cyanobacterial bloom waters
c. to remove the effected-aquatic vegetation waters
d. to implement the optical classification of waters
e. to develop the algorithm of Chl, PC, SPM/TSS, etc



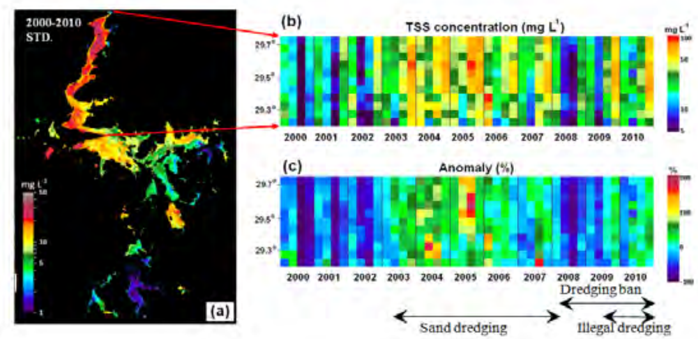
$$R_{rc,\lambda} = \pi L^{*}_{t,\lambda} / \left(F_{0,\lambda} \times cos\theta_0\right) - R_{r,\lambda}$$

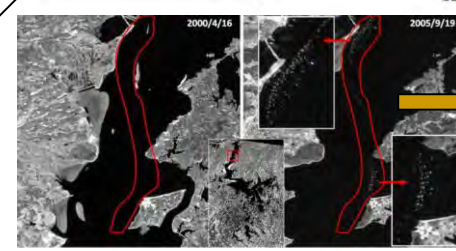
$$\textbf{TSS (mg } L^{-1}\textbf{)} = 0.6786exp\left(34.366 \times R_{rc,645-nearest\ 1240}\right)$$





Sand Dredging induced turbidity increase





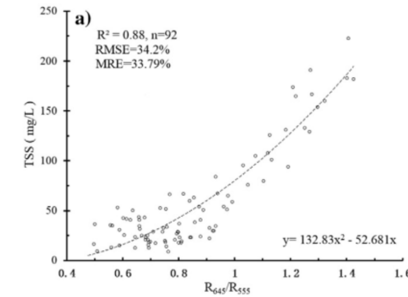
Feng L., Hu C., Chen X., Tian L., Chen L. Human induced turbidity changes in Poyang Lake between 2000 and 2010: Observations from MODIS. Journal of Geophysical Research. 2012, 117: C07006, doi:10.1029/2011JC007864

NIGLAS 1940

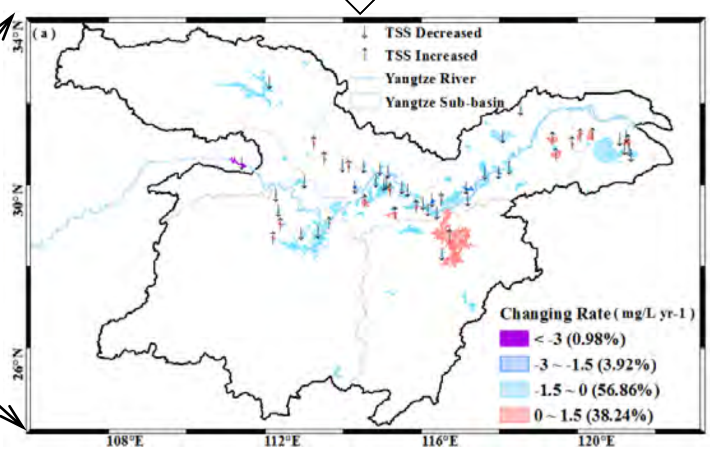
Lake Color/Environment Remote Sensing in China

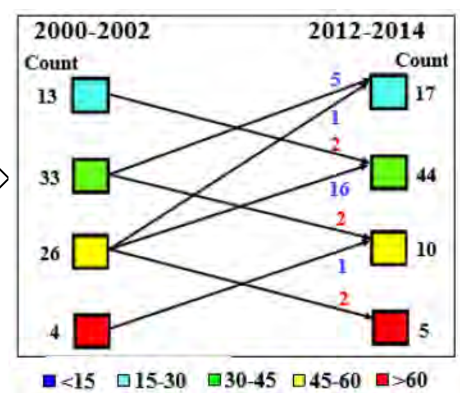
a. to remove the atmospheric effect
b. to remove the covered-cyanobacterial bloom waters
c. to remove the effected-aquatic vegetation waters
d. to implement the optical classification of waters
e. to develop the algorithm of Chl, PC, SPM/TSS, etc

$$[TSS](mg\ L^{-1}) = 132.83 \times (R_{645}/R_{555})^2 - 52.618 \times (R_{645}/R_{555})$$



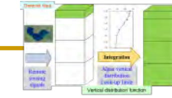
58 lakes/reservoirs in situ data
102 large water bodies, Middle and Lower Yangtze River basin, China
2516 MODIS 8-day composites of the atmospherically corrected reflectance
15-year of 2000-2014 TSS





Hou X., Feng L., Duan H., Chen X., Sun D., Shi K. Fifteen-year monitoring of the turbidity dynamics in large lakes and reservoirs in the middle and lower basin of the Yangtze River, China. Remote Sensing of Environment. 2017, 190: 107-121

- Lake number & spatial distribution
- IOPs & AOPs of lake waters
- Pigments retrieval in surface waters
- Phytoplankton biomass estimation
- Cyanobacterial bloom remote sensing



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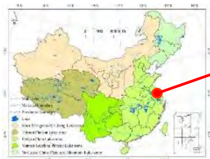
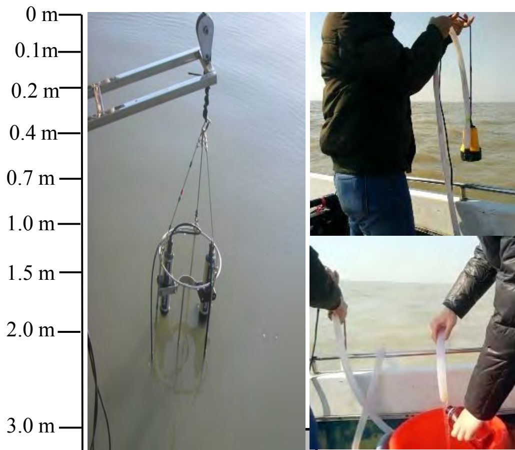
Lake Color/Environment Remote Sensing in China

Lake Chaohu

to determine the vertical distribution type by the field

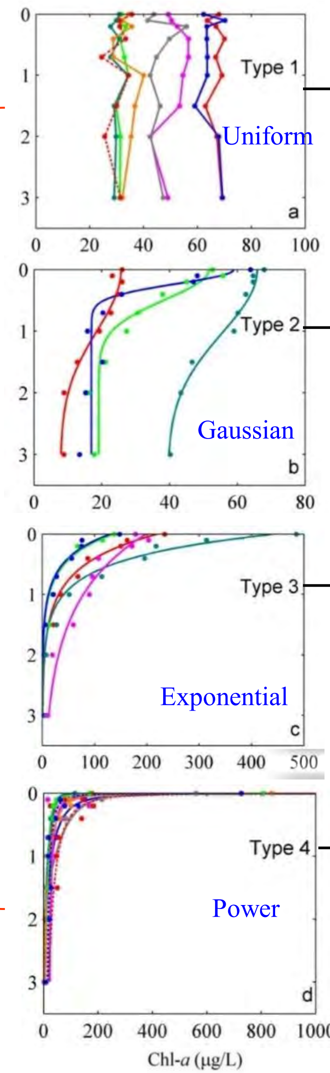


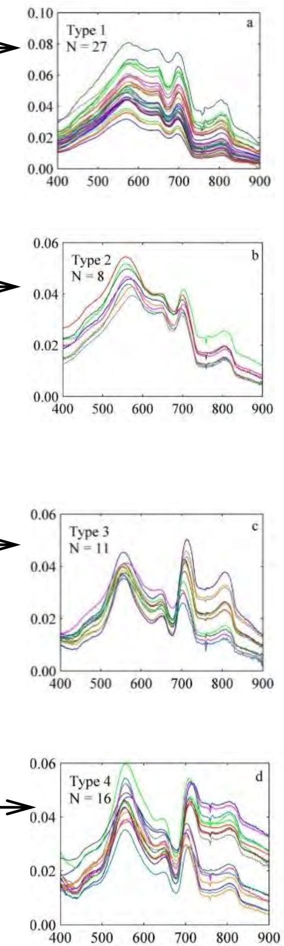
Sampling in vertical by TriOS



E_u: Upwelling irradiance
E_d: Downwelling irradiance
L_u: Upwelling radiance
Chl, SPM, DOC, POC, PC, a, bb, Kd

Distribution type in vertical	Distribution function	Remote sensing reflectance
Type 1 Uniform	$f_1(z) = C$	Type 1, N = 27
Type 2 Gaussian	$(z) = C_0 + \frac{h}{\sigma\sqrt{2\pi}}\exp[-\frac{1}{2}(\frac{z}{\sigma})^2]$	Type 2, N = 8
Type 3 Exponential	$f_3(z) = m_1 \times \exp(m_2 \times z)$	Type 3, N = 11
Type 4 Power	$f_4(z) = n_1 \times z^{n_2}$	Type 4, N = 16





Kun Xue, Yuchao Zhang, Hongtao Duan, Ronghua Ma, Steven Loiselle, Minwei Zhang. A remote sensing approach to estimate vertical profile classes of phytoplankton in a eutrophic lake. Remote Sensing. 2015, 7: 14403-14427.

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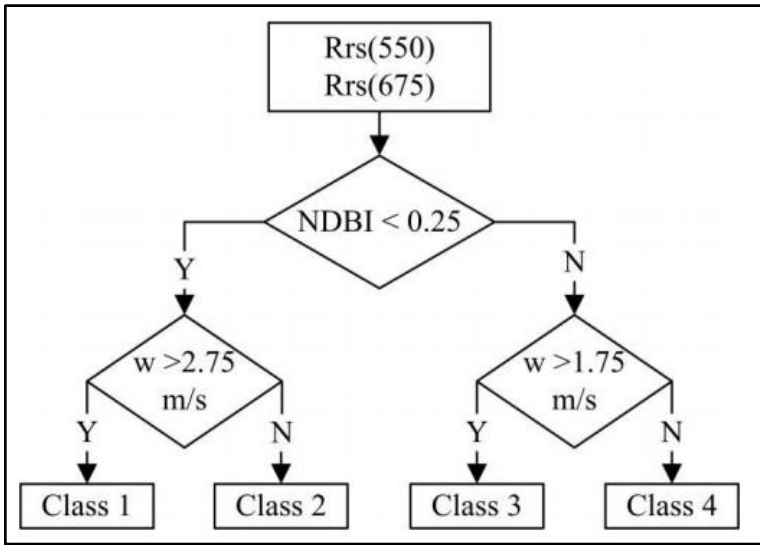
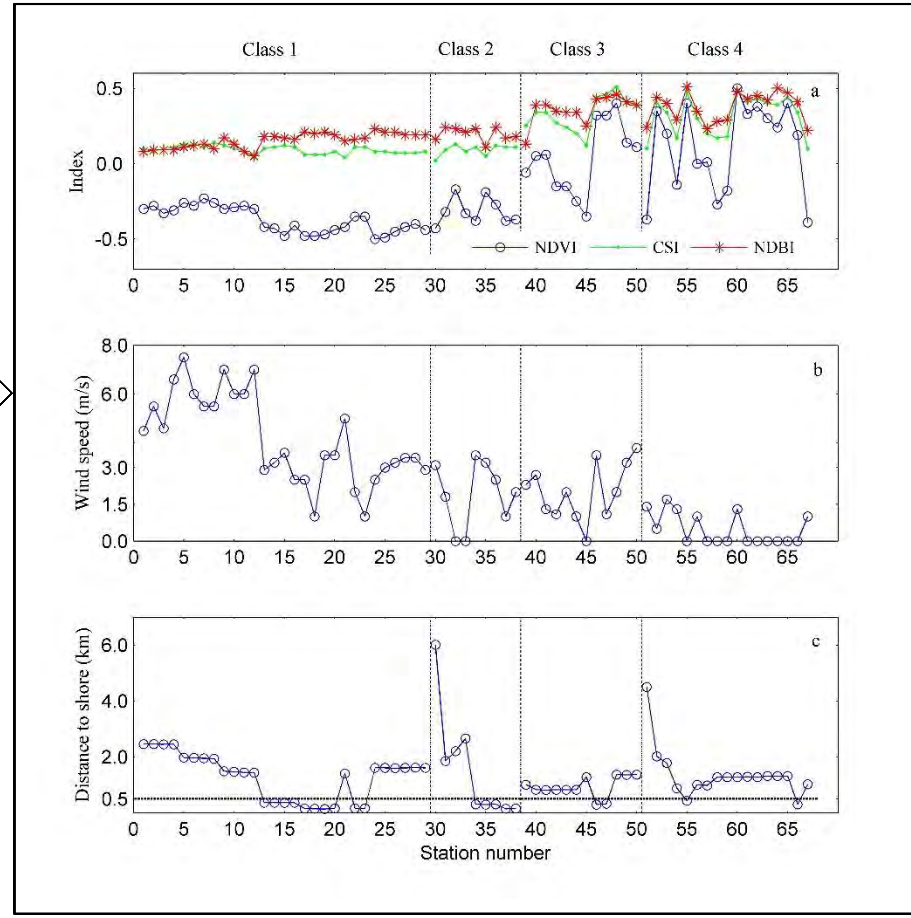
Lake Color/Environment Remote Sensing in China

Lake Chaohu

to determine the vertical distribution type by in situ R_{rs}, NDBI and wind speed



$$NDBI_{Rrs} = (R_{rs}(550) - R_{rs}(675)) / (R_{rs}(550) + R_{rs}(675))$$



Kun Xue, Yuchao Zhang, Hongtao Duan, Ronghua Ma, Steven Loiselle, Minwei Zhang. A remote sensing approach to estimate vertical profile classes of phytoplankton in a eutrophic lake. Remote Sensing. 2015, 7: 14403-14427.

To determine the vertical distribution type

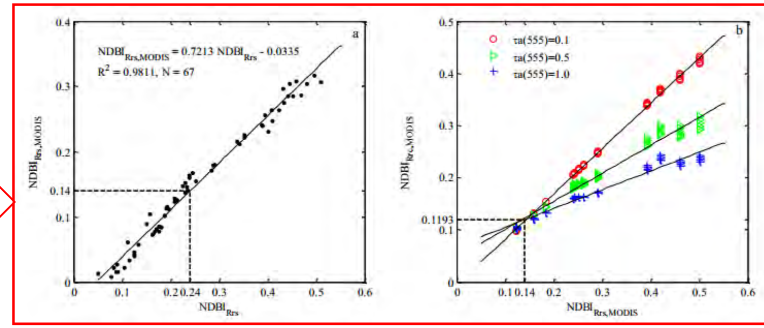
By MODIS R_{rc}, NDBI, wind speed and the distance to shore

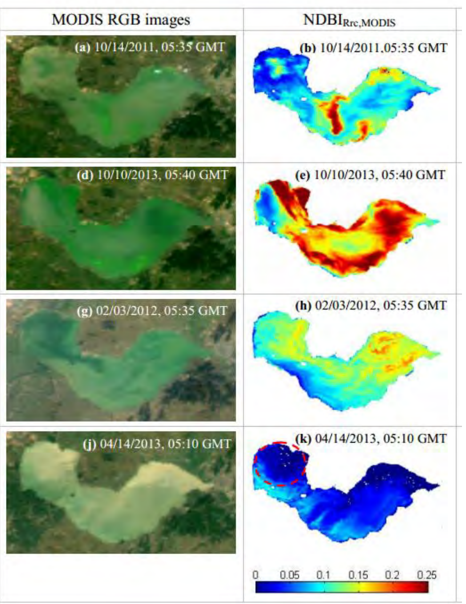
$$NDBI_{Rrs} = (R_{rs}(550) - R_{rs}(675)) / (R_{rs}(550) + R_{rs}(675))$$

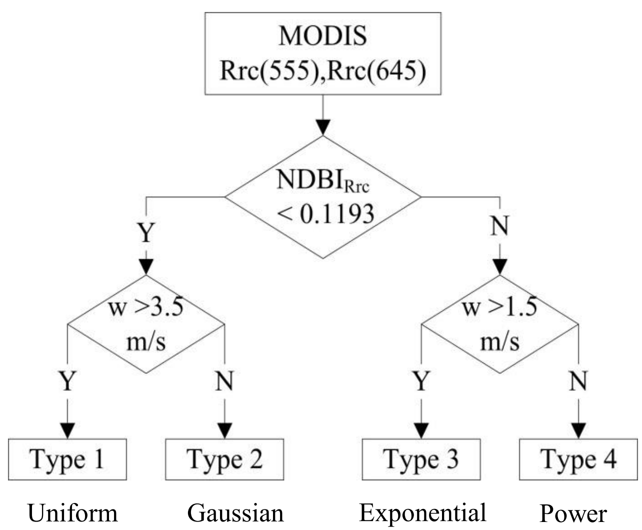
In situ, $NDBI_{Rrs}$ → MODIS, $NDBI_{Rrc}$

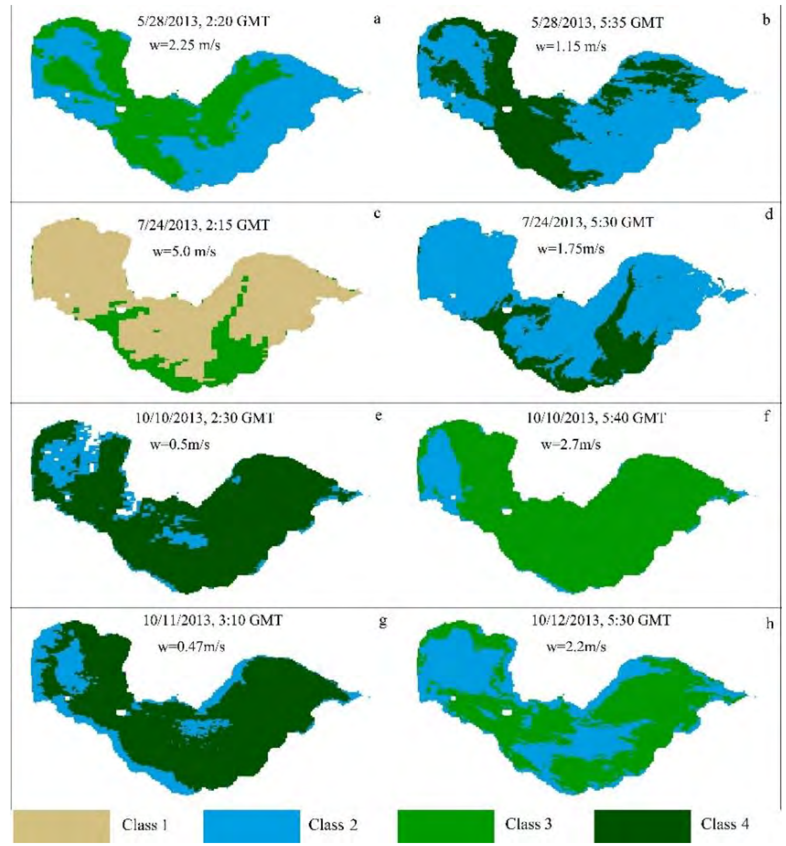
$$R_{rc}(\lambda) = \rho_t(\lambda) - \rho_r(\lambda) = \rho_a(\lambda) + \pi t(\lambda) t_0(\lambda) Rrs(\lambda)$$

$$NDBI_{Rrc} = (R_{rc}(550) - R_{rc}(675)) / (R_{rc}(550) + R_{rc}(675))$$







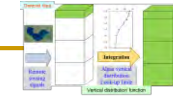


Kun Xue, Yuchao Zhang, Hongtao Duan, Ronghua Ma. Variability of light absorption properties in optically complex inland waters of Lake Chaohu, China. Journal of Great Lakes Research, 2017, 43: 17-31

The validation of Chl vertical profile class derived using concurrent in situ and MODIS based measurements with different wind speed on 28 May, 24 July and 11-12 October 2013

Day	GMT Time	Wind Speed (m/s)	$NDBI_{RRC,MODIS}$	Chla Vertical Class	
				in situ Class	Estimated Class
28 May 2013	1:00	2.25	0.118	2	2
28 May 2013	2:25	2.25	0.159	4	4
28 May 2013	3:25	2.25	0.160	4	4
24 July 2013	1:55	5.00	0.101	2	1
24 July 2013	2:25	5.00	0.101	2	1
24 July 2013	2:55	5.00	0.101	1	1
11 October 2013	2:30	0.43	0.135	4	4
11 October 2013	3:10	0.43	0.135	4	4
11 October 2013	3:50	0.43	0.135	4	4
12 October 2013	1:30	2.20	0.101	2	2
12 October 2013	2:05	2.20	0.101	2	2
12 October 2013	2:40	2.20	0.101	2	2

Xue K., Zhang Y., Ma R., Duan H. An approach to correct the effects of phytoplankton vertical nonuniform distribution on remote sensing reflectance of cyanobacterial bloom waters. Limnology and Oceanography: methods, 2017, DOI: 10.1002/lom3.10158



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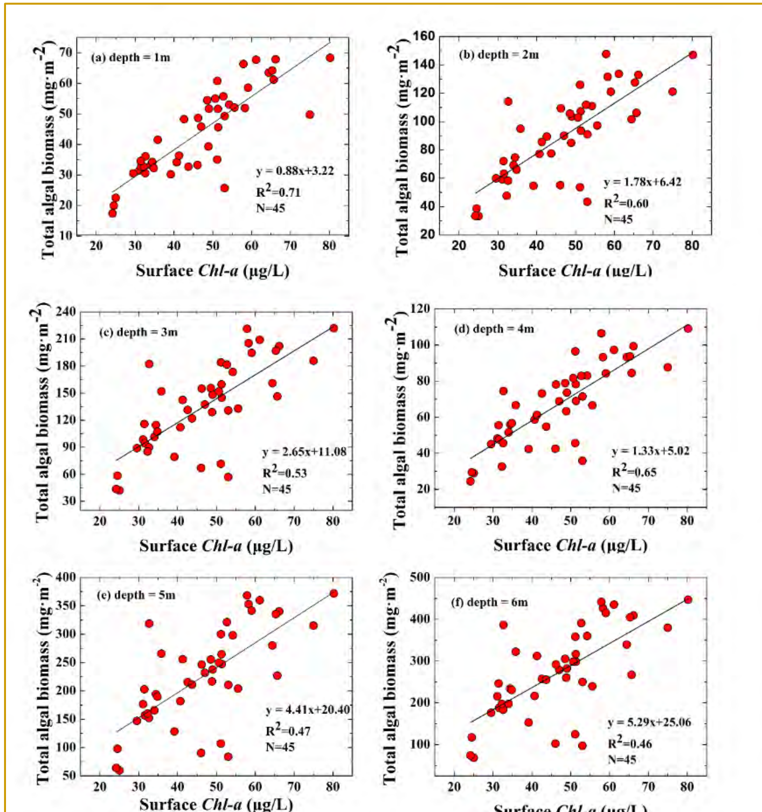
Lake Color/Environment Remote Sensing in China | **Lake Chaohu**

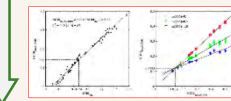
To estimate the algal biomass in different biomass by the quantitative function



$R_{rc}(\lambda) = \rho_t(\lambda) - \rho_r(\lambda) = \rho_a(\lambda) + \pi t(\lambda) t_0(\lambda) Rrs(\lambda)$

$$R_{rc} = \pi L_t^* / (F_0 \cos\theta_0) - R_r$$

In situ, $NDBI_{Rrs}$



MODIS, $NDBI_{Rrc}$

$$NDBI_{R_{rc}} = \frac{R_{rc}(555) - R_{rc}(645)}{R_{rc}(555) + R_{rc}(645)}$$

$$Chl = 1.935 \times e^{26.165 \times NDBI(R_{rc})}$$

$$AI = a \cdot chl + b$$

$$a = 0.8114 \cdot z + 0.021$$
$$b = 4.479 \cdot z - 2.0978$$

Algal biomass in different depth

Chl-a concentration/biomass in the water surface

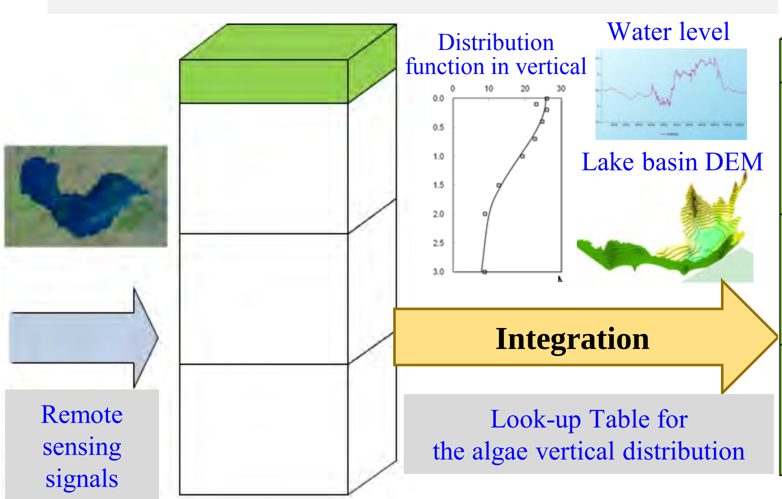
Kun Xue, Yuchao Zhang, Hongtao Duan, Ronghua Ma. Variability of light absorption properties in optically complex inland waters of Lake Chaohu, China. Journal of Great Lakes Research, 2017, 43: 17-31

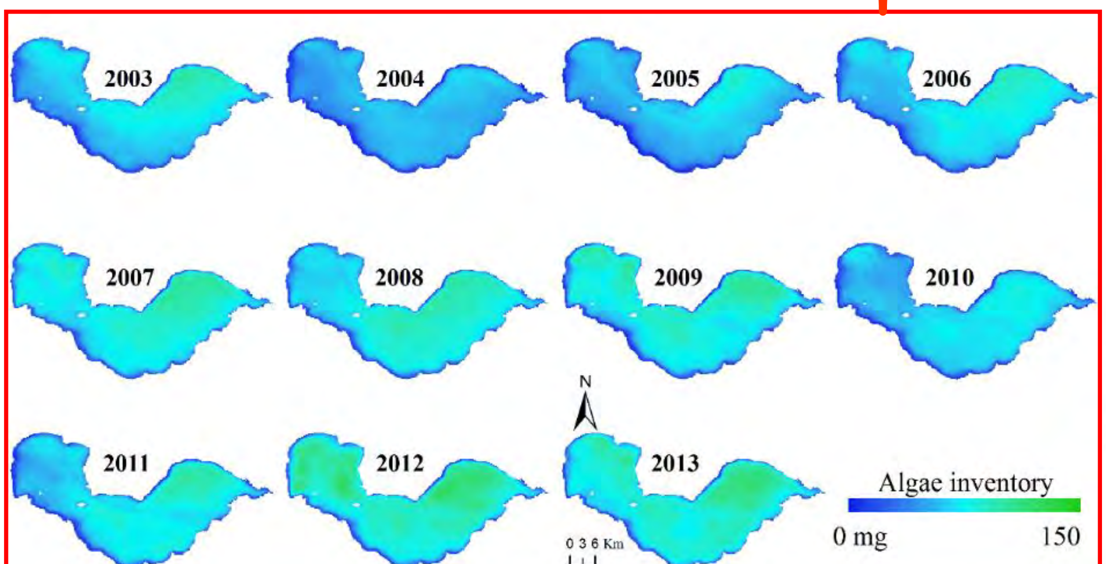
Li J., Zhang Y., Ma R., Duan H., Loiselle S., Xue K., Liang Q. Satellite-Based Estimation of Column-Integrated Algal Biomass in Nonalgae Bloom Conditions: A Case Study of Lake Chaohu, China IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, 2, 2017: 450-462

International Ocean Colour Science Meeting 2017

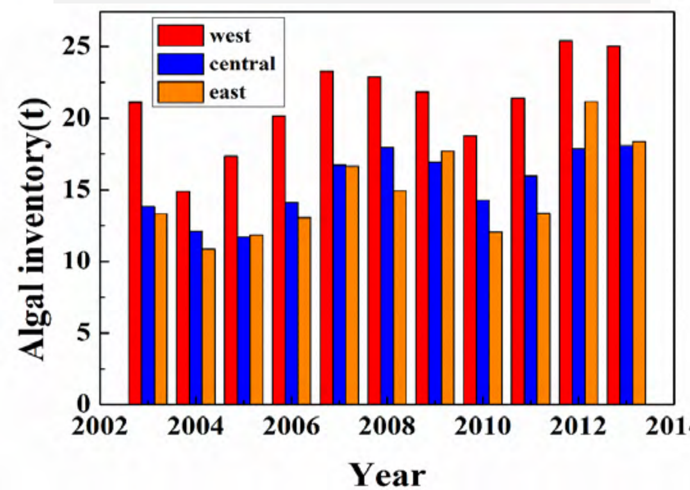
Lake Color/Environment Remote Sensing in China

To estimate the total biomass in Lake Chaohu by MODIS imageries





A range of 37.97t in 2004 to 64.58t in 2014 in the whole lake, with a mean of 51.51t



Li J., Zhang Y., Ma R., Duan H., Loiselle S., Xue K., Liang Q. Satellite-Based Estimation of Column-Integrated Algal Biomass in Nonalgae Bloom Conditions: A Case Study of Lake Chaohu, China IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, 2, 2017: 450-462

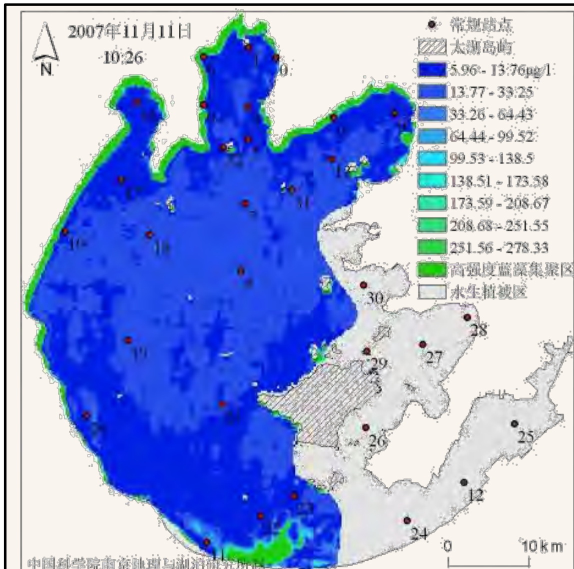
NIGLAS

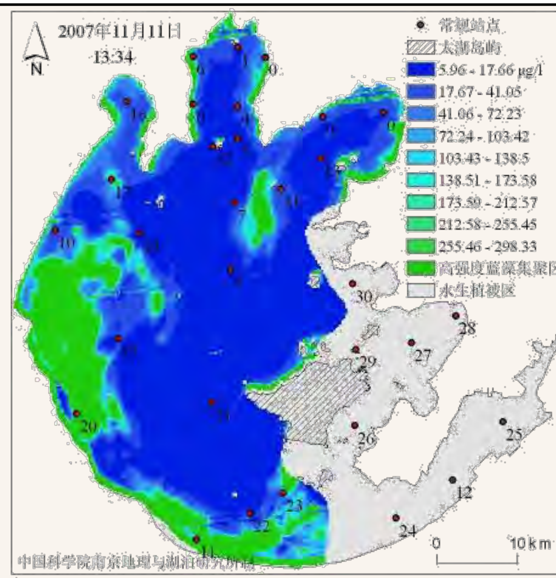
- Lake number & spatial distribution
- IOPs & AOPs of lake waters
- Pigments retrieval in surface waters
- Phytoplankton biomass estimation
- Cyanobacterial bloom remote sensing

Lake Color/Environment Remote Sensing in China

Lake area: not so big as sea area
Lake water quality change: a small spatial range

Satellite images with a higher spatial resolution





Frequently change in hour

Satellite images with
a higher temporal resolution

Satellite images with
a higher spatio-temporal resolution

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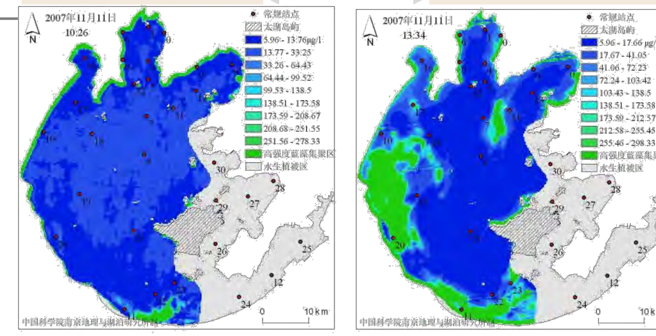
Lake cyanobacterial blooms:

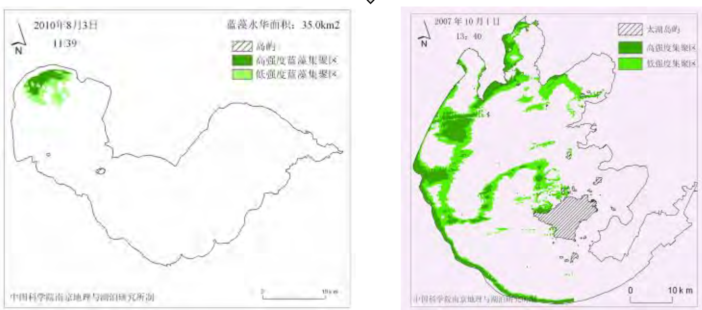
- frequently change in hours
- significant spatial heterogeneity in meters

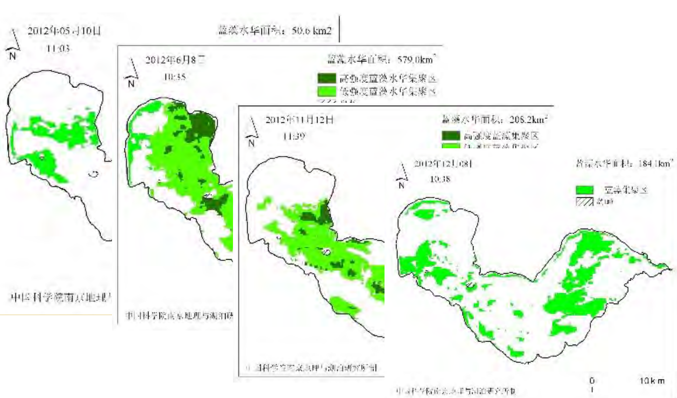
The first important is temporal resolution. MODIS is the most appropriate sensor at present, but with low spatial resolution.

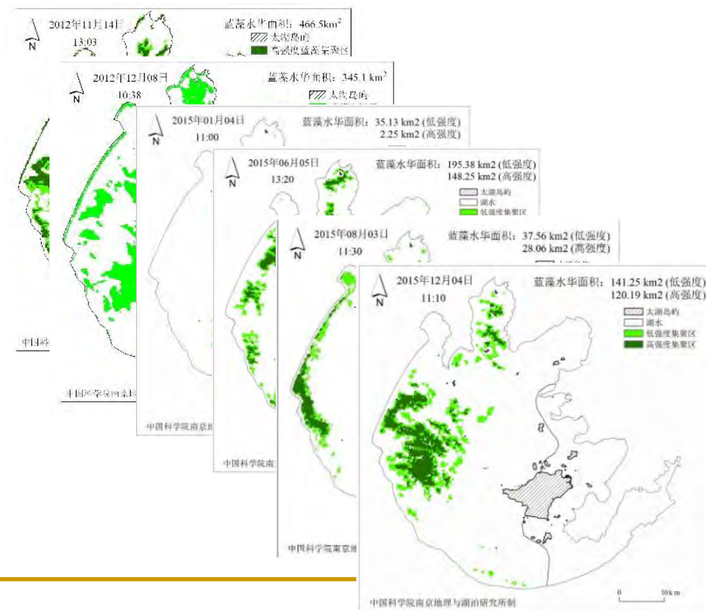
a. to remove the atmospheric effect
b. to remove the covered-cyanobacterial bloom waters
c. to remove the effected-aquatic vegetation waters
d. to implement the optical classification of waters
e. to develop the algorithm of Chl, PC, etc

10:26 11 Nov. 2007 — Difference of 3 hours — 13:34 11 Nov. 2007









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Lake Color/Environment Remote Sensing in China

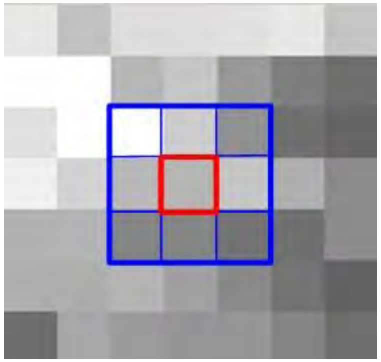
To decompose algal bloom coverage to sub-pixel level in order to improve the area precision of algal blooming

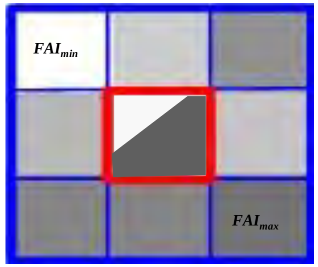
a. to remove the atmospheric effect

…vered-cyanobacterial bloom waters

…ected-aquatic vegetation waters

…optical classification of waters





A 3×3 pixels window
FAI_{max}: maximum *FAI*.
FAI_{min}: minimum *FAI*

FAI

0	0	0	0	0	0	0
0	0.027	0.018	0.023	0.027	0.027	0
0	0.032	0.027	0.032	0.032	0.027	0
0	0.036	0.036	0.041	0.036	0.023	0
0	0.041	0.045	0.041	0.032	0.027	0
0	0.045	0.054	0.036	0.036	0.027	0
0	0	0	0	0	0	0

α_{pixel}: Algal bloom partial coverage at sub-pixel scales

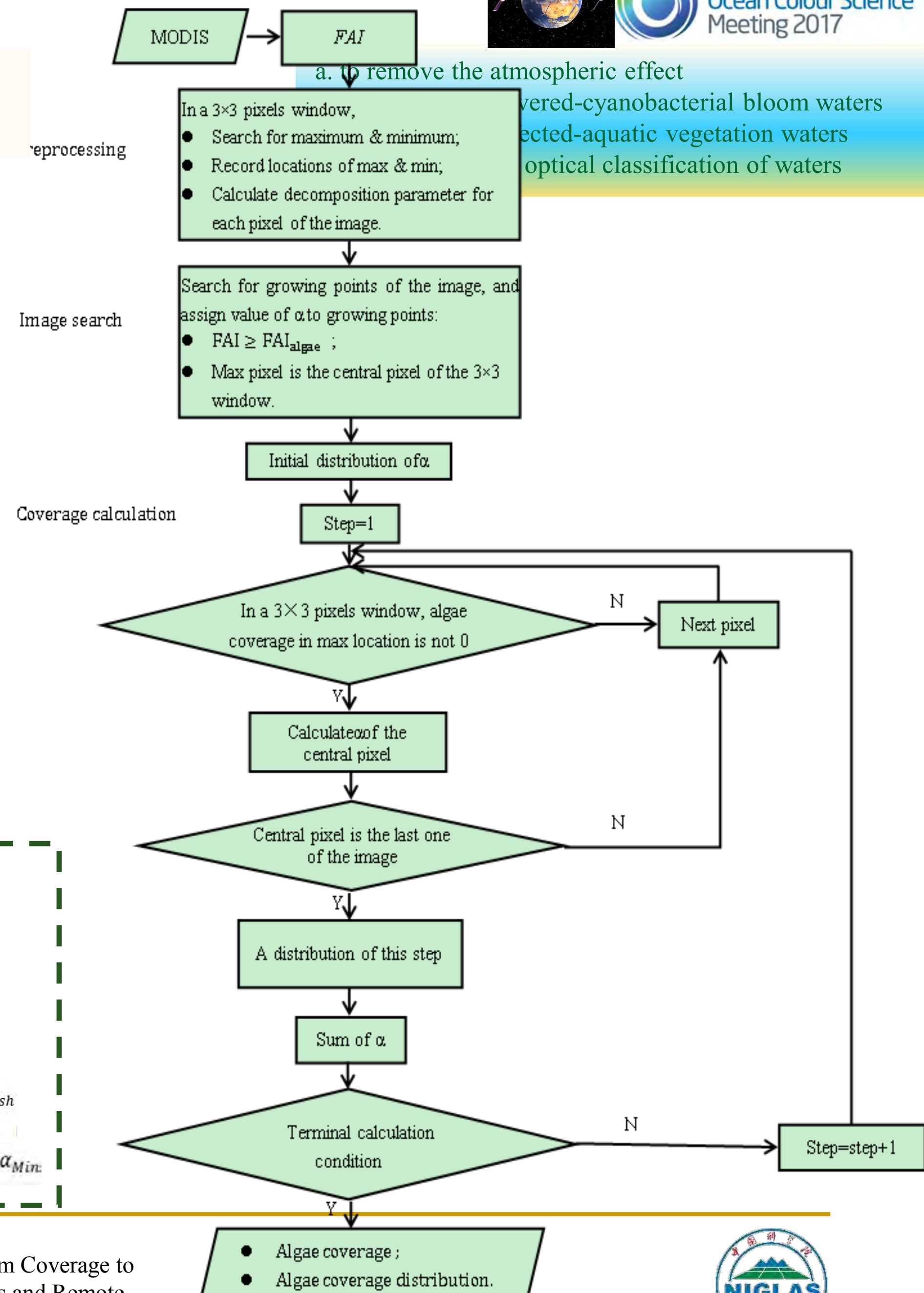
For growing points:

$$\alpha_{pixel} = \begin{cases} 1 & FAI \geq FAI_{algae} \\ \frac{FAI_{pixel} - FAI_{non-algae}}{FAI_{algae} - FAI_{non-algae}} & FAI_{algae} > FAI_{pixel} > FAI_{non-algae} \\ 0 & FAI < FAI_{non-algae} \end{cases}$$

$$FAI_{center} = \gamma \cdot FAI_{max} + (1-\gamma) \cdot FAI_{min}$$

$$FAI = \alpha \cdot FAI_{algae}{}^{thresh} + (1-\alpha) \cdot FAI_{water}{}^{thresh} = (FAI_{algae}{}^{thresh} - FAI_{water}{}^{thresh}) \cdot \alpha + FAI_{water}{}^{thresh}$$

$$FAI_{center} = (FAI_{algae}{}^{thresh} - FAI_{water}{}^{thresh}) \cdot \alpha_{center} + FAI_{water}{}^{thresh} \qquad \alpha_{center} = \gamma \cdot \alpha_{Max} + (1-\gamma) \cdot \alpha_{Min}$$



Zhang Y., Ma R., Duan H., Steven A. L., Xu J., Ma M. A Novel Algorithm to Estimate Algal Bloom Coverage to Subpixel Resolution in Lake Taihu. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, 2014, 7: 3060-3068

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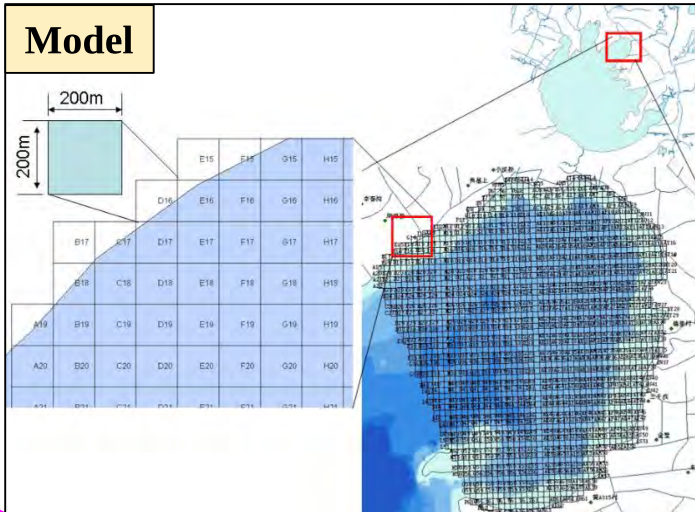
Lake Color/Environment Remote Sensing in China

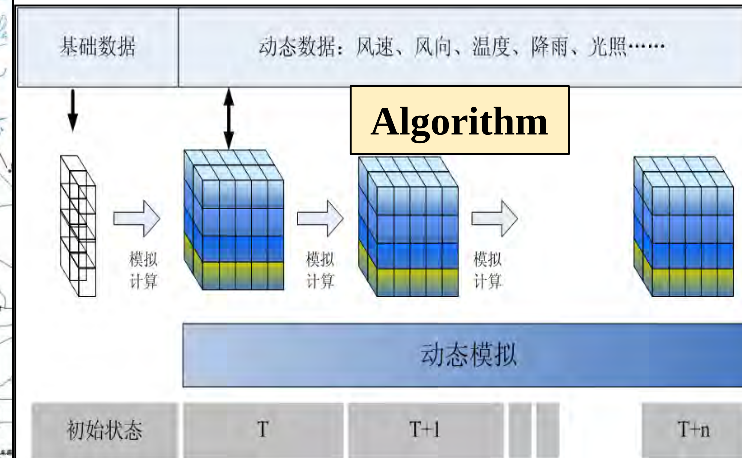
A model/software integrating cyanobacteria growing, water dynamic, and nutrient distribution model

Data

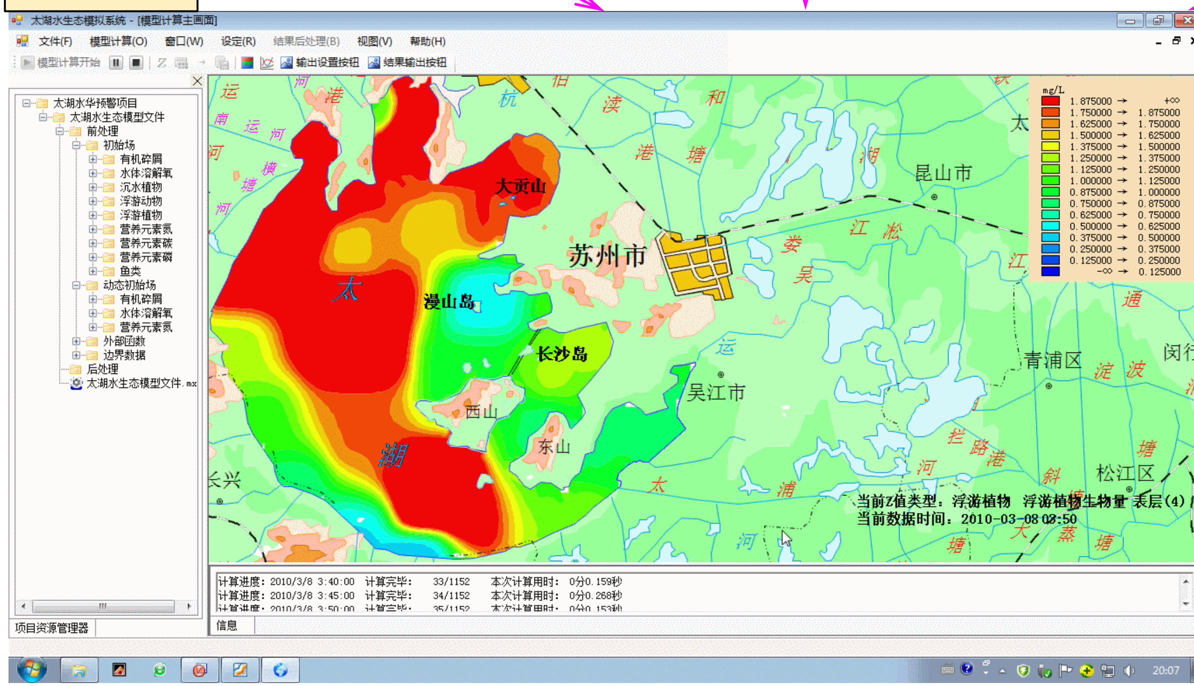
Model



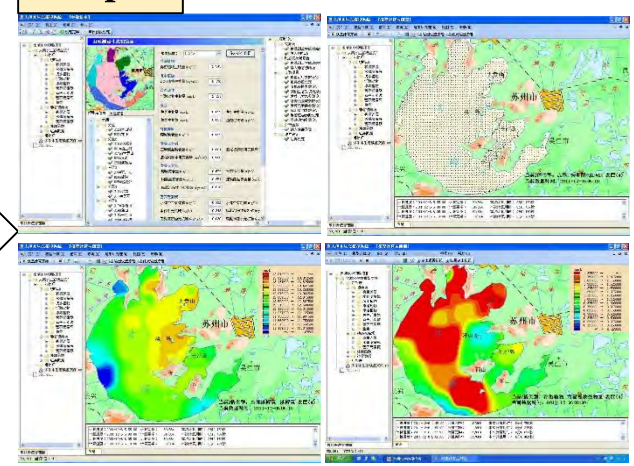
Algorithm



Software



Output



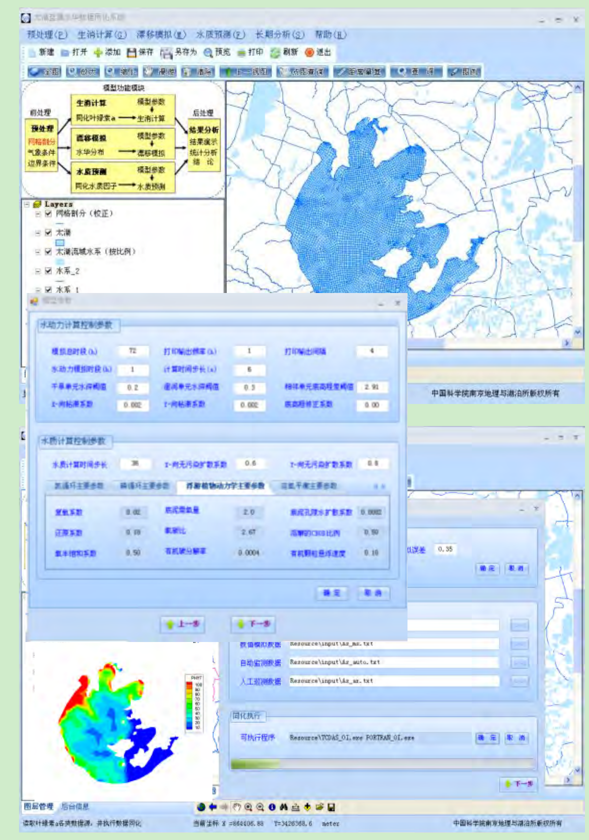
Lake Color/Environment Remote Sensing in China

International Ocean Colour Science Meeting 2017

A software for lake cyanobacterial blooms monitoring by MODIS

MODIS satellite broadcasting and relay system

Lake cyanobacterial blooms monitoring system for MODIS



Data assimilation system for cyanobacterial blooms monitoring and forecast in Lake Taihu

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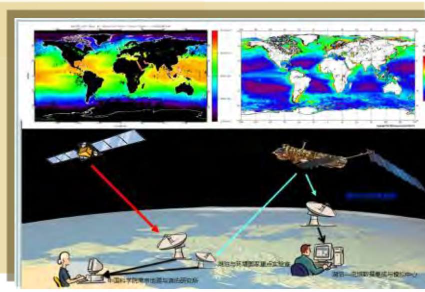
Lake Color/Environment Remote Sensing in China

Lake Taihu cyanobacteria blooming/forcast report for local government



Lake Taihu cyanobacteria blooming monitoring report for local government

太湖蓝藻卫星遥感监测报告

总第 918 期

中国科学院南京地理与湖泊研究所 2016 年 06 月 13 日

2016 年 06 月 13 日 11 时 00 分的 MODIS 卫星影像显示……面出现蓝藻水华，通过 APA 算法计算，高低强度藻华……424.4km²，涉及面积 616.12km²（详情见表 1 和表 2）。太……华 MODIS 卫星遥感反演结果分别见图 1-图 5。

受陆地地表影响，沿岸水体叶绿素和藻蓝素的反演结……参考。太湖温度分布较为均一，沿岸温度略高于湖中心温……

表 1 太湖水体卫星遥感反演结果

	平均叶绿素 (μg/l)	平均藻蓝素 (μg/l)	平均表层水温 (℃)	绝对面积 (km2)
11 时 00 分	27.2	88.9	28.3	424.4

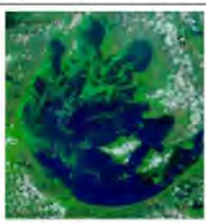


图 1 太湖 MODIS 卫星影像

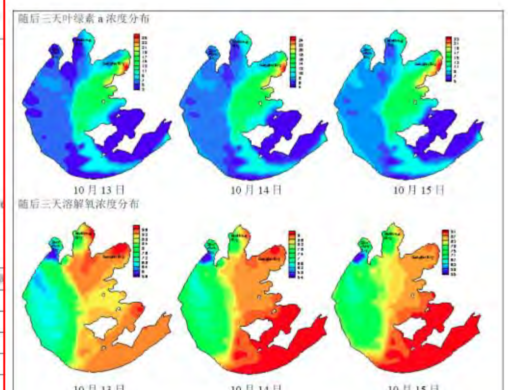
图 2 太湖分区图

太湖蓝藻及湖泛监测预警半周报

太湖蓝藻及湖泛监测预警工作小组 2015-10-12

中国科学院南京地理与湖泊研究所太湖蓝藻及湖泛监测预警半周报

Lake Taihu cyanobacteria blooming forecast report for local government



区域	发生水华概率	出现异味水体概率
太湖沙塘段	40%	20%
沙塘符渎段	60%	30%
符渎塘东段	60%	30%
塘东八房段	40%	20%
吴塘于子段	60%	10%
漏河新开段	60%	10%
梅梁湾	60%	10%

To forecast the cyanobacteria blooming site and probability

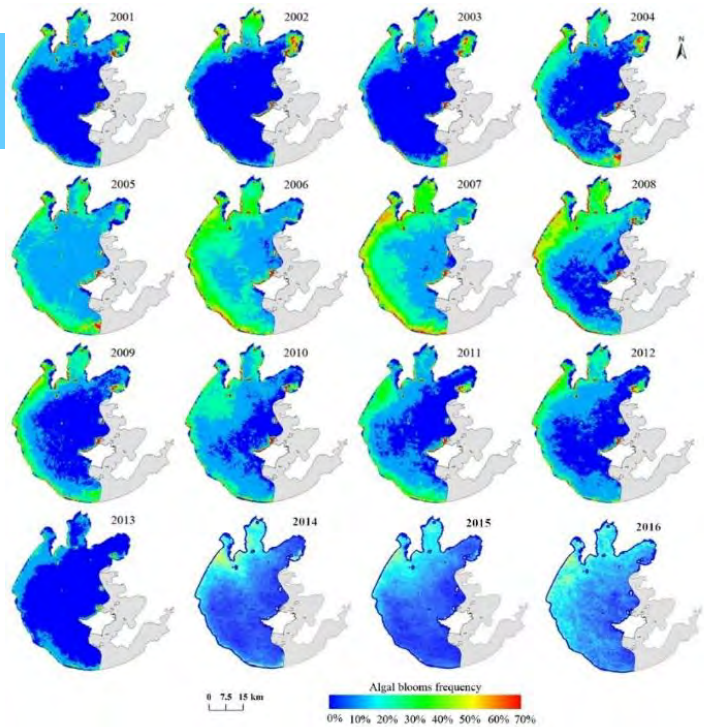
P38

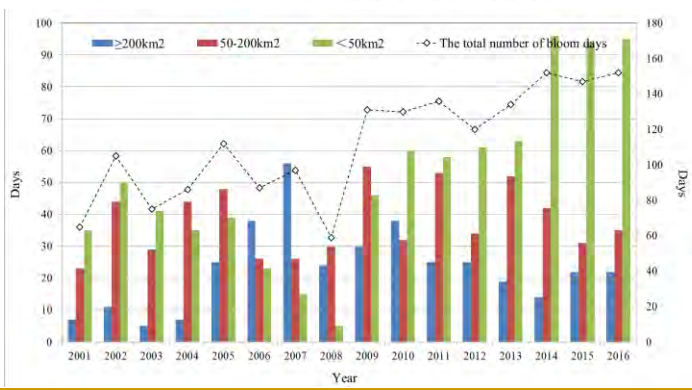
Lake Color/Environment Remote Sensing in China

Long characteristics of algal blooms in Lake Taihu and Lake Chaohu

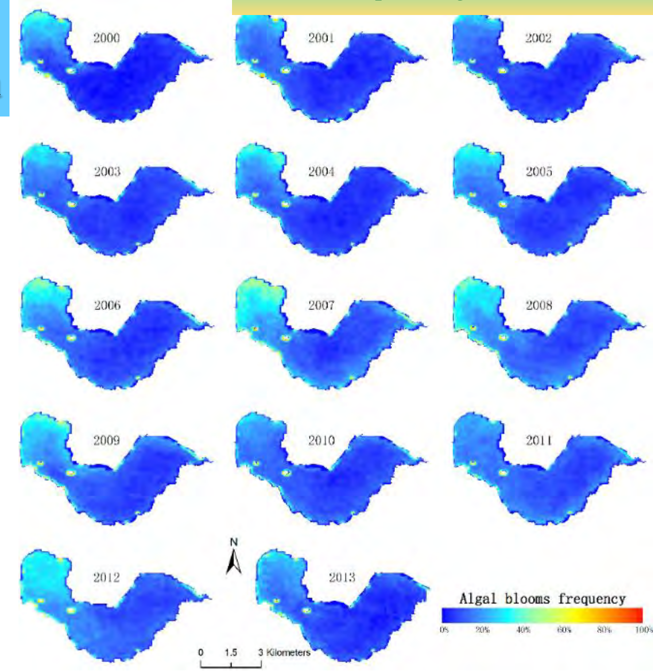
a. to remove the atmospheric effect
b. to remove the covered-cyanobacterial bloom waters
c. to remove the effected-aquatic vegetation waters
d. to implement the optical classification of waters
e. to develop the algorithm of Chl, PC, etc

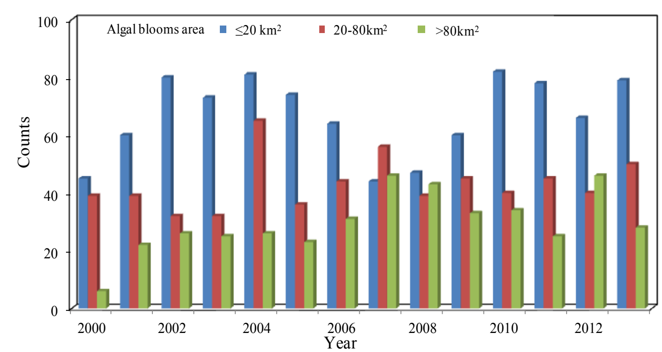
Lake Taihu





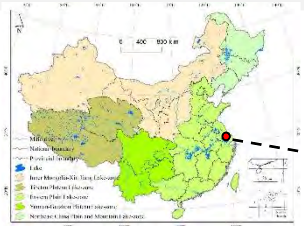
Lake Chaohu



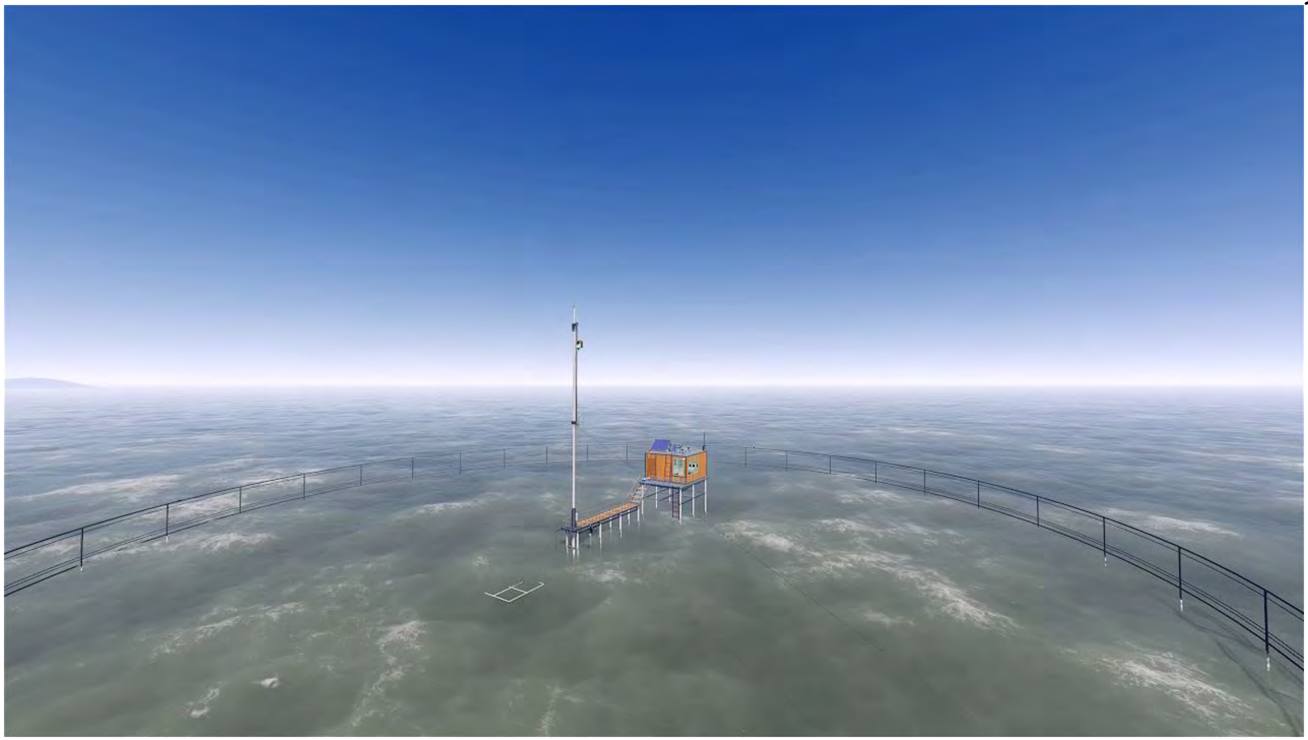


Zhang Y., Ma R., Zhang M., Duan H., Loiselle, S. L., Xu J. Fourteen-Year Record (2000–2013) of the Spatial and Temporal Dynamics of Floating Algae Blooms in Lake Chaohu, Observed from Time Series of MODIS Images. Remote Sensing, 2015,7, 10523-10542
Zhang Y., Ma R., Duan H., Loiselle S. L., Xu J. Satellite analysis to identify changes and drivers of cyanohabs dynamics in lake taihu. Water Science and Technology: Water Supply 2016, ws2016074.

FTP (Field Test Platform) in Lake Taihu for lake color remote sensing

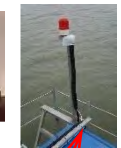


Simulation scene



Control system on the platform

Wind speed/direction instrument



HyperSpec® VNIR (400-1000nm)

In situ photo

HSAS Hyperspectral Above Water System

Underwater instruments:

- HeadWall HyperSpec® VNIR (400-1000nm)
- RAMSES Underwater Hyperspectral (RAMSES-ARC/ACC-UV/VIS)
- HS-6P
- AC-S absorption attenuation meter
- Flow velocity and direction instrument
- On-line water quality monitoring system/Cyclops-7 Submersible Sensors (chl-a, turbidity, water temperature, DO, conductivity, blue-green algae, etc.)

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Thank you