Seasonal, inter-annual and spatial variations in NDVI in Lake Taihu

Yale-NUIST Center on Atmospheric Environment
Yale Univ. and Nanjing Univ. of Infor. Sci. & Tech.
www.yale.edu www.nuist.edu.cn

Deng lichen
2014-09-05

Outline

- Cyanobacteria Blooms in Taihu Lake

[Hu, C. (2010), Moderate Resolution Imaging Spectroradiometer (MODIS) observations of cyanobacteria blooms in Taihu Lake, China. *Journal of Geophysical Research: Oceans*]

- Aquatic Vegetation Changes in Taihu Lake

[Ma, R. (2008), Detecting Aquatic Vegetation Changes in Taihu Lake, China Using Multi-temporal Satellite Imagery. *Sensors*]

- Conclusion

Cyanobacteria Blooms

- Coastal eutrophication is a serious global problem, especially in developing countries where excessive nutrients and other pollutants from rapidly growing agriculture, aquaculture, and industries are delivered to lakes, estuaries, and other coastal waters.
- There has been little published work on establishing a long-term, reliable record of phytoplankton blooms in any estuaries based on satellite data alone.

Study Area

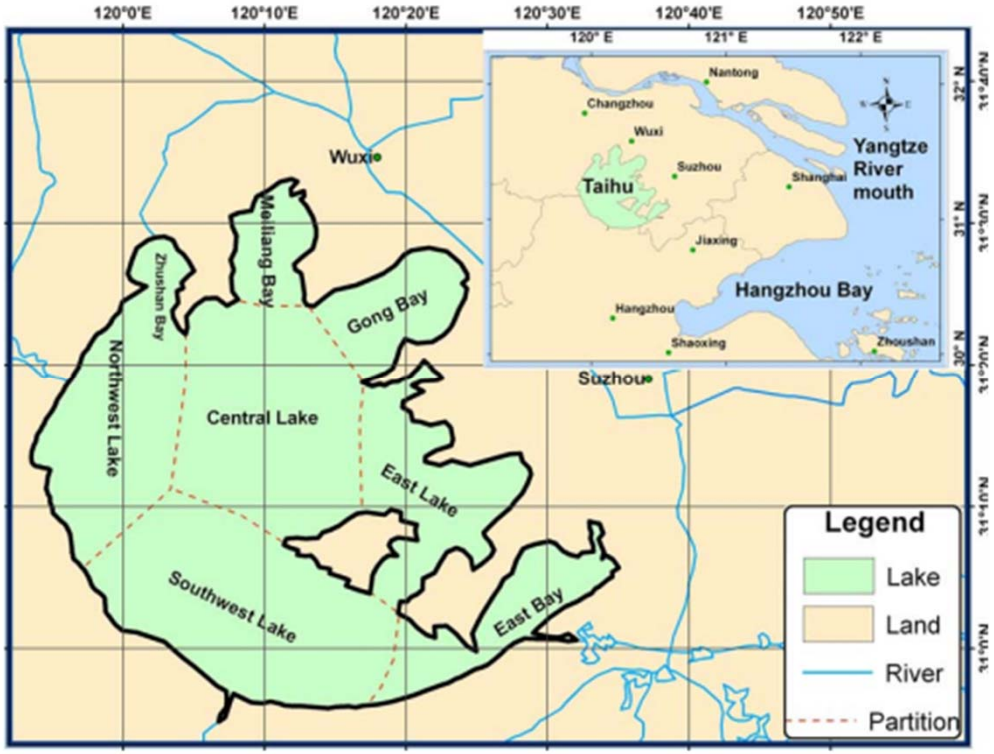

Figure 1. The lake is characterized by seven major segments, including four embayments: Zhushan Bay, Meiliang Bay, Gong Bay, and East Bay[*Hu et al. , 2010*]

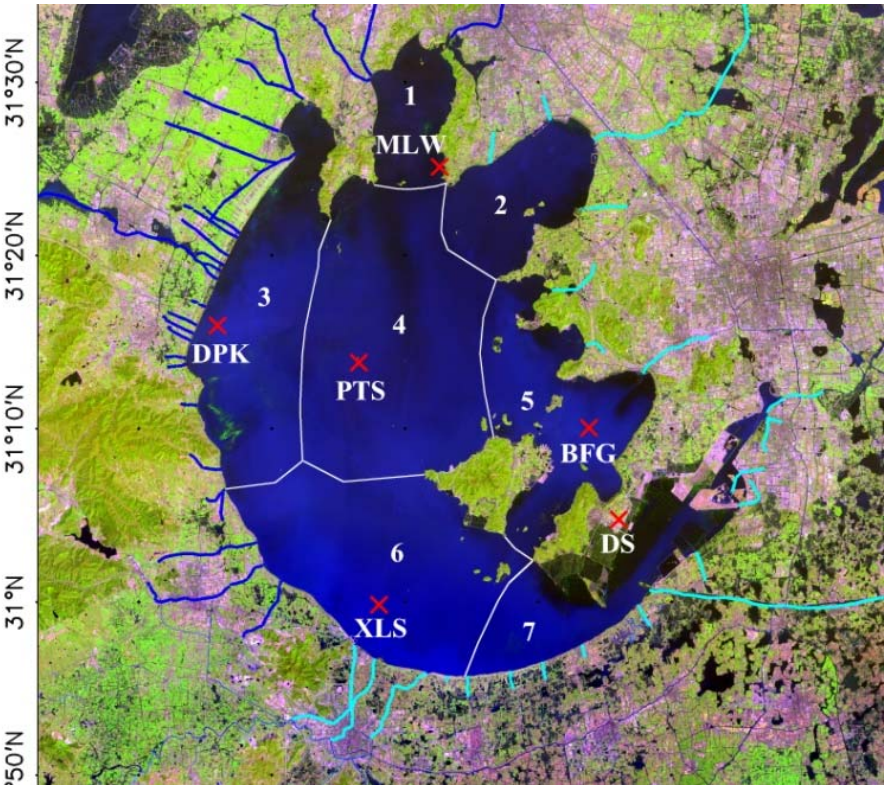

Figure 2. Location of Taihu Lake, China.

How to extract cyanobacteria?

- NDVI = $[R_{rc}(859) - R_{rc}(645)]/[R_{rc}(859) + R_{rc}(645)]$
- FAI = $R_{rc}(859) - R'_{rc}(859)$

$R'_{rc}(859) = R_{rc}(645)+[R_{rc}(1240)-R_{rc}(645)](859-645)/(1240-645)$

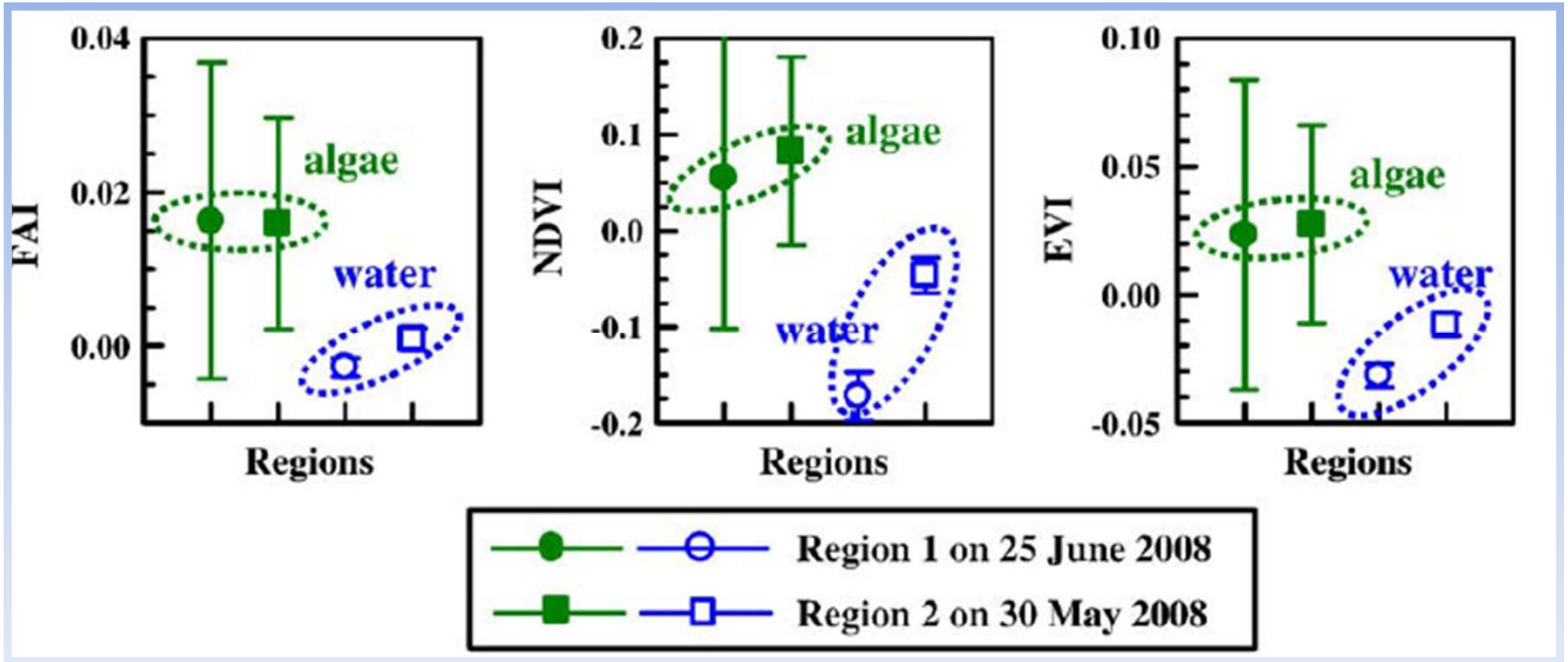

Fig 3. Mean and standard deviation of various index values over floating algae pixels and water pixels in two regions of the Yellow Sea Bay[*Hu et al. , 2009*]

2. Satellite data

(1) MODIS , 250 and 500 m, 1-day, level 0 (raw digital counts),2000-2008. [*Hu et al. , 2010*]

(2) MODIS , 1000m , 16-days, level 3 (Product Data),2003-2013. [*In my stduy*]

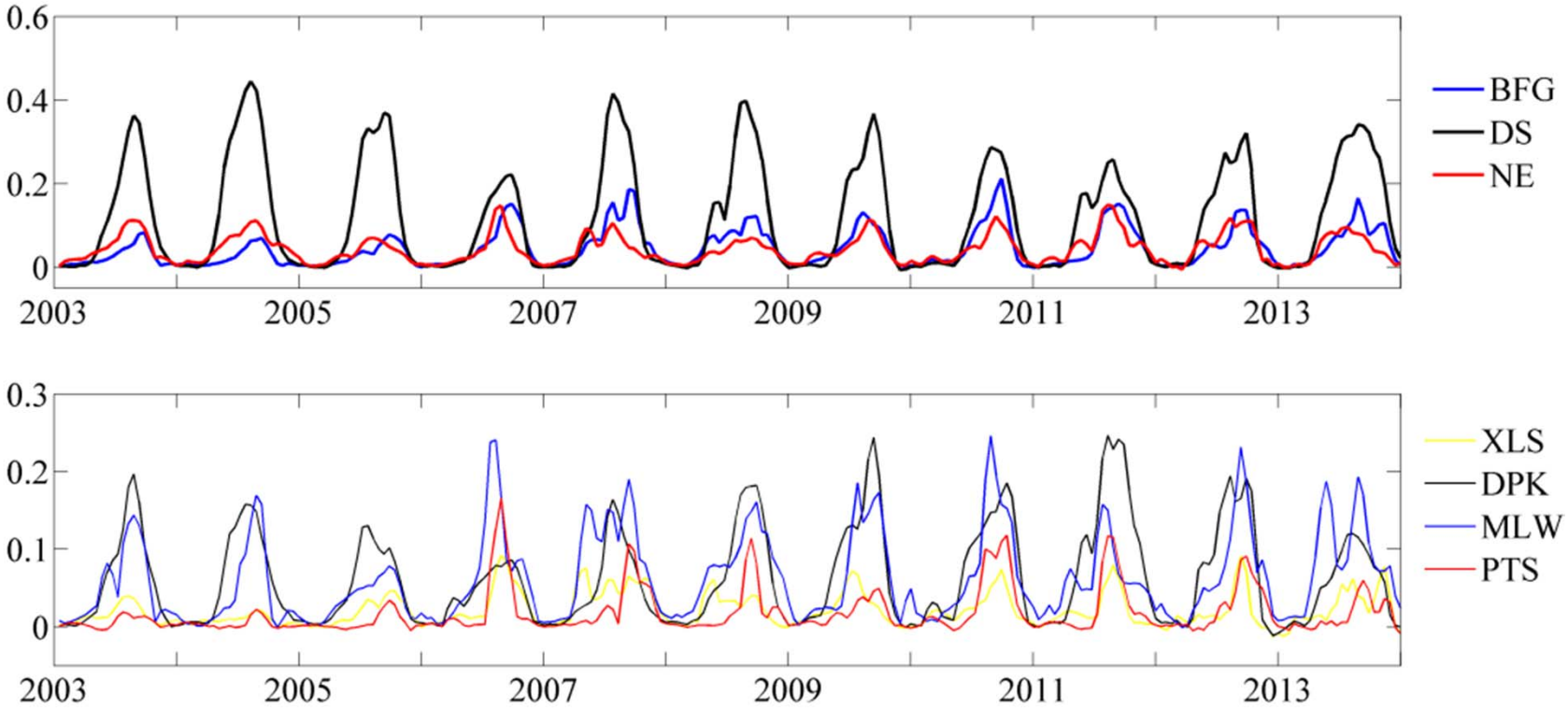

Fig 4. The 16-days changes of NDVI(mean) for each lake segment**.**

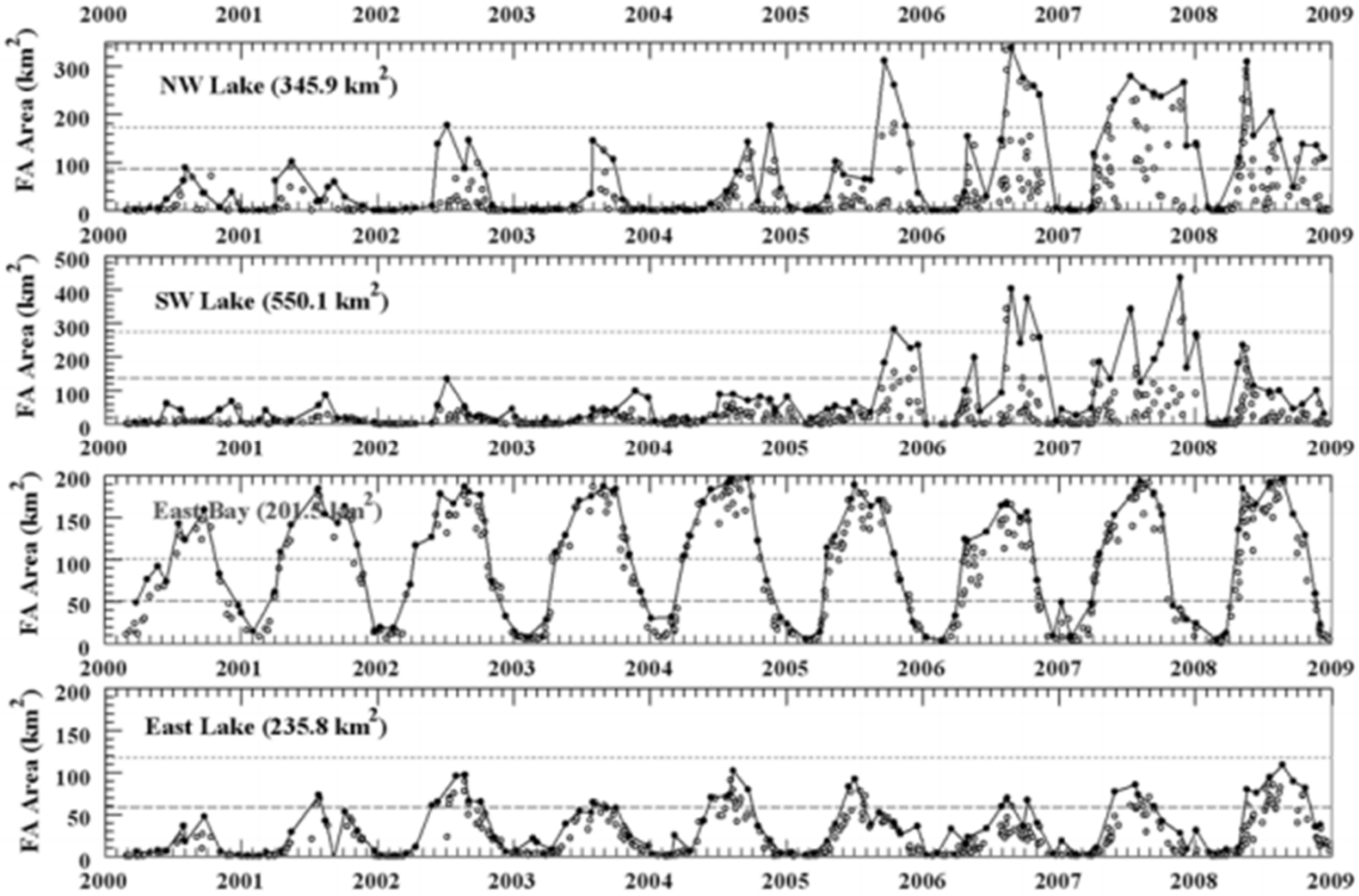

Figure 5(a). Daily area coverage of floating algae (i.e., cyanobacteria bloom) for each lake segment and for the entire Taihu Lake. The dashed and dotted lines represent 25% and 50% of the lake segment area, respectively. [*Hu et al., 2010*]

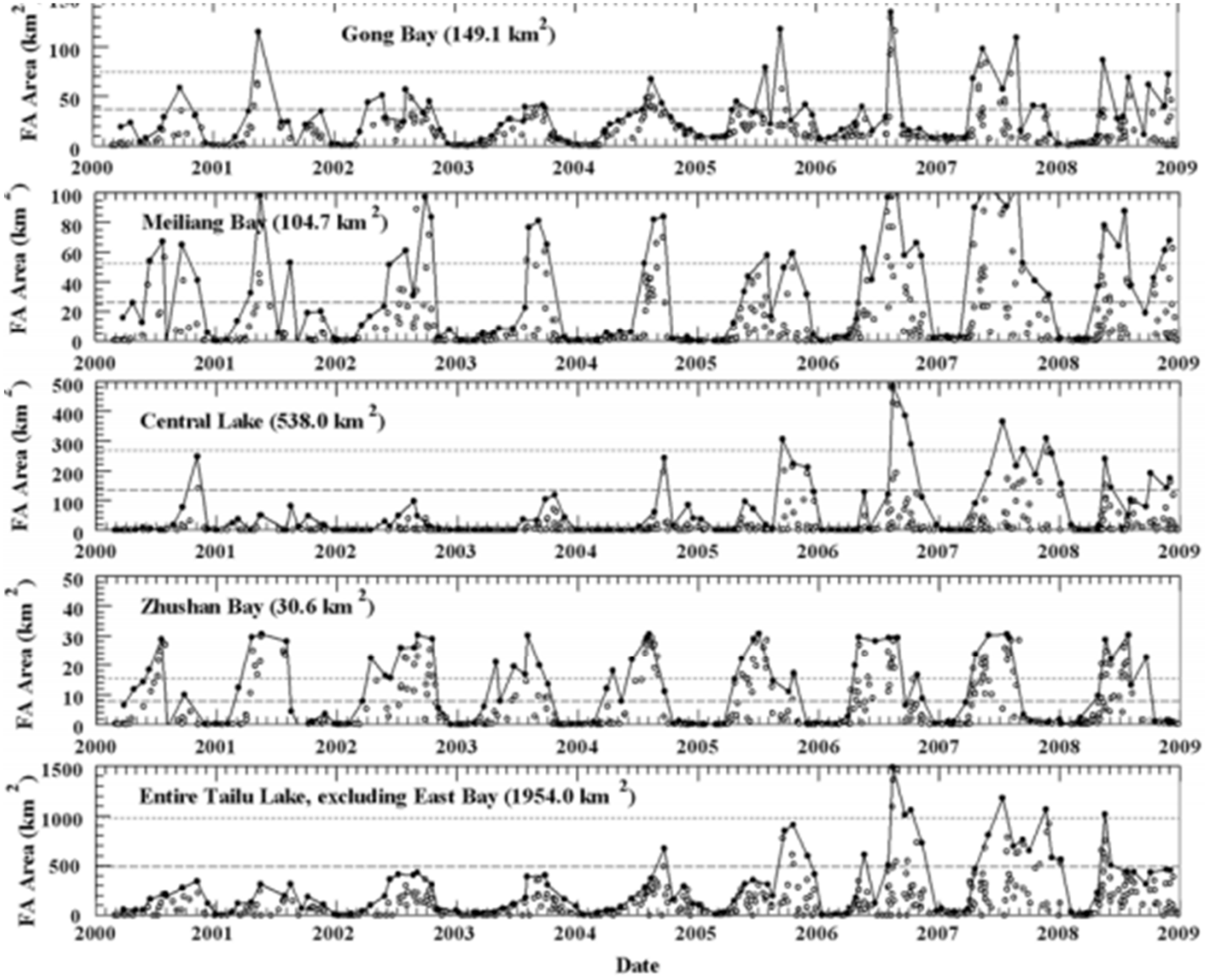

Figure 5(b). Daily area coverage of floating algae (i.e., cyanobacteria bloom) for each lake segment and for the entire Taihu Lake. [*Hu et al. , 2010*]

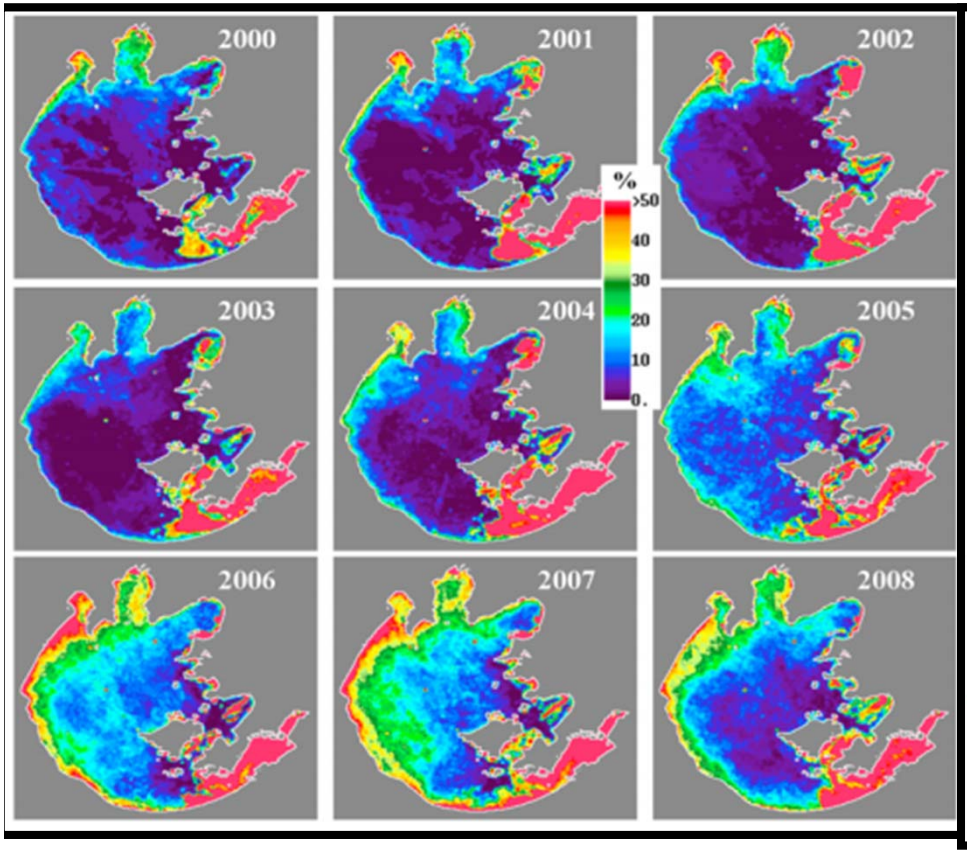

Figure 6. Percentage of MODIS measurements when cyanobacteria blooms (FAI > −0.004) were found from MODIS FAI imagery. [*Hu et al., 2010*]

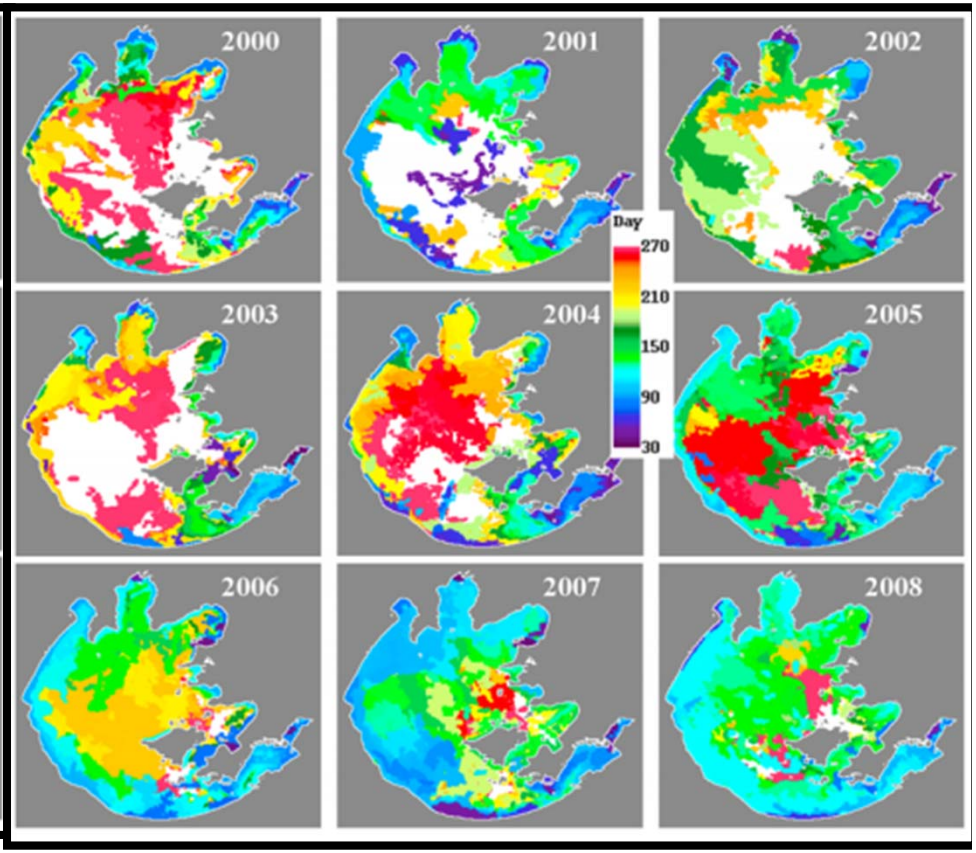

Figure 7. Timing of cyanobacteria blooms during each year after January. For each location (pixel), the first day when cyanobacteria bloom (FAI > −0.004) appeared was color-coded. White represents no bloom for the entire year. [*Hu et al., 2010*]

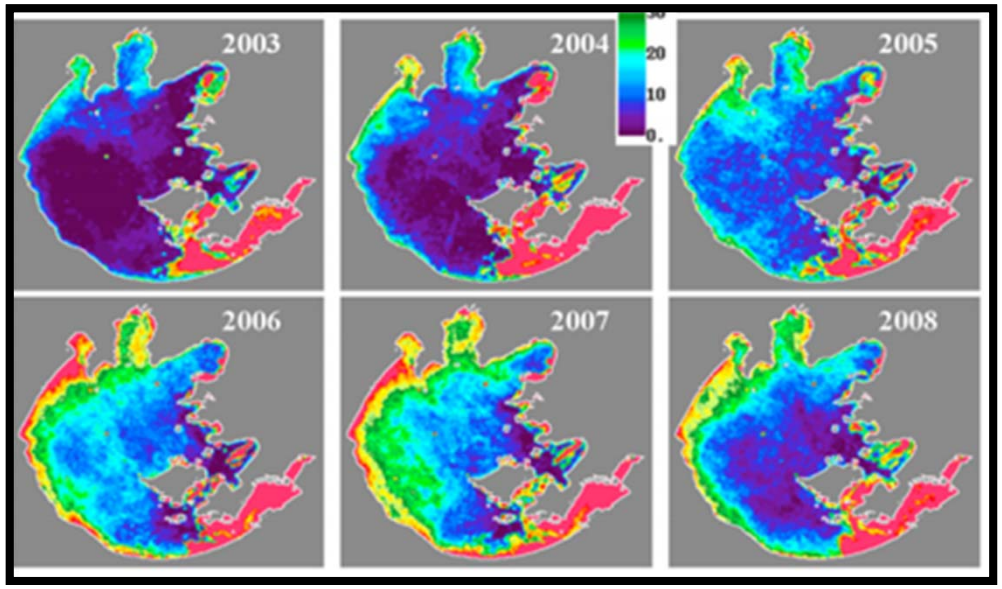

Figure 8. Percentage of MODIS measurements when cyanobacteria blooms (FAI > −0.004) were found from MODIS FAI imagery. [*Hu et al., 2010*]

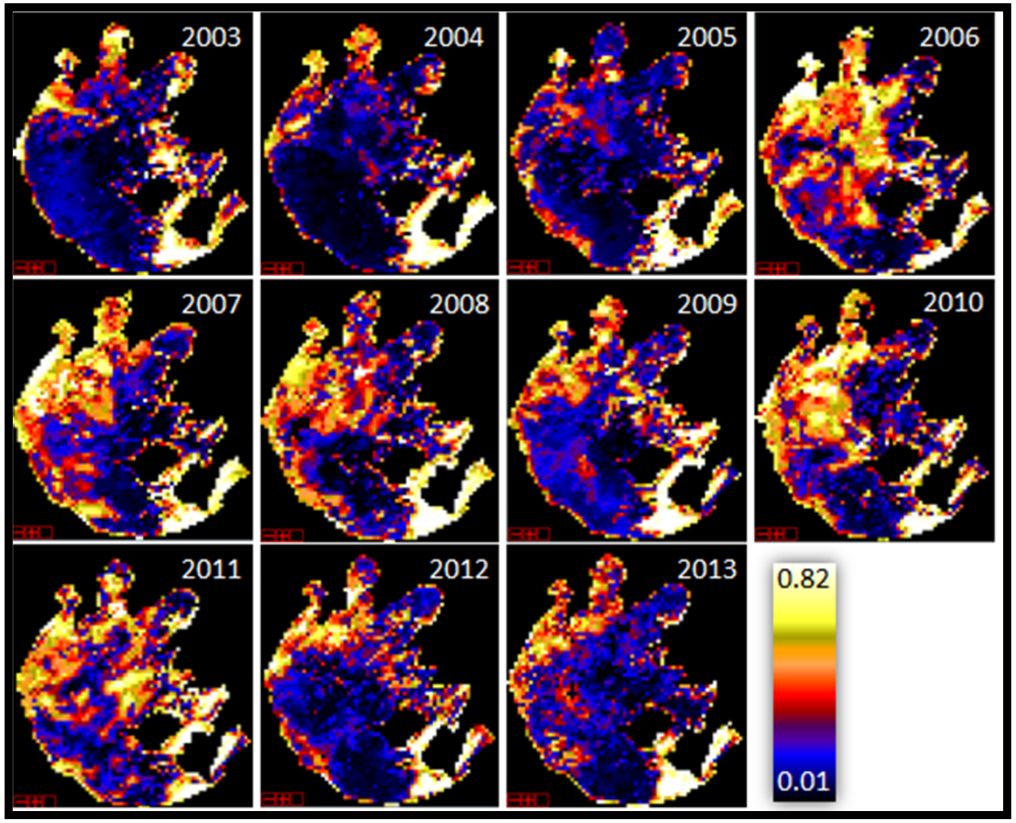

Figure 9. Inter-annual and spatial variations in NDVI in Lake Taihu

Table 1. Timing and Duration of Significant Cyanobacteria Blooms in Each Lake Segment [*Hu et al. , 2010*]

	Northwest Lake		Southwest Lake		East Bay[b]		East Lake[c]		Gong Bay[c]		Meiliang Bay		Central Lake		Zhushan Bay		Taihu Lake[d]	
Year	Starting Days	Duration	Starting Days	Duration	Starting Days	Duration	Starting Days	Duration	Starting Days	Duration	Starting Days	Duratio	Starting Days	Duration	Starting Days	Duration	Starting Days	Duration
2000	214	1	−1	0	114	197	−1	0	262	1	159	152	308	3	114	154	−1	0
2001	132	3	−1	0	88	241	202	10	123	14	106	120	−1	0	65	147	−1	0
2002	162	108	−1	0	78	254	146	131	103	187	162	127	−1	0	78	220	−1	0
2003	213	55	−1	0	105	243	213	30	213	62	213	62	−1	0	116	159	−1	0
2004	261	74	−1	0	86	242	163	100	215	48	204	59	261	2	86	177	261	2
2005	132	202	262	92	104	228	167	45	123	209	142	190	257	77	110	181	257	77
2006	122	192	139	175	109	204	212	69	139	101	139	175	224	57	97	217	139	175
2007	94	274	94	274	94	200	149	106	110	216	108	227	149	194	94	149	139	204
2008	116	230	115	27	109	215	138	158	138	208	119	227	138	200	116	148	128	30

b Results in East Bay are mainly from aquatic vegetation, not cyanobacteria.

c In these lake segments the results come from both cyanobacteria blooms and some aquatic vegetation [*Ma et al., 2008b*].

d Taihu Lake is defined as the entire lake excluding East Bay for its prevailing aquatic vegetation.

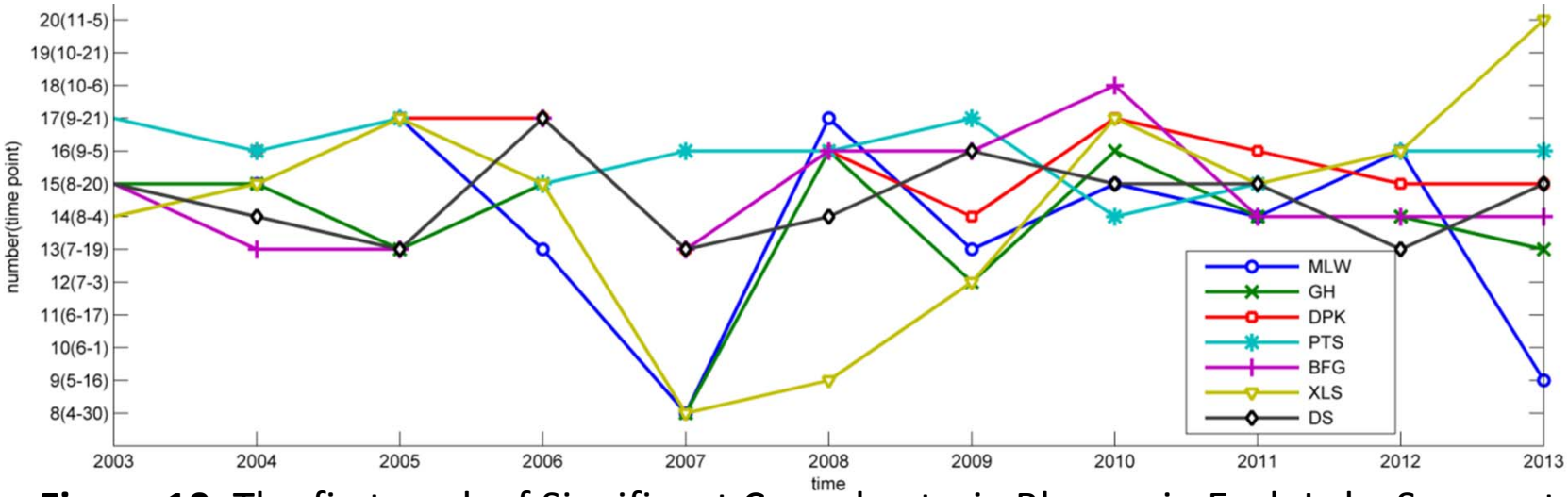

Figure 10. The first peak of Significant Cyanobacteria Blooms in Each Lake Segment

Table 2. Mean and Standard Deviation of Annual Coverage of Cyanobacteria Blooms in Each Lake Segment[*Hu et al. , 2010*]

	Northwest Lake	Southwest Lake	East Bay[b]	East Lake[c]	Gong Bay[c]	Meiliang Bay	Central Lake	Zhushan Bay	Taihu Lake[d]
Total Area (km^2)	346	550	202	236	149	105	538	31	1954
2000	30 (30)	28 (26)	94 (40)	15 (16)	22 (17)	32 (26)	40 (82)	11 (10)	165 (103)
2001	31 (33)	25 (26)	104 (61)	22 (25)	24 (33)	22 (30)	24 (26)	9 (13)	136 (108)
2002	54 (67)	30 (39)	112 (67)	41 (37)	26 (20)	32 (33)	21 (30)	15 (12)	199 (173)
2003	28 (47)	33 (30)	113 (70)	35 (22)	19 (15)	23 (32)	28 (42)	11 (10)	154 (140)
2004	44 (59)	46 (32)	122 (67)	39 (35)	26 (18)	20 (32)	38 (70)	11 (12)	191 (190)
2005	94 (103)	106 (97)	99 (68)	36 (29)	38 (32)	26 (23)	91 (104)	12 (12)	354 (297)
2006	124 (127)	143 (148)	96 (66)	32 (24)	28 (35)	42 (38)	129 (168)	14 (13)	483 (502)
2007	161 (113)	176 (127)	104 (70)	37 (32)	43 (37)	52 (43)	172 (130)	13 (14)	581 (391)
2008	126 (84)	104 (85)	106 (76)	54 (37)	35 (31)	39 (32)	109 (77)	10 (12)	408 (259)

b Results in East Bay are mainly from aquatic vegetation, not cyanobacteria.

c In these lake segments the results come from both cyanobacteria blooms and some aquatic vegetation [*Ma et al., 2008b*].

d Taihu Lake is defined as the entire lake excluding East Bay for its prevailing aquatic vegetation.

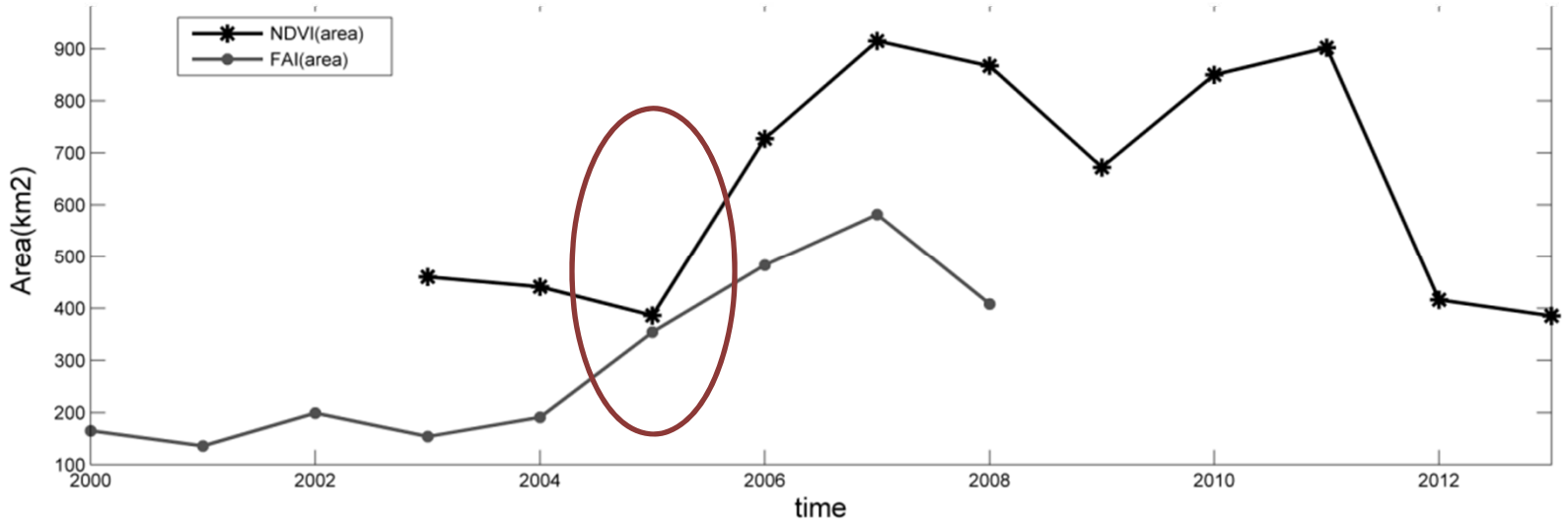

Figure 10. Annual Coverage of Cyanobacteria Blooms in Each Lake Segment(NDVImax>0.4)

Aquatic Vegetation Changes

Aquatic vegetation, generally existing in the shallow near-shore area, is a key component of lake ecosystems. It plays an important role in maintaining a clean lake water quality by stabilizing sediments and providing a substrate for periphyton that actively removes nitrogen and phosphorus from the water column. It almost becomes a token indicator to determine whether the water quality can be expected to be good or not.

1. Field data

The campaign was carried out along the preset transects for 94 samples on 10-18 June 2007

2. Satellite data

(1)IRS P6 (Indian Remote Sensing Satellite Resourcesat-1) LISS-3 (Linear Imaging Self-Scanning Sensor-3) image with a spatial resolution of 23.5 m;

(2)Landsat TM images, with a spatial resolution of 30 m, with hardly any cloud cover.

3. *Image classification*

the aquatic vegetation zone is divided into two types:

(a) Type one, including the floating-leaved and emergent vegetation, named a floating vegetation-dominated zone;

(b) Type two, submerged and floating vegetation, named as the submerged vegetation-dominated zone.

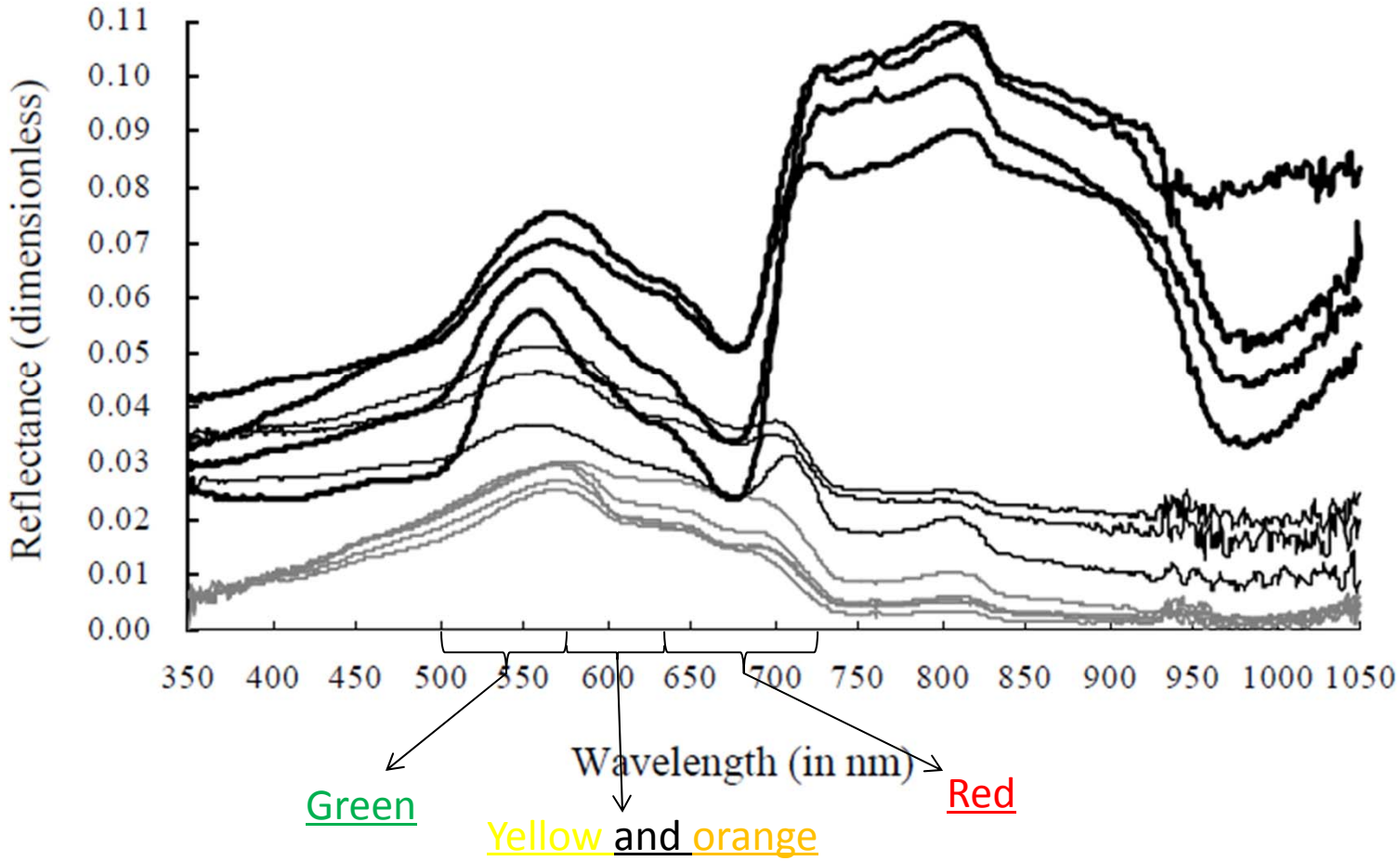

Figure 11. Comparisons between remote sensing reflectance only due to water (the thin gray curves), reflectance due to Type one (the thick black curves), reflectance due to Type two (the thin black curves), all of which were measured in situ. [*Ma et al. , 2008*]

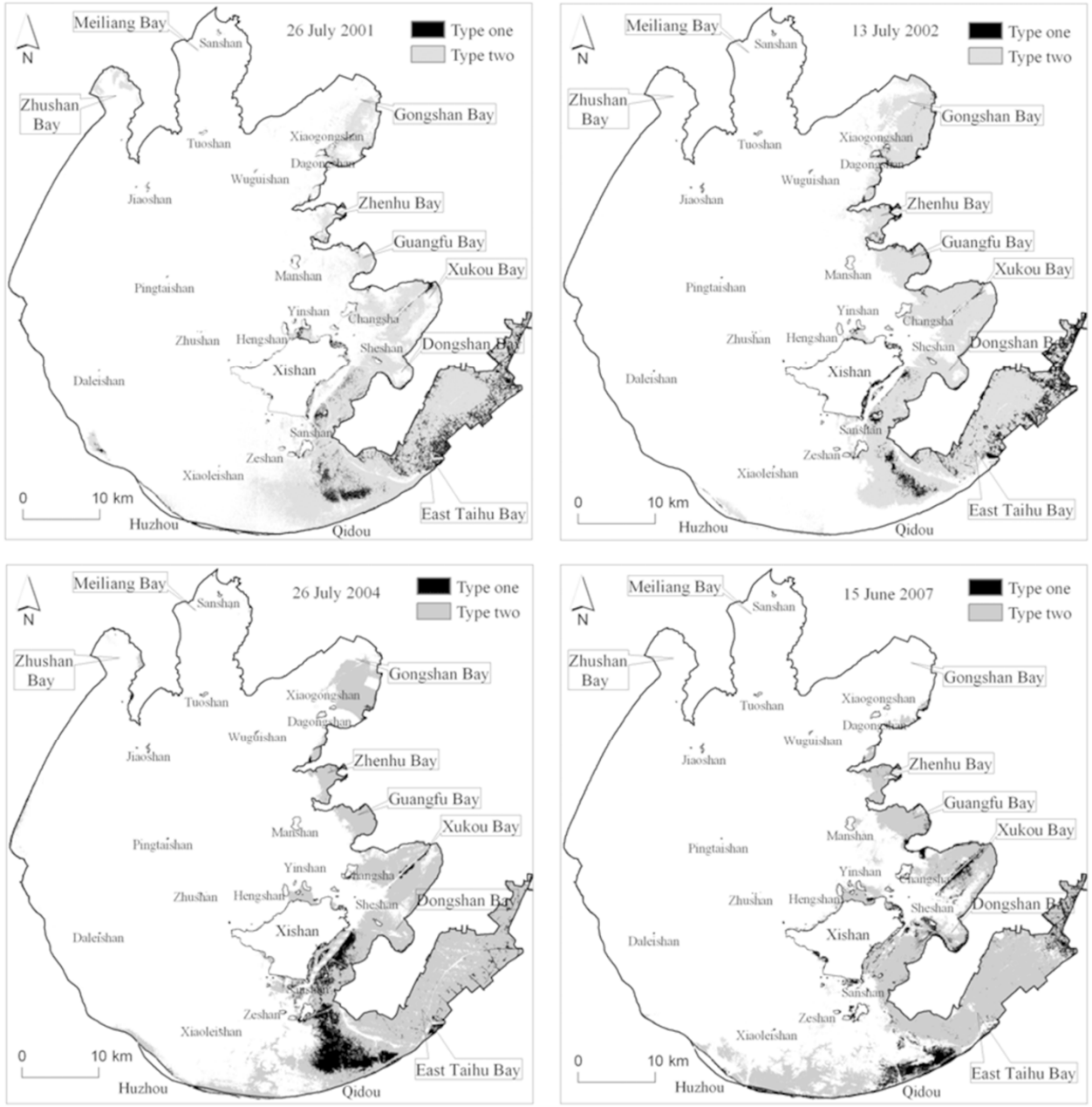

Figure 12. Spatial distribution of the aquatic vegetation except Phragmites communi on 26 July 2001, 13 July 2002, 26 July 2004, and 16 June 2007; Type one and Type two, respectively, are the floating vegetation-dominated hydrophyte, and the submerged vegetation-dominated hydrophyte. [*Ma et al. , 2008*]

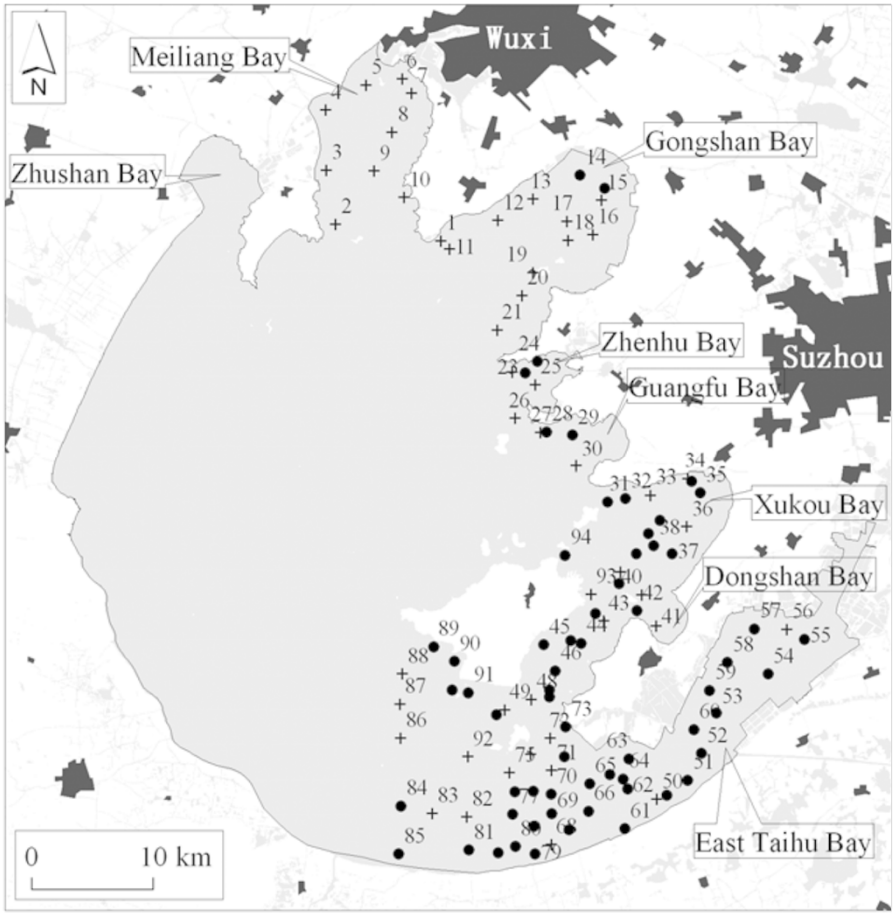

Figure 13. Locations of field samples investigated on 10-19 June 2007; there is aquatic vegetation in the black circle samples and there isn't in the cross samples. [*Ma et al. , 2008*]

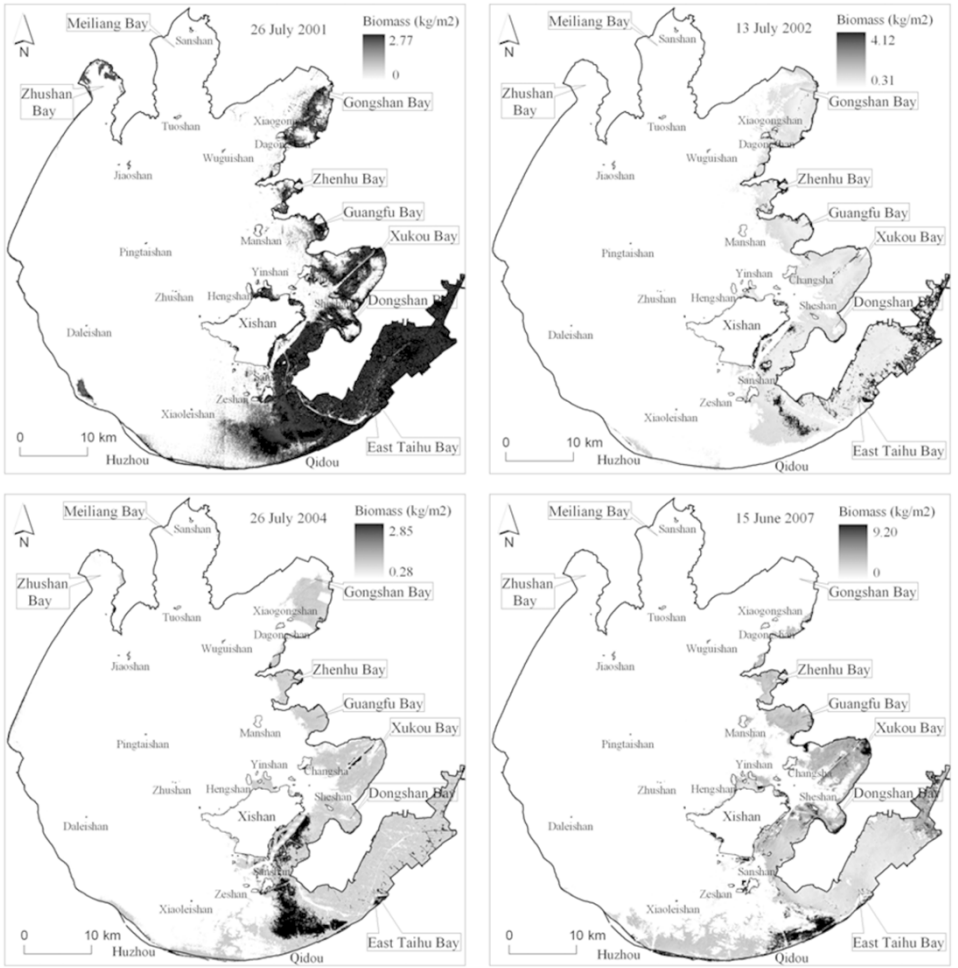

Figure 14. The satellite-estimated biomass of aquatic vegetation on 26 July 2001, 13 July 2002, 26 July 2004, and 16 June 2007. [*Ma et al. , 2008*]

Table 3. The covering area of aquatic vegetation and its biomass in Taihu Lake, no containing *Phragmites communi*; [*Ma et al. , 2008*]

Date	Type one (km^2)	Type two (km^2)	Total area (km^2)	Total biomass (thousand ton)
15 June 2007	72.4	291.7	364.1	406
26 July 2004	89.1	393.1	482.2	528
13 July 2002	71.7	380.0	451.7	482
26 July 2001	75.8	378.8	454.6	489

The satellite image classification shows in Taihu Lake that the aquatic vegetation has undergone a great spatial change since 2001. The coverage area in both 2001 and 2002 were basically constant around 450 km^2, and in 2004 increased up to 482 km^2. However in 2007, it decreased rapidly to 361 km2. The vegetation in Gongshan Bay, Zhenhu Bay, Guangfu Bay and Xukou Bay were spreading around in 2001-2002; however in 2002-2004, they began to move back towards to the bay interior or one side of the shore.

Conclusion

1. Data quality has a significant impact on analysis of results.

2. It is not only dependent on the quality of the raw data that obtain high quality .

3. How about the status of aquatic vegetation and the cyanobacteria in Taihu Lake in higher resolution products (e.g. MODIS 250 m).


Thank You!