RADI 中国科学院遥感与数字地球研究所 Institute of Remote Sensing and Digital Earth, CAS

AquaWatch The GEO Water Quality Initiative GloboLakes

August 2018
Stirling

Trophic state assessment of global large inland waters using the MODIS-derived FUI

Shenglei Wang
Junsheng Li & Bing Zhang
Evangelis Spyrakos & Andrew N. Tyler

- **RADI, Chinese Academy of Sciences**
- **BES, University of Stirling**

Background:

Eutrophication represents a serious global environmental problem

Three classes:

oligotrophic, mesotrophic, eutrophic

Five related variables:

Chl-a, SD, TP, TN, COD

Trophic state assessment method:

TSI (Carlson, 1977)

TLI (Burns and Bryers, 2000)

Global remote sensing of inland waters are facing many challenges

i.e. **Optical complexity;**

Algorithm applicability;

Mission Capacity;

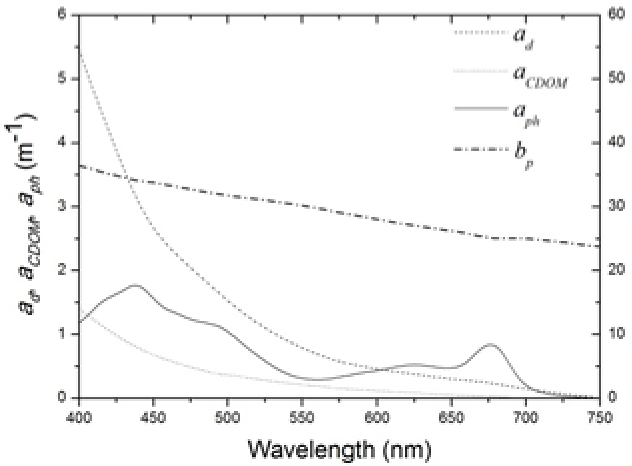
Atmospheric correction…

Lack of global EO product for lake trophic state

Background:

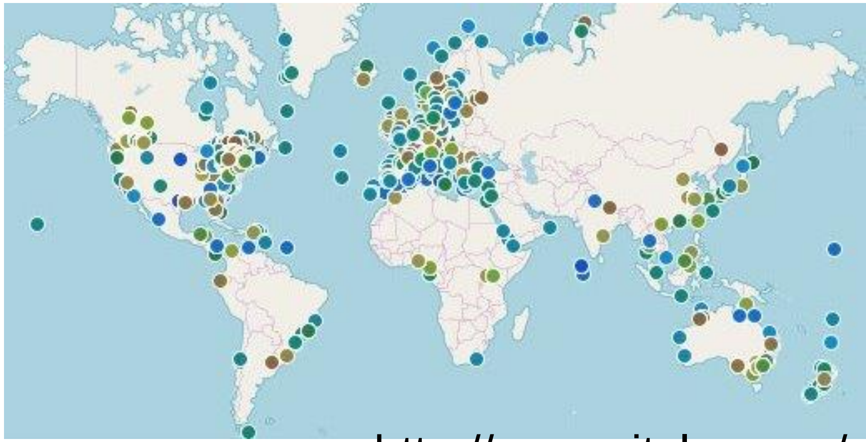
Water colour of inland waters varies in a wide range

IOPs



Water colour could play an important role

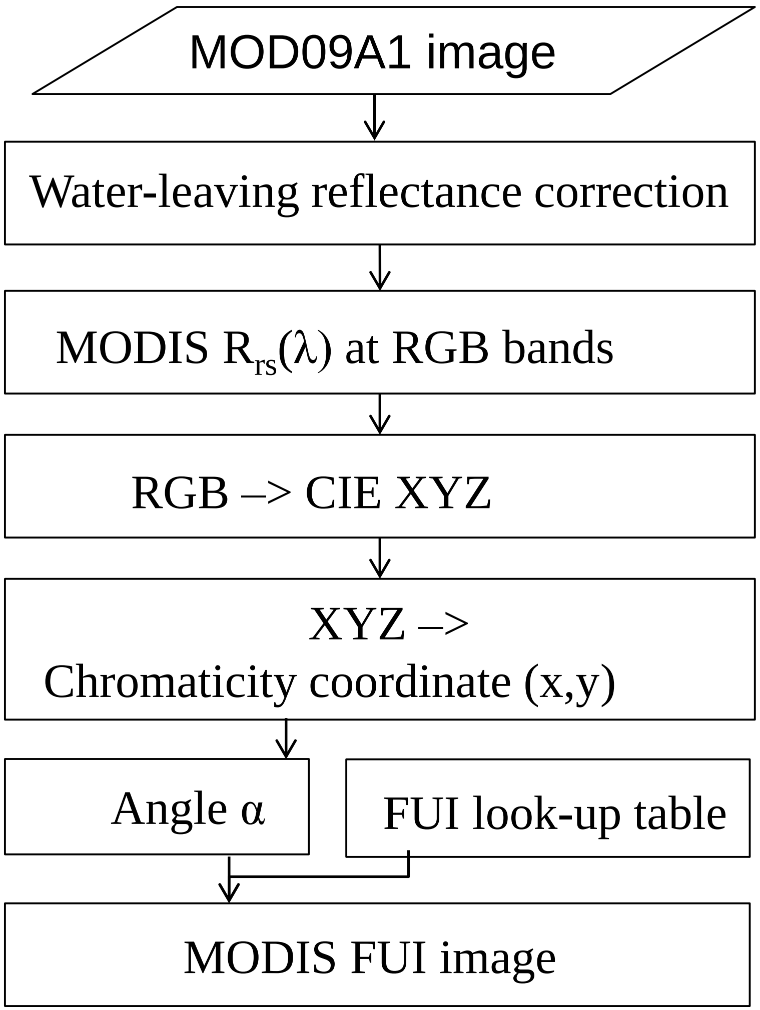
Forel-Ule color scale



http://monocle-h2020.eu/Home

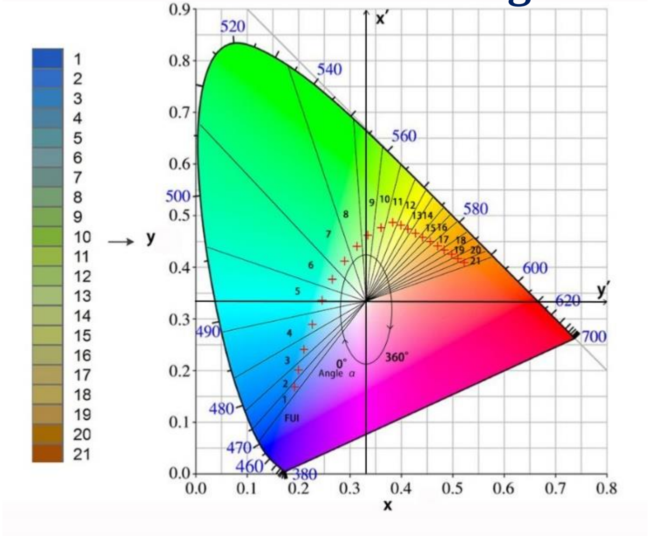
http://www.citclops.eu/

FUI retrieval from MODIS surface reflectance product (MOD09)

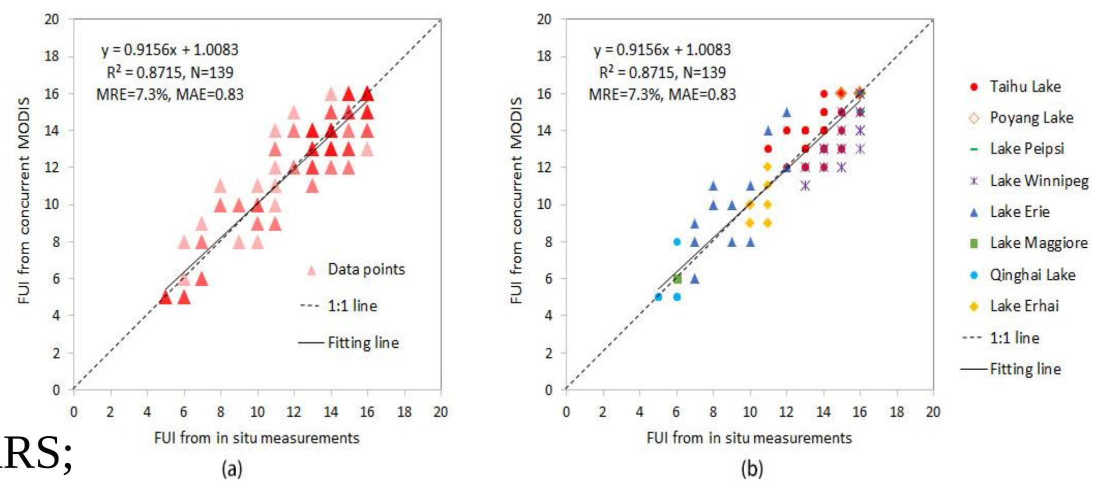


FUI retrieval scheme from MODIS surface reflectance product (MOD09).

FUI division in CIE diagram

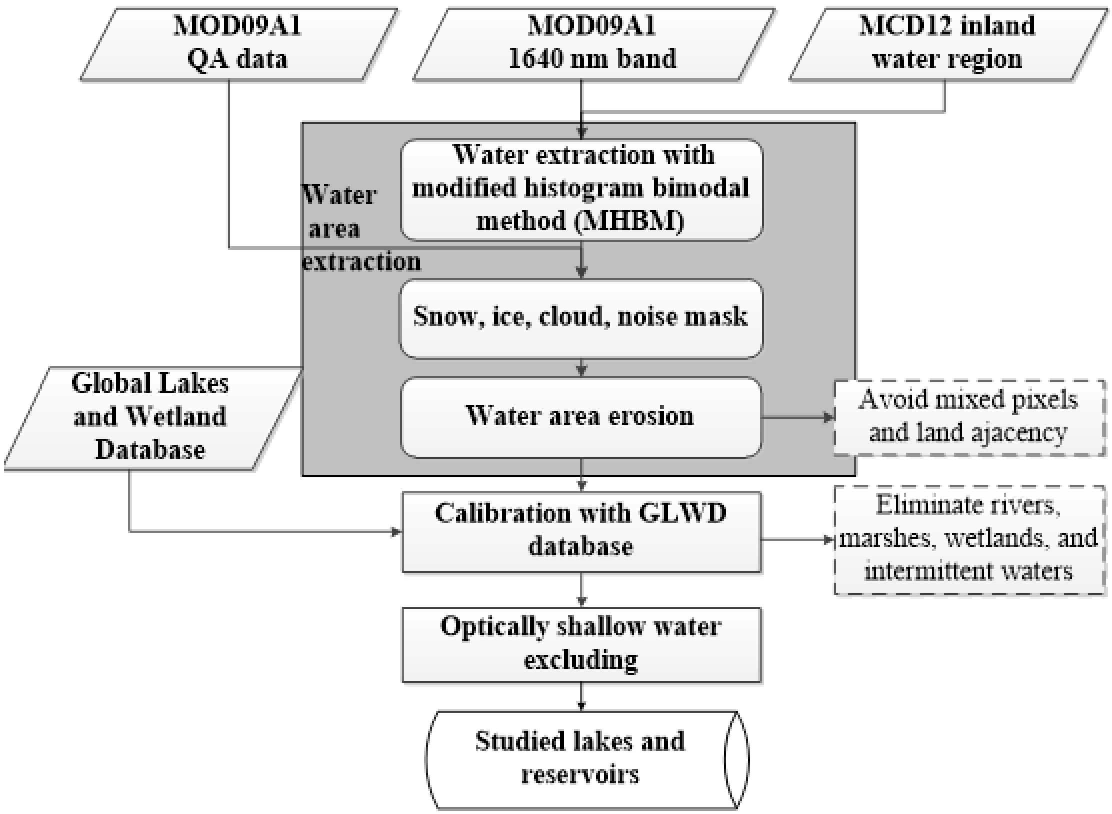


Comparison between concurrent MODIS FUI and in-situ FUI **MRD = 7.3%,**



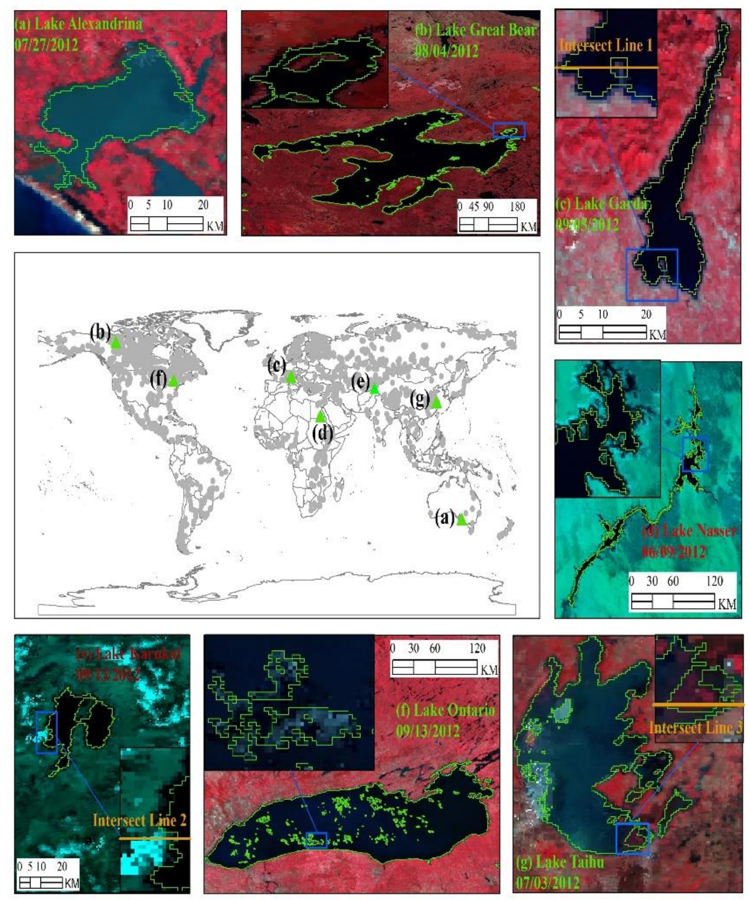
Wang, S., Li, J., et al. (2015). IEEE JSTARS;
Wang, S., Li, J., et al. (2016). International Journal of Remote Sensing.

Water body extraction and identification from MODIS



Flowchart of water body extraction and calibration from MOD09A1

Shorelines of water bodies extracted

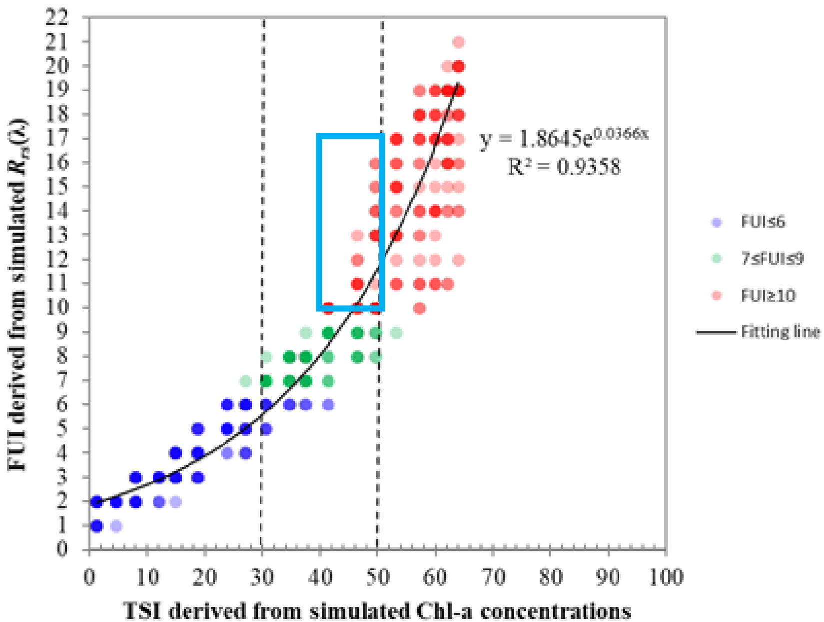


Totally 2058 large lakes (> 25 km²) in the summer of 2012 were identified and extracted.

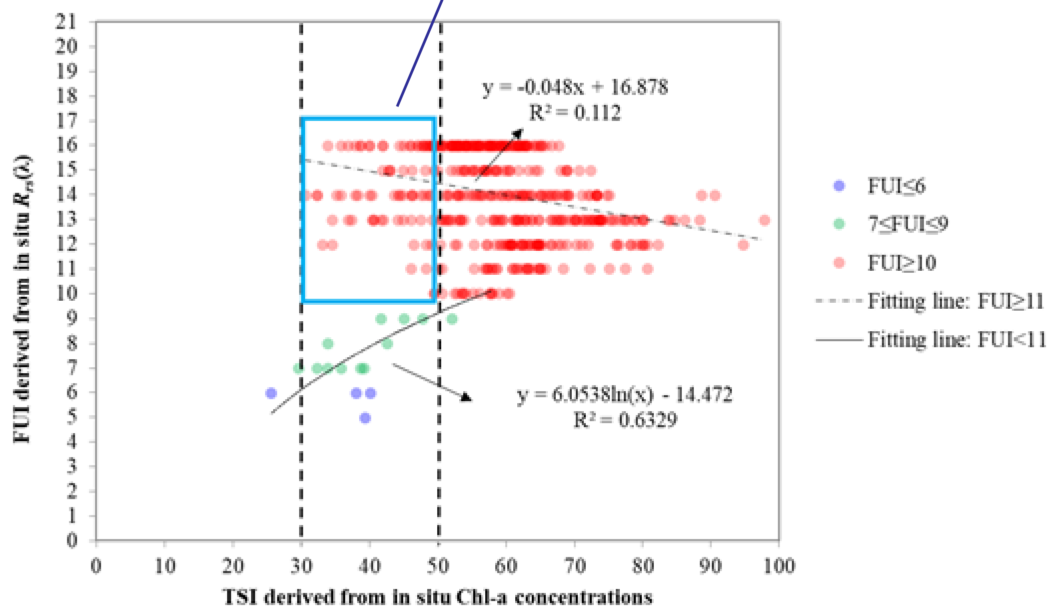
Relationship built between FUI and TSI(Chl-a)

Lake	Latitude	Longitude	Chl-a	N	Data Source
Lake Maggiore	46.01 N	8.67 E	2.41	3	In-situ (Giardino et al., 2013)
Lake Winnipeg	51.9 N	97.3 W	5.33	58	In-situ (Binding et al., 2013)
Lake Erie	41.9 N	82.1 W	9.34	24	In-situ (Binding et al., 2013)
Lake Peipsi	58.47 N	27.34 E	17.95	26	In-situ (Kutser et al. 2013)
Lake Erhai	25.86 N	100.15 E	19.11	21	In-situ
Yuqiao Reservoir	40.04 N	117.55 E	20.73	13	In-situ
Guanting Reservoir	40.35 N	115.73 E	26.8	31	In-situ
Taihu Lake	31.20 N	120.18 E	42.6	239	In-situ
Chaohu Lake	31.55 N	117.57 E	64.47	29	In-situ
Dianchi Lake	24.82 N	102.71 E	85.2	25	In-situ

Most of the points in the cyan box dominated by CDOM, and some of them dominated by high suspended sediments

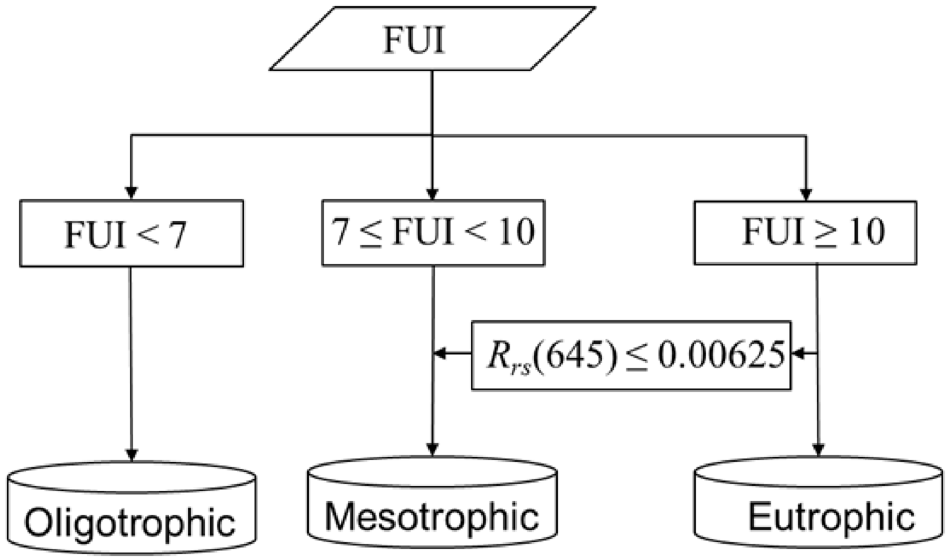


Scatterplot of FUI and TSI(Chl-a) based on **simulated dataset** (IOCCG, 2006).

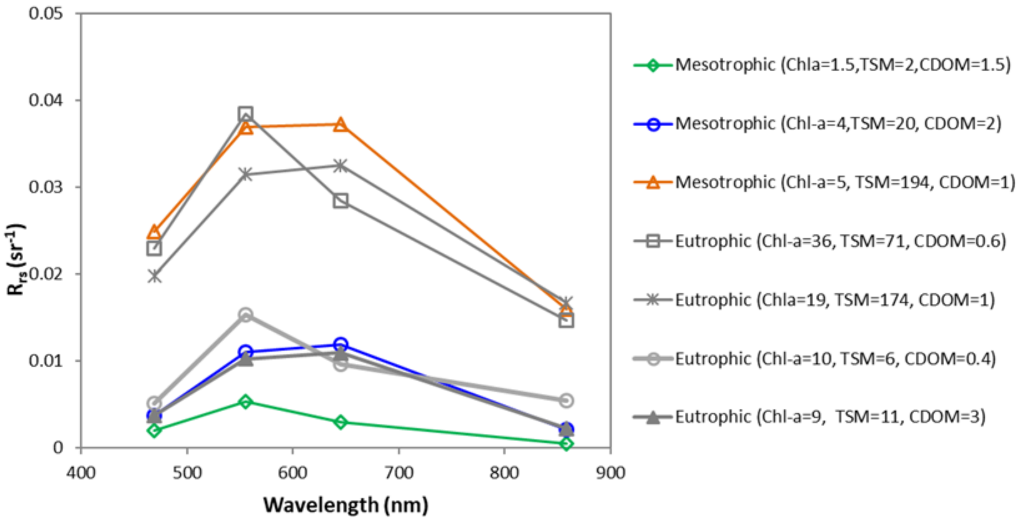


Scatterplot of FUI and TSI(Chl-a) based on **in situ measurements from 10 lakes around the world**.

Trophic state assessment decision tree based on FUI and $R_{rs}(645)$



Modelling accuracy is 87%, based on the in situ dataset



Through analysis, it shows that the confusing mesotrophic state points mainly in three situations:

- High CDOM with low TSM
- High CDOM with relatively high TSM
- High TSM

But the MODIS can only identify the first situation with Rrs(645)<0.00625.

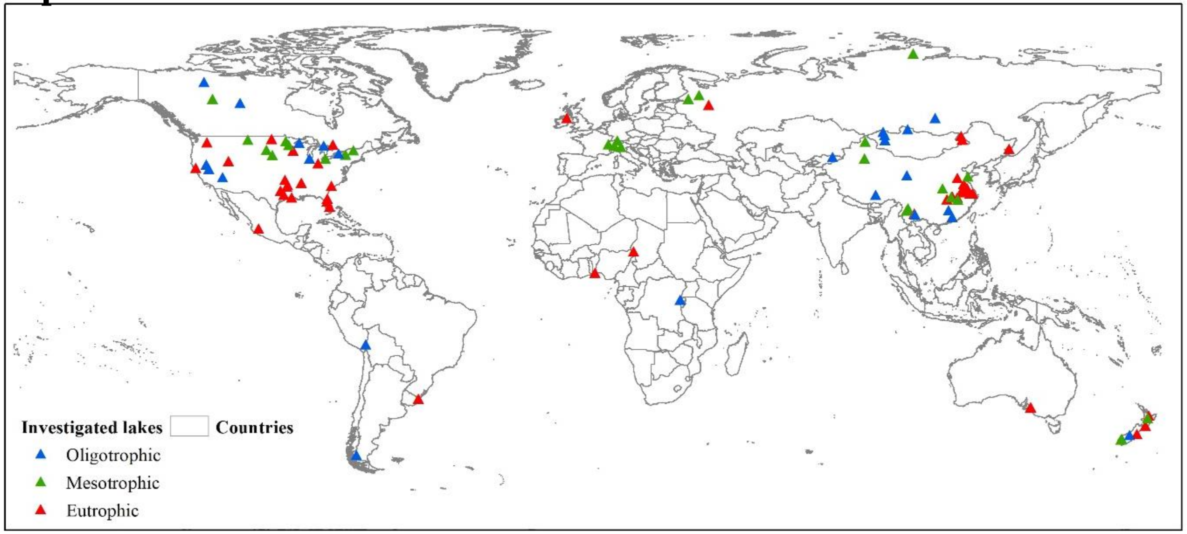
Results: Trophic state validation with independent data

Published studies and online reports:

i.e. China Environmental State Bulletin (MEPPRC, 2012),

the National Lake Assessment from the US Environmental Protection Agency (USEPA, 2016).

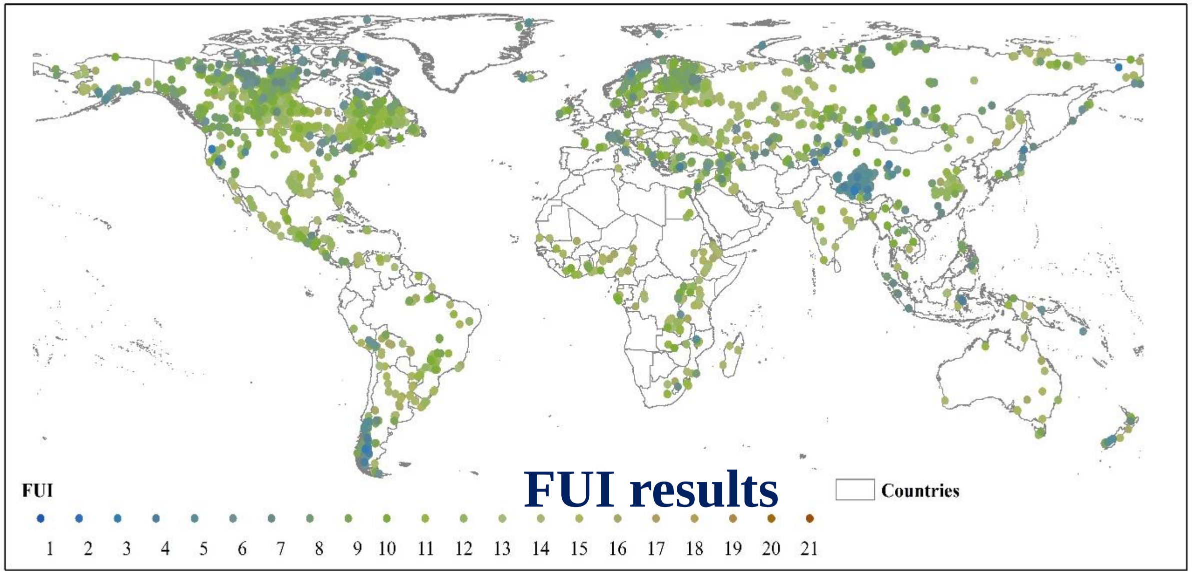
Spatial distribution of the 100 water bodies used for validation



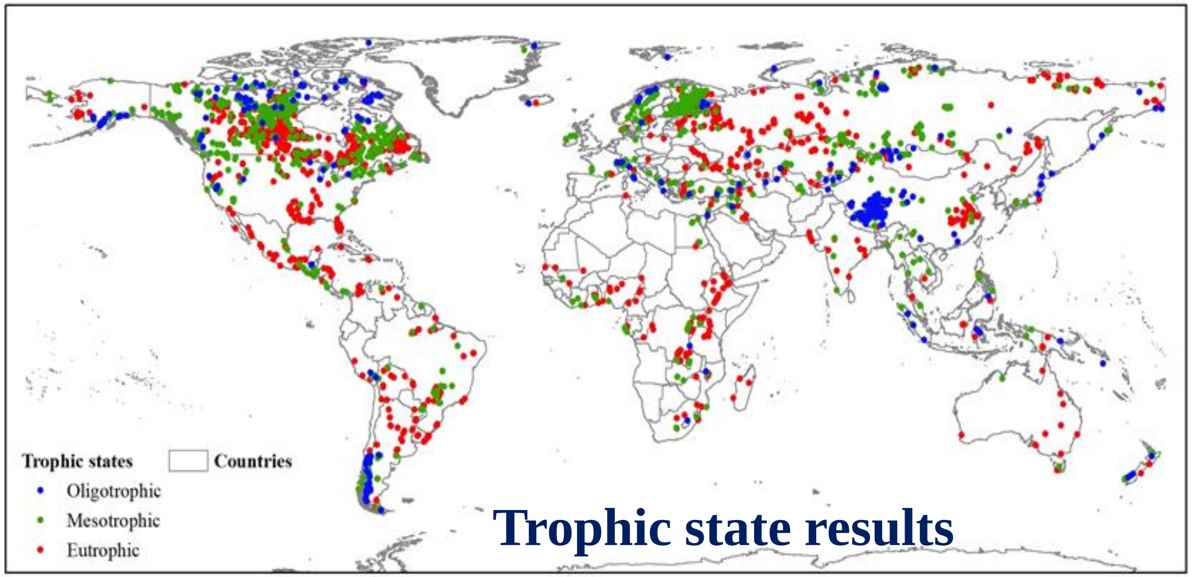
Confusion matrix of Forel-Ule index (FUI)-based trophic state assessment for the investigated 100 lakes

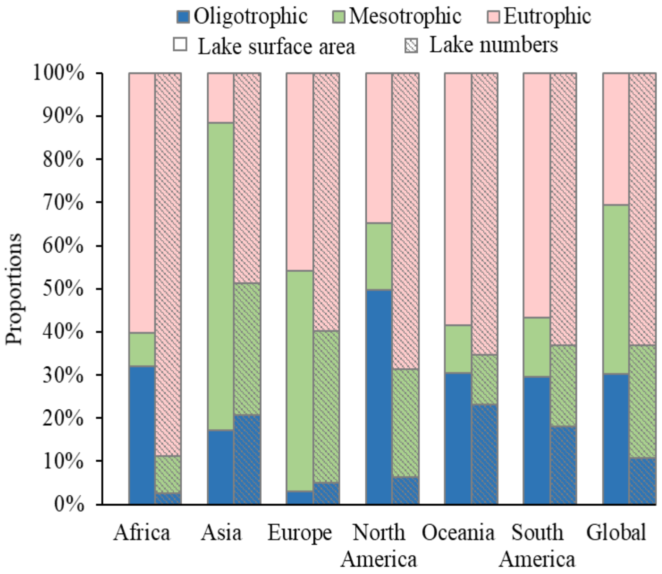
FUI-based Assessment \ Comparison Data	Oligotrophic	Mesotrophic	Eutrophic	Total	User accuracy
Oligotrophic	19	0	0	19	100.0%
Mesotrophic	5	14	2	21	66.7%
Eutrophic	0	13	47	63	78.3%
Total	24	27	49	100	
Producer accuracy	79.2%	51.9%	95.5%		
Kappa coefficient	0.67				
Overall accuracy	**80.0%**				

Results: Global results for 2058 large lakes in the summer of 2012



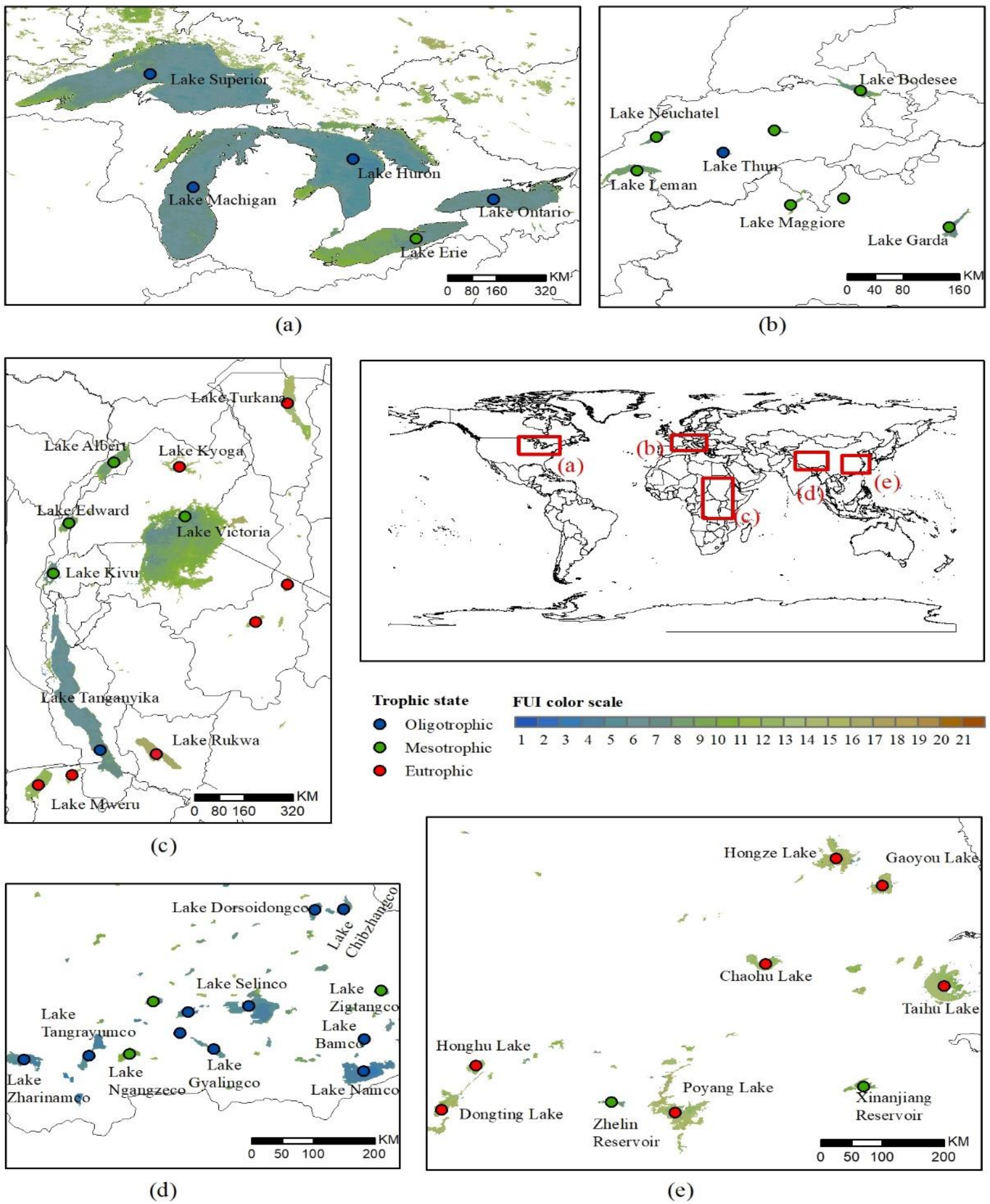
In lake number:
Oligotrophic10.7%;
Mesotrophic 26.2%;
Eutrophic 63.1%
In surface area:
Oligotrophic 30.1%;
Mesotrophic 39.4%;
Eutrophic 30.5%





Shenglei Wang, Junsheng Li, Bing Zhang, Evangelos Spyrakos, Andrew N. Tyler et al. Trophic state assessment of global inland waters using a MODIS-derived Forel-Ule index. ***Remote Sensing of Environment (Accepted).***

Results: The FUI and trophic state of regional lake groups



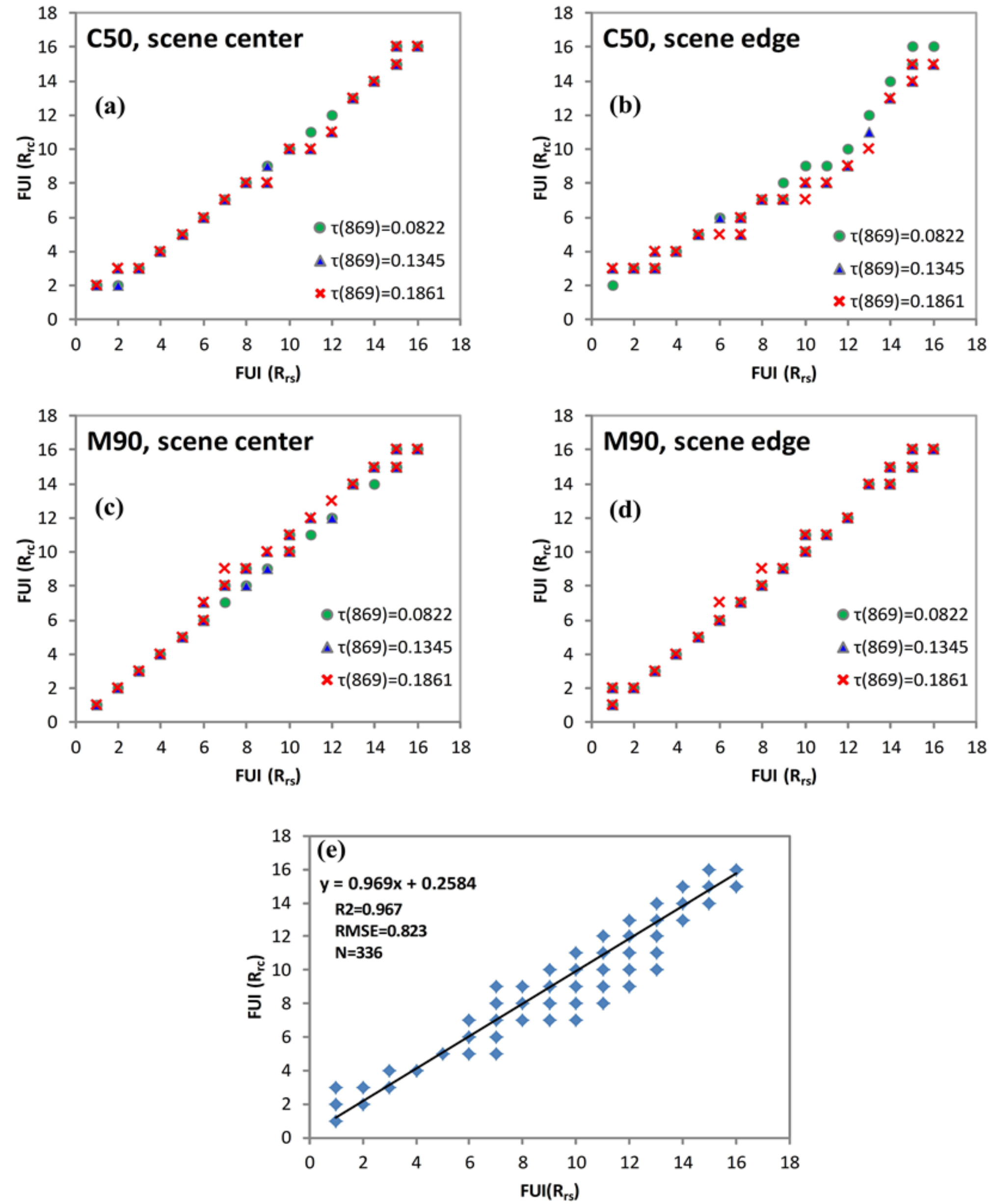
(a) North America Great Lakes region;
(b) central south European lake region;
(c) African Great Lakes region;
(d) Tibet Plateau lake region;
(e) middle-lower Yangtze lake region

FUI sensitivity to aerosol perturbations and observation conditions

FUI is nearly immune to the considered perturbations, taking advantage of the normalization process in calculation.

Relationship between Rrc-based FUI and Rrs-based FUI with various atmospheric conditions (aerosol type and optical thickness τ(869)) and solar/viewing geometry.

•C50: Coastal aerosol with 50% relative humidity
•M90: Maritime aerosol with 90% relative humidity.



Conclusions and limitations

The successful outcome can be attributed to two factors:

(1) **FUI can be retrieved from satellite data with high accuracy (~90%),** because it has a relatively high tolerance to aerosol and observational perturbations, which is critical to FUI's application on the global scale.

(2) The in-situ measurements used represent a wide range of optical and water quality properties. This led to a robust trophic state assessment method for global inland waters, and an overall accuracy of 80% was achieved.

Limitations:

The relationship between FUI and TSI is scattered over turbid waters, affected by other water constituents other than Chl-a.

FUI can just be used to roughly classify the water trophic state into three classes.

Thanks to:

Tiit Kuster; Moritz Lehmann; Qian Shen; Fangfang Zhang; Yanhong Wu; Dailiang Peng;

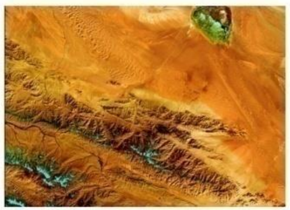
the UK NERC GloboLakes project
and China Scholarship Council.

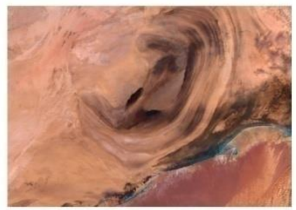
AquaWatch The GEO Water Quality Initiative

GloboLakes

August 2018
Stirling

谢 谢！






Thank you for your attention.

Shenglei Wang (shenglei.wang@stir.ac.uk)
University of Stirling / Chinese Academy of sciences

中国科学院遥感与数字地球研究所

地址：北京市海淀区邓庄南路9号（100094）
电话：86-10-82178008 传真：86-10-82178009
邮箱：office@radi.ac.cn
网址：www.radi.cas.cn