Inland Water Atmospheric Correction Based on Turbidity Classification Using OLCI and SLSTR Synergistic Observations

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1. Abstract

Atmospheric correction is an essential prerequisite for obtaining accurate inland water color information. An inland water atmospheric correction algorithm (ACbTC) was proposed in this study by using OLCI and SLSTR synergistic observations for the first time. This method includes two main steps: (1) water turbidity classification by the GRA index; and (2) atmospheric correction by synergistic use of OLCI and SLSTR images. The algorithm was validated with 72 in situ sampling sites in Lake Erhai, Lake Hongze, and Lake Taihu, and compared with other atmospheric correction methods, i.e., C2RCC, MUMM, FLAASH, POLYMER, and BPAC. The results show that (1) the GRA index performed better than the proposed turbidity classification indices, i.e., the Diff and the Tind, in inland lakes by using the reflectance peak at 1020 nm in clean water; (2) the synergistic use of OLCI and SLSTR performed feasibly for atmospheric correction, and the ACbTC algorithm achieved full-band average values of the MAPE = 29.55%, MRPE = 13.98%, and the RMSE = 0.0039 sr−1, which were more reliable than C2RCC, MUMM, FLAASH, POLYMER, and BPAC; and (3) the synergistic use of the 17th band (865 nm) on OLCI and the 5th band (1613 nm) on SLSTR are suitable for clean inland lakes, while both the 5th band (1613 nm) and 6th band (2250 nm) on SLSTR are advisable for the turbidity.

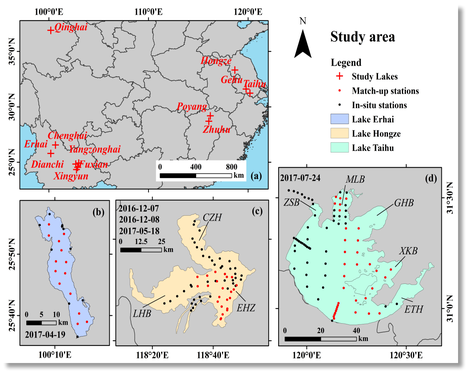
2. Introduction

- The atmospheric correction, i.e., the removal of atmospheric effects, is an essential prerequisite for obtaining accurate water color information.
- The traditional algorithm (the dark pixel method proposed by Gordon 1994) has been successfully used in the open ocean but its hypothesis is invalid for turbid water due to the unnegligible water signal in the NIR.
- The turbidity of inland water varies strongly. Therefore, it is necessary to use different reference bands to correct the atmospheric effects after the detection of water turbid types.
- The band settings of OLCI is insufficient for turbidity classification and aerosol correction especially in the SWIR bands. Thus, the combination of OLCI and SLSTR, which has two additional SWIR bands, is an urgent need.

3. Objective and Study area

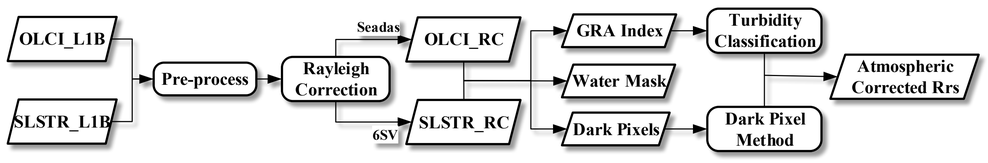
The objective of this study is to provide a procedure for inland atmospheric correction by the synergistic use of the OLCI and SLSTR data based on water turbidity identification:

a) To propose an index to effectively detect the turbidity in inland waters;
b) To construct an atmospheric correction algorithm by taking advantages of the two data sources.



4. Methods

Processing environments:
IDL, ENVI, SNAP and Seadas.



The processing procedure of the ACbTC:

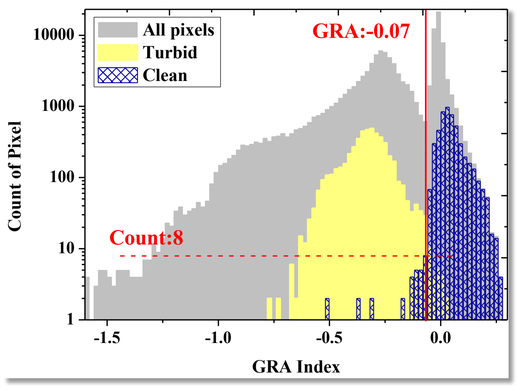
- The Rayleigh correction for the OLCI and SLSTR were conducted by Seadas and 6SV respectively. Due to the weak Rayleigh scatter effect at long wavelength, the 6SV can be used to supplement Seadas at SL05-1613 nm and SL06-2250 nm.
- Aerosol reflectance calculation by turbidity detection:
  - Dark pixel selection based on the intersection of the two 10th percentiles of OL17-865 nm and SL05-1613 nm.
  - Turbidity detection by the proposed GRA index.

$$GRA=(GRA_1+GRA_2)\times10^4$$
$$GRA_1=[Rrs(885)-Rrs(1020)]/(885-1020)$$
$$GRA_2=[Rrs(885)-Rrs(1613)]/(885-1613)$$

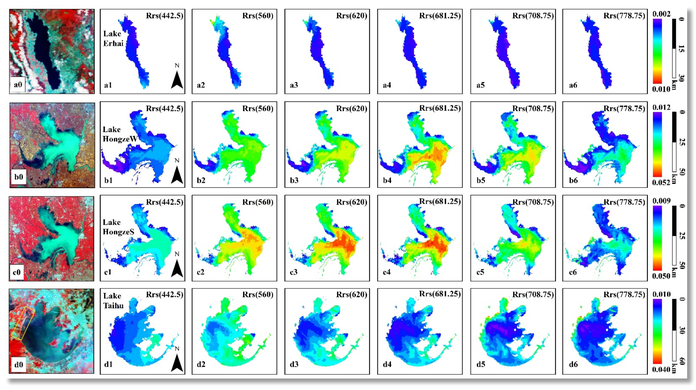
  - We temporarily define -0.07 as the threshold of the GRA. Thus, a pixel with a GRA < -0.07 is considered as turbid water. Otherwise, it belongs to the clean water category.

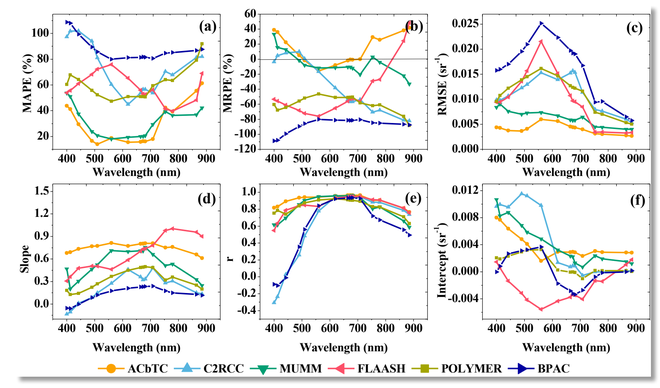
Accuracy assessment:

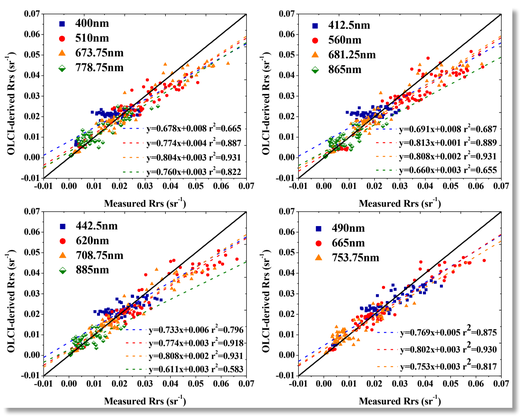
The statistical analysis considered the comparison between the in-situ measured R_{rs} vs. OLCI-derived R_{rs}. Six popular indices, namely, the MAPE, MRPE, RMSE, slope, intercept, and Pearson correlation coefficient, were used for assessing the accuracy of atmospheric correction.



5. Results

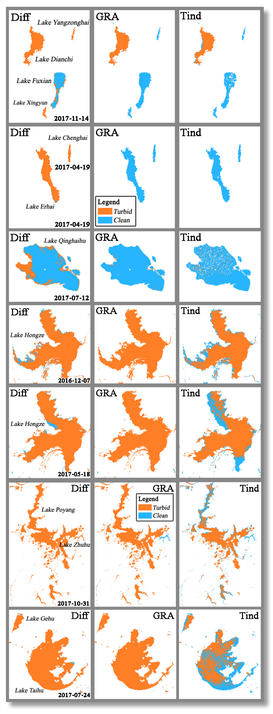


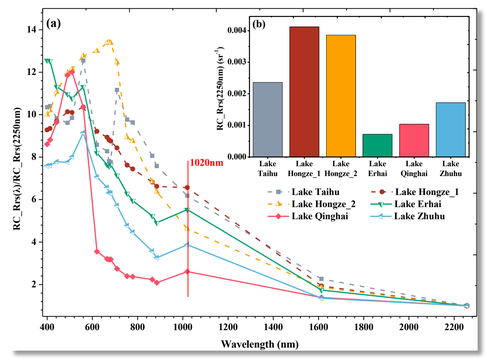


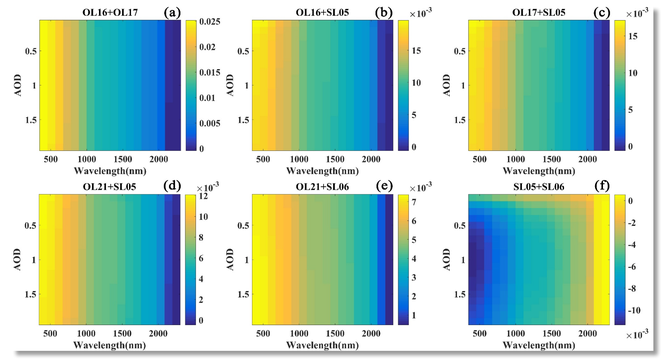


- **Visual inspection of atmospherically corrected images**: The atmospherically-corrected R_{rs} at different bands corresponds to the water quality status according to previous studies.
- **Comparison with in situ measurements**: The ACbTC fails to distinguish the different water conditions at 400 and 412.5 nm but performs better after 490 nm. The overcorrection occurs between 500 and 700 nm in the turbid areas.
- **Comparison with other atmospheric algorithms**: FLAASH, C2RCC and BPAC obtained the most inferior results especially before the NIR. POLYMER performed more stably than FLAASH and C2RCC, but MUMM and ACbTC showed excellent and stable correction effect, but the latter was more accurate for the overall state of the spectrum, showing better statistical results.

6. Discussion



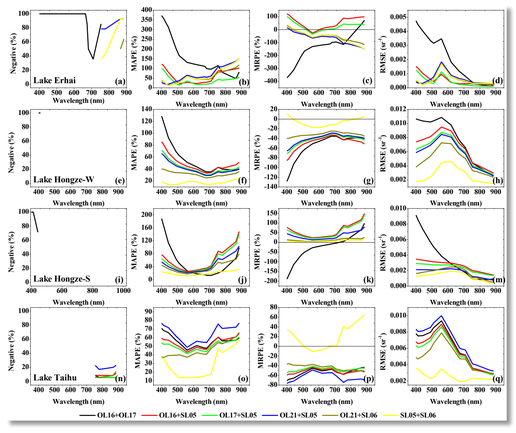




- The OL21-1020 nm is unsuitable for atmospheric correction of inland lakes because it is a vulnerable band easily affected by land stray light. However, the 1020 nm peak could be an indicator to discriminate between clean and turbid water excluding pixels near the shore.
- The method of turbidity classification based on the spectral morphology, the GRA index, is simple, but effective when comparing to the Diff and Tind indices.
- The stray light affects the atmospheric correction results especially for the clean inland lakes.

Index	Combinations	Lake Erhai	Lake HongzeW	Lake HongzeS	Lake Taihu
MAPE (%)	OL16 + OL17	160.02	58.11	59.91	56.19
	OL16 + SL05	61.18	49.45	61.04	53.54
	OL17 + SL05	**40.05**	43.24	54.91	50.17
	OL21 + SL05	65.78	40.84	45.80	64.52
	OL21 + SL06	53.09	31.70	37.33	45.17
	SL05 + SL06	60.41	**17.10**	**19.95**	**32.96**
MRPE (%)	OL16 + OL17	−143.87	−58.11	−31.44	−53.90
	OL16 + SL05	54.69	−49.45	60.26	−51.63
	OL17 + SL05	**28.43**	−43.24	53.75	−47.85
	OL21 + SL05	−60.99	−40.84	34.22	−63.58
	OL21 + SL06	−44.35	−31.48	13.01	−42.98
	SL05 + SL06	−49.98	**−5.57**	**7.77**	**18.39**
RMSE (sr^{-1})	OL16 + OL17	0.00202	0.00772	0.00362	0.00602
	OL16 + SL05	0.00056	0.00667	0.00267	0.00569
	OL17 + SL05	**0.00045**	0.00604	0.00239	0.00542
	OL21 + SL05	0.00060	0.00578	0.00180	0.00658
	OL21 + SL06	0.00052	0.00476	0.00174	0.00486
	SL05 + SL06	0.00054	**0.00267**	**0.00134**	**0.00251**

7. Conclusion



- The GRA index is proposed to distinguish turbid inland water from clean water, especially for small clean inland lakes. The threshold of the GRA index was determined as -0.07 in this study. The classification results of GRA index performed better than Diff and Tind indices.
- The synergistic use of OLCI and SLSTR was verified to provide additional atmospheric correction bands (SL05-1613 nm and SL06-2250 nm) for inland lakes to satisfy the dark pixel assumption. OL17+SL05 and SL05+SL06 are recommended for the clean and turbid inland waters respectively.
- Compared to the in situ measurements, the ACbTC performed more accurate than the CR2CC, MUMM, FLAASH, POLYMER and BPAC with its full-band average values of MAPE = 29.55%, MRPE = 13.98% and RMSE = 0.0039 sr^{-1}.

8. Major references

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