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Estimation of Secchi Disk Depth in Lake Kasumigaura from MERIS

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ABSTRACT

Secchi Disk Depth (Z_{SD}), also called transparency, is an important indicator of water quality. The manual and point-based measurement of Z_{SD} has a long history with more than 200 years. With the development of remote sensing, satellite image can provide the potential for large spatial and long time-series monitoring of Z_{SD}, which is also developing to an important way for lake environment management. In this study, MERIS images from 2003 to 2012 were employed to retrieve Z_{SD} in the Japanese turbid Lake Kasumigaura. The absorption and backscattering coefficients were firstly retrieved using two versions of quasi-analytical algorithm: QAA_V6 and QAA_turbid, and then Z_{SD} were estimated based on the new method proposed by Lee in 2015. Results were validated using in-situ Z_{SD}, the RMSE and MAPE of Z_{SD} estimated using QAA_turbid were 0.10m and 14.96% respectively, the estimated Z_{SD} using QAA_V6 showed overestimation with RMSE and MAPE of 0.65m and 97.83%. This indicated that Z_{SD} estimation using absorption and backscattering coefficients from QAA_turbid was more accurate than that from QAA_V6. Long time-series results of Z_{SD} estimated from MERIS using QAA_turbid matched the in-situ Z_{SD} well, all of them showed an increase trend from 2003 to 2012 in Lake Kasumigaura. Results in this study implied that estimation of Z_{SD} from MERIS images is a potential way for long time-series Z_{SD} monitoring in lakes.

1. INTRODUCTION

Secchi Disk Depth (Z_{SD}), also termed transparency, has been recorded for more than 200 years in natural waters. Measuring Z_{SD} is a direct and efficient way for water condition evaluation[1][2]. The general way to measure Z_{SD} is by lowering down a 25 or 30 cm white disk or white-and-black disk into the water, and Z_{SD} is recorded as the depth when the disk can no longer be seen[1][3]. Lee et al.[3] developed a mechanistic model to estimate Z_{SD} in different types of waters from remote sensing, which can be applied to satellite images to produce large coverage and high frequency Z_{SD} observations. In this method, absorption and backscattering coefficients are key parameters for Z_{SD} estimation, which is a big challenge for turbid waters. At present, quasi-analytical algorithm is a solution for absorption and backscattering coefficients retrieval, QAA_V6[4] and QAA_turbid[5] are two typical algorithms which can be used for absorption and backscattering coefficients retrieval in turbid waters. But the performance of those two algorithms still need more tests in turbid inland lakes, because usually the inland turbid waters are more complicated than ocean waters. Knowing the importance and challenges of Z_{SD} retrieval in inland turbid waters, the objectives of this study were to: (1) evaluate the performance of Lee's Z_{SD} model combined with two quasi-analytical algorithms, QAA_V6 and QAA_turbid, in the turbid Lake Kasumigaura, and (2) produce the long time series of Z_{SD} from MERIS satellite image in Lake Kasumigaura.

2. METHOD

In this study, totally 507 MERIS images covering Lake Kasumigaura were downloaded from ESA, those images were further pre-processed in BEAM software following the steps as: research area subset, radiometric correction, case-2 atmospheric correction. Absorption and backscattering coefficients were then estimated from the pre-processed images using QAA_V6 and QAA_turbid respectively, and then the diffuse attenuation coefficients were estimated[6], at last, Z_{SD} were estimated using Lee's Z_{SD} model[3]. The in-situ Z_{SD} data covering 2003-2012 from the National Institute for Environmental Studies (NIES) were used for result validation, it is noted that the in-situ data were collected every month in 10 monitoring sites in Lake Kasumigaura.

3. RESULTS

By searching the in-situ database, 19 matched in-situ Z_{SD} were found, Fig.1 shows the results of validation using in-situ Z_{SD} data which collected on the same day with satellite image. It is clear that Z_{SD} estimated using QAA_V6 shows overestimation, with RMSE and MAPE of 0.65 m and 97.83% respectively. Z_{SD} estimated using QAA_turbid shows good correlation with in-situ data, the RMSE and MAPE are 0.10 m and 14.96%, which are significant better than the results using QAA_V6.

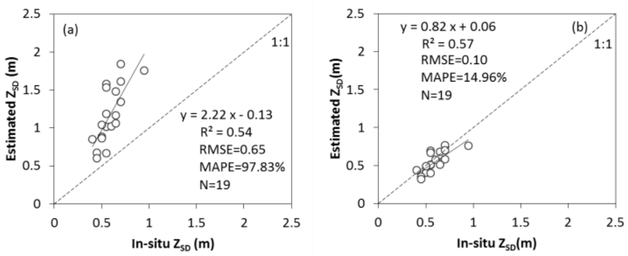

Fig1. Validation results of retrieved Z_{SD}. (a) Z_{SD} retrieved using QAA_V6, (b) Z_{SD} retrieved using QAA_turbid.

All estimated Z_{SD} were averaged to monthly mean Z_{SD} to compare with in-situ data, Fig2. shows the results of monthly mean Z_{SD} changes from 2003 to 2012 in the center of the lake. We can see that the retrieved Z_{SD} using QAA_V6 is apparently higher than the in-situ Z_{SD}, while QAA_turbid matches well with the in-situ data. Furthermore, both of the retrieved Z_{SD} and in-situ Z_{SD} show an increase trend during the 10 years.

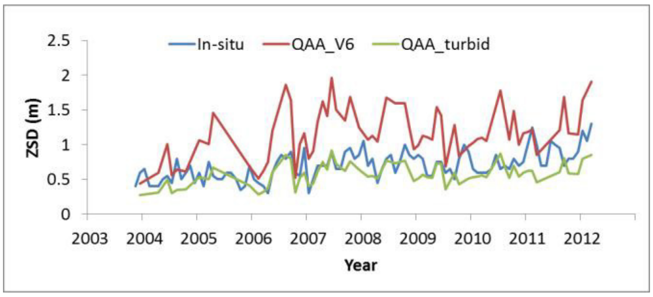

Fig.2 Z_{SD} changes in the center of Lake Kasumigaura from 2003 to 2012

4. DISCUSSION

Absorption and backscattering coefficients describe the inherent optical properties of the water, they are key parameters in Z_{SD} retrieval when using Lee's Z_{SD} model. The QAA_V6 from IOCCG can be generally used for both turbid and clear waters according to previous studies, but for extreme turbid inland waters, such as Lake Kasumigaura in this study, QAA_V6 gave an overestimation of Z_{SD}, the potential reason is that QAA_V6 is mainly used for ocean waters, therefore the retrieved absorption and backscattering coefficients are lower than the true values when using it for turbid inland waters, this leads to the overestimation of Z_{SD}. QAA_turbid was developed for turbid waters, it gives the accurate absorption and backscattering coefficients, so the estimated Z_{SD} is reasonable. Moreover, the estimated long time series Z_{SD} using QAA_turbid in this study showed the same change trend with in-situ data, that means combining Lee's Z_{SD} model with QAA_turbid can be used for Z_{SD} monitoring from satellite images in turbid inland lakes.

5. CONCLUSION

This study used MERIS images to evaluate Lee's Z_{SD} model combined with QAA_V6 and QAA_turbid in the turbid Lake Kasumigaura, results revealed that Lee's Z_{SD} model with QAA_V6 lead to overestimation of Z_{SD} in extreme turbid waters, but QAA_turbid performed well. Results in this study also indicated that long time Z_{SD} monitoring using Lee's Z_{SD} model based on QAA_turbid is reasonable in Lake Kasumigaura, retrieved results agreed with in-situ data and showed increase Z_{SD} from 2003 to 2012.

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