Spatial-temporal variation of backscattering coefficient of TSM in the Yangtze estuary

Introduction

Particulate backscattering coefficients (b_b) have traditionally been used to quantify the concentration of total suspended matter (TSM). In this study, we investigated the spatial-temporal variations of bb in the Yangtze estuary. A robust relationship between b_b and TSM concentration is observed from the *in-situ* data set, which enable us to map TSM distributions from earth observation data. We first retrieved b_b from atmospheric corrected GOCI (Geostationary Ocean Color Imager) products using the improved 2SeaColor model, the derived b_b product is then converted to TSM mapping product.

Methodology

1 Dataset

In-situ dataset. Two campaigns were carried out in July 2011 and March 2013 in the Yangtze estuary. Absorption, scattering and backscattering coefficients (*a, b* and b_b) and remote sensing reflectance (R_{rs}) were measured at each sampling site using Wetlabs ac-s, bb9 and Satlantic HyperSAS, respectively. Water samples were collected and analyzed for their content of TSM in the lab. Absorption coefficient (*a*) measured by the ac-s was corrected for scattering errors using the Boss method (Boss et al., 2013).

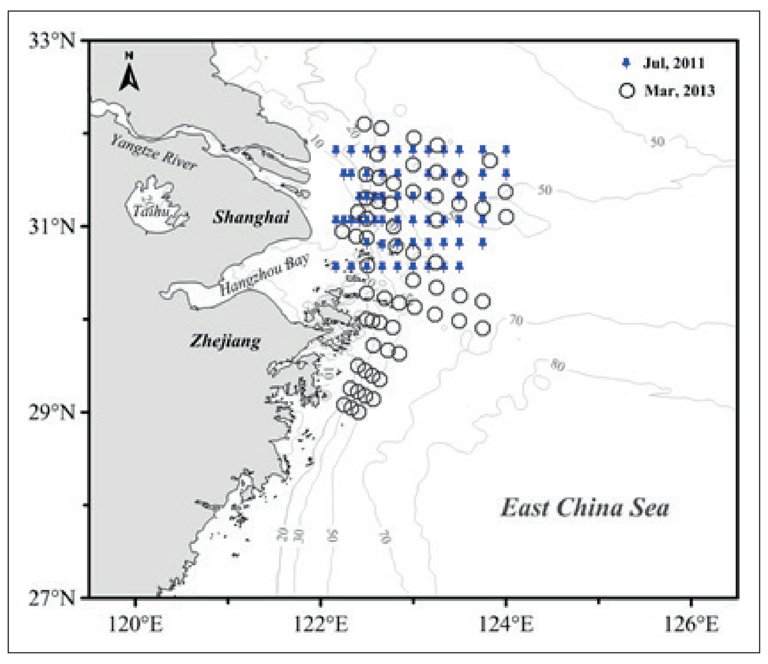

Fig.1 Location of the sampling stations in the two cruise campaigns.

GOCI images. In total, sixteen GOCI images were captured from March 4th to March18th of 2013 with 18 concurrent measurements of Rrs, IOPs and TSM that were sampled within 1h of the GOCI overpass. All GOCI images were processed using the standard atmospheric correction algorithm of the GOCI Data Processing System (GDPS version 1.3).

2 2SeaColor model

Backscattering coefficient can be derived from R_{rs} by the inversion scheme of the 2SeaColor model (Salama and Verhoef, 2015) using spectral optimization with the improved parameterizations of *a* and b_b (Yu et al., 2016).

Results

1. Spatial-temporal distribution of *b* (532), b_b (532) and b_b/b (532)

As shown in Fig.2, both *b* (532) and b_b (532) show decreasing trend from inshore to offshore in the Yangtze estuary in both summer and winter. The opposite trend of the spatial distribution of the backscattering ratio b_b / *b* (532) in summer and winter can be attributed to the differences in the type and size of particulate matter. In summer, lower value of b_b / *b* is expected to be found in phytoplankton-dominated offshore waters compared to inshore waters dominated by non-algae particles. While in winter with less active phytoplankton, the variation of b_b / *b* could be dominated by the size of the suspended particulate matter. Fine particles with larger b_b / *b* is more likely transported further and presented in the offshore waters.

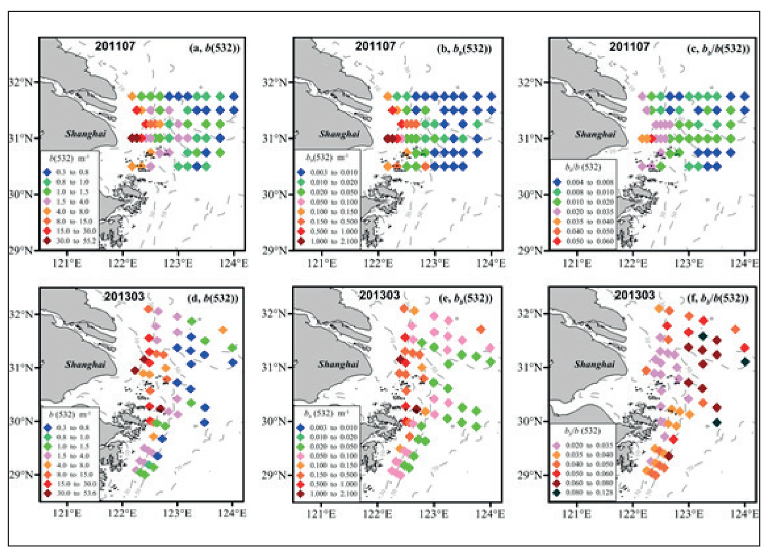

Fig.2 Spatial distribution of *b*, *bb* and b_b/*b* at 532nm over the Yangtze estuary in summer and winter seasons.

2. Retrieving b_b from Rrs using the 2SeaColor model

For the in-situ measurements, we retrieved b_b (532) from field observed R_{rs} and compared with b_b (532) measured by the Wetlabs bb9 scattering meter, as shown in Fig. 3. The derived values from 2SeaColor model are in good agreement with the field measurements with a root mean square error (RMSE) of 0.254 m^{-1} and determination coefficient (R^2) of 0.842. Therefore, employing the 2SeaColor model to retrieve b_b from atmospheric corrected GOCI images can provide fairly accurate b_b estimates.

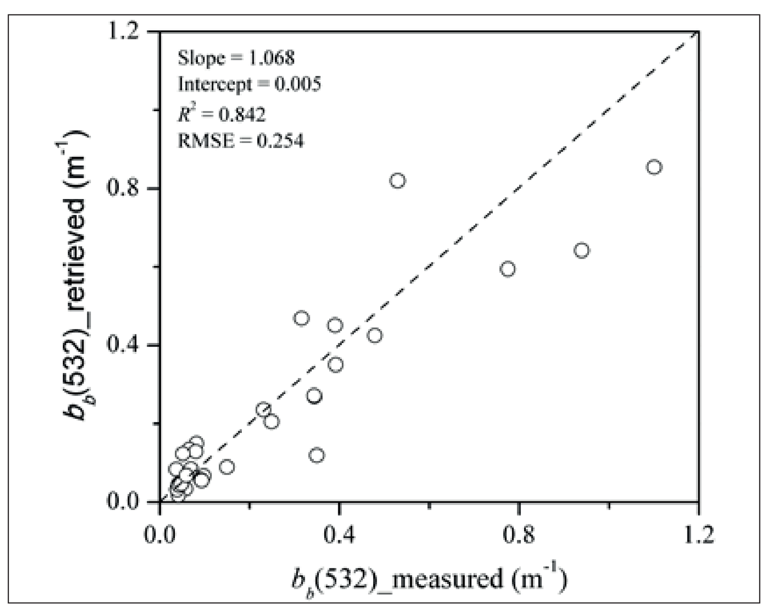

Fig.3 Retrieved b_b (532) from 2SeaColor model validated with field measurements.

3. Relationship between b_b and TSM concentration

It is a clear demonstration of the Lambert-Beer law from Fig.4 whereby the scattering intensity is linearly related to the concentration. Moreover, a more robust relationship is found for b_b and TSM with a higher linearity as shown in Fig. 4b. Therefore, retrieved bb from GOCI images using the 2SeaColor model can be linearly converted to TSM concentration using the sIOP of 0.0214 m^2 g^{-1}.

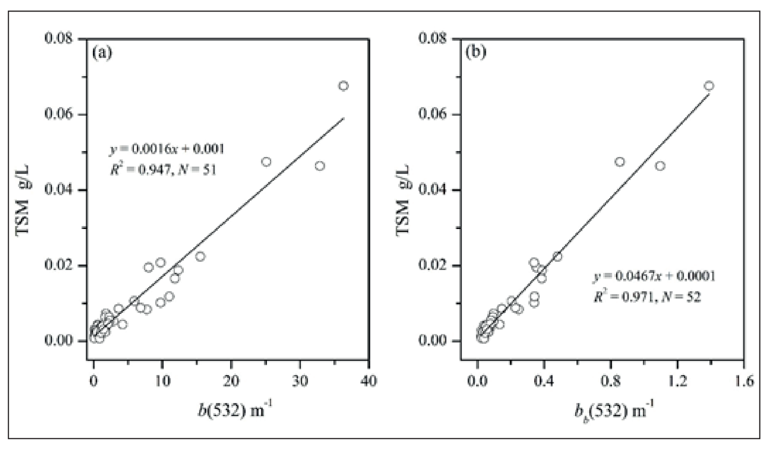

Fig.4 Relationship between TSM and field measured *b*(532) and b_b (532).

4. Validation of TSM retrieval

The b_b-TSM model was compared with the GOCI TSM algorithm for the matchup pixels, as shown in Fig.5. Statistic results shows that the accuracy of retrieved TSM concentrations from our model (RMSE=17.24 mg/L, black circle in Fig.5) is improved with respect to the GOCI TSM products (RMSE=39.16 mg/L, red circle in Fig. 5), which overestimate the TSM concentration for the matchup samples with field TSM concentration ranging from 10 to 70 mg/L.

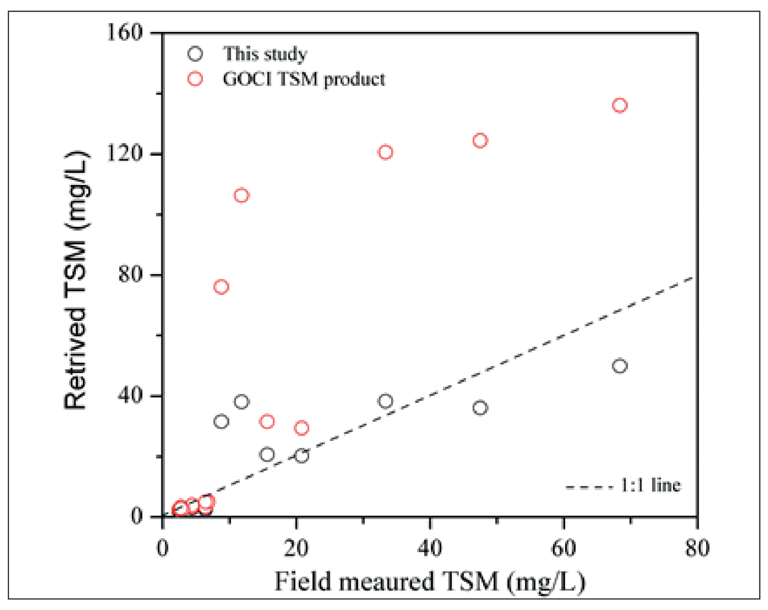

Fig.5 Validation of the b_b-TSM model and GOCI standard TSM product with field match-ups.

Diurnal varaition of TSM in the Yangtze estuary

Eight GOCI images on March 8th (cloud-free) are captured from 00:16 UTC to 07:16 UTC to map the distribution of TSM during a tidal cycle. The TSM mapping product was produced by inverting the 2SeaColor model and the established b_b-TSM relationship on GOCI images, as shown in Fig.6, where a significant variation of TSM concentration is observed.

The tidal type in the Yangtze estuary is typical semi-diurnal tide. Therefore, From the 8 images acquired from 00:16 UTC to 07:16 UTC, we can observe the variation of TSM during at least half a tidal cycle. Two hydrometric stations with tidal level recorded every hour, BeiCaoZhong and JiGuJiao, in our sampling area were selected to understand the potential influence of tide on the variation of TSM concentration.

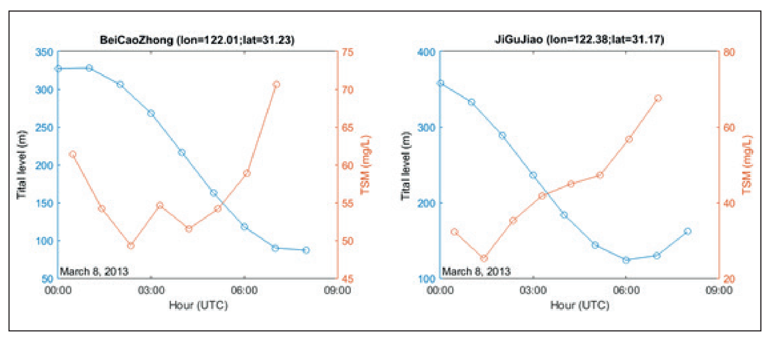

Fig.7 Variation of TSM (right Y-axis) at the two hydrometric stations corresponding to the variation of tidal level (left Y-axis).

During a tidal period, the minimum TSM concentration is observed during the ebb tide and is approximately 1 hour after the tide reaches the highest level (Fig7). Subsequently, the maximum TSM concentration appears during the flood tide and is about 1 hour after the tide reaches the lowest level. This can be well explained by the transportation of suspended sediment during the tidal period.

During the ebb tide, tidal current transits from inshore to offshore carrying large amount of suspended sediment. The 1 hour lag effect should be attributed to the shear stress that results in the phase difference between current velocity and TSM concentration that is determined by sediments deposit and resuspension.

Conclusion

In this study, we retrieved accurate estimates of b_b from the 2SeaColor and adopted a locally calibrated sIOP of 0.0214 m^2/g to covert b_b to TSM in the medium-turbid and clear waters in the Yangtze estuary. This TSM model was applied to GOCI time-series images to map TSM distribution in the Yangtze estuary.

An approximate one hour lag between tide and maximum turbidity is observed at two hydrometric station with comparing to GOCI derived TSM concentration. However, the developed model underestimates TSM concentration in turbid waters, which requires further examination on the b_b-TSM relationship, especially in turbid waters.

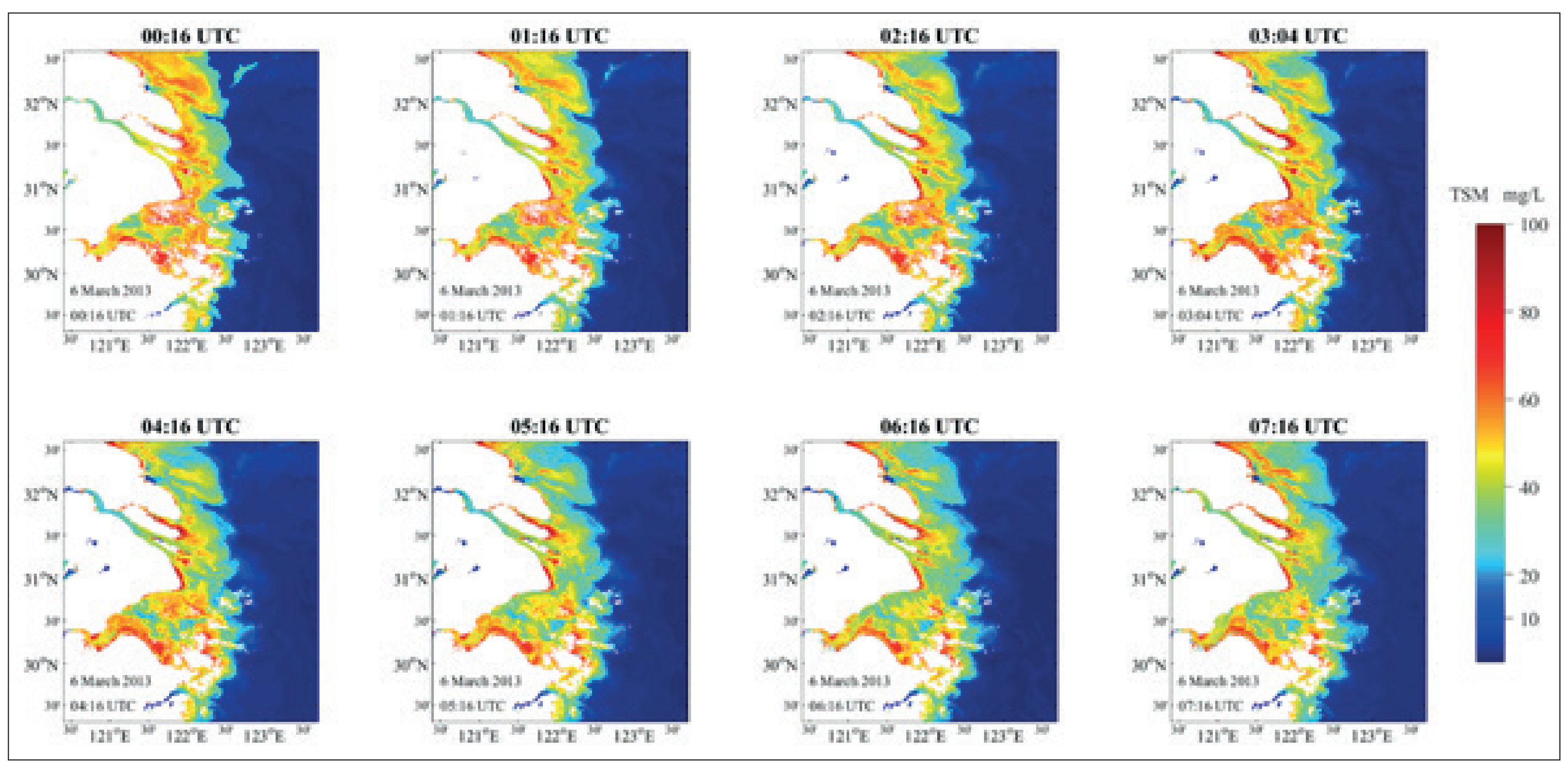

Fig.6 Time-series of TSM concentration mapping product over the Yangtze estuary on March 8th.

References

Salama, M.S., & Verhoef, W. (2015). Two-stream remote sensing model for water quality mapping: 2SeaColor. Remote Sensing of Environment, 157, 111-122

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For more information

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