NIR-BASED Ocean Color IOP Algorithm for Coastal and Inland Waters

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Summary

- Three-year (2009–2011) observations in highly turbid waters of the western Pacific from (MODIS) on the satellite Aqua are used to conduct this study. SWIR atmospherics correction with band set of 1640 nm and 2130 nm is conducted to derive $nL_w(\lambda)$ at the red, near-infrared (NIR), and shortwave infrared (SWIR) .
- NIR ocean reflectance spectral shape represented by reflectance ratio of $\rho_{wN}(748)/\rho_{wN}(869)$ is highly dynamic in a large coverage of turbid waters.
- In turbid waters, ocean IOP modeling can be significantly simplified. It is feasible to analytically derive some IOP properties in turbid waters with combined visible-NIR $nL_w(\lambda)$ spectra data.
- IOP properties such as $b_{bp}(\lambda)$ can be derived from satellite $nL_w(\lambda)$ measurements in the NIR wavelengths. Backscattering spectral slopes can also be reasonably derived in the coastal turbid regions.
- This work is published in *Limnology and Oceanography* (Shi and Wang, 2014).

West Pacific Highly Turbid Waters

The BS, YS, and ECS are the three major marginal seas in the western Pacific Ocean bounded by China, Korea, and Japan (Fig. 1). They cover some of the most turbid waters in the world (Shi and Wang 2010, 2012). Major rivers in this region such as the Yangtze River and Yellow River transport large amounts of sediments into the BS, YS, and ECS.

In the coastal region of the YS (Sta. 1, 2 in Fig. 1), Subei Shoal of the YS (Sta. 3 in Fig. 1), Yangtze River estuary (Sta. 5 in Fig. 1), Hangzhou Bay (Sta. 6 in Fig. 1), and Lake Taihu (Sta. 7 in Fig. 1), normalized water-leaving radiance at the red band nL_w (645) can be over ~5 mW cm^{-2} μm^{-1} sr^{-1} in the winter season (Shi and Wang 2012; Wang et al. 2011). Normalized water-leaving radiance at 859 nm ($nL_w(859)$) normally is also over ~2 mW cm^{-2} μm^{-1} sr^{-1} at these stations.

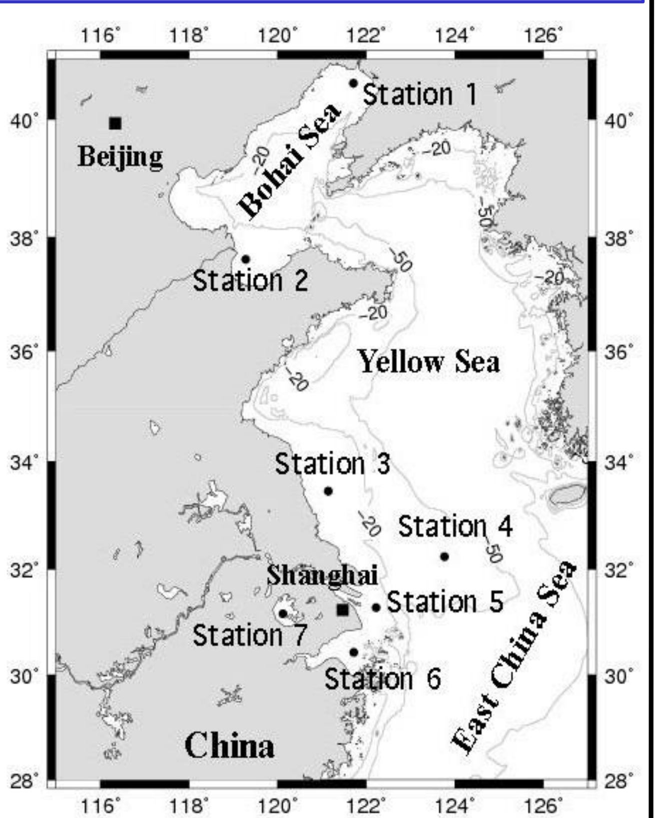

Figure 1 Map of the Bohai Sea, Yellow Sea, and East China Sea. Locations of the seven pseudo-stations for representative turbid waters in the three seas are also marked

Three-year MODIS-Aqua observations from 2009–2011 are used to derive $nL_w(645)$, $nL_w(748)$, $nL_w(859)$, $nL_w(869)$, and $nL_w(1240)$ using the SWIR atmospheric correction with the band set of 1640 and 2130 nm (Wang 2007).

Spectral Features of $nL_w(\lambda)$in the Read, NIR and SWIR

- NIR reflectance spectral shapes represented with $\rho_{wN}(748)$:$\rho_{wN}(869)$ is highly dynamic. It drops from ~1.8−2.0 for moderately turbid water to 1.1−1.2 for highly turbid waters.

$\rho_{wN}(748)/\rho_{wN}(869)$ vs. $\rho_{wN}(869)$ at Different Stations

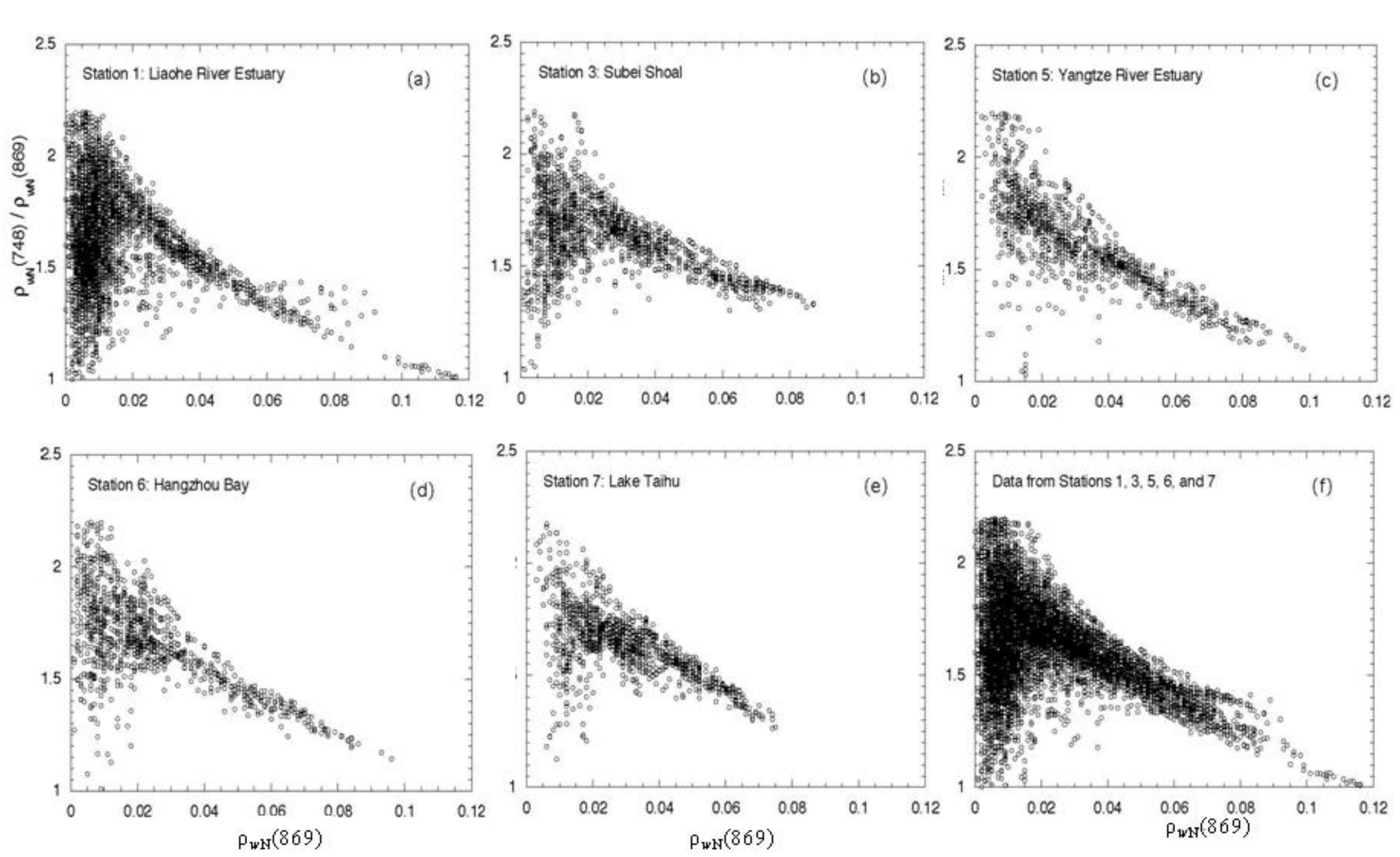

Figure 2. $\rho_{wN}(748)$:$\rho_{wN}(869)$ vs. $\rho_{wN}(869)$ between 2009 and 2011 in a 5×5 box centered at (a) Sta. 1, (b) Sta. 3, (c–e) Sta. 5–7, and (f) Sta. 1, 3, 5, 6, and 7.

Concept of NIR-based IOP Retrieval Modeling

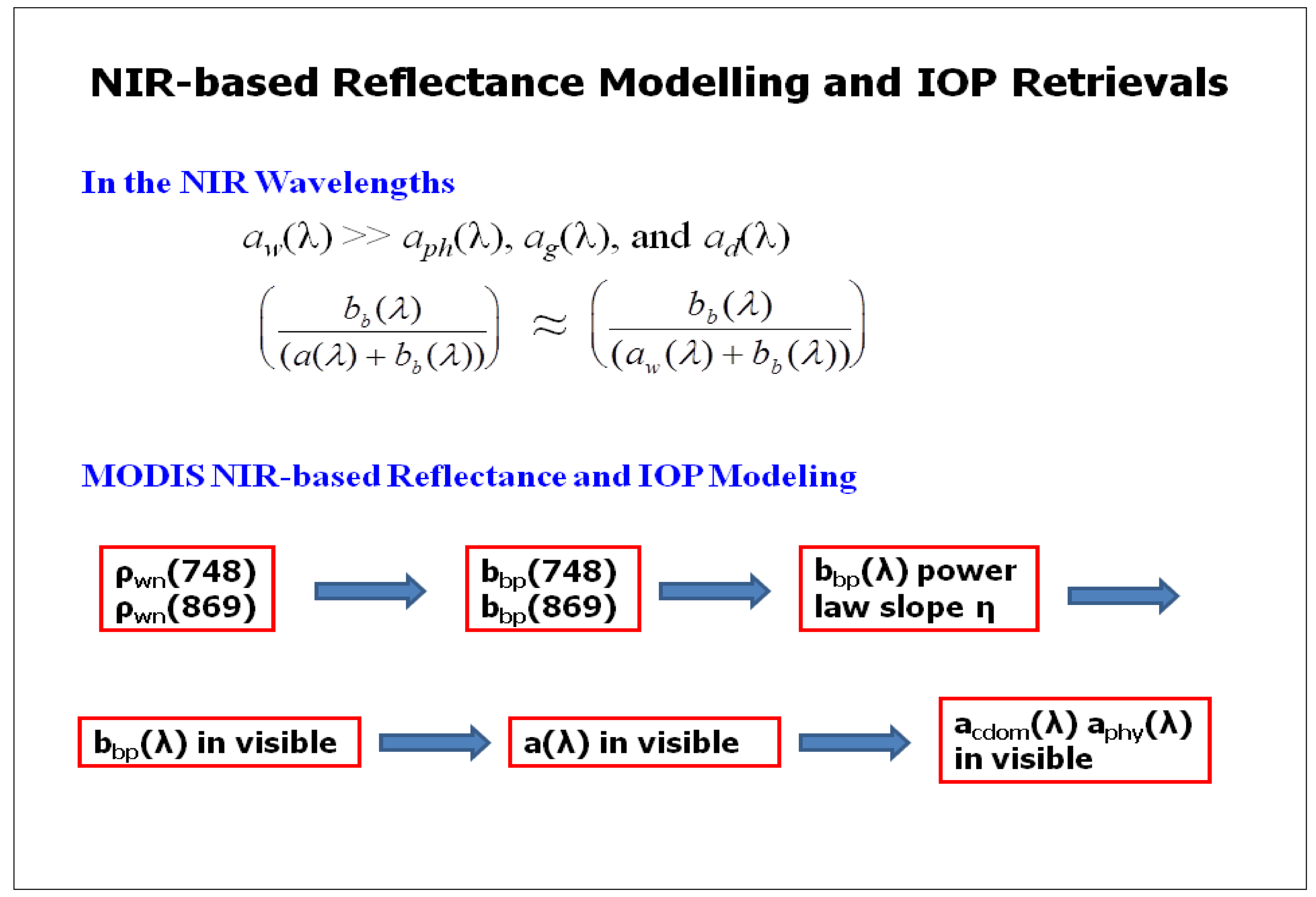

Figure 3. Schematic chart shows how the IOP properties are retrieved in coastal turbid waters.

NIR-based IOP Model Test with IOCCG Synthetic Data

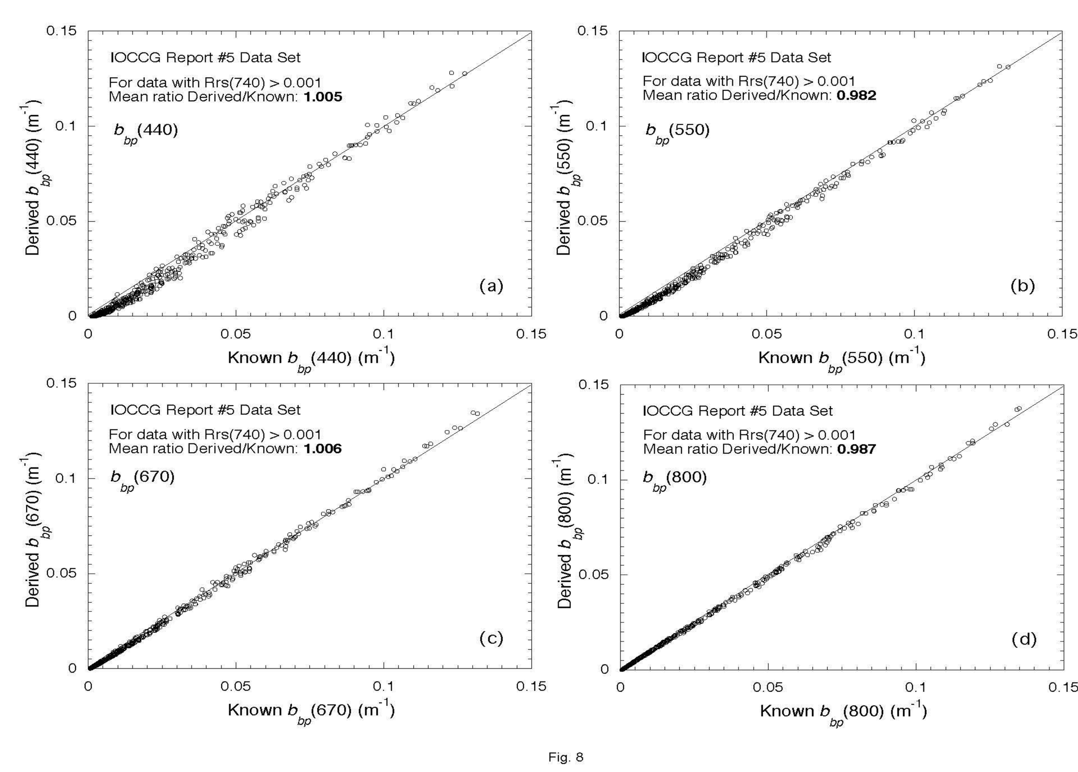

Figure 4. Comparison between the model-derived particle backscattering coefficient $b_{bp}(\lambda)$ and the true values from the IOCCG synthetic dataset for (a) $b_{bp}(440)$, (b) $b_{bp}(550)$, (c) $b_{bp}(670)$, and (d) $b_{bp}(800)$.

NIR-based IOP Retrievals in the Turbid Waters

$b_{bp}(859)$ Derived from MODIS-Aqua Measurements

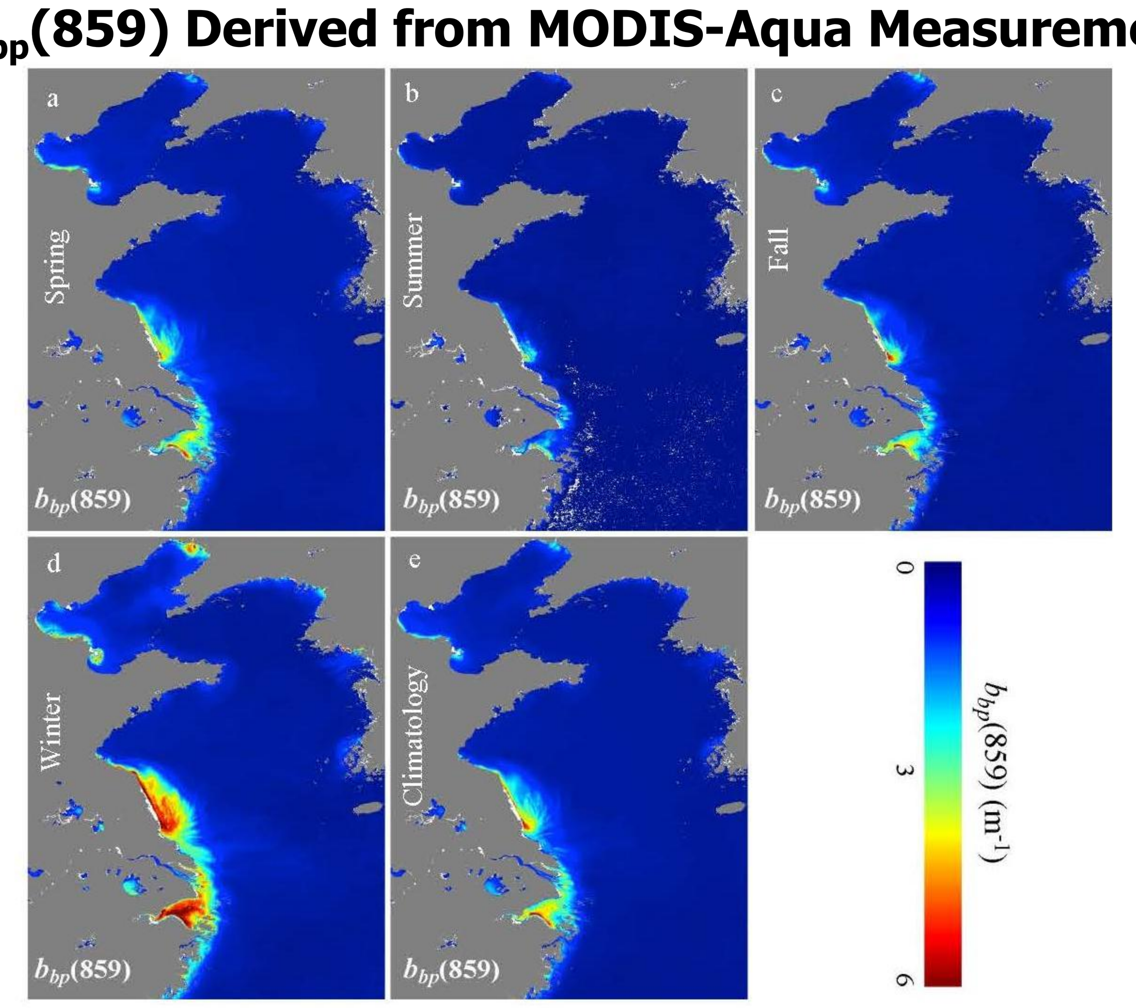

Figure 5. Three-year mean images of backscattering coefficient at the wavelength of 859 nm $b_{bp}(859)$ derived from MODIS-Aqua measurements from 2009 to 2011 for (a) spring (March−May), (b) summer (June−August), (c) fall (September−November), (d) winter (December−February), and (e) three-year climatology.

Backscattering Power Law Slope η vs. $b_{bp}(859)$

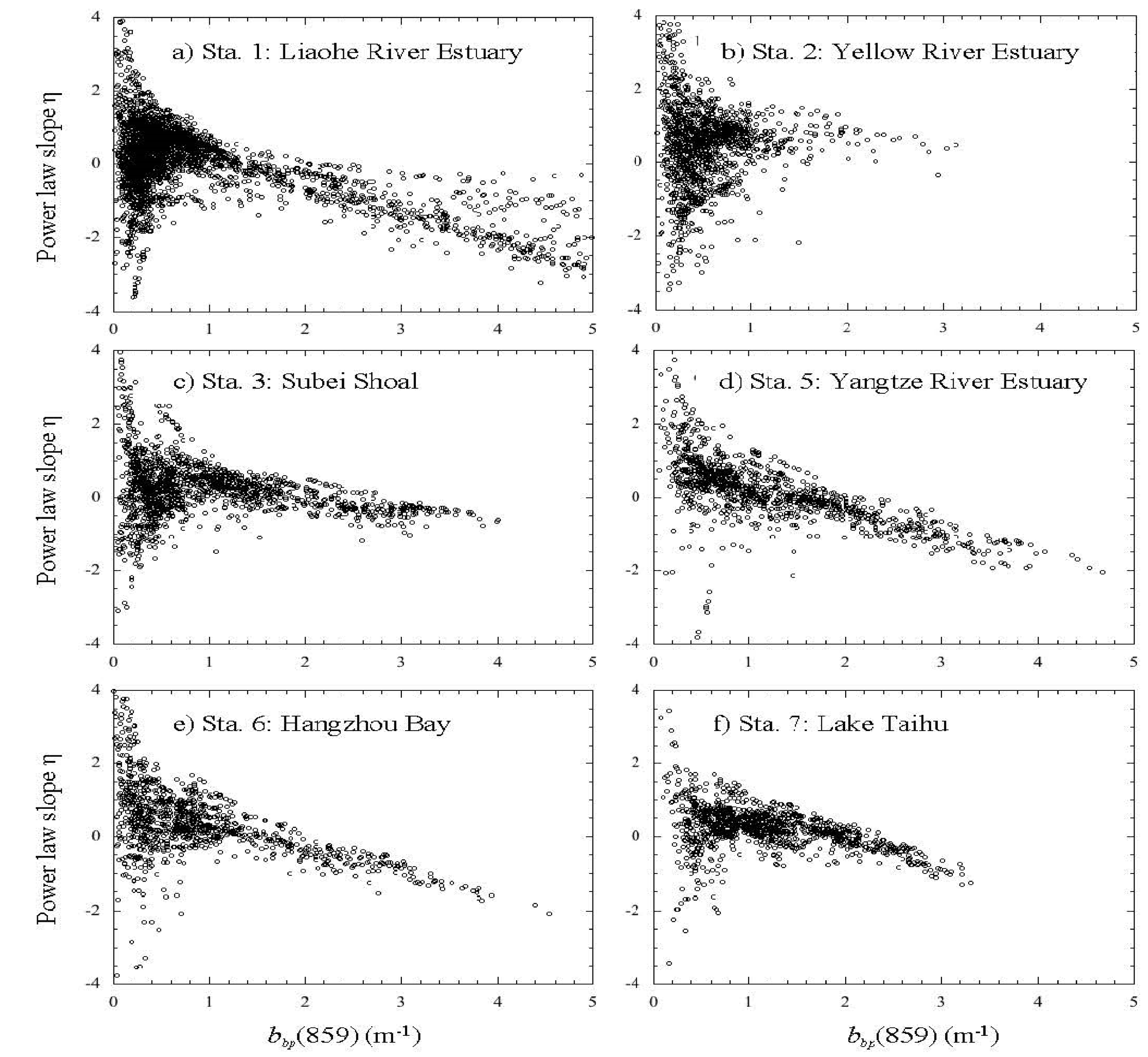

Figure 6. Scatter plots of MODIS-Aqua-derived power law slope η vs. $b_{bp}(859)$ from 2009–2011 in a 5×5 box centered at (a) Sta. 1, (b) Sta. 2, (c) Sta. 3, (d) Sta. 5, (e) Sta. 6, and (f) Sta. 7.

Conclusion Remarks

- This study quantifies and characterizes the normalized water-leaving radiance spectra $nL_w(\lambda)$ in wavelengths of the red, NIR, and SWIR in highly turbid coastal regions of the BS, YS, and ECS.
- NIR ocean reflectance spectral shape represented by reflectance ratio of $\rho_{wN}(748)/\rho_{wN}(869)$ is highly dynamic in a large coverage of turbid waters.
- In turbid waters, ocean IOP modeling can be significantly simplified. It is feasible to analytically derive some IOP properties in turbid waters with combined visible-NIR $nL_w(\lambda)$ spectra data.
- We demonstrate IOP properties such as $b_{bp}(\lambda)$ can be derived from satellite $nL_w(\lambda)$ measurements in the NIR wavelengths. Backscattering spectral slopes can also be reasonably derived in the coastal turbid regions.
- SWIR atmospheric correction with the MODIS SWIR band set of 1240 and 2130 nm can be safely used for $nL_w(\lambda)$ retrievals for waters with $nL_w(859)$ less than ~2.5 mW cm^{-2} μm^{-1} sr^{-1}.
- Current existing algorithms for *Chl-a*, $K_d(490)$, TSM, and IOPs using the ocean reflectance at the red band for coastal regions are all limited and cannot be applied to highly turbid waters with $\rho_{wN}(859)$ > ~0.05.

References

SHI, W., and M. WANG. 2010. Characterization of global ocean turbidity from Moderate Resolution Imaging Spectroradiometer ocean color observations. *J. Geophys. Res.* **115**: C11022, doi:10.1029/2010JC006160

SHI, W., and M. WANG. 2012. Satellite views of the Bohai Sea, Yellow Sea, and East China Sea. *Prog. Oceanogr*. **104**: 35–45.

WANG, M. 2007. Remote sensing of the ocean contributions from ultraviolet to near-infrared using the shortwave infrared bands: simulations. *Appl. Opt.* **46**: 1535–1547.

WANG, M., W. SHI, and J. TANG. 2011. Water property monitoring and assessment for China's inland Lake Taihu from MODIS-Aqua measurements. *Remote Sens. Environ.* **115**: 841–854.

SHI, W., and M. WANG. 2014. Ocean reflectance spectra at the red, near-infrared, and shortwave infrared from highly turbid waters: A study in the Bohai Sea, Yellow Sea, and East China Sea, *Limnol. Oceanogr.* **59**: 427–444.

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