Recent advances in remote sensing of water quality in Tampa Bay

Z. Chen, C. Hu and F. E. Muller-Karger
zchen@marine.usf.edu, hu@marine.usf.edu, carib@marine.usf.edu
College of Marine Science, Institute of Marine Remote Sensing (IMaRS), 140 7th Avenue South, Saint Petersburg, FL, 33701

Abstract

We present advances in monitoring of water quality indices (sediment/turbidity and water clarity, color and chlorophyll) in estuarine waters using MODIS and SeaWiFS images, focusing on Tampa Bay as a case study. We found that, after cross-calibration, atmospheric correction and data quality control, the remote sensing reflectance at MODIS 645 nm (250-m), showed a good relationship with *in situ* turbidity measurements. The SeaWiFS-derived attenuation coefficient at 490 nm derived from a novel semi-analytical algorithm, was closely related to *in situ* Secchi disk depth measurements. The ratios of remote sensing reflectance at MODIS 443 nm to 551 nm showed strong correlation with color in the Bay. Finally, although the absorption based algorithm failed to estimate chlorophyll but the sun-induce chlorophyll fluorescence does provide promises to accurately monitor this important indices. These frequent, repeated and synoptic products collected over several years revealed more reliable and consistent variability and trends of water quality than field survey conducted once per month, demonstrating promises for migrating research tools into operations.

Estuarine water quality and advantages of remote sensing

Most or all existing field surveys suffer from:

- Limited spatial resolution and non-synoptic (Fig. 1)

Figure 1. MODIS 250-m quasi-true color image showing the monitoring stations in the Environmental Protection Commission of Hillsborough County (EPCHC) Tampa Bay water quality monitoring program. The stations are visited once per month but span 3 different weeks (denoted with different symbols, such as the Old Tampa Bay is sampled at the first week of a month, and Hillsborough Bay at the second week and so forth). The inset shows the relative location of Tampa Bay estuary.

- Temporal aliasing (Fig. 2)

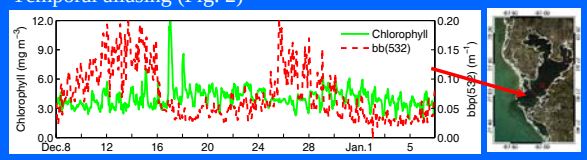

Figure 2. Short-term variability of chlorophyll and backscattering coefficient collected at one of Tampa Bay buoys from Dec. 8, 2004 to Jan. 7, 2005 using a fluorometer and a backscattering sensor. This figure shows that there are significant short-term changes in water quality, which are potentially missed by once per month field surveys.

Latest development in sensor design-increased resolution

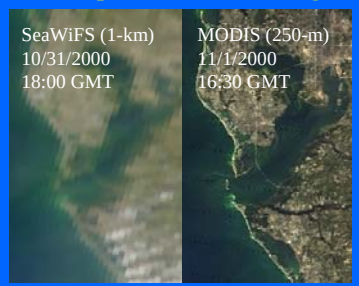

Figure 3. The comparison of SeaWiFS (1-km) and MODIS (250-m) images at two close days. The figure shows that MODIS (250-m) images significantly improve the images clarity as compared to traditional 1-km ocean color images and suitable for coastal applications (Hu et al, 2004; Miller and Mckee, 2004).

MODIS 250-m water turbidity-how accurate?

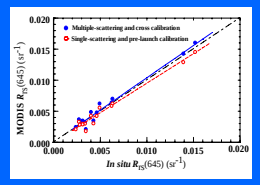

Figure 4. The comparison of R_{rs}(645) between *in situ* measurements and estimates from two different atmospheric corrections and calibrations (Chen et al., 2007a).

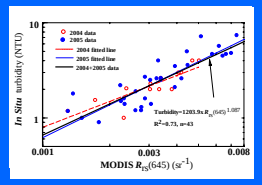

Figure 5. The comparison of MODIS R_{rs}(645) between *in situ* turbidity measurements, showing a robust and consistent relationship between R_{rs}(645) and turbidity across the Bay and seasons.

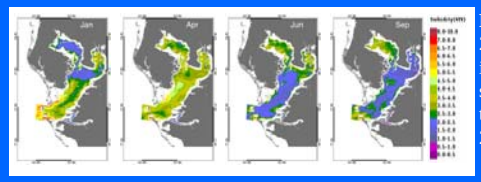

Figure 6. The MODIS 250-m derived turbidity images showing seasonal variability in the Bay (Chen et al., 2007a).

Water clarity-a novel algorithm shows significant improvement

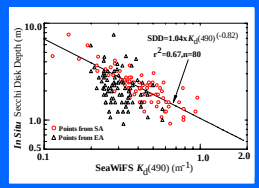

Figure 7. The comparison between *in situ* SDD measurements and SeaWiFS derived K_d(490) from the empirical (triangles) and the semi-analytical (open circles, Lee et al., 2005) algorithms, showing that the new algorithm significantly improve the relationship between K_d(490) and SDD. The relationship appears robust throughout the times and the Bay.

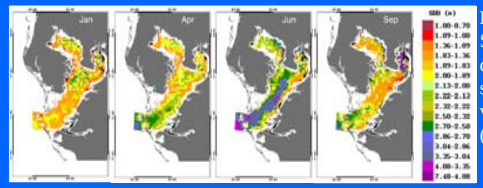

Figure 8. The SeaWiFS (1-km) derived SDD images showing the seasonal variability in the Bay (Chen et al., 2007b).

Water color-a new algorithm for MODIS

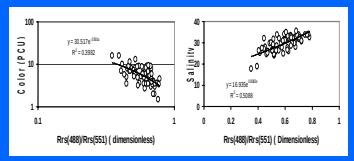

Figure 9. The scatter plot between MODIS Rrs(443)/ Rrs(551) and Color (PCU) and salinity in the middle and lower Bay.

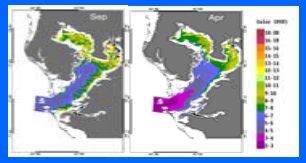

Figure 10. The seasonal variation of color (PCU) derived from MODIS images collected from Jul 2002 to Dec. 2006.

Chlorophyll concentration- a great challenge but promising

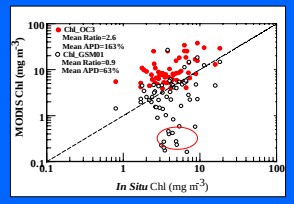

Figure 11. The comparison of chlorophyll between in situ measurements and MODIS estimates using band ratio (Chl_OC3) and a semi-analytical method (Chl_GSM01), showing the band ratio and semi-analytical algorithms, respectively, tends overestimate and underestimate chlorophyll for the Bay.

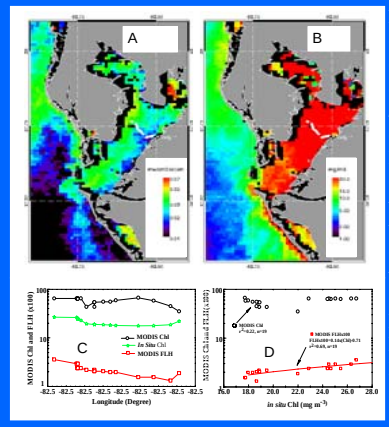

Figure 12. (A) MODIS FLH (mW $cm^{-2}\mu m^{-1}sr^{-1}$); (B) OC3 chlorophyll (mg m^{-3}) images acquired on Oct. 22, 2003, An *in situ* transect line was overlaid onto both images; (C) *In situ* Chl, MODIS Chl and MODIS FLH (x100 to facilitate comparison with MODIS Chl along the transect line in panel A and B; (D) Scatter plots of *in situ* Chl versus MODIS FLH and MODIS Chl obtained along the transect line. Solid line is the regression line between *in situ* Chl and MODIS FLH, showing FLH shows better correction than OC3.

Summary

- MODIS and SeaWiFS reveal distinctive spatial and temporal variability of water turbidity, water clarity and color across the Bay because satellites provide more 'realistic' and consistent estimates due to the synoptic and frequent observations;
- Satellite remote sensing of chlorophyll is still a change for Tampa Bay using absorption-based algorithms but MODIS fluorescence does show promises;
- Satellite observations show that most of the developed algorithms are robust and can be used for operational monitoring of these two important water quality indices.

References

Hu, et al.. (2004). *Remote Sensing of Environment* , 93: 423-441.
Lee, et al..(2005). *Journal of Geophysical Research*, 110, C02016, doi:10.1029/2004JC002275.1
Miller, R.L. and Mckee, B.A.. (2004). *Remote Sensing of Environment*, 93, 259-266.
Chen, et al.. (2007a). *Remote Sensing of Environment*, doi:10.1016/j.rse.2006.12.019
Chen, et al.. (2007b). *Remote Sensing of Environment*, doi:10.1016/j.rse.2007.01.002

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