Using MODIS to Estimate Water Turbidity in Taiwan

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ABSTRACT

Bathymetric lidar technology can collect both under- and above- water elevation in coastal area with short turn around time. The underwater efficiency is significantly affected by water turbidity. However, a water turbidity dataset with extensive temporal and spatial coverage is rarely found, both in coastal are and open ocean, which is much needed by field operation. In this paper, we proposed a procedure for estimating water turbidity from MODIS data by incorporating in-situ observations, including absorption coefficient, beam attenuation coefficient, backscattering coefficient, and secchi depth. The error rate of the resultant water turbidity, reported in secchi depth, is found to be ±30% for 67% of the in-situ observations, and ±50% for 87% of the in-situ observations.

INTRODUCTION

Bathymetric lidar has proven to be cost-effective for shallow water mapping in the coastal areas if the system operated in a favorable situation. The most important factor that affects the performance of bathymetric system is water turbidity. Most of commercial bathymetric lidar systems can measure up to 2~3 secchi depth.

MODIS sensor onboard Aqua satellite with 1 km spatial resolution, daliy revisit, and multispectral capability can provide extensive temporal and spatial imageries. The Quasi-Analytical Algorithm (QAA) based on radiative transfer equations considers different constituents in water (Lee, et al., 2002) can extract water optical properties from MODIS images. In this paper, MODIS Aqua images collected from 2004 to 2007 along with in-situ measurement are used to show the seasonal variation of secchi depth in coastal water of Taiwan.

METHOD

Absorption coefficient (a) and backscattering coefficient (b_b) are extracted from MODIS images based on QAA. A regression correction, equation (1), is applied to the QAA-derived values based on 19 concurrent in-situ measurements (figure 1). The determined regression parameters (α, β) are employed for all the conversion of QAA-derived results.

$$a_{est} = \frac{a - \beta_a}{\alpha_a}$$
$$b_{best} = \frac{b - \beta_{b_b}}{\alpha_{b_b}} \qquad \text{..............(1)}$$

(A) (B)

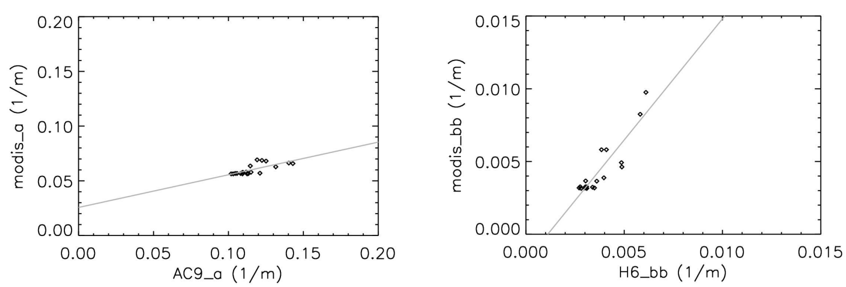

Figure 1. Regression correction of QAA result and in-situ data. (A) absorption coefficient (1/m), (B) backscattering coefficient (1/m).

The relationship between water optical properties and secchi depth can be described by underwater visibility equation $(c + K_d)Z_{SD} = \Gamma$, where c and K_d are water beam attenuation coefficient and diffuse attenuation coefficient, respectively, Z_{SD} is the secchi depth, and Γ is a constant, that is a function of water scattering properties (i.e., the scattering phase function) (Hou et al., 2007).

By definition, $c = a + b = a_{est} + m \cdot b_{best}$, m is the ratio of backscattering coefficient and scattering coefficient. The value of Γ and m, determined from the in-situ data, are 5.8 and 51.2 respectively.

K_d can be estimated by the use of Gershun's equation $K_d = a_{est}(z)/\bar{\mu}(z)$, where $a_{est}(z)$ and $a_{est}(z)$ are the water absorption coefficient and average cosine of the underwater light field at the depth of z. The average cosine at different depth is determined according to the underwater light model from Berwald et al. (1995).

To estimate the secchi depth, the underwater visibility equation is rearranged and is expressed as $Z_{SD} = \Gamma/(c + K_d)$.

In-Situ Data

Depth profiles of the water absorption coefficient and beam attenuation coefficient were collected with WET Labs AC9 and the depth profiles of backscattering coefficient were measured with a HOBI Labs HydroScat-6. Two instruments performed the profiling tasks in sequence, not in any particular order. The profile was lowered down to the depth of 20 m or 2~3 m above sea floor to prevent collision with the sea floor. Additionally, secchi depth were measured. A total of 65 measurements are collected, from May 2007 to May 2008. Figure 2 shows the in-site sites.

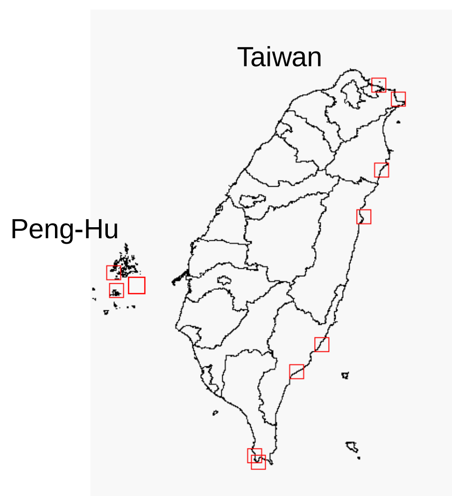

Figure 2. Map of Taiwan and Peng-Hu islands. The red rectangles denote the eleven sites with in-situ data collection.

The vertical profile data are processed by median filter to remove environmental noise. The m profile is calculated by $m = (c_{AC9} - a_{AC9})/b_{bH6}$, where AC9 and H6(HydroScat-6) denote the source of instrument.

Satellite Data

Level 1A MODIS Aqua images are obtained through NASA ocean color website (http://oceancolor.gsfc.nasa.gov/) and processed by SeaDAS 5.1 which is provided by NASA for Ocean Color studies. MODIS Aqua images are further processed to level 2 products based on QAA and to extract the absorption coefficient and backscattering coefficient.

RESULTS

Due to excessive cloud coverage, MODIS images contain large data blanks, both spatially and temporally. In order to reveal the annual variation of secchi depth of Peng-Hu islands, five regions of interest around the island are selected. Acceptable daily image should have more than 40% valid pixels within a region of interest. Then, a median value from each region of interest is obtained. Further, a weekly value based on the median operation of 7 consecutive daily values is determined. Figure 3 shows significant temporal variation of secchi depth with the maximum values from week 20 to 40.

Figure 4 shows seasonal secchi depth variation by employing mean operation of 90 daily MODIS images. The spring is from January to March. The coastal water around Taiwan shows better secchi depth in summer. Comparing the seasonal MODIS values and in-situ data, 67% of the observations are within 30% error and 87% of the observations are within 50% error.

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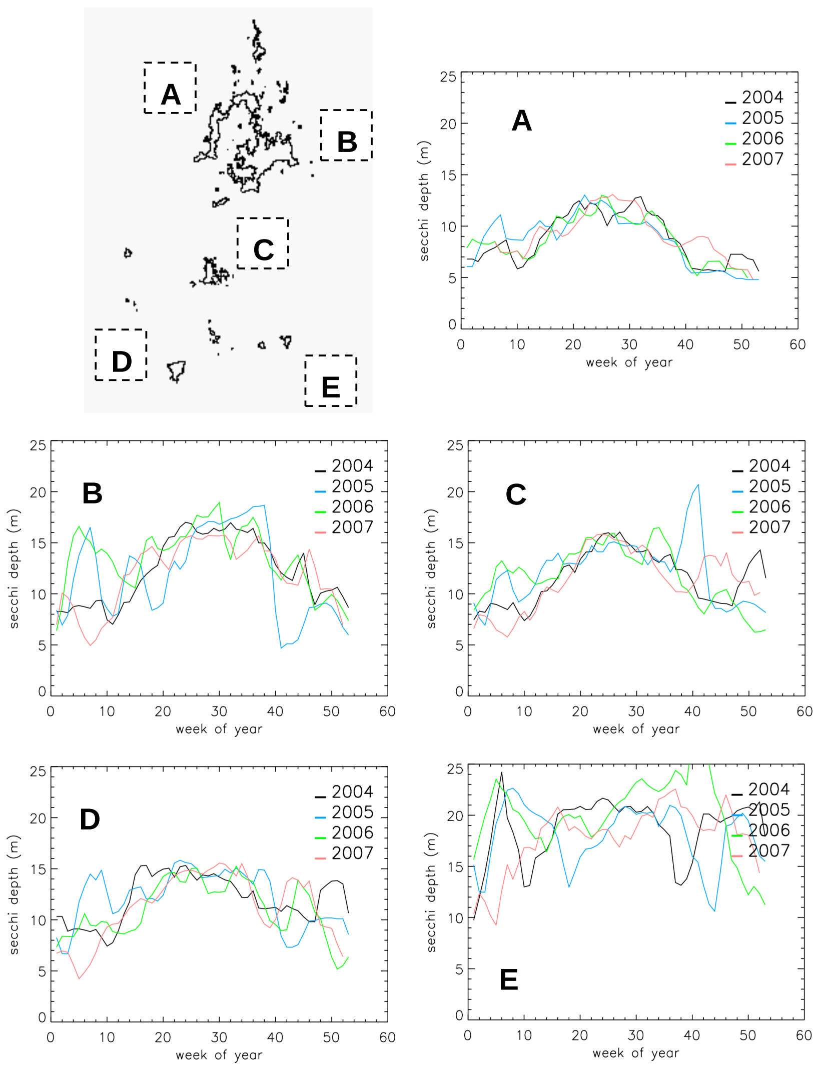

Figure 3. Temporal variation of secchi depth at Peng-Hu islands from 2004 to 2007.

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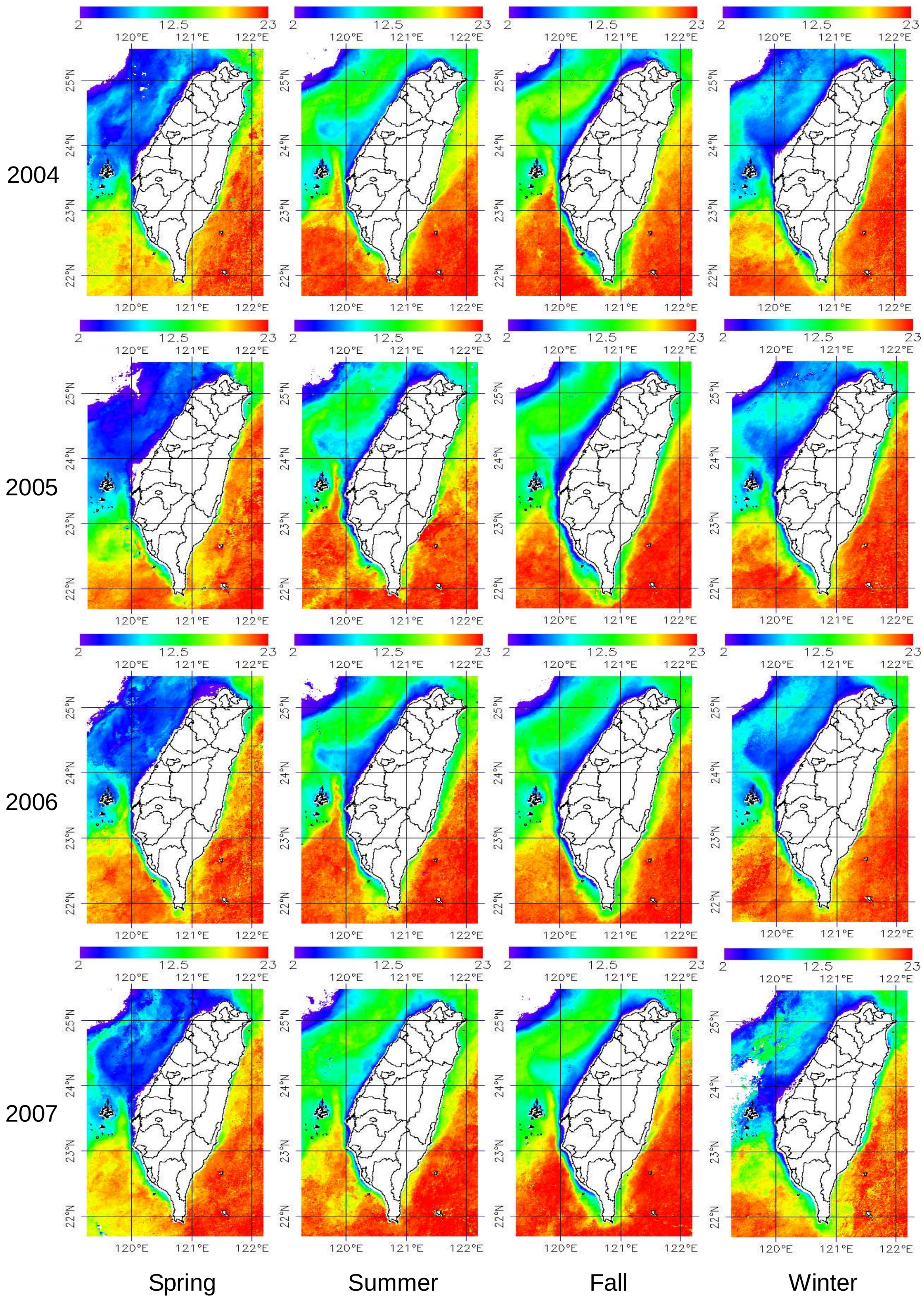

Figure 4. Seasonal variation of secchi depth of Taiwan from 2004 to 2007.