On the modeling of hyperspectral remote-sensing reflectance of high-sediment-load waters in the Vis-SWIR domain

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Abstract:
We evaluated three key components in modeling hyperspectral remote sensing reflectance in the visible to shortwave-infrared (Vis-SWIR) domain of high-sediment-load (HSL) waters, which are: the relationship between remote-sensing reflectance ($r_s$) and inherent optical properties (IOP), absorption coefficient of pure water ($a_w$) in the IR-SWIR region, and the spectral variation of sediment absorption coefficient ($a_{sed}$). Results from this study indicate that it is necessary to use a more sophisticated $r_s$-IOP model to describe the spectral variation of $r_s$ of HSL waters, otherwise it may result in spectrally distorted $r_s$ spectrum if a constant model parameter is used. For $a_w$ in the IR-SWIR region, the values reported in Kou et al (1993) provided a much better match with the spectral variation of $r_s$. For $a_{sed}$ spectrum, an empirical $a_{sed}$ spectral shape derived from sample measurements is found working much better than the traditional exponential-decay function of wavelength in modeling the spectral variation of $r_s$ in the visible domain. These results would improve our understandings of the spectral signatures of $r_s$ of HSL waters in the Vis-SWIR domain and subsequently improve the retrieval of IOPs and sediment loading of such waters from ocean color remote sensing.

1. Is $r_s$ model adequate for Vis-SWIR?

$$r_s(\lambda) = g \frac{b_h(\lambda)}{a(\lambda) + b_p(\lambda)}$$

(Eq. 1)

How $g$ varies with $b_p/(a+b_p)$?

$$g(\lambda) = \frac{b_h(\lambda)}{b_p(\lambda) + b_p(\lambda)} + 0.197 \left( 1 - 0.636 \exp \left( -2.552 \frac{b_h(\lambda)}{a(\lambda) + b_p(\lambda)} \right) \right)$$

(Eq. 2)

2. Which $a_w$ spectrum to use?

Fig. 2 (Left) Spectrum of $a_w$, and their NFDs, respectively; S_81: Segelstein 1981; K_93: Kou et al 1993. (Right) Comparison between the spectrum of the NFD of an Rrs spectrum and the NFDs of 1/$a_w$ spectrum.

3. Is $a_{sed}$ an exponential function?

Fig. 3. Comparison between exponential function (red) and measured $a_{sed}$ spectral shape (green), and their NFDs (red and blue, respectively). Exponential function does not accurately reflect the spectra curvature of $a_{sed}$. An empirical model is developed for $a_{sed}$ shape.

$$a_{sed}(\lambda) = A_{sed}(440)a_{sed}(\lambda) + B_{sed}$$

5. Conclusions:
1) Because the model parameter ($g$) of $r_s$ varies widely for different combinations of $b_p$ and $a$, it is necessary to employ a more generalized $r_s$ model developed for aquatic environments; 2) The hyperspectral $a_w$ spectrum of Kou et al is found working very well in representing the Rs spectral shape in the NIR-SWIR domain; 3) The conventional exponential function of wavelength used for ased does not reflect the spectral curvature well, which further affects the closure of Rs spectrum and the accuracy in retrieving IOPs if an exponential function is used.

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