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_{rs}) 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_{rs}-IOP model to describe the spectral variation of R_{rs} of HSL waters, otherwise it may result in spectrally distorted R_{rs} 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_{rs}. 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_{rs} in the visible domain. These results would improve our understandings of the spectral signatures of R_{rs} 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_{rs} model adequate for Vis-SWIR?

$$r_{rs}(\lambda) = g\frac{b_b(\lambda)}{a(\lambda)+b_b(\lambda)} \qquad \text{(Eq.1)}$$

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

$$g(\lambda) = 0.113\frac{b_{bw}(\lambda)}{b_{bw}(\lambda)+b_{bp}(\lambda)} + 0.197\left[1-0.636Exp\left(-2.552\frac{b_{bp}(\lambda)}{a(\lambda)+b_b(\lambda)}\right)\right]\frac{b_{bp}(\lambda)}{b_{bw}(\lambda)+b_{bp}(\lambda)} \qquad \text{(Eq.2)}$$

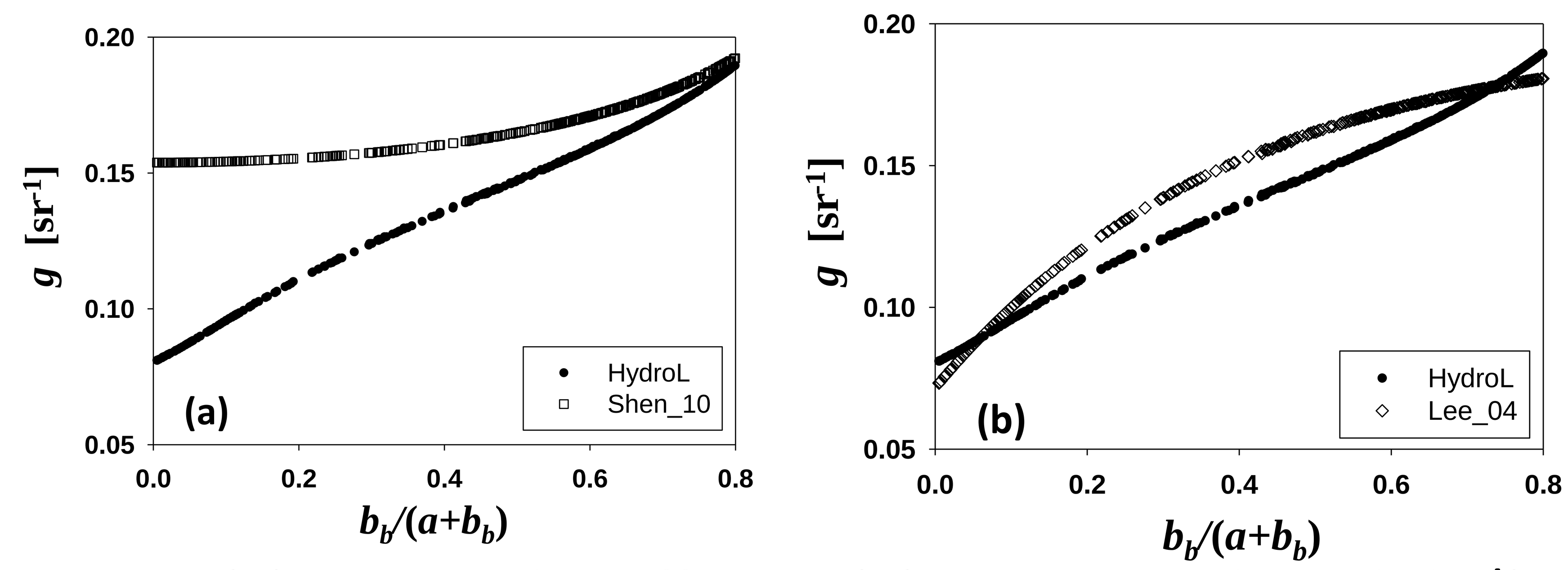

Fig. 1 (a) r_{rs}-model coefficient (g) varies widely with $b_b/(a+b_b)$; Shen_10 model for g works for wavelengths of high $b_b/(a+b_b)$ ratio.. (b) The g model of Lee_04 (Eq. 2) reasonably represents the variation of g for wide range of $b_b/(a+b_b)$ values.

2. Which a_w spectrum to use?

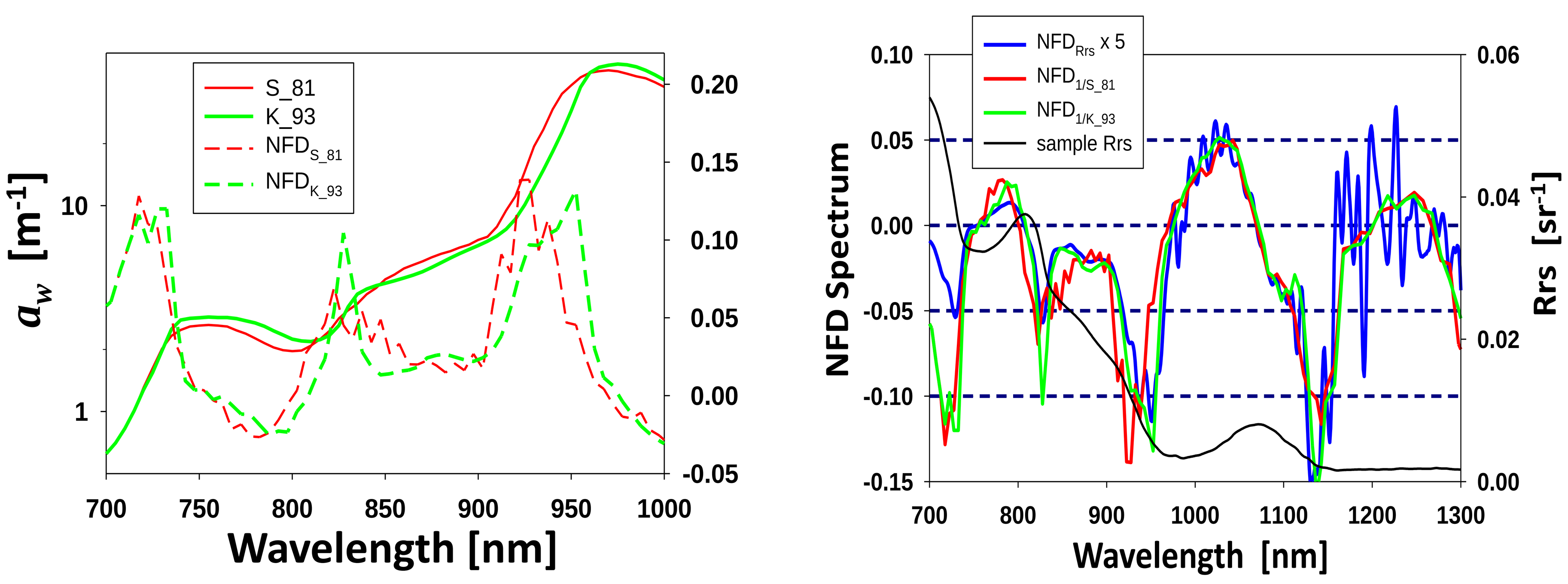

Fig. 2 (Left) Spectrum of aw, and their NFDs, respectively; S_81: Segelstein 1981; K_93: Kou et al 1993. (right) Comparison between the spectrum of the NFD of an Rrs spectrum and the NFDs of $1/a_w$ spectrum.

Normalized first-order derivative:

$$NFD_S(\lambda_x) = \frac{S(\lambda_2)-S(\lambda_1)}{S(\lambda_2)+S(\lambda_1)}$$

Comparison of the NFDs indicates that the a_w spectrum reported in Kou et al (1993) works best to model hyperspectral Rrs in the NIR-SWIR range.

3. Is a_{sed} an exponential function?

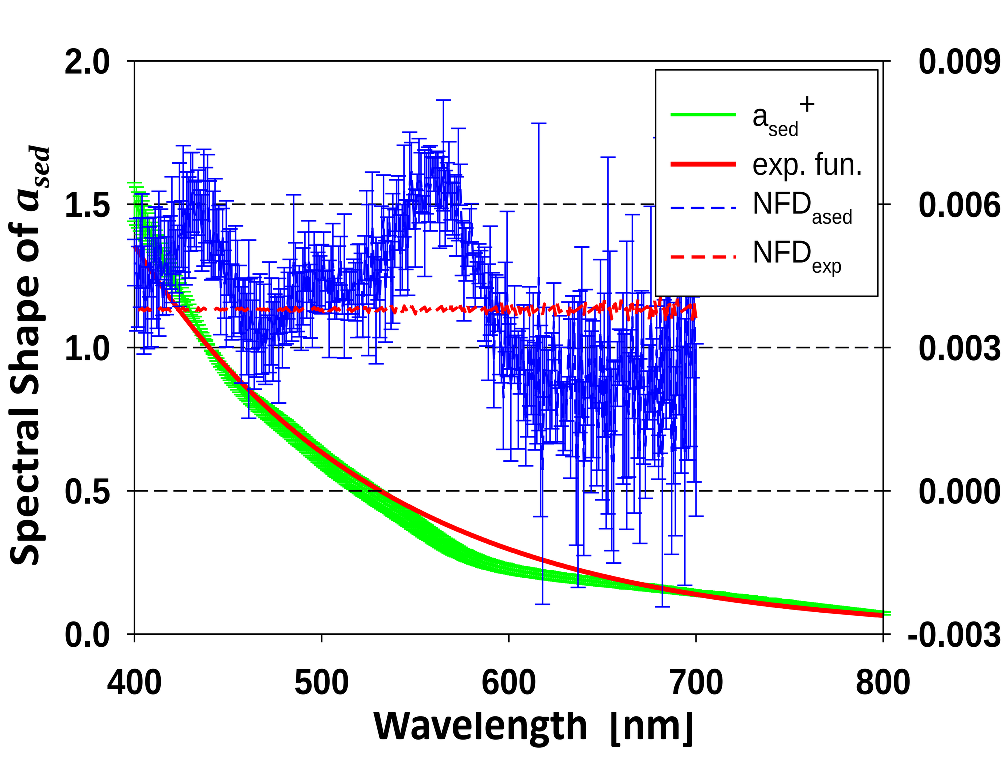

Fig. 3. Comparison between exponential function (red) and measured a_{sed} spectral shape (green), and their NFDs (red and blue, respectively). Exponential function **does not** accurately reflect the spectra curvature of a_{sed}. An empirical model is developed for a_{sed} shape.

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

4. Impact on Rrs closure and IOP inversion

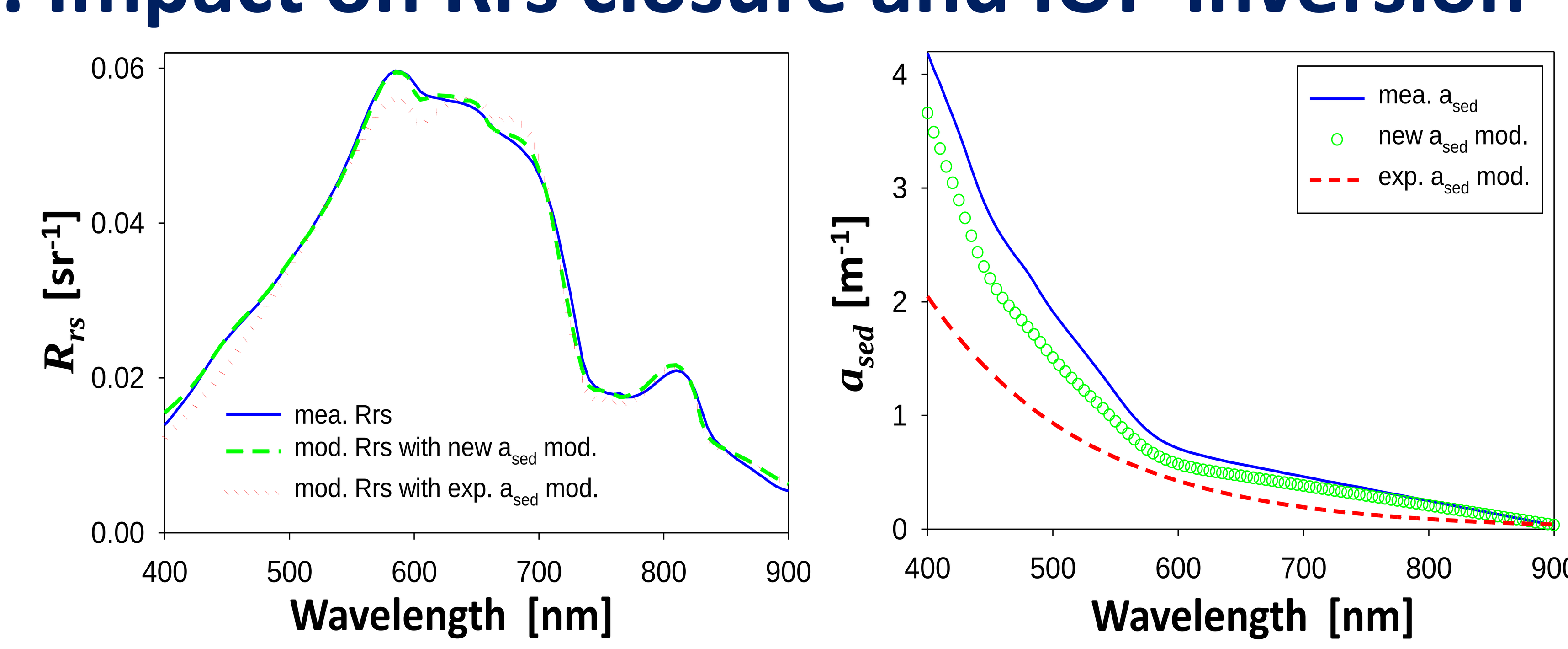

Fig. 4. Examples of different a_{sed} spectral model on the closure of Rrs spectrum (left) and retrieval of a_{sed}.

5. Conclusions:

1) Because the model parameter (g) of r_{rs} varies widely for different combinations of b_b and a, it is necessary to employ a more generalized rrs model developed for aquatic environments; 2) The hyperspectral aw spectrum of Kou et al is found working very well in representing the Rrs 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 Rrs spectrum and the accuracy in retrieving IOPs if an exponential function is used.

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