Estimating surface irradiance for optically shallow waters

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Introduction

_ Remote sensing reflectance (Rrs) is crucial to ocean color studies, and can be derived from surface irradiance reflectance R(0)=-Eu(0)/Ed(0).
_ In optically shallow waters, e.g. the Chesapeake Light Tower (CLT in Figure 1), bottom reflectance has a significant effect on Eu(0) and Ed(0).
_ Optically shallow waters are important to people, and need to be understood.
_ Radiative transfer models, e.g. Hydrolight, are complex in predicting R(0). Is there a simple way for estimating R(0) for optically shallow waters?

Model

For optically shallow waters, Eu(0) and Ed(0), are contributed from water column and bottom reflectance together, and can be expressed as (*Pan*, in manuscript).

$$E_{ds}(0) = E_{di}(0)*[1+(R_i+0.467)*G] \quad (1)$$

$$E_{us}(0) = E_{di}(0)*(R_i+G) \quad (2)$$

$$R_s(0) = \frac{R_i+G}{1+(R_i+0.467)*G} \quad (3)$$

where $G = \frac{W(R_D - R_i)\exp(-kD)}{(1-R_i*R_D)(1-0.467*R_i)-0.467W^2R_D}$

W≈exp[-2D(a+bb)]
s and i: optically shallow and infinitely deep water, respectively.
D: bottom depth for optically shallow water.
a and b_b: absorption and backscattering coefficients.

Results

_ This model works well to calculate Ed(0) and Eu(0) for optically shallow waters, regardless of bottom conditions and solar situation (Figures 2 and 3).
_ The relative difference between this model and Hydrolight simulations is typically <10% for _<550 nm, but could be >20% for wavelengths around 590 nm (Figure 4 and 5).
_ The reason for the difference between these two models is that in this model the average cosine was thought to equal to 0.5 for bottom reflected light. It could be much different to 0.5 in 550-620 nm.

Conclusions

This model is reasonably successful in predicting Ed(0) and Eu(0) for optically shallow waters, and even provides a simpler way for inverse modeling to predict chlorophyll, absorption, and backscattering coefficients.

References
Mobley, C., *Light and Water: Radiative Transfer in Natural Waters* (Academic, San Diego, 1994).
Pan, X., Estimating surface irradiances for optically shallow waters, *Apply Optics* (in manuscript).

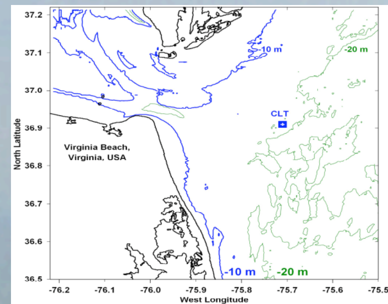

Figure 1. The Chesapeake Light Tower (CLT) locates ~25 km off the coast of Virginia Beach, Virginia. The water depth around CLT is ~11m, and the normal bottom irradiance reflectance f<0.1. The inputs of inherent optical properties (IOP's) for modeling were adopted from the observations at this site from 2000-2002.

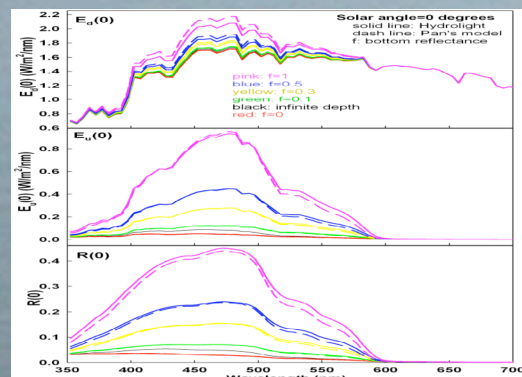

Figure 2. Comparisons of surface downwelling irradiance *Ed(0)*, upwelling irradiance *Eu(0)*, and surface irradiance reflectance *R(0)* for Hydrolight simulations and this paper. The same absorption and backscattering spectral inputs were used for these two models. The bottom depth was10 m, and the bottom reflectance (f) was independent to wavelengths. The incident solar zenith angle was set to 0 degrees.

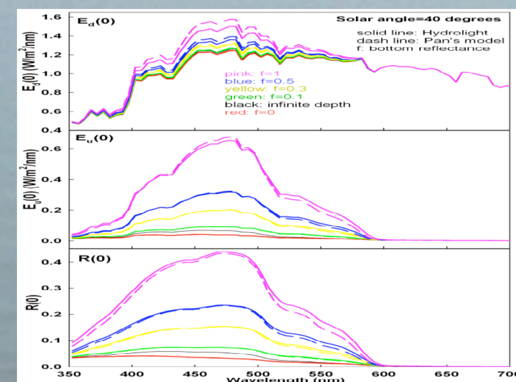

Figure 3. Same as Figure 2 except solar zenith angle set at 40 degrees.

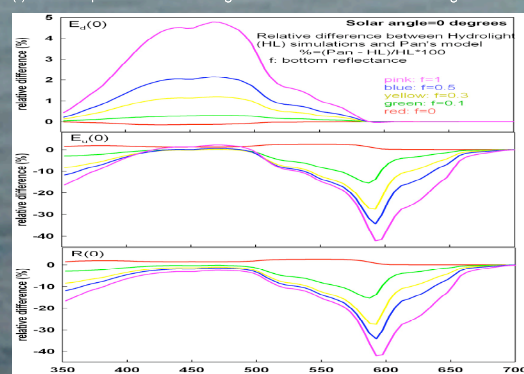

Figure 4. Relative differences of Hydrolight simulations and Pan's models for Figure 2.

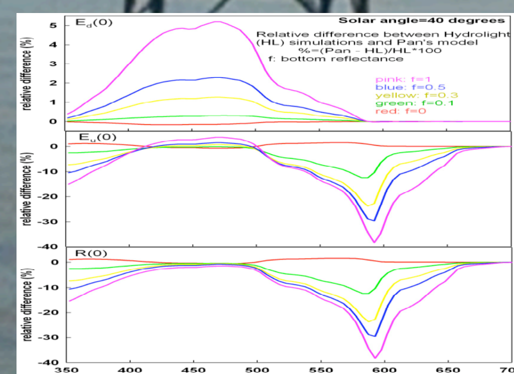

Figure 5 Relative differences of Hydrolight simulations and Pan's models for Figure 3.