Methods in Oceanography 7 (2013) 63–78

Contents lists available at ScienceDirect

Methods in Oceanography

journal homepage: www.elsevier.com/locate/mio

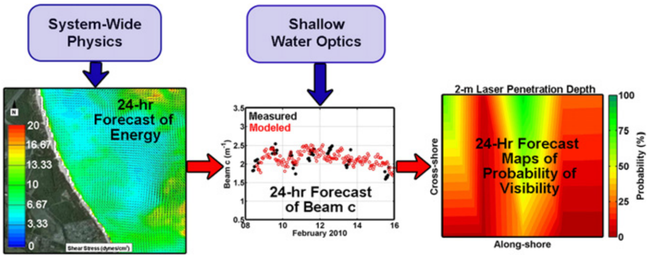
Full length article

Prediction of optical variability in dynamic nearshore environments☆

Grace Chang[a,*], Craig Jones[a], Michael Twardowski[b]

[a] *Sea Engineering, Inc., 200 Washington St., Suite 101, Santa Cruz, CA 95060, United States*
[b] *WET Labs, Inc., Department of Research, 70 Dean Knauss Dr., Narragansett, RI 02882, United States*

GRAPHICAL ABSTRACT



HIGHLIGHTS

- We developed a novel shallow-water underwater visibility prediction model.
- We validated the model with site-specific optical conditions.
- We produced maps of spatially resolved visibility conditions.
- We predicted object detection probability to 75% accuracy for 2-m diver visibility.

☆ Approved for public release, distribution unlimited. This project was sponsored by the Defense Advanced Research Projects Agency (DARPA) and the National Defense Center of Excellence for Research in Ocean Sciences (CEROS). The content of the information does not necessarily reflect the position or the policy of the Federal Government or the State of Hawaii. No official endorsement should be inferred.

* Corresponding author. Tel.: +1 831 421 0871.

E-mail addresses: gchang@seaengineering.com (G. Chang), cjones@seaengineering.com (C. Jones), mtwardo@wetlabs.com (M. Twardowski).

2211-1220/$ – see front matter
http://dx.doi.org/10.1016/j.mio.2013.12.002

ARTICLE INFO

Article history:
Available online 17 December 2013

Keywords:
Underwater visibility
Diver visibility
Hydrodynamic modeling
Beam attenuation coefficient
Nearshore coastal waters

ABSTRACT

Forecasting Optics REaltime in Shallow Energetic Environments (FORESEE) was developed for predictions of underwater visibility in dynamic surf zone environments. FORESEE employs key measurements of physical forcing and beam attenuation coefficient (beam c) and numerical wave and hydrodynamic models to: (1) generate predictions of energy variation, (2) relate energy characteristics to the optical property of interest, beam c, and (3) produce 24-hr forecast maps of spatially resolved visibility conditions at a site of interest. FORESEE beam c prediction performance was very good using site-specific data collected in Waimanalo, Hawaii (average root mean squared error of 0.38 m^{-1}). Predictions of probability of object detection (P_d) were on average within 75% accuracy for 2-m diver visibility. Differences between modeled and measured P_d may have been affected by a phytoplankton bloom that was observed during field data collection. The addition of a growth term and a bottom-type term to the model could account for biological processes and differing bottom types in nearshore regions. Further improvements could also be made with more accurate model boundary conditions.

1. Introduction

A priori knowledge of underwater visibility in nearshore coastal areas is beneficial for many applications including, for example, commercial diving projects, coastal surveys, search and salvage operations, habitat restoration efforts, harbor security, or military operations. Accurate forecasts of diver visibility can greatly facilitate planning efforts, reduce costs, and increase human safety associated with commercial diving activities such as inspections, surveys, and construction of bridges, piers, dams, and pipelines. Active and passive coastal habitat restoration efforts can benefit from predictions of turbidity effects on underwater light levels by enhancing environmental monitoring, management, and evaluation protocols. A system for forecasting marine optical conditions in nearshore waters would ensure safe passage of Navy assets by enabling successful, rapid identification of underwater targets (e.g., mine-like objects) using divers, passive sensors, or laser penetration systems.

The following relationship describes the attenuation of the difference in radiances between a target and background based on radiative transfer theory (Duntley, 1963; Jerlov, 1976; Preisendorfer, 1976 and Zaneveld and Pegau, 2003) (wavelength notation suppressed; see Abbreviations and Symbols):

$$[L_{Tr}(\theta, \phi, z) - L_{Br}(\theta, \phi, z)] = [L_{T0}(\theta, \phi, z_T) - L_{B0}(\theta, \phi, z_T)]e^{-cr}, \tag{1}$$

where the difference in the radiances of a target, $L_{T0}(\theta, \phi, z)$, and background, $L_{B0}(\theta, \phi, z)$, attenuates as e^{-cr}, r is the distance between the target and the detector, and c is the beam attenuation coefficient (also referred to as beam c). The depth of observation is z, the depth of the target is z_T, the zenith angle is represented by θ, and ϕ is the azimuthal angle. Eq. (1) holds true for any two radiances next to each other, i.e. with the same path function, or background scattered light. An object is detectable when the difference in radiances between the object and the background is above the contrast threshold for a sensing device. Zaneveld and Pegau (2003), Lythgoe (1971) and Davies-Colley (1988) suggested and evaluated a simple relationship for the horizontal visibility range for a black target, y_{BT}, based on Eq. (1):

$$y_{BT} = 4.8/c, \tag{2}$$

where c is weighted to the photopic response of the human eye. The Naval Oceanographic Office (NAVOCEANO) employs the following visibility products, derived from early radiative transfer and