Worldwide Ocean Optics Database (WOOD)

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LONG-TERM GOALS

The long-term objective is to provide a comprehensive worldwide optics database that includes data on a broad range of important optical properties, including diffuse attenuation, beam attenuation, and scattering. Data from ONR-funded bio-optical cruises will be given priority for loading into the database, but data from other scientific programs (NASA, NOAA, NSF) and from other countries will also be routinely added to the WOOD[1]. The database shall be easy to use, Internet accessible, and frequently updated with data from recent at-sea measurements. The database shall be capable of supporting a wide range of applications, such as environmental assessments, sea test planning, and Navy applications. The database shall include derived optical parameters so that if measured data are not available, the user can obtain values computed from empirical algorithms (e.g., beam attenuation estimated from diffuse attenuation and backscatter data). Error estimates will also be provided for the computed results. Extensive algorithm evaluation and validation will be conducted to ensure that the derived results are optimized as a function of wavelength, season, and geographic location.

OBJECTIVES

A main analysis objective has been to "validate" the algorithms and error estimates to be used in the generation of "Derived Parameters." An on-going objective is to acquire and add new optics data to WOOD. Finally, the data are to be provided periodically to NAVOCEANO.

APPROACH

Validation of derived parameters is being performed for open ocean data, continental shelf data, and shallow coastal data. Multi-wavelength AC-9 data are being used so that the spectral dependence of the algorithms can be assessed. Data from a variety of seasons and locations are being analyzed in order to determine seasonal and geographic dependencies. Our focus is on the empirical relationships among the inherent optical properties (IOPs) known as absorption (**a**), scattering (**b**), and total beam attenuation (**c**), and on the relationship of the various IOPs to the diffuse attenuation coefficient (K). In an attempt to obtain improved results, the accuracy of published empirical relationships (e.g., Morel's relationships[2] between chlorophyll and optical properties) are compared to new algorithms being developed and tested. The accuracy of each algorithm is assessed in terms of absolute errors (such as the root-mean-square difference between measured and calculated values) and in relative terms (such as the median absolute *percent* error). The absolute error is used to treat high or low values

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14. ABSTRACT

The long-term objective is to provide a comprehensive worldwide optics database that includes data on a broad range of important optical properties, including diffuse attenuation, beam attenuation, and scattering. Data from ONR-funded bio-optical cruises will be given priority for loading into the database, but data from other scientific programs (NASA, NOAA, NSF) and from other countries will also be routinely added to the WOOD1. The database shall be easy to use, Internet accessible, and frequently updated with data from recent at-sea measurements. The database shall be capable of supporting a wide range of applications, such as environmental assessments, sea test planning, and Navy applications. The database shall include derived optical parameters so that if measured data are not available, the user can obtain values computed from empirical algorithms (e.g., beam attenuation estimated from diffuse attenuation and backscatter data). Error estimates will also be provided for the computed results. Extensive algorithm evaluation and validation will be conducted to ensure tha

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equally. The relative (percentage) error is used to account for the great variability in attenuation coefficients as a function of depth.

Empirical algorithms are being developed using data from the Sea of Japan, the Yellow Sea, and the Gulf of Oman/Persian Gulf regions. Specifically, during the past year we have examined the following ratios: **c**:K, **b**:**c**, K:$\mathbf{b_b}$, **a**:K. Where appropriate, we examine these relationships as a function of wavelength and also as a function of depth domain (e.g. shallow versus nepheloid layer). The best available data are being used to develop these algorithms (though some of these data cannot be posted on the WOOD public website). We are using high quality NAVOCAENO survey data from the Middle East and the Yellow Sea. For the Sea of Japan, we used data provided by Greg Mitchell acquired as part of a major ONR field program conducted there recently. Besides these important datasets, many others are being provided by ONR Principal Investigators or are being downloaded from various public websites.

WORK COMPLETED

The main thrusts of our work involved 1) preparing/loading new data into WOOD, 2) developing empirical algorithms and, 3) building regional environmental optics characterizations.

1. Add New Datasets to WOOD/Upgrade WOOD: With respect to the preparation and loading of new datasets, the following was accomplished. First, Greg Mitchell's Sea of Japan AC-9, MER spectral radiometer, and Hydroscat optical datasets were processed, analyzed, and loaded into WOOD. Second, the public NASA public pigment files (of HPLC, calibrated fluorometers, phaeophytin, etc.) were processed and loaded. Third, several Gulf of Maine datasets were processed and loaded. Table 1 summarizes the data that were processed and loaded into WOOD this past year.

Table 1. Data Loaded into WOOD During GFY 02

Data Description	***Number Profiles***
Mitchell Sea of Japan	38 of $a(\lambda)$,$b_b(\lambda)$,$c(\lambda)$,$K_d(\lambda)$,$E_d(\lambda)$, $E_u(\lambda)$,$L_u(\lambda)$,T, Sal, RelFl
NASA HPLC	731
NASA Chl_a (fluorometer)	30,276
NASA "Total Pigment"	16,751
NASA Phaeophytin	12,144
Bigelow Gulf of Maine "AL96"	12 of $a(\lambda)$, $b_b(\lambda)$, $c(\lambda)$, tot_chl, K490, T, Sal
CSC May96 Gulf of Maine	~ 50 of $K_d(\lambda)$, $E_d(\lambda)$, $E_s(\lambda)$, $L_u(\lambda)$, c660, turbidity, T
NEGOM Gulf of Mexico	895 of c660, rel_back, rel_fluor, T, sal, O2, nutrients, chlor_a
Bigelow Gulf of Maine "AL97"	48 of c488, chlor_a, T, Sal

The task of preparing and loading data into WOOD is an on-going task. Table 2 summarizes data presently being processed for loading into WOOD.

Table 2. Data Presently Being Processed for Loading into WOOD

Data Description	Number Profiles
NASA SEABASS	> 4,700 of a, c, K, b_b, E_d, E_u, L_u, chlor, etc.
Cornell Hyperspectra	CoBOP & HyCODE spectra (20 in 1999, 26 in 2001, 21 in 2001)
Bigelow Gulf of Maine (from Phinney)	AL98: 30 of chlor_a, Phaeo, $E_s(\lambda)$, $L_u(\lambda)$, T, Sal DE97: 28 of c488, T, rel_fluor, sal

Besides processing/adding new data to the database, we also significantly upgraded the WOOD software/hardware to make it more "supportable" and more efficient (speed & cost). We migrated the system to a new Pentium III, 1.0GHz/dual processor CPU using Windows 2000 (instead of the old Windows NT) operating system, and we converted from our very old version of Oracle to Microsoft SQL Server. We also switched from the WOOD Version 3 GUI software to Version 4 (which uses exclusively the 3-tier approach so all users come in through Port 80, which is far better for security). Finally, we replaced the old DBDB-5 water depth data with the latest data from NAVOCEANO (DBDB-V).

2. Empirical Algorithms: The other focus this year has been on assessing the dependencies of empirical algorithms on location (e.g. open ocean versus continental shelf regions) and wavelength. As an example of this work, Figure 1 shows a summary of b:c ratios as a function of region and wavelength. The figure shows the slope, **m**, defined by the equation:

$$\mathbf{b}-\mathbf{b}_w = \mathbf{m} * (\mathbf{c}-\mathbf{c}_w) \quad \ldots\ldots (1),$$

where $\mathbf{b}_w$ and $\mathbf{c}_w$ are the pure water components of **b** and **c**, respectively. Above 525 nm, the b:c ratio is relatively constant within a given locale (about 0.80 to 0.85), but at shorter wavelengths the b:c ratio consistently decreases. At 412 nm, the lowest b:c ratios occurred in the relatively clear CMO (US continental shelf) and Sea of Japan waters, and the highest b:c ratios occurred in the more turbid Yellow Sea waters. The decrease in the b:c ratio below 525 nm is attributed to the presence of Colored

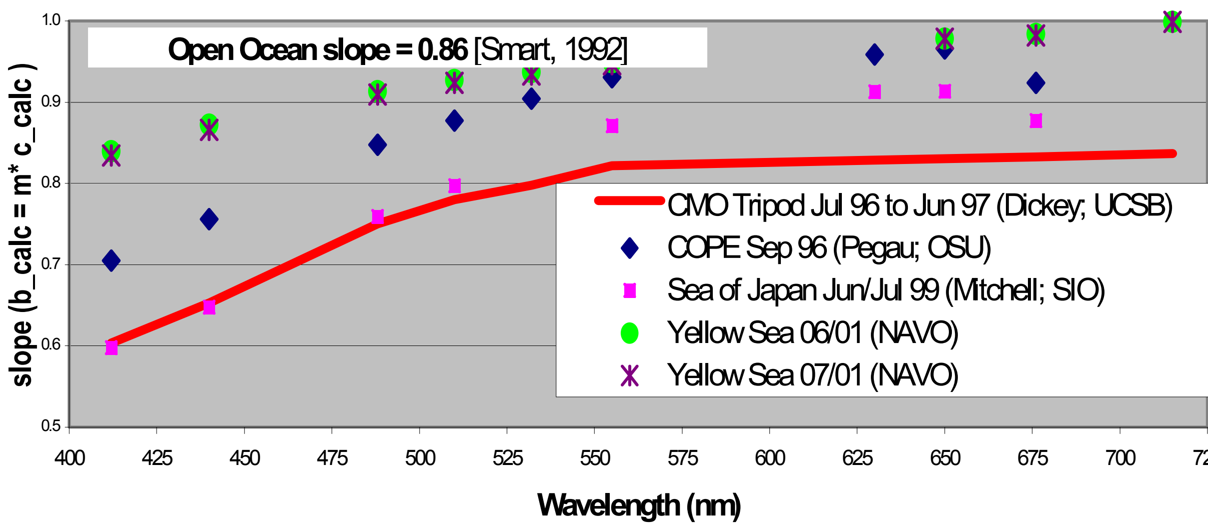

Figure 1. Wavelength Dependence of b:c Ratio [The b:c ratio is nearly independent of λ between 550 and 725 nm; the b:c consistently decreases between 550 and 412 nm]

Dissolved Organic Materials (CDOM). On-going work will establish whether the results shown in Figure 1 are typical for a wide range of locations and seasons.

We have also investigated the accuracy of several algorithms that can be used to estimate c from K. Figure 2 summarizes the relative accuracies of these techniques in the CMO continental shelf data acquired off the US East Coast. Similar results were obtained in the Sea of Japan and in a trans-Atlantic open ocean dataset.

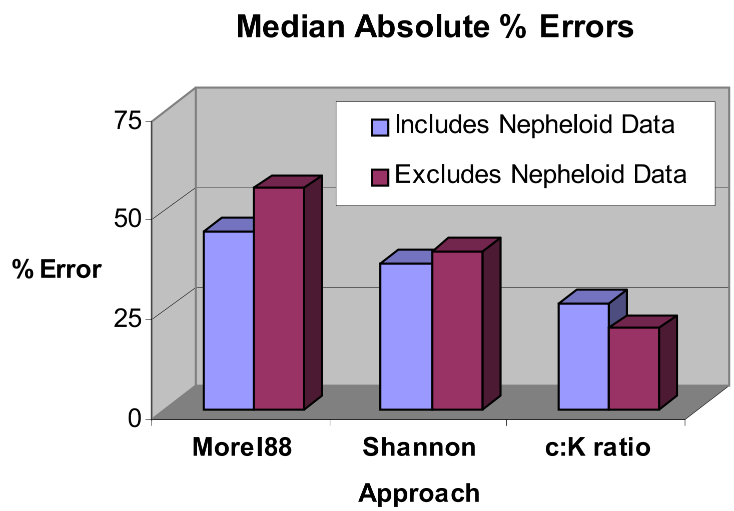

Figure 2. Median Errors in Estimating c from K in the Summer 1996 CMO Data for Various Empirical Methods [Morel88 method errors are 45 to 56 %; Shannon

3. Regional Environmental Optics Characterizations: As an example of our work in building region-specific optical characterizations, Figure 3 shows the median K profile (and 10% and 90% bounds) from the Gulf of Oman and the modelled/observed relationship between b_b and K. A paper describing the techniques used to produce statistical regional characterizations was presented at the conference "Fifth International Symposium: Technology And The Mine Problem." Except in the nepheloid layer data, the b_b versus K data generally fall between the "Old Gordon-Morel" relationship[3] and the empirical "lower limit" published in Smart[4].

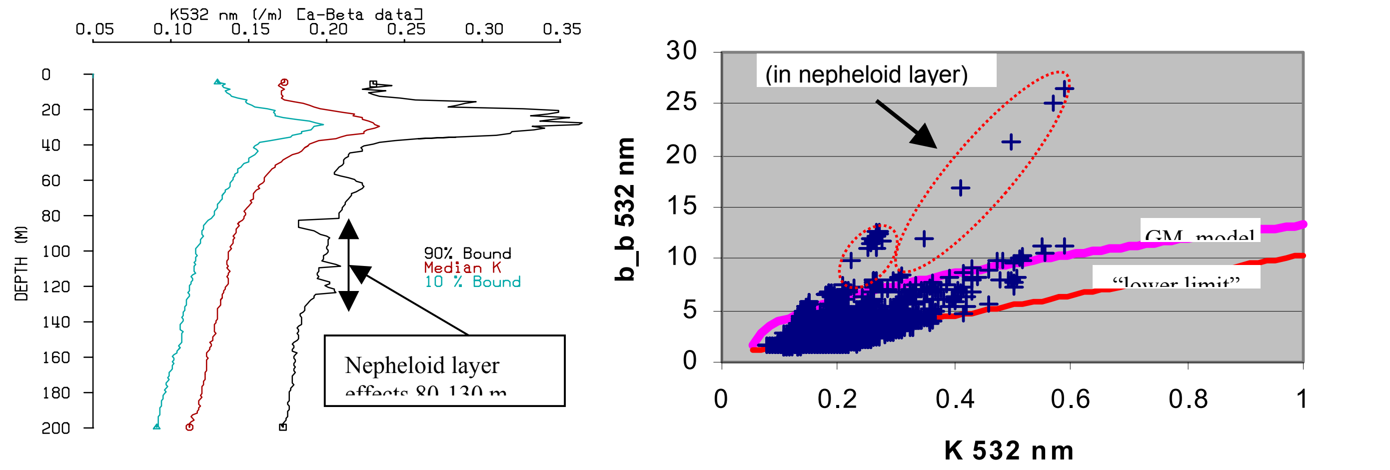

Figure 3. Statistical Variability in Gulf of Oman K Profiles (left) & b_b vs K relationship (right) [Median K532 varies from ~ 0.1 to 0.24 /m and 90% bounds reach 0.35/m from 0 to 200 m; nepheloid b_b values are much higher than K to b_b model predictions.]

RESULTS

Many investigators from around the world have already made use of the WOOD. For example, over the 10-month period from May 2001 through February 2002, WOOD was accessed nearly 17,000 times by 2391 different IP sites, which included 211 schools, colleges, universities, and research institutes and 57 DoD/US Government/State-Local Government agencies. As an example of US Navy use, the ONR Littoral Warfare Advanced Development (LWAD) Program used WOOD data in planning for the LWAD 01-2 Sea Test in the East China Sea and for the SHAREM 142 exercise being planned in the Yellow Sea for next fall.

IMPACT/APPLICATIONS

The availability of a single location, uniform-format optics database has already saved the US Navy thousands of dollars in test planning and other naval applications. By providing the Navy and the research community with this resource, both types of users benefit from improved knowledge of the optical properties of the ocean. Access to historical optics data can also be useful for assessing newly acquired data. One can compare the two to see if the new results are atypical, and if so, one might go on to determine the cause (e.g. unusual forcing conditions, influx of a different water mass, or perhaps even an instrument calibration problem).

TRANSITIONS

A clone of WOOD was developed for the Advanced Processor Build (APB) November 2001 sea test as part of the ARCI Environmental Workstation. During the November sea test, the system was used to monitor real-time BQH1A and sonar dome sound velocity measurements. For related information at the unclassified level, see the Submarine Operational and Research Database (SOARED) website at http://wood.jhuapl.edu/soared/welcome.html

RELATED PROJECTS

The Laboratory is an official member of the NASA "SEABASS" community that has access to proprietary bio-optics data. In order to obtain this privilege, US Navy permission was obtained to provide unclassified ONR LWAD optics data (collected by JHU/APL scientists) to SEABASS. (The LWAD East China Sea optical data have been submitted to SEABASS.) We have also had preliminary discussions with the Project manager for the Advanced SEAL Delivery Vehicle System (ASDS) Trainer System; he wants to use WOOD data to develop more realistic environmental simulations. Finally, contingent upon funding, ONR's Common Environmental Picture (CEP) program is interested in the development of a DoD-restricted version of WOOD to support non-acoustic ASW needs. This database would have the entire contents of WOOD, all the non-public (but unclassified) data from NAVOCEANO surveys, airborne environmental lidar surveys, optic data from various US Navy-funded field exercises, and optics data from classified sources (up to the SECRET level).

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PUBLICATIONS

"Optical Climatologies for US Navy Missions," paper presented at the Fifth International Symposium: Technology And The Mine Problem, Monterrey, CA, April 22-25, 2002

"Regional And Global Empirical Relationships Among Optical Variables," to be published in Ocean Optics XVI, November 2002