

Upgraded 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 is 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 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.” For locations of special interest to the US Navy (such as the Yellow Sea, Gulf of Oman, and Persian Gulf), we are developing region-specific algorithms. 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 relationships² 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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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 examined the following ratios: $c:K$, $b:c$, $K:b$, $a:K$ in the Yellow Sea and in the Gulf of Oman/Persian Gulf. Where appropriate, we examined 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. We are also adding new features to the WOOD website, including the addition of hyperspectral data and a hyperspectral display, and options to automatically convert data from one wavelength to another. The wavelength conversion option allows a user to obtain data at a specific wavelength of interest (e.g. 490 or 532 nm) when the measured data are at a different wavelength.

1. Add New Datasets to WOOD/Upgrade WOOD: With respect to the preparation and loading of new datasets, the following was accomplished (as of 26 August 2003). All the Cornell and University of South Florida (USF) CoBOP hyperspectral data from 1998 to 2001 were processed and loaded into WOOD (see Table 1).

Table 1. Data Loaded into WOOD During GFY 03

Data Description	Number & Types of Profiles
Cornell CoBOP 1999	19 $Ed(\lambda)$ & $Lu(\lambda)$ [hyperspectral data]
Cornell CoBOP 2000	26 $Ed(\lambda)$ & $Lu(\lambda)$ [hyperspectral data]
Cornell CoBOP 2001	22 $Ed(\lambda)$ & $Lu(\lambda)$ [hyperspectral data]
USF CoBOP 1998	44 $ap(\lambda)$, $ag(\lambda)$, $ad(\lambda)$, $Rrs(\lambda)$ [hyperspectral data]; chl_a+Phaeo
USF CoBOP 1999	41 $ap(\lambda)$, $ag(\lambda)$, $ad(\lambda)$, $Rrs(\lambda)$ [hyperspectral data]
USF CoBOP 2000	34 $ap(\lambda)$, $ag(\lambda)$, $ad(\lambda)$, $Rrs(\lambda)$ [hyperspectral data]

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 & Type of Profiles
NASA SEABASS	> 4,700 of a, c, K, b _b , E _d , E _u , L _u , chlor, etc.
NOAA WOD01	> 100,000 stations of chlorophyll, Phaeophytin, Secchi depths, nutrients, turbidity, fluorometer & CTD data
PROSOPE	70 stations with chlor_a, Phaeo, AC9, T, Sal, bottle samples
MBARI South China Sea	29 stations of Ed(λ) & Lu(λ)
CHORS 1994 Arabian Sea	16 Ed, Eu, Es, Lu, Kd(λ) [MER data]
CHORS 1995 Arabian Sea	91 Ed, Es, Lu, Kd(λ) [MER data] & chlor_a & c660 nm
USF CoBOP W. Florida Shelf	74 AC9, Hydroscat, CTD profiles

Besides processing/adding new data to the database, we also documented the WOOD software and hardware to make it straightforward to rebuild the system if/when the system is maliciously attacked by hackers. (Attacks occurred on at least two occasions and the second attack required a complete system “re-build” from backups)

2. *Empirical Algorithms:* Nepheloid layer data are expected to follow different empirical relationships than non-nepheloid layer data. Figure 1 shows an example of this difference.

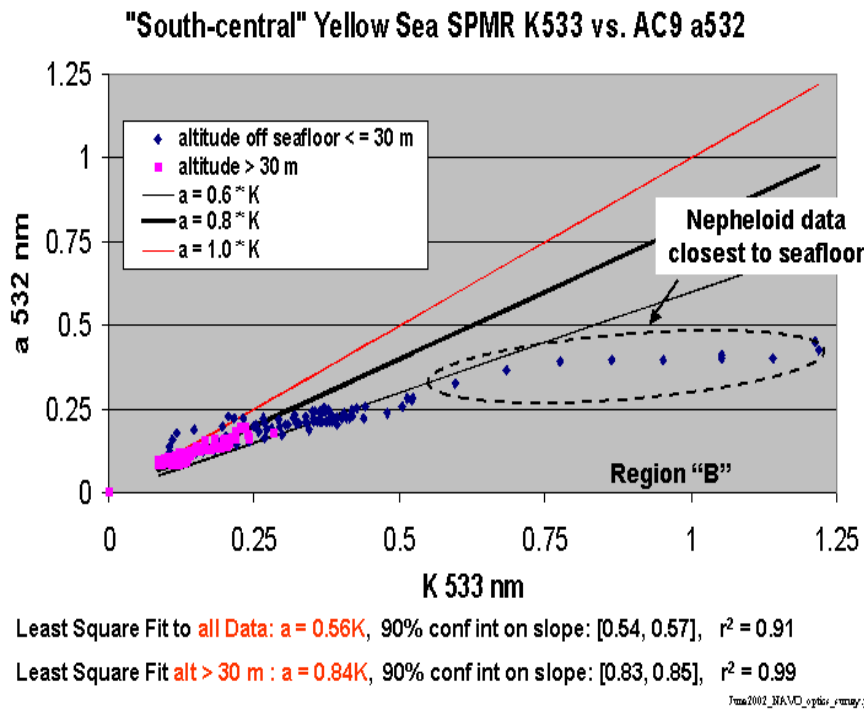


Figure 1. Relationship of Absorption (a) to Diffuse Attenuation (K) in the Yellow Sea Using July 2001 Data from NAVOCEANO. [a:K ranges from 0.6 to 1.0 outside the nepheloid layer with a least squares fit (LSF) value of 0.84; the LSF a:K value inside the nepheloid layer is 0.54.]

3. *Regional Environmental Optics Characterizations*: Closely related to our work on empirical algorithms is our development of regional empirical algorithms that depend on location, proximity to the seafloor, and season. Using Yellow Sea and Gulf of Oman/Persian Gulf data provided by the US Naval Oceanographic Office (NAVOCEANO), we have begun to examine relationships between bb and K , c and K , and a and K . The goal is to see whether each region, season, and depth domain requires a separate set of algorithms, or whether some generalized algorithms exist. As an example of this work, Figure 2 shows a summary of Yellow Sea $c:K$ ratios from three different months as a function of altitude off the seafloor. These $c:K$ ratios are quite similar within a single sub-region of the Yellow Sea, but our more detailed analysis shows that using these same curves in adjacent sub-regions leads to significantly higher errors in predicting c from K .

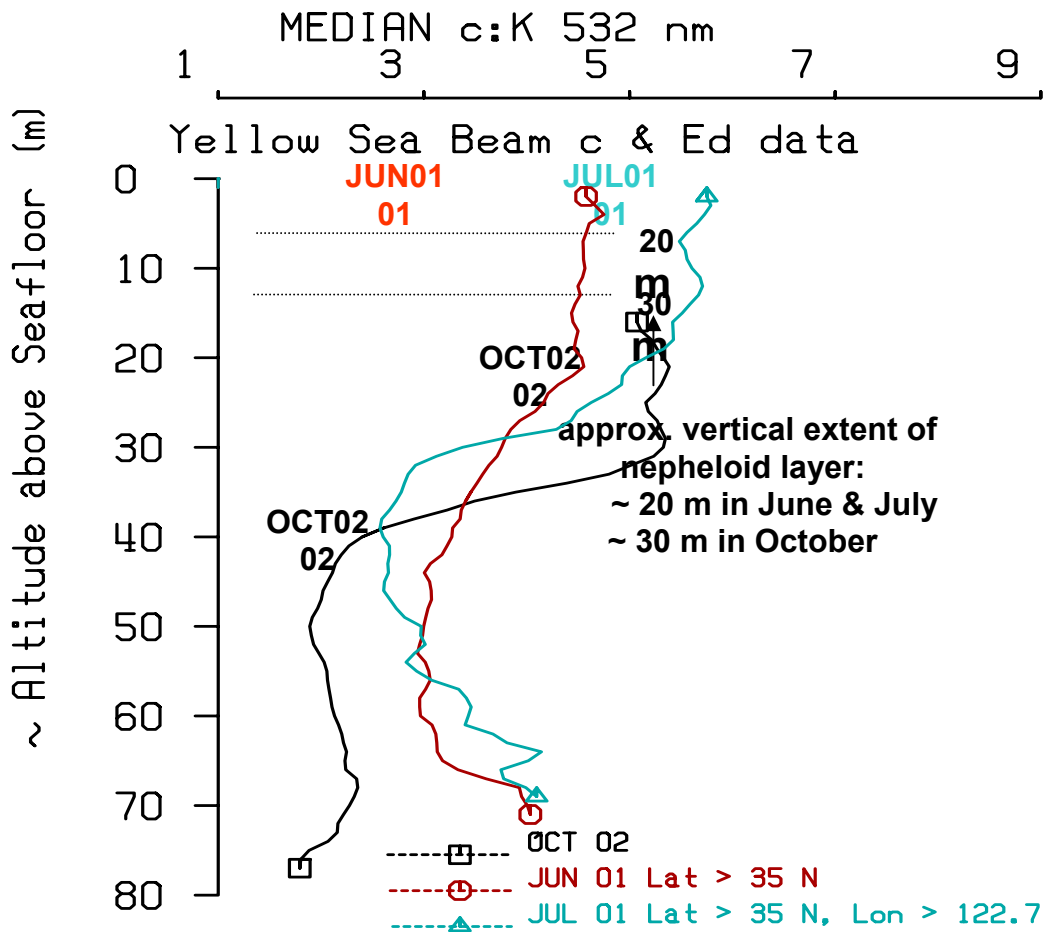


Figure 2. Median June, July, and October Yellow Sea $c:K$ Ratio Profiles (vs. Altitude).
[$c:K$ ratios are ~ 4 to 6 within 20-30 m of the seafloor; in the clearer waters above those depths values are ~ 2]

New Features To The WOOD Website. As part of our continual efforts to upgrade and improve WOOD, we have added the ability to store, retrieve, and display hyperspectral optical data. Figure 3 is an example of a hyperspectral downwelling irradiance data plot created at the WOOD website. We have

also designed an automated interface to convert profiles of optical parameters from one wavelength to another, and this design will be implemented in the next few months.

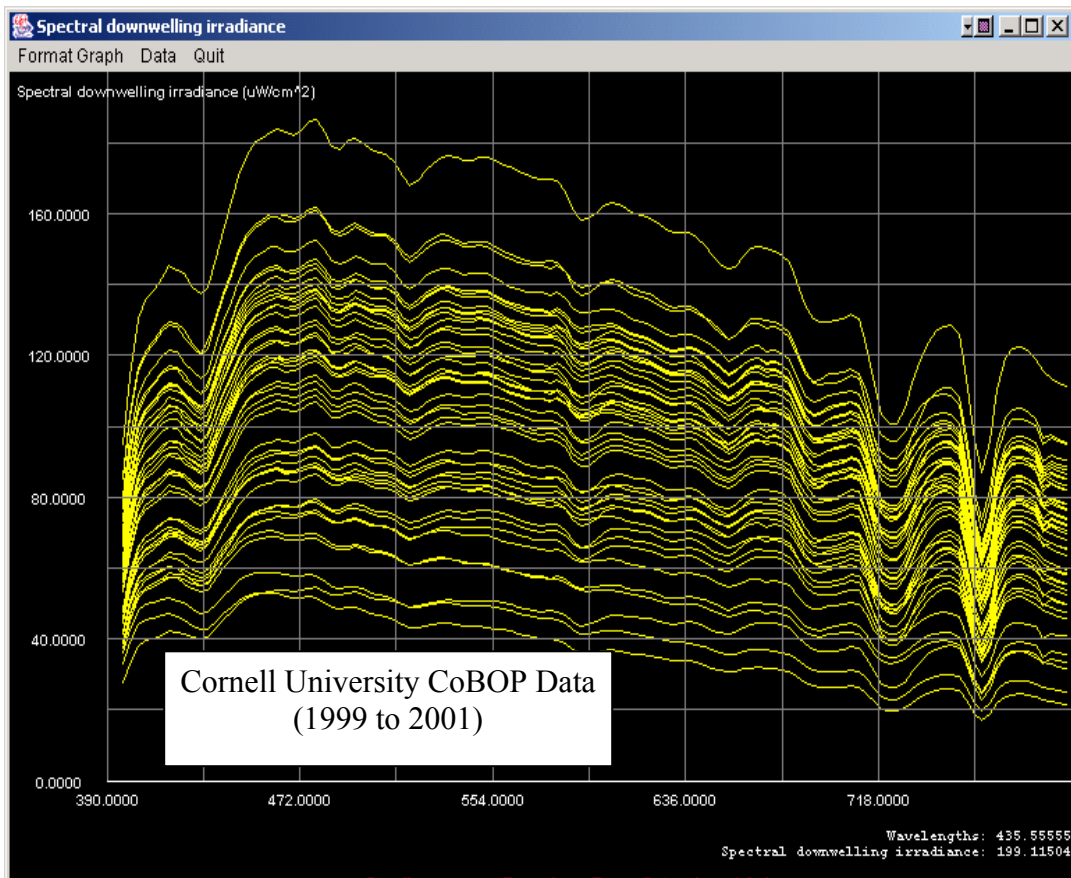


Figure 3. Example of Hyperspectral Downwelling Irradiance Data Extracted from WOOD. [Cornell University CoBOP Irradiance data from 396.6 to 798 nm are shown with a 2 nm resolution. Peak values occur at about 480 nm. Local minima occur near 440, 720, and 760 nm.]

RESULTS

Many investigators from around the world make use of the WOOD. Over the 6-month period from October 2002 through March 2003, WOOD was accessed over 36,000 times by 2061 different IP sites, which included 279 schools, colleges, universities, and research institutes and 65 DoD/US Government/State-Local Government agencies. The Navy-related “hits” included the following:

- Commander-In-Chief, Pacific Fleet
- Marine Corps Air Station
- Naval Air Warfare Center
- Naval Command Control & Ocean Surveillance Center
- Naval Postgraduate School
- Naval Research Laboratory
- Naval Surface Warfare Center
- Naval Undersea Warfare Center
- Office of the Chief of Naval Research

➤ Space and Naval Warfare Command

As a specific 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 (July 2001), for the SHAREM 142 exercise in the Yellow Sea (October 2002), and for WESTPAC DEMO 03 for October 2003.

IMPACT/APPLICATIONS

By requiring all projects funded by ONR's Ocean Optics Program to submit their data to the WOOD, ONR is ensuring that these valuable data continue to be available for current and future investigators. Furthermore, the availability of a single location, uniform-format optics database has 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, called FAST TACTIC, was developed and deployed as a prototype for the US Navy Advanced Processor Build (APB) November 2001 sea test. Information about FAST TACTIC was recently displayed and demonstrated at the Oceanology International 2003 conference in New Orleans. For related information at the unclassified level, see the Submarine Operational and Research Database (SOARED) website at <http://wood.jhuapl.edu/soared/welcome.htm>.

RELATED PROJECTS

The project's Principal Investigator, Jeff Smart, is a member of the ONR Littoral Warfare Advanced Development (LWAD) project that conducts numerous at-sea tests, including tests involving optics in overseas areas of special interest to the US Navy. For example, via the LWAD project, the WOOD project has obtained important optical data in the East China Sea and the Yellow Sea. In addition, 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 LWAD optics data (collected by JHU/APL scientists) to SEABASS. (For example, the LWAD East China Sea optical data have been submitted to SEABASS.)

REFERENCES

1. WOOD Website: <http://wood.jhuapl.edu>
2. Morel, Andre, "Optical Modeling of the Upper Ocean in Relation to its Biogenous Matter Content (Case I Waters) JGR Vol. 93, No. C9 pp 10,749-10,768) Sept 1988

PUBLICATIONS

FAST Tactical Integration Console (FAST TACTIC), *Oceanology International 03*, New Orleans, LA (4-6 Jun 2003)

“Regional And Global Empirical Relationships Among Optical Variables,” Ocean Optics XVI,
November 2002