Bio-optical Calibration and Measurements Protocols for U.S. JGOFS Equatorial Pacific Cruises

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The accurate determination of in-water upwelled (E_u) and downwelled (E_d) spectral irradiances and upwelled spectral radiance (L_u) require adherence to strict calibration and measurement protocols. NASA sponsored a workshop (8--12 April, 1991) to establish calibration standards, protocols, and sampling strategies for ocean optical measurements to be used for SeaWiFS baseline algorithm development and system validation. Calibration and measurement protocols for JGOFS EqPac cruises will follow those protocols. This document gives a brief overview; for a more detailed review refer to the proceedings (Mueller and Austin, 1991) from that workshop. There are two major sources of measurement errors in determining E_d, E_u and L_u; (1) the perturbation of the in-water radiant energy field caused by the ship and (2) the estimation of quantitative corrections for atmospheric variability in the radiant energy incident on the surface during the in-water measurements. To correct for these potential problems the following protocols will be followed during the transect and time series cruises.

Participants:

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                        Transect Cruises:
Spring:   Charles Trees (CHORS)   Fall:   Daniel Sullivan (CHORS)
          James Aiken (PML, U.K.)         Ian Bellan (PML, U.K.)

                       Time Series Cruises:
Spring:   Curtiss Davis (JPL)     Fall:   Joseph Rhea (JPL)
          Joseph Rhea (JPL)               Michael Hamilton (JPL)
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1. The bio-optical profiling systems for the transect and time series cruises are similar in that they include a Biospherical spectroradiometer (MER 1032 and 1048), a Sea Tech transmissometer (660 nm) and a Sea Tech fluorometer. Both MERs have also been adapted to measure solar stimulated fluorescence [(L_u(683 nm)]. The two surface incident irradiance detectors are different in that one was built by Biospherical (Dr. Davis') whereas we built out own. The MERs and surface incident irradiance detectors will be calibrated before and after each cruise. The calibration of these optical instruments will be performed at the CHORS Calibration Facility, using standard sources traceable to the National Institute of Standards and Technology (NIST). In addition, both MERs will be optically characterized to define their performance characteristics. This characterization includes linearity, cosine response of the irradiance detectors, field of view of radiance detectors, irradiance and radiance immersion factors, spectral response, wavelength calibration and instrument stability and precision checks. The CHORS MER has already been characterized and will go through a second characterization prior to the first transect cruise in Jan. 1992. Dr. Davis' MER will be shipped back to CHORS after his first time series cruise (June, 1992) for a post-cruise calibration and its first characterization. Characterization needs to be performed every 3--5 years.

   Dr. James Aiken will deploy his towed multi-sensor Undulating Oceanographic Re-corder (UOR),

which measures downwelled and upwelled spectral irradiance (cosine collectors), fluorescence and beam transmission (660 nm) during its undulations from near surface to *ca* 70 meters. The UOR irradiance sensors will be calibrated at CHORS before and after each cruise. In addition, a partial characterization of the sensors will be performed to document their cosine responses, immersion factors, linearity and spectral responses.

QA/QC: CHORS Calibration Facility has a complete capability for characterizing and calibrating environmental radiometers, following the procedures described in the NASA report (Mueller and Austin, 1991). These procedures have been routinely applied to our own equipment, as well as characterizing and calibrating ocean radiometer systems for NOARL, the Naval Oceanographic Office and Dalhousie University (Dr. Marlon Lewis' expendable L_u meter). We have cross-checked MER instrument calibrations with Dr. Ken Voss at the University of Miami and with Biospherical Instruments, Inc. and realized agreements in irradiance calibrations within <5 % with both, and also agree with the University of Miami for radiance within <5 %. In 1989, we compared a Multispectral Airborne Radiometer System radiance calibration using our facilities, with a calibration performed at Goddard Space Flight Center, and obtained agreement within 5 %.

2. Between the laboratory calibrations of the MER's, secondary checks of the instruments performance will be performed using stable lamps in rugged fixed geometric configurations. These portable secondary calibrations in the field will provide a record of the instruments stability and will assist in evaluating possible corrections to the optical data if inconsistencies appear later. More importantly these sources would give advance warnings of potential problems, which could be corrected in the field. The CHORS Portable Secondary Standard (PSS) will be taken on the transect cruises. Intercalibration using the standard will be performed on Dr. Davis' MER prior to the departure of the time series legs. Because of prior commitments, the PSS has to be shipped back to CHORS after each transect cruise.

3. The profiling spectroradiometers (MER 1032 and 1048) will be deployed from the stern using the starboard crane fully extended (65 ft). In addition the ship will be positioned with the sun off the stern and will maintain that orientation throughout the optical cast (approximately 30 minutes). These two measurement protocols will help to minimize the errors in the determination of E_d, E_u, and L_u caused by ship shadow. At least one bio-optical profile should be made daily with the cast being close to local apparent noon (LAN) as long as the solar zenith angles are greater than 10 degrees. At angles less than this errors can be introduced in measurements of E_u and L_u by the instrument's own shadow. There will be times during these cruises when measurements will have to be made a few hours before of or after LAN to minimize this self-shadowing effect.

4. The dark current of optical sensors is frequently temperature dependent and as a consequence, collection of accurate optical data requires careful attention to dark current variability. We will make dark current measurements before and after each cast and we will ordinarily use the post-cast dark readings, when the instrument temperature is closer to ambient conditions. When there is a large temperature difference between the instrument on the deck and the water temperature, the instrument will be allowed to equilibrate with the water temperature at the beginning of each cast.

5. Surface incident spectral irradiance will be measured during the optical cast to correct for atmospheric variability in radiant energy incident on the sea surface. This instrument will be mounted as high up on the ship as possible and away from any structures that might cause a

shadow on or a reflection into the instrument.

6. The windows on the Sea Tech transmissometers will be cleaned with lens cleaner and a tissue, then rinsed with distilled water, and finally rinsed with isopropyl alcohol and wiped dry. Cleaning of the windows and reading of these ‘‘on-deck air calibrations’’ will be performed before each cast to verify that the windows are clean. An air calibration to check for temporal degradation in the transmissometer’s source and detector will be performed in the laboratory before and after each cruise. In addition a characterization of the A-to-D system in the MER’s will be performed so that a known input voltage generates a predicted output voltage. For transmissometers used on the CTD, an end-to-end check of the instrument is required unless the CTD A-to-D channels are also calibrated. Transmissometer data collected with the CTD will be corrected for temperature, salinity and pressure using the algorithm provided by Sea Tech. In addition, the data will be evaluated for temperature hysteresis effects which, if deemed significant, will be corrected for using a modified algorithm developed by Bishop (1986).

7. The windows on the fluorometers will be cleaned with lens cleaner and rinsed with distilled water. Since the measurements of fluorescence are in relative units no additional calibration is planned, except that the voltage measuring A-to-D system recording the fluorescence must be characterized as described for the transmissometers.

8. The MERs have scalar PAR (photosynthetically available radiation) collectors for measuring broad banded radiation from 400--700 nm. Because of the difficulty in calibrating and accurately measuring radiant energy over this broad spectral band (Gordon and McCluney, 1975; Kirk, 1983), PAR will be calculated (Morel and Smith, 1974) from the downwelling spectral irradiance data (E_d).
9. Sky radiance will be estimated by occulting the sun’s image on the deck cell measuring incident spectral irradiance. This measurement is useful for estimating the mean cosine at the surface and can be used with profile measurements of E_d, E_u, and c to estimate by (Gordon, 1990). The ability to exploit this and similar relationships will greatly enhance both the development and verification of bio-optical algorithms.
10. All-sky photographs will be taken before each optical cast to document the cloud cover. This information is important for identifying measurements made under questionable environmental conditions.

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