Acquiring accurate in situ underwater light data and its application to ocean color remote sensing

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1. Abstract

The proper mobilization of the latest-generation instruments such as C-OPS (Compact-Optical Profiling System, Biospherical Instruments Inc.) is required for measuring the apparent optical properties (AOP) of aquatic environments (Hooker, 2014). The protocols are designed for the Hybrid Sensors for Environmental AOP samping (HySEAS) class of instruments, but are applicable to the community of practice for AOP measurements, especially the Japanese ocean optics team in the OMIX project.

2. Procedures and Results

2.1 Upgrading to LabVIEW 2015 or What is Referred to as v15 in DACPRO Updates

The following procedures are needed to use the latest version of DACPRO, a data acquisition software for C-OPS.

1. Install 32-bit LabVIEW (e.g., LabVIEW 2015). Do NOT install 64-bit LabVIEW.
2. 2. Backup existing NI VISA configuration by going to to the folder System Disk, Library, Preferences, Nivisa and copy visaconf.ini into another folder.
3. Install LabVIEW NI-VISA package (NI-VISA_15.0).
4. Restore the NI VISA configuration as follows:
   a) Open old visaconf.ini;
   b) Copy the [ASRL-RSRC-ALIAS] and [ALIASES] sections;
   c) Put them into the new visaconf.ini file; and
   d) Delete the empty [ASRL-RSRC-ALIAS] and [ALIASES] sections.

2.2 For High-Quality Data Products, e.g., $L_W(\lambda)$, Platform Perturbations MUST be Negligible

Whether made using above- or in-water light sensors, the most significant problem with making AOP measurements is minimizing the perturbations from the sampling platform the light sensors are deployed on or from. In the case of large platforms, the reflections from the superstructure and submerged hull brighten the ambient light field, whereas the platform's shadow darkens it. In all cases, corrections can be produced, but they require significant modeling efforts and involve a large dynamic range in solar illumination, sky conditions, and viewing geometries, which is not practical unless a platform is used for extensive periods of time. The simplest expedient, therefore, is simply to sample outside the perturbation areas.

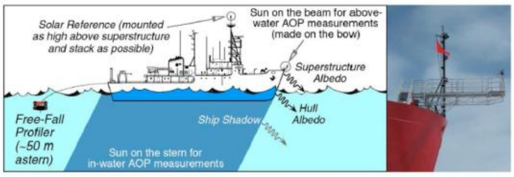

Fig 1. A schematic representation of the platform perturbations associated with a ship and preferred deployment locations for AOP measurements.

2.3 In an Above-Water Method, It is Critical to Properly Site the Solar Reference (it is the only E_d data)

The importance of positioning a solar reference can be shown by comparing the bow and stern references. The bow sensor is assumed to provide the best data (i.e., the closest to truth), because it 1s mounted the highest and the farthest away from the ship's superstructure. If properly sited, two solar references should agree to within the calibration uncertainty (about 2.5%). The stern sensor exceeds this threshold 49% of the time and all data agree with the bow sensor to within 2.5% only twice. This means R_{rs} (λ) values will be corrupted, but band ratios can be significantly less degraded.

2.4 For Deriving L_w (λ) Using an In-Water Method, the Instrumentation is a Source of Perturbations

The in-water instrumentation is a source of perturbations. Because the surfaces are either black or red, the principal perturbation is from shading. The position of the profiler with respect to the Sun can minimize the shading, but ultimately a correction must be applied to the upwelled radiances to remove the contamination. Under normal protocols, an above-water method does not require an instrument shading correction, so this is an advantage of the above-water approach-the disadvantage is above-water radiometry provides no data on water-column properties, e.g., K_d.

2.5 C-OPS with C-PrOPS: State-of-the-art Free-Falling 19-Channel Profiler for L_w(λ) Spanning 313–875 nm

C-OPS (Fig. 2; Hooker, 2014) uses 7 cm (OD) sensors: a) E_d cosine collector; b) bumper; c) cluster of 19 microradiometers; d) aggregator and support electronics; e) adjustable v-blocks counter pitch biases; f) hydrobaric buoyancy (compressible bladders) allows nearsurface loitering; g) adjustable flotation counters roll biases; h) weights (and floats) set terminal velocity; i) temperature probe; j) pressure transducer; k) conductivity and temperature probe; I) digital thruster (one on each side); and m) thruster guard.

The thrusters vertically orient the backplane in the water column (right). When thrust is removed, the residual momentum gently pushes the irradiance aperture to the surface, and the profile begins with minimal tilts (ø < 5°) and planar apertures.

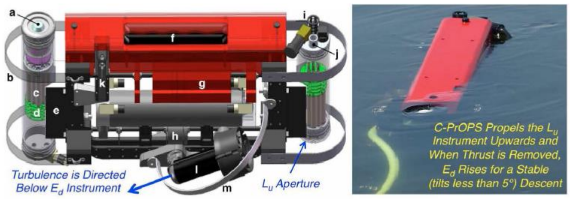

Fig. 2 Compact-Optical Profiling System (C-OPS) with C-PrOPS (Compact-Propulsion Option for Profiling Systems).

2.6 Reduced L_w(λ) UV-NIR Uncertainties from C-OPS Hydrobaric Buoyancy Control (and C-PrOPS)

C-OPS hydrobaric buoyancy improves

sampling resolution by more than an order of magnitude with respect to legacy (SPMR) instruments. The resulting improved sampling resolution reduces the aliasing of wave-focusing effects at the surface and allows extrapolation intervals for all $L_W(\lambda)$ values to be derived for all water masses.

2.7 Near-Surface Vertical Resolution Ceaslessly Improved to Reduce $L_W(\lambda)$ Uncertainties

Wave focusing, vertical complexity (thin layers of differing optical properties), and vertical tilts above 5° degrade establishing an extrapolation interval with sufficient data density to ensure high-quality L_W (A) derivations. Converging E_s (0^-) and $E_d(0^-)$ links data acquisition to data processing, constrains the extrapolation interval, and improves the estimation of $Lu(0^-)$ and, thus, $L_W(\lambda)$ and $R_{rs}(\lambda)$.

2.8 The In-Water Methodology for Deriving $L_W(\lambda)$ at z = 0, i.e., Transmitting $L_u(0^-)$ Through the Surface

1. Primary data product is $L_W(\lambda)$, from which normalized forms are computed.
2. Governing equation is $L_W = 0.54\ L_u(0^-)$, where $L_u(0^-)$is the upwelling radiance a tnull depth, and 0.54 accurately transmits L_u through the sea surface (Mobley, 1999).
3. Needed measurements are geolocation, UTC time, L_u, E_d (the downward irradiance), E_s (the global solar irradiance, which is needed for the normalized forms), ø (vertical tilt for all instruments), T_W (water temperature), S (salinity, if possible), plus IOPs (e.g., Chi *a*) and E_i (diffuse solar irradiance, if possible).
4. Corrections are dark current subtraction at all gain stages, slow (linear) changes in E_s, aperture offsets with respect to the pressure transducer, and self-shading.
5. Objective constraints are vertical tilt filtering to within 5°.
6. Choosing the extrapolation interval is subjective, but constraining $E_d(0^-)$ to within 5% of E_s (0^-) links K_d to L_W and, thus, to R_{rs} (L_W/E_s) . Improvements in Rrs result in improved algorithm performance, which typically use R_{rs} band ratios, e.g., Chl *a*.
7. Laboratory characterizations are NIST-traceable calibrations, plus immersion factors for E_d (requires an immersion tank) and L_u (computed).
8. Field characterizations are dark current measurements at all gain stages.
9. Uncertainty in $L_W(\lambda)$ is less than 3.5% at all wavelengths.

3. Acknowledgement

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4. References

1. Hooker, S. B. (2014) Mobilization protocols for hybrid sensors for environmental AOP sampling observations. NASA Tech. Memo. 2014-217518, NASA Goddard Space Flight Center, Greenbelt, 105 pp.
2. Mobley, C. D. (2009) Estimation of the

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5. Accomplishment paper

1. Suzuki, K., A. Kamimura, and S. B. Hooker (2015) Rapid and highly sensitive analysis of chlorophylls and carotenoids from marine phytoplankton using ultra-high performance liquid chromatography (UHPLC) with the first derivative spectrum chromatogram (FDSC) technique. Mar. Chem., 176, 96–109, doi:10.1016/j.marchem.2015.07.010.