JRC Activities in Support of Satellite Ocean Color Cal/Val

Ocean Color Team
of the
Water Resources Unit
Institute for Environment and Sustainability

Prepared by Giuseppe Zibordi (May 2015)
Preface

... adequately sampled, carefully calibrated, quality controlled, and archived data for key elements of the climate system will be useful indefinitely.

Field Measurement Programs
Primary objective of these JRC field programs is to support ocean color standardization and validation activities in view of the generation of highly accurate satellite ocean color data products for Climate Data Records applicable at regional, continental and global scale.
Time-series of AOPs and IOPs measurements performed applying identical and consolidated technology, measurement and calibration protocols, processing codes and quality assurance criteria.

Geographically distributed measurements of AOP and IOP produced applying cross-site identical and consolidated: technology, measurement and calibration protocols, processing codes and quality assurance criteria.

CoASTS and BiOMaP measurements

Field measurements

- Profiles of $L_u(z, \lambda)$, $E_u(z, \lambda)$, and $E_d(z, \lambda)$
- Profiles of $c(z, \lambda)$ and $a(z, \lambda)$ (from 01/97)
- Profiles of $b_b(z, \lambda)$ (from 04/00)
- $E_d(0^+, \lambda)$ and $E_i(0^+, \lambda)$
- $E_s(0^+, \lambda)$
- Ancillary $(T_w(z), S_w(z), P_a, RH, T_a, W_s, W_d, C, M)$

Related laboratory analysis from field water samples

- Pigments (HPLC)
- $a_{ph}(\lambda)$ and $a_{dp}(\lambda)$
- $a_{ys}(\lambda)$
- TSM

Profiles (manned)

Samples (conditioned)

CoASTS AAOT

BiOMaP Ships
BiOMaP (Bio-Optical Marine Properties): $L_{WN}$ spectra from the various European Seas

AERONET-OC sites

AERONET-OC generates globally distributed highly consistent time-series of standardized \( L_{WN}(\lambda) \) and \( \tau_a \) measurements.

- **Current sites**
- **Planned sites**
- **Potential sites**

- **NASA** manages the network infrastructure (i.e., handles the instruments calibration and, data collection, processing and distribution within AERONET).

- **JRC** has the scientific responsibility of the processing algorithms and performs the quality assurance of data products (in addition to the management of 5 out of 15 sites).

- **PIs** establish and maintain individual AERONET-OC sites.

Cross-Mission Validation of $L_{WN}$

Matchups with +/-1 hr $\Delta t$ for the period April 2002 till November 2012

Principles

The correction factors $g_f$ are determined by applying the methodology established by Bailey et al. 2008.

$g_f(\lambda) = \frac{L^{COMP}_{ToA}[L^{WN}_{WN}(\lambda)]}{L^{SAT}_{ToA}(\lambda)}$

Assessment of aerosol products

### Match-up Performance Matrix

<table>
<thead>
<tr>
<th>INDICES (0-10) (0=lowest and 10 =highest)</th>
<th>AERONET-OC (AAOT)</th>
<th>CoASTS (AAOT)</th>
<th>BiOMaP (ships)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measured Quantities</td>
<td>2</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Matchups/Deployment-Time</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Accuracy</td>
<td>8</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Temporal Representativity</td>
<td>10</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Geographic Representativity</td>
<td>5</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>Matchup/Cost</td>
<td>10</td>
<td>0.5</td>
<td>0.2</td>
</tr>
<tr>
<td><strong>Overall</strong></td>
<td><strong>7.5</strong></td>
<td><strong>5.9</strong></td>
<td><strong>6.5</strong></td>
</tr>
</tbody>
</table>

The cost per matchup:
- Less than 0.5 K€
- more than 10 K€
- more than 25 K€
Field and Laboratory Methods
Calibration Equation and Laboratory Characterizations

The conversion from relative to physical units of the radiometric quantity $\mathcal{I}(\lambda)$ (either $E(\lambda)$ or $L(\lambda)$) at wavelength $\lambda$ is performed through

$$\mathcal{I}(\lambda) = C_3(\lambda) I_f(\lambda) N(\lambda) DN(\mathcal{I}(\lambda))$$

where $DN(\mathcal{I}(\lambda))$ indicates the digital output corrected for the dark value, $C_3(\lambda)$ is the in–air absolute calibration coefficient (i.e., the absolute responsivity), $I_f(\lambda)$ is the immersion factor accounting for the change in responsivity of the sensor when immersed in water with respect to air, and $N(\lambda)$ (for simplicity only expressed as a function of $\lambda$) corrects for any deviation from the ideal performance of the measuring system.

In the case of an ideal radiometer $N(\lambda)=1$, but in general

$$N(\lambda)= N_i(i(\lambda)) N_j(j(\lambda)) ... N_k(k(\lambda))$$

where $N_i(i(\lambda))$, $N_j(j(\lambda))$, ..., and $N_k(k(\lambda))$ are correction terms for different factors indexed by i, j, ..., k affecting the non-ideal performance of the considered radiometer (e.g., linearity, temperature response, polarization sensitivity, stray-light perturbations, spectral response, geometrical response, ...).
JRC (FEL plus Plaque) and NASA-GSFC (Sphere) vs NIST (CIRCUS) Absolute Radiance Calibration

![Graph showing calibration results](seaprim080_gsfcjrc_final.opj)

Courtesy of Carol B. Johnson (NIST)

Results from $I_f$ measurements of RAMSES radiometers

Determination of the Cosine Error


\[ f_c(\lambda, \theta, \varphi) = 100\left[ \frac{E(\theta, \varphi, \lambda)}{E(0, \varphi, \lambda) \cos \theta} - 1 \right] \]
$L_{\text{wn}}(\lambda) = R_{s}(\lambda)E_{0}(\lambda)$

**L_{WN} uncertainties**

Considering the measurement equation for \( L_{WN} \)

\[
L_{WN} = L_W C_A C_Q \text{ with } L_W = L_T - \rho L_i, \text{ i.e. } L_{WN} = f(L_W, L_T, L_i, C_A, C_Q, ...) \]

where \( L_T \) is the total radiance measured above the sea surface, \( L_i \) is the sky radiance, \( \rho \) is the surface reflectance, \( C_A \) removes the basic dependence on sun zenith, atmosphere and sun-earth distance, and \( C_Q \) removes the dependence from the viewing geometry and bidirectional effects.

The combined standard uncertainty of the normalized water-leaving radiance \( u(L_{WN}) \) is the composition in quadrature of any independent uncertainty due to sources \( \varepsilon_i \) affecting \( L_{WN} \):

\[
u^2(L_{WN}) = \sum u^2(L_{WN}(\varepsilon_i))
\]

Alternatively, following the *Guide to the Expression of Uncertainty in Measurement (GUM)* and neglecting correlations and non-linearity, the combined standard uncertainty of the normalized water-leaving radiance \( u(L_{WN}) \) is given by:

\[
u^2(L_{WN}) = (C_Q C_A)^2 u^2(L_W) + (L_W C_A)^2 u^2(C_Q) + (L_W C_Q)^2 u^2(C_A)
\]

with

\[
u^2(L_W) = u^2(L_T) + L_i^2 u^2(\rho) + \rho^2 u^2(L_i).
\]

The uncertainties \( u(L_T) \) and \( u(L_i) \) should account for contributions due to the following sources \( \varepsilon_i \): absolute calibration, sensitivity change during the deployment period of the measuring system, and environmental perturbations caused by sea surface roughness and environmental changes during measurements.

M. Gergely and G. Zibordi, “Assessment of AERONET \( L_{WN} \) uncertainties,” Metrologia **51**, 40–47
Relative combined uncertainties \( u(L_{WN})/L_{WN} \) (%) and (in square brackets) combined standard uncertainties \( u(L_{WN}) \) and median \( L_{WN} \) (mW cm\(^{-2}\) sr\(^{-1}\) μm\(^{-1}\)), respectively, at different \( \lambda \) (nm) for various AERONET-OC sites.


Consistency of AERONET and BiOMaP/CoASTS $L_{WN}$

$$L_{wn} (\lambda) = L_w (\lambda) / E_s (\lambda)$$

Thank you!