INHERENT AND APPARENT OPTICAL PROPERTIES

The inherent optical properties (IOPs), i.e. the absorption coefficient $a(z)$, the scattering coefficient $b(z)$, and the scattering phase function $p(z, \Theta)$, where $\Theta$ is the scattering angle, depend exclusively on the physical properties of the water and its constituents, and are independent of the illumination conditions. In contrast, the apparent optical properties (AOPs), such as $L_s(z)/E_z(z)$, where $L_s$ is the nadir-viewing radiance and $E_z$ the downward irradiance, depend on both the physical properties of the water and its constituents and the illumination conditions. Since it is relatively easy to measure $L_s$ and $E_z$ compared to IOPs, a desirable goal is to infer the IOPs from measured profiles of the AOPs. We describe our attempt to develop an algorithm to invert IOPs from AOPs. Once the IOPs are retrieved, the ocean impurity profiles can be inferred from the IOPs by another algorithm.

OCEAN IMPURITIES INVERSION ALGORITHM

The ocean impurities and the IOPs are connected by a bio-optical model. We assumed that there are two types of ocean impurity particles, algal particles (CHL) and non-algal particles (MIN), in addition to colored dissolved organic matter (CDOM), present in the water column. The IOPs of the ocean impurities are computed as follows:

$$ a_{\text{CHL}}(\lambda) = A(z) \chi_{\text{CHL}}(\lambda) \quad a_{\text{MIN}}(\lambda) = a_{\text{CHL}}(\lambda) \quad a_{\text{CDOM}}(\lambda) = a_{\text{CHL}}(\lambda) $$

where $A(z)$ and E(\lambda) are provided by Briand et al. (1998), $\nu = 0.5 \times (\log_{10}\text{CHL} - 0.3)$, when CHL < 2.0, and $\nu = 0$ when CHL > 2.0. The total IOPs of the ocean impurities are computed as:

$$ \text{a_{total}} = a_{\text{CHL}} + a_{\text{MIN}} + a_{\text{CDOM}} $$

Once the IOPs are retrieved from the AOPs, we subtract the pure water IOPs to obtain the ocean impurity IOPs. Then we apply a nonlinear Optimal Estimation/Levenberg-Marquardt (OE/LM) algorithm to retrieve the ocean impurity iteratively. In each iteration, the ocean impurities are estimated as follows:

$$ X = X_{0} + \left( [\frac{S}{1} \frac{S_{1}}{1} \frac{S_{2}}{1}] \right) \cdot \theta $$

where $X$ is the state vector, and in our algorithm $X = [\text{CHL}, \text{MIN}, \text{CDOM}]$. $\gamma$ is the Levensberg-Marquardt parameter. $X_{0}$ and $S$ are the a priori state vector and covariance matrix, respectively. $K$ is the Jacobians and $S_{0}$ is the measurement error covariance matrix. $X_{0}$ and $S_{0}$ are the measured and simulated IOPs, respectively.

VALIDATION USING BP09 DATASET

The BP09 experiment conducted by the Centre for Maritime Research and Experimentation (CMRE) in the Ligurian Sea in March 2009 provided paired vertical radiances $L_s(z)$ and downward irradiances $E_z(z)$ and the IOPs, $a(z)$, $b(z)$ and $b_0(z)$. There are also in-situ measurement of CHL, MIN and CDOM available in the BP09 dataset, which makes it a good validation dataset for our algorithm.

CONCLUSION AND DISCUSSION

- We successfully modernized and numerically implemented the Gordon/Boynston method to invert IOPs from AOPs and developed a bio-optical model based algorithm that retrieves ocean impurity profiles from the IOPs.
- Validation using BP09 dataset shows good agreement between measured and retrieved IOPs, with R$^2$ values of 0.88, 0.96 and 0.93 for absorption, scattering and backscattering coefficients, respectively (Figures 3 and 4).
- Good agreement was also found between measured and retrieved ocean impurities, with R$^2$ values of 0.80, 0.78 and 0.73 for CHL, MIN and CDOM, respectively (Figure 5).
- IOPs retrieved algorithm can be improved by including other irradiances, $E_v(z)$, in the algorithm.
- A comparison between measured and retrieved ocean impurities indicates that adjustments should be made to the bio-optical model to improve the agreement with the measurements.