Hyperspectral optical measurements (and simulations) on discrete samples

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Accurate quantification of the spectral absorption coefficient of natural waters is essential for characterizing Harmful Algal Blooms (HABs) and their ecological impacts. Absorption spectra contain diagnostic features that enable discrimination among phytoplankton groups when measured with sufficient spectral resolution. However, reliable retrieval of these features is complicated by light scattering, which adds a spectrally broad background signal that masks pigment-specific absorption peaks. Scattering-induced errors can therefore degrade the ability to detect and classify HABs using optical methods.

The Point Source Integrating Cavity Absorption Meter (PSICAM), distributed by Sunstone Scientific, remains the state-of-the-art instrument for laboratory measurements of water absorption due to its accuracy and its ability to minimize scattering artifacts. The Quantitative Filter Technique-Integrating Cavity Absorption Meter (QFT-ICAM), also commercialized by Sunstone Scientific, extends this concept to particulate absorption on filters. Both the PSICAM and the QFT-ICAM combine an integrating cavity with a compact spectrophotometric design, enabling rapid and reliable absorption measurements of field and laboratory samples.

The new Hyper-a (developed by Sequoia Scientific in collaboration with Sunstone Scientific) is currently the only submersible hyperspectral absorption meter based on an integrating cavity design. It employs a fluorilon integrating cavity and dual spectrometers to provide full-range hyperspectral data (300–750 nm) with minimal scattering error. Monte Carlo ray-tracing simulations quantified the effects of scattering on photon pathlengths and showed that the integrating cavity architecture substantially mitigates scattering-induced bias relative to reflective-tube absorption meters.

Beyond spectral absorption, spectral polarization offers an additional optical method for characterizing HABs. It is known that photosynthetic organisms, including microalgae and cyanobacteria, can generate spectrally varying circularly polarized scattered light due to their intrinsic chirality (optical activity). We used the MASCOT (Multi-Angle Scattering Optical Tool) instrument, a non-commercial prototype, to experimentally demonstrate the laboratory detection of dinoflagellates, as previously only predicted theoretically.

These advances in hyperspectral measurement and modeling improve the accuracy of pigment retrievals and strengthen the use of optical methods for HABs detection in complex, scattering-dominated coastal waters.