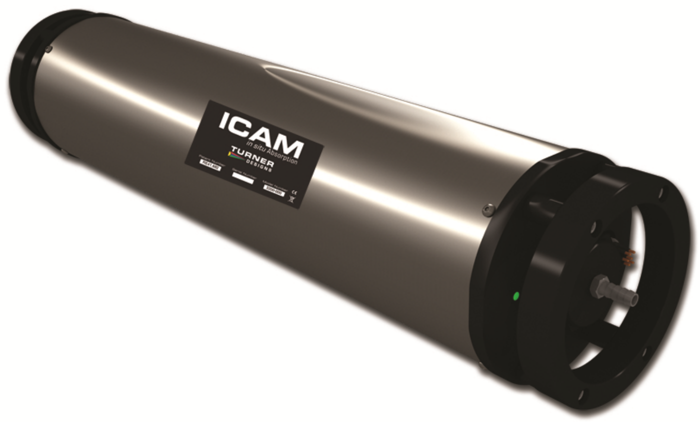
Introduction

Water is primarily characterized by its Inherent Optical Properties (IOPs), absorption and scattering. Accurately measuring these properties provides a fundamental understanding required for assessing light dynamics in water and in the presence of materials such as phytoplankton, dissolved organics, suspended particles/sediments, or impurities. Oceanographers are constantly working at trying to obtain good estimates for these properties but are faced with limitations of both available instrumentation and the measurement mode. For example, absorbance is typically measured via 180 degree detection allowing for potential interferences, such as scattering and reflection/refraction of light that cause significant error in measurements. As incident light passes through the media, a good portion of that light is scattered or reflected and won't ever reach the detector. If the scattering or reflection isn't accounted for, the overall accuracy of the absorbance measurement is greatly reduced. Generally speaking, it is a difficult task to measure the scattered or reflected light as most spectrophotometers don't have the detectors in place for that type of a measurement. With those instruments that do have the capability for detecting this strayed light, calibration of the scatter detector coupled with the various scattering effects from different particles or materials may make it a difficult task regardless.

In situ instrumentation used for measuring absorption is limited, probably for the reasons previously mentioned -- difficulty in obtaining an accurate absorption measurement. There are instruments that offer scatter correction algorithms, but those instruments are limited to a certain range or concentration of scattering materials. In other words, if the amount of scattering particles is beyond a specific limit, absorption cannot be measured due to the overwhelming interference experienced by the high degree of scattering.

Turner Designs, partnering with Texas A&M, developed ICAM, Integrating Cavity Absorption Meter, which is capable of measuring absorption at nine different wavelengths spanning the light spectrum from UV to Red. At each wavelength, water absorption coefficients (a_w), which indicate how light becomes attenuated throughout this media, are calculated based on water's absorption properties. These absorption coefficients can be used to characterize water parcels or types, making ICAM a useful research tool for a broad range of applications. ICAM also offers a big advantage over conventional *in situ* absorption meters in that scattering errors are greatly minimized so that little or no correction is required, even for highly turbid samples.

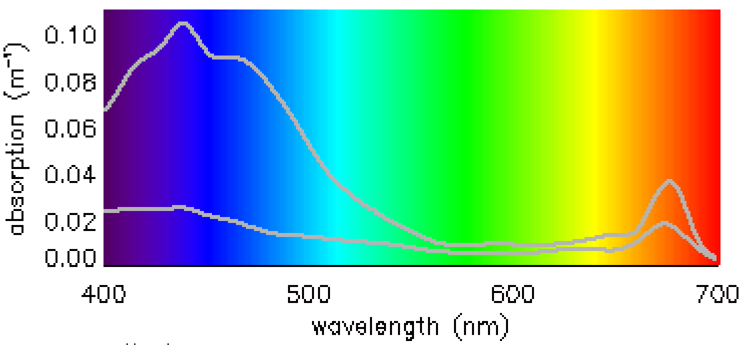


Minimal scattering effect is only one of the many benefits ICAM has to offer. ICAM also includes the ability to measure UV absorption, fast sampling rate (multiple readings per second), solid state electronics and optics (little to no drift in signal), no moving parts, titanium housing, and more.
Measuring absorption of water systems generates data that are used in modeling to help with bloom predictions, water mixing or transport, satellite imagery, etc. Here are some more examples of applications where ICAM can be used:

Applications

Plant Physiology

Phytoplanktons are primary water constituents that contain light harvesting pigments, chlorins and carotenoids, which absorb light across most of the light spectrum. Spectral variations determined via phytoplankton absorption coefficients (a_p) can be used to characterize changes in phytoplankton physiology. For example, changes in the slope over specific wavelengths have been correlated to variation of cellular pigment ratios between high and low light-adapted phytoplankton and the concentration of photoprotective or photosynthetic carotenoids, respectively (SooHoo et al. 1956). These changes can be linked to mixing and irradiance (Claustre et al. 1994), providing greater detail about not only the biological, but also the physical aspects of the system under study.



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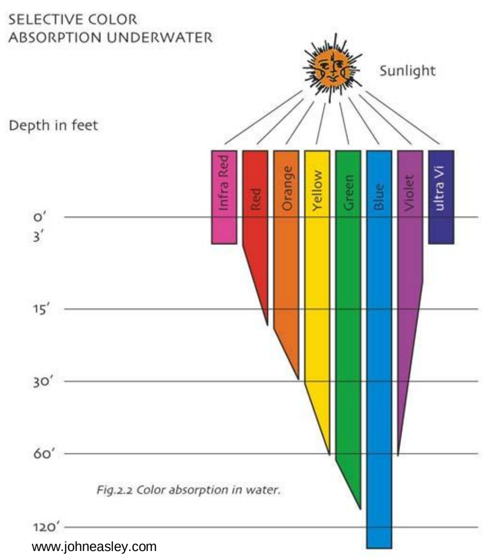
Oceanography

Dissolved organic materials (DOM) are ubiquitous in aquatic habitats. Dissolved or particulate organic materials primarily absorb ultraviolet light. One of the roles DOM plays is UV attenuation, which reduces the effects of expected photodamage on phytoplankton pigments. Determination of DOM absorption coefficients (a_{cdom}) can help establish models for site-specific UV attenuation profiles which may aid in forecasting nuisance bloom activity and potentially remote sensing of water color. Characterization of a_{cdom} over time, space, or event will aid research geared toward environmental impacts related to carbon turnover rates and dynamics for given systems.



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Laboratory Research

Typically, research laboratories have highly analytical spectrophotometers that are extremely expensive and designated only for lab use. ICAM is a highly analytical instrument that can be used not only *in situ* but also in the laboratory. The benefit to using ICAM in laboratory research is the ability users gain to correlate ICAM responses with their lab spectrophotometers and then collect field data in real time. This provides researchers with real-time data sets equivalent to those generated by their high-end lab spectrophotometer without the time lag resulting from transportation of grab samples which can potentially cause samples to change. Correlations between ICAM and lab spectrophotometers can be made for almost any organic or inorganic materials in water that have absorptive properties.

Industry/Government

Water quality is a significant issue for water municipalities, reservoir management agencies, and state-run departments that supply water to the public. Algal blooms are a primary concern as they greatly shorten filter run times and can lead to plant shut downs. The easiest way to determine the algal content of water is via *in situ* fluorescence detection. Sensitivity to algal type and increased variability due to algal life history or stress can lead to considerable inaccuracies in estimating algal abundance. Absorption is not as impacted by these factors, making this criterion superior to fluorescence detection. Other benefits to using ICAM for water quality monitoring are evident in the fact that you can measure multiple water quality parameters using one instrument, providing users with a detailed data set that can be used for characterizing water systems and potentially predicting bloom activity, saving both time and money.
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Wastewater Monitoring

Wastewater monitoring using fluorescence detection can be a challenging effort due to all the impurities and other materials that may convolute or interfere with detection of a specific compound. The other option would be to measure absorption using flow through spectrophotometry. But most spectrophotometers detect absorbance at 180 degrees making it almost impossible to accurately estimate absorption of wastewater when there is a high concentration of suspended sediments, primarily due to particle scattering. The little to no scattering effects, even at high suspended sediment loads, makes ICAM superior for this type of monitoring providing continuous accurate absorption estimates for wastewater monitoring efforts.

Measurement Modes and Deployment

ICAM can be deployed as a non-integrated profiler or as an integrated or self-contained instrument to a maximum of 200 meters depth. Each mode requires the use of certain accessories, most of which are offered by Turner Designs. For flow through mode, users will have to supply their own pumps based on specified flow rates appropriate for the ICAM.

Profiling Mode (Non-Integrated)

In non-integrated profiling mode, ICAM's GUI is used to communicate with, configure and collect data. Sample intervals are user-defined and can be set as fast as 6 samples per second generating a robust data set for shallow water profiles. For this mode, it is recommended ICAM be deployed in a cage or with some protection to keep the instrument from slamming into objects during deployment and recovery, causing damage to the instrument and resulting in instrument failure. The following accessories available from Turner Designs may be required for this type of a deployment:

-	Boosters (required for cable lengths greater than 10 meters)	2200-900
-	Extender cable 10 meters	105-2595
-	Extender cable 25 meters	105-2596
-	Extender cable 50 meters	105-2597

Integrated Mode

ICAM will output ASCII data that can be integrated into third party data loggers when datalogging mode is enabled. Sample intervals are user-defined and can be set to a maximum data streaming rate of once per second with simultaneous internal datalogging providing a backup for data captured via integration. The following accessory cable is available from Turner Designs and is required for integrating ICAM with other instrumentation:

-	0.6 meter pigtail interface cable with locking sleeve	2200-170

Users must first set a sampling interval, enable datalogging mode using the ICAM GUI, then follow the wiring diagram in the ICAM manual for integrating the ICAM. Once power is supplied to the instrument, it will sample at the set sample interval; sleep mode will be enabled when not sampling so that power is conserved between sampling events.

Self-Contained Datalogging Mode

With self-contained datalogging mode, ICAM will log data internally at a maximum rate of once per second. Slower sample rates can be set if desired. The self-contained mode requires the use of the battery and battery cable for powering ICAM. A maximum of 64,000 measurements can be logged. Data are downloaded using the ICAM GUI.

-	Submersible battery, charger and cable	3200-600

Flow Through

Flow rates of up to 4.5 liters per minute can be used to flow samples through the ICAM. Flow rates that exceed 4.5 liters per minute may decrease accuracy of measurement. ICAM's total flow tube volume is approximately 0.4 liters. To help further increase accuracy of measurement, Turner Designs recommends deploying the ICAM vertically to help release any bubbles trapped within the flow tube.