THE AC-SPECTRA, AN INSTRUMENT FOR HYPERSPECTRAL CHARACTERIZATION OF INHERENT OPTICAL PROPERTIES IN NATURAL WATERS

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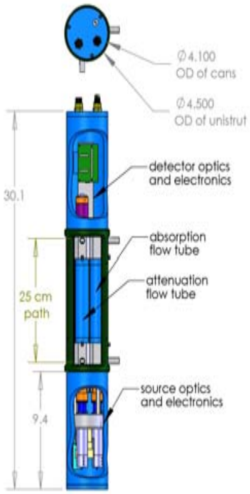
A newly designed instrument couples a high spectral resolution scanning spectral source with proven sampling optics to provide in situ beam attenuation and absorption coefficients at 4 nm resolution from 400 nm to 720 nm. The dual path instrument incorporates two Argon filled incandescent bulbs that are spectrally dispersed by a rotationally scanning linear variable filter. Light propagates through the water via separate 25 cm length optical paths. The attenuation measurement employs a collimated beam within the optical path that is refocused upon a narrow aperture receiver. The absorption measurement also uses a collimated beam propagated through a reflective tube onto a large area detector.

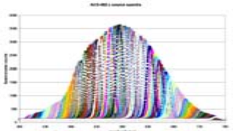
DESCRIPTION

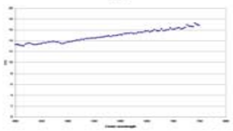
The ac-s is composed of two pressure housings separated by a unistrut frame. The lower housing holds the source optics which include two incandescent lamps that couple into a single scanning filter spectrometer. Light output from the spectrometer is collimated and then propagates into the volume separating the two housings. Within this volume two continuous flow cells surround the optical paths. The absorption path is surrounded by a reflective quartz tube which constrains scattered light within the diameter of the tube. The attenuation path tube has blackened walls which absorbs scattered light from the attenuation beam path. Light reaching the end of the absorption tube is collected by a large area detector. Light reaching the end of the attenuation path propagates into the second receiver housing and is refocused upon a small aperture and detector. The receiver housing also holds the acquisition and control electronics for the sensor.



SOURCE SPECTROMETER

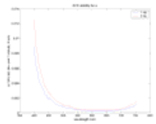
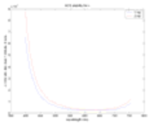
The ac-s uses a linear variable filter (LVF) scanning spectrometer to provide its spectral output. The scanning spectrometer provides a minimum resolution of approximately 3 nm although the spot size of the beam creates an effective 4-5 nm resolution for the instrument. Center wavelength bands and FWHM resolution of the source spectrometer were determined by projection of a white-light source through the scanning filter upon a calibrated grating spectrometer and determining wavelength as a function of encoder position.



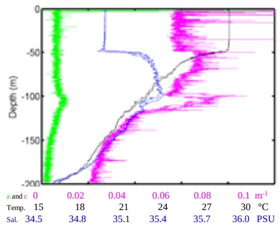


For the beam spot size used, the LVF filter demonstrated effective full-width-half-maximum (FWHM) bandwidths ranging from 13 to 17 nm.

PERFORMANCE

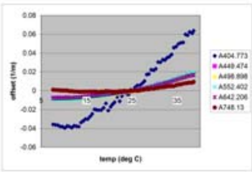



Noise and temperature performance are two of the most defining aspects of ac-s sensor behavior. Noise performance ultimately limits the meter's ability to resolve signals in the water. In very approximate terms an attenuation signal resolvable to 0.001/m represents the ability to see changes in total suspended mass levels on the order of 1 part per billion (Howard, 1979). The above plots show the average noise (standard deviation in inverse meters) in the ac-s as a function of wavelength.

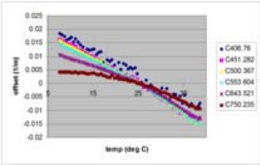


In-situ measurements demonstrate instrument stability and precision. Absorption (673nm, green line), Beam attenuation (650nm, magenta line), Temperature (black line) and Salinity (blue line) profiles taken at the Hawaii Ocean Time Series (HOTS) Aloha site near 22.75°N, 158°W (approximately 100 km north of Oahu, Hawaii) on August 11, 2004. The data were obtained during one down and up profile.

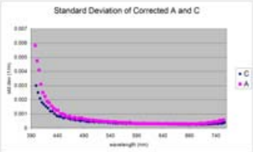
A



B

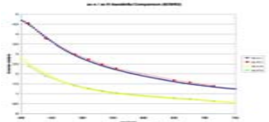


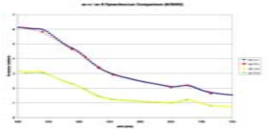
C

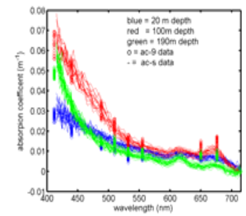


The sensor's response to temperature is critical in defining its over all stability. Plots A and B show uncorrected attenuation and absorption values of selected wavelengths subjected to a 30 degree C temperature change. Plot C demonstrates net change after temperature correction through the entire 30 degree temperature cycle.

AC-S - AC-9 COMPARISON







The ac-s underwent extensive evaluation in comparison with an ac-9. The ac-9 response is well understood, and has been proven effective in measurement of natural waters. It thus serves as a viable platform for comparison. Basic comparison tests proved critical even during prototyping of the instrument. These were the defining litmus tests in pursuing the described design path.

Data obtained at near the HOTS Aloha site show multiple spectra obtained at three depths, by an ac-s and co-loacted ac-9. The data, which has been corrected for water temperature and salinity values shows that ac-s and ac-9 measurements agree to within 0.005 m^{-1}.

DISCUSSION

The ac-s represents both a logical evolution of a proven design and a significant departure from the original effort. While the fundamental optical design is largely preserved with respect to the ac-9, the meter holds new solutions for the scanning spectrometer, the control and acquisition electronics and other critical system components. As a result the instrument offers ac-9 measurement performance with improved spectral discrimination, and is in many respects simpler to build, easier to tune, and simpler to characterize than its predecessor.

Critical development tasks remain. Presently optical throughput below 450 nm limits sensor precision. Efforts are currently underway to improve this performance. Additionally, new software will provide more completely processed data. Our goal is to automate the application of temperature, salinity, and scattering corrections to *in situ* absorption measurements. The ac-s was designed as part of a larger platform for providing a multi-parametric determination of specific biogenics in the water. Another component yet to be implemented on this device will be an in-line spectral fluorescence measurement concurrent with the attenuation and absorption coefficient determinations.

ACKNOWLEDGEMENTS

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