Calibration and data processing of ac9-271
Deployment: NASA SABOR EN542
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SENSOR NAME: WET Labs ac-9
S/N: 271

1) Introduction and Summary

The WET Labs ac-9 is an absorption and attenuation meter. It makes concurrent measurements of absorption and attenuation through the use of dual 25 cm flow tubes. Each flow path has a separate light source and detector. The two paths share a filter wheel that contains nine filters at wavelengths from 412 nm to 715 nm (see calibration table for a complete list). A more detailed description of the optics, use, and data processing of the ac-9 can be found in the WET Labs ac-9 User's Guide (WL_ac-9_User's_Guide.pdf) and the WET Labs ac Meter Protocol Document (WL_ac_Meter_Protocol_Document.pdf).

2) Calibration/Maintenance

2.1) Manufacturer calibrations/coefficients

The manufacturer provides an instrument-specific device file that contains a temperature correction and clean water offset calibration performed at the factory. The most recent factory calibration for this instrument was performed on March 9, 2010. The device file is provided as ac90271_device_file.dev.

2.2) Self calibration methods and results

Multiple calibrations were performed prior to, during, and after the cruise, following the procedure described in the ac Meter Protocol Document. The values were then normalized to a reference temperature of 12°C to account for the dependency of pure water absorption on temperature, using the values from Sullivan et al. (2006) multiplied by the coefficient $\frac{0.0029}{0.0042}$. After thorough analysis of all applicable calibrations, the best calibration for this cruise was determined to be a post-cruise calibration performed on August 13, 2014. The results of the calibration, as applied to the complete data set, are shown below:

Wavelength (nm)	Absorption "a" calibration	Attenuation "c" calibration

412	0.1013683920	0.0737901880
440	-0.0040632635	0.0027650270
488	-0.0546732300	0.0281204865
510	-0.0697007460	0.0251850975
532	-0.0797000590	0.0315858105
555	-0.0896734105	0.0324112265
650	-0.1081021355	-0.0184341470
676	-0.1033809115	0.0411567795
715	-0.1416100690	0.0019625460

3) Deployment

3.1) Measurement methods

Two types of measurements were made with the ac-9 during this deployment: unfiltered and open-path casts. For the unfiltered casts, both the a-tube and c-tube paths had separate intakes with a coarse mesh screen to exclude large particles (~ > 1 mm) from entering and clogging the flow path. For the open-path casts, the c-tube was removed to measure open-path attenuation while the a-tube remained in the standard configuration. A Sea-Bird Electronics pump was used to induce flow through the instrument.

3.2) Package design

The instrument was placed in an instrument cage in a vertical position. The sample flow path, from intake to outflow of the pump, was oriented to ensure that any air present would be able to escape from the flow path.

4) Data processing

4.1) Data analysis

Data processing began during the initial extraction using WET Labs Archive Processing (WAP) software. WAP uses the device file to convert the raw binary data to engineering units and apply the factory calibration. The data was then binned to 1 m depth bins by averaging all points occurring within that bin. Processing the ac-9 data required the corresponding temperature and salinity values from the CTD. All calculations are performed for each of the nine wavelengths. The processing steps and equations used are listed below:

1. The field water calibration and temperature and salinity[1] corrections were applied to the binned data.

$$a = a_m - \left(\left(T - T_{ref}\right) * \Psi_T\right) - \left(S * \Psi_{Sa}\right) - a_w$$
$$c = c_m - \left(\left(T - T_{ref}\right) * \Psi_T\right) - \left(S * \Psi_{Sc}\right) - c_w$$

where:

a_m and c_m are measured a and c from the ac-9
T and S are measured temperature and salinity from the CTD
a_w and c_w are the field water calibration
T_{ref} is the reference temperature, 12 °C
Ψ_T, Ψ_{Sa}, and Ψ_{Sc} are the temperature and salinity corrections

For the unfiltered casts, the absorption and attenuation coefficients of Gelbstoff + particles, a_{gp} and c_{gp}, were further processed. The measured attenuation coefficient of Gelbstoff + particles, cgp, is included in the data set as ac90271_cgp.

2. The absorption coefficient of Gelbstoff, a_g, was obtained from the corresponding filtered cast of ac90270. These values were matched by density to the a_{gp} values measured by ac90271. The density-matched a_g values are included in the data set as ac90271_ag.

3. The density-matched absorption and attenuation coefficients of Gelbstoff, a_g, was subtracted from the measured absorption and attenuation coefficients of Gelbstoff + particles, a_{gp} and c_{gp}, to obtain the absorption and attenuation coefficients of particles, a_p and c_p. The absorption coefficient of particles, a_p, was then corrected for scattering using the baseline method, where the value of a_p at 715 nm is set equal to zero. The scattering-corrected absorption coefficient of particles, a_p, and the attenuation coefficient of particles, c_p, are included in the data set as ac90271_ap and ac90271_cp.

$$a_p = a_{gp} - a_g; a_p 715 = 0$$
$$c_p = c_{gp} - a_g$$

4. The scattering-corrected absorption coefficient of particles, a_p, was added to the density-matched absorption coefficient of Gelbstoff, a_g, to obtain the fully corrected absorption coefficient of Gelbstoff + particles, a_{gp}, which is included in the data set as ac90271_agp.

$$a_{gp} = a_p - a_g$$

5. The scattering-corrected absorption coefficient of Gelbstoff + particles, a_{gp}, was subtracted from the attenuation coefficient of Gelbstoff + particles, c_{gp}, to obtain the scattering coefficient of particles, b_p, which is included in the data set as ac90271_bp.

$$b_p = c_{gp} - a_{gp}$$

6. The calculated absorption coefficient of water, a_w, at the measured temperature and salinity was added to the absorption and attenuation coefficients of Gelbstoff + particles, a_{gp} and c_{gp}, to obtain the total absorption and attenuation coefficients, a and c. These are included in the data set as ac90271_a and ac90271_c.

$$a = a_{gp} + a_w$$

$$c = c_{gp} + a_w$$

7. The absorption due to chlorophyll was then calculated by subtracting the value of $a_{gp}676$ interpolated between the measured $a_{gp}650$ and $a_{gp}715$ from the measured value of $a_{gp}676$, then dividing by the coefficient a* (= 0.014 m^2/mg). This is included in the data set as ac90271_CHL.

4.2) Quality control

Following the application of the field water calibration and the temperature and salinity corrections, the ac-9 data was visually reviewed. The bins whose shape or value differed significantly from the bulk of the data, indicative of bubbles or other contamination in the flow cell, were replaced with a null value.

5) References

1. Sullivan, J.M., M.S. Twardowski, J.R. V. Zaneveld, C.M. Moore, A.H. Barnard, P.L. Donaghay and B. Rhoades, "Hyperspectral temperature and salt dependencies of absorption by water and heavy water in the 400-750 nm spectral range," Applied Optics 45:5294-5309 (2006).