NURC Optical instrumentation, world class high accuracy measurements and unique within glider sensor calibration

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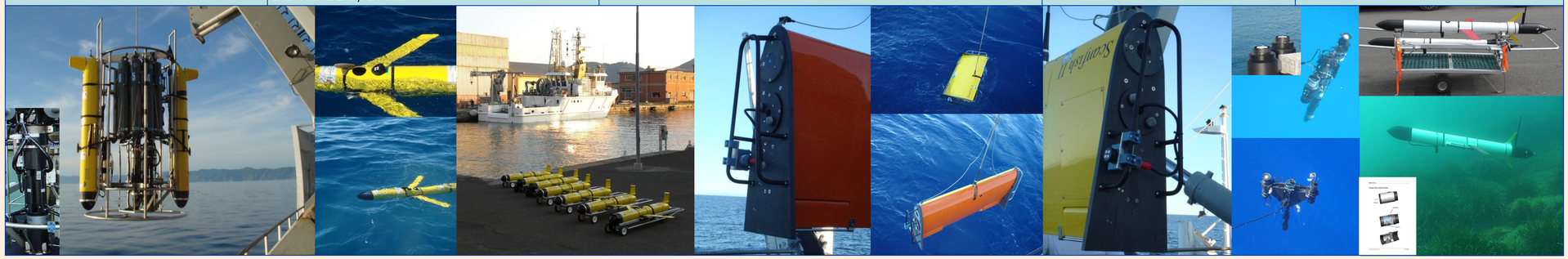
ABSTRACT

Due to the increased use of optics measurements in different oceanographic disciplines, from ocean colour to bio-optical modelling, NURC's engineering department has acquired instruments and knowledge on optical data collection, validation and calibration. *In Situ* observations still play an essential role in 'initializing/ground truthing' various models and remote sensing imagery. However, due to the yet-to-mature technologies applied on optical instruments and the related lack of calibration standards, a lot of effort must be spent on data quality control in order to improve and standardize pre/post deployment calibration procedures. The recently commissioned NIST standard Optical Calibration Laboratory in addition to the variety of different sensors, platforms and procedures, enable a unique high quality characterization of the optical properties of water masses.

Current NURC Optical packages

CTD PACKAGE	**SLOCUM Glider Fleet**	**EIVA SCANFISHII**	**SATLANTIC HyperPROII**	**NURC/GRAALTECH Folaga**
SBE9 plus, AC-S, Transmissiometer, Turbidimeter, Fluorometer.	Sophie: BBFL2, Irradiance 504. Elettra: BBFL2, Irradiance 504. Zoe: BBFL2, Irradiance 504. Natalie: BBFL2, BAM. Laura: BB3, BAM.	SBE49, AC-S, Irradiance504, BBFL2.	Unit 102, BBFL2. Unit 071, BBFL2.	(prototype AUV) BBFL2, Irradiance 504.



AC-S:

WetLabs Hyper Spectral Absorption and Attenuation Meter

- Spectral Range 400-730 nm
- Band Pass 15nm/channel
- Pathlength 25 cm
- Linearity >99 % R^2
- Output wavelengths 80+
- Resolution 4 nm
- Precision 450-750nm +/- 0.001 m^{-1}
- Accuracy +/-0.01 m^{-1}
- Dynamic Range 0.001-10 m^{-1}
- Sample Rate 4scans/sec., nominal

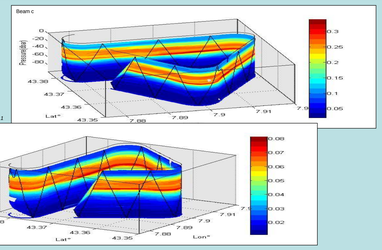
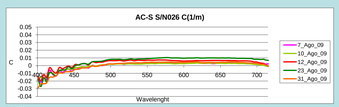


Fig. 1 and 2: Scanfish AC-S Beam c and Beam a
Fig. 3 and 4: AC-S Biotin c and Beam a Calibration plots

- ✓ 'Pure water' (MilliQ level) calibration procedure performed every two days. Room and water temperature are monitored
- ✓ Constant monitoring of the instrument drift and of any other changes that might occur on the sensor performance
- ✓ Data acquired with different units become comparable thanks to the constantly monitored base line that characterize each single instrument
- ✓ AC-S data are used as an *in situ* reference for the characterization and check of the smaller and single wavelength beam attenuation meters (BAM) installed on the Slocum gliders.



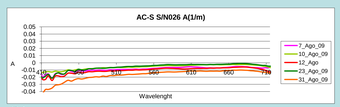


Fig. 3
Fig. 4

BAM:

WetLabs 532nm Beam Attenuation Meter

- Represent the 'Diver Visibility' parameter
- Pathlenght 10cm
- Acceptance angle ~1deg
- Linearity 99%R^2
- Sample rate to 8 Hz
- Long term stability 0.02 percent F.S./Hr

BAM stability and characterization is obtained with pure water and dark count measurements, quantitative data, instead ,are given through *in situ* AC-S data comparison and correction.

Fig. 5

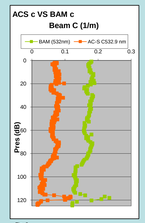


Fig. 6

Fig. 5: Slocum glider BAM
Fig. 6: AC-S Beam c (532.9 nm) vs. BAM (532 nm) data

Irradiance 504:

Satlantic 4 channels irradiance sensor

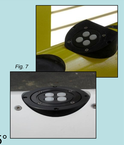


Fig. 7

- Field of view cosine
- Collector area 86mm^2
- Spectral bandwidth 10nm or 20nm
- Cosine response within 3% 0°- 60° within 10% 60°- 85°
- Detectors custom 17mm^2 silicon photodiodes
- Filter type custom low fluorescence interference

In House calibration.
In situ comparison with hyper spectral radiometric profiles.

Fig. 7: Slocum glider and FOLAGA Irradiance 504

ECOTRIPLETS:

WetLabs triplets

Fig. 8

- Wavelengths custom
- Depth rating 200m
- Sample rate to 4 Hz
- Linearity 99% R^2

Configuration:

- BBFL2 (Chl, CDOM, BB) 8 units
- BB3 (3 channels BB) 1 unit

Validation:

✓ Monitored for Dark counts before and after each deployment

✓ Characterization of the sensor drift

✓ Biofouling induced errors

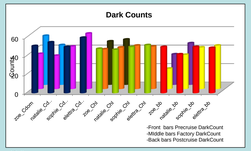


Fig. 9

✓ Quantitative data results more problematic, Eco triplets, like all the other fluorescence based sensors, present the same difficulties on calibration that are related to those kind of measurements

✓ Chl channel monitored with a Diet Coke solution in a Black Bath (hull shaped)*

✓ CDOM channel monitored with a Sprite Zero solution*

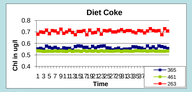


Fig. 10

Fig. 11

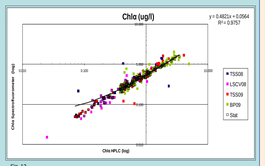


Fig. 12

- ✓ Quantitative data computed from discrete samples, describing the real *in situ* population
- ✓ Samples analyzed using the spectrofluorometric method
- ✓ Correction for the results based on a 3 years cross-sampling with HPLC extraction and analysis procedure

Fig. 8: Slocum glider Eco triplets
Fig. 9: Eco triplets dark counts comparison
Fig. 10: Eco triplets Diet Coke Readings
Fig. 11: Slocum glider Eco triplets black bath
Fig. 12: HPLC – spectrofluorometric cross sampling results

* *Based on Cetinic, Toro-Farmer, Ragan, Oberg and Jones," Calibration procedure for Slocum glider deployed optical instruments", Optics Express, 17 (19): 15420 -15430 .*

BB9:

WetLabs 9 angles scattering meter

- Sample Rate 1 Hz
- Angles 80 120 170 70 110 170 90 140 150
- Range, typical ~0.0024-5 m^{-1}
- Wavelength 532 nm
- Linearity 99%R^2
- Sensitivity 7.70 x 10^{-6}

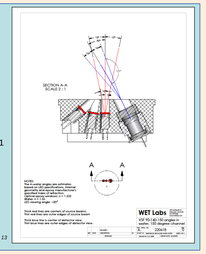


Fig. 13: BB9, example of one of the 3 faces

HyperPROII:

Satlantic hyperspectral Irradiance/Radiance/Reference unit

- Spectral range 350-800nm
- Entrance slit 70 x 2500µm
- Pixel Size 25 x 2500µm
- Spectral sampling 3.3nm/pixel
- Spectral resolution 10nm (3 pixel slit image)
- Spectral accuracy 0.3nm
- Stray light ≦ 1x10^{-3}
- Detector type 256 channel Silicon photodiode array
- Field of view Irradiance Cosine corrected single collector Radiance 8.5° half angle baffled Gershun tube

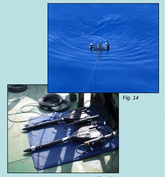


Fig. 14

Fig. 15

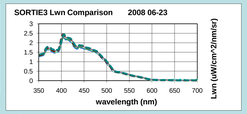


Fig. 16

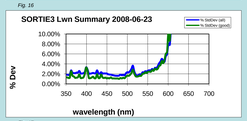


Fig. 17

Fig. 14 and 15: HyperPROII freefalling profiler in the water and on deck
Fig. 16 and 17: HyperPROII retrieved Normalized water leaving Radiance comparison between unit 102 and unit071 and related StdDev values

- ✓ Characterized for: Spectral Range, Spectral Resolution, Spectral Accuracy, Field of View, Cosine Response, Thermal Response, Immersion Effects
- ✓ Calibrated for absolute radiometric: Irradiance and Radiance
- ✓ Proposed as a portable radiometer of a radiometric uncertainty comparable to MOBY buoy (NASA Standard Buoy)
- ✓ MOBY Buoy comparison (SORTIE3 experiment, Maui, Hawaii 2008)
- ✓ SIRCUS (Spectral Irradiance/Radiance Responsivity Calibration with Uniform Sources) Stray Light Correction Matrix (NIST)

AOP Calibration Laboratory:

Produce low uncertainties in absolute radiometric calibration

✓ Meet NIST standards

✓ Clean/Dark room to isolate instruments from airborne particulate and ambient light

✓ Enable calibration for absolute Radiance and Irradiance:

- ❑HyperPROII units
- ❑ Glider /AUV mounted 504s

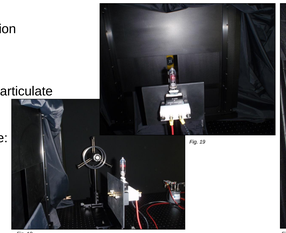


Fig. 18

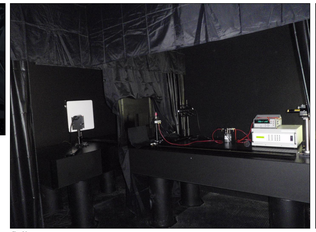


Fig. 19

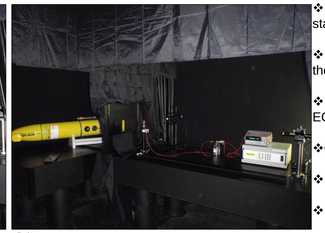


Fig. 20

Fig. 21

Fig. 18: Lamp and Reference system
Fig. 19: Slocum glider mounted 504 under calibration
Fig. 20: Radiance calibration configuration
Fig. 21: Slocum glider Irradiance calibration configuration

- ❖ Lamp, based on the international 1000W FEL irradiance standard lamp
- ❖ Reflectance system in combination with the lamp provides the high accuracy radiance source
- ❖ Alignment System verified with a 2.5mW HeNe (Class IIIa, EC 3R) laser
- ❖Optical Benches
- ❖ Mounting and Baffling Systems
- ❖ High repeatability with a monitored precision power supply

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