

Radiometric Data Quality Assurance for HyCODE

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LONG-TERM GOALS

My long term goal is to improve the quality of radiometric field data to assure investigators that variations observed during experiments are not due to instrument stability or calibration.

OBJECTIVES

Although instrument manufacturers often employ the most advanced technologies in the design and manufacturing of radiometers, these systems are always challenged by field deployments in less than ideal conditions, where resulting data may be critical to a particular program. Tracking instrument stability between calibrations has been for most users, impossible. Absolute radiometric calibrations at best are good to the 3-4% level. The SQM-II is a highly stable field deployed light source designed for field radiometer data quality assurance. Field experiments are increasing in complexity, often with multiple instrument manufacturers with various calibration labs and techniques. Devices like the SQM-II must be deployed in the field to get to the 1% matchup level required by many programs to assure that the variations seen in data are not a function of the instrumentation.



Figure 1. SQM-II setup at the HyCODE LEO-15 field site.

[photo: The SQM-II (at left) at the HyCODE LEO-15 field site calibrating a HyperTSRB radiometer]

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APPROACH

This project was funded to provide radiometric data quality assurance to HyCODE at the LEO-15 field site in July of 2000 and 2001. Since research done to date using the SQM-II has only been done with Satlantic radiometers, modifications to the system are required to accept the other types of radiometers that will be used during HyCODE.

WORK COMPLETED

The SQM-II system was deployed at the LEO-15 field site during HyCODE field program in July of 2000. Investigators were requested to provide their radiometers for evening sessions where they were compared to a reference instrument using the SQM-II. This data will allow radiometer stability to be computed during the experiment and the comparison data will allow calibration corrections to be made, if necessary, to provide data comparability between radiometers to better than 1%.

A total of 19 radiometers were monitored for stability over a 3 week period and intercalibrated with the reference sensors at least once. A final report on this work was submitted in September, 2000.

During the HyCODE project meeting in January, 2001 it was decided to get more radiometers involved in the intercomparison. To facilitate this, the SQM was made available at three sites (Rutgers Field Station, R/V Endeavor and NRL DC). The individual radiometer stability tests were not done as this precluded a multi-site effort.

During July-August of 2001 a total of 49 radiometers (6 ASD, 3 BSI, 6 Hobi, 1 PHILLS and 33 Satlantic) were intercalibrated using the SQM-II. In preparation for this work, 12 SQM sessions were conducted from May through September of 2001. HyCODE PIs were very cooperative in providing access to the radiometers for this project, only two systems of the 51 in the project were not able to be intercalibrated. A final report on this work was submitted in September, 2001, concluding this project.

RESULTS

Results from HyCODE-00 show that the radiometer data from the 19 instruments evaluated was stable to better than 1% during the experiment. Some difficulty was experienced getting the desired intercomparability in various instrument types as had been done in the past (Hooker and Aiken 1997, Hooker et.al. 1999). It was hypothesized that this was caused by the different loading factors of the various instrument designs. An experiment to investigate this was conducted using extremes of a black plate and a mirror. Loading was found to be insignificant.

Table 1. List of radiometers provided by investigators during HyCODE 2001 at LEO-15.

Owner/PI	Instrument	Serial Number	Radiometers	Type
CalPoly/Moline	Hobi HydroRad-3	710	Lu, Eu, Ed	Hyperspectral
NRL DC/Davis	PHILLS	001	Lt	Hyperspectral
NRL DC/Rhea	ASD FS Dual	901	Lr, Lt	Hyperspectral
NRL DC/Rhea	ASD FR	6220	Lr	Hyperspectral
NRL SSC/Gould	ASD FS	702	Lr	Hyperspectral
NRL SSC/Gould	ASD FS Dual	903	Lr, Lt	Hyperspectral
OSU/Pegau	Satlantic HyperTSRB	016	Lu, Es	Hyperspectral
OSU/Pegau	Satlantic SPMR	009	Lu, Ed	Multispectral
Rutgers/Schofield	PRR601/610	9633/9634	Es, Lu, Ed	Hyperspectral
Rutgers/Schofield	Hobi HydroRad-3	609	Lu1, Lu2, Es	Hyperspectral
Rutgers/Schofield	Satlantic HyperTSRB	005	Lu, Es	Hyperspectral
Rutgers/Schofield	Satlantic MVD	034	Es	Multispectral
Rutgers/Schofield	Satlantic TBS	003	Lu1, Lu2, Ed1, Ed2	Multispectral
Satlantic/Lewis	Satlantic HyperPro	116/118	Ed / Lu	Hyperspectral
Satlantic/Lewis	Satlantic SPMR	001	Lu, Ed	Multispectral
Satlantic/Lewis	Satlantic HyperTSRB	002	Lu, Es	Hyperspectral
Satlantic/Lewis	Satlantic/HyperBubble	018	Lu, Es	Hyperspectral
Satlantic/McLean	Satlantic MiniSpec	108	Lu (ref)	Hyperspectral
Satlantic/McLean	Satlantic MiniSpec	109	Es (ref)	Hyperspectral
Satlantic/McLean	Satlantic MiniSpec	112	Ed (ref)	Hyperspectral
Satlantic/McLean	Satlantic MVD	(063, 064, 092, 125)	Ed	Multispectral
Satlantic/McLean	Satlantic MicroPro	006	Lu1, Lu2, Ed1, Ed2	Multispectral
Satlantic/McLean	Satlantic OCR-507	037	Lu	Multispectral
WHOI/Purcell	Satlantic REMUS OCR-507	001	Lu	Multispectral
WHOI/Purcell	Satlantic REMUS OCI-507	002	Ed	Multispectral

Results from HyCODE-01 show very high intercomparability between Satlantic radiance instruments of generally less than 4%. Figure 2 below shows the comparison between TA108 (the hyperspectral radiance reference) and two other hyperspectral radiance sensors, showing excellent agreement (above 400nm – below 400nm the SQM flux is too low for comparisons).

This is the first time a hyperspectral reference sensor has been used to transfer calibrations to a multispectral instrument. It is also the first time non-Satlantic instruments have been used with the SQM-II. Normally each instrument type has a reference sensor of the same design (Hooker and Aiken 1997). Since the SQM-II is a very uniform light source, it was expected that a single hyperspectral reference would be well suited for radiance intercomparisons of different instrument types. Generally this worked well, but there were some significant differences between the multispectral and hyperspectral radiometers, particularly in the range 550-650nm where difference of up to 15% were observed. Further work is required to improve the intercomparisons between hyperspectral and multispectral radiance sensors. Comparisons between the reference sensor and the NRL PHILLS sensor were within 12% (5% of this variation is due to the wide field of view of the PHILLS sensor that resulted in some of the pixels viewing outside the uniform part of the SQM diffuser). More work would be required to determine the source of the remaining discrepancy, but these results are quite good. Preliminary results from NASA's SIMRIC-1 (SIMBIOS Radiometric Intercomparison) show only 2-3% differences between NRL and Satlantic absolute radiometric calibrations. The ASD sensors were not provided with calibration data so they could not be compared as the other sensors were (these sensors are typically used in relative mode, so absolute calibration is not necessary). Two of the HydroRads were different from the reference by about 50%, while the third was within about 5-20%. Calibrated radiances were provided for these systems by a CalPoly scientist using HoboLabs provided software and calibration data.

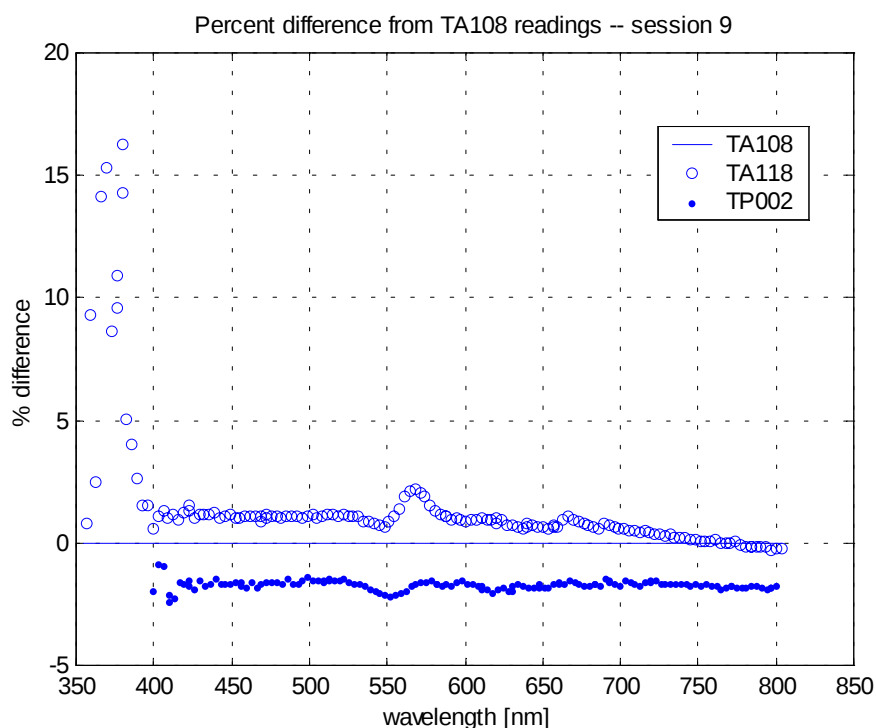


Figure 2. Comparison between two hyperspectral radiance sensors and reference
[graph: comparison between two hyperspectral radiance sensors and reference from
400 to 800nm showing differences in calibration of 1-2%]

The intercomparability of the in-air irradiance sensors was generally within 10% for Satlantic instruments. The intercomparability of the in-water irradiance sensors was generally within 10% for Satlantic instruments and 60-80% for the HydroRads. Intercomparisons between irradiances sensors, compared to a single reference sensor, proved to be much more difficult as the diffuser designs were quite different (particularly between hyperspectral and multispectral designs) and likely contributed the significant differences.

For the first time instruments of different designs can be intercompared in the field. More work is required to resolve the differences observed, but the overall results are quite encouraging. No corrections to calibration files are recommended, although discrepancies between the different HydroRad spectrographs should be resolved.

IMPACT/APPLICATION

Much of the pioneering work to develop the SQM-II and associated protocols has been done with NIST, NASA and Satlantic almost exclusively with Satlantic radiometers of various types. The challenge in the HyCODE program is that there are five manufacturers of radiometers to be deployed at the LEO-15 site (all calibrated at different laboratories) which have never been used with the SQM-II before, although it has been designed to take radiometers up to 8" in diameter. This challenge represents the next level of field radiometry and should prove to be a major step for the oceanographic community. As a result, HyCODE will be a model for future radiometric field programs.

TRANSITIONS

The techniques developed for the SQM-II for radiometer data quality assurance will be used by investigators around the world.

REFERENCES

- Hooker, S.B. and J. Aiken (1997), Calibration evaluation and radiometric testing of field radiometers with the SeaWiFS Quality Monitor (SQM), *Journal of Oceanic and Atmospheric Technology*, Vol 15, p995-1007.
- Hooker, S.B., G. Zibordi, G. Lazin and S.McLean (1999), The SeaBOARR-98 Field Campaign. NASA Technical Memorandum 1999-206892, Vol 3, S.B. Hooker, and E.R. Firestone Eds., NASA Goddard Space Flight Center, Greenbelt, MD, 40pp.
- Hooker, S.B., G. Zibordi, G. Lazin and S.McLean (1999), The SeaBOARR-99 Field Campaign. NASA Technical Memorandum 1999-206892, Vol 7, S.B. Hooker, and E.R. Firestone Eds., NASA Goddard Space Flight Center, Greenbelt, MD.
- Johnson, B.C., P.S. Shaw, S.B. Hooker and D. Lynch (1998), Radiometric and engineering performance of the SeaWiFS Quality Monitor (SQM): A portable light source for field radiometers, *Journal of Oceanic and Atmospheric Technology*, Vol 15, p1008-1022.

McLean, S.D., S. Feener, J. Scrutton, M. Small, S. Hooker and M. Lewis (1998): SQM-II: A commercial portable light source for field radiometer data quality assurance, Proc. SPIE Ocean Optics XIV.

Mueller, J.L. and R.W. Austin (1995), Ocean optics protocols for the SeaWiFS validation, Revision 1, NASA Technical Memorandum 104566, Vol 25, S.B. Hooker, E.R. Firestone, and J.G. Acker Eds., NASA Goddard Space Flight Center, Greenbelt, MD, 66pp.

Shaw, P.S., B.C. Johnson, S.B. Hooker and D. Lynch (1996), The SeaWiFS Quality Monitor - a portable field calibration light source, Proceedings of the SPIE Vol. 2963: Ocean Optics XIII, p772-776.