”MOBY-NET, an ocean color vicarious calibration system”

UNIVERSITY
OF MIAMI

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3.5 year annual report.

MOBY-NET

Objective: Develop a vicarious calibration instrument which can return MOBY level Lw data from alternate sites and meets the recent IOCCG white paper goals of developing multiple vic/cal sites with:

A) identical instrumentation

B) centrally, and consistently characterized and calibrated

C) consistent and uniform data processing

D) Work with commercial vendors for a path towards additional instruments when required.

This system would take advantage of the work to update and enhance the current MOBY instrument.

MOBY-NET

Specific Project: Develop a prototype MOBY-NET buoy that has:

A) a buoy hull with the major structure similar to MOBY but can fit in a 40’ container and be able to accept a modular optical system.

B) a modular, stable, optical system allowing installation and removal from buoy hull as one intact piece with appropriate capabilities.

C) A separate stable source and radiometer, transported with the MOBY-NET optical system with sufficient stability to verify system performance pre/post deployment at the chosen remote site.

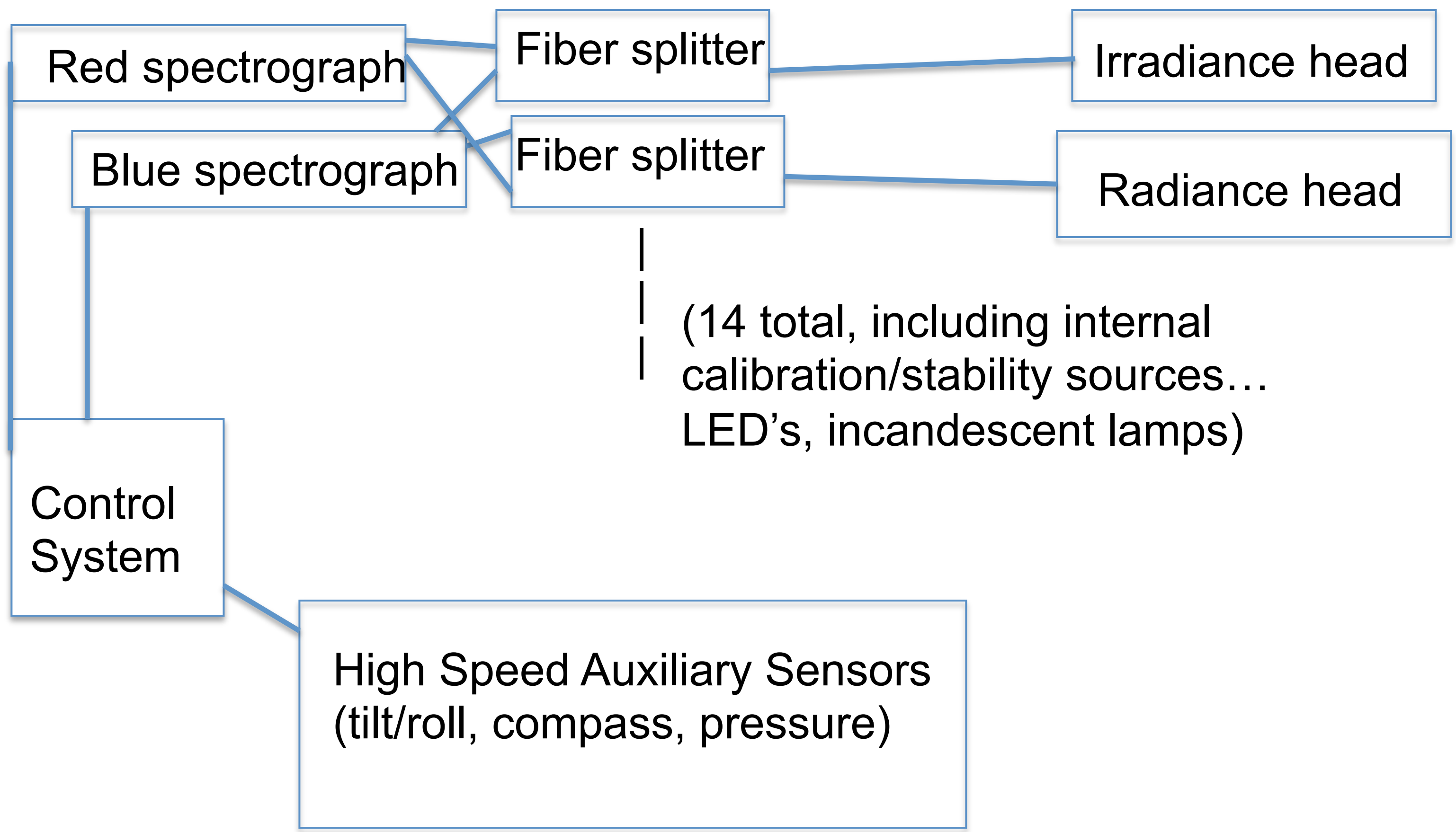
Progress in past 6 months

- MOBY Hull: Carbon parts at MSI. Other parts being constructed at MSI.
- MOBY Optics: continuing testing of blue spectrometer in the field , finalizing splitter design.
- Field stability source and monitor: have been doing long term stability tests of monitor including transportation of monitor system.

MOBY Hull, last 6 months

- Being supplied by Mooring Systems Inc. with input from our group (Mark Yarbrough) and carbon parts were fabricated by Hall Spars (experts in marine carbon manufacturing).
- Unfortunately Hall Spars has gone out of business, we have found an alternate vendor for future buoys if required.
- Splitter external dimensions have been determined, a sample splitter/dual BSG/RSG system will soon be shipped to MSI to build the bottom cage.

MOBY optics, main components

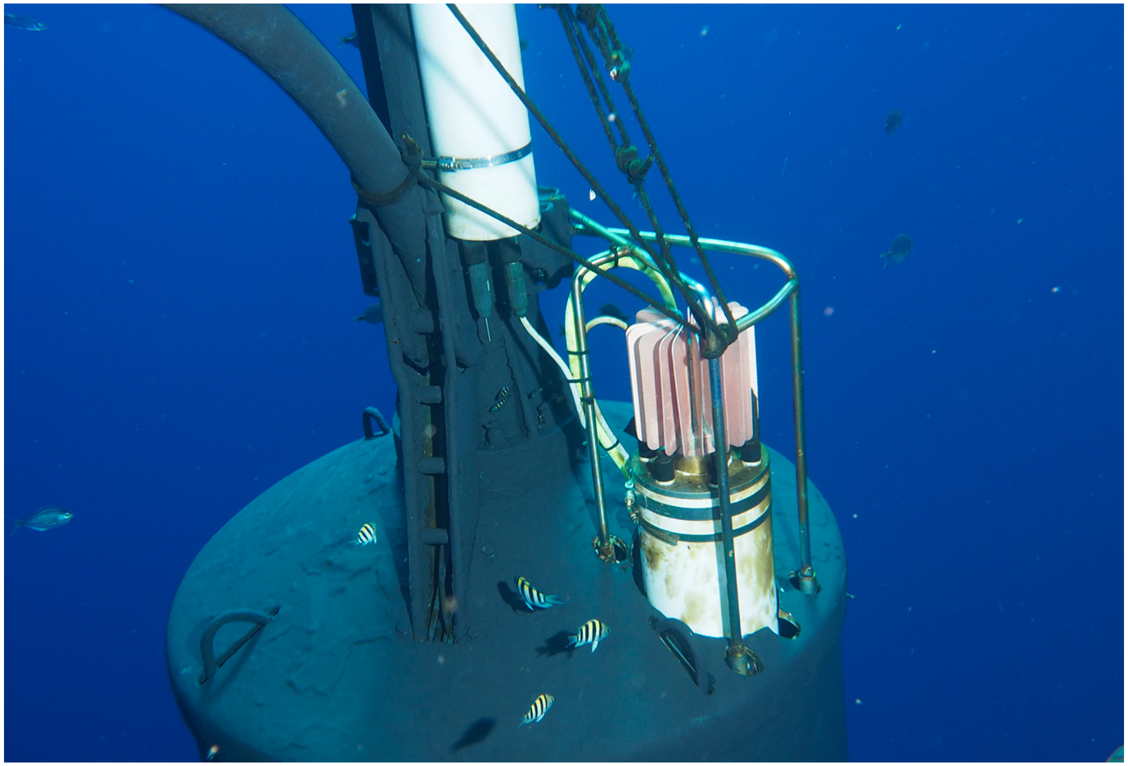


Progress in last 6 months

- Field testing Blue spectrograph, along side MOBY.
- Checking stability of the system during deployment.
- Running different test acquisition cycles to optimize final acquisition protocol.
- Totally redesigned the fiber optic splitter to improve temperature stability of the system.

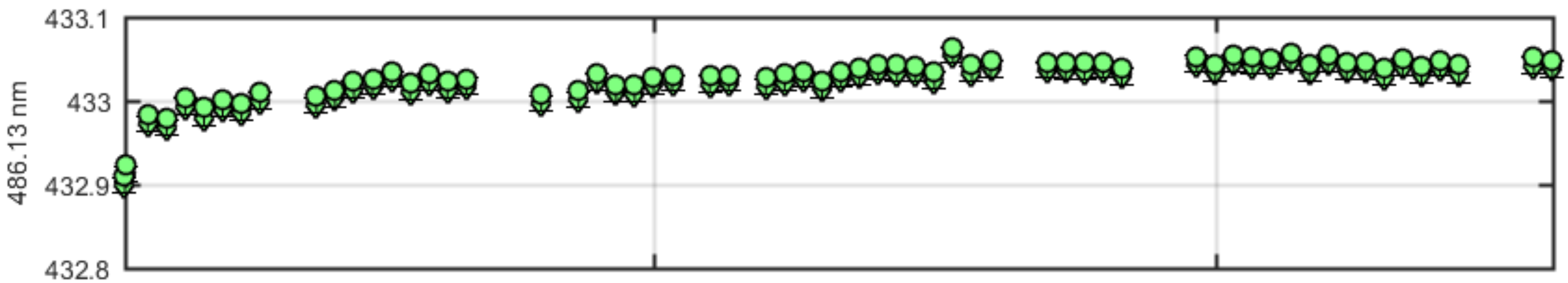
Field testing of prototype blue spectrograph

We are currently operating a blue spectrograph alongside the heritage MOBY system. We are now in our 4th deployment of the BSG along side the MOBY heritage instrument.



Stability of BSG during deployment: Spectral stability

With our high spectral resolution (1 nm FWHM, 0.3 nm/pixel) we can track fraunhofer lines during deployments to track stability.

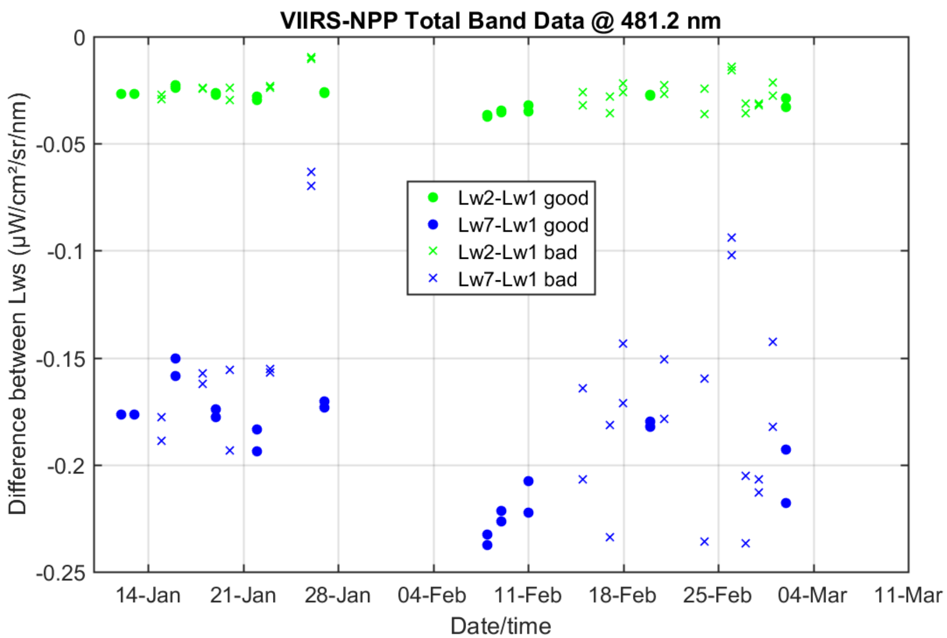


NOTE Y axis is pixel location of fraunhofer line on array, x axis is time during the deployment (3 month period). This example is for 3 months during deployment M263. As can be seen, the spectral shift during this deployment was approximately 0.15 pixels which translates to a 0.05 nm shift. For deployments M261 and M264 similar small shifts were seen (0.1nm over 4 months for M261 and 0.05 nm for the current deployment over 2 months).

M262 was an anomaly in many ways (mooring broke free, MOBY had to be retrieved and redeployed) and there was a larger shift (1nm over 5 months) during this deployment. We are investigating this spectrometer.

Stability of BSG during deployment: radiometric stability

We are working on different ways to track radiometric stability.

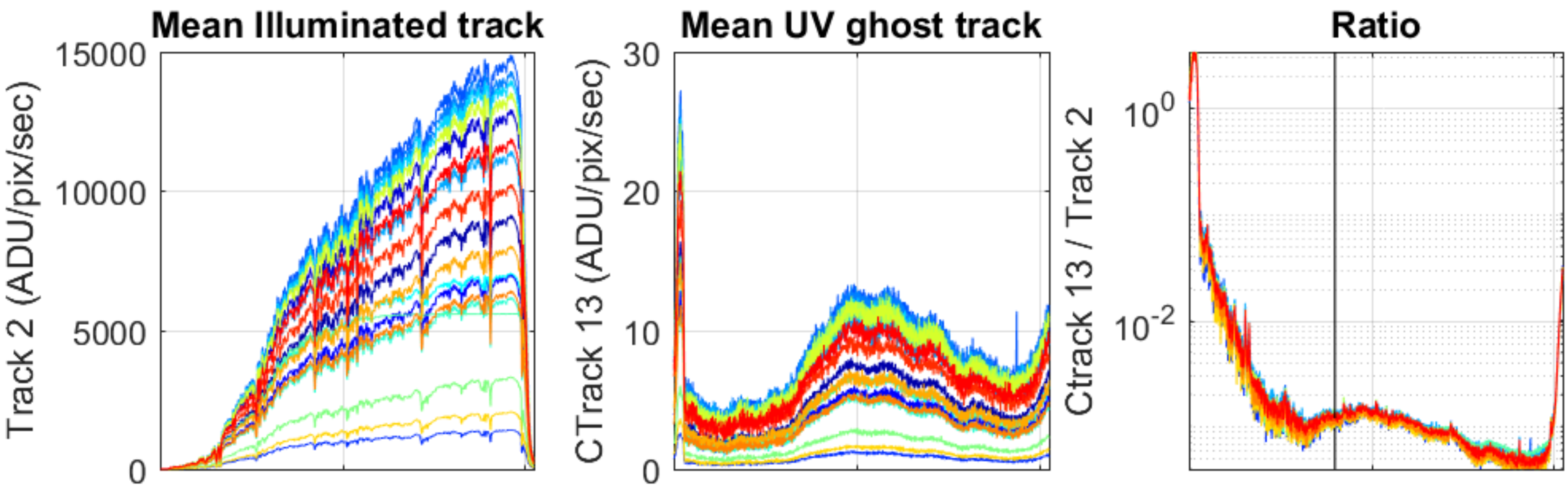


This is a graph of the difference between Lw calculated using the different arm measurements. What is important here is the variation over the deployment (in this case most recent deployment M264). Green dots are fundamentally based on the top arm measured Lu, while the blue dots is the difference (sort of) between the top and middle arm Lu.

If one focuses on the blue dots, the relative stability between the top and middle arm is about 3%, excluding the period around February 11. Interestingly, earlier that week, the call had been made that MOBY needed a diver cleaning. This cleaning happened around Feb 16th, and after this date the blue dots came up more inline with where they were before. So this difference is a nice indication of bio-fouling, which previously was more difficult to separate from irradiance variations…

Special acquisitions for data investigation

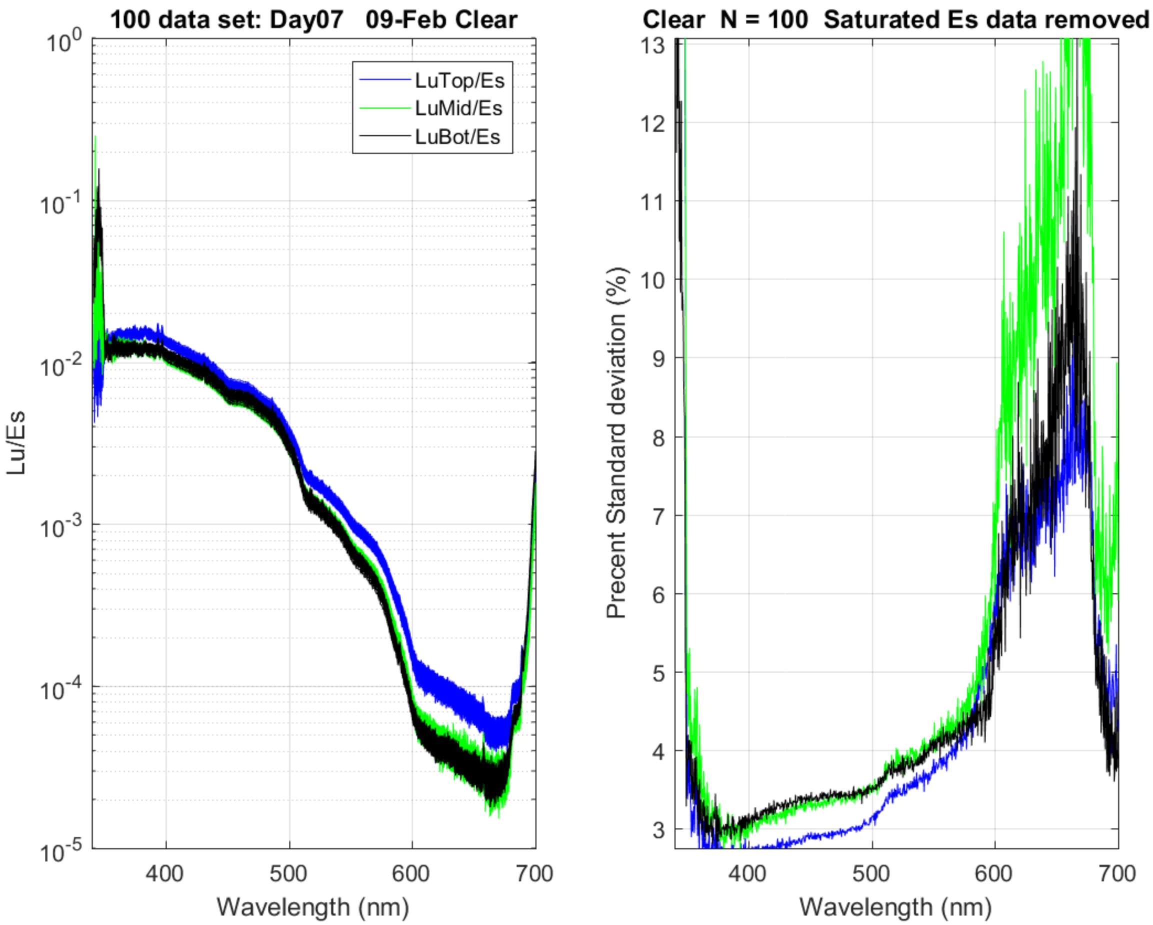
We recently began some special acquisitions to look at various aspects of the data and acquisition strategies. .



In this test we illuminated only one track, then looked at the how much signal went to other tracks. In this case, Track 2 is the large Es signal. It shows up at significantly less than 1% in track 13. Track 13 is chosen, actually because it has a worse case reflection in the UV, which we believe can be eliminated with a wedged window in the camera (we have some cameras with wedges, some without, only shows up in cameras without wedged windows). The nice thing is the normalized signal (ratio) is very consistent, which lends itself to a correction scheme.

Special acquisitions for data investigation

Another test was to take 100 images in as quick a succession as possible (6 seconds/image) to look at wave focusing and statistics. .

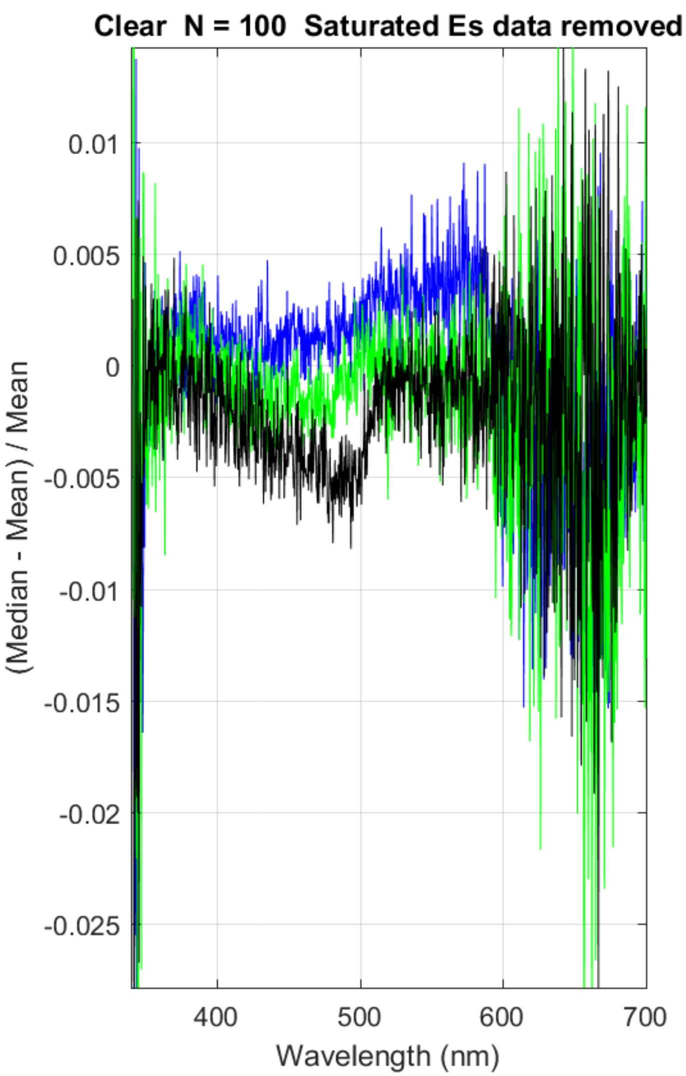


As can be seen, the % std for these (right panel) is on the order of 3-4%, growing above 600 nm.

This is predominately a measure of wave focusing.

There have been few studies of spectral wave focusing statistics for upwelling light.

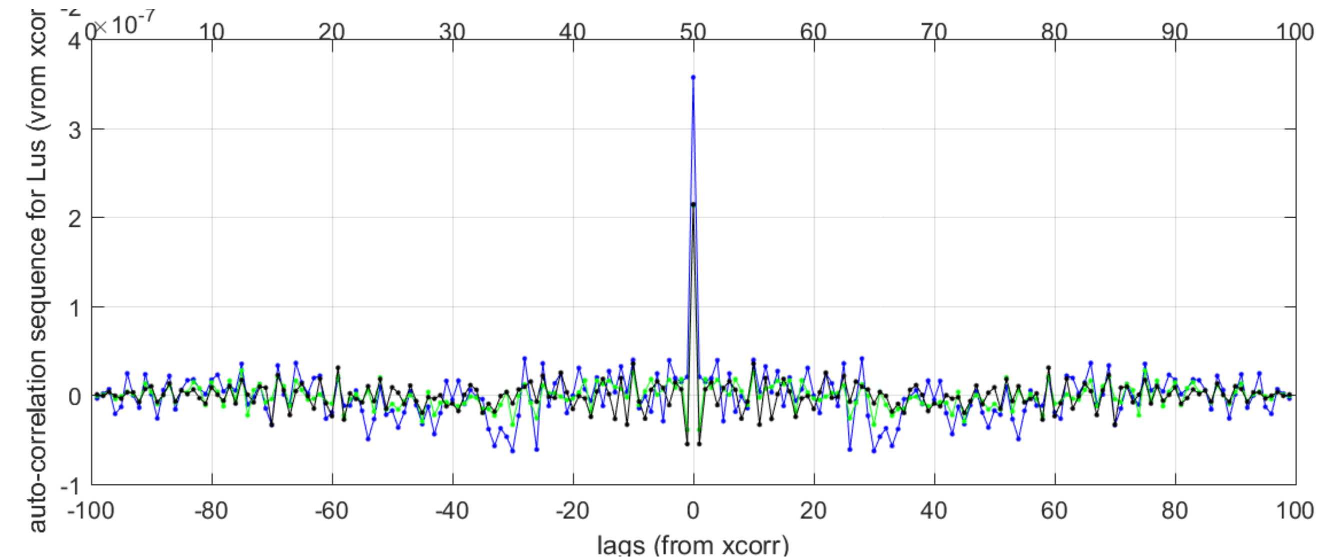
Statistics of 100 point samples

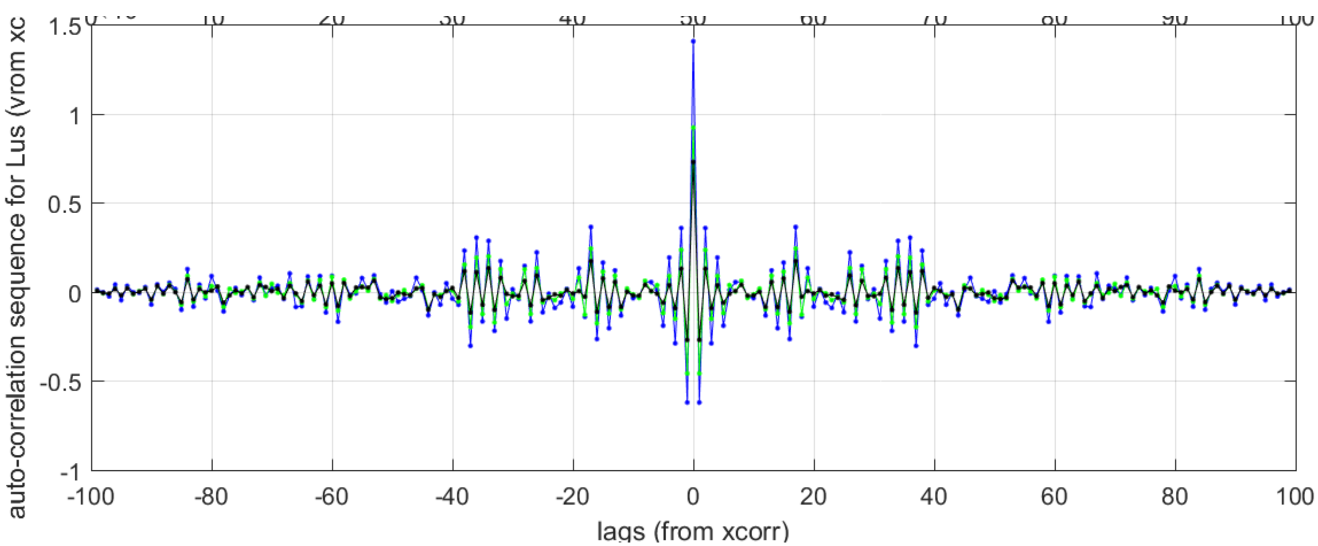


While these samples are not really normally distributed, there is a tail towards the higher intensity events. To get a measure on how non-normal the distribution is, we are looking at the normalized difference between the median and mean. This is very small for the most part (less than 0.5%), so it is close to a normal distribution….which makes using statistics to determine the error of the mean easier..hence estimating how many samples one would need to average.

Averaging 20 samples would reduce the standard error of the mean to approximately 1 %.

Statistics of 100 point samples

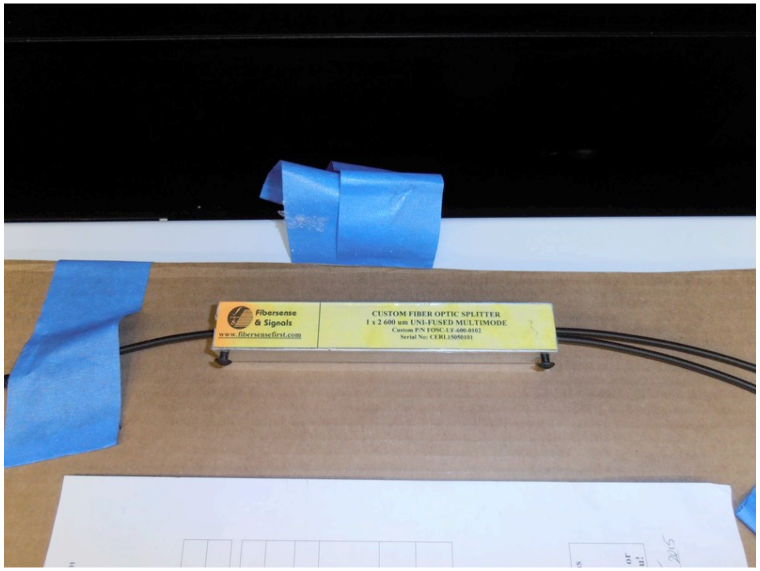


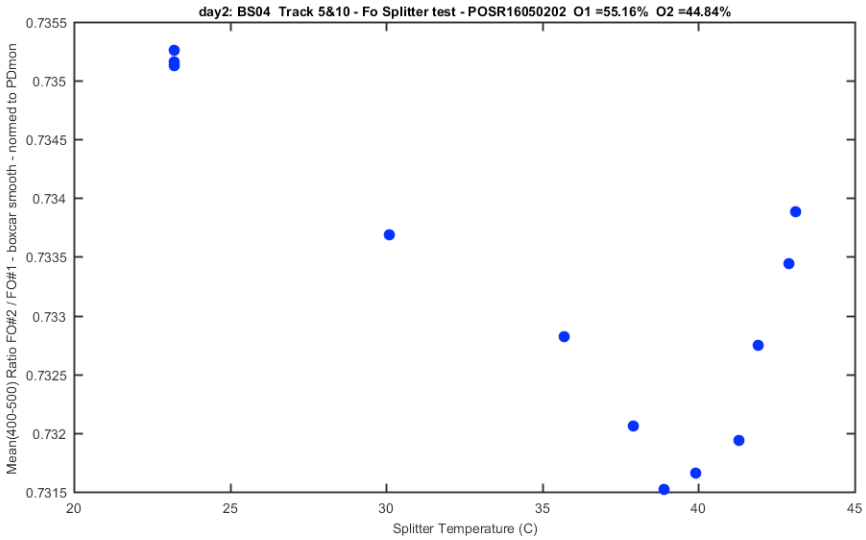


Also interesting to look at the autocorrelation of the samples to check randomness. These are for two clear days. In the top it is random, other than the correlation with itself (no lag) there is no structure. The second case seems to have peaks at a lag of 18 or so, which correlates to 90 seconds….so one would want to make sure to average over this whole period at least. The lower case had less wind than the other (typically stronger wave focusing in low wind).

Fiber Splitters

- As discussed previously, we need to use fiber optic splitters to divide the light between the red and blue spectrometers.
- Previous tests have shown the splitters are insensitive to the mode structure in the fibers, as our radiance and irradiance collectors are illuminated with extremes of incident light fields.
- We did a test of the temperature sensitivity of the splitting ratio in the fibers, and found that over a larger temperature range than we will experience, the sensitivity of the splitting ratio to temperature is very small.



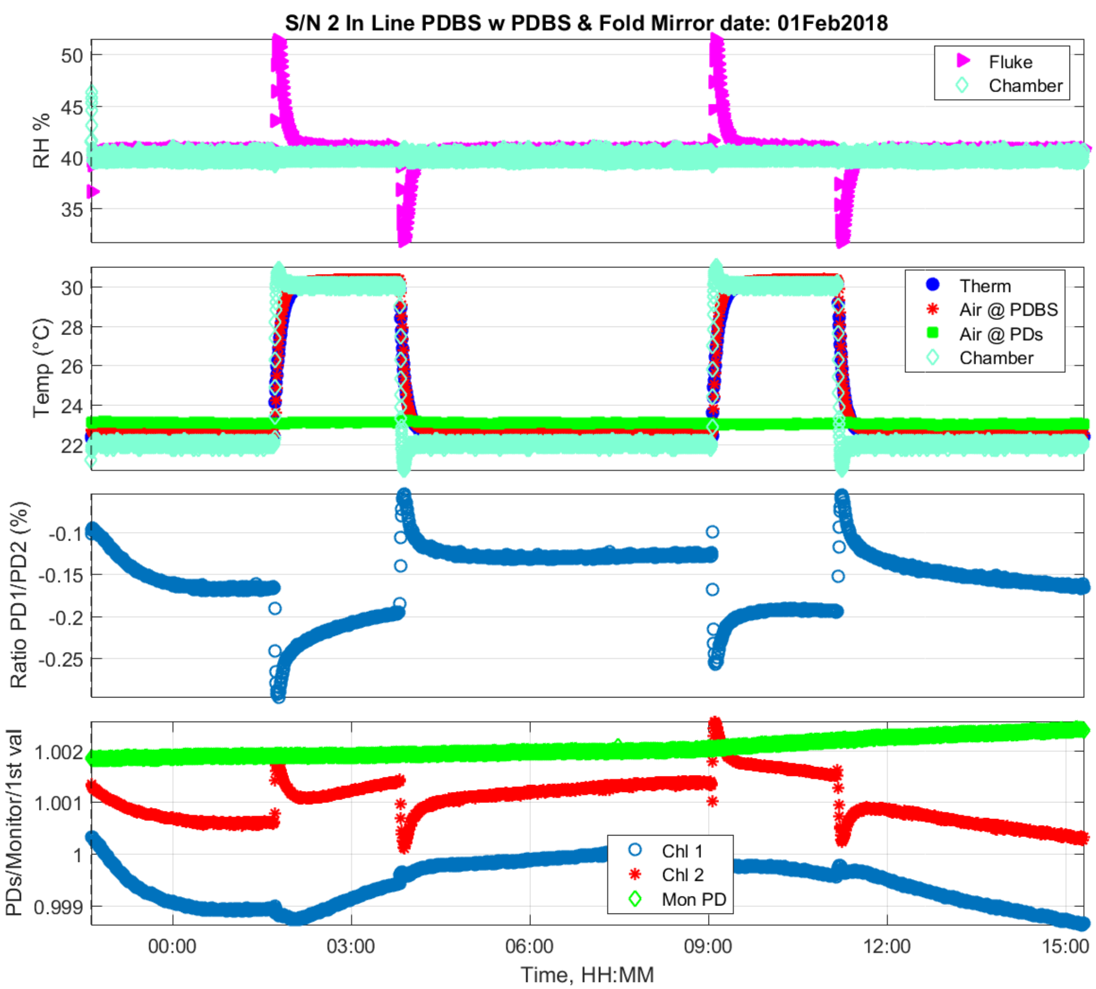


Fiber Splitters

- There was a problem with the fiber splitters however. While acquiring the data for the previous slide, we had a complete failure of the fiber splitter (no light out of either side).
- The splitter was sent back to the manufacturer to find out why there was this failure. We are concerned because the optical system may experience large temperature ranges during shipment, in the MOBY-Net concept, much more then it will have during operation.
- We are working with the manufacturer on the specifications/cost of an extended temperature device to avoid this failure in the future. This has slowed finalizing the design of the fiber splitter and housing.
- We then did another test in a NIST environmental chamber where we looked at the total throughput of the system as a function of temperature. What we found was that these fiber splitters had very high, and somewhat unrepeatable temperature instabilities.
- This then required a whole new design.

Fiber Splitters

- We are now working with an optical beam splitter based on a polkadot beam splitter. So far this has much less of a problem with temperature coefficients



An example of the temperature tests with one of the latest designs is shown to the left. The temperature was varied from 22 C to 30 C. The green line on the bottom graph is the monitor, while the two paths are shown in the blue and red. Once the device temperature has settled, the shift appears to be on the order of 0.05% in the ratio, and similar for one channel, with the other channel barely changed. The splitter is made of titanium, which has a relatively low thermal conductivity, hence it slowly responds to temperature. In use, our system will be in a constant thermal environment, so that is good.

Finally for the MOBY-NET system:

We have been testing the controller and lower power junction (hardware and software on the operational MOBY system for over a year and it is working well.

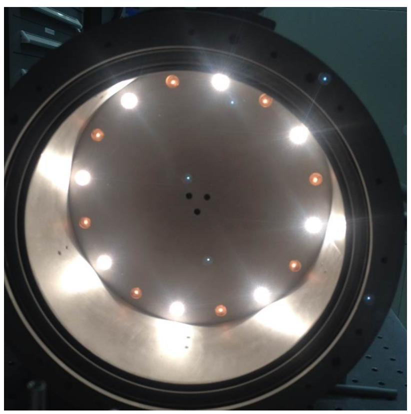
We will be deploying the dual RSG/BSG system in April, along side MOBY.

We have developed the software subsystems for spectrometer control which we have been using in the deployed BSG. We are working on the software for the dual system now.

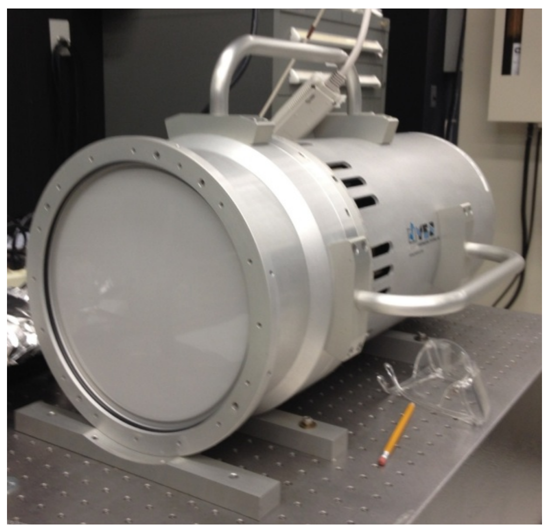
Stability System – Portable Stability Source and Spectroradiometer

Source: Satellite Quality Monitor (SQM) from Yankee Environmental Systems

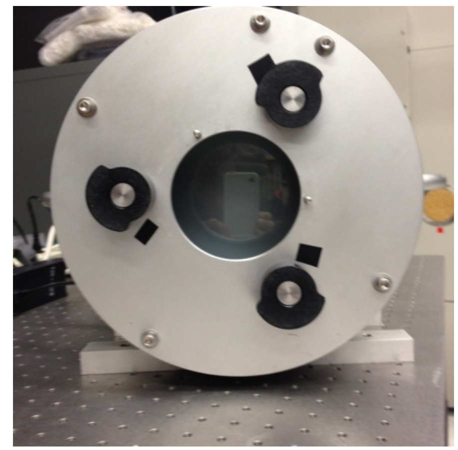
Eight 4.4 W lamps, eight 17 W lamps, three filtered & temperature controlled monitor photodiodes, power supplies, heaters, fan, & microprocessor.
78 cm x 30 cm at 37 kg



SQM Light Chamber

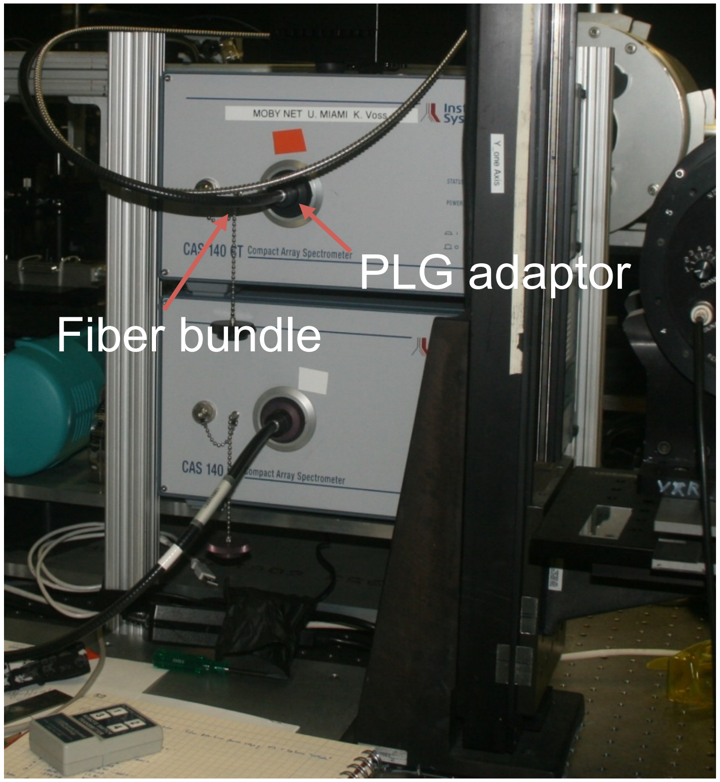


Diffuser & Window Installed



Device Under Test (DUT) Flange Installed

Spectroradiometer: CAS140CT-156 UV-VIS-NIR fiber coupled spectrograph from Instrument Systems.



Front view of two CAS'

300 nm to 1100 nm, 3.7 nm resolution, 0.8 nm/pixel spacing, internal shutter and order sorting filter, integration time 10 ms to 64 s, filter wheel with four neutral density filters (OD 1 to 4), 15 bit A/D, 1024x128 back-illuminated CCD, binning mode in slit direction, CCD cooled to -10?C.

Two foreoptics:
Instrument Systems EOP-146 with fiber bundle E055 for irradiance

MOBY-NET custom radiance head with fiber bundle E054

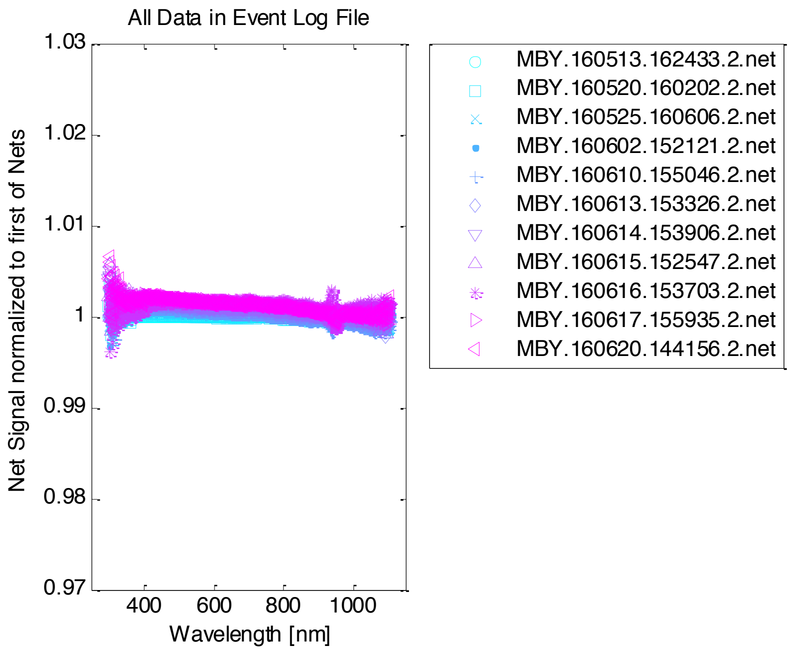
Stability System Major Accomplishments

SQM:
•Acrylic window replaced with roughened quartz to increase UV flux;
•Servicing addressed (spare replacement lamps & fixtures, minor machining, documentation & parts list);
•Data acquisition software (designed for non expert user) written – it is compatible with MLML's data base system;
•Automated processing of log files and posting to MOBY-NET internal web site;
•Radiometric testing (stability, repeatability, uniformity) with MOBY NET CAS, a filter radiometer, and a second spectroradiometer.

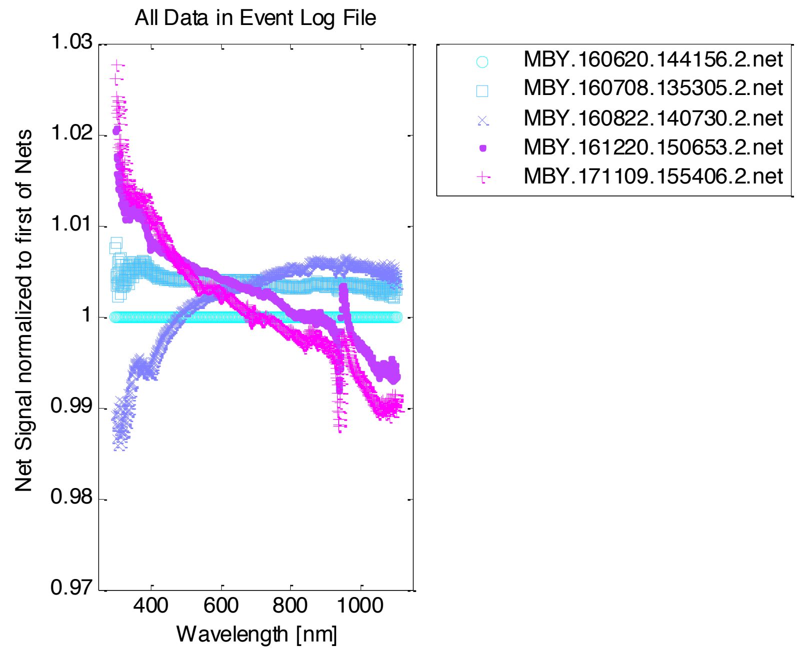
MOBY-NET CAS:
•Time series for stability and repeatability: irradiance & radiance foreoptics;
•Development of radiance foreoptic (views external to or mounted in SQM);
•Characterizations for wavelength accuracy and stability, warm-up interval, efficacy of kinematic design, effect of disconnect/reconnect at PLG, linearity, integration time, and OD filter;
•Transported between NIST labs and once to MOBY site in Honolulu.

The CAS/SQM system was tested for stability with shipment in December 2017 (NIST to UM).

CAS Irradiance Results



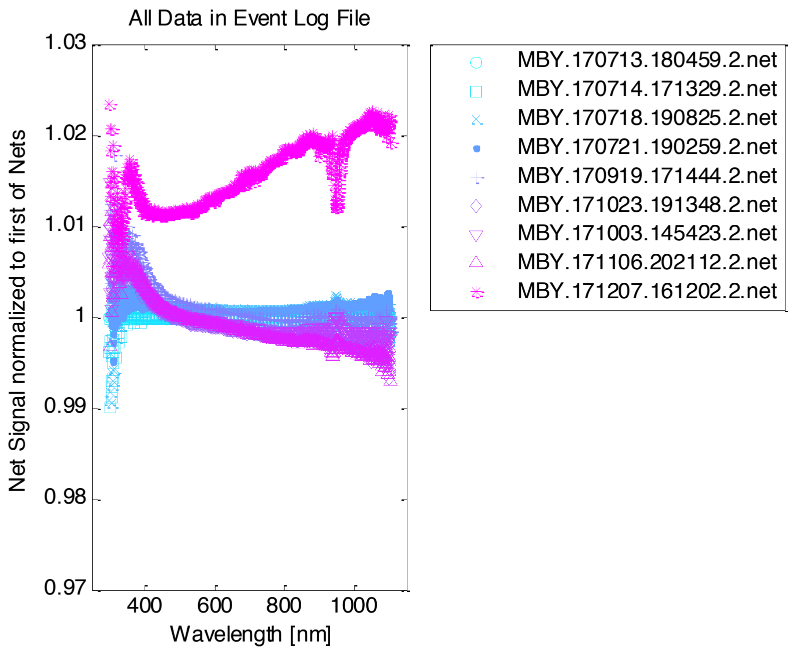
Irradiance with same FEL lamp: nothing moved over 2 month interval



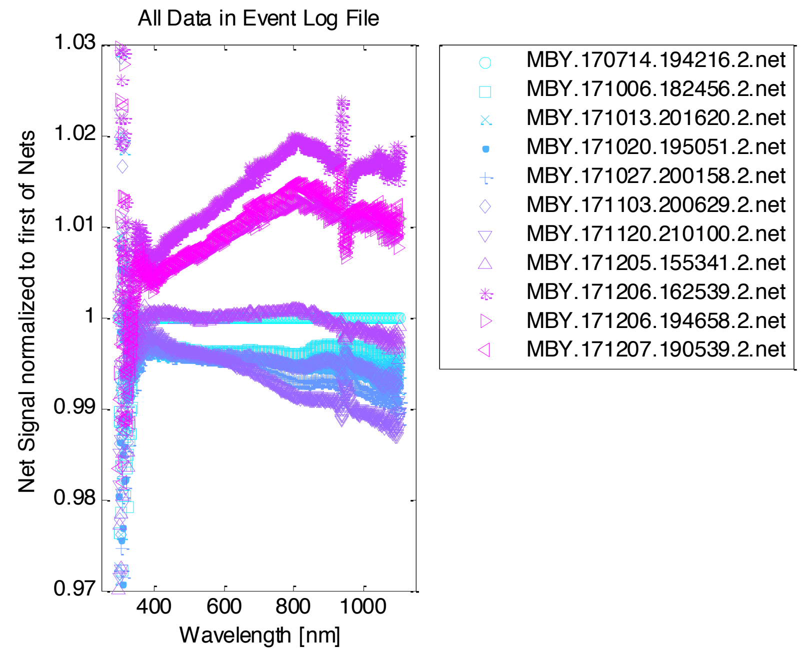
Irradiance with same FEL lamp: CAS was transported inside NIST and to Honolulu

We joined an ongoing spectroradiometer stability study at NIST – will help distinguish issues between the CAS & the SQM, and the CAS itself vs its foreoptics. The stability (when the CAS is not moved and when the lamp is stable) is very good. However, the repeatability (shipment, transport, realignment) is not as good – we'd like to see ±0.5% or so.

CAS Radiance Results



CAS radiance foreoptic and a stable NIST integrating sphere



CAS radiance foreoptic mounted to SQM (17 W lamp set)

In radiance mode, we look at a number of sources and the testing includes realignment. The NIST sphere result is the most similar to the irradiance stability testing. The outlier is during the December 2017 test at Univ. of Miami. A change was also seen for the SQM in Miami, with about the same relative difference. However, the first day's results were fine; we observed a difference when we tested the stability system outdoors. Post trip measurements are in progress.

Schedule

- We are in our 1 year NCE now.

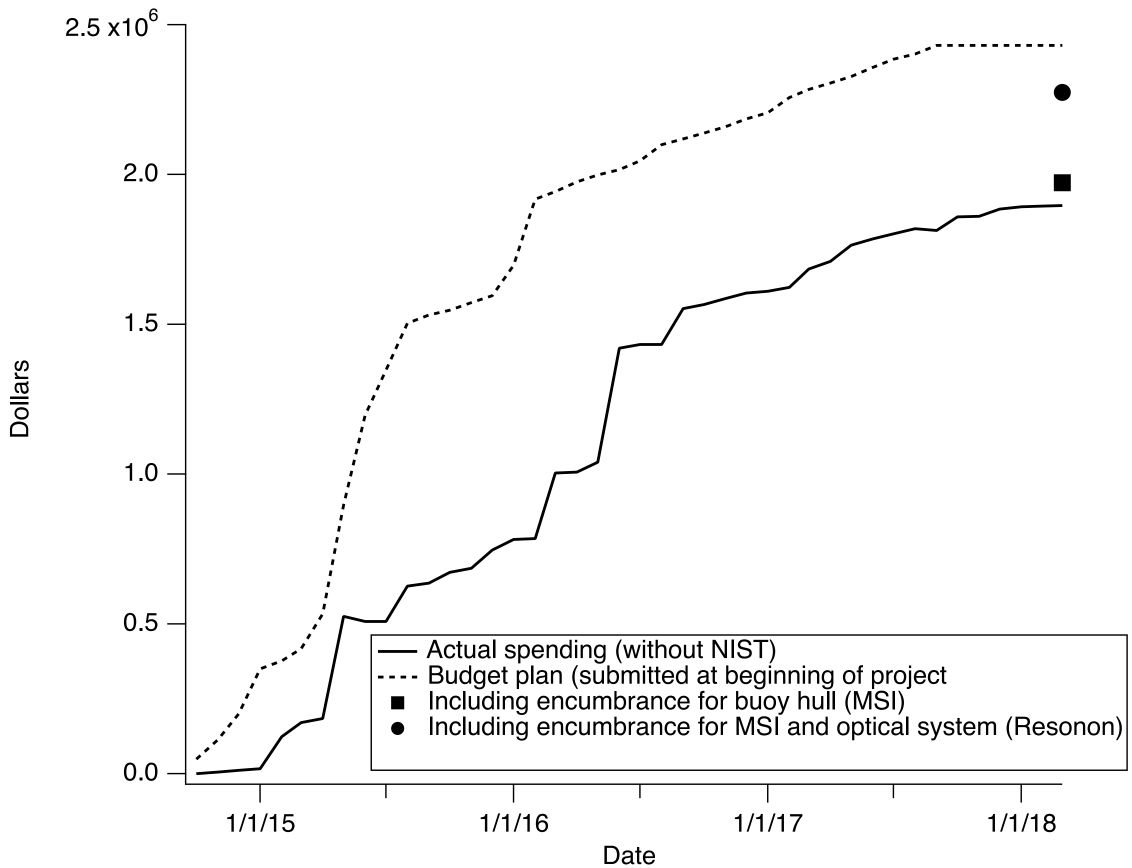
-complete optical system (Red spec, Blue spec, and fiber splitter) on MOBY buoy for side-by-side use on April 2018 deployment.

-Stability system (monitor and source) moved between Hawaii, Miami and NIST to test stability during movement in December 2017, we are continuing to test stability of the systems.

-test setting up optical system on new MOBY structure and removing while maintaining calibration. Late spring 2018.

-test carbon arm/buoy structure Summer 2018.

Costing



The initial delay was in getting PO's out to MLML, Resonon and MSI. The black line is where costing is at, and the black circle show where costing would be once the Resonon and MSI encumbrance is taken into account. This does not show NIST costing, which would make the overall picture look better, NIST money is taken off NASA books almost immediately.