”MOBY past, current and future”

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MOBY TEAM (Carol Johnson, NIST, and Mark Yarbrough and many at Moss Landing Marine lab)

6/18/15.

1) Short history of the MOBY project and its beginnings

2) Current Status of the project

3) Future directions

The driving force for MOBY came out of CZCS experience

- CZCS launched 10/24/1978
- 3 post launch validation cruises:
  - Gulf of Mexico, R/V Athena (14 days)
  - Baja California, Gulf of California, R/V Velero IV (22 days)
  - East coast US, R/V Athena (25 days)
- These 61 days of ship time with 55 stations, resulting in only 9 stations suitable for calibration.

Leads Dennis Clark to the idea of an autonomous platform

- Collect and send back data daily
- Site requirements:
  - Reasonable clear sky statistics
  - Homogeneous waters with a clean atmosphere
  - Logistically possible (close to a source of ships, reasonable chance of low sea state)
  - Communication daily (cell phone)

MOBY timeline

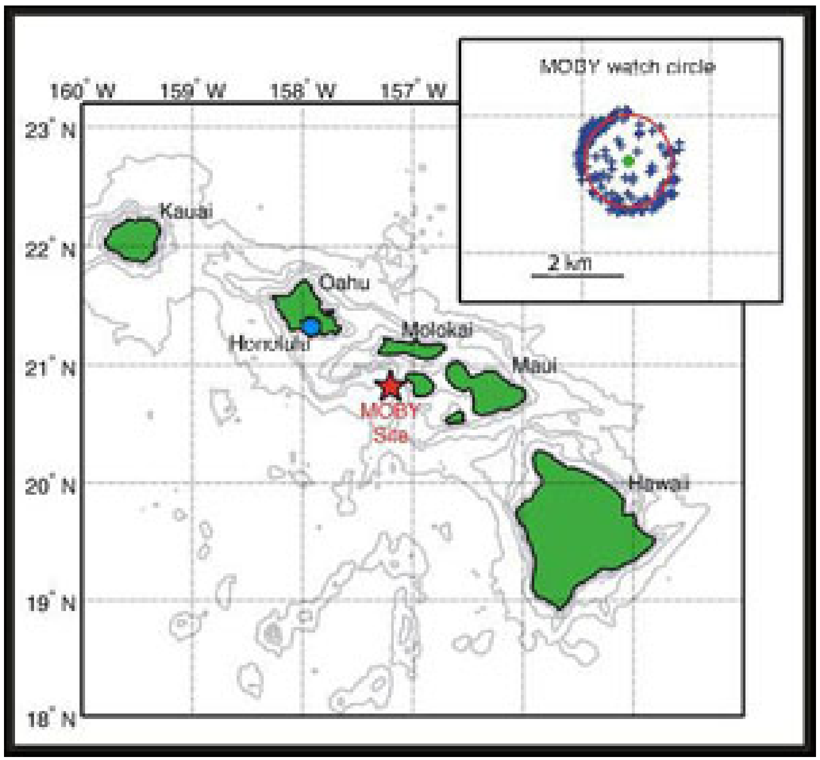
- Dennis begins development in 1985 (30 years ago)
- MODIS(NASA) funding started around 1990, then SeaWiFS provided accelerated funding in 1991.
- First prototype deployment in Monterrey, 1993 (24 years ago)
- Prototype in Hawaii, 1995
- Operational deployed in 1997 (18 years ago), funded by NASA.
- Funded by NOAA since 2007

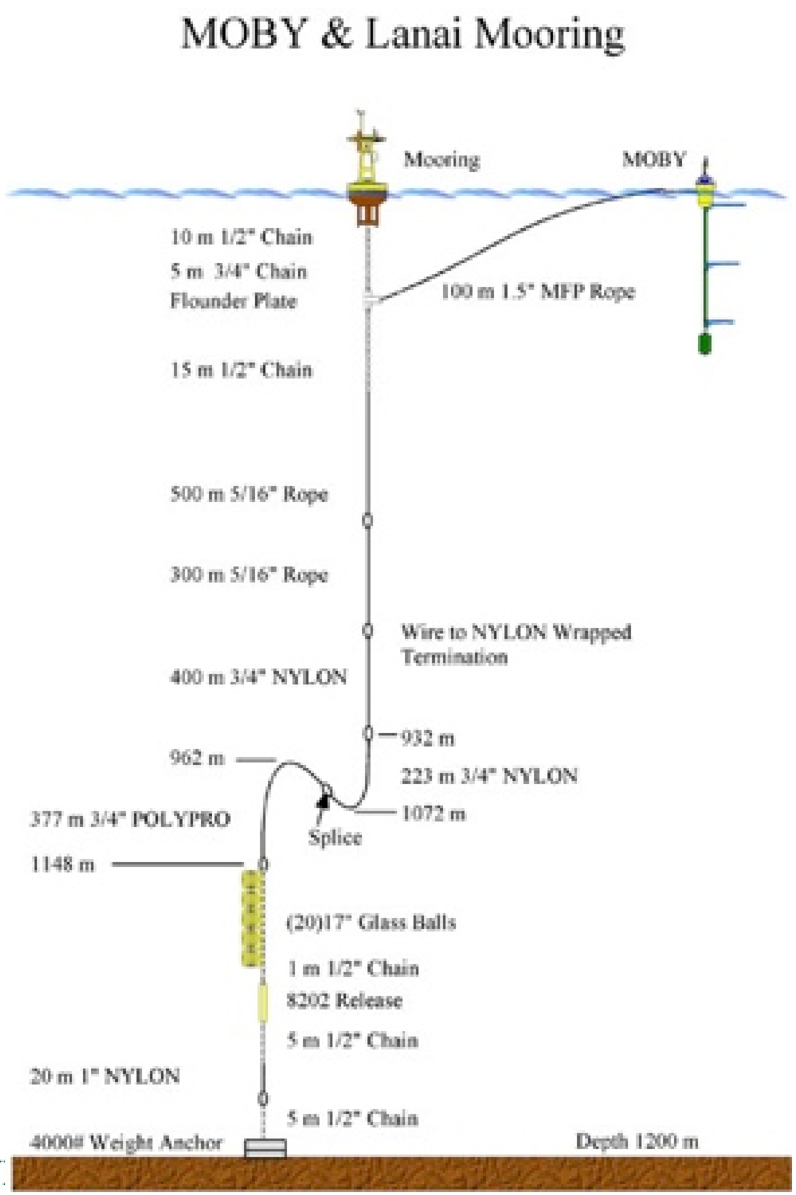
Basically 2 instruments have been in the field, operating alternately for 18+ years.

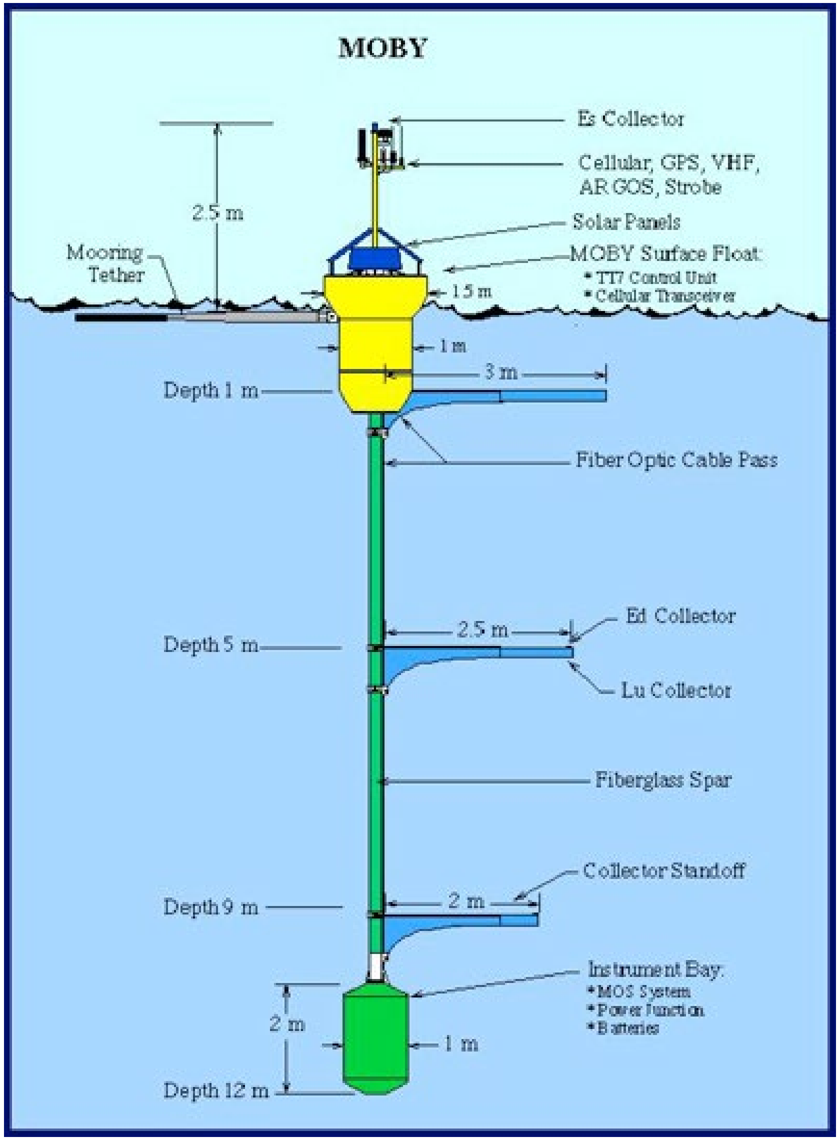
Site chosen was off of Lanai, Hawaii.

Tent constructed on UHMC site

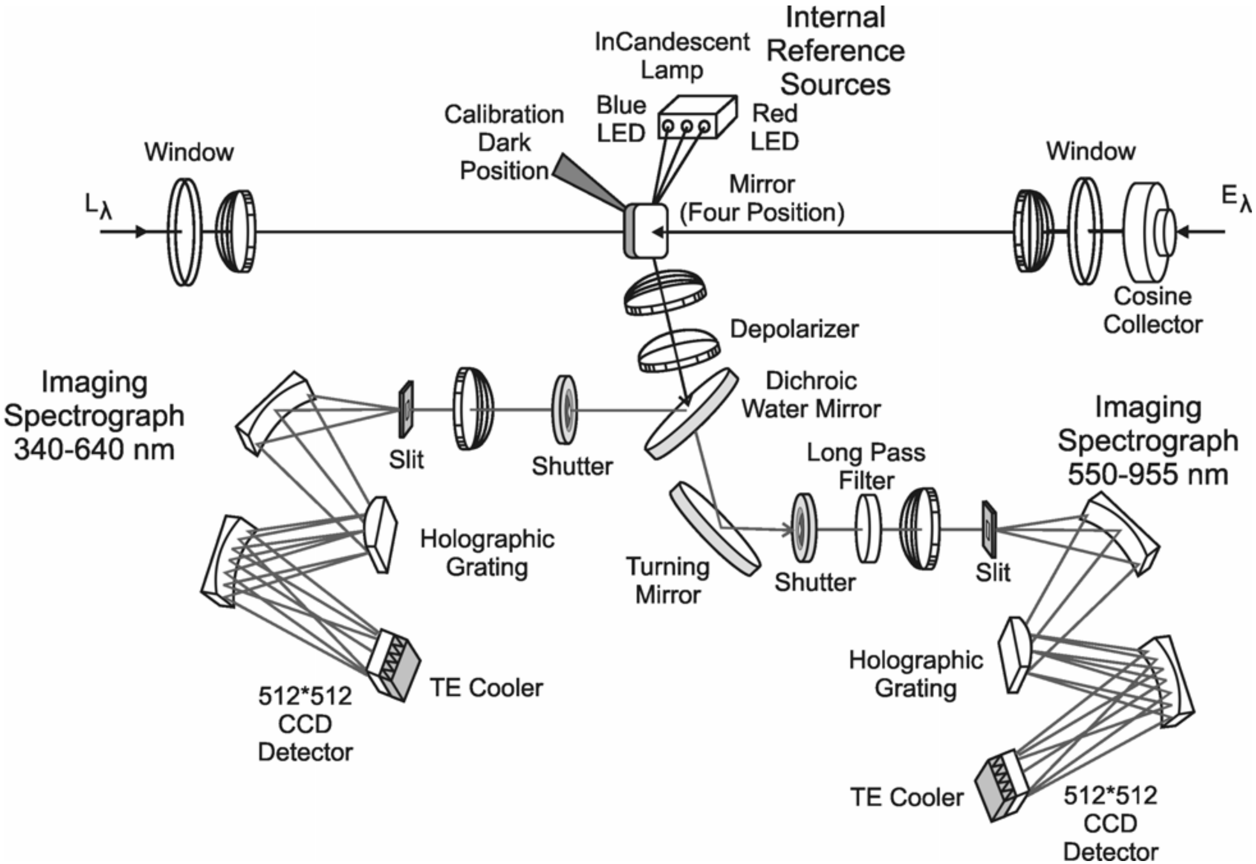
Ships available




MOBY & Lanai Mooring
Mooring
MOBY
10 m 1/2" Chain
5 m 3/4" Chain
Flounder Plate
100 m 1.5" MFP Rope
15 m 1/2" Chain
500 m 5/16" Rope
300 m 5/16" Rope
Wire to NYLON Wrapped Termination
400 m 3/4" NYLON
932 m
962 m
223 m 3/4" NYLON
1072 m
377 m 3/4" POLYPRO
Splice
1148 m
(20)17" Glass Balls
1 m 1/2" Chain
8202 Release
5 m 1/2" Chain
20 m 1" NYLON
5 m 1/2" Chain
4000# Weight Anchor
Depth 1200 m


MOBY
Es Collector
Cellular, GPS, VHF, ARGOS, Strobe
2.5 m
Solar Panels
Mooring Tether
MOBY Surface Float:
* TT7 Control Unit
* Cellular Transceiver
1.5 m
1 m
3 m
Depth 1 m
Fiber Optic Cable Pass
Ed Collector
2.5 m
Depth 5 m
Lu Collector
Fiberglass Spar
Collector Standoff
2 m
Depth 9 m
Instrument Bay:
*MOS System
*Power Junction
*Batteries
2 m
1 m
Depth 12 m

Schematic of Current MOBY



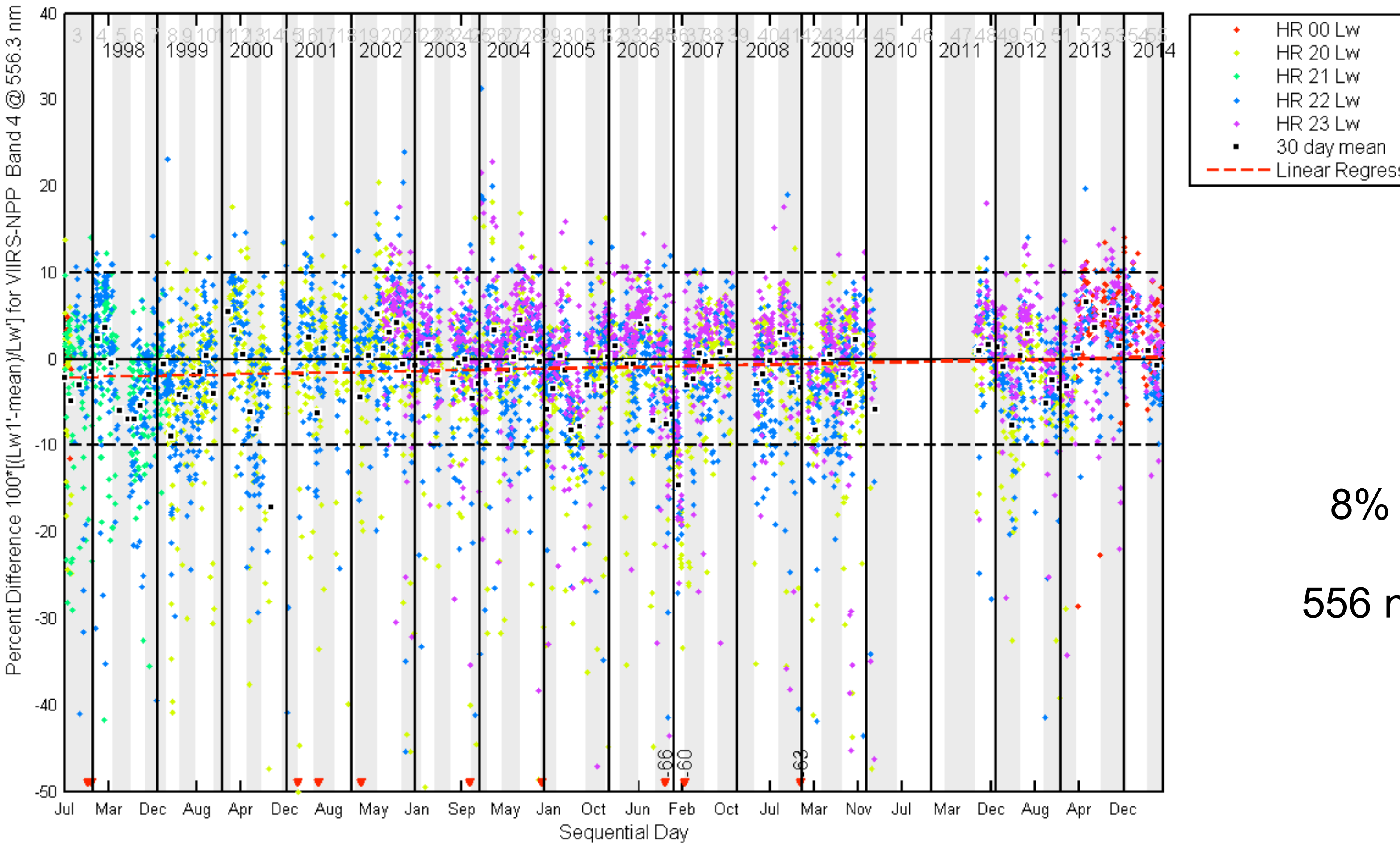
Hyperspectral,0.57 nm spacing in blue spectral region, 0.91 nm FWHM 0.81 nm and 1.2 nm FWHM in red.

Hyperspectral, with this much resolution, allows the same system (one site) to be used for multiple satellite sensor systems, including out-of-band response, to tie these systems together.

This system has been extensively characterized

- Stray light characteristics on SIRCUS repeatedly measured, with corrections added to data
- Pre-post radiometric response with direct traceability to NIST scales and additional custom instruments monitoring of calibration sources
- Diver calibrations/cleaning monthly
- On board sources monitored
  daily
- Area around the site has been
  characterized

18 year time series (with repeating annual trend removed).



8% std

556 nm

Note over the 18 years, there has been a change in the time of acquisitions, due to satellite mission requirements, now measurements are later in the day compared to earlier in the mission…causes an apparent trend in the data.

Our current understanding of the MOBY uncertainties, first radiances:

Laboratory L(lambda)

ID	Component description	M1=410 nm	M2=443 nm	M3=486 nm	M4=551 nm
1	Reference source	0.81	0.72	0.61	0.53
2	Reference source drift	0.42	0.46	0.51	0.53
3	Uniformity of source	0.2	0.2	0.2	0.2
4	Interpolation to MOBY λ	0.2	0.15	0.03	0.03
5	Reproducibility, Pre/Post	1.43	1.12	0.95	0.87
6	Wavelength calibration	0.38	0.29	0.22	0.14
	RSS, Radiometric, 1-6	**1.76**	**1.46**	**1.27**	**1.02**

Going to Lu(lambda)

ID	Component description	M1=410 nm	M2=443 nm	M3=486 nm	M4=551 nm
7	Immersion	0.1	0.1	0.1	0.1
8	Stray Light Correction	1.79	0.6	0.24	0.55
9	calibration measurement uncertainty	0.51	0.21	0.22	0.12
10	in situ measurement uncertainty	0.88	0.74	0.76	1.03
11	integration time correction	0.15	0.15	0.15	0.15
12	instrument temperature correction	0.16	0.16	0.16	0.16
	RSS, Radiometric & Measurement (1-12), LuTOP	**2.72**	**1.77**	**1.53**	**1.68**

Then Es uncertainties

Laboratory

ID	Component description	M1=410nm	M2=443nm	M3=486nm	M4=551nm
1	Reference source	0.52	0.46	0.43	0.39
2	Reference source drift	0.77	0.75	0.69	0.67
3	Effects of EG&G bench	0.49	0.49	0.49	0.49
4	Interpolation to MOBY λ	0.1	0.1	0.1	0.1
5	Reproducibility, Pre/Post	1.14	0.92	0.76	0.69
6	Wavelength calibration	0.34	0.25	0.19	0.12
	RSS, Radiometric	**1.59**	**1.39**	**1.23**	**1.15**

Field

ID	Component description	M1=410 nm	M2=443 nm	M3=486 nm	M4=551 nm
7	Stray Light Correction	1.07	0.35	0.11	0.05
8	calibration measurement uncertainty	0.31	0.14	0.10	0.06
9	in situ measurement uncertainty	2.68	2.51	2.56	2.67
10	integration time correction	0.15	0.15	0.15	0.15
11	instrument temperature correction	0.16	0.16	0.16	0.16
	RSS, Radiometric & Measurement (1-11), Es	**3.31**	**2.91**	**2.86**	**2.92**

Finally derived Products

Lw

ID	Component description	M1=410nm	M2=443nm	M3=486nm	M4=551nm
1	Lu	2.72	1.77	1.53	1.68
2	f alpha to zero (tilt)	0.3	0.3	0.3	0.3
3	Kl zero to one	0.58	0.49	0.50	0.69
4	self shading	0.32	0.37	0.45	0.87
	RSS, (1-4), Lw	**2.81**	**1.90**	**1.70**	**2.03**

nLw, or Lwn

ID	Component description	M1=410nm	M2=443nm	M3=486nm	M4=551nm
1	Lw	2.81	1.90	1.70	2.03
2	Es	3.31	2.91	2.86	2.92
	RSS, (1-2), Lwn	**4.35**	**3.47**	**3.33**	**3.56**

What has worked?

- 3 arms: KL between different arms is a very sensitive measure of relative calibrations. Incorporates redundancy.
- Dedicated long term personnel focused on QC/data reduction, calibration/characterization, and engineering/site management has been key.
- Weather accessiblity a large fraction of the time very important(reduce wasted ship time).
- Close collaboration with NIST, from the beginning has enabled continual progress. Important to start this collaboration at the beginning.

What has worked(2)

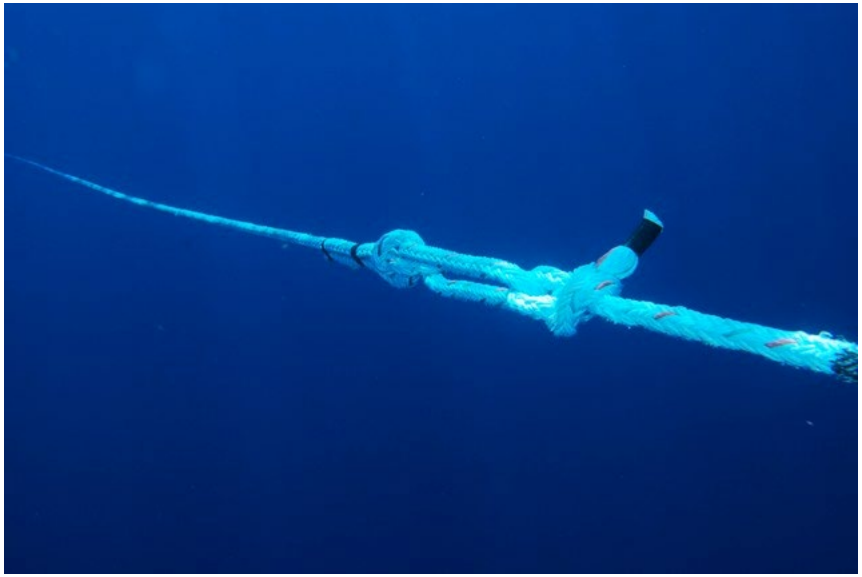
- As many references as you can get (internal lamps, LED’s, etc.)
  - The ratio of our Pre/Post deployments is on average 1.007, instrument has been very stable
- Regions of spectral overlap (Blue and Red spectrograph overlap for +90 nm) allowed system checks.

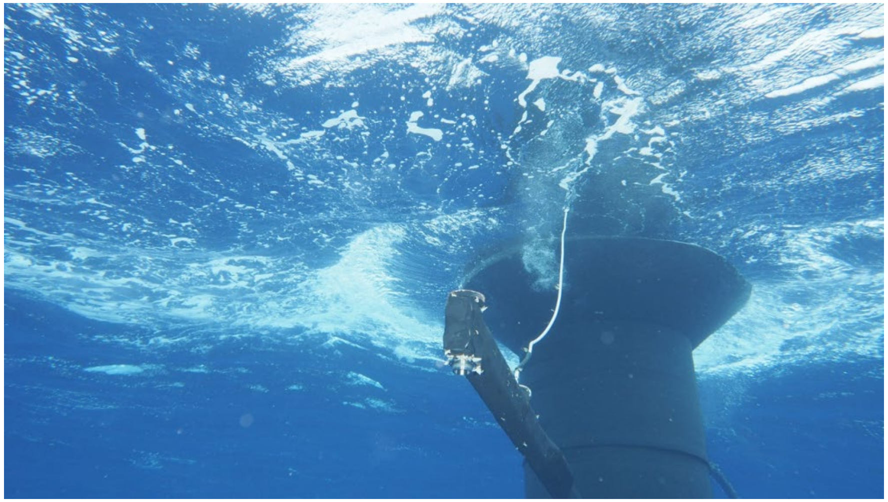
What has worked (3)

- Site far enough away from casual recreational boating.

Upper arm
Twisted, window
Cracked

Success or failure?





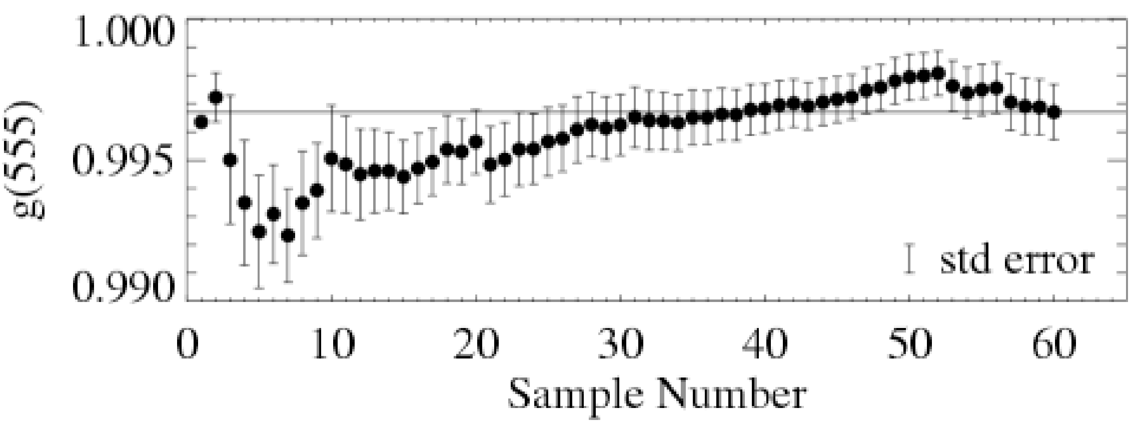
Improvements we wish we had, and are working towards

- Simultaneous measurements of radiometric parameters.
- Reduced stray light in system.
- Simultaneous measurement of auxiliary parameters (compass, tilt, roll) at high frequency.
- Increased resistance to bio fouling.

From Constant Mazeran presentation at ESRIN

Because the MOBY site is relatively uncomplicated, our estimated uncertainties can account for a significant portion of the variability in the vicarious gain factors…

lambda	**MOBY** $(\sigma_g^{IS}/\sigma_g)^2$ (%)
412	64.41
443	94.88
490	104.41
510	52.54
	22.08
	0.60

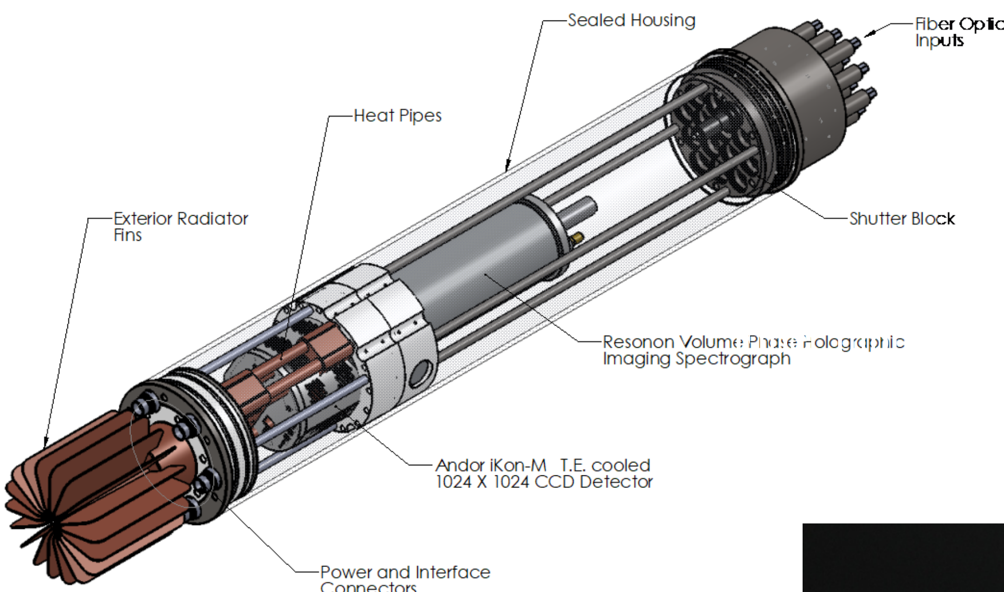


Werdell et al., 2006, Ocean Optics XVIII, http://oceancolor.gsfc.nasa.gov/cgi/obpgpubs.cgi

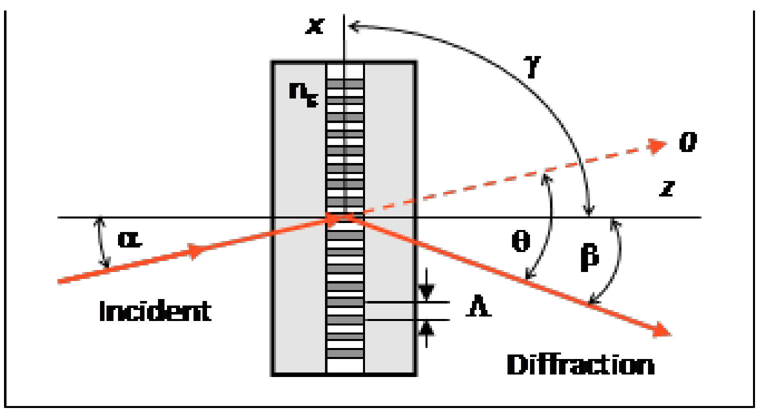
Take home: Improvements in the MOBY measurement can have a large effect on the vicarious calibration process.

MOBY (near) future

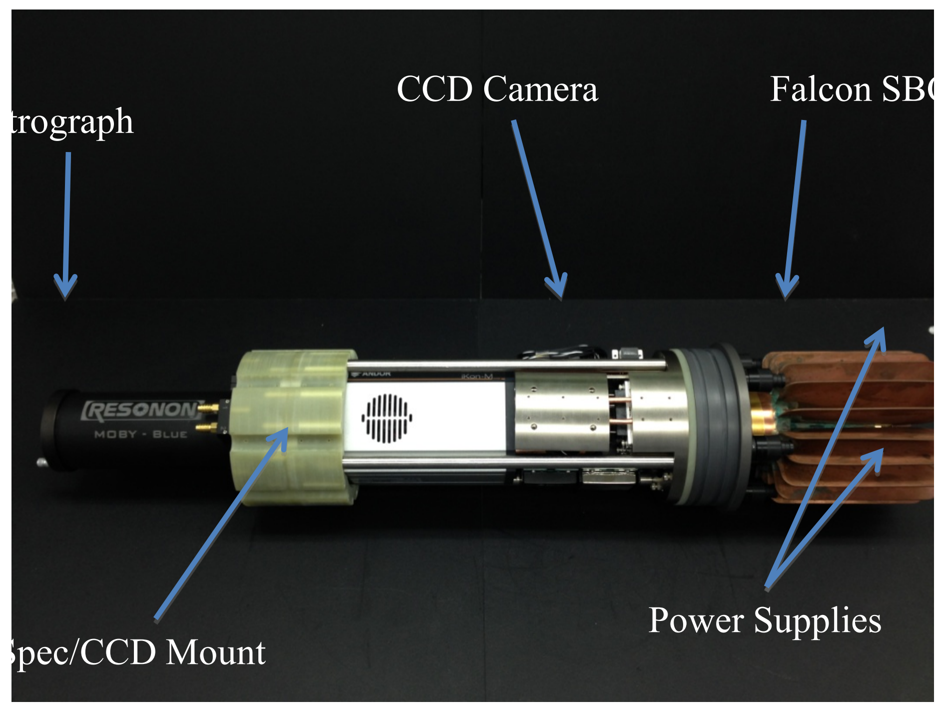
MOBY Refresh, NOAA support



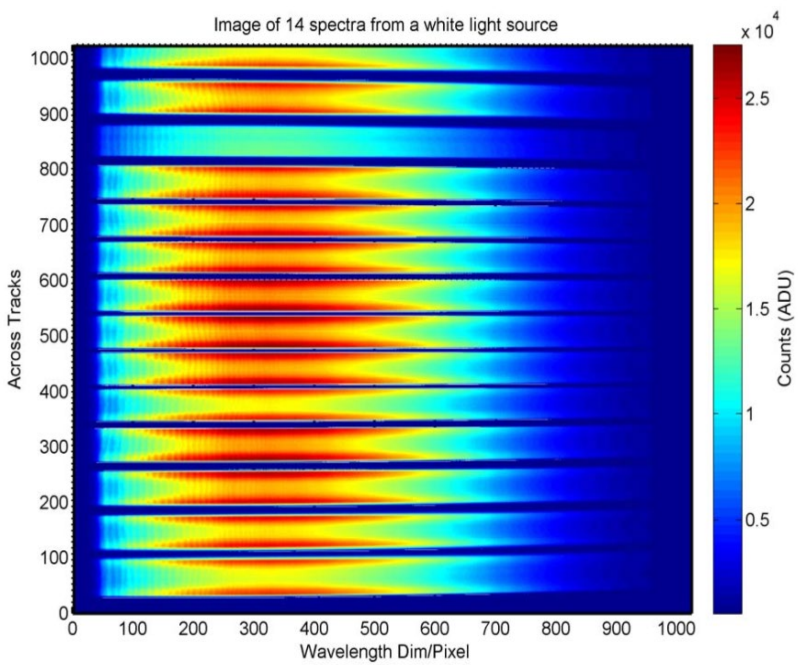
In-line Volume Phase Holographic grating

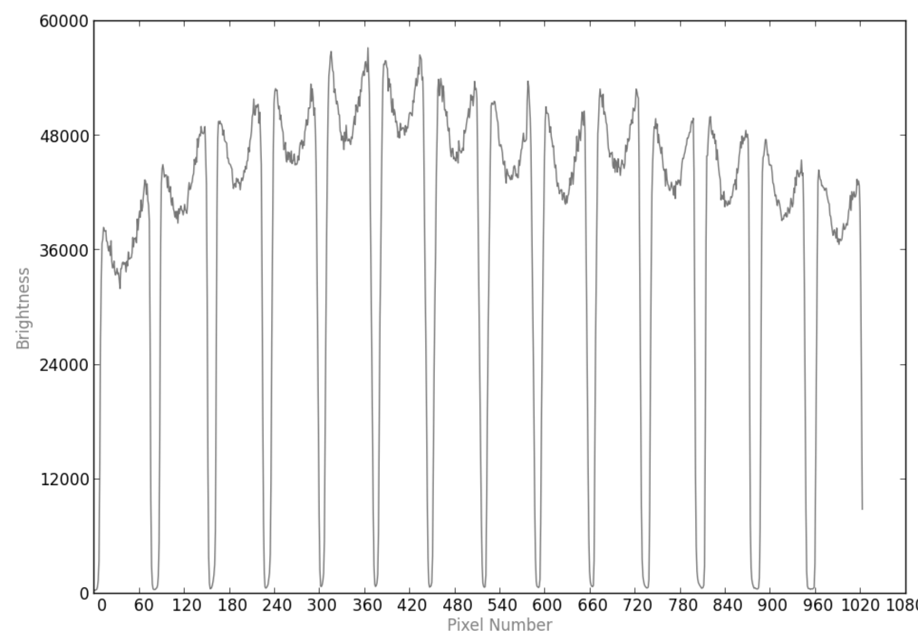


From http://www.bayspec.com/technical-support/definitions/vpg/



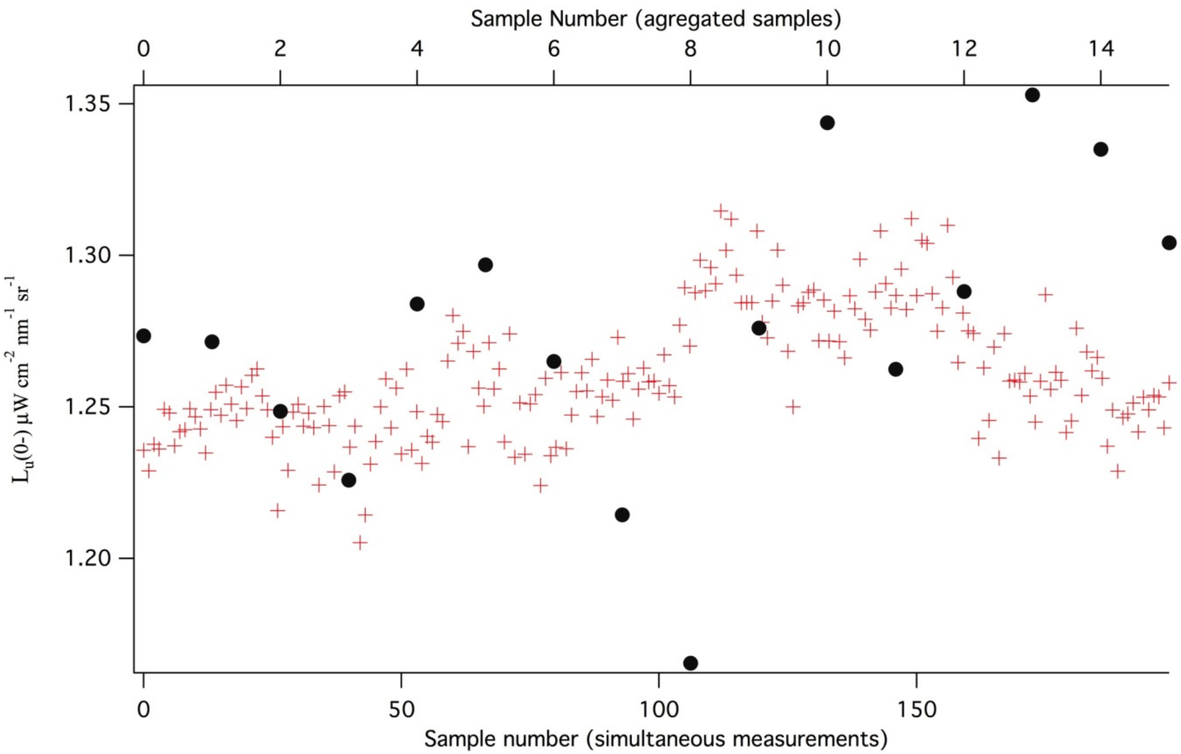
Allows simultaneous acquisition of all radiometric channels





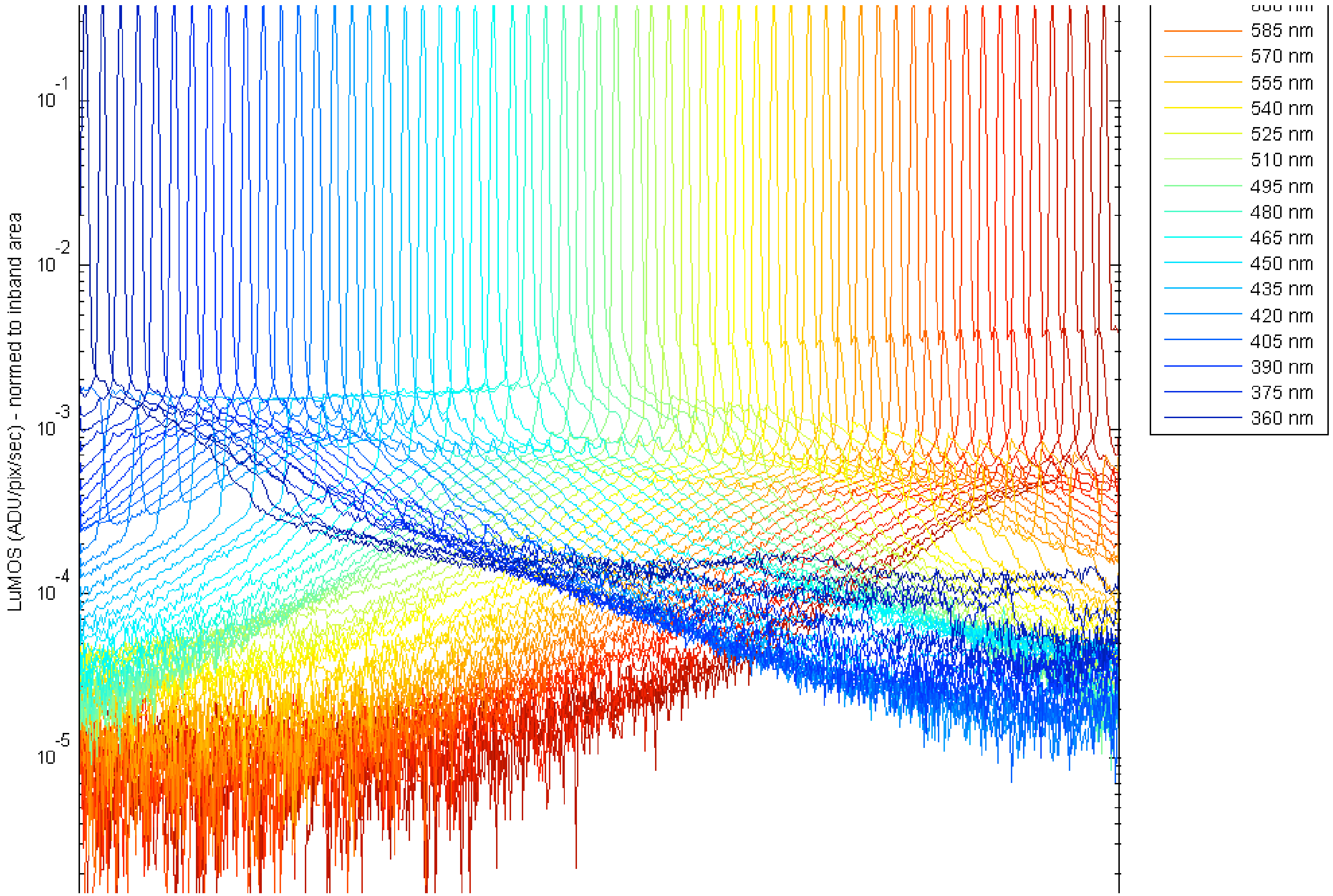
Reduced Environmental Noise with new instrument

Comparison of simultaneous measurements and sequential with test data set. Sequential measurement has %std around 0.04, while simultaneous has 0.01. Because of correlations, simultaneous much better. Reduced noise here reduces noise in *g*, reducing number of matchups required to obtain *g* within desired accuracy.

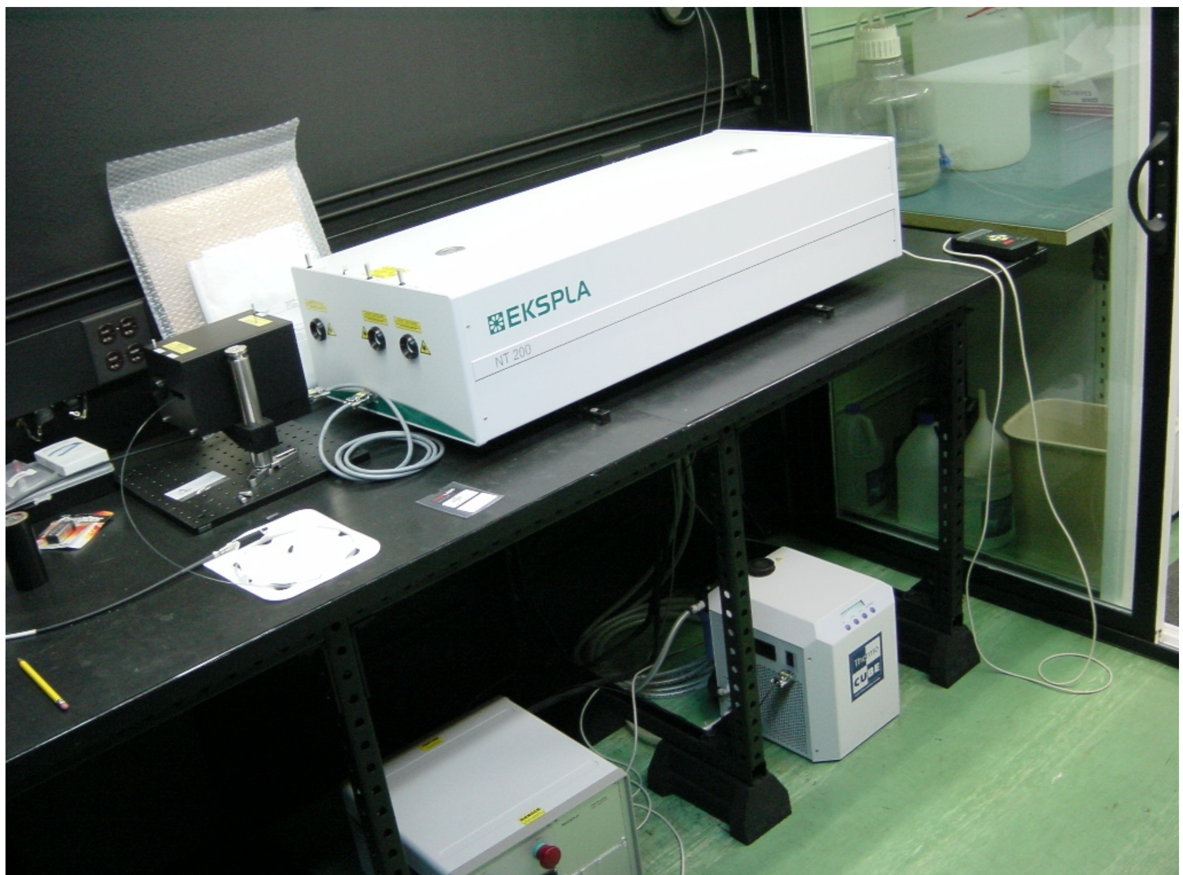


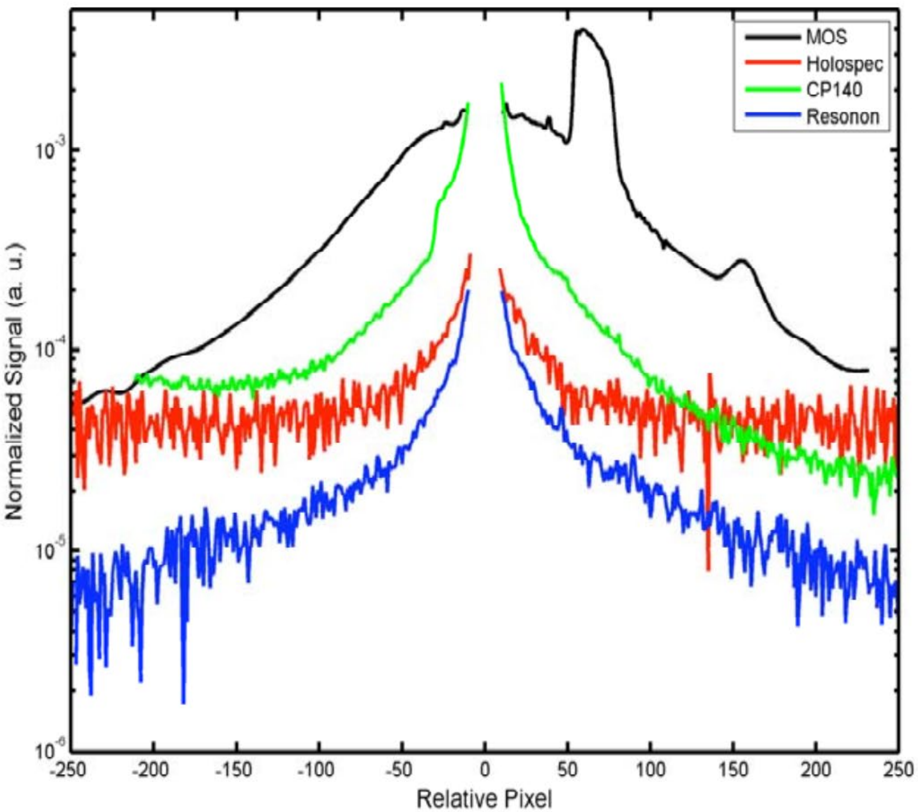
Instrument used was a prototype of the new optical system with simultaneous measurements at different depths.

Laser data for SLC characterization



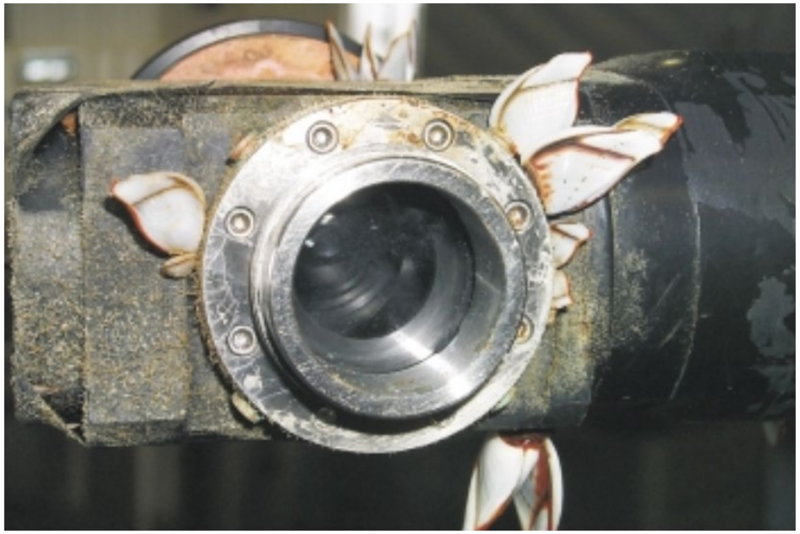
We can do the stray light characterizations in Hawaii (rather than Sircus) with a tunable laser (Ekspla). Allows more frequent characterizations if necessary.



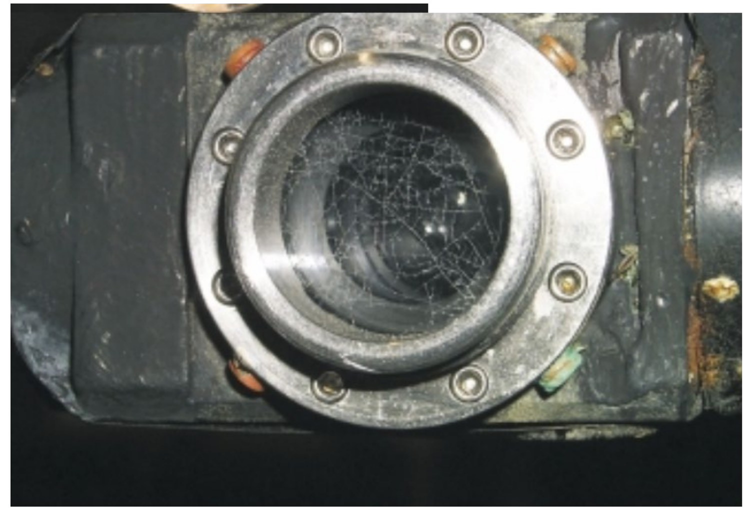


New system has much better stray light characteristics, so uncertainties due to stray light correction much reduced.

Bio fouling, very bad cases



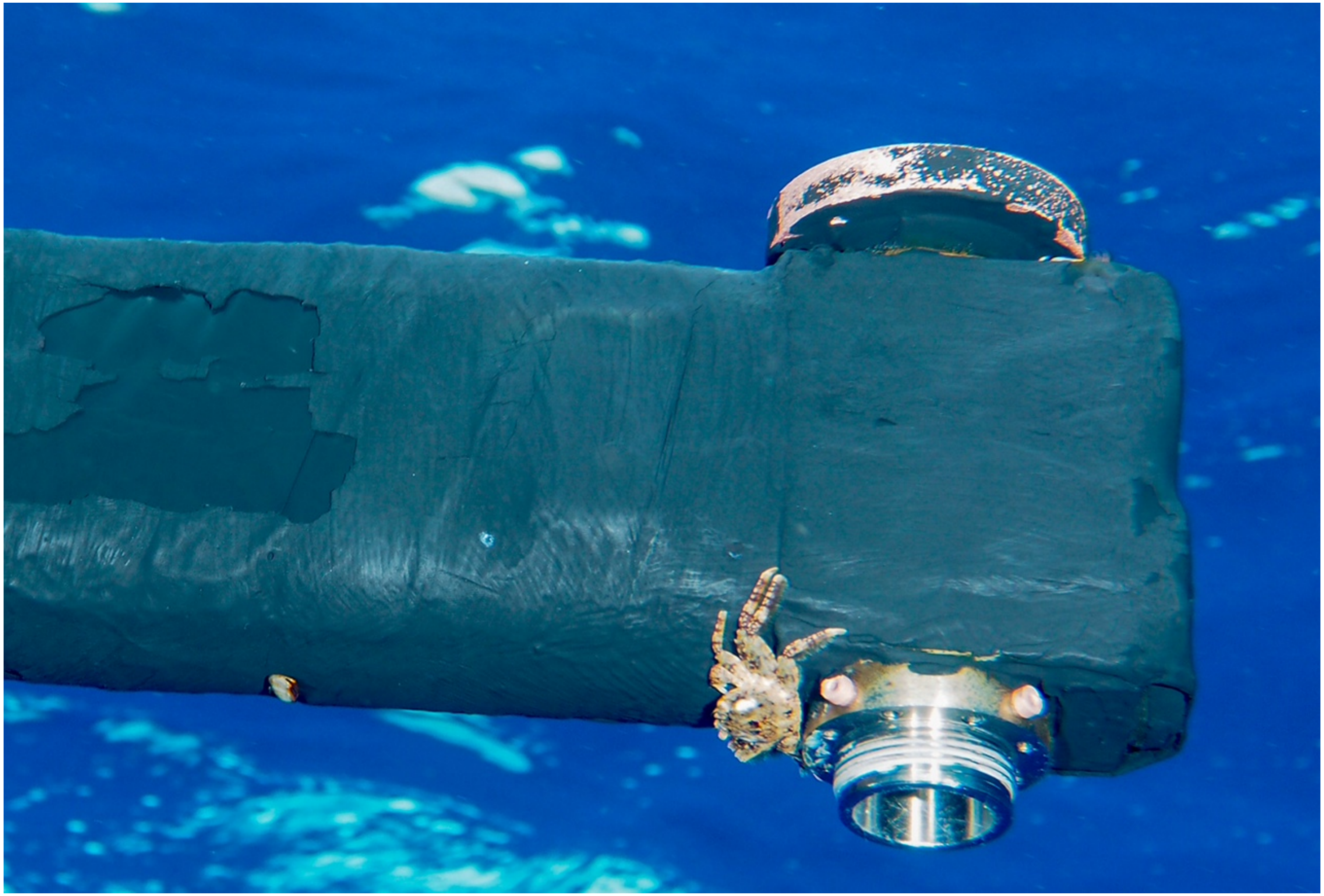
Deployment M217
6/2/2001 – 9/25/2001



Deployment M225
11/12/2003 – 2/3/2004

- Add UV Led Bio fouling unit to radiometer heads. Illuminate window with 285 nm.

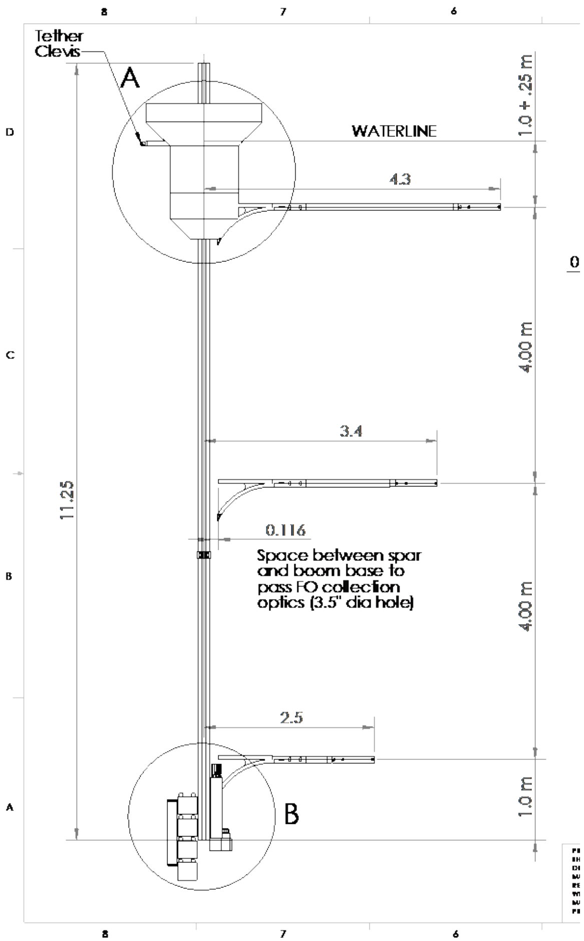
Will be difficult to stop these….



New NASA support for MOBY-Net (Netflix model)

- MOBY-like structure suitable for transporting in 40’ shipping container.
- Modular optical system: designed to be installed/removed from the hull and arm structure without changing calibration.
- Associated source/validation device for confirming calibration stability after shipment and installation (three scales, verify which has changed).
- Measurement down to 350 nm (PACE req.)

MOBY structure



Important features:

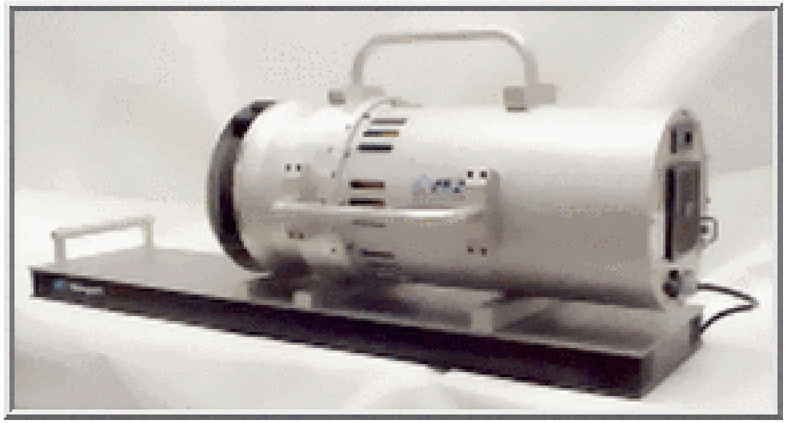
1) Carbon fiber main spar to reduce bending and allow easier deployment.

2) Integrated fiber channel on spar, arm bases permanently attached to spar.

3) removable arms for transportation (and replacement).

Instrument Systems CAS 140CT system to be used for monitoring stability source.

Yankee Environmental Systems SQM – 5002 source that we will be using as the stability source. It also has internal detectors (two filtered detectors, one unfiltered) to monitor the lamp rings and integrating cavity. (system originally designed for SIMBIOS)



Between the source (with its internal monitors), the external radiometer, and MOBY-Net we should be able to monitor MOBY stability pre/post deployment and after shipping and installation, 2% goal.

Scheme envisioned

- Selection of additional site with sufficient logistical/technical support for instrument assembly and deployment.
- Two MOBY hull structures on site. Allows more efficient use of ship time..one cruise to deploy and retrieve system.
- While the optics for one instrument is in field, the other is being sent back for calibration (with traveling source/monitor)…the Netflix part.
- Data forwarded to central location for common processing with MOBY/Hawaii.
- Central/common calibration and characterization site.

Last two items are requirements of the INSITU-OCR White paper

Conclusions

- MOBY has provided vicarious calibration data for virtually all ocean color sensors (that can see it) since 1997.
- Now we have an 18 year time series that allows us to look for trending, improve our understanding of the uncertainties and other aspects of the data stream.
- Thanks to the dedicated group of people at Moss Landing, NIST, and NOAA this program has kept going with very high standards.
- Also, just as importantly, we need to thank the continued support of NASA and NOAA, and many dedicated people in these agencies for their support over the many years.