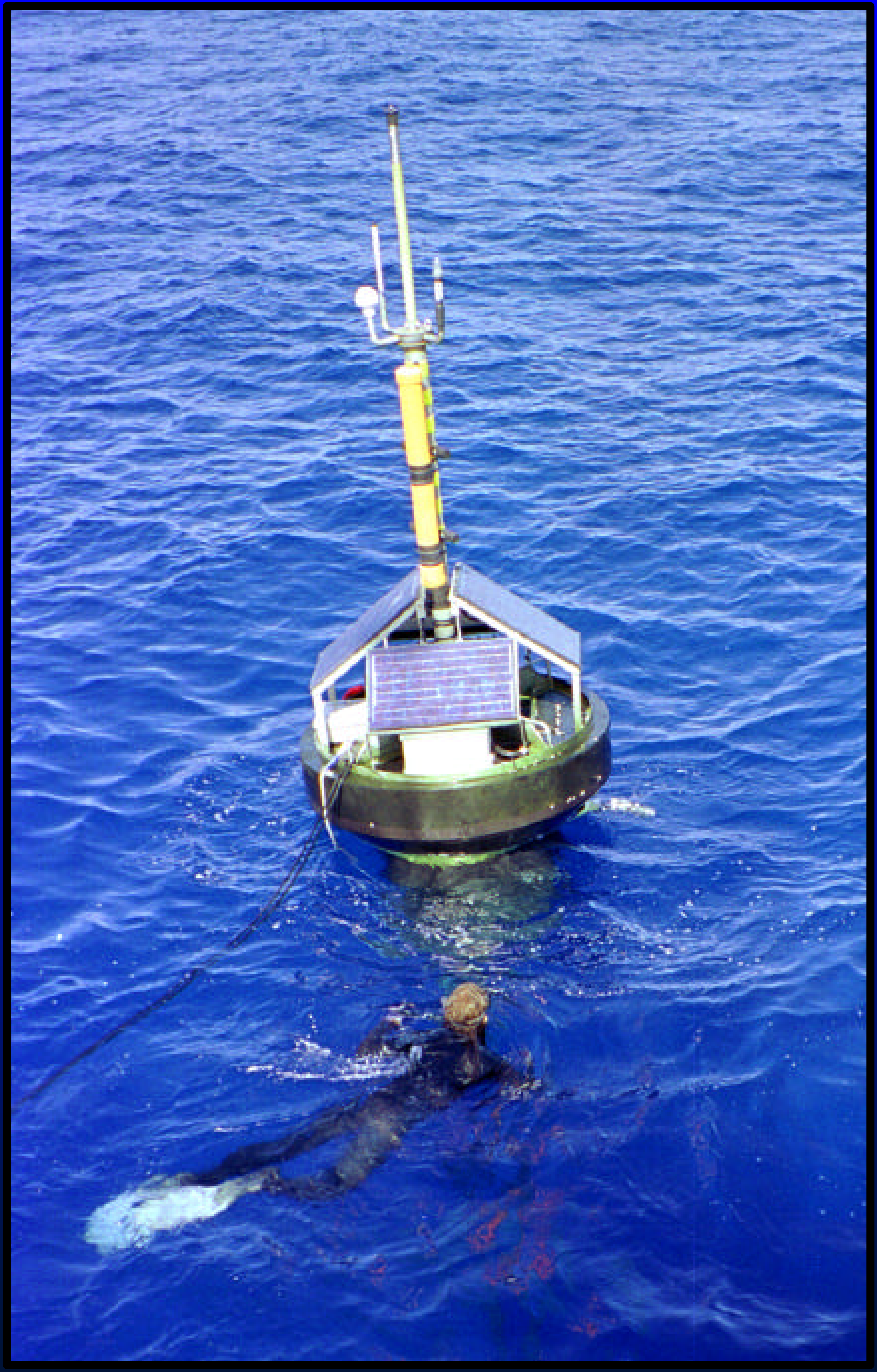


Stray Light Characterization for MOBY

Carol Johnson
NIST Optical Technology Division

Team:

D. Clark (NOAA)

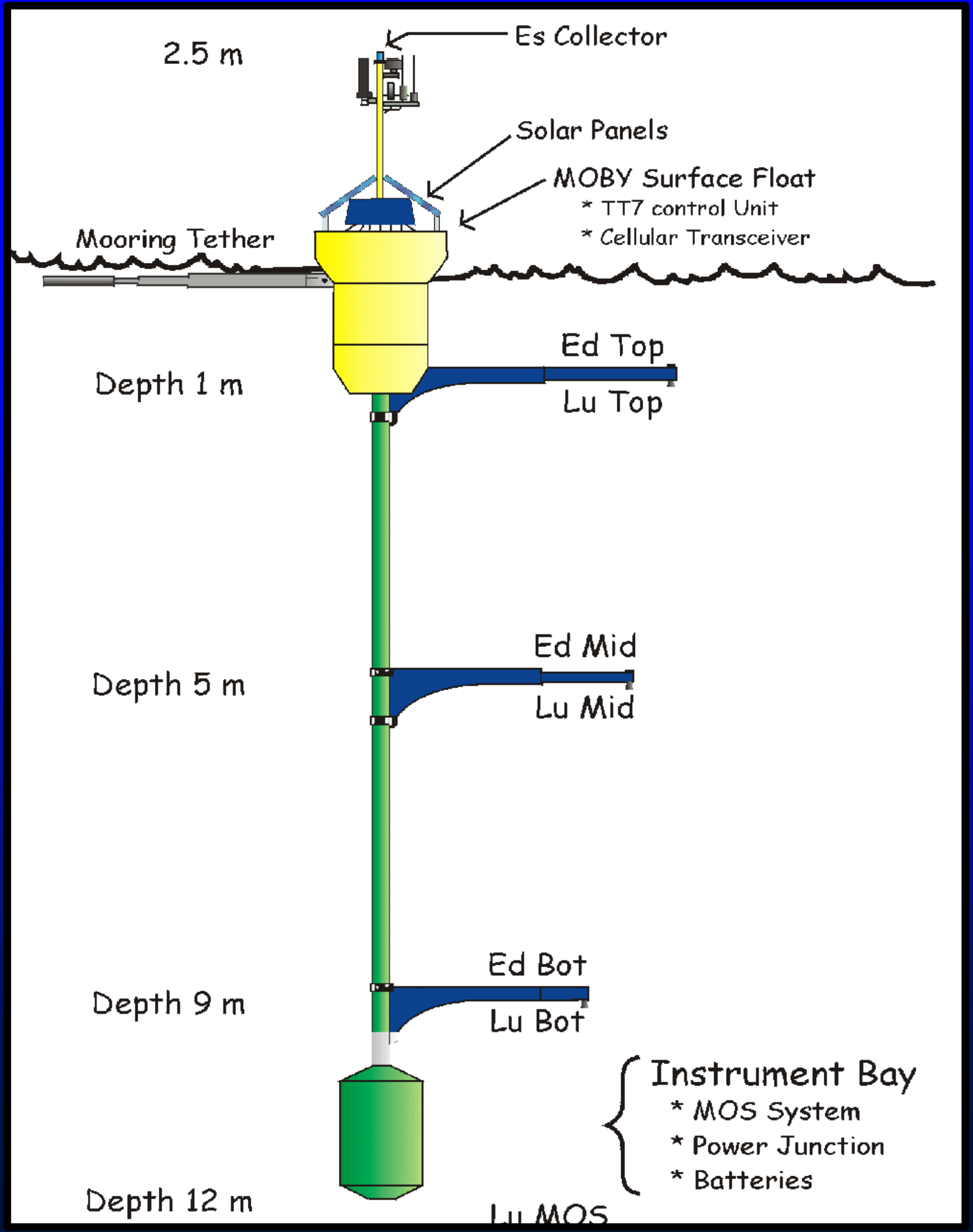
M. Feinholz, S. Flora,
M. Yarbrough (MLML)

S. Brown, C. Johnson, K. Lykke (NIST)

MOBY & MOS

MOS--
Dichroic beamsplitter and two single grating CCD spectrographs;
High resolution (<1 nm);
Wide coverage (345 to 955 nm);
Robust calibration procedures;
Profiler and buoy operation.

MOBY--
Fiber optic coupling to MOS;
Time series since 1996;
SeaWiFS and MODIS overpasses;
Band-averaged Lw's reported;
Satellite gain coefficients.



MOBY Calibration Procedures

Science requirements: 5 % nLw

MOBY is currently 4 % to 8 %; achieved using rigorous, multi-step approach

Features:

Pre- and Post Calibrations

E and L sources NIST-traceable

Sources recalibrated every 50 h

Sources verified during use with SLMs (NIST-designed radiometers)

Daily scans of three internal sources (blue and red LED; lamp)

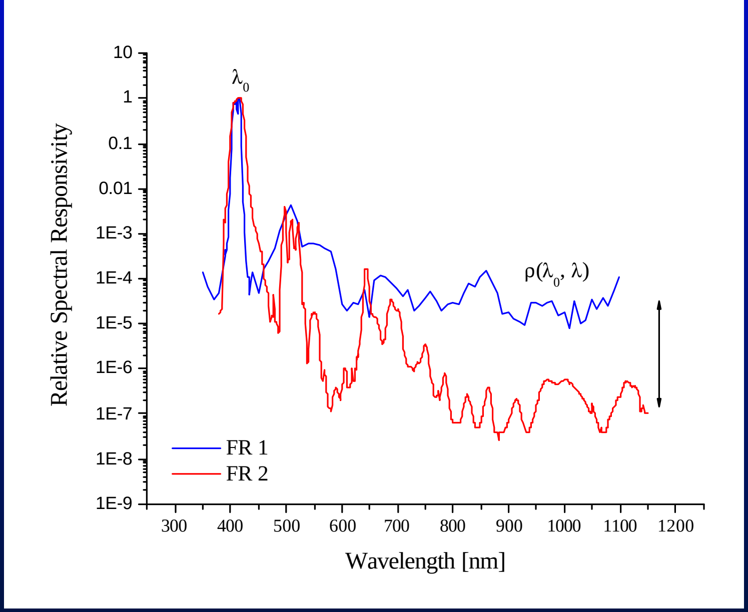
Monthly measurements with stable, diver-deployed lamps

"Stray Light" in Filter Radiometers

Relative spectral responsivity, $r(l_0, l)$

Separate function for each channel (band)

Describes response to flux at $l \neq l_0$



Measurement Equation

$$S(l_0) = R(l_0) \int r(l_0, l) L(l) \, dl$$

Common Simplification

$$S(l_0) = R(l_0) L(l_0) \, dl$$

S = Measured signal

R = System response

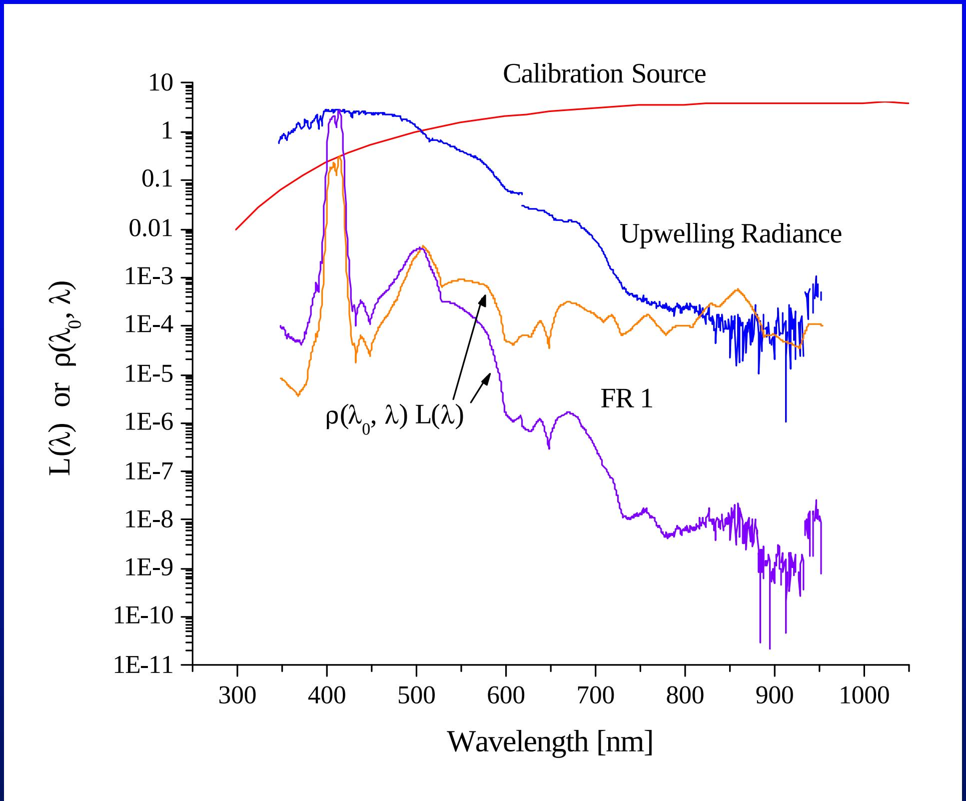
L = Spectral radiance

dl = Bandwidth of channel

l_0 = Wavelength of channel

l = Wavelength of flux

Result of (Over)Simplification

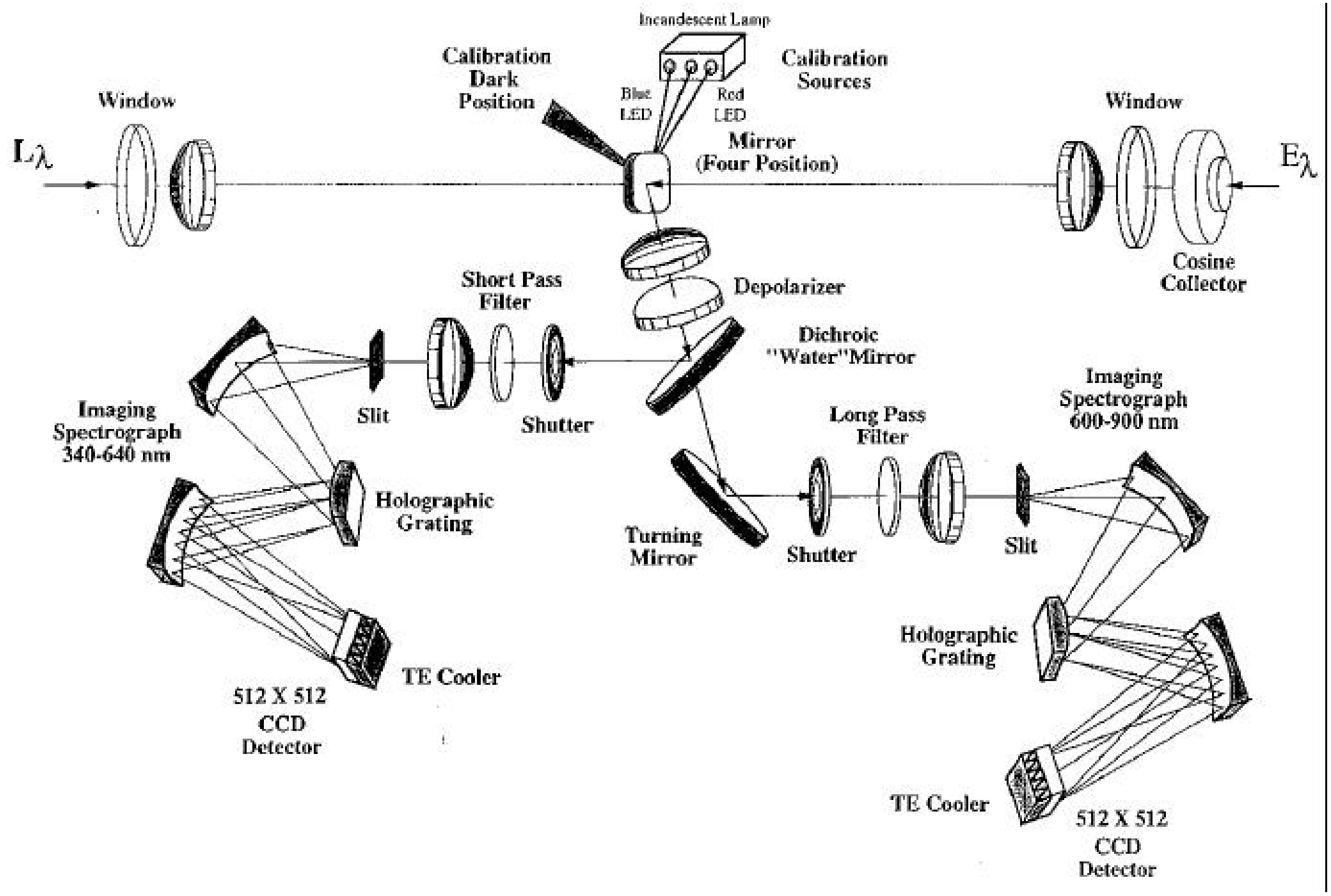


The ratio of the signals is **not** proportional to the ratio of the spectral radiances at l_0 because the out-of-band contribution is different.

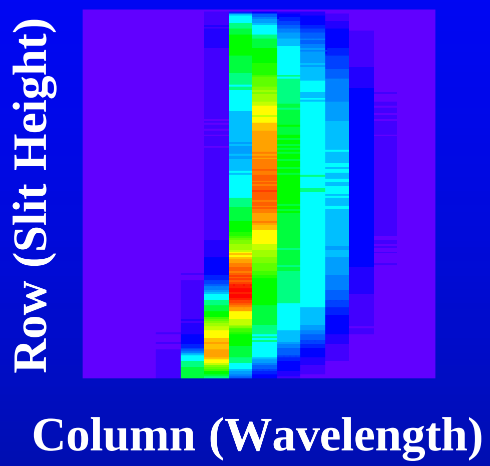
It depends on $L(l)$!

For this example, FR 1 would be incorrect by about 5.7%;
FR 2 by about 0.8 %.

Marine Optical System (MOS)



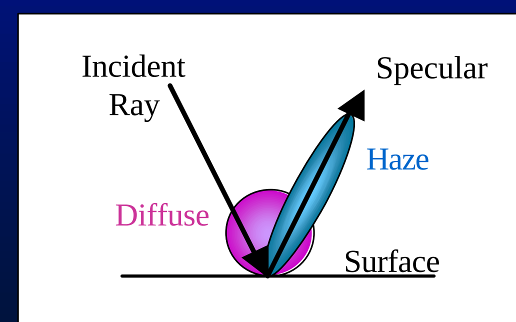
Spectrographs & Monochromators



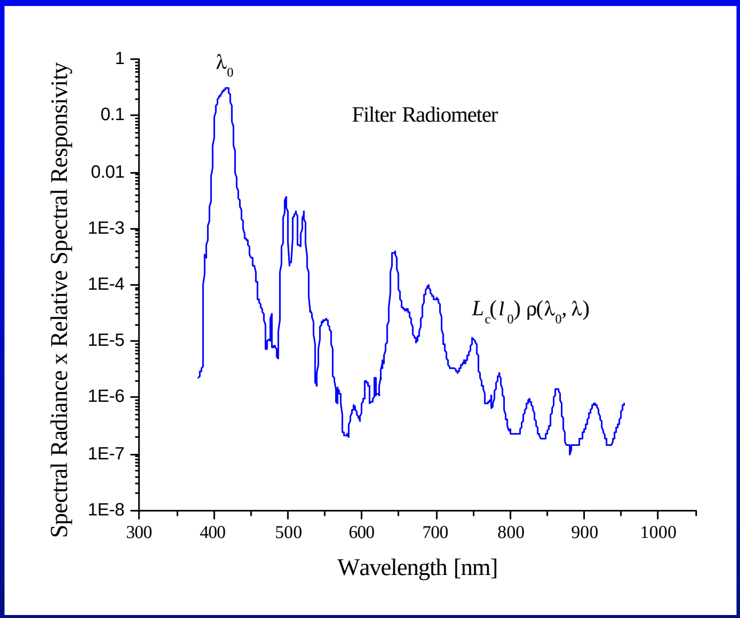
The image appearance in monochromatic light depends on instrument parameters and other effects (the example is not well focused).

Signal = In-band + Out-of-Band

Haze and diffuse scatter contribute to the specular flux. For a grating, this compromises the desired optical interference effect.



Filter Radiometer Measurement Equation



$r(l_0, l)$ and $L_c(l)$ are known. Thus $R(l_0)$ and the fraction of signal from the out-of-band ("stray light") can be determined.

$$R(l_0) = \frac{S_c(l_0)}{\int r(l_0, l) L_c(l)\, dl}$$

The correct $L_u(l)$ solves the equation

$$S_u(l_0) = R(l_0) \int r(l_0, l) L_u(l)\, dl$$

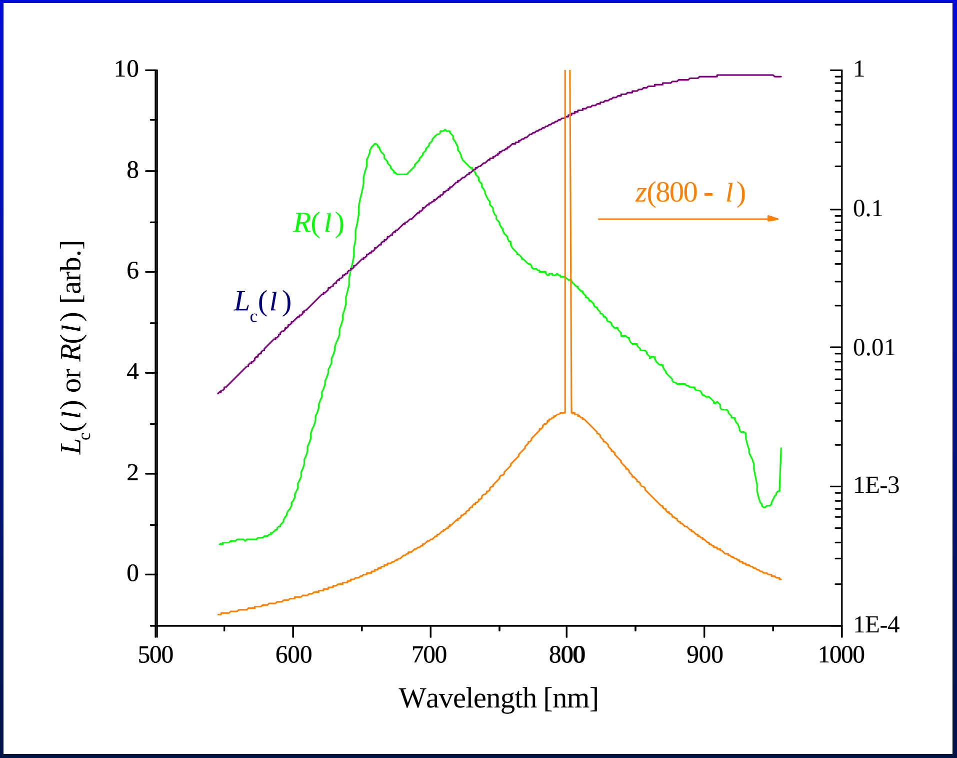
Note this requires knowledge of $L_u(l)$ at all wavelengths—a) additional channels and deconvolution or b) delta-function for $r(l_0, l)$.

In MOS, the equivalent of $R(l_0)\ r(l_0, l)$ is not known, but we have lots of (1024) channels.

Spectrograph Measurement Equation

$$S(l_i) = \int R(l)\, z(l_i - l)\, L(l)\, dl \;=\; R(l_i)\, L(l_i)\, dl + \sum R(l)\, z(l_i - l)\, L(l)\, \Delta l$$

$$= \text{In band} + \text{Out of band}$$

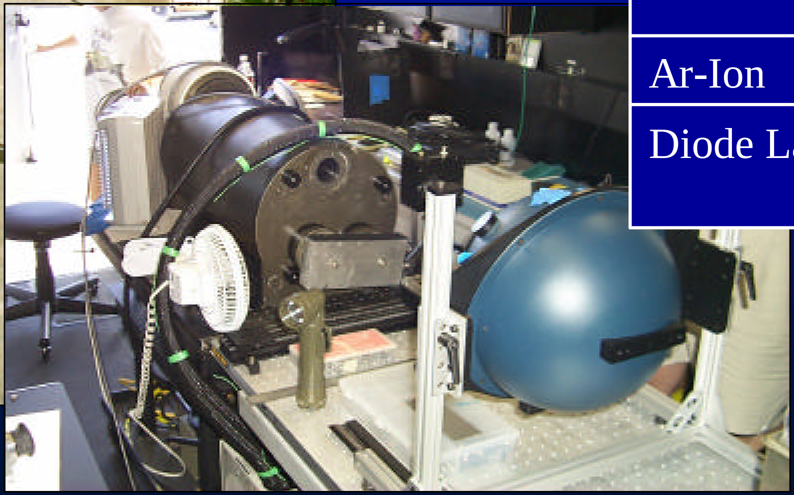


$z(l_i - l)$ is the slit scatter function.

We use an iterative solution to find the system response, followed by an iterative solution for the in-water measurements.

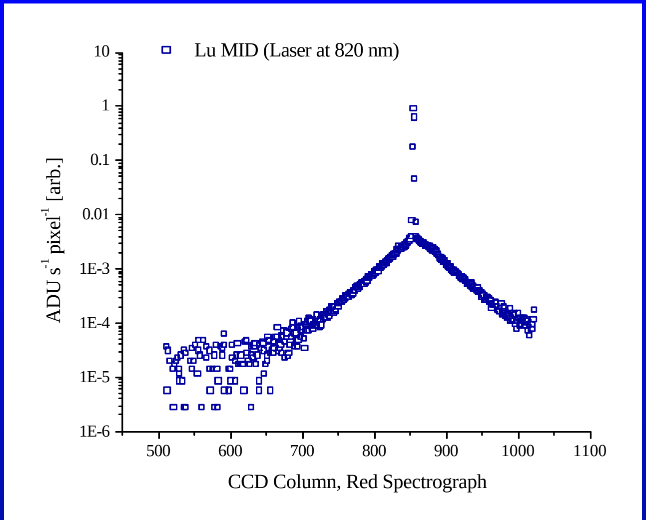
First, we must characterize the optical systems (MOS and MOBY).

Experimental



Tunable Lasers	Tuning Range [nm]
Ti:Sapphire	690 to 900 380 to 430
Dye Laser	580 to 600 610 to 690
Discrete Lasers	**Wavelengths [nm]**
HeNe's	543, 594, 612, 633
Ar-Ion	458, 488, 514
Diode Lasers	412, 440, 645, 660, 675, 690

Characterization using Tunable Lasers



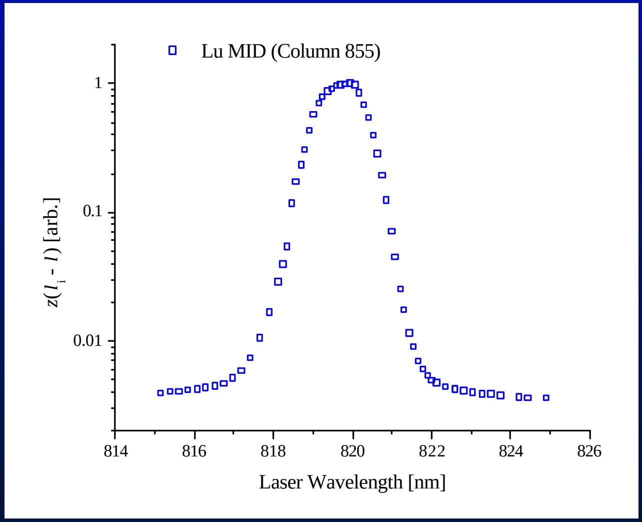
Laser-illuminated integrating sphere:
←←Result at single wavelength

This source is:
Monochromatic (width << dl);
Uniform, stable, and bright;
Radiance is measured (trap detector).

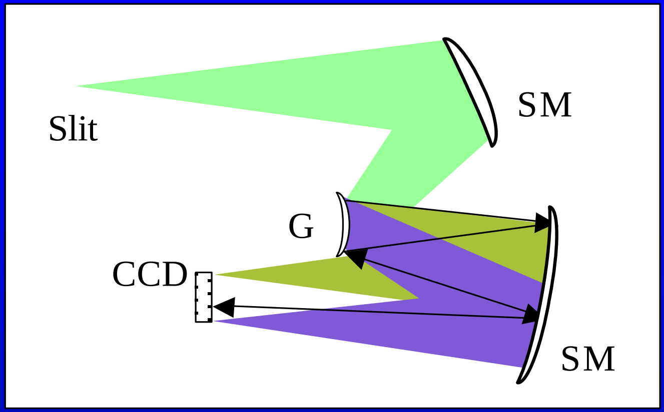
Fine Scans

The laser wavelength is varied by up to 10 nm in steps of about 0.1 nm (60 to 100 measurements). One column will be near the center of this scan.

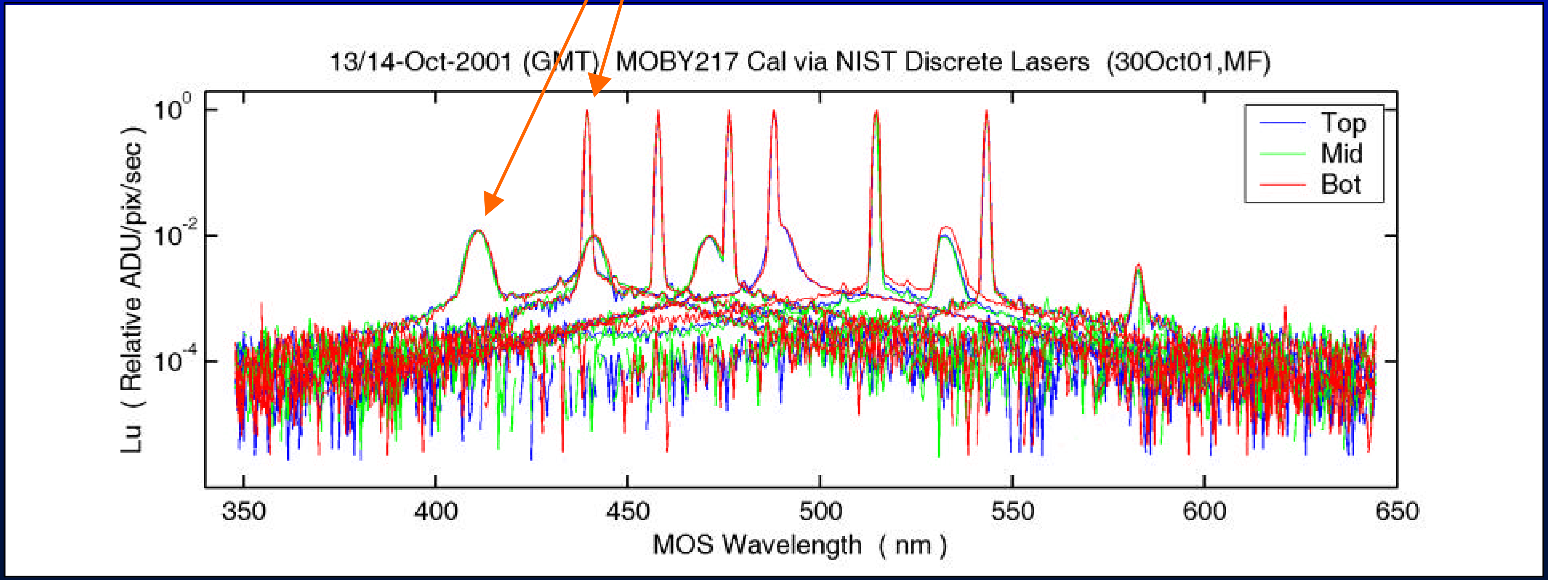
Gives dl and a fit to an analytical function for $z(l_i - l)$



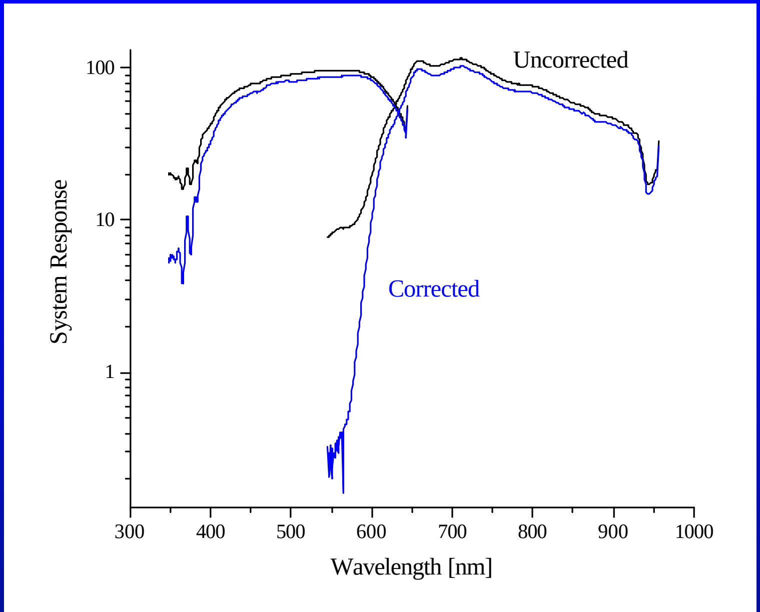
Reflection Peaks



Interreflection of 2nd order causes secondary image (MOS is designed to operate in 1st order).

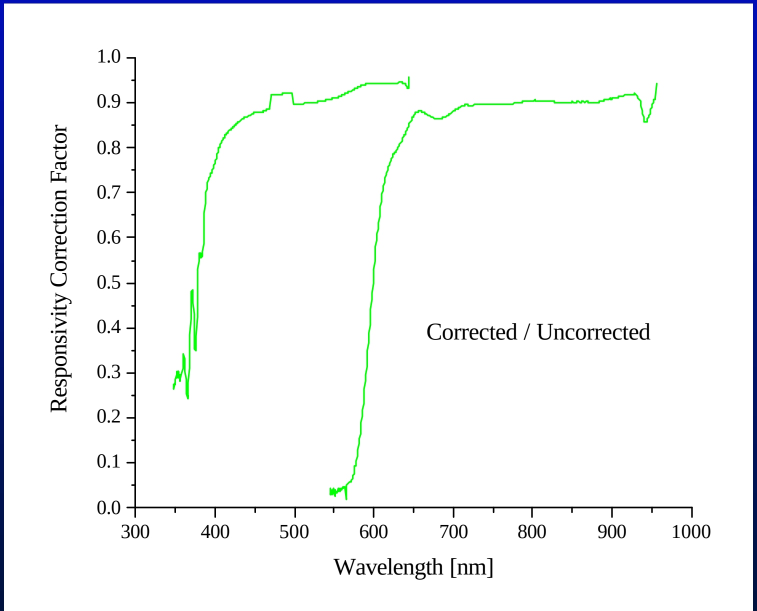


Effect on System Response

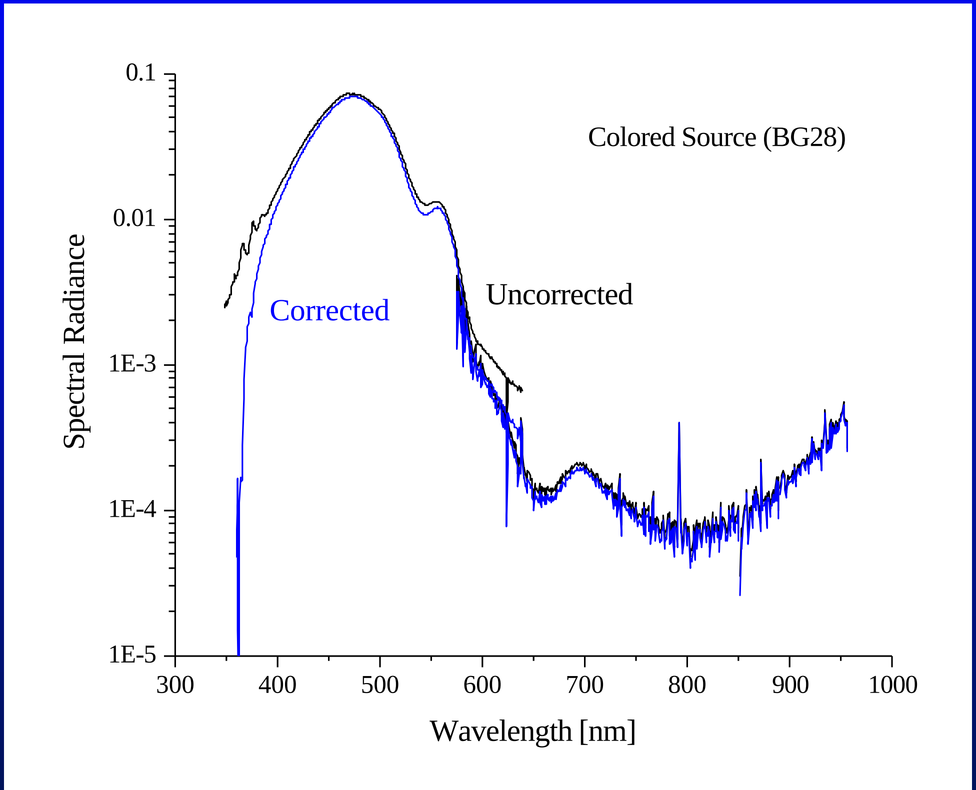


Corrected and Uncorrected System Response

Ratio



Colored Source (CS) for Validation



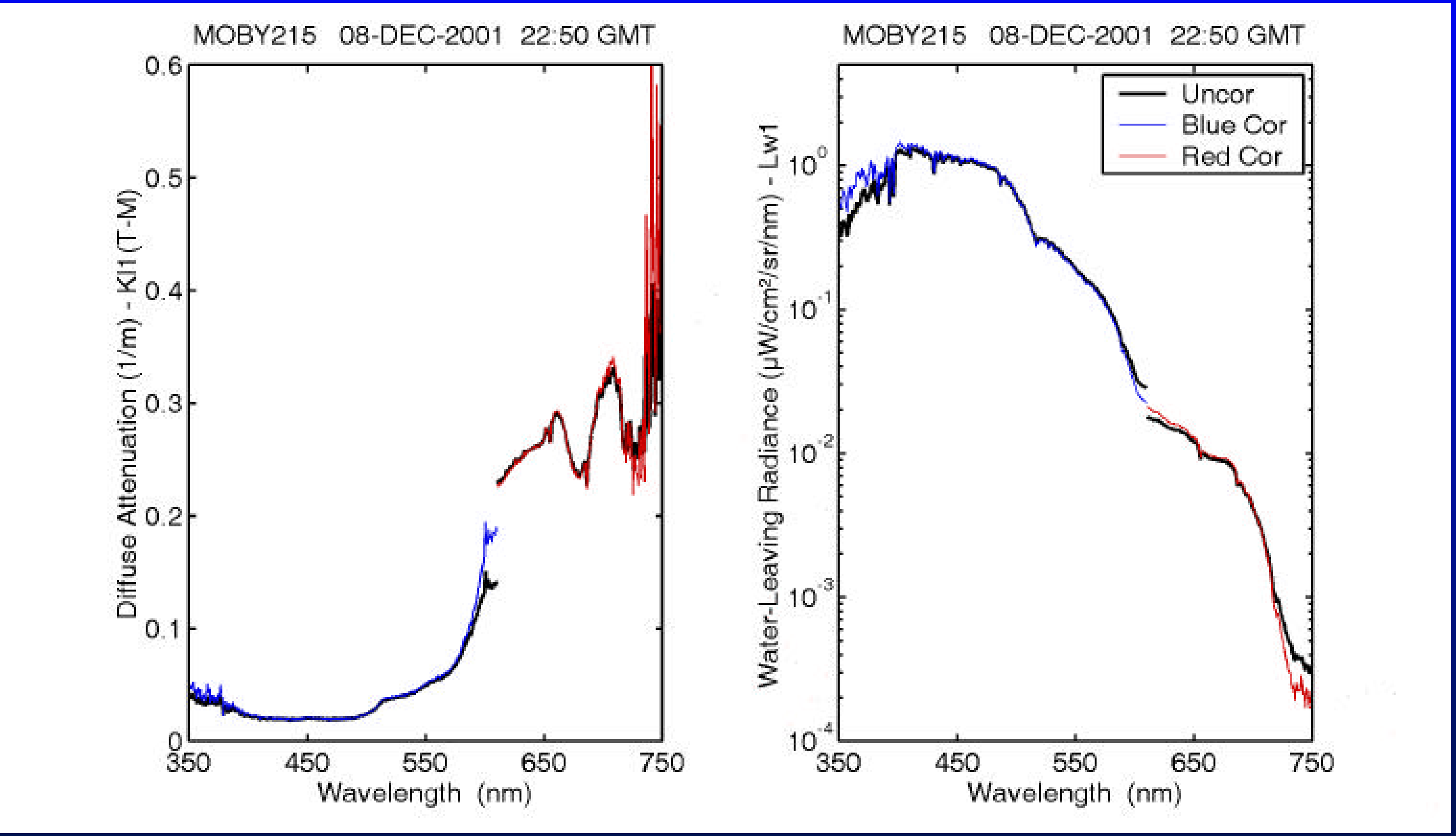
Filtered Sphere Source

L(λ) from measurements with double grating monochromator;

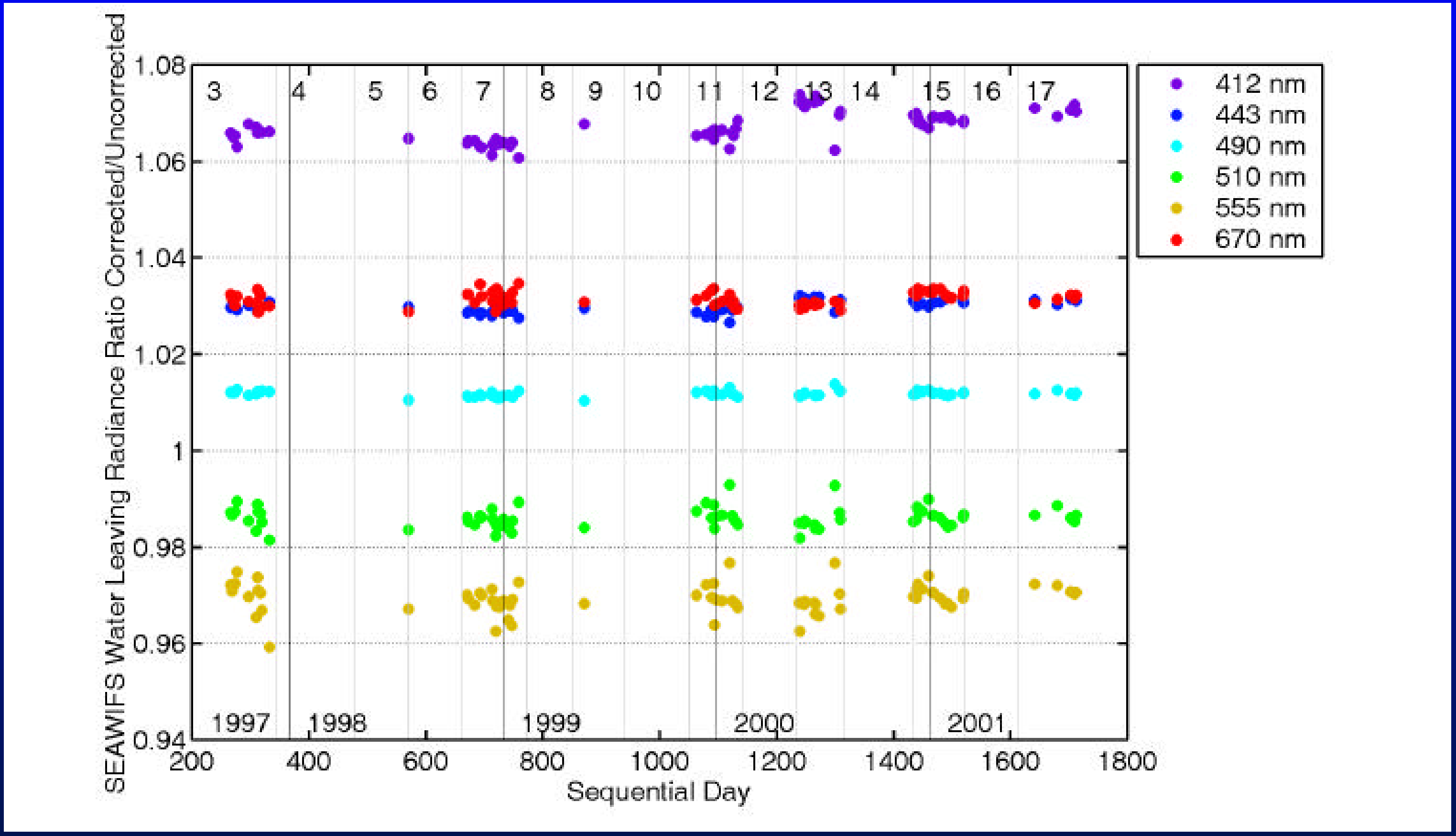
MOBY/MOS measurements of the CS serve as test Lu data sets;

Different glass filters to correspond to Case I or Case II waters; interference filters to test modeling of the reflection peaks.

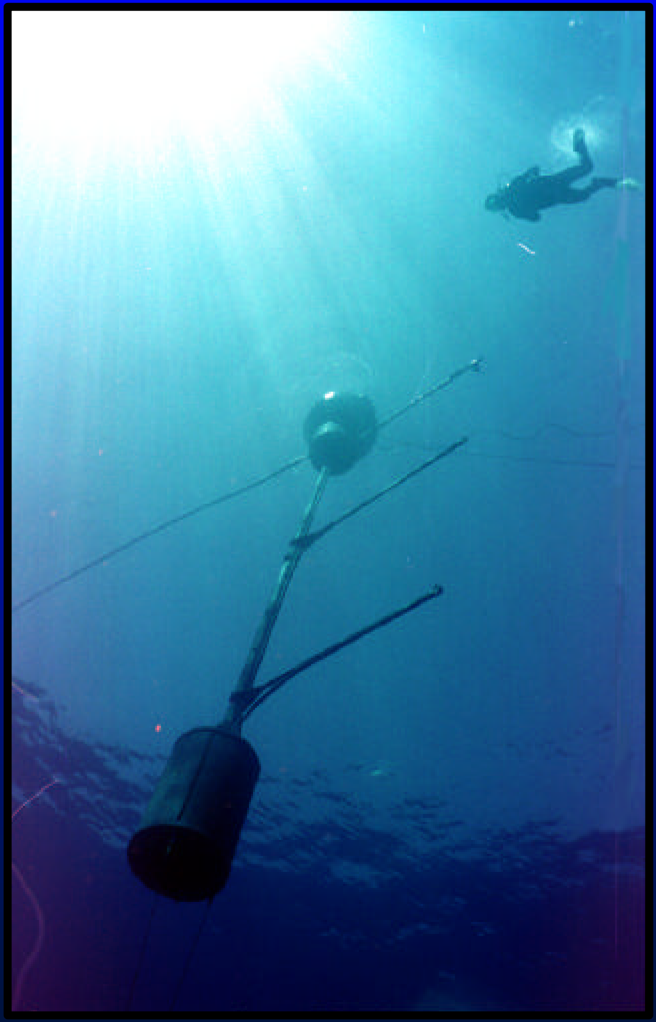
Result for MOBY215



SeaWiFS Match-Ups



Summary



Correction of 6.8% to –3.0% for SeaWiFS bands

Improved accuracy of MOBY-derived satellite calibration coefficients

Same set of stray light correction parameters (from MOBY217) “works” with all MOBY/MOS205—can go backwards and forwards

Analysis of MOBY/MOS204 and MOS202 (profiler in MOCE cruises) is underway

Thanks to:

MODIS, SeaWiFS, SIMBIOS, NOAA, NIST, CCG