MOBY system processing and calibration

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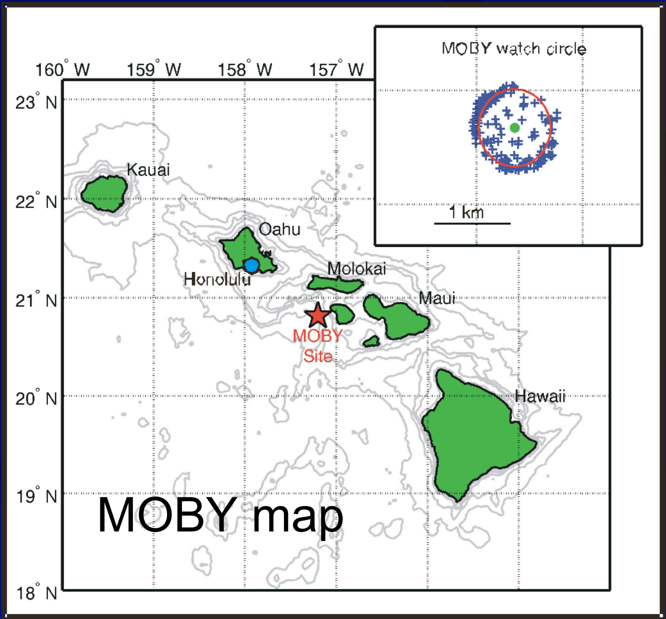
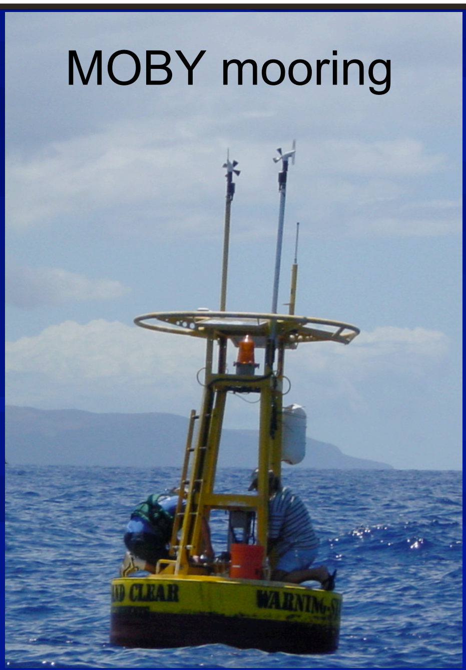
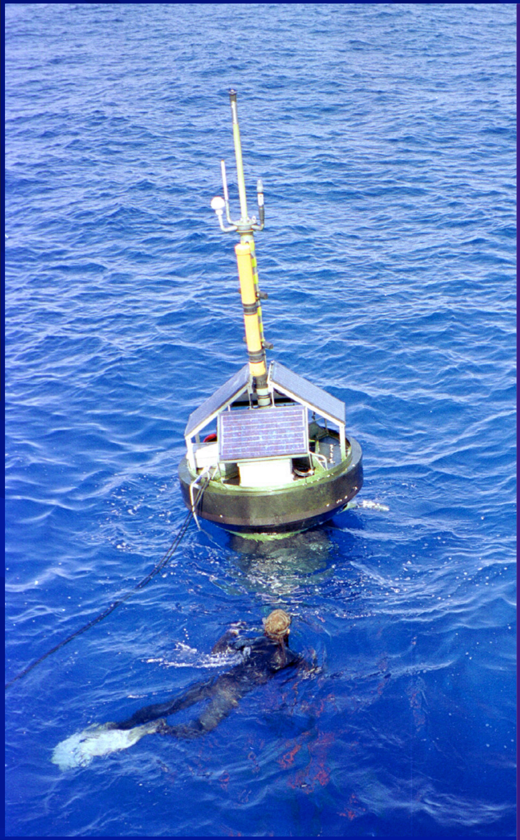
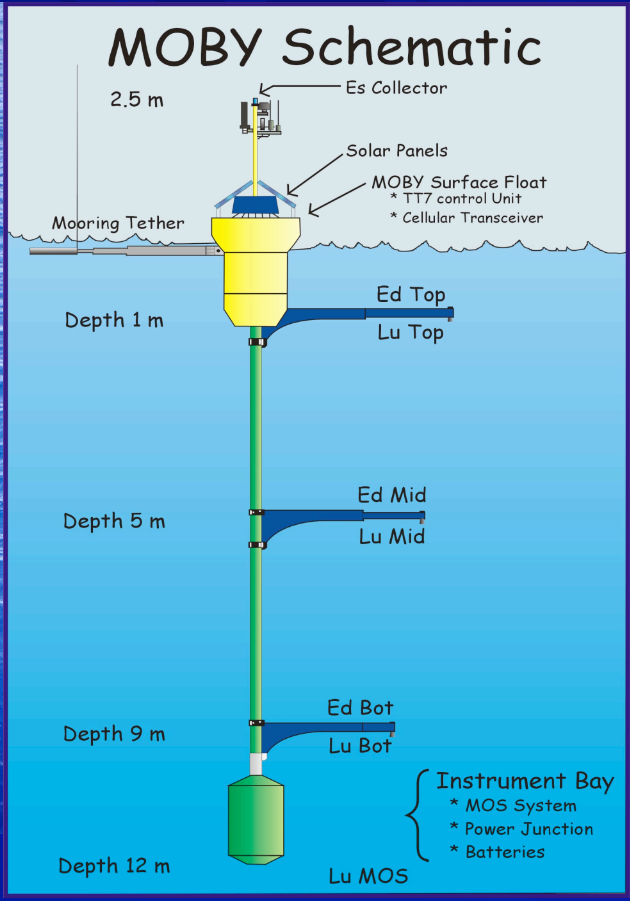
MOBY overview



MOBY map


MOBY mooring

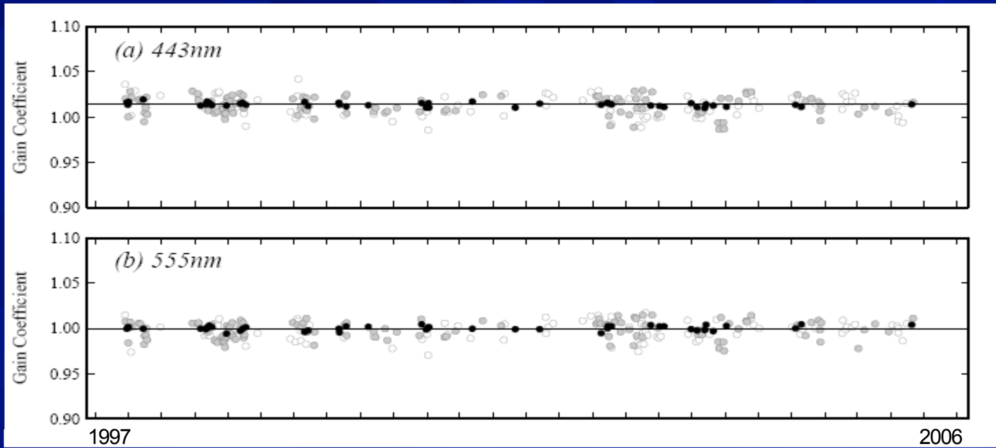

MOBY in-water



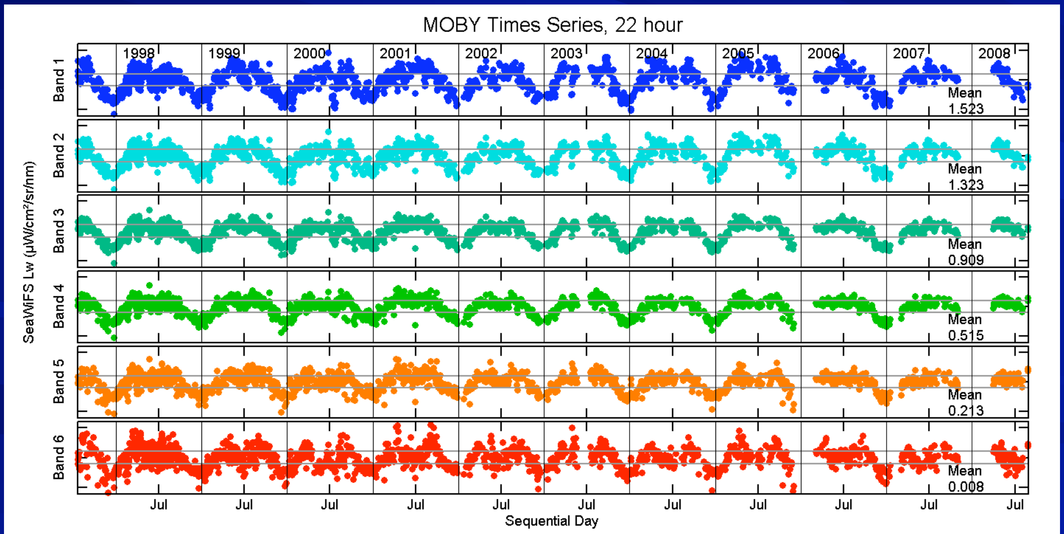
MOBY schematic

MOBY Science Objective

SI-traceable, climate-quality, *in-situ* spectroradiometry in Case 1 waters for vicarious calibration of ocean color satellite sensors.



Gain ratios for two SeaWiFS bands for 9 years – 1997-2006 (Franz et al. Appl. Optics, 46, 5068-5082 (2007).



Daily measurements with the hyperspectral, high resolution sensors are processed and reported to the community. Shown are the results for 10 years of total-band averaged using SeaWiFS spectral responsivities.

MOBY Cal/Val Elements & Rigor

- Achieving the objective requires:
  - Stable, well-designed system & measurement approach;
  - Measurement redundancy using multiple ancillary radiometric instruments or sensors;
  - Short and robust measurement chain to NIST;
  - Thorough instrument characterization;
  - Ability to revise correction algorithms and reprocess data sets

Cal/Val Measurement Methodology

- Instrument Design
  - Calibrate wavelength scale and *L* and *E* responsivities pre- and post deployment, and perform other lab tests;
  - Monitor *in situ* status with three internal sources (every day) and ~monthly diver lamp checks
  - Monitor the internal sources with Si detectors;
  - Measure system temperature & other housekeeping data.
- Radiometry
  - Two NIST calibrations of reference standards (start and end of lamp life); replace lamps every 50 h;
  - Monitor output of standards using NIST-calibrated custom filter radiometers, Standard Lamp Monitors (SLMs)
  - Validate standards with independent NIST assets and participation (VXR and NPR);
  - Participate in community intercomparisons (SIRREX, SIMBIOS, SORTIE).
  - Adjust sampling frequency and order to give the best uncertainty

MOBY Tests & Characterizations

- Integration time, bin factor, linearity
- Immersion coefficients
- Repeatability of radiometric calibrations
- Stray light response, full spectral range
- Ambient temperature
- Cosine response of irradiance (Es)
  (not yet implemented)

MOBY Uncertainty (k=1) in Lu(1m,λ)

MODIS-Terra

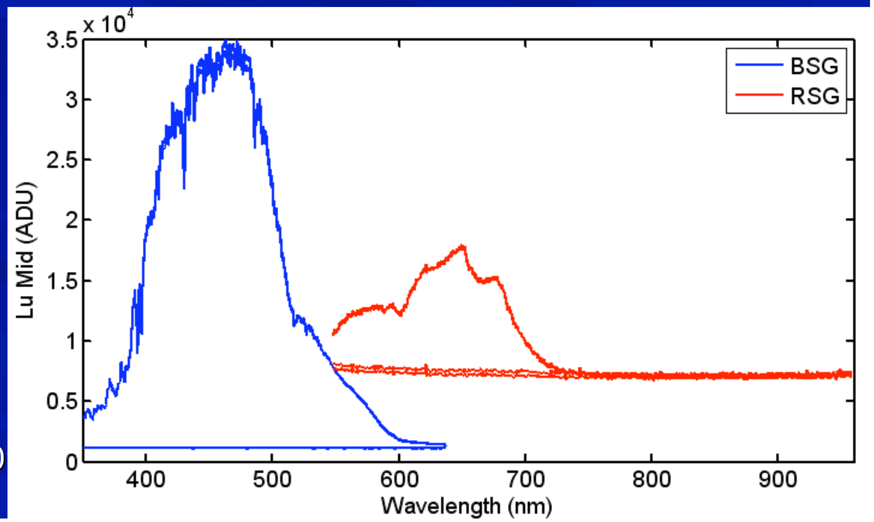
Uncertainty Component [%]	8	9	10	11	12	13
	411.8	442.1	486.9	529.7	546.8	665.6
Radiometric Calibration Source						
Spectral Radiance (NIST)	0.65	0.6	0.53	0.47	0.45	0.35
Stability	0.41	0.46	0.51	0.53	0.53	0.48
Transfer to MOBY						
Interpolation to MOBY wavelengths	0.2	0.15	0.03	0.03	0.03	0.03
Reproducibility	0.37	0.39	0.42	0.44	0.42	0.3
Wavelength accuracy	0.29	0.08	0.04	0.03	0.01	0.04
Stray light	0.75	0.3	0.1	0.15	0.3	0.3
Temperature	0.25	0.25	0.25	0.25	0.25	0.25
MOBY stability during deployment						
System response	1.59	1.3	1.19	1.11	1.08	0.92
In-water internal calibrations	0.43	0.42	0.44	0.46	0.51	0.55
Wavelength stability	0.132	0.138	1.122	0.816	1.368	0.65
Environmental						
Type A (good scans & good days)	0.8	0.83	0.87	1.02	0.64	1.31
Temporal overlap	0.3	0.3	0.3	0.3	0.3	0.3
In-water bio-fouling	1	1	1	1	1	1
Self-shading	1	1	1.2	1.75	2.5	12
*Self-shading (upon correction)***	*0.2*	*0.2*	*0.24*	*0.35*	*0.5*	*2.4*
Combined Standard Uncertainty	2.63	2.36	2.64	2.84	3.44	12.21
*Combined Standard Uncertainty***	*2.44*	*2.15*	*2.36*	*2.27*	*2.42*	*3.28*

#1-10 = Cals

MOBY Data collection

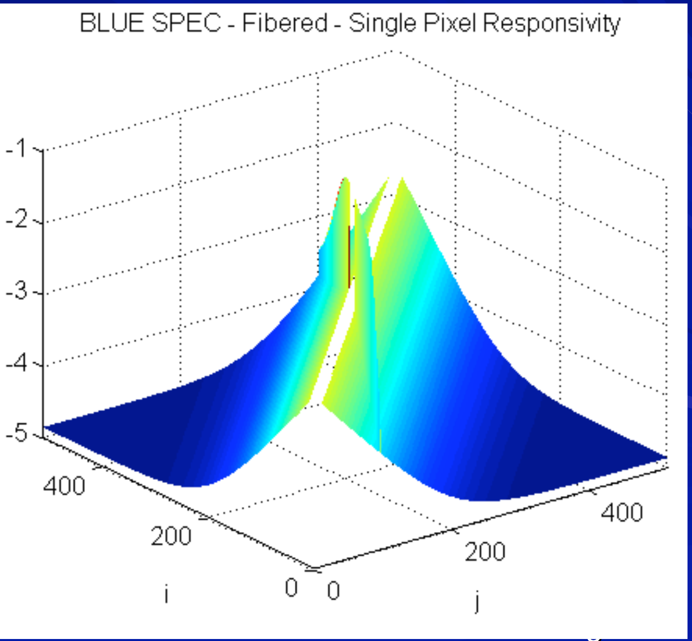
- Currently acquires data 3 times a day
- Es, Lu and Ed (3 internal cal lamps at end)
- Data is collected sequentially (25-30 min)
- Each scan set consists of 1 dark, 3-5 light scans followed by 1 dark scan. Es is measured before and after each Lu and Ed scan set
- Each scan results in 2 partially overlapping spectra, 340-950 nm

  0.6 – 0.8 nm resolution



Processing Raw data

- Spikes are removed
- Each scan is checked for problems (arm out of the water, cloud contamination, broken fiber).
- Divided by integration time (calibrated) and CCD binning factor, light and dark scans are averaged and net radiance or irradiance is calculated
- Thermal correction is applied (~0.5% per degree C)
- Es taken before and after the Lu and Ed scans are averaged to obtain one net Es for each sensor and depth
- Stray light correction is applied (Jan 2005 version)



Conversion

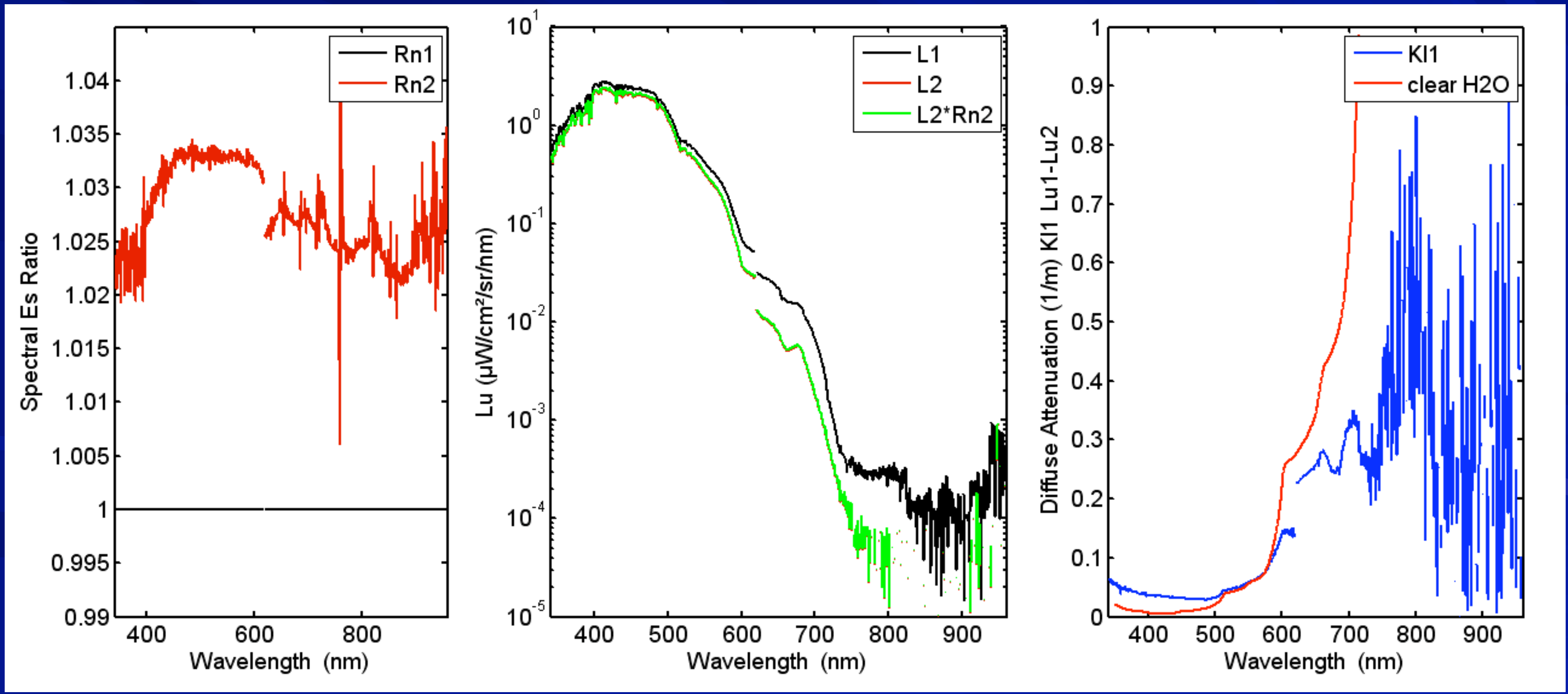
- Each collector's measurement is divided by its system response
- Immersion factors are applied to Lu and Ed
- Initially all deployments are processed with the pre-deployment calibration
- The blue – red overlap is removed at 620 nm.
- If the top arm is missing or damaged, the middle and bottom are used

Derived Products, Kl

$$R_{N1} = \frac{E_{SR}}{E_{s1}}$$

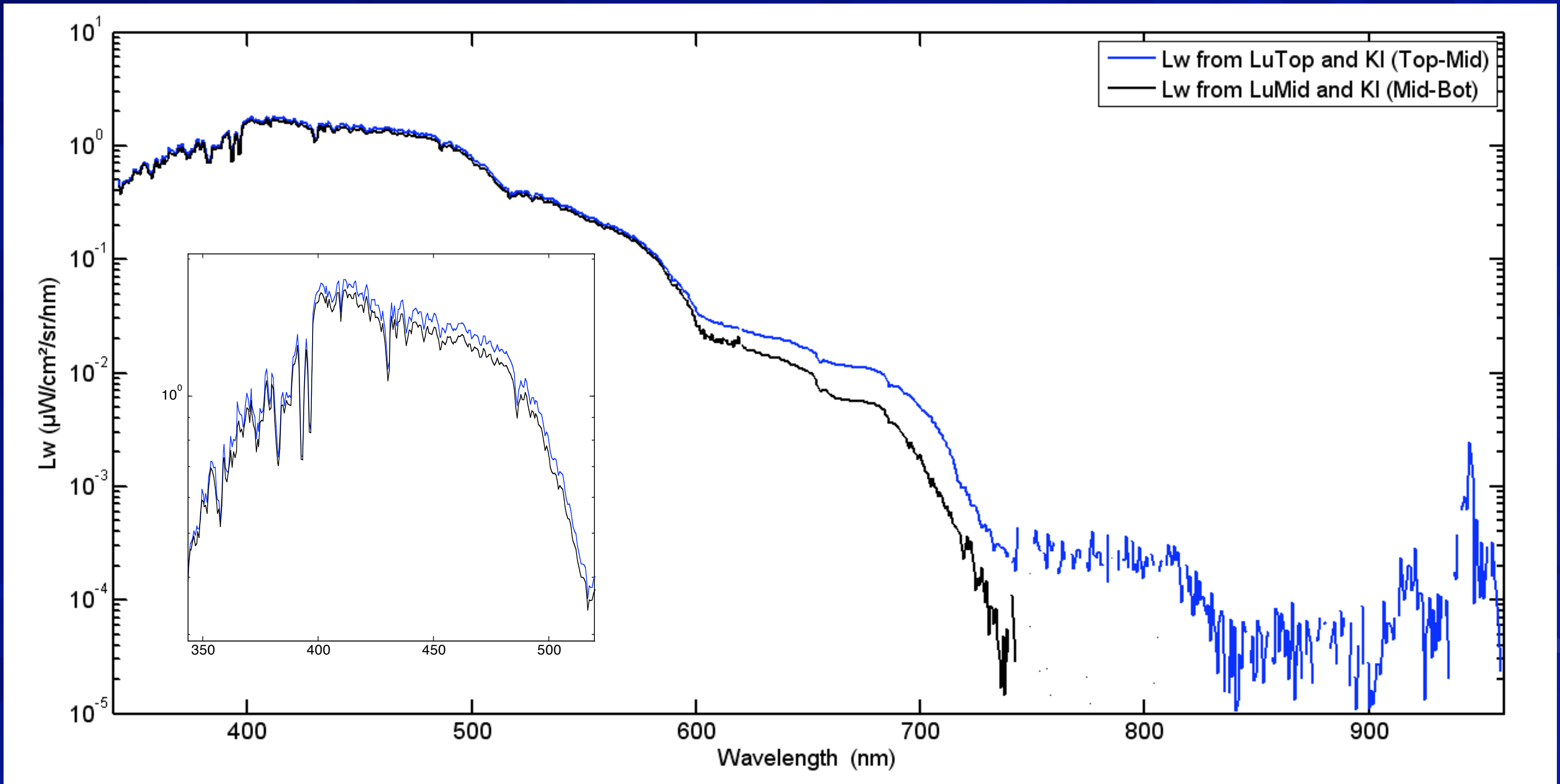
$$R_{N2} = \frac{E_{SR}}{E_{s2}}$$

$$K_L = -\frac{\ln\left[\dfrac{L_2 \times R_{N2}}{L_1 \times R_{N1}}\right]}{z_2 - z_1}$$



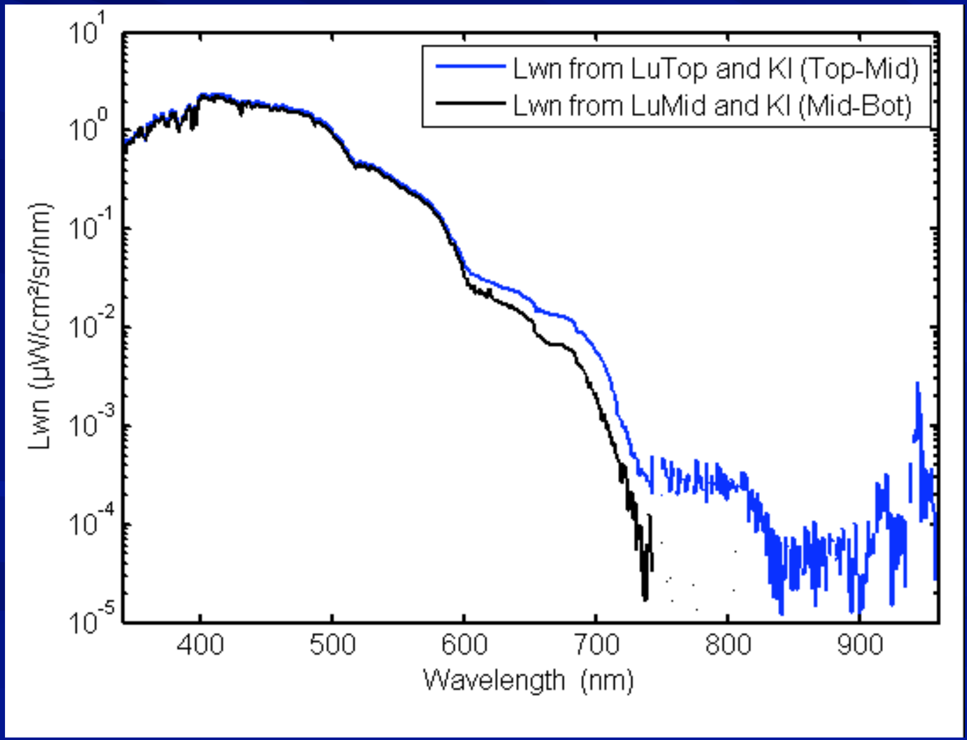
Water Leaving Radiance , Lw

$$L_w = 0.543\ L_u(\lambda)\ \exp(K_L\ (Z_2 - Z_1))$$



Solar normalized Lw (Lwn)

- Using fixed climatology
- Using RSR and Fo



$$L_{WN} = \frac{L_w}{F_N}$$

$$F_N = \frac{t(\lambda,\theta_0)(1-\rho(\theta_0))\cos(\theta_0)}{r_{es}^{\ 2}}$$

$$t(\lambda,\theta_0) = \exp\left[-(\frac{\tau_R}{2} + \tau_{oz})/\cos(\theta_0)\right]$$

$$r_{es} = \frac{1}{1 + 0.0167\cos\left(\frac{D-3}{365}\right)}$$

$$\rho = \frac{1}{2}\frac{\sin^2(\theta_a - \theta_w)}{\sin^2(\theta_a + \theta_w)} + \frac{1}{2}\frac{\tan^2(\theta_a - \theta_w)}{\tan^2(\theta_a + \theta_w)}$$

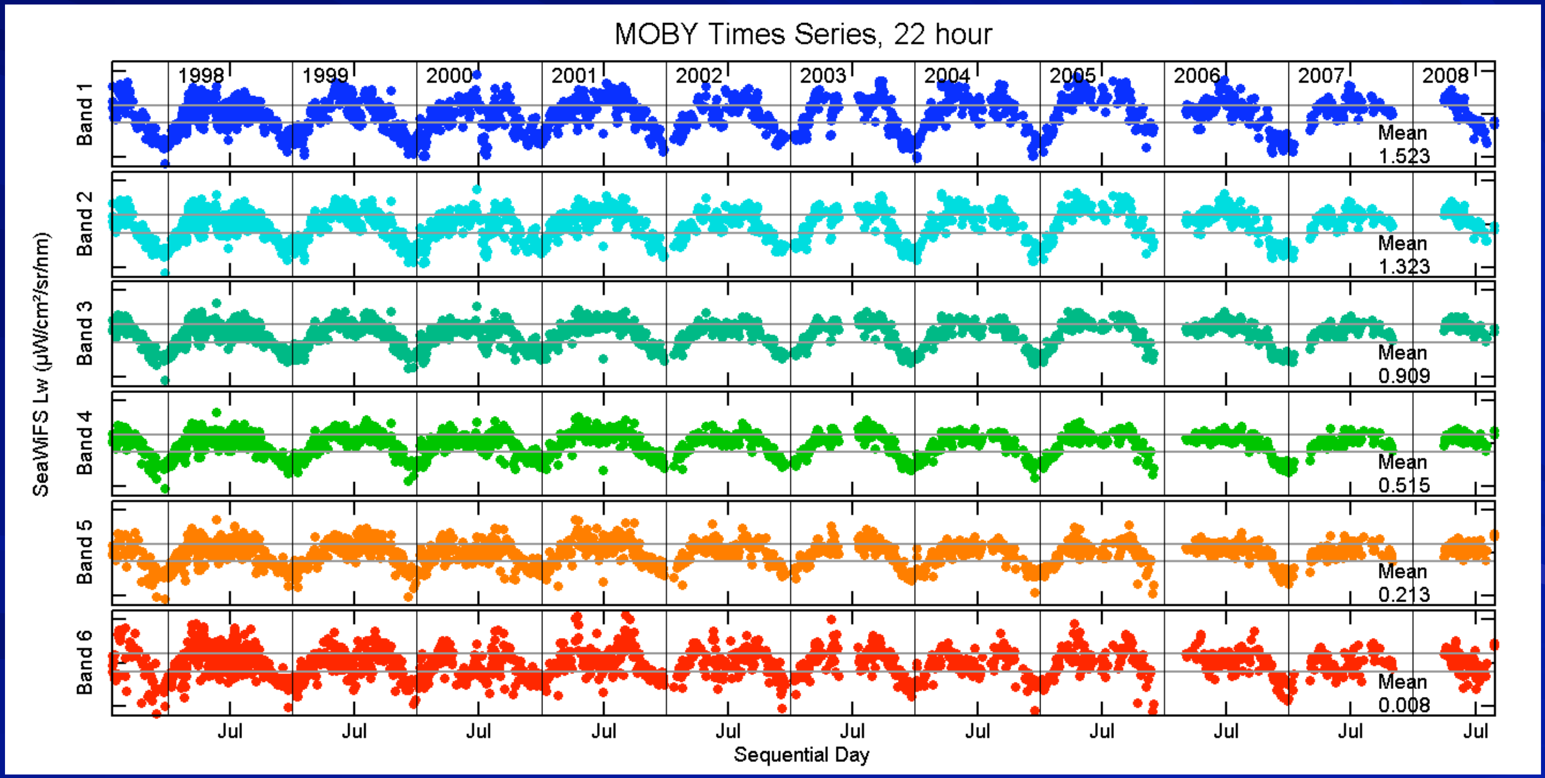
$$L_{wn}(\lambda) = \frac{\frac{L_w}{E_s}}{F_o r_{es}}$$

Quality checks

- GOES visible images of the MOBY site are used to determine if the file may be cloud contaminated
- Kl's must be above clear water (Mueller, 2003) in the blue and the 3 Kl's calculated are visually checked for consistency (%std ~< 12% @ 443 nm)
- Lu's %std < 7% and Es's %std < 2%
- Data is marked good, bad or questionable

Satellite Weighted

- Weighted data is available on the MLML website. Both weighted and spectral data are available on the SeaBASS website. Soon the data will also be available through NOAA.
- Satellite sensors supported: SeaWiFS, MODIS- Terra, MODIS-Aqua, MERIS, POLDER, GLI, and MISR



Additional Processing

- MOBY data are routinely reprocessed for...
  - pre/post deployment MOBY calibrations
  - pre/post radiometric reference standards calibrations
- If more than one arm is damaged then a mean Kl is used to calculate an Lw using the working arm
- All auxiliary data is processed and on the website, where it is monitored for quality control

Processor Status & History

- Modified to include stray light (Jan 2005)
- Modified to include ambient temperature (Jan 2005)
- Desired/anticipated revisions
  - Stray light: using the 2008 complete characterization at NIST. Also must develop method to account for temporal changes in MOS stray light performance
  - Include cosine correction in Es retrievals
  - Actual buoy attitude: tilt (Lwn and cosine correction); solar azimuth angle (needed for self-shading correction)
  - Revisions to the radiometric scale based on SLM monitoring and VXR/NPR validations
  - Self-shading correction algorithm based on Mueller's Monte Carlo approach for MOBY and field measurements to be performed using simultaneous hyperspectral radiometry
  - Uncertainty included along with results

Recommendations & Summary

- Vicarious calibration means going the extra mile
  - MOBY system has all the necessary attributes
    - Fiber-coupled inputs;
    - Repeat calibrations & robust characterization;
    - Internal sources and auxiliary measurements;
  - NOAA's proposed hardware intent for the future:
    - Simultaneous, multi-channel acquisition;
    - System level *in situ* stability sources;
    - In situ mitigation of bio-fouling using UV LEDs;
    - Blue-rich calibration sources;
  - Processor will expand its capabilities
    - Quality control charts;
    - Increased synergy among various data streams;
    - Uncertainty assessment and sensitivity tests;
    - Stray light correct data specially and spectrally;
    - Better Lwn calculations using ???

Thank You – Questions?