

Assessing Simulated HypsIRI Imagery for
Detecting and Quantifying Coral Reef Coverage
and Water Quality;

Autonomous In Situ Surveys In Support of Remote Sensing

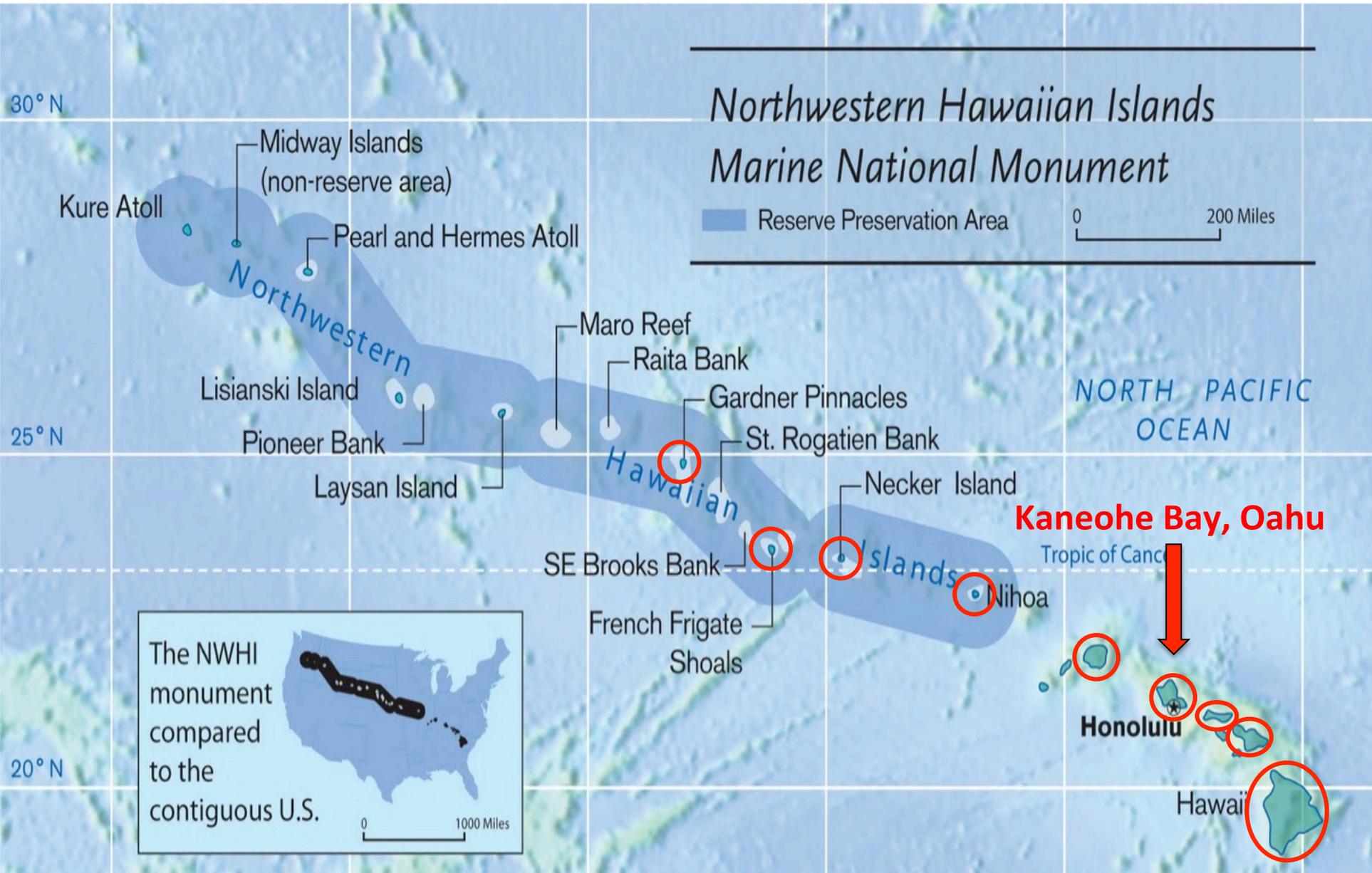
Steven G. Ackleson

Naval Research Laboratory, DC

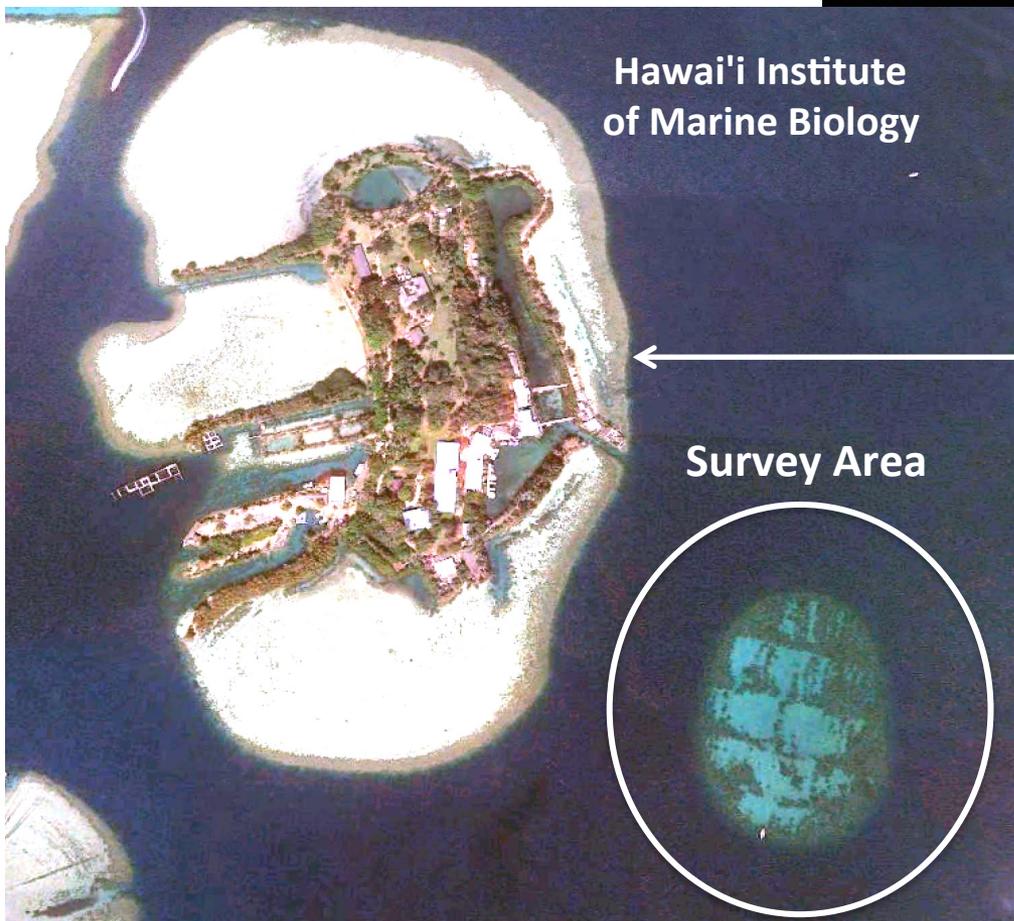
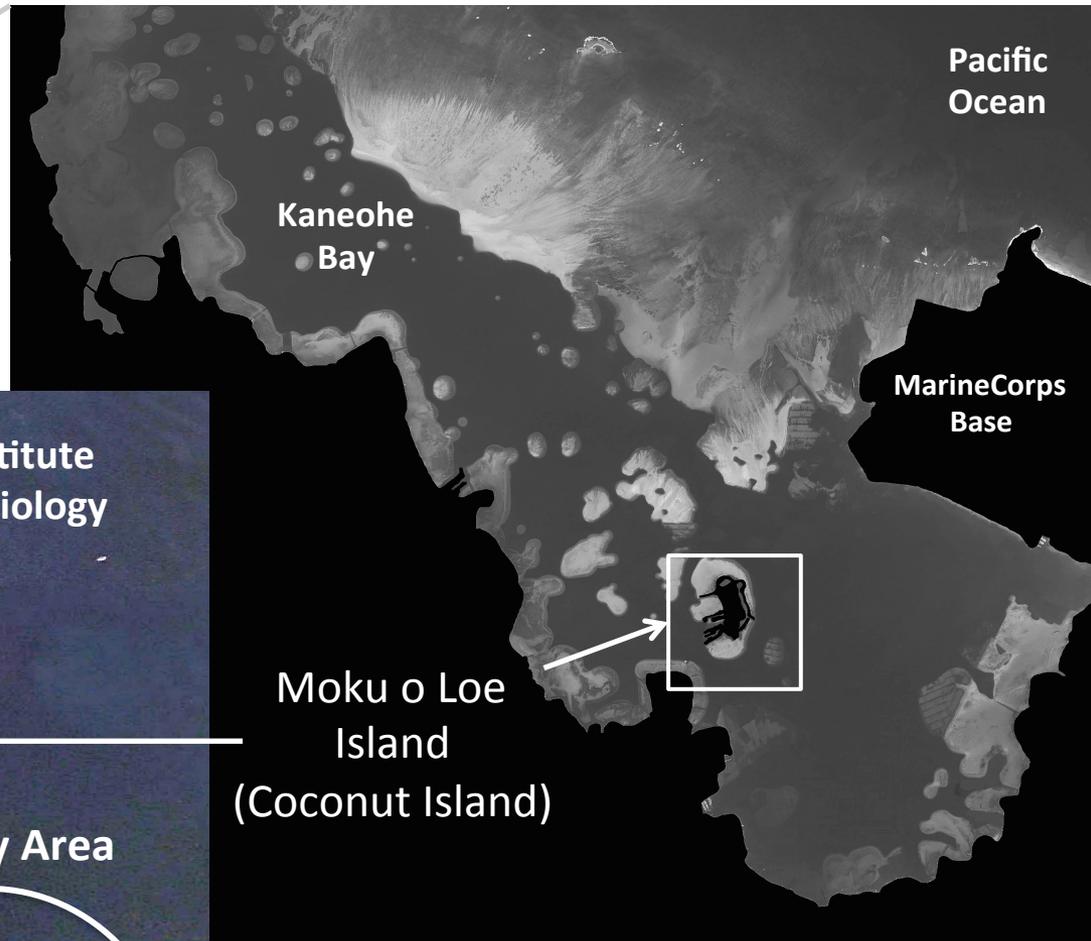
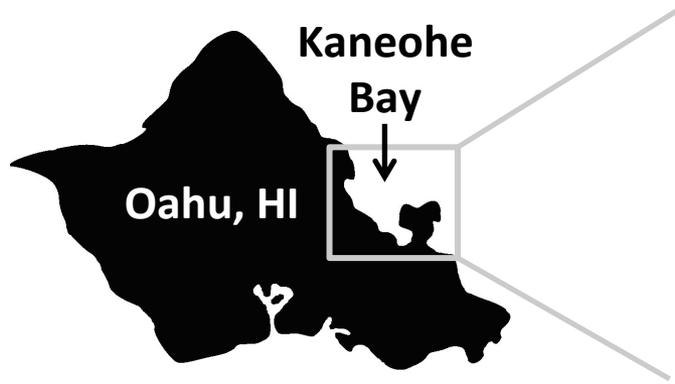
202-767-3398; steve.ackleson@nrl.navy.mil

HyspIRI Coral Field Campaign

12 January - 3 March 2017



Primary Study Site

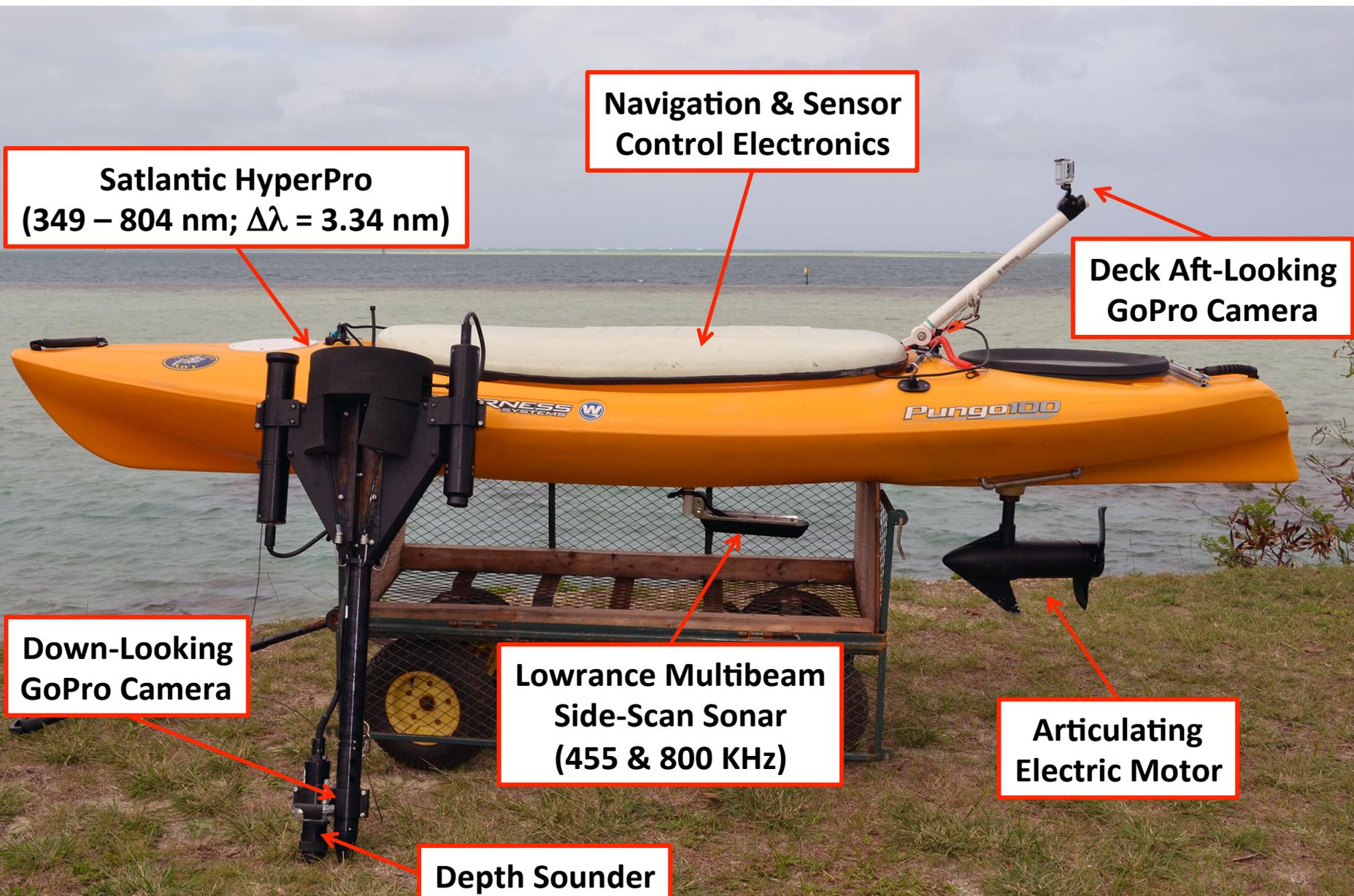


- Patch reef dredged during WWII
- Average Depth \approx 4 m
- Reef Surveys: 12 & 18 February 2017
- AVIRIS Overflights:
Jan 27, Feb 7,8 & 22, and Mar 3.

AVIRIS, 03 March 2017
(f170303t01p00r07)



Autonomous Kayak and Sensors



Satlantic HyperPro
(349 – 804 nm; $\Delta\lambda = 3.34$ nm)

Navigation & Sensor
Control Electronics

Deck Aft-Looking
GoPro Camera

Down-Looking
GoPro Camera

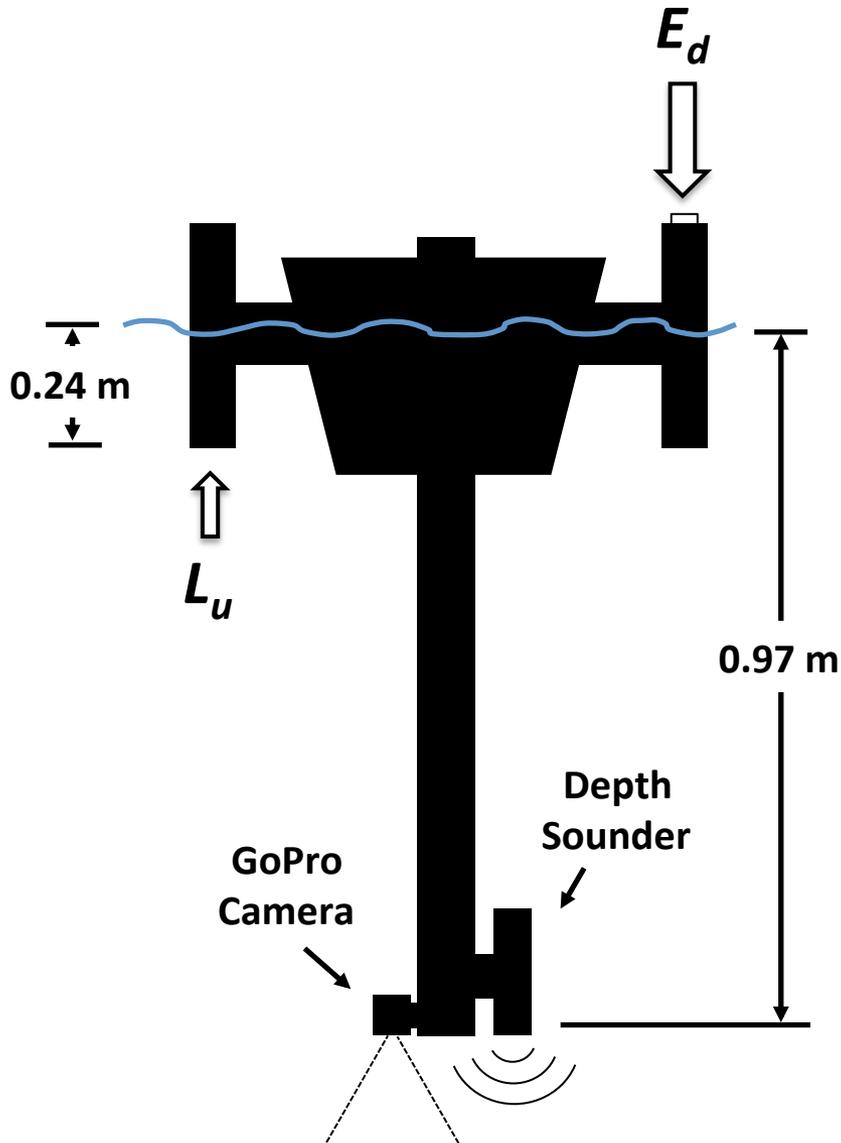
Lowrance Multibeam
Side-Scan Sonar
(455 & 800 KHz)

Articulating
Electric Motor

Depth Sounder

Towed Hyperspectral Radiometer System

Measurements



Computations

$$R_w = R_{od} (1 - e^{-KD}) + \frac{\rho_b}{\pi} e^{-KD}$$

R_w = water column reflectance

R_{od} = Optically deep water reflectance

D = water depth (m)

$K = K_d + K_u$

ρ_b = Bottom reflectance

- Propagate E_d through water surface and down to 0.24 m using modeled values of K_d .

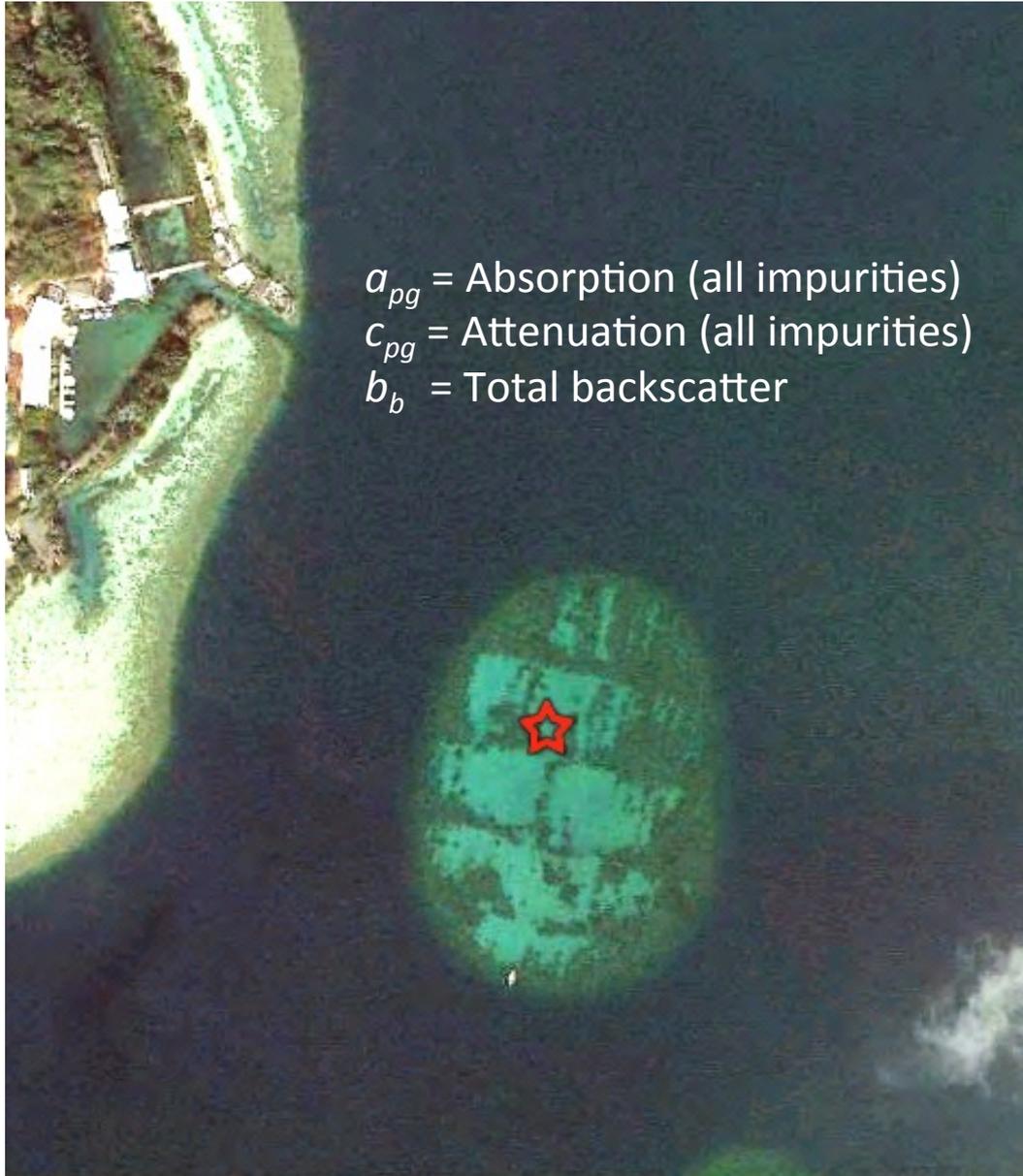
- Compute r_{rs} and invert the shallow-water equation for ρ_b .

$$\rho_b = \pi e^{KD} [R_w - R_{od} (1 - e^{-KD})]$$

- Compute R_{rs} .

In Situ Water Optical Properties: 17 February 2017

(B. Russell, UCONN)



a_{pg} = Absorption (all impurities)
 c_{pg} = Attenuation (all impurities)
 b_b = Total backscatter

Computations

- Total absorption and scatter:

$$a = a_{pg} + a_w$$

$$b = c_{pg} - a_{pg} + a_w$$

- Diffuse Attenuation:

$$K_\mu = \frac{b}{\mu} \left[1 + (0.425 \mu - 0.19) \frac{b}{a} \right]^{1/2}$$

μ = average cosine

(Kirk, 1984)

- Water Column Reflectance:

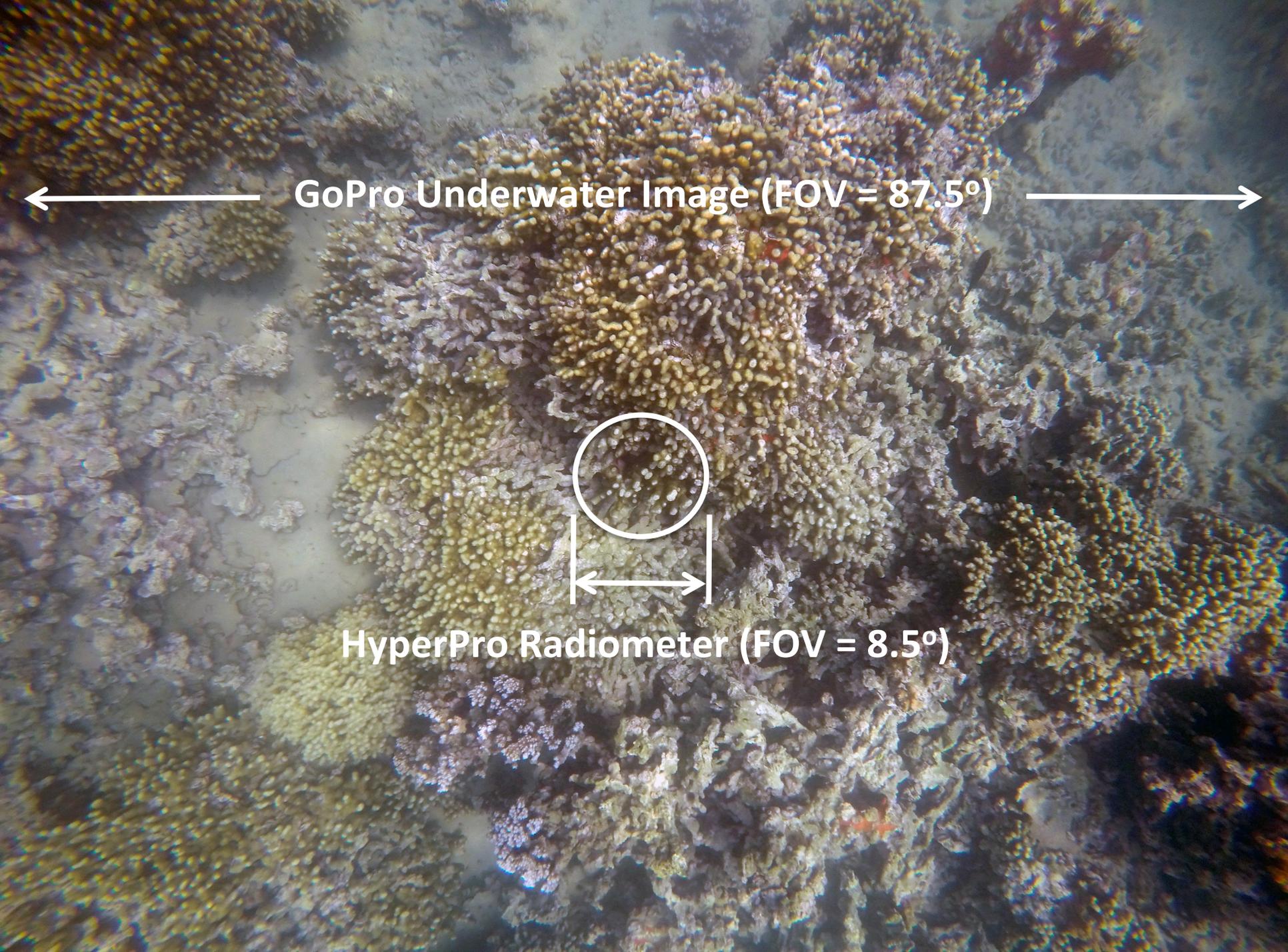
$$r_{rs} = \sum_{i=1}^2 g_i \left(\frac{b_b}{a + b_b} \right)^i$$

$$g_1 = 0.0949; g_2 = 0.0794$$

(Gordon et al., 1988)

- Remote Sensing Reflectance:

$$R_{rs} = \frac{0.52 r_{rs}}{1 - 1.7 r_{rs}}$$



GoPro Underwater Image (FOV = 87.5°)

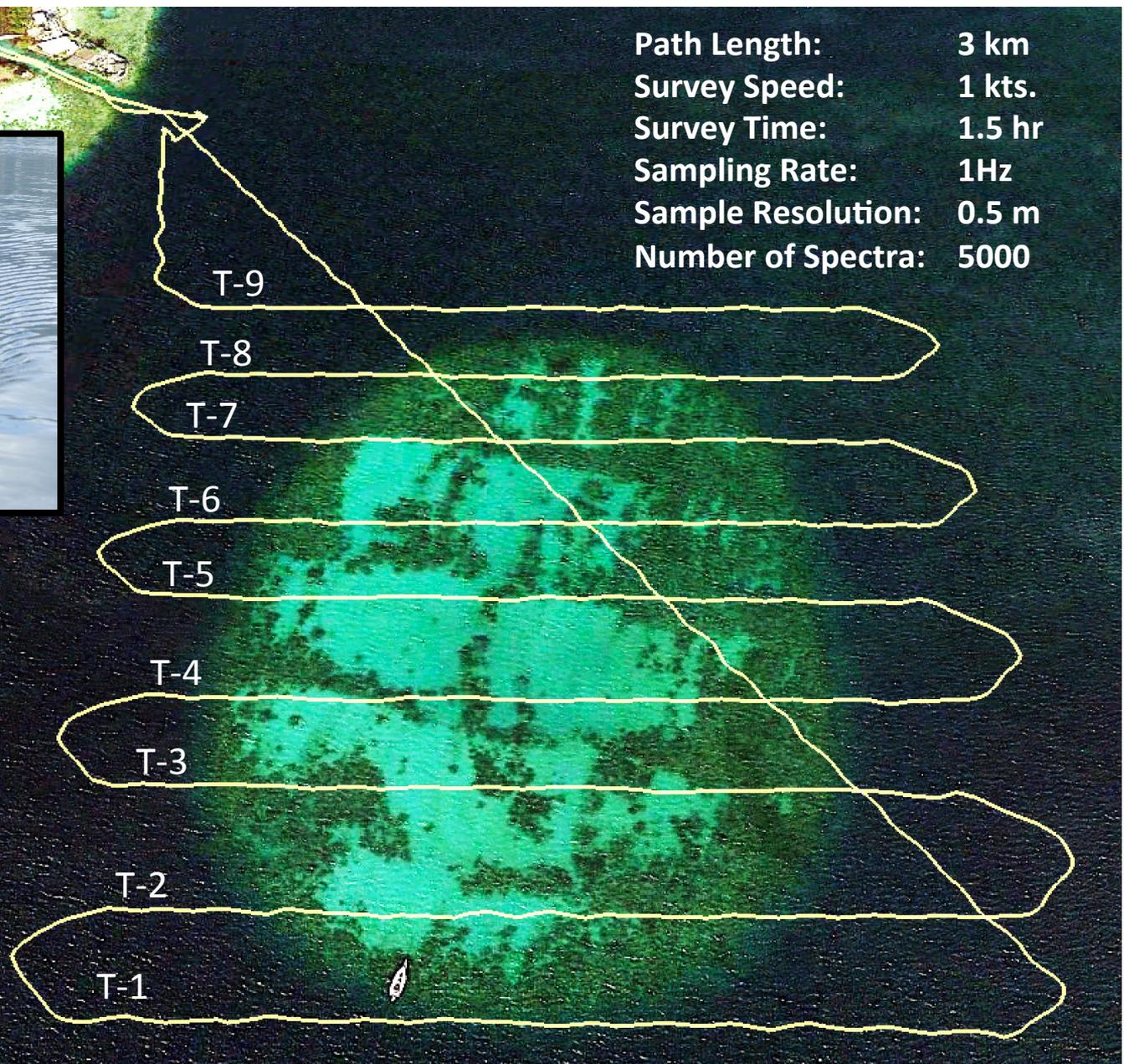
The image shows a wide-angle view of a coral reef. A white double-headed arrow spans the width of the image, indicating the field of view of the GoPro camera. In the center, a white circle highlights a specific area of the reef. Below this circle, a white double-headed arrow indicates the field of view of the HyperPro Radiometer, which is a much smaller area than the GoPro image.

HyperPro Radiometer (FOV = 8.5°)

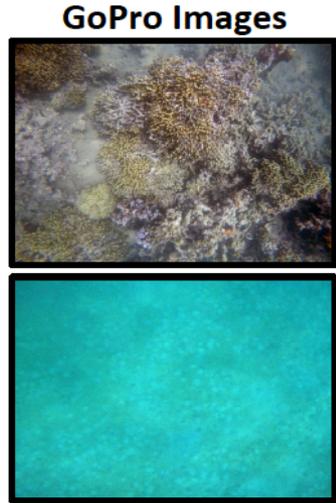
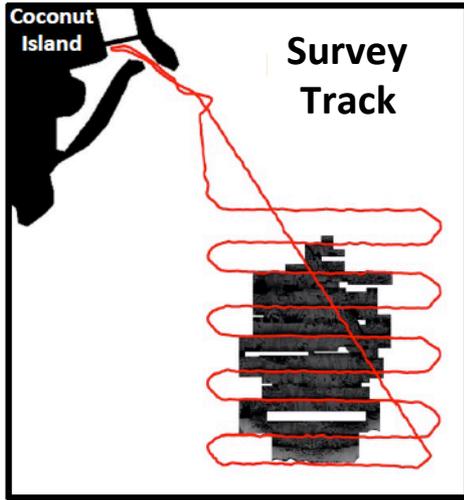
Survey Track: 12 February 2017



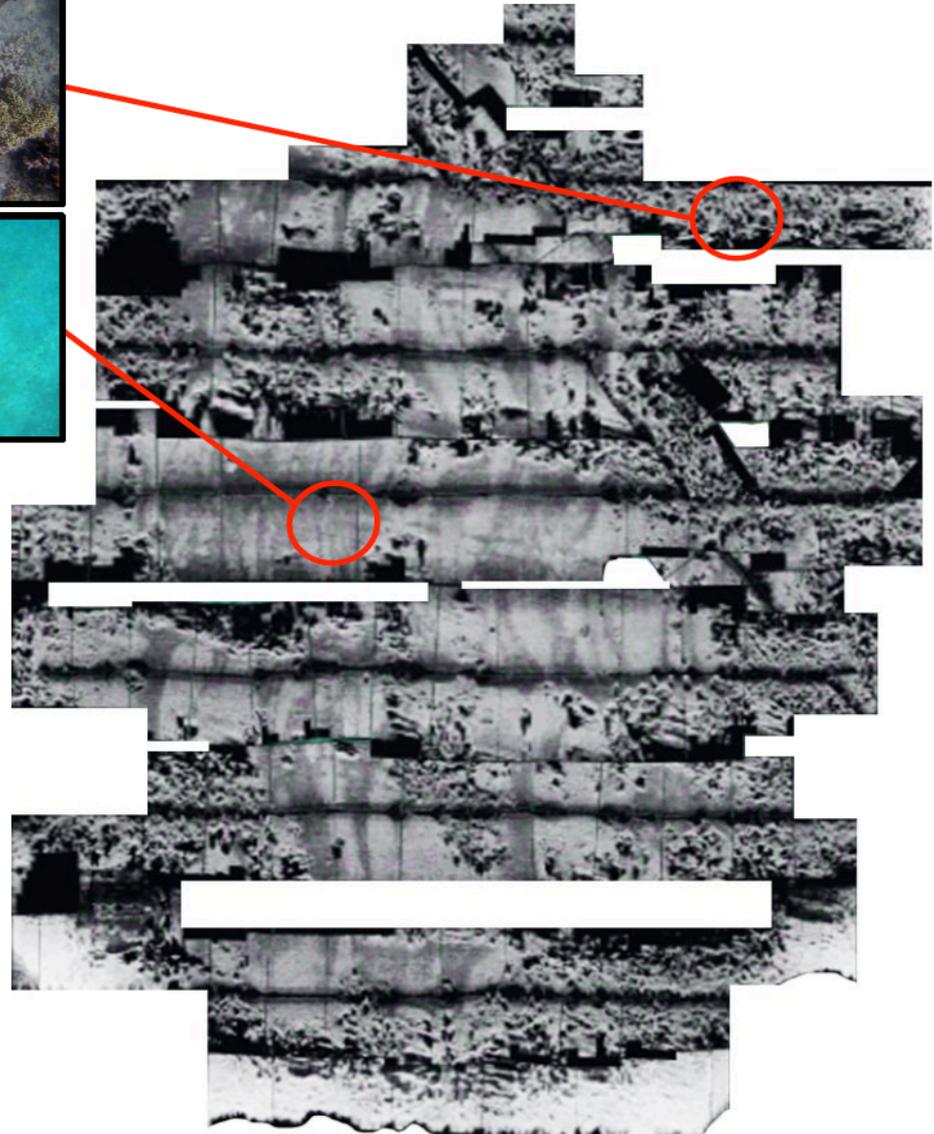
Path Length: 3 km
Survey Speed: 1 kts.
Survey Time: 1.5 hr
Sampling Rate: 1Hz
Sample Resolution: 0.5 m
Number of Spectra: 5000



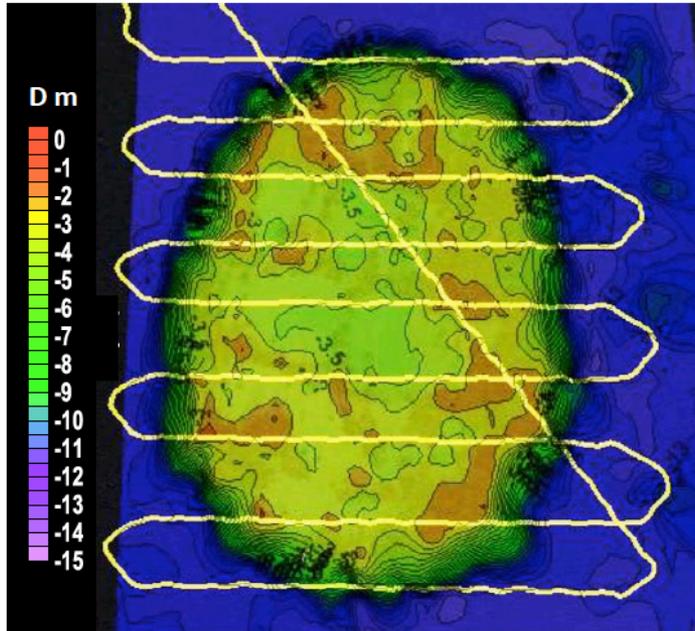
Bathymetric Information



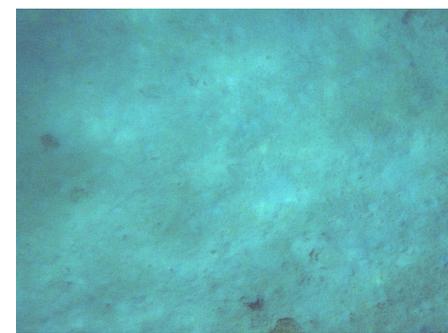
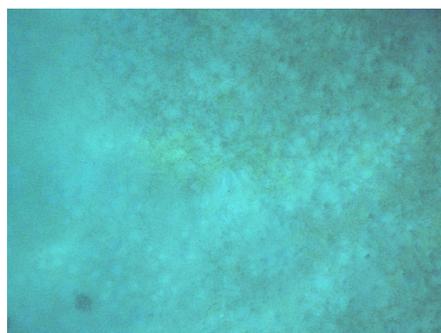
Acoustical Backscatter



Bathymetry



Example Spectra: Sand

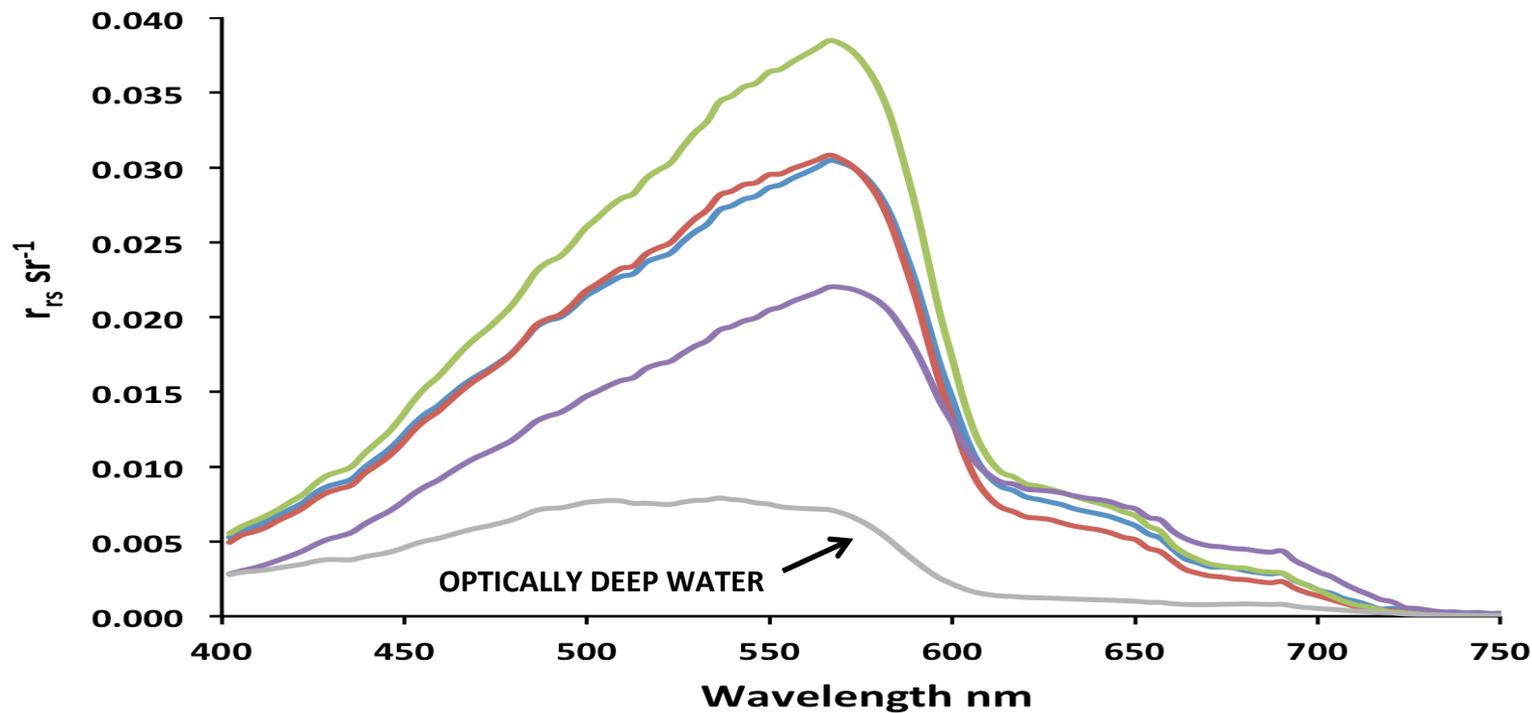


GoPro: 43431
Depth: 3.5 m

GoPro: 43500
Depth: 4.0 m

GoPro: 43537
Depth: 3.8 m

GoPro: 43602
Depth: 3.8 m



Example Spectra: Coral



GoPro: 43348
Depth: 2.5 m



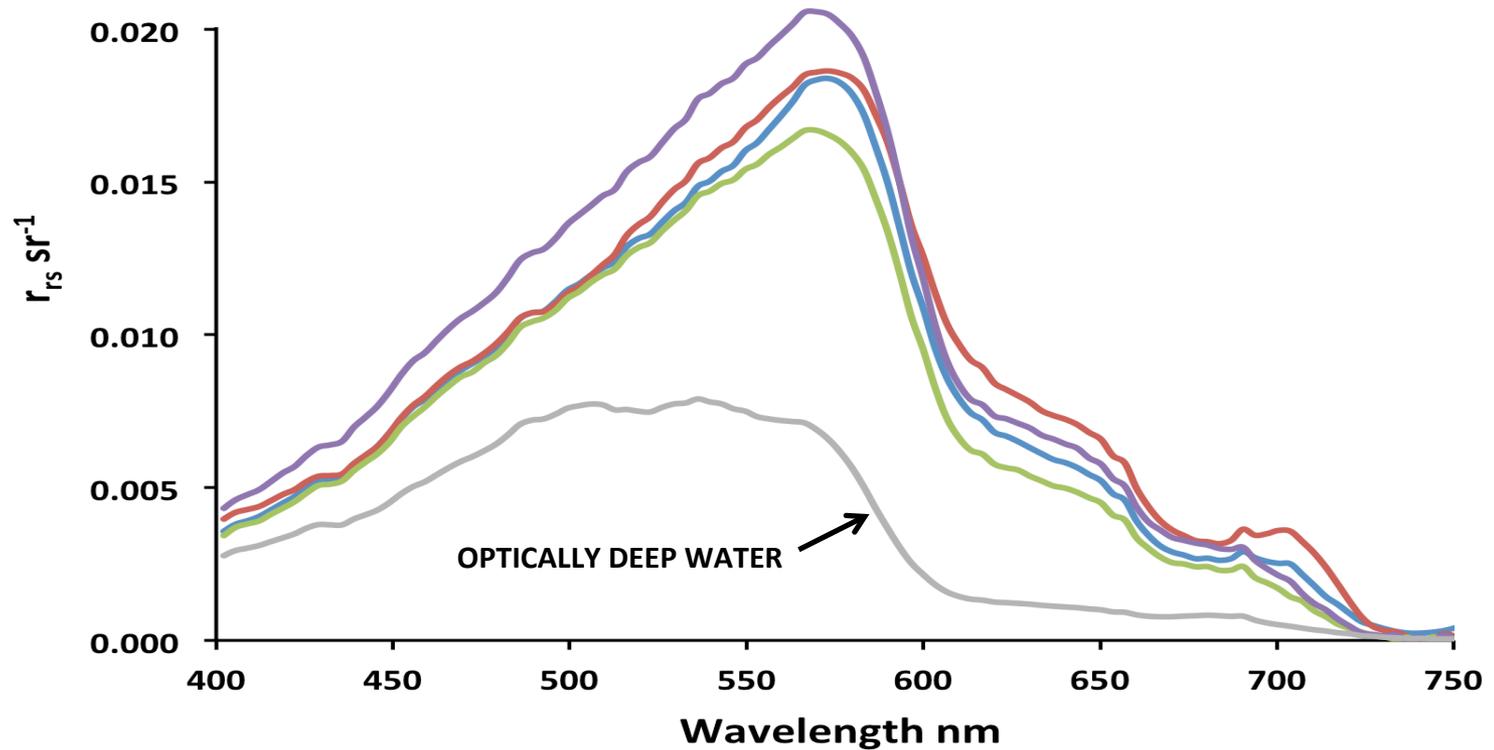
GoPro: 43386
Depth: 2.1 m



GoPro: 43571
Depth: 2.6 m



GoPro: 43648
Depth: 2.7 m



Example Spectra: Turf Algae

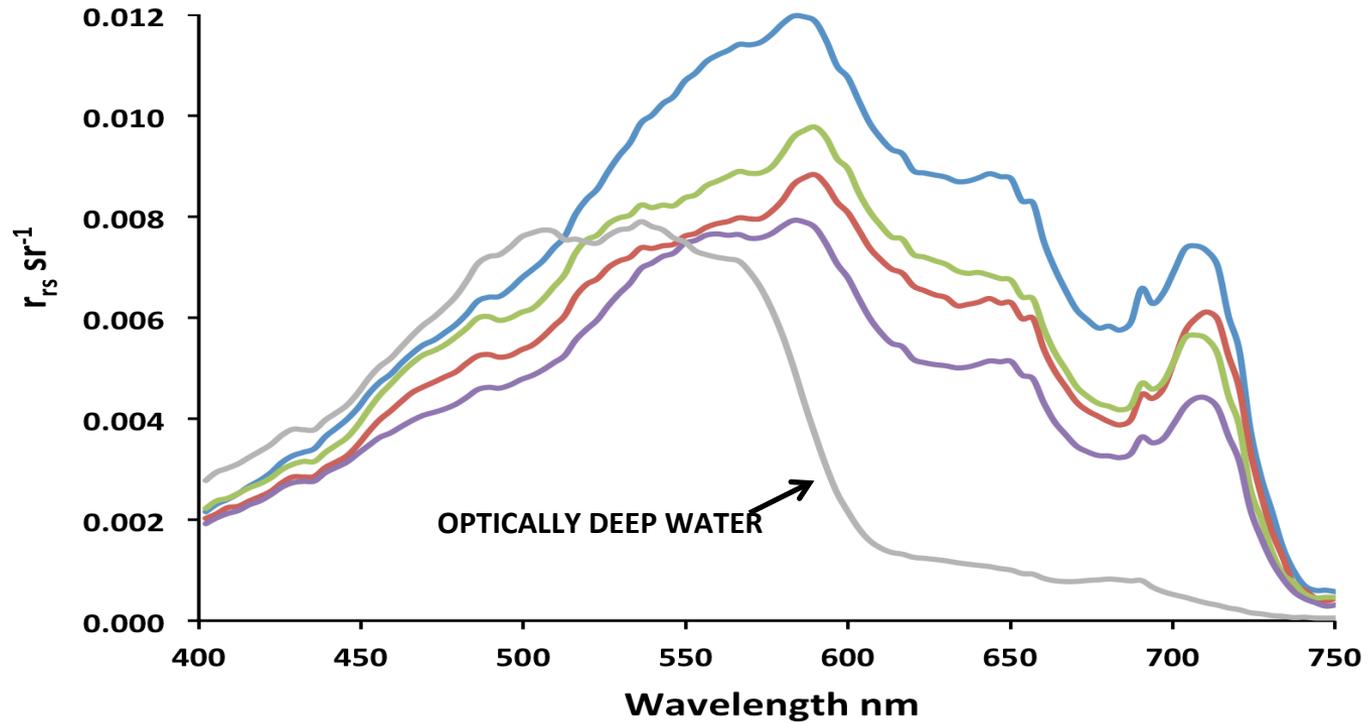


GoPro: 42803
Depth: 2.7 m

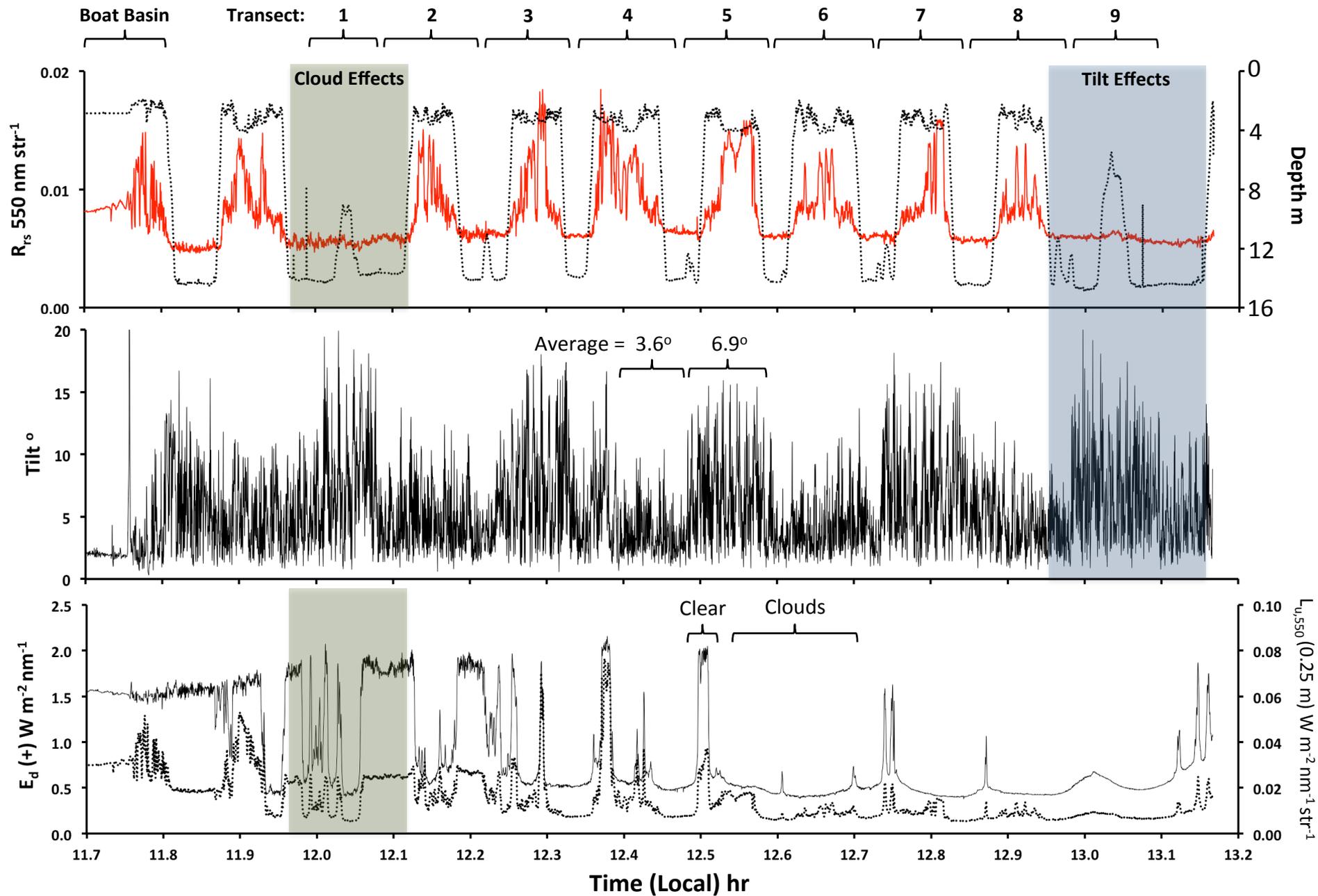
GoPro: 42807
Depth: 2.8 m

GoPro: 42811
Depth: 3.1 m

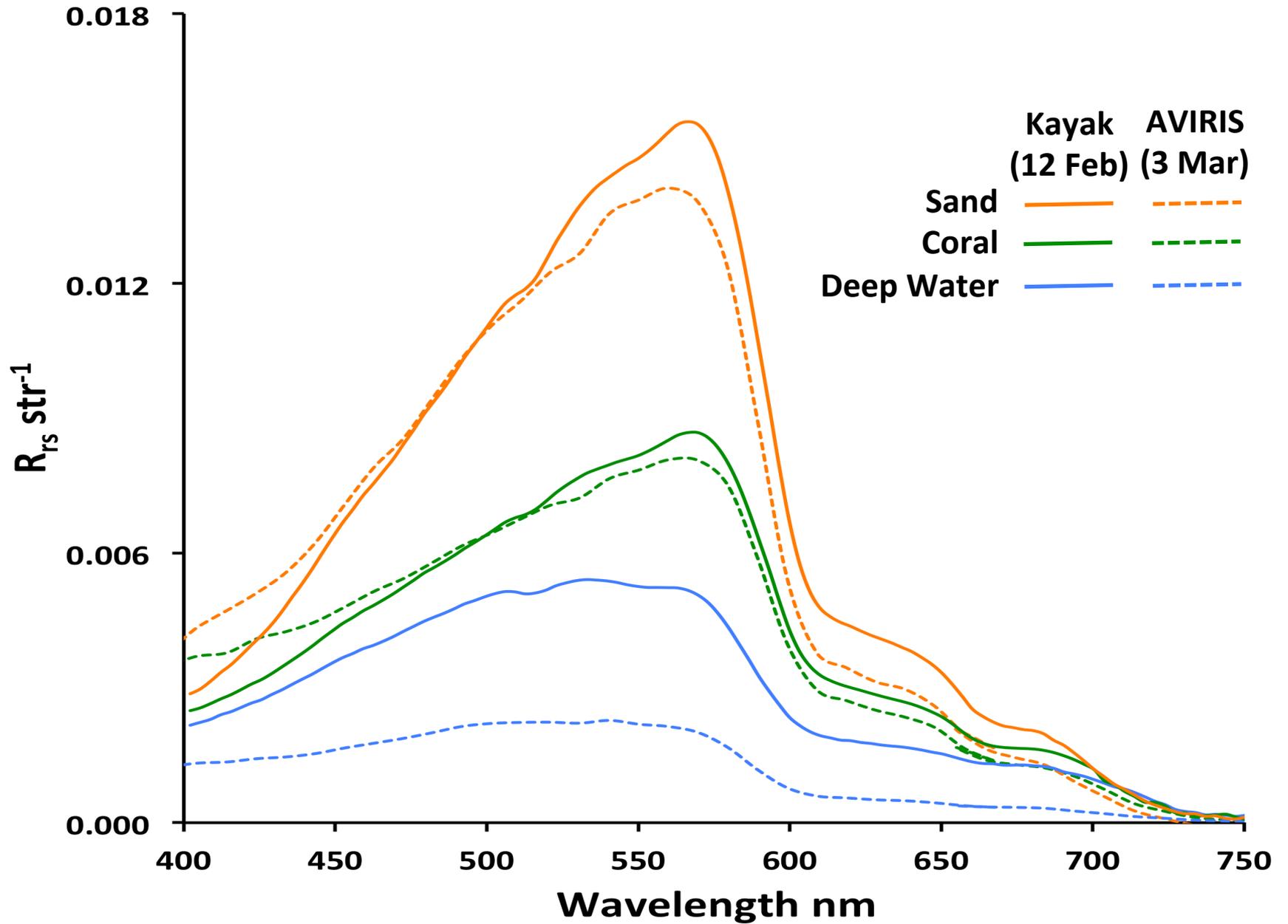
GoPro: 42820
Depth: 2.7 m



Effects of Buoy Orientation and Clouds?



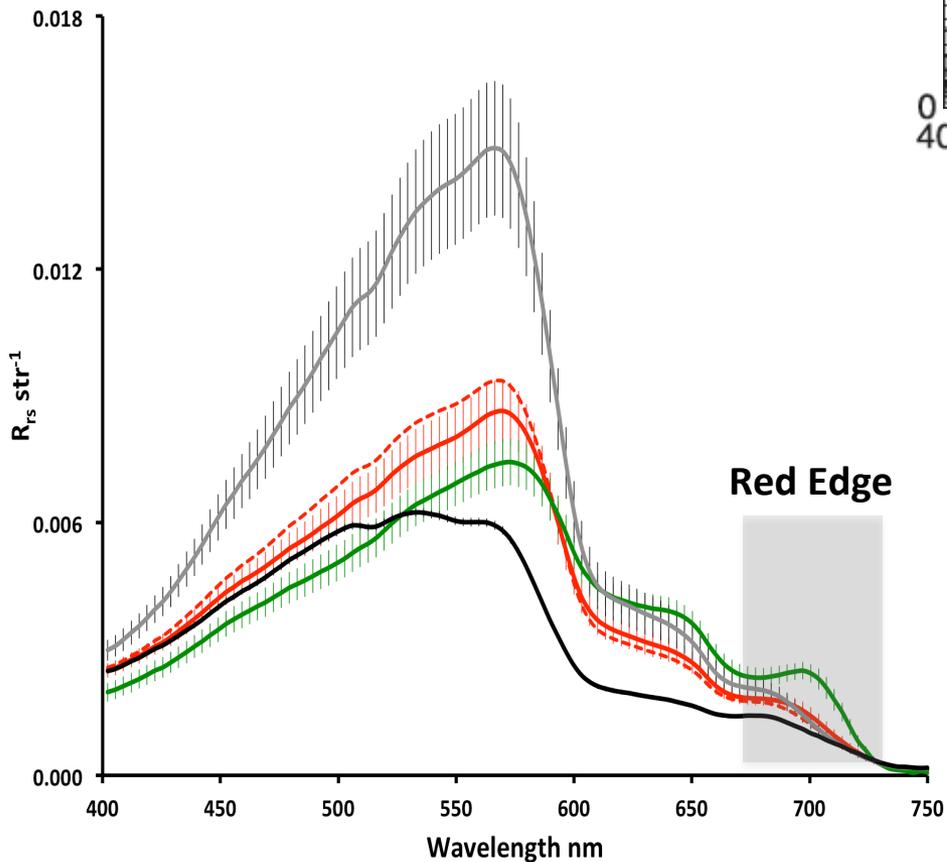
AVIRIS Vs. Kayak R_{rs}



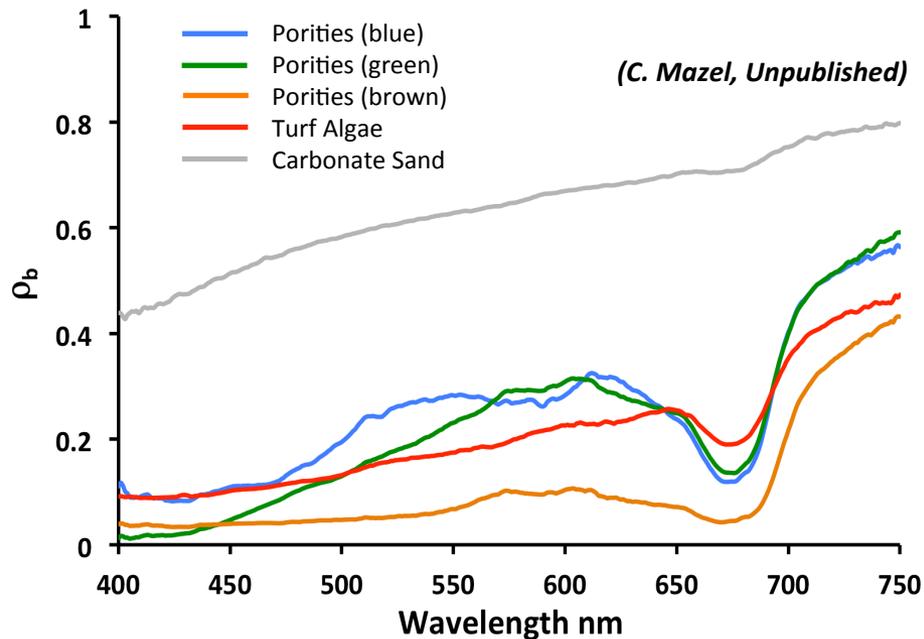
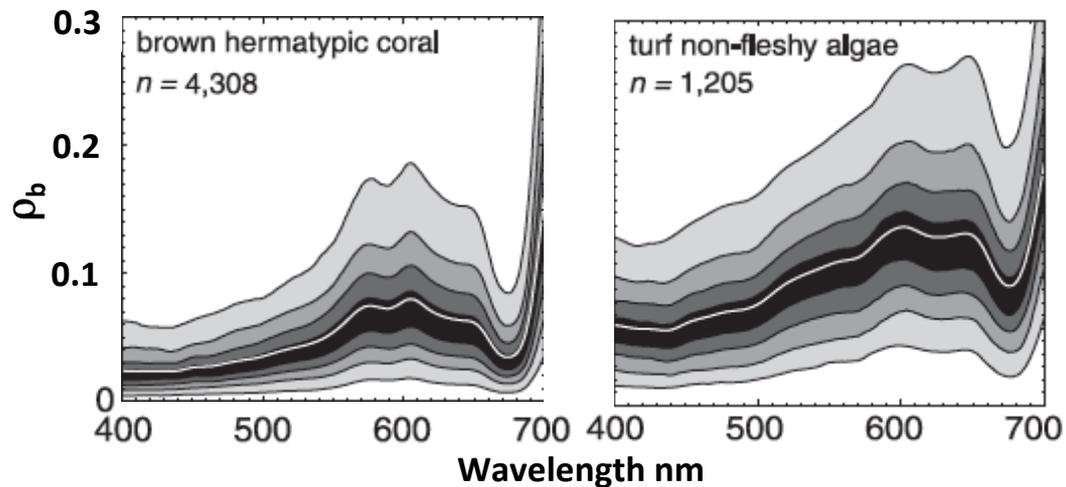
Red Edge Signal

In Situ: Coconut Reef

- Coral: D = 2.0-3.0 m
- - Coral: D = 3.0-4.0 m
- Algae: D = 1.5-2.5 m
- Sand: D = 3.0-4.0 m
- Deep Water; D > 14 m



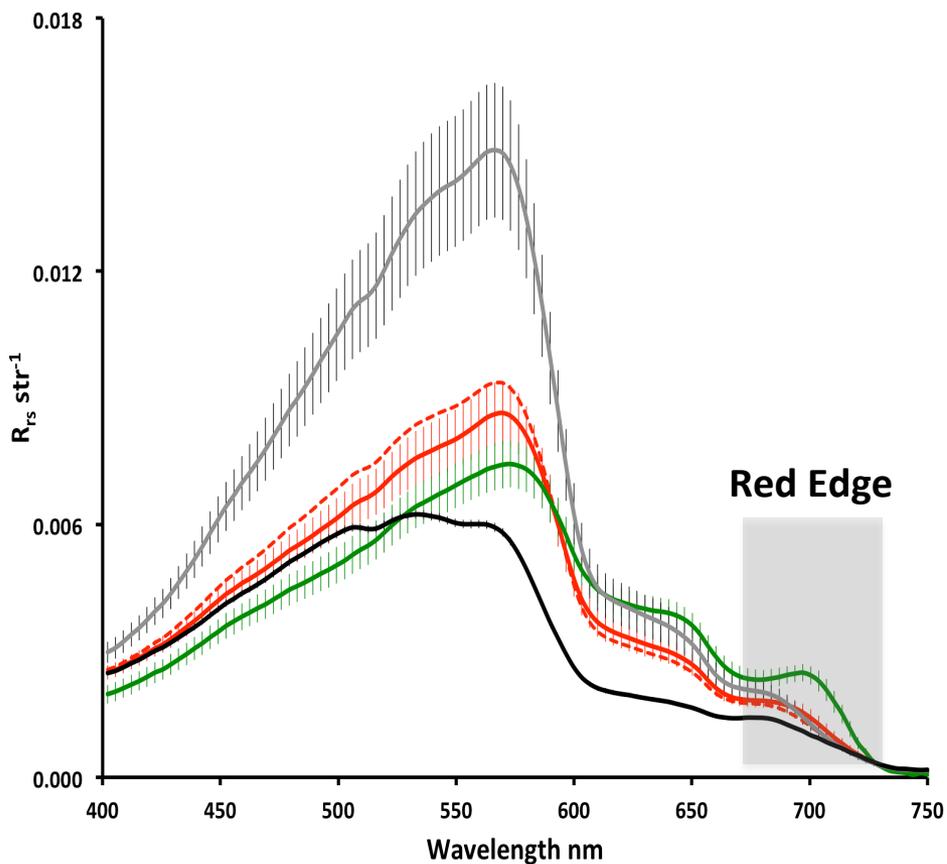
Benthic Reflectance (Hochberg et al., 2003)



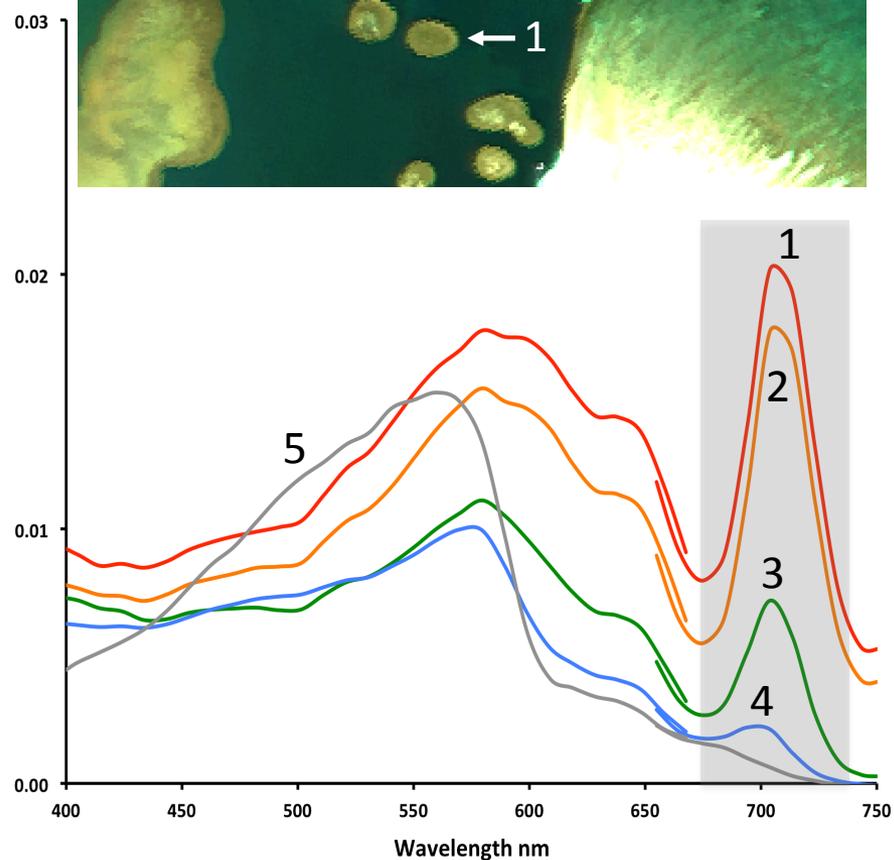
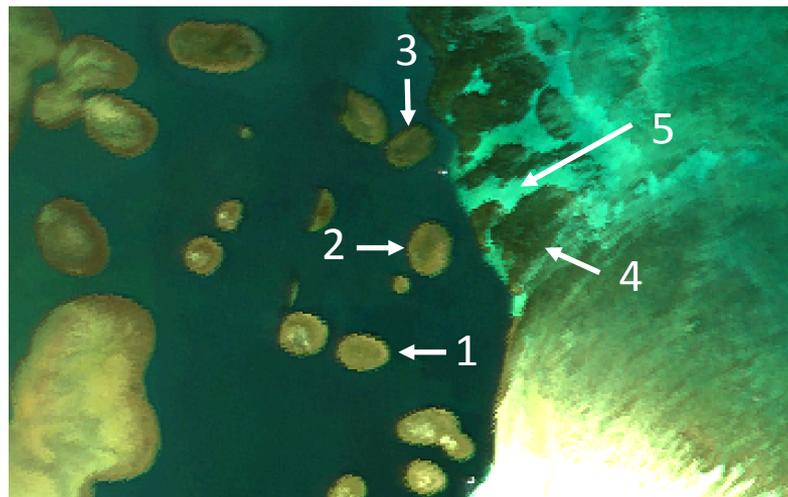
Red Edge Signal

In Situ: Coconut Reef

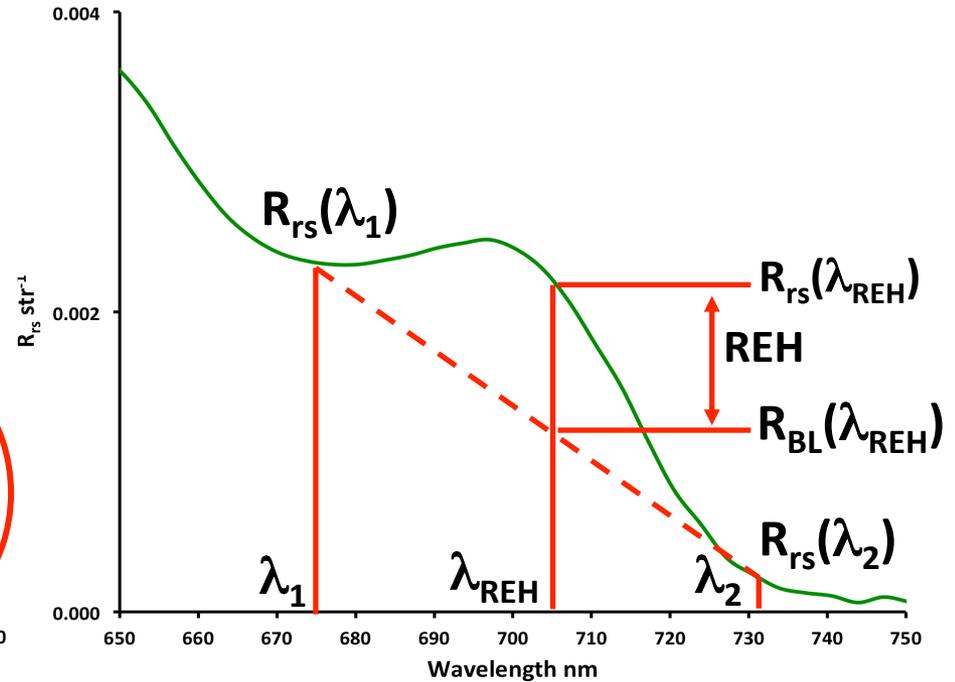
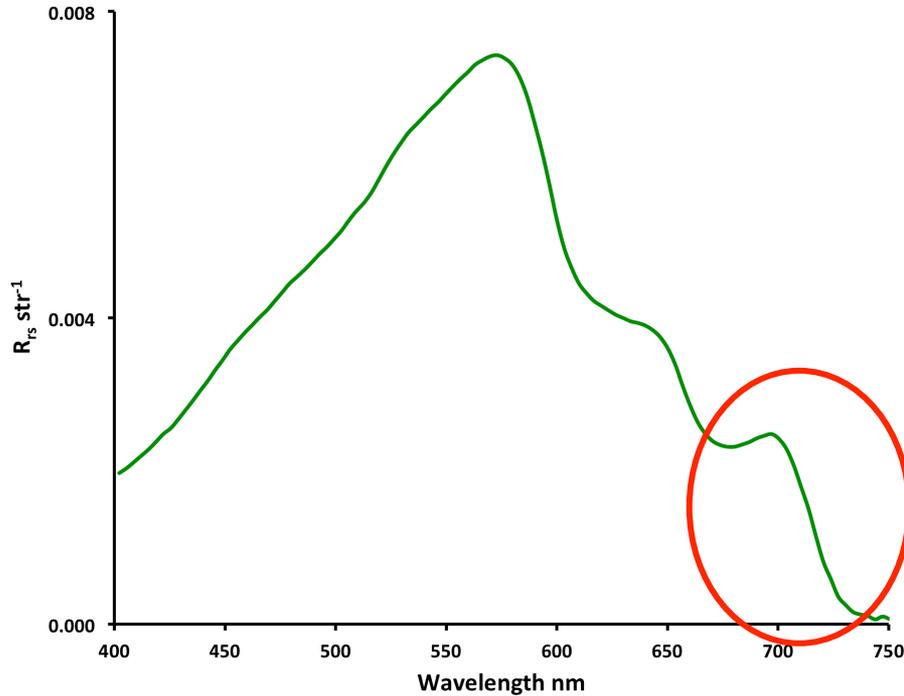
- Coral: D = 2.0-3.0 m
- - Coral: D = 3.0-4.0 m
- Algae: D = 1.5-2.5 m
- Sand: D = 3.0-4.0 m
- Deep Water; D > 14 m



AVIRIS: Patch Reefs



The Red Edge Height Computation



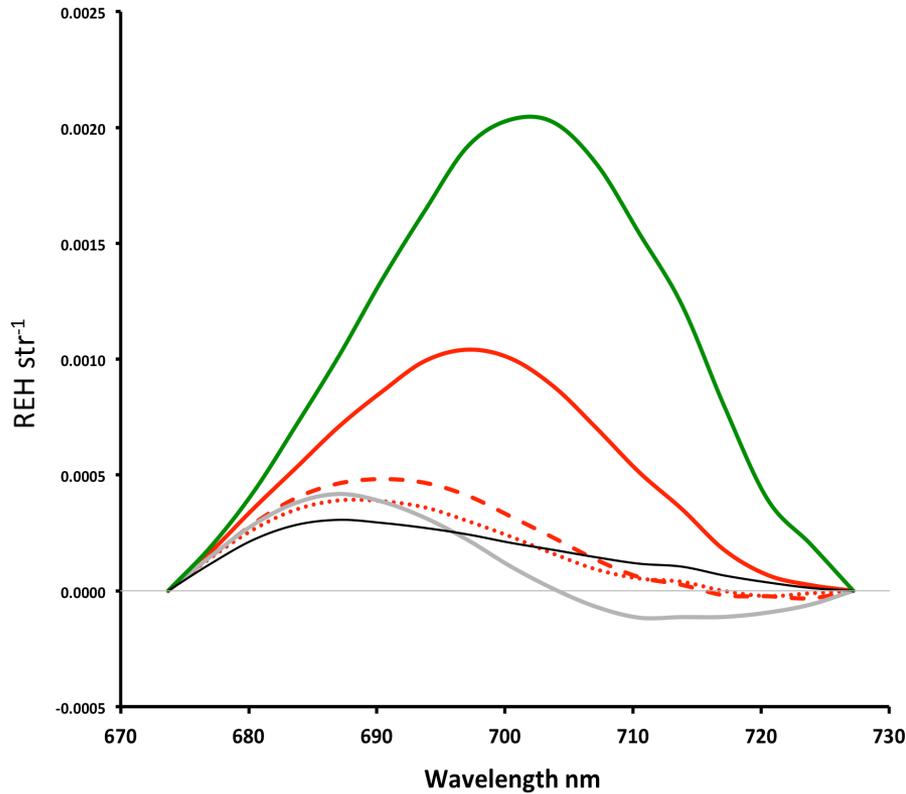
$$REH = R_{rs}(\lambda_{REH}) - R_{BL}(\lambda_{REH})$$

$$R_{BL}(\lambda_{REH}) = \frac{r_{rs}(\lambda_2) - r_{rs}(\lambda_1)}{\lambda_2 - \lambda_1} \cdot (\lambda_{REH} - \lambda_1) + R_{rs}(\lambda_1)$$

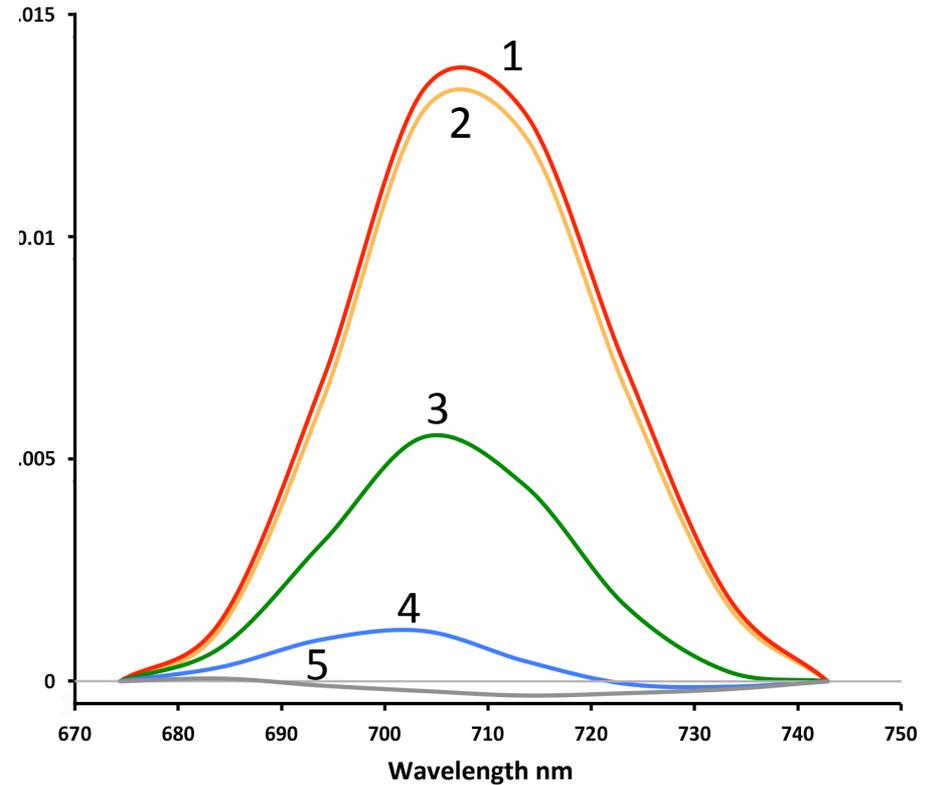
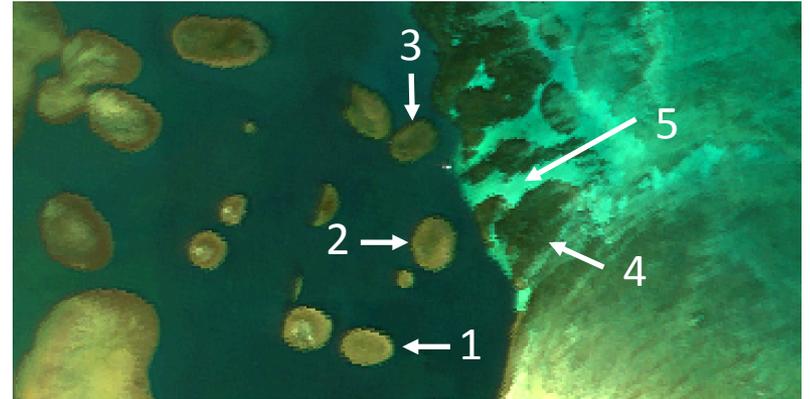
Red Edge Height

In Situ: Coconut Reef

- Coral: D = 1.5-2.5 m; N = 105
- - - Coral: D = 3.0-3.5 m; N = 345
- ⋯ Coral: D = 3.5-4.5 m; N = 144
- Algae: D = 1.5-2.5 m; N = 10
- Sand: D = 3.5-5.0 m; N = 386
- Deep Water; D > 14 m; N = 1,464



AVIRIS: Patch Reefs



Concluding Remarks

- **Autonomous approaches to collecting in situ observations over shallow coastal environments (e.g., coral reefs) in support of remote sensing are emerging rapidly.**
- **The diversity of conditions represented within autonomous data sets allows many more questions to be asked within the context of remote sensing including vicarious calibration, sources of uncertainty, and empirical approaches to algorithm development.**
- **In situ reflectance does not appear to be significantly impacted by radiometer orientation or cloud cover.**
- **A preliminary comparison between AVIRIS and in situ reflectance is quite good in both magnitude and spectra.**