Measuring In Water Radiometric Quantities and AOPs

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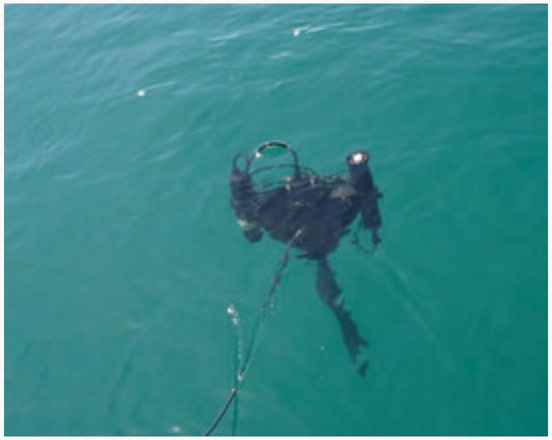
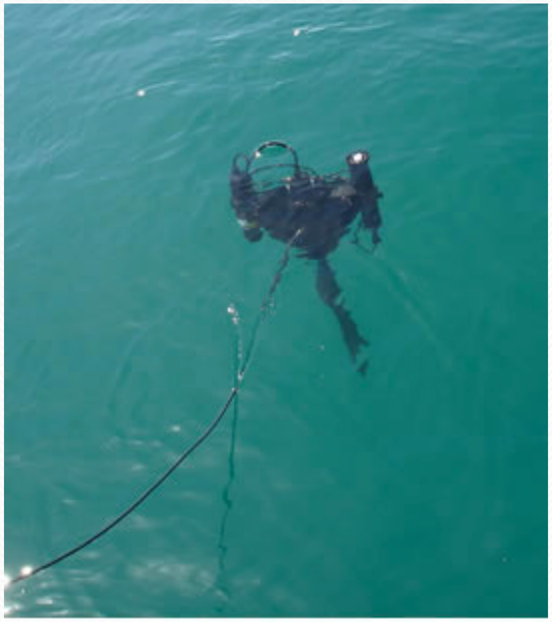
Radiometric Instruments: SatLantic HyperPro Profiling Radiometer

- Primary Radiometric Measurements:
  - Surface (above water) irradiance - $E_d(\lambda, 0+)$ or $E_s(\lambda)$
  - Submarine downwelling irradiance - $E_d(\lambda, z)$
  - Submarine upwelling radiance - $L_u(\lambda, z)$
- Ancillary Measures
  - C,T,D
  - Chl *a* Fluorescence
- Normally capable of radiometric profiles in depths exceeding 5 m
- By increasing the buoyancy (decreasing the drop rate), we can obtain profiles in 3 to 5 m depths typical of giant kelp forests



SatLantic HyperPro Profiling Radiometer QA/QC issues

- Reject frames when tilt exceeds 5°
  - mostly near the surface (<0.5 m)
- Correct for temporal variation in $E_s(\lambda)$ during profile collection (multiple casts over 5 to 20 min, depending on profile depth and repeatability)



What HyperPro measures:

- Above water downwelling spectral irradiance - $E_d(\lambda,0+)$
  - aka $E_s(\lambda)$
- In water downwelling spectral irradiance - $E_d(\lambda,z)$
- In water Upwelling spectral radiance - $L_u(\lambda,z)$

What we calculate from the profiles:

- Downwelling irradiance attenuation - $K_d(\lambda,z)$
- Upwelling radiance attenuation - $K_{Lu}(\lambda,z)$
- Remote sensing reflectance - $R_{rs}(\lambda)$

When we can't profile in shallow water:

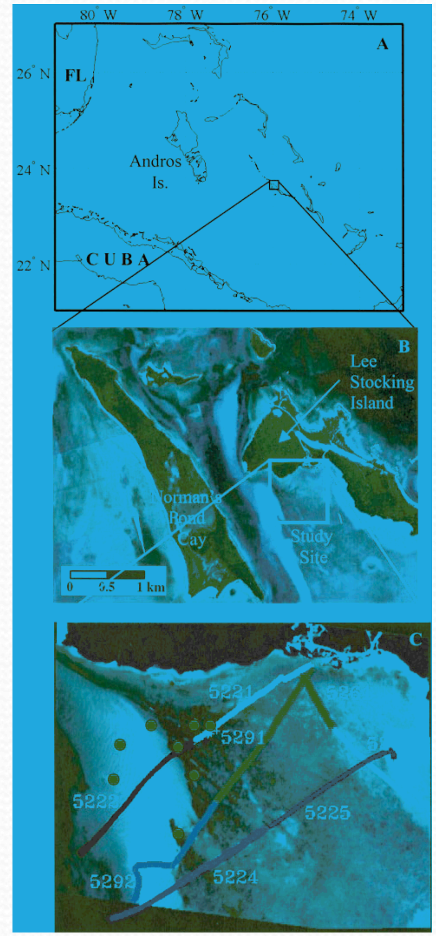
- Deploy HyperPro and HTSRB as floating buoys
  - Calculate $K_{\mathrm{Lu}}(\lambda)$ from difference in upwelling radiances measured by HyperPro at 0.2 m and HTSRB at 0.65 m depth, respectively
  - Calculate $R_{\mathrm{rs}}(\lambda)$ by propagating L_{u} to the surface and across the air-water interface
  - Unable to determine $K_{\mathrm{d}}(\lambda, z)$
  - Requires precise radiometric calibration among sensors

HyperPro and HTSRB data processing involve:

- Radiometric conversion of each channel
  - mfr-provided CAL files
  - renewed annually or before major expedition
- Dark current correction using shuttered spectra collected on each profile/deployment
- Common wavelength registration among channels
  - each spectrograph array is unique wrt pixel wavelength calibration
  - cubic spline interpolation to 1.0 nm (native res ~3 nm)
  - common wavelength registration required to calculate AOPs via channel ratios

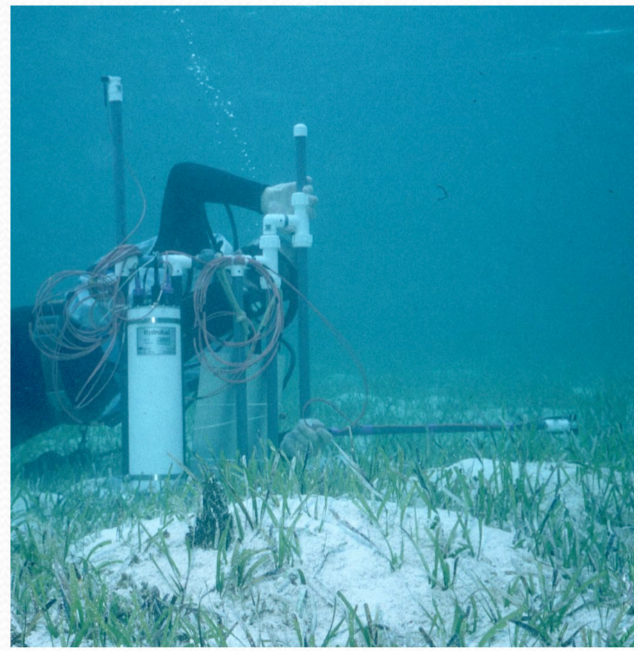
We can tow the HTSRB to obtain spatial estimates of $R_b(\lambda)$, bottom type, seagrass LAI, etc.

- Integrated depth sounder and GPS recorded with each spectral frame
- Need to know $K_{Lu}(\lambda)$
  - Periodic HyperPro profiles
  - IOPs and R/T modeling (e.g., *Hydrolight*)
- For details, see Dierssen et al. 2002. Limnol. Oceanogr. 48:444-455



Radiometric Instruments: Diver-Operated Benthic Bio-Optical Spectrometer (DOBBS)

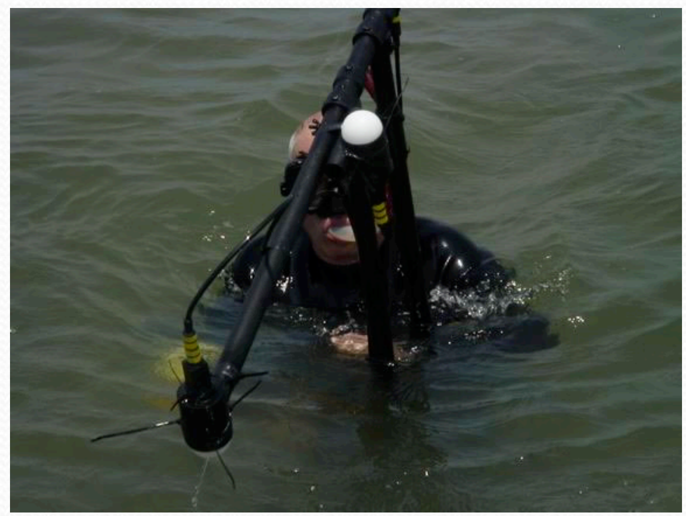
- 3-channel HydroRad (HOBI Labs)
- Measured radiometric quantities:
  - Reference $E_d(\lambda)$ 1 m above substrate
  - $E_d(\lambda)$ and $E_u(\lambda)$ deployed on ht-adjustable wand
- Calculated AOPs:
  - $R_b(\lambda)$ as $E_{u\text{-wand}}(\lambda)/E_{d\text{-wand}}(\lambda)$
  - $K_d(\lambda)$ as $\dfrac{-\ln\left(\dfrac{E_{d\text{-wand}}(\lambda,h)}{E_{d\text{-ref}}(\lambda,1)}\right)}{1-h}$



Radiometric Instruments:
Diver-Operated Benthic Bio-Optical Spectrometer (DOBBS)

- Vertical profiles of $E_d(\lambda)$ and $E_u(\lambda)$ within and beneath vegetation canopies
- Correct for temporal variation in $E_d(\lambda)$ during profiles using $E_{d\text{-ref}}(\lambda)$
- Calculate $K_{d\text{-canopy}}(\lambda)$ and $K_{d\text{-water}}(\lambda)$ separately
- Determine $R_{canopy}(\lambda)$

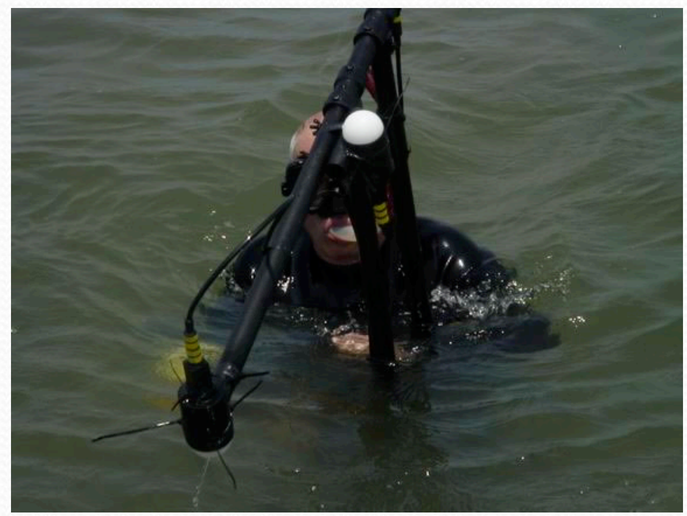
Radiometric Instruments: Robust Underwater Benthic Light Estimator (RU



- 4-channel HydroRad (HOBI Labs) mounted to a portable frame
- 2 plane irradiance ($E_d(\lambda)$) sensors
  - mount at different heights to compute $K_d(\lambda)$
- 2 Gershun sensors
  - $E_{G\text{-up}} = ½ [E_0(\lambda) + E(\lambda)]$
  - $E_{G\text{-dn}} = ½ [E_0(\lambda) - E(\lambda)]$

Calculating derived radiometric quantities and AOPs from RUBLE data

- Gershun sensors:
  - $E_o(l) = E_{G\text{-up}}(l) + E_{G\text{-dn}}(l)$
  - $E(l) = E_{G\text{-up}}(l) - E_{G\text{-dn}}(l)$
- Plane irradiance sensors:
  - $K_d(l) = -\ln[E_d(l,0)/E_d(l,h)]/h$
    - h is typically 1 m
- Plane and Gershun sensors combined:
  - $E_u(l) = \mathrm{Ed}(l) – \mathrm{E}(l)$
  - $\bar{\mu}(\lambda) = \dfrac{E_d(\lambda) + E_u(\lambda)}{E_o(\lambda)}$

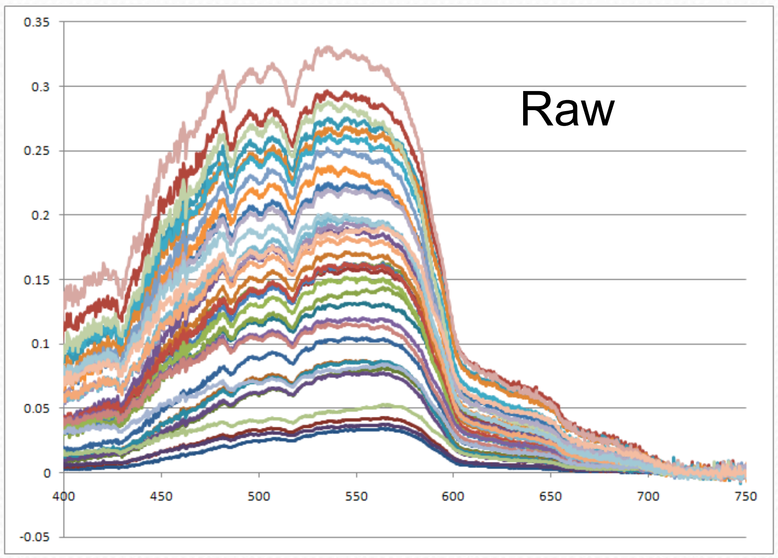


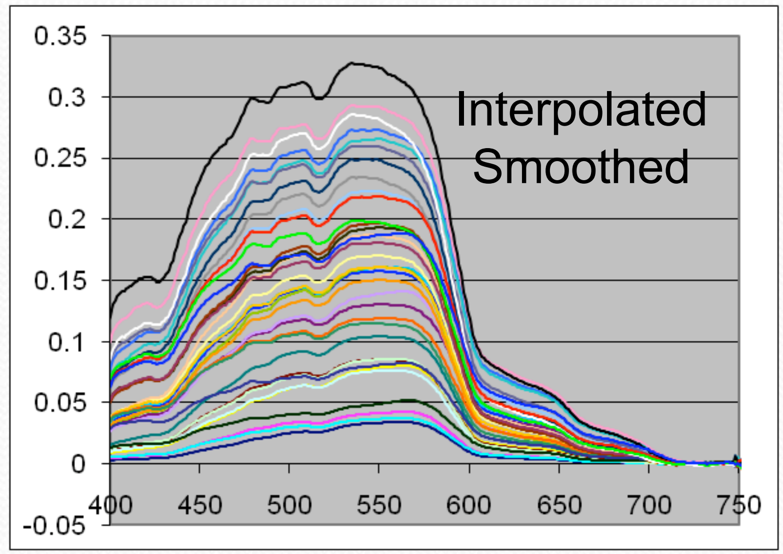
DOBBS and RUBLE data processing involve:

- Spectrum averaging of each channel
  - usually 10 spectral frames per sample
  - programmable feature of HR-3 controller
- Radiometric conversion of each channel
  - mfr-provided CAL files
  - renewed annually or before major expedition
- Common wavelength registration among channels to calculate AOPs via channel ratios
  - each spectrograph array is unique wrt pixel wavelength calibration
  - cubic spline interpolation to 1.0 nm (~0.3 nm native res)
  - smooth with 21 nm running mean (boxcar)

Example Data

Sub-canopy $E_d(\lambda)$ at Mohawk Reef





Thank you !