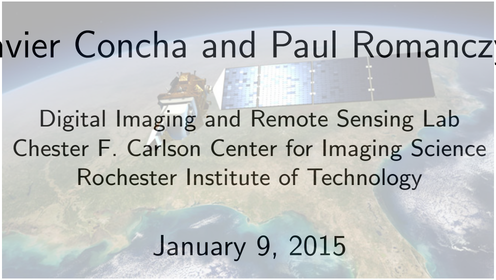
Intro to Instrumentation and Field Measurements in Remote Sensing



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Chester F. Carlson Center for Imaging Science
Rochester Institute of Technology

January 9, 2015

Presented for 2015 Intersession Term

Outline

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Outline

Course Goals

- Learn the importance of field measurements
- Learn how to take field measurements
- Learn about DIRS instruments

Course Description

- Friday: Introduction
- Monday: Introduction (con't) and DIRS instruments exhibition
- Tuesday: Lab: Reflectance measurements
- Wednesday: Lab: LIDAR measurements

Definitions

- **Remote Sensing:**
  "Remote sensing is the science of obtaining information about objects or areas from a distance, typically from aircraft or satellites."

- **Field Measurements or Groundtruth or Ground-based data or reference data or ancillary data:**
  "Observations or measurements made at or near the surface of the earth in support of remote sensing."

Motivation

Why is it important?

- Validation: comparison to know how close a model is to the field measurements (accuracy)
- Calibration or Correction: adjust model or instrument to be more precise (data fitting)
- Data collection to get characteristics of target, materials, etc.

Example: Field Data Collection

Area of Study

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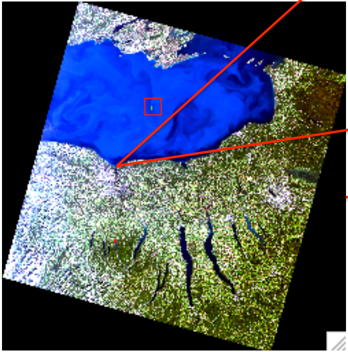
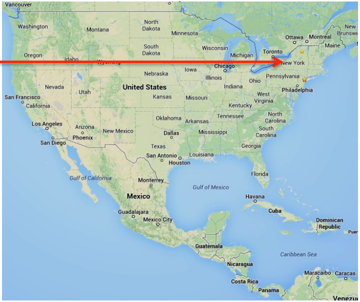
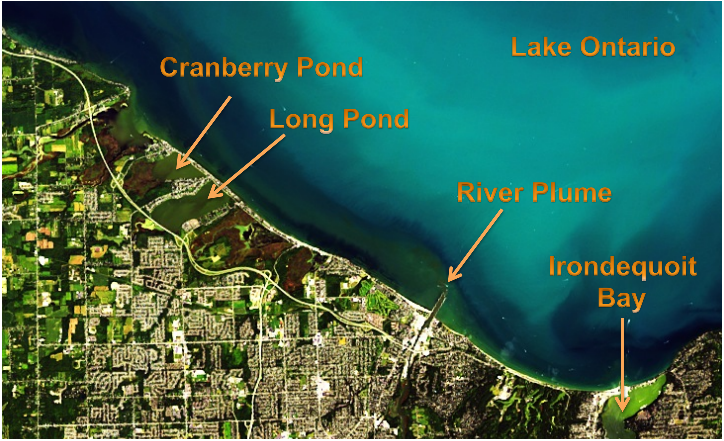


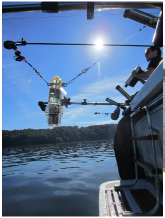


Field Data Collection (con't)

Area of Study

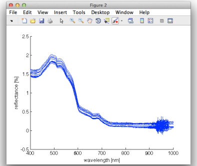


Field Data Collection (con't)



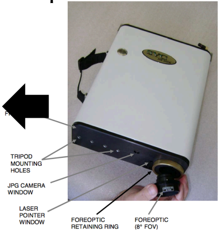
Water Samples

Lab Analysis



Water Leaving Reflectance

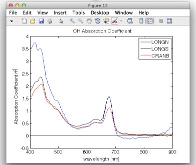
Spectroradiometer



Backscattering

Field Data Collection (con't)
Lab Measurements

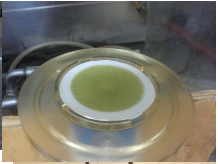
Spectrophotometer

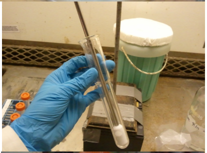


IOPs

Hydrolight

Filtration and Spectrophotometric Analysis





Concentrations

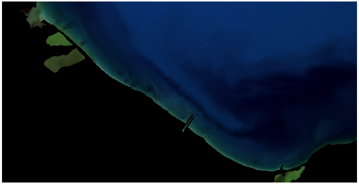
Field Data Collection (con't)

2013 and 2014 Seasons

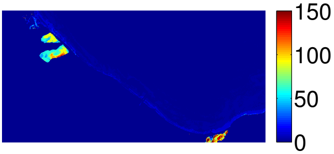
		IOPs		Concentrations		Reflectances		Backscattering	
Date		Ponds	Lake	Ponds	Lake	Ponds	Lake	Ponds	Lake
2013	25-Aug	✔	✗	✔	✗	✗	✗	✗	✗
	19-Sep	✔	✔	✔	✔	✗	✔	✔	✔
	26-Sep	✔	✔	✔	✔	✗	✔	✗	✔
2014	17-May	✔	✗	✔	✗	✔	✗	✔	✗
	02-Jun	✗	✔	✗	✔	✗	✔	✗	✔
	11-Jul	✔	✔	✔	✔	✔	✔	✗	✔
	28-Aug	✗	✔	✗	✔	✗	✗	✗	✗
	29-Sep	✔	✔	✔	✔	✔	✔	✔	✔

Retrieval
Concentration Maps

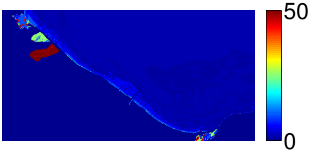
RGB image



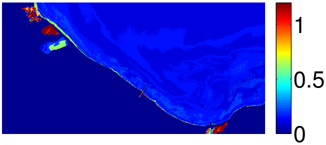
<CHL>, [µg/L]



<TSS>, [mg/L]



a_{CDOM}(440nm), [1/m]



Field Data Use

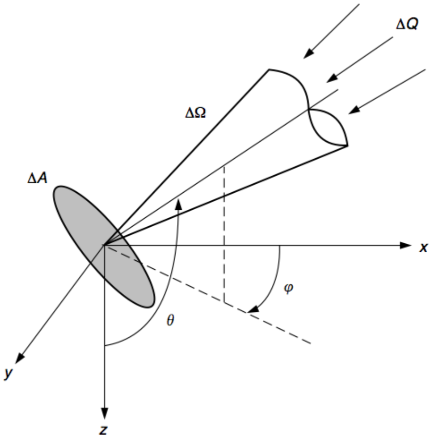
- Reflectance: Atmospheric Correction
- Chl-*a* concentration: comparison with model

Outline

Examples of Kind of Measurements

- Reflectance: Radiometer
- Concentration: Spectrophotometer
- Location: GPS
- Structure: LIDAR
- Leaf Area Index (LAI): Ceptometer

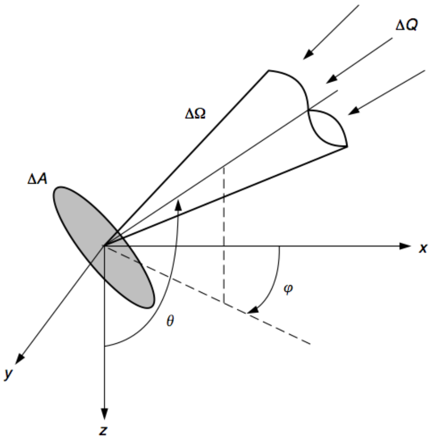
Radiometric Quantities: Radiance



ΔQ: radian energy incident
Δt: time interval
ΔA: surface area at location (x,y,z)
$\Delta\Omega$: solid angle in direction (θ,φ)
$\Delta\lambda$: photons wavelength interval

$$L(x,y,z,t,\theta,\varphi,\lambda) \equiv \frac{\Delta Q}{\Delta t \Delta A \Delta\Omega \Delta\lambda} \quad \left[Js^{-1}m^{-2}sr^{-1}nm^{-1}\right] \qquad (1)$$

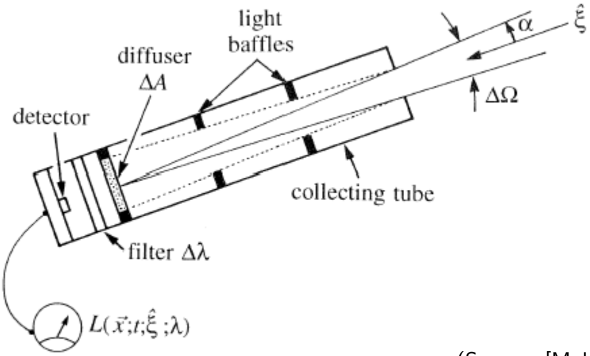
Radiometric Quantities: Radiance



ΔQ: radian energy incident
Δt: time interval
ΔA: surface area at location (x,y,z)
$\Delta\Omega$: solid angle in direction (θ,φ)
$\Delta\lambda$: photons wavelength interval

$$L(x,y,z,t,\theta,\varphi,\lambda) \equiv \frac{\partial^4 Q}{\partial t \partial A \partial \Omega \partial \lambda} \quad \left[Js^{-1}m^{-2}sr^{-1}nm^{-1}\right] \qquad (1)$$

Radiance Sensor



(Source: [Mobley, 2010])

Radiometric Quantities: Irradiance

Spectral downwelling scalar irradiance at depth z:

$$E_{od}(z,\lambda) = \int_{2\pi_d} L(z,\theta,\varphi,\lambda)d\Omega \quad \left[Wm^{-2}nm^{-1}\right] \tag{2}$$

Spectral upwelling scalar irradiance at depth z:

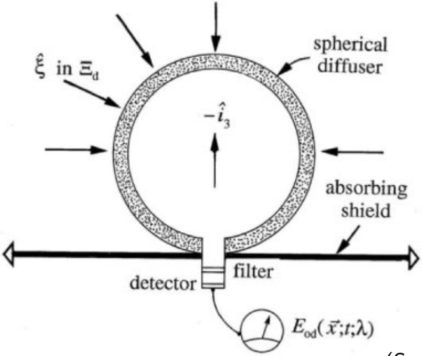
$$E_{ou}(z,\lambda) = \int_{2\pi_u} L(z,\theta,\varphi,\lambda)d\Omega \quad \left[Wm^{-2}nm^{-1}\right] \tag{3}$$

Spectral scalar irradiance at depth z:

$$E_o(z,\lambda) \equiv E_{od}(z,\lambda) + E_{ou}(z,\lambda) \tag{4}$$

$$= \int_{4\pi} L(z,\theta,\varphi,\lambda)d\Omega \tag{5}$$

Scalar Irradiance Sensor



(Source: [Mobley, 2010])

Radiometric Quantities: Irradiance

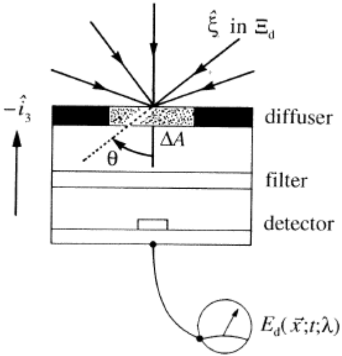
Spectral downwelling plane irradiance at depth z:

$$E_d(z,\lambda) = \int_{2\pi_d} L(z,\theta,\varphi,\lambda)|cos\theta|d\Omega \quad \left[Wm^{-2}nm^{-1}\right] \qquad (6)$$

Photosynthetic available radiation, **PAR**:

$$PAR(z) \equiv \int_{350nm}^{700nm} \frac{\lambda}{hc} E_o(z,\lambda)d\lambda \quad \left[photons\ s^{-1}m^{-2}\right] \qquad (7)$$

Planar Irradiance Sensor



(Source: [Mobley, 2010])

Reflectance

- **Irradiance reflectance:**

$$R(z,\lambda) \equiv \frac{E_u(z,\lambda)}{E_d(z,\lambda)} \tag{8}$$

- **Remote sensing reflectance (water):**

$$R_{rs}(\theta,\varphi,\lambda) \equiv \frac{L_w(\theta,\varphi,\lambda)}{E_d(\lambda)} \quad \left[sr^{-1}\right] \tag{9}$$

where L_w is the **water-leaving radiance**

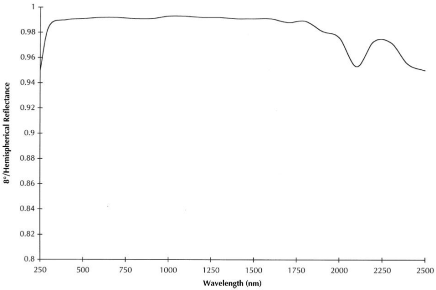
- **Bidirectional Reflectance Distribution Function (BRDF):**

$$r_{BRDF} = \frac{L(\theta_o,\phi_o)}{E(\theta_i,\phi_i)} \quad \left[sr^{-1}\right] \tag{10}$$

Outline

Diffuse white reference panel (Spectralon)

- For a Lambertian surface: $L = \frac{E_d r}{\pi} \Rightarrow E_d = \frac{L\pi}{r}$
- For spectralon $r \approx 1$ ($\approx 100\%$) $\Rightarrow E_d = L\pi$



Diffuse white reference panel (Spectralon)

$$L = \underbrace{E_s' \cdot \cos\sigma' \cdot \tau_1 \cdot \tau_2 \cdot \frac{\rho}{\pi}}_{\text{solar}} + \underbrace{F \cdot E_{ds} \cdot \tau_2 \cdot \frac{\rho_d}{\pi}}_{\text{sky}} + \underbrace{(1-F) \cdot E_{bs} \cdot \tau_2 \cdot \frac{\rho_d}{\pi}}_{\text{adjacency}} + \underbrace{L_{us}}_{\text{upwelling}} \tag{11}$$

Eqn. 4.69 from [Schott, 2007].

$$L = m \cdot \rho + b \tag{12}$$
$$L_{tar} = m \cdot \rho_{tar} + b \tag{13}$$
$$L_{ref} = m \cdot \rho_{ref} + b \tag{14}$$
$$\rho_{tar} = \frac{L_{tar} - b}{m} \tag{15}$$
$$m = \frac{L_{ref} - b}{\rho_{ref}} \tag{16}$$
$$\rho_{tar} = \frac{L_{tar} - b}{L_{ref} - b} \cdot \rho_{ref} \tag{17}$$

Reflectance

- **Reflectance:** $R(z, \lambda) \equiv \dfrac{L_u(z, \lambda)}{E_d(z, \lambda)}$
- Two measurements:
  - E_d: Spectralon
  - L_u: Target or sample

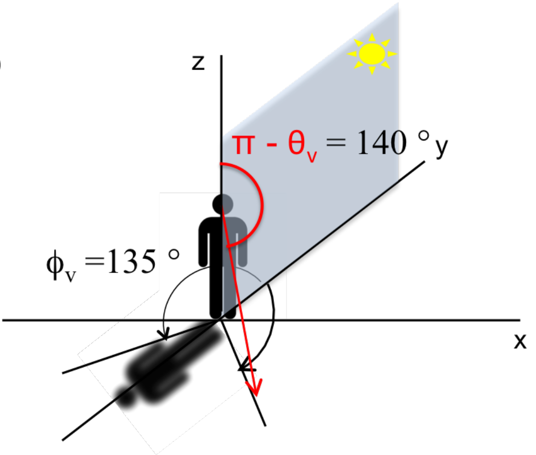
Remote-Sensing Reflectance

- 3 measurements:
  - L_g (spectralon)
  - $L_t = L_r + L_w$ (water)
  - L_{sky}
- Remote-sensing reflectance:

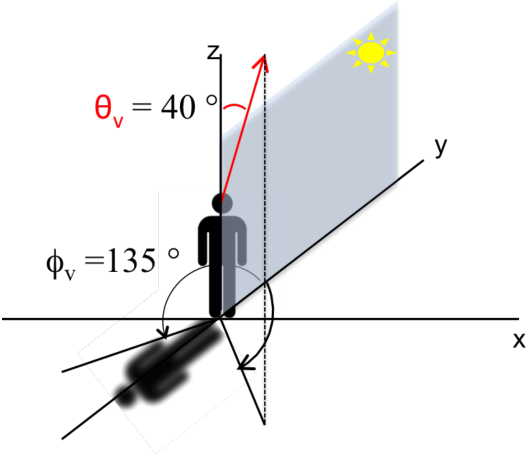
$$R_{rs} = L_w / E_d$$
$$= (L_t - L_r)/E_d$$

with $L_r = 0.028 * L_{sky}$

- $E_d = L_g * \pi$
- ϕ : azimuthal angle
- θ : zenith angle



L_{sky}



Things to consider for a field campaign

- Planning ahead: permits, what kind of measurements, how many people, what conditions, instruments availability, shipping, prioritization of data.
- Equipment check list
- Contact list: phone numbers, emergency numbers, emails
- Risk management form (RIT requirement)
- Direction how to get to the place

Things to consider for a field campaign

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- Have a good datasheet
- Download and look data from the instrument ASAP!!!
- Tools for in-field repairs and cleaning
- Water, food, field clothes, first aid kit
- Plan collection ahead of time
- Write down procedure
- Setting up plots/sites
- Take pictures

Things to consider for a field campaign

- Read instrument manual
- Check and charge batteries in advance
- Check instrument in advance
- The data should be taken as close to the time of acquisition as possible (due to inevitable landscape changes)
- Weather conditions
- Take measurement in same illumination conditions

Outline

DIRS Lab Instruments

- ASD (Spectroradiometer; reflectance, radiance)
- SVC (Spectroradiometer; reflectance, radiance)
- RIT LIDAR
- GRIT (Goniometer; BRDF)
- GPS (Location)
- HydroScat-2 (Backscattering)
- AccuPAR LP-80 (PAR energy)

DIRS Lab Instruments (con't)

- WASP (Multispectral Instrument)
- WASP Lite (Multispectral Instrument)
- MISI (Multispectral Instrument)
- Thermistor (Temperature)
- Spectrophotometer (Absorbance)
- Camera

DIRS Lab Instruments (con't)

ASD

- FieldSpec 4 Spectroradiometer
- Spectral Range: 350-2500 nm (UV, VIS, NIR and SWIR)
- Sampling Interval:
  - 1.4 nm (350-1000 nm)
  - 2 nm (100-2500 nm)

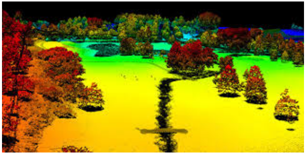
DIRS Lab Instruments (con't)
SVC

- Spectra Vista Corp. (SVC) Spectroradiometer
- Spectral Range: 350-2500 nm (UV, VIS, NIR and SWIR)
- Sampling Interval:
    - 1.5 nm, 350-1000 nm
    - 3.8 nm, 1000-1890 nm
    - 9.5 nm, 1890-2500 nm

DIRS Lab Instruments (con't)

LIDAR

- Light Detection and Ranging (LiDAR)
- Similar to RADAR but it uses laser light.
- Generate 3D models of the environment



Outline

Data Extraction

- Raw data in proprietary format (depending of the instrument). Ex: *.dat, *.SPC
- Translate or export to ASCII (*.txt, *.ASC)
- Text files manipulation (IDL, Matlab, Python, C++, bash).

Data in ASCII format

ASD


```
Text conversion of header file \Data\ASD_2014_toughbook\2014_08_28_LANDSAT\water2b00004.asd.rad
 -------------------------------------------------------------
water
The instrument number was  6142/12
New ASD spectrum file: Program version = 6.00 file version = 1.00
Spectrum saved: 08/28/2014 at 12:21:57
VNIR integration time : 34
VNIR channel 1 wavelength = 350 wavelength step = 1
There were 10 samples per data value
xmin = 350 xmax= 2500
ymin= 0 ymax= 1
The instrument digitizes spectral values to 16 bits
SWIR1 gain was 42 offset was 2064
SWIR2 gain was 16 offset was 2076
Join between VNIR and SWIR1 was 1000 nm
Join between SWIR1 and SWIR2 was 1830 nm
VNIR dark signal subtracted
10 dark measurements taken Thu Aug 28 12:15:46 2014
DCC value was 0
Data is not compared to a white reference
There was a 3-degree FOV foreoptic attached
GPS-Latitude is S0
GPS-Longitude is E0
GPS-Altitude is 0
GPS-UTC is Wed Dec 31 19:00:00 1969

Smart Detector
Serial#  0
Signal (A)  0.000E00
Dark (A)  0.000E00
Ref (A)  0.000E00
Status  0 - Uninitialized
Gain  E-4
Averaging  0
Temp (C)  0.0
Humid (%)  0.0

Wavelength      water2b00004.asd.rad
350      4.17592842131853E-03
351      4.22246055677533E-03
352      4.17632004246116E-03
```

Data in ASCII format

SVC

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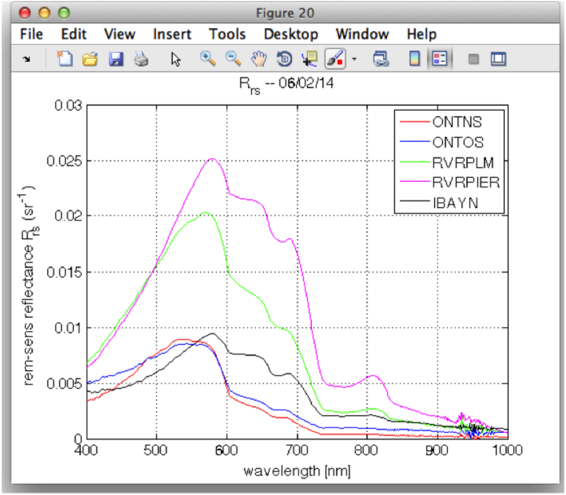
```
/*** Spectra Vista SIG Data ***/
name= gr092413_142.sig
instrument= HI: 9122002 (HR-1024i)
integration= 10.0, 30.0, 10.0, 1000.0, 40.0, 10.0
scan method= Time-based, Time-based
scan coadds= 200, 61, 156, 2, 46, 156
scan time= 2, 2
scan settings= AI, AI
external data set1= 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
external data set2= 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
external data dark= 0,0,0,0,0,0,0,0
external data mask= 0
optic= LENS 4(1), LENS 4(1)
temp= 36.1, -4.6, -10.2, 36.1, -4.6, -10.1
battery= 7.78, 7.74
error= 3, 1
units= Radiance, Radiance
time= 9/19/2013 12:08:32 PM, 9/19/2013 12:08:53 PM
longitude= 07732.3414W     , 07732.3417W
latitude= 4316.3654N      , 4316.3657N
gpstime= 151249.000       , 151309.000
comm=
memory slot= 152, 153
factors= 1.053, 1.013, 1.000 [Overlap: Remove @ 980,1903, Matching Type: Radiance @ 961 - 1000
data=
334.0  7105.27  101.36  1.43
335.5  7798.39  129.59  1.66
337.0  8765.39  127.53  1.45
338.5  9767.27  162.84  1.67
340.0  10394.63  151.98  1.46
341.5  11282.51  197.12  1.75
```

Text files manipulation
SVC



Outline

Field Campaigns

- Negative
  - Weather dependent
  - Extreme environmental conditions (too cold or too hot)
  - Instrumentation failure
  - Long days
- Positive
  - Brings theory to practice
  - Appreciate nature (nice to be outside your office)
  - Get to know more about your colleagues
  - Know new places
  - It is FUN!

Field Campaigns in Pictures

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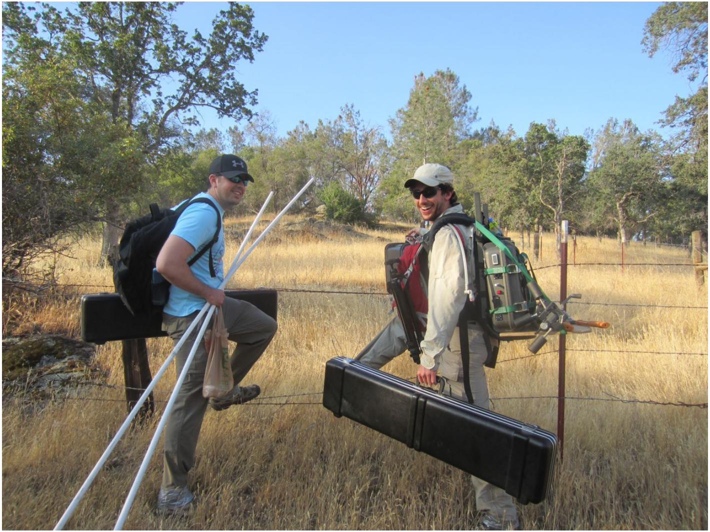

Field Campaigns in Pictures

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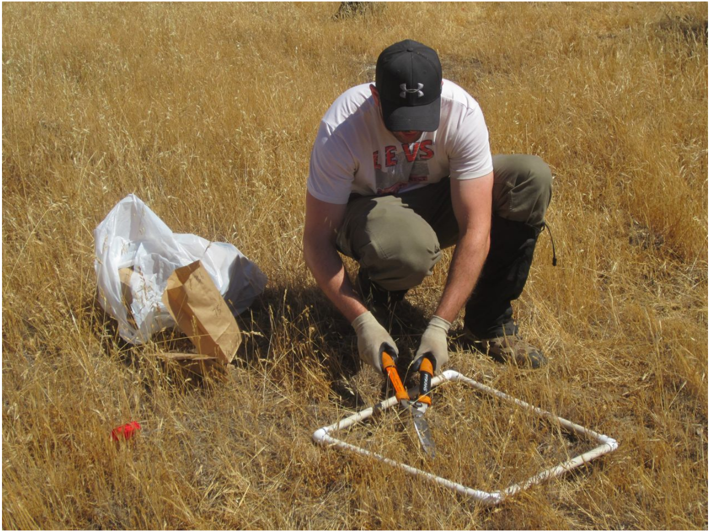

Field Campaigns in Pictures

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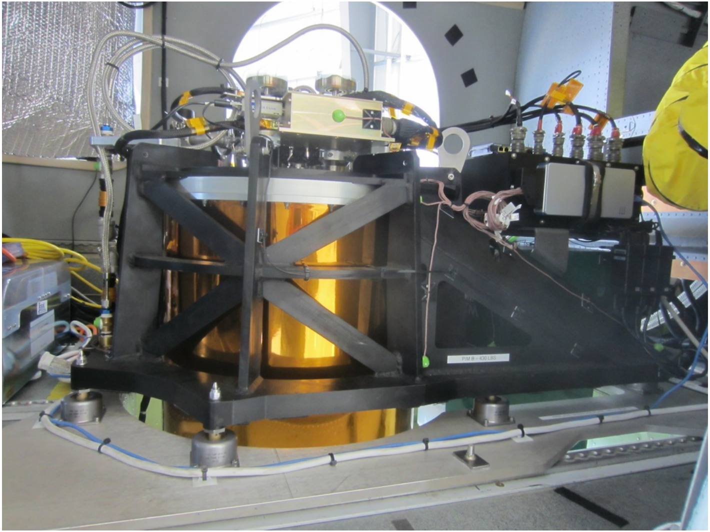

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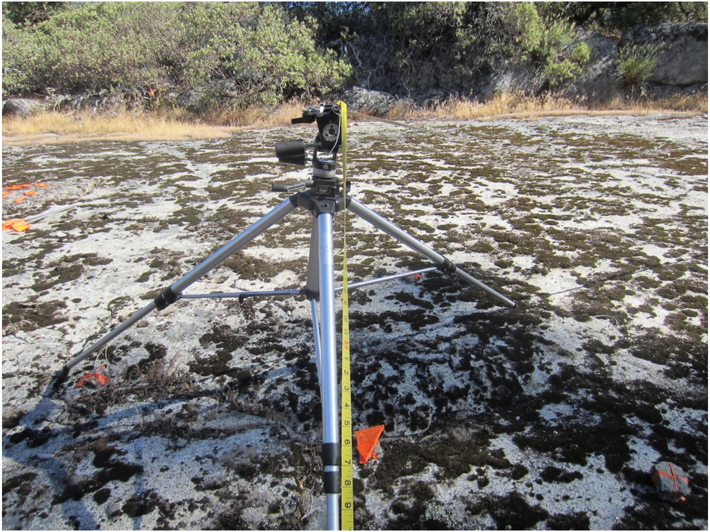

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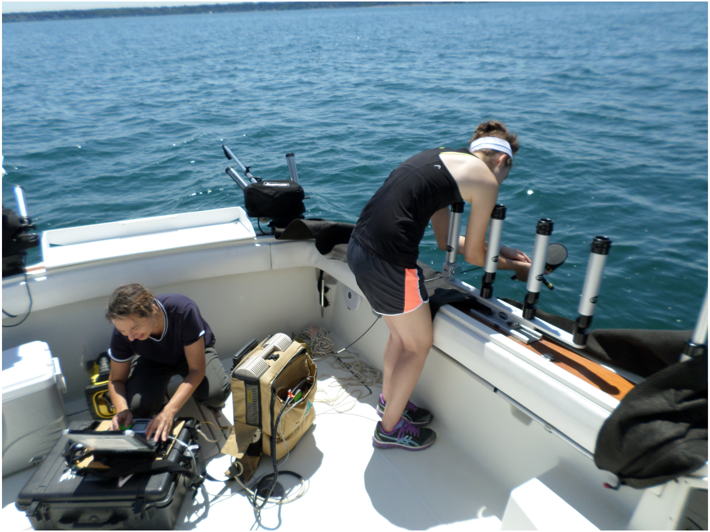

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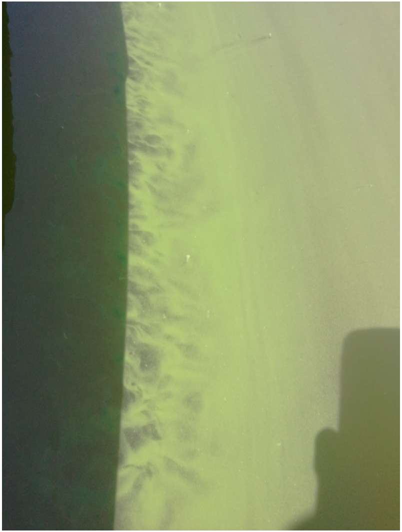

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Thanks for your attention!

QUESTIONS?

Thanks for your attention!

QUESTIONS?

References

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http://www.oceanopticsbook.info/.

[[Schott, 2007]]Schott, J. R. (2007).
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Oxford University Press, USA, 2 edition.