

# Intro to Instrumentation and Field Measurements in Remote Sensing

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Presented for 2015 Intersession Term

# Outline

- ① Introduction
- ② Background
- ③ Preparation
- ④ Taking Measurements
- ⑤ DIRS Instruments
- ⑥ Data Processing
- ⑦ Conclusions

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# 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:**

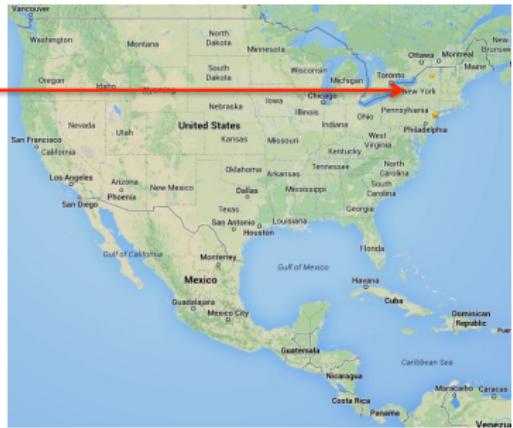
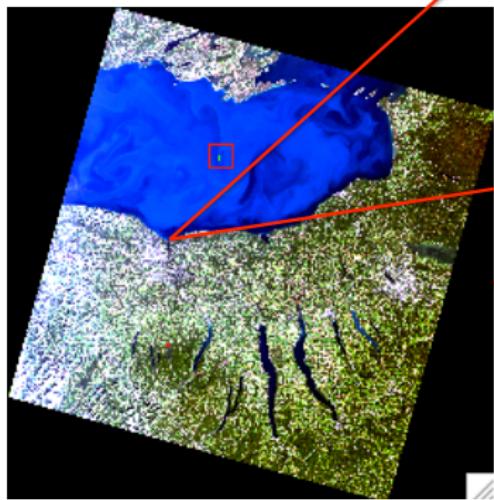
“Observations or measurements made at or near the surface of the earth in support of remote sensing.”

# 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



# Field Data Collection (con't)

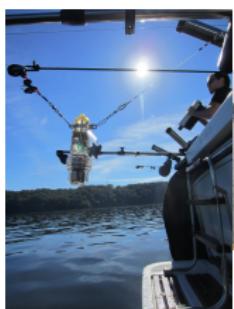
## Area of Study



# Field Data Collection (con't)

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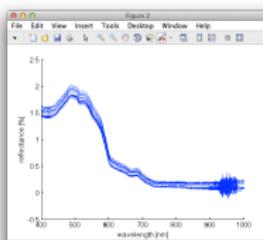
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Water Samples



Lab Analysis



Water Leaving  
Reflectance



Backscattering

Spectroradiometer



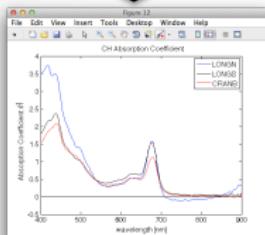
# Field Data Collection (con't)

## Lab Measurements

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### 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

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/Users/javier/Desktop/Javier/PH

# Field Data Use

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

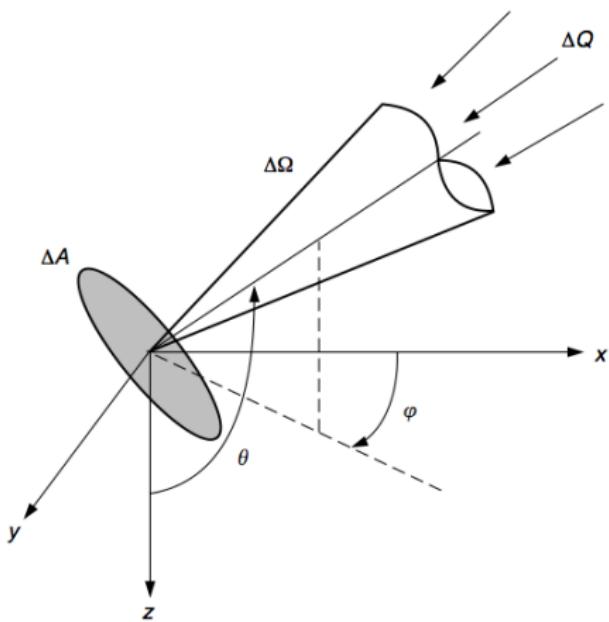
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# Examples of Kind of Measurements

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

# Radiometric Quantities: Radiance



$\Delta Q$ : radian energy  
incident

$\Delta t$ : time interval

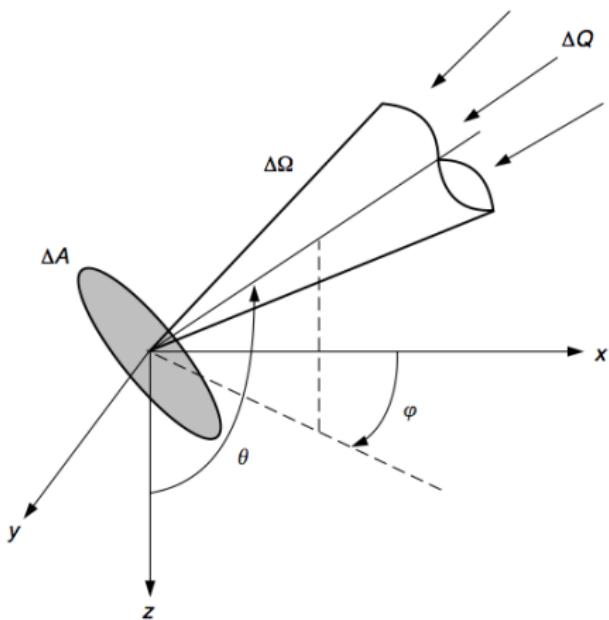
$\Delta A$ : surface area at  
location  $(x,y,z)$

$\Delta\Omega$ : solid angle in  
direction  $(\theta,\varphi)$

$\Delta\lambda$ : photons wavelength  
interval

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

# Radiometric Quantities: Radiance



$\Delta Q$ : radian energy  
incident

$\Delta t$ : time interval

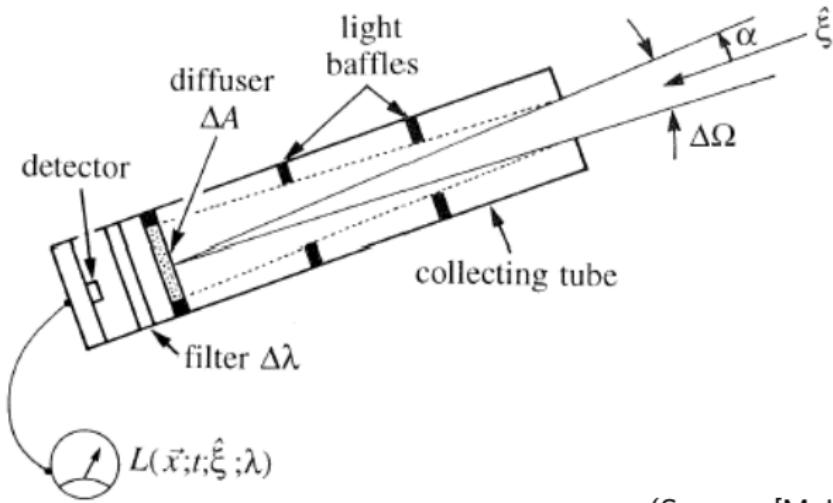
$\Delta A$ : surface area at  
location  $(x,y,z)$

$\Delta\Omega$ : solid angle in  
direction  $(\theta,\varphi)$

$\Delta\lambda$ : photons wavelength  
interval

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

# Radiance Sensor



(Source: [Mobley, 2010])

# Radiometric Quantities: Irradiance

**Spectral downwelling scalar irradiance** at depth  $z$ :

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

**Spectral upwelling scalar irradiance** at depth  $z$ :

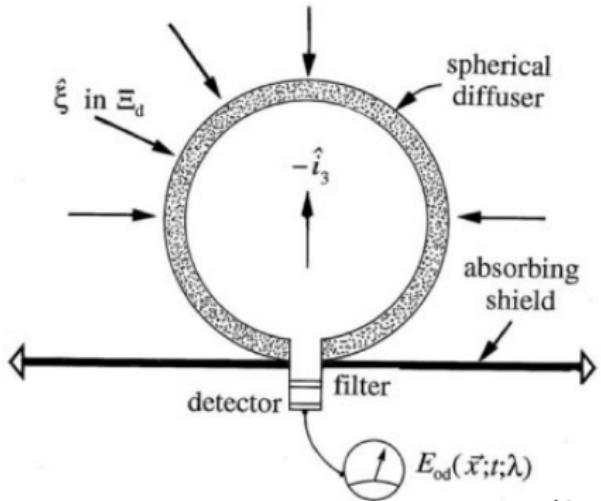
$$E_{ou}(z, \lambda) = \int_{2\pi_u} L(z, \theta, \varphi, \lambda) d\Omega \quad [Wm^{-2}nm^{-1}] \quad (3)$$

**Spectral scalar irradiance** at depth  $z$ :

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

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

# Scalar Irradiance Sensor



(Source: [Mobley, 2010])

# Radiometric Quantities: Irradiance

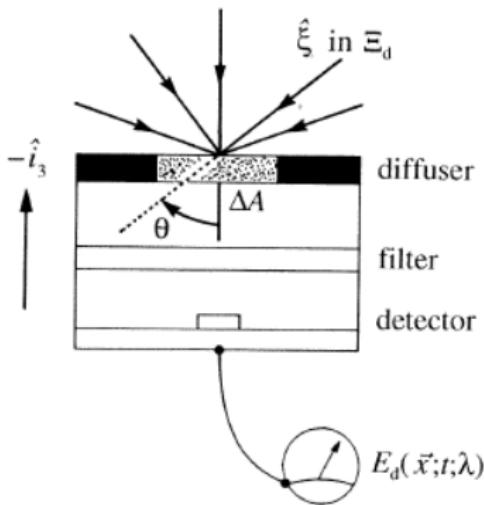
**Spectral downwelling plane irradiance** at depth  $z$ :

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

Photosynthetic available radiation, **PAR**:

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

# Planar Irradiance Sensor



(Source: [Mobley, 2010])

## Reflectance

- Irradiance reflectance:

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

- Remote sensing reflectance (water):

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

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

- Bidirectional Reflectance Distribution Function (BRDF):

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

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# Preparation

What do I want to collect?

- What instruments do I need?
- Where do I need to go?
- When do I need to go?
- How many people do I need?

# Preparation

## Permits and forms

- RIT Risk management  
<https://www.rit.edu/fa/grms/sites/rit.edu.fa.grms/files/docs/Agreement.pdf>
- Permits do do research
- RIT IRB
- Equipment checklist
- Data sheets

# Preparation

## Safety

- Have a contact list (email, cell phone, other)
  - Everyone in the field
  - People back at RIT
  - External contacts
  - Emergency numbers
- First aid kit
- Water
- Food

# Preparation

## Instruments

- Know how to use the instruments
- Make sure the batteries are charged
- Make sure there is room for new data

# Preparation

## Other things to consider

- Shipping
- Driving
- How to get to the field
- Prioritization of data
- Ensure equipment availability
- Tools
- Write down procedure
- Sampling
- Take pictures

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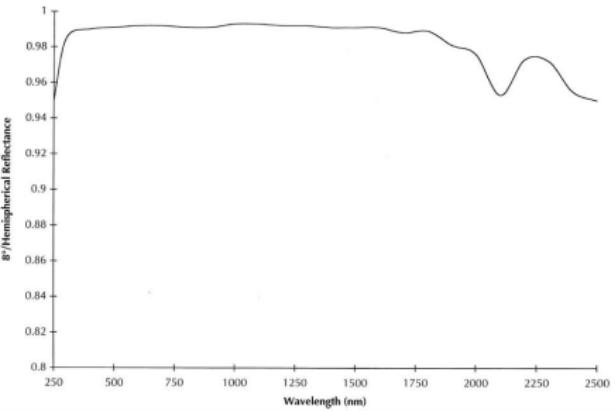
## Diffuse white reference panel (Spectralon)

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- 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)

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

Eqn. 4.69 from [Schott, 2007].

$$L = m \cdot \rho + b \quad (12)$$

$$L_{tar} = m \cdot \rho_{tar} + b \quad (13)$$

$$L_{ref} = m \cdot \rho_{ref} + b \quad (14)$$

$$\rho_{tar} = \frac{L_{tar} - b}{m} \quad (15)$$

$$m = \frac{L_{ref} - b}{\rho_{ref}} \quad (16)$$

$$\rho_{tar} = \frac{L_{tar} - b}{L_{ref} - b} \cdot \rho_{ref} \quad (17)$$

# Reflectance

- **Reflectance:**  $R(z, \lambda) \equiv \frac{L_u(z, \lambda)}{E_d(z, \lambda)}$
- 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)
    - $L_{sky}$

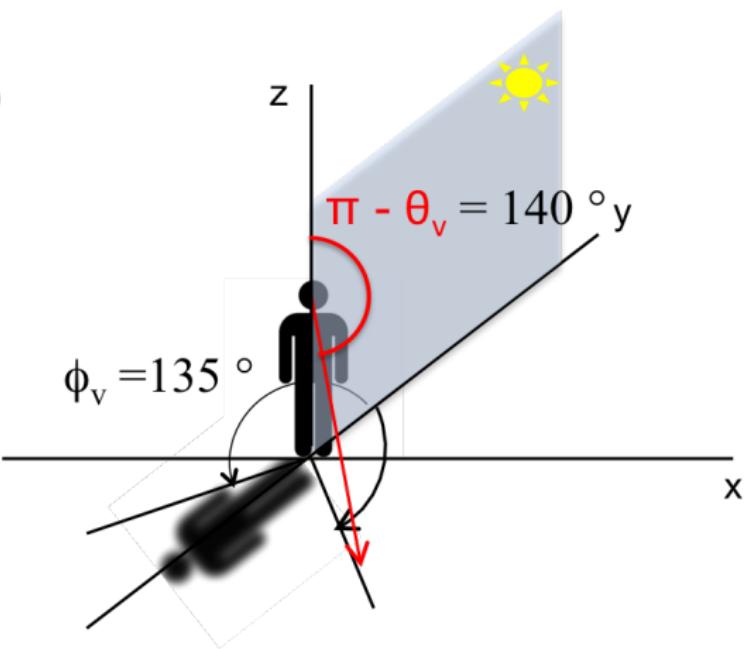
- Remote-sensing reflectance:

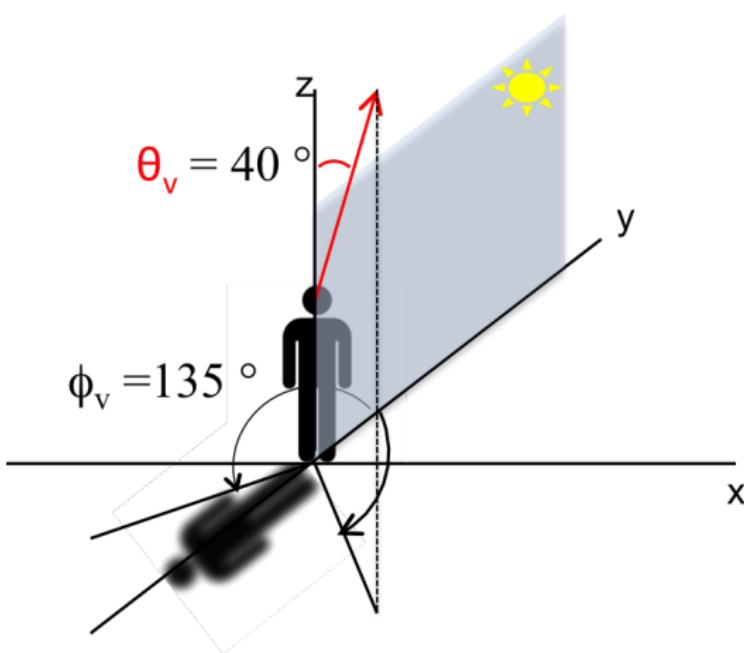
$$R_{rs} = L_w/E_d$$

$$= (L_t - L_r)/E_d$$

with  $L_r = 0.028 * L_{sky}$

- $E_d = L_g * \pi$
  - $\phi$  : azimuthal angle
  - $\theta$  : zenith angle





# 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

- 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

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# 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

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# 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 50  
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

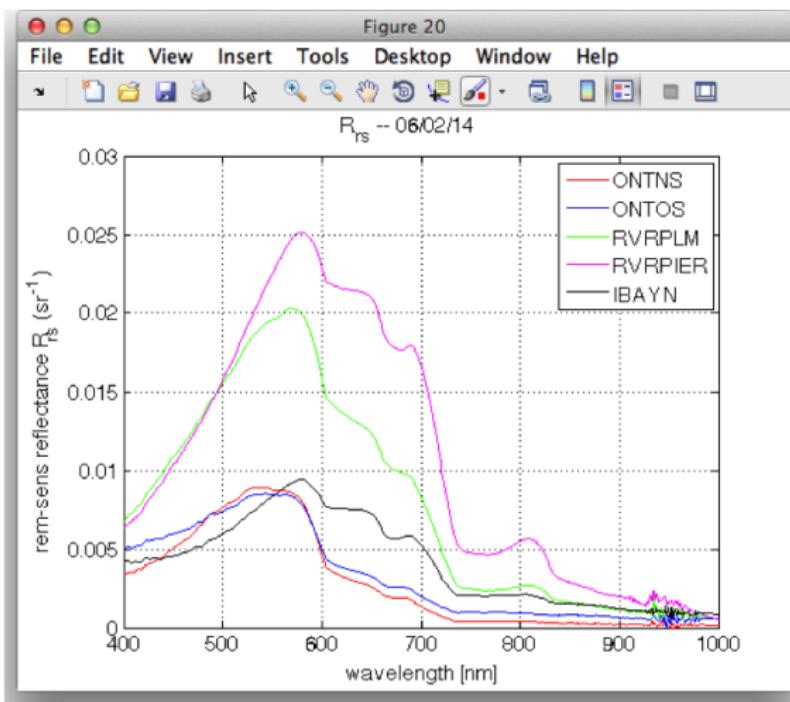
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```
/** Spectra Vista SIG Data **/  
name= gr092413_142.sig  
instrument= HI: 9122002 (HR-1024i)  
integration= 10.0, 30.0, 10.0, 1000.0, 40.0, 10.0  
scan method= Time-based, Time-based  
scan coadds= 200, 61, 156, 2, 46, 156  
scan time= 2, 2  
scan 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



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# 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



# Field Campaigns in Pictures



# Field Campaigns in Pictures

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Introduction      Background      Preparation  
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Taking Measurements  
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DIRS Instruments  
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Data Processing  
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# Field Campaigns in Pictures

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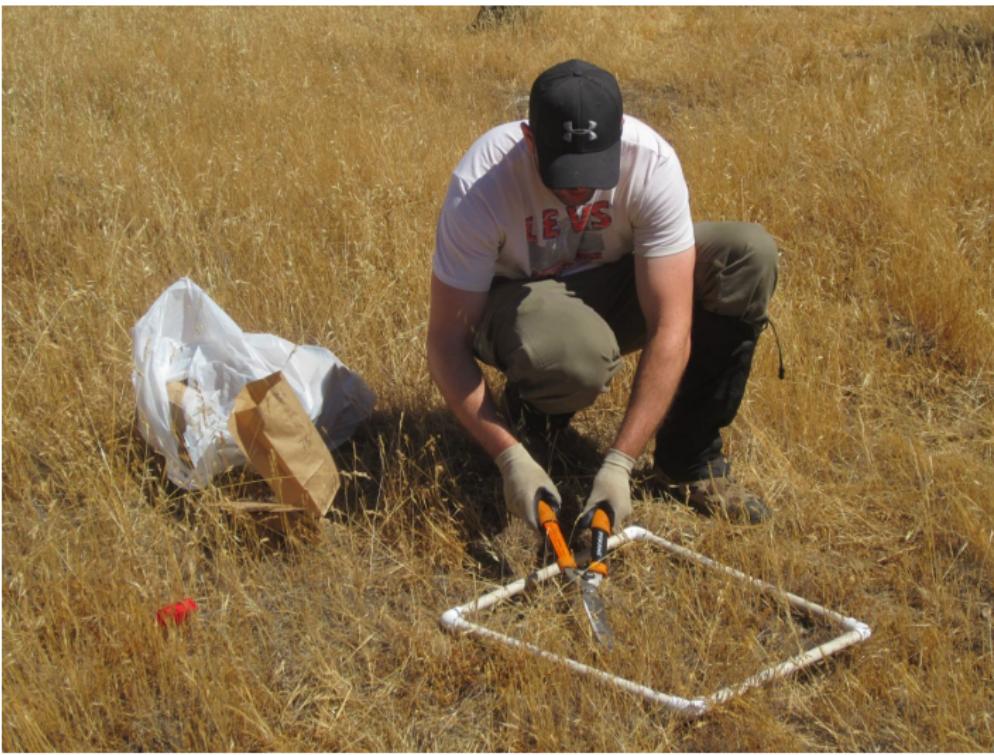
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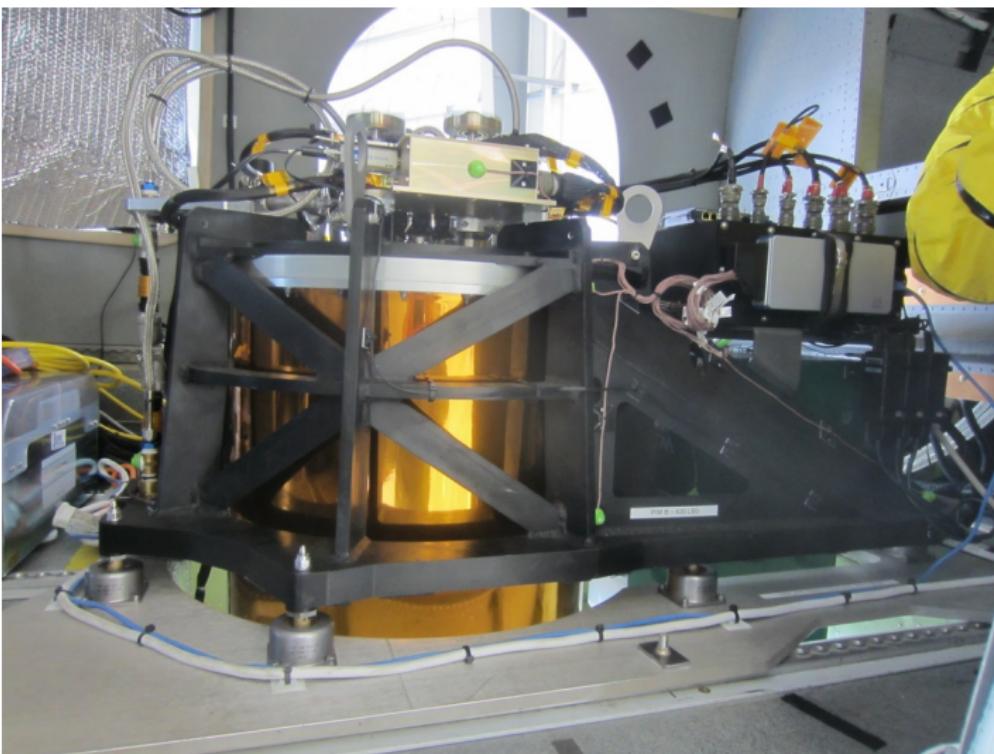
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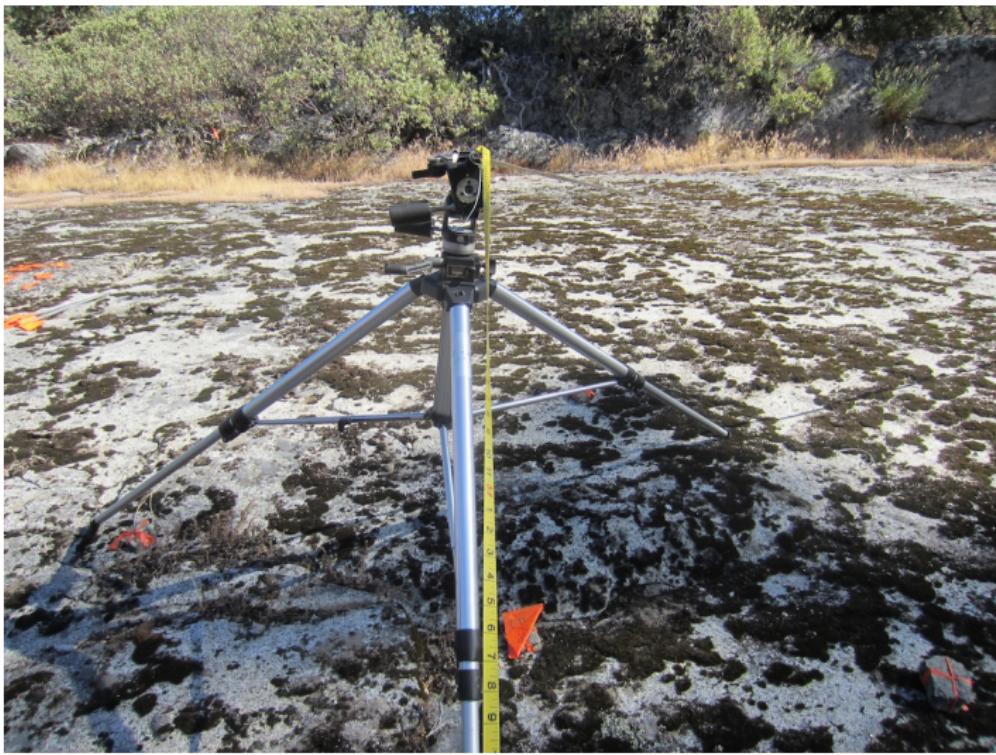
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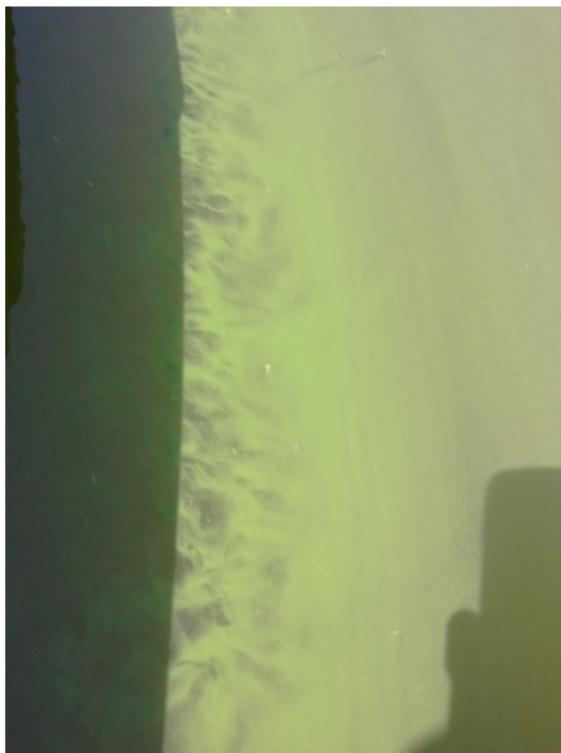
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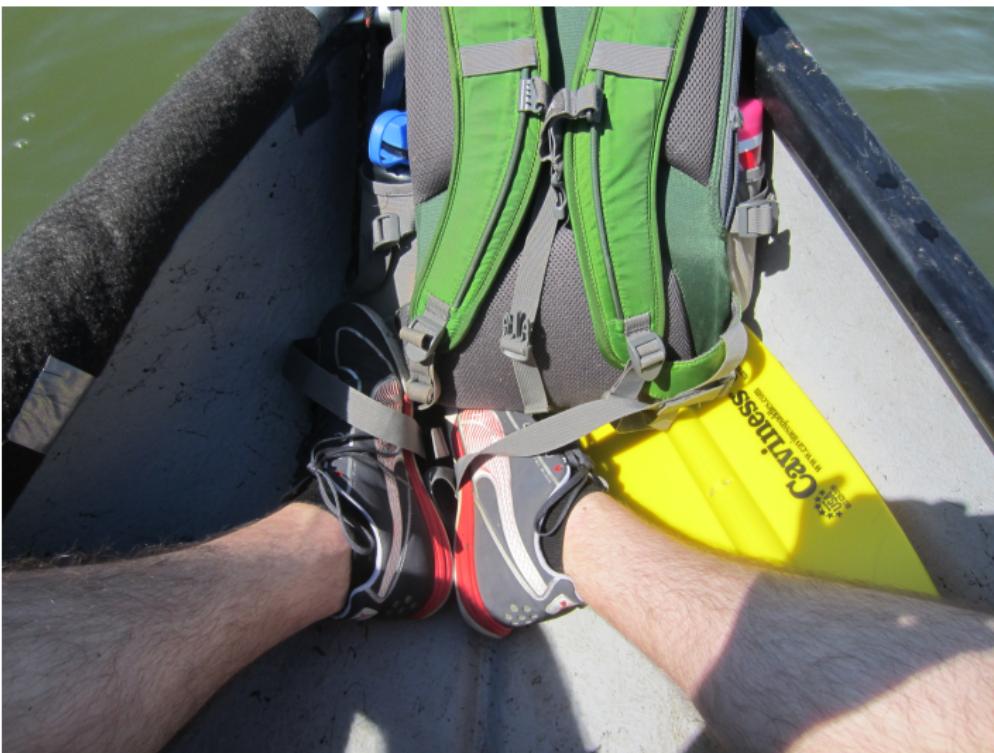
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# Field Campaigns in Pictures



# Field Campaigns in Pictures



Thanks for your attention!

QUESTIONS?



Thanks for your attention!

# QUESTIONS?



# References

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