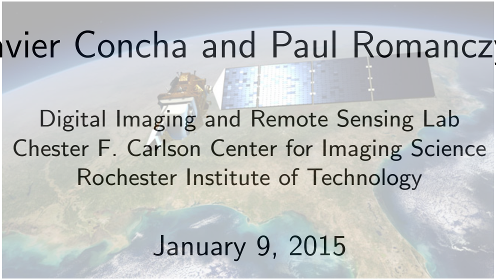
Intro to Instrumentation and Field Measurements in Remote Sensing



Javier Concha and Paul Romanczyk

Digital Imaging and Remote Sensing Lab
Chester F. Carlson Center for Imaging Science
Rochester Institute of Technology

January 9, 2015

Presented for 2015 Intersession Term

Outline

Outline

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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.

Motivation
Examples

Include:
Javier's example (over water mea.)
Paul's example (LIDAR and trees?)

Field Data Collection
Area of Study

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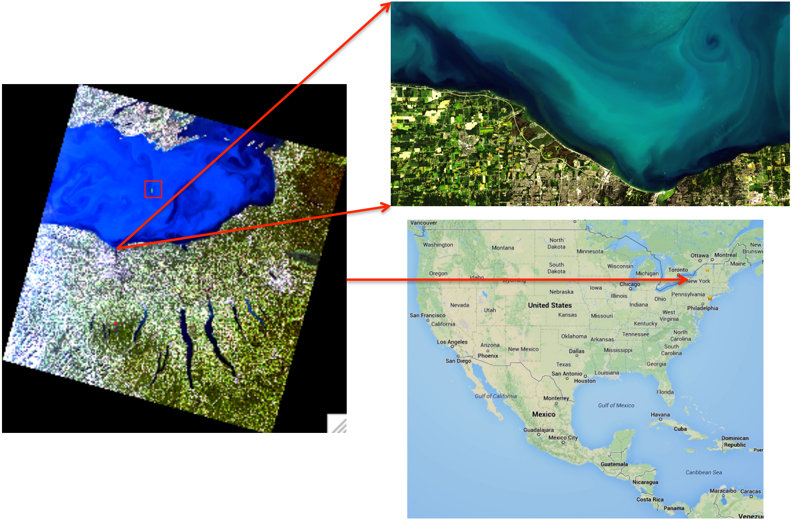
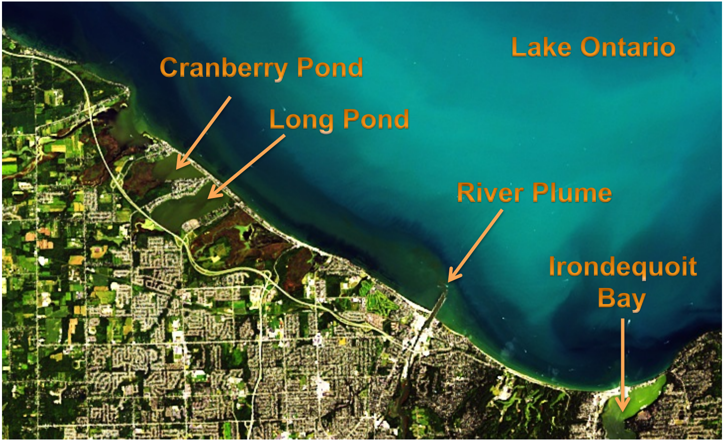
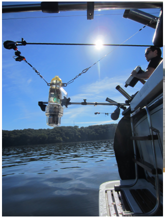


Field Data Collection (con't)

Area of Study

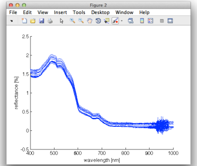


Field Data Collection (con't)



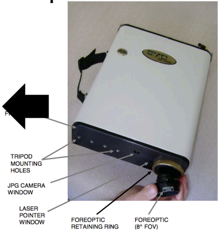
Water Samples

Lab Analysis



Water Leaving Reflectance

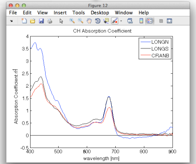
Spectroradiometer



Backscattering

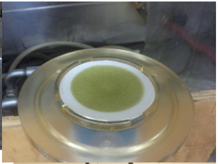
Field Data Collection (con't)
Lab Measurements

Spectrophotometer

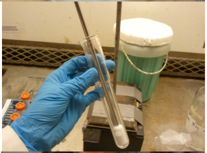


IOPs

Hydrolight



Filtration and Spectrophotometric Analysis



Concentrations

Field Data Collection (con't)

2013 and 2014 Seasons

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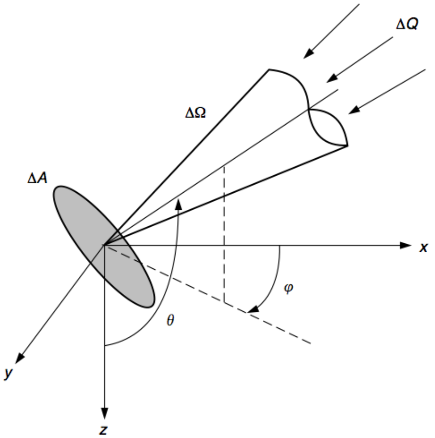
		IOPs		Concentrations		Reflectances		Backscattering	
Date		Ponds	Lake	Ponds	Lake	Ponds	Lake	Ponds	Lake
2013	25-Aug	✔	✗	✔	✗	✗	✗	✗	✗
	19-Sep	✔	✔	✔	✔	✗	✔	✔	✔
	26-Sep	✔	✔	✔	✔	✗	✔	✗	✔
2014	17-May	✔	✗	✔	✗	✔	✗	✔	✗
	02-Jun	✗	✔	✗	✔	✗	✔	✗	✔
	11-Jul	✔	✔	✔	✔	✔	✔	✗	✔
	28-Aug	✗	✔	✗	✔	✗	✗	✗	✗
	29-Sep	✔	✔	✔	✔	✔	✔	✔	✔

Outline

Examples of Kind of Measurements

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

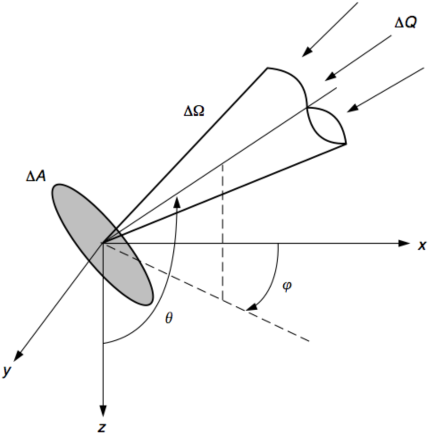
Radiometric Quantities: Radiance



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

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

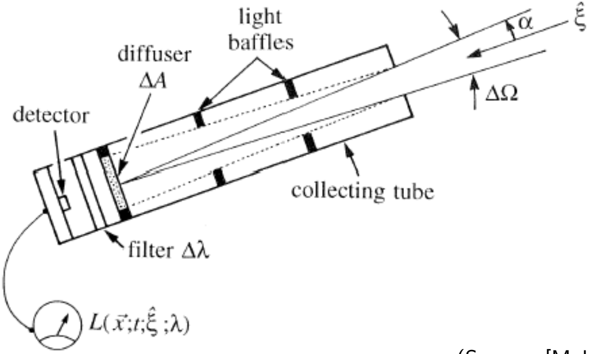
Radiometric Quantities: Radiance



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

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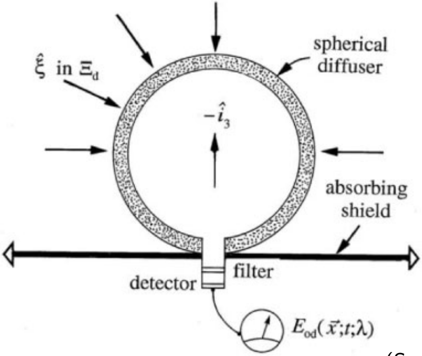


(Source: [Mobley, 2010])

Radiometric Quantities: Irradiance

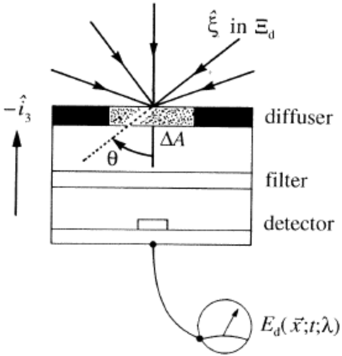
Spectral downwelling plane irradiance at depth z:

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

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**

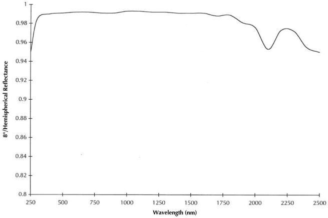
- **Bidirectional Reflectance Distribution Function (BRDF):**

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

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

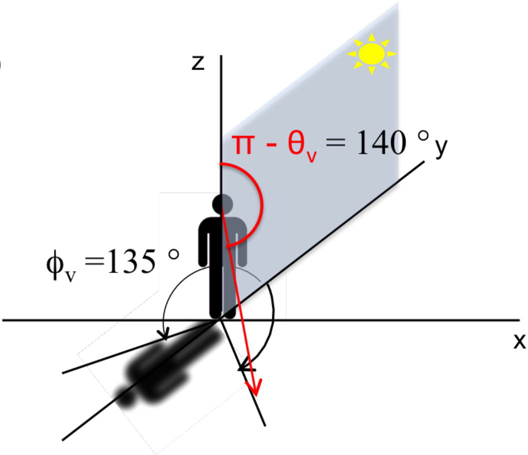
Remote-Sensing Reflectance

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

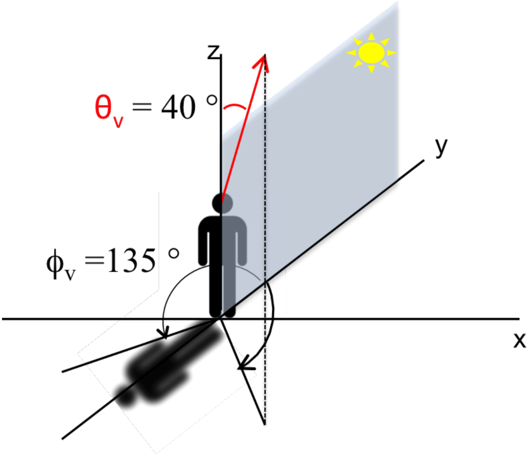
$$R_{rs} = L_w / E_d$$
$$= (L_t - L_r)/E_d$$

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

- have a good datasheet
- download and look data ASAP
- tools for in-field repairs and cleaning
- water, food, field clothes, first aid
- plan collection ahead of time
- write down procedure
- setting up plots/sites
- take pictures
- read manual
- charge batteries
- check batteries
- check instrument in advance
- The data should be taken as close to the time of acquisition as possible (due to inevitable landscape changes)

Field Campaigns

- Brings theory to practice
- It is FUN!

SHOW PICTURES HERE!

Outline

DIRS Lab Instruments

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- ASD
- SVC
- RIT LIDAR
- GRIT
- WASP
- GPS
- HydroScat-2
- AccuPAR LP-80
- WASP
- WASP Lite
- MISI
- Thermistor
- Camera
- Tape measures

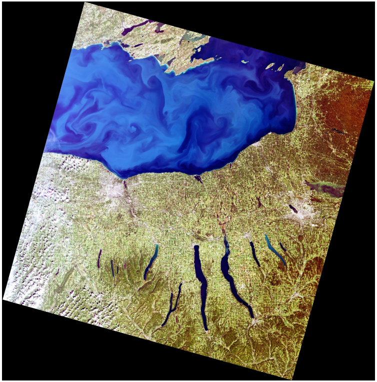
Data Extraction

- Data in proprietary format
- Translate or export to ASCII (text file)
- Text files manipulation (IDL, Matlab, Python, C++, bash).

Thanks for your attention!

QUESTIONS?

Javier A. Concha
jxc4005@rit.edu



(09/19/2013)

Thanks for your attention!

QUESTIONS?

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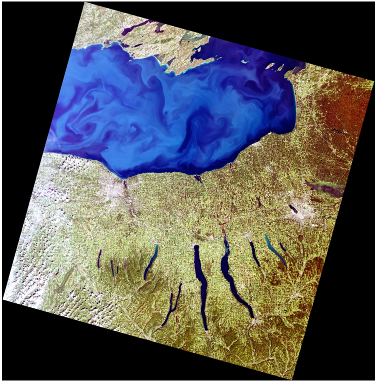

(09/19/2013)

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