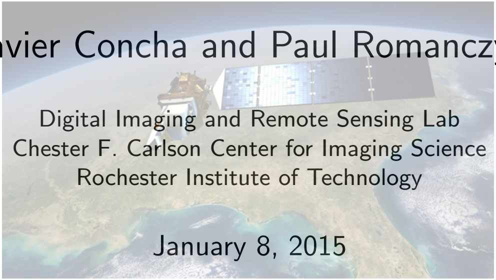
Intro to Instrumentation and Field Measurements in Remote Sensing



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

January 8, 2015

Presented for 2015 Intersession Term

Outline

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1. Introduction
2. Background
3. Taking Measurements

Course Goals

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

Course Description

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- 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 see how close a model to the field measurements is (accuracy)
- Calibration or Correction: adjust model to be more precise (data fitting)

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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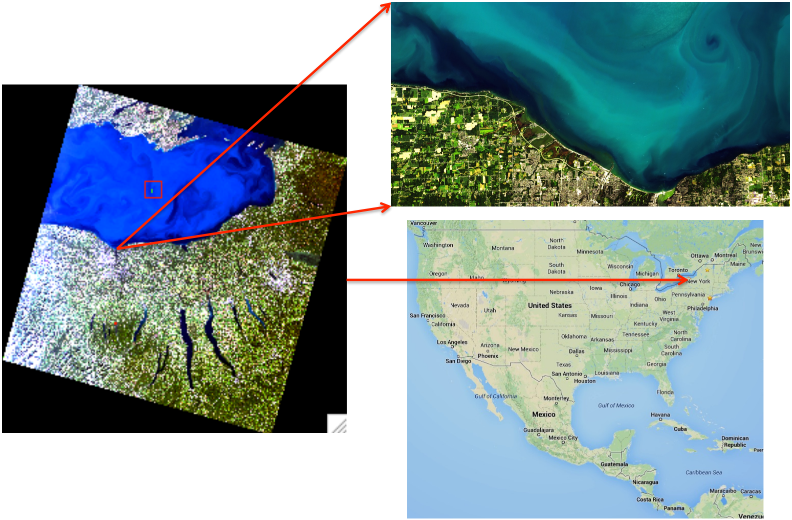
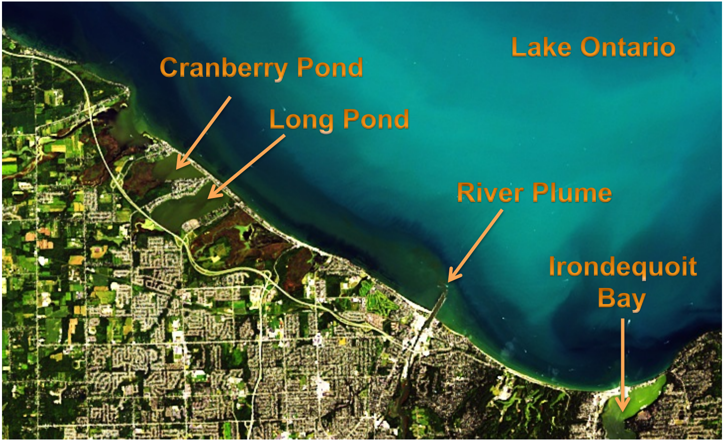
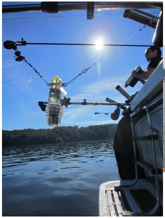


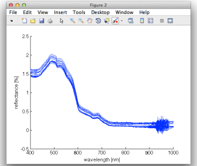
Field Data Collection (con't)

Area of Study

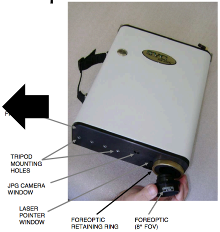


Field Data Collection (con't)





Spectroradiometer



Water Leaving Reflectance

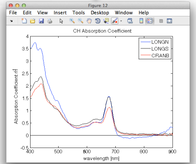
Water Samples

Lab Analysis

Backscattering

Field Data Collection (con't)
Lab Measurements

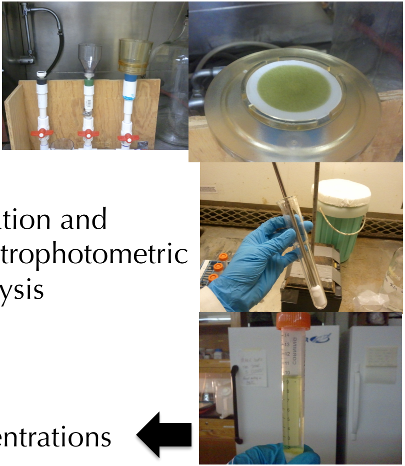
Spectrophotometer



IOPs

Hydrolight

Filtration and Spectrophotometric Analysis



Concentrations

Field Data Collection (con't)

2013 and 2014 Seasons

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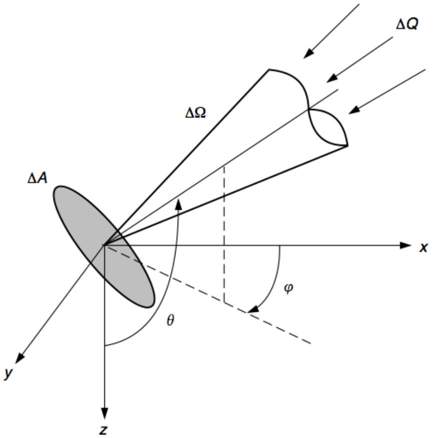
		IOPs		Concentrations		Reflectances		Backscattering	
Date		Ponds	Lake	Ponds	Lake	Ponds	Lake	Ponds	Lake
2013	25-Aug	✔	✗	✔	✗	✗	✗	✗	✗
	19-Sep	✔	✔	✔	✔	✗	✔	✔	✔
	26-Sep	✔	✔	✔	✔	✗	✔	✗	✔
2014	17-May	✔	✗	✔	✗	✔	✗	✔	✗
	02-Jun	✗	✔	✗	✔	✗	✔	✗	✔
	11-Jul	✔	✔	✔	✔	✔	✔	✗	✔
	28-Aug	✗	✔	✗	✔	✗	✗	✗	✗
	29-Sep	✔	✔	✔	✔	✔	✔	✔	✔

Outline

Kind of Measurements

- Reflectance: Radiometer
- Concentration: Spectrophotometer
- Location: GPS

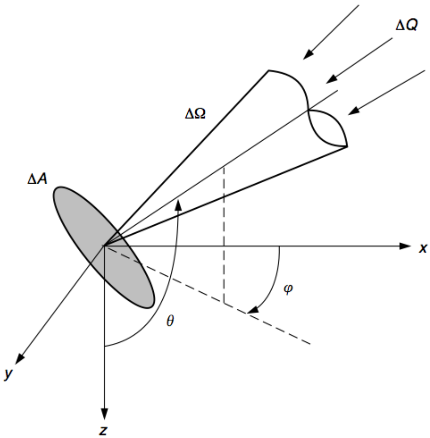
Radiometric Quantities: Radiance



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

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

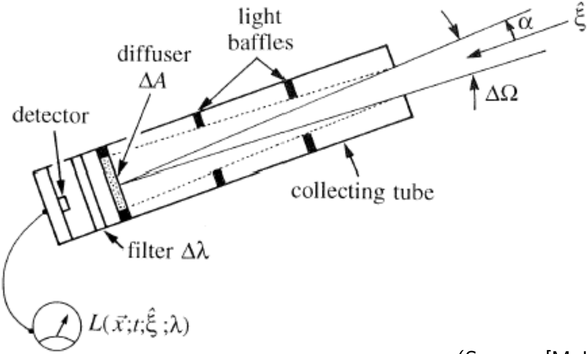
Radiometric Quantities: Radiance



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

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

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:

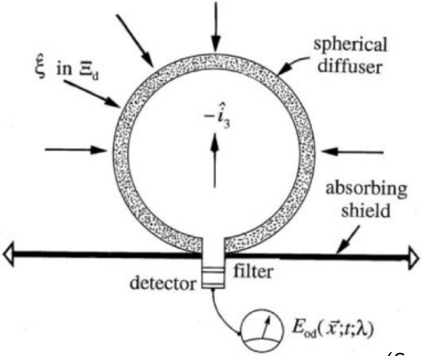
$$E_{ou}(z,\lambda) = \int_{2\pi_u} L(z,\theta,\varphi,\lambda)d\Omega \quad \left[Wm^{-2}nm^{-1}\right] \tag{3}$$

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

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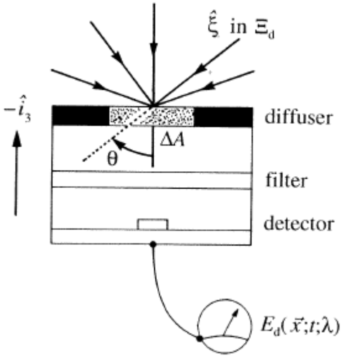

(Source: [Mobley, 2010])

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):**

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

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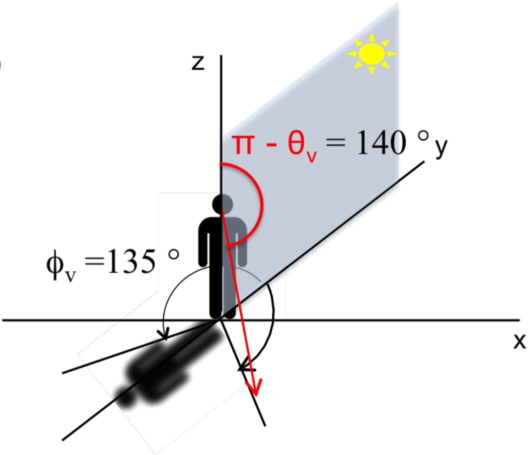
Remote-Sensing Reflectance

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

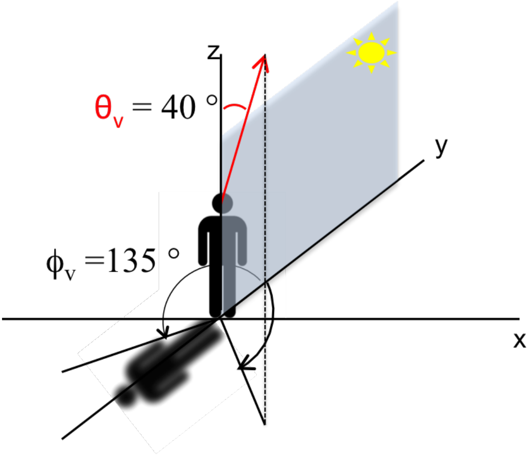
$$R_{rs} = L_w / E_d$$
$$= (L_t - L_r)/E_d$$

with $L_r = 0.028 * L_{sky}$

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

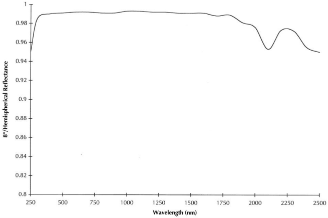


L_{sky}



Diffuse white reference panel (Spectralon)

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



Thanks for your attention!

QUESTIONS?

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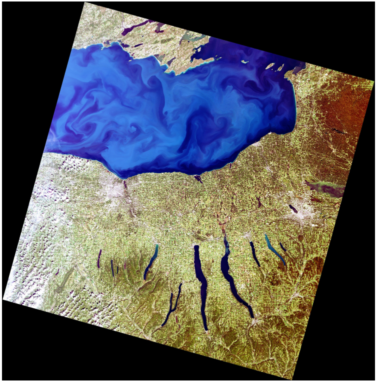

(09/19/2013)

Thanks for your attention!

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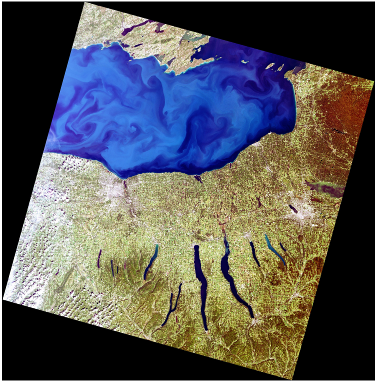

(09/19/2013)

References

[[Mobley, 2010]]Mobley, C. D. (2010).
Ocean optics web book.
http://www.oceanopticsbook.info/.