

# 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

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# Outline

① Introduction

② Background

③ Taking Measurements

④ DIRS Instruments

# Outline

## ① Introduction

## ② Background

## ③ Taking Measurements

## ④ DIRS Instruments

# 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



# Field Data Collection (con't)

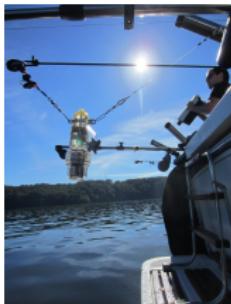
## Area of Study

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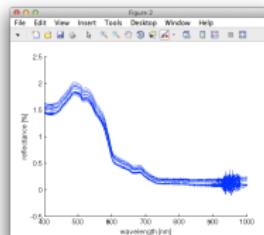
# Field Data Collection (con't)



Water Samples

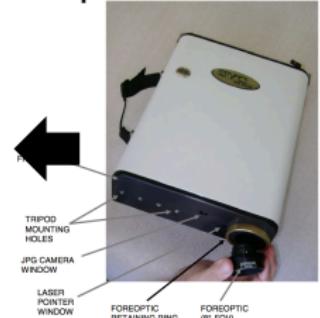


Lab Analysis



Water Leaving  
Reflectance

Spectroradiometer



Backscattering

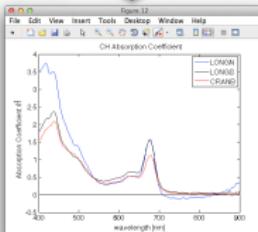
# Field Data Collection (con't)

## Lab Measurements

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### Spectrophotometer



IOPs

Hydrolight



### Filtration and Spectrophotometric Analysis



← Concentrations

# Field Data Collection (con't)

2013 and 2014 Seasons

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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	✓	✓	✓	✓	✓	✓	✓	✓

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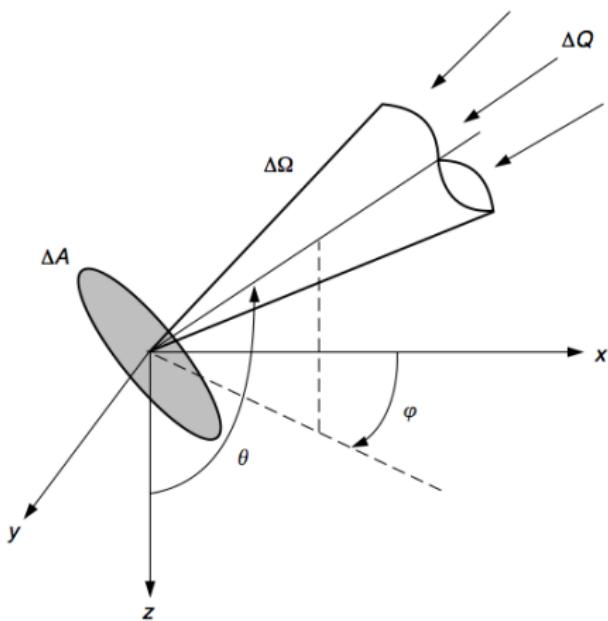
③ Taking Measurements

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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

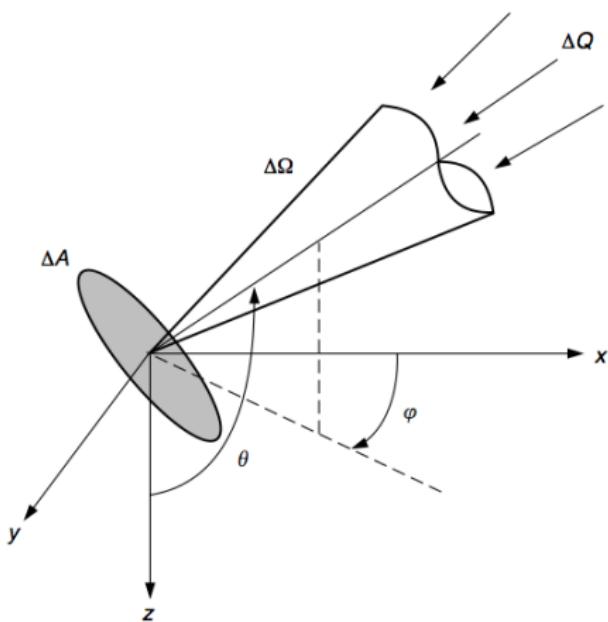
$\Delta A$ : surface area at location  $(x,y,z)$

$\Delta\Omega$ : 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

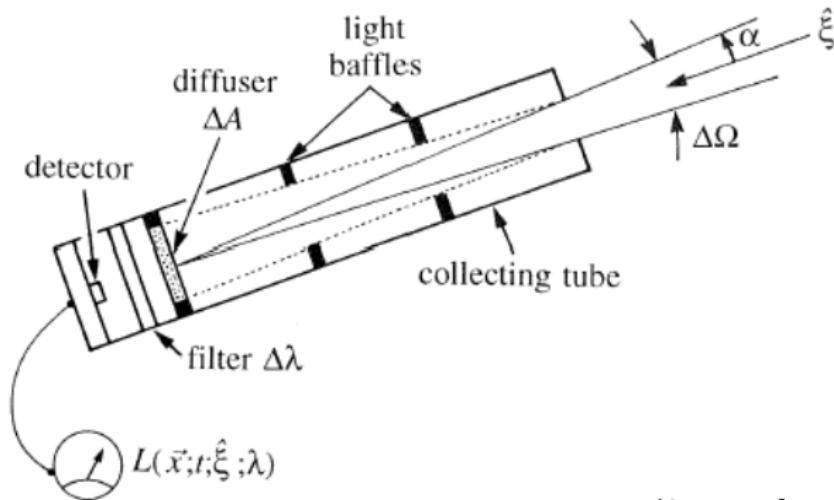
$\Delta A$ : surface area at  
location  $(x,y,z)$

$\Delta\Omega$ : 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  $z$ :

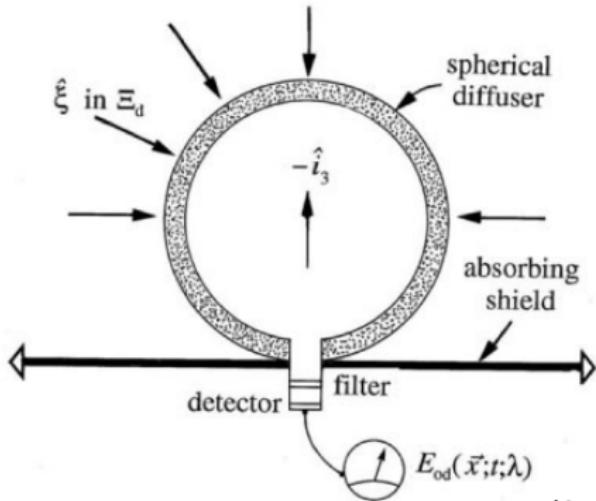
$$E_{ou}(z, \lambda) = \int_{2\pi_u} L(z, \theta, \varphi, \lambda) d\Omega \quad [Wm^{-2}nm^{-1}] \quad (3)$$

**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

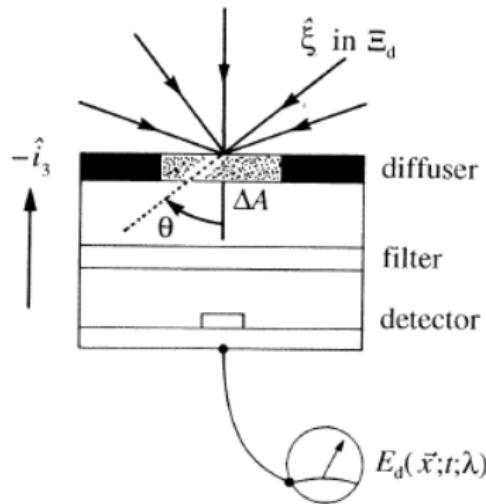
**Spectral downwelling plane irradiance** at depth  $z$ :

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

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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# Diffuse white reference panel (Spectralon)

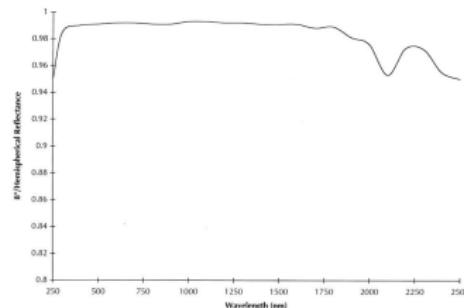
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- For a Lambertian surface:

$$L = \frac{E_d r}{\pi} \Rightarrow E_d = \frac{L\pi}{r}$$

- For spectralon  $r \approx 1$   
( $\approx 100\%$ )  
 $\Rightarrow E_d = L\pi$



# 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

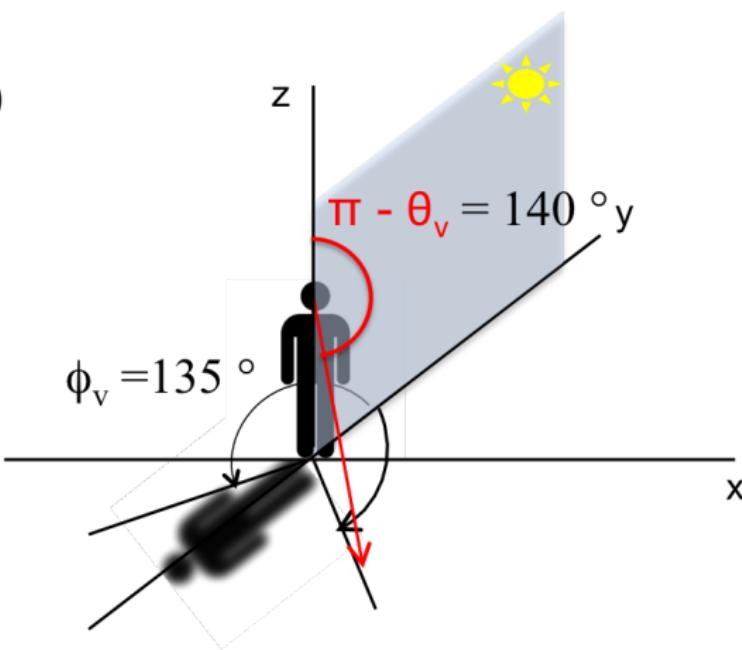
- 3 measurements:
  - $L_g$  (spectralon)
  - $L_t = L_r + L_w$  (water)
  - $L_{sky}$

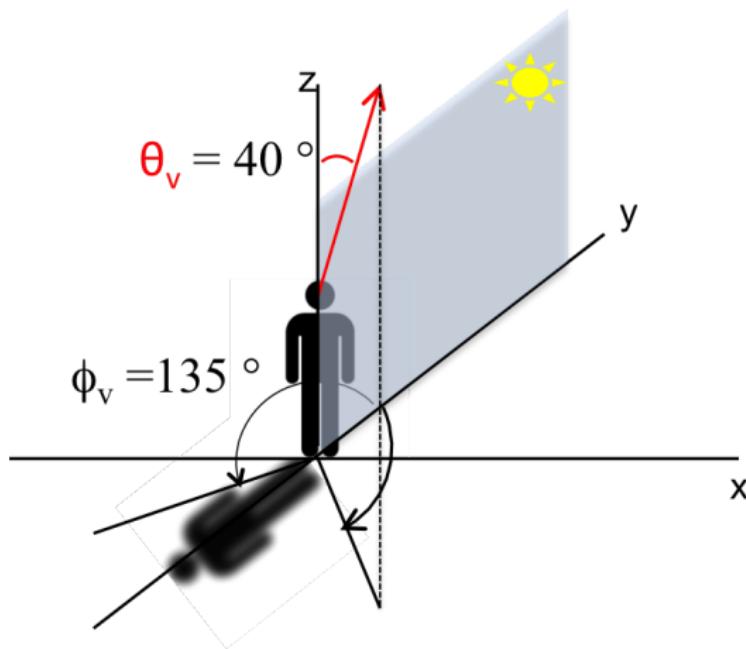
- Remote-sensing reflectance:

$$\begin{aligned} R_{rs} &= L_w/E_d \\ &= (L_t - L_r)/E_d \end{aligned}$$

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

- 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!

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# DIRS Lab Instruments

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

# 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

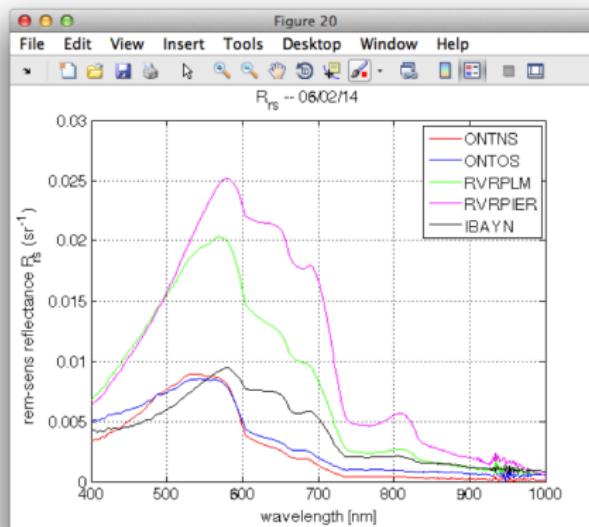
```
/** Spectra Vista SIG Data **/  
name= gr092413_142.sig  
instrument= HI: 9122002 (HR-1024i)  
integration= 10.0, 30.0, 10.0, 1000.0, 40.0, 10.0  
scan method= Time-based, Time-based  
scan coadds= 200, 61, 156, 2, 46, 156  
scan time= 2, 2  
scan settings= AI, AI  
external data set1= 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0  
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
```

# Reflectance from Matlab

## SVC

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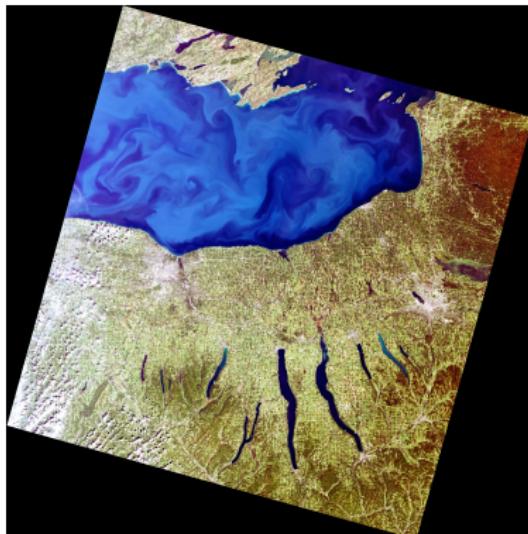
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Thanks for your attention!

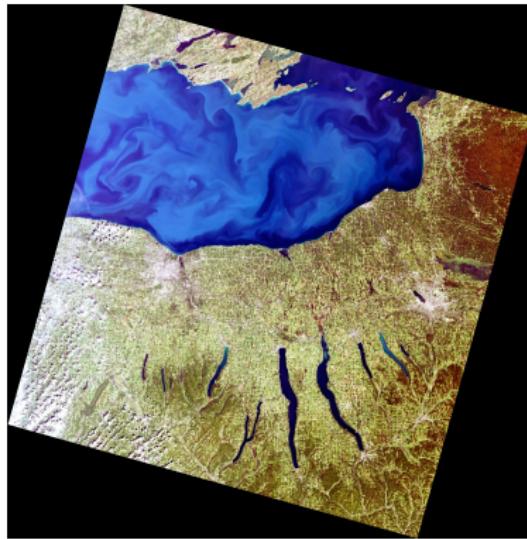
QUESTIONS?

Javier A. Concha  
jxc4005@rit.edu



Thanks for your attention!  
**QUESTIONS?**

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jxc4005@rit.edu



# References



[[Mobley, 2010]

Ocean optics web book.

[http://www.oceanopticsbook.info/.](http://www.oceanopticsbook.info/)

]Mobley, C. D. (2010).