

The Use of Landsat 8 for Monitoring of Fresh and Coastal Water



By Javier A. Concha

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Outline

- Definitions
 - Remote Sensing
 - Atmospheric Correction: ELM
 - Water Optical Classification
 - Satellite Landsat-8
 - Physics Model: HydroLight
- Project
 - Goal
 - Retrieval Process
 - Ground Truth Collect
 - Lab Measurements
- Future Work and Take Home Points
- RIT and IEEE-GRSS ?

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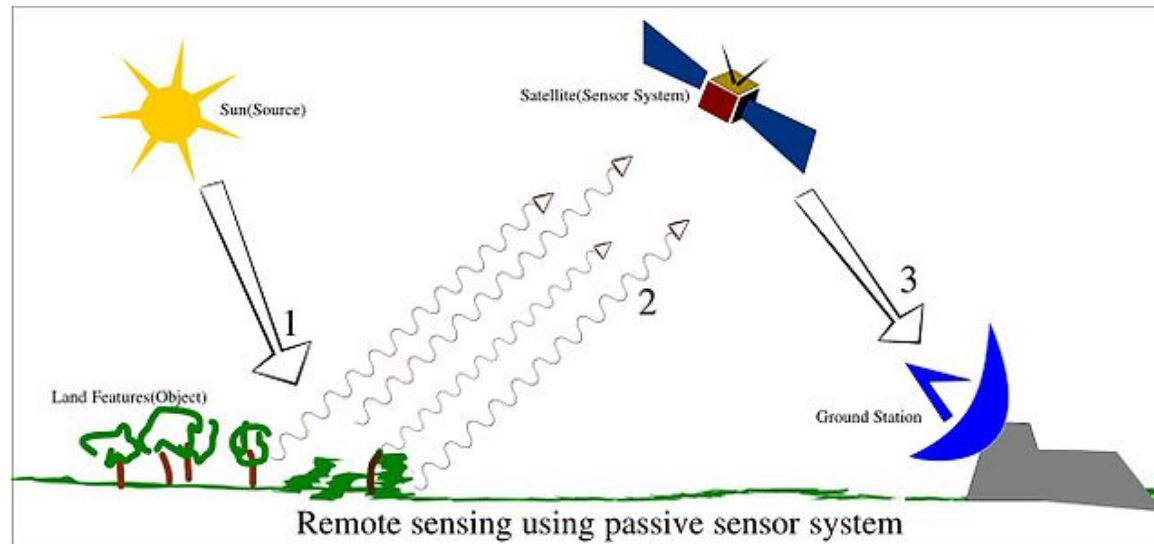
Remote Sensing (Percepción Remota)

- “The field of study associated with extracting information about an object without coming into physical contact with it” (Schott, 2007)

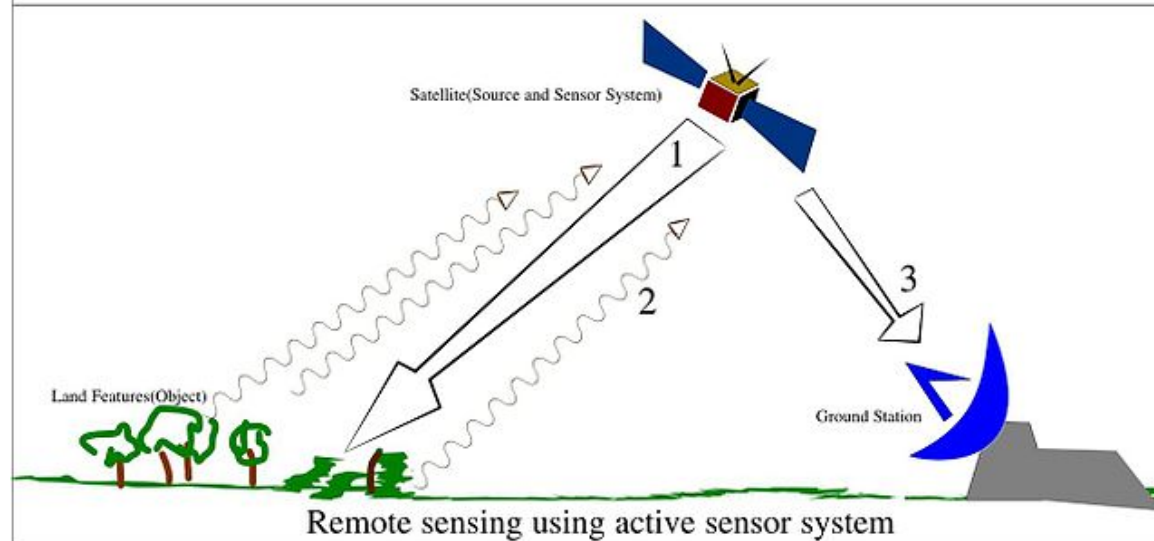


Remote Sensing

Passive



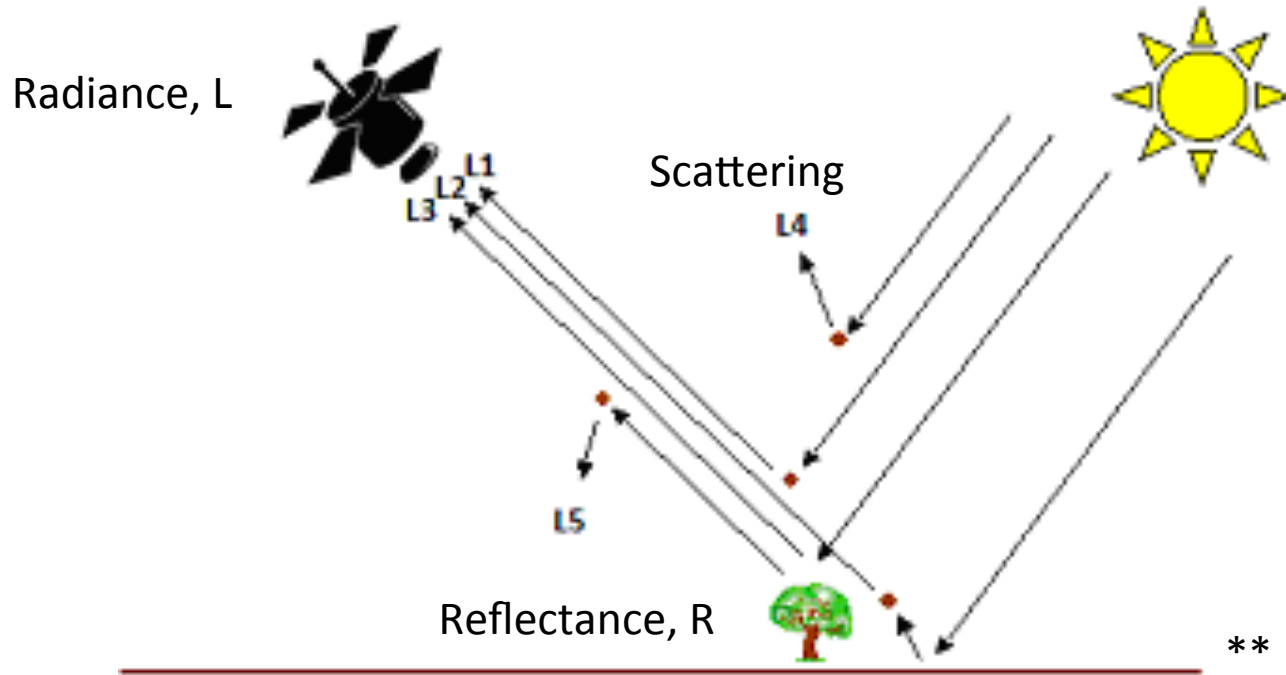
Active



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Radiance, Reflectance and Atmospheric Correction



- **Radiance:** radiation reflected by a surface and falls within a given solid angle in specific direction*
- **Reflectance:** fraction of incident electromagnetic power that is reflected at an interface*
- **Atmospheric Correction:** process of removing the atmospheric effects*

Atmospheric Correction (con't)

Radiance, L

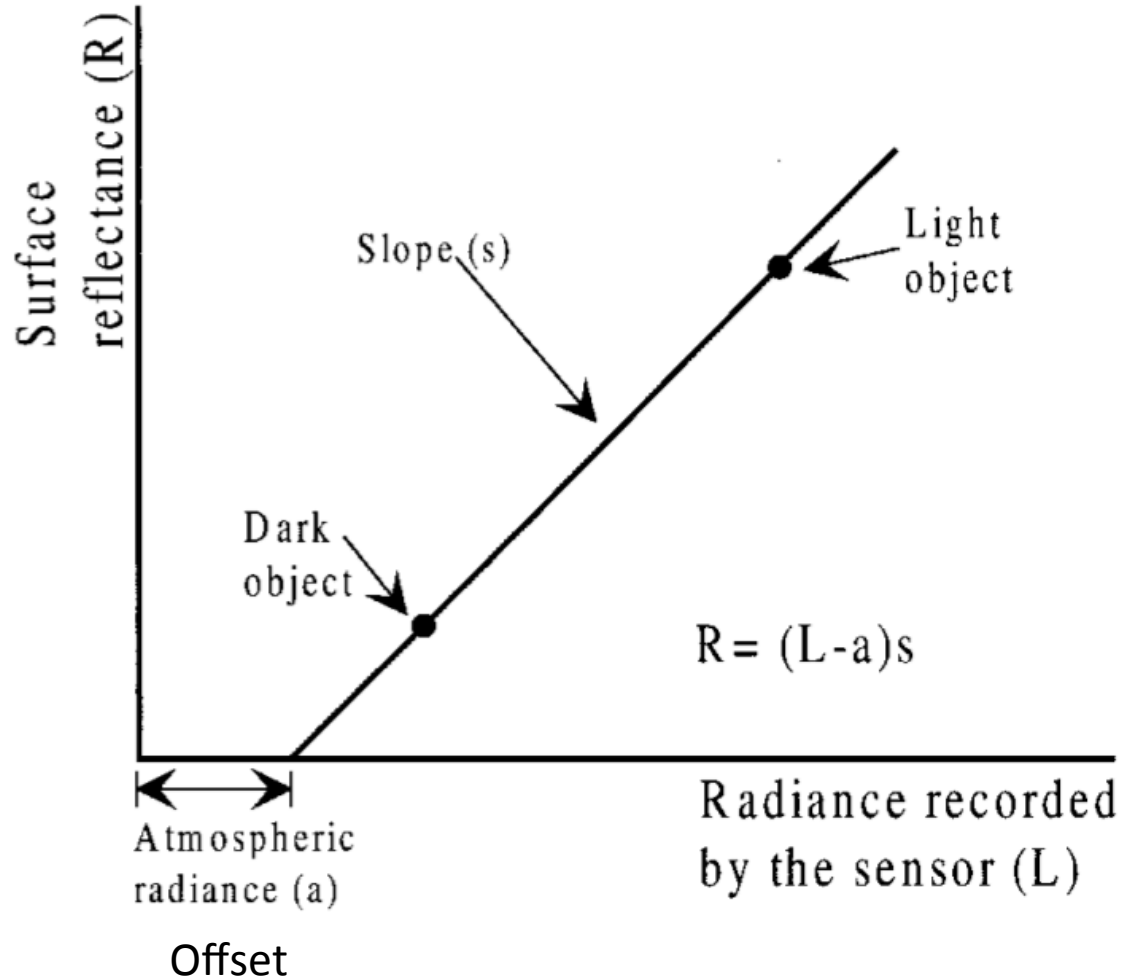


Reflectance, R



Empirical Line Method (ELM)

- Two pixels in the scenes with known reflectance
- Linear relationship between radiance L and reflectance R
- Conversion pixel by pixel



* Smith and Milton, 1999

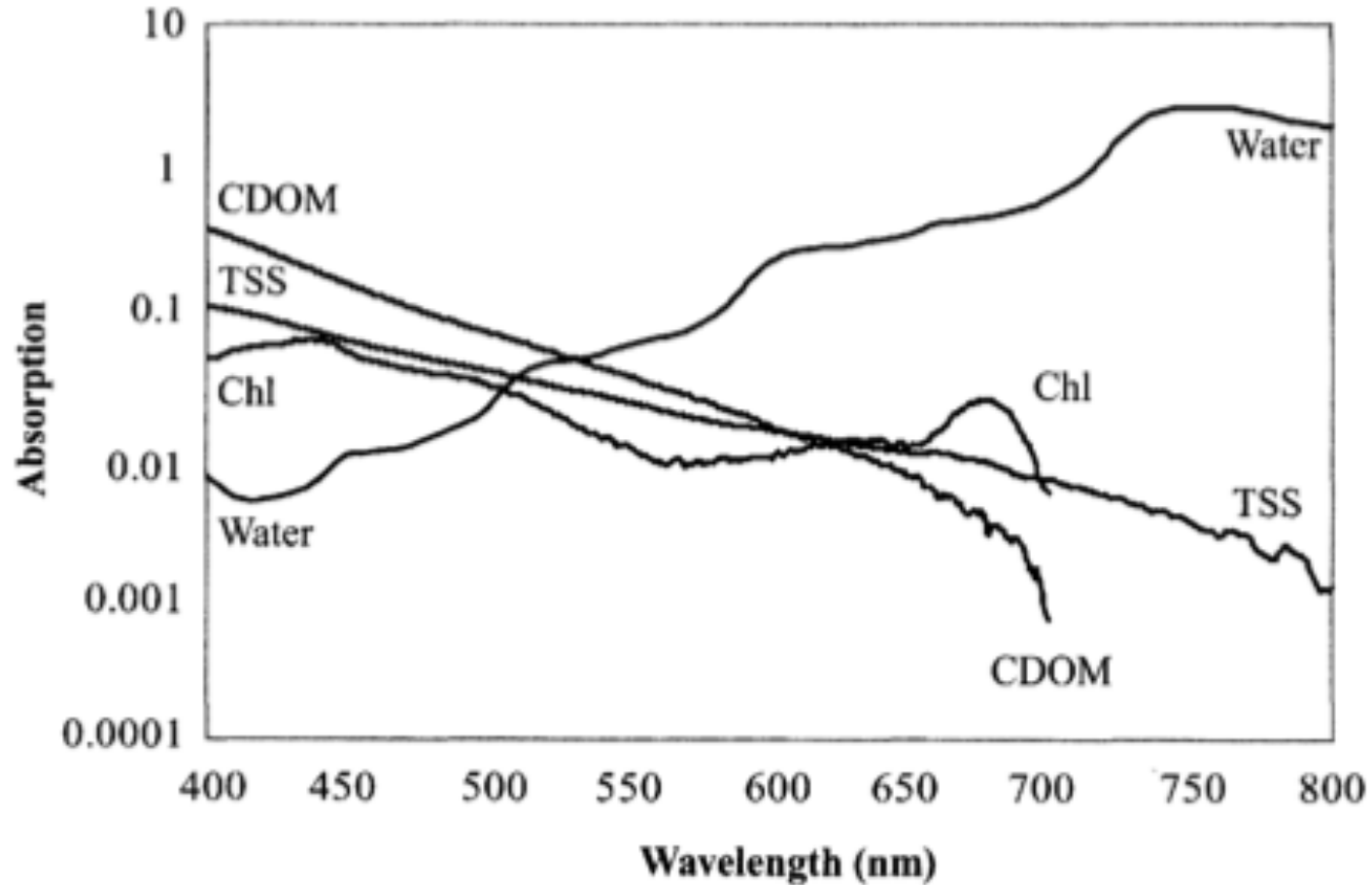
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Water Optical Classification

- Case 1 Water:
 - Open Ocean
 - Chlorophyll is the main driver
- Case 2 Water:
 - Inland and Coastal Waters
 - Optically complex
 - Significant levels of:
 - **Chlorophyll-*a***
 - **Suspended Materials**
 - **Colored dissolved organic matter (CDOM)**

Case 2 Water

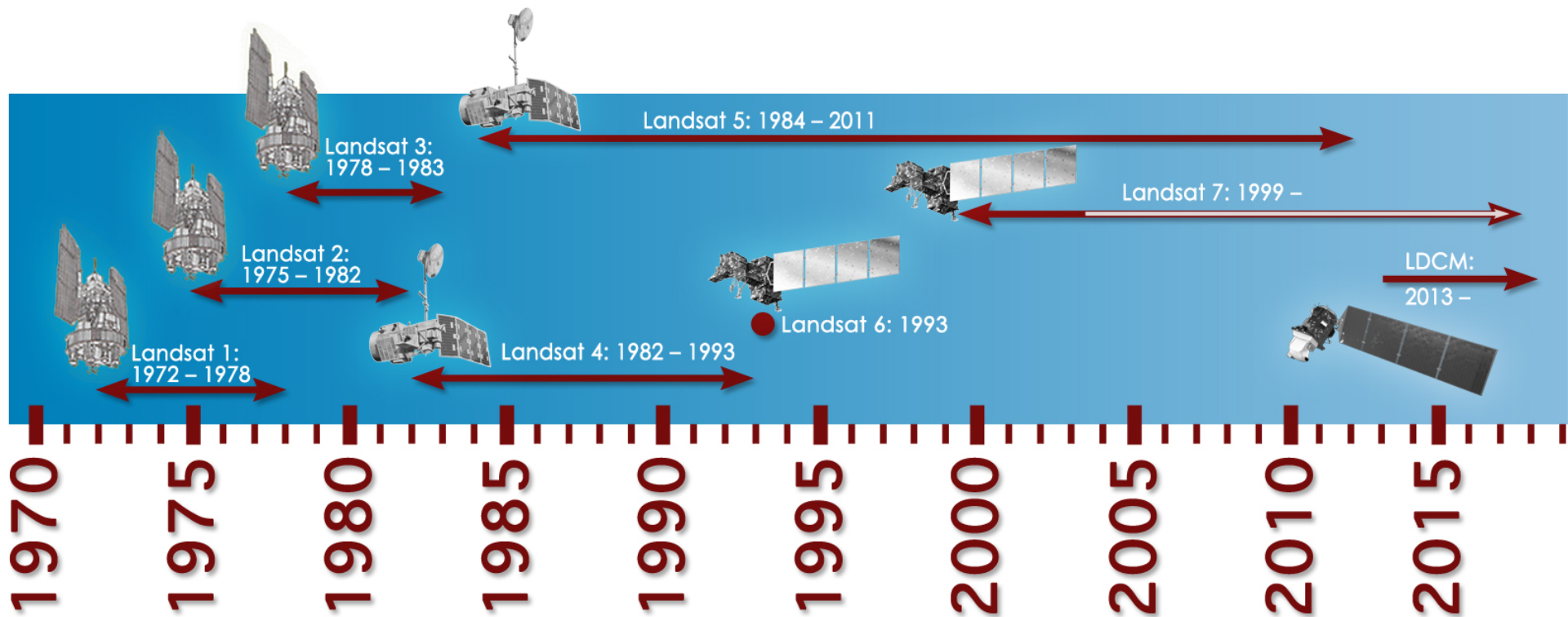


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Landsat Program

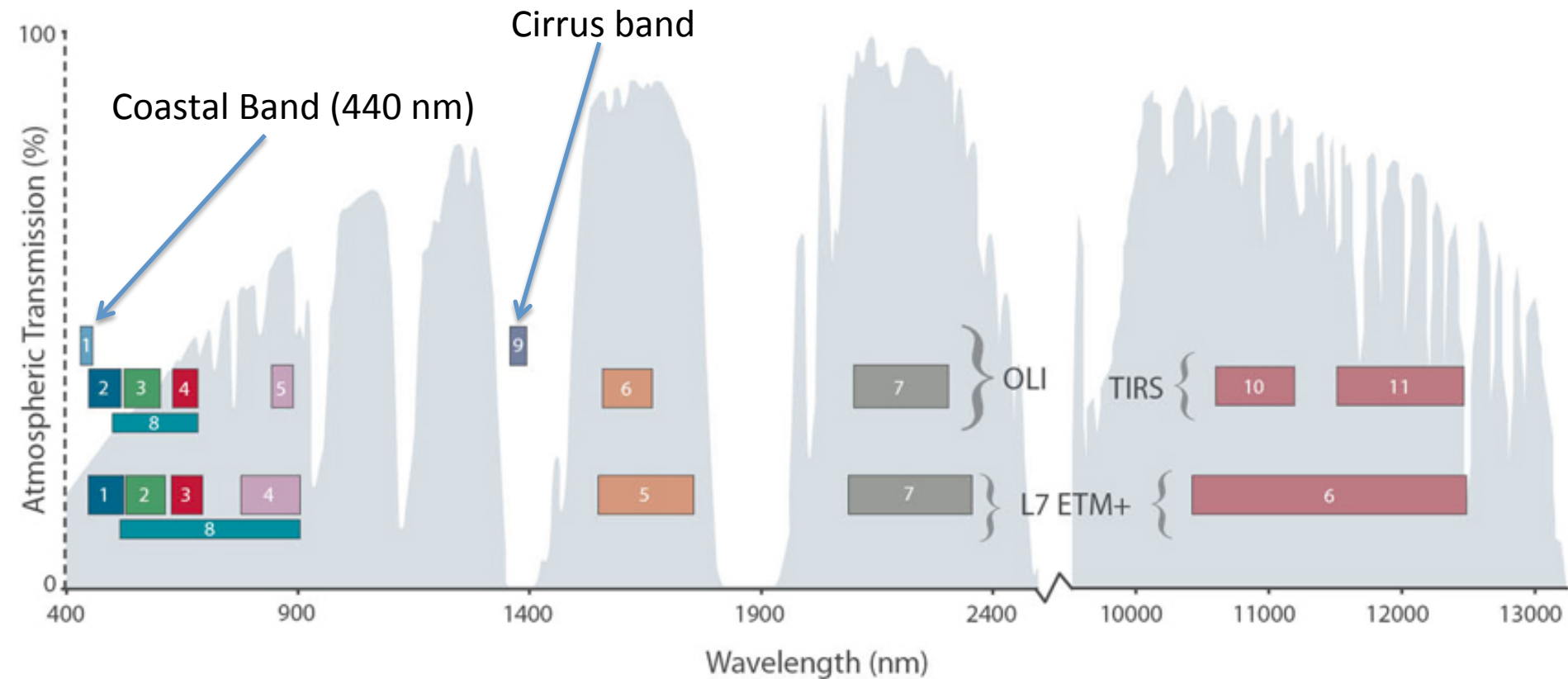
40+ Years of Global Observations!



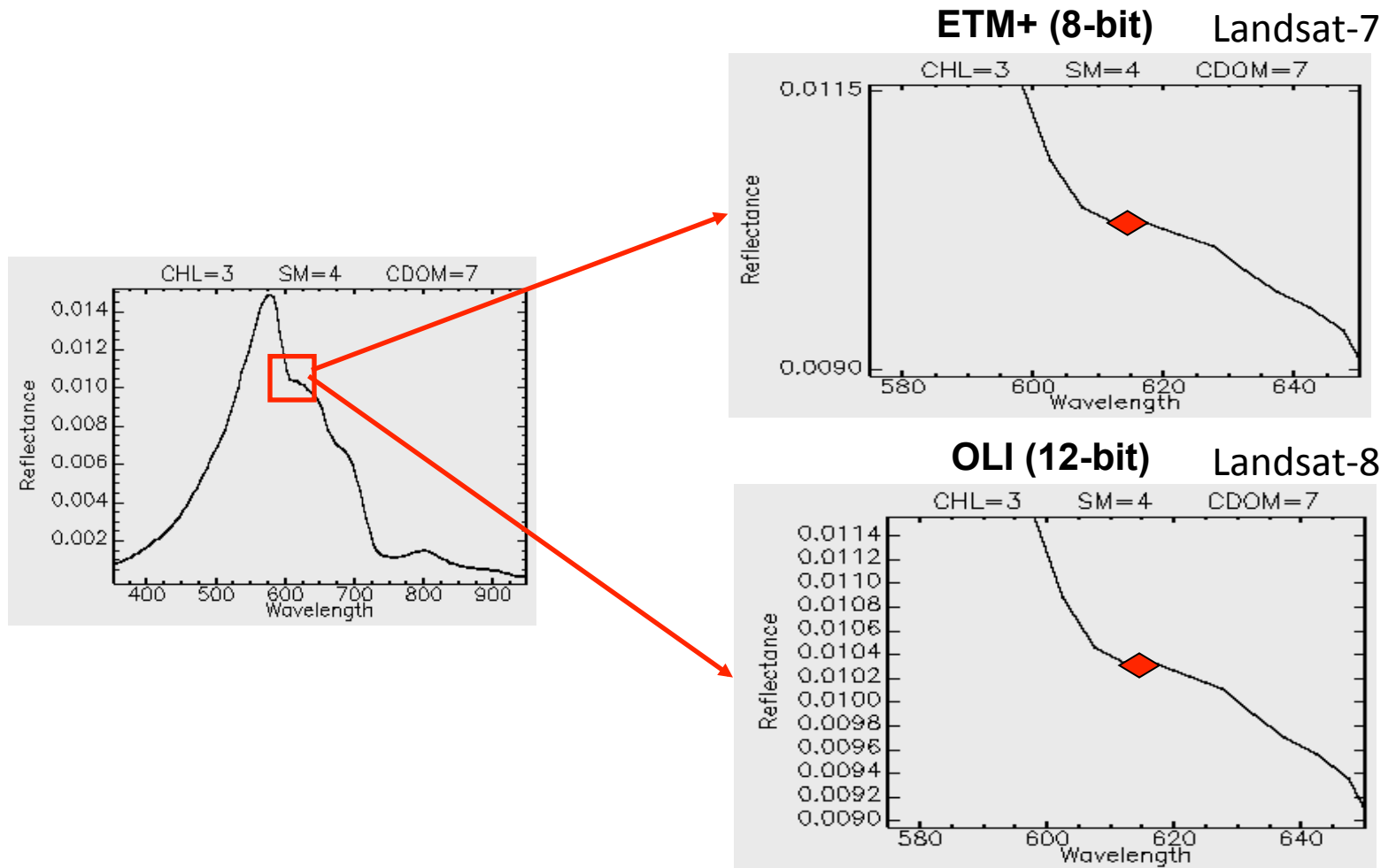
Landsat-8 Specifications

- Optical Satellite (Passive)
- Multispectral satellite: 4 VIS, 1 NIR, 2 SWIR, 1 Panchromatic spectral bands
- Spatial Resolution: 15/30/100 m
- Temporal Resolution: 16 days
- Bit depth: 12-bits quantization (4096 levels)
- Push broom satellite

Landsat-8 – Spectral Bands

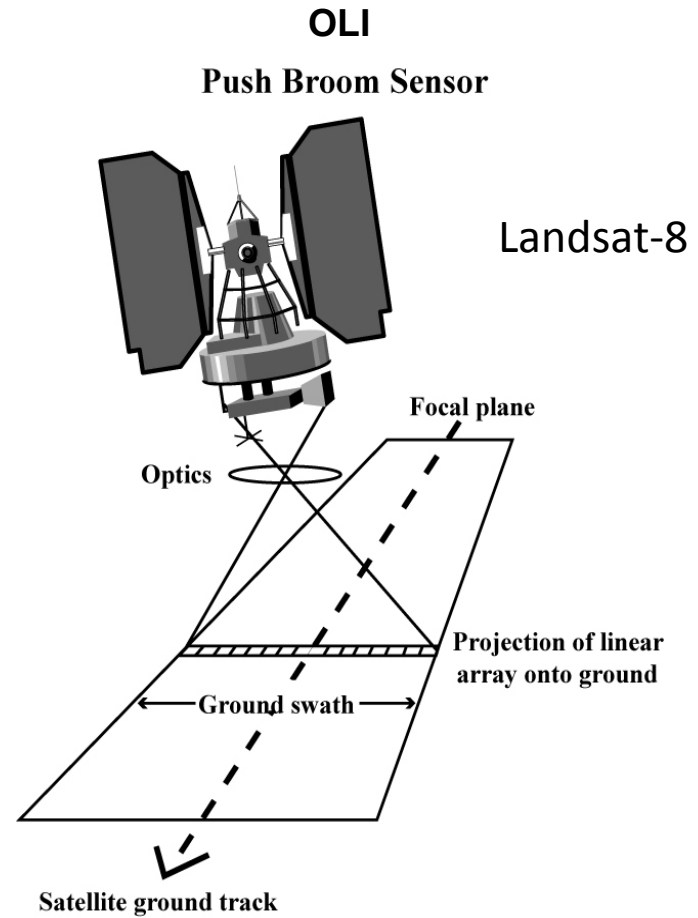
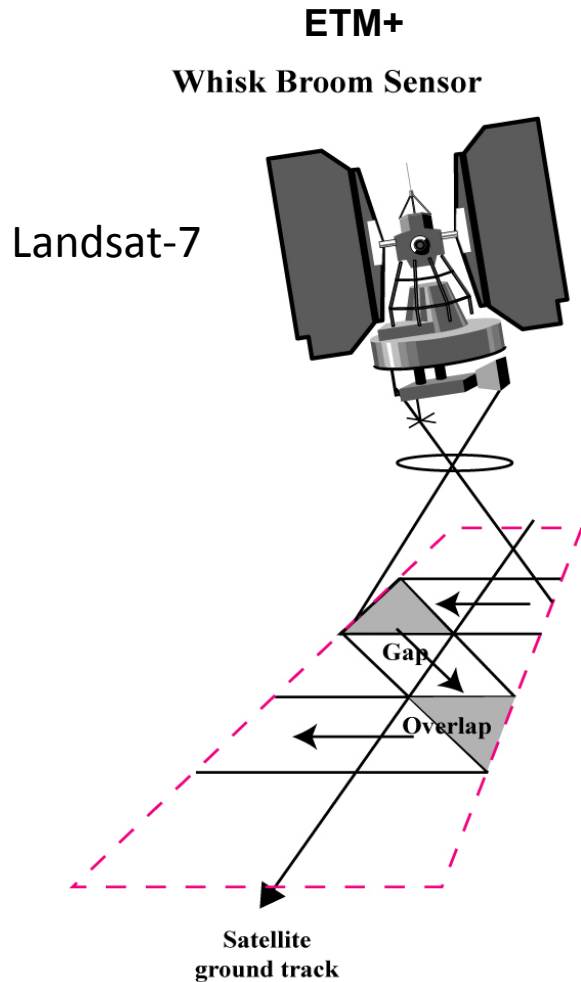


Landsat 8 - Quantization



* Courtesy of Dr. Aaron Gerace

Landsat 8



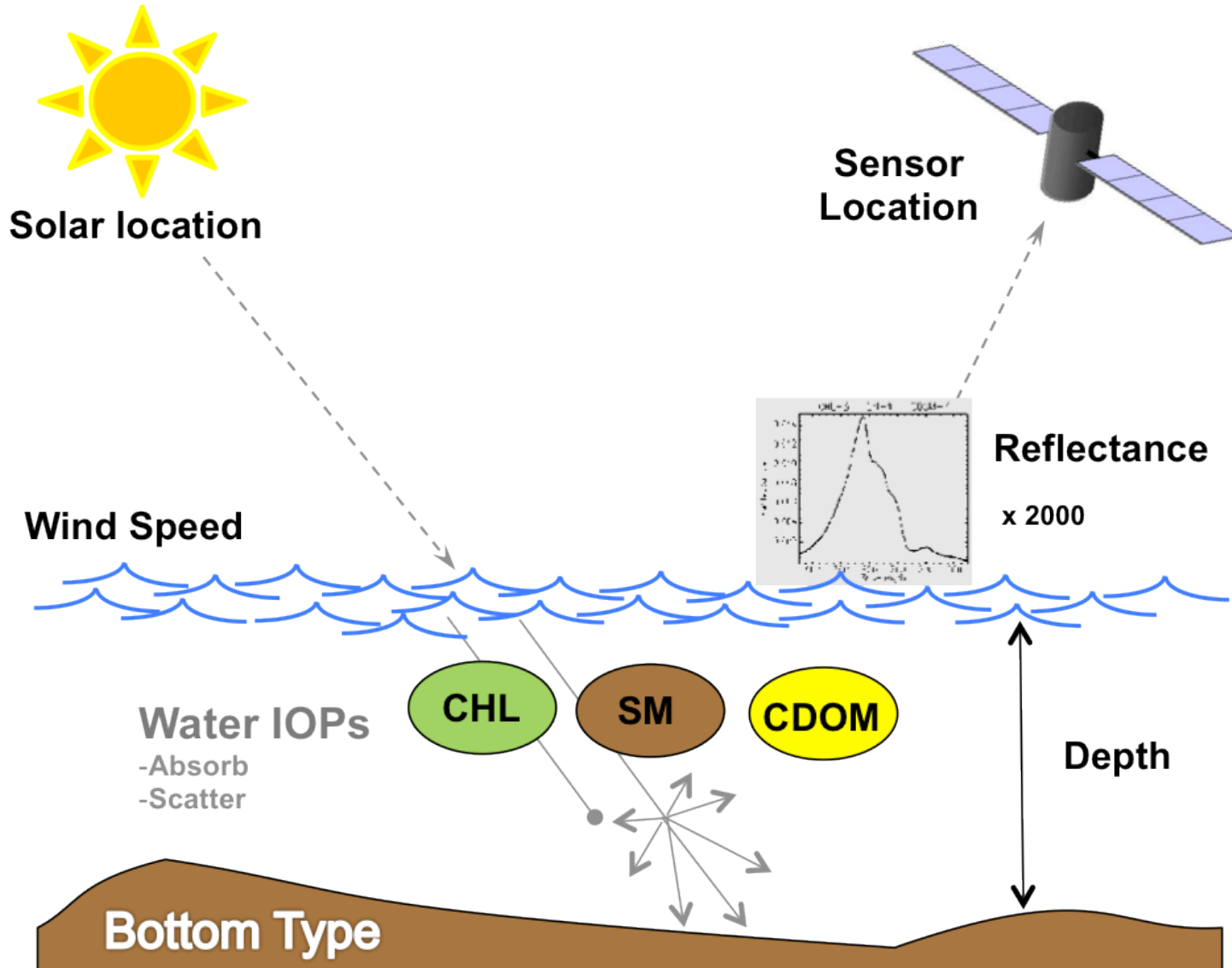
- About a factor of 5 improvement in SNR.

* Courtesy of Dr. Aaron Gerace

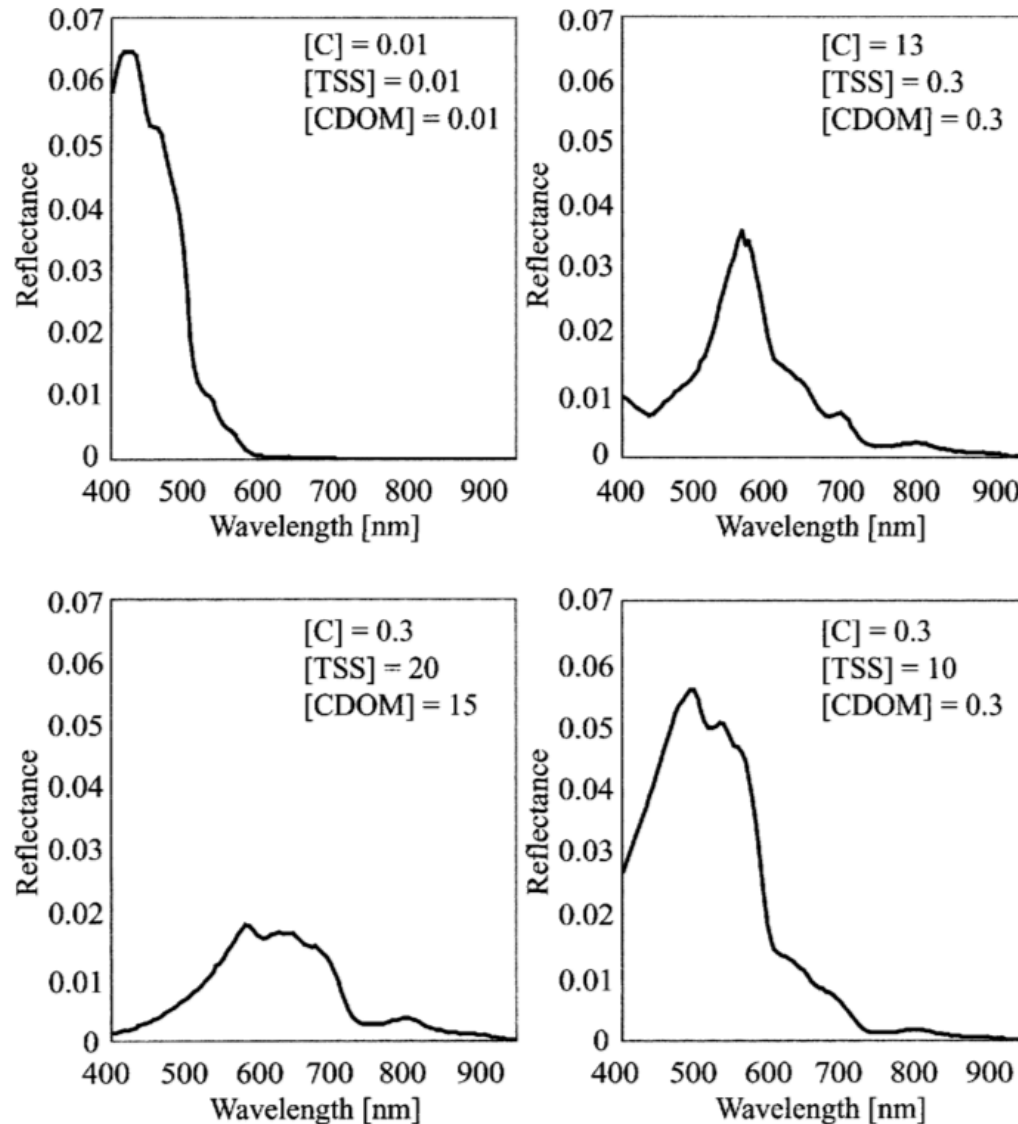
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HydroLight



HydroLight



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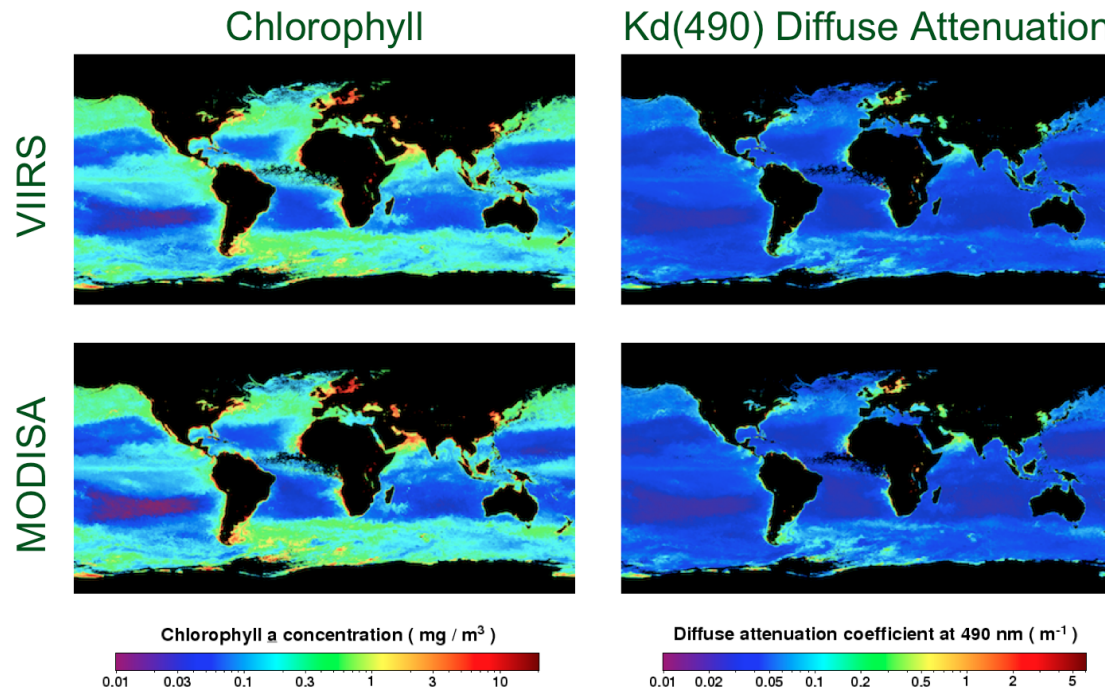
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Motivation

- Ocean color satellite (e.g. MODIS, VIRSS, SeaWiFS): global studies

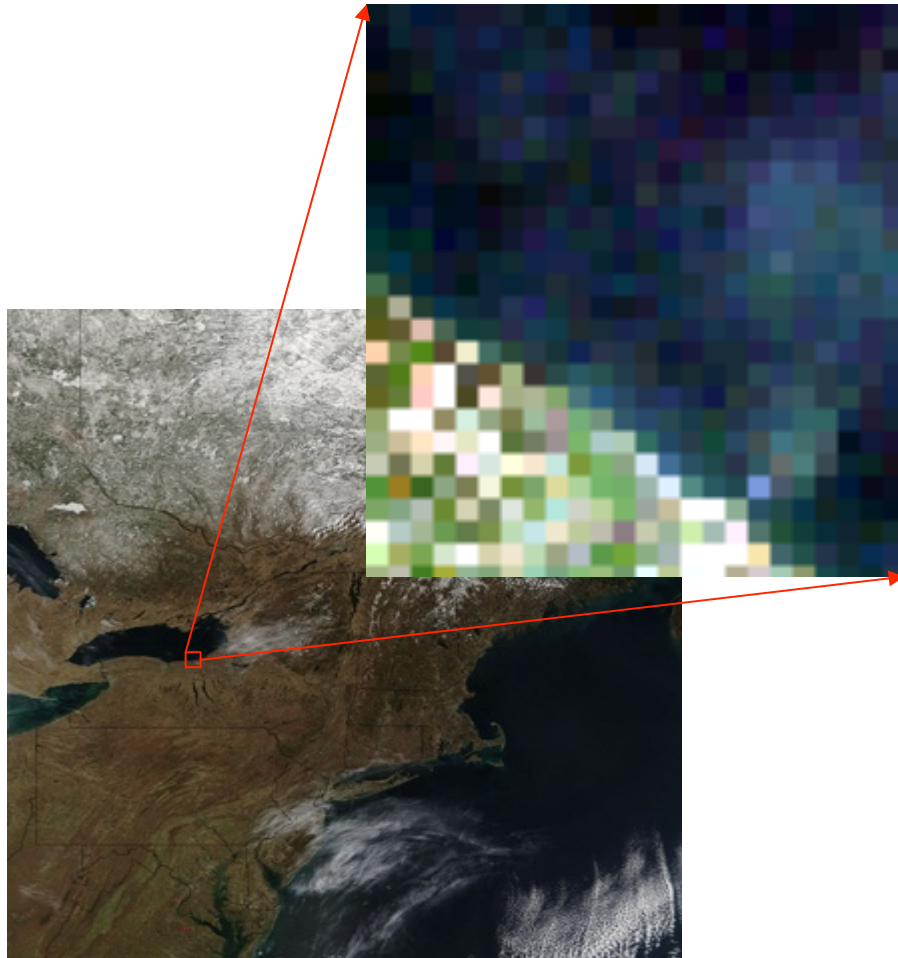
VIIRS & MODISA Winter 2012

NASA/OBPG Calibration & Processing

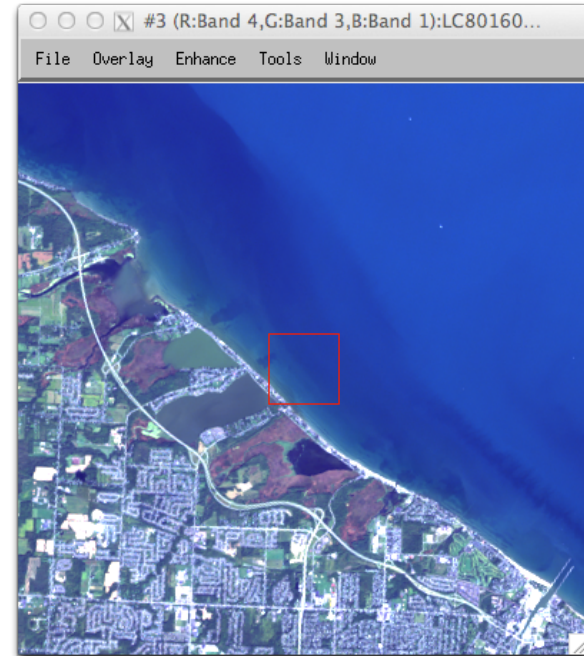


Motivation

Spatial Resolution: 1000 – 250 m
MODIS



30 m
Landsat-8



Motivation

- Product not available for medium spatial resolution satellites
- Monitoring the Earth's fresh water supply:
Create a water components product for fresh and coastal water

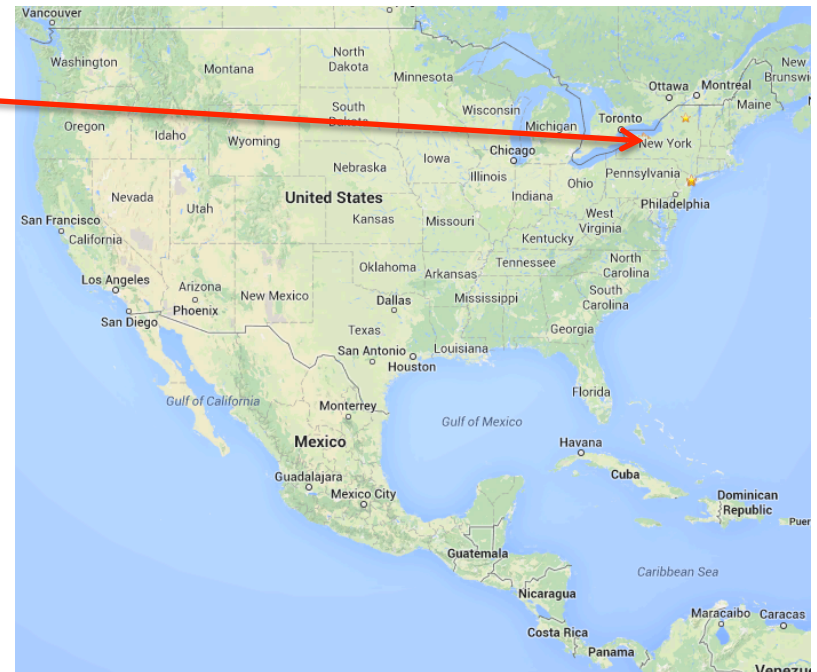
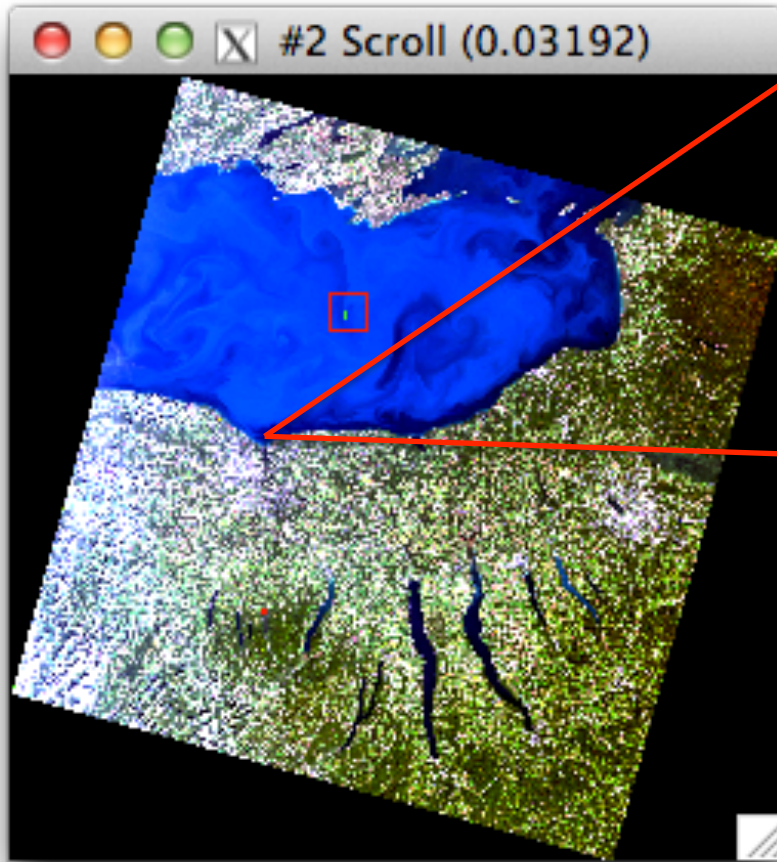
Hypothesis

- “The L8 sensor can be utilized to simultaneously quantify the concentration of water constituents (specifically chlorophyll, suspended solids, and colored dissolved organic matter) in fresh and coastal waters.”

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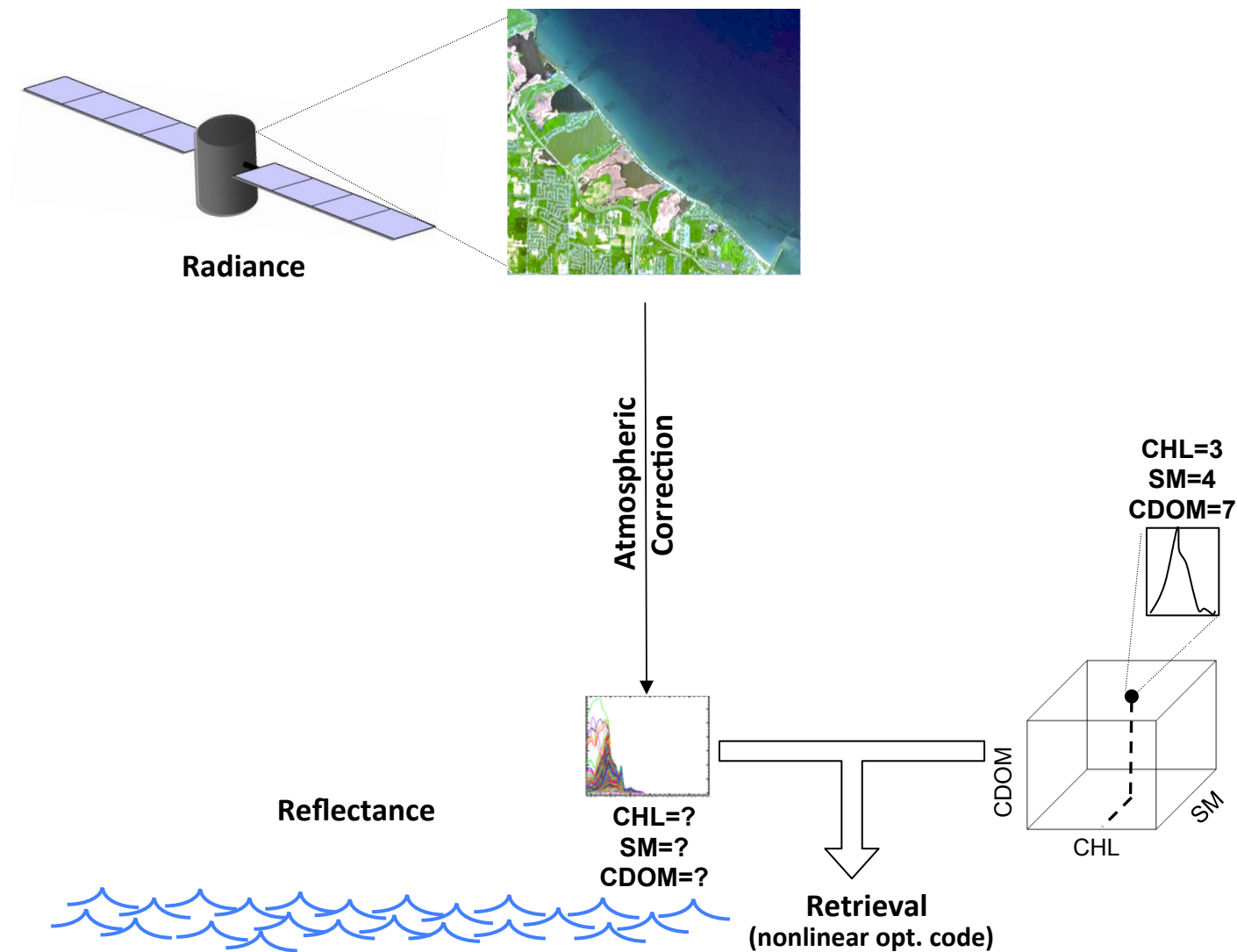
Area of Study



Lake Ontario, Rochester, NY:

- Lake Shoreline
- Genesee River Plume
- Ponds

Retrieval Process



Difficulties

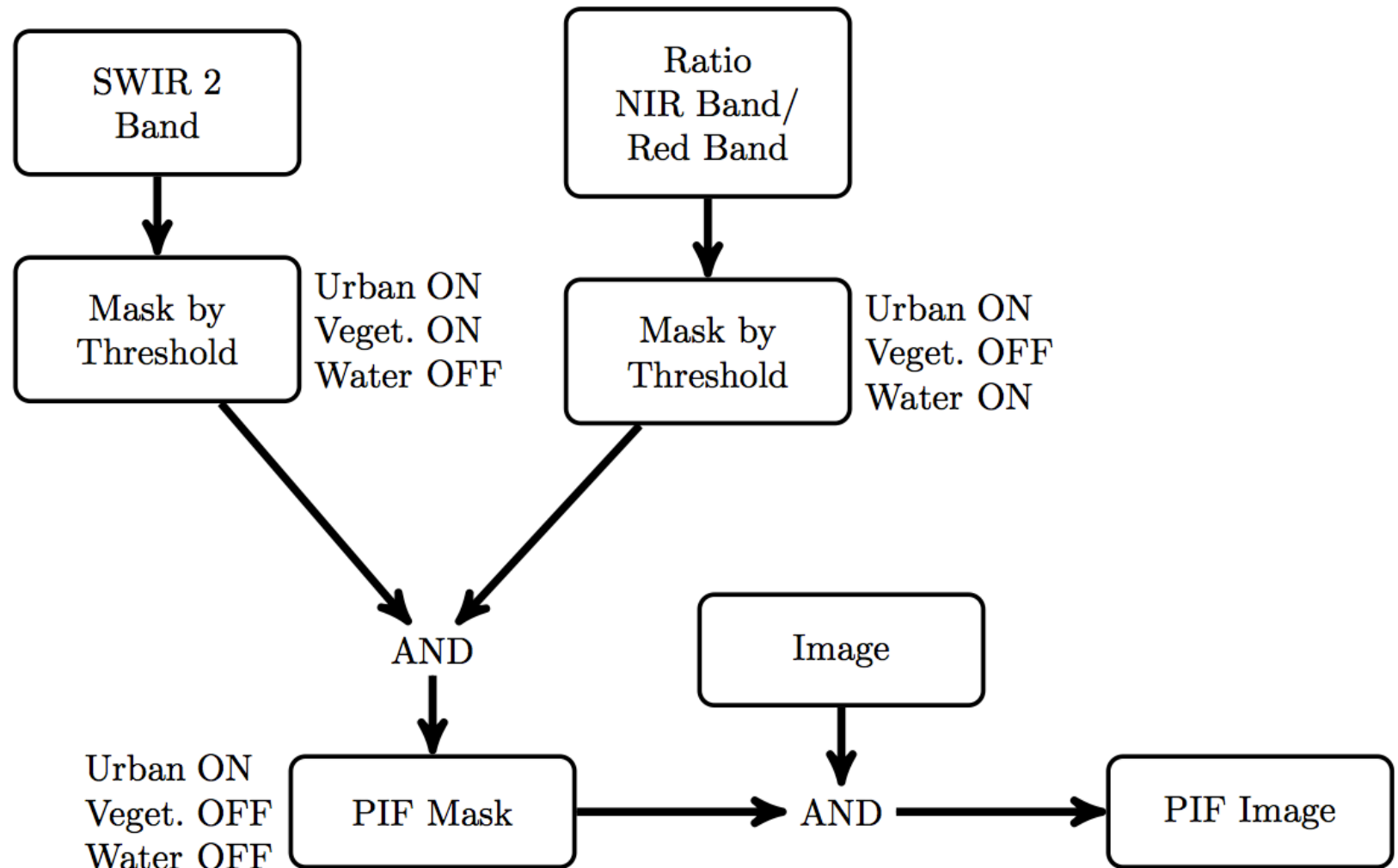
- The signal leaving the water is small in comparison to the signal produced by the atmospheric effects (e.g. scattering)
- Few spectral bands (5 bands) to capture all details in the signal leaving the water
- Wider bands than the Ocean color satellite such as MODIS, SeaWiFS

Atmospheric Correction

- A Model Based Empirical Line Method (ELM) Atmospheric Correction Method
 - Bright pixel :
 - Radiance (Data Spectra): Pseudo Invariant Features (PIF) from L8 image
 - Reflectance (Field Spectra): PIF from Landsat reflectance product (CDR)
 - Dark pixel:
 - Radiance (Data Spectra): water ROI from L8 image
 - Reflectance (Field Spectra): HydroLight (estimated concentration)

ELM-based Atm. Correction Method

Pseudo Invariant Features mask

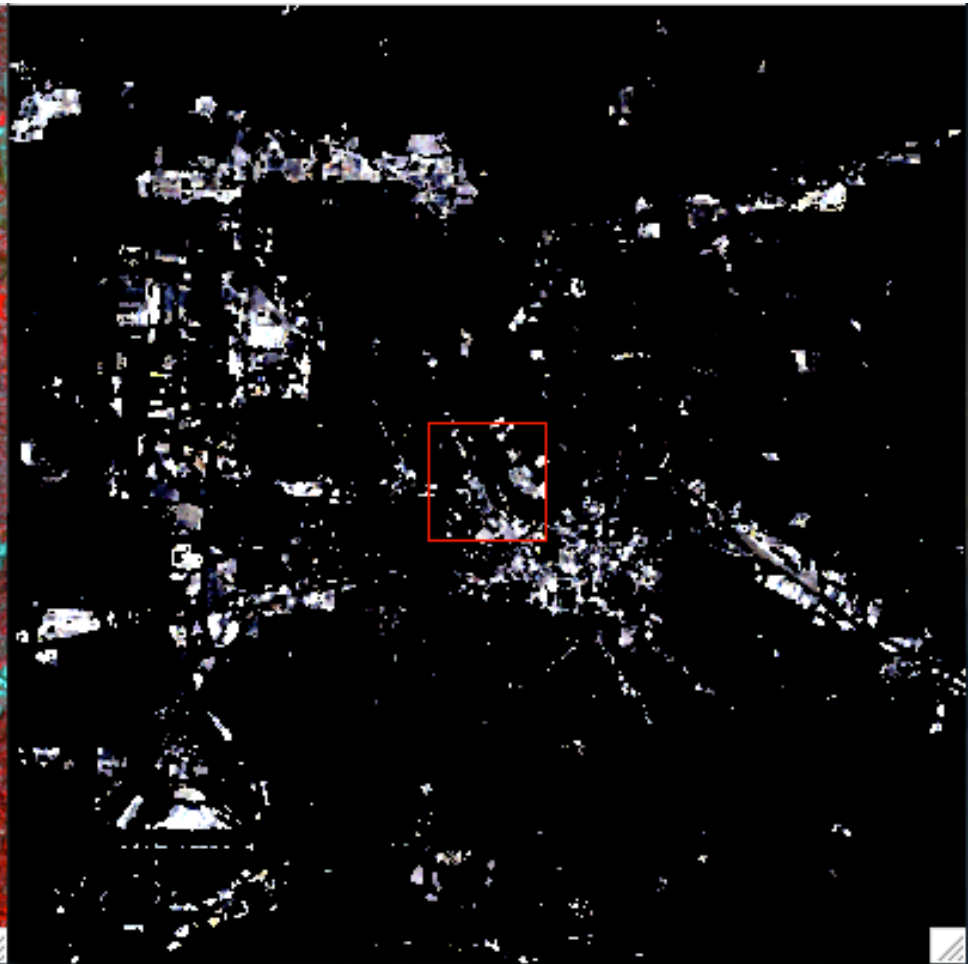


ELM-based Atm. Correction Method

Bright Pixel



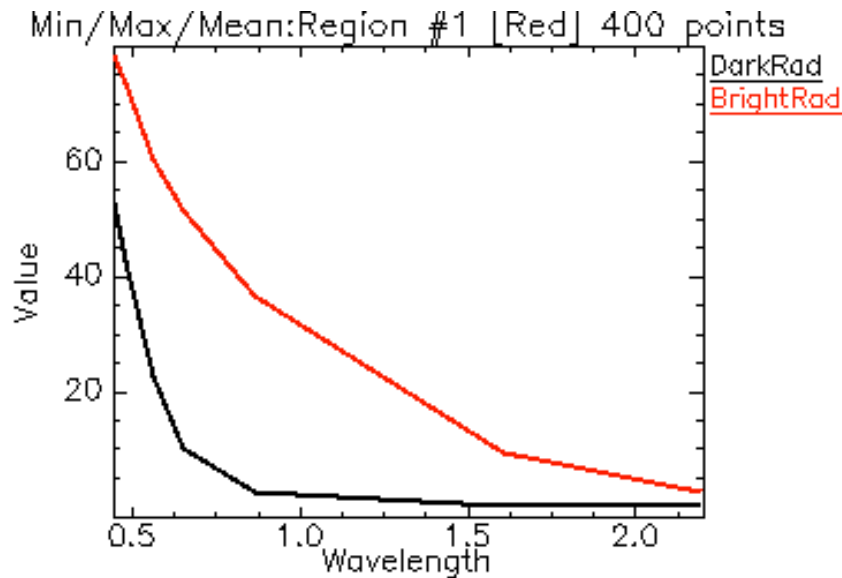
False color image (red = vegetation)



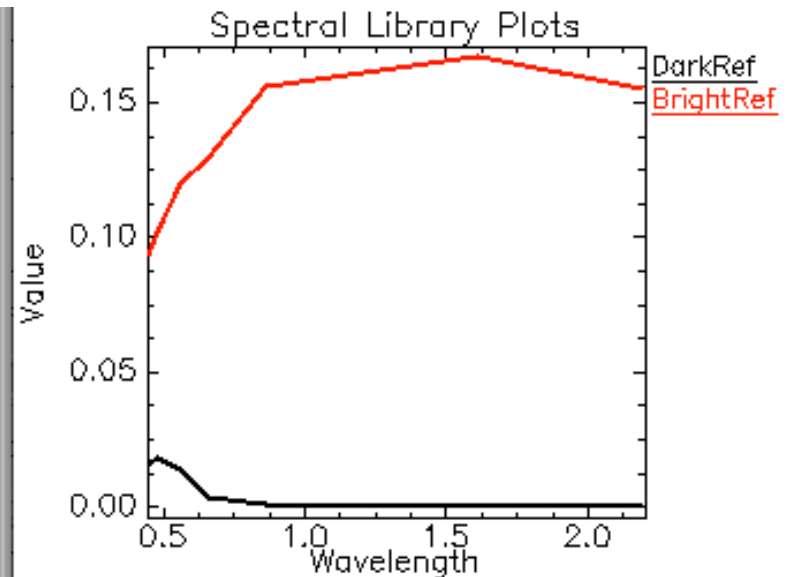
City Pixels (Bright px)

ELM-based Atm. Correction Method

Bright and Dark Pixels

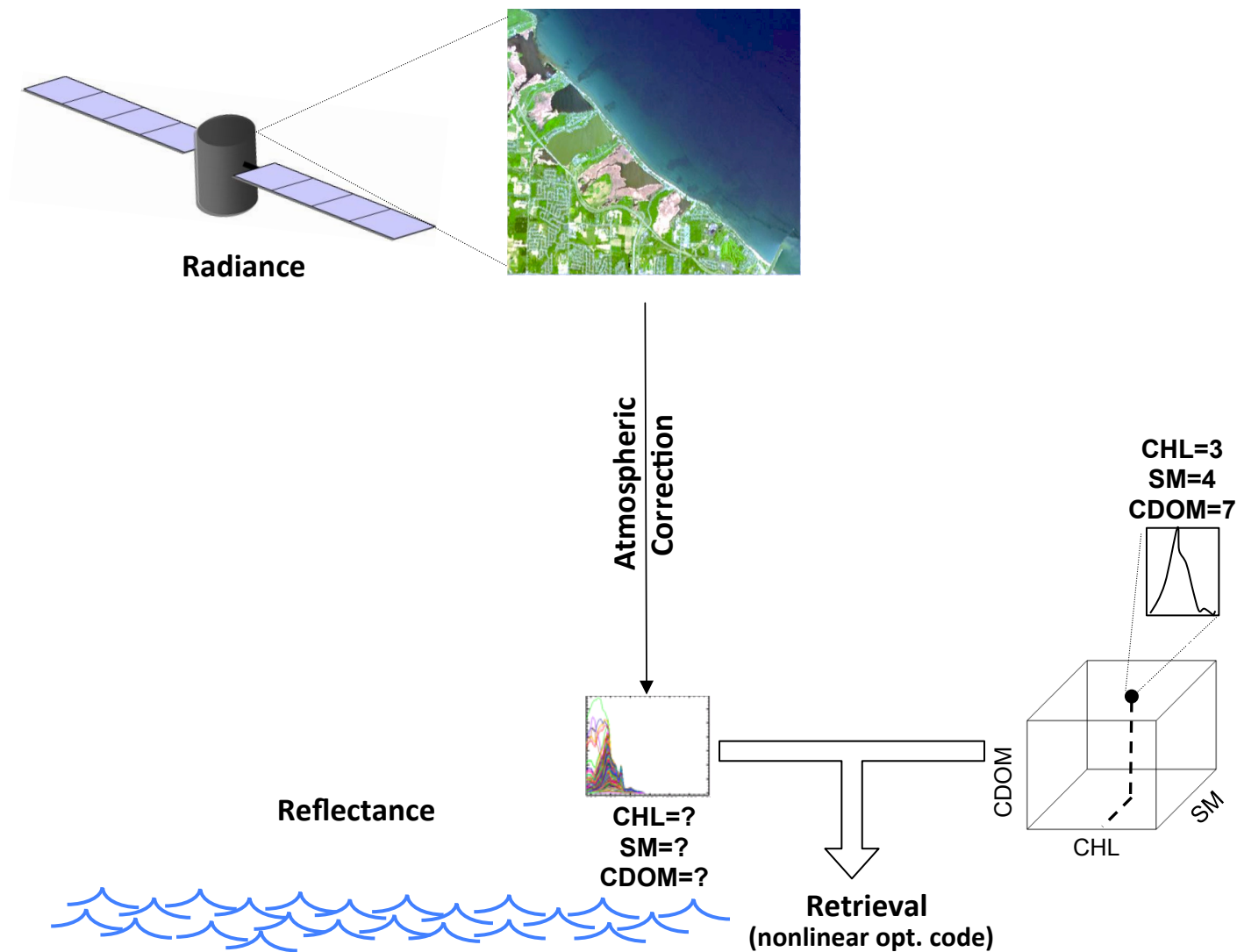


Data Spectra
Radiance
[W/m²/sr]

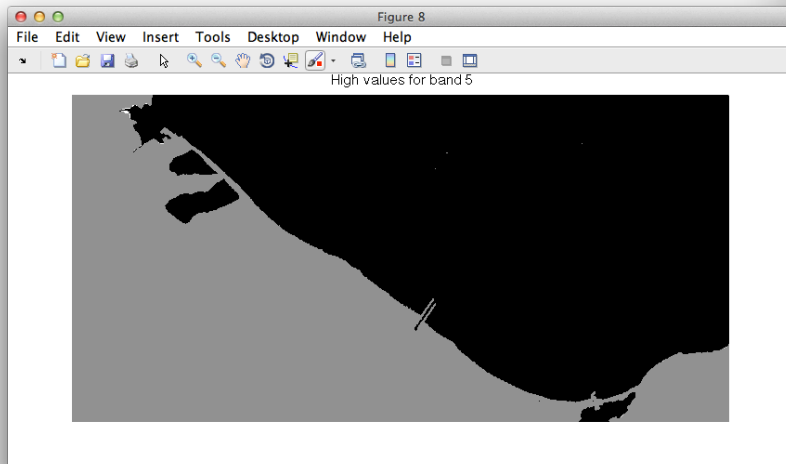


Field Spectra
Reflectance

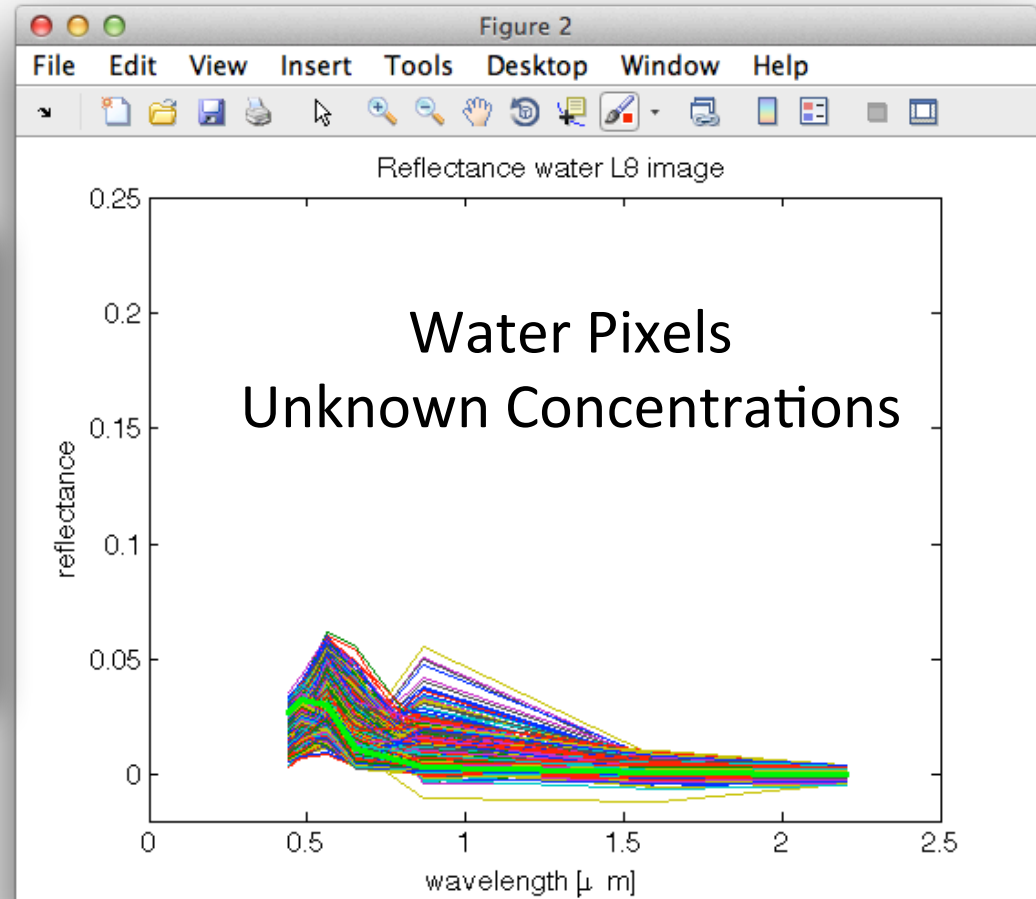
Retrieval Process



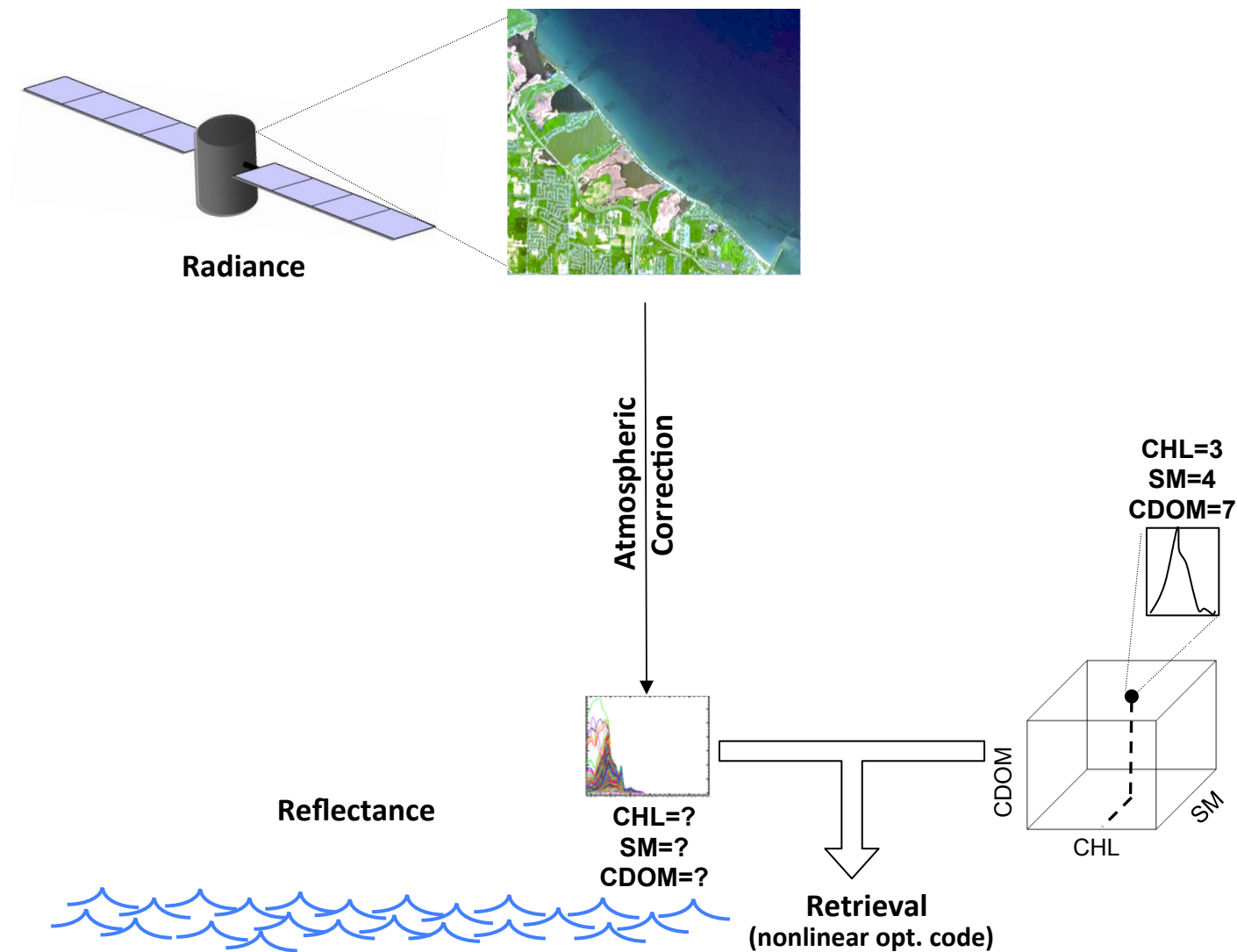
Water Pixels



Water Mask



Retrieval Process

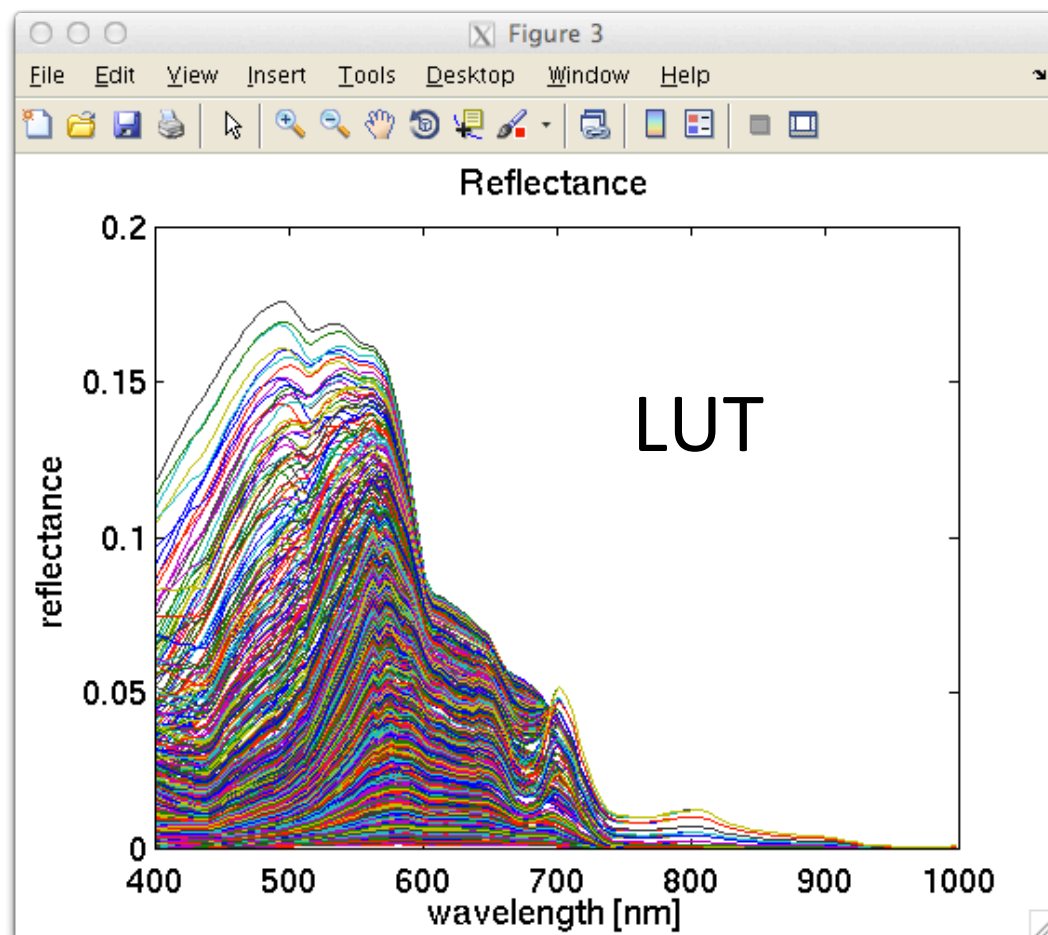


LUT: HydroLight

- Case 2: 4-component IOP model
 1. Pure Water
 2. Chlorophyll-bearing particles
 3. CDOM
 4. Mineral Particles
- Output: Water Leaving Reflectance Curves

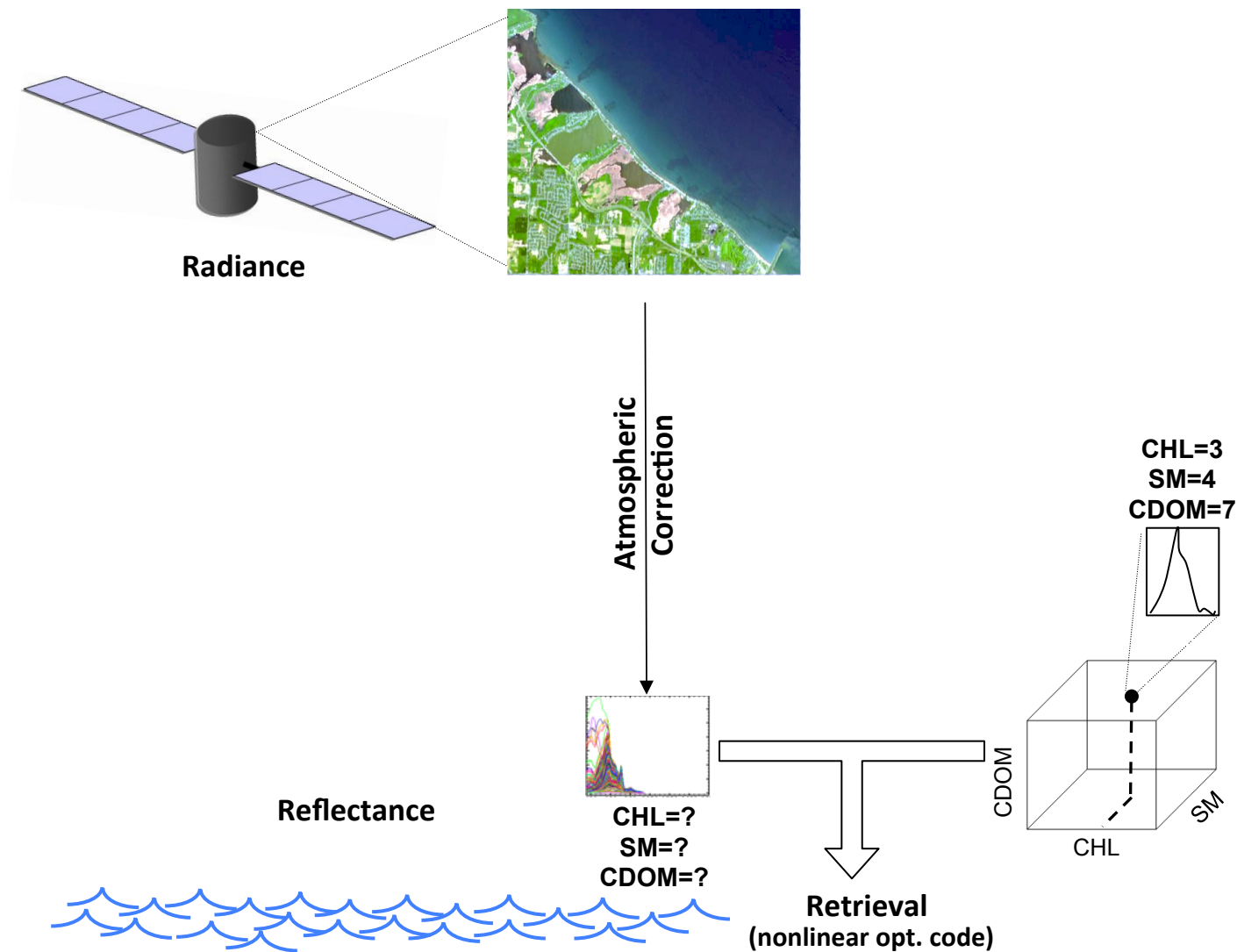
LUT: HydroLight (con't)

CHL [ug/L]	SM [mg/L]	CDOM
0.25	0.25	0.25
0.5	0.5	0.5
1.0	1.0	0.75
3.0	2.0	1.0
5.0	4.0	2.0
7.0	8.0	4.0
12.0	10.0	7.0
24.0	14.0	10.0
46.0	20.0	12.0
68.0	24.0	14.0

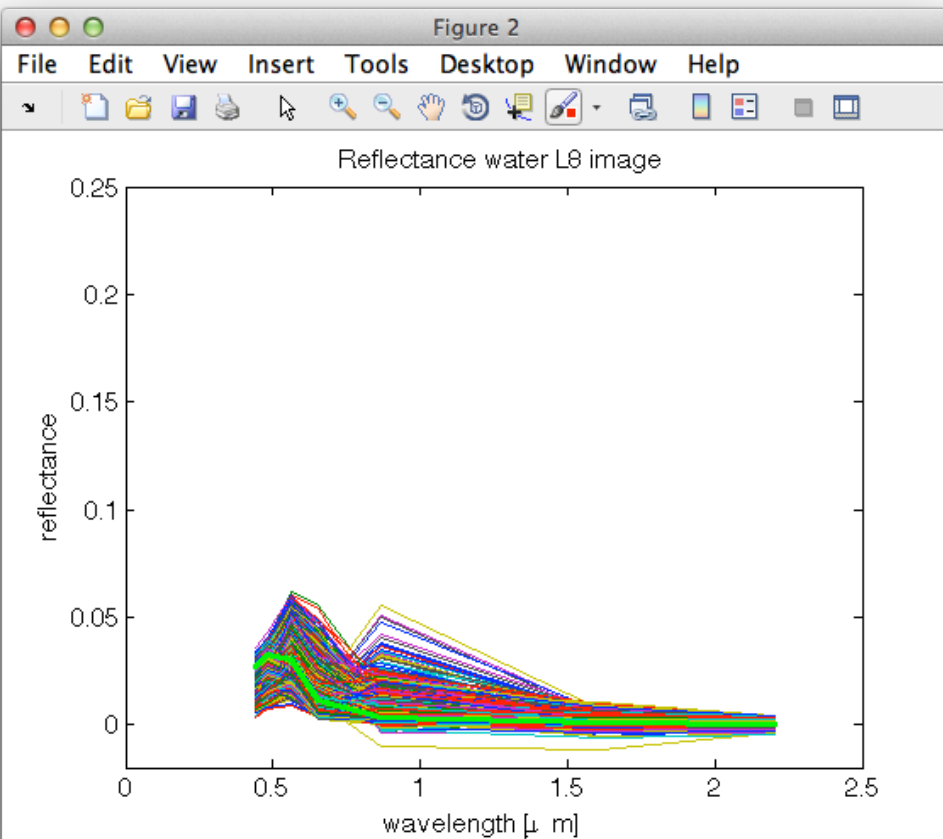


Known Concentrations

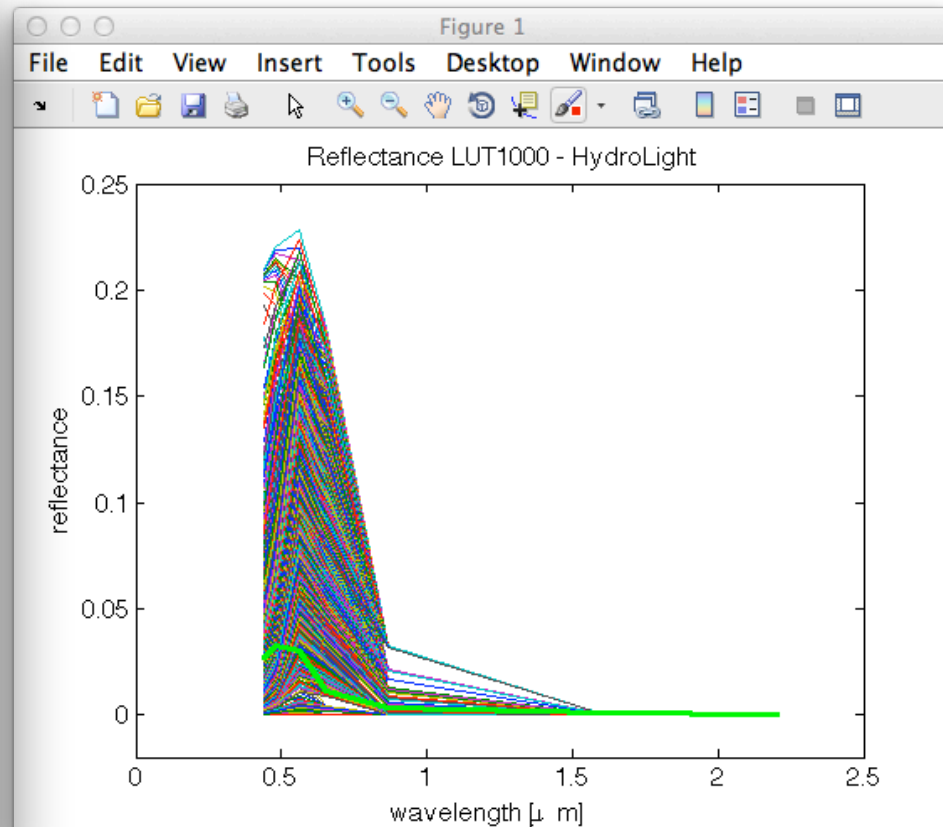
Retrieval Process



Non-linear Optimization Routine



Water Pixels



LUT

Non-linear Optimization Routine (con't)

- **lsqnonlin in Matlab:** Solve nonlinear least-squares (nonlinear data-fitting) problems of the form

$$\min_x f(x) = f_1(x)^2 + f_2(x)^2 + f_3(x)^2 + \cdots + f_m(x)^2$$

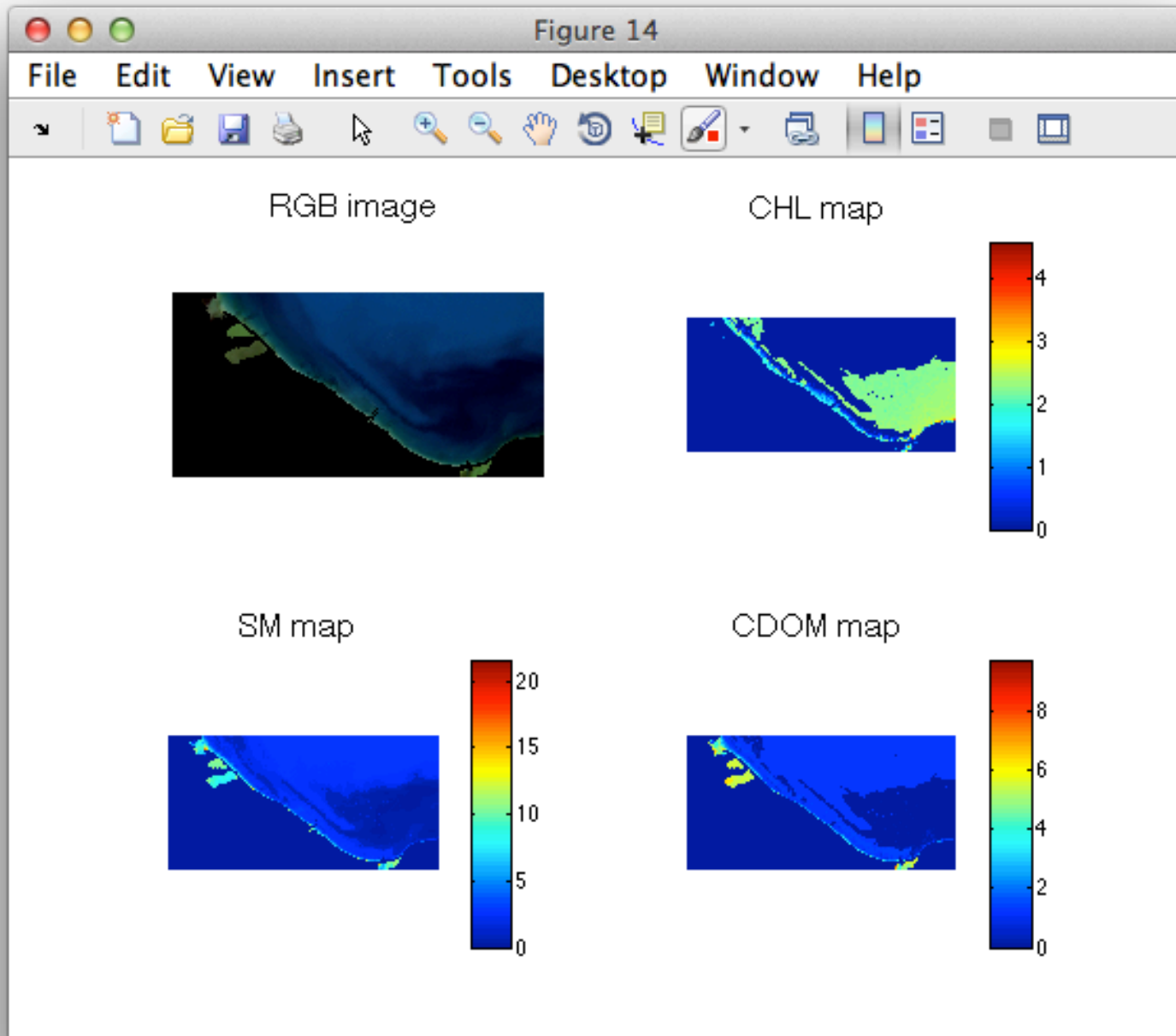
- `function f = myfun_mod(x0,f1,f2,f3,LUT,Ytest)`
 `...`
 `f = Ytest-F;`

Where `Ytest`: pixel with unknown concentration

`F`: estimated curve from the LUT

- It uses a tripolar interpolation to estimate $\bar{F}$.

Retrieval Results



Outline

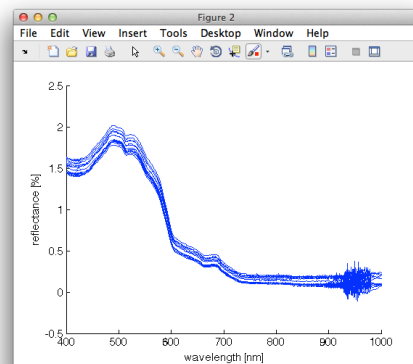
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Ground Truth Collect

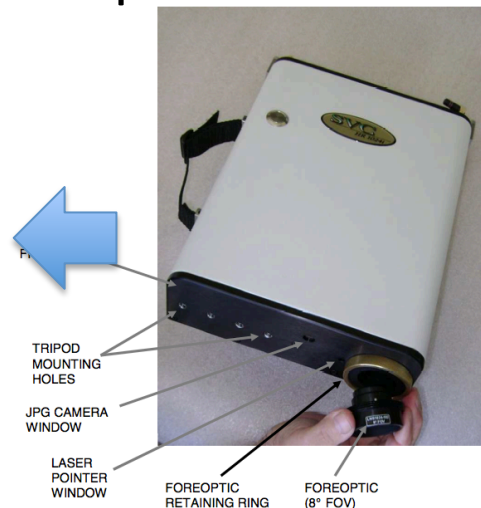
- Spring and Summer 2013, 2014:
 - When Landsat 8 passes over Rochester
 - Three successful images in 2013
- Data:
 - Water samples: IOPs and Concentrations
 - Reflectances

Ground Truth Collect

Spectroradiometer



Water Leaving
Reflectance



Water Samples



Lab Analysis



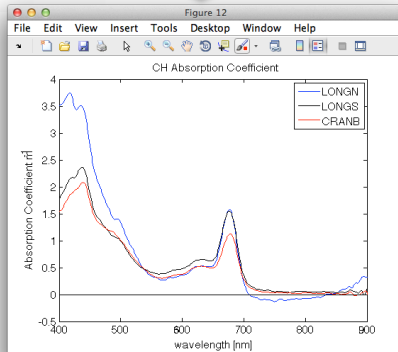
Backscattering

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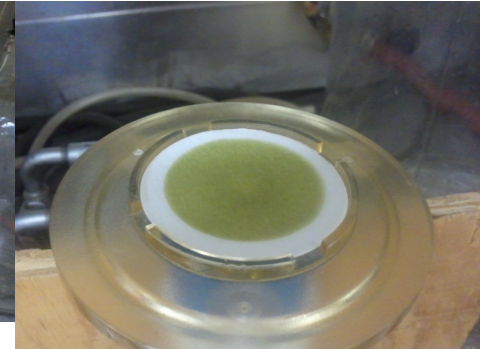
Lab Measurements

Spectrophotometer

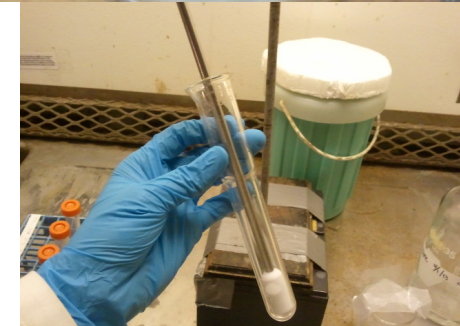


IOPs

HydroLight



Filtration and Spectrophotometric Analysis



Concentrations

Sept 19th Ground Truth Collect



RIT Ground Truth Collection Summary

Date	IOPs		Concentrations		Reflectances		Backscattering	
	Ponds	Lake	Ponds	Lake	Ponds	Lake	Ponds	Lake
25-Aug	✓	✗	✓	✗	✗	✗	✗	✗
19-Sep	✓	✓	✓	✓	✗	✓	✓	✓
26-Sep	✓	✓	✓	✓	✗	✓	✗	✓

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Future Work

- Include a glint correction
- Try in a different water body
- Validation by comparing with products from ocean color satellites
- Integration with Hydrodynamics models

Take Home Points

- Landsat-8 has great potential to help in fresh and coastal water quality studies
- Atmospheric correction over water is a essential step
- HydroLight is a excellent tool but needs specific water characteristics

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- Founded in 1829
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Student Body

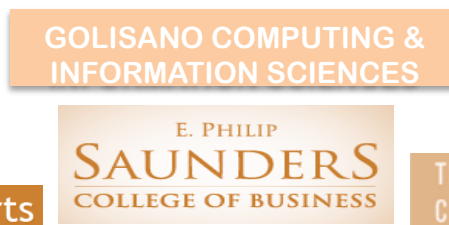
- 17,600 students
- 2,900 graduate students
- 110 countries represented
- 106,000+ alumni



Academic Programs

- ✓ Business, Management, Communication
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- ✓ Engineering, Engineering Technology
- ✓ Photography, Film, Design, Fine Arts, Graphic Communications
- ✓ Science, Health Sciences, Mathematics, Imaging Science
- ✓ Sustainability

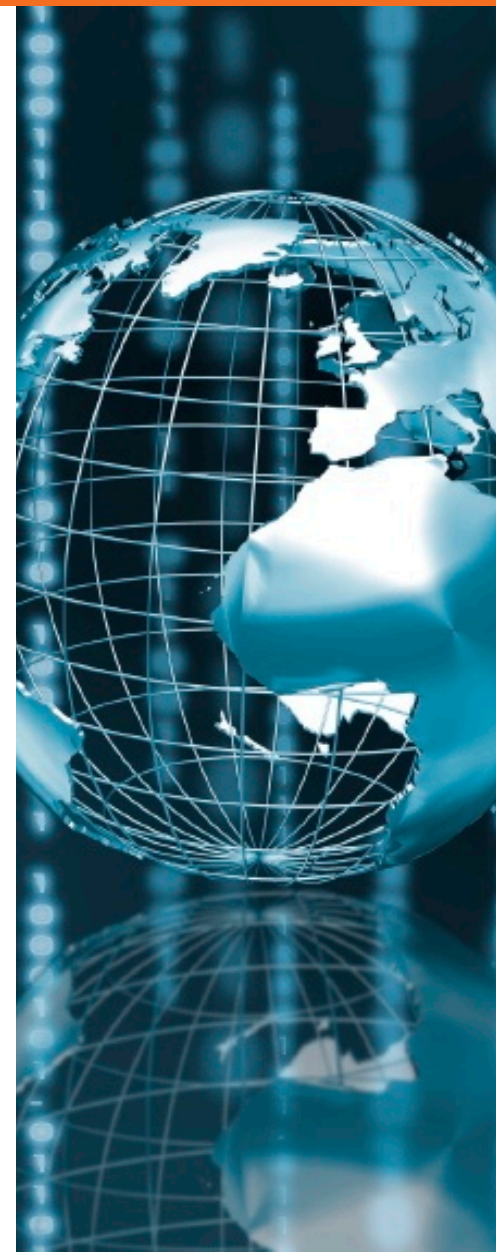
**70+ graduate
6 PhD programs**



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Financial Aid and Scholarships

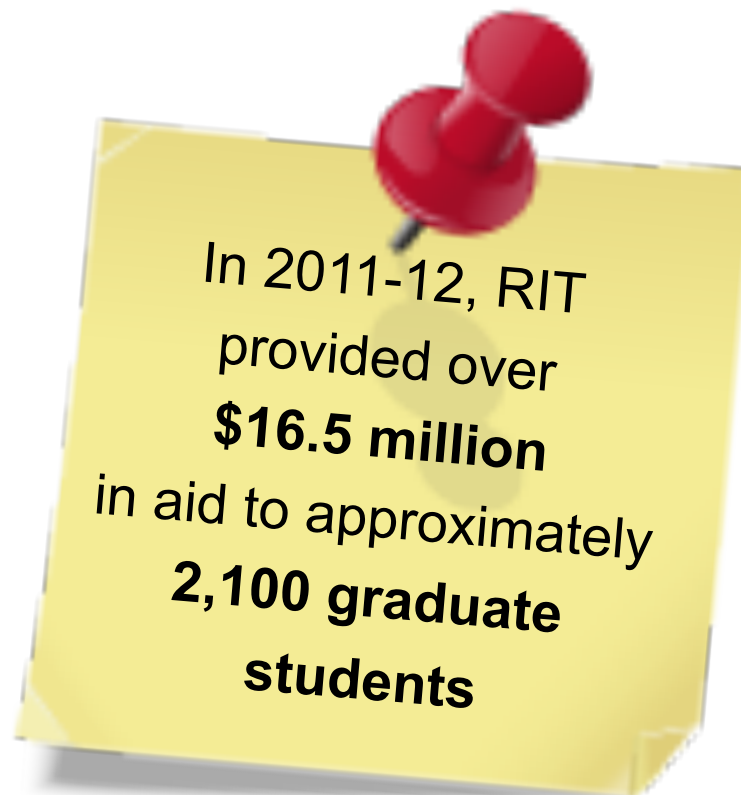
Awards

- Scholarships, based on merit
- Graduate Assistantships

Employment

- Sponsored Research & Fellowships
- Student Employment (8,000 campus jobs available)

Student Loans



IEEE Geoscience and Remote Sensing Society (IEEE GRSS)





IEEE is the largest academic and professional society in the world

- 425,000 MEMBERS IN 160 COUNTRIES
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- 38 SOCIETIES AND 7 TECHNICAL COUNCILS REPRESENTING WIDE RANGING IEEE TECHNICAL INTERESTS





IEEE GRSS

(Geoscience and Remote Sensing Society)

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Earth Science, Imaging Systems and Spatial Analysis → Geoscience and Remote Sensing

- *Optical imaging systems*
- *Hyperspectral imaging systems*
- *Lidar systems and applications*
- *Radar altimetry and applications*
- *Microwave imaging radar systems*
- *Microwave and mm-wave radiometer systems*
- *Geospatial information processing and applications in Earth and Planetary systems*

IEEE GRSS Applications

- Earth's Environment Monitoring
- Earth's Biomass Monitoring and Analyses
- Monitoring & Mitigation of Natural Hazards
- Urban Studies/Planning
- Natural Resource Exploration
- Space & Planetary Exploration and Applications
- etc.

IEEE Geoscience and
Remote Sensing Society

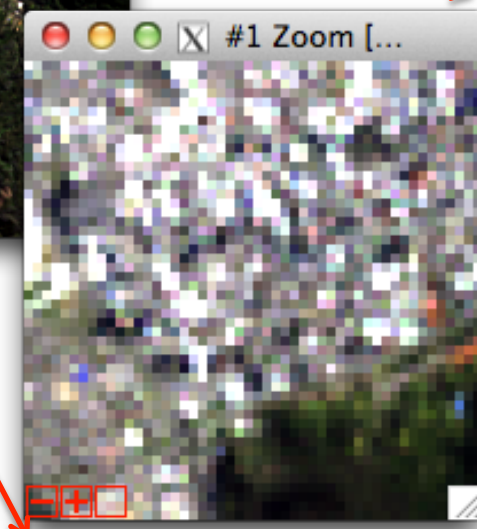
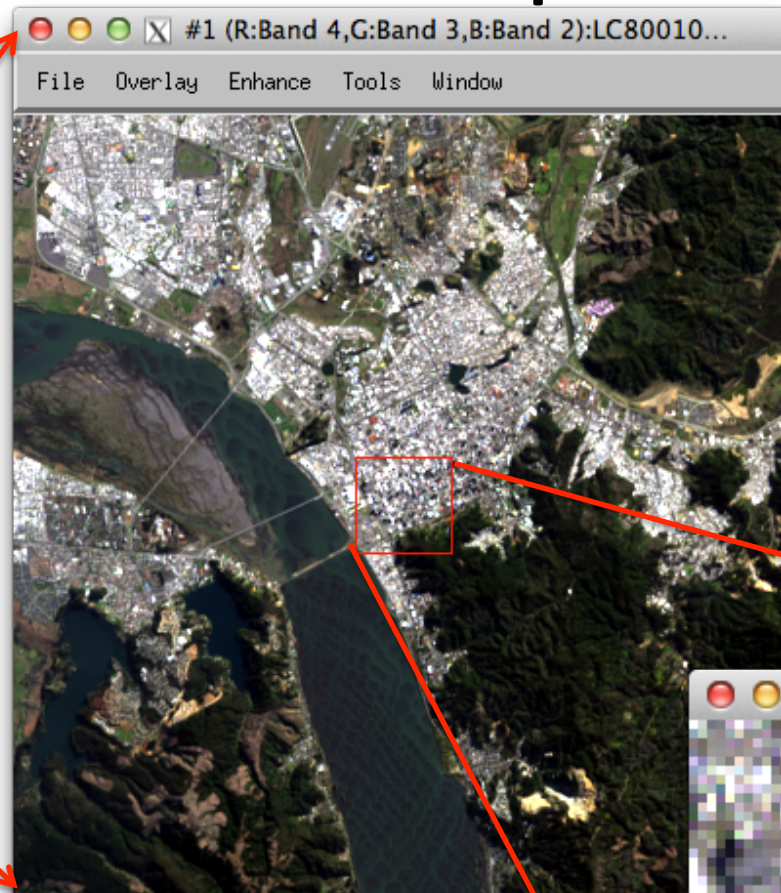
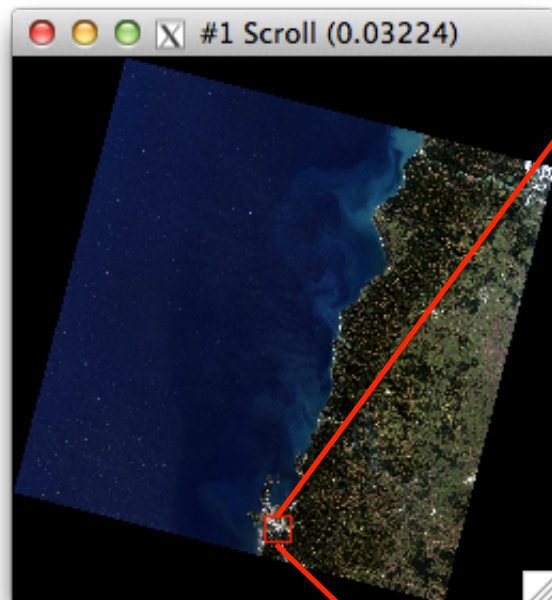
IEEE GRSS

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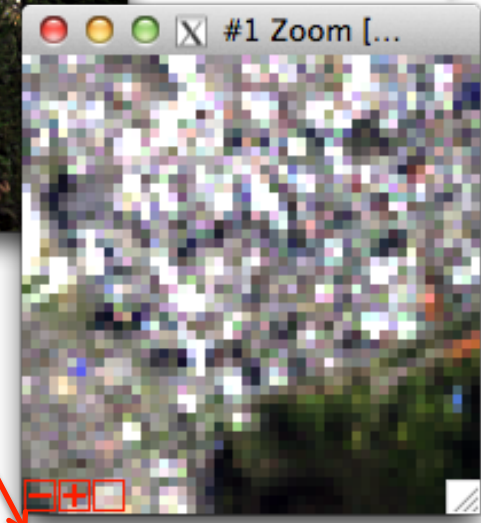
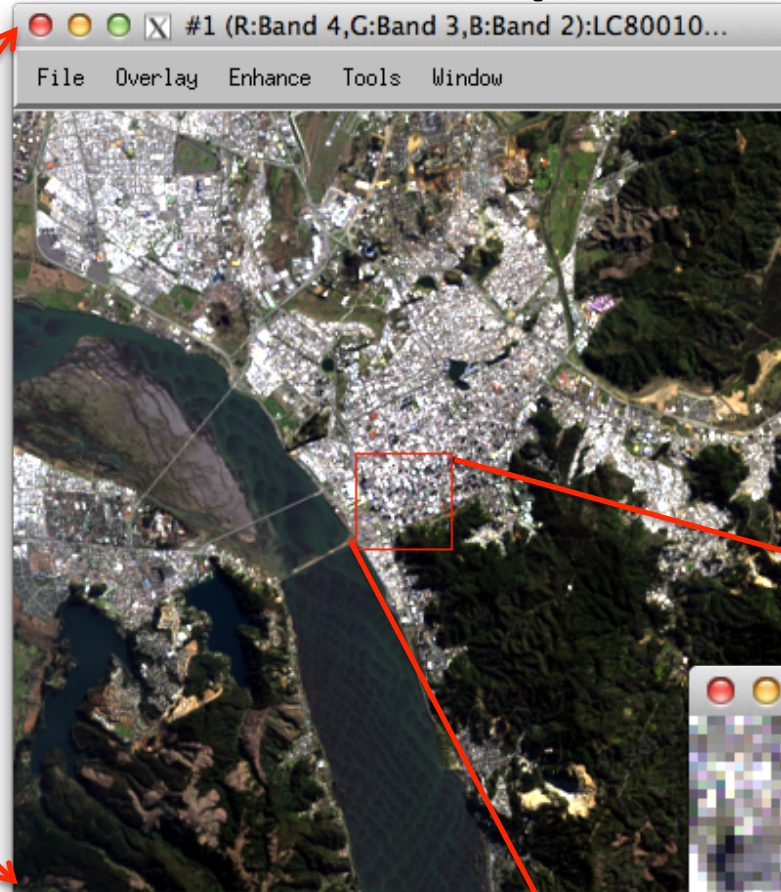
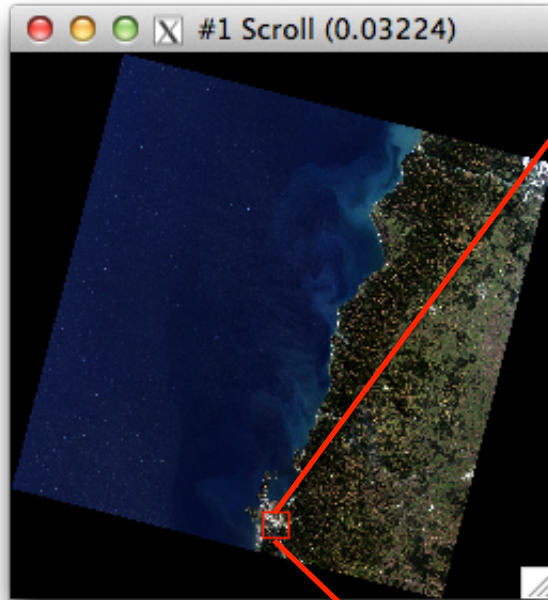
www.grss-ieee.org



Landsat 8 – Concepción



Landsat 8 – Concepción



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QUESTIONS?