



National Aeronautics and  
Space Administration



## ARSET

Applied Remote Sensing Training

<http://arset.gsfc.nasa.gov>

 @NASAARSET

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# Introduction to Remote Sensing for Ocean and Coastal Applications

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Sherry L. Palacios

Week 1: July 6, 2016

# Course Structure

- One lecture per week – every Wednesday July 6 – July 27
- 1:00 – 2:00 PM EDT (UTC-4)
  - Lectures
  - In-class demonstration
  - Homework exercises
- Webinar recordings, presentations, and homework assignments can be found after each session at:
  - <http://arset.gsfc.nasa.gov/land/webinars/coastal-oceans-2016>
- Q/A: Following each lecture and/or by email ([sherry.l.palacios@nasa.gov](mailto:sherry.l.palacios@nasa.gov))

# Homework and Certificates

- Homework
  - Answers must be submitted via Google Form
- Certificate of Completion:
  - Attend all 4 webinars
  - Complete assignments by deadline (Wednesday, August 10th)
  - You will receive certificate approximately 3 months after the completion of the course from: [marines.martins@ssaihq.com](mailto:marines.martins@ssaihq.com)

# Prerequisite

- Fundamentals of Remote Sensing
  - Session 1
  - On-demand webinar available anytime
  - <http://arset.gsfc.nasa.gov/webinars/fundamentals-remote-sensing>

**Fundamentals of Remote Sensing**

These webinars are available for viewing at any time. They provide basic information about the fundamentals of remote sensing, and are often a prerequisite for other ARSET trainings.

**Learning Objectives:**

Participants will become familiar with satellite orbits, types, resolutions, sensors and processing levels. In addition to a conceptual understanding of remote sensing, attendees will also be able to articulate its advantages and disadvantages. Participants will also have a basic understanding of NASA satellites, sensors, data, tools, portals and applications to environmental monitoring and management.

**Course Format:**

- One-hour sessions
- Currently two available sessions
- No certificates are available for this training

**Prerequisites:**

No previous remote sensing experience is required for this training.

**Audience:**

These webinars are appropriate for...

**Registration Information:**

This webinar series is free.

**Course Agenda:**

- On Demand Agenda...

**Session 1: Fundamentals**

A general overview to remote sensing resource and wildfire management.

- Presentation Slides

**Session 2A: Satellites, Sensors**

Specific satellites, sensors and applications to environmental monitoring and management.

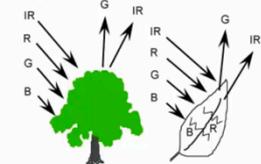
**ARSET**

- Webinars
- Workshops
- Suggest a Training
- Personnel
- Resources

**Upcoming Training**

- Land
- Remote Sensing of Forest Cover and Change
- Assessment for Carbon

**Interaction with Earth Surface: Vegetation**



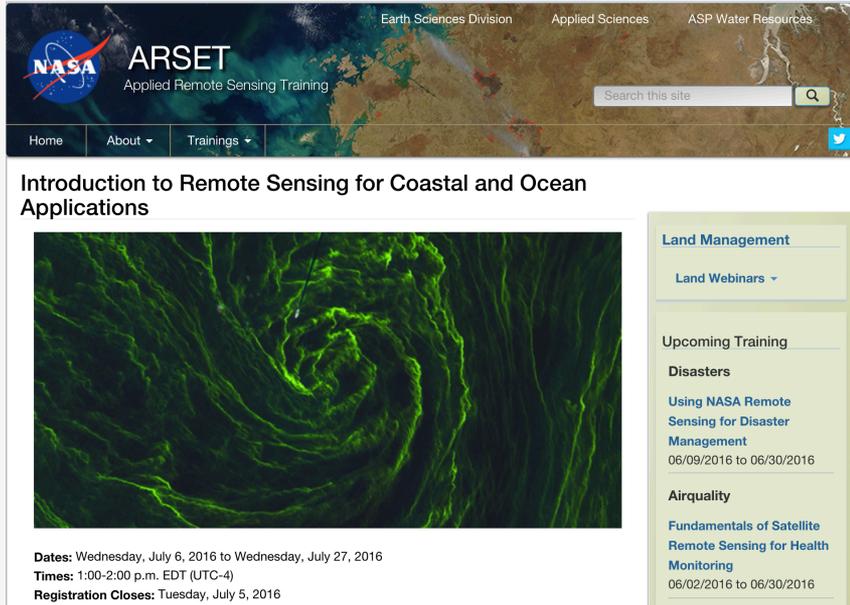
Example: Healthy, green vegetation **absorbs Blue and Red** wavelengths and **reflects Green and Infrared**

Since we cannot see infrared radiation, we see healthy vegetation as green



# Accessing Course Materials

<http://arset.gsfc.nasa.gov/land/webinars/coastal-oceans-2016>



The screenshot shows the ARSET (Applied Remote Sensing Training) website. The header includes the NASA logo, the text "ARSET Applied Remote Sensing Training", and navigation links for "Earth Sciences Division", "Applied Sciences", and "ASP Water Resources". A search bar is present. Below the header, there are navigation tabs for "Home", "About", and "Trainings". The main content area features the title "Introduction to Remote Sensing for Coastal and Ocean Applications" and a large satellite image of a coastal area with green and blue patterns. To the right of the image is a sidebar with links for "Land Management", "Land Webinars", "Upcoming Training", "Disasters", "Using NASA Remote Sensing for Disaster Management", "Airquality", and "Fundamentals of Satellite Remote Sensing for Health Monitoring".

**Introduction to Remote Sensing for Coastal and Ocean Applications**

**Dates:** Wednesday, July 6, 2016 to Wednesday, July 27, 2016  
**Times:** 1:00-2:00 p.m. EDT (UTC-4)  
**Registration Closes:** Tuesday, July 5, 2016

**Land Management**

**Land Webinars**

**Upcoming Training**

**Disasters**

**Using NASA Remote Sensing for Disaster Management**  
06/09/2016 to 06/30/2016

**Airquality**

**Fundamentals of Satellite Remote Sensing for Health Monitoring**  
06/02/2016 to 06/30/2016

## Course Agenda:

[Agenda.pdf](#)

### Session One: Overview of Satellite Remote Sensing of Aquatic Environments

July 6, 2016

An overview of themes in coastal and ocean applied science, how remote sensing is used for coastal and ocean applied science, fundamentals of remote sensing (spatial, temporal, spectral resolutions), and the advantages and limitations of remote sensing in aquatic environments. [View the recording »](#)

- [Presentation Slides »](#)

### Session Two: Platforms and Sensors for Ocean Observations, Data Access, and Processing Tools

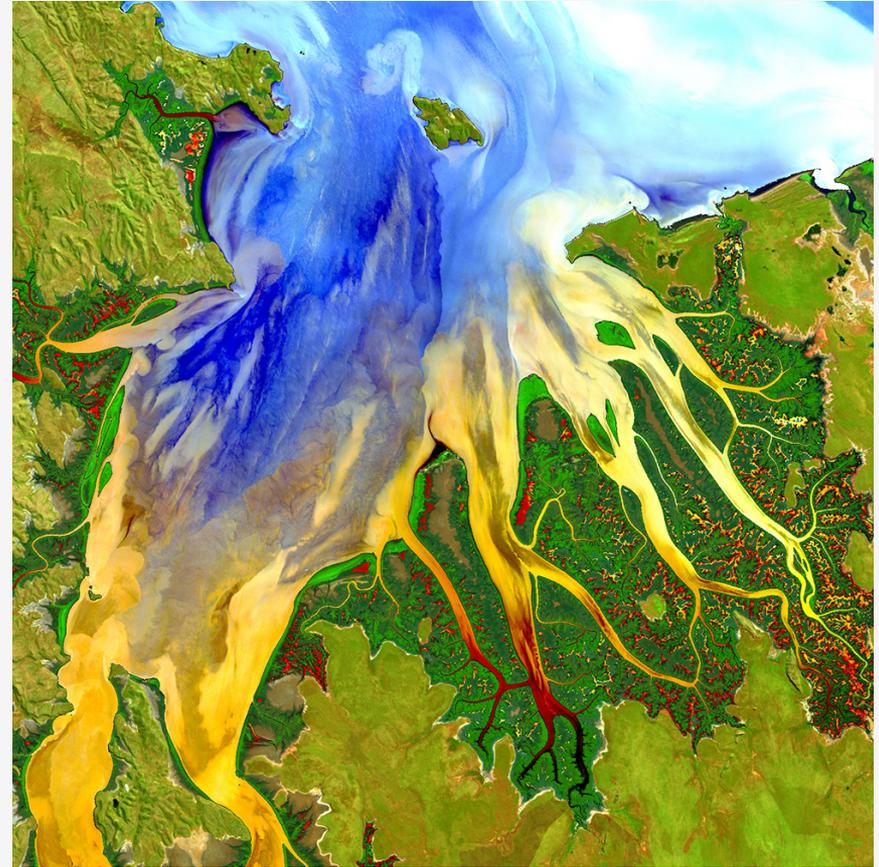
July 13, 2016

Satellites and sensors for coastal and ocean applications, satellite data processing levels, NASA satellite data access tools and data processing tools. [View the recording »](#)

- [Presentation Slides »](#)

# Course Objectives

- Overview of NASA Earth Observation resources available for open ocean and coastal applications including:
  - A basic understanding of remote sensing of aquatic systems
  - How to access and visualize NASA Earth science data
  - How to use NASA Earth science data, tools, and products for ocean and coastal applied science issues
- Conduct live demonstrations of useful ocean and coastal applied science tools



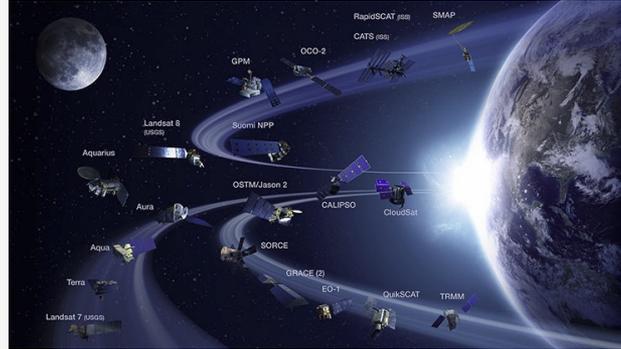
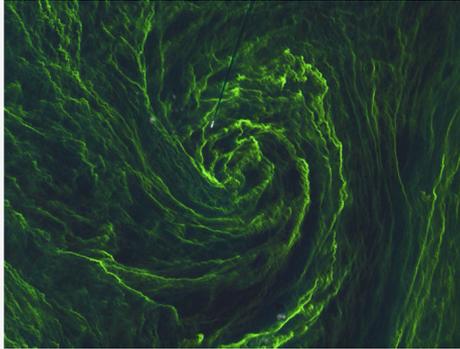
Credit: NASA/USGS Landsat; Geoscience Australia

## Expected Outcomes

- Gain knowledge and ability to access, analyze, and apply satellite remote sensing data for coastal and ocean applied science
- Learn about advantages and limitations of using remote sensing observations for coastal and ocean applications

# Course Outline

Week 1  
Overview of  
Satellite  
Remote Sensing

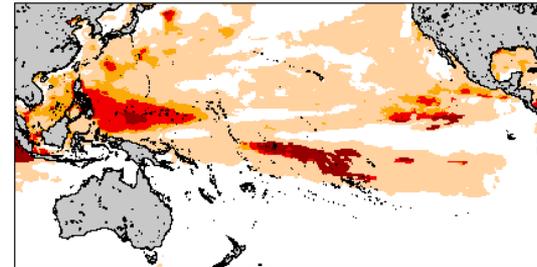


Week 2  
Platforms  
and Sensors  
for Ocean  
Observations

Week 3  
Animal  
Movement



2016 May 17 NOAA 90% Probability Bleaching Thermal Stress for May–Aug 2016  
Experimental, v3.0, CFSv2–based, 28–member



Potential Stress Level: Watch Warning Alert Level 1 Alert Level 2

Week 4  
Coral Reefs

# Week 1 Agenda

- Course Structure and Objectives
- Overview of ARSET
- Overview of Themes in Coastal and Open Ocean Applied Science
- Coastal and Open Ocean Applied Science Thematic Areas
- Fundamentals of Aquatic Remote Sensing
- Advantages and Limitations of Remote Sensing in Aquatic Environments



ARSET  
Applied Remote SEnsing Training Program

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<http://arset.gsfc.nasa.gov>

# Applied Remote Sensing Training Program (ARSET)

<http://arset.gsfc.nasa.gov>

Training activities for environmental professionals to increase usage of NASA observational and modeling data for decision-making support.



## Online Webinars

- 1 hr a week, 4-6 weeks
- Live & recorded
- Include demos on data access

## In-person Workshops

- Held in a computer lab for 2 - 4 days
- Focus on data access
- Locally relevant case studies

## Train the Trainers

- Courses & training manuals for those interested in doing their own remote sensing trainings

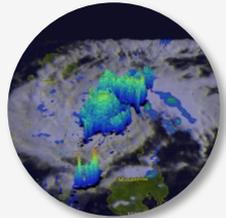
# Applied Remote Sensing Training Program (ARSET)

<http://arset.gsfc.nasa.gov>

Provide online and on-site trainings tailored to:

- policy makers
- regulatory agencies
- applied environmental professionals

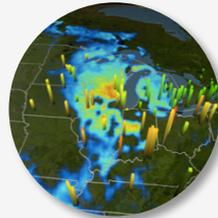
to increase the use of NASA Earth Science models & data for environmental applications:



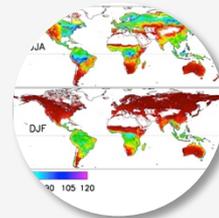
Disasters



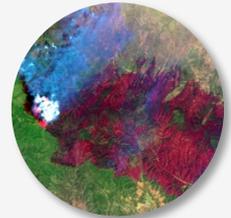
Ecoforecasting



Health &  
Air Quality



Water Resources



Wildfires

# ARSET Trainings

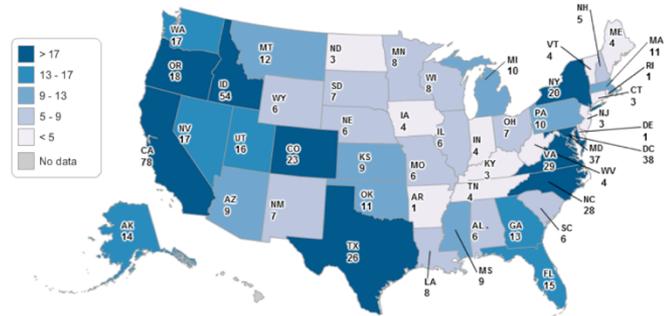
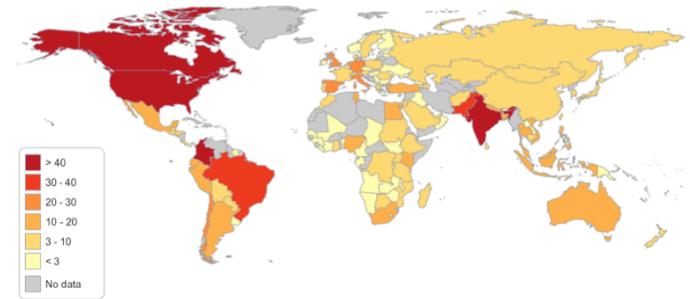
## Impact & Accomplishments

- 68 Trainings Completed
- 4,900+ participants worldwide from:
  - 1,600+ organizations
  - 130+ countries
- More participants trained in 2015 than all previous years combined

*“The greatest benefit [of this training] is knowing where to find and access remote sensing data concerning vegetation cover and basic tools for analyzing habitat trends and characterizing rate of change.”*

– U.S. Federal Government Employee,  
2016 Advanced NDVI webinar

Number of Participating Organizations by Country & U.S. States (2008-2015)



# ARSET Trainings

## Gradual Learning Approach

### Basic Trainings

Webinars & Workshops  
Assumes no prior RS knowledge

Example: 2014 Webinar  
Water Quality Monitoring Using  
Remote Sensing Measurements

<http://arset.gsfc.nasa.gov/water-resources/webinars/water-quality-monitoring-using-remote-sensing-measurements>

### Advanced Trainings

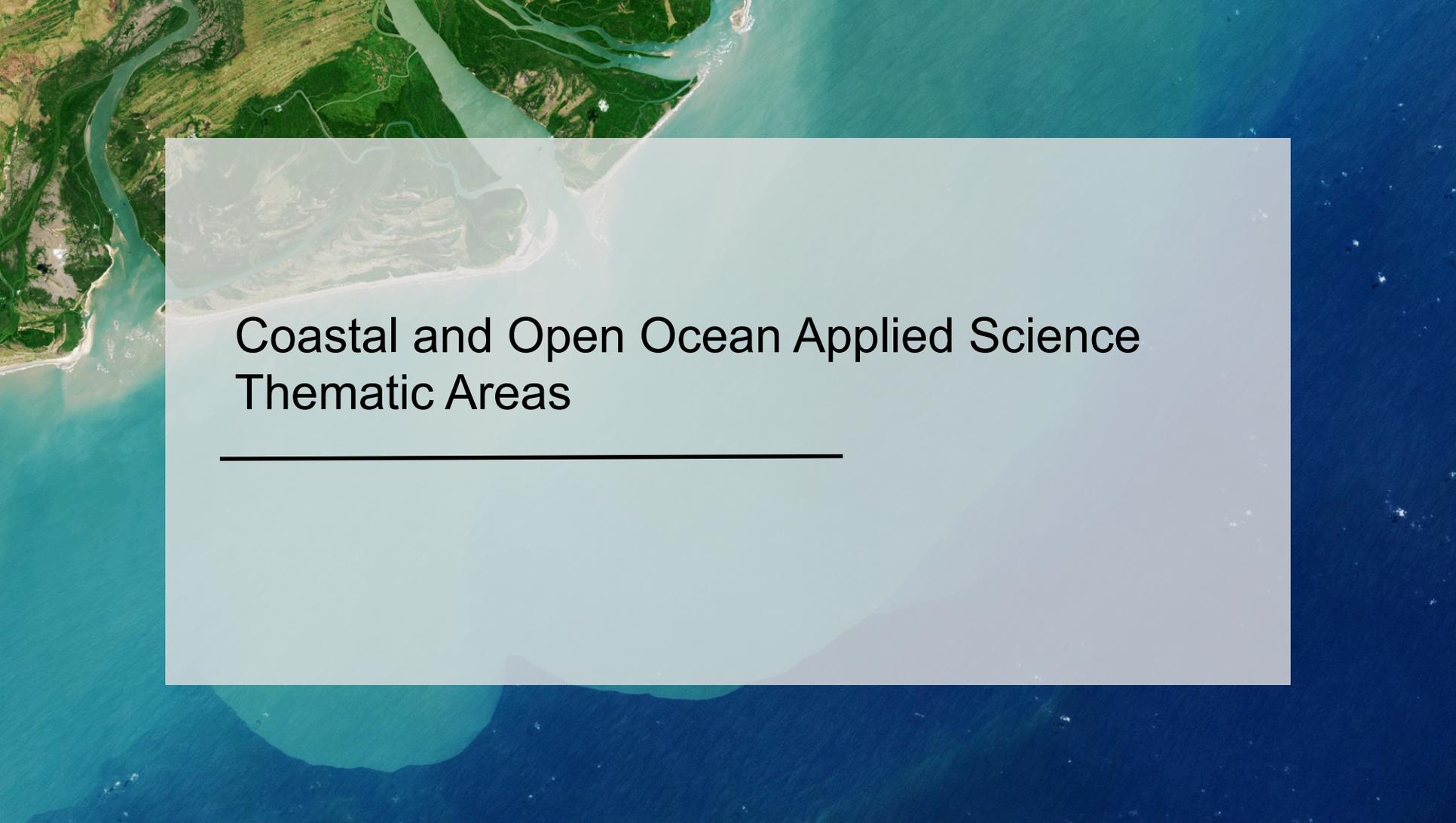
Webinars & Workshops  
Requires basic training  
Focuses on specific application  
problems and data

Example:  
Algal bloom monitoring in the  
Great Lakes

# ARSET ListServ

For information on upcoming courses and program updates, please sign up for the listserv

<https://lists.nasa.gov/mailman/listinfo/arset>

An aerial photograph of a coastal region. On the left, a river with a complex delta system flows into the ocean. The land is green with some brown patches, and there are some small white structures. The ocean is a deep blue, and the water near the shore is a lighter turquoise color. A semi-transparent white rectangular box is overlaid on the right side of the image, containing the text.

# Coastal and Open Ocean Applied Science Thematic Areas

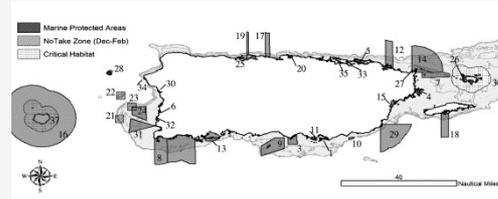
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# Coastal and Open Ocean Applied Science Thematic Areas

- Marine Protected Areas
- Marine Fisheries
- Animal Migrations
- Water Quality
- Harmful Algal Blooms (HABs)
- Eutrophication
- Coral Reef Health
- Marsh Subsidence
- Coastal Development
- Coastal Hazards – flooding, sea level rise

# Coastal and Open Ocean Applied Science Thematic Areas

- Marine Protected Areas
- Marine Fisheries
- Animal Migrations
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- Harmful Algal Blooms (HABs)



TURTLEWATCH



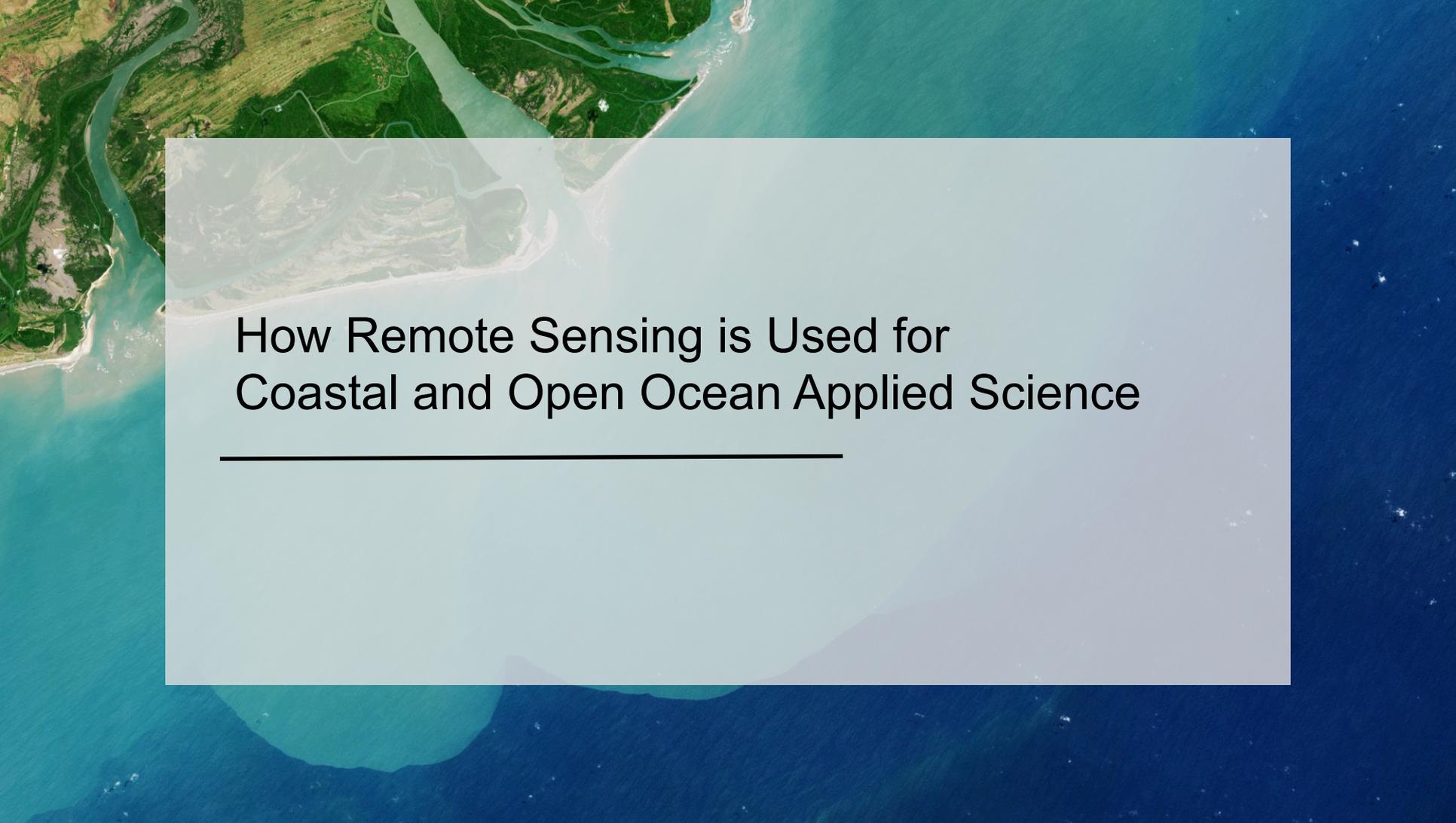
# Coastal and Open Ocean Applied Science Thematic Areas



- Eutrophication
- Coral Reef Health
- Marsh Subsidence
- Coastal Development
- Coastal Hazards – flooding, sea level rise

# Coastal and Open Ocean Applied Science Thematic Areas

- Marine Protected Areas
  - Marine Fisheries
  - Animal Migrations
  - Water Quality
  - Harmful Algal Blooms (HABs)
- Eutrophication
  - Coral Reef Health
  - Marsh Subsidence
  - Coastal Development
  - Coastal Hazards – flooding, sea level rise

An aerial photograph of a coastal region. In the upper left, a river with a complex delta system flows into the sea. The land is green and brown, showing vegetation and some structures. The ocean is a deep blue, with a lighter turquoise area near the coast. A semi-transparent white rectangular box is overlaid on the right side of the image, containing the title text.

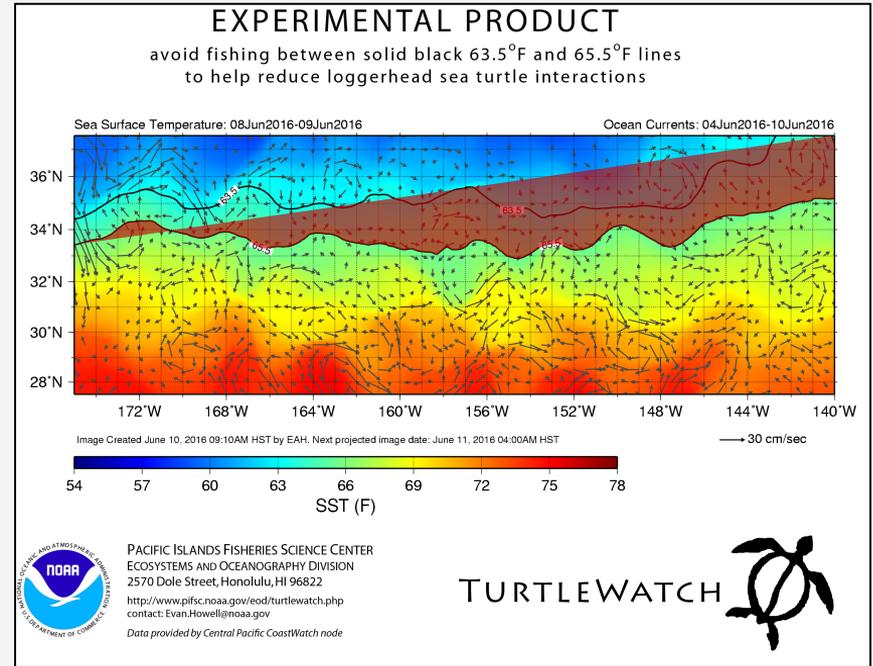
# How Remote Sensing is Used for Coastal and Open Ocean Applied Science

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# Marine Fisheries – Reducing Turtle By-Catch

<http://pifsc-www.irc.noaa.gov/eod/turtlewatch.php>

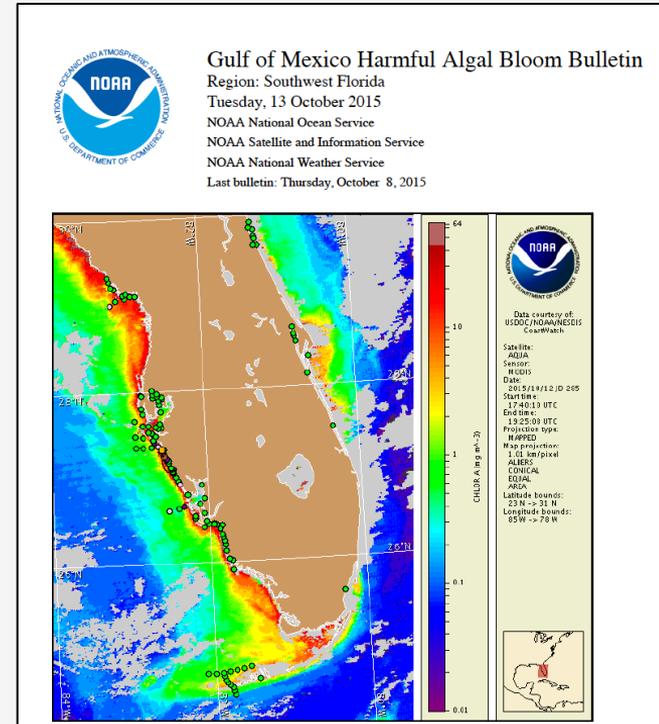
- *TurtleWatch* provides up-to-date information about thermal habitat of loggerhead sea turtles in the Pacific Ocean north of the Hawaiian Islands
- Created to reduce interactions between Hawaii-based long-line fishing vessels and loggerhead turtles
- Predicts the location of waters preferred by these turtles based on sea surface temperature and ocean current conditions



# Harmful Algal Bloom Monitoring

<http://tidesandcurrents.noaa.gov/hab/bulletins.html>

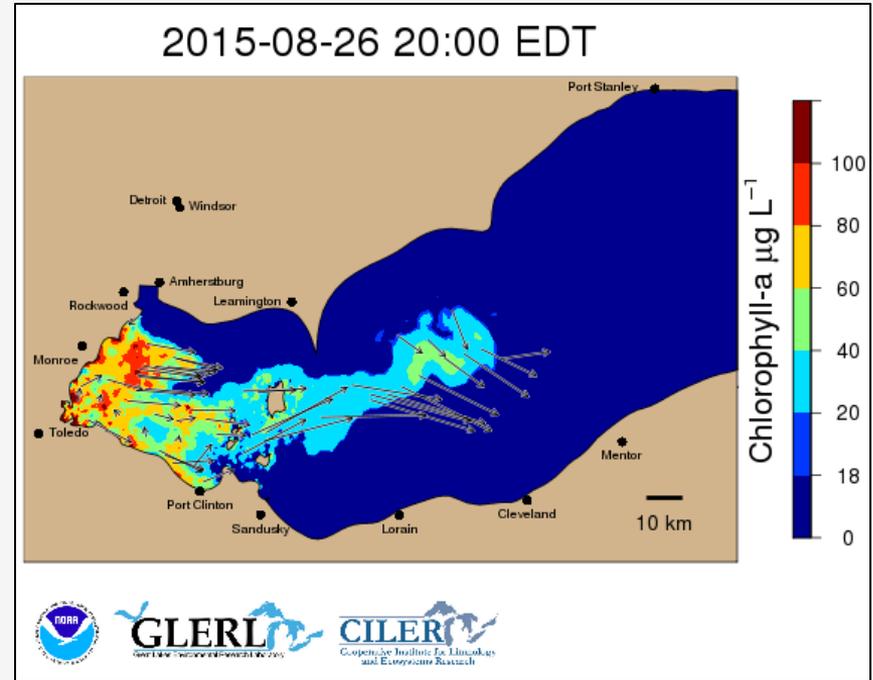
- The phytoplankton, *Karenia brevis*, produces an airborne toxin
- The toxin causes respiratory distress in vulnerable people
- Tourism is negatively affected during blooms
- NOAA monitors for the species
- The HAB Bulletin is published to guide the public, the tourism industry, and resource managers



# HAB Forecasting – NOAA GLERL HAB Tracker

[http://www.glerl.noaa.gov/res/HABs\\_and\\_Hypoxia/](http://www.glerl.noaa.gov/res/HABs_and_Hypoxia/)

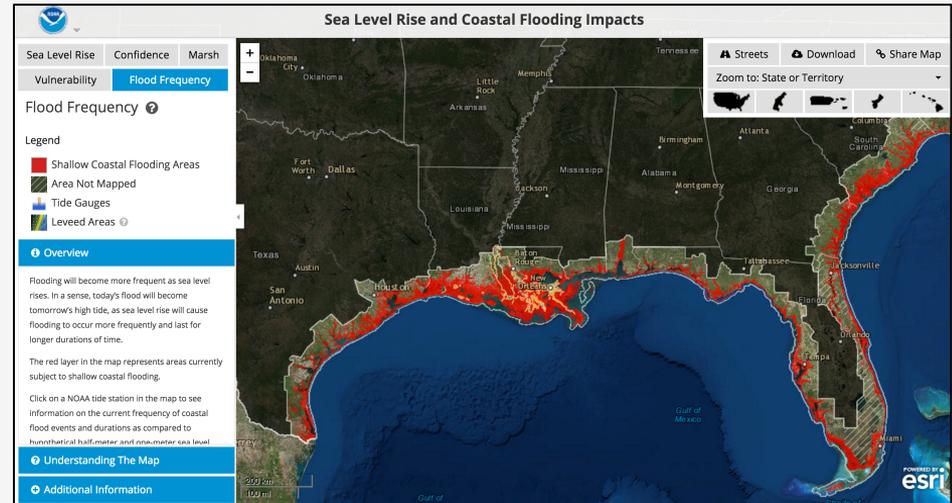
- Lake Erie (USA) hosts toxic cyanobacteria blooms
- Blooms can be identified using remote sensing imagery
- Bloom location can be forecast using coupled remote sensing and fluid dynamic models

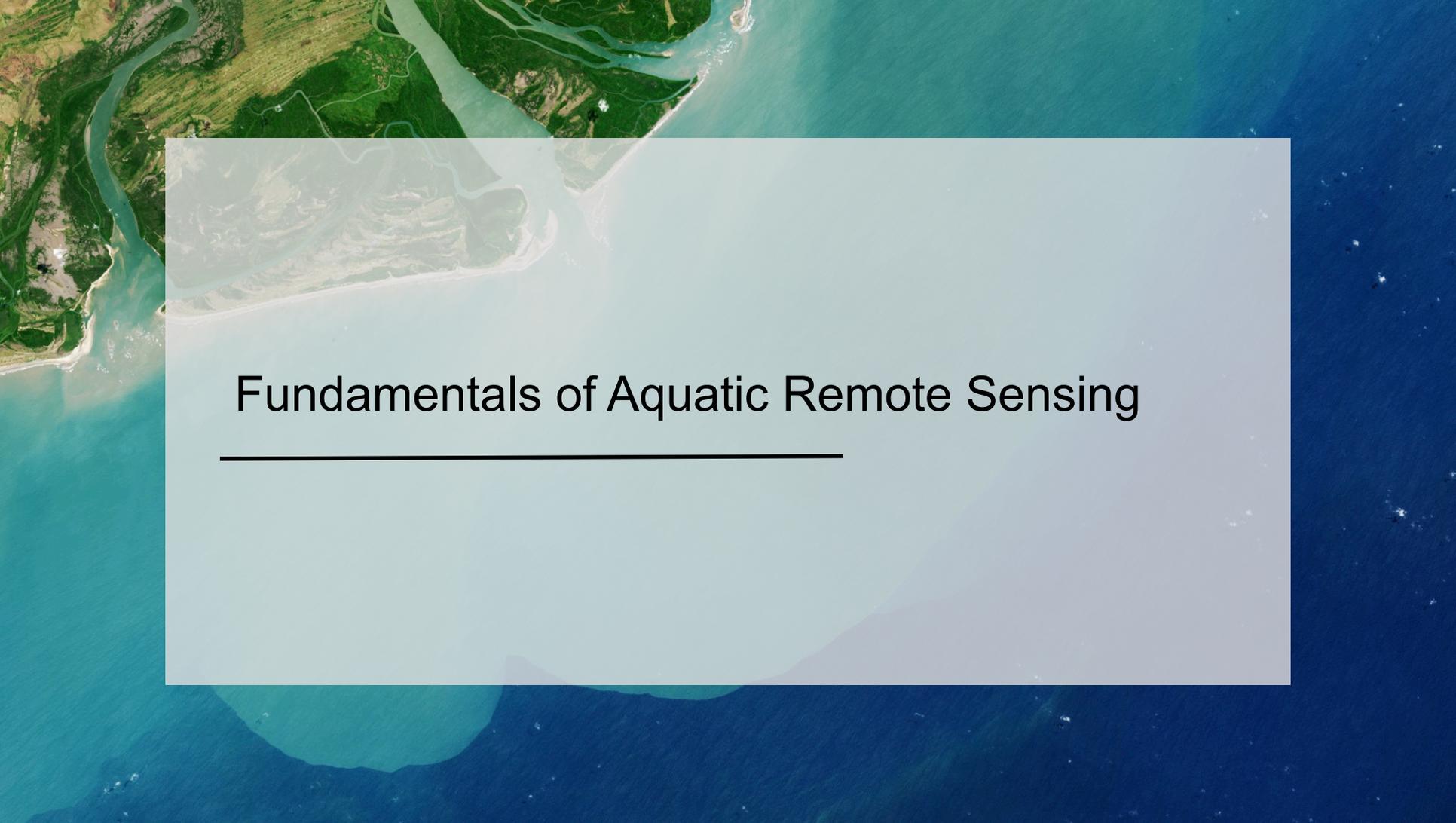


# Forecasting Sea Level Rise and Coastal Flooding Impacts

<http://coast.noaa.gov/slr/>

- This tool provides coastal managers and scientists with a preliminary look at sea level rise and coastal flooding impacts
- It is a screening-level tool using nationally consistent data sets and analyses
- Data and maps can be used at several scales to gauge trends and prioritize actions for different scenarios



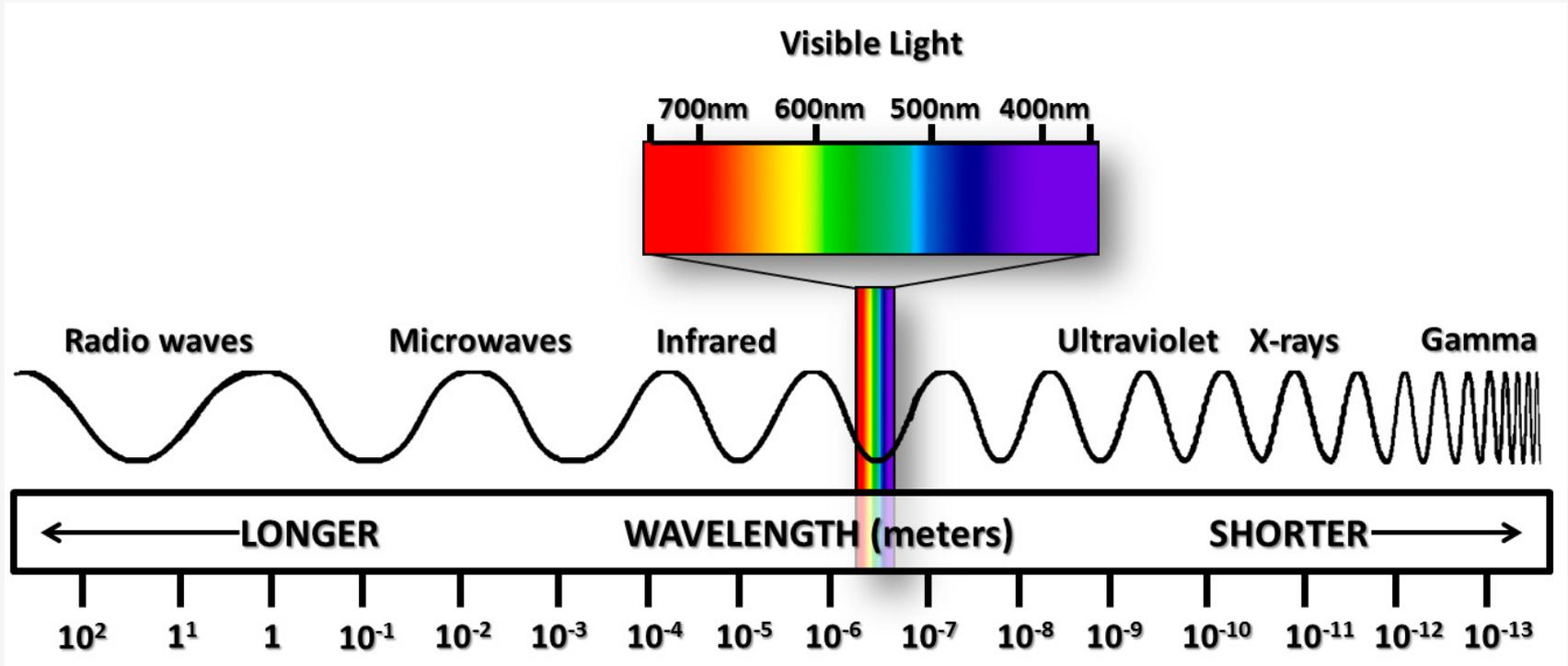
An aerial photograph of a coastal region. A river with a complex delta system flows from the top left towards the center. The water in the delta is a light, milky turquoise color, contrasting with the deeper blue of the open ocean to the right. The land is green with some brown patches, and a sandy beach is visible where the river meets the sea. A semi-transparent white rectangular box is overlaid on the right side of the image, containing the title text.

# Fundamentals of Aquatic Remote Sensing

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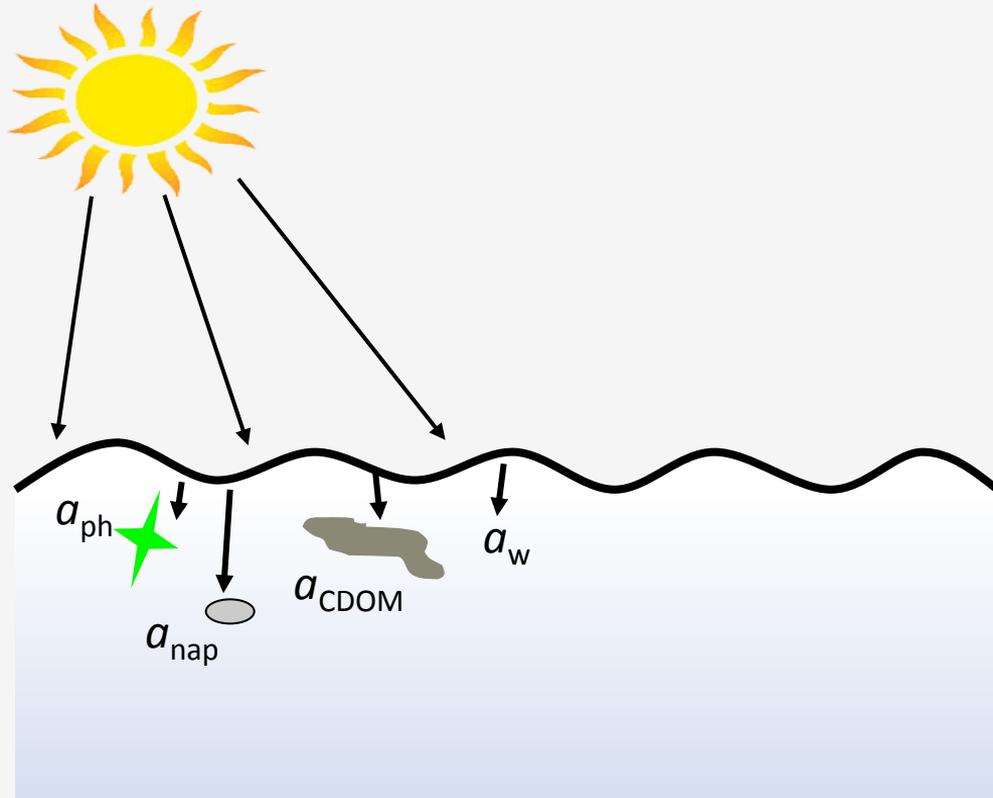
# First, An Aquatic Optics Primer...

## The Electromagnetic Spectrum



# How Light Interacts with the Water

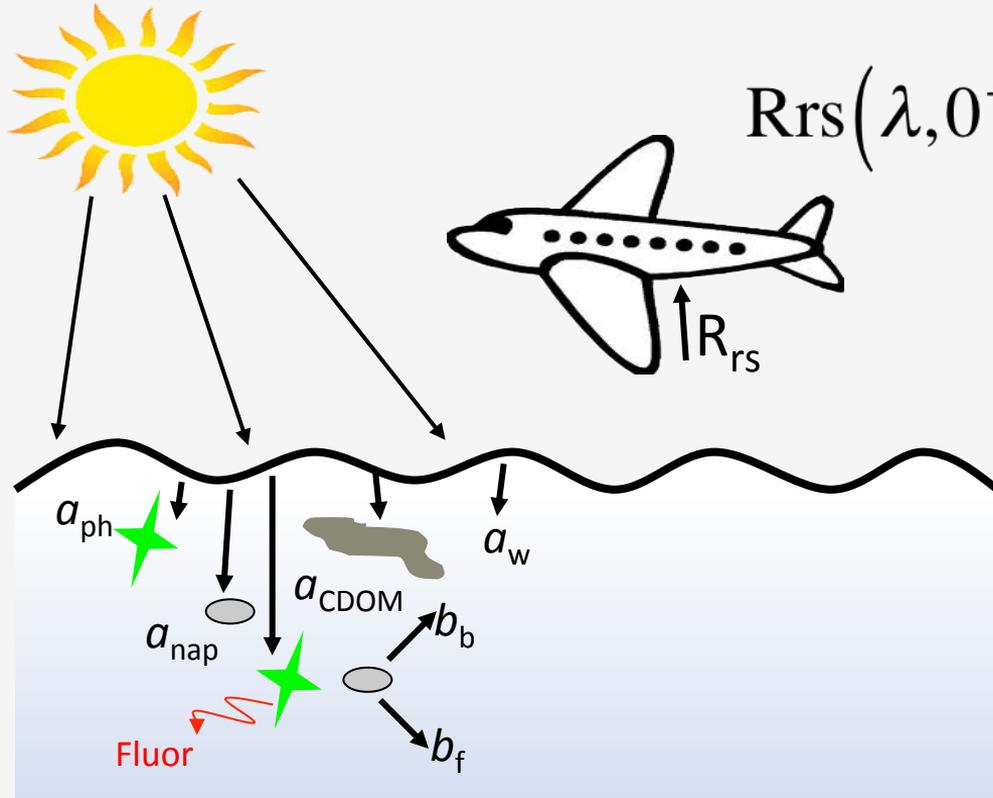
Defining Remote Sensing Reflectance ( $R_{rs}$ ) – or ‘Ocean Color’



$a$  = absorption by ...  
phytoplankton (ph)  
non-algal particles (nap)  
colored dissolved organic matter (CDOM)  
water (w)

# How Light Interacts with the Water

Defining Remote Sensing Reflectance (R<sub>rs</sub>) – or ‘Ocean Color’



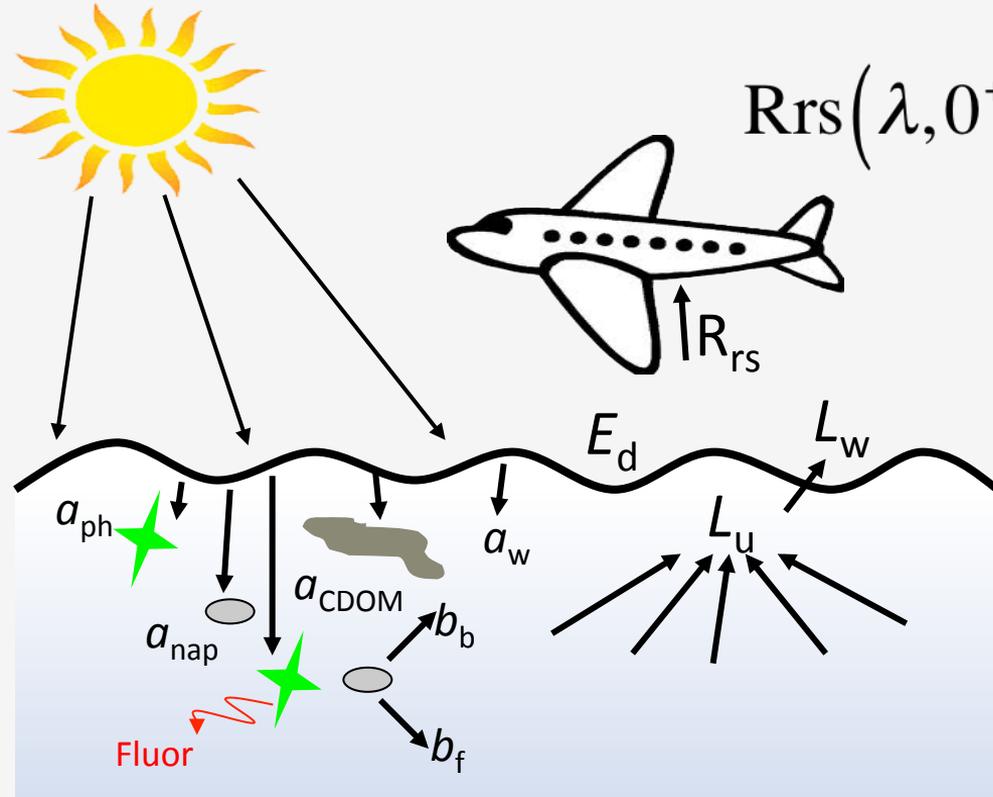
$$R_{rs}(\lambda, 0^+) \cong C \frac{b_b(\lambda)}{a(\lambda) + b_b(\lambda)}$$

$a$  = absorption

$b$  = scattering in  
forward (f) and  
backward (b) directions

# How Light Interacts with the Water

Defining Remote Sensing Reflectance (R<sub>rs</sub>) – or ‘Ocean Color’



$$R_{rs}(\lambda, 0^+) \cong C \frac{b_b(\lambda)}{a(\lambda) + b_b(\lambda)} = \frac{L_w(\lambda)}{E_d(\lambda, 0^+)}$$

$a$  = absorption

$b$  = scattering

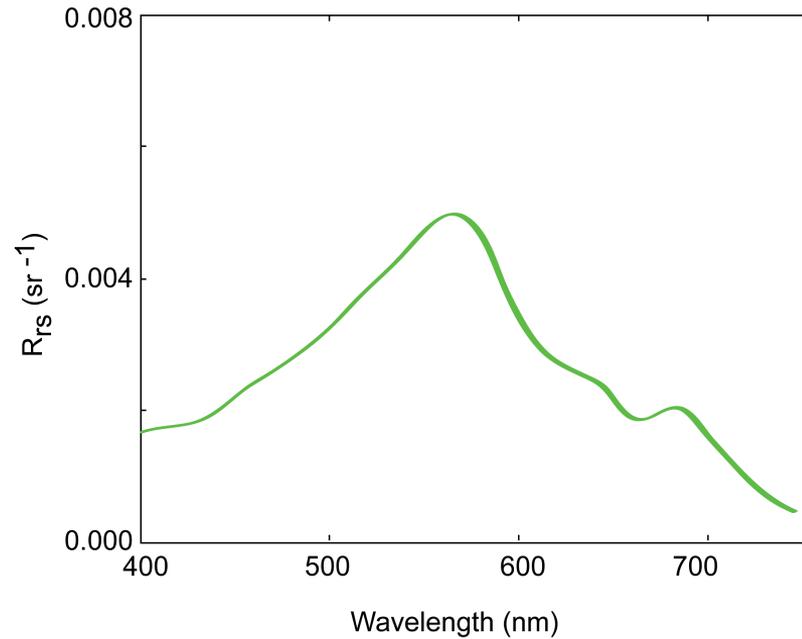
$L_w$  = water leaving radiance

$L_u$  = upwelling radiance

$E_d$  = downwelling irradiance

$R_{rs}$  = remote sensing (rs) Reflectance

# Remote Sensing Reflectance ( $R_{rs}$ ) of a Phytoplankton Bloom

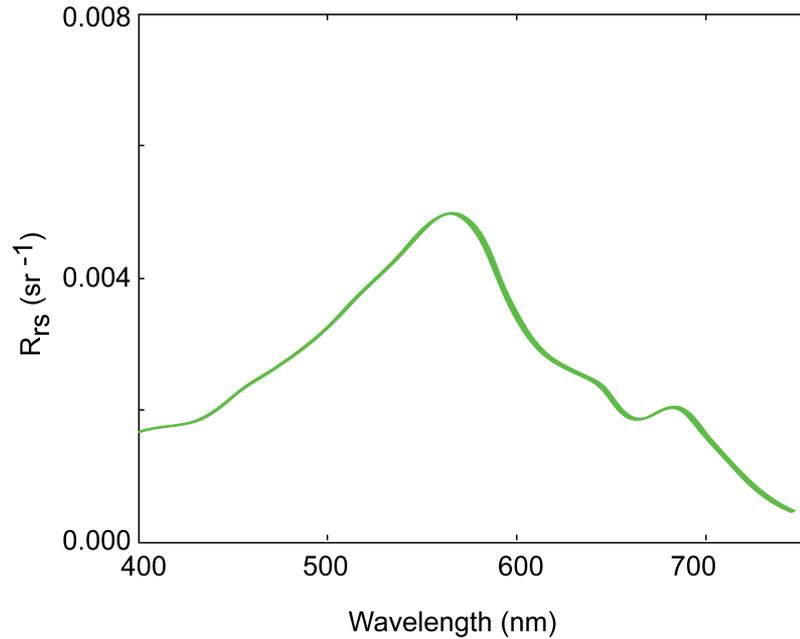


# What Can We Observe from Space?

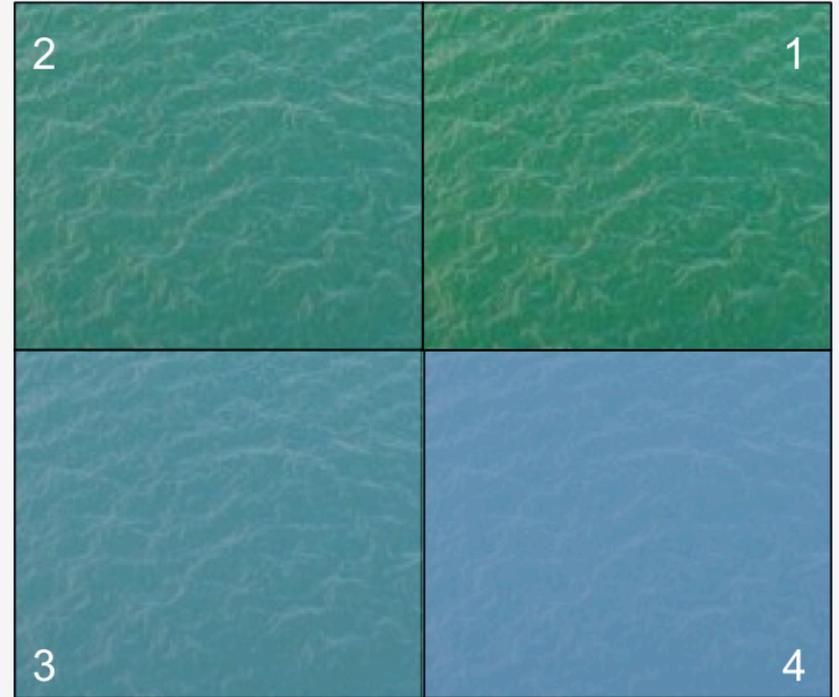
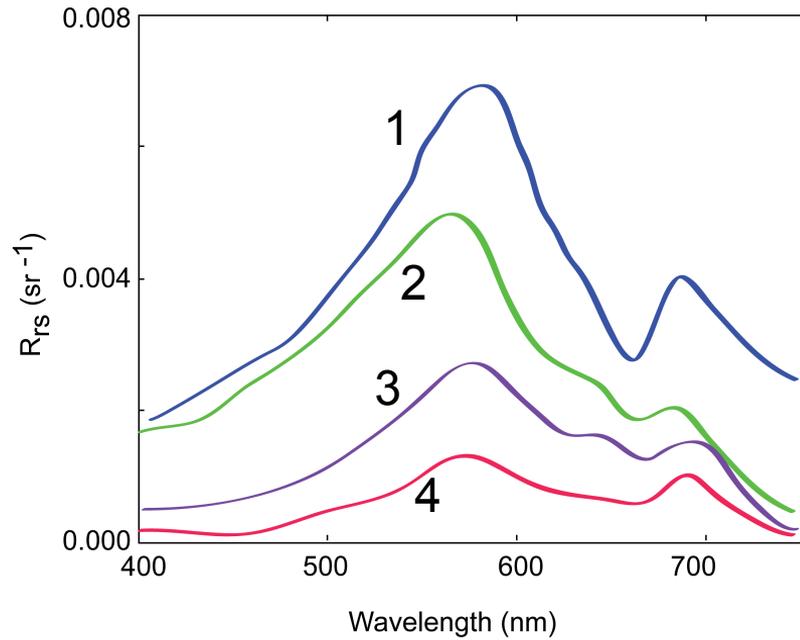
## Ocean Properties Derived from Remote Sensing Imagery

- Chlorophyll-a (proxy for phytoplankton biomass)
- Water Turbidity
- Colored Dissolved Organic Matter (CDOM)
- Sea Surface Temperature (SST)
- Surface winds
- Salinity

# Chlorophyll-a from Remote Sensing Reflectance ( $R_{rs}$ )

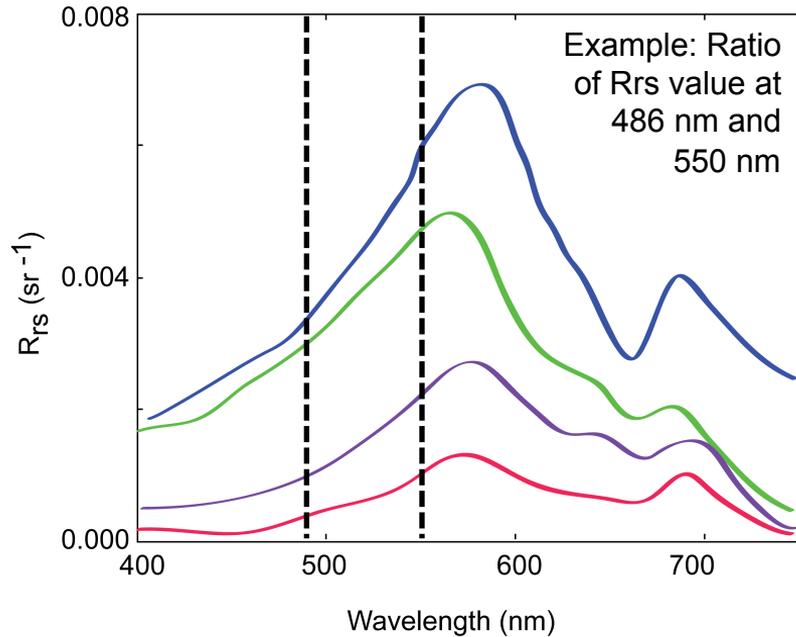


# Rrs at Different Chlorophyll-a Concentrations



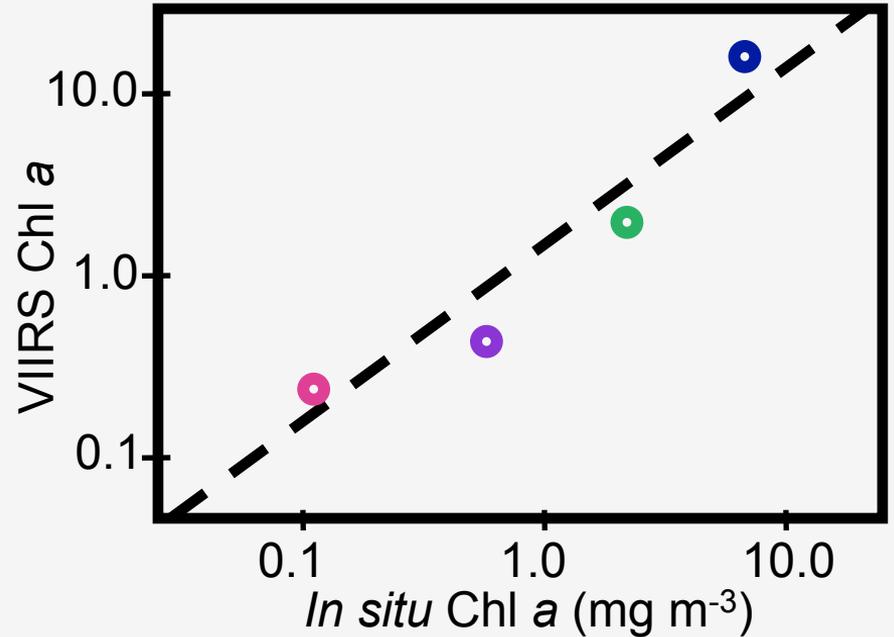
# Chlorophyll-a Estimates

Estimates are a Function of the Ratio of Rrs Values

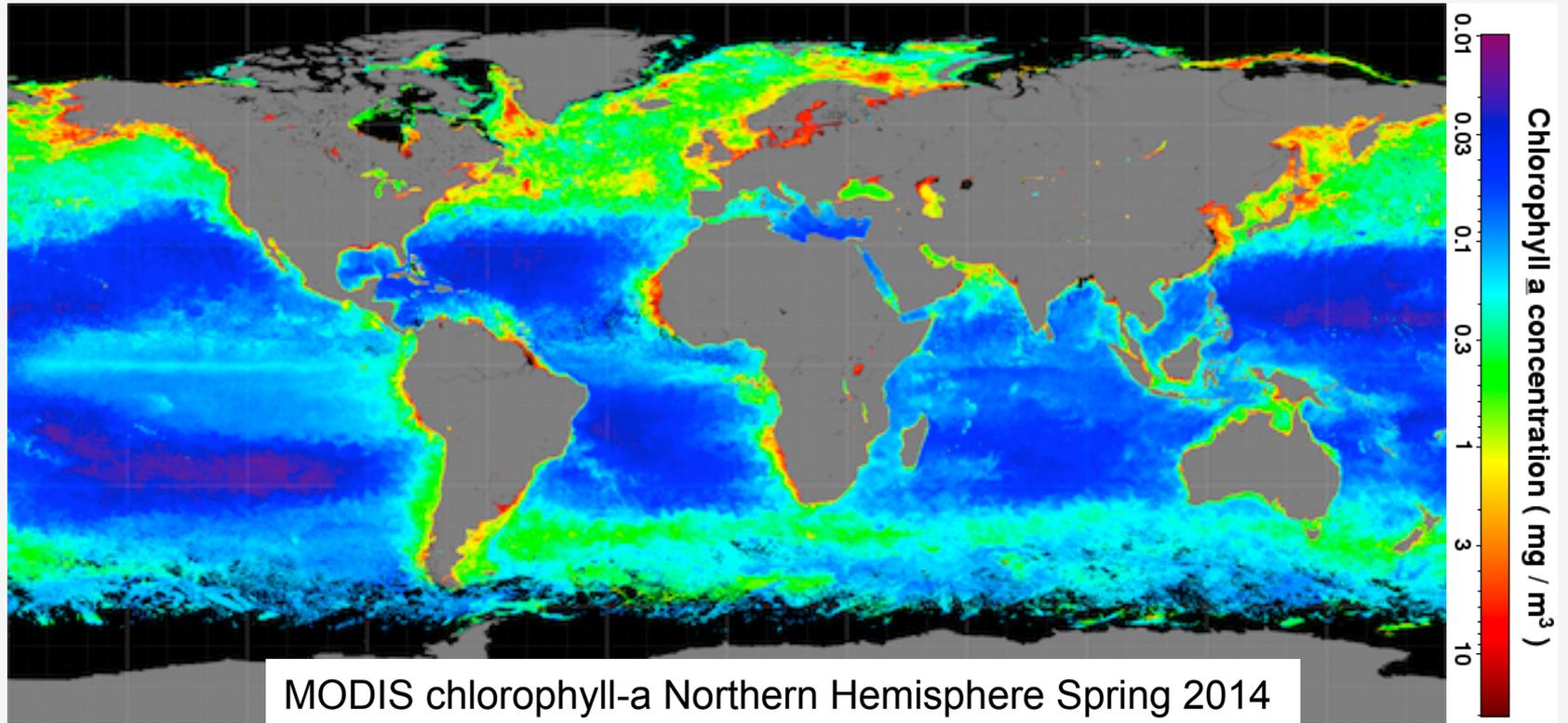


Algorithm description:

[http://oceancolor.gsfc.nasa.gov/cms/atbd/chlor\\_a](http://oceancolor.gsfc.nasa.gov/cms/atbd/chlor_a)



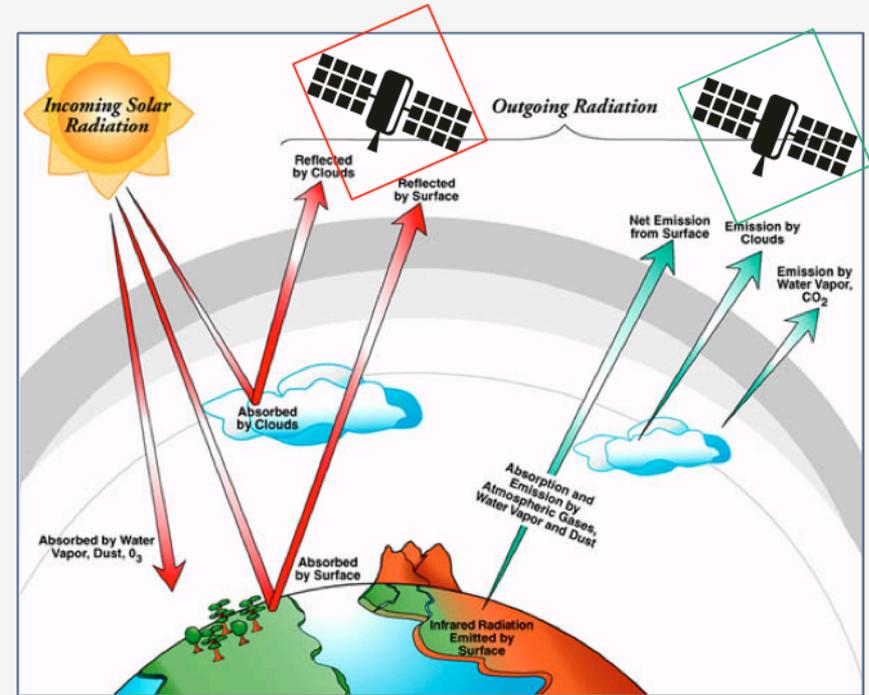
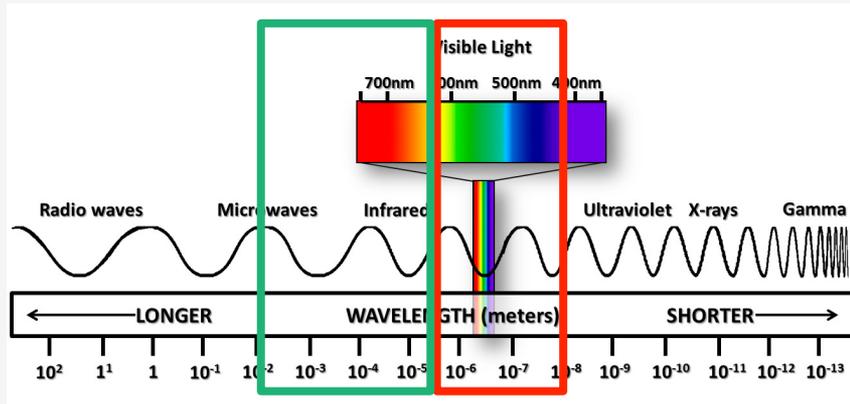
# Chlorophyll-a from Space



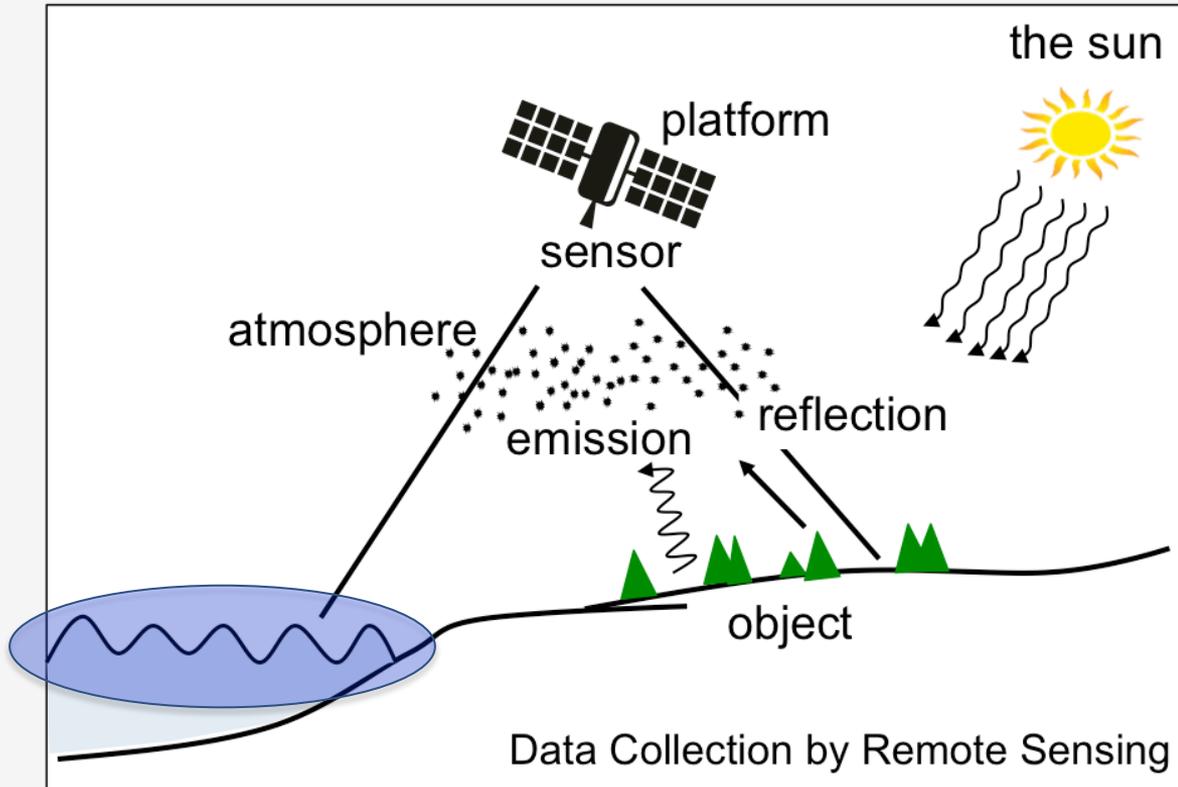
# Second: An Overview of Satellite Remote Sensing

Satellites carry instruments/sensors to measure:

- **reflected solar radiation**
- **emitted infrared and microwave radiation**



# Satellite Measurements Carry Information About:



## Atmosphere

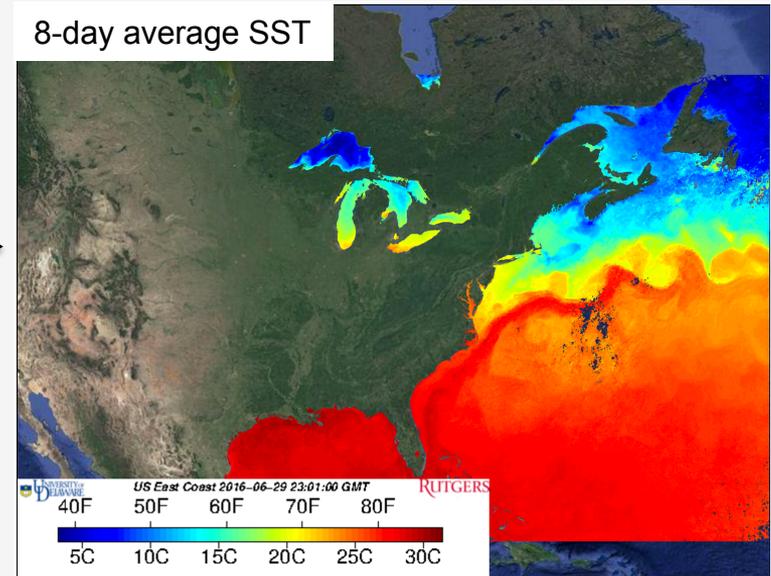
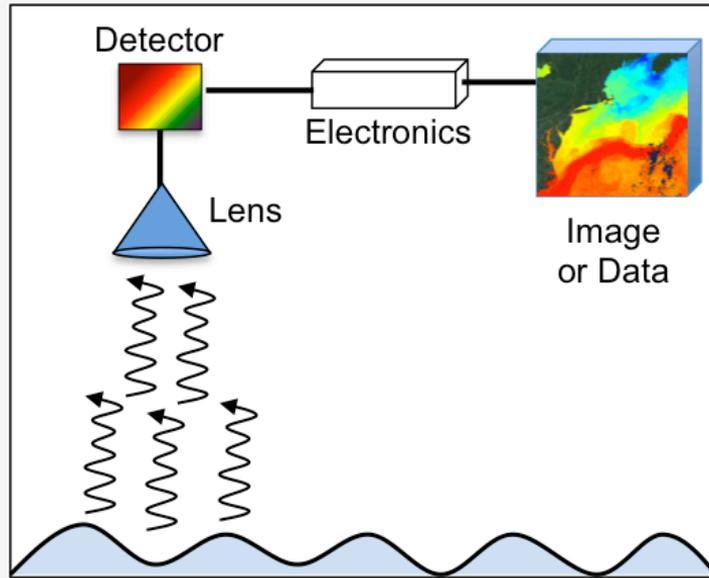
- Clouds
- Aerosols
- Gases

## Earth's Surface

- Snow/Ice
- Land (land use, vegetation)
- **Water**

# Remote Sensing of Water Bodies

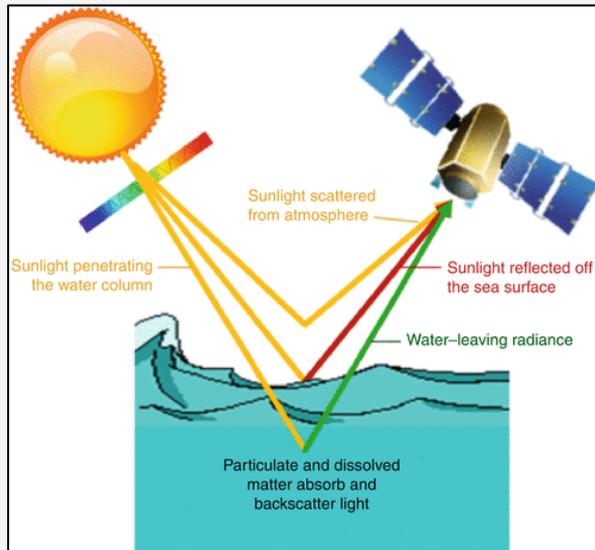
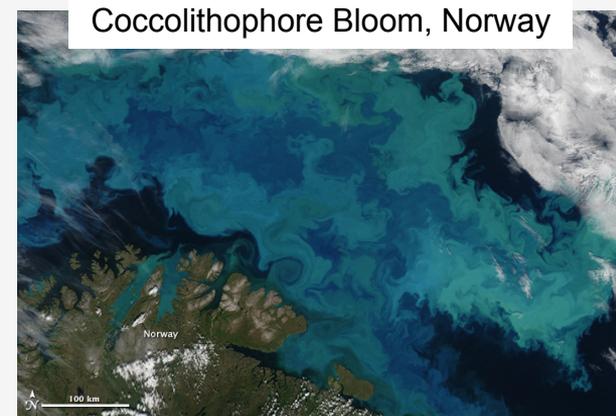
Emitted Thermal Radiation: measured by satellite sensors and used to derive the surface temperature of water bodies.



MARACOOS, ORB Lab, courtesy M. Oliver

# Remote Sensing of Water Bodies

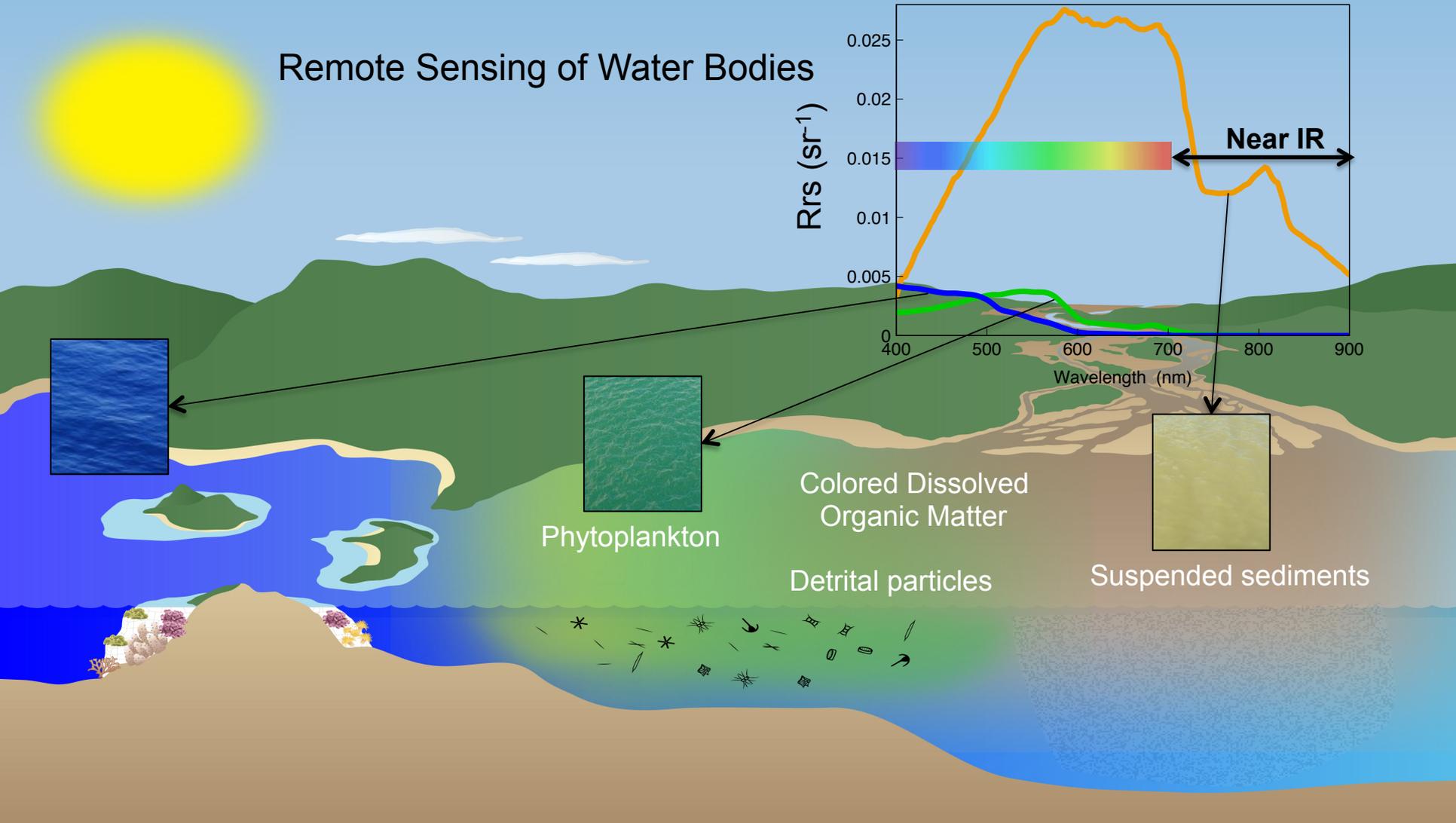
Reflected Solar Radiation (~color of water): measured by satellite sensors, and used to derive the properties of optically-active water constituents:



- Suspended sediments
- Algae
- Colored Dissolved Organic Matter
- Detrital Organic Matter
- Submerged/Floating Vegetation
- Oil

- Contaminants
- Pathogens

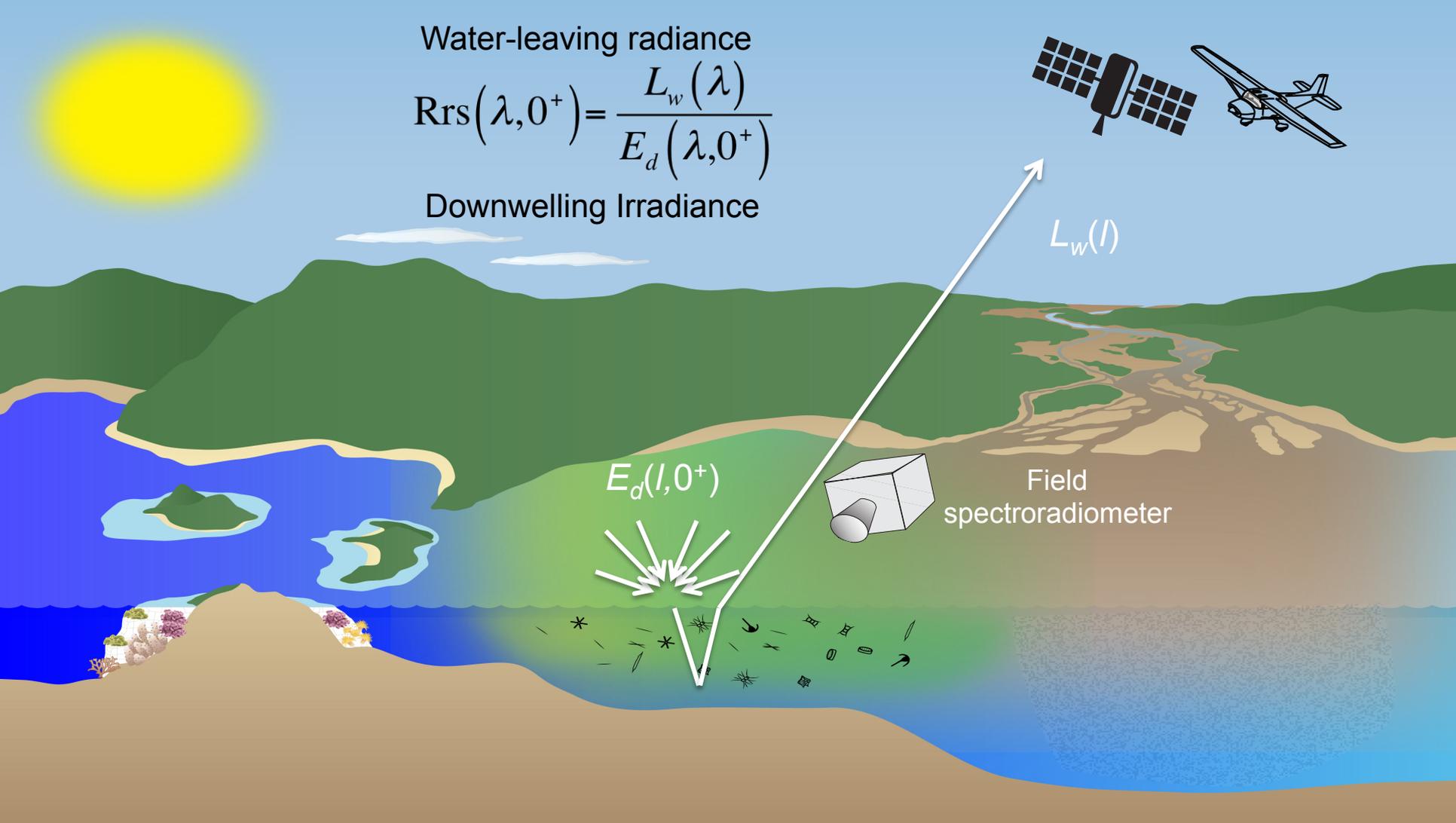
# Remote Sensing of Water Bodies



Water-leaving radiance

$$R_{rs}(\lambda, 0^+) = \frac{L_w(\lambda)}{E_d(\lambda, 0^+)}$$

Downwelling Irradiance



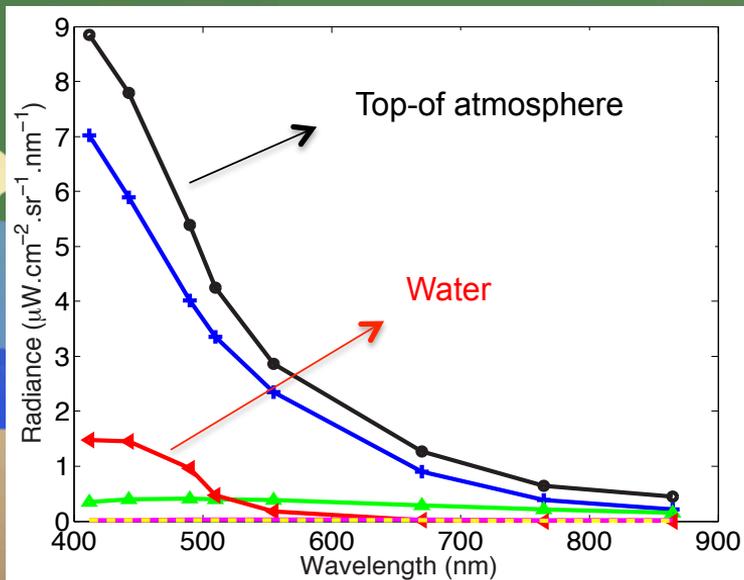
# Atmospheric Correction



$$L_t(\lambda) = L_r(\lambda) + L_a(\lambda) + L_{ra}(\lambda) + T(\lambda, \theta)L_g(\lambda) + t(\lambda, \theta)L_{wc}(\lambda) + t(\lambda, \theta)L_w(\lambda)$$

>90%

<10%



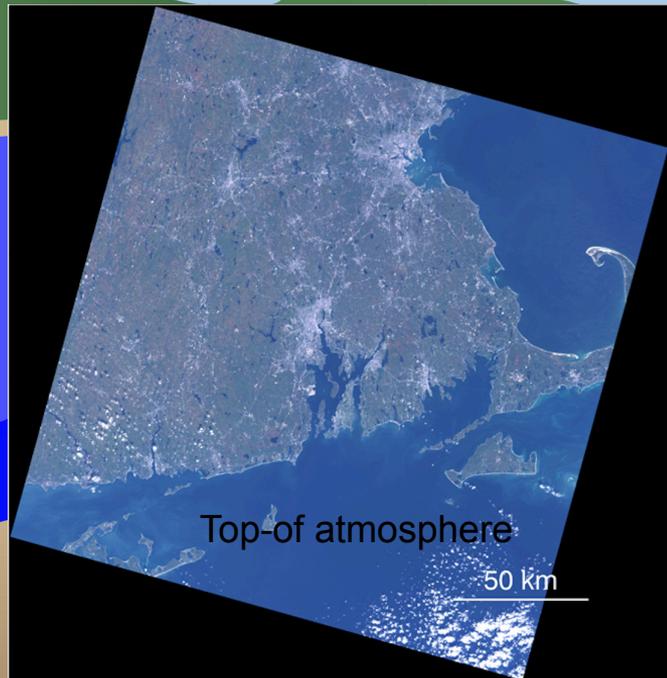
# Atmospheric Correction



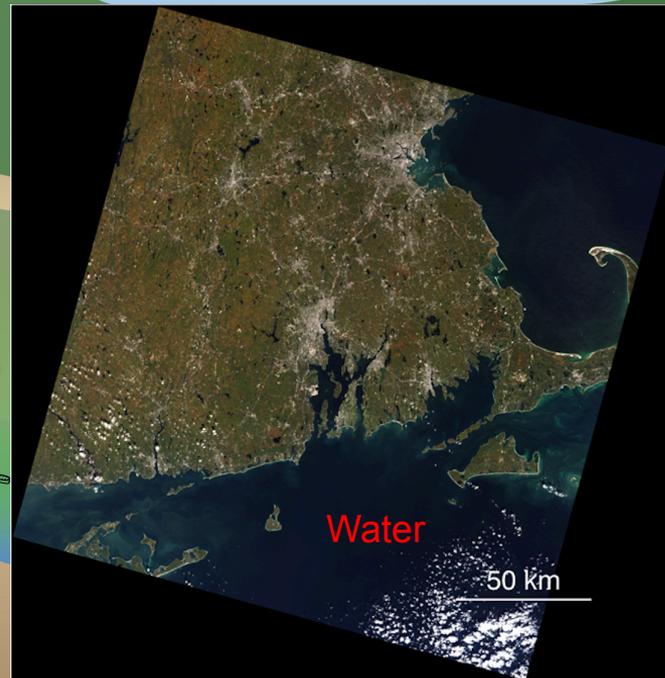
$$L_t(\lambda) = L_r(\lambda) + L_a(\lambda) + L_{ra}(\lambda) + T(\lambda, \theta)L_g(\lambda) + t(\lambda, \theta)L_{wc}(\lambda) + t(\lambda, \theta)L_w(\lambda)$$

>90%

<10%



Atmospheric correction



# | Interested in a More In-Depth Understanding of Aquatic Optics and Remote Sensing Imagery?

For a solid foundation in aquatic optics:

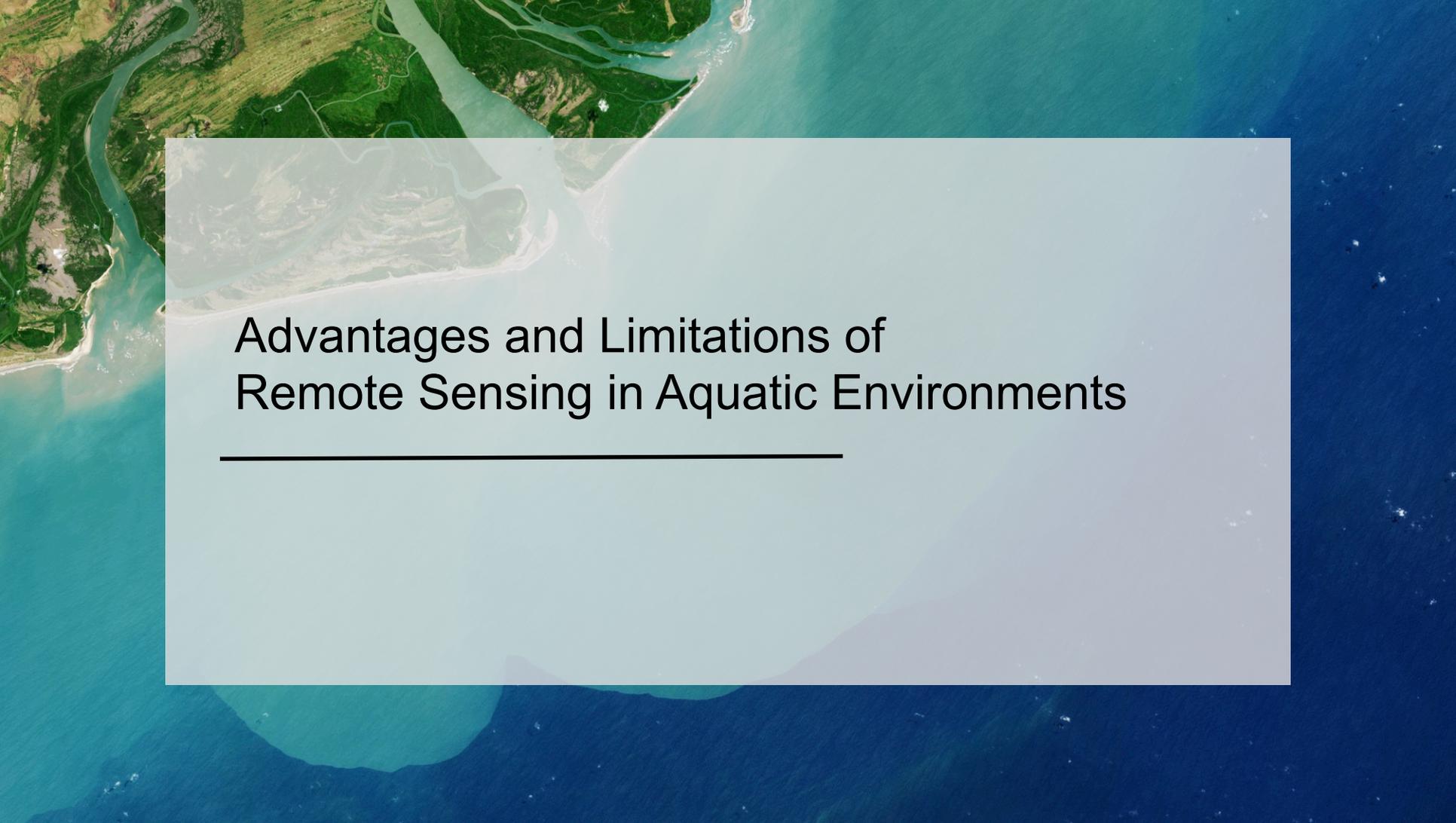
Ocean Optics Web Book

<http://www.oceanopticsbook.info/>

For remote sensing imagery information, data access, and processing tools:

NASA's Ocean Color Web

<http://oceancolor.gsfc.nasa.gov/cms/>

An aerial photograph of a coastal region. A river with a complex delta system flows from the top left towards the center. The water is a vibrant turquoise color, contrasting with the deep blue of the open ocean. The land is green and brown, showing vegetation and some structures. A semi-transparent white rectangular box is overlaid on the right side of the image, containing the title text.

# Advantages and Limitations of Remote Sensing in Aquatic Environments

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# Advantages of Remote Sensing of Aquatic Environments

- Synoptic coverage
- Temporal frequency needed to capture dynamic aquatic processes
- Observations of remote ocean locations, infrequently accessed by sea-based platforms

# Limitations

- Temporal frequency of satellite overpasses limits which processes can be observed
  - e.g. effects of tides
  - e.g. diel vertical migration of harmful algal bloom species
- Water is a dark target
  - requires satellite sensors with the appropriate sensitivity (signal-to-noise)
  - the atmosphere accounts for 80 – 90% of the light in the signal, so accurate atmospheric correction is very important
- Water (and the material in it) moves
- Clouds

An aerial photograph of a coastal region. A river with a complex delta system flows from the top left towards the center. The water is a vibrant turquoise color, contrasting with the deep blue of the open ocean. The land is a mix of green vegetation and sandy areas. A semi-transparent white rectangular box is overlaid on the right side of the image, containing the text 'Week 1 Summary' and a horizontal line.

# Week 1 Summary

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# Week 1 Summary

- Course Structure and Objectives
- Overview of ARSET
- Overview of Themes in Coastal and Open Ocean Applied Science
- Coastal and Open Ocean Applied Science Thematic Areas
- Fundamentals of Aquatic Remote Sensing
- Advantages and Limitations of Remote Sensing in Aquatic Environments

# Announcements

- Remember to review “Fundamentals of Remote Sensing,” Session 1
  - <http://arset.gsfc.nasa.gov/webinars/fundamentals-remote-sensing>
- Homework
  - First will be assigned 13 July, second on 27 July
  - Both are due August 10<sup>th</sup>
- Next session 13 July 2016, 1:00 – 2:00 pm EDT (UTC-4)

# Contacts

- Your Course Instructors
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- ARSET Website:
  - <http://arset.gsfc.nasa.gov/>



National Aeronautics and  
Space Administration



## ARSET

Applied Remote Sensing Training

<http://arset.gsfc.nasa.gov>

 @NASAARSET

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# Thank you!

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Next Week:

Platforms and Sensors for Ocean Observations, Data Access,  
and Processing Tools