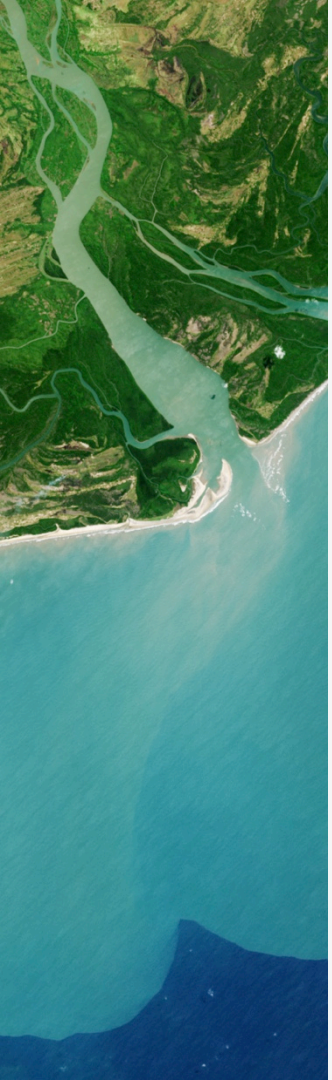


National Aeronautics and Space Administration

ARSET

Applied Remote Sensing Training

http://arset.gsfc.nasa.gov

@NASAARSET

Introduction to Remote Sensing for Ocean and Coastal Applications

Sherry L. Palacios

Week 1: July 6, 2016

Course Structure

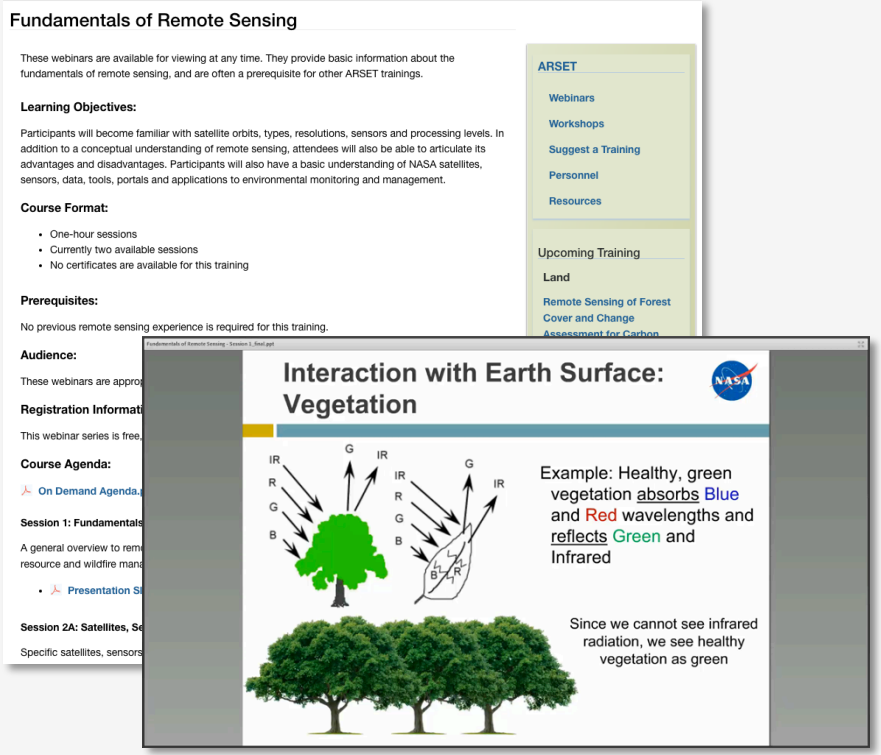
- One lecture per week – every Wednesday July 6 – July 27
- 1:00 – 2:00 PM EDT (UTC-4)
  - Lectures
  - In-class demonstration
  - Homework exercises
- Webinar recordings, presentations, and homework assignments can be found after each session at:
  - http://arset.gsfc.nasa.gov/land/webinars/coastal-oceans-2016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

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

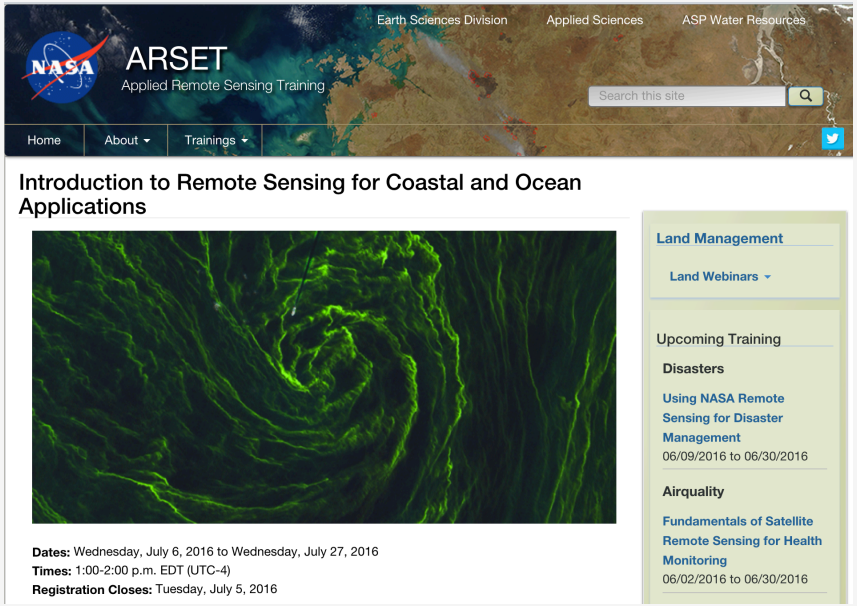
Prerequisite

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



Accessing Course Materials

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

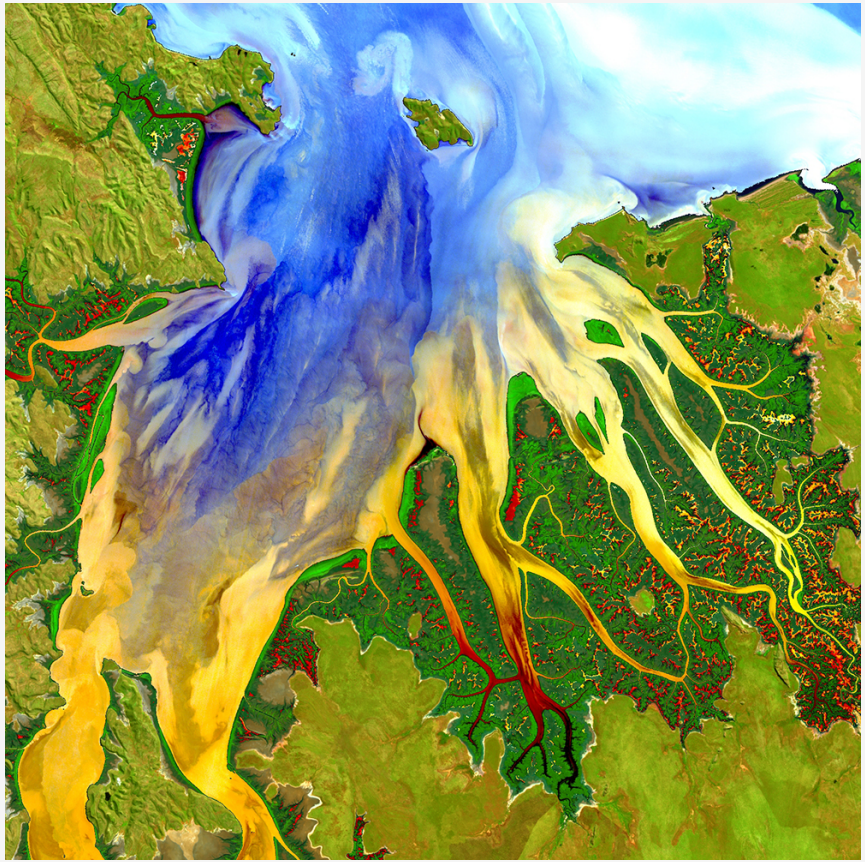
July 13, 2016

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



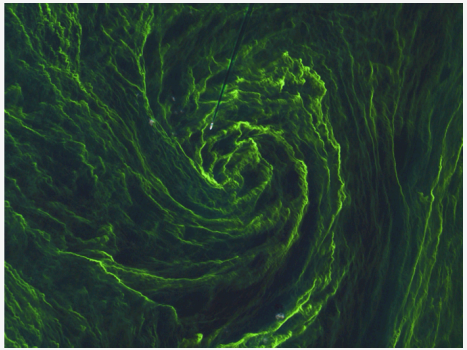
Credit: NASA/USGS Landsat; Geoscience Australia

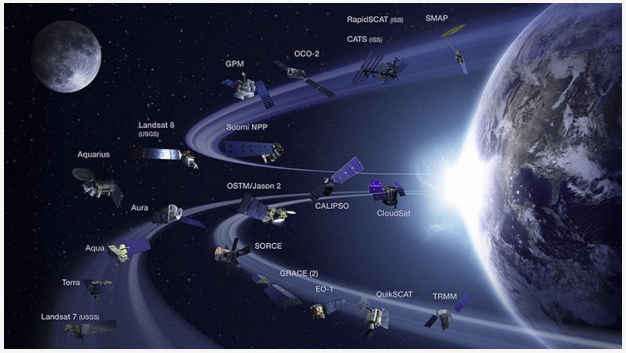
Expected Outcomes

- 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

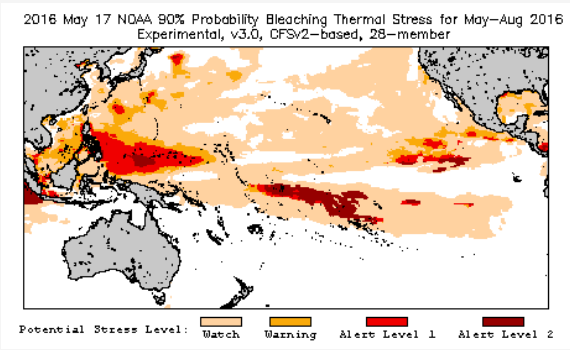
Week 1
Overview of
Satellite
Remote Sensing





Week 2
Platforms
and Sensors
for Ocean
Observations

Week 3
Animal
Movement



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

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

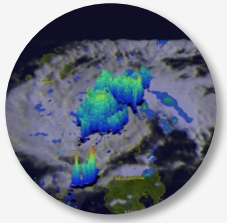
Applied Remote Sensing Training Program (ARSET)

http://arset.gsfc.nasa.gov

Provide online and on-site trainings tailored to:

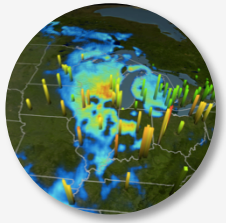
- policy makers
- regulatory agencies
- applied environmental professionals

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

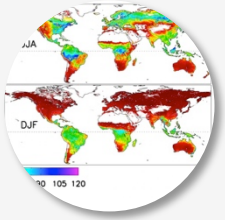


Disasters

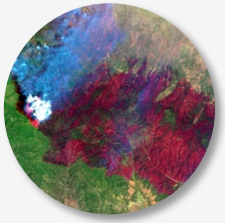
Ecoforecasting



Health &
Air Quality



Water Resources



Wildfires

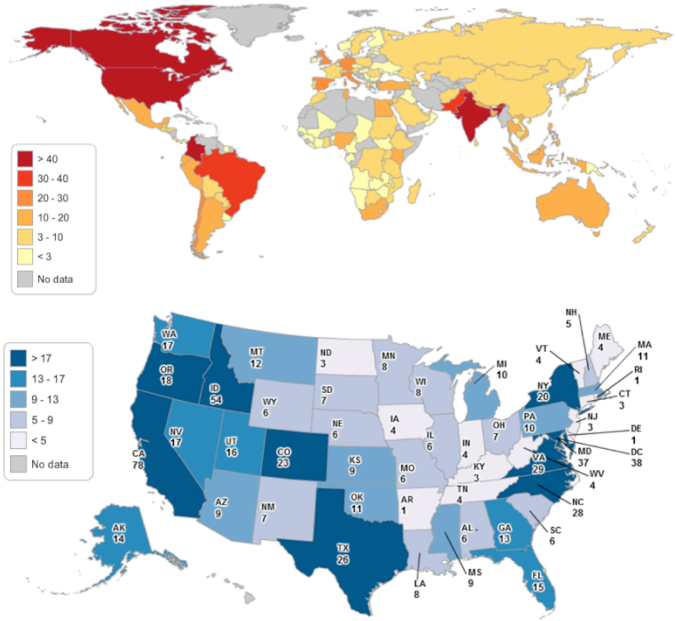
ARSET Trainings

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

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

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

Coastal and Open Ocean Applied Science Thematic Areas

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

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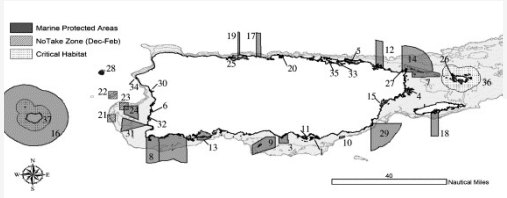

Coastal and Open Ocean Applied Science Thematic Areas

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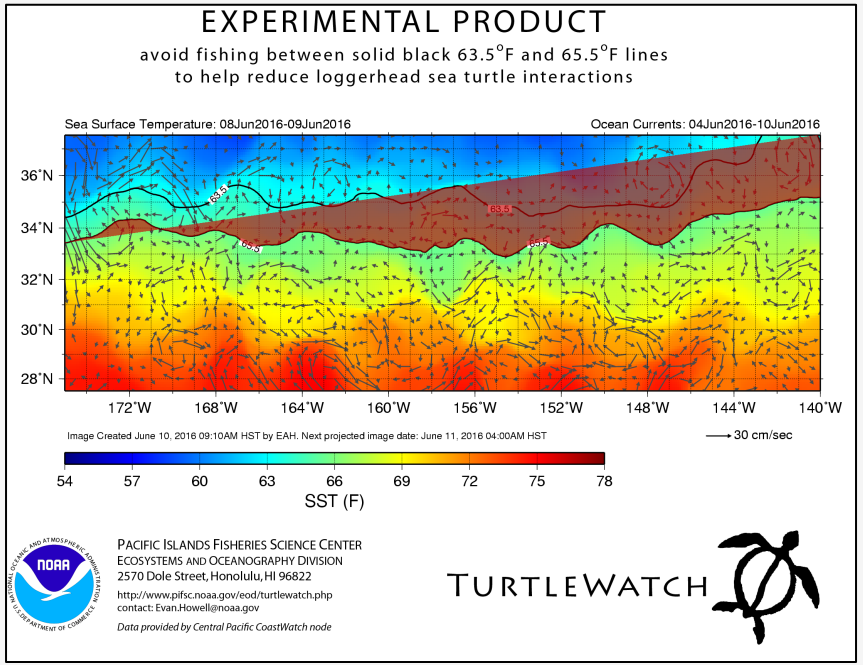
- Coral Reef Health
- Marsh Subsidence
- Coastal Development
- Coastal Hazards – flooding, sea level rise

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

Marine Fisheries – Reducing Turtle By-Catch

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

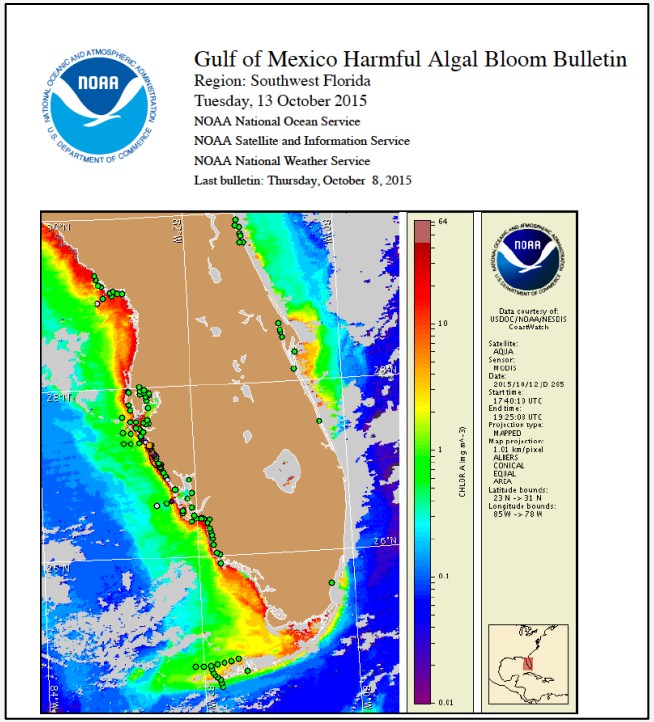
- *TurtleWatch* provides up-to-date information about thermal habitat of loggerhead sea turtles in the Pacific Ocean north of the Hawaiian Islands
- Created to reduce interactions between Hawaii-based long-line fishing vessels and loggerhead turtles
- Predicts the location of waters preferred by these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



Harmful Algal Bloom Monitoring

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

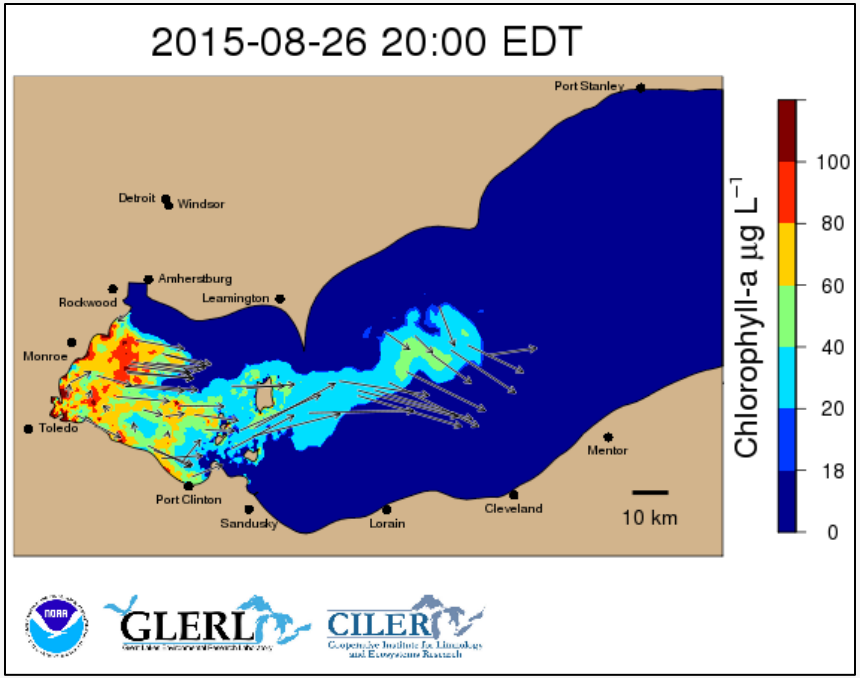
- The phytoplankton, *Karenia brevis*, produces an airborne toxin
- The toxin causes respiratory distress in vulnerable people
- Tourism is negatively affected during blooms
- NOAA monitors for the species
- The HAB Bulletin is published to guide the public, the tourism industry, and resource managers



HAB Forecasting – NOAA GLERL HAB Tracker

http://www.glerl.noaa.gov/res/HABs_and_Hypoxia/

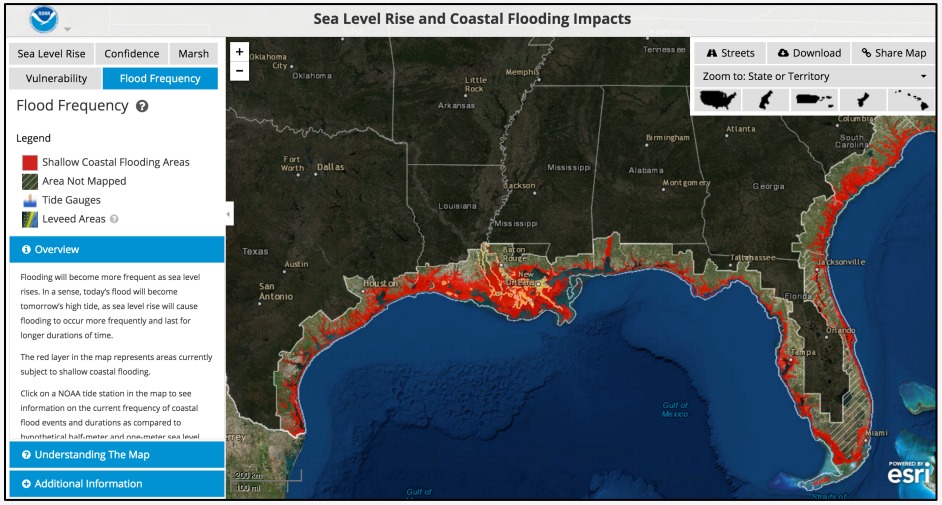
- Lake Erie (USA) hosts toxic cyanobacteria blooms
- Blooms can be identified using remote sensing imagery
- Bloom location can be forecast using coupled remote sensing and fluid dynamic models



Forecasting Sea Level Rise and Coastal Flooding Impacts

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

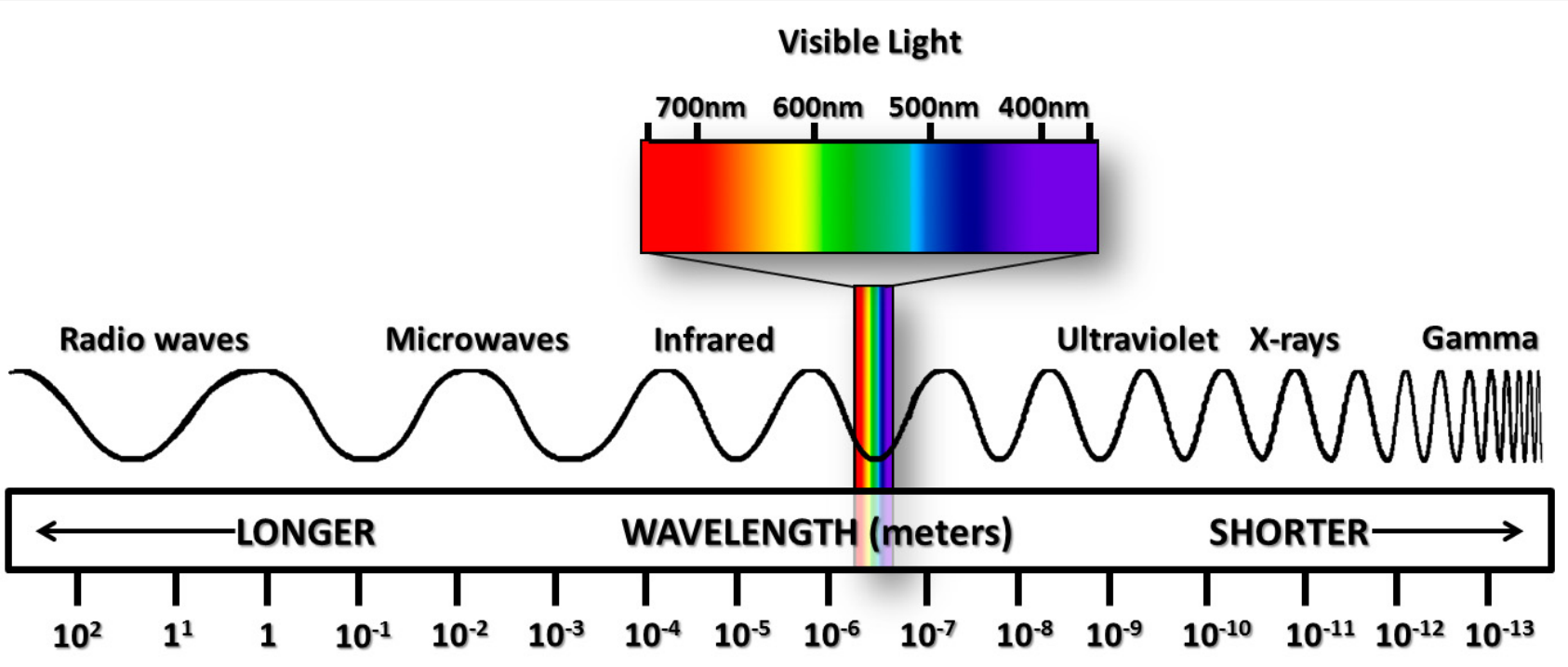
- This tool provides coastal managers and scientists with a preliminary look at sea level rise and coastal flooding impacts
- It is a screening-level tool using nationally consistent data sets and analyses
- Data and maps can be used at several scales to gauge trends and prioritize actions for different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



Fundamentals of Aquatic Remote Sensing

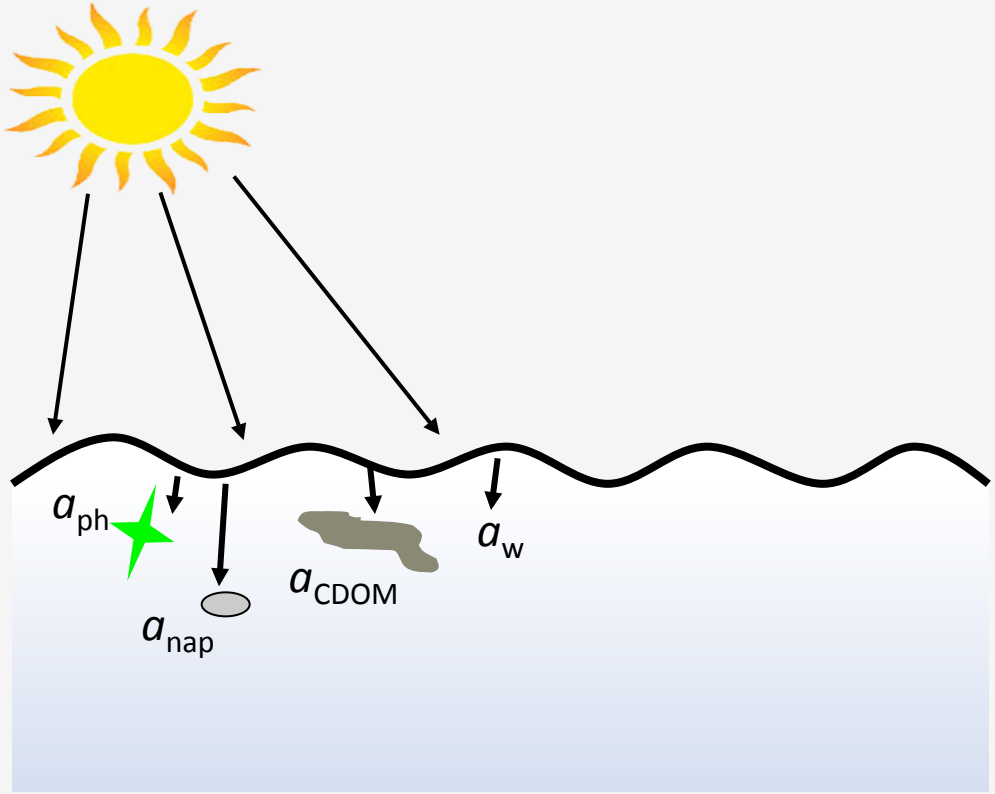
First, An Aquatic Optics Primer…

The Electromagnetic Spectrum



How Light Interacts with the Water

Defining Remote Sensing Reflectance (Rrs) – or 'Ocean Color'

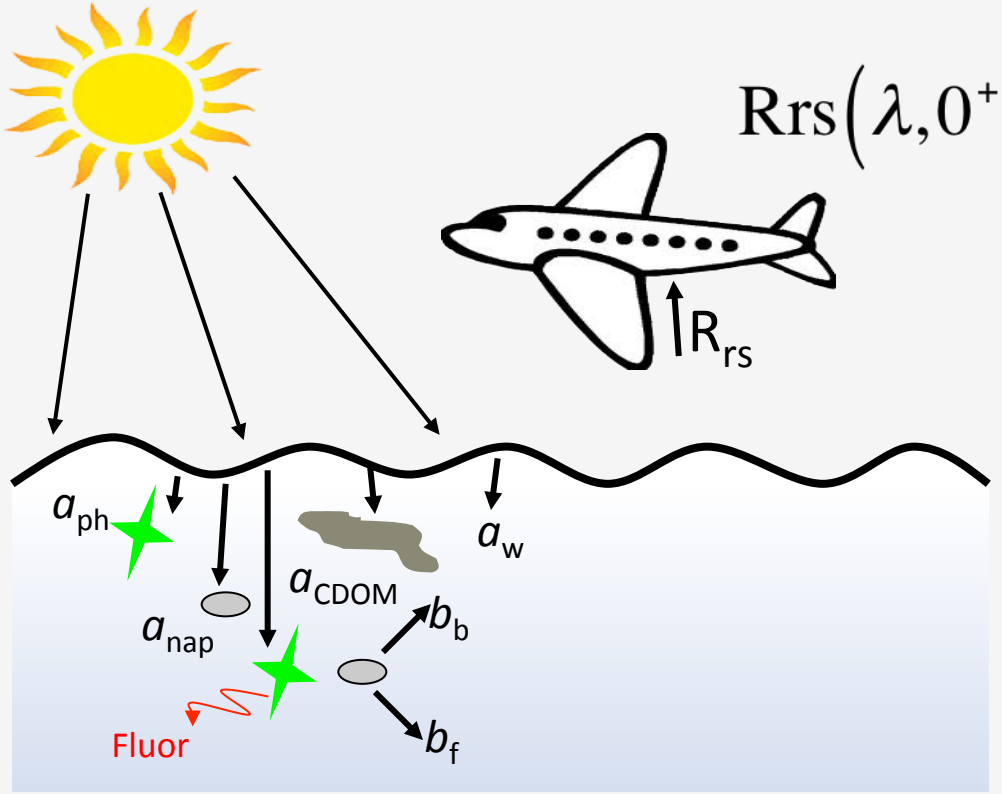


a = absorption by …

- phytoplankton (ph)
- non-algal particles (nap)
- colored dissolved organic matter (CDOM)
- water (w)

How Light Interacts with the Water

Defining Remote Sensing Reflectance (Rrs) – or 'Ocean Color'



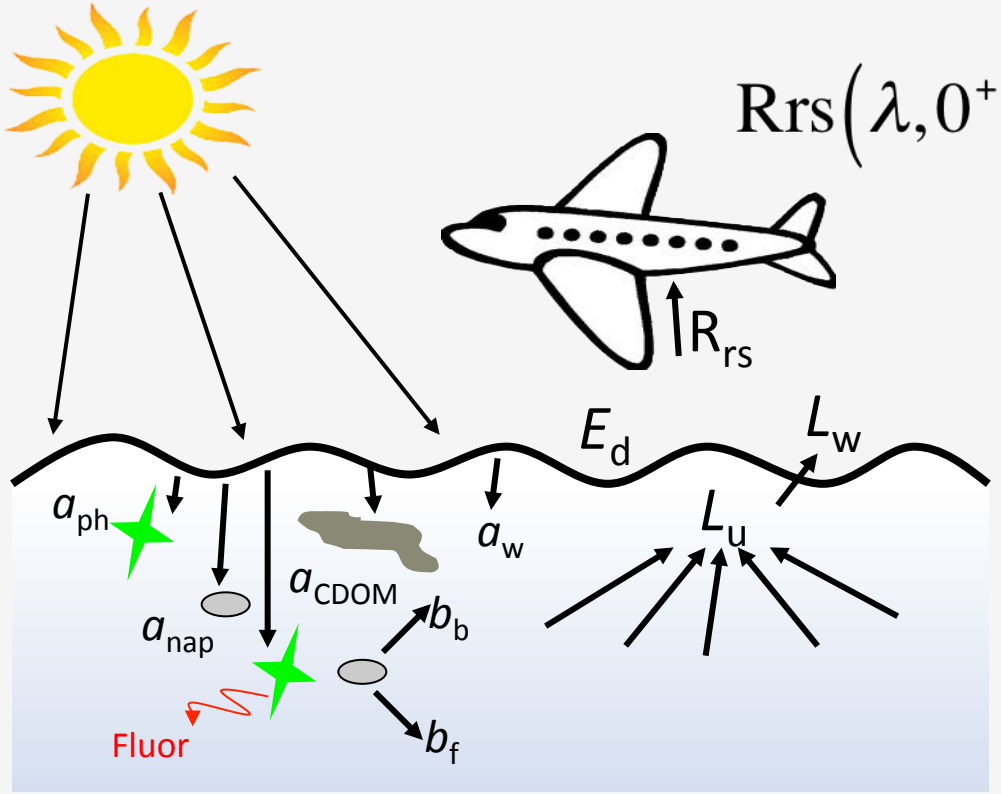
$$\mathrm{Rrs}\left(\lambda,0^{+}\right)\cong C\,\frac{b_b(\lambda)}{a(\lambda)+b_b(\lambda)}$$

a = absorption

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

How Light Interacts with the Water

Defining Remote Sensing Reflectance (Rrs) – or 'Ocean Color'

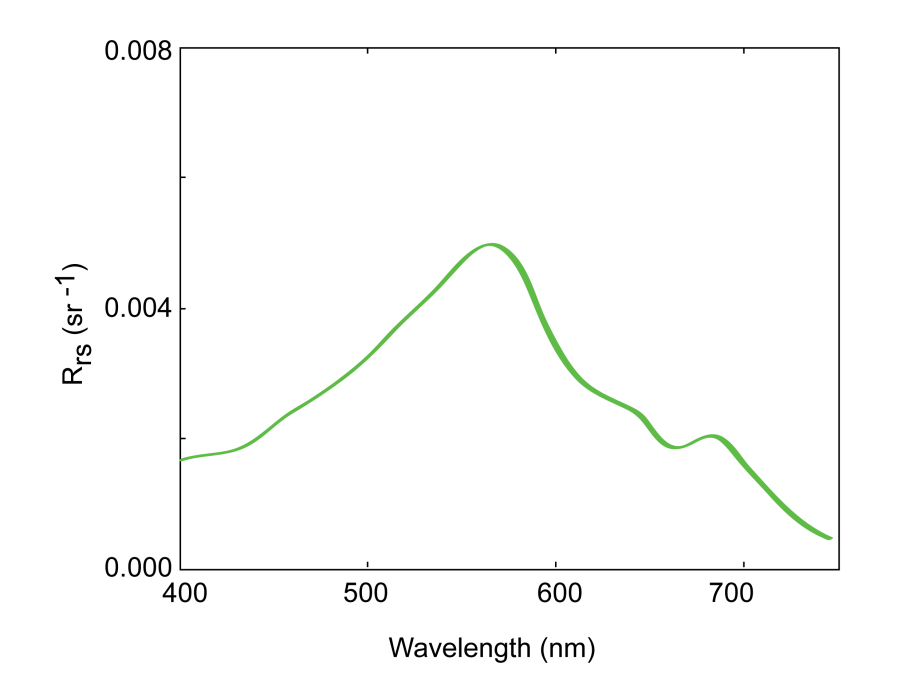


$$\mathrm{Rrs}(\lambda,0^+) \cong C\,\frac{b_b(\lambda)}{a(\lambda)+b_b(\lambda)} = \frac{L_w(\lambda)}{E_d(\lambda,0^+)}$$

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 (Rrs) of a Phytoplankton Bloom

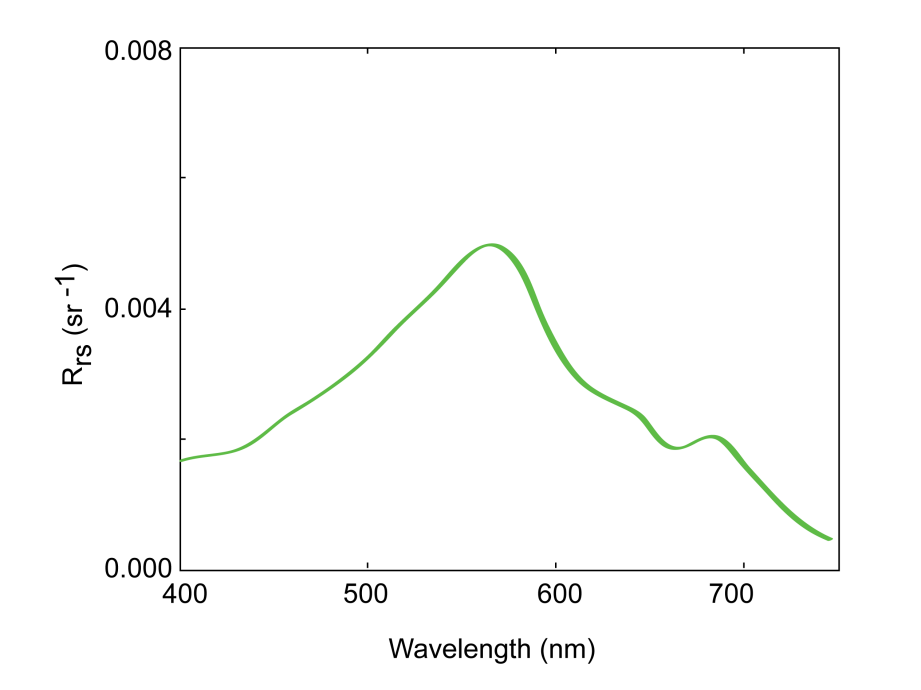


What Can We Observe from Space?

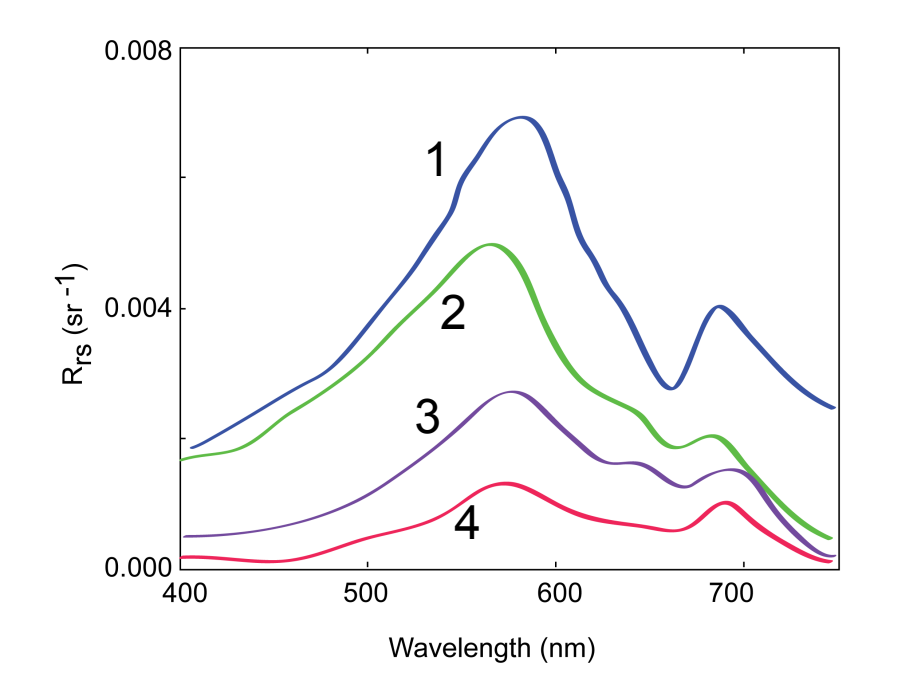
Ocean Properties Derived from Remote Sensing Imagery

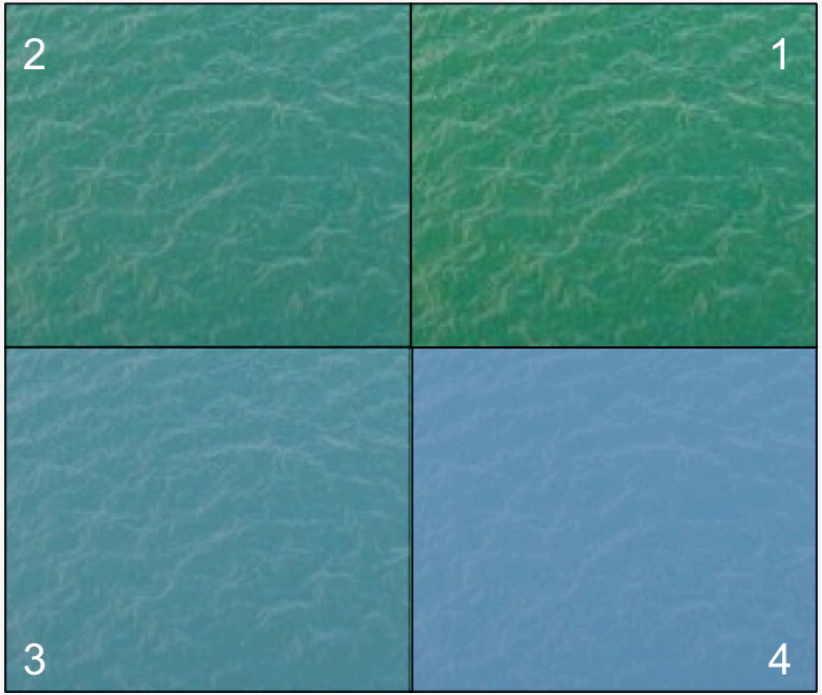
- Chlorophyll-a (proxy for phytoplankton biomass)
- Water Turbidity
- Colored Dissolved Organic Matter (CDOM)
- Sea Surface Temperature (SST)
- Surface winds
- Salinity

Chlorophyll-a from Remote Sensing Reflectance (Rrs)



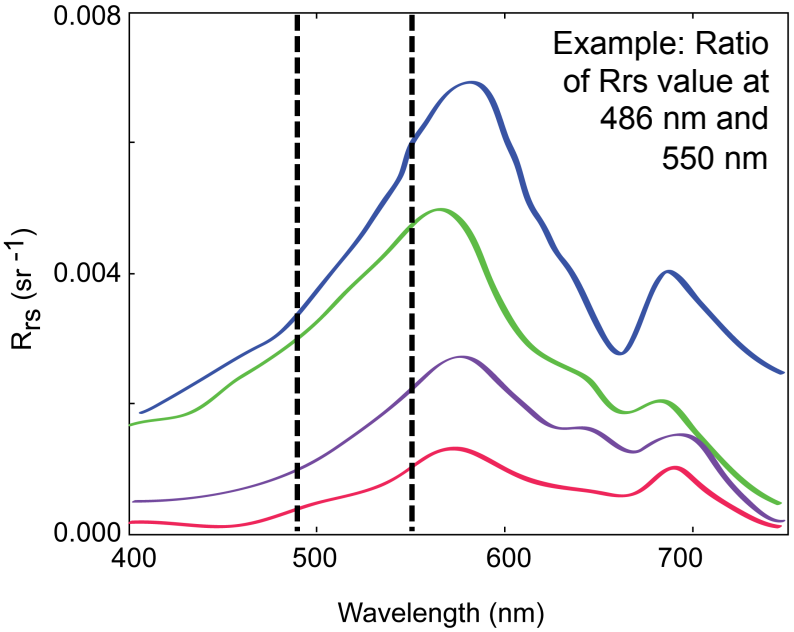
Rrs at Different Chlorophyll-a Concentrations

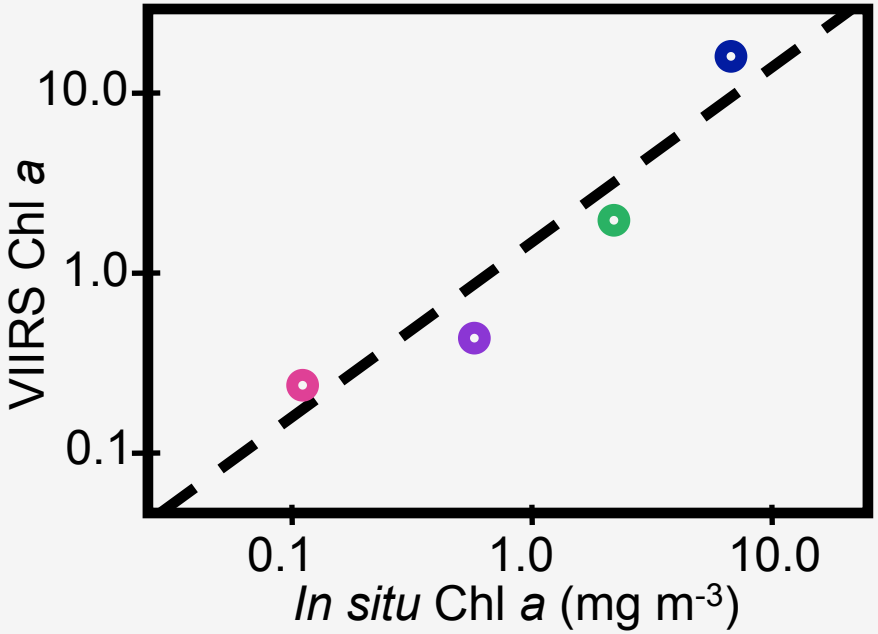




Chlorophyll-a Estimates

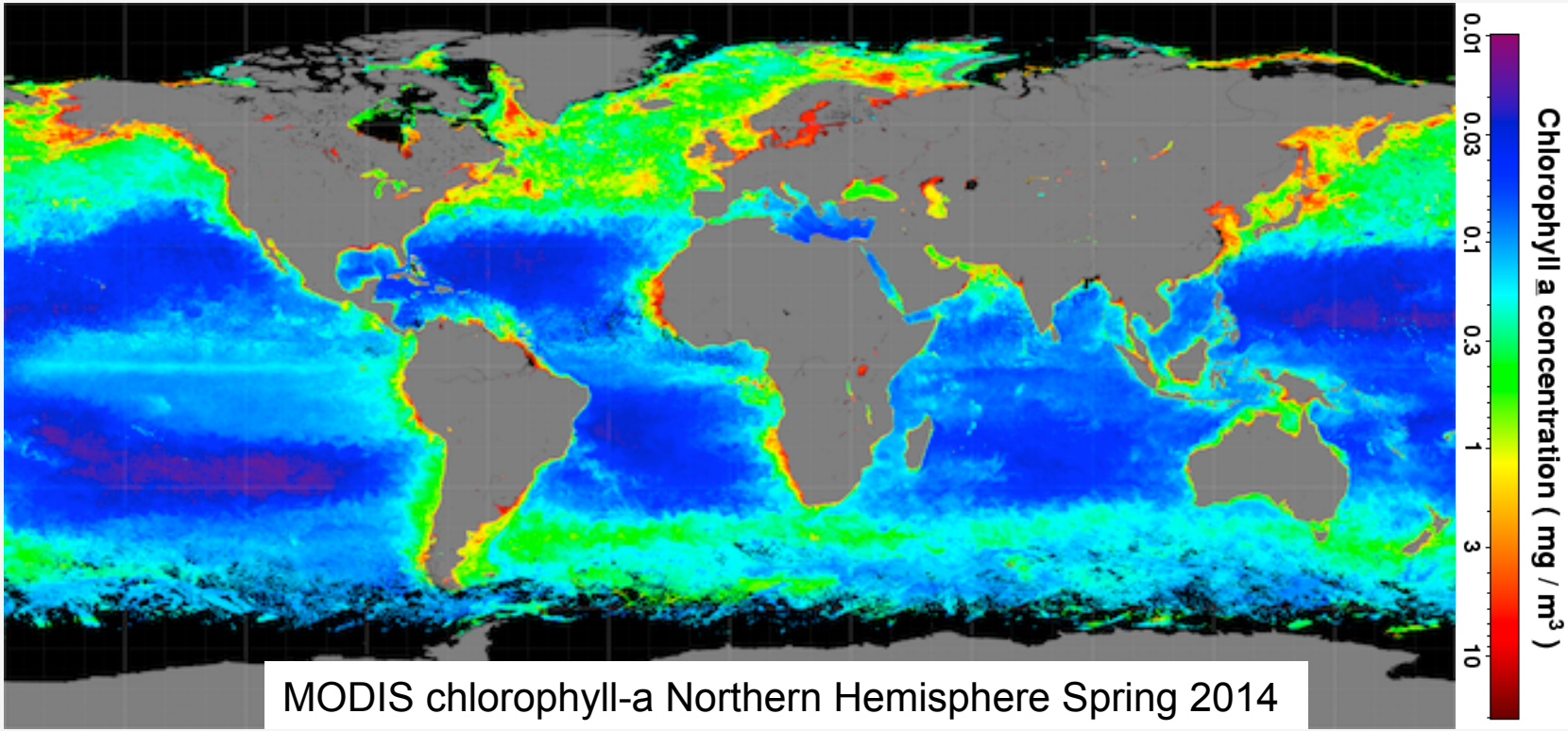
Estimates are a Function of the Ratio of Rrs Values





Algorithm description:
http://oceancolor.gsfc.nasa.gov/cms/atbd/chlor_a

Chlorophyll-a from Space

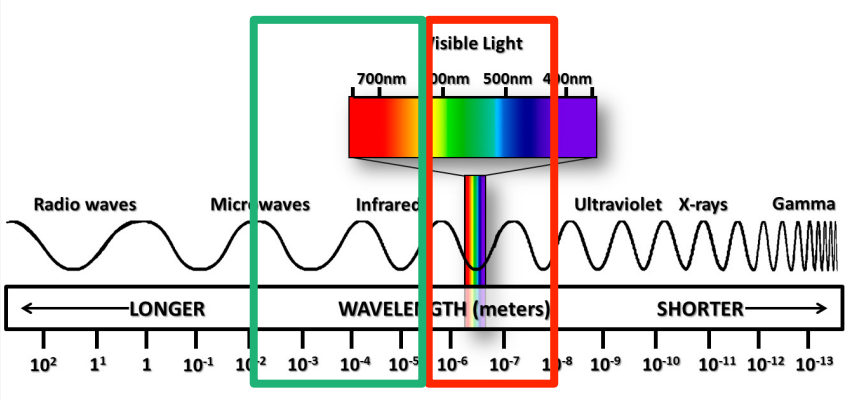


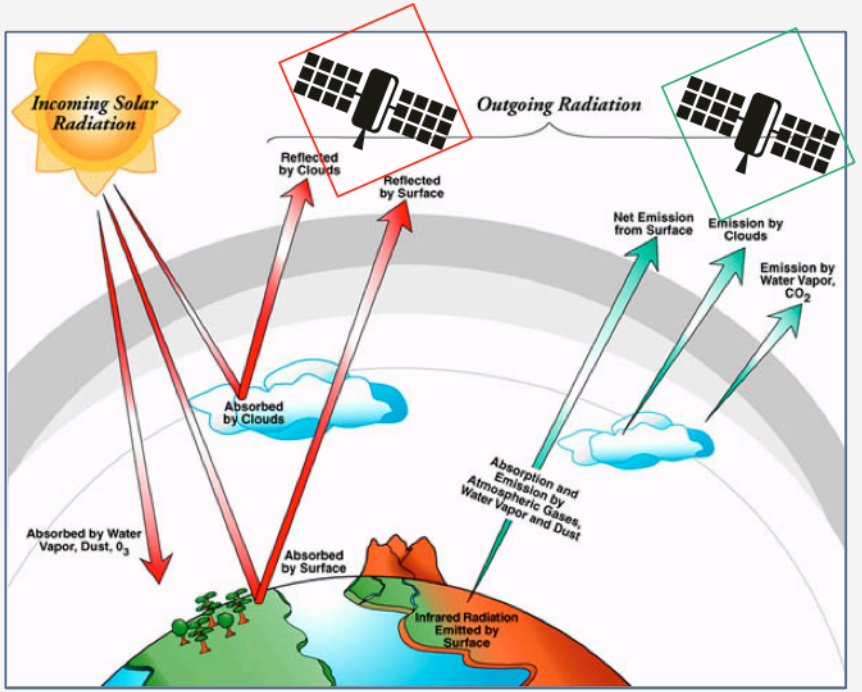
MODIS chlorophyll-a Northern Hemisphere Spring 2014

Second: An Overview of Satellite Remote Sensing

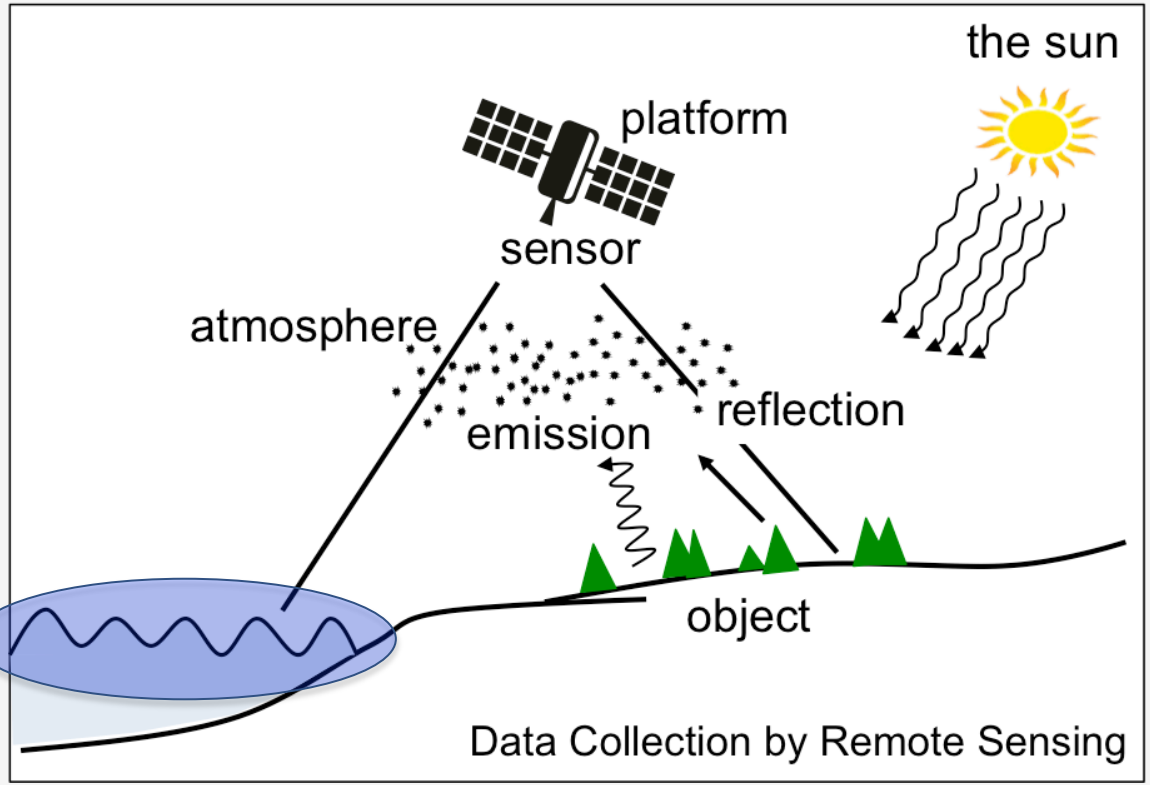
Satellites carry instruments/sensors to measure:

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





Satellite Measurements Carry Information About:



Atmosphere

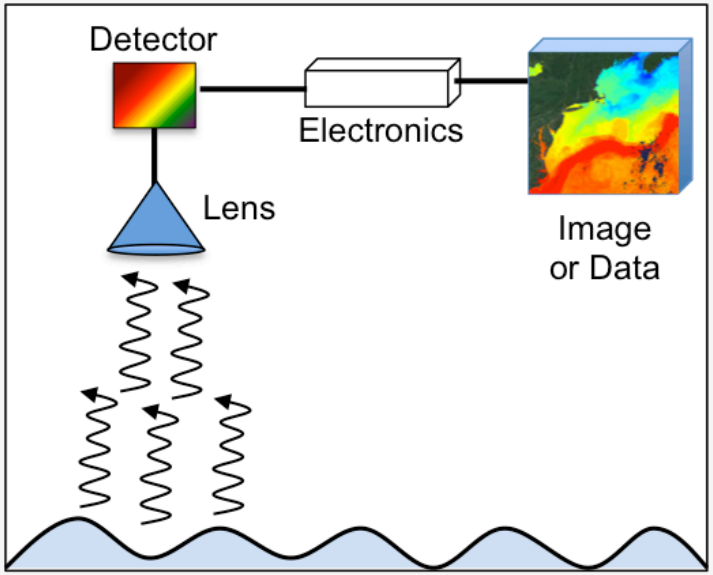
- Clouds
- Aerosols
- Gases

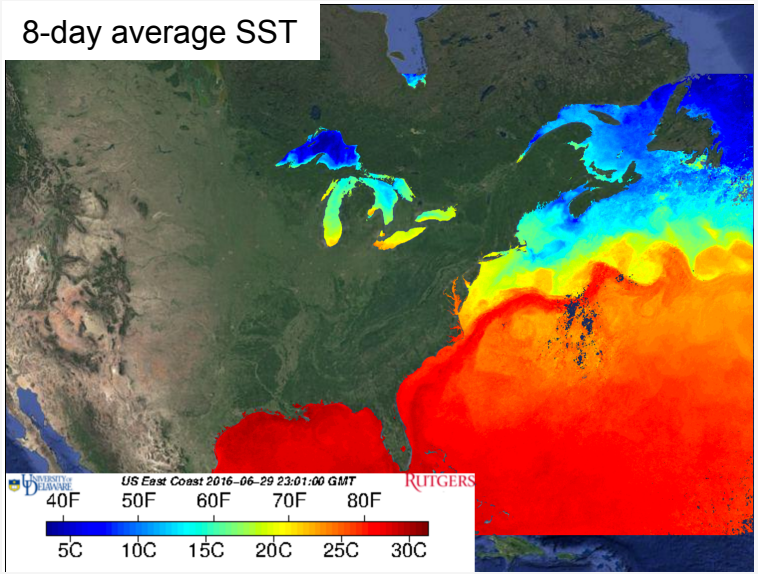
Earth's Surface

- 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.

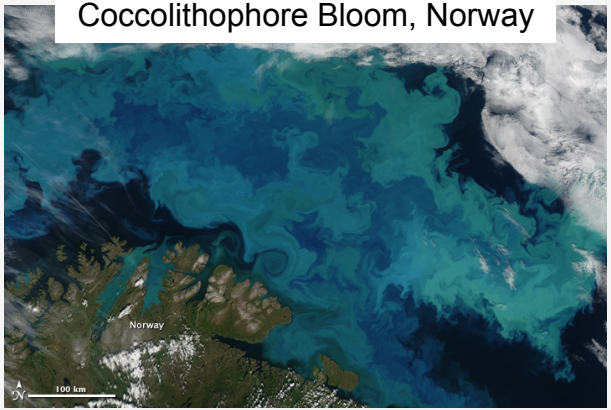




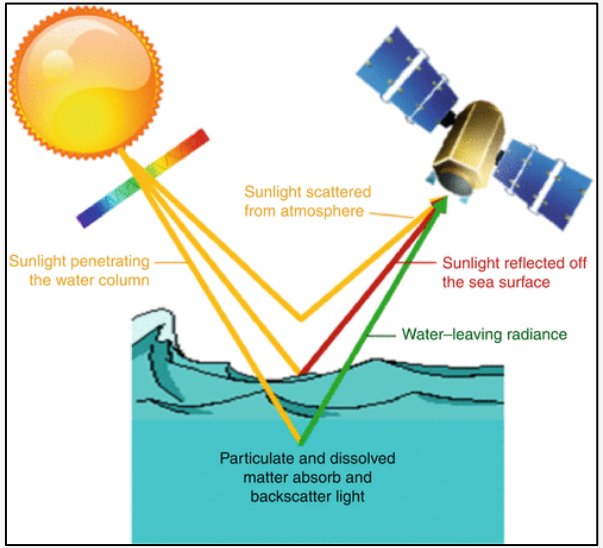
MARACOOS, ORB Lab, courtesy M. Oliver

Remote Sensing of Water Bodies

Coccolithophore Bloom, Norway

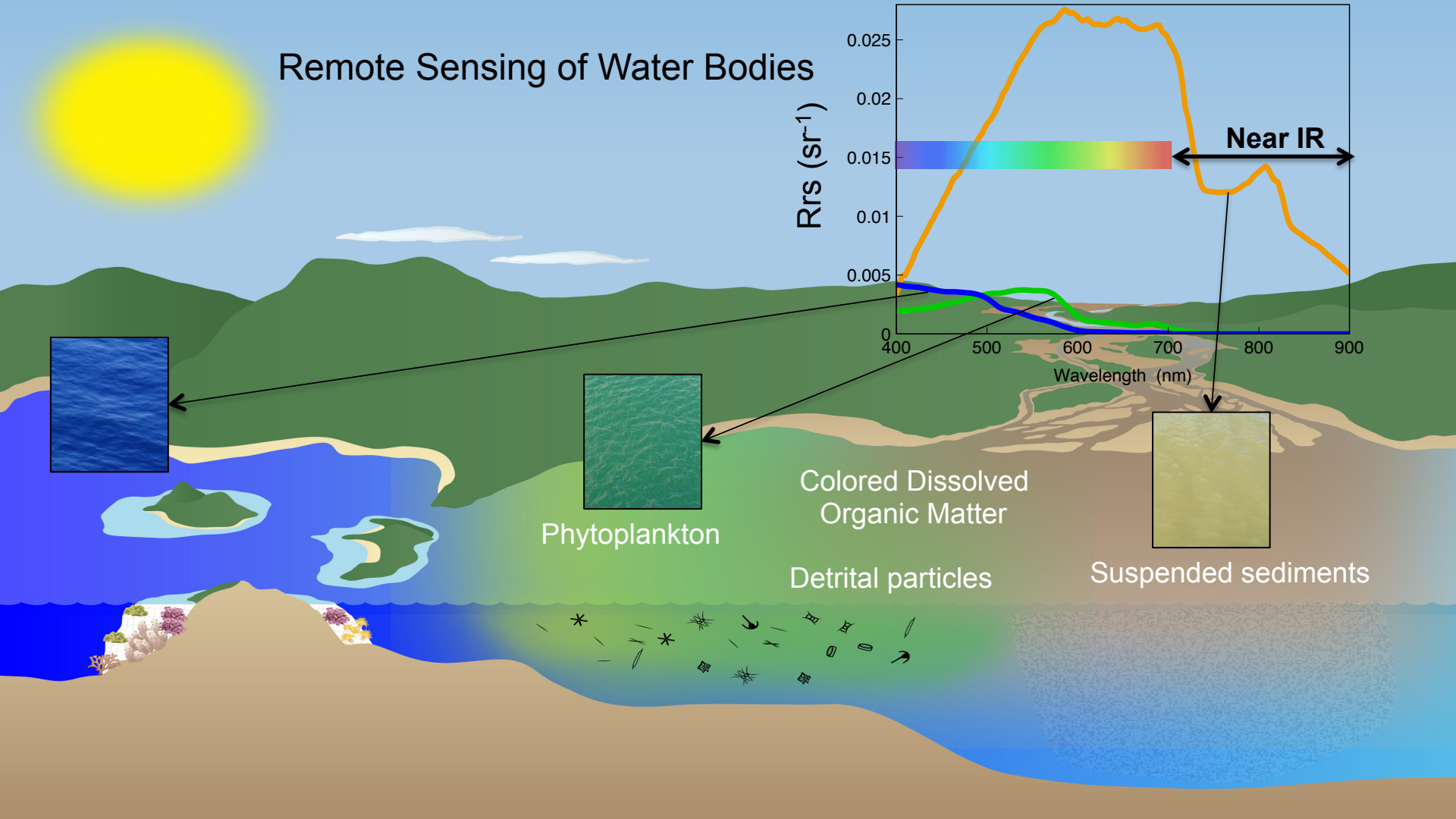


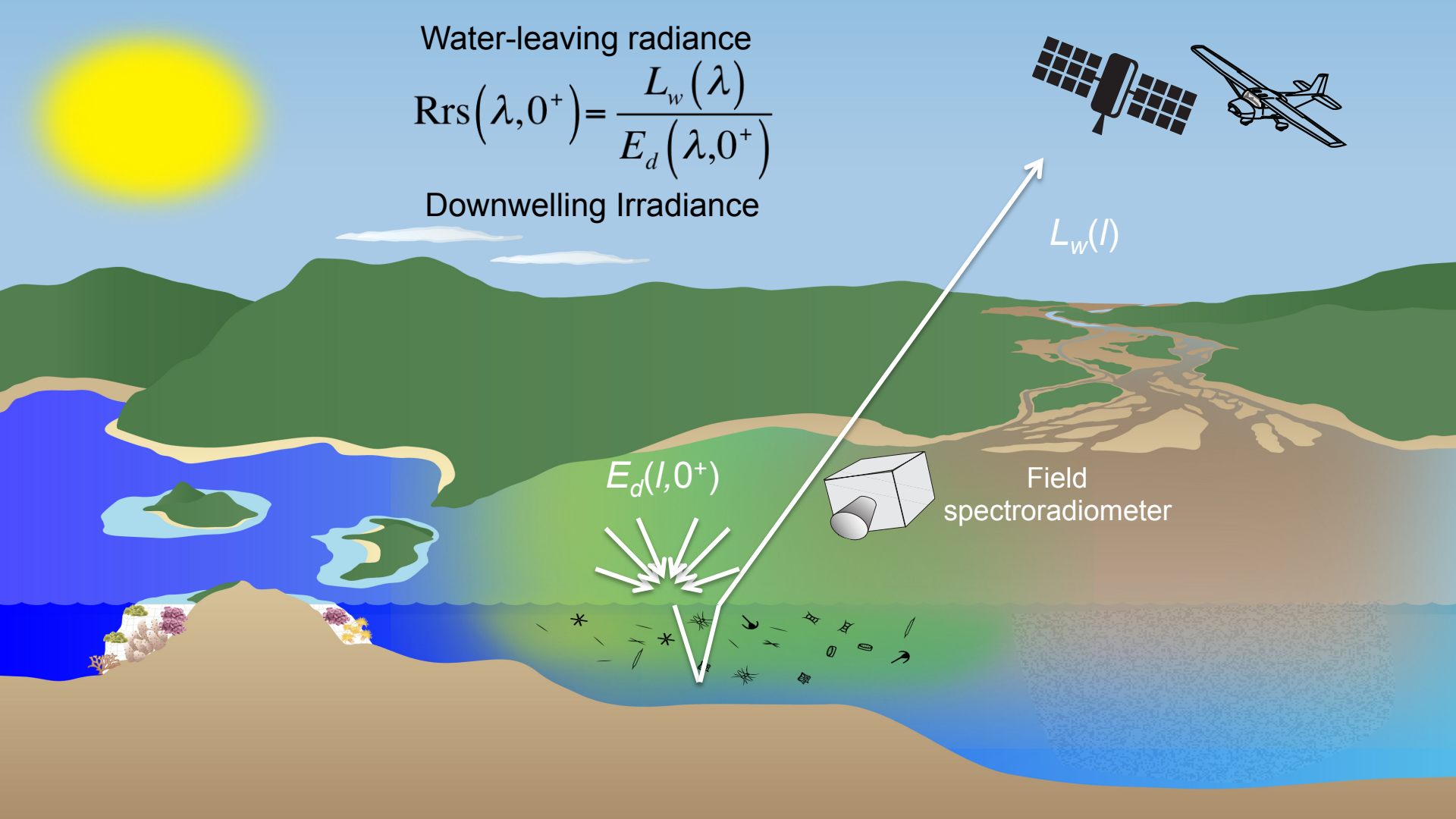
Reflected Solar Radiation (~color of water): measured by satellite sensors, and used to derive the properties of optically-active water constituents:



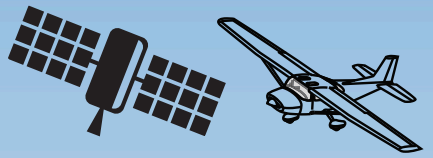
- Suspended sediments
- Algae
- Colored Dissolved Organic Matter
- Detrital Organic Matter
- Submerged/Floating Vegetation
- Oil

- Contaminants
- Pathogens


Remote Sensing of Water Bodies
Rrs (sr-1)
0.025
0.02
0.015
0.01
0.005
0
400
500
600
700
800
900
Wavelength (nm)
Near IR
Phytoplankton
Colored Dissolved Organic Matter
Detrital particles
Suspended sediments


Water-leaving radiance
$Rrs(\lambda,0^+) = \frac{L_w(\lambda)}{E_d(\lambda,0^+)}$
Downwelling Irradiance
$L_w(l)$
$E_d(l,0^+)$
Field
spectroradiometer

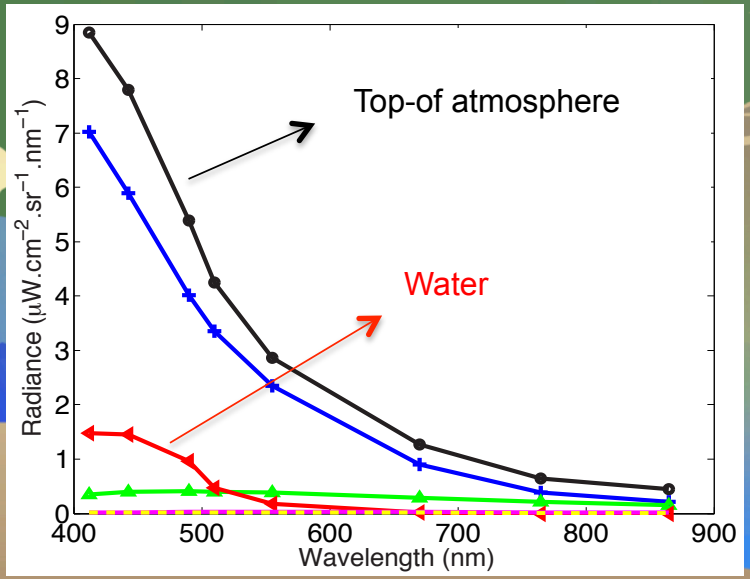
Atmospheric Correction



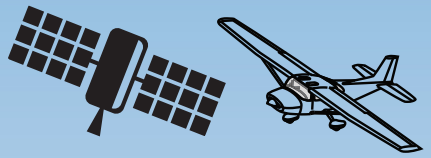
$$L_t(\lambda) = L_r(\lambda) + L_a(\lambda) + L_{ra}(\lambda) + T(\lambda,\theta)L_g(\lambda) + t(\lambda,\theta)L_{wc}(\lambda) + t(\lambda,\theta)L_w(\lambda)$$

>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%

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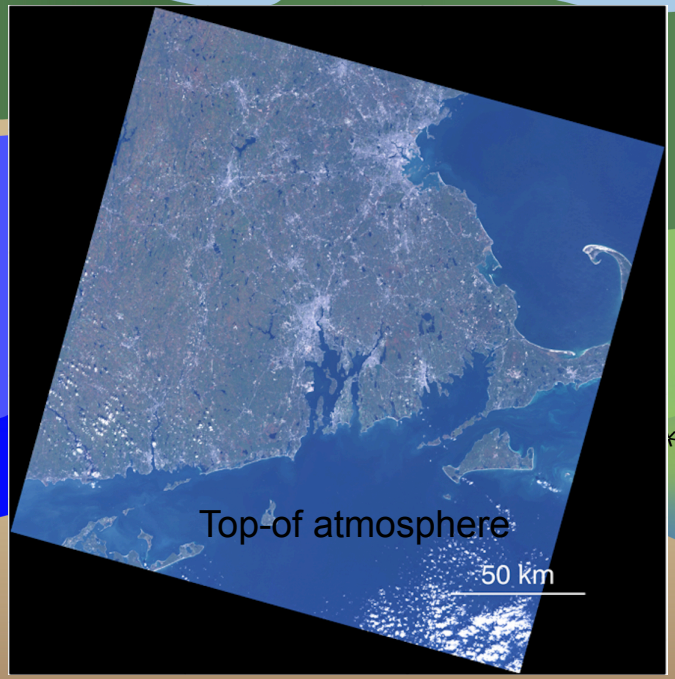
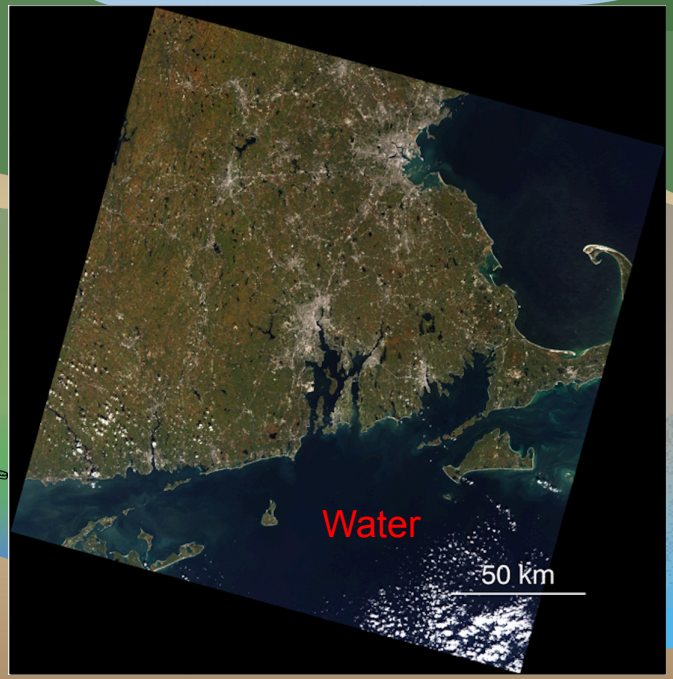


Atmospheric correction



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/

Advantages and Limitations of Remote Sensing in Aquatic Environments

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

Week 1 Summary

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 10th
- Next session 13 July 2016, 1:00 – 2:00 pm EDT (UTC-4)

Contacts

- Your Course Instructors
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  - Cindy Schmidt: cynthia.l.schmidt@nasa.gov
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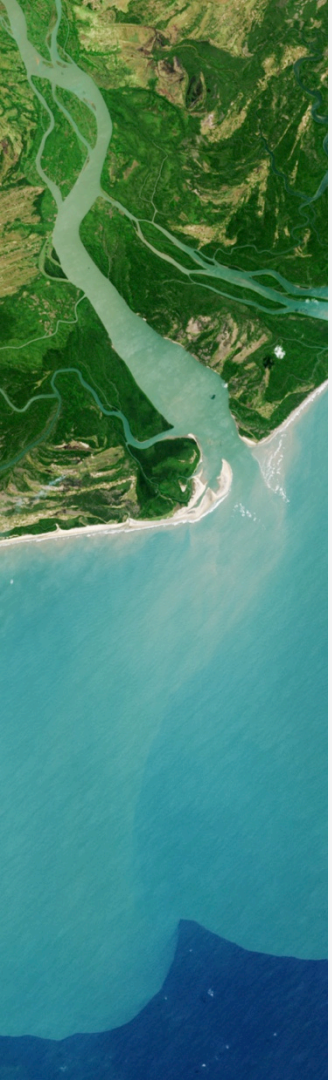
  - Ana Prados: aprados@umbc.edu

- ARSET Website:
  - http://arset.gsfc.nasa.gov/



National Aeronautics and Space Administration

ARSET

Applied Remote Sensing Training

http://arset.gsfc.nasa.gov

@NASAARSET

Thank you!

Next Week:

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