Part 3: Aquatic Remote Sensing Skill Development and Best Practices

Instructors: Sherry L. Palacios & Amita Mehta

APPLIED REMOTE SENSING TRAINING PROGRAM
10 YEARS OF TRAINING
TRAIN - EMPOWER - ADVANCE

Training Objectives

Learn to:

- Understand which data products are used for water quality monitoring
- Follow rigorous practices for obtaining and processing aquatic remote sensing data
- Build skills in image processing for water quality monitoring for coastal and inland water bodies using NASA's SeaDAS image processing software

Training Outline

June 5

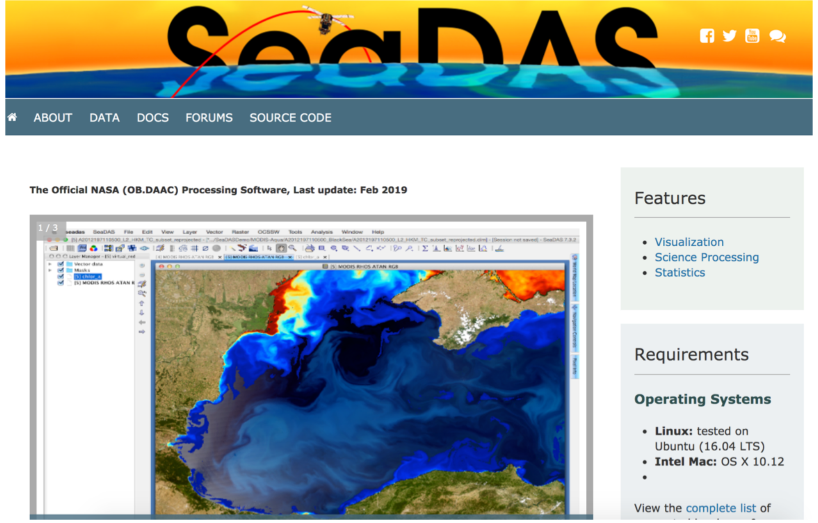
Water Quality in the Coastal Zone

June 12

Water Quality of Larger Inland Water Bodies

June 19

Aquatic Remote Sensing Skill Development and Best Practices



Outline for Part 3

- Review Parts 1 & 2
- Water Quality Monitoring Program Workflow & Best Practices
- Designing an Effective Water Quality Monitoring Program using Remote Sensing
- Demo: Using Remote Sensing in a Water Quality Monitoring Program
- Exercise: Using Remote Sensing in a Water Quality Monitoring Program using Data and Methods from the Wisconsin Department of Natural Resources
- Exercise: Advanced Skills with SeaDAS
- Laboratory work time

Review of Parts 1 & 2

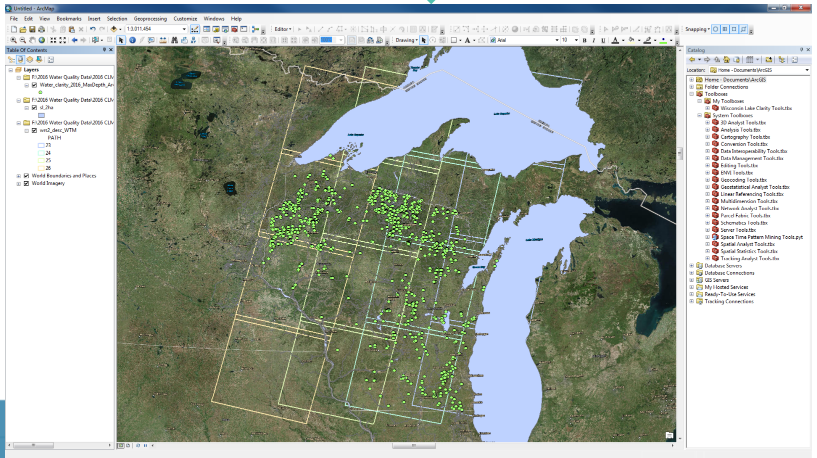
Current Satellite Missions for Water Quality Monitoring

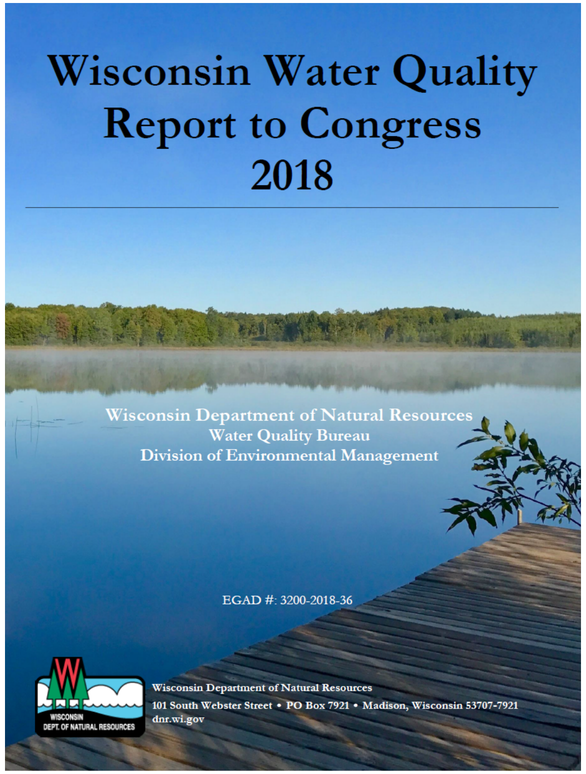
- Landsat 7 (4/15/1999 – present)
- Landsat 8 (2/1/2013 – present)
- Terra (12/18/1999 – present)
- Aqua (5/4/2002 – present)
- Suomi National Polar Partnership (SNPP) (11/21/2011 – present)
- Sentinel-2A (6/23/2015 - present)
- Sentinel-2B (3/7/2017 – present)
- Sentinel-3A (2/16/2016 – present)

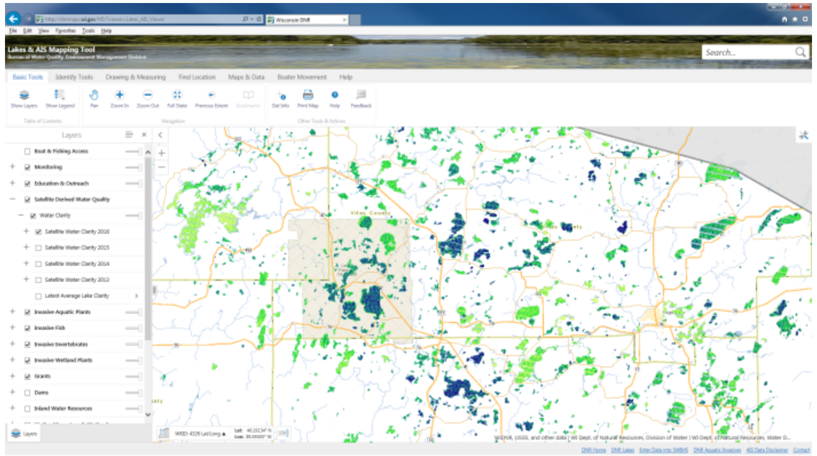
Guest Presentation: Satellite Water Clarity Monitoring

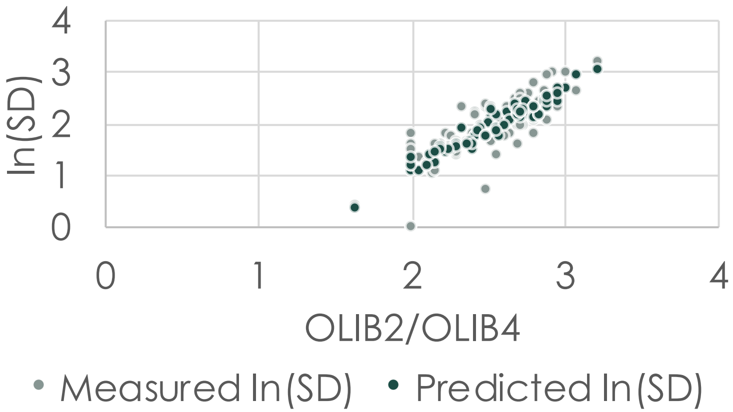
Dr. Daniela Gurlin, Wisconsin Department of Natural Resources

Photo credit: Amy Kowalski









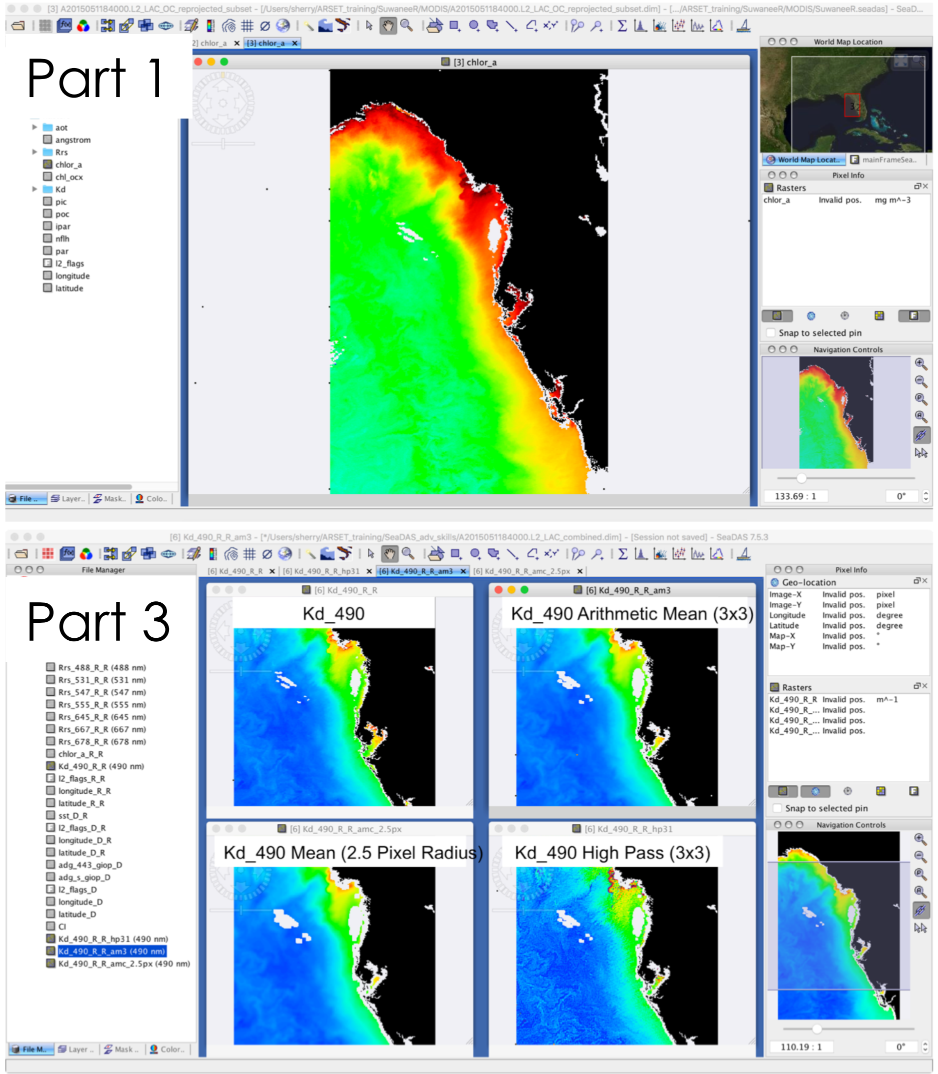
Advantages & Disadvantages of Remote Sensing for Freshwater Systems

- Advantages
  - Longtime imagery record for time series analysis
  - Ongoing commitment from space agencies to continue data collection
  - Reliable data for operational early warning and forecasting systems
  - Some sensors have spatial resolution appropriate for lakes
  - Imagery is typically freely available and of high quality

- Disadvantages
  - Shallow water – interference from the bottom
  - Water bodies too small for the spatial resolution of sensors
  - Limited number of standard algorithms for these optically complex waters
  - Atmospheric correction
  - Highly variable systems
  - Ground truthing is costly

Homework & Certificates

- Homework:
  - 3 homework assignments
  - Answers to homework from Parts 1 & 3 must be submitted via Google Forms
  - There is no form to complete for Part 2 homework
- Certificate of Completion
  - Attend all live webinars
  - Complete the homework assignments by June 21
- You will receive certificates approximately 2 months after the completion of the course from: marines.martins@ssaihq.com



Water Quality Monitoring Workflow & Best Practices

Water Quality Monitoring Program Workflow

Identify Water Quality Problem

Evaluate if Remote Sensing can Complement *In Situ* Sampling Effort

Choose Sensor(s) & Data Product(s) Appropriate for Problem

Build Sampling Strategy for Coincident *In Situ* & Remote Sensing Monitoring

In Situ

collect sample data within 2 hours of aircraft or satellite overpass

collect field samples

process field samples

QA/QC data

Remote Sensing

identify aircraft or satellite overpass dates/times

download imagery

pre-process imagery & derive L2 data product

extract pixel values at sample site locations

Compare *In Situ* & Remote Sensing Matchups & Run Statistics

Communicate Results to Stakeholders

Designing an Effective Water Quality Monitoring Program

- Logistics
- Incorporating citizen science
- Quality control
- Interpreting results
- Data management
- Communicating to stakeholders

Further Reading: Gholizadeh et al. 2016

Logistics: *In Situ* Observations

- Choose which observations to make
- Build a rigorous sampling design
  - statistics
  - remote sensing
- Identify airplane or satellite overpass times
- Time sampling based on tides or human-controls on water level
- Schedule boat time
- Schedule personnel
- Prepare for contingencies

Pinto Lake, CA
my favorite local cyanoHAB

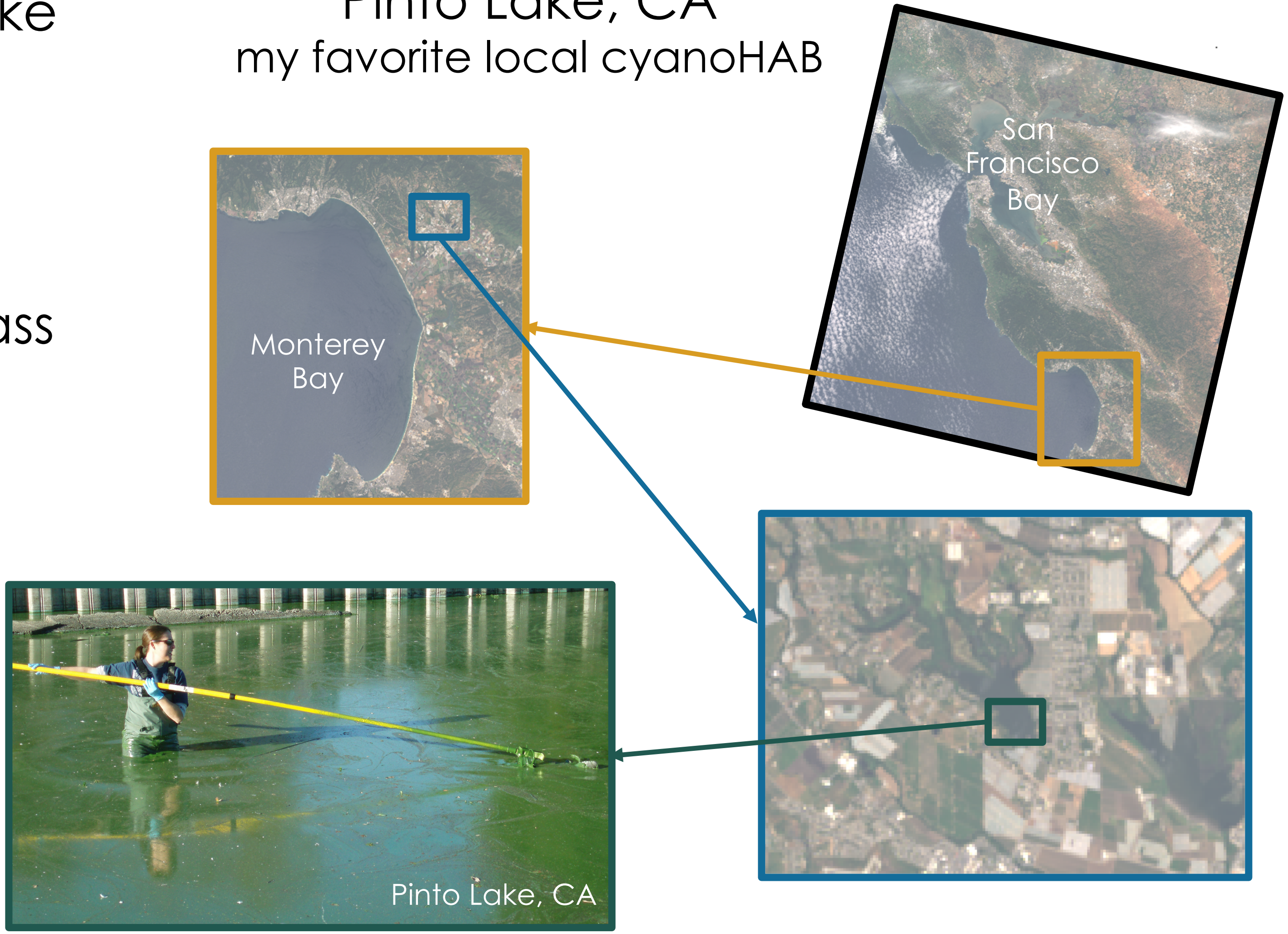


Image Credit: (bottom left) CA Water Boards

Logistics: Sampling Small Water Bodies

Land	Land	Land	Land	Land
Land	Water	Water	Mixed	Land
Land	Mixed	Water	Water	Mixed
Land	Land	Land	Land	Land

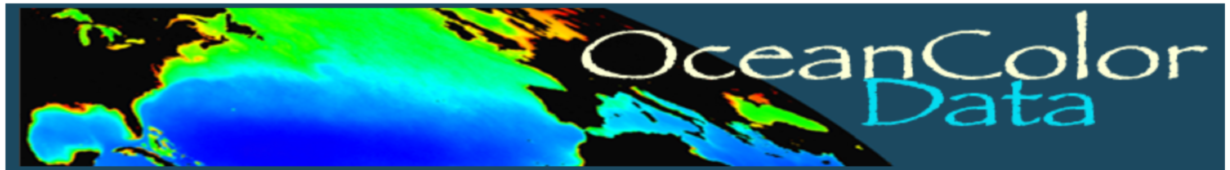
- Mixed pixels limit our ability to monitor small water bodies
- Water bodies with at least three pixels in all directions are candidates for sampling: "3 pixel rule"

- False color sharpens the distinction between land and water
- Reddish pixels at left include land
- Using the 3-pixel rule, which water bodies are candidates?

Slide credit: R. Stumpf

Logistics: Planning for Satellite Overpasses

https://oceandata.sci.gsfc.nasa.gov/cgi/overpass_pred



Missions ▾ Data ▾ Documents ▾ Analyses ▾ People Forum ▾ Services ▾ Links

Sensor(s):

☑ MODIS-Aqua ☐ MODIS-Terra ☐ VIIRS-NPP ☐ VIIRS-JPSS1 ☐ OCM-2 ☑ OLI ☐ MSI ☑ OLCI-S3A ☑ OLCI-S3B

Start date:

2019 6 1

End date:

2019 6 6

Location

Latitude (+/- 90): 37.4
Longitude (+/- 180): -122
Height above sea level (km): 0

Sun Status

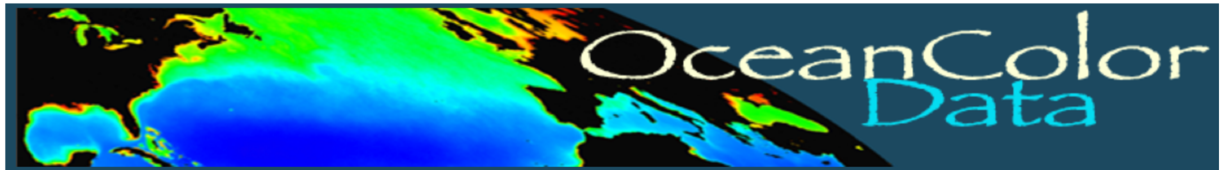
☑ Daytime ☐ Nighttime

Output Format

◉ Table ○ Text

Submit

Please be patient, it takes upwards of 2-3 seconds per day of prediction per sensor.
If the page disconnects after three minutes, shorten/split the date range.



Missions ▾ Data ▾ Documents ▾ Analyses ▾ People Forum ▾ Services ▾ Links

MODIS-Aqua: Viewing Times

Date	Time (UTC)	Lat (DEG)	Lon (DEG)	Sat. Azi.	Sat. Elev.	Range (km)	Sun Azi.	Sun Elev.	Tilt	Flags*
1 Jun 2019	21:00:33	37.400	-122.000	74.12	58.07	816	221.47	70.69	NADIR	4
2 Jun 2019	21:43:17	37.400	-122.000	260.46	48.45	908	240.95	64.15	NADIR	
3 Jun 2019	20:48:22	37.400	-122.000	72.20	42.86	984	214.10	72.42	NADIR	4
4 Jun 2019	21:31:01	37.400	-122.000	258.69	66.47	762	236.65	66.46	NADIR	
5 Jun 2019	20:36:11	37.400	-122.000	70.27	32.22	1190	205.41	73.87	NADIR	3
6 Jun 2019	21:18:47	37.400	-122.000	263.20	89.38	705	231.57	68.64	NADIR	4

* 1 = tilt in progress; 2 = tilt schedule unknown, estimated tilt
3 = Sat. view ang. > 45 deg; 4 = Possible sunglint; 5 = nighttime pass
6 = old TLE, accuracy will be degraded

OLI: Viewing Times

Date	Time (UTC)	Lat (DEG)	Lon (DEG)	Sat. Azi.	Sat. Elev.	Range (km)	Sun Azi.	Sun Elev.	Tilt	Flags*
4 Jun 2019	18:45:50	37.400	-122.000	285.93	88.85	708	125.11	67.14	NADIR	4

* 1 = tilt in progress; 2 = tilt schedule unknown, estimated tilt
3 = Sat. view ang. > 45 deg; 4 = Possible sunglint; 5 = nighttime pass
6 = old TLE, accuracy will be degraded

OLCI-S3A: Viewing Times

Date	Time (UTC)	Lat (DEG)	Lon (DEG)	Sat. Azi.	Sat. Elev.	Range (km)	Sun Azi.	Sun Elev.	Tilt	Flags*
2 Jun 2019	19:00:11	37.400	-122.000	287.80	51.54	997	132.33	69.23	NADIR	4
3 Jun 2019	18:34:24	37.400	-122.000	108.23	89.55	807	120.86	65.18	NADIR	4
6 Jun 2019	18:56:30	37.400	-122.000	287.20	55.99	951	129.35	68.93	NADIR	4

Incorporating Citizen Science

Where non-scientists are actively engaged in new discovery

Types of Activities

- Observations of biological, chemical, and physical water quality parameters
- Observations of water optical properties using mobile devices
- Mapping extent of water systems
- Measurements of water flow
- Algorithm development
- Education & outreach

A Few Examples

- Surface Water Ambient Monitoring Program: SWAMP
- EarthEcho Water Challenge (formerly World Water Monitoring Challenge)
- Malaysian Borneo, Kinabatangan River efforts
- Water Keeper Alliance
- FirstFlush
- Hui O Ka Wai Ola

More reading: Buytaert et al. 2014, volunteer programs

Quality Control

The scientific enterprise is built on the foundation of trust

Scientific Considerations

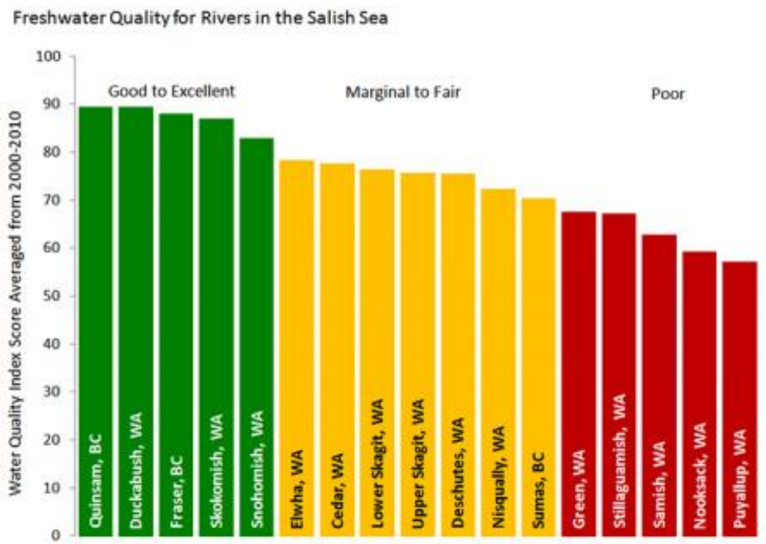
- Use statistical approaches appropriate to the study problem
- Establish thresholds for statistical significance prior to obtaining measurements (this may be proscribed by law)
- Establish the meaning of outliers *a priori* so analyst can objectively remove these without bias

Regulatory Considerations

- Many regulatory agencies (e.g., US EPA) publish standards for water quality parameters and the protocols used to measure them
- Use the protocols to guide quality control of data

Interpreting Results

- Regulatory agencies set standards for water quality parameters at the federal, state or provincial, or local level
- These standards serve as benchmarks in statistically evaluating the observed water quality parameters
- Sometimes an index, or "score" is derived from water quality parameters to quickly communicate the state of the water body



Freshwater Quality Index Scores for Major Salish Sea Rivers from 2000 to 2010

River	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Average
Quinsam, BC	88	94	83	82	94	94	100	88	88	82		89
Duckabush, WA	93	95	94	90	74	94	89	85	88	96	86	89
Fraser, BC					89	94	79	89	89	89		88
Skokomish, WA	95	95	94	85	70	67	92	89	89	94	86	87
Snohomish, WA	92	91	89	81	74	75	89	75	81	85	79	83
Elwha, WA	86	88	83	76	73	74	86	67	66	81	81	78
Cedar, WA	87	76	60	78	72	84	81	79	79	81	77	78
Lower Skagit, WA	89	91	71	76	61	73	77	77	75	76	74	76
Upper Skagit, WA	87	86	59	85	64	81	84	75	75	81	56	76
Deschutes, WA	62	72	70	73	61	83	88	88	83	76	74	75
Nisqually, WA	40	60	79	79	69	71	74	75	91	74	83	72
Sumas, BC					70	73	70	68	72	70		70
Green, WA	82	73	66	67	75	49	72	68	60	69	63	68
Stillaguamish, WA	81	60	44	72	55	67	71	69	75	75	71	67
Samish, WA	86	75	32	49	34	71	67	74	59	80	63	63
Nooksack, WA	65	68	58	57	52	54	61	51	60	69	56	59
Puyallup, WA	60	58	57	55	51	58	59	58	61	49	62	57

Image Credit: EPA Freshwater Quality of the Salish Sea

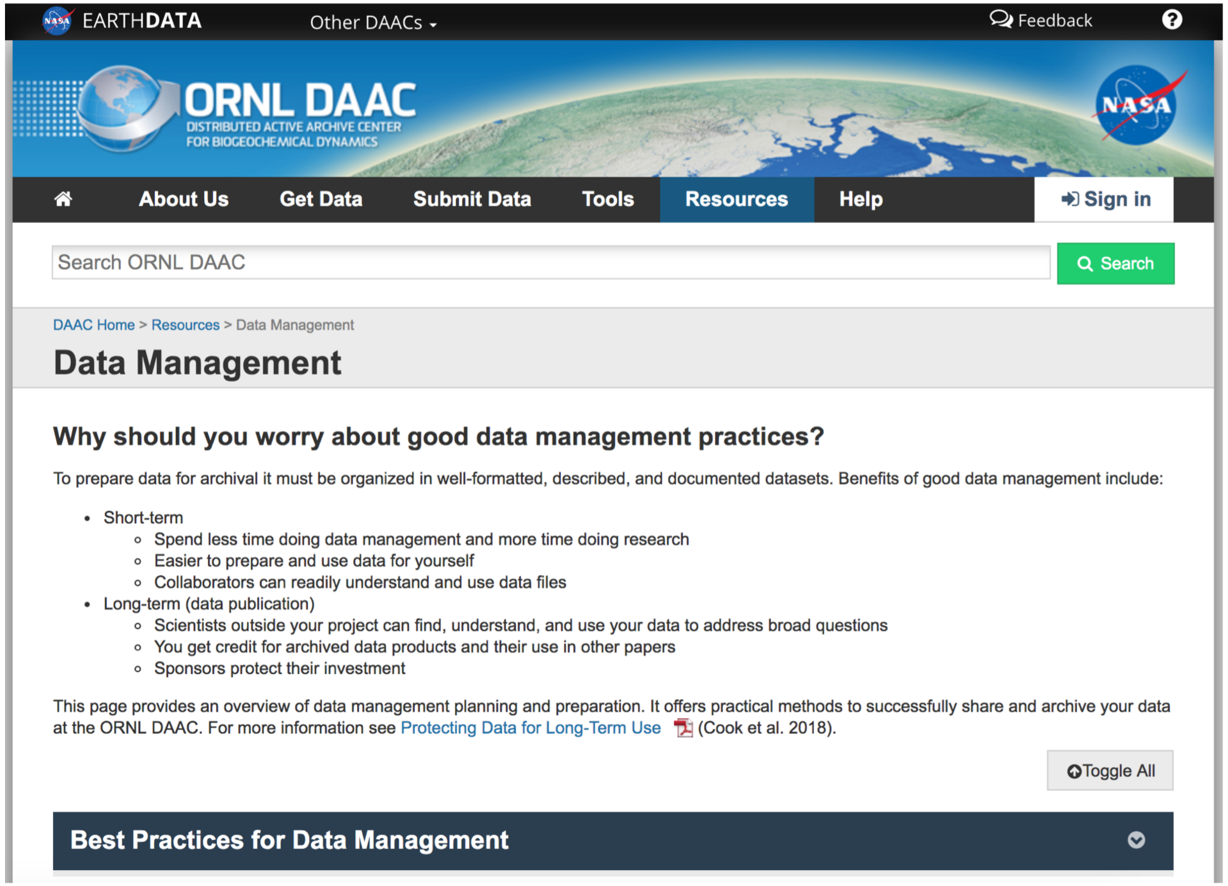
Data Management

- Build a data management and dissemination plan
- Store data and products locally and in the cloud
- Follow all domain-specific guidance for meta-data
- Write up your data management plan and share it with your organization
- Update the data management plan as needed
- When required, upload data to community data servers for use by other researchers and water quality managers (e.g., SeaBASS, OB.DAAC)

Best Practices for Preparing Datasets for Sharing and Archiving

Oak Ridge National Lab - Distributed Active Archive Center

1. Use stable file formats
2. Define the contents of your data files
3. Assign descriptive file names
4. Use consistent data organization
5. Preserve information with version control
6. Document your data
7. Perform basic data quality assurance
8. Protect your data
9. Publish your data



Communicating to Stakeholders

- Know your audience
- Use clear and concise language appropriate for your audience's reading level
- Limit the number of main points in your message
- Use figures or graphics that deliver the message on their own
- If numbers are used, explain what they mean
- If risk is communicated as probability, explain the meaning
- Cite sources

Guidance for Water Quality Monitoring Communication

1. Main Message / Call to Action
2. Language
3. Information Design
4. State of the Science
5. Behavioral Recommendations
6. Numbers
7. Risk

Adapted from: Assessing clarity of message communication for mandated USEPA drinking water quality reports and the CDC

Guidance for Water Quality Monitoring Communication

1. Main Message / Call to Action
2. Language
3. Information Design
4. State of the Science
5. Behavioral Recommendations
6. Numbers
7. Risk

- Does the material contain one main message?
- Is the main message at the top, beginning, or front of the material?
- Is the main message emphasized with visual cues?
- Does the material contain at least one visual that conveys or supports the main message?
- Does the material include one or more call to action for the primary audience?

Adapted from: Assessing clarity of message communication for mandated USEPA drinking water quality reports and the CDC

Guidance for Water Quality Monitoring Communication

1. Main Message / Call to Action
2. Language
3. Information Design
4. State of the Science
5. Behavioral Recommendations
6. Numbers
7. Risk

- Do both the main message and the call to action use the active voice?
- Does the material always use language the primary audience would use?

Adapted from: Assessing clarity of message communication for mandated USEPA drinking water quality reports and the CDC

Guidance for Water Quality Monitoring Communication

1. Main Message / Call to Action
2. Language
3. Information Design
4. State of the Science
5. Behavioral Recommendations
6. Numbers
7. Risk

- Is the most important information the primary audience needs summarized in the first paragraph or section?
- Is the material organized in chunks with headings?
- Does the material use bulleted or numbered lists?

Adapted from: Assessing clarity of message communication for mandated USEPA drinking water quality reports and the CDC

Guidance for Water Quality Monitoring Communication

1. Main Message / Call to Action
2. Language
3. Information Design
4. State of the Science
5. Behavioral Recommendations
6. Numbers
7. Risk

- Does the material explain what authoritative sources, such as subject matter experts and agency spokespersons, know and don't know about the topic?

Adapted from: Assessing clarity of message communication for mandated USEPA drinking water quality reports and the CDC

Guidance for Water Quality Monitoring Communication

1. Main Message / Call to Action
2. Language
3. Information Design
4. State of the Science
5. Behavioral Recommendations
6. Numbers
7. Risk

- Does the material include one or more behavioral recommendations for the primary audience?
- Does the material explain why the behavioral recommendation(s) is important?
- Does the behavioral recommendation(s) include specific directions about how to perform the behavior?

Adapted from: Assessing clarity of message communication for mandated USEPA drinking water quality reports and the CDC

Guidance for Water Quality Monitoring Communication

1. Main Message / Call to Action
2. Language
3. Information Design
4. State of the Science
5. Behavioral Recommendations
6. Numbers
7. Risk

- Does the material always present numbers the primary audience uses?
- Does the material always explain what the numbers mean?
- Does the audience have to conduct mathematical calculations?

Adapted from: Assessing clarity of message communication for mandated USEPA drinking water quality reports and the CDC

Guidance for Water Quality Monitoring Communication

1. Main Message / Call to Action
2. Language
3. Information Design
4. State of the Science
5. Behavioral Recommendations
6. Numbers
7. Risk

- Does the material explain the nature of the risk?
- Does the material address both the risks and benefits of the recommended behaviors?
- If the material uses numeric probability to describe risk, is the probability also explained with words or a visual?

Adapted from: Assessing clarity of message communication for mandated USEPA drinking water quality reports and the CDC

Teachings from the Webinar

Training Objectives

Learn to:

- Understand which data products are used for water quality monitoring
- Follow rigorous practices for obtaining and processing aquatic remote sensing data
- Build skills in image processing for water quality monitoring for coastal and inland water bodies using NASA's SeaDAS image processing software

Water Quality Monitoring Program Workflow

Identify Water Quality Problem

Evaluate if Remote Sensing can Complement *In Situ* Sampling Effort

Choose Sensor(s) & Data Product(s) Appropriate for Problem

Build Sampling Strategy for Coincident *In Situ* & Remote Sensing Monitoring

In Situ

collect sample data within 2 hours of aircraft or satellite overpass

collect field samples

process field samples

QA/QC data

Remote Sensing

identify aircraft or satellite overpass dates/times

download imagery

pre-process imagery & derive L2 data product

extract pixel values at sample site locations

Compare *In Situ* & Remote Sensing Matchups & Run Statistics

Communicate Results to Stakeholders

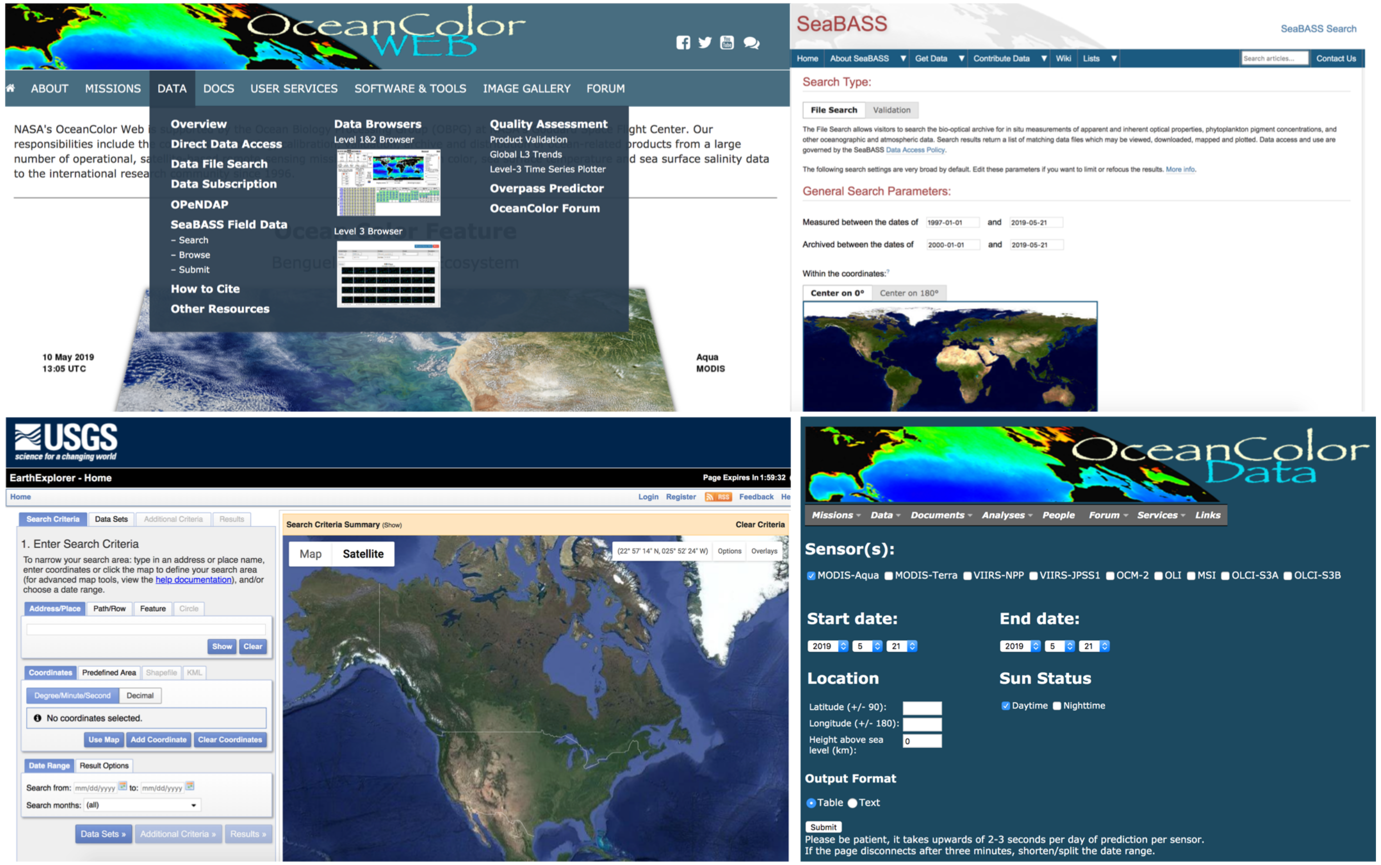
Case Studies: Water Quality Monitoring Incorporating Remote Sensing Observations

- UNESCO
  - Water Quality Information and Capacity Building Portal
- European Space Agency (ESA)
  - Earth Observation for Sustainable Development: Water Quality Monitoring
- Finnish Environment Institute
  - Monitoring Water Quality in Baltic Seas and Finnish Lakes
- UN-SPIDER Knowledge Portal
- National Oceanic and Atmospheric Administration (NOAA)
  - Harmful Algal Bloom (HAB) Bulletin
  - HAB Tracker
  - Great Lakes Hyperspectral Monitoring
- Wisconsin Department of Natural Resources
  - Satellite Water Clarity Monitoring
- Florida Fish & Wildlife Conservation Commission
  - Evaluating Suwannee River Discharge Effects on Water Quality in Big Bend Region

Technical Skills Learned

Data Access & Download

- NASA’s OceanColor Web
  – Level 1 & 2 Browser
  – SeaBASS Field Data
  – Overpass Predictor
- USGS EarthExplorer



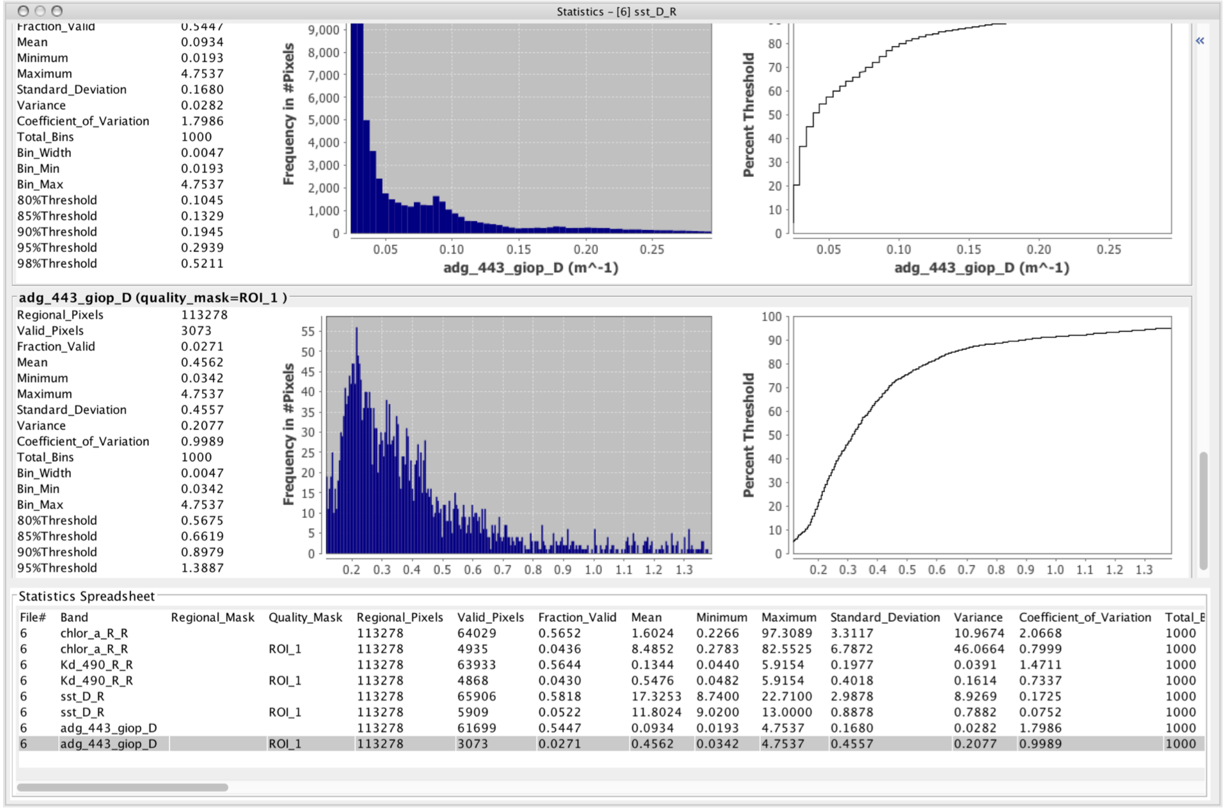
Technical Skills Learned

Image Processing using SeaDAS

- no data
- land masks
- zooming
- synchronizing
- flags
- map location
- adjust color bar
- create color bar
- gridlines
- export image
- reproject
- crop
- collocate bands
- band math (math band)
- mask area
- statistics
- filter band
- pixel extraction
- combine (mosaic) two images
- link to *in situ* data from SeaBASS
- OCSSW processing to derive data products
- OCSSW processing for atmospheric correction

Homework Reminder

- Complete all Exercises from Parts 1 & 3
- Use the Exercises to answer questions to Part 1 and Part 3 Homework
- Submit answers for Part 1 & Part 3 Homework on or before June 21, 2019



Outline for Part 3

- Review Parts 1 & 2
- Water Quality Monitoring Program Workflow & Best Practices
- Designing an Effective Water Quality Monitoring Program using Remote Sensing
- Demo: Using Remote Sensing in a Water Quality Monitoring Program
- Exercise: Using Remote Sensing in a Water Quality Monitoring Program using Data and Methods from the Wisconsin Department of Natural Resources
- Exercise: Advanced Skills with SeaDAS
- Laboratory work time

Demo: Using Remote Sensing in a Water Quality Monitoring Program

Dr. Amita Mehta

Exercise: Using Remote Sensing in a Water Quality Monitoring Program using Data and Methods from the Wisconsin Department of Natural Resources

Dr. Amita Mehta

Exercise: Advanced Skills with SeaDAS

Dr. Sherry L. Palacios

Laboratory Work Time

Thank you!