Workshop on the Validation of Satellite-derived Optical and Water Quality Parameters for Coastal and Inland Waters

7-9 June 2022

University of Wisconsin-Madison

NASA

GEO AQUA WATCH

Validation Workshop Program Committee

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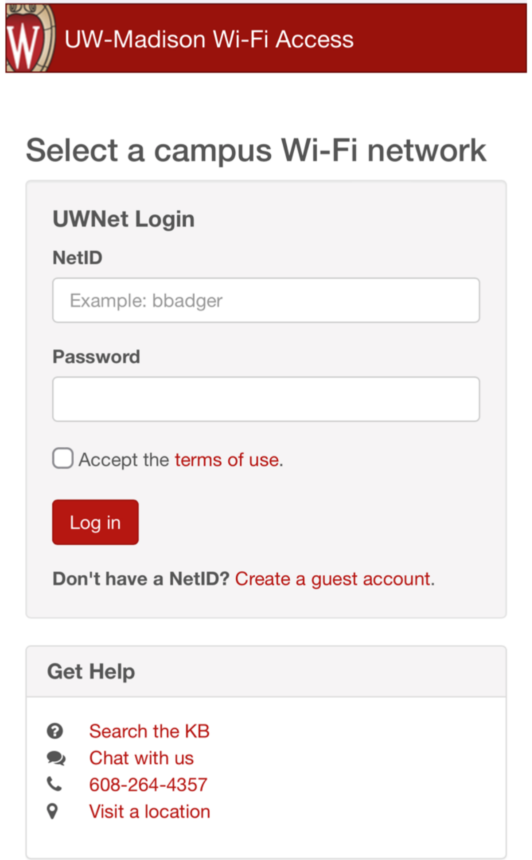
- Internet
- Group Picture at noon today
- CovId testing
- Other rooms for breakouts
- Lunch and Dinner
- Dinner on Thurday



Validation

- The process of assessing, by independent means, the quality of the data products derived from those system outputs [CEOS/ISO:19159].
- Validation and uncertainty assessment are crucial requirements from the end user perspective of a satellite data product and only through confidence in quantifiable uncertainties will there be increased uptake of these data products [Otto et al., 2016].
- Errors in satellite data products are known unknowns. However, quantifying the quality of these products by decomposing the inherent uncertainty components can be a very challenging task [Loew et al. 2017].

Workshop Impetus

- Palmer et al. (2015) pointed to the need for the inland community to be actively engaged in cal/val activities for Sentinel and future EO missions.

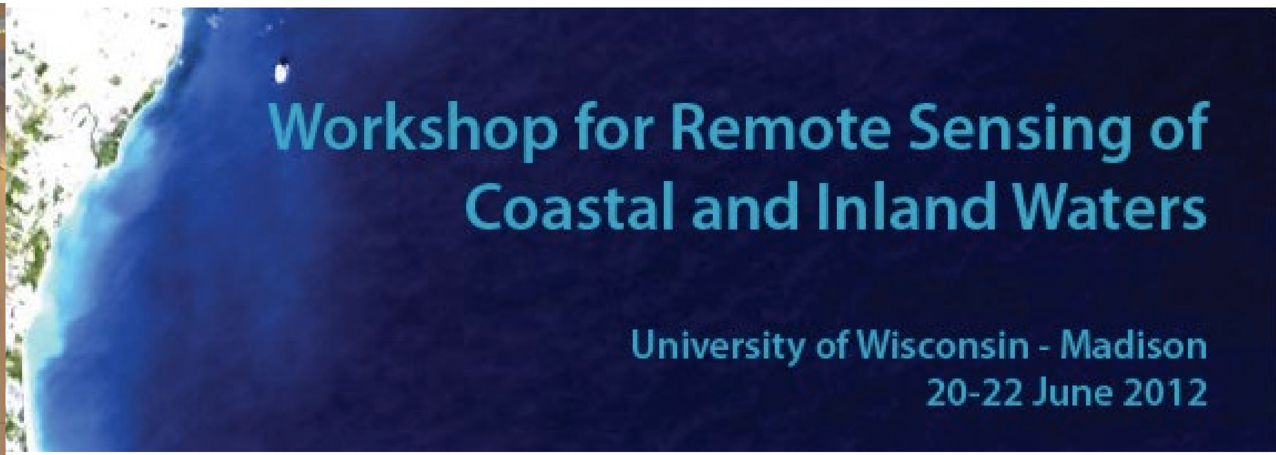
- Mouw et al. (2015) suggested an increased need of *in situ* observations for algorithm development and product validation efforts.

- AquaWatch, the Group on Earth Observations (GEO) water quality community of practice met in August of 2018 to discuss the work plans and future activities and there was an overwhelming consensus that issues and shortcomings surrounding validation of satellite-derived products were a priority facing the community

Workshop Objectives

- Review and evaluation of current and planned validation-related activities.
- Identifying validation gaps in spatial coverage as well as water types.
- Review and evaluation of current *in situ* and laboratory optical measurements and data acquisition protocols including instrument characterization and absolute radiometric calibration.
- Review and evaluation of satellite measurements in terms of representativeness for coastal and inland systems (e.g. pixel window, match-up timing).
- Assessing current optical and water quality database resources including repository archive, preservation, stewardship, and access.
- Building global coordination through international partnerships for validation activities.

Where we were…. 10 years ago



The goals of the workshop were to:

- Provide an overview of the state of the science.
- Identify pressing needs for the advancement of remote sensing in optically complex waters.
- Establish an inventory of unresolved issues.
- Provide scientific basis/guidance for the next generation of remote sensing of coastal and inland water including a framework and recommendations for future research directions.
- Foster the development of new collaborations.

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Review

Aquatic color radiometry remote sensing of coastal and inland waters: Challenges and recommendations for future satellite missions

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A B S T R A C T

Aquatic color radiometry remote sensing of coastal and inland water bodies is of great interest to a wide variety of research, management, and commercial entities as well as the general public. However, most current satellite radiometers were primarily designed for observing the global ocean and not necessarily for observing coastal and inland waters. Therefore, deriving coastal and inland aquatic applications from existing sensors is challenging. We describe the current and desired state of the science and highlight unresolved issues in four fundamental elements of aquatic satellite remote sensing namely, mission capability, in situ observations, algorithm development, and operational capacity. We discuss solutions, future plans, and recommendations that directly affect the science and societal impact of future missions with capability for observing coastal and inland aquatic systems.

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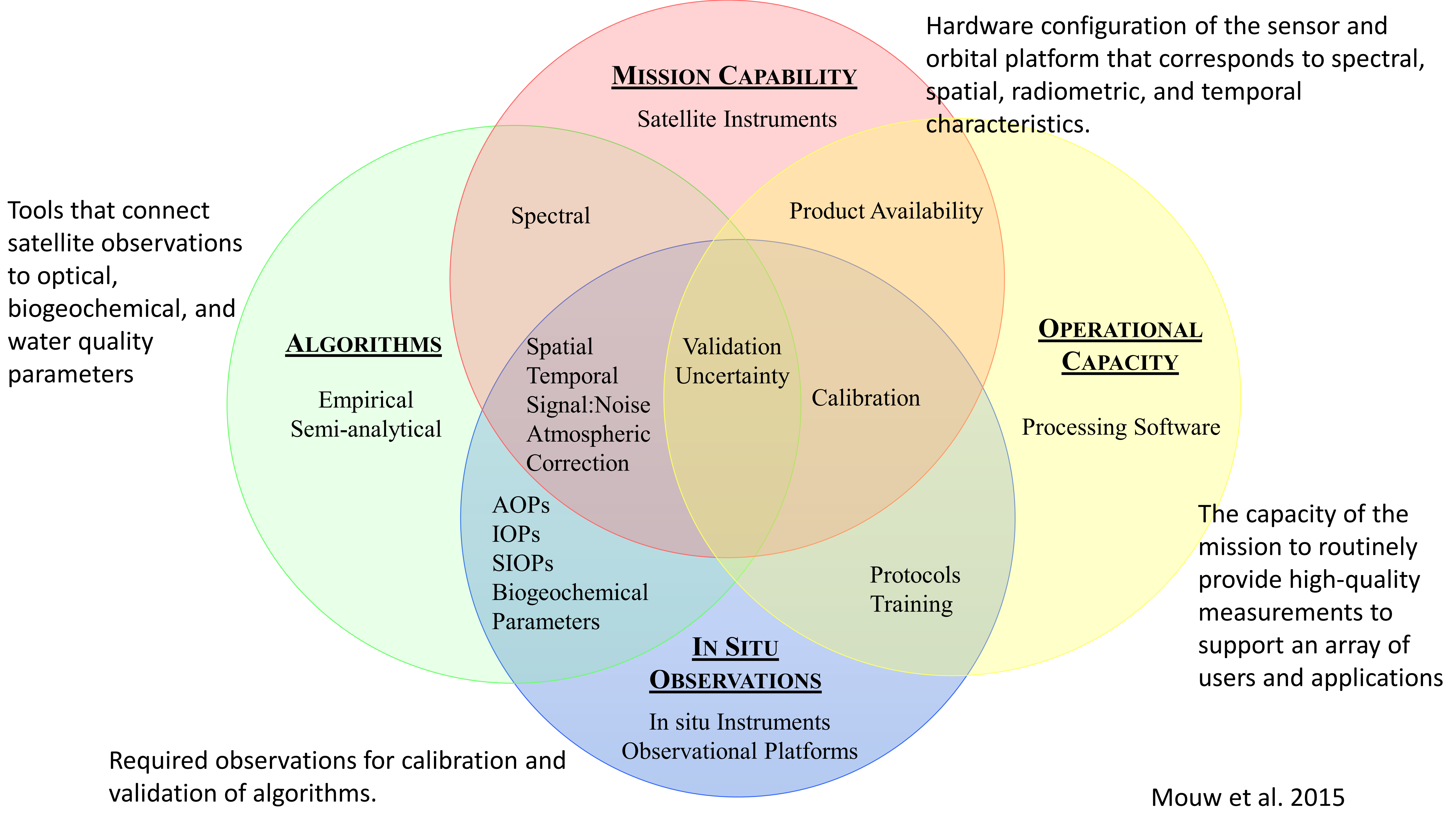
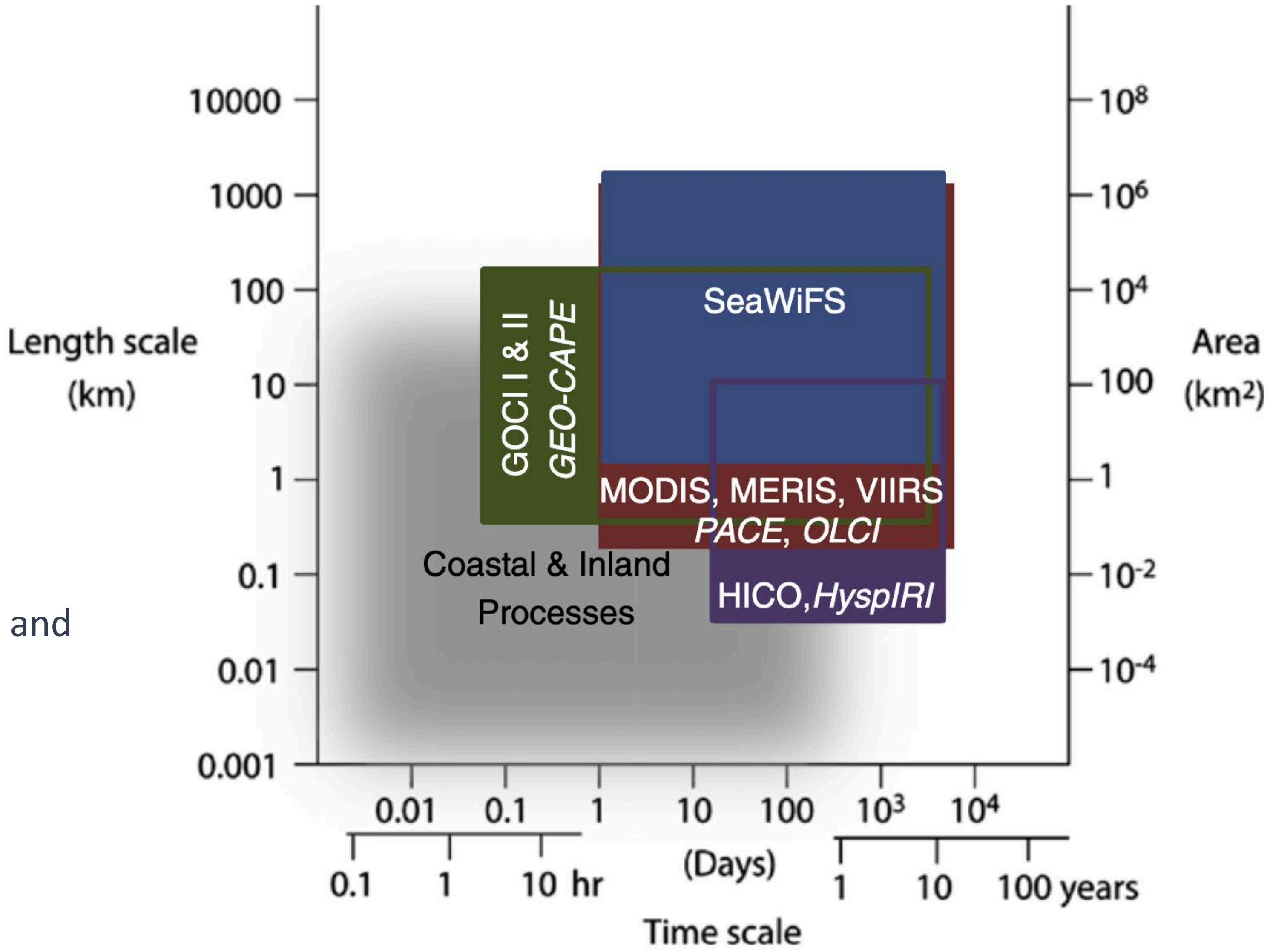

Hardware configuration of the sensor and orbital platform that corresponds to spectral, spatial, radiometric, and temporal characteristics.
MISSION CAPABILITY
Satellite Instruments
Tools that connect satellite observations to optical, biogeochemical, and water quality parameters
Spectral
Product Availability
ALGORITHMS
Empirical
Semi-analytical
Spatial
Temporal
Signal:Noise
Atmospheric
Correction
Validation
Uncertainty
Calibration
OPERATIONAL CAPACITY
Processing Software
AOPs
IOPs
SIOPs
Biogeochemical
Parameters
Protocols
Training
The capacity of the mission to routinely provide high-quality measurements to support an array of users and applications
IN SITU OBSERVATIONS
In situ Instruments
Observational Platforms
Required observations for calibration and validation of algorithms.
Mouw et al. 2015

Spatial and Temporal Resolution



Need to consider
spectral resolution and
spectral sensitivity
as well!

Adopted from Robinson, 2010

Mouw et al., 2015

Gap Analysis

	Previous/Existing	Desired	Needed
Mission Capability	*300 m – 1 km, multispectral, polar orbiting.*	*100 – 500 m, polar orbiting and geostationary with greater spectral resolution and coverage, wide dynamic range and high signal to noise to allow for detection across broad parameter ranges.*	*Investment in geostationary and coastal/inland focused missions to optimize coverage, resolution and availability of new and improved measurements.*
Algorithms	*Multiple approaches optimized to different datasets for various regions.*	*A menu of algorithm choices with clear information about their respective strengths and limitations.*	• *Coordinated algorithm comparison to condense and clarify strengths and limitations and identify fit for purpose options.* • *Research into biogeochemical property variability and relationships with optical properties.*

Mouw et al., 2015

	Previous/Existing	Desired	Needed
***In Situ* Observation**	• *Non-coordinated, multi-agency efforts with data going to many different data repositories, if any and often with limited public data access.* • *Some coincident observations but not all minimum required observations.*	• *Limited number of centralized publically-available data repositories ensuring access to consistent high-quality data.* • *Protocols that cover a dynamic range of variability.* • *At minimum, collect coincident observations of the standard suite of parameters (Table 4); if possible collect a broader suite of data products.*	• *Invest in technology development to address instrumentation gaps; such as sensors designed for high turbidity waters, and hyperspectral b_b.* • *Clear, consistent and coordinated data sharing policies across agencies.* • *Update protocols.* • *Investment in sustaining and increasing observation networks.*

Mouw et al., 2015

	Previous/Existing	Desired	Needed
Operational Capacity	• *Global - open ocean mission /product heritage.* • *Tailored products available for some regions and applications.* • *Support and training often geared more to expert users.* • *Limited access to some satellite color data streams, especially in NRT mode.*	• *Routine and sustained delivery of high-quality operational color data in NRT and delayed modes for coastal and inland waters.* • *Development of merged/blended remote sensing and integrated remote sensing-in situ (information) products.* • *Development of robust color-derived proxies and indicators.* • *Optimal algorithms identified for most/all coastal and inland regions with limitations and uncertainties clearly indicated.*	• *Ongoing coordinated field observations for each coastal/inland region[1] to ensure continual validation.* • *Identification of best performing practices and approaches and continual evaluation as new approaches are developed.* • *Facilitate user data/product access and utilization, including development of application portals.* • *Expanded user outreach and training.* • *Free, open and timely access (NRT and delayed modes) to all satellite color data streams.* • *Implement user-driven community of practice for remote sensing of coastal and inland water to facilitate communication, best practices and harmonization efforts.*

Standard *In Situ* Observations

Table 4
Recommended standard in situ observations for algorithm development, refinement and validation.

	Minimum parameters	Additional parameters
AOPs	$R_{rs}(\lambda)$, $K_d(\lambda)$, Z_{eu} (or $Z_{10\%}$)	
IOPs	$a(\lambda)$, $a_{CDOM}(\lambda)$, $a_{NAP}(\lambda)$, $a_{ph}(\lambda)$, $b_{bp}(\lambda)$	$b_{bp,NAP}(\lambda)$, $b_{bp,ph}(\lambda)$
Biogeochemical	[Chl], TSM, POM, PIM, DOM, DIM	HPLC pigments, primary productivity

*Spectral parameters should be observed at the highest spectral resolution allowed by the instrumentation or at 2–5 nm increments.

Mouw et al. 2015

Standard Remotely Sensed Products

Table 3
Recommended standard remotely sensed products.

	Standard products	Additional products
AOPs	$R_{rs}(\lambda)$, $K_d(\lambda)$, Z_{eu} (or $Z_{10\%}$)	
IOPs	$a(\lambda)$, $a_{CDOM}(\lambda)$, $a_{NAP}(\lambda)$, $a_{ph}(\lambda)$, $b_{bp}(\lambda)$	
Biogeochemical	[Chl], TSM, POM, PIM, DOM, DIM	Primary productivity, phytoplankton functional types

Mouw et al., 2015

Prioritized Implementation

Priority	Immediate	Near-term	Long-term
1	***In Situ Observations*:** *Establish limited number of centralized publically available data repositories.* ***Operational Capacity:*** *Provide more training opportunities for non-specialists.*	***In Situ Observations:*** *Invest in data collection in complex waters and the characterization of MSIOP variability.* ***Operational Capacity:*** *Work to ensure free, open, and timely (NRT or other) access to all satellite color data streams.*	***Mission Capability*:** *Ensure satellite mission capability with flexibility to handle appropriate sensitivity, spectral, spatial, and temporal scales found in coastal and inland systems. Move toward sensor agnostic designs with greater spectral resolution and coverage that could be resampled for various applications.*

Mouw et al., 2015

Prioritized Implementation

Priority	Immediate	Near-term	Long-term
2	***<u>In Situ Observations:</u>*** *Establish standard measurements for any in situ campaign supporting remote sensing. Update community (NASA et al.) protocols to include consideration of the dynamic range of properties encountered in these systems and extend to include biogeochemical properties.*	***<u>Operational Capacity:</u>*** *Identify best practices and approaches for use of color remote sensing data in applications. Develop decision support information and tools for algorithm and product selection. Develop application portals to facilitate access and fit for purpose use of color remote sensing data and derived products.*	

Mouw et al., 2015

Prioritized Implementation

Priority	Immediate	Near-term	Long-term
3	***Operational Capacity:*** *Establishment of a user-driven community of practice for remote sensing of coastal and inland waters to link freshwater and marine, satellite and in situ data, data providers and users, science, and societal considerations, to work collaboratively with IOCCG, space agencies et al.*	***Algorithms:*** *Perform an algorithm intercomparison for consolidation and/or simplification of algorithm choices.* ***In Situ Observations:*** *Create a 'NOMAD-like' dataset/s with coincident observations for the inland/coastal waters.*	

Mouw et al., 2015

Where are we going?

- How did we do?
- Where are we now?
- What are the new considerations/directions for coastal/inland remote sensing validation?

Workshop Questions

1) What are the target levels of uncertainties for spectral R_{rs} and water quality products desired/required by the various end-user communities?
2) What are the minimum/desired essential optical and biogeochemical parameters and their needed temporal and spatial coverage for current and future validation needs?
3) Are current above/below-water radiometric methods and instrumentation; and laboratory inherent optical property methods adequate for water quality applications in complex and shallow waters?
4) What protocols should be followed for processing and quality control of the above data (the requirements for ocean systems may not all apply to inland lake environments)?
5) What assessment protocols and metrics should be used to assess the quality of the satellite data products?
6) How can disparate validation databases be merged and integrated with satellite imagery?
7) How can the water quality community better coordinate these critical validation needs and what resources can be identified to support this effort?