Great Lakes Workshop Series
On Remote Sensing of Water Quality

Held in 2014

Supported by
NASA Applied Science Water Resources Program

Thanks to Brad Doorn, Jared Entin, Christine Lee, and Lawrence Friedl

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National Aerona ministratio

Approx. 60 in-person attendees and 18 web participants took part in Workshop 1

~45 in-person attendees and 10 web participants took part in Workshop 2

http://mtri.org/workshops/nasagreatlakes2014

2014 Great Lakes Workshop Series for Remote Sensing of Water Quality

http://mtri.org/workshops/nasagreatlakes2014

The Great Lakes

- Great Lakes contain approximately 18% of the world's surface fresh water and 95% of the U.S. supply
- They provide drinking water to over 40 million people and have have over 500 recreational beaches
- Commercial and sport fishing contributes more than $1 billion and $4 billion to the economy respectively.

Background/Significance

- RECENT ADVANCEMENT--Remote sensing of water quality and associated features (wetlands, ice, land cover) has advanced significantly in recent years
  - Freshwater-specific optical algorithms
  - Aquatic applications of radar, lidar & hyperspectral sensors
  - Increasingly capable unmanned aerial vehicles (UAVs), autonomous underwater vehicles (AUVs), and other novel platforms
- NEED COORDINATION--Existing regional institutions (e.g. the Great Lakes Observing System, the Great Lakes Commission, NOAA GLERL) need to coordinate research and facilitate data sharing
- NEED DEVELOPMENT--A Great Lakes regional remote sensing community of practice is still, however, only in its early stages
- GLOBAL GENERALIZATION--GEO & USGEO's effort towards global network & systems

Goal for the Workshop Series

Identification of gaps in science and technology for remote sensing of water quality

Featuring:

- ***An emphasis on Great Lakes waters***
- ***Building upon results of past 2 workshops***
- ***Formulation of potential, short, pilot projects***

Workshop Focus

Workshop 1

March 12-13, 2014
NASA GRC, Cleveland

Focus:

- Remote sensing data requirements for the Great Lakes
- Modeling & algorithm
- Data, sensor, platform, & technology gaps

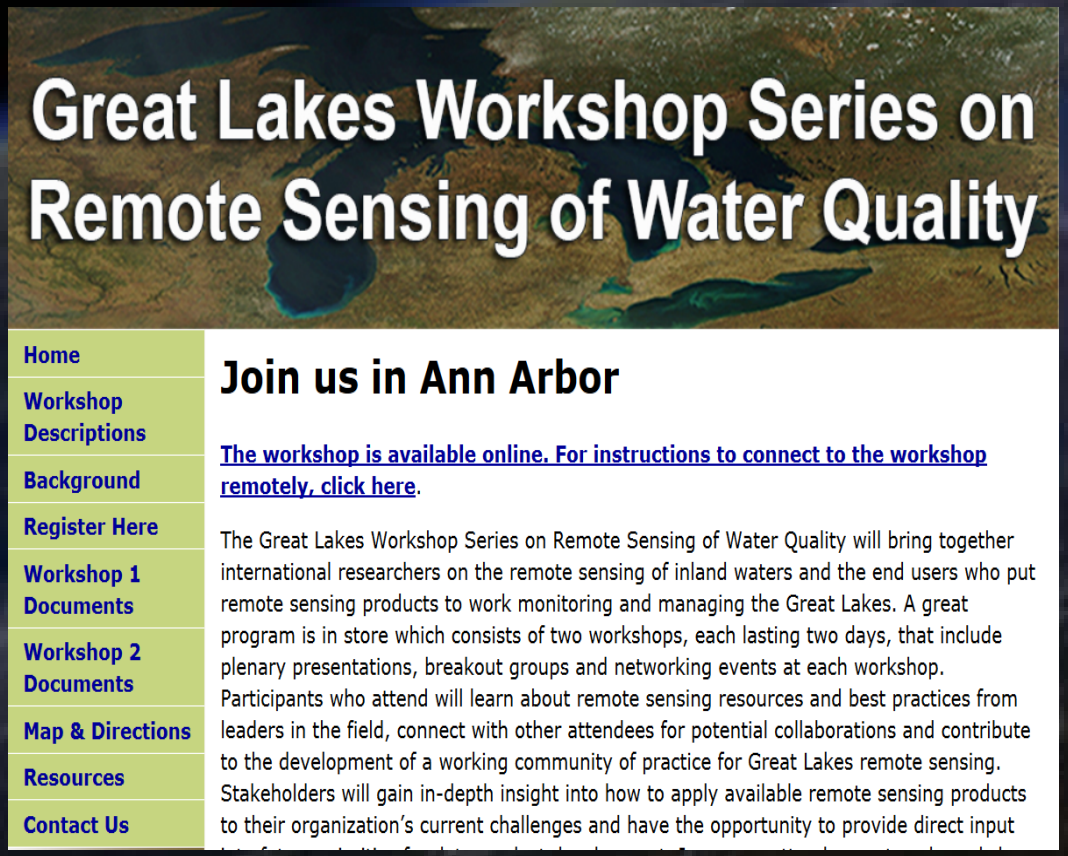
Workshop 2

May 7-8, 2014
NOAA GLERL, Ann Arbor

Focus:

- Data distribution, sharing and credit
- Algorithm comparison study
- Priorities & recommendations
- Great Lakes remote sensing strategy & community

Workshop Series Website



- Slides from plenary talks
- Notes from breakout sessions
- Pilot project ideas
- Link to join the Google Group

http://mtri.org/workshops/nasagreatlakes2014

Great Lakes Remote Sensing Users' Applications

- Underlined by the stakeholders--EPA GLRI, NOAA, USGS, USFWS, and NPS:
  - HABs
  - Water quality monitoring
  - Bathymetric mapping
  - Thermal plumes
  - River plume studies
  - Ice monitoring
  - Nuisance vegetation growth
  - Invasive species monitoring

Cameron Davis speaks on EPA's Great Lakes Restoration Initiatives (GLRI)

Collaboration Ensued—*an impact*

New projects resulted from the workshop

- Joint summer flight/field campaign
- Proposal to ROSES 14 Health & Air Quality
- Regional partnering
  - AFRL, America View
- Working Group on Great Lakes Remote Sensing (WGGLRS)

Summary of Gaps

- Sensors needs
  - Better spatial & temporal coverage by hyperspectral remote sensing
  - Wider spectral range and inland water specific bands
  - Multispectral lidar
- RS Data & Derived Products
  - Better resolution & temporality
  - Turn-key operational products/imageries for lakes & rivers
  - Quantities need to be sensed incorporating models: Phosphorous, hypoxia, microplastics, E. coli, etc
- Technologies
  - Buoys, gliders, AUVs, UAVs, balloons
  - Frequent & agile platforms such as aircraft and cubesat
  - US SAR for ice & vegetation mapping

Summary of Gaps (Cont'd)

- New applications
  - Water quality parameters: Plume constituents, illicit discharge, oil spills, algal composition
  - Physical properties: Bottom/sediment type, drain tile mapping, watershed
- Algorithm & Modeling
  - Independent review and assessment of algorithms
  - Better integration of RS, in-situ, and modeling capabilities
- RS Mission and Platform
  - Need Earth imaging lidar, hyperspectral, tandem SAR, & dedicated Great Lakes water quality & oil spill monitoring (Airborne)
  - New & unconventional platforms, e.g., UAV, AUV, balloons, kites, cabled observations, etc.
  - Crowd sourcing via amateur and commercial pilots & vessels

Summary of Gaps (Cont'd)

- RS Strategy
  - Research agenda via IAGLR & AGU engagement
  - Priority referencing GLWQA, GLRI, etc
  - Form Great Lakes remote sensing community of practice
- Data Distribution
  - Vast majority of Great Lakes data is not accessible
  - Non specialists do not know how to access available data
- Algorithm
  - Cal/val and metrics unclear with some
  - Standardization of measurements and cal/val
  - Documentation should include atmospheric correction
  - Atmospheric correction for Great Lakes/inland waters
  - Non-vested party such as the Alliance for Coastal Technology (ACT) can best assess algorithms

Summary of Gaps (Cont'd)

Maintaining a community of practice

- Form the Working Group on Great Lakes Remote Sensing (WGGLRS)
- Conduct annual group meetings
- Education & Public Outreach, and reaching the GEO water network
- Inland water advisory to NASA
- Permanent website
- Publication
- Generate position papers summarizing how remote sensing can address federal, state and local needs related to Great Lakes issues
- Coordinate collection of airborne & ground-based validation data

Pilot Projects

Participants in both workshops were asked to suggest short (10 week) pilot projects

- Projects suitable for the NASA DEVELOP program and others
- 25 projects suggested
- Point persons for follow-up identified
- Project ideas are available for review on the website

Workshop Summary

- **Workshop series laid the foundation** for open collaboration in developing a regional working strategy for remote sensing, applications, and data management methods
- **Gaps Identified:** The regional community has done a lot with sensors that were not optimized for freshwater, but filling certain gaps (hyperspectral, SAR, a better replacement for MERIS) would enable substantive advances
- **Awareness highlited:**
  - Existing remote sensing resources and capabilities—data portals need to be user-friendly, perhaps include a remote sensing primer
  - Integration of remote sensing data & modeling holds great potential for better estimation of features that cannot be remotely sensed (e.g. oxygen, carbon, nutrients, bacteria)
- **Future Plan: Community development will continue** through the website, Google Group, annual update meeting and pilot projects

Transition Recommendation

- Maintain this Great Lakes Remote Sensing community
  - Convene bi-annually and for special topics
  - A building block community for water applied science
    - Consultation and trial for RS ideas and projects
  - A prototype for other regions nationally and globally

Additional Information

Next Steps for the Working Group on Great Lakes Remote Sensing

- Generate a report on the workshop findings
- Continue to expand and maintain the community website
- Develop a regional remote sensing strategy
  - Follow existing models (**Application Readiness Level**, Traceability Matrix)
  - Include science strategy, priority issues, & stakeholder engagement strategy
- Reach out to non-remote sensing Great Lakes stakeholders about how remote sensing could benefit their work in the near and long term
  - Development of a “primer” webpage on remote sensing data for non-specialists
- Select pilot projects to pursue from the list generated by workshop participants
- Generate position papers summarizing how remote sensing can address federal, state and local needs related to Great Lakes issues
- NASA GRC will continue in a leading role in development of this community

Breakout Discussions

- Six breakout sessions made up the heart of each workshop
- Each discussion resulted in a set of notes/table of information

Workshop 1 Breakout groups

Day 1

1. Update sensor requirements for remote sensing of inland lakes
2. Remote sensing data and derived product gaps
3. Technology gaps (sensors, instruments, & other hardware)

Day 2

1. New potential applications for remote sensing of inland waters
2. Algorithms/modeling current approaches: status/strengths/deficiencies
3. Platform/mission gaps and recommendations

Workshop 2 Breakout groups

Day 1

1. Moving forward with a regional remote sensing strategy
2. Distribution of Great Lakes data
3. Algorithm comparison studies

Day 2

4. Create plan to maintain an active Great Lakes RS community
5. Remote sensing derived products sharing & credit to originators
6. Define time series RS datasets (i.e. HABs, primary productivity)

Workshop 1, Breakout 1: Update Sensor Requirements for Remote Sensing of Inland Lakes

- Group came to consensus on positive support of the continuing development of PACE, GeoCape, HyspIRI, Sentinel-3, and OLCI
- Hyperspectral provides the potential to separate algal & mineral composition
  - Need for hyperspectral capabilities available on a shorter timescale
    - Aircraft or drones on demand
    - Venture class (disposable) satellites and microsats
- Need for wider spectral range, for example to differentiate sediment from plankton.
- Need for enhanced dynamic range in the visible.
  - Many of the instruments in orbit are optimized for land or open ocean in terms of band placement and temporal repeat as well as dynamic range.
- Lidar: Development of multispectral lidar to get near surface profiles (3-4m) higher spatial resolution potential to differentiate CPAs.
  - Caveat that the results would potentially be noisy and not get beyond the first optical depth.

Workshop 1, Breakout 2: Remote Sensing Data and Derived Product Gaps

- Landsat-like imagery with daily temporal coverage
- Higher-resolution hyperspectral imagery
- Turnkey operational products from ocean color imagery for the Great Lakes
- Higher-resolution (~100 m) ocean color imagery
- Better water quality values (CPA estimates) for nearshore areas
- Operational, high-resolution river plume product
- Ice surface temperature
- Development/improvement of models for features that can't be sensed directly but could potentially utilize remote sensing data as inputs
  - Phosphorus
  - Salinity
  - Hypoxia
  - Microplastics
  - E. coli
- Development of a user-friendly data portal tailored based on location and user type

Workshop 1, Breakout 3: Technology Gaps (Sensors, Instruments, & Other Hardware)

- Power-charging docking stations for remote / unmanned mobile devices (underwater, airborne)
- Cabled observatories in the Great Lakes – deployment for longer time periods than buoys
- Wireless data transmission underwater – more rugged, fewer cables
- Crowd-sourcing data collection tools / technologies – making it easier for the citizen scientist to contribute data
- Ice thickness sensors – use for shipping, science / impacts of a changing climate
- Webcams – digital imaging sensors that are easily
- SAR platforms – no U.S. data source currently exists for radar data for ice monitoring, vegetation mapping, etc.
- Cubesats & other small satellites – could be used more to lower the cost of satellite imagery collection & make it more frequent
- Buoys, gliders, AUVs, UAVs, surface vehicles, balloons – there is a need to take greater advantage of these rapidly developing hardware platforms

Workshop 1, Breakout 4: New Potential Applications for Remote Sensing of Inland Waters

- **Water Quality**
  - Mapping invasive and/or emergent aquatic plant species
  - Detection/tracking of plumes
  - Algal composition mapping
  - Plume constituent mapping
  - Illicit discharges
  - Oil spills
  - Microplastic monitoring
  - Beach monitoring/health
- **Physical Properties**
  - Bottom substrate/sediment type mapping
    - habitat mapping
    - fisheries
    - modeling
    - substrate
  - Dangerous (rip) current hazard maps
  - Real-time dangerous current alerts on nearshore winds, waves, and currents
  - Drainage tile mapping
  - Mapping tsunami-like waves created by storms
  - Fine-scale water height and/or flooding
  - Watershed modeling

Workshop 1, Breakout 5: Algorithms/Modeling Current Approaches: Status/Strengths/Deficiencies

- Integration of modeling & remote sensing
  - Need better integration between remote sensing data, in situ data & modeling communities
  - Increase use of RS to validate and improve forecasting methods
  - RS is better used as a component of an integrated system rather than as standalone tools
  - Modeling and RS should inform each other
- Algorithm development
  - Community responsibility for algorithms – need to open up algorithm development to be testable by others
  - Multiple algorithms can often be best for the same problem – there's no single approach that works best for all datasets
  - Similar experiments should be conducted in different environments – what works in one lake might not in another

Workshop 1, Breakout 6: Platform/Mission Gaps and Recommendations

- Missions
  - Earth-imaging lidar
  - Hyperspectral
  - Tandem SAR
  - Dedicated Great Lakes water quality and oil spill monitoring mission (airborne fleet)
- Platforms
  - Sounding Rockets
  - Kites
  - Balloons
  - Microsats/smallsats
  - Unmanned aerial vehicles (RC helicopters, etc.)
  - Autonomous underwater vehicles
  - Additional buoys
  - Additional fixed observation platforms
  - Cabled observatories
  - Utilize private vessels (commercial aircraft, charter boats, private aircraft) as platforms

Workshop 2, Breakout 1: Moving Forward with a Regional Remote Sensing Strategy

- **Strategy Components:**
  - Science strategy: research agenda development engagement (AGU, IAGLR)
  - Prioritization criteria
  - Priority issues or topics: from other sources (GLWQA, GLRI, etc.)
  - Proposed organization of Great Lakes RS community of practice
  - Recommended portfolio of existing, modified, or future platforms, instruments, and products, and ways to coordinate feedback
  - Stakeholder engagement strategy: intermediaries (CGLG, DNRs, CGLI, America View, HOW) and designer/operator professional societies (WEF, ASCE, AWWA, EPRI)
  - Timeline matched to deadlines of parallel activities
- **Format:**
  - Follow Application Readiness Level, Traceability Matrix Models
  - Include consideration of “coolness” vs. “usefulness”
  - Include letters of support from key organizations

GLERL
Great Lakes Environmental Research Laboratory

Workshop 2, Breakout 2: Distribution of Great Lakes Data

- The vast majority of Great Lakes data is inaccessible
  - Recovery of older/archived data, especially when not yet digitized, is a major issue and undertaking
  - Many datasets are shared internally but not in an open online format
  - GEO Great Lakes has a prioritization process to identify the most important of these inaccessible datasets
- Remote sensing can be seen as too much of a hurdle by non-specialists
  - The issue is not just how to access data but how to make data discoverable and “on the radar” of non-specialists
- Formulated a list of candidate datasets for distribution via GLOS-DMAC, including notes on the most useful product format, current status and end user groups
  - Next steps: refine/finalize the list, ask user communities for review and feedback, prioritize datasets, incorporate into GLOS preproposals

Workshop 2, Breakout 3: Algorithm Comparison Studies

- What constitutes “real” algorithm validation?
  - Everyone has their own metrics, they’re sometimes hard to interpret
- Strict cal/val would give us confidence and help with algorithm development
- Standard suite of measurements with strong cal/val standard needed
  - Protocols for collection of calibration data, data storage & processing methods
  - Central community archive for regional RS calibration data
  - Community data gathering cruises would be useful for validating models under development
  - Validation activities should be run by a third, non-vested party such as the Alliance for Coastal Technology (ACT)
- Atmospheric correction is part of the algorithm and should be included in algorithm documentation
  - Improvements needed for the Great Lakes - Some atmospheric correction procedures have been validated over land but not water and currently produce negative radiance values over water

Workshop 2, Breakout 4: Create Plan to Maintain an Active Great Lakes RS Community

- Annual group meetings
  - Perhaps associated with a larger conference
  - Include a poster session in future meetings
- Draft a formal statement of purpose
- Education & Public Outreach (focused and general public outreach)
  - Healing our Waters
  - State Aerospace and Technology Committee
  - Media Day around upcoming summer flight
- Offer something similar to the NASA Planetary advisory Committee, but for freshwater or inland and coastal
- Communication
  - Google Group listserv
  - Permanent website
    - Exchanging documents
    - Discussion forum
- Publication
  - Workshop summary report (with executive summary)
  - Generate position papers summarizing how remote sensing can address federal, state and local needs related to Great Lakes issues
- Coordinate collection of ground-based validation data
  - Community data cruises/expeditions?
  - Compile a database of on-going water sampling

Workshop 2, Breakout 5: Data Sharing & Credit

- Obstacles
  - Preparing and submitting data requires effort & resources & often isn't funded
  - Concerns of data originators about rights & acknowledgement
  - Concerns about data misuse
- Potential solutions
  - Reward data originators by updating them on who has used and cited their data
  - Grade datasets (e.g., using stars like on Amazon)
  - Register users and ask how they plan to use data
  - Good metadata might help control data misuse
  - Identify operational vs. research data – Level of review scale?
  - Give data users guidance on how to cite/credit datasets

Workshop 2, Breakout 6: Define Time Series Remote Sensing Datasets

- Generated a prioritized list of useful time series products, including status/feasibility and applications
- The baseline used for time series varies between products – need to clearly communicate what baseline is used
- Smooth vs. exact interpolations are preferred for different applications – important to document processing flow
- Temporal resolution is limited by cloud cover for many imagery-based products
- Many end users don't want to work with the raw data, they just want the derived products delivered in an accessible way
  - The GRACE point and click interface for time series charts is a good example of user-friendly functionality